Director General of Civil Aviation Authority of the Republic of Kosovo,

Pursuant to Article 3.1, 3.4, 15.1 items (a), (c), (f), (j), and 21.2, 79, 80 of Law No. 03/L-051 on Civil Aviation ("Official Gazette of the Republic of Kosovo" Year III, No. 28, 4 June 2008),

For the purpose of regulating provision of Aeronautical Telecommunications in the Republic of Kosovo in line with Standards and Recommended Practices laid down in Annex 10 to the Convention on International Civil Aviation,

After having completed public consultation process with all interested parties pursuant to the Administrative Instruction no. 01/2012 on public consultation of interested parties,

Hereby issues the following:

REGULATION No. 2 /2016 ON IMPLEMENTATION OF ANNEX 10 TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION ON AERONAUTICAL TELECOMMUNICATIONS

Article 1
Scope of Application

1.1 The present Regulation lays down requirements for provision of Aeronautical Telecommunications in accordance with respective Standards and Recommended Practices (SARPs) of International Civil Aviation Organization (ICAO), laid down in Annex 10 to the Convention on International Civil Aviation.

1.2 Provision of Aeronautical Telecommunications in the Republic of Kosovo shall be governed by SARPs of Annex 10 Volume I, II, III, IV, V, all relevant Appendixes and Attachments as published in Sixth Edition July 2006 for Volume I, Sixth Edition October 2001 for Volume II, Second Edition July 2007 for Volume III, Fifth Edition July 2014 for Volume IV and Third Edition July 2013 for Volume V by ICAO.

Article 2
Implementation of SARPs

2.1 Annex 10 Volume I, II, III, IV and V on Aeronautical Telecommunications, as specified under Article 1 paragraph 2 of the present Regulation shall be applicable in accordance with provisions of the present Regulation.

2.2 Applicable SARPs specified under Annex 10 and its Appendixes and Attachments shall be applicable in the Republic of Kosovo.

Article 3
Terms and Definitions

For the purposes of the present Regulation terms “Contracting State”, “The State” directly or indirectly either used in singular or plural in the Annex 10 to the Convention on International Civil Aviation, as specified above in Article 1 paragraph 2, shall be read “the Republic of Kosovo”.

Article 4
Availability

The SARPs of Annex 10, as specified in Article 1, paragraph 2, in accordance with provisions of the present Regulation, are appended to the present Regulation as Annex 1.

Article 5
Entry into force

The present Regulation shall enter into force on 20 February 2016.

Done at Prishtinë, on 5 February 2016

Dritan Gjonbalaj
Director General

International Standards
and Recommended Practices

Annex 10
to the Convention on
International Civil Aviation

Aeronautical Telecommunications

Volume I
Radio Navigation Aids

This edition incorporates all amendments adopted by the Council prior to 25 February 2006 and supersedes, on 23 November 2006, all previous editions of Annex 10, Volume I.
For information regarding the applicability of the Standards and Recommended Practices, see Foreword.

Sixth Edition
July 2006

International Civil Aviation Organization

INTERNATIONAL STANDARDS

AND RECOMMENDED PRACTICES

CHAPTER 1. DEFINITIONS

Note 1.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radiocommunication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies(Doc 9718).

Note 2.— Annex 10, Volume I includes Standards and Recommended Practices for certain forms of equipment for air navigation aids. While the Contracting State will determine the necessity for specific installations in accordance with the conditions prescribed in the relevant Standard or Recommended Practice, review of the need for specific installation and the formulation of ICAO opinion and recommendations to Contracting States concerned is carried out periodically by Council, ordinarily on the basis of recommendations of Regional Air Navigation Meetings (Doc 8144 — Directives to Regional Air Navigation Meetings and Rules of Procedure for their Conduct).

When the following terms are used in this volume, they have the following meanings:

Altitude. The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).

Area navigation (RNAV). A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground- or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

Note.— Area navigation includes performance-based navigation as well as other operations that do not meet the definition of performance-based navigation.

Effective acceptance bandwidth. The range of frequencies with respect to the assigned frequency for which reception is assured when all receiver toleranceshave been taken into account.

Effective adjacent channel rejection. The rejection that is obtained at the appropriate adjacent channel frequency when all relevant receiver tolerances have been taken into account.

Elevation. The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.

Essential radio navigation service. A radio navigation service whose disruption has a significant impact on operations in the affected airspace or aerodrome.

Fan marker beacon. A type of radio beacon, the emissions of which radiate in a vertical fan-shaped pattern.

Height. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

Human Factors principles. Principles which apply to design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

Mean power (of a radio transmitter). The average power supplied to the antenna transmission line by a transmitter during an interval of time sufficiently long compared with the lowest frequency encountered in the modulation taken under normal operating conditions.

Note.— A time of 1/10 second during which the meanpower is greatest will be selected normally.

Navigation specification. A set of aircraft and flight crew requirements needed to support performance-based navigation operations within a defined airspace. There are two kinds of navigation specifications:

Required navigation performance (RNP) specification. A navigation specification based on area navigation that includes the requirement for performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP APCH.

Area navigation (RNAV) specification. A navigation specification based on area navigation that does not include the requirement for performance monitoringand alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

Note.1— The Performance-based Navigation (PBN) Manual(Doc 9613), Volume II, contains detailed guidance on navigation specifications.

Note 2.— The term RNP, previously defined as "a statement of the navigation performance necessary for operation within a defined airspace", has been removed from this Annex as the concept of RNP has been overtaken by the concept of PBN. The term RNP in this Annex is now solely used in the context of navigation specifications that require performance monitoring and alerting, e.g. RNP 4 refers to the aircraft and operating requirements, including a 4 NM lateral performance with on-board performance monitoring and alerting that are detailed in Doc 9613.

Performance-based navigation (PBN). Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.

Note.— Performance requirements are expressed in navigation specifications (RNAV specification, RNP specification) in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept.

Pressure-altitude. An atmospheric pressure expressed in terms of altitudewhich corresponds to that pressure in the Standard Atmosphere.

Protected service volume. A part of the facility coverage where the facilityprovides a particular service in accordance with relevant SARPs and within which the facility is afforded frequency protection.

Radio navigation service. A service providing guidance information or position data for the efficient and safe operation of aircraft supported by one or more radio navigation aids.

Touchdown. The point where the nominal glide path intercepts the runway.

Note.— "Touchdown" as defined above is only a datum and is not necessarily the actual point at which the aircraft will touch the runway.

Z marker beacon. A type of radio beacon, the emissions of which radiate in a vertical cone-shaped pattern.

CHAPTER 2. GENERAL PROVISIONS FOR
RADIO NAVIGATION AIDS

2.1 Standard radio navigation aids

2.1.1 The standard radio navigation aids shall be:

a) the instrument landing system (ILS) conforming to the Standards contained in Chapter 3, 3.1;

b) the microwave landing system (MLS) conforming to the Standards contained in Chapter 3, 3.11;

c) the global navigation satellite system (GNSS) conforming to the Standards contained in Chapter 3, 3.7;

d) the VHF omnidirectional radio range (VOR) conforming to the Standards contained in Chapter 3, 3.3;

e) the non-directional radio beacon (NDB) conforming to the Standards contained in Chapter 3, 3.4;

f) the distance measuring equipment (DME) conforming to the Standards contained in Chapter 3, 3.5; and

g) the en-route VHF marker beacon conforming to the Standards contained in Chapter 3, 3.6.

Note 1.— Since visual reference is essential for the final stages of approach and landing, the installation of a radio navigation aid does not obviate the need for visual aids to approach and landing in conditions of low visibility.

Note 2.— It is intended that introduction and application of radio navigation aids to support precision approach and landing operations will be in accordance with the strategy shown in Attachment B.

Note 3.— Categories of precision approach and landing operations are classified in Annex 6, Part I, Chapter 1.

Note 4.— Information on operational objectives associated with ILS facility performance categories is given in Attachment C, 2.1 and 2.14.

Note 5.— Information on operational objectives associated withMLS facility performance is given in Attachment G, 11.

2.1.2 Differences in radio navigation aids in any respect from the Standards of Chapter 3 shall be published in an Aeronautical Information Publication (AIP).

2.1.3 Wherever there is installed a radio navigation aid that is neither an ILS nor an MLS, but which may be used in whole or in part with aircraft equipment designed for use with the ILS or MLS, full details of parts that may be so used shall be published in an Aeronautical Information Publication (AIP).

Note.— This provision is to establish a requirement for promulgation of relevant information rather than to authorize such installations.

2.1.4 GNSS-specific provisions

2.1.4.1 It shall be permissible to terminate a GNSS satelliteservice provided by one of its elements (Chapter 3, 3.7.2) on the basis of at least a six-year advance notice by a service provider.

2.1.4.2 Recommendation.— A State that approves GNSS-based operations should ensure that GNSS data relevant to those operations are recorded.

Note 1.— These recorded data are primarily intended for use in accident and incident investigations. They may also support periodic confirmation that accuracy, integrity, continuity and availability are maintained within the limits required for the operations approved.

Note 2.— Guidance material on the recording of GNSS parameters is contained in Attachment D, 11.

2.1.4.3 Recommendation.— Recordings should be retained for a period of at least 14 days. When the recordings are pertinent to accident and incident investigations, they should be retained for longer periods until it is evident that they will no longer be required.

2.1.5 Precision approach radar

2.1.5.1 A precision approach radar (PAR) system, where installed and operated as a radio navigation aid together with equipment for two-way communication with aircraft and facilities for the efficient coordination of these elements with air traffic control, shall conform to the Standards contained in Chapter 3, 3.2.

Note 1.— The precision approach radar (PAR) element of the precision approach radar system may be installed and operated without the surveillance radar element (SRE), when it is determined that the SRE is not necessary to meet the requirements of air traffic control for the handling of aircraft.

Note 2.— Although SRE is not considered, in any circumstances, a satisfactory alternative to the precision approach radar system, the SRE may be installed and operated without the PAR for the assistance of air traffic control in handling aircraft intending to use a radio navigation aid, or for surveillance radar approaches and departures.

2.1.6 Recommendation.— When a radio navigation aid is provided to support precision approach and landing, it should be supplemented, as necessary, by a source or sources of guidance information which, when used in conjunction with appropriate procedures, will provide effective guidance to, and efficient coupling (manual or automatic) with, the desired reference path.

Note.— DME, GNSS, NDB, VOR and aircraft navigation systems have been used for such purposes.

2.2 Ground and flight testing

2.2.1 Radio navigation aids of the types covered by the specifications in Chapter 3 and available for use by aircraft engaged in international air navigation shall be the subject of periodic ground and flight tests.

Note.— Guidance on the ground and flight testing of ICAO standard facilities, including the periodicity of the testing, is contained in Attachment C and in the Manual on Testing of Radio Navigation Aids (Doc 8071).

2.3 Provision of information on the operational status of radio navigation services

2.3.1 Aerodrome control towers and units providing approach control service shall be provided with information on the operational status of radio navigation services essential for approach, landing and take-off at the aerodrome(s) with which they are concerned, on a timely basis consistent with the use of the service(s) involved.

2.4 Power supply for radio navigation aids and communication systems

2.4.1 Radio navigation aids and ground elements of communication systems of the types specified in Annex 10 shall be provided with suitable power supplies and means to ensure continuity of service consistent with the use of the service(s) involved.

Note.— Guidance material on power supply switch-over is contained in Attachment C, 8.

2.5 Human Factors considerations

2.5.1 Recommendation.— Human Factors principles should be observed in the design and certification of radio navigation aids.

Note.— Guidance material on Human Factors principles can be found in the Human Factors Training Manual (Doc 9683) and Circular 249(Human Factors Digest No. 11 – Human Factors in CNS/ATM Systems).

CHAPTER 3. SPECIFICATIONSFOR RADIO NAVIGATION AIDS

Note.— Specifications concerning the siting and construction of equipment and installations on operational areas aimed at reducing the hazard to aircraft to a minimum are contained in Annex 14, Chapter 8.

3.1 Specification for ILS

3.1.1 Definitions

Angular displacement sensitivity. The ratio of measured DDM to the corresponding angular displacement from the appropriate reference line.

Back course sector. The course sector which is situated on the opposite side of the localizer from the runway.

Course line. The locus of points nearest to the runway center line in any horizontal plane at which the DDM is zero.

Course sector. A sector in a horizontal plane containing the course line and limited by the loci of points nearest to the course line at which the DDM is 0.155.

DDM — Difference in depth of modulation. The percentage modulation depth of the larger signal minus the percentage modulation depth of the smaller signal, divided by 100.

Displacement sensitivity (localizer). The ratio of measured DDM to the corresponding lateral displacement from the appropriate reference line.

Facility Performance Category I — ILS. An ILS which provides guidance information from the coverage limit of the ILS to the point at which the localizer course line intersects the ILS glide path at a height of 60 m (200 ft) or less above the horizontal plane containing the threshold.

Note.— This definition is not intended to preclude the use of Facility Performance Category I — ILS below the height of 60 m (200 ft), with visual reference where the quality of the guidance provided permits, and where satisfactory operational procedures have been established.

Facility Performance Category II — ILS. An ILS which provides guidance information from the coverage limit of the ILS to the point at which the localizer course line intersects the ILS glide path at a height of 15 m (50 ft) or less above the horizontal plane containing the threshold.

Facility Performance Category III — ILS. An ILS which, with the aid of ancillary equipment where necessary, provides guidance information from the coverage limit of the facility to, and along, the surface of the runway.

Front course sector. The course sector which is situated on the same side of the localizer as the runway.

Half course sector. The sector, in a horizontal plane containing the course line and limited by the loci of points nearest to the course line at which the DDM is 0.0775.

Half ILS glide path sector. The sector in the vertical plane containing the ILS glide path and limited by the loci of points nearest to the glide path at which the DDM is 0.0875.

ILS continuity of service. That quality which relates to the rarity of radiated signal interruptions. The level of continuity of service of the localizer or the glide path is expressed in terms of the probability of not losing the radiated guidance signals.

ILS glide path. That locus of points in the vertical plane containing the runway centre line at which the DDM is zero, which, of all such loci, is the closest to the horizontal plane.

ILS glide path angle. The angle between a straight line which represents the mean of the ILS glide path and the horizontal.

ILS glide path sector. The sector in the vertical plane containing the ILS glide path and limited by the loci of points nearest to the glide path at which the DDM is 0.175.

Note.— The ILS glide path sector is located in the vertical plane containing the runway centre line, and is divided by the radiated glide path in two parts called upper sector and lower sector, referring respectively to the sectors above and below the glide path.

ILS integrity. That quality which relates to the trust which can be placed in the correctness of the information supplied by the facility. The level of integrity of the localizer or the glide path is expressed in terms of the probability of not radiating false guidance signals.

ILS Point "A". A point on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 7.5 km (4 NM) from the threshold.

ILS Point "B". A point on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 1 050 m (3 500 ft) from the threshold.

ILS Point "C". A point through which the downward extended straight portion of the nominal ILS glide path passes at a height of 30 m (100 ft) above the horizontal plane containing the threshold.

ILS Point "D". A point 4 m (12 ft) above the runway centre line and 900 m (3 000 ft) from the threshold in the direction of the localizer.

ILS Point "E". A point 4 m (12 ft) above the runway centre line and 600 m (2 000 ft) from the stop end of the runway in the direction of the threshold.

Note.— See Attachment C, Figure C-1.

ILS reference datum (Point "T"). A point at a specified height located above the intersection of the runway centre line and the threshold and through which the downward extended straight portion of the ILS glide path passes. Two-frequency glide path system. An ILS glide path in which coverage is achieved by the use of two independent radiation field patterns spaced on separate carrier frequencies within the particular glide path channel.

Two-frequency localizer system. A localizer system in which coverage is achieved by the use of two independent radiation field patterns spaced on separate carrier frequencies within the particular localizer VHF channel.

3.1.2 Basic requirements

3.1.2.1 The ILS shall comprise the following basic components:

a) VHF localizer equipment, associated monitor system, remote control and indicator equipment;

b) UHF glide path equipment, associated monitor system, remote control and indicator equipment;

c) VHF marker beacons, or distance measuring equipment (DME) in accordance with section 3.5, together with associated monitor system and remote control and indicator equipment.

Note.— Guidance material relative to the use of DME as an alternative to the marker beacon component of the ILS is contained in Attachment C, 2.11.

3.1.2.1.1 Facility Performance Categories I, II and III — ILS shall provide indications at designated remote control points of the operational status of all ILS ground system components, as follows:

a) for all Category II and Category III ILS, the air traffic services unit involved in the control of aircraft on the final approach shall be one of the designated remote control points and shall receive information on the operational status of the ILS, with a delay commensurate with the requirements of the operational environment;

b) for a Category I ILS, if that ILS provides an essential radio navigation service, the air traffic services unit involved in the control of aircraft on the final approach shall be one of the designated remote control points and shall receive information on the operational status of the ILS, with a delay commensurate with the requirements of the operational environment.

Note 1.— The indications required by this Standard are intended as a tool to support air traffic management functions, and the applicable timeliness requirements are sized accordingly (consistently with 2.8.1). Timeliness requirements applicable to the ILS integrity monitoring functions that protect aircraft from ILS malfunctions are specified in 3.1.3.11.3.1 and 3.1.5.7.3.1.

Note 2.— It is intended that the air traffic system is likely to call for additional provisions which may be found essential for the attainment of full operational Category III capability, e.g. to provide additional lateral and longitudinal guidance during the landing roll-out, and taxiing, and to ensure enhancement of the integrity and reliability of the system.

3.1.2.2 The ILS shall be constructed and adjusted so that, at a specified distance from the threshold, similar instrumental indications in the aircraft represent similar displacements from the course line or ILS glide path as appropriate, irrespective of the particular ground installation in use.

3.1.2.3 The localizer and glide path components specified in 3.1.2.1 a) and b) which form part of a Facility Performance Category I — ILS shall comply at least with the Standards in 3.1.3 and 3.1.5 respectively, excepting those in which application to Facility Performance Category II — ILS is prescribed.

3.1.2.4 The localizer and glide path components specified in 3.1.2.1 a) and b) which form part of a Facility Performance Category II — ILS shall comply with the Standards applicable to these components in a Facility Performance Category I — ILS, as supplemented or amended by the Standards in 3.1.3 and 3.1.5 in which application to Facility Performance Category II — ILS is prescribed.

3.1.2.5 The localizer and glide path components and other ancillary equipment specified in 3.1.2.1.1,which form part of a Facility Performance Category III — ILS, shall otherwise comply with the Standards applicable to these components in Facility Performance Categories I and II — ILS, except as supplemented by the Standards in 3.1.3 and 3.1.5 in which application to Facility Performance Category III — ILS is prescribed.

3.1.2.6 To ensure an adequate level of safety, the ILS shall be so designed and maintained that the probability of operation within the performance requirements specified is of a high value, consistent with the category of operational performance concerned.

Note.— The specifications for Facility Performance Categories II and III — ILS are intended to achieve the highest degree of system integrity, reliability and stability of operation under the most adverse environmental conditions to be encountered. Guidance material to achieve this objective in Categories II and III operations is given in 2.8 of Attachment C.

3.1.2.7 At those locations where two separate ILS facilities serve opposite ends of a single runway, an interlock shall ensure that only the localizer serving the approach direction in use shall radiate, except where the localizer in operational use is Facility Performance Category I — ILS and no operationally harmful interference results.

3.1.2.7.1 Recommendation.— At those locations where two separate ILS facilities serve opposite ends of a single runway and where a Facility Performance Category I — ILS is to be used for auto-coupled approaches and landings in visual conditions an interlock should ensure that only the localizer serving the approach direction in use radiates, providing the other localizer is not required for simultaneous operational use.

Note.— If both localizers radiate there is a possibility of interference to the localizer signals in the threshold region. Additional guidance material is contained in 2.1.9 and 2.13 of Attachment C.

3.1.2.7.2 At locations where ILS facilities serving opposite ends of the same runway or different runways at the same airport use the same paired frequencies, an interlock shall ensure that only one facility shall radiate at a time. When switching from one ILS facility to another, radiation from both shall be suppressed for not less than 20 seconds.

Note.— Additional guidance material on the operation of localizers on the same frequency channel is contained in 2.1.9 of Attachment C and Volume V, Chapter 4.

3.1.3 VHF localizer and associated monitor

Introduction. The specifications in this section cover ILS localizers providing either positive guidance information over 360 degrees of azimuth, or providing such guidance only within a specified portion of the front coverage (see 3.1.3.7.4). Where ILS localizers providing positive guidance information ina limited sector are installed, information from some suitably located navigation aid, together with appropriate procedures, will generally be required to ensure that any misleading guidance information outside the sector is not operationally significant.

3.1.3.1 General

3.1.3.1.1 The radiation from the localizer antenna system shall produce a composite field pattern which is amplitude modulated by a 90 Hz and a 150 Hz tone. The radiation field pattern shall produce a course sector with one tone predominating on one side of the course and with the other tone predominating on the opposite side.

3.1.3.1.2 When an observer faces the localizer from the approach end of a runway, the depth of modulation of the radio frequency carrier due to the 150 Hz tone shall predominate on the observer’s right hand and that due to the 90 Hz tone shall predominate on the observer’s left hand.

3.1.3.1.3 All horizontal angles employed in specifying the localizer field patterns shall originate from the centre of the localizer antenna system which provides the signals used in the front course sector.

3.1.3.2 Radio frequency

3.1.3.2.1 The localizer shall operate in the band 108 MHz to 111.975 MHz. Where a single radio frequency carrier is used, the frequency tolerance shall not exceed plus or minus 0.005 per cent. Where two radio frequency carriers are used, the frequency tolerance shall not exceed 0.002 per cent and the nominal band occupied by the carriers shall be symmetrical about the assigned frequency. With all tolerances applied, the frequency separation between the carriers shall not be less than 5 kHznor more than 14 kHz.

3.1.3.2.2 The emission from the localizer shall be horizontally polarized. The vertically polarized component of the radiation on the course line shall not exceed that which corresponds to a DDM error of 0.016 when an aircraft is positioned on the course line and is in a roll attitude of 20 degrees from the horizontal.

3.1.3.2.2.1 For Facility Performance Category II localizers, the vertically polarized component of the radiation on the course line shall not exceed that which corresponds to a DDM error of 0.008 when an aircraft is positioned on the course line and is in a roll attitude of 20 degrees from the horizontal.

3.1.3.2.2.2 For Facility Performance Category III localizers, the vertically polarized component of the radiation within a sector bounded by 0.02 DDM either side of the course line shall not exceed that which corresponds to a DDM error of 0.005 when an aircraft is in a roll attitude of 20 degrees from the horizontal.

3.1.3.2.3 For Facility Performance Category III localizers, signals emanating from the transmitter shall contain no components which result in an apparent course line fluctuation of more than 0.005 DDM peak to peak in the frequency band 0.01 Hz to 10 Hz.

3.1.3.3 Coverage

Note.— Guidance material on localizer coverage is given in Attachment C, 2.1.10 and Figures C-7A, C-7B, C-8A and C-8B.

3.1.3.3.1 The localizer shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation within the localizer and glide path coverage sectors. The localizer coverage sector shall extend from the centre of the localizer antenna system to distances of:

46.3 km (25 NM) within plus or minus 10 degrees from the front course line;

31.5 km (17 NM) between 10 degrees and 35 degrees from the front course line;

18.5 km (10 NM) outside of plus or minus 35 degrees from the front course line if coverage is provided;

except that, where topographical features dictate or operational requirements permit, the limits may be reduced down to 33.3 km (18 NM) within the plus or minus 10-degree sector and 18.5 km (10 NM) within the remainder of the coverage when alternative navigational means provide satisfactory coverage within the intermediate approach area. The localizer signals shall be receivable at the distances specified at and above a height of 600 m (2 000 ft) above the elevation of the threshold, or 300 m (1 000 ft) above the elevation of the highest point within the intermediate and final approach areas, whichever is the higher, except that, where needed to protect ILS performance and if operational requirements permit, the lower limit of coverage at angles beyond 15 degrees from the front course line shall be raised linearly from its height at 15 degrees to as high as 1 350 m (4 500 ft) above the elevation of the threshold at 35 degrees from the front course line. Such signals shall be receivable, to the distances specified, up to a surface extending outward from the localizer antenna and inclined at 7 degrees above the horizontal.

Note.— Where intervening obstacles penetrate the lower surface, it is intended that guidance need not be provided at less than line-of-sight heights .

3.1.3.3.2 In all parts of the coverage volume specified in 3.1.3.3.1, other than as specified in 3.1.3.3.2.1, 3.1.3.3.2.2 and

3.1.3.3.2.3, the field strength shall be not less than 40 microvolts per metre (minus 114 dBW/m2).

Note.— This minimum field strength is required to permit satisfactory operational usage of ILS localizer facilities.

3.1.3.3.2.1 For Facility Performance Category I localizers, the minimum field strength on the ILS glide path and within the localizer course sector from a distance of 18.5 km (10 NM) to a height of 60 m (200 ft) above the horizontal plane containing the threshold shall be not less than 90 microvolts per metre (minus 107 dBW/m2).

3.1.3.3.2.2 For Facility Performance Category II localizers, the minimum field strength on the ILS glide path and within the localizer course sector shall be not less than 100 microvolts per metre (minus 106 dBW/m2) at a distance of 18.5 km (10 NM) increasing to not less than 200 microvolts per metre (minus 100 dBW/m2) at a height of 15 m (50 ft) above the horizontal plane containing the threshold.

3.1.3.3.2.3 For Facility Performance Category III localizers, the minimum field strength on the ILS glide path and within the localizer course sector shall be not less than 100 microvolts per metre (minus 106 dBW/m2) at a distance of 18.5 km (10 NM), increasing to not less than 200 microvolts per metre (minus 100 dBW/m2) at 6 m (20 ft) above the horizontal plane containing the threshold. From this point to a further point 4 m (12 ft) above the runway centre line, and 300 m (1 000 ft) from the threshold in the direction of the localizer, and thereafter at a height of 4 m (12 ft) along the length of the runway in the direction of the localizer, the field strength shall be not less than 100 microvolts per metre (minus 106 dBW/m2).

Note.— The field strengths given in 3.1.3.3.2.2 and 3.1.3.3.2.3 are necessary to provide the signal-to-noise ratio required for improved integrity.

3.1.3.3.3 *Recommendation.—* Above 7 degrees, the signals should be reduced to as low a value as practicable.

Note 1.— The requirements in 3.1.3.3.1, 3.1.3.3.2.1, 3.1.3.3.2.2 and 3.1.3.3.2.3 are based on the assumption that the aircraft is heading directly toward the facility.

Note 2.— Guidance material on significant airborne receiver parameters is given in 2.2.2 and 2.2.4 of Attachment C.

3.1.3.3.4 When coverage is achieved by a localizer using two radio frequency carriers, one carrier providing a radiation field pattern in the front course sector and the other providing a radiation field pattern outside that sector, the ratio of the two carrier signal strengths in space within the front course sector to the coverage limits specified at 3.1.3.3.1 shall not be less than 10 dB.

Note.— Guidance material on localizers achieving coverage with two radio frequency carriers is given in the Note to 3.1.3.11.2 and in 2.7 of Attachment C.

3.1.3.3.5 Recommendation.— For Facility Performance Category III localizers, the ratio of the two carrier signal strengths in space within the front course sector should not be less than 16 dB.

3.1.3.4 Course structure

3.1.3.4.1 For Facility Performance Category I localizers, bends in the course line shall not have amplitudes which exceed the following:

Zone	Amplitude (DDM) (95% probability)
Outer limit of coverage to ILS Point “A”	0.031
ILS Point “A” to ILS Point “B”	0.031 at ILS Point “A” decreasing at a linear rate to 0.015 at ILS Point “B”
ILS Point “B” to ILS Point “C”	0.015

3.1.3.4.2 For Facility Performance Categories II and III localizers, bends in the course line shall not have amplitudes which exceed the following:

Zone	Amplitude (DDM) (95% probability)
Outer limit of coverage to ILS Point “A”	0.031
ILS Point “A” to ILS Point “B”	0.031 at ILS Point “A” decreasing at a linear rate to 0.005 at ILS Point “B”
ILS Point “B” to ILS Point “C”	0.005

and, for Category III only:

ILS reference datum to ILS Point “D”	0.005
ILS Point “D” to ILS Point “E” I	0.005 at ILS Point “D” increasing at a linear rate to 0.010 at ILS Point “E”

Note 1.— The amplitudes referred to in 3.1.3.4.1 and 3.1.3.4.2 are the DDMs due to bends as realized on the mean course line, when correctly adjusted.

Note 2.— Guidance material relevant to the localizer course structure is given in 2.1.4, 2.1.6 and 2.1.7 of Attachment C.

3.1.3.5 Carrier modulation

3.1.3.5.1 The nominal depth of modulation of the radio frequency carrier due to each of the 90 Hz and 150 Hz tones shall be 20 per cent along the course line.

3.1.3.5.2 The depth of modulation of the radio frequency carrier due to each of the 90 Hz and 150 Hz tones shall be within the limits of 18 and 22 per cent.

3.1.3.5.3 The following tolerances shall be applied to the frequencies of the modulating tones:

a) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 2.5 per cent;

b) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 1.5 per cent for Facility Performance Category II installations;

c) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 1 per cent for Facility Performance Category III installations;

d) the total harmonic content of the 90 Hz tone shall not exceed 10 per cent; additionally, for Facility Performance Category III localizers, the second harmonic of the 90 Hz tone shall not exceed 5 per cent;

e) the total harmonic content of the 150 Hz tone shall not exceed 10 per cent.

3.1.3.5.3.1 ***Recommendation****.— For Facility Performance Category I — ILS, the modulating tones should be 90 Hz and 150 Hz within plus or minus 1.5 per cent where practicable.*

3.1.3.5.3.2 For Facility Performance Category III localizers, the depth of amplitude modulation of the radio frequency carrier at the power supply frequency or its harmonics, or by other unwanted components, shall not exceed 0.5 per cent.
Harmonics of the supply, or other unwanted noise components that may intermodulate with the 90 Hz and 150 Hz navigation tones or their harmonics to produce fluctuations in the course line, shall not exceed 0.05 per cent modulation depth of the radio frequency carrier.

3.1.3.5.3.3 The modulation tones shall be phase-locked so that within the half course sector, the demodulated 90 Hz

and 150 Hz wave forms pass through zero in the same direction within:

a) for Facility Performance Categories I and II localizers: 20 degrees; and

b) for Facility Performance Category III localizers: 10 degrees,

of phase relative to the 150 Hz component, every half cycle of the combined 90 Hz and 150 Hz wave form.

Note 1.— The definition of phase relationship in this manner is not intended to imply a requirement to measure the phase within the half course sector.

Note 2.— Guidance material relative to such measurement is given at Figure C-6 of Attachment C.

3.1.3.5.3.4 With two-frequency localizer systems, 3.1.3.5.3.3 shall apply to each carrier. In addition, the 90 Hz modulating tone of one carrier shall be phase-locked to the 90 Hz modulating tone of the other carrier so that the demodulated wave forms pass through zero in the same direction within:

a) for Categories I and II localizers: 20 degrees; and

b) for Category III localizers: 10 degrees,

of phase relative to 90 Hz. Similarly, the 150 Hz tones of the two carriers shall be phase-locked so that the demodulated wave forms pass through zero in the same direction within:

1) for Categories I and II localizers: 20 degrees; and

2) for Category III localizers: 10 degrees,

of phase relative to 150 Hz.

3.1.3.5.3.5 Alternative two-frequency localizer systems that employ audio phasing different from the normal in-phase conditions described in 3.1.3.5.3.4 shall be permitted. In this alternative system, the 90 Hz to 90 Hz phasing and the 150 Hz to 150 Hz phasing shall be adjusted to their nominal values to within limits equivalent to those stated in 3.1.3.5.3.4.

Note.— This is to ensure correct airborne receiver operation in the region away from the course line where the two carrier signal strengths are approximately equal.

3.1.3.5.3.6 **Recommendation.—** The sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones should not exceed 60 per cent or be less than 30 per cent within the required coverage.

3.1.3.5.3.6.1 For equipment first installed after 1 January 2000, the sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones shall not exceed 60 per cent or be less than 30 per cent within the required coverage.

Note 1.— If the sum of the modulation depths is greater than 60 per cent for Facility Performance Category I localizers, the nominal displacement sensitivity may be adjusted as provided for in 3.1.3.7.1 to achieve the above modulation limit.

Note 2.— For two-frequency systems, the standard for maximum sum of modulation depths does not apply at or near azimuths where the course and clearance carrier signal levels are equal in amplitude (i.e. at azimuths where both transmitting systems have a significant contribution to the total modulation depth).

Note 3.— The standard for minimum sum of modulation depths is based on the malfunctioning alarm level being set as high as 30 per cent as stated in 2.3.3 of Attachment C.

3.1.3.5.3.7 When utilizing a localizer for radiotelephone communications, the sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones shall not exceed 65 per cent within 10 degrees of the course line and shall not exceed 78 per cent at any other point around the localizer.

3.1.3.5.4 Recommendation.— Undesired frequency and phase modulation on ILS localizer radio frequency carriers that can affect the displayed DDM values in localizer receivers should be minimized to the extent practical.

Note.— Relevant guidance material is given in 2.15 of Attachment C.

3.1.3.6 Course alignment accuracy

3.1.3.6.1 The mean course line shall be adjusted and maintained within limits equivalent to the following displacements from the runway centre line at the ILS reference datum:

a) for Facility Performance Category I localizers: plus or minus 10.5 m (35 ft), or the linear equivalent of 0.015 DDM, whichever is less;

b) for Facility Performance Category II localizers: plus or minus 7.5 m (25 ft);

c) for Facility Performance Category III localizers: plus or minus 3 m (10 ft).

3.1.3.6.2 Recommendation.— For Facility Performance Category II localizers, the mean course line should be adjusted and maintained within limits equivalent to plus or minus 4.5 m (15 ft) displacement from runway centre line at the ILS reference datum.

Note 1.— It is intended that Facility Performance Categories II and III installations be adjusted and maintained so that the limits specified in 3.1.3.6.1 and 3.1.3.6.2 are reached on very rare occasions. It is further intended that design and operation of the total ILS ground system be of sufficient integrity to accomplish this aim.

Note 2.— It is intended that new Category II installations are to meet the requirements of 3.1.3.6.2.

Note 3.— Guidance material on measurement of localizer course alignment is given in 2.1.3 of Attachment C.

3.1.3.7 Displacement sensitivity

3.1.3.7.1 The nominal displacement sensitivity within the half course sector shall be the equivalent of 0.00145 DDM/m (0.00044 DDM/ft) at the ILS reference datum except that for Category I localizers, where the specified nominal displacement sensitivity cannot be met, the displacement sensitivity shall be adjusted as near as possible to that value. For Facility Performance Category I localizers on runway codes 1 and 2, the nominal displacement sensitivity shall be achieved at the ILS Point "B". The maximum course sector angle shall not exceed six degrees.

Note.— Runway codes 1 and 2 are defined in Annex 14.

3.1.3.7.2 The lateral displacement sensitivity shall be adjusted and maintained within the limits of plus or minus:

a) 17 per cent of the nominal value for Facility Performance Categories I and II;

b) 10 per cent of the nominal value for Facility Performance Category III.

3.1.3.7.3 Recommendation.— For Facility Performance Category II — ILS, displacement sensitivity should be adjusted and maintained within the limits of plus or minus 10 per cent where practicable.

Note 1.— The figures given in 3.1.3.7.1, 3.1.3.7.2 and 3.1.3.7.3 are based upon a nominal sector width of 210 m (700 ft) at the appropriate point, i.e. ILS Point "B" on runway codes 1 and 2, and the ILS reference datum on other runways.

Note 2.— Guidance material on the alignment and displacement sensitivity of localizers using two radio frequency carriers is given in 2.7 of Attachment C.

Note 3.— Guidance material on measurement of localizer displacement sensitivity is given in 2.9 of Attachment C.

3.1.3.7.4 The increase of DDM shall be substantially linear with respect to angular displacement from the front course line (where DDM is zero) up to an angle on either side of the front course line where the DDM is 0.180. From that angle to plus or minus 10 degrees, the DDM shall not be less than 0.180. From plus or minus 10 degrees to plus or minus 35 degrees, the DDM shall not be less than 0.155. Where coverage is required outside of the plus or minus 35 degrees sector, the DDM in the area of the coverage, except in the back course sector, shall not be less than 0.155.

Note 1. — The linearity of change of DDM with respect to angular displacement is particularly important in the neighbourhood of the course line.

Note 2. — The above DDM in the 10-35 degree sector is to be considered a minimum requirement for the use of ILS as a landing aid. Wherever practicable, a higher DDM, e.g. 0.180, is advantageous to assist high speed aircraft to execute large angle intercepts at operationally desirable distances provided that limits on modulation percentage given in 3.1.3.5.3.6 are met.

Note 3. — Wherever practicable, the localizer capture level of automatic flight control systems is to be set at or below 0.175 DDM in order to prevent false localizer captures.

3.1.3.8 Voice

3.1.3.8.1 Facility Performance Categories I and II localizers may provide a ground-to-air radiotelephone communication channel to be operated simultaneously with the navigation and identification signals, provided that such operation shall not interfere in any way with the basic localizer function.

3.1.3.8.2 Category III localizers shall not provide such a channel, except where extreme care has been taken in the design and operation of the facility to ensure that there is no possibility of interference with the navigational guidance.

3.1.3.8.3 If the channel is provided, it shall conform with the following Standards:

3.1.3.8.3.1 The channel shall be on the same radio frequency carrier or carriers as used for the localizer function, and the radiation shall be horizontally polarized. Where two carriers are modulated with speech, the relative phases of the modulations on the two carriers shall be such as to avoid the occurrence of nulls within the coverage of the localizer.

3.1.3.8.3.2 The peak modulation depth of the carrier or carriers due to the radiotelephone communications shall not exceed 50 per cent but shall be adjusted so that:the ratio of peak modulation depth due to the radiotelephone communications to that due to the identification signal is approximately 9:1;

b) the sum of modulation components due to use of the radiotelephone channel, navigation signals and identification signals shall not exceed 95 per cent.

3.1.3.8.3.3 The audio frequency characteristics of the radiotelephone channel shall be flat to within 3 dB relative to the level at 1 000 Hz over the range 300 Hz to 3 000 Hz.

3.1.3.9 Identification

3.1.3.9.1 The localizer shall provide for the simultaneous transmission of an identification signal, specific to the runway and approach direction, on the same radio frequency carrier or carriers as used for the localizer function. The transmission of the identification signal shall not interfere in any way with the basic localizer function.

3.1.3.9.2 The identification signal shall be produced by Class A2A modulation of the radio frequency carrier or carriers using a modulation tone of 1 020 Hz within plus or minus 50 Hz. The depth of modulation shall be between the limits of 5 and 15 per cent except that, where a radiotelephone communication channel is provided, the depth of modulation shall be adjusted so that the ratio of peak modulation depth due to radiotelephone communications to that due to the identification signal modulation is approximately 9:1 (see 3.1.3.8.3.2). The emissions carrying the identification signal shall be horizontally polarized. Where two carriers are modulated with identification signals, the relative phase of the modulations shall be such as to avoid the occurrence of nulls within the coverage of the localizer.

3.1.3.9.3 The identification signal shall employ the International Morse Code and consist of two or three letters. It may be preceded by the International Morse Code signal of the letter “I”, followed by a short pause where it is necessary to distinguish the ILS facility from other navigational facilities in the immediate area.

3.1.3.9.4 The identification signal shall be transmitted by dots and dashes at a speed corresponding to approximately seven words per minute, and shall be repeated at approximately equal intervals, not less than six times per minute, at all times during which the localizer is available for operational use. When the transmissions of the localizer are not available for operational use, as, for example, after removal of navigation components, or during maintenance or test transmissions, the identification signal shall be suppressed. The dots shall have a duration of 0.1 second to 0.160 second. The dash duration shall be typically three times the duration of a dot. The interval between dots and/or dashes shall be equal to that of one dotplus or minus 10 per cent. The interval between letters shall not be less than the duration of three dots.

3.1.3.10 Siting

3.1.3.10.1 For Facility Performance Categories II and III, the localizer antenna system shall be located on the extension on the centre line of the runway at the stop end, and the equipment shall be adjusted so that the course lines will be in a vertical plane containing the centre line of the runway served. The antenna height and location shall be consistent with safe obstruction clearance practices.

3.1.3.10.2 For Facility Performance Category I, the localizer antenna system shall be located and adjusted as in

3.1.3.10.1, unless site constraints dictate that the antenna be offset from the centre line of the runway.

3.1.3.10.2.1 The offset localizer system shall be located and adjusted in accordance with the offset ILS provisions of the Procedures for Air Navigation Services — Aircraft Operations(PANS-OPS) (Doc 8168), Volume II, and the localizer standards shall be referenced to the associated fictitious threshold point.

3.1.3.11 Monitoring

3.1.3.11.1 The automatic monitor system shall provide a warning to the designated control points and cause one of the following to occur, within the period specified in 3.1.3.11.3.1, if any of the conditions stated in 3.1.3.11.2 persist:

a) radiation to cease; and

b) removal of the navigation and identification components from the carrier.

3.1.3.11.2 The conditions requiring initiation of monitor action shall be the following:

a) for Facility Performance Category I localizers, a shift of the mean course line from the runway centre line equivalent to more than 10.5 m (35 ft), or the linear equivalent to0.015 DDM, whichever is less, at the ILS reference datum;

b) for Facility Performance Category II localizers, a shift of the mean course line from the runway centre line equivalent to more than 7.5 m (25 ft) at the ILS reference datum;

c) for Facility Performance Category III localizers, a shift of the mean course line from the runway centre line equivalent to more than 6 m (20 ft) at the ILS reference datum;

d) in the case of localizers in which the basic functionsare provided by the use ofa single-frequency system, a reduction of power output to a level such that any of the requirements of 3.1.3.3, 3.1.3.4 or 3.1.3.5 are no longer satisfied, or to a level that is less than 50 per cent of the normal level (whichever occurs first);

e) in the case of localizers in which the basic functions are provided by the use of a two-frequency system, a reduction of power output for either carrier to less than 80 per cent of normal, except that a greater reduction to between 80 per cent and 50 per cent of normal may be permitted, provided the localizer continues to meet the requirements of 3.1.3.3, 3.1.3.4 and 3.1.3.5;

Note.— It is important to recognize that a frequency change resulting in a loss of the frequency difference specified in 3.1.3.2.1 may produce a hazardous condition. This problem is of greater operational significance for Categories II and III installations. As necessary, this problem can be dealt with through special monitoring provisions or highly reliable circuitry.

f) change of displacement sensitivity to a value differing by more than 17 per cent from the nominal value for the localizer facility.

Note.— In selecting the power reduction figure to be employed in monitoring referred to in 3.1.3.11.2 e), particular attention is directed to vertical and horizontal lobe structure (vertical lobing due to different antenna heights) of the combined radiation systems when two carriers are employed. Large changes in the power ratio between carriers may result in low clearance areas and false courses in the off-course areas to the limits of the vertical coverage requirements specified in 3.1.3.3.1.

3.1.3.11.2.1 **Recommendation.—** In the case of localizers in which the basic functions are provided by the use of a two-frequency system, the conditions requiring initiation of monitor action should include the case when the DDM in the required coverage beyond plus or minus 10 degrees from the front course line, except in the back course sector, decreases below 0.155.

3.1.3.11.3 The total period of radiation, including period(s) of zero radiation, outside the performance limits specified in a), b), c), d), e) and f) of 3.1.3.11.2 shall be as short as practicable, consistent with the need for avoiding interruptions of the navigation service provided by the localizer.

3.1.3.11.3.1 The total period referred to under 3.1.3.11.3 shall not exceed under any circumstances:

10 seconds for Category I localizers;

5 seconds for Category II localizers;

2 seconds for Category III localizers.

Note 1.— The total time periods specified are never-to-be-exceededlimits and are intended to protect aircraft in the final stages of approach against prolonged or repeated periods of localizer guidance outside the monitor limits. For this reason, they include not only the initial period of outside tolerance operation but also the total of any or all periods of outside tolerance radiation including period(s) of zero radiation and time required to remove the navigation and identification components from the carrier, which might occur during action to restore service, for example, in the course of consecutive monitor functioning and consequent changeover(s) to localizer equipment or elements thereof.

Note 2.— From an operational point of view, the intention is that no guidance outside the monitor limits be radiated after the time periods given, and that no further attempts be made to restore service until a period in the order of 20 secondshas elapsed.

3.1.3.11.3.2 Recommendation.— Where practicable, the total period under 3.1.3.11.3.1 should be reduced so as not to exceed two seconds for Category II localizers and one second for Category III localizers.

3.1.3.11.4 Design and operation of the monitor system shall be consistent with the requirement that navigation guidance and identification will be removed and a warning provided at the designated remote control points in the event of failure of the monitor system itself.

Note.— Guidance material on the design and operation of monitor systems is given in Attachment C, 2.1.7.

3.1.3.12 Integrity and continuity of service requirements

3.1.3.12.1 The probability of not radiating false guidance signals shall not be less than 1 – 0.5 × 10–9 in any one landing for Facility Performance Categories II and III localizers.

3.1.3.12.2 **Recommendation**.— The probability of not radiating false guidance signals should not be less than 1 – 1.0 × 10–7in any one landing for Facility Performance Category I localizers.

3.1.3.12.3 The probability of not losing the radiated guidance signal shall be greater than:

a) 1 – 2 × 10–6 in any period of 15 seconds for Facility Performance Category II localizers or localizers intended to be used for Category III A operations (equivalent to 2 000 hours mean time between outages); and

b) 1 – 2 × 10–6 in any period of 30 seconds for Facility Performance Category III localizers intended to be used for the full range of Category III operations (equivalent to 4 000 hours mean time between outages).

3.1.3.12.4 **Recommendation.—** The probability of not losing the radiated guidance signal should exceed 1 – 4 × 10–6 in any period of 15 seconds for Facility Performance Category I localizers (equivalent to 1 000 hours mean time between outages).

Note.— Guidance material on integrity and continuity of service is given in Attachment C, 2.8.

3.1.4 Interference immunity performance for ILS localizer receiving systems

3.1.4.1 The ILS localizer receiving system shall provide adequate immunity to interference from two-signal, third order intermodulation products caused by VHF FM broadcast signals having levels in accordance with the following:

$$2N1 + N2 + 72 \leq 0$$

for VHF FM sound broadcasting signals in the range 107.7 – 108.0 MHz and 1

2 2 3 24 20 log 00.4fNN Δ ( ) + +− ≤ | |

for VHF FM sound broadcasting signals below 107.7 MHz, where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two-signal, third-order intermodulation product on the desired ILS localizer frequency.

N1 and N2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the ILS localizer receiver input. Neither level shall exceed the desensitization criteria set forth in 3.1.4.2.

Δf = 108.1 – f1, where f1is the frequency of N1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

3.1.4.2 The ILS localizer receiving system shall not bed esensitized in the presence of VHF FM broadcast signals having levels in accordance with the following table:

Frequency	Maximum level of unwanted signal at receiver input
(MHz)	(dBm)
88-102	+15

104	+10
106	+5
107.9	–10

Note 1.— The relationship is linear between adjacent points designated by the above frequencies.

Note 2.— Guidance material on immunity criteria to be used for the performance quoted in 3.1.4.1 and 3.1.4.2 is contained in Attachment C, 2.2.2.

3.1.5 UHF glide path equipment and associated monitor

Note.— θ is used in this paragraph to denote the nominal glide path angle.

3.1.5.1 General

3.1.5.1.1 The radiation from the UHF glide path antenna system shall produce a composite field pattern which is amplitude modulated by a 90 Hz and a 150 Hz tone. The pattern shall be arranged to provide a straight line descent path in the vertical plane containing the centre line of the runway, with the 150 Hz tone predominating below the path and the 90 Hz tone predominating above the path to at least an angle equal to 1.75 θ.

Recommendation.—The ILS glide path angle should be 3 degrees. ILS glide path angles in excess of 3 degrees should not be used except where alternative means of satisfying obstruction clearance requirements are impracticable.

3.1.5.1.2.1 The glide path angle shall be adjusted and maintained within:

a) 0.075 θ from θfor Facility Performance Categories I and II — ILS glide paths;

b) 0.04 θ from θfor Facility Performance Category III — ILS glide paths.

Note 1.— Guidance material on adjustment and maintenance of glide path angles is given in 2.4 of Attachment C.

Note 2.— Guidance material on ILS glide path curvature, alignment and siting, relevant to the selection of the height of the ILS reference datum is given in 2.4 of Attachment C and Figure C-5.

3.1.5.1.3 The downward extended straight portion of the ILS glide path shall pass through the ILS reference datum at a height ensuring safe guidance over obstructions and also safe and efficient use of the runway served.

3.1.5.1.4 The height of the ILS reference datum for Facility Performance Categories II and III — ILS shall be 15 m (50 ft). A tolerance of plus 3 m (10 ft) is permitted.

3.1.5.1.5 Recommendation.— The height of the ILS reference datum for Facility Performance Category I — ILS should be 15 m (50 ft). A tolerance of plus 3 m (10 ft) is permitted.

Note 1.— In arriving at the above height values for the ILS reference datum, a maximum vertical distance of 5.8 m (19 ft) between the path of the aircraft glide path antenna and the path of the lowest part of the wheels at the threshold was assumed.

For aircraft exceeding this criterion, appropriate steps may have to be taken either to maintain adequate clearance at threshold or to adjust the permitted operating minima.

Note 2.— Appropriate guidance material is given in 2.4 of Attachment C.

3.1.5.1.6 ***Recommendation***.— The height of the ILS reference datum for Facility Performance Category I — ILS used on short precision approach runway codes 1 and 2 should be 12 m (40 ft). A tolerance of plus 6 m (20 ft) is permitted.

3.1.5.2 Radio frequency

3.1.5.2.1 The glide path equipment shall operate in the band 328.6 MHz to 335.4 MHz. Where a single radio frequency carrier is used, the frequency tolerance shall not exceed 0.005 per cent. Where two carrier glide path systems are used, the frequency tolerance shall not exceed 0.002 per cent and the nominal band occupied by the carriers shall be symmetrical about he assigned frequency. With all tolerancesapplied, the frequency separation between the carriers shall not be less than 4 kHznor more than 32 kHz.

3.1.5.2.2 The emission from the glide path equipment shall be horizontally polarized.

3.1.5.2.3 For Facility Performance Category III — ILS glide path equipment, signals emanating from the transmitter shall contain no components which result in apparent glide path fluctuations of more than 0.02 DDM peak to peak in the frequency band 0.01 Hz to 10 Hz.

3.1.5.3 Coverage

3.1.5.3.1 The glide path equipment shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation in sectors of 8 degrees in azimuth on each side of the centre line of the ILS glide path, to a distance of at least18.5 km (10 NM) up to 1.75 θ and down to 0.45 θ above the horizontal or to such lower angle, down to 0.30 θ, as required to safeguard the promulgated glide path intercept procedure.

3.1.5.3.2 In order to provide the coverage for glide path performance specified in 3.1.5.3.1, the minimum field strength within this coverage sector shall be 400 microvolts per metre (minus 95 dBW/m2). For Facility Performance Category I glide paths, this field strength shall be provided down to a height of 30 m (100 ft) above the horizontal plane containing the threshold. For Facility Performance Categories II and III glide paths, this field strength shall be provided down to a height of 15 m (50 ft) above the horizontal plane containing the threshold.

Note 1.— The requirements in the foregoing paragraphs are based on the assumption that the aircraft is heading directly toward the facility.

Note 2.— Guidance material on significant airborne receiver parameters isgiven in 2.2 of Attachment C.

Note 3.— Material concerning reduction in coverage outside 8 degrees on each side of the centre line of the ILS glide path appears in 2.4 of Attachment C.

3.1.5.4 ILS glide path structure

3.1.5.4.1 For Facility Performance Category I — ILS glide paths, bends in the glide path shall not have amplitudes which exceed the following:

Zone	*Amplitude (DDM) (95% probability)*
Outer limit of coverage to ILS Point "C"	*0.03*

3.1.5.4.2 For Facility Performance Categories II and III — ILS glide paths, bends in the glide path shall not have amplitudes which exceed the following:

Zone	*Amplitude (DDM) (95% probability)*
Outer limit of coverage to ILS Point "A"	0.035

ILS Point “A” to ILS Point “B”	0.035 at ILS Point “A” decreasing at a linear rate to 0.023 at ILS Point “B”
ILS Point “B” to the ILS reference datum	0.023

Note 1.— The amplitudes referred to in 3.1.5.4.1 and 3.1.5.4.2 are the DDMs due to bends as realized on the mean ILS glide path correctly adjusted.

Note 2.— In regions of the approach where ILS glide path curvature is significant, bend amplitudes are calculated from the mean curved path, and not the downward extended straight line.

Note 3.— Guidance material relevant to the ILS glide path course structure is given in 2.1.4 of Attachment C.

3.1.5.5 Carrier modulation

3.1.5.5.1 The nominal depth of modulation of the radio frequency carrier due to each of the 90 Hz and 150 Hz tones shall be 40 per cent along the ILS glide path. The depth of modulation shall not deviate outside the limits of 37.5 per cent to42.5 per cent.

3.1.5.5.2 The following tolerances shall be applied to the frequencies of the modulating tones:

a) the modulating tones shall be 90 Hz and 150 Hz within 2.5 per cent for Facility Performance Category I — ILS;

b) the modulating tones shall be 90 Hz and 150 Hz within1.5 per cent for Facility Performance Category II — ILS;

c) the modulating tones shall be 90 Hz and 150 Hz within 1 per cent for Facility Performance Category III — ILS;

d) the total harmonic content of the 90 Hz tone shall not exceed 10 per cent: additionally, for Facility Performance Category III equipment, the second harmonic of the 90 Hz tone shall not exceed 5 per cent;

e) the total harmonic content of the 150 Hz tone shall not exceed 10 per cent.

3.1.5.5.2.1 Recommendation.— For Facility Performance Category I — ILS, the modulating tones should be 90 Hz and 150 Hz within plus or minus 1.5 per cent where practicable.

3.1.5.5.2.2 For Facility Performance Category III glide path equipment, the depth of amplitude modulation of the radio frequency carrier at the power supply frequency or harmonics, orat other noise frequencies, shall not exceed 1 per cent.

3.1.5.5.3 The modulation shall be phase-locked so that within the ILS half glide path sector, the demodulated 90 Hz and 150 Hz wave forms pass through zero in the same direction within:

a) for Facility Performance Categories I and II — ILS glide paths: 20 degrees;

b) for Facility Performance Category III — ILS glide paths: 10 degrees, of phase relative to the 150 Hz component, every half cycle of the combined 90 Hz and 150 Hz wave form.

Note 1.— The definition of phase relationship in this manner is not intended to imply a requirement for measurement of phase within the ILS half glide path sector.

Note 2.— Guidance material relating to such measures is given at Figure C-6 of Attachment C.

3.1.5.5.3.1 With two-frequency glide path systems, 3.1.5.5.3 shall apply to each carrier. In addition, the 90 Hz modulating tone of one carrier shall be phase-locked to the 90 Hz modulating tone of the other carrier so that the demodulated wave forms pass through zero in the same direction within:

a) for Categories I and II — ILS glide paths: 20 degrees;

b) for Category III — ILS glide paths: 10 degrees, of phase relative to 90 Hz. Similarly, the 150 Hz tones of the two carriers shall be phase-locked so that the demodulated wave forms pass through zero in the same direction, within:

1) for Categories I and II — ILS glide paths: 20 degrees;

2) for Category III — ILS glide paths: 10 degrees, of phase relative to 150 Hz.

3.1.5.5.3.2 Alternative two-frequency glide path systems that employ audio phasing different from the normal in-phase condition described in 3.1.5.5.3.1 shall be permitted. In these alternative systems, the 90 Hz to 90 Hz phasing and the 150 Hz to 150 Hz phasing shall be adjusted to their nominal values to within limits equivalent to those stated in 3.1.5.5.3.1.

Note.— This is to ensure correct airborne receiver operation within the glide path sectorwhere the two carrier signal strengths are approximately equal.

3.1.5.5.4 Recommendation.— Undesired frequency and phase modulation on ILS glide path radio frequency carriers that can affect the displayed DDM values in glide path receivers should be minimized to the extent practical.

Note.— Relevant guidance material is given in 2.15 of Attachment C.

3.1.5.6 Displacement sensitivity

3.1.5.6.1 For Facility Performance Category I — ILS glide paths, the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at angular displacements above and below the glide path between 0.07 θand 0.14 θ.

Note.— The above is not intended to preclude glide path systems which inherently have asymmetrical upper and lower sectors.

3.1.5.6.2 Recommendation.— For Facility Performance Category I — ILS glide paths, the nominal angular displacement sensitivity should correspond to a DDM of 0.0875at an angular displacement below the glide path of 0.12 θ with a tolerance of plus or minus 0.02 θ. The upper and lower sectors should be as symmetrical as practicable within the limits specified in 3.1.5.6.1.

3.1.5.6.3 For Facility Performance Category II — ILS glide paths, the angular displacement sensitivity shall be as symmetrical as practicable. The nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at an angular displacement of:

a) 0.12 θ below path with a tolerance of plus or minus 0.02 θ;

b) 0.12 θabove path with a tolerance of plus 0.02 θand minus 0.05 θ

3.1.5.6.4 For Facility Performance Category III — ILS glide paths, the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 atangular displacements above and below the glide path of 0.12 θwith a tolerance of plus or minus 0.02 θ.

3.1.5.6.5 The DDM below the ILS glide path shall increase smoothly for decreasing angle until a value of 0.22 DDM is reached. This value shall be achieved at an angle not less than 0.30 θabove the horizontal. However, if it is achieved at an angle above 0.45 θ, the DDM value shall not be less than 0.22 at least down to 0.45 θor to such lower angle, down to 0.30 θ, as required to safeguard the promulgated glide path intercept procedure.

Note.— The limits of glide path equipment adjustment are pictorially represented in Figure C-11 of Attachment C.

3.1.5.6.6 For Facility Performance Category I — ILS glide paths, the angular displacement sensitivityshall be adjusted and maintained within plus or minus 25 per cent of the nominal value selected.

3.1.5.6.7 For Facility Performance Category II — ILS glide paths, the angular displacement sensitivity shall be adjusted and maintained within plus or minus 20 per cent of the nominal value selected.

3.1.5.6.8 For Facility Performance Category III — ILS glide paths, the angular displacement sensitivity shall be adjusted and maintained within plus or minus 15 per cent of the nominal value selected.

3.1.5.7 Monitoring

3.1.5.7.1 The automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the periods specifiedin 3.1.5.7.3.1 if any of the following conditions persist:

a) shift of the mean ILS glide path angle equivalent to more than minus 0.075 θto plus 0.10 θfrom θ;

b) in the case of ILS glide paths in which the basic functions are provided by the use of a single-frequency system, a reduction of power output to less than 50 per cent of normal, provided the glide path continues to meet the requirements of 3.1.5.3, 3.1.5.4 and 3.1.5.5;

c) in the case of ILS glide paths in which the basic functions are provided by the use of two-frequency systems, a reduction of power output for either carrier to less than 80 per cent of normal, except that a greater reduction to between 80 per cent and 50 per cent of normal may be permitted, provided the glide path continues to meet the requirements of 3.1.5.3, 3.1.5.4 and 3.1.5.5;

Note.— It is important to recognize that a frequency change resulting in a loss of the frequency difference specified in 3.1.5.2.1 may produce a hazardous condition. This problem is of greater operational significance for Categories II and III installations. As necessary, this problem can be dealt with through special monitoring provisions or highly reliable circuitry.

d) for Facility Performance Category I — ILS glide paths, a change of the angle between the glide path and the line below the glide path (150 Hz predominating) at which a DDM of 0.0875 is realized by more than the greater of:

i) plus or minus 0.0375 θ; or

ii) an angle equivalent to a change of displacement sensitivity to a value differing by 25 per cent from the nominal value;

e) for Facility Performance Categories II and III — ILS glide paths, a change of displacement sensitivity to a value differing by more than 25 per cent from the nominal value;

f) lowering of the line beneath the ILS glide path at which a DDM of 0.0875 is realized to less than 0.7475 θ from horizontal;

g) a reduction of DDM to less than 0.175 within the specified coverage below the glide path sector.

Note 1.— The value of 0.7475 θ from horizontal is intended to ensure adequate obstacle clearance. This value was derived from other parameters of the glide path and monitor specification. Since the measuring accuracy to four significant figures is not intended, the value of 0.75 θ may be used as a monitor limit for this purpose. Guidance on obstacle clearance criteria is given in the Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS) (Doc 8168).

Note 2.— Subparagraphs f) and g) are not intended to establish a requirement for a separate monitor to protect against deviation of the lower limits of the half-sector below 0.7475 θ from horizontal.

Note 3.— At glide path facilities where the selected nominal angular displacement sensitivity corresponds to an angle below the ILS glide path which is close to or at the maximum limits specified in 3.1.5.6, it may be necessary to adjust the monitor operating limits to protect against sector deviations below 0.7475 θfrom horizontal.

Note 4.— Guidance material relating to the condition described in g) appears in Attachment C, 2.4.12.

3.1.5.7.2 Recommendation.— Monitoring of the ILS glide path characteristics to smaller tolerances should be arranged in those cases where operational penalties would otherwise exist.

3.1.5.7.3 The total period of radiation, including period(s) of zero radiation, outside the performance limits specified in

3.1.5.7.1 shall be as short as practicable, consistent with the need for avoiding interruptions of the navigation service provided by the ILS glide path.

3.1.5.7.3.1 The total period referred to under 3.1.5.7.3 shall not exceed under any circumstances:

6 seconds for Category I — ILS glide paths;

2 seconds for Categories II and III — ILS glide paths.

Note 1.— The total time periods specified are never-to-be-exceeded limits and are intended to protect aircraft in the final stages of approach against prolonged or repeated periods of ILS glide path guidance outside the monitor limits. For this reason, they include not only the initial period of outside tolerance operation but also the total of any or all periods of outside tolerance radiation, including periods of zero radiation, which might occur during action to restore service, for example, in the course of consecutive monitor functioning and consequent changeovers to glide path equipments or elements thereof.

Note 2.— From an operational point of view, the intention is that no guidance outside the monitor limits be radiated after the time periods given, and that no further attempts be made to restore service until a period in the order of 20 secondshas elapsed.

3.1.5.7.3.2 Recommendation.— Where practicable, the total period specified under 3.1.5.7.3.1 for Categories II and III — ILS glide paths should not exceed 1 second.

3.1.5.7.4 Design and operation of the monitor system shall be consistent with the requirement that radiation shall cease and a warning shall be provided at the designated remote control points in the event of failure of the monitor system itself.

Note.— Guidance material on the design and operation of monitor systems is given in 2.1.7 of Attachment C.

3.1.5.8 Integrity and continuity of service requirements

3.1.5.8.1 The probability of not radiating false guidance signals shall not be less than 1 – 0.5 × 10–9in any one landing for Facility Performance Categories II and III glide paths.

3.1.5.8.2 **Recommendation**.— The probability of not radiating false guidance signals should not be less than 1 – 1.0 × 10–7in any one landing for Facility Performance Category I glide paths.

3.1.5.8.3 The probability of not losing the radiated guidance signal shall be greater than 1 – 2 × 10–6in any period of 15 seconds for Facility Performance Categories II and III glide paths (equivalent to 2 000 hours mean time between outages).

3.1.5.8.4 Recommendation.— The probability of not losing the radiated guidance signal should exceed 1 – 4 × 10–6in any period of 15 seconds for Facility Performance Category I glide paths (equivalent to 1 000 hours mean time between outages).

Note.— Guidance material on integrity and continuity of service is given in 2.8 of Attachment C.

3.1.6 Localizer and glide path frequency pairing

3.1.6.1 The pairing of the runway localizer and glide path transmitter frequencies of an instrument landing system shall be taken from the following list in accordance with the provisions of Volume V, Chapter 4, 4.2:

Localizer (MHz)	Glide path (MHz)	Localizer (MHz)	Glide path (MHz)
108.1	334.7	110.1	334.4
108.15	334.55	110.15	334.25
108.3	334.1	110.3	335.0
108.35	333.95	110.35	334.85
108.5	329.9	110.5	329.6
108.55	329.75	110.55	329.45
108.7	330.5	110.7	330.2
108.75	330.35	110.75	330.05
108.9	329.3	110.9	330.8
108.95	329.15	110.95	330.65
109.1	331.4	111.1	331.7
109.15	331.25	111.15	331.55
109.3	332.0	111.3	332.3
109.	35 331.85	111.35	332.15
109.5	332.6	111.5	332.9
109.55	332.45	111.55	332.75
109.7	333.2	111.7	333.5
109.75	333.05	111.75	333.35
109.9	333.8	111.9	331.1

109.95	333.65	111.95	330.95

3.1.6.1.1 In those regions where the requirements for runway localizer and glide path transmitter frequencies of an instrument landing system do not justify more than 20 pairs, they shall be selected sequentially, as required, from the following list:

Sequence number	Localizer (MHz)	Glide path (MHz)
1	110.3	335.0
2	109.9	333.8
3	109.5	332.6
4	110.1	334.4
5	109.7	333.2
6	109.3	332.0
7	109.1	331.4
8	110.9	330.8
9	110.7	330.2
10	110.5	329.6
11	108.1	334.7
12	108.3	334.1
13	108.5	329.9
14	108.7	330.5
15	108.9	329.3
16	111.1	331.7
17	111.3	332.3
18	111.5	332.9
19	111.7	333.5
20	111.9	331.1

3.1.6.2 Where existing ILS localizers meeting national requirements are operating on frequencies ending in even tenths of a megahertz, they shall be reassigned frequencies, conforming with 3.1.6.1 or 3.1.6.1.1 as soon as practicable and may continue operating on their present assignments only until this reassignment can be effected.

3.1.6.3 Existing ILS localizers in the international service operating on frequencies ending in odd tenths of a megahertz shall not be assigned new frequencies ending in odd tenths plus one twentieth of a megahertz except where, by regional agreement, general use may be made of any of the channels listed in 3.1.6.1 (see Volume V, Chapter 4, 4.2).

3.1.7 VHF marker beacons

3.1.7.1 General

a) There shall be two marker beacons in each installation except as provided in 3.1.7.6.5. A third marker beacon may be added whenever, in the opinion of the Competent Authority, an additional beacon is required because of operational procedures at a particular site.

b) The marker beacons shall conform to the requirements prescribed in 3.1.7. When the installation comprises only two marker beacons, the requirements applicable to the middle marker and to the outer marker shall be complied with.

c) The marker beacons shall produce radiation patterns to indicate predetermined distance from the threshold along the ILS glide path.

3.1.7.1.1 When a marker beacon is used in conjunction with the back course of a localizer, it shall conform with the marker beacon characteristics specified in 3.1.7.

3.1.7.1.2 Identification signals of marker beacons used in conjunction with the back course of a localizer shall be clearly distinguishable from the inner, middle and outer marker beacon identifications, as prescribed in 3.1.7.5.1.

3.1.7.2 Radio frequency

3.1.7.2.1 The marker beacons shall operate at 75 MHz with a frequency tolerance of plus or minus 0.005 per cent and shall utilize horizontal polarization.

3.1.7.3 Coverage

3.1.7.3.1 The marker beacon system shall be adjusted to provide coverageover the following distances, measured on

the ILS glide path and localizer course line:

a) inner marker (where installed):150 m plus or minus 50 m (500 ft plus or minus 160 ft);

b) middle marker: 300 m plus or minus 100 m (1 000 ft plus or minus 325 ft);

c) outer marker: 600 m plus or minus 200 m (2 000 ft plus or minus 650 ft).

3.1.7.3.2 The field strength at the limits of coverage specified in 3.1.7.3.1 shall be 1.5 millivolts per metre (minus 82 dBW/m2). In addition, the field strength within the coverage area shall rise to at least 3.0 millivolts per metre (minus 76 dBW/m2).

Note 1.— In the design of the ground antenna, it is advisable to ensure that an adequate rate of change of field strength is provided at the edges of coverage. It is also advisable to ensure that aircraft within the localizer course sector will receive visual indication.

Note 2.— Satisfactory operation of a typical airborne marker installation will be obtained if the sensitivity is so adjusted that visual indication will be obtained when the field strength is 1.5 millivolts per metre (minus 82 dBW/m2).

3.1.7.4 Modulation

3.1.7.4.1 The modulation frequencies shall be as follows:

a) inner marker (when installed): 3 000 Hz;

b) middle marker:1 300 Hz;

c) outer marker:400 Hz.

The frequency tolerance of the above frequencies shall be plusor minus 2.5 per cent, and the total harmonic content of each of the frequencies shall not exceed 15 per cent.

3.1.7.4.2 The depth of modulation of the markers shall be 95 per cent plus or minus 4 per cent.

3.1.7.5 Identification

3.1.7.5.1 The carrier energy shall not be interrupted. The audio frequency modulation shall be keyed as follows:

a) inner marker (when installed):6 dots per second continuously;

b) middle marker: a continuous series of alternate dots and dashes, the dashes keyed at the rate of 2 dashes per second, and the dots at the rate of 6 dots per second;

c) outer marker: 2 dashes per second continuously.

These keying rates shall be maintained to within plus or minus 15 per cent.

3.1.7.6 Siting

3.1.7.6.1 The inner marker, when installed, shall be located so as to indicate in low visibility conditions the imminence of arrival at the runway threshold.

3.1.7.6.1.1 **Recommendation.—** If the radiation pattern is vertical, the inner marker, when installed, should be located between 75 m (250 ft) and 450 m (1 500 ft) from the threshold and at not more than 30 m (100 ft) from the extended centre line of the runway.

Note 1.— It is intended that the inner marker pattern should intercept the downward extended straight portion of the nominal ILS glide path at the lowest decision height applicable in Category II operations.

Note 2.— Care must be exercised in siting the inner marker to avoid interference between the inner and middle markers. Details regarding the siting of inner markers are contained in Attachment C, 2.10.

3.1.7.6.1.2 **Recommendation.**— If the radiation pattern is other than vertical, the equipment should be located so as to produce a field within the course sector and ILS glide path sector that is substantially similar to that produced by an antenna radiating a vertical pattern and located as prescribed in 3.1.7.6.1.1.

3.1.7.6.2 The middle marker shall be located so as to indicate the imminence, in low visibility conditions, of visual approach guidance.

3.1.7.6.2.1 **Recommendation.—** If the radiation pattern is vertical, the middle marker should be located 1 050 m (3 500 ft) plus or minus 150 m (500 ft), from the landing threshold at the approach end of the runway and at not more than 75 m (250 ft) from the extended centre line of the runway.

Note.— See Attachment C, 2.10, regarding the siting of inner and middle marker beacons.

3.1.7.6.2.2 Recommendation.— If the radiation pattern is other than vertical, the equipment should be located so as to produce a field within the course sector and ILS glide path sector that is substantially similar to that produced by an antenna radiating a vertical pattern and located as prescribed in 3.1.7.6.2.1.

3.1.7.6.3 The outer marker shall be located so as to provide height, distance and equipment functioning checks to aircraft on intermediate and final approach.

3.1.7.6.3.1 **Recommendation.**— The outer marker should be located 7.2 km(3.9 NM) from the threshold except that, where for topographical or operational reasons this distance is not practicable, the outer marker may be located between 6.5 and 11.1 km (3.5 and 6 NM) from the threshold.

3.1.7.6.4 Recommendation.— If the radiation pattern is vertical, the outer marker should be not more than 75 m (250 ft) from the extended centre line of the runway. If the radiation pattern is other than vertical, the equipment should be located so as to produce a field within the course sector and ILS glide path sector that is substantially similar to that produced by an antenna radiating a vertical pattern.

3.1.7.6.5 The positions of marker beacons, or where applicable, the equivalent distance(s) indicated by the DME when used as an alternative to part or all of the marker beacon component of the ILS, shall be published in accordance with the provisions of Annex 15.

3.1.7.6.5.1 When so used, the DME shall provide distance information operationally equivalent to that furnished by marker beacon(s).

3.1.7.6.5.2 When used as an alternative for the middle marker, the DME shall be frequency paired with the ILS localizer and sited so as to minimize the error in distance information.

3.1.7.6.5.3 The DME in 3.1.7.6.5 shall conform to the specification in 3.5.

3.1.7.7 Monitoring

3.1.7.7.1 Suitable equipment shall provide signals for the operation of an automatic monitor. The monitor shall transmit a warning to a control point if either of the following conditions arise:

a) failure of the modulation or keying;

b) reduction of power output to less than 50 per cent of normal.

3.1.7.7.2 Recommendation.— For each marker beacon, suitable monitoring equipment should be provided which will indicate at the appropriate location a decrease of the modulation depth below 50 per cent.

3.2 Specification for precision approach radar system

Note.— Slant distances are used throughout this specification.

3.2.1 The precision approach radar system shall comprise the following elements:

3.2.1.1 The precision approach radar element (PAR).

3.2.1.2 The surveillance radar element (SRE).

3.2.2 When the PAR only is used, the installation shall be identified by the term PAR or precision approach radar and not by the term "precision approach radar system".

Note.— Provisions for the recording and retention of radar data are contained in Annex 11, Chapter 6.

3.2.3 The precision approach radar element (PAR)

3.2.3.1 Coverage

3.2.3.1.1 The PAR shall be capable of detecting and indicating the position of an aircraft of 15 m2echoing area or larger, which is within a space bounded by a 20-degree azimuth sector and a 7-degreeelevation sector, to a distance of at least 16.7 km (9 NM) from its respective antenna.

Note.— For guidance in determining the significance of the echoing areas of aircraft, the following table is included:

private flyer (single-engined): 5 to 10 m2;

small twin-engined aircraft: from 15 m2;

medium twin-engined aircraft: from 25 m2;

four-engined aircraft: from 50 to 100 m2.

3.2.3.2 Siting

3.2.3.2.1 The PAR shall be sited and adjusted so that it gives complete coverage of a sector with its apex at a point 150 m (500 ft) from the touchdown in the direction of the stop end of the runway and extending plus or minus 5 degrees about the runway centre line in azimuth and from minus 1 degree to plus 6 degrees in elevation.

Note 1.— Paragraph 3.2.3.2.1 can be met by siting the equipment with a set-back from the touchdown, in the direction of the stop end of the runway, of 915 m (3 000 ft) or more, for an offset of 120 m (400 ft) from the runway centre line, or of 1 200 m (4 000 ft) or more, for an offset of 185 m (600 ft) when the equipment is aligned to scan plus or minus 10 degrees about the centre line of the runway. Alternatively, if the equipment is aligned to scan 15 degrees to one side and 5 degrees tothe other side of the centre line of the runway, then the minimum set-back *can be reduced to 685 m (2 250 ft) and 915 m (3 000 ft) for offsets of 120 m (400 ft) and 185 m (600 ft) respectively.*

Note 2.— Diagrams illustrating the siting of PAR are given in Attachment C (Figures C-14 to C-17 inclusive).

3.2.3.3 Accuracy

3.2.3.3.1 Azimuth accuracy. Azimuth information shall be displayed in such a manner that left-right deviation from the on-course line shall be easily observable. The maximum permissible error with respect to the deviation from the on-course line shall be either 0.6 per cent of the distance from the PAR antenna plus 10 per cent of the deviation from the on-course line or 9 m (30 ft), whichever is greater. The equipment shall be so sited that the error at the touchdown shall not exceed 9 m (30 ft). The equipment shall be so aligned and adjusted that the displayed error at the touchdown shall be a minimum and shall not exceed 0.3 per cent of the distance from the PAR antenna or 4.5 m (15 ft), whichever is greater. It shall be possible to resolve the positions of two aircraft which are at 1.2 degrees in azimuth of one another.

3.2.3.3.2 Elevation accuracy. Elevation information shall be displayed in such a manner that up-down deviation from the descent path for which the equipment is set shall be easily observable. The maximum permissible error with respect to the deviation from the on-course line shall be 0.4 per cent of the distance from the PAR antenna plus 10 per cent of the actual linear displacement from the chosen descent path or 6 m (20 ft), whichever is greater. The equipment shall be so sited that theerror at the touchdown shall not exceed 6 m (20 ft). The equipment shall be so aligned and adjusted that the displayed error atthe touchdown shall be a minimum and shall not exceed 0.2 per cent of the distance from the PAR antenna or 3 m (10 ft), whichever is greater. It shall be possible to resolve the positions of two aircraft that are at 0.6 degree in elevation of one another.

3.2.3.3.3 Distance accuracy. The error in indication of the distance from the touchdown shall not exceed 30 m (100 ft) plus 3 per cent of the distance from the touchdown. It shall be possible to resolve the positions of two aircraft which are at 120 m (400 ft) of one another on the same azimuth.

3.2.3.4 Information shall be made available to permit the position of the controlled aircraft to be established with respect to other aircraft and obstructions. Indications shall also permit appreciation of ground speed and rate of departure from or approach to the desired flight path.

3.2.3.5 Information shall be completely renewed at least once every second.

3.2.4.1 A surveillance radar used as the SRE of a precision approach radar system shall satisfy at least the following broad performance requirements.

3.2.4.2 Coverage

3.2.4.2.1 The SRE shall be capable of detecting aircraft of 15 m2 echoing area and larger, which are in line of sight of the antenna within a volume described as follows: The rotation through 360 degrees about the antenna of a vertical plane surface bounded by a line at an angle of 1.5 degrees above the horizontal plane of the antenna, extending from the antenna to 37 km (20 NM); by a vertical line at 37 km (20 NM) from the intersection with the 1.5-degree line up to 2 400 m (8 000 ft) above the level of the antenna; by a horizontal line at 2 400 m (8 000 ft) from 37 km (20 NM) back towards the antenna to the intersection with a line from the antenna at 20 degrees above the horizontal plane of the antenna, and by a 20-degree line from the intersection with the 2 400 m (8 000 ft) line to the antenna.

3.2.4.2.2 **Recommendation**.— Efforts should be made in development to increasethe coverage on an aircraft of 15 m2echoing area to at least the volume obtained by amending 3.2.4.2.1 with the following substitutions:

– *for1.5 degrees, read 0.5 degree;*

– *for 37 km (20 NM), read 46.3 km (25 NM);*

– *for 2 400 m (8 000 ft), read 3 000 m (10 000 ft);*

– *for 20 degrees, read 30 degrees.*

Note.— A diagram illustrating the vertical coverage of SRE is given in Attachment C (Figure C-18).

3.2.4.3 Accuracy

3.2.4.3.1 Azimuth accuracy. The indication of position in azimuth shall be within plus or minus 2 degrees of the true position. It shall be possible to resolve the positions of two aircraft which are at 4 degrees of azimuth of one another.

3.2.4.3.2 Distance accuracy. The error in distance indication shall not exceed 5 per cent of true distance or 150 m (500 ft), whichever is the greater. It shall be possible to resolve the positions of two aircraft that are separated by a distance of 1 per cent of the true distance from the point of observation or 230 m (750 ft), whichever is the greater.

3.2.4.3.2.1 **Recommendation**.— The error in distance indication should not exceed 3 per cent of the true distance or 150 m (500 ft), whichever is the greater.

3.2.4.4 The equipment shall be capable of completely renewing the information concerning the distance and azimuth of any aircraft within the coverage of the equipment at least once every 4 seconds.

3.2.4.5 **Recommendation.**— Efforts should be made to reduce, as far as possible, the disturbance caused by ground echoes or echoes from clouds and precipitation.

3.3 Specification for VHF omnidirectional radio range (VOR)

3.3.1 General

3.3.1.1 The VOR shall be constructed and adjusted so that similar instrumental indications in aircraft represent equal clockwise angular deviations (bearings), degree for degree from magnetic North as measured from the location of the VOR.

3.3.1.2 The VOR shall radiate a radio frequency carrier with which are associated two separate 30 Hz modulations. One of these modulations shall be such that its phase is independent of the azimuth of the point of observation (reference phase). The other modulation (variable phase) shall be such that its phase at the point of observation differs from that of thereference phase by an angle equal to the bearing of the point of observation with respect to the VOR.

3.3.1.3 The reference and variable phase modulations shall be in phase along the reference magnetic meridian through the station.

Note.— The reference and variable phase modulations are in phase when the maximum value of the sum of the radio frequency carrier and the sideband energy due to the variable phase modulation occurs at the same time as the highest instantaneous frequency of the reference phase modulation.

3.3.2 Radio frequency

3.3.2.1 The VOR shall operate in the band 111.975 MHz to 117.975 MHz except that frequencies in the band 108 MHz to 111.975 MHz may be used when, in accordance with the provisions of Volume V, Chapter 4, 4.2.1 and 4.2.3.1, the use of such frequencies is acceptable. The highest assignable frequency shall be 117.950 MHz. The channel separation shall be in increments of 50 kHz referred to the highest assignable frequency. In areas where 100 kHz or 200 kHz channel spacing is in general use, the frequency tolerance of the radio frequency carrier shall be plus or minus 0.005 per cent.

3.3.2.2 The frequency tolerance of the radio frequency carrier of all new installations implemented after 23 May 1974 in areas where 50 kHz channel spacing is in use shall be plus or minus 0.002 per cent.

3.3.2.3 In areas where new VOR installations are implemented and are assigned frequencies spaced at 50 kHz from existing VORs in the same area, priority shall be given to ensuring that the frequency tolerance of the radio frequency carrierof the existing VORs is reduced to plus or minus 0.002 per cent.

3.3.3 Polarization and pattern accuracy

3.3.3.1 The emission from the VOR shall be horizontally polarized. The vertically polarized component of the radiation shall be as small as possible.

Note.— It is not possible at present to state quantitatively the maximum permissible magnitude of the vertically polarized component of the radiation from the VOR. (Information is provided in the Manual on Testing of Radio Navigation Aids (Doc 8071) as to flight checks that can be carried out to determine the effects of vertical polarization on the bearing accuracy.)

3.3.3.2 The ground station contribution to the error in the bearing information conveyed by the horizontally polarized radiation from the VOR for all elevation angles between 0 and 40 degrees, measured from the centre of the VOR antenna system, shall be within plus or minus 2 degrees

3.3.4.1 The VOR shall provide signals such as to permit satisfactory operation of a typical aircraft installation at the levels and distances required for operational reasons, and up to an elevation angle of 40 degrees.

3.3.4.2 **Recommendation.—** The field strength or power density in space of VOR signals required to permit satisfactory operation of a typical aircraft installation at the minimum service level at the maximum specified service radius should be 90 microvolts per metre or minus 107 dBW/m2.

Note.— Typical equivalent isotropically radiated powers (EIRPs) to achieve specified ranges are contained in 3.1 of Attachment C. The definition of EIRP is contained in 3.5.1.

3.3.5 Modulations of navigation signals

3.3.5.1 The radio frequency carrier as observed at any point in space shall be amplitude modulated by two signals as follows:

a) a subcarrier of 9 960 Hz of constant amplitude, frequency modulated at 30 Hz:

1) for the conventional VOR, the 30 Hz component of thisFM subcarrier is fixed without respect to azimuth and is

termed the “reference phase” and shall have a deviation ratio of 16 plus or minus 1 (i.e. 15 to 17);

2) for the Doppler VOR, the phase of the 30 Hz component varies with azimuth and is termed the “variable phase” and shall have a deviation ratio of 16 plus or minus 1 (i.e. 15 to 17) when observed at any angle of elevation up to 5 degrees, with a minimum deviation ratio of 11 when observed at any angle of elevation above 5 degrees and up to 40 degrees;

b) a 30 Hz amplitude modulation component:

1) for the conventional VOR, this component results from a rotating field pattern, the phase of which varies with azimuth, and is termed the “variable phase”;

2) for the Doppler VOR, this component, of constant phase with relation to azimuth and constant amplitude, is radiated omnidirectionally and is termed the “reference phase”.

3.3.5.2 The nominal depth of modulation of the radio frequency carrier due to the 30 Hz signal or the subcarrier of 9 960 Hz shall be within the limits of 28 per cent and 32 per cent.

Note.— This requirement applies to the transmitted signal observed in the absence of multipath.

3.3.5.3 The depth of modulation of the radio frequency carrier due to the 30 Hz signal, as observed at any angle of elevation up to 5 degrees, shall be within the limits of 25 to 35 per cent. The depth of modulation of the radio frequency carrier due to the 9 960 Hz signal, as observed at any angle of elevation up to 5 degrees, shall be within the limits of 20 to 55 per cent on facilities without voice modulation, and within the limits of 20 to 35 per cent on facilities with voice modulation.

Note.— When modulation is measured during flight testing under strong dynamic multipath conditions, variations in the received modulation percentages are to be expected. Short-term variations beyond these values may be acceptable. The Manual on Testing of Radio Navigation Aids(Doc 8071) contains additional information on the application of airborne modulation tolerances.

3.3.5.4 The variable and reference phase modulation frequencies shall be 30 Hz within plus or minus 1 per cent.

3.3.5.5 The subcarrier modulation mid-frequency shall be 9 960 Hz within plus or minus 1 per cent

3.3.5.6

a) For the conventional VOR, the percentage of amplitude modulation of the 9 960 Hz subcarrier shall not exceed 5 per cent.

b) For the Doppler VOR, the percentage of amplitude modulation of the 9 960 Hz subcarrier shall not exceed 40 per cent when measured at a point at least 300 m (1 000 ft) from the VOR.

3.3.5.7 Where 50 kHz VOR channel spacing is implemented, the sideband level of the harmonics of the 9 960 Hz component in the radiated signal shall not exceed the following levels referred to the level of the 9 960 Hz sideband:

Subcarrier	Level
9 960 Hz	0 dB reference
2nd harmonic	–30 dB
3rd harmonic	–50 dB
4th harmonic and above	–60 dB

3.3.6 Voice and identification

3.3.6.1 If the VOR provides a simultaneous communication channel ground-to-air, it shall be on the same radio frequency carrier as used for the navigational function. The radiation on this channel shall be horizontally polarized.

3.3.6.2 The peak modulation depth of the carrier on the communication channel shall not be greater than 30 per cent.

3.3.6.3 The audio frequency characteristics of the speech channel shall be within 3 dB relative to the level at 1 000 Hz over the range 300 Hz to 3 000 Hz.

3.3.6.4 The VOR shall provide for the simultaneous transmission of a signal of identification on the same radio frequency carrier as that used for the navigational function. The identification signal radiation shall be horizontally polarized.

3.3.6.5 The identification signal shall employ the International Morse Code and consist of two or three letters. It shall be sent at a speed corresponding to approximately 7 words per minute. The signal shall be repeated at least once every 30 seconds and the modulation tone shall be 1 020 Hz within plus or minus 50 Hz.

3.3.6.5.1 **Recommendation.—** The identification signal should be transmitted at least three times each 30 seconds, spaced equally within that time period. One of these identification signals may take the form of a voice identification.

Note.— Where a VOR and DME are associated in accordance with 3.5.2.5, the identification provisions of 3.5.3.6.4 influence the VOR identification.

3.3.6.6 The depth to which the radio frequency carrier is modulated by the code identification signal shall be close to, but not in excess of 10 per cent except that, where a communication channel is not provided, it shall be permissible to increase the modulation by the code identification signal to a value not exceeding 20 per cent.

3.3.6.6.1 **Recommendation.—** If the VOR provides a simultaneous communication channel ground-to-air, the modulation depth of the code identification signal should be 5 plus or minus 1 per cent in order to provide a satisfactory voice quality.

3.3.6.7 The transmission of speech shall not interfere in any way with the basic navigational function. When speech is being radiated, the code identification shall not be suppressed.

3.3.6.8 The VOR receiving function shall permit positive identification of the wanted signal under the signal conditions encountered within the specified coverage limits, and with the modulation parameters specified at 3.3.6.5, 3.3.6.6 and 3.3.6.7.

3.3.7 Monitoring

3.3.7.1 Suitable equipment located in the radiation field shall provide signals for the operation of an automatic monitor. The monitor shall transmit a warning to a control point, and either remove the identification and navigation components from the carrier or cause radiation to cease if any one or a combination of the following deviations from established conditions arises:

a) a change in excess of 1 degree at the monitor site of the bearing information transmitted by the VOR;

b) a reduction of 15 per cent in the modulation components of the radio frequency signals voltage level at the monitor of either the subcarrier, or 30 Hz amplitude modulation signals, or both.

3.3.7.2 Failure of the monitor itself shall transmit a warning to a control point and either:

a) remove the identification and navigation components from the carrier; or

b) cause radiation to cease.

Note. — Guidance material on VOR appears in Attachment C, 3, and Attachment E.

3.3.8 Interference immunity performance for VOR receiving systems

3.3.8.1 The VOR receiving system shall provide adequate immunity to interference from two signal, third-order intermodulation products caused by VHF FM broadcast signals having levels in accordance with the following:

$$2N1 + N2 + 72 \leq 0$$

for VHF FM sound broadcasting signals in the range 107.7 – 108.0 MHz

and 12 232420log00.4f

NN Δ ( ) + +− ≤ | | ( )

for VHF FM sound broadcasting signals below 107.7 MHz,

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two-signal, third-order

intermodulation product on the desired VOR frequency.

N1 and N2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VOR receiver input. Neither level shall exceed the desensitization criteria set forth in 3.3.8.2.

Δf = 108.1 – f1, where f1is the frequency of N1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

3.3.8.2 The VOR receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels in accordance with the following table:

Frequency (MHz)	Maximum level of unwanted signal at (dBm)	Frequency receiver input
88-102	+15	
104	+10	
106	+ 5	
107.9	–10	

Note 1.— The relationship is linear between adjacent points designated by the above frequencies.

Note 2.— Guidance material on immunity criteria to be used for the performance quoted in 3.3.8.1 and 3.3.8.2 is contained in Attachment C, 3.6.5.

3.4 Specification for non-directional radio beacon (NDB)

3.4.1 Definitions

Note.— In Attachment C, guidance is given on the meaning and application of rated coverage and effective coverage and on coverage of NDBs.

Average radius of rated coverage. The radius of a circle having the same area as the rated coverage.

Effective coverage. The area surrounding an NDB within which bearings can be obtained with an accuracy sufficient for the nature of the operation concerned.

Locator. An LF/MF NDB used as an aid to final approach.

Note.— A locator usually has an average radius of rated coverage of between 18.5 and 46.3 km (10 and 25 NM).

Rated coverage. The area surrounding an NDB within which the strength of the vertical field of the ground wave exceeds the minimum value specified for the geographical area in which the radio beacon is situated.

Note.— The above definition is intended to establish a method of rating radio beacons on the normal coverage to be expected in the absence of sky wave transmission and/or anomalous propagation from the radio beacon concerned or interference from other LF/MF facilities, but taking into account the atmospheric noise in the geographical area concerned.

3.4.2 Coverage

3.4.2.1 **Recommendation.—** The minimum value of field strength in the rated coverage of an NDB should be 70°microvolts per metre.

Note 1.— Guidance on the field strengths required particularly in the latitudes between 30°N and 30°S is given in 6.1 of Attachment C, and the relevant ITU provisions are given in Chapter VIII, Article 35, Section IV, Part B of the Radio Regulations.

Note 2.— The selection of locations and times at which the field strength is measured is important in order to avoid abnormal results for the locality concerned; locations on air routes in the area around the beacon are operationally most significant.

3.4.2.2 All notifications or promulgations of NDBs shall be based upon the average radius of the rated coverage.

Note 1.— In classifying radio beacons in areas where substantial variations in rated coverage may occur diurnally and seasonally, such variations should be taken into account.

Note 2.— Beacons having an average radius of rated coverage of between 46.3 and 278 km (25 and 150 NM) may be designated by the nearest multiple of 46.3 km (25 NM) to the average radius of rated coverage, and beacons of rated coverage over 278 km (150 NM) to the nearest multiple of 92.7 km (50 NM).

3.4.2.3 **Recommendation**.—Where the rated coverage of an NDB is materially different in various operationally significant sectors, its classification should be expressed in terms of the average radius of rated coverage and the angular limits of each sector as follows:

Radius of coverage of sector/angular limits of sector expressed as magnetic bearing clockwise from the beacon.

Where it is desirable to classify an NDB in such a manner, the number of sectors should be kept to a minimum and preferably should not exceed two.

Note.— The average radius of a given sector of the rated coverage is equal to the radius of the corresponding circlesector of the same area. Example:

150/210° –30°
100/30° –210°.

3.4.3 Limitations in radiated power

The power radiated from an NDB shall not exceed by more than 2 dB that necessary to achieve its agreed rated coverage, except that this power may be increased if coordinated regionally or if no harmful interference to other facilities will result.

3.4.4 Radio frequencies

3.4.4.1 The radio frequencies assigned to NDBs shall be selected from those available in that portion of the spectrum between 190 kHz and 1 750 kHz.

3.4.4.2 The frequency tolerance applicable to NDBs shall be 0.01 per cent except that, for NDBs of antenna power above 200 W using frequencies of 1 606.5 kHz and above, the tolerance shall be 0.005 per cent.

3.4.4.3 **Recommendation.—** Where two locators are used as supplements to an ILS, the frequency separation between the carriers of the two should be not less than 15 kHz to ensure correct operation of the radio compass, and preferably not more than 25 kHz in order to permit a quick tuning shift in cases where an aircraft has only one radio compass.

3.4.4.4 Where locators associated with ILS facilities serving opposite ends of a single runway are assigned a common frequency, provision shall be made to ensure thatthe facility not in operational use cannot radiate.

Note.— Additional guidance on the operation of locator beacons on common frequency channels is contained in Volume V, Chapter 3, 3.2.2.

3.4.5 Identification

3.4.5.1 Each NDB shall be individually identified by a two- or three-letter International Morse Code group transmitted at a rate corresponding to approximately 7 words per minute.

3.4.5.2 The complete identification shall be transmitted at least once every 30 seconds, except where the beacon identification is effected by on/off keying of the carrier. In this latter case, the identification shall be at approximately 1-minute intervals, except that a shorter interval may be used at particular NDB stations where this is found to be operationally desirable.

3.4.5.2.1 Recommendation.— Except for those cases where the beacon identification is effected by on/off keying of the carrier, the identification signal should be transmitted at least three times each 30 seconds, spaced equally within that time period.

3.4.5.3 For NDBs with an average radius of rated coverage of 92.7 km (50 NM) or less that are primarily approach and holding aids in the vicinity of an aerodrome, the identification shall be transmitted at least three times each 30 seconds, spaced equally within that time period.

3.4.5.4 The frequency of the modulating tone used for identification shall be 1 020 Hz plus or minus 50 Hz or 400 Hz plus or minus 25 Hz.

Note.— Determination of the figure to be used would be made regionally, in the light of the considerations contained in Attachment C, 6.5.

3.4.6 Characteristics of emissions

Note.— The following specifications are not intended to preclude employment of modulations or types of modulations that may be utilized in NDBs in addition to those specified for identification, including simultaneous identification and voice modulation, provided that these additional modulations do not materially affect the operational performance of the NDBs in conjunction with currently used airborne direction finders, and provided their use does not cause harmful interference to other NDB services.

3.4.6.1 Except as provided in 3.4.6.1.1, all NDBs shall radiate an uninterrupted carrier and be identified by on/off keying of an amplitude modulating tone (NON/A2A).

3.4.6.1.1 NDBs other than those wholly or partly serving as holding, approach and landing aids, or those having an average radius of rated coverage of less than 92.7 km (50 NM), may be identified by on/off keying of the un modulated carrier (NON/A1A) if they are in areas of high beacon density and/or where the required rated coverage is not practicable of achievement because of:

a) radio interference from radio stations;

b) high atmospheric noise;

c) local conditions.

Note.— In selecting the types of emission, the possibility of confusion, arising from an aircraft tuning from a NON/A2A facility to a NON/A1A facility without changing the radio compass from "MCW" to "CW" operation, will need to be kept in mind.

3.4.6.2 For each NDB identified by on/off keying of an audio modulating tone, the depth of modulation shall be maintained as near to 95per cent as practicable.

3.4.6.3 For each NDB identified by on/off keying of an audio modulating tone, the characteristics of emission during identification shall be such as to ensure satisfactory identification at the limit of its rated coverage.

Note 1.— The foregoing requirement necessitates as high a percentage modulation as practicable, together with maintenance of an adequate radiated carrier power during identification.

Note 2.— With a direction-finder pass band of plus or minus 3 kHz about the carrier, a signal to noise ratio of 6 dB at the limit of rated coverage will, in general, meet the foregoing requirement.

Note 3.— Some considerations with respect to modulation depth are contained in Attachment C, 6.4.

3.4.6.4 **Recommendation**.— The carrier power of an NDB with NON/A2A emissions should not fall when the identity signal is being radiated except that, in the case of an NDB having an average radius of rated coverage exceeding 92.7 km (50 NM), a fall of not more than 1.5 dB may be accepted.

3.4.6.5 Unwanted audio frequency modulations shall total less than 5 per cent of the amplitude of the carrier.

Note.— Reliable performance of airborne automatic direction-finding equipment (ADF) may be seriously prejudiced if the beacon emission contains modulation by an audio frequency equal or close to the loop switching frequency or its second harmonic. The loop switching frequencies in currently used equipment lie between 30 Hz and 120 Hz.

3.4.6.6 The bandwidth of emissions and the level of spurious emissions shall be kept at the lowest value that the state of technique and the nature of the service permit.

Note.— Article S3 of the ITU Radio Regulations contains the general provisions with respect to technical characteristics of equipment and emissions. The Radio Regulations contain specific provisions relating to necessary bandwidth, frequency tolerance, spurious emissions and classification of emissions (see Appendices APS1, APS2 and APS3).

3.4.7 Siting of locators

3.4.7.1 **Recommendation**.— Where locators are used as a supplement to the ILS, they should be located at the sites of the outer and middle marker beacons. Where only one locator is used as a supplement to the ILS, preference should be given to location at the site of the outer marker beacon. Where locators are employed as an aid to final approach in the absence of an ILS, equivalent locations to those applying when an ILS is installed should be selected, taking into account the relevant obstacle clearance provisions of the PANS-OPS (Doc 8168).

3.4.7.2 **Recommendation.**— Where locators are installed at both the middle and outer marker positions, they should be located, where practicable, on the same side of the extended centre line of the runway in order to provide a track between the locators which will be more nearly parallel to the centre line of the runway.

3.4.8 Monitoring

3.4.8.1 For each NDB, suitable means shall be provided to enable detection of any of the following conditions at an appropriate location:

a) a decrease in radiated carrier power of more than50 per cent below that required for the rated coverage;

b) failure to transmit the identification signal;

c) malfunctioning or failure of the means of monitoring itself.

3.4.8.2 **Recommendation**.— When an NDB is operated from a power source having a frequency which is close to airborne ADF equipment switching frequencies, and where the design of the NDB is such that the power supply frequency is likely to appear as a modulation product on the emission, the means of monitoring should be capable of detecting such power supply modulation on the carrier in excess of 5 per cent.

3.4.8.3 During the hours of service of a locator, the means of monitoring shall provide for a continuous check on the functioning of the locator as prescribed in 3.4.8.1 a), b) and c).

3.4.8.4 **Recommendation.**— During the hours of service of an NDB other than a locator, the means of monitoring should provide for a continuous check on the functioning of the NDB as prescribed in 3.4.8.1 a), b) and c).

Note.— Guidance material on the testing of NDBs is contained in 6.6 of Attachment C.

3.5 Specification for UHFdistance measuring equipment (DME)

Note.— In the following section, provision is made for two types of DME facility: DME/N for general application, and DME/P as outlined in 3.11.3.

3.5.1 Definitions

Control motion noise (CMN). That portion of the guidance signal error which causes control surface, wheel and column motion and could affect aircraft attitude angle during coupled flight, but does not cause aircraft displacement from the desired course and/or glide path. (See 3.11.)

DME dead time. A period immediately following the decoding of a valid interrogation during which a received interrogation will not cause a reply to be generated.

Note.— Dead time is intended to prevent the transponder from replying to echoes resulting from multipath effects.

DME/N. Distance measuring equipment, primarily serving operational needs of en-route or TMA navigation, where the "N" stands for narrow spectrum characteristics.

DME/P. The distance measuring element of the MLS, where the "P" stands for precise distance measurement. The spectrum characteristics are those of DME/N.

Equivalent isotropically radiated power (EIRP). The product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).

Final approach (FA) mode. The condition of DME/P operation which supports flight operations in the final approach and runway regions.

Initial approach (IA) mode. The condition of DME/P operation which supports those flight operations outside the final approach region and which is interoperable with DME/N.

Key down time. The time during which a dot or dash of a Morse character is being transmitted.

MLS approach reference datum. A point on the minimum glide path at a specified height above the threshold. (See 3.11.)

MLS datum point. The point on the runway centre line closest to the phase centre of the approach elevation antenna. (See 3.11.)

Mode W, X, Y, Z. A method of coding the DME transmissions by time spacing pulses of a pulse pair, so that each frequency can be used more than once.

Partial rise time. The time as measured between the 5 and 30 per cent amplitude points on the leading edge of the pulse envelope, i.e. between points h and i on Figures 3-1 and 3-2.

Path following error (PFE). That portion of the guidance signal error which could cause aircraft displacement from the desired course and/or glide path. (See 3.11.)

Pulse amplitude. The maximum voltage of the pulse envelope, i.e. A in Figure 3-1.

Pulse decay time. The time as measured between the 90 and 10 per cent amplitude points on the trailing edge of the pulse envelope, i.e. between points e and g on Figure 3-1.

Pulse code. The method of differentiating between W, X, Y and Z modes and between FA and IA modes.

Pulse duration. The time interval between the 50 per cent amplitude point on leading and trailing edges of the pulse envelope, i.e. between points b and f on Figure 3-1.

Pulse rise time. The time as measured between the 10 and 90 per cent amplitude points on the leading edge of the pulse envelope, i.e. between points a and c on Figure 3-1.

Reply efficiency. The ratio of replies transmitted by the transponder to the total of received valid interrogations.

Search. The condition which exists when the DME interrogator is attempting to acquire and lock onto the response to its own interrogations from the selected transponder.

System efficiency. The ratio of valid replies processed by the interrogator to the total of its own interrogations.

Track. The condition which exists when the DME interrogator has locked onto replies in response to its own interrogations, and is continuously providing a distance measurement.

Transmission rate. The average number of pulse pairs transmitted from the transponder per second.

Virtual origin. The point at which the straight line through the 30 per cent and 5 per cent amplitude points on the pulse leading edge intersects the 0 per cent amplitude axis (see Figure 3-2).

3.5.2 General

3.5.2.1 The DME system shall provide for continuous and accurate indication in the cockpit of the slant range distance of an equipped aircraft from an equipped ground reference point.

3.5.2.2 The system shall comprise two basic components, one fitted in the aircraft, the other installed on the ground. The aircraft component shall be referred to as the interrogator and the ground component as the transponder.

3.5.2.3 In operation, interrogators shall interrogate transponders which shall, in turn, transmit to the interrogator replies synchronized with the interrogations, thus providing means for accurate measurement of distance.

3.5.2.4 DME/P shall have two operating modes, IA and FA.

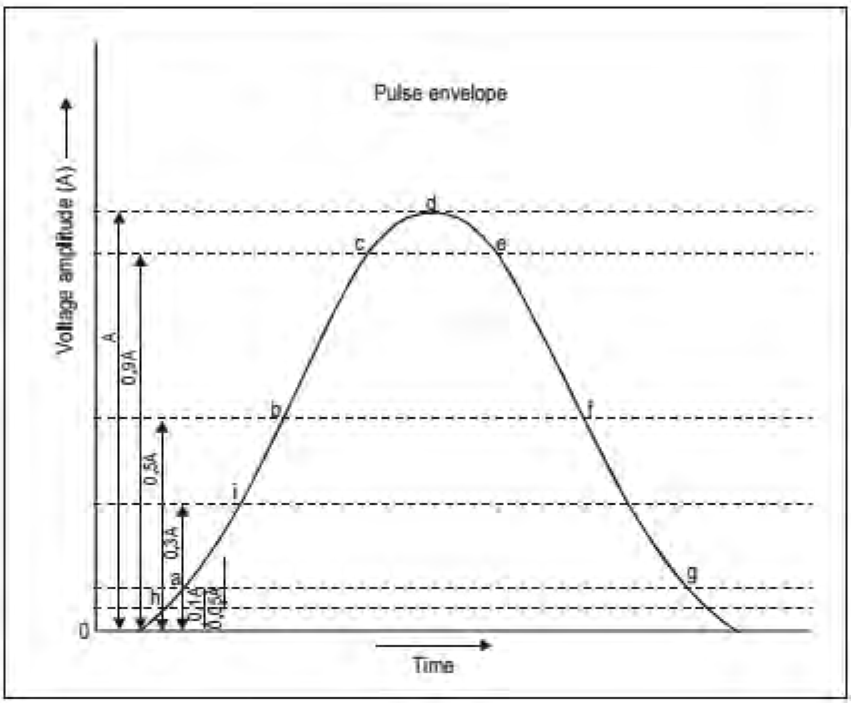

Figure 3-1

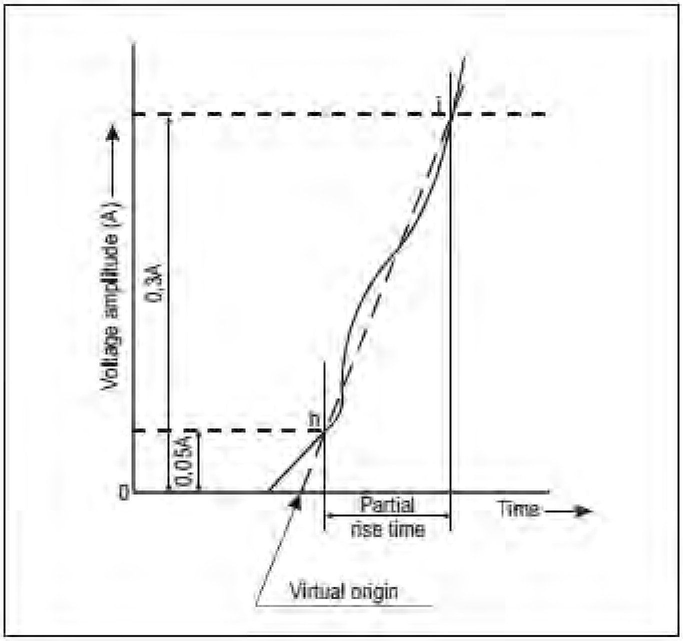

Figure 3-2

3.5.2.5 When a DME is associated with an ILS, MLS or VOR for the purpose of constituting a single facility, they shall:

a) be operated on a standard frequency pairing in accordance with 3.5.3.3.4;

b) be collocated within the limits prescribed for associated facilities in 3.5.2.6; and

c) comply with the identification provisions of 3.5.3.6.4.

3.5.2.6 Collocation limits for a DME facility associated with an ILS, MLS or VOR facility

3.5.2.6.1 Associated VOR and DME facilities shall be collocated in accordance with the following:

a) for those facilities used in terminal areas for approach purposes or other procedures where the highest position fixing accuracy of system capability is required, the separation of the VOR and DME antennas does not exceed 80 m (260 ft);

b) for purposes other than those indicated in a), the separation of the VOR and DME antennas does not exceed 600 m (2 000 ft).

3.5.2.6.2 Association of DME with ILS

Note.— Attachment C, 2.11 gives guidance on the association of DME with ILS.

3.5.2.6.3 Association of DME with MLS

3.5.2.6.3.1 **Recommendation**.— If a DME/P is used to provide ranging information, it should be sited as close as possible to the MLS azimuth facility.

Note.— Attachment G, 5 and Attachment C, 7.1.6 give guidance on siting of DME with MLS. This guidance sets forth, in particular, appropriate steps to be taken to prevent different zero range indication if DME/P associated with MLS and DME/N associated with ILS serve the same runway.

3.5.2.7 The Standards in 3.5.3, 3.5.4 and 3.5.5 denoted by ‡ shall apply only to DME equipment first installed after 1 January 1989.

3.5.3 System characteristics

3.5.3.1 Performance

3.5.3.1.1 **Range.** The system shall provide a means of measurement of slant range distance from an aircraft to a selected transponder to the limit of coverage prescribed by the operational requirements for the selected transponder.

3.5.3.1.2 Coverage

3.5.3.1.2.1 When associated with a VOR, DME/N coverage shall be at least that of the VOR to the extent practicable.

3.5.3.1.2.2 When associated with either an ILS or an MLS, DME/N coverage shall be at least that of the respective ILS or of the MLS azimuth angle guidance coverage sectors.

3.5.3.1.2.3 DME/P coverage shall be at least that provided by the MLS azimuth angle guidance coverage sectors.

Note.— This is not intended to specify the operational range and coverage to which the system may be used; spacing of facilities already installed may limit the range in certain areas.

3.5.3.1.3 Accuracy

3.5.3.1.3.1 *System accuracy*. The accuracy standards specified in 3.5.3.1.4, 3.5.4.5 and 3.5.5.4 shall be met on a 95 per cent probability basis.

3.5.3.1.4 DME/P accuracy

Note 1.— In the following, two accuracy standards, 1 and 2, are stated for the DME/P to accommodate a variety of applications.

Note 2.— Guidance on accuracy standards is given in Attachment C, 7.3.2.

3.5.3.1.4.1 *Error components***.** The path following error (PFE) shall be comprised of those frequency components of the DME/P error at the output of the interrogator which lie below 1.5 rad/s. The control motion noise (CMN) shall be comprised of those frequency components of the DME/P error at the output of the interrogator which lie between 0.5 rad/s and 10 rad/s.

Note.— Specified error limits at a point are to be applied overa flight path that includes that point. Information on the interpretation of DME/P errors and the measurement of those errors over an interval appropriate for flight inspection is provided in Attachment C, 7.3.6.1.

3.5.3.1.4.2 Errors on the extended runway centre line shall not exceed the values given in Table B at the end of this chapter.

3.5.3.1.4.3 In the approach sector, away from the extended runway centre line, the allowable PFE for both standard 1 and standard 2 shall be permitted to increase linearly with angle up to plus or minus 40 degrees MLS azimuth angle where the permitted error is 1.5 times that on the extended runway centre line at the same distance. The allowable CMN shall not increase with angle. There shall be no degradation of either PFE or CMN with elevation angle.

3.5.3.2 Radio frequencies and polarization. The system shall operate with vertical polarization in the frequency band 960 MHz to 1 215 MHz. The interrogation and reply frequencies shall be assigned with 1MHz spacing between channels.

3.5.3.3 Channelling

3.5.3.3.1 DME operating channels shall be formed by pairing interrogation and reply frequencies and by pulse coding on the paired frequencies.

3.5.3.3.2 *Pulse coding*. DME/P channels shall have two different interrogation pulse codes as shown in the table in

3.5.4.4.1. One shall be used in the initial approach (IA) mode; the other shall be used in the final approach (FA) mode.

3.5.3.3.3 DME operating channels shall be chosen from Table A (located at the end of this chapter), of 352 channels in which the channel numbers, frequencies, and pulse codes are assigned.

3.5.3.3.4 *Channel pairing*. When a DME transponder is intended to operate in association with a single VHF navigation facility in the 108 MHz to 117.95 MHz frequency band and/or an MLS angle facility in the 5 031.0 MHz to 5 090.7 MHz frequency band, the DME operating channel shall be paired with the VHF channel and/or MLS angle frequency as given in Table A.

Note.— There may be instances when a DME channel will be paired with both the ILS frequency and an MLS channel (see Volume V, Chapter 4, 4.3).

3.5.3.4 Interrogation pulse repetition frequency

Note.— If the interrogator operates on more than one channel in one second, the following specifications apply to the sum of interrogations on all channels.

3.5.3.4.1 DME/N. The interrogator average pulse repetition frequency (PRF) shall not exceed 30 pairs of pulses per second, based on the assumption that at least 95 per cent of the time is occupied for tracking.

3.5.3.4.2 DME/N. If it is desired to decrease the time of search, the PRF may be increased during search but shall not exceed 150 pairs of pulses per second.

3.5.3.4.3 DME/N. **Recommendation.—** After 15 000 pairs of pulses have been transmitted without acquiring indication of distance, the PRF should not exceed 60 pairs of pulses per second thereafter, until a change in operating channel is made or successful search is completed.

‡3.5.3.4.4 DME/N. When, after a time period of 30 seconds, tracking has not been established, the pulse pair repetition

frequency shall not exceed 30 pulse pairs per second thereafter.

3.5.3.4.5 DME/P. The interrogator pulse repetition frequency shall notexceed the following number of pulse pairs per second:

a) search 40

b) aircraft on the ground 5

c) initial approach mode track 16

d) final approach mode track 40

Note 1.— A pulse repetition frequency (PRF) of 5 pulse pairs per second for aircraft on the ground may be exceeded if the aircraft requires accurate range information.

Note 2.— It is intended that all PRF changes be achieved by automatic means

3.5.3.5 Aircraft handling capacity of the system

3.5.3.5.1 The aircraft handling capacity of transponders in an area shall be adequate for the peak traffic of the area or 100 aircraft, whichever is the lesser.

3.5.3.5.2 **Recommendation**.— Where the peak traffic in an area exceeds 100 aircraft, the transponder should be capable of handling that peak traffic.

Note.— Guidance material on aircraft handling capacity will be found in Attachment C, 7.1.5.

3.5.3.6 Transponder identification

3.5.3.6.1 All transponders shall transmit an identification signal in one of the following forms as required by 3.5.3.6.5:

a) an "independent" identification consisting of coded (International Morse Code) identity pulses which can be used with all transponders;

b) an "associated" signal which can be used for transponders specifically associated with a VHF navigation or an MLS angle guidance facility which itself transmits an identification signal.

Note.— An MLS angle guidance facility provides its identification as a digital word transmitted on the data channel into the approach and back azimuth coverage regions as specified in 3.11.4.6.2.1.

3.5.3.6.2 Both systems of identification shall use signals, which shall consist of the transmission for an appropriate period of a series of paired pulses transmitted at a repetition rate of 1 350 pulse pairs per second, and shall temporarily replace all reply pulses that would normally occur at that time except as in 3.5.3.6.2.2. These pulses shall have similar characteristics to the other pulses of the reply signals.

‡3.5.3.6.2.1 DME/N. Reply pulses shall be transmitted between key down times.

3.5.3.6.2.2 DME/N. **Recommendation**.— If it is desired to preserve a constant duty cycle, an equalizing pair of pulses, having the same characteristics as the identification pulse pairs, should be transmitted 100 microseconds plus or minus 10 microseconds after each identity pair.

3.5.3.6.2.3 DME/P. Reply pulses shall be transmitted between key down times.

3.5.3.6.2.4 For the DME/P transponder, reply pulse pairs to valid FA mode interrogations shall also be transmitted during key down times and have priority over identification pulse pairs.

3.5.3.6.2.5 The DME/P transponder shall not employ the equalizing pair of pulses of 3.5.3.6.2.2.

3.5.3.6.3 The characteristics of the "independent" identification signal shall be as follows:

a) the identity signal shall consist of the transmission of the beacon code inthe form of dots and dashes (International Morse Code) of identity pulses at least once every 40 seconds, at a rate of at least 6 words per minute; and

b) the identification code characteristic and letter rate for the DME transponder shall conform to the following to ensure that the maximum total key down time does not exceed 5 seconds per identification code group. The dots shall be a time duration of 0.1 second to 0.160 second. The dashes shall be typically 3 times the duration of the dots.

The duration between dots and/or dashes shall be equal to that of one dot plus or minus 10 per cent. The time duration between letters or numerals shall not be less than three dots. The total period for transmission of an identification code group shall not exceed 10 seconds.

Note.— The tone identification signal is transmitted at a repetition rate of 1 350 pps. This frequency may be used directly in the airborne equipment as an aural output for the pilot, or other frequencies may be generated at the option of theinterrogator designer (see 3.5.3.6.2).

3.5.3.6.4 The characteristics of the "associated" signal shall be as follows:

a) when associated with a VHF or an MLS angle facility, the identification shall be transmitted in the form of dots and dashes (International Morse Code) as in 3.5.3.6.3 and shall be synchronized with the VHF facility identification code;

b) each 40-second interval shall be divided into four or more equal periods, with the transponder identification transmitted during one period only and the associated VHF and MLS angle facility identification, where these are provided, transmitted during the remaining periods;

c) for a DME transponder associated with an MLS, the identification shall be the last three letters of the MLS angle facility identification specified in 3.11.4.6.2.1.

3.5.3.6.5 Identification implementation

3.5.3.6.5.1 The “independent” identification code shall be employed wherever a transponder is not specifically associated with a VHF navigational facility or an MLS facility.

3.5.3.6.5.2 Wherever a transponder is specifically associated with a VHF navigational facility or an MLS facility, identification shall be provided by the “associated” code.

3.5.3.6.5.3 When voice communications are being radiated on an associated VHF navigational facility, an “associated” signal from the transponder shall not be suppressed.

3.5.3.7 DME/P mode transition

3.5.3.7.1 The DME/P interrogator for standard 1 accuracy shall change from IA mode track to FA mode track at 13 km (7 NM) from the transponder when approaching the transponder, or any other situation when within 13 km (7 NM).

3.5.3.7.2 For standard 1 accuracy, the transition from IA mode to FA mode track operation may be initiated within 14.8 m (8 NM) from the transponder. Outside 14.8 km (8 NM), the interrogator shall not interrogate in the FA mode.

Note.— Paragraph 3.5.3.7.1 does not apply if the transponder is a DME/N or if the DME/P transponder FA mode is inoperative.

3.5.3.8 System efficiency. The DME/P system accuracy of 3.5.3.1.4 shall be achieved with a system efficiency of 50 per cent or more.

3.5.4 Detailed technical characteristics of transponder and associated monitor

3.5.4.1 Transmitter

3.5.4.1.1 Frequency of operation. The transponder shall transmit on the reply frequency appropriate to the assigned DME channel (see 3.5.3.3.3).

3.5.4.1.2 Frequency stability. The radio frequency of operation shall not vary more than plus or minus 0.002 per cent from the assigned frequency.

3.5.4.1.3 Pulse shape and spectrum. The following shall apply to all radiated pulses:

a) Pulse rise time.

1) DME/N. Pulse rise time shall not exceed 3 microseconds.

2) DME/P. Pulse rise time shall not exceed 1.6 microseconds. For the FA mode, the pulse shall have a partial rise time of 0.25 plus or minus 0.05 microsecond. With respect to the FA mode and accuracy standard 1, the slope of the pulse in the partial rise time shall not vary by more than plus or minus 20 per cent. For accuracy standard 2, the slope shall not vary by more than plus or minus 10 per cent.

3) DME/P. **Recommendation**.— Pulse rise time should not exceed 1.2 microseconds.

b) Pulse duration shall be 3.5 microseconds plus or minus 0.5 microsecond.

c) Pulse decay time shall nominally be 2.5 microseconds but shall not exceed 3.5 microseconds.

d) The instantaneous amplitude of the pulse shall not, at any instant between the point of the leading edge which is 95 per cent of maximum amplitude and the point of the trailing edge which is 95 per cent of the maximum amplitude, fall below a value which is 95 per cent of the maximum voltage amplitude of the pulse.

e) For DME/N and DME/P: the spectrum of the pulse modulated signal shall be such that during the pulse the EIRP contained in a 0.5 MHz band centred on frequencies 0.8 MHz above and 0.8 MHz below the nominal channel frequency in each case shall not exceed 200 mW, and the EIRP contained in a 0.5 MHz band centred on frequencies 2 MHz above and 2 MHz below the nominal channel frequency in each case shall not exceed 2 mW. The EIRP contained within any 0.5 MHz band shall decrease monotonically as the band centre frequency moves away from the nominal channel frequency.

Note.— Guidance material relating to the pulse spectrum measurement is provided in Document EUROCAE ED-57 (including Amendment No. 1).

f) To ensure proper operation of the thresholding techniques, the instantaneous magnitude of any pulse turn-on transients which occur in time prior to the virtual origin shall be less than one per cent of the pulse peak amplitude. Initiation of the turn-on process shall not commence sooner than 1 microsecond prior to the virtual origin.

Note 1.— The time "during the pulse" encompasses the total interval from the beginning of pulse transmission to its end. For practical reasons, this interval may be measured between the 5 per cent points on the leading and trailing edges of the pulse envelope.

Note 2.— The power contained in the frequency bands specified in 3.5.4.1.3 e) is the average power during the pulse. Average power in a given frequency band is the energy contained in this frequency band divided by the time of pulse transmission according to Note 1.

3.5.4.1.4 Pulse spacing

3.5.4.1.4.1 The spacing of the constituent pulses of transmitted pulse pairs shall be as given in the table in 3.5.4.4.1.

3.5.4.1.4.2 DME/N. The tolerance on the pulse spacing shall be plus or minus 0.25 microsecond.

3.5.4.1.4.3 DME/N. **Recommendation.—** The tolerance on the DME/N pulse spacing should be plus or minus 0.10 microsecond.

3.5.4.1.4.4 DME/P. The tolerance on the pulse spacing shall be plus or minus 0.10 microsecond.

3.5.4.1.4.5 The pulse spacings shall be measured between the half voltage points on the leading edges of the pulses.

3.5.4.1.5 Peak power output

3.5.4.1.5.1 DME/N. Recommendation.— The peak EIRP should not be less than that required to ensure a peak pulse power density of approximately minus 83 dBW/m2at the maximum specified service range and level.

‡3.5.4.1.5.2 DME/N. The peak equivalent isotropically radiated power shall not be less than that required to ensure a peak pulse power density of minus 89 dBW/m2 under all operational weather conditions at any point within coverage specified in 3.5.3.1.2.

Note.— Although the Standard in 3.5.4.1.5.2 implies an improved interrogator receiver sensitivity, it is intended that the power density specified in 3.5.4.1.5.1 be available at the maximum specified service range and level.

3.5.4.1.5.3 DME/P. The peak equivalent isotropically radiated power shall not be less than that required to ensure the following peak pulse power densities under all operational weather conditions:

a) minus 89 dBW/m2 at any point within the coverage specified in 3.5.3.1.2 at ranges greater than 13 km (7 NM) from the transponder antenna;

b) minus 75 dBW/m2at any point within the coverage specified in 3.5.3.1.2 at ranges less than 13 km (7 NM) from the transponder antenna;

c) minus 70 dBW/m2at the MLS approach reference datum;

d) minus 79 dBW/m2at 2.5 m (8 ft) above the runway surface, at the MLS datum point, or at the farthest point on the runway centre line which is in line of sight of the DME transponder antenna.

Note.— Guidance material relating to the EIRP may be found in Attachment C, 7.2.1 and 7.3.8.

3.5.4.1.5.4 The peak power of the constituent pulses ofany pair of pulses shall not differ by more than 1 dB.

3.5.4.1.5.5 **Recommendation**.— The reply capability of the transmitter should be such that the transponder should be capable of continuous operation at a transmission rate of 2 700 plus or minus 90 pulse pairs per second (if 100 aircraft are to be served).

Note.— Guidance on the relationship between number of aircraft and transmission rate is given in Attachment C, 7.1.5.

3.5.4.1.5.6 The transmitter shall operate at a transmission rate, including randomly distributed pulse pairs and distance reply pulse pairs, of not less than 700 pulse pairs per second except during identity. The minimum transmission rate shall be as close as practicable to 700 pulse pairs per second. For DME/P, in no case shall it exceed 1 200 pulse pairs per second.

Note.— Operating DME transponders with quiescent transmission rates close to 700 pulse pairs per second will minimize the effects of pulse interference, particularly to other aviation services such as GNSS.

3.5.4.1.6 Spurious radiation. During intervals between transmission of individual pulses, the spurious power received and measured in a receiver having the same characteristics as a transponder receiver, but tuned to any DME interrogation or reply frequency, shall be more than 50 dB below the peak pulse power received and measured in the same receiver tuned to the reply frequency in use during the transmission of the required pulses. This provision refers to all spurious transmissions, including modulator and electrical interference.

‡3.5.4.1.6.1 DME/N. The spurious power level specified in 3.5.4.1.6 shall be more than 80 dB below the peak pulse power level.

3.5.4.1.6.2 DME/P. The spurious power level specified in 3.5.4.1.6 shall be more than 80 dB below the peak pulse power level.

3.5.4.1.6.3 Out-of-band spurious radiation. At all frequencies from 10 to 1 800 MHz, but excluding the band of frequencies from 960 to 1 215 MHz, the spurious output of the DME transponder transmitter shall not exceed minus 40 dBm in any one kHz of receiver bandwidth.

3.5.4.1.6.4 The equivalent isotropically radiated power of any CW harmonic of the carrier frequency on any DME operating channel shall not exceed minus 10 dBm.

3.5.4.2 Receiver

3.5.4.2.1 Frequency of operation. The receiver centre frequency shall be the interrogation frequency appropriate to the assigned DME operating channel (see 3.5.3.3.3).

3.5.4.2.2 Frequency stability. The centre frequency of the receiver shall not vary more than plus or minus 0.002 per cent from the assigned frequency.

3.5.4.2.3 Transponder sensitivity

3.5.4.2.3.1 In the absence of all interrogation pulse pairs, with the exception of those necessary to perform the sensitivity measurement, interrogation pulse pairs with the correct spacing and nominal frequency shall trigger the transponder if the peakpower density at the transponder antenna is at least:

a) minus 103 dBW/m2 for DME/N with coverage range greater than 56 km (30 NM);

b) minus 93 dBW/m2 for DME/N with coverage range not greater than 56 km (30 NM);

c) minus 86 dBW/m2 for DME/P IA mode;

d) minus 75 dBW/m2 for DME/P FA mode.

3.5.4.2.3.2 The minimum power densities specified in 3.5.4.2.3.1 shall cause the transponder to reply with an efficiency of at least:

a) 70 per cent for DME/N;

b) 70 per cent for DME/P IA mode;

c) 80 per cent for DME/P FA mode.

‡3.5.4.2.3.3 DME/N dynamic range. The performance of the transponder shall be maintained when the power density of the interrogation signal at the transponder antenna has any value between the minimum specified in 3.5.4.2.3.1 up to a maximum of minus 22 dBW/m2when installed with ILS or MLS and minus 35 dBW/m2 when installed for other applications.

3.5.4.2.3.4 DME/P dynamic range. The performance of the transponder shall be maintained when the power density of the interrogation signal at the transponder antenna has any value between the minimum specified in 3.5.4.2.3.1 up to a maximum of minus 22 dBW/m2.

3.5.4.2.3.5 The transponder sensitivity level shall not vary by more than 1 dB for transponder loadings between 0 and 90 per cent of its maximum transmission rate.

‡3.5.4.2.3.6 DME/N. When the spacing of an interrogator pulse pair varies from the nominal value by up to plus or minus 1 microsecond, the receiver sensitivity shall not be reduced by more than 1 dB.

3.5.4.2.3.7 DME/P. When the spacing of an interrogator pulse pair varies from the nominal value by up to plus or minus 1 microsecond, the receiver sensitivity shall not be reduced by more than 1 dB.

3.5.4.2.4 Load limiting

3.5.4.2.4.1 DME/N. **Recommendation**.— When transponder loading exceeds90 per cent of the maximum transmission rate, the receiver sensitivity should be automatically reduced in order to limit the transponder replies, so as to ensure that the maximum permissible transmission rate is not exceeded. (The available range of sensitivity reduction should be at least 50 dB.)

3.5.4.2.4.2 DME/P. To prevent transponder overloading the transponder shall automatically limit its replies, so as to ensure that the maximum transmission rate is not exceeded. If the receiver sensitivity reduction is implemented to meet this requirement, it shall be applied to the IA mode only and shall not affect the FA mode.

3.5.4.2.5 Noise. When the receiver is interrogated at the power densities specified in 3.5.4.2.3.1 to produce a transmission rate equal to 90 per cent of the maximum, the noise generated pulse pairs shall not exceed 5 per cent of the maximum transmission rate.

3.5.4.2.6 Bandwidth

3.5.4.2.6.1 The minimum permissible bandwidth of the receiver shall be such that the transponder sensitivity level shall not deteriorate by more than 3 dB when the total receiver drift is added to an incoming interrogation frequency drift of plus or minus 100 kHz.

3.5.4.2.6.2 DME/N. The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3

3.5.4.2.6.3 DME/P — IA mode. The receiver bandwidth shall be sufficient to allow compliance with3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3. The 12 dB bandwidth shall not exceed 2 MHz and the 60 dB bandwidth shall not exceed 10 MHz.

3.5.4.2.6.4 DME/P — FA mode. The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3. The 12 dB bandwidth shall not exceed 6 MHz and the 60 dB bandwidth shall not exceed 20 MHz.

3.5.4.2.6.5 Signals greater than 900 kHz removed from the desired channel nominal frequency and having power densities up to the values specified in 3.5.4.2.3.3 for DME/N and 3.5.4.2.3.4 for DME/P shall not trigger the transponder. Signals arriving at the intermediate frequency shall be suppressed at least 80 dB. All other spurious response or signals within the 960 MHz to 1 215 MHz band and image frequencies shall be suppressed at least 75 dB.

3.5.4.2.7 Recovery time. Within 8 microseconds of the reception of a signal between 0 dB and 60 dB above minimum sensitivity level, the minimum sensitivity level of the transponder to a desired signal shall be within 3 dB of the value obtained in the absence of signals. This requirement shall be met with echo suppression circuits, if any, rendered inoperative. The 8 microseconds are to be measured between the half voltage points on the leading edges of the two signals, both of which conform in shape, with the specifications in 3.5.5.1.3.

3.5.4.2.8 Spurious radiations. Radiation from any part of the receiver or allied circuits shall meet the requirements stated in 3.5.4.1.6.

3.5.4.2.9 CW and echo suppression

Recommendation.— CW and echo suppression should be adequate for the sites at which the transponders will be used.

Note.— In this connection, echoes mean undesired signals caused by multipath transmission (reflections, etc.).

3.5.4.2.10 Protection against interference

Recommendation.— Protection against interference outside the DME frequency band should be adequate for the sites at which the transponders will be used.

3.5.4.3 Decoding

3.5.4.3.1 The transponder shall include a decoding circuit such that the transponder can be triggered only by pairs of received pulses having pulse duration and pulse spacings appropriate to interrogator signals as described in 3.5.5.1.3 and 3.5.5.1.4.

3.5.4.3.2 The decoding circuit performance shall not be affected by signals arriving before, between, or after, the constituent pulses of a pair of the correct spacing.

‡3.5.4.3.3 DME/N — Decoder rejection. An interrogation pulse pair with a spacing of plus or minus 2 microseconds,

or more, from the nominal value and with any signal level up to the value specified in 3.5.4.2.3.3 shall be rejected such that the transmission rate does not exceed the value obtained when interrogations are absent.

3.5.4.3.4 DME/P — Decoder rejection. An interrogation pulse pair with a spacing of plus or minus 2 microseconds, or more, from the nominal value and with any signal level up to the value specified in 3.5.4.2.3.4 shall be rejected such that the transmission rate does not exceed the value obtained when interrogations are absent.

3.5.4.4 Time delay

3.5.4.4.1 When a DME is associated only with a VHF facility, the time delay shall be the interval from the half voltage point on the leading edge of the second constituent pulse of the interrogation pair and the half voltage point on the leading edge of the second constituent pulse of the reply transmission. This delay shall be consistent with the following table, when it is desired that aircraft interrogators are to indicate distance from the transponder site.

Channel suffix	Operating mode	Pulse pair spacing (µs) Interrogation	Reply	Time delay (µs) 1st pulse timing	2nd pulse timing
X	DME/N	12	12	50	50
	DME/P IA M	12	12	50	–
	DME/P FA M	18	12	56	–
Y	DME/N	36	30	56	50
	DME/P IA M	36	30	56	–
	DME/P FA M	42	30	62	–
W	DME/N	–	–	–	–
	DME/P IA M	24	24	50	–
	DME/P FA M	30	24	56	–
Z	DME/N	–	–	–	–
	DME/P IA M	21	15	56	–
	DME/P FA M	27	15	62	–

Note 1.— W and X are multiplexed on the same frequency.

Note 2.— Z and Y are multiplexed on the same frequency.

3.5.4.4.2 When a DME is associated with an MLS angle facility, the time delay shall be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pair and the half voltage point on the leading edge of the first constituent pulse of the reply transmission. This delay shall be 50 microseconds for mode X channels and 56 microseconds for mode Y channels, when it is desired that aircraft interrogators are to indicate distance from the transponder site.

3.5.4.4.2.1 For DME/P transponders, no time delay adjustment shall be permitted.

3.5.4.4.3 **Recommendation**.— For the DME/N the transponder time delay should be capable of being set to an appropriate value between the nominal value of the time delay minus 15 microseconds and the nominal value of the time delay, to permit aircraft interrogators to indicate zero distance at a specific point remote from the transponder site.

Note.— Modes not allowing for the full 15 microseconds range of adjustment in transponder time delay may only be adjustable to the limits given by the transponder circuit delay and recovery time.

‡3.5.4.4.3.1 DME/N. The time delay shall be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pair and the half voltage point on the leading edge of the first constituent pulse of the reply transmission.

3.5.4.4.3.2 DME/P — IA mode. The time delay shall be the interval from the half voltage point on the leading edge of the first constituent pulse of the interrogation pulse pair to the half voltage point on the leading edge of the first constituent pulse of the reply pulse pair.

3.5.4.4.3.3 DME/P — FA mode. The time delay shall be the interval from the virtual origin of the first constituent pulse of the interrogation pulse pair to the virtual origin of the first constituent pulse of the reply pulse pair. The time of arrival measurement points shall be within the partial rise time of the first constituent pulse of the pulse pair in each case.

3.5.4.4.4 DME/N. **Recommendation**.— Transponders should be sited as near to the point at which zero indication is required as is practicable.

Note 1.— It is desirable that the radius of the sphere at the surface of which zero indication is given be kept as small as possible in order to keep the zone of ambiguity to a minimum.

Note 2.— Guidance material on siting DME with MLS is provided in 7.1.6 of Attachment C and 5 of Attachment G. This guidance material sets forth, in particular, appropriate steps to be taken to prevent different zero range indication if DME/P associated with MLS and DME/N associated with ILS serve the same runway.

3.5.4.5 *Accuracy*

3.5.4.5.1 DME/N. The transponder shall not contribute more than plus or minus 1 microsecond (150 m (500 ft)) to the overall system error.

3.5.4.5.1.1 DME/N. **Recommendation**.— The contribution to the total system error due to the combination of the transponder errors, transponder location coordinate errors, propagation effects and random pulse interference effects should be not greater than plus or minus 340 m (0.183 NM) plus 1.25 per cent of distance measure.

Note.— This error contribution limit includes errors from all causes except the airborne equipment, and assumes that the airborne equipment measures time delay based on the first constituent pulse of a pulse pair.

‡3.5.4.5.1.2 DME/N. The combination of the transponder errors, transponder location coordinate errors, propagation effects and random pulse interference effects shall not contribute more than plus or minus 185 m (0.1 NM) to the overall system error.

Note.— This error contribution limit includes errors from all causes except the airborne equipment, and assumes that the airborne equipment measures time delay based on the first constituent pulse of a pulse pair.

‡3.5.4.5.2 DME/N.A transponder associated with a landing aid shall not contribute more than plus or minus 0.5 microsecond (75 m (250 ft)) tothe overall system error.

3.5.4.5.3 DME/P — FA mode

3.5.4.5.3.1 Accuracy standard 1. The transponder shall not contribute more than plus or minus 10 m (plus or minus 33 ft) PFE and plus or minus 8 m (plus or minus 26 ft) CMN to the overall system error.

3.5.4.5.3.2 Accuracy standard 2.The transponder shall not contribute more than plus or minus 5 m (plus or minus 16 ft) PFE and plus or minus 5 m (plus or minus 16 ft) CMN to the overall system error.

3.5.4.5.4 DME/P — IA mode.The transponder shall not contribute more than plus or minus 15 m (plus or minus 50 ft) PFE and plus or minus 10 m (plus or minus 33 ft) CMN to the overall system error.

3.5.4.5.5 **Recommendation**.— When a DME is associated with an MLS angle facility, the above accuracy should include the error introduced by the first pulse detection due to the pulse spacing tolerances.

3.5.4.6 *Efficiency*

3.5.4.6.1 The transponder reply efficiency shall be at least 70 per cent for DME/N and DME/P (IA mode) and 80 per cent for DME/P (FA mode) at all values of transponder loading up to the loading corresponding to 3.5.3.5 and at the minimum sensitivity level specified in 3.5.4.2.3.1 and 3.5.4.2.3.5.

Note.— When considering the transponder reply efficiency value, account is to be taken of the DME dead time and of the loading introduced by the monitoring function.

3.5.4.6.2 Transponder dead time. The transponder shall be rendered inoperative for a period normally not to exceed 60 microseconds after a valid interrogation decode has occurred. In extreme cases when the geographical site of the transponder is such as to produce undesirable reflection problems, the dead time may be increased but only by the minimum amount necessary to allow the suppression of echoes for DME/N and DME/P IA mode.

3.5.4.6.2.1 In DME/P the IA mode dead time shall not blank the FA mode channel and vice versa.

3.5.4.7 Monitoring and control

3.5.4.7.1 Means shall be provided at each transponder site for the automatic monitoring and control of the transponder in use.

3.5.4.7.2 *DME/N monitoring action*

3.5.4.7.2.1 In the event that any of the conditions specified in 3.5.4.7.2.2 occur, the monitor shall cause the following action to take place:

a) a suitable indication shall be given at a control point;

b) the operating transponder shall be automatically switched off; and

c) the standby transponder, if provided, shall be automatically placed in operation.

3.5.4.7.2.2 The monitor shall cause the actions specified in 3.5.4.7.2.1 if:

a) the transponder delay differs from the assigned value by 1 microsecond (150 m (500 ft)) or more;

‡b) in the case of a DME/N associated with a landing aid, the transponder delay differs from the assigned value by 0.5 microsecond (75 m (250 ft)) or more.

3.5.4.7.2.3 **Recommendation.—** The monitor should cause the actions specified in 3.5.4.7.2.1 if the spacing between the first and second pulse of the transponder pulse pair differs from the nominal value specified in the table following 3.5.4.4.1 by 1 microsecond or more.

3.5.4.7.2.4 **Recommendation.—** The monitor should also cause a suitable indication to be given at a control point if any of the following conditions arise:

a) a fall of 3 dB or more in transponder transmitted power output;

b) a fall of 6 dB or more in the minimum transponder receiver sensitivity (provided that this is not due to the action of the receiver automatic gain reduction circuits);

c) the spacing between the first and second pulse of the transponder reply pulse pair differs from the normal value specified in 3.5.4.1.4 by 1 microsecond or more;

d) variation of the transponder receiver and transmitter frequencies beyond the control range of the reference circuits (if the operating frequencies are not directly crystal controlled).

3.5.4.7.2.5 Means shall be provided so that any of the conditions and malfunctioning enumerated in 3.5.4.7.2.2, 3.5.4.7.2.3 and 3.5.4.7.2.4 which are monitored can persist for a certain period before the monitor takes action. This period shall be as low as practicable, but shall not exceed 10 seconds, consistent with the need for avoiding interruption, due to transient effects, of the service provided by the transponder.

3.5.4.7.2.6 The transponder shall not be triggered morethan 120 times per second for either monitoring or automatic frequency control purposes, or both.

3.5.4.7.3 DME/P monitoring action

3.5.4.7.3.1 The monitor system shall cause the transponder radiation to cease and provide a warning at a control point if any of the following conditions persist for longer than the period specified:

a) there is a change in transponder PFEthat exceeds the limits specified in either3.5.4.5.3 or 3.5.4.5.4 for more than one second. If the FA mode limit is exceeded, but the IA mode limit is maintained, the IA mode may remain operative;

b) there is a reduction in the EIRP to less than that necessary to satisfy the requirements specified in 3.5.4.1.5.3 for a period of more than one second;

c) there is a reduction of 3 dB or more in the transponder sensitivity necessary to satisfy the requirements specified in

3.5.4.2.3 for a period of more than five seconds in FA mode and ten seconds in IA mode (provided that this is not due to the action of the receiver automatic sensitivity reduction circuits);

d) the spacing between the first and second pulse of the transponder reply pulse pair differs from the value specified in the table in 3.5.4.4.1 by 0.25 microsecond or more for a period of more than one second.

3.5.4.7.3.2 **Recommendation.—** The monitor should cause a suitable indication to be given at a control point if there is an increase above 0.3 microseconds or a decrease below 0.2 microseconds of the reply pulse partial rise time which persists for more than one second.

3.5.4.7.3.3 The period during which erroneous guidance information is radiated shall not exceed the periods specified in 3.5.4.7.3.1. Attempts to clear a fault by resetting the primary ground equipment or by switching to standby ground equipment, if fitted, shall be completed within this time. If the fault is not cleared within the time allowed, the radiation shall cease. After shutdown, no attempt shall be made to restore service until a period of 20 seconds has elapsed.

3.5.4.7.3.4 The transponder shall not be triggered for monitoring purposes more than 120 times per second in the IA mode and 150 times per second in the FA mode.

3.5.4.7.3.5 DME/N and DME/P monitor failure. Failure of any part of the monitor itself shall automatically produce the same results as the malfunctioning of the element being monitored.

3.5.5 Technical characteristics of interrogator

Note.— The following subparagraphs specify only those interrogator parameters which must be defined to ensure that the interrogator:

a) does not jeopardize the effective operation of the DME system, e.g. by increasing transponder loading abnormally; and

b) is capable of giving accurate distance readings.

3.5.5.1 Transmitter

3.5.5.1.1 Frequency of operation. The interrogator shall transmit on the interrogation frequency appropriate to the assigned DME channel (see 3.5.3.3.3).

Note.— This specification does not preclude the use of airborne interrogators having less than the total number of operating channels.

3.5.5.1.2 Frequency stability. The radio frequency of operation shall not vary more than plus or minus 100 kHz from the assigned value.

3.5.5.1.3 Pulse shape and spectrum. The following shall apply to all radiated pulses:

a) Pulse rise time.

1) DME/N. Pulse rise time shall not exceed 3 microseconds.

2) DME/P. Pulse rise time shall not exceed 1.6 microseconds. For the FA mode, the pulse shall have a partial rise time of 0.25 plus or minus 0.05 microsecond. With respect to the FA mode and accuracy standard 1, the slope of the pulse in the partial rise time shall not vary by more than plus or minus 20 per cent. For accuracy standard 2 the slope shall not vary by more than plus or minus 10 per cent.

3) DME/P. **Recommendation.—** Pulse rise time should not exceed 1.2 microseconds.

b) Pulse duration shall be 3.5 microseconds plus or minus 0.5 microsecond.

c) Pulse decay time shall nominally be 2.5 microseconds, but shall not exceed 3.5 microseconds.

d) The instantaneous amplitude of the pulse shall not, at any instant between the point of the leading edge which is 95 per cent of maximum amplitude and the point of the trailing edge which is 95 per cent of the maximum amplitude, fall below a value which is 95 per cent of the maximum voltage amplitude of the pulse.

e) The spectrum of the pulse modulated signal shall be such that at least 90 per cent of the energy in each pulse shall be within 0.5 MHz in a band centred on the nominal channel frequency.

f) To ensure proper operation of the thresholding techniques, the instantaneous magnitude of any pulse turn-on transients which occur in time prior to the virtual origin shall be less than one per cent of the pulse peak amplitude.

Initiation of the turn-on process shall not commence sooner than 1 microsecond prior to the virtual origin.

Note 1.— The lower limit of pulse rise time (see 3.5.5.1.3 a)) and decay time (see 3.5.5.1.3 c)) are governed by the spectrum requirements in 3.5.5.1.3 e).

Note 2.— While 3.5.5.1.3 e) calls for a practically attainable spectrum, it is desirable to strive for the following spectrum control characteristics: the spectrum of the pulse modulated signal is such that the power contained in a 0.5 MHz band centred on frequencies 0.8 MHz above and 0.8 MHz below the nominal channel frequency is, in each case, at least 23 dB below the power contained in a 0.5 MHz band centred on the nominal channel frequency. The power contained in a 0.5 MHz band centred on frequencies 2 MHz above and 2 MHz below the nominal channel frequency is, in each case, at least 38 dB below the power contained in a 0.5 MHz band centred on the nominal channel frequency. Any additional lobe of the spectrum is of less amplitude than the adjacent lobe nearer the nominal channel frequency.

3.5.5.1.4 Pulse spacing

3.5.5.1.4.1 The spacing of the constituent pulses of transmitted pulse pairs shall be as given in the table in 3.5.4.4.1.

3.5.5.1.4.2 DME/N. The tolerance on the pulse spacing shall be plus or minus 0.5 microsecond.

3.5.5.1.4.3 DME/N. **Recommendation.—** The tolerance on the pulse spacing should be plus or minus 0.25 microsecond.

3.5.5.1.4.4DME/P. The tolerance on the pulse spacing shall be plus or minus 0.25 microsecond.

3.5.5.1.4.5 The pulse spacing shall be measured between the half voltage points on the leading edges of the pulses.

3.5.5.1.5 Pulse repetition frequency

3.5.5.1.5.1 The pulse repetition frequency shall be as specified in 3.5.3.4.

3.5.5.1.5.2 The variation in time between successive pairs of interrogation pulses shall be sufficient to prevent false lock-on.

3.5.5.1.5.3 DME/P. In order to achieve the system accuracy specifiedin 3.5.3.1.4, the variation in time between successive pairs of interrogation pulses shall be sufficiently random to decorrelate high frequency multipath errors.

Note.— Guidance on DME/P multipath effects is given in Attachment C, 7.3.7.

3.5.5.1.6 Spurious radiation. During intervals between transmission of individual pulses, the spurious pulse power received and measured in a receiver having the same characteristics of a DME transponder receiver, but tuned to any DME interrogation or reply frequency, shall be more than 50 dB below the peak pulse power received and measured in the same receiver tuned to the interrogation frequency in use during the transmission of the required pulses. This provision shall apply to all spurious pulse transmissions. The spurious CW power radiated from the interrogator on any DME interrogation or reply frequency shall not exceed 20 microwatts (minus 47 dBW).

Note.— Although spurious CW radiation between pulses is limited to levels not exceeding minus 47 dBW, States are cautioned that where DME interrogators and secondary surveillance radar transponders are employed in the same aircraft, it may be necessary to provide protection to airborne SSR in the band 1 015 MHz to 1 045 MHz. This protection may be provided by *limiting conducted and radiated CW to a level of the order of minus 77 dBW. Where this level cannot be achieved, the required degree of protection may be provided in planning the relative location of the SSR and DME aircraft antennas. It is to be noted that only a few of these frequencies are utilized in the VHF/DME pairing plan.*

3.5.5.1.7 **Recommendation.—** The spurious pulse power received and measured under the conditions stated in 3.5.5.1.6 should be 80 dB below the required peak pulse power received.

Note.— Reference 3.5.5.1.6 and 3.5.5.1.7 — although limitation of spurious CW radiation between pulses to levels not exceeding 80 dB below the peak pulse power received is recommended, States are cautioned that where users employ airborne secondary surveillance radar transponders in the same aircraft, it may be necessary to limit direct and radiated CW to not more than 0.02 microwatt in the frequency band 1 015 MHz to 1 045 MHz. It is to be noted that only a few of these frequencies are utilized in the VHF/DME pairing plan.

3.5.5.1.8 DME/P. The peak EIRP shall not be less than that required to ensure the power densities in 3.5.4.2.3.1 under all operational weather conditions.

3.5.5.2 Time delay

3.5.5.2.1 The time delay shall be consistent with the table in 3.5.4.4.1.

3.5.5.2.2 DME/N. The time delay shall be the interval between the time of the half voltage point on the leading edge of the second constituent interrogation pulse and the time at which the distance circuits reachthe condition corresponding to zero distance indication.

‡3.5.5.2.3 DME/N. The time delay shall be the interval between the time of the half voltage point on the leading edge of the first constituent interrogation pulse and the time at which the distance circuits reach the condition corresponding to zero distance indication.

3.5.5.2.4 DME/P — IA mode. The time delay shall be the interval between the time of the half voltage point on the leading edge of the first constituent interrogation pulse and the time at which the distance circuits reach the condition corresponding to zero distance indication.

3.5.5.2.5 DME/P — FA mode. The time delay shall be the interval between the virtual origin of the leading edge of the first constituent interrogation pulse and the time at which the distance circuits reach the condition corresponding to zero distance indication. The time of arrival shall be measured within the partial rise time of the pulse.

3.5.5.3 Receiver

3.5.5.3.1 Frequency of operation. The receiver centre frequency shall be the transponder frequency appropriate to the assigned DME operating channel (see 3.5.3.3.3).

3.5.5.3.2 Receiver sensitivity

‡3.5.5.3.2.1 DME/N. The airborne equipment sensitivity shall be sufficient to acquire and provide distance information to the accuracy specified in 3.5.5.4 for the signal power density specified in 3.5.4.1.5.2.

Note.— Although the Standard in 3.5.5.3.2.1 is for DME/N interrogators, the receiver sensitivity is better than that necessary in order to operate with the power density of DME/N transponders given in 3.5.4.1.5.1 in order to assure interoperability with the IA mode of DME/P transponders.

3.5.5.3.2.2 DME/P. The airborne equipment sensitivity shall be sufficient to acquire and provide distance information to the accuracy specified in 3.5.5.4.2 and 3.5.5.4.3 for the signal power densities specified in 3.5.4.1.5.3.

‡3.5.5.3.2.3 DME/N. The performance of the interrogator shall be maintained when the power density of the transponder signal at the interrogator antenna is between the

3.5.5.3.2.4 DME/P. The performance of the interrogator shall be maintained when the power density of the transponder signal at the interrogator antenna is between the minimum values given in 3.5.4.1.5 and a maximum of minus 18 dBW/m2.

3.5.5.3.3 Bandwidth

3.5.5.3.3.1 DME/N.T he receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3, when the input signals are those specified in 3.5.4.1.3.

3.5.5.3.3.2 DME/P — IA mode. The receiver bandwidth shall be sufficient to allow compliance with3.5.3.1.3 when the input signals are those specified in 3.5.4.1.3. The 12-dB bandwidth shall not exceed 2 MHz and the 60-dB bandwidth shall not exceed 10 MHz.

3.5.5.3.3.3 DME/P — FA mode. The receiver bandwidth shall be sufficient to allow compliance with 3.5.3.1.3 when the input signals are those specified in 3.5.5.1.3. The 12-

dB bandwidth shall not exceed 6 MHz and the 60-dB bandwidth shall not exceed 20 MHz.

3.5.5.3.4Interference rejection

3.5.5.3.4.1 When there is a ratio of desired to undesired co-channel DME signals of at least 8 dB at the input terminals of the airborne receiver, the interrogator shall display distance information and provide unambiguous identification from the stronger signal.

Note.— Co-channel refers to those reply signals that utilize the same frequency and the same pulse pair spacing.

‡3.5.5.3.4.2 DME/N.DME signals greater than 900 kHz removed from the desired channel nominal frequency and having amplitudes up to 42 dB above the threshold sensitivity shall be rejected.

3.5.5.3.4.3 DME/P.DME signals greater than 900 kHz removed from the desired channel nominal frequency and having amplitudes up to 42 dB above the threshold sensitivity shall be rejected.

3.5.5.3.5 Decoding

3.5.5.3.5.1 The interrogator shall include a decoding circuit such thatthe receiver can be triggered only by pairs of received pulses having pulse duration and pulse spacings appropriate to transponder signals as described in 3.5.4.1.4.

‡3.5.5.3.5.2 DME/N — Decoder rejection. A reply pulse pair with a spacing of plus or minus 2 microseconds, or more, from the nominal value and with any signal level up to42 dB above the receiver sensitivity shall be rejected.

3.5.5.3.5.3 DME/P — Decoder rejection. A reply pulse pair with a spacing of plus or minus 2 microseconds, or more, from the nominal value and with any signal level up to42 dB above the receiver sensitivity shall be rejected.

3.5.5.4 Accuracy

‡3.5.5.4.1 DME/N. The interrogator shall not contribute more than plus or minus 315 m (plus or minus 0.17 NM) or 0.25 per cent of indicated range, whichever is greater, to the overall system error.

3.5.5.4.2 DME/P — IA mode. The interrogator shall not contribute more than plus or minus 30 m (plus or minus 100 ft) to the overall system PFE and not more than plus or minus 15 m (plus or minus 50 ft) to the overall system CMN.

3.5.5.4.3 DME/P – FA mode

3.5.5.4.3.1 Accuracy standard 1.The interrogator shall not contribute more than plus or minus 15 m (plus or minus 50 ft) to the overall system PFE and not more than plus or minus 10 m (plus or minus 33 ft) to the overall system CMN.

3.5.5.4.3.2 Accuracy standard 2.The interrogator shall not contribute more than plus or minus 7 m (plus or minus 23 ft) to the overall system PFE and not more than plus or minus 7 m (plus or minus 23 ft) to the overall system CMN.

Note.— Guidance material on filters to assist in achieving this accuracy is given in Attachment C, 7.3.4.

3.5.5.4.4 DME/P. The interrogator shall achieve the accuracy specified in3.5.3.1.3.4 with a system efficiency of 50 per cent or more.

Note.— Guidance material on system efficiency is given in Attachment C, 7.1.1.

3.6 Specification for en-route VHF marker beacons (75 MHz)

3.6.1 Equipment

3.6.1.1 Frequencies. The emissions of an en-route VHF marker beacon shall have a radio frequency of 75 MHz plus or minus 0.005 per cent.

3.6.1.2 Characteristics of emissions

3.6.1.2.1 Radio marker beacons shall radiate an uninterrupted carrier modulated to a depth of not less than 95 per cent or more than 100 per cent. The total harmonic content of the modulation shall not exceed 15 per cent.

3.6.1.2.2 The frequency of the modulating tone shall be 3 000 Hz plus or minus 75 Hz.

3.6.1.2.3 The radiation shall be horizontally polarized.

3.6.1.2.4 Identification. If a coded identification is required at a radio marker beacon, the modulating tone shall be keyed so as to transmit dots or dashes or both in an appropriate sequence. The mode of keying shall be such as to provide a dot-and-dash duration together with spacing intervals corresponding to transmission at a rate equivalent to approximately six to ten words per minute. The carrier shall not be interrupted during identification.

3.6.1.2.5 Coverage and radiation pattern

Note.— The coverage and radiation pattern of marker beacons will ordinarily be established by Contracting States on the basis of operational requirements, taking into account recommendations of regional meetings.

The most desirable radiation pattern would be one that:

a) in the case of fan marker beacons, results in lamp operation only when the aircraft is within a rectangular parallelepiped, symmetrical about the vertical line through the marker beacon and with the major and minor axes adjusted in accordance with the flight path served;

b) in the case of a Z marker beacon, results in lamp operation only when the aircraft is within a cylinder, the axis of which is the vertical line through the marker beacons.

In practice, the production of such patterns is impracticable and a compromise radiation pattern is necessary. In Attachment C, antenna systems currently in use and which have proved generally satisfactory are described for guidance. Such designs and any new designs providing a closer approximation to the most desirable radiation pattern outlined above will normally meet operational requirements.

3.6.1.2.6 Determination of coverage. The limits of coverage of marker beacons shall be determined on the basis of the field strength specified in 3.1.7.3.2.

3.6.1.2.7 Radiation pattern. Recommendation.— The radiation pattern of a marker beacon normally should be such that the polar axis is vertical, and the field strength in the pattern is symmetrical about the polar axis in the plane or planes containing the flight paths for which the marker beacon is intended.

Note.— Difficulty in siting certain marker beacons may make it necessary to accept a polar axis that is not vertical.

3.6.1.3 Monitoring. **Recommendation.—** For each marker beacon, suitable monitoring equipment should be provided which will show at an appropriate location:

a) a decrease in radiated carrier power below 50 per cent of normal;

b) a decrease of modulation depth below 70 per cent;

c) a failure of keying.

3.7 Requirements for the Global Navigation Satellite System (GNSS)

3.7.1 Definitions

Aircraft-based augmentation system (ABAS). An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft.

Alert. An indication provided to other aircraft systems or annunciation to the pilot to identify that an operating parameter of a navigation system is out of tolerance.

Alert limit. For a given parameter measurement, the error tolerance not to be exceeded without issuing an alert.

Channel of standard accuracy (CSA). The specified level of positioning, velocity and timing accuracy that is available to any GLONASS user on a continuous, worldwide basis.

Core satellite constellation(s). The core satellite constellations are GPS and GLONASS.

Global navigation satellite system (GNSS). A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation.

Global navigation satellite system (GLONASS). The satellite navigation system operated by the Russian Federation.

Global positioning system (GPS). The satellite navigation system operated by the United States.

GNSS position error. The difference between the true position and the position determined by the GNSS receiver.

Ground-based augmentation system (GBAS). An augmentation system in which the user receives augmentation information directly from a ground-based transmitter.

Ground-based regional augmentation system (GRAS). An augmentation system in which the user receives augmentation information directly from one of a group of ground-based transmitters covering a region.

Integrity. A measure of the trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts).

Pseudo-range. The difference between the time of transmission by a satellite and reception by a GNSS receiver multiplied by the speed of light in a vacuum, including bias due to the difference between a GNSS receiver and satellite time reference.

Satellite-based augmentation system (SBAS). A wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter.

Standard positioning service (SPS). The specified level of positioning, velocity and timing accuracy that is available to any global positioning system (GPS) user on a continuous, worldwide basis.

Time-to-alert. The maximum allowable time elapsed from the onset of the navigation system being out of tolerance until the equipment enunciates the alert.

3.7.2 General

3.7.2.1 Functions

3.7.2.1.1 The GNSS shall provide position and time data to the aircraft.

Note.— These data are derived from pseudo-range measurements between an aircraft equipped with a GNSS receiver and various signal sources on satellites or on the ground.

3.7.2.2 GNSS elements

3.7.2.2.1 The GNSS navigation service shall be provided using various combinations of the following elements installed on the ground, on satellites and/or on board the aircraft:

a) Global Positioning System (GPS) that provides the Standard Positioning Service (SPS) as defined in 3.7.3.1;

b) Global Navigation Satellite System (GLONASS) that provides the Channel of Standard Accuracy (CSA) navigation signal as defined in 3.7.3.2;

c) aircraft-based augmentation system (ABAS) as defined in 3.7.3.3;

d) satellite-based augmentation system (SBAS) as defined in 3.7.3.4;

e) ground-based augmentation system (GBAS) as defined in 3.7.3.5;

f) ground-based regional augmentation system (GRAS) as defined in 3.7.3.5; and

g) aircraft GNSS receiver as defined in 3.7.3.6.

3.7.2.3 Space and time reference

3.7.2.3.1 Space reference. The position information provided by the GNSS to the user shall be expressed in terms of the World Geodetic System — 1984 (WGS-84) geodetic reference datum.

Note 1.— SARPs for WGS-84 are contained in Annex 4, Chapter 2, Annex 11, Chapter 2, Annex 14, Volumes I and II, Chapter 2 and Annex 15, Chapter 3.

Note 2.— If GNSS elements using other than WGS-84 coordinates are employed, appropriate conversion parameters are to be applied.

3.7.2.3.2 Time reference. The time data provided by the GNSS to the user shall be expressed in a time scale that takes the Universal Time Coordinated (UTC) as reference.

3.7.2.4 Signal-in-space performance

3.7.2.4.1 The combination of GNSS elements and a fault-free GNSS user receiver shall meet the signal-in-space requirements defined in Table 3.7.2.4-1 (located at the end of section 3.7).

Note.— The concept of a fault-free user receiver is applied only as a means of defining the performance of combinations of different GNSS elements. The fault-free receiver is assumed to be a receiver with nominal accuracy and time-to-alert performance. Such a receiver is assumed to have no failures that affect the integrity,availability and continuity performance.

3.7.3 GNSS elements specifications

3.7.3.1 GPS Standard Positioning Service (SPS) (L1)

3.7.3.1.1 Space and control segment accuracy

Note.— The following accuracy standards donot include atmospheric or receiver errors as described in Attachment D, 4.1.2.

3.7.3.1.1.1 Positioning accuracy. The GPS SPS position errors shall not exceed the following limits:

	Global average 95% of the time	*Worst site 95% of the time*
Horizontal position error	*13 m (43 ft)*	*36 m (118 ft)*
Vertical position error	*22 m (72 ft)*	*77 m (253 ft)*

3.7.3.1.1.2 Time transfer accuracy. The GPS SPS time transfer errors shall not exceed 40 nanoseconds 95 per cent of the time.

3.7.3.1.1.3 Range domain accuracy. The range domain error shall not exceed the following limits:

a) range error of any satellite — the larger of:

— 30 m (100 ft); or

— 4.42 times the broadcast user range accuracy (URA), not to exceed 150 m (490 ft);

b) range rate error of any satellite — 0.02 m (0.07 ft) per second;

c) range acceleration error of any satellite — 0.007 m (0.02 ft) per second-squared; and

d) root-mean-square range error over all satellites — 6 m (20 ft).

3.7.3.1.2 Availability. The GPS SPS availability shall be as follows:

≥99 per cent horizontal service availability, average location (36 m 95 per cent threshold)

≥99 per cent vertical service availability, average location (77 m 95 per cent threshold)

≥90 per cent horizontal service availability, worst-case location (36 m 95 per cent threshold)

≥90 per cent vertical service availability, worst-case location (77 m 95 per cent threshold)

3.7.3.1.3 Reliability. The GPS SPS reliability shall be within the following limits:

a) frequency of a major service failure — not more than three per year for the constellation (global average);

b) reliability — at least 99.94 per cent (global average); and

c) reliability — at least 99.79 per cent (single point average).

3.7.3.1.4 Coverage. The GPS SPS shall cover the surface of the earth up to an altitude of 3 000 kilometres.

Note.— Guidance material on GPS accuracy, availability, reliability and coverage is given in Attachment D, 4.1.

3.7.3.1.5 Radio frequency (RF) characteristics

Note.— Detailed RF characteristics are specified in Appendix B, 3.1.1.1.

3.7.3.1.5.1 Carrier frequency. Each GPS satellite shall broadcast an SPS signal at the carrier frequency of 1 575.42 MHz (GPS L1) using code division multiple access (CDMA).

Note.— A new civil frequency will be added to the GPS satellites and will be offered by the United States for critical safety-of-life applications. SARPs for this signal may be developed at a later date.

3.7.3.1.5.2 Signal spectrum. The GPS SPS signal power shall be contained within a ±12 MHz band (1 563.42 – 1 587.42 MHz) centred on the L1 frequency.

3.7.3.1.5.3 Polarization. The transmitted RF signal shall be right-hand (clockwise) circularly polarized.

3.7.3.1.5.4 Signal power level. Each GPS satellite shall broadcast SPS navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the output of a 3 dBi linearly-polarized antenna is within the range of –158.5 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.5.5 Modulation. The SPS L1 signal shall be bipolar phase shift key (BPSK) modulated with a pseudo random noise (PRN) 1.023 MHz coarse/acquisition (C/A) code. The C/A code sequence shall be repeated each millisecond. The transmitted PRN code sequence shall be the Modulo-2 addition of a 50 bits per second navigation message and the C/A code.

3.7.3.1.6 GPS time. GPS time shall be referenced to UTC (as maintained by the U.S. Naval Observatory).

3.7.3.1.7 Coordinate system. The GPS coordinate system shall be WGS-84.

3.7.3.1.8 Navigation information. The navigation data transmitted by the satellites shall include the necessary information to determine:

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) propagation delay effects;

f) time transfer to UTC; and

g) constellation status.

Note.— Structure and contents of data are specified in Appendix B, 3.1.1.2 and 3.1.1.3, respectively.

3.7.3.2 GLONASS Channel of Standard Accuracy (CSA) (L1)

Note.— In this section, the term GLONASS refers to all satellites in the constellation. Standards relating only to GLONASS-M satellites are qualified accordingly.

3.7.3.2.1 Space and control segment accuracy

Note.— The following accuracy Standards donot include atmospheric or receiver errors as described in Attachment D, 4.2.2.

3.7.3.2.1.1 Positioning accuracy. The GLONASS CSA position errors shall not exceed the following limits:

	Global average 95% of the time	*Worst site 95% of the time*
Horizontal position error	*5m (17 ft)*	*12 m (40 ft)*
Vertical position error	*9m (29 ft)*	*25 m (97 ft)*

3.7.3.2.1.2 Time transfer accuracy. The GLONASS CSA time transfer errors shall not exceed 700 nanoseconds 95 per cent of the time.

3.7.3.2.1.3 Range domain accuracy. The range domain error shall not exceed the following limits:

a) range error of any satellite — 18 m (59.7 ft);

b) range rate error of any satellite — 0.02 m (0.07 ft) per second;

c) range acceleration error of any satellite — 0.007 m (0.023 ft) per second squared;

d) root-mean-square range error over all satellites — 6 m (19.9 ft).

3.7.3.2.2 Availability. The GLONASS CSA availability shall be as follows:

a) ≥99 per cent horizontal service availability, average location (12 m, 95 per cent threshold);

b) ≥99 per cent vertical service availability, average location (25 m, 95 per cent threshold);

c) ≥90 per cent horizontal service availability, worst-case location (12 m, 95 per cent threshold);

d) ≥90 per cent vertical service availability, worst-case location (25 m, 95 per cent threshold).

3.7.3.2.3 Reliability. The GLONASS CSA reliability shall be within the following limits:

a) frequency of a major service failure — not more than three per year for the constellation (global average); and

b) reliability — at least 99.7 per cent (global average).

3.7.3.2.4 Coverage. The GLONASS CSA shall cover the surface of the earth up toan altitude of 2 000 km.

Note.— Guidance material on GLONASS accuracy, availability, reliability and coverage is given in Attachment D, 4.2.

3.7.3.2.5 RF characteristics

Note.— Detailed RF characteristics are specified in Appendix B, 3.2.1.1.

3.7.3.2.5.1 Carrier frequency. Each GLONASS satellite shall broadcast CSA navigation signal at its own carrier frequency in the L1 (1.6 GHz) frequency band using frequency division multiple access (FDMA).

Note 1.— GLONASS satellites may have the same carrier frequency but in this case they are located in antipodal slots of the same orbital plane.

Note 2.— GLONASS-M satellites will broadcast an additional ranging code at carrier frequencies in the L2 (1.2 GHz) frequency band using FDMA.

3.7.3.2.5.2 Signal spectrum. GLONASS CSA signal power shall be contained within a ±5.75 MHz band centred on each GLONASS carrier frequency.

3.7.3.2.5.3 Polarization. The transmitted RF signal shall be right-hand circularly polarized.

3.7.3.2.5.4 Signal power level. Each GLONASS satellite shall broadcast CSA navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the output of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

Note 1.— The power limit of 155.2 dBW is based on the predetermined characteristics of a user antenna, atmospheric losses of 0.5 dB and an error of an angular position of a satellite that does not exceed one degree (in the direction causing the signal level to increase).

Note 2.— GLONASS-M satellites will also broadcast a ranging code on L2 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the output of a 3 dBi linearly polarized antenna is not less then –167 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.2.5.5 Modulation

3.7.3.2.5.5.1 Each GLONASS satellite shall transmit atits carrier frequency the navigation RF signal using a BPSK modulated binary train. The phase shift keying of the carrier shall be performed at π-radians with the maximum error ±0.2 radian. The pseudo-random code sequence shall be repeated each millisecond.

3.7.3.2.5.5.2 The modulating navigation signal shall be generated by the Modulo-2 addition of the following three binary signals:

a) ranging code transmitted at 511 kbits/s;

b) navigation message transmitted at 50 bits/s; and

c) 100 Hz auxiliary meander sequence.

3.7.3.2.6 GLONASS time. GLONASS time shall be referenced to UTC(SU) (as maintained by the National Time Service of Russia).

3.7.3.2.7 Coordinate system. The GLONASS coordinate system shall be PZ-90.

Note.— Conversion from the PZ-90 coordinate system used by GLONASS to the WGS-84 coordinates is defined in Appendix B, 3.2.5.2.

3.7.3.2.8 Navigation information. The navigation data transmitted by the satellite shall include the necessary information to determine:

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) time transfer to UTC; and

f) constellation status.

Note.— Structure and contents of data are specified in Appendix B, 3.2.1.2 and 3.2.1.3, respectively.

3.7.3.3 Aircraft-based augmentation system (ABAS)

3.7.3.3.1 Performance. The ABAS function combined with one or more of the other GNSS elements and both a fault free GNSS receiver and fault-free aircraft system used for the ABAS function shall meet the requirements for accuracy, integrity, continuity and availability as stated in 3.7.2.4.

3.7.3.4 Satellite-based augmentation system (SBAS)

3.7.3.4.1 Performance. SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for system accuracy, integrity, continuity and availability for the intended operation as stated in 3.7.2.4.

Note.— SBAS complements the core satellite constellation(s) by increasing accuracy, integrity, continuity and availability of navigation provided within a service area, typically including multiple aerodromes.

3.7.3.4.2 Functions. SBAS shall perform one or more of the following functions:

a) ranging: provide an additional pseudo-range signal with an accuracy indicator from an SBAS satellite (3.7.3.4.2.1 and Appendix B, 3.5.7.2);

b) GNSS satellite status: determine and transmit the GNSS satellite health status(Appendix B, 3.5.7.3);

c) basic differential correction: provide GNSS satellite ephemeris and clock corrections (fast and long-term) to be applied to the pseudo-range measurements from satellites (Appendix B, 3.5.7.4); and

d) precise differential correction: determine and transmit the ionospheric corrections (Appendix B, 3.5.7.5).

Note.— If all the functions are provided, SBAS in combination with core satellite constellation(s) can support departure, en-route, terminal and approach operations including Category I precision approach. The level of performance that can be achieved depends upon the infrastructure incorporated into SBAS and the ionospheric conditions in the geographic area of interest.

3.7.3.4.2.1 Ranging

3.7.3.4.2.1.1 Excluding atmospheric effects, the range error for the ranging signal from SBAS satellites shall not exceed 25 m (82 ft) (95 per cent).

3.7.3.4.2.1.2 The probability that the range error exceeds 150 m (490 ft) in any hour shall not exceed 10–5.

3.7.3.4.2.1.3 The probability of unscheduled outages of the ranging function from an SBAS satellite in any hour shall not exceed 10–3.

3.7.3.4.2.1.4 The range rate error shall not exceed 2 m (6.6 ft) per second.

3.7.3.4.2.1.5 The range acceleration error shall not exceed 0.019 m (0.06 ft) per second-squared.

3.7.3.4.3 Service area. The SBAS service area shall be a defined area within an SBAS coverage area where SBAS meets the requirements of 3.7.2.4 and supports the corresponding approved operations.

Note 1.— The coverage area is that area within which the SBAS broadcast can be received (e.g. the geostationary satellite footprints).

Note 2.— SBAS coverage and service areas are discussed in Attachment D, 6.2.

3.7.3.4.4 RF characteristics

Note.— Detailed RF characteristics are specified in Appendix B, 3.5.2.

3.7.3.4.4.1 Carrier frequency. The carrier frequency shall be 1 575.42 MHz.

Note.— After 2005, when the upper GLONASS frequencies are vacated, another type of SBAS may be introduced using some of these frequencies.

3.7.3.4.4.2 Signal spectrum. At least 95 per cent of the broadcast power shall be contained within a ±12 MHz band centred on the L1 frequency. The bandwidth of the signal transmitted by an SBAS satellite shall be at least 2.2 MHz.

3.7.3.4.4.3 Signal power level

3.7.3.4.4.3.1 Each SBAS satellite shall broadcast navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the output of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.4.4.3.2 Each SBAS satellite placed inorbit after 31 December 2013 shall broadcast navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satelliteis observed at or above the minimum elevation angle for which a trackable GEO signal needs to be provided, the level of the received RF signal at the output of the antenna specified in Appendix B, Table B-87, is at least –164.0 dBW.

3.7.3.4.4.3.2.1 Minimum elevation angle. The minimum elevation angle used to determine GEO coverage shall not be less than 5 degrees for a user near the ground.

3.7.3.4.4.3.2.2 The level of a received SBAS RF signal at the output of a 0 dBic antenna located near the ground shall not exceed –152.5 dBW.

3.7.3.4.4.4 Polarization. The broadcast signal shall be right-hand circularly polarized.

3.7.3.4.4.5 Modulation. The transmitted sequence shall be the Modulo-2 addition of the navigation message at a rate of 500 symbols per second and the 1 023 bit pseudo-random noise code. It shall then be BPSK-modulated onto the carrier at a rate of 1.023 mega chips per second.

3.7.3.4.5 SBAS network time (SNT). The difference between SNT and GPS time shall not exceed 50 nanoseconds.

3.7.3.4.6 Navigation information. The navigation data transmitted by the satellites shall include the necessary information to determine:

a) SBAS satellite time of transmission;

b) SBAS satellite position;

c) corrected satellite time for all satellites;

d) corrected satellite position for all satellites;

e) ionospheric propagation delay effects;

f) user position integrity;

g) time transfer to UTC; and

h) service level status.

Note.— Structure and contents of data are specified in Appendix B, 3.5.3 and 3.5.4, respectively.

3.7.3.5Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

Note 1.— Except where specifically annotated, GBAS Standards and Recommended Practices apply to GBAS and GRAS.

Note 2.— Except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.

3.7.3.5.1 Performance. GBAS combined with one or more of the other GNSS elements and a fault-free GNSS receiver shall meet the requirements for system accuracy, continuity, availability and integrity for the intended operation as stated in 3.7.2.4.

Note.— GBAS is intended to support all types of approach, landing, departure and surface operations and may support en-route and terminal operations. GRAS is intended to support en-route, terminal, non-precision approach, departure, and approach with vertical guidance. The following SARPs are developed to support Category I precision approach, approach with vertical guidance, and a GBAS positioning service. In order to achieve interoperability and enable efficient spectrum utilization, it is intended that the data broadcast is the same for all operations.

3.7.3.5.2 Functions. GBAS shall perform the following functions:

a) provide locally relevant pseudo-range corrections;

b) provide GBAS-related data;

c) provide final approach segment data when supporting precision approach;

d) provide predicted ranging source availability data; and

e) provide integrity monitoring for GNSS ranging sources.

3.7.3.5.3 Coverage

3.7.3.5.3.1 Category I precision approach and approach with vertical guidance.The GBAS coverage to support each Category I precision approach or approach with vertical guidance shall be as follows, except where topographical features dictate and operational requirements permit:

a) laterally, beginning at 140 m (450 ft) each side of the landing threshold point/fictitious threshold point (LTP/FTP) and projecting out ±35 degrees either side of the final approach path to 28 km (15 NM) and ±10 degrees either side of the final approach path to 37 km (20 NM); and

b) vertically, within the lateral region, up to the greater of 7 degrees or 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the glide path interception point (GPIP) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure. This coverage applies between 30 m (100 ft) and 3 000 m (10 000 ft) height above threshold (HAT).

Note.— LTP/FTP and GPIP are defined in Appendix B, 3.6.4.5.1.

3.7.3.5.3.1.1 Recommendation.—For Category I precision approach, the data broadcast as specified in 3.7.3.5.4 should extend down to 3.7 m (12 ft) above the runway surface.

3.7.3.5.3.1.2 Recommendation.—The data broadcast should be omnidirectional when required to support the intended applications.

Note.— Guidance material concerning coverage for Category I precision approach and APV is provided in Attachment D, 7.3.

3.7.3.5.3.2 GBAS positioning service. The GBAS positioning service area shall be that area where the data broadcast can be received and the positioning service meets the requirements of 3.7.2.4 and supports the corresponding approved operations.

Note.— Guidance material concerning the positioning service coverage is provided in Attachment D, 7.3.

3.7.3.5.4 Data broadcast characteristics

*Note.— RF characteristics are specified in Appendix B, 3.6.*2.

3.7.3.5.4.1 Carrier frequency. The data broadcast radio frequencies used shall be selected from the radio frequencies in the band 108 to 117.975 MHz. The lowest assignable frequency shall be 108.025 MHz and the highest assignable frequency shall be 117.950 MHz. The separation between assignable frequencies (channel spacing) shall be 25 kHz.

Note 1.— Guidance material on VOR/GBAS frequency assignments and geographical separation criteria is given in Attachment D, 7.2.1.

Note 2.— ILS/GBAS geographical separation criteria and geographical separation criteria for GBAS and VHF communication services operating in the 118 – 137 MHz band are under development. Until these criteria are defined and included in SARPs, it is intended that frequencies in the band 112.050 – 117.900 MHz will be used.

3.7.3.5.4.2 Access technique. A time division multiple access (TDMA) technique shall be used with a fixed frame structure. The data broadcast shall be assigned one to eight slots.

Note.— Two slots is the nominal assignment. Some GBAS facilities that use multiple VHF data broadcast (VDB) transmit antennas to improve VDB coverage may require assignment of more than two time slots. Guidance on the use of multiple antennas is given in Attachment D, 7.12.4; some GBAS broadcast stations in a GRAS may use one time slot.

3.7.3.5.4.3 Modulation. GBAS data shall be transmitted as 3-bit symbols, modulating the data broadcast carrier by D8PSK, at a rate of 10 500 symbols per second.

3.7.3.5.4.4 Data broadcast RF field strength and polarization

Note.— GBAS can provide a VHF data broadcast with either horizontal (GBAS/H) or elliptical (GBAS/E) polarization that employs both horizontal polarization (HPOL) and vertical polarization (VPOL) components. Aircraft using a VPOL component will not be able to conduct operations with GBAS/H equipment. Relevant guidance material is provided in Attachment D, 7.1.

3.7.3.5.4.4.1 GBAS/H

3.7.3.5.4.4.1.1 A horizontally polarized signal shall be broadcast.

3.7.3.5.4.4.1.2 The effective radiated power (ERP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m2) and a maximum field strength of 0.350 volts per metre (–35 dBW/m2) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and any VPOL components shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL users throughout the coverage volume.

3.7.3.5.4.4.2 GBAS/E

3.7.3.5.4.4.2.1 **Recommendation.—** An elliptically polarized signal should be broadcast whenever practical.

3.7.3.5.4.4.2.2 When an elliptically polarized signal isbroadcast, the horizontally polarized component shall meet the requirements in 3.7.3.5.4.4.1.2, and the effective radiated power (ERP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre (–103 dBW/m2) and a maximum field strength of 0.221 volts per metre (–39 dBW/m2) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and VPOL components, shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL and VPOL users throughout the coverage volume.

Note.— The minimum and maximum field strengths in 3.7.3.5.4.4.1.2 and 3.7.3.5.4.4.2.2 are consistent with a minimum receiver sensitivity of –87 dBm and minimum distance of 200 m (660 ft) from the transmitter antenna for a coverage range of 43 km (23 NM).

3.7.3.5.4.5 Power transmitted in adjacent channels. The amount of power during transmission under all operating conditions when measured over a 25 kHz bandwidth centred on the i-th adjacent channel shall not exceed the values shown in Table 3.7.3.5-1 (located at the end of section 3.7).

3.7.3.5.4.6 Unwanted emissions. Unwanted emissions, including spurious and out-of-band emissions, shall be compliant with the levels shown in Table 3.7.3.5-2 (located at the end of section 3.7). The total power in any VDB harmonic or discrete signal shall not be greater than –53 dBm.

3.7.3.5.5 Navigation information. The navigation data transmitted by GBAS shall include the following information:

a) pseudo-range corrections, reference time and integrity data;

b) GBAS-related data;

c) final approach segment data when supporting precision approach; and

d) predicted ranging source availability data.

Note.— Structure and contents of data are specified in Appendix B, 3.6.3.

3.7.3.6 Aircraft GNSS receiver

3.7.3.6.1 The aircraft GNSS receiver shall process the signals ofthose GNSS elements that it intends to use as specified in Appendix B, 3.1 (for GPS), Appendix B, 3.2 (for GLONASS), Appendix B, 3.3 (for combined GPS and GLONASS), Appendix B, 3.5 (for SBAS) and Appendix B, 3.6 (for GBAS and GRAS).

3.7.4 Resistance to interference

3.7.4.1 GNSS shall comply with performance requirements defined in 3.7.2.4 and Appendix B, 3.7 in the presence of the interference environment defined in Appendix B, 3.7.

Note.— GPS and GLONASS operating in the frequency band 1 559 – 1 610 MHz are classified by the ITU as providing a radio navigation satellite service (RNSS) and aeronautical radio navigation service (ARNS) and are afforded special spectrum protection status for RNSS. In order to achieve the performance objectives for precision approach guidance to be supported by the GNSS and its augmentations, RNSS/ARNS is intended to remain the only global allocation in the 1 559 –1 610 MHz band and emissions from systems in this and adjacent frequency bands are intended to be tightly controlled by national and/or international regulation.

3.7.5 Database

Note.— SARPs applicable to aeronautical data are provided in Annex 4,Annex 11, Annex 14 and Annex 15.

3.7.5.1 Aircraft GNSS equipment that uses a database shall provide a means to:

a) update the electronic navigation database; and

b) determine the Aeronautical Information Regulation and Control (AIRAC) effective dates of the aeronautical database.

Note.— Guidance material on the need for a current navigation database in aircraft GNSS equipment is provided in Attachment D, 11.

Table 3.7.2.4-1 Signal-in-space performance requirements

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

NOTES.—

1. The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), If applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment D, 3.2.

2. The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. For Category I precision approach, a vertical alert limit (VAL) greater than 10 m for a specific system design may only be used if a system-specific safety analysis has been completed. Further guidance on the alert limits is provided in Attachment D, 3.3.6 to 3.3.10. These alert limits are:

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A
En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I	40 m (130 ft)	50 m (164 ft)
APV- II	40 m (130 ft)	20.0 m (66 ft)
Category I precision approach	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33 ft)

3. The accuracy and time-to-alert requirements include the nominal performance of a fault-free receiver.

4. Ranges of values are given for the continuity requirement for en-route, terminal, initial approach, NPA and departure operations, as this requirement is dependent upon several factors including the intended operation, traffic density, complexity of airspace and availability of alternative navigation aids. The lower value given is the minimum requirement for areas with low traffic density and airspace complexity. The higher value given is appropriate for areas with high traffic density and airspace complexity (see Attachment D, 3.4.2). Continuity requirements for APV and Category I operations apply to the average risk (over time) of loss of service, normalized to a 15-second exposure time (see Attachment D, 3.4.3).

5. A range of values is given for the availability requirements as these requirements are dependent upon the operational need which is based upon several factors including the frequency of operations, weather environments, the size and duration of the outages, availability of alternate navigation aids, radar coverage, traffic density and reversionary operational procedures. The lower values given are the minimum availabilities for which a system is considered to be practical but are not adequate to replace non-GNSS navigation aids. For en-route navigation, the higher values given are adequate for GNSS to be the only navigation aid provided in an area. For approach and departure, the higher values given are based upon the availability requirements at airports with a large amount of traffic assuming that operations to or from multiple runways are affected but reversionary operational procedures ensure the safety of the operation (see Attachment D, 3.5).

6. A range of values is specified for Category I precision approach. The 4.0 m (13 feet) requirement is based upon ILS specifications and represents a conservative derivation from these specifications (see Attachment D, 3.2.7).

7. GNSS performance requirements for Category II and III precision approach operations are under review and will be included at a later date.

8. The terms APV-I and APV-II refer to two levels of GNSS approach and landing operations with vertical guidance (APV) and these terms are not necessarily intended to be used operationally.

Table 3.7.3.5-1. GBAS broadcast power transmitted in adjacent channels

Channel	Relative power	Maximum power
1st adjacent	−40 dBc	12 dBm
2nd adjacent	−65 dBc	−13 dBm
4th adjacent	−74 dBc	−22 dBm
8th adjacent	−88.5 dBc	−36.5 dBm
16th adjacent	−101.5 dBc	−49.5 dBm
32nd adjacent	−105 dBc	−53 dBm
64th adjacent	−113 dBc	−61 dBm
76th adjacent and beyond	−115 dBc	−63 dBm

NOTES.—
1. The maximum power applies if the authorized transmitter power exceeds 150 W.
2. The relationship is linear between single adjacent points designated by the adjacent channels identified above.

Table 3.7.3.5-2. GBAS broadcast unwanted emissions

Frequency	Relative unwanted emission level (Note 2)	Maximum unwanted emission level (Note 1)
9 kHz to 150 kHz	−93 dBc (Note 3)	−55 dBm/1 kHz (Note 3)
150 kHz to 30 MHz	−103 dBc (Note 3)	−55 dBm/10 kHz (Note 3)
30 MHz to 106.125 MHz	−115 dBc	−57 dBm/100 kHz
106.425 MHz	−113 dBc	−55 dBm/100 kHz
107.225 MHz	−105 dBc	−47 dBm/100 kHz
107.625 MHz	−101.5 dBc	−53.5 dBm/10 kHz
107.825 MHz	−88.5 dBc	−40.5 dBm/10 kHz
107.925 MHz	−74 dBc	−36 dBm/1 kHz
107.9625 MHz	−71 dBc	−33 dBm/1 kHz
107.975 MHz	−65 dBc	−27 dBm/1 kHz
118.000 MHz	−65 dBc	−27 dBm/1 kHz
118.0125 MHz	−71 dBc	−33 dBm/1 kHz
118.050 MHz	−74 dBc	−36 dBm/1 kHz
118.150 MHz	−88.5 dBc	−40.5 dBm/10 kHz
118.350 MHz	−101.5 dBc	−53.5 dBm/10 kHz
118.750 MHz	−105 dBc	−47 dBm/100 kHz
119.550 MHz	−113 dBc	−55 dBm/100 kHz
119.850 MHz to 1 GHz	−115 dBc	−57 dBm/100 kHz
1 GHz to 1.7 GHz	−115 dBc	−47 dBm/1 MHz

NOTES.—
1. The maximum unwanted emission level (absolute power) applies if the authorized transmitter power exceeds 150 W.
2. The relative unwanted emission level is to be computed using the same bandwidth for desired and unwanted signals. This may require conversion of the measurement for unwanted signals done using the bandwidth indicated in the maximum unwanted emission level column of this table.
3. This value is driven by measurement limitations. Actual performance is expected to be better.
4. The relationship is linear between single adjacent points designated by the adjacent channels identified above.

3.8 (Reserved)

3.9 System characteristics of airborne ADF receiving systems

3.9.1 Accuracy of bearing indication

3.9.1.1 The bearing given by the ADF system shall not be in error by more than plus or minus 5 degrees with a radio signal from any direction having a field strength of 70 microvolts per metre or more radiated from an LF/MF NDB or locator operating within the tolerances permitted by this Annex and in the presence also of an unwanted signal from a direction 90 degrees from the wanted signal and:

a) on the same frequency and 15 dB weaker; or

b) plus or minus 2 kHz away and 4 dB weaker; or

c) plus or minus 6 kHz or more away and 55 dB stronger.

Note. — The above bearing error is exclusive of aircraft magnetic compass error.

3.10 (Reserved)

3.11 Microwave landing system (MLS) characteristics

3.11.1 Definitions

Auxiliary data. Data, transmitted in addition to basic data, that provide ground equipment siting information for use in refining airborne position calculations and other supplementary information.

Basic data. Data transmitted by the ground equipment that are associated directly with the operation of the landing guidance system.

Beam centre. The midpoint between the two minus 3-dB points on the leading and trailing edges of the scanning beam main lobe.

Beamwidth. The width of the scanning beam main lobe measured at the minus 3-dB points and defined in angular units on the bore sight, in the horizontal plane for the azimuth function and in the vertical plane for the elevation function.

Clearance guidance sector. The volume of airspace, inside the coverage sector, within which the azimuth guidance information provided is not proportional to the angular displacement of the aircraft, but is a constant left or right indication of which side the aircraft is with respect to the proportional guidance sector.

Control motion noise (CMN). That portion of the guidance signal error which causes control surface, wheel and column motion and could affect aircraft attitude angle during coupled flight, but does not cause aircraft displacement from the desired course and/or glide path. (See 3.5.)

Coordinate system — conical. A function is said to use conical coordinates when the decoded guidance angle varies as the minimum angle between the surface of a cone containing the receiver antenna, and a plane perpendicular to the axis of the cone and passing through its apex. The apex of the cone is at the antenna phase centre. For approach azimuth or back azimuth functions, the plane is the vertical plane containing the runway centre line. For elevation functions, the plane is horizontal.

Coordinate system — planar. A function is said to use planar coordinates when the decoded guidance angle varies as the angle between the plane containing the receiver antenna and a reference plane. For azimuth functions, the reference plane is the vertical plane containing the runway centre line and the plane containing the receiver antenna is a vertical plane passing through the antenna phase centre.

Coverage sector. A volume of airspace within which service is provided by a particular function and in which the signal power density is equal to or greater than the specified minimum.

DME/P. The distance measuring element of the MLS, where the "P" stands for precise distance measurement. The spectrum characteristics are those of DME/N.

Function. A particular service provided by the MLS, e.g. approach azimuth guidance, back azimuth guidance or basic data, etc.

Mean course error. The mean value of the azimuth error along the runway extended centre line.

Mean glide path error. The mean value of the elevation error along the glide path of anelevation function.

Minimum glide path. The lowest angle of descent along the zero degree azimuth that is consistent with published approach procedures and obstacle clearance criteria.

Note.— This is the lowest elevation angle which hasbeen approved and promulgated for the instrument runway.

MLS antenna boresight. The plane passing through the antenna phase centre perpendicular to the horizontal axis contained in the plane of the antenna array.

Note.— In the azimuth case, the boresight of the antenna and the zero degree azimuth are normally aligned.
However, the preferred designation in a technical context is "boresight" whereas the preferred designation in an operational context is "zero degree azimuth" (see definition below).

MLS azimuth. The locus of points in any horizontal plane where the decoded guidance angle is constant.

MLS approach reference datum. A point at a specified height above the intersection of the runway centre line and the threshold.

MLS back azimuth reference datum. A point at a specified height above the runway centre line at the runway midpoint.

MLS datum point. The point on the runway centre line closest to the phase centre of the approach elevation antenna.

MLS elevation. The locus of points in any vertical plane where the decoded guidance angle is constant.

MLS zero degree azimuth. The MLS azimuth where the decoded guidance angle is zero degrees.

Out-of-coverage indication signal. A signal radiated into areas outside the intended coverage sector where required to specifically prevent invalid removal of an airborne warning indication in the presence of misleading guidance information.

Path following error (PFE). That portion of the guidance signal error which could cause aircraft displacement from the desired course and/or glide path.

Path following noise (PFN). That portion of the guidance signal error which could cause aircraft displacement from the mean course line or mean glide path as appropriate.

Proportional guidance sector. The volume of airspace within which the angular guidance information provided by a function is directly proportional to the angular displacement of the airborne antenna with respect to the zero angle reference.

3.11.2 General

3.11.2.1 MLS is a precision approach and landing guidance system which provides position information and various ground to air data. The position information is provided in a wide coverage sector and is determined by an azimuth angle measurement, an elevation angle measurement and a range (distance) measurement.

Note.— Unless specifically indicated as the MLS airborne equipment, the text in 3.11 refers to the MLS ground equipment.

3.11.3 MLS configurations

3.11.3.1 **Basic MLS**. The basic configuration of the MLS shall be composed of the following:

a) approach azimuth equipment, associated monitor, remote control and indicator equipment;

b) approach elevation equipment, associated monitor, remote control and indicator equipment;

c) a means for the encoding and transmission of essential data words, associated monitor, remote control and indicator equipment;

Note.— The essential data are those basic and essential auxiliary data words specified in 3.11.5.4.

d) DME/N, associated monitor, remote control and indicator equipment.

3.11.3.2 Recommendation.— If precise ranging information throughout the azimuth coverage sector is required, the option of DME/P, conforming to the Standards of Chapter 3, 3.5 should be applied.

Note.— DME is the MLS ranging element and is expected to be installed as soon as possible. However, marker beacons installed for ILS may be used temporarily with MLS while ILS service is maintained at the same runway.

3.11.3.3 Expanded MLS configurations. It shall be permissible to derive expanded configurations from the basic MLS, by addition of one or more of the following functions or characteristic improvements:

a) back azimuth equipment, associated monitor, remote control and indicator equipment;

b) flare elevation equipment, associated monitor, remote control and indicator equipment;

c) DME/P, associated monitor, remote control and indicator equipment;

d) a means for the encoding and transmission of additional auxiliary data words, associated monitor, remote control and indicator equipment;

e) a wider proportional guidance sector exceeding the minimum specified in 3.11.5.

Note 1.— Although the Standard has been developed to provide for flare elevation function, this function is not implemented and is not intended for future implementation.

Note 2.— The MLS signal format allows further system growth to include additional functions, such as 360 degrees azimuth.

3.11.3.4 Simplified MLS configurations. It shall be permissible to derive simplified configurations from the basic MLS (3.11.3.1), by relaxation of characteristics as follows:

a) an approach azimuth coverage provided in approach region (3.11.5.2.2.1.1) only;

b) an approach azimuth and elevation coverage (3.11.5.2.2 and 3.11.5.3.2) not extending below a height of 30 m (100 ft) above the threshold;

c) accuracy limits for PFE and PFN expanded to be not greater than 1.5 times the values specified in 3.11.4.9.4 for approach azimuth guidance and in 3.11.4.9.6for elevation guidance;

d) ground equipment contribution to the mean course error and to the mean glide path error expanded to be 1.5 times the values specified in 3.11.5.2.5 and 3.11.5.3.5, respectively;

e) CMN requirements (3.11.4.9.4 and 3.11.4.9.6) waived; and

f) monitor and control action period (3.11.5.2.3 and 3.11.5.3.3) expanded to a six-second period.

Note.— Guidance material on application of the simplified MLS configurations is provided in Attachment G, 15.

3.11.4 Signal-in-space characteristics — angle and data functions

3.11.4.1 Channelling

3.11.4.1.1 Channel arrangement. The MLS angle and data functions shall operate on any one of the 200 channels assigned on the frequencies from 5 031.0 MHz to 5 090.7 MHz as shown in Table A.

3.11.4.1.1.1 Channel assignments in addition to those specified in 3.11.4.1.1 shall be made within the 5 030.4 to 5 150.0 MHz sub-band as necessary to satisfy future air navigation requirements.

3.11.4.1.2 Channel pairing with DME.The channel pairing of the angle and data channel with the channel of the ranging function shall be in accordance with Table A.

3.11.4.1.3 Frequency tolerance. The operating radio frequency of the ground equipment shall not vary more than plus or minus 10 kHz from the assigned frequency. The frequency stabilityshall be such that there is no more than a plus or minus 50 Hz deviation from the nominal frequency when measured over a one-second interval.

3.11.4.1.4 Radio frequency signal spectrum

3.11.4.1.4.1 The transmitted signal shall be such that, during the transmission time, the mean power density above a height of 600 m (2 000 ft) shall not exceed –94.5 dBW/m2 for angle guidance or data signals, as measured in a 150 kHz bandwidth centred 840 kHz or more from the nominal frequency.

3.11.4.1.4.2 The transmitted signal shall be such that, during the transmission time, the mean power density beyond a distance of 4 800 m (2.6 NM) from any antennas and for a height below 600 m (2 000 ft) shall not exceed –94.5 dBW/m² for angle guidance or data signals, as measured in a 150 kHz bandwidth centred 840 kHz or more from the nominal frequency.

Note 1.— Requirements in 3.11.4.1.4.2 are applicable when the operational coverage of another MLS ground station has overlap with the radio-horizon of the considered ground station.

Note 2.— Guidance material on MLS frequency planning is provided in Attachment G, 9.3.

3.11.4.2 Polarization. The radio frequency transmissions from all ground equipment shall be nominally vertically polarized. The effect of any horizontally polarized component shall not cause the guidance information to change by more than 40 per cent of the PFE allowed at that location with the airborne antenna rotated 30 degrees from the vertical position or cause the PFE limit to be exceeded.

3.11.4.3 Time-division-multiplex (TDM) organization

3.11.4.3.1 Both angle information and data shall be transmitted by TDM on a single radio frequency channel.

3.11.4.3.2 Synchronization. The transmissions from the various angle and data ground equipment serving a particular runway shall be time synchronized to assure interference-free operations on the common radio frequency channel of operation.

3.11.4.3.3 Function rates. Each function transmitted shall be repeated at the rates shown in the following table:

Function	Average rate (Hz) measured over any 10-second period
Approach azimuth guidance	13 ± 0.5
High rate approach azimuth guidance	39 ± 1.5
Back azimuth guidance	6.5 ± 0.25
Approach elevation guidance	39 ± 1.5
Flare elevation guidance	39 ± 1.5
Basic data	see Appendix A, Table A-7
Auxiliary data	see Appendix A, Tables A-10 and A-12

3.11.4.3.3.1 **Recommendation.—** When the proportional guidance sector is not greater than plus or minus 40 degrees and a need for flare elevation or other growth functions at that facility is not anticipated, the high rate approach azimuth function should be used.

Note.— Application information is contained in Attachment G, 2.3.3.

3.11.4.3.4 Function timing. Timing standards for each angle and data function shall be as specified in Appendix A, Tables A-1 through A-6 and A-8.The ground equipment internal timing accuracy of each listed event including jitter shall be the specified nominal value plus or minus 2 microseconds. The timing jitter shall be less than 1 microsecond root mean square (RMS).

Note 1.— The timing of each listed event indicates the beginning of the event time slot and the end of the previous event time slot. The characteristics and timing of the actual transmissions are as specified in the applicable paragraphs.

Note 2.— Information on the measurement of the timing accuracy is contained in Attachment G, 2.2.2.

3.11.4.3.5 Function sequence. The time interval between repetitive transmissions of any one function shall be varied in a manner which provides protection from synchronous interference.

Note 1.— Each function transmission is an independent entity which can occur in any position in the TDM sequence (with the exception that back azimuth must be preceded by basic data word 2).

Note 2.— Some sequences which have demonstrated protection from synchronous interference are illustrated in Attachment G, 2.1.4.

3.11.4.4 Preamble

3.11.4.4.1 A preamble signal shall be transmitted throughout the applicable coverage sector to identify the particular function to follow. The preamble shall consist of a radio frequency carrier acquisition period, a receiver reference time code,and a function identification code. The timing of the preamble transmissions shall be as specified in Appendix A, Table A-1.

3.11.4.4.2 Carrier acquisition. The preamble transmission shall begin with a period of unmodulated radio frequency carrier as specified in Appendix A, Table A-1.

3.11.4.4.3 Modulation and coding

3.11.4.4.3.1 Differential phase shift keying (DPSK).The preamble codes and the basic and auxiliary data signals specified in 3.11.4.8 shall be transmitted by DPSK of the radio frequency carrier. A “zero” shall be represented by a 0 degrees plus or minus 10 degrees phase shift and a “one” shall be represented by a 180 degrees plus or minus 10 degrees phase shift. The modulation rate shall be 15 625 bauds. The internal timing accuracy of the DPSK transition shall be as specified in 3.11.4.3.4. There shall be no amplitude modulation applied during the phase transition. The transition time shall not exceed 10 microseconds, and the phase shall advance or retard monotonically throughout the transition region.

3.11.4.4.3.2 Receiver reference time. All preambles shall contain the receiver reference time code, 11101 (bits I1to I5). The time of the last phase transition midpoint in the code shall be the receiver reference time. The receiver reference time code shall be validated by decoding a valid function identification immediately following the receiver reference time code.

3.11.4.4.3.3 Function identification A code for function identification shall follow the receiver reference time code. This code shall consist of the five information bits (I6to I10) allowing identification of 31 different functions, plus two parity bits (I11and I12) as shown in the following table:

Function	Code						
	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}
Approach azimuth	0	0	1	1	0	0	1
High rate approach azimuth	0	0	1	0	1	0	0
Approach elevation	1	1	0	0	0	0	1
Flare elevation	0	1	1	0	0	0	1
Back azimuth	1	0	0	1	0	0	1
360° azimuth	0	1	0	0	1	0	1
Basic data 1	0	1	0	1	0	0	0
Basic data 2	0	1	1	1	1	0	0
Basic data 3	1	0	1	0	0	0	0
Basic data 4	1	0	0	0	1	0	0
Basic data 5	1	1	0	1	1	0	0
Basic data 6	0	0	0	1	1	0	1
Auxiliary data A	1	1	1	0	0	1	0
Auxiliary data B	1	0	1	0	1	1	1
Auxiliary data C	1	1	1	1	0	0	0

Note.— The function identification codes have been chosen so that parity bits I11and I12satisfy the equations:

$$I6+ I7+ I8+ I9+ I10+ I11= EVEN$$

$$I6+ I8+ I10+ I12= EVEN$$

3.11.4.5 Angle guidance parameters. Angle guidance information shall be encoded by the amount of time separation between the centres of the received TO and FRO scanning beam main lobes. The coding shall be interpreted in the airborne equipment as a linear function of time as follows:

$$\theta= (T0- t)\ V/2$$

where:

θ = Azimuth or elevation guidance angle in degrees

t = Time separation in microseconds between TO and FRO beam centres

T0 = Time separation in microseconds between TO and FRO beam centres corresponding to zero degrees

V = Scan velocity scaling constant in degrees per microsecond.

3.11.4.5.1 The values of the angle guidance parameters shall be as shown in the following table:

Function	*Maximum scan angle (degrees)*	*Value of t for maximum scan angle (µs)*	T_o *(µs)*	*V (degrees /µs)*
Approach azimuth	−62 to +62	13 000	6 800	0.020
High rate approach azimuth	−42 to +42	9 000	4 800	0.020
Back azimuth	−42 to +42	9 000	4 800	−0.020
Approach elevation	−1.5 to +29.5	3 500	3 350	0.020
Flare elevation	−2 to +10	3 200	2 800	0.010

Note 1.— Between the end of the TO scan and the beginning of the FRO scan there is a pause time of no radiation of appropriate duration. Additional information is provided in Attachment G, 2.2.1.

Note 2.— The maximum scan angles shown recognize that the scan angle must exceed the proportional guidance sector limit by at least one half of the width of the detected scanning beam envelope (in equivalent angle) to allow successful decoding.

3.11.4.5.2 The tolerances on the ground equipment scanning beam velocity and the time separation between TO and FRO pulses corresponding to zero degrees shall be sufficient to satisfy the accuracy requirements specified in 3.11.4.9.

3.11.4.5.3 The TO and FRO scan transmissions shall be symmetrically disposed about the mid-scan point listed in each of Tables A-2 through A-5 of Appendix A. The mid-scan point and the centre of the time interval between the TO and FRO scan transmissions shall coincide with a tolerance of plus or minus 10 microseconds.

3.11.4.6 Azimuth guidance functions

3.11.4.6.1 Each transmission of a guidance angle shall consist of a clockwise TO scan followed by a counterclockwise FRO scan as viewed from above the antenna. For approach azimuth functions, increasing angle values shall be in the direction of the TO scan. For the back azimuth functions, increasing angle values shall be in the direction of the FRO scan.

Note.— A diagram illustrating the scanning conventions is provided in Attachment G, 2.3.1.

3.11.4.6.2 Sector signals. The transmission format of any azimuth function shall include time slots for airborne antenna selection, out-of-coverage indication, and test pulses as specified in Appendix A, Tables A-2 and A-3. The internal timing accuracy of the sector signals shall conform to the internal timing accuracy of the DPSK transitions specified in 3.11.4.3.4.

3.11.4.6.2.1 Ground equipment identification. The MLS providing services for a particular runway shall be identified by a four-character alphabetic designator starting with the letter M. This designator less the first letter shall be transmitted as a digital word as listed in Appendix A, Table A-7.

Note.— It is not required that MLS ground equipment will transmit identification outside the angle guidance coverage sectors. If MLS channel identification is operationally required outside angle guidance coverage sectors, it may be derived from associated omnidirectional DME. (See 3.11.5.5.2 and Attachment G, 8.2.)

3.11.4.6.2.1.1 The signal shall be transmitted on the data channel into the approach and back azimuth coverage regions.

3.11.4.6.2.1.2 The code bit in the time slot previously allocated for the alternate (Morse code) ground equipment identification following the azimuth preamble shall be fixed in the "ZERO" state.

3.11.4.6.2.2 Airborne antenna selection signal. A signal for airborne antenna selection shall be transmitted as a "zero" DPSK signal lasting for a six-bit period. The signal shall be available throughout the coverage sector in which approach or back azimuth guidance is provided.

Note.— The signal provides an opportunity for the selection of the most appropriate antenna in a multiple antenna airborne installation.

3.11.4.6.2.3 Azimuth out-of-coverage indication pulses. Where out-of-coverage indication pulses are used, they shall be:

a) greater than any guidance signal in the out-of-coverage sector;

b) at least 5 dB less than the fly-left (fly-right) clearance level within the fly-left (fly-right) clearance sector; and

c) at least 5 dB less than the scanning beam level within the proportional coverage region. The duration of each pulse measured at the half amplitude point shall be at least 100 microseconds, and the rise and fall times shall be less than 10 microseconds.

3.11.4.6.2.3.1 If desired, it shall be permissible to sequentially transmit two pulses in each out-of-coverage indication time slot. Where the pulse pairs are used, the duration of each pulse shall be at least 50 microseconds and the rise and fall times shall be less than 10 microseconds.

3.11.4.6.2.3.2 The transmissions of out-of-coverage indication pulses radiated from antennas with overlapping coverage patterns shall be separated by at least 10 microseconds.

3.11.4.6.2.4 Ground radiated test signals

Note.— Time has been reserved in the azimuth angle guidance signal formats for the future use of a ground radiated test signal.

3.11.4.6.2.5 Clearance guidance. Where the proportional guidance sector provided is less than the minimum coverage specified in 3.11.5.2.2.1.1 a) and 3.11.5.2.2.2 a), clearance guidance shall be provided to supplement the coverage sector by the transmission of fly-left/fly-right clearance pulses in the formats for the approach azimuth, high rate approach azimuth and back azimuth functions. Alternatively, it shall be permissible to provide clearance guidance by permitting the scanning beam to scan beyond the designated proportional guidance sector to provide fly-left or fly-right clearance information as appropriate when the decoded angle exceeds the designated limits of proportional guidance coverage.

3.11.4.6.2.5.1 Clearance guidance information shall be provided by transmitting pairs of pulses within the angle scan time slots. One pair shall consist of one pulse adjacent to the start time of the scanning beam TO scan and one pulse adjacent to the stop time of the FRO scan. A second pair shall consist of one pulse adjacent to the stop time of the scanning beam TO scan, and one pulse adjacent to the start time of the FRO scan. The fly-right clearance pulses shall represent positive angles and the fly-left clearance pulses shall represent negative angles. The duration of each clearance pulse shall be 50 microseconds with a tolerance of plus or minus 5 microseconds. The transmitter switching time between the clearance pulses and the scanning beam transmissions shall not exceed 10microseconds. The rise time at the edge of each clearance pulse not adjacent to the scanning beam shall be less than 10 microseconds.

3.11.4.6.2.5.2 The signal-in-space characteristics of the clearance guidance pulses shall be as follows:

a) within the fly-right clearance guidance sector, the fly-right clearance guidance signal shall exceed the scanning beam side lobes and all other guidance and out-of-coverage indication signals by at least 5 dB;

b) within the fly-left clearance guidance sector, the fly-left clearance guidance signal shall exceed the scanning beam side lobes and all other guidance and out-of-coverage indication signals by at least 5 dB;

c) within the proportional guidance sector, the clearance guidance signals shall be at least 5 dB below the scanning beam main lobe.

3.11.4.6.2.5.3 The power density of the clearance signal shall be as required in 3.11.4.10.1.

Note 1.— Attachment G, 2.3.4 contains guidance information on the following:

a) clearance and scanning beam timing arrangements;

b) pulse envelopes in the transition regions between clearance and scanning beam signals;

c) clearance (fly-right/fly-left) convention changes.

Note 2.— The proportional coverage limits are transmitted in basic data as specified in 3.11.4.8.2.

3.11.4.7 Elevation guidance functions

3.11.4.7.1 Scanning conventions. For the approach elevation function, increasing elevation guidance angles shall be in the upward direction. Zero elevation angle shall coincide with a horizontal plane through the respective antenna phase centre. Each guidance angle transmission shall consist of a TO scan followed by a FRO scan. The TO scan shall be in the direction of increasing angle values.

3.11.4.7.2 Sector signal. Provision for transmission of one out-of-coverage indication pulse shall be made in the format for the approach elevation function. Where an out-of-coverage indication pulse is used, it shall be: (1) greater than any guidance signal in the out-of-coverage indication sector and (2) at least 5 dB less than the guidance signals within the guidance sector. The elevation out-of-coverage indication timing shall be as shown in Appendix A, Table A-4. The duration of each pulse measured at the half amplitude points shall be at least 100 microseconds, and the rise and fall times shall be less than 10 microseconds.

3.11.4.7.2.1 If desired, it shall be permissible to sequentially transmit two pulses in each obstacle clearance indication time slot. Where pulse pairs are used, the duration of each pulse shall be at least 50 microseconds, and the rise and fall times shall be less than 10 microseconds.

3.11.4.8 Data functions. Provision shall be made in the MLS signal format for the transmission of basic data and auxiliary data.

Note.— Ground equipment data coverage and monitoring requirements are specified in 3.11.5.4

3.11.4.8.1 Data transmission. Data shall be transmitted as specified in 3.11.4.4.3.1.

3.11.4.8.2 Basic data structure and timing. Basic data shall be encoded as 32-bit words consisting of a function preamble (12 bits) specified in 3.11.4.4, and data content as specified in Appendix A, Table A-7. The timing of the basic data words shall be as specified in Appendix A, Table A-6. The content, maximum interval between transmission of the same word and organization of the words shall be as specified in Appendix A, Table A-7. Data containing digital information shall be transmitted with the least significant bit first. The smallest binary number shall represent the lower absolute range limit with increments in binary steps to the upper absolute range limit specified in Appendix A, Table A-7.

3.11.4.8.2.1 Basic data contents. The data items specified in Appendix A, Table A-7 shall be defined as follows:

a) Approach azimuth antenna to threshold distance shall represent the minimum distance between the approach azimuth antenna phase centre to the vertical plane perpendicular to the centre line which contains the runway threshold.

b) Approach azimuth proportional coverage limit shall represent the limit of the sector in which proportional approach azimuth guidance is transmitted.

c) Clearance signal type shall indicate the method of providing the azimuth clearance signal.

d) Minimum glide pathshall represent the lowest angle of descent along the zero-degree azimuth as defined in 3.11.1.

e) Back azimuth statusshall represent the operational status of the back azimuth equipment.

f) DME statusshall represent the operational status of the DME equipment.

g) Approach azimuth statusshall represent the operational statusof the approach azimuth equipment.

h) Approach elevation status shall represent the operational status of the approach elevation equipment.

i) Beamwidth shall represent, for a particular function, the antenna beamwidth as defined in 3.11.1.

j) DME distance shall represent the minimum distance between the DME antenna phase centre and the vertical plane perpendicular to the runway centre line which contains the MLS datum point.

k) Approach azimuth magnetic orientation shall represent the angle measured in the horizontal plane clockwise from Magnetic North to the zero-degree approach azimuth, originating from the approach azimuth antenna. The vertex of the measured angle shall be the approach azimuth antenna phase centre.

l) Back azimuth magnetic orientation shall represent the angle measured in the horizontal plane clockwise from Magnetic North to the zero-degree back azimuth, originating from the back azimuth antenna. The vertex of the measured angle shall be the back azimuth antenna phase centre.

m) Back azimuth proportional coverage limit shall represent the limit of the sector in which proportional back azimuth guidance is transmitted.

n) MLS ground equipment identification shall represent the last three characters of the system identification specified in 3.11.4.6.2.1. The characters shall be encoded in accordance with International Alphabet No. 5 (IA-5) using bits b1through b6.

Note 1.— International Alphabet No. 5 (IA-5) is defined in Annex 10, Volume III.

Note 2.— Bit b7of this code may be reconstructed in the airborne receiver by taking the complement of bit b6.

3.11.4.8.3 Auxiliary data organization and timing. Auxiliary data shall be organized into 76-bit words consisting of the function preamble (12 bits) as specified in 3.11.4.4, the address (8 bits) as specified in Appendix A, Table A9, and data content and parity (56 bits) as specified in Appendix A, Tables A-10,A-11, A-12, A-13 and A-15. Three function identification codes are reserved to indicate transmission of auxiliary data A, auxiliary data B and auxiliary data C. The timing of the auxiliary data function shall be as specified in Appendix A, Table A-8. Two auxiliary data word formats shall be provided, one for digital data and one for alphanumeric character data. Data containing digital information shall be transmitted with the least significant bit first. Alpha characters in data words B1through B39 shall be encoded in accordance with International Alphabet No. 5 (IA5) using bits b1to b5with b1transmitted first. Alphanumeric data characters in other data words shall been coded in accordance with IA-5 using seven information bits, plus one even parity bit added to each character. Alphanumeric data shall be transmitted in the order in which they are to be read. The serial transmission of a character shall be with the lower order bit transmitted first and the parity bit transmitted last.

Note 1.— International Alphabet No. 5 (IA5) is defined in Annex 10, Volume III.

Note 2.— Auxiliary data A contents are specified in 3.11.4.8.3.1. Auxiliary data B contents are specified in 3.11.4.8.3.2. Auxiliary data C contents are reserved for national use.

3.11.4.8.3.1 Auxiliary data A content. The data items contained in auxiliary data words A1 through A4 as specified in Appendix A, Table A-10 shall be defined as follows:

a) Approach azimuth antenna offset shall represent the minimum distance between the approach azimuth antenna phase centre and a vertical plane containing the runway centre line.

b) Approach azimuth antenna to MLS datum point distance shall represent the minimum distance between the approach azimuth antenna phase centre and the vertical plane perpendicular to the runway centre line which contains the MLS datum point.

c) Approach azimuth alignment with runway centre line shall represent the minimum angle between the zero-degree approach azimuth and the runway centre line.

d) Approach azimuth antenna coordinate system shall represent the coordinate system (planar or conical) of the angle data transmitted by the approach azimuth antenna.

Note.— Although the above Standard has been developed to provide for alternate coordinate systems, the planar coordinate system is not implemented and it is not intended for future implementation.

e) Approach azimuth antenna height shall represent the vertical location of the antenna phase centre with respect to the MLS datum point.

f) Approach elevation antenna offset shall represent the minimum distance between the elevation antenna phase centre and a vertical plane containing the runway centre line.

g) MLS datum point to threshold distance shall represent the distance measured along the runway centre line from the MLS datum point to the runway threshold.

h) Approach elevation antenna height shall represent the vertical location of the elevation antenna phase centre with respect to the MLS datum point.

i) MLS datum point elevation shall represent the datum point elevation relative to mean sea level (msl).

j) Runway threshold height shall represent the vertical location of the intersection of the runway threshold and centre line with respect to the MLS datum point.

k) DME offset shall represent the minimum distance between the DME antenna phase centre and a vertical plane containing the runway centre line.

l) DME to MLS datum point distance shall represent the minimum distance between the DME antenna phase centre

and the vertical plane perpendicular to the runway centre line which contains the MLS datum point.

m) DME antenna height shall represent the vertical location of the antenna phase centre with respect to the MLS datum point.

n) Runway stop-end distance shall represent the distance along centre line between the runway stop-end and the MLS datum point.

o) Back azimuth antenna offset shall represent the minimum distance between the back azimuth antenna phase centre and a vertical plane containing the runway centre line.

p) Back azimuth to MLS datum point distance shall represent the minimum distance between the back azimuth antenna and the vertical plane perpendicular to the runway centre line which contains the MLS datum point.

q) Back azimuth alignment with runway centre line shall represent the minimum angle between the zero-degree back azimuth and the runway centre line.

r) Back azimuth antenna coordinate system shall represent the coordinate system (planar or conical) of the angle data transmitted by the back azimuth antenna.

Note.— Although the above Standard has been developed to provide for alternate coordinate systems, the planar coordinate system is not implemented and it is not intended for future implementation.

s) Back azimuth antenna height shall represent the vertical location of the antenna phase centre with respect to the MLS datum point.

Note.— It is intended that no additional auxiliary data A words be defined.

3.11.4.8.3.2 Auxiliary data B content. Auxiliary data B words shall be defined as specified in Appendix A, Tables A-11 and A-13.

3.11.4.8.3.2.1 Microwave landing system/area navigation (MLS/RNAV) procedure data. Where required, auxiliary data words B1 through B39 shall be used to transmit data to support MLS/RNAV procedures. It shall be permissible to divide this procedure data into two separate databases: one for transmission in the approach azimuth sector, the other for transmission in the back azimuth sector. Data for each procedure shall be transmitted in the database for the coverage sector in which the procedure commences. Missed approach procedure data shall be included in the database containing the associated approach procedure.

3.11.4.8.3.2.2 Procedure database structure. Where used, each procedure database shall be constructed as follows:

a) a map/CRC word shall identify the size of the database, the number of procedures defined, and the cyclic redundancy check (CRC) code for validation of the database;

b) procedure descriptor words shall identify all named approach and departure procedures within the database; and

c) way-point data words shall define the location and sequence of way-points for the procedures.

Note.— The structure and coding of auxiliary B words B1 through B39 are defined in Appendix A, Tables A-14 through A-17. Guidance material concerning the coding of MLS/RNAV procedures is given in Attachment G.

3.11.4.9 System accuracy. The accuracy standards specified herein shall be met on a 95 per cent probability basis unless otherwise stated.

Note 1.— The overall error limits include errors from all causes such as those from airborne equipment, ground equipment, and propagation effects.

Note 2.— It is intended that the error limits are to be applied over a flight path interval that includes the approach reference datum or back azimuth reference datum. Information on the interpretation of MLS errors and the measurement of these errors over an interval appropriate for flight inspection is provided in Attachment G, 2.5.2.

Note 3.— To determine the allowable errors for degradation allowances at points other than the appropriate reference datum, the accuracy specified at the reference datum should first be converted from its linear value into its equivalent angular value with an origin at the antenna.

3.11.4.9.1 MLS approach reference datum. The height of the MLS approach reference datum shall be 15 m (50 ft). A tolerance of plus 3 m (10 ft) shall be permitted.

Note 1.— The operational objective of defining the height of the MLS approach reference datum is to ensure safe guidance over obstructions and also safe and efficient use of the runway served. The heights noted in 3.11.4.9.1 assume Code 3 or Code 4 runways as defined by Annex 14.

Note 2.— At the same time, the reference datum is to provide a convenient point at which the accuracy and other parameters of the function may be specified.

Note 3.— In arriving at the above height values for the MLS approach reference datum, a maximum vertical distance of 5.8 m (19 ft) between the path of the aircraft MLS antenna selected for final approach and the path of the lowest part of the wheels at the threshold was assumed. For aircraft exceeding this criterion, appropriate steps may have to be taken either to maintain adequate clearance at threshold or to adjust the permitted operating minima.

3.11.4.9.2 MLS back azimuth reference datum. The height of the MLS back azimuth reference datum shall be 15 m (50 ft). A tolerance of plus 3 m (10 ft) shall be permitted.

Note.— The objective of defining the MLS back azimuth reference datum is to provide a convenient point at which the accuracy and other parameters of the function may be specified.

3.11.4.9.3 The PFE shall be comprised of those frequency components of the guidance signal error at the output of the airborne receiver which lie below 0.5 rad/s for azimuth guidance information or below 1.5 rad/s for elevation guidance information. The control motion noise shall be comprised of those frequency components of the guidance signal error at the output of the airborne receiver which lie above 0.3 rad/s for azimuth guidance or above 0.5 rad/s for elevation guidance information. The output filter corner frequency of the receiver used for this measurement is 10 rad/s.

3.11.4.9.4 Approach azimuth guidance functions. Except as allowed for simplified MLS configurations in 3.11.3.4, at the approach reference datum, the approach azimuth function shall provide performance as follows:

a) the PFE shall not be greater than plus or minus 6 m (20 ft);

b) the PFN shall not be greater than plus or minus 3.5 m (11.5 ft);

c) the CMN shall not be greater than plus or minus 3.2 m (10.5 ft) or 0.1 degree, whichever is less.

3.11.4.9.4.1 **Recommendation.—** At the approach reference datum, the PFE should not be greater than plus or minus 4 m (13.5 ft).

3.11.4.9.4.2 The linear accuracy specified at the reference datum shall be maintained throughout the runway coverage region specified in 3.11.5.2.2.1.2 except where degradation is allowed as specified in 3.11.4.9.4.3.

3.11.4.9.4.3 Degradation allowance. Except as allowed for simplified MLS configurations in 3.11.3.4, the approach azimuth angular PFE, PFN and CMN shall be allowed to degrade linearly to the limits of coverage as follows:

a) With distance. The PFE limit and PFN limit, expressed in angular terms at 37 km (20 NM) from the runway threshold along the extended runway centre line, shall be2 times the value specified at the approach reference datum. The CMN limit shall be 0.1 degree at 37 km (20 NM) from the approach reference datum along the extended runway centre line at the minimum glide path angle.

b) With azimuth angle. The PFE limit and PFN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, shall be 1.5 times the value on the extended runway centre line at the same distance from the approach reference datum. The CMN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle is 1.3 times the value on the extended runway centre line at the same distance from the approach reference datum.

c) With elevation angle. The PFE limit and PFN limit shall not degrade upto an elevation angle of 9 degrees. The PFE limit and PFN limit, expressed in angular terms at an elevation angle of 15 degrees from the approach azimuth antenna phase centre, shall be 2 times the value permitted below 9 degrees at the same distance from the approach reference datum and the same azimuth angle. The CMN limit shall not degrade with elevation angle.

d) Maximum CMN. The CMN limits shall not exceed 0.2 degree in any region of coverage.

3.11.4.9.4.3.1 **Recommendation**.— The CMN should not exceed 0.1 degree in any region of coverage.

3.11.4.9.4.4 Maximum angular PFE and PFN.Except as allowed for simplified MLS configurations in 3.11.3.4, in any region within coverage, the angular error limits shall be as follows:

a) the PFE shall not exceed plus or minus 0.25 degree; and

b) the PFN shall not exceed plus or minus 0.15 degree.

3.11.4.9.5 Back azimuth guidance function. At the back azimuth reference datum, the back azimuth function shall provide performance as follows:

a) the PFE shall not be greater than plus or minus 6 m (20 ft);

b) the PFN component shall not be greater than plus or minus 3.5 m (11.5 ft);

c) the CMN shall not be greater than plus or minus 3.2 m (10.5 ft) or 0.1 degree, whichever is less.

3.11.4.9.5.1 Degradation allowance. The back azimuth angular PFE, PFN and CMN shall be allowed to degrade linearly to the limits of coverage as follows:

a) With distance. The PFE limit and PFN limit, expressed in angular terms at the limit of coverage along the extended runway centre line, shall be 2 times the value specified at the back azimuth reference datum. The CMN limit, expressed in angular terms at 18.5 km (10 NM) from the runway stop end along the extended runway centre line, shall be 1.3 times the value specified at the back azimuth reference datum.

b) With azimuth angle. The PFE limit and PFN limit, expressed in angular terms at plus or minus 20 degrees azimuth angle, shall be 1.5 times the value on the extended runway centre line at the same distance from the back azimuth reference datum. The CMN limit, expressed in angular terms at plus or minus 20 degrees azimuth angle, shall be 1.3 times the value on the extended runway centre line at the same distance from the back azimuth reference datum.

With elevation angle. The PFE limit and PFN limit shall not degrade up to an elevation angle of 9 degrees. The PFE limit and PFN limit, expressed in angular terms at an elevation angle of 15 degrees from the back azimuth antenna phase centre, shall be 2 times the value permitted below 9 degrees at the same distance from the back azimuth reference datum and the same azimuth angle. The CMN limit shall not degrade with elevation angle.

d) Maximum CMN. The CMN limits shall not exceed 0.2 degree in any region of coverage.

3.11.4.9.5.2 Maximum angular PFE and PFN.In any region within coverage, the angular error limits shall be as follows:

a) the PFE shall not exceed plus or minus 0.50 degree; and

b) the PFN shall not exceed plus or minus 0.30 degree.

3.11.4.9.6 Elevation guidance function. For equipment sited to provide a minimum glide path of nominally 3 degrees or lower, except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation function shall provide performance at the approach reference datum as follows:

a) the PFE shall not be greater than plus or minus 0.6 m (2 ft);

b) the PFN shall not be greater than plus or minus 0.4 m (1.3 ft);

c) the CMN shall not be greater than plus or minus 0.3 m (1 ft).

3.11.4.9.6.1 Degradation allowance. Except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation angular PFE, PFN and CMN shall be allowed to degrade linearly to the limits of coverage as follows:

a) With distance. The PFE limit and PFN limit, expressed in angular terms at 37 km (20 NM) from the runway threshold on the minimum glide path, shall be 0.2 degree. The CMN limit shall be 0.1 degree at 37 km (20 NM) from the approach reference datum along the extended runway centre line at the minimum glide path angle.

b) With azimuth angle. The PFE limit and PFN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, shall be 1.3 times the value on the extended runway centre line at the same distance from the approach reference datum. The CMN limit, expressed in angular terms at plus or minus 40 degrees azimuth angle, shall be 1.3 times the value on the extended runway centre line at the same distance from the approach reference datum.

c) With elevation angle.For elevation angles above the minimum glide path or 3 degrees, whichever is less and up to the maximum of the proportional guidance coverage and at the locus of points directly above the approach reference datum the PFE limit, PFN limit and the CMN limit expressed in angular terms shall be allowed to degrade linearly such that at an elevation angle of 15 degrees the limits are 2 times the value specified at the reference datum. In no case shall the CMN directly above the reference datum exceed plus or minus 0.07 degree. For other regions of coverage within the angular sector from an elevation angle equivalent to the minimum glide path up to the maximum angle of proportional coverage, the degradations with distance and azimuth angle specified in a) and b) shall apply.

d) The PFE, PFN and CMN limits shall not degrade with elevation angle in the region between the minimum glide path and 60 per cent of the minimum glide path. For elevation angles below 60 per cent of the minimum glide path and down to the limit of coverage specified in 3.11.5.3.2.1.2, and at the locus of points directly below the approach reference datum the PFE limit, the PFN limit and the CMN limit expressed in angular terms, shall be allowed to increase linearly to 6 times the value at the approach reference datum. For other regions of coverage within the angular sector from an elevation angle equivalent to 60 per cent of the minimum glide path angle value, and down to the limit of coverage, the degradation with distance and azimuth angle specified in a) and b) shall apply. In no case shall the PFE be allowed to exceed 0.8 degree, or the CMN be allowed to exceed 0.4 degree.

e) Maximum CMN. For elevation angles above 60 per cent of the minimum glide path, the CMN limits shall not exceed 0.2 degree in any region of coverage.

3.11.4.9.6.2 Maximum angular PFE and PFN. Except as allowed for simplified MLS configurations in 3.11.3.4, in any region within coverage, the angular error limits for elevation angles above 60 per cent of the minimum glide path shall be as follows:

a) the PFE shall not exceed plus or minus 0.25 degree; and

b) the PFN shall not exceed plus or minus 0.15 degree.

3.11.4.9.6.3 **Recommendation.—** The limit expressed in angular terms on the linear degradation of the PFE limit, the PFN limit and the CMN limit at angles below 60 per cent of the minimum glide path and down to the limit of coverage should be 3 times the value permitted at the approach reference datum.

Note.— For other regions of coverage within the angular sector from an elevation angle equivalent to 60 per cent of the minimum glide path and down to the limit of coverage, the degradation with distance and azimuth angle specified in 3.11.4.9.6.1 a) and b) applies.

3.11.4.9.6.4 **Recommendation.—**Maximum CMN. For elevation angles above 60 per cent of the minimum glide path, the CMN limits should not exceed 0.1 degree in any region of coverage.

3.11.4.9.6.5 **Recommendation.—** The PFE should not exceed 0.35 degree, and the CMN should not exceed 0.2 degree.

3.11.4.9.6.6 Approach elevation equipment sited to provide a minimum glide path higher than 3 degrees shall provide angular accuracies not less than those specified for equipment sited for a 3-degree minimum glide path within the coverage volume.

3.11.4.10 Power density

3.11.4.10.1 The power density for DPSK, clearance and angle guidance signals shall be at least the values shown in the following table under all operational weather conditions at any point within coverage except as specified in 3.11.4.10.2.

Function	DPSK signals (dBW/m^2)	Angle signals (dBW/m^2) 1°	2°	3° (antenna beamwidth)	Clearance signals (dBW/m^2)
Approach azimuth guidance	−89.5	−85.7	−79.7	−76.2	−88.0
High rate approach azimuth guidance	−89.5	−88.0	−84.5	−81.0	−88.0
Back azimuth guidance	−89.5	−88.0	−82.7	−79.2	−88.0
Approach elevation guidance	−89.5	−88.0	−84.5	N/A	N/A

N/A = not applicable

Note.— The table above specifies the minimum power densities for clearance signals and scanning beam signals. The relative values of the two signals are specified in 3.11.4.6.2.5.2.

3.11.4.10.2 The power density of the approach azimuth angle guidance signals shall be greater than that specified in 3.11.4.10.1 by at least:

a) 15 dB at the approach reference datum;

b) 5 dB for one degree or 9 dB for 2 degree or larger beamwidth antennas at 2.5 m (8 ft) above the runway surface, at the MLS datum point, or at the farthest point of the runway centre line which is in line of sight of the azimuth antenna.

Note 1.— Near the runway surface the approach azimuth equipment will normally provide power densities higher than those specified for angle signals in 3.11.4.10.1 to support auto-land operations. Attachment G provides guidance as regards antenna beamwidth and power budget considerations.

Note 2.— The specifications for coverage in 3.11.5.2.2 and 3.11.5.3.2 make provision for difficult ground equipment siting conditions in which it may not be feasible to provide the power density specified in 3.11.4.10.2.

3.11.4.10.3 Multipath relative power densities

3.11.4.10.3.1 Within the MLS azimuth coverage at 60 m (200 ft) or more above threshold, the duration of a reflected scanning beam signal whose power density is higher than four decibels below the approach azimuth guidance, or high rate azimuth guidance scanning beam signal power density, shall be shorter than one second, as seen by an aircraft on a published approach.

3.11.4.10.3.2 Within the MLS azimuth proportional guidance sector, below 60 m (200 ft) above threshold, the power density of any reflected approach azimuth guidance or high rate approach azimuth guidance scanning beam signal shall be less than ten decibels above the power density of the approach azimuth guidance or high rate approach azimuth guidance scanning beam signal. On the runway centre line, this reflected signal shall not degrade the azimuth scanning beam shape and generate at the output of a receiver an error beyond the tolerances as stated in 3.11.4.9.

3.11.4.10.3.3 Within the MLS elevation coverage, the duration of a reflected approach elevation guidance scanning beam signal whose power density is higher than four decibels below the approach elevation guidance scanning beam signal power density shall be shorter than one second, as seen by an aircraft on a published approach.

3.11.5 Ground equipment characteristics

3.11.5.1 Synchronization and monitoring. The synchronization of the time-division-multiplexed angle guidance and data transmissions which are listed in 3.11.4.3.3 shall be monitored.

Note.— Specific monitoring requirements for various MLS functions are specified in 3.11.5.2.3 and 3.11.5.3.3.

3.11.5.1.1 Residual radiation of MLS functions. The residual radiation of an MLS function at times when another function is radiating shall be at least 70 dB below the level provided when transmitting.

Note.— The acceptable level of residual radiation for a particular function is thatlevel which has no adverse effect on the reception of any other function and is dependent upon equipment siting and aircraft position.

3.11.5.2 Azimuth guidance equipment

3.11.5.2.1 Scanning beam characteristics. Azimuth ground equipment antennas shall produce a fan-shaped beam which is narrow in the horizontal plane, broad in the vertical plane and which is scanned horizontally between the limits of the proportional guidance sector.

3.11.5.2.1.1 Coordinate system. Azimuth guidance information shall be radiated in either conical or planar coordinates.

3.11.5.2.1.2 Antenna beamwidth. The antenna beamwidth shall not exceed 4 degrees.

Note.— It is intended that the detected scanning beam envelope, throughout the coverage should not exceed 250 microseconds (equivalent to a beamwidth of 5 degrees) in order to ensure proper angle decoding by the airborne equipment.

3.11.5.2.1.3 Scanning beam shape. The minus 10-dB points on the beam envelope shall be displaced from the beam centre by at least 0.76 beamwidth, but not more than 0.96 beamwidth.

Note.— The beam shape described applies on boresight in a multipath free environment using a suitable filter. Information on beam shape and side lobes is provided in Attachment G, 3.1 and 3.2.

3.11.5.2.2Coverage

Note.— Diagrams illustrating the coverage requirements specified herein are contained in Attachment G, Figures G-5A, G5-B and G-6.

3.11.5.2.2.1 Approach azimuth. Except as allowed for simplified MLS configurations in 3.11.3.4, the approach azimuth ground equipment shall provide guidance information in at least the following volumes of space:

3.11.5.2.2.1.1 Approach region.

a) Laterally, within a sector of 80 degrees (normally plus and minus 40 degrees about the antenna boresight) which originates at the approach azimuth antenna phase centre.

b) Longitudinally, from the approach azimuth antenna to 41.7 km (22.5 NM).

c) Vertically, between:

1) a lower conical surface originating at the approach azimuth antenna phase centre and inclined upward to reach, at the longitudinal coverage limit, a height of 600 m (2 000 ft) above the horizontal plane which contains the antenna phase centre; and

2) an upper conical surface originating at the approach azimuth antenna phase centre inclined at 15 degrees above the horizontal to a height of 6 000 m (20 000 ft).

Note 1.— Where intervening obstacles penetrate the lower surface, it is intended that guidance need not be provided at less than line-of-sight heights.

Note 2.— Where it is determined that misleading guidance information exists outside the promulgated coverage sector and appropriate operational procedures cannot provide an acceptable solution, techniques to minimize the effects are available. These techniques include adjustment of the proportional guidance sector or use of out-of-coverage indication signals. Guidance material on the use of these techniques is contained in Attachment G, 8.

Note 3.— Where the proportional guidance sector provided is less than the minimum lateral coverage specified in 3.11.5.2.2.1.1 a), clearance guidance signals specified in 3.11.4.6.2.5 are required.

3.11.5.2.2.1.2 Runway region.

a) Horizontally within a sector 45m (150 ft) each side of the runway centre line beginning at the stop end and extending parallel with the runway centre line in the direction of the approach to join the minimum operational coverage region as described in 3.11.5.2.2.1.3.

b) Vertically between:

1) a horizontal surface which is 2.5 m (8 ft) above the farthest point of the runway centre line which is in line of sight of the azimuth antenna; and

2) a conical surface originating atthe azimuth ground equipment antenna inclined at 20 degrees above the horizontal up to a height of 600 m (2 000 ft).

Note 1.— Information on the determination of the point referred to in b) 1) is given in Attachment G, 2.3.6.

Note 2.— It is intended that guidance below the line of sight may be allowed as long as the signal quality can satisfy the accuracy requirements in 3.11.4.9.4.

3.11.5.2.2.1.2.1 Recommendation.— The lower level of the coverage in the runway region should be 2.5 m (8 ft) above the runway centre line.

3.11.5.2.2.1.2.2 Where required to support automatic landing, roll-out or take-off, the lower level of coverage in the runway region shall not exceed 2.5 m (8 ft) above the runway centre line.

Note.— The lower coverage limit of 2.5 m (8 ft) is intended to serve all runways. Information on the possibility of relaxing the power density requirements in 3.11.4.10.2 at 2.5 m (8 ft) is provided at Attachment G, 2.3.6.

3.11.5.2.2.1.3 Minimum operational coverage region.

a) Laterally, within a sector of plus and minus 10 degrees about the runway centre line which originates at the MLS datum point.

b) Longitudinally, from the runway threshold in the direction of the approach to the longitudinal coverage limit specified in 3.11.5.2.2.1.1 b).

c) Vertically, between:

1) a lower plane which contains the line 2.5 m (8 ft) above the runway threshold and is inclined upward to reach the height of the surface specified in 3.11.5.2.2.1.1 c) 1) at the longitudinal coverage limit; and

2) the upper surface specified in 3.11.5.2.2.1.1 c) 2).

3.11.5.2.2.1.4 **Recommendation.—** The approach azimuth ground equipment should provide guidance vertically to 30 degrees above the horizontal. 3.11.5.2.2.1.5 The minimum proportional guidance sector shall be as follows:

Approach azimuth antenna to threshold distance (AAT)	Minimum proportional coverage
AAT < 500 m (1 640 ft)	±8°
500 m (1 640 ft) < AAT < 3 100 m (10 170 ft)	±6°
3 100 m (10 170 ft) < AAT	±4°

3.11.5.2.2.2 Back azimuth. The back azimuth ground equipment shall provide information in at least the following volume of space:

a) Horizontally, within a sector plus or minus 20 degrees about the runway centre line originating at the back azimuth ground equipment antenna and extending in the direction of the missed approach at least 18.5 km (10 NM) from the runway stop end.

b) Vertically, in the runway region between:

1) a horizontal surface 2.5 m (8 ft) above the farthest point of runway centre line that is in line-of-sight of the back azimuth antenna; and

2) a conical surface originating at the back azimuth ground equipment antenna inclined at 20 degrees above the horizontal up to a height of 600 m (2 000 ft).

c) Vertically, in the back azimuth region between:

1) a conical surface originating 2.5 m (8 ft) above the runway stop end, inclined at 0.9 degree above the horizontal; and

2) a conical surface originating at the back azimuth ground equipment antenna, inclined at 15 degrees above the horizontal up to a height of 3 000 m (10 000 ft).

Note 1.— Information on the determination of the point referred to in b) 1) is given in Attachment G, 2.3.6.

Note 2.— When physical characteristics of the runway or obstacles prevent the achievement of the Standards in b) and c), it is intended that guidance need not be provided at less than line-of-sight heights.

3.11.5.2.2.2.1 **Recommendation**.— The back azimuth facility should provide guidance information to 30 degrees above the horizontal.

3.11.5.2.2.2.2 The minimum proportional guidance sector shall be plus or minus 10 degrees about the runway centre line.

Note.— Application information is provided in Attachment G, 7.5.

3.11.5.2.3 Monitor and control

3.11.5.2.3.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the approach azimuth and back azimuth monitor systems shall cause the radiation of their respective functions to cease and a warning shall be provided at the designated control points if any of the following conditions persist for longer than the periods specified:

a) there is a change in the ground equipment contribution to the mean course error such that the PFE at the approach reference datum or in the direction of any azimuth radial exceeds the limits specified in 3.11.4.9.4 and 3.11.4.9.5 for a period of more than one second;

b) there is a reduction in the radiated power to less than that necessary to satisfy the requirements specified in

3.11.4.10.1 and 3.11.4.6.2.5.2 for a period of more than one second;

c) there is an error in the preamble DPSK transmissions which occurs more than once in any one-second period;

d) there is an error in the TDM synchronization of a particular azimuth function such that the requirement specified in

3.11.4.3.2 is not satisfied, and this condition persists for more than one second.

Note.— Guidance material is provided in Attachment G, 6.

3.11.5.2.3.2 Design and operation of the monitor system shall cause radiation to cease and a warning shall be provided at the designated control points in the event of failure of the monitor system itself.

3.11.5.2.3.3 The period during which erroneous guidance information is radiated, including period(s) of zero radiation, shall not exceed the periods specified in 3.11.5.2.3.1. Any attempts to clear a fault by resetting the primary ground equipmentor by switching to standby ground equipment shall be completed within this time, and any period(s) of zero radiation shall not exceed 500 milliseconds. If the fault is not cleared within the time allowed, the radiation shall cease. After shutdown, noattempt shall be made to restore service until a period of 20 seconds has elapsed.

3.11.5.2.4 Integrity and continuity of service requirements for MLS azimuth 3.11.5.2.4.1 The probability of not radiating false guidance signals shall not be less than 1 – 0.5 × 109 in any one landing for an MLS azimuth intended to be used for Categories II and III operations.

3.11.5.2.4.2 **Recommendation.—** The probability of not radiating false guidance signals should not be less than 1 – 1.0 × 10–7 in any one landing for an MLS azimuth intended to be used for Category I operations.

3.11.5.2.4.3 The probability of not losing the radiated guidance signal shall be greater than:

a) 1 – 2 × 10–6 in any period of 15 seconds for an MLS azimuth intended to be used for Category II or Category IIIA operations (equivalent to 2 000 hours mean time between outages); and

b) 1 – 2 × 10–6in any period of 30 seconds for an MLS azimuth intended to be used for the full range of Category III operations (equivalent to 4 000 hours mean time between outages).

3.11.5.2.4.4 **Recommendation**.— The probability of not losing the radiated guidance signal should exceed 1 – 4 × 10–6in any period of 15 seconds for an MLS azimuth intended to be used for Category I operations (equivalent to 1 000 hours mean time between outages).

Note.— Guidance material on integrity and continuity of service is given in Attachment G, 11.

3.11.5.2.5 Ground equipment accuracy

3.11.5.2.5.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the ground equipment contribution to the mean course error shall not exceed an error equivalent to plus or minus 3 m (10 ft) at the MLS approach reference datum.

3.11.5.2.5.2 **Recommendation.**— The ground equipment contribution to the CMN at the reference datum should not exceed 1 m (3.3 ft) or 0.03 degree, whichever isless, on a 95 per cent probability basis.

Note 1.— This is the equipment error, and does not include any propagation effects.

Note 2.— Guidance on the measurement of this parameter can be found in Attachment G, 2.5.2.

3.11.5.2.6 Siting

Note 1.— It is not intended to restrict the installation of MLS when it is not possible to site the azimuth ground equipment on the extension of the runway centre line.

Note 2.— Guidance material on critical and sensitive areas for azimuth antennas is provided in Attachment G, 4.3.

3.11.5.2.6.1 Normally, the approach azimuth ground equipment antenna shall be located on the extension of the runway centre line beyond the stop end and shall be adjusted so that the vertical plane containing the zero degree course line will contain the MLS approach reference datum. Siting of the antenna shall be consistent with safe obstacle clearance SARPs in Annex 14.

3.11.5.2.6.2 The back azimuth ground equipment antenna shall normally be located on the extension of the runway centre line at the threshold end, and the antenna shall be adjusted so that the vertical plane containing the zero degree course line will contain the back azimuth reference datum.

3.11.5.3 Elevation guidance equipment

3.11.5.3.1 Scanning beam characteristics. The elevation ground equipment antenna shall produce a fan-shaped beam that is narrow in the vertical plane, broad in the horizontal plane and which is scanned vertically between the limits of the proportional guidance sector.

3.11.5.3.1.1 Coordinate system. Approach elevation guidance information shall be radiated in conical coordinates.

3.11.5.3.1.2 Antenna beamwidth. The antenna beamwidth shall not exceed 2.5 degrees.

3.11.5.3.1.3 Scanning beam shape. The minus 10-dB points on the beam envelope shall be displayed from the centre line by at least 0.76 beamwidth but not more than 0.96 beamwidth.

Note.— The beam shape described applies on boresight in a multipath-free environment using a suitable filter. Information on beam shape and side lobes is provided in Attachment G, 3.1 and 3.2.

3.11.5.3.2 Coverage

Note.— Diagrams illustrating the coverage requirements specified herein are contained in Attachment G, Figure G-10A.

3.11.5.3.2.1 Approach elevation. Except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation ground equipment shall provide proportional guidance information in at least the following volume of space:

3.11.5.3.2.1.1 Approach region.

a) Laterally, within a sector originating at the elevation antenna phase centre which has an angular extent at least equal to the proportional guidance sector provided by the approach azimuth ground equipment at the longitudinal coverage limit.

b) Longitudinally, from the elevation antenna in the direction of the approach to 37 km (20 NM) from threshold.

c) Vertically, between:

1) a lower conical surface originating at the elevation antenna phase centre and inclined upward to reach, at the longitudinal coverage limit, a height of 600 m (2 000 ft) above the horizontal plane which contains the antenna phase centre; and

2) an upper conical surface originating at the elevation antenna phase centre and inclined 7.5 degrees above the horizontal up to a height of 6 000 m (20 000 ft).

Note.— When the physical characteristics of the approach region prevent the achievement of the Standards under a), b) and c) 1), it is intended that guidance need not be provided below the line of sight.

3.11.5.3.2.1.1.1 **Recommendation.—** The approach elevation ground equipment should provide proportional guidance to angles greater than 7.5 degrees above the horizontal when necessary to meet operational requirements.

3.11.5.3.2.1.2 Minimum operational coverage region.

a) Laterally, within a sector originating at the MLS datum point, of plus and minus 10 degrees about the runway centre line;

b) Longitudinally, 75 m (250 ft) from the MLS datum point in the direction of threshold, to the far coverage limit specified in 3.11.5.3.2.1.1 b);

c) Vertically, between the upper surface specified in 3.11.5.3.2.1.1 c) 2), and the higher of:

1) a surface which is the locus of points 2.5 m (8 ft) above the runway; or

2) a plane originating at the MLS datum point and inclined upward to reach, at the longitudinal coverage limit, the height of the surface specified in 3.11.5.3.2.1.1 c) 1).

Note.— Information related to the horizontal radiation pattern of the approach elevation is provided in Attachment G, 3.3.

3.11.5.3.3 Monitor and control

3.11.5.3.3.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the approach elevation monitor system shall cause the radiation of its respective functions to cease and a warning shall be provided at the designated control point if any of the following conditions persist for longer than the periods specified:

a) there is a change in the ground equipment contribution to the mean glide path error component such that the PFE at the approach reference datum or on any glide path consistent with published approach procedures exceeds the limits specified in 3.11.4.9.6 for a period of more than one second;

b) there is a reduction in the radiated power to less than that necessary to satisfy the requirements specified in 3.11.4.10.1 for a period of more than one second;

c) there is an error in the preamble DPSK transmissions which occurs more than once in any one-second period;

d) there is an error in the TDM synchronization of a particular elevation function such that the requirement specified in 3.11.4.3.2 is not satisfied and this condition persists for more than one second.

Note.— Guidance material is provided in Attachment G, 6.

3.11.5.3.3.2 Design and operation of the monitor system shall cause radiation to cease and a warning shall be provided at the designated control points in the event of failure of the monitor system itself.

3.11.5.3.3.3 The period during which erroneous guidance information is radiated, including period(s) of zero radiation, shall not exceed the periods specified in 3.11.5.3.3.1. Any attempts to clear a fault by resetting the primary ground equipmentor by switching to standby ground equipment shall be completed within this time, and any period(s) of zero radiation shall not exceed 500 milliseconds. If the fault isnot cleared within the time allowed, radiation shall cease. After shutdown, no attempt shall be made to restore service until a period of 20 seconds has elapsed.

3.11.5.3.4 Integrity and continuity of service requirements for MLS approach elevation

3.11.5.3.4.1 The probability of not radiating false guidance signals shall not be less than 1 – 0.5 × 10–9in any one landing for an MLS approach elevation intended to be used for Categories II and III operations.

3.11.5.3.4.2 **Recommendation.—** The probability of not radiating false guidance signals should not be less than 1 – 1.0 × 10–7in any one landing on MLS approach elevation intended to be used for Category I operations.

3.11.5.3.4.3 The probability of not losing the radiated guidance signal shall be greater than 1 – 2 × 10–6in any period of 15 seconds for an MLS approach elevation intended to be used for Categories II and III operations (equivalent to 2 000 hours mean time between outages).

3.11.5.3.4.4 **Recommendation.—** The probability of not losing the radiated guidance signal should exceed 1 – 4 × 10-6 in any period of 15 seconds for an MLS approach elevation intended to be used for Category I operations (equivalent to 1 000 hours mean time between outages).

Note.— Guidance material on integrity and continuity of service is given in Attachment G, 11.

3.11.5.3.5 Ground equipment accuracy

3.11.5.3.5.1 Except as allowed for simplified MLS configurations in 3.11.3.4, the ground equipment contribution to the mean glide path error component of the PFE shall not exceed an error equivalent to plus or minus 0.3 m (1 ft) at the approach reference datum.

3.11.5.3.5.2 Recommendation.— The ground equipment contribution to the CMN at the reference datum should not exceed 0.15 m (0.5 ft) on a 95 per cent probability basis.

Note 1.— This is the equipment error, anddoes not include any propagation effects.

Note 2.— Guidance on the measurement of this parameter can be found in Attachment G, 2.5.2.

3.11.5.3.6 Siting

Note.— Guidance material on critical areas for elevation antennas is provided in Attachment G, 4.2.

3.11.5.3.6.1 The approach elevation ground equipment antenna shall be located beside the runway. Siting of the antennas shall be consistent with obstacle clearance Standards and Recommended Practices in Annex 14.

3.11.5.3.6.2 The approach elevation ground equipment antenna shall be sited so that the asymptote of the minimum glide path crosses the threshold at the MLS approach reference datum.

3.11.5.3.6.2.1 **Recommendation.—** The minimum glide path angle is normally 3 degrees and should not exceed 3 degrees except where alternative means of satisfying obstacle clearance requirements are impractical.

Note.— It is intended that the choice of a minimum glide path angle higher than 3 degrees be determined by operational rather than technical factors.

3.11.5.3.6.2.2 **Recommendation.—** The approach elevation ground equipment antenna should be sited so that the height of the point which corresponds to the decoded guidance signal of the minimum glide path above the threshold does not exceed 18 m (60 ft).

Note. — The offset of the elevation antenna from the runway centre line will cause the minimum glide path elevation guidance to be above the approach reference datum.

3.11.5.3.6.3 Recommendation.— When ILS and MLS simultaneously serve the same runway, the ILS reference datum and the MLS approach reference datum should coincide within a tolerance of 1 m (3 ft).

Note 1. — It is intended that this recommendation would apply only if the ILS reference datum satisfies the height specifications in 3.1.5.1.4 and 3.1.5.1.5.

Note 2. — Information related to collocated MLS/ILS siting is provided in Attachment G, 4.1.

3.11.5.4 Data coverage and monitoring

Note 1. — Guidance material relating to data applications is provided in Attachment G, 2.7.

Note 2. — The essential data are basic data and essential auxiliary data transmitted in auxiliary data words A1, A2, A3 and A4.

3.11.5.4.1 Basic data

3.11.5.4.1.1 The basic data words 1, 2, 3, 4 and 6 shall be transmitted throughout the approach azimuth coverage sector.

Note. — The composition of the basic data words is given in Appendix A, Table A-7.

3.11.5.4.1.2 Where the back azimuth function is provided, basic data words 4, 5 and 6 shall be transmitted throughout the approach azimuth and back azimuth coverage sectors.

3.11.5.4.2 Auxiliary data

3.11.5.4.2.1 Auxiliary data words A1, A2 and A3 shall be transmitted throughout the approach azimuth coverage sector.

3.11.5.4.2.2 Where the back azimuth function is provided, auxiliary data words A3 and A4 shall be transmitted throughout the approach azimuth and back azimuth coverage sectors.

Note.— Auxiliary data words B42 and B43 are transmitted in place of A1 and A4, respectively, to support applications which require azimuth antenna rotation beyond the alignment range available in A1 and A4.

3.11.5.4.2.3 When provided, auxiliary data B words shall be transmitted throughout the approach azimuth sector, except that the words comprising the back azimuth procedure database shall be transmitted throughout the back azimuth sector.

3.11.5.4.2.4 **Recommendation.—** If the back azimuth function is provided, the appropriate auxiliary data B words should be transmitted.

Note.— The composition of the auxiliary data words is given in Appendix A, Tables A-10, A-12 and A-15.

3.11.5.4.3 Monitor and control

3.11.5.4.3.1 The monitor system shall provide a warning to the designated control point if the radiated power is less than that necessary to satisfy the DPSK requirement specified in 3.11.4.10.1.

3.11.5.4.3.2 If a detected error in the basic data radiated into the approach azimuth coverage occurs in at least two consecutive samples, radiation of these data, approach azimuth and elevation functions shall cease.

3.11.5.4.3.3 If a detected error in the basic data radiated into the back azimuth coverage occurs in at least two consecutive samples, radiation of these data and the back azimuth function shall cease.

3.11.5.5 Distance measuring equipment

3.11.5.5.1 DME information shall be provided at least throughout the coverage volume in which approach and back azimuth guidance is available.

3.11.5.5.2 **Recommendation.—** DME information should be provided throughout 360° azimuth if operationally required.

Note.— Siting of DME ground equipment is dependent on runway length, runway profile and local terrain. Guidance on siting of DME ground equipment is given in Attachment C, 7.1.6 and Attachment G, 5.

3.11.6 Airborne equipment characteristics

3.11.6.1 Angle and data functions

3.11.6.1.1 Accuracy

3.11.6.1.1.1 Where the DPSK and scanning beam signal power densities are the minimum specified in 3.11.4.10.1, the airborne equipment shall be able to acquire the signal and any decoded angle signal shall have a CMN not exceeding 0.1 degree, except that the back azimuth guidance function CMN shall not exceed 0.2 degree.

Note 1.— It is intended that basic and auxiliary data words which contain information essential for the desired operation be decoded within a time period and with an integrity which is suitable for the intended application.

Note 2.— Information related to the acquisition and validation of angle guidance and data functions is given in Attachment G, 7.3.

3.11.6.1.1.2 Where the radiated signal power density is high enough to cause the airborne receiver noise contribution to be insignificant, the airborne equipment shall not degrade the accuracy of any decoded angle guidance signal by greater than plus or minus 0.017 degree (PFE), and plus or minus 0.015 degree (azimuth), and plus or minus 0.01 degree (elevation) CMN.

3.11.6.1.1.3 In order to obtain accurate guidance to 2.5 m (8 ft) above the runway surface, the airborne equipment shall produce less than 0.04 degree CMN with the power densities indicated in 3.11.4.10.2 b).

3.11.6.1.2 Dynamic range

3.11.6.1.2.1 The airborne equipment shall be able to acquire the signal and the performance in 3.11.6.1.1.2 shall be met where the power density of any of the radiated signals has any value between the minimum specified in 3.11.4.10.1 up to a maximum of minus 14.5 dBW/m2.

3.11.6.1.2.2 The receiver performance shall not degrade beyond the specified limits when the maximum differential levels permitted in 3.11.6.1.2.1 exist between signal power densities of individual functions.

3.11.6.1.3 Receiver angle data output filter characteristics

3.11.6.1.3.1 For sinusoidal input frequencies, receiver output filters shall not induce amplitude variations or phase lags in the angle data which exceed those obtained with a single pole low-pass filter with a corner frequency of 10 rad/s by more than 20 per cent.

Note.— Receiver outputs intended only to operate visual displays may benefit from appropriate additional filtering. Additional information on output data filtering is given in Attachment G, 7.4.2.

3.11.6.1.4 Adjacent channel spurious response. The receiver performance specified in 3.11.6 shall be met when the ratio between the desired tracked signals and the noise produced by the adjacent channel signals in a 150 kHz bandwidth centred around the desired frequency is equal to or greater than the signal-to-noise ratio (SNR) values:

a) as specified in Table X1 when the power density received from the desired ground station is equal to or higher than the values as specified in Table Y, or

b) as specified in the Table X2 when the power density received from the desired ground station is between the minimum density power values specified in 3.11.4.10.1 and the values specified in Table Y.

Table Y

Function	*Beam width (Note 2)* 1°	2°	3°
Approach azimuth guidance	−69.8 dBW/m²	−63.8 dBW/m²	−60.2 dBW/m²
High rate approach azimuth guidance	−74.6 dBW/m²	−69.5 dBW/m²	−65 dBW/m²
Approach elevation guidance	−71 dBW/m²	−65 dBW/m²	N/A
Back azimuth	N/A (Note 4)	N/A (Note 4)	N/A (Note 4)

Table X1

		SNR (Note 1)		
		Beam width (Note 2)		
Function	*Data*	*1°*	*2°*	*3°*
Approach azimuth guidance	5 dB	24.7 dB	30.7 dB	34.3 dB
High rate approach azimuth guidance	5 dB	19.9 dB	26 dB	29.5 dB
Approach elevation guidance	5 dB	23.5 dB	29.5 dB	N/A
Back azimuth (Note 4)	5 dB	5.2 dB	11.2 dB	14.8 dB

Table X2

Function	Data	SNR (Note 1) Beam width (Note 2) 1°	2°	3°
Approach azimuth guidance	5 dB	8.2 dB	14.3 dB	17.8 dB
High rate approach azimuth guidance	5 dB	3.5 dB	9.5 dB	13 dB
Approach elevation guidance	5 dB	3.5 dB	9.5 dB	N/A
Back azimuth (Note 4)	5 dB	5.2 dB	11.2 dB	14.8 dB

Note 1.— When the radiated desired signal power density is high enough to cause the airborne receiver noise contribution to be insignificant, the airborne CMN contribution for elevation and approach azimuth guidance (not for back azimuth) is required as stated in 3.11.6.1.1, to be reduced compared to the CMN contribution when the radiated desired signal power density is at the minimum specified in 3.11.4.10.1 and the minimum SNR values are therefore higher.

Note 2.— The relationship is linear between adjacent points designated by the beam widths.

Note 3.— These SNR values are to be protected through application of frequency separation criteria as explained in Attachment G, 9.3.

Note 4.— As there is no change in back azimuth guidance accuracy when the airborne receiver noise may be considered as insignificant, the same SNR values are applied for back azimuth.

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Table A. DME/MLS angle, DME/VOR and DME/ILS/MLS channelling and pairing

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
*1X	–	–	–	1 025	12	–	–	962	12
**1Y	–	–	–	1 025	36	–	–	1 088	30
*2X	–	–	–	1 026	12	–	–	963	12
**2Y	–	–	–	1 026	36	–	–	1 089	30
*3X	–	–	–	1 027	12	–	–	964	12
**3Y	–	–	–	1 027	36	–	–	1 090	30
*4X	–	–	–	1 028	12	–	–	965	12
**4Y	–	–	–	1 028	36	–	–	1 091	30
*5X	–	–	–	1 029	12	–	–	966	12
**5Y	–	–	–	1 029	36	–	–	1 092	30
*6X	–	–	–	1 030	12	–	–	967	12
**6Y	–	–	–	1 030	36	–	–	1 093	30
*7X	–	–	–	1 031	12	–	–	968	12
**7Y	–	–	–	1 031	36	–	–	1 094	30
*8X	–	–	–	1 032	12	–	–	969	12
**8Y	–	–	–	1 032	36	–	–	1 095	30
*9X	–	–	–	1 033	12	–	–	970	12
**9Y	–	–	–	1 033	36	–	–	1 096	30
*10X	–	–	–	1 034	12	–	–	971	12
**10Y	–	–	–	1 034	36	–	–	1 097	30
*11X	–	–	–	1 035	12	–	–	972	12
**11Y	–	–	–	1 035	36	–	–	1 098	30
*12X	–	–	–	1 036	12	–	–	973	12
**12Y	–	–	–	1 036	36	–	–	1 099	30
*13X	–	–	–	1 037	12	–	–	974	12
**13Y	–	–	–	1 037	36	–	–	1 100	30
*14X	–	–	–	1 038	12	–	–	975	12
**14Y	–	–	–	1 038	36	–	–	1 101	30
*15X	–	–	–	1 039	12	–	–	976	12
**15Y	–	–	–	1 039	36	–	–	1 102	30
*16X	–	–	–	1 040	12	–	–	977	12
**16Y	–	–	–	1 040	36	–	–	1 103	30

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
V17X	108.00	–	–	1 041	12	–	–	978	12
17Y	108.05	5 043.0	540	1 041	36	36	42	1 104	30
17Z	–	5 043.3	541	1 041	–	21	27	1 104	15
18X	108.10	5 031.0	500	1 042	12	12	18	979	12
18W	–	5 031.3	501	1 042	–	24	30	979	24
18Y	108.15	5 043.6	542	1 042	36	36	42	1 105	30
18Z	–	5 043.9	543	1 042	–	21	27	1 105	15
19X	108.20	–	–	1 043	12	–	–	980	12
19Y	108.25	5 044.2	544	1 043	36	36	42	1 106	30
19Z	–	5 044.5	545	1 043	–	21	27	1 106	15
20X	108.30	5 031.6	502	1 044	12	12	18	981	12
20W	–	5 031.9	503	1 044	–	24	30	981	24
20Y	108.35	5 044.8	546	1 044	36	36	42	1 107	30
20Z	–	5 045.1	547	1 044	–	21	27	1 107	15
21X	108.40	–	–	1 045	12	–	–	982	12
21Y	108.45	5 045.4	548	1 045	36	36	42	1 108	30
21Z	–	5 045.7	549	1 045	–	21	27	1 108	15
22X	108.50	5 032.2	504	1 046	12	12	18	983	12
22W	–	5 032.5	505	1 046	–	24	30	983	24
22Y	108.55	5 046.0	550	1 046	36	36	42	1 109	30
22Z	–	5 046.3	551	1 046	–	21	27	1 109	15
23X	108.60	–	–	1 047	12	–	–	984	12
23Y	108.65	5 046.6	552	1 047	36	36	42	1 110	30
23Z	–	5 046.9	553	1 047	–	21	27	1 110	15
24X	108.70	5 032.8	506	1 048	12	12	18	985	12
24W	–	5 033.1	507	1 048	–	24	30	985	24
24Y	108.75	5 047.2	554	1 048	36	36	42	1 111	30
24Z	–	5 047.5	555	1 048	–	21	27	1 111	15
25X	108.80	–	–	1 049	12	–	–	986	12
25Y	108.85	5 047.8	556	1 049	36	36	42	1 112	30
25Z	–	5 048.1	557	1 049	–	21	27	1 112	15
26X	108.90	5 033.4	508	1 050	12	12	18	987	12
26W	–	5 033.7	509	1 050	–	24	30	987	24
26Y	108.95	5 048.4	558	1 050	36	36	42	1 113	30
26Z	–	5 048.7	559	1 050	–	21	27	1 113	15
27X	109.00	–	–	1 051	12	–	–	988	12
27Y	109.05	5 049.0	560	1 051	36	36	42	1 114	30
27Z	–	5 049.3	561	1 051	–	21	27	1 114	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
28X	109.10	5 034.0	510	1 052	12	12	18	989	12
28W	–	5 034.3	511	1 052	–	24	30	989	24
28Y	109.15	5 049.6	562	1 052	36	36	42	1 115	30
28Z	–	5 049.9	563	1 052	–	21	27	1 115	15
29X	109.20	–	–	1 053	12	–	–	990	12
29Y	109.25	5 050.2	564	1 053	36	36	42	1 116	30
29Z	–	5 050.5	565	1 053	–	21	27	1 116	15
30X	109.30	5 034.6	512	1 054	12	12	18	991	12
30W	–	5 034.9	513	1 054	–	24	30	991	24
30Y	109.35	5 050.8	566	1 054	36	36	42	1 117	30
30Z	–	5 051.1	567	1 054	–	21	27	1 117	15
31X	109.40	–	–	1 055	12	–	–	992	12
31Y	109.45	5 051.4	568	1 055	36	36	42	1 118	30
31Z	–	5 051.7	569	1 055	–	21	27	1 118	15
32X	109.50	5 035.2	514	1 056	12	12	18	993	12
32W	–	5 035.5	515	1 056	–	24	30	993	24
32Y	109.55	5 052.0	570	1 056	36	36	42	1 119	30
32Z	–	5 052.3	571	1 056	–	21	27	1 119	15
33X	109.60	–	–	1 057	12	–	–	994	12
33Y	109.65	5 052.6	572	1 057	36	36	42	1 120	30
33Z	–	5 052.9	573	1 057	–	21	27	1 120	15
34X	109.70	5 035.8	516	1 058	12	12	18	995	12
34W	–	5 036.1	517	1 058	–	24	30	995	24
34Y	109.75	5 053.2	574	1 058	36	36	42	1 121	30
34Z	–	5 053.5	575	1 058	–	21	27	1 121	15
35X	109.80	–	–	1 059	12	–	–	996	12
35Y	109.85	5 053.8	576	1 059	36	36	42	1 122	30
35Z	–	5 054.1	577	1 059	–	21	27	1 122	15
36X	109.90	5 036.4	518	1 060	12	12	18	997	12
36W	–	5 036.7	519	1 060	–	24	30	997	24
36Y	109.95	5 054.4	578	1 060	36	36	42	1 123	30
36Z	–	5 054.7	579	1 060	–	21	27	1 123	15
37X	110.00	–	–	1 061	12	–	–	998	12
37Y	110.05	5 055.0	580	1 061	36	36	42	1 124	30
37Z	–	5 055.3	581	1 061	–	21	27	1 124	15
38X	110.10	5 037.0	520	1 062	12	12	18	999	12
38W	–	5 037.3	521	1 062	–	24	30	999	24
38Y	110.15	5 055.6	582	1 062	36	36	42	1 125	30
38Z	–	5 055.9	583	1 062	–	21	27	1 125	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
39X	110.20	–	–	1 063	12	–	–	1 000	12
39Y	110.25	5 056.2	584	1 063	36	36	42	1 126	30
39Z	–	5 056.5	585	1 063	–	21	27	1 126	15
40X	110.30	5 037.6	522	1 064	12	12	18	1 001	12
40W	–	5 037.9	523	1 064	–	24	30	1 001	24
40Y	110.35	5 056.8	586	1 064	36	36	42	1 127	30
40Z	–	5 057.1	587	1 064	–	21	27	1 127	15
41X	110.40	–	–	1 065	12	–	–	1 002	12
41Y	110.45	5 057.4	588	1 065	36	36	42	1 128	30
41Z	–	5 057.7	589	1 065	–	21	27	1 128	15
42X	110.50	5 038.2	524	1 066	12	12	18	1 003	12
42W	–	5 038.5	525	1 066	–	24	30	1 003	24
42Y	110.55	5 058.0	590	1 066	36	36	42	1 129	30
42Z	–	5 058.3	591	1 066	–	21	27	1 129	15
43X	110.60	–	–	1 067	12	–	–	1 004	12
43Y	110.65	5 058.6	592	1 067	36	36	42	1 130	30
43Z	–	5 058.9	593	1 067	–	21	27	1 130	15
44X	110.70	5 038.8	526	1 068	12	12	18	1 005	12
44W	–	5 039.1	527	1 068	–	24	30	1 005	24
44Y	110.75	5 059.2	594	1 068	36	36	42	1 131	30
44Z	–	5 059.5	595	1 068	–	21	27	1 131	15
45X	110.80	–	–	1 069	12	–	–	1 006	12
45Y	110.85	5 059.8	596	1 069	36	36	42	1 132	30
45Z	–	5 060.1	597	1 069	–	21	27	1 132	15
46X	110.90	5 039.4	528	1 070	12	12	18	1 007	12
46W	–	5 039.7	529	1 070	–	24	30	1 007	24
46Y	110.95	5 060.4	598	1 070	36	36	42	1 133	30
46Z	–	5 060.7	599	1 070	–	21	27	1 133	15
47X	111.00	–	–	1 071	12	–	–	1 008	12
47Y	111.05	5 061.0	600	1 071	36	36	42	1 134	30
47Z	–	5 061.3	601	1 071	–	21	27	1 134	15
48X	111.10	5 040.0	530	1 072	12	12	18	1 009	12
48W	–	5 040.3	531	1 072	–	24	30	1 009	24
48Y	111.15	5 061.6	602	1 072	36	36	42	1 135	30
48Z	–	5 061.9	603	1 072	–	21	27	1 135	15
49X	111.20	–	–	1 073	12	–	–	1 010	12
49Y	111.25	5 062.2	604	1 073	36	36	42	1 136	30
49Z	–	5 062.5	605	1 073	–	21	27	1 136	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
50X	111.30	5 040.6	532	1 074	12	12	18	1 011	12
50W	–	5 040.9	533	1 074	–	24	30	1 011	24
50Y	111.35	5 062.8	606	1 074	36	36	42	1 137	30
50Z	–	5 063.1	607	1 074	–	21	27	1 137	15
51X	111.40	–	–	1 075	12	–	–	1 012	12
51Y	111.45	5 063.4	608	1 075	36	36	42	1 138	30
51Z	–	5 063.7	609	1 075	–	21	27	1 138	15
52X	111.50	5 041.2	534	1 076	12	12	18	1 013	12
52W	–	5 041.5	535	1 076	–	24	30	1 013	24
52Y	111.55	5 064.0	610	1 076	36	36	42	1 139	30
52Z	–	5 064.3	611	1 076	–	21	27	1 139	15
53X	111.60	–	–	1 077	12	–	–	1 014	12
53Y	111.65	5 064.6	612	1 077	36	36	42	1 140	30
53Z	–	5 064.9	613	1 077	–	21	27	1 140	15
54X	111.70	5 041.8	536	1 078	12	12	18	1 015	12
54W	–	5 042.1	537	1 078	–	24	30	1 015	24
54Y	111.75	5 065.2	614	1 078	36	36	42	1 141	30
54Z	–	5 065.5	615	1 078	–	21	27	1 141	15
55X	111.80	–	–	1 079	12	–	–	1 016	12
55Y	111.85	5 065.8	616	1 079	36	36	42	1 142	30
55Z	–	5 066.1	617	1 079	–	21	27	1 142	15
56X	111.90	5 042.4	538	1 080	12	12	18	1 017	12
56W	–	5 042.7	539	1 080	–	24	30	1 017	24
56Y	111.95	5 066.4	618	1 080	36	36	42	1 143	30
56Z	–	5 066.7	619	1 080	–	21	27	1 143	15
57X	112.00	–	–	1 081	12	–	–	1 018	12
57Y	112.05	–	–	1 081	36	–	–	1 144	30
58X	112.10	–	–	1 082	12	–	–	1 019	12
58Y	112.15	–	–	1 082	36	–	–	1 145	30
59X	112.20	–	–	1 083	12	–	–	1 020	12
59Y	112.25	–	–	1 083	36	–	–	1 146	30
**60X	–	–	–	1 084	12	–	–	1 021	12
**60Y	–	–	–	1 084	36	–	–	1 147	30
**61X	–	–	–	1 085	12	–	–	1 022	12
**61Y	–	–	–	1 085	36	–	–	1 148	30
**62X	–	–	–	1 086	12	–	–	1 023	12
**62Y	–	–	–	1 086	36	–	–	1 149	30
**63X	–	–	–	1 087	12	–	–	1 024	12
**63Y	–	–	–	1 087	36	–	–	1 150	30

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
**64X	–	–	–	1 088	12	–	–	1 151	12
**64Y	–	–	–	1 088	36	–	–	1 025	30
**65X	–	–	–	1 089	12	–	–	1 152	12
**65Y	–	–	–	1 089	36	–	–	1 026	30
**66X	–	–	–	1 090	12	–	–	1 153	12
**66Y	–	–	–	1 090	36	–	–	1 027	30
**67X	–	–	–	1 091	12	–	–	1 154	12
**67Y	–	–	–	1 091	36	–	–	1 028	30
**68X	–	–	–	1 092	12	–	–	1 155	12
**68Y	–	–	–	1 092	36	–	–	1 029	30
**69X	–	–	–	1 093	12	–	–	1 156	12
**69Y	–	–	–	1 093	36	–	–	1 030	30
70X	112.30	–	–	1 094	12	–	–	1 157	12
**70Y	112.35	–	–	1 094	36	–	–	1 031	30
71X	112.40	–	–	1 095	12	–	–	1 158	12
**71Y	112.45	–	–	1 095	36	–	–	1 032	30
72X	112.50	–	–	1 096	12	–	–	1 159	12
**72Y	112.55	–	–	1 096	36	–	–	1 033	30
73X	112.60	–	–	1 097	12	–	–	1 160	12
**73Y	112.65	–	–	1 097	36	–	–	1 034	30
74X	112.70	–	–	1 098	12	–	–	1 161	12
**74Y	112.75	–	–	1 098	36	–	–	1 035	30
75X	112.80	–	–	1 099	12	–	–	1 162	12
**75Y	112.85	–	–	1 099	36	–	–	1 036	30
76X	112.90	–	–	1 100	12	–	–	1 163	12
**76Y	112.95	–	–	1 100	36	–	–	1 037	30
77X	113.00	–	–	1 101	12	–	–	1 164	12
**77Y	113.05	–	–	1 101	36	–	–	1 038	30
78X	113.10	–	–	1 102	12	–	–	1 165	12
**78Y	113.15	–	–	1 102	36	–	–	1 039	30
79X	113.20	–	–	1 103	12	–	–	1 166	12
**79Y	113.25	–	–	1 103	36	–	–	1 040	30
80X	113.30	–	–	1 104	12	–	–	1 167	12
80Y	113.35	5 067.0	620	1 104	36	36	42	1 041	30
80Z	–	5 067.3	621	1 104	–	21	27	1 041	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
81X	113.40	–	–	1 105	12	–	–	1 168	12
81Y	113.45	5 067.6	622	1 105	36	36	42	1 042	30
81Z	–	5 067.9	623	1 105	–	21	27	1 042	15
82X	113.50	–	–	1 106	12	–	–	1 169	12
82Y	113.55	5 068.2	624	1 106	36	36	42	1 043	30
82Z	–	5 068.5	625	1 106	–	21	27	1 043	15
83X	113.60	–	–	1 107	12	–	–	1 170	12
83Y	113.65	5 068.8	626	1 107	36	36	42	1 044	30
83Z	–	5 069.1	627	1 107	–	21	27	1 044	15
84X	113.70	–	–	1 108	12	–	–	1 171	12
84Y	113.75	5 069.4	628	1 108	36	36	42	1 045	30
84Z	–	5 069.7	629	1 108	–	21	27	1 045	15
85X	113.80	–	–	1 109	12	–	–	1 172	12
85Y	113.85	5 070.0	630	1 109	36	36	42	1 046	30
85Z	–	5 070.3	631	1 109	–	21	27	1 046	15
86X	113.90	–	–	1 110	12	–	–	1 173	12
86Y	113.95	5 070.6	632	1 110	36	36	42	1 047	30
86Z	–	5 070.9	633	1 110	–	21	27	1 047	15
87X	114.00	–	–	1 111	12	–	–	1 174	12
87Y	114.05	5 071.2	634	1 111	36	36	42	1 048	30
87Z	–	5 071.5	635	1 111	–	21	27	1 048	15
88X	114.10	–	–	1 112	12	–	–	1 175	12
88Y	114.15	5 071.8	636	1 112	36	36	42	1 049	30
88Z	–	5 072.1	637	1 112	–	21	27	1 049	15
89X	114.20	–	–	1 113	12	–	–	1 176	12
89Y	114.25	5 072.4	638	1 113	36	36	42	1 050	30
89Z	–	5 072.7	639	1 113	–	21	27	1 050	15
90X	114.30	–	–	1 114	12	–	–	1 177	12
90Y	114.35	5 073.0	640	1 114	36	36	42	1 051	30
90Z	–	5 073.3	641	1 114	–	21	27	1 051	15
91X	114.40	–	–	1 115	12	–	–	1 178	12
91Y	114.45	5 073.6	642	1 115	36	36	42	1 052	30
91Z	–	5 073.9	643	1 115	–	21	27	1 052	15
92X	114.50	–	–	1 116	12	–	–	1 179	12
92Y	114.55	5 074.2	644	1 116	36	36	42	1 053	30
92Z	–	5 074.5	645	1 116	–	21	27	1 053	15
93X	114.60	–	–	1 117	12	–	–	1 180	12
93Y	114.65	5 074.8	646	1 117	36	36	42	1 054	30
93Z	–	5 075.1	647	1 117	–	21	27	1 054	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
94X	114.70	–	–	1 118	12	–	–	1 181	12
94Y	114.75	5 075.4	648	1 118	36	36	42	1 055	30
94Z	–	5 075.7	649	1 118	–	21	27	1 055	15
95X	114.80	–	–	1 119	12	–	–	1 182	12
95Y	114.85	5 076.0	650	1 119	36	36	42	1 056	30
95Z	–	5 076.3	651	1 119	–	21	27	1 056	15
96X	114.90	–	–	1 120	12	–	–	1 183	12
96Y	114.95	5 076.6	652	1 120	36	36	42	1 057	30
96Z	–	5 076.9	653	1 120	–	21	27	1 057	15
97X	115.00	–	–	1 121	12	–	–	1 184	12
97Y	115.05	5 077.2	654	1 121	36	36	42	1 058	30
97Z	–	5 077.5	655	1 121	–	21	27	1 058	15
98X	115.10	–	–	1 122	12	–	–	1 185	12
98Y	115.15	5 077.8	656	1 122	36	36	42	1 059	30
98Z	–	5 078.1	657	1 122	–	21	27	1 059	15
99X	115.20	–	–	1 123	12	–	–	1 186	12
99Y	115.25	5 078.4	658	1 123	36	36	42	1 060	30
99Z	–	5 078.7	659	1 123	–	21	27	1 060	15
100X	115.30	–	–	1 124	12	–	–	1 187	12
100Y	115.35	5 079.0	660	1 124	36	36	42	1 061	30
100Z	–	5 079.3	661	1 124	–	21	27	1 061	15
101X	115.40	–	–	1 125	12	–	–	1 188	12
101Y	115.45	5 079.6	662	1 125	36	36	42	1 062	30
101Z	–	5 079.9	663	1 125	–	21	27	1 062	15
102X	115.50	–	–	1 126	12	–	–	1 189	12
102Y	115.55	5 080.2	664	1 126	36	36	42	1 063	30
102Z	–	5 080.5	665	1 126	–	21	27	1 063	15
103X	115.60	–	–	1 127	12	–	–	1 190	12
103Y	115.65	5 080.8	666	1 127	36	36	42	1 064	30
103Z	–	5 081.1	667	1 127	–	21	27	1 064	15
104X	115.70	–	–	1 128	12	–	–	1 191	12
104Y	115.75	5 081.4	668	1 128	36	36	42	1 065	30
104Z	–	5 081.7	669	1 128	–	21	27	1 065	15
105X	115.80	–	–	1 129	12	–	–	1 192	12
105Y	115.85	5 082.0	670	1 129	36	36	42	1 066	30
105Z	–	5 082.3	671	1 129	–	21	27	1 066	15
106X	115.90	–	–	1 130	12	–	–	1 193	12
106Y	115.95	5 082.6	672	1 130	36	36	42	1 067	30
106Z	–	5 082.9	673	1 130	–	21	27	1 067	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
107X	116.00	–	–	1 131	12	–	–	1 194	12
107Y	116.05	5 083.2	674	1 131	36	36	42	1 068	30
107Z	–	5 083.5	675	1 131	–	21	27	1 068	15
108X	116.10	–	–	1 132	12	–	–	1 195	12
108Y	116.15	5 083.8	676	1 132	36	36	42	1 069	30
108Z	–	5 084.1	677	1 132	–	21	27	1 069	15
109X	116.20	–	–	1 133	12	–	–	1 196	12
109Y	116.25	5 084.4	678	1 133	36	36	42	1 070	30
109Z	–	5 084.7	679	1 133	–	21	27	1 070	15
110X	116.30	–	–	1 134	12	–	–	1 197	12
110Y	116.35	5 085.0	680	1 134	36	36	42	1 071	30
110Z	–	5 085.3	681	1 134	–	21	27	1 071	15
111X	116.40	–	–	1 135	12	–	–	1 198	12
111Y	116.45	5 085.6	682	1 135	36	36	42	1 072	30
111Z	–	5 085.9	683	1 135	–	21	27	1 072	15
112X	116.50	–	–	1 136	12	–	–	1 199	12
112Y	116.55	5 086.2	684	1 136	36	36	42	1 073	30
112Z	–	5 086.5	685	1 136	–	21	27	1 073	15
113X	116.60	–	–	1 137	12	–	–	1 200	12
113Y	116.65	5 086.8	686	1 137	36	36	42	1 074	30
113Z	–	5 087.1	687	1 137	–	21	27	1 074	15
114X	116.70	–	–	1 138	12	–	–	1 201	12
114Y	116.75	5 087.4	688	1 138	36	36	42	1 075	30
114Z	–	5 087.7	689	1 138	–	21	27	1 075	15
115X	116.80	–	–	1 139	12	–	–	1 202	12
115Y	116.85	5 088.0	690	1 139	36	36	42	1 076	30
115Z	–	5 088.3	691	1 139	–	21	27	1 076	15
116X	116.90	–	–	1 140	12	–	–	1 203	12
116Y	116.95	5 088.6	692	1 140	36	36	42	1 077	30
116Z	–	5 088.9	693	1 140	–	21	27	1 077	15
117X	117.00	–	–	1 141	12	–	–	1 204	12
117Y	117.05	5 089.2	694	1 141	36	36	42	1 078	30
117Z	–	5 089.5	695	1 141	–	21	27	1 078	15
118X	117.10	–	–	1 142	12	–	–	1 205	12
118Y	117.15	5 089.8	696	1 142	36	36	42	1 079	30
118Z	–	5 090.1	697	1 142	–	21	27	1 079	15
119X	117.20	–	–	1 143	12	–	–	1 206	12
119Y	117.25	5 090.4	698	1 143	36	36	42	1 080	30
119Z	–	5 090.7	699	1 143	–	21	27	1 080	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
120X	117.30	–	–	1 144	12	–	–	1 207	12
120Y	117.35	–	–	1 144	36	–	–	1 081	30
121X	117.40	–	–	1 145	12	–	–	1 208	12
121Y	117.45	–	–	1 145	36	–	–	1 082	30
122X	117.50	–	–	1 146	12	–	–	1 209	12
122Y	117.55	–	–	1 146	36	–	–	1 083	30
123X	117.60	–	–	1 147	12	–	–	1 210	12
123Y	117.65	–	–	1 147	36	–	–	1 084	30
124X	117.70	–	–	1 148	12	–	–	1 211	12
**124Y	117.75	–	–	1 148	36	–	–	1 085	30
125X	117.80	–	–	1 149	12	–	–	1 212	12
**125Y	117.85	–	–	1 149	36	–	–	1 086	30
126X	117.90	–	–	1 150	12	–	–	1 213	12
**126Y	117.95	–	–	1 150	36	–	–	1 087	30

* These channels are reserved exclusively for national allotments.

** These channels may be used for national allotment on a secondary basis.
The primary reason for reserving these channels is to provide protection for the secondary surveillance radar (SSR) system.

∇ 108.0 MHz is not scheduled for assignment to ILS service. The associated DME operating channel No. 17X may be assigned for emergency use. The reply frequency of channel No. 17X (i.e. 978 MHz) is also utilized for the operation of the universal access transceiver (UAT). Standards and Recommended Practices for UAT are found in Annex 10, Volume III, Part I, Chapter 12.

Table B. Allowable DME/P errors

Location	Standard	Mode	PFE	CMN
37 km (20 NM) to 9.3 km (5NM) from MLS approach reference datum	1 and 2	IA	±250 m (±820 ft) reducing linearly to ±85 m (±279 ft)	±68 m (±223 ft) reducing linearly to ±34 m (±111 ft)
9.3 km (5 NM) to MLS approach reference datum	1	FA	±85 m (±279 ft) reducing linearly to ±30 m (±100 ft)	±18 m (±60 ft)
	2	FA	±85 m (±279 ft) reducing linearly to ±12 m (±40 ft)	±12 m (±40 ft)
	see Note	IA	±100 m (±328 ft)	±68 m (±223 ft)
At MLS approach reference datum and through runway coverage	1	FA	±30 m (±100 ft)	±18 m (±60 ft)
	2	FA	±12 m (±40 ft)	±12 m (±40 ft)
Throughout back azimuth coverage volume	1 and 2	FA	±100 m (±328 ft)	±68 m (±223 ft)
	see Note	IA	±100 m (±328 ft)	±68 m (±223 ft)

Note.— At distances from 9.3 km (5 NM) to the MLS approach reference datum and throughout the back azimuth coverage, the IA mode may be used when the FA mode is not operative.

APPENDIX A. MICROWAVE LANDING SYSTEM

(MLS) CHARACTERISTICS

Table A-1. Preamble timing*

(see 3.11.4.3.4)

Event	Event time slot begins at 15.625 kHz Clock pulse (number)	Time (milliseconds)
Carrier acquisition (CW transmission)	0	0
Receiver reference time code		
$I_1 = 1$	13	0.832
$I_2 = 1$	1	0.896
$I_3 = 1$	15	0.960
$I_4 = 0$	16	1.024
$I_5 = 1$	17	1.088**
Function identification		
I_6	18	1.152
I_7	19	1.216
I_8	20	1.280
I_9 (see 3.11.4.4.3.3)	21	1.344
I_{10}	22	1.408
I_{11}	23	1.472
I_{12}	24	1.536
End preamble	25	1.600

* Applies to all functions transmitted.
** Reference time for receiver synchronization for all function timing.

Table A-2. Approach azimuth function timing

(see 3.11.4.3.4)

	Event time slot begins at	
Event	15.625 kHz Clock pulse (number)	Time (milliseconds)
Preamble	0	0
Morse Code (see 3.11.4.6.2.1.2)	25	1.600
Antenna select	26	1.664
Rear OCI	32	2.048
Left OCI	34	2.176
Right OCI	36	2.304
TO test	38	2.432
TO scan*	40	2.560
Pause		8.760
Midscan point		9.060
FRO scan*		9.360
FRO test		15.560
End function (airborne)		15.688
End guard time; end function (ground)		15.900

* The actual commencement and completion of the TO and FRO scan transmissions are dependent on the amount of proportional guidance provided. The time slots provided will accommodate a maximum scan of plus or minus 62.0 degrees. Scan timing shall be compatible with accuracy requirements.

Table A-3. High rate approach azimuth and back azimuth function timing

(see 3.11.4.3.4)

	Event time slot begins at	
Event	15.625 kHz Clock pulse (number)	Time (milliseconds)
Preamble	0	0
Morse Code (see 3.11.4.6.2.1.2)	25	1.600
Antenna select	26	1.664
Rear OCI	32	2.048
Left OCI	34	2.176
Right OCI	36	2.304
TO test	38	2.432
TO scan*	40	2.560
Pause		6.760
Midscan point		7.060
FRO scan*		7.360
FRO test pulse		11.560
End function (airborne)		11.688
End guard time; end function (ground)		11.900

* The actual commencement and completion of the TO and FRO scan transmissions are dependent on the amount of proportional guidance provided. The time slots provided will accommodate a maximum scan of plus or minus 42.0 degrees. Scan timing shall be compatible with accuracy requirements.

Table A-6. Basic data function timing

(see 3.11.4.3.4)

Event	Event time slot begins at 15.625 kHz Clock pulse (number)	Time (milliseconds)
Preamble	0	0
Data transmission (Bits I_{13} - I_{30})	24	1.600
Parity transmission (Bits I_{31} - I_{32})	43	2.752
End function (airborne)	45	2.880
End guard time; end function (ground)		3.100

Table A-7. Basic data

(see 3.11.4.8.2.1)

Word	Data content	Maximum time between transmissions (seconds)	Bits used	Range of values	Least significant bit	Bit number
1	PREAMBLE	1.0	12	see Note 10		I_1 - I_{12}
	Approach azimuth antenna to threshold distance		6	0 m to 6 300 m	100 m	I_{13} - I_{18}
	Approach azimuth proportional guidance sector negative limit		5	0° to 60° (see Note 11)	2°	I_{19} - I_{23}
	Approach azimuth proportional guidance sector positive limit		5	0° to 60° (see Note 11)	2°	I_{24} - I_{28}
	Clearance signal type		1	see Note 9		I_{29}
	SPARE		1	see Note 12		I_{30}
	PARITY		2	see Note 1		I_{31} - I_{32}
2	PREAMBLE	0.16	12	see Note 10		I_1 - I_{12}
	Minimum glide path		7	2° to 14.7°	0.1°	I_{13} - I_{19}
	Back azimuth status		1	see Note 2		I_{20}
	DME status		2	see Note 7		I_{21} - I_{22}
	Approach azimuth status		1	see Note 2		I_{23}
	Approach elevation status		1	see Note 2		I_{24}
	SPARE		6	see Notes 6 and 12		I_{25} - I_{30}
	PARITY		2	see Note 1		I_{31} - I_{32}

Word	Data content	Maximum time between transmissions (seconds)	Bits used	Range of values	Least significant bit	Bit number
3	PREAMBLE	1.0	12	see Note 10		I_1 - I_{12}
	Approach azimuth beamwidth		3	0.5° to 4° (See Note 8)	0.5°	I_{13} - I_{15}
	Approach elevation beamwidth		3	0.5° to 2.5° (See Note 8)	0.5°	I_{16} - I_{18}
	DME distance		9	0 m to 6 387.5 m	12.5 m	I_{19} - I_{27}
	SPARE		3	see Note 12		I_{28} - I_{30}
	PARITY		2	see Note 1		I_{31} - I_{32}
4	PREAMBLE	1.0	12	see Notes 4 and 10		I_1 - I_{12}
	Approach azimuth magnetic Orientation		9	0° to 359°	1°	I_{13} - I_{21}
	Back azimuth magnetic orientation		9	0° to 359°	1°	I_{22} - I_{30}
	PARITY		2	see Note 1		I_{31} - I_{32}
5	PREAMBLE	1.0	12	see Notes 5 and 10		I_1 - I_{12}
	Back azimuth proportional guidance sector negative limit		5	0° to 40° (see Note 11)	2°	I_{13} - I_{17}
	Back azimuth proportional guidance sector positive limit		5	0° to 40° (see Note 11)	2°	I_{18} - I_{22}
	Back azimuth beamwidth		3	0.5° to 4.0° (see Note 8)	0.5°	I_{23} - I_{25}
	Back azimuth status		1	see Note 2		I_{26}
	SPARE		4	see Notes 3 and 12		I_{27} - I_{30}
	PARITY		2	see Note 1		I_{31} - I_{32}
6	PREAMBLE	1.0	12	see Notes 4 and 10		I_1 - I_{12}
	MLS ground equipment Identification			Letters A to Z		
	Character 2		6			I_{13} - I_{18}
	Character 3		6			I_{19} - I_{24}
	Character 4		6			I_{25} - I_{30}
	PARITY		2	see Note 1		I_{31} - I_{32}

NOTES.—

1. Parity bits I_{31} and I_{32} are chosen to satisfy the equations:
   $I_{13} + I_{14} ... + I_{29} + I_{30} + I_{31} = ODD$
   $I_{14} + I_{16} + I_{18} ... + I_{28} + I_{30} + I_{32} = ODD$.
2. Coding for status bit:
   0 = function not radiated, or radiated in test mode (not reliable for navigation);
   1 = function radiated in normal mode (in Basic data word 2 the back azimuth status also indicates that back azimuth transmission is to follow).
3. These bits are reserved for future applications. One possible application is to define the back azimuth deviation scale factor.
4. Basic data words 4 and 6 are transmitted in both approach azimuth and back azimuth coverages if back azimuth guidance is provided, while retaining the maximum specified time between transmissions in each coverage sector.
5. Basic data word 5 is transmitted in both approach azimuth and back azimuth coverages if back azimuth guidance is provided, while retaining the maximum specified time between transmissions in each coverage sector.
6. These bits are reserved for future applications requiring high transmission rates.
7. Coding for I_{21} and I_{22}:

I_{21}	I_{22}	
0	0	DME transponder inoperative or not available
1	0	Only IA mode or DME/N available
0	1	FA mode, Standard 1, available
1	1	FA mode, Standard 2, available

8. The value coded is the actual beamwidth (as defined in Chapter 3, 3.11.1) rounded to the nearest 0.5 degree.
9. Code for I_{29} is:
   0 = pulse clearance signal
   1 = scanning clearance signal.
10. The 12 data bits of the preamble are preceded by an 0.832 millisecond interval (13 clock pulses) of CW for carrier acquisition (see Table A-1).
11. The scan limits are greater than the proportional guidance sector limits shown in Basic data words 1 and 5 as described in 3.11.4.5.1.
12. All spare bits are set to ZERO.

Table A-8. Auxiliary data function timing

(see 3.11.4.3.4)

Event	Event time slot begins at: 15.625 kHz Clock pulse (number)	Time (milliseconds)
Preamble	0	0
Address transmission (Bits I_{13} - I_{20})	25	1.600
Data transmission (Bits I_{21} - I_{69})	33	2.112
Parity transmission (Bits I_{70} - I_{76})	82	5.248
End function (airborne)	89	5.696
End guard time; end function (ground)		5.900

Table A-9. Auxiliary data words address codes

No.	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{18}	I_{19}	I_{20}	No.	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{18}	I_{19}	I_{20}
1	0	0	0	0	0	1	1	1	33	1	0	0	0	0	1	0	1
2	0	0	0	0	1	0	1	0	34	1	0	0	0	1	0	0	0
3	0	0	0	0	1	1	0	1	35	1	0	0	0	1	1	1	1
4	0	0	0	1	0	0	1	1	36	1	0	0	1	0	0	0	1
5	0	0	0	1	0	1	0	0	37	1	0	0	1	0	1	1	0
6	0	0	0	1	1	0	0	1	38	1	0	0	1	1	0	1	1
7	0	0	0	1	1	1	1	0	39	1	0	0	1	1	1	0	0
8	0	0	1	0	0	0	1	0	40	1	0	1	0	0	0	0	0
9	0	0	1	0	0	1	0	1	41	1	0	1	0	0	1	1	1
10	0	0	1	0	1	0	0	0	42	1	0	1	0	1	0	1	0
11	0	0	1	0	1	1	1	1	43	1	0	1	0	1	1	0	1
12	0	0	1	1	0	0	0	1	44	1	0	1	1	0	0	1	1
13	0	0	1	1	0	1	1	0	45	1	0	1	1	0	1	0	0
14	0	0	1	1	1	0	1	1	46	1	0	1	1	1	0	0	1
15	0	0	1	1	1	1	0	0	47	1	0	1	1	1	1	1	0
16	0	1	0	0	0	0	1	1	48	1	1	0	0	0	0	0	1
17	0	1	0	0	0	1	0	0	49	1	1	0	0	0	1	1	0
18	0	1	0	0	1	0	0	1	50	1	1	0	0	1	0	1	1
19	0	1	0	0	1	1	1	0	51	1	1	0	0	1	1	0	0
20	0	1	0	1	0	0	0	0	52	1	1	0	1	0	0	1	0
21	0	1	0	1	0	1	1	1	53	1	1	0	1	0	1	0	1
22	0	1	0	1	1	0	1	0	54	1	1	0	1	1	0	0	0
23	0	1	0	1	1	1	0	1	55	1	1	0	1	1	1	1	1
24	0	1	1	0	0	0	0	1	56	1	1	1	0	0	0	1	1
25	0	1	1	0	0	1	1	0	57	1	1	1	0	0	1	0	0
26	0	1	1	0	1	0	1	1	58	1	1	1	0	1	0	0	1
27	0	1	1	0	1	1	0	0	59	1	1	1	0	1	1	1	0
28	0	1	1	1	0	0	1	0	60	1	1	1	1	0	0	0	0
29	0	1	1	1	0	1	0	1	61	1	1	1	1	0	1	1	1
30	0	1	1	1	1	0	0	0	62	1	1	1	1	1	0	1	0
31	0	1	1	1	1	1	1	1	63	1	1	1	1	1	1	0	1
32	1	0	0	0	0	0	1	0	64	0	0	0	0	0	0	0	0

Note.— Parity bits I_{19} and I_{20} are chosen to satisfy the equations:

$I_{13} + I_{14} + I_{15} + I_{16} + I_{17} + I_{18} + I_{19} = \text{EVEN}$

$I_{14} + I_{16} + I_{18} + I_{20} = \text{EVEN}$

Table A-10. Auxiliary data

(see 3.11.4.8.3.1)

Word	Data content	Type of data	Maximum time between transmissions (seconds)	Bits used	Range of values	Least significant bit	Bit number
A1	PREAMBLE	digital	1.0	12	see Note 6		I_1 - I_{12}
	Address			8			I_{13} - I_{20}
	Approach azimuth antenna offset			10	–511 m to +511 m (see Note 3)	1 m	I_{21} - I_{30}
	Approach azimuth antenna to MLS datum point distance			13	0 m to 8 191 m	1 m	I_{31} - I_{43}
	Approach azimuth alignment with runway centre line			12	–20.47° to +20.47° (see Notes 3 and 7)	0.01°	I_{44} - I_{55}
	Approach azimuth antenna coordinate system			1	See Note 2		I_{56}
	Approach azimuth antenna height			7	–63 m to +63 m (see Note 3)	1 m	I_{57} - I_{63}
	SPARE			6	See Note 8		I_{64} - I_{69}
	PARITY			7	See Note 1		I_{70} - I_{76}
A2	PREAMBLE	digital	1.0	12	See Note 6		I_1 - I_{12}
	Address			8			I_{13} - I_{20}
	Approach elevation antenna offset			10	–511 m to +511 m (see Note 3)	1 m	I_{21} - I_{30}
	MLS datum point to threshold distance			10	0 m to 1 023 m	1 m	I_{31} - I_{40}
	Approach elevation antenna height			7	–6.3 m to +6.3 m (see Note 3)	0.1 m	I_{41} - I_{47}
	MLS datum point elevation			13	–4 095 m to +4 095 m (see Note 3)	1 m	I_{48} - I_{60}
	Runway threshold height			7	–6.3 m to +6.3 m (see Note 3)	0.1 m	I_{61} - I_{67}
	SPARE			2	See Note 8		I_{68} - I_{69}
	PARITY			7	See Note 1		I_{70} - I_{76}
A3	PREAMBLE (see Note 4)	digital	1.0	12	See Note 6		I_1 - I_{12}
	Address			8			I_{13} - I_{20}
	DME offset			12	–2 047 m to +2 047 m (see Note 3)	1 m	I_{21} - I_{32}
	DME to MLS datum point distance			14	–8 191 m to +8 191 m (see Note 3)	1 m	I_{33} - I_{46}

Word	Data content	Type of data	Maximum time between transmissions (seconds)	Bits used	Range of values	Least significant bit	Bit number
	DME antenna height			7	–63 m to +63 m (see Note 3)	1 m	I_{47} - I_{53}
	Runway stop-end distance			14	0 m to 16 383 m	1 m	I_{54} - I_{67}
	SPARE			2	See Note 8		I_{68} - I_{69}
	PARITY			7	See Note 1		I_{70} - I_{76}
A4	PREAMBLE (see Note 5)	digital	1.0	12	See Note 6		I_{1} - I_{12}
	Address			8			I_{13} - I_{20}
	Back azimuth antenna offset			10	–511 m to +511 m (see Note 3)	1 m	I_{21} - I_{30}
	Back azimuth to MLS datum point distance			11	0 m to 2 047 m	1 m	I_{31} - I_{41}
	Back azimuth alignment with runway centre line			12	–20.47° to +20.47° (see Notes 3 and 7)	0.01°	I_{42} - I_{53}
	Back azimuth antenna coordinate system			1	See Note 2		I_{54}
	Back azimuth antenna height			7	–63 m to +63 m (see Note 3)	1 m	I_{55} - I_{61}
	SPARE			8	See Note 8		I_{62} - I_{69}
	PARITY			7	See Note 1		I_{70} - I_{76}

NOTES.—

1. Parity bits I70to I76are chosen to satisfy the equations which follow.

For bit I70

EVEN =(I13+ ... + I18) + I20+ I22+ I24+ I25+ I28+ I29+ I31+ I32+ I33+ I35+ I36 + I38+ I41+ I44+ I45+ I46+ I50+ (I52+ ... + I55) + I58+ I60+ I64+ I65+ I70

For bit I71

EVEN =(I14+ ... + I19) + I21+ I23+ I25+ I26+ I29+ I30+ I32+ I33+ I34+ I36+ I37 + I39+ I42+ I45+ I46+ I47+ I51+ (I53+ ... + I56) + I59+ I61+ I65+ I66+ I71

For bit I72

EVEN =(I15+ ... + I20) + I22+ I24+ I26+ I27+ I30+ I31+ I33+ I34+ I35+ I37+ I38 + I40+ I43+ I46+ I47+ I48+ I52+ (I54+ ... + I57) + I60+ I62+ I66+ I67+ I72

For bit I73

EVEN =(I16+ ... + I21) + I23+ I25+ I27+ I28+ I31+ I32+ I34+ I35+ I36+ I38+ I39 + I41+ I44+ I47+ I48+ I49+ I53+ (I55+ ... + I58) + I61+ I63+ I67+ I68+ I73

For bit I74

EVEN =(I17+ ... + I22) + I24+ I26+ I28+ I29+ I32+ I33+ I35+ I36+ I37I39+ I40 + I42+ I45+ I48+ I49+ I50+ I54+ (I56+ ... + I59) + I62+ I64+ I68+ I69+ I74

For bit I75

EVEN =(I13+ ... + I17) + I19+ I21+ I23+ I24+ I27+ I28+ I30+ I31+ I32+ I34+ I35+ I37 + I40+ I43+ I44+ I45+ I49+ (I51+ ... + I54) + I57+ I59+ I63+ I64+ I69+ I75

For bit I76

EVEN =I13+ I14+ ... + I75+ I76

2. Code for antenna coordinate system is 0 = conical.

3. The convention for the coding of negative numbers is as follows:

MSB is the sign bit:

0 = positive

1 = negative

Other bits represent the absolute value.

The convention for the antenna location is as follows:

As viewed from the MLS approach reference datum looking toward the MLS datum point, a positive number represents a location to the right of the runway centre line (lateral offset) or above the runway (vertical offset), or towards the stop end of the runway (longitudinal distance). The convention for the alignment is as follows:

As viewed from above, a positive number represents clockwise rotation from the runway centre line to the respective zero-degree azimuth.

4. Data word A3 is transmitted in both approach azimuth and back azimuth coverages if back azimuth guidance is provided, while retaining the maximum specified time between transmissions in each coverage sector.

5. Data word A4 is transmitted in both approach azimuth and back azimuth coverages if back azimuth guidance is provided, while retaining the maximum specified time between transmissions in each coverage sector.

6. The 12 data bits of the preamble are preceded by an 0.832 millisecond interval (13 clock pulses) of CW for carrier acquisition (see Table A-1).

7. See Table A-12 for data words B42 and B43 which are defined for applications that require azimuth antenna rotation greater than the +20.47° supported by the data items in A1, for azimuth, and A4, for back azimuth. At a facility with the approach azimuth rotation greater than +20.47°, B42 is transmitted in place of A1. At a facility with the back azimuth rotation greater than +20.47°, B43 is transmitted in place of A4.

8. All spare bits are set to ZERO.

Table A-11. Definitions of auxiliary data B items

(see 3.11.4.8.3.2)

Note.— Definitions of auxiliary data B items supporting MLS/RNAV procedures are shown in Table A-13.

a) Latitude of MLS datum point shall be the latitude coordinate of the MLS datum point as defined by the World Geodetic

System —1984 (WGS-84) reference ellipsoid, coordinate system and associated datum.

b) Longitude of the MLS datum point shall be the longitude coordinate of the MLS datum point as defined by the same

reference ellipsoid, coordinate system, and datum noted in item a).

c) Vertical coordinate of the MLS datum point shall be the vertical coordinate of the MLS datum point as defined by the same reference ellipsoid, coordinate system, and datum noted in item a).

Note.— Although WGS-84 has been approved as the ICAO Standard for geographical coordinates indicating latitude and longitude, introduction of vertical WGS-84 coordinates is pending. Until this introduction, an elevation referenced to mean sea level (msl) can continue to be used.

d) Approach azimuth true north orientation shall represent the angle measured in the horizontal plane clockwise from True North to the zero-degree approach azimuth, originating from the approach azimuth antenna. The vertex of the measured angle shall be the approach azimuth antenna phase centre.

e) Runway visual range (RVR)shall represent measurement of instrument RVR at touchdown zone, mid-point and stop end of the runway together with the trend indication, provided in accordance with Annex 3, Chapter 4.

f) Surface wind shall represent wind speed and wind direction (magnetic), provided in accordance with Annex 3, Chapter 4.

g) Approach azimuth antenna offset shall represent the minimum distance between the approach azimuth antenna phase centre and a vertical plane containing the runway centre line.

h) Approach azimuth antenna to MLS datum point distance shall represent the minimum distance between the approach azimuth antenna phase centre and the vertical plane perpendicular to the runway centre line and containing the MLS datum point.

i) Approach azimuth alignment with runway centre line shall represent the minimum angle between the zero-degree

approach azimuth and the runway centre line.

j) Approach azimuth antenna height shall represent the vertical location of the antenna phase centre with respect to the MLS datum point.

k) Back azimuth antenna offset shall represent the minimum distance between the back azimuth antenna phase centre and a vertical plane containing the runway centre line.

l) Back azimuth antenna to MLS datum point distance shall represent the minimum distance between the back azimuth antenna and the vertical plane perpendicular to the runway centre line which contains the MLS datum point.

m) Back azimuth alignment with runway centre line shall represent the minimum angle between the zero-degree back azimuth and the runway centre line.

n) Back azimuth antenna height shall represent the vertical location of the antenna phase centre with respect to the MLS datum point.

o) Primary runway number shall represent the primary runway number as defined in Annex 14, Volume I, Chapter 5.

p) Primary runway letter shall represent the primary runway letter as defined in Annex 14, Volume I, Chapter 5, where used to differentiate between parallel runways.

q) Secondary runway number shall represent the secondary runway number as defined in Annex 14, Volume I, Chapter 5.

r) Secondary runway letter shall represent the secondary runway letter as defined in Annex 14, Volume I, Chapter 5, where used to differentiate between parallel runways.

s) Elevation guidance to secondary runway shall indicate whether or not elevation guidance may be used to the secondary runway, and if so, whether it is directly usable as a raw angle or requires computed glide path.

t) Minimum glide path to secondary runway shall represent the lowest angle of descent along the secondary runway centre line.

u) Approach azimuth alignment with secondary runway centre line shall represent the minimum angle between the zero degree approach azimuth and the secondary runway centre line.

v) Secondary runway threshold X coordinate shall represent the minimum distance between the secondary runway threshold and the vertical plane perpendicular to the primary runway centre line containing the MLS datum point.

w) Secondary runway threshold Y coordinate shall represent the minimum distance between the secondary runway threshold and the vertical plane containing the primary runway centre line.

x) Secondary runway threshold Z coordinate shall represent the height of the secondary runway threshold above the MLS datum point.

y) Secondary runway threshold crossing height shall represent the height above the secondary runway threshold at which the computed glide path crosses the threshold.

z) Virtual azimuth to secondary runway threshold distance shall represent the distance to the secondary runway threshold from the point to be considered as the origin for lateral guidance to that runway.

Note.— This distance may be used by the MLS receiver in a manner similar to the approach azimuth antenna to threshold distance, to establish the lateral deviation scale factor.

Table A-12. Auxiliary data B

(see 3.11.4.8.3)

Word	Data content	Type of data	Maximum time between transmissions (seconds)	Bits used	Bits used	Least significant bit	Bit number
Words B1 through B39: Time-invariant (fixed) data items supporting MLS/RNAV procedures (see Table A-15)							
Words B40 through B54: Other fixed data items							
B40	PREAMBLE	digital	2.0	12	see Note 6		I_1 - I_{12}
	Address			8			I_{13} - I_{20}
	Latitude of MLS datum point			23	–324 000.0 arc seconds to +324 000.0 arc seconds (see Note 2)	0.1 arc seconds	I_{21} - I_{43}
	Longitude of MLS datum point			24	–648 000.0 arc seconds to +648 000.0 arc seconds (see Note 2)	0.1 arc seconds	I_{44} - I_{67}
	SPARE			2	see Note 9		I_{68} - I_{69}
	PARITY			7	see Note 1		I_{70} - I_{76}
B41	PREAMBLE	digital	2.0	12	see Note 6		I_1 - I_{12}
	Address			8			I_{13} -I_{20}
	Vertical coordinate of MLS datum point			13	–4 095 m to +4 095 m (see Note 2)	1 m	I_{21} - I_{33}
	Approach azimuth True North orientation			16	0° to 359.99°	0.01°	I_{34} - I_{45}
	SPARE			20			I_{50} - I_{69}
	PARITY			7	see Note 1		I_{70} - I_{76}
B42	PREAMBLE (see Note 5)	digital	1.0	12	see Note 6		I_1 - I_{12}
	Address			8			I_{13} - I_{20}
	Approach azimuth antenna offset			10	–511 m to +511 m (see Note 2)	1 m	I_{21} - I_{30}
	Approach azimuth antenna to MLS datum point distance			13	0 m to 8 191 m	1 m	I_{31} - I_{43}
	Approach azimuth alignment with runway centre line			14	–81.91° to +81.91° (see Note 2)	0.01°	I_{44} - I_{67}
	Approach azimuth antenna height			7	–63 m to +63 m (see Note 2)	1 m	I_{58} - I_{64}
	SPARE			5	see Note 9		I_{65} - I_{69}

Word	Data content	Type of data	Maximum time between transmissions (seconds)	Bits used	Bits used	Least significant bit	Bit number
	PARITY			7	see Note 1		I_{70} - I_{76}
B43	PREAMBLE (see Notes 4 and 5)	digital	1.0	12	see Note 6		I_{1} - I_{12}
	Address			8			I_{13} - I_{20}
	Back azimuth antenna offset			10	–511 m to +511 m (see Note 2)	1 m	I_{21} - I_{30}
	Back azimuth antenna to MLS datum point distance			11	0 m to 2 047 m	1 m	I_{31} - I_{41}
	Back azimuth alignment with runway centre line			14	–81.91° to +81.91° (see Note 2)	0.01°	I_{42} - I_{55}
	Back azimuth antenna height			7	–63 m to +63 m (see Note 2)	1 m	I_{56} - I_{62}
	SPARE			7	see Note 9		I_{63} - I_{69}
	PARITY			7	see Note 1		I_{70} - I_{76}
B44	PREAMBLE	digital	2.0	12	see Note 6		I_{1} - I_{12}
	Address			8			I_{13} - I_{20}
	Primary runway number			6	0 to 36 (see Note 10)		I_{21} - I_{26}
	Primary runway letter			2	see Note 7		I_{27} - I_{28}
	Secondary runway number			6	0 to 36 (see Note 10)		I_{29} - I_{34}
	Secondary runway letter			2	see Note 7		I_{35} - I_{36}
	Elevation guidance to secondary runway			2	see Note 8		I_{37} - I_{38}
	Minimum glide path to secondary runway			7	2° to 14.7°	0.1°	I_{39} - I_{45}
	Approach azimuth alignment with secondary runway centre line			16	±180.00°	0.01°	I_{46} - I_{61}
	SPARE			8	see Note 9		I_{62} - I_{69}
	PARITY			7	see Note 1		I_{70} - I_{76}
B45	PREAMBLE	digital	2.0	12	see Note 6		I_{1} - I_{12}
	Address			8			I_{13} - I_{20}
	Secondary runway threshold X coordinate			15	±16 384 m	1 m	I_{21} - I_{35}
	Secondary runway threshold Y coordinate			15	±16 384 m	1 m	I_{36}- I_{50}

Word	Data content	Type of data	Maximum time between transmissions (seconds)	Bits used	Bits used	Least significant bit	Bit number
	Secondary runway threshold Z coordinate			8	±127 m	1 m	I_{51} - I_{58}
	Secondary runway threshold crossing height			5	0 to 31 m	1 m	I_{59} - I_{63}
	Virtual azimuth to secondary runway threshold distance			6	0 to 6 300 m	100 m	I_{64} - I_{69}
	PARITY			7	see Note 1		I_{70} - I_{76}

Words B55 through B64: Time-varying data items. *(Note.— Word B55 only is defined below.)*

Word	Data content	Type of data	Maximum time between transmissions (seconds)	Bits used	Bits used	Least significant bit	Bit number
B55	PREAMBLE	digital	10.0	12	see Note 6		I_1 - I_{12}
	Address			8			I_{13} - I_{20}
	RVR (touchdown zone)			11	0 - 2 555 m (see Note 3)	5 m	I_{21} - I_{31}
	RVR (mid-point)			11	0 - 2 555 m (see Note 3)	5 m	I_{32} - I_{42}
	RVR (stop end)			11	0 - 2 555 m (see Note 3)	5 m	I_{43} - I_{53}
	Surface wind speed			7	0 - 127 kt	1 kt	I_{54} - I_{60}
	Surface wind direction (magnetic)			9	0 - 359°	1°	I_{61} - I_{69}
	PARITY			7	see Note 1		I_{70} - I_{76}

NOTES.—

1. Parity bits I_{70} to I_{76} are chosen to satisfy the equations which follow.

For bit I_{70}

$$EVEN = (I_{13} + ... + I_{18}) + I_{20} + I_{22} + I_{24} + I_{25} + I_{28} + I_{29} + I_{31} + I_{32} + I_{33} + I_{35} + I_{36} + I_{38} + I_{41} + I_{44} + I_{45} + I_{46} + I_{50} + (I_{52} + ... + I_{55}) + I_{58} + I_{60} + I_{64} + I_{65} + I_{70}$$

For bit I_{71}

$$EVEN = (I_{14} + ... + I_{19}) + I_{21} + I_{23} + I_{25} + I_{26} + I_{29} + I_{30} + I_{32} + I_{33} + I_{34} + I_{36} + I_{37} + I_{39} + I_{42} + I_{45} + I_{46} + I_{47} + I_{51} + (I_{53} + ... + I_{56}) + I_{59} + I_{61} + I_{65} + I_{66} + I_{71}$$

For bit I_{72}

$$EVEN = (I_{15} + ... + I_{20}) + I_{22} + I_{24} + I_{26} + I_{27} + I_{30} + I_{31} + I_{33} + I_{34} + I_{35} + I_{37} + I_{38} + I_{40} + I_{43} + I_{46} + I_{47} + I_{48} + I_{52} + (I_{54} + ... + I_{57}) + I_{60} + I_{62} + I_{66} + I_{67} + I_{72}$$

For bit I_{73}

$$EVEN = (I_{16} + ... + I_{21}) + I_{23} + I_{25} + I_{27} + I_{28} + I_{31} + I_{32} + I_{34} + I_{35} + I_{36} + I_{38} + I_{39} + I_{41} + I_{44} + I_{47} + I_{48} + I_{49} + I_{53} + (I_{55} + ... + I_{58}) + I_{61} + I_{63} + I_{67} + I_{68} + I_{73}$$

For bit I_{74}

$$EVEN = (I_{17} + ... + I_{22}) + I_{24} + I_{26} + I_{28} + I_{29} + I_{32} + I_{33} + I_{35} + I_{36} + I_{37} + I_{39} + I_{40} + I_{42} + I_{45} + I_{48} + I_{49} + I_{50} + I_{54} + (I_{56} + ... + I_{59}) + I_{62} + I_{64} + I_{68} + I_{69} + I_{74}$$

For bit I_{75}

$$EVEN = (I_{13} + ... + I_{17}) + I_{19} + I_{21} + I_{23} + I_{24} + I_{27} + I_{28} + I_{30} + I_{31} + I_{32} + I_{34} + I_{35} + I_{37} + I_{40} + I_{43} + I_{44} + I_{45} + I_{49} + (I_{51} + ... + I_{54}) + I_{57} + I_{59} + I_{63} + I_{64} + I_{69} + I_{75}$$

For bit I_{76}

EVEN = $I_{13} + I_{14} + \ldots + I_{75} + I_{76}$

2. The convention for the coding of negative numbers is as follows:
   MSB is the sign bit:
   0 = positive
   1 = negative
   Other bits represent the absolute value.
   The convention for the antenna location is as follows:
   As viewed from the MLS approach reference datum looking toward the MLS datum point, a positive number represents a location to the right of the runway centre line (lateral offset) or above the runway (vertical offset), or towards the stop end of the runway (longitudinal distance).
   The convention for the alignment is as follows:
   As viewed from above, a positive number represents clockwise rotation from the runway centre line to the respective zero-degree guidance radial.
   The convention for geodetic coordinates is as follows:
   A positive number represents a northern latitude or eastern longitude.
   A negative number represents a southern latitude or western longitude.
3. The tenth and eleventh bits transmitted for each RVR value are used to provide trend information. The convention for coding is as follows:

	Tenth bit	Eleventh bit
Off	0	0
Decreasing	1	0
Equal	0	1
Increasing	1	1

4. When used, data word B43 is transmitted in both approach azimuth and back azimuth coverage sectors if back azimuth guidance is provided, while retaining the specified maximum time between transmissions in each area.
5. Data words B42 and B43 are defined for applications that require azimuth antenna rotation greater than the 20.47° supported by the data items in A1, for azimuth, and A4, for back azimuth. At a facility with approach azimuth rotation greater than 20.47°, B42 is transmitted in place of A1. At a facility with the back azimuth rotation greater than 20.47°, B43 is transmitted in place of A4.
6. The 12 data bits of the preamble are preceded by an 0.832 millisecond interval (13 clock pulses) of CW for carrier acquisition (see Table A-1).
7. The convention for coding is as follows:
   0 = no letter
   1 = R (right)
   2 = C (centre)
   3 = L (left)
8. The convention for coding is as follows:
   0 = not provided
   1 = raw elevation guidance
   2 = computed glide path
   3 = code not allowed
9. All spare bits are set to ZERO.
10. Runway number designation 0 is for heliport operations.

Table A-13. Definitions of auxiliary data B items concerning MLS/RNAV procedure database

(see 3.11.4.8.3.2)

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a) *Number of approach azimuth procedure descriptors* shall represent the total number of named approach and departure procedures for which procedure descriptor words are transmitted in the approach azimuth coverage sector.

Note.— Missed approaches are not counted, as they do not use procedure descriptor words. Computed centre line procedures to the primary runway are counted if a procedure descriptor is transmitted, even though associated waypoint data are not transmitted in auxiliary words B1 to B39.

b) *Number of back azimuth procedure descriptors* shall represent the total number of named approach and departure procedures for which procedure descriptor words are transmitted in the back azimuth coverage sector.

Note.— Missed approaches are not counted, as they do not use procedure descriptor words.

c) *Last approach azimuth database word* shall represent the address code of the last auxiliary data word within the range B1 to B39 which is transmitted in the approach azimuth coverage sector, as defined by bits I_{13} to I_{18} of that word.

d) *First back azimuth database word* shall represent the address code of the first auxiliary data word within the range B1 to B39 which is transmitted in the back azimuth coverage sector, as defined by bits I_{13} to I_{18} of that word.

e) *Approach azimuth CRC code* shall represent the coefficients of the cyclic redundancy check code for the approach azimuth procedure database.

f) *Back azimuth CRC code* shall represent the coefficients of the cyclic redundancy check code for the back azimuth procedure database.

g) *Word B42 transmitted* shall indicate whether auxiliary data word B42 is transmitted in lieu of word A1.

h) *Word A4 transmitted* shall indicate whether auxiliary data word A4 is transmitted.

i) *Word B43 transmitted* shall indicate whether auxiliary data word B43 is transmitted.

j) *Back azimuth map/CRC indicator* shall indicate whether auxiliary data word B39 is employed as a back azimuth map/CRC word or as an approach azimuth waypoint data word.

k) *Basic indicator* shall represent the name of the first flown waypoint in an approach procedure, or the last flown waypoint in a departure procedure. The name shall consist of five alpha characters coded in accordance with bits b_1 to b_5 of International Alphabet No. 5.

l) *Validity indicator* shall represent the revision level of the approach or departure procedure. The validity indicator shall be a number from 1 to 9.

m) *Route indicator* shall represent the route to or from the waypoint named by the basic indicator. The route indicator shall be a single alpha character coded in accordance with bits b_1 to b_5 of International Alphabet No. 5. The letters "I" and "O" shall not be used. Each of the 24 available route indicators shall be assigned not more than once within the combined set of approach azimuth and back azimuth procedure descriptor words.

Note.— The restriction on the unique assignment of route indicators for MLS/RNAV operations is a departure from normal route assignment practice necessary to enhance the integrity of procedure selection and reduce pilot workload.

n) *Runway number* shall represent the runway number as defined in Annex 14, Volume I, Chapter 5.

o) *Runway letter* shall represent the runway letter as defined in Annex 14, Volume I, Chapter 5, where used to differentiate between parallel runways.

p) *Procedure type* shall indicate whether the procedure is an approach procedure or a departure procedure.

q) *First waypoint index* shall represent the sequential position, within the approach azimuth database or back azimuth database, of the waypoint definition data for the first encoded waypoint of the procedure.

r) *X coordinate* shall represent the X coordinate of a given waypoint in the coordinate system defined.

s) *Y coordinate follows* shall indicate whether or not the Y coordinate is transmitted for a given waypoint. If the Y coordinate is not transmitted, the Y coordinate is assumed to be zero.

t) *Y coordinate* shall represent the Y coordinate of a given waypoint in the coordinate system defined.

u) *Z coordinate follows* shall indicate whether or not the Z coordinate is transmitted for a given waypoint.

v) *Z coordinate* shall represent the Z coordinate of given waypoint in the coordinate system defined.

w) *Next segment/field identifier* shall indicate whether the next segment of a given procedure is straight or curved and indicate which data fields follow the waypoint coordinates.

x) *Threshold waypoint height* shall represent the height of the primary runway threshold waypoint above the runway threshold.

y) *Virtual azimuth to waypoint distance* shall represent the distance to the waypoint from the point to be considered as the origin for lateral guidance for an approach procedure not leading to the primary runway threshold.

Note.— This distance may be used by the MLS receiver in a manner similar to the approach azimuth antenna to threshold distance, to establish the lateral deviation scale factor for the procedure.

z) *Next waypoint index* shall represent the sequential position, within the approach azimuth database or back azimuth database, of the waypoint definition data for the next waypoint in the procedure.

Note.— The next waypoint index may be used to permit sharing of one or more waypoints which have been explicitly defined as a part of another procedure. The shared waypoints are the final ones for approach procedures and the initial ones for missed approach and departure procedures.

aa) *Missed approach index* shall represent the sequential position, within the approach azimuth database or back azimuth database, of the waypoint definition data for the first encoded (last flown) waypoint of the associated missed approach procedure.

Table A-14. MLS/RNAV procedure database structure

(see 3.11.4.8.3.2)

Database	Word	Data content
Approach azimuth	B1	Approach azimuth map/CRC word
	B2	Procedure 1 descriptor word
	. . .	. . .
	. . .	. . .
	B(M+1)	Procedure "M" descriptor word (see Note 1)
	B(M+2) to B(a)	Waypoint data words
	B(a+1) to B(b–1)	Not used.
Back azimuth (see Note 2)	B(b)	Procedure 1 descriptor word
	. . .	. . .
	. . .	. . .
	B(b+N–1)	Procedure "N" descriptor word (see Note 1)
	B(b+N) to B(38)	Waypoint data words
	B39	Back azimuth map/CRC word

NOTES.—

1. Parameter "M" represents the number of named approach and departure procedures which commence within the approach azimuth coverage sector. Parameter "N" represents the number of named approach and departure procedures which commence within the back azimuth coverage sector.
2. A facility without a back azimuth database may employ all words up to B39 for the approach azimuth database.

Table A-15. Auxiliary data B words B1 through B39

(see 3.11.4.8.3.2)

Word	Data content	Type of data	Maximum time (seconds)	Bits used	Range of values	Bit numbers
Approach azimuth map/CRC word						
B1	PREAMBLE	digital	2.5	12		I_1 to I_{12}
	Address			8		I_{13} to I_{20}
	Number of approach azimuth procedure descriptors			4	0 to 15	I_{21} to I_{24}
	Last approach azimuth database word			6	see Note 2	I_{25} to I_{30}
	Approach azimuth CRC code			32	see Note 3	I_{31} to I_{62}
	Word B42 transmitted			1	see Note 4	I_{63}
	Word A4 transmitted			1	see Note 4	I_{64}
	Word B43 transmitted			1	see Note 4	I_{65}
	Spare			4	see Note 12	I_{66} to I_{69}
	PARITY			7	see Note 13	I_{70} to I_{76}

Word	Data content	Type of data	Maximum time (seconds)	Bits used	Range of values	Bit numbers
Procedure descriptor words						
B2 to B(M+1) (approach azimuth database) (see Note 1) B(b) to B(b+N–1) (back azimuth database)						
	PREAMBLE	digital	2.5	12		I_1 to I_{12}
	Address			8		I_{13} to I_{20}
	Basic indicator			25	see Note 5	I_{21} to I_{45}
	Validity indicator			4	1 to 9 (see Note 14)	I_{46} to I_{49}
	Route indicator			5	see Note 5	I_{50} to I_{54}
	Runway number			6	0 to 36 (see Note 15)	I_{55} to I_{60}
	Runway letter			2	see Note 6	I_{61} to I_{62}
	Procedure type			1	see Note 7	I_{63}
	First waypoint index			6	0 to 63 (see Notes 8, 9)	I_{64} to I_{69}
	PARITY			7	see Note 13	I_{70} to I_{76}
Waypoint data words (see Table A-16)						
B(M+2) to B(a) (approach azimuth database) (see Notes 1 and 11) B(b+N) to B(38) (back azimuth database)						
	PREAMBLE	digital	2.5	12		I_1 to I_{12}
	Address			8		I_{13} to I_{20}
	Waypoint definition data items			49	see Notes 10, 11	I_{21} to I_{69}
	PARITY			7	see Note 13	I_{70} to I_{76}
Back azimuth map/CRC word (see Notes 1 and 11)						
B39	PREAMBLE	digital	2.5	12		I_1 to I_{12}
	Address			8		I_{13} to I_{20}
	Number of back azimuth procedure descriptors			4	0 to 15	I_{21} to I_{24}
	First back azimuth database word			6	see Note 2	I_{25} to I_{30}
	Back azimuth CRC code			32	see Note 3	I_{31} to I_{62}
	Word B43 transmitted			1	see Note 4	I_{63}
	Spare			5	see Note 12	I_{64} to I_{68}
	Back azimuth map/CRC indicator			1	see Note 11	I_{69}
	PARITY			7	see Note 13	I_{70} to I_{76}

NOTES.—

1. Variables used in word numbers correspond to those used in Table A-14.

2. This field is coded in accordance with Table A-9, using bits I13through I18. In this table, bit I25carries the information of bit I13from Table A-9 and is transmitted first.

3. The CRC code contains the remainder, R(x), of the modulo 2 division of two polynomials:

32() ()()() ()mod 2x Mx Rx QxGx Gx⎡⎤=+⎢⎥⎣⎦

M(x) is the information field, which consists of the approach azimuth or back azimuth database defined below, excluding the preambles, addresses, parity bits, and CRC code bits. For auxiliary data words these are bits I21to I69, and for basic data words bits I13to I30. The database consists of the following data words in the order listed:

Approach azimuth database:
B1 (bits I21to I30, I63to I69)
B2 to B(a)
B40, B41
A1 or B42, A2, A3
A4 or B43 (if transmitted)
Basic data word
6

Back azimuth database:
B(b) to B38
B39 (bits I21to I30, I63to I69)
B40, B41, A3
A4 or B43 (if transmitted)
Basic data word 6

M(x) is multiplied by x32, which appends 32 zero bits to the end of the dividend.

G(x) is the generator polynomial, defined as follows:

G(x) = x32+ x31+ x14+ x13+ x9+ x8+ x4+ 3+ x + 1

Q(x) is the quotient of the division.

The CRC code, R(x), is transmitted with the coefficient of x31as bit I31and the coefficient of x0as bit I62.

4. The convention for coding is as follows:
   0 = no
   1 = yes

5. Alpha characters are coded as defined in3.11.4.8.3 for data words B1 through B39.

6. The convention for coding is as follows:
   0 = no letter
   1 = R (right)

2 = C (centre)
3 = L (left)

7. The convention for coding is as follows:
   0 = approach procedure
   1 = departure procedure

8. Waypoint index numbers are assigned by sequentially numbering all waypoints in the approach azimuth or back azimuth database. If a waypoint at the primary runway threshold is coded using only a threshold crossing height, it is omitted from the waypoint index sequence.

9. A value of zero in this field indicates that the procedure is a computed centre line procedure based on data contained in auxiliary data words A1 (or B42), A2, A3 and A4 (or B43).

10. Waypoint definitions are of variable length and are coded sequentially without conforming to word boundaries. Spare bits are not permitted between waypoint definitions. Any spare bit sat the end of the last waypoint data word are set to zero. Waypoint definitions for an approach procedure are coded in the order that the aircraft flies the procedure. Waypoint definitions for a missed approach or departure are coded in the reverse order. Missed approach or departure waypoints which are not shared with approach waypoints are coded after the last approach waypoint in the database.

11. A facility without a back azimuth data base may employ auxiliary word B39 as a waypoint data word for the approach azimuth database. Bit I69of word B39 is used to indicate the application of this word. The convention for coding is as follows:
   0 = word B39 is a waypoint data word
   1 = word B39 is the back azimuth map/CRC word

12. All spare bits are set to ZERO.

13. Parity bits I70to I76are chosen to satisfy the equations given in Note 1 of Table A-12.

14. The coded value 0000 is not allowed.

15. Runway number designation 0 is for heliport operations.

Table A-16. Way point definition data items

(see 3.11.4.8.3.2)

Data content	Bits used	Range of values	Least significant bit
X coordinate	15	±41 940 m (see Notes 1, 2)	2.56 m
Y coordinate follows	1	See Note 3	
Y coordinate	15	±41 940 m (see Notes 1, 2)	2.56 m
Z coordinate follows	1	See Note 3	
Z coordinate	13	–100 to +8 091 m (see Notes 1, 4)	1 m
Next segment/field identifier	3	See Note 5	
Threshold waypoint height	6	0 to 31.5 m (see Note 5)	0.5 m
Virtual azimuth to waypoint distance	6	0 to 6 300 m (see Note 5)	100 m
Next waypoint index	6	See Notes 5, 6	
Missed approach index	6	See Notes 5, 6	

NOTES.—

1. The origin of the coordinate system is the MLS datum point. The X-axis is horizontal, and lies in the vertical plane containing the runway centre line, with a positive number representing a location toward the approach referencedatum. The Y-axis is horizontal and perpendicular to the X-axis, with a positive number representing a location to the left of centre line as viewed from the MLS datum point looking toward the approach reference datum. The Z-axis is vertical, with a positive number representing a location abovethe MLS datum point. Earth curvature is not consideredwhen determining waypoint coordinate values.

2. The convention for coding is as follows:

Most significant bit is the sign bit:
0 = positive
1 = negative

The other bits represent the absolute value.

3. The convention for coding is as follows:
0 = no
1 = yes

The "Y coordinate follows" bit is set to ZERO (no) to indicate that the Y coordinate for the waypoint is zero. In this case, the Y coordinate field is not used. The "Z coordinate follows" bit is set to ZERO (no) to indicate either that the waypoint is two-dimensional or that it lies on a constant gradient between two waypoints for which the Z coordinate is transmitted. In either of these two cases, the Z coordinate field is not used.

4. This field is coded as an unsigned value with an offset of –100 m. A value of zero in this field would therefore represent a Z coordinate of –100 m.

5. Data fields which follow the next segment/field identifier are transmitted only for certain cases. The coding of the next segment/field identifier and use of subsequent data fields are defined in Table A-17.

6. Waypoint index numbers are assigned by sequentially numbering all waypoints in the approach azimuth or back azimuth database. If a waypoint at the primary runway threshold is coded using only a threshold crossing height, it is omitted from the waypoint index sequence. The next waypoint index field always refers to an index number lower than that of the current waypoint. The missed approach index field always refers to an index number higher than that of the current waypoint.

Table A-17. Next segment/field identifiers

(see 3.11.4.8.3.2)

<table>
<tr><th colspan="4">Application</th><th rowspan="2">Next segment/ field identifier</th><th colspan="3">Data field(s) to follow identifier</th></tr>
<tr><th>Next waypoint location</th><th>Next waypoint shared (Note 1)</th><th>Linked to missed approach</th><th>Segment type</th><th>Approach procedure</th><th>Missed approach procedure</th><th>Departure procedure</th></tr>
<tr><td rowspan="4">Any</td><td rowspan="2">No</td><td rowspan="4">No</td><td>Straight</td><td>0</td><td colspan="3" rowspan="2">Next waypoint X coordinate</td></tr>
<tr><td>Curved</td><td>1</td></tr>
<tr><td rowspan="2">Yes</td><td>Straight</td><td>2</td><td colspan="3" rowspan="2">1. Next waypoint index
2. Next procedure first waypoint X coordinate</td></tr>
<tr><td>Curved</td><td>3</td></tr>
<tr><td rowspan="2">Primary runway threshold</td><td rowspan="4">No</td><td>No</td><td rowspan="2">Straight</td><td>4</td><td>1. Threshold waypoint height
2. Next procedure first way-point X coordinate</td><td colspan="2">Next procedure first waypoint X coordinate</td></tr>
<tr><td>Yes</td><td>5</td><td>1. Threshold waypoint height
2. Missed approach index
3. Next procedure first way-point X coordinate</td><td colspan="2">Not allowed (see Note 3)</td></tr>
<tr><td rowspan="2">None</td><td>No</td><td>None (see Note 2)</td><td>6</td><td>1. Virtual azimuth to waypoint distance
2. Next procedure first way-point X coordinate</td><td colspan="2">Next procedure first waypoint X coordinate</td></tr>
<tr><td>Yes</td><td>Straight to first flown missed approach waypoint</td><td>7</td><td>1.Virtual azimuth to waypoint distance
2. Missed approach index
3. Next procedure first way-point X coordinate</td><td colspan="2">Not allowed (see Note 3)</td></tr>
</table>

NOTES.—

1. A shared waypoint is a waypoint that is identified in the current procedure by waypoint index number only. The waypoint coordinates are explicitly defined as part of another procedure.

2. Beyond this waypoint, guidance information is provided relative to the straight line extended from the current waypoint, tangent to the path entering the waypoint. In the case of a missed approach procedure, this line intersects the last approach waypoint.

3. Next segment/field identifier values 5 and 7 are reserved for use in approach procedures only. Missed approach and departure procedures may share

approach waypoints which use these values, ignoring the data fields for threshold waypoint height, virtual azimuth to threshold distance and missed approach index.

APPENDIX B. TECHNICAL SPECIFICATIONS FOR

THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

1. DEFINITIONS

GBAS/E. A ground-based augmentation system transmitting an elliptically-polarized VHF data broadcast.

GBAS/H. A ground-based augmentation system transmitting a horizontally-polarized VHF data broadcast.

Receiver. A subsystem that receives GNSS signal sand includes one or more sensors.

Reserved (bits/words/fields). Bits/words/fields that are not allocated, butwhich are reserved for a particular GNSS application.

Spare (bits/words/fields). Bits/words/fields that are not allocated or reserved, and which are available for future allocation.

Note.— All spare bits are set to zero.

2. GENERAL

Note.— The following technical specifications supplement the provisions of Chapter 3, 3.7.

3. GNSS ELEMENTS

3.1 Global Positioning System (GPS) Standard Positioning Service (SPS) (L1)

3.1.1 NON-AIRCRAFT ELEMENTS

3.1.1.1 RADIO FREQUENCY (RF)CHARACTERISTICS

3.1.1.1.1 Carrier phase noise. The carrier phase noise spectral density of the un modulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian (1 sigma).

3.1.1.1.2 *Spurious emissions.* In-band spurious emissions shall be at least 40 dB below the unmodulated L1 carrier over the allocated channel bandwidth.

3.1.1.1.3 *Correlation loss.* The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 1 dB.

Note.— The loss in signal power is the difference between the broadcast power in a 2.046 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with1-chip correlator spacing and a 2.046 MHz bandwidth.

3.1.1.1.4 *Coarse/acquisition (C/A) code generation and timing.* Each C/A code pattern Gi(t) shall be formed by the Modulo-2 sum of two 1 023-bit linear patterns, G1 and G2i. The G2isequence shall be formed by effectively delaying the G2 sequence by an integer number of chips to produce one of 36 unique Gi(t) patterns defined in Table B-1. The G1 and G2 sequences shall be generated by 10-stage shift registers having the following polynomials as referred to in the shift register input:

a) G1: X10+ X3+ 1; and

b) G2: X10+ X9+ X8+ X6+ X3+ X2+ 1.

The initialization vector for the G1 and G2 sequences shall be "1111111111". The code phase assignments shall be as shown in Table B-1. The G1 and G2 registers shall be clocked at a 1.023 MHz rate. Timing relationships related to the C/A code shall be as shown in Figure B-1.**i**

3.1.1.2 *Data structure*. The navigation message shall be formatted as shown in Figure B-2. Each page, as shown in Figure B-6, shall utilize a basic format of a 1 500-bit-long frame with up to 5 sub frames, each of 300 bits in length. All words shall be transmitted most significant bit (MSB) first.

3.1.1.2.1 *Sub frame structure.* Each subframe and/or page of a subframe shall start with a telemetry (TLM) word followed by a handover word (HOW). The HOW shall be followed by 8 data words. Each word in each frame shall contain 6 parity bits. The TLM word and HOW formats shall be as shown in Figures B-3 and B-4, respectively.

3.1.1.2.2 *End/start of week.* At the end/start of week:

a) the cyclic paging of subframes 1 through 5 shall restart with subframe 1 regardless of which subframe was last transmitted prior to the end/start of week; and

b) the cycling of 25 pages of subframes 4 and 5 shall restart with page 1 of each of the subframes, regardless of which page was transmitted prior to the end/start of week. All upload and page cutovers shall occur on frame boundaries (i.e. Modulo 30 seconds relative to the end/start of week).

Note.— New data in subframes 4 and 5 may start to be transmitted with any of the 25 pages of these subframes.

3.1.1.2.3 *Data parity.* Words 1 through 10 of subframes 1 through 5 shall each contain 6 parity bits as their least significant bits (LSBs). In addition, two non-information bearing bits shall be provided as bits 23 and 24 of words 2 and 10 for parity computation purposes.

3.1.1.2.4 Telemetry (TLM) word. Each TLM word shall be 30 bits long, occur every 6 seconds in the data frame and be the first word in each subframe. The TLM format shall be as shown in Figure B-3. Each TLM word shall begin with a preamble, followed by 16 reserved bits and 6 parity bits.

3.1.1.2.5 *Handover word (HOW).* The HOW shall be 30 bits long and shall be the second word in each subframe/page, immediately following the TLM word. A HOW shall occur every 6 seconds in the data frame. The HOW format and content shall be as shown in Figure B-4. The full time-of-week (TOW) count shall consist of the 19 LSBs of the 29-bit Z-count (3.1.1.2.6). The HOW shall begin with the 17 MSBs of the TOW count. These 17 bits shall correspond to the TOW count at the 1.5-second epoch that occurs at the start (leading edge) of the next following subframe.

3.1.1.2.5.1 *Bit 18*. On satellites designed by configuration code 001, bit 18 shall be an "alert" flag. When this flag is raised (bit 18 is a "1"), it shall indicate to the user that the satellite user range accuracy (URA) may be worse than indicated in subframe 1 and that use of the satellite is at the user's risk.

i All figures are located at the end of the appendix.

3.1.1.2.5.2 Bit 19.Bit 19 shall be reserved.

3.1.1.2.5.3 Bits 20, 21 and 22. Bits 20, 21 and 22 of the HOW shall provide the identification (ID) of the subframe in

which that particular HOW is the second word. The ID code shall be as defined below:

ID	Code
1	001
2	010
3	011
4	100
5	101

3.1.1.2.6 *Satellite Z-count*. Each satellite shall internally derive a 1.5-second epoch that shall contain a convenient unit for precisely counting and communicating time. Time stated in this manner shall be referred to as a Z-count. The Z-count shall be provided to the user as a 29-bit binary number consisting of two parts as follows.

3.1.1.2.6.1 *Time-of-week (TOW) count.* The binary number represented by the 19 LSBs of the Z-count shall be referred to as the TOW count and is defined as being equal to the number of 1.5-second epochs that have occurred since the transition from the previous week. The count shall be short-cycled such that the range of the TOW count is from 0 to 403 199 1.5-second epochs (equalling one week) and shall be reset to zero at the end of each week. The TOW count's zero state shall be the 1.5-second epoch that is coincident with the start of the present week. A truncated version of the TOW count, consisting of its 17 MSBs, shall be contained in the HOW of the L1 downlink data stream. The relationship between the actual TOW count and its truncated HOW version shall be as indicated in Figure B-5.

Note.— The above-mentioned epoch occurs at (approximately) midnight Saturday night/Sunday morning, where midnight is defined as 0000 hours on the UTC scale which is nominally referenced to the Greenwich Meridian.

3.1.1.2.6.2 *Week count*. The 10 MSBs of the Z-count shall be a binary representation of the sequential number assigned to the present GPS week (Modulo 1024). The range of this count shall be from 0 to 1 023. Its zero state shall be that week which starts with the 1.5-second epoch occurring at (approximately) the UTC zero time point (3.1.4). At the expiration of GPS week number 1 023, the GPS week number shall roll over to zero. The previous 1 024 weeks in conversions from GPS time to a calendar date shall be accounted for by the user.

3.1.1.3DATA CONTENT

3.1.1.3.1 *Subframe 1 — satellite clock and health data.* The content of words 3 through 10 of subframe 1 shall contain the clock parameters and other data as indicated in Table B-2. The parameters in a data set shall be valid during the interval of time in which they are transmitted and shall remain valid for an additional period of time after transmission of the next data set has started.

3.1.1.3.1.1 *Week number*. The 10 MSBs of word 3 shall contain the 10 MSBs of the 29-bit Z-count and shall represent the number of the current GPS week at the start of the data set transmission interval with all zeros indicating week "zero." The GPS week number shall increment at each end/start of week epoch.

3.1.1.3.1.2 *User range accuracy (URA*). Bits 13 through 16 of word 3 shall provide the predicted satellite URA as shown in Table B-3.

Note 1.— The URA does not include error estimates due to inaccuracies of the single-frequency ionospheric delay model.

Note 2.— The URA is a statistical indicator of the contribution of the apparent clock and ephemeris prediction accuracies to the ranging accuracies obtainable with a specific satellite based on historical data.

Table B-2. Subframe 1 parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
Week number	10	1		weeks
Satellite accuracy	4			
Satellite health	6	1		discretes
T_{GD}	8*	2^{-31}		seconds
IODC	10			
t_{oc}	16	2^{4}	604 784	seconds
a_{f2}	8*	2^{-55}		seconds/second^2
a_{f1}	16*	2^{-43}		seconds/second
a_{f0}	22*	2^{-31}		seconds

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.
** See Figure B-6 for complete bit allocation.
*** Unless otherwise indicated in this column, effective range is the maximum range.

Table B-3. User range accuracy

URA	Accuracy
0	2 m
1	2.8 m
2	4 m
3	5.7 m
4	8 m
5	11.3 m
6	16 m
7	32 m
8	64 m
9	128 m
10	256 m
11	512 m
12	1 024 m
13	2 048 m
14	4 096 m
15	Do not use

3.1.1.3.1.3 *Health*. The transmitting satellite 6-bit health indication shall be provided by bits 17 through 22 of word 3.

The MSB shall indicate a summary of the health of the navigation data, where:

a) 0 = all navigation data are valid; and

b) 1 = some of the navigation data are not valid

The 5 LSBs shall indicate the health of the signal components in accordance with 3.1.1.3.3.4. The health indication shall be provided relative to the capabilities of each satellite as designated by the configuration code in 3.1.1.3.3.5. Any satellite that does not have a certain capability shall be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a receiver standpoint and does not require that capability. Additional health data shall be given in subframes 4 and 5.

Note.— The data given in subframe 1 may differ from that shown in subframes 4 and/or 5 of other satellites since the latter may be updated at a different time.

3.1.1.3.1.4 *Issue of data, clock (IODC).* Bits 23 and 24 of word 3 in subframe 1 shall be the 2 MSBs of the 10-bit IODC term. Bits 1 through 8 of word 8 in subframe 1 shall contain the 8 LSBs of the IODC. The IODC shall indicate the issue number of data set. The transmitted IODC shall be different from any value transmitted by the satellite during the preceding 7 days.

Note.— The relationship between the IODC and the Issue of Data, Ephemeris (IODE) terms is defined in 3.1.1.3.2.2.

3.1.1.3.1.5 *Estimated group delay differential.* Bits 17 through 24 of word 7 shall contain the correction term, TGD, to account for the effect of satellite group delay differential.

Note.— TGD does not include any C/A to P(Y) code relative group delay error.

3.1.1.3.1.6 *Satellite clock correction parameters.* Bits 9 through 24 of word 8, bits 1 through 24 of word 9, and bits 1 through 22 of word 10 shall contain the parameters needed by the users for apparent satellite clock correction (toc, af2,af1 and af0).

3.1.1.3.1.7 *Reserved data fields*. Reserved data fields shall be as indicated in Table B-4. All reserved data fields shall support valid parity within their respective words.

3.1.1.3.2 *Subframes 2 and 3 — satellite ephemeris data.* Subframes 2 and 3 shall contain the ephemeris representation of the transmitting satellite.

3.1.1.3.2.1 *Ephemeris parameters*. The ephemeris parameters shall be as indicated in Table B-5. For each parameter in subframe 2 and 3, the number of bits, the scale factor of the LSB, the range, and the units shall be as specified in Table B-6.

3.1.1.3.2.2 *Issue of data, ephemeris (IODE).* The IODE shall be an 8-bit number equal to the 8 LSBs of the 10-bit IODC of the same data set. The IODE shall be provided in both subframes 2 and 3 for the purpose of comparison with the 8 LSBs of the IODC term in subframe 1. Whenever these three terms do not match, as a result of a data set cutover, new data shall be collected. The transmitted IODE shall be different from any value transmitted by the satellite during the preceding six hours (Note 1). Any change in the subframe 2 and 3 data shall be accomplished in concert with a change in both IODE words. Change to new data sets shall occur only on hour boundaries except for the first data set of a new upload. Additionally,the to evalue, for at least the first data set transmitted by a satellite after an upload, shall be different from that transmitted prior to the change (Note 2).

Table B-4. Subframe 1 reserved data fields

Word	Bit
3	11 – 12
4	1 – 24
5	1 – 24
6	1 – 24
7	1 – 16

Table B-5. Ephemeris data

M_0	Mean anomaly at reference time
Δn	Mean motion difference from computed value
e	Eccentricity
$\sqrt{A}$	Square root of the semi-major axis
$OMEGA_0$	Longitude of ascending node of orbit plane at weekly epoch
i_0	Inclination angle at reference time
ω	Argument of perigee
OMEGADOT	Rate of right ascension
iDOT	Rate of inclination angle
C_{uc}	Amplitude of the cosine harmonic correction term to the argument of latitude
C_{us}	Amplitude of the sine harmonic correction term to the argument of latitude
C_{rc}	Amplitude of the cosine harmonic correction term to the orbit radius
C_{rs}	Amplitude of the sine harmonic correction term to the orbit radius
C_{ic}	Amplitude of the cosine harmonic correction term to the angle of inclination
C_{is}	Amplitude of the sine harmonic correction term to the angle of inclination
t_{oe}	Reference time, ephemeris
IODE	Issue of data, ephemeris

Table B-6. Ephemeris parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
IODE	8			
C_{rs}	16*	2^{-5}		metres
Δn	16*	2^{-43}		semi-circles/second
M_0	32*	2^{-31}		semi-circles
C_{uc}	16*	2^{-29}		radians
e	32	2^{-33}	0.03	dimensionless
C_{us}	16*	2^{-29}		radians
$\sqrt{A}$	32	2^{-19}		$\text{metres}^{1/2}$
t_{oe}	16	2^{4}	604 784	seconds
C_{ic}	16*	2^{-29}		radians
$OMEGA_0$	32*	2^{-31}		semi-circles
C_{is}	16*	2^{-29}		radians
i_0	32*	2^{-31}		semi-circles
C_{rc}	16*	2^{-5}		metres
ω	32*	2^{-31}		semi-circles
OMEGADOT	24*	2^{-43}		semi-circles/second
iDOT	14*	2^{-43}		semi-circles/second

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.
** See Figure B-6 for complete bit allocation in subframe.
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.

Note 1.— The IODE/IODC terms provide the receiver with a means for detecting any changes in the ephemeris/clock representation parameters.

Note 2.— The first data set may change (3.1.1.2.2) at any time during the hour and therefore may be transmitted by the satellite for less than 1 hour.

3.1.1.3.2.3 *Reserved data fields*. Within word 10, subframe 2, bits 17 through 22 shall be reserved. Reserved data fields shall support the valid parity within their respective words.

3.1.1.3.3 *Subframes 4 and 5 – support data*. Both subframes 4 and 5 shall be subcommutated 25 times each. With the possible exception of "reserved" pages and explicit repeats, each page shall contain different data in words 3 through 10. The pages of subframe 4 shall use 6 different formats, and the pages of subframe 5 shall use two different formats as indicated in Figure B-6.

Pages of subframe 4 shall be as follows:

a) Pages 2, 3, 4, 5, 7, 8, 9 and 10: almanac data for satellites 25 through 32 respectively. If the 6-bit health status word of page 25 is set to 6 “ones” (3.1.1.3.3.4) then the satellite ID of the page shall not have a value in the range of 25 through 32;

Note.— These pages may be designed for other functions. The format and content for each page is defined by the satellite ID of that page.

b) Page 17: special messages;

c) Page 18: ionospheric and UTC data;

d) Page 25: satellite configurations for 32 satellites; and

e) Pages 1, 6, 11, 12, 13, 14, 15, 16, 19, 20, 21, 22, 23 and 24: reserved.

Pages of subframe 5 shall be as follows:

a) Pages 1 through 24: almanac data for satellite 1 through 24; and

b) Page 25: satellite health data for satellite 1 through 24, the almanac reference time and the almanac reference week number.

3.1.1.3.3.1 *Data ID.* The two MSBs of word 3 in each page shall contain the data ID that defines the applicable GPS navigation data structure. The data ID shall be as indicated in Table B-7 in accordance with the following:

a) for those pages which are assigned to contain the almanac data of one specific satellite, the data ID shall define the data structure utilized by that satellite whose almanac data are contained in that page;

b) for all other pages, the data ID shall denote the data structure of the transmitting satellite; and

c) data ID “1” (denoted by binary state 00) shall not be used.

3.1.1.3.3.2 *Satellite ID.* The satellite ID shall be provided by bits 3 through 8 of word 3 in each page. The satellite IDs shall be utilized two ways:

a) for those pages which contain the almanac data of a given satellite, the satellite ID shall be the same number that is assigned the PRN code phase of that satellite in accordance with Table B-1; and

b) for all other pages the satellite ID assigned in accordance with Table B-7 shall serve asthe "page ID". IDs 1 through 32 shall be assigned to those pages which contain the almanac data of specific satellites (pages 1 through 24 of subframe 5 and pages 2 through 5, and 7 through 10 of subframe 4). The "0" ID (binary all zeros) shall be assigned to indicate a dummy satellite, while IDs 51 through 63 shall be utilized for pages containing other than almanac data for a specific satellite (Notes 1 and 2).

Note 1.— Specific IDs are reserved for eachpage of subframes 4 and 5; however, the satellite ID of pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 may change for each page to reflect the alternate contents for that page.

Note 2.— The remaining IDs (33 through 50) are unassigned.

Table B-7. Data IDs and satellite IDs in subframes 4 and 5

	Subframe 4		Subframe 5	
Page	Data ID	Satellite ID*	Data ID	Satellite ID*
1	***	57	**	1
2****	**	25	**	2
3****	**	26	**	3
4****	**	27	**	4
5****	**	28	**	5
6	***	57	**	6
7****	**	29	**	7
8****	**	30	**	8
9****	**	31	**	9
10****	**	32	**	10
11	***	57	**	11
12	***	62	**	12
13	***	52	**	13
14	***	53	**	14
15	***	54	**	15
16	***	57	**	16
17	***	55	**	17
18	***	56	**	18
19	***	58*****	**	19
20	***	59*****	**	20
21	***	57	**	21
22	***	60*****	**	22
23	***	61*****	**	23
24	***	62	**	24
25	***	63	***	51

* "0" indicates "dummy" satellite. When using "0" to indicate a dummy satellite, the data ID of the transmitting satellite is used.
** Data ID of that satellite whose satellite ID appears in that page.
*** Data ID of transmitting satellite.
**** Pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 may contain almanac data for satellites 25 through 32, respectively, or data for other functions as identified by a different satellite ID from the value shown.
***** Satellite ID may vary.

3.1.1.3.3.3 *Almanac.* Pages 1 through 24 of subframe 5, as well as pages 2 through 5 and 7 through 10 of subframe 4 shall contain the almanac data and a satellite health status word(3.1.1.3.3.4) for up to 32 satellites. The almanac data shallbe a reduced-precision subset of the clock and ephemeris parameters. The data shall occupy all bits of words 3 through 10 of each page except the 8 MSBs of word 3 (data ID and satellite ID), bits 17 through 24 of word5 (satellite health), and the 50 bits devoted to parity. The number of bits, the scale factor(LSB), the range and the units of the almanac parameters shall be as indicated in Table B-8. The almanac message for any dummy satellite shall contain alternating "ones" and "zeros" with a valid parity.

3.1.1.3.3.3.1 *Almanac reference time*. The almanac reference time, toa, shall be a multiple of 212seconds occurring approximately 70 hours after the first valid transmission time for this almanac data set. The almanac shall be updated often enough to ensure that GPS time, t, will differ from to a by less than 3.5 days during the transmission period. The almanac parameters shall be updated at least once every 6 days during normal operations.

3.1.1.3.3.3.2 *Almanac time parameters*. The almanac time parameters shall consist of an 11-bit constant term (af0) and an 11-bit first order term (af1).

3.1.1.3.3.3.3 Almanac reference week. Bits 17 through 24 of word 3 in page 25 of subframe 5 shall indicate the number of the week (WN

a) to which the almanac reference time (to a) is referenced. The WNaterm shall consist of the 8 LSBs of the full week number. Bits 9 through 16 of word 3 in page 25 of subframe 5 shall contain the value of toathat is referenced to this WNa.

3.1.1.3.3.4 *Health summary.* Subframes 4 and 5 shall contain two types of satellite health data:

a) each of the 32 pages that contain the clock/ephemeris related almanac data shall provide an 8-bit satellite health status word regarding the satellite whose almanac data they carry; and

b) the 25th pages of subframes 4 and 5 jointly shall contain 6-bit health data for up to 32 satellites.

3.1.1.3.3.4.1 The 8-bit health status words shall occupy bits 17 through 24 of word 5 in those 32 pages that contain the almanac data for individual satellites. The 6-bit health status words shall occupy the 24 MSBs of words 4 through 9 in page 25 of subframe 5, and bits 19 through 24 of word 8, the 24 MSBs of word 9, and the 18 MSBs of word 10 in page 25 of subframe 4.

Table B-8. Almanac parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
e	16	2^{-21}		dimensionless
t_{oa}	8	2^{12}	602 112	seconds
δ_i****	16*	2^{-19}		semi-circles
OMEGADOT	16*	2^{-38}		semi-circles/second
$\sqrt{A}$	24*	2^{-11}		metres$^{1/2}$
$OMEGA_0$	24*	2^{-23}		semi-circles
ω	24*	2^{-23}		semi-circles
M_0	24*	2^{-23}		semi-circles
a_{f0}	11*	2^{-20}		seconds
a_{f1}	11*	2^{-38}		seconds/second

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.
** See Figure B-6 for complete bit allocation in subframe.
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.
**** Relative to i_0 = 0.30 semi-circles.

3.1.1.3.3.4.2 The 3 MSBs of the 8-bit health status words shall indicate healthof the navigation data in accordance with the code given in Table B-9. The 6-bit words shall provide a 1-bit summary of the navigation data's health status in the MSB position in accordance with 3.1.1.3.1.3. The 5 LSBs of both the 8-bit and the 6-bit health status words shall provide the health status of the satellite's signal components in accordance with the code given in Table B-10.

Table B-9. Navigation data health indication

Bit position in page			
137	138	139	Indication
0	0	0	ALL DATA OK
0	0	1	PARITY FAILURE — some or all parity bad
0	1	0	TLM/HOW FORMAT PROBLEM — any departure from standard format (e.g. preamble misplaced and/or incorrect), except for incorrect Z-count, as reported in HOW
0	1	1	Z-COUNT in HOW BAD — any problem with Z-count value not reflecting actual code phase
1	0	0	SUBFRAMES 1, 2, 3 — one or more elements in words 3 through 10 of one or more subframes are bad
1	0	1	SUBFRAMES 4, 5 — one or more elements in words 3 through 10 of one or more subframes are bad
1	1	0	ALL UPLOADED DATA BAD — one or more elements in words 3 through 10 of any one (or more) subframes are bad
1	1	1	ALL DATA BAD — TLM word and/or HOW and one or more elements in any one (or more) subframes are bad

Table B-10. Codes for health of satellite signal components

MSB				LSB	Indication
0	0	0	0	0	ALL SIGNALS OK
1	1	1	0	0	SATELLITE IS TEMPORARILY OUT — do not use this satellite during current pass ___
1	1	1	0	1	SATELLITE WILL BE TEMPORARILY OUT — use with caution ___
1	1	1	1	0	SPARE
1	1	1	1	1	MORE THAN ONE COMBINATION WOULD BE REQUIRED TO DESCRIBE ANOMALIES, EXCEPT THOSE MARKED BY ___
All other combinations					SATELLITE EXPERIENCING CODE MODULATION AND/OR SIGNAL POWER LEVEL TRANSMISSION PROBLEMS. The user may experience intermittent tracking problems if satellite is acquired.

3.1.1.3.3.4.3 A special meaning shall be assigned, to the 6 “ones” combination of the 6-bit health status words in the 25th pages of subframes 4 and 5; it shall indicate that “the satellite which has that ID is not available and there may be no data regarding that satellite in the page of subframe 4 or 5 that is assigned to normally contain the almanac data of that satellite”.

Note.— This special meaning applies to the 25th pages of subframes 4 and 5 only. There may be data regarding another satellite in the almanac page referred to above as defined in 3.1.1.3.3.3.

3.1.1.3.3.4.4 The health indication shall be provided relative to the capabilities of each satellite as designated by the configuration code in 3.1.1.3.3.5. Accordingly, any satellite that does not have a certain capability shall be indicated as “healthy” if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from areceiver standpoint and does not require that capability. The predicted health data shall be updated at the time of upload.

Note 1.— The transmitted health data may not correspond tothe actual health of the transmitting satellite or other satellites in the constellation.

Note 2.— The data given in subframes 1, 4 and 5 of the other satellites may differ from that shown in subframes 4 and/or 5 since the latter may be updated at a different time.

3.1.1.3.3.5 Satellite configuration summary. Page 25 of subframe 4 shall contain a 4-bit-long term for each of up to 32 satellites to indicate the configuration code of each satellite. These 4-bit terms shall occupy bits 9 through 24 of words 3, the 24 MSBs of words 4 through 7, and the 16 MSBs of word 8, all in page 25 of subframe 4. The MSB of each 4-bit term shall indicate whether anti-spoofing is activated (MSB = 1) or not activated (MSB = 0). The 3 LSBs shall indicate the configuration of each satellite using the following code:

Code	Satellite configuration
001	Block II/IIA/IIR satellite
010	Block IIR-M satellite
011	Block IIF satellite

3.1.1.3.3.6 *UTC parameters*. Page 18 of subframe 4 shall include:

a) the parameters needed to relate GPS time to UTC time; and

b) notice to the user regarding the scheduled future or past (relative to navigation message upload) value of the delta time due to leap seconds (tLSF), together with the week number (WNLSF) and the day number (DN) at the end of which the leap second becomes effective. "Day one" shall be the first day relative to the end/start of week and the WNLSF value consists of the 8 LSBs of the full week number. The absolute value of the difference between the untruncated WN and WNlsf values shall not exceed 127.

Note.— The user is expected to account for the truncated nature of this parameter as well as truncation of WN, WNt and WNLSF due to rollover of the full week number (3.1.1.2.6.2).

3.1.1.3.3.6.1 The 24 MSBs of words 6 through 9, and the 8 MSBs of word 10 in page 18 of subframe 4 shall contain the parameters related to correlating UTC time with GPS time. The bit length, scale factors, ranges, and units of these parameters shall be as specified in Table B-11.

3.1.1.3.3.7 Ionospheric parameters. The ionospheric parameters that allow the GPS SPS user to utilize the ionospheric model for computation of the ionospheric delay shall be contained in page 18 of subframe 4 as specified in Table B-12.

3.1.1.3.3.8 *Special message*. Page 17 of subframe 4 shall be reserved for special messages.

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
A_o	32*	2^{-30}		seconds
A_1	24*	2^{-50}		seconds/second
Δt_{LS}	8*	1		seconds
t_{ot}	8	2^{12}	602 112	seconds
WN_t	8	1		weeks
WN_{LSF}	8	1		weeks
DN	8****	1	7	days
Δt_{LSF}	8*	1		seconds

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.
** See Figure B-6 for complete bit allocation in subframe.
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.
**** Right justified.

Table B-12. Ionospheric parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
α_0	8*	2^{-30}		seconds
α_1	8*	2^{-27}		seconds/semi-circle
α_2	8*	2^{-24}		seconds/semi-circle^2
α_3	8*	2^{-24}		seconds/semi-circle^3
β_0	8*	2^{11}		seconds
β_1	8*	2^{14}		seconds/semi-circle
β_2	8*	2^{16}		seconds/semi-circle^2
β_3	8*	2^{16}		seconds/semi-circle^3

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.
** See Figure B-6 for complete bit allocation in subframe.
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.

3.1.1.3.3.9 *Reserved data fields*. All bits of words 3 through 10, except the 58bits used for data ID, satellite (page) ID, parity (six LSBs of each word) and parity computation (bits 23 and 24 of word 10) of pages 1, 6, 11, 12, 13, 14, 15, 16, 19, 20, 21, 22, 23 and 24 of subframe 4, and those almanac pages assigned satellite ID of zero shall be designated as reserved. Other reserved bits in subframes 4 and 5 shall be as shown in Table B-13. Reserved bit positions of each word shall contain a pattern of alternating ones and zeros with a valid word parity.

3.1.2 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters that are not transmitted, but are used by either or both non-aircraft and aircraft elements, and that define terms applied to determine the navigation solution and its integrity.

Table B-13. Reserved bits in subframes 4 and 5

Subframe	Pages	Words	Reserved bit position in word
4	17	10	17 – 22
4	18	10	9 – 22
4	25	8	17 – 18
4	25	10	19 – 22
5	25	10	4 – 22

Table B-14. Parityencoding algorithms

$D_1 = d_1 \oplus D^*_{30}$

$D_2 = d_2 \oplus D^*_{30}$

$D_3 = d_3 \oplus D^*_{30}$

• •

• •

• •

• •

$D_{24} = d_{24} \oplus D^*_{30}$

$D_{25} = D^*_{29} \oplus d_1 \oplus d_2 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_{10} \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{17} \oplus d_{18} \oplus d_{20} \oplus d_{23}$

$D_{26} = D^*_{30} \oplus d_2 \oplus d_3 \oplus d_4 \oplus d_6 \oplus d_7 \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{18} \oplus d_{19} \oplus d_{21} \oplus d_{24}$

$D_{27} = D^*_{29} \oplus d_1 \oplus d_3 \oplus d_4 \oplus d_5 \oplus d_7 \oplus d_8 \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{19} \oplus d_{20} \oplus d_{22}$

$D_{28} = D^*_{30} \oplus d_2 \oplus d_4 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{20} \oplus d_{21} \oplus d_{23}$

$D_{29} = D^*_{30} \oplus d_1 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_7 \oplus d_9 \oplus d_{10} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{18} \oplus d_{21} \oplus d_{22} \oplus d_{24}$

$D_{30} = D^*_{29} \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{10} \oplus d_{11} \oplus d_{13} \oplus d_{15} \oplus d_{19} \oplus d_{22} \oplus d_{23} \oplus d_{24}$

where:

$D_1, D_2, D_3, \ldots D_{29}, D_{30}$ are the bits transmitted by the satellite;
$D_{25}, \ldots D_{30}$ are the computed parity bits;
$d_1, d_2, \ldots d_{24}$ are the source data bits;
$\oplus$ is the Modulo-2 or "Exclusive-Or" operation; and
* is used to identify the last two bits of the previous word of the subframe.

3.1.2.1 Parity algorithm. GPS parity algorithms are defined as indicated in Table B-14.

3.1.2.2Satellite clock correction parameters. GPS system time tis defined as:

$$t = t_{sv} - (\Delta t_{sv})_{L1}$$

where

t	=	GPS system time (corrected for beginning and end-of-week crossovers);
t_{sv}	=	satellite time at transmission of the message;
$(\Delta t_{sv})_{L1}$	=	the satellite PRN code phase offset;
$(\Delta t_{sv})_{L1}$	=	$a_{f0} + a_{f1}(t - t_{oc}) + a_{f2}(t - t_{oc})^2 + \Delta t_r - T_{GD}$

where

a_{f0}, a_{f1} and a_{f2} and t_{oc}, are contained in subframe 1; and

Δt_r = the relativistic correction term (seconds)

Δt_r = $Fe\sqrt{A}\sin E_k$

where

e and A are contained in subframes 2 and 3;

E_k is defined in Table B-15; and

$$F = \frac{-2(\mu)^{½}}{c^2} = -4.442807633(10)^{-10}\ s/m^{½}$$

where

μ	=	WGS-84 universal gravitational parameter ($3.986005 \times 10^{14}\ m^3/s^2$)
c	=	the speed of light in a vacuum (2.99792458×10^8 m/s)

Note.— The value of t is intended to account for the beginning or end-of-week crossovers. That is, if the quantity t-tocis greater than 302 400 seconds, subtract 604 800 seconds from t. If the quantity t-tocis less than –302 400 seconds, add 604 800 seconds to t.

3.1.2.3 *Satellite position.* The current satellite position (Xk, Yk, Zk) is defined as shown in Table B-15.

3.1.2.4 *Ionospheric correction.* The ionospheric correction (Tiono) is defined as:

$$T_{iono}=\begin{cases} F\times\left[5{,}0\times10^{-9}+AMP\left(1-\frac{x^2}{2}+\frac{x^4}{24}\right)\right], |x|<1{,}57 \\ F\times\left(5{,}0\times10^{-9}\right)+ \quad |x|\geq1{,}57 \end{cases} \text{(seconds)}$$

where

$$AMP=\begin{cases} \sum_{n=0}^{3}\alpha_n\phi_m^n, & AMP\geq0 \\ \text{si } AMP<0, & AMP=0 \end{cases} \text{(seconds)}$$

$$x=\frac{2\pi(t-50\ 400)}{PER}, \text{(radians)}$$

$$PER=\begin{cases} \sum_{n=0}^{3}\beta_n\phi_m^n, & PER\geq72\ 000 \\ \text{si } PER<72\ 000, & PER=72\ 000 \end{cases} \text{(seconds)}$$

$$F = 1.0 + 16.0[0.53 - E]^3$$

α_n and β_n are the satellite transmitted data words with n = 0, 1, 2 and 3

$\phi_m = \phi_i + 0.064 \cos(\lambda_i - 1.617)$ (semi-circles)

$\lambda_i = \lambda_u + \frac{\psi \text{ sen } A}{\cos\phi_i}$ (semi-circles)

$\bar{\phi}_i = \phi_u + \psi \cos A$ (semi-circles)

$$\phi_i=\begin{cases} \phi_i=\bar{\phi}_i \text{ si } |\bar{\phi}_i|\leq0.416 \\ \phi_i=+0.416 \text{ si } \bar{\phi}_i>0.416, \\ \phi_i=-0.416 \text{ si } \bar{\phi}_i<-0.416 \end{cases} \text{(semi-circles)}$$

$\psi = \frac{0.0137}{E+0.11} - 0.022$ (semi-circles)

t = $4.32 \times 10^4 \lambda_i$ + GPS time (seconds) where $0 \leq t < 86\ 400$, therefore: if $t \geq 86\ 400$ seconds, subtract 86 400 seconds; and if $t < 0$ seconds, add 86 400 seconds

E = satellite elevation angle

3.1.2.4.1 The terms used in computation of ionospheric delay are as follows:

a) Satellite transmitted terms

αn = the coefficients of a cubic equation representing the amplitude of the vertical delay (4 coefficients =

8 bits each)

βn = the coefficients of a cubic equation representing the period of the model (4 coefficients = 8 bits each)

b) Receiver generated terms

E = elevation angle between the user and satellite (semi-circles)

A = azimuth angle between the user and satellite, measured clockwise positive from the true North (semi-circles)

φu = user geodetic latitude (semi-circles) WGS-84 λu = user geodetic longitude (semi-circles) WGS-84 GPS time = receiver computed system time

c) Computed terms

x = phase (radians)

F = obliquity factor (dimensionless)

t = local time (seconds)

φm = geomagnetic latitude of the earth projection of the ionospheric intersection point (mean ionospheric height assumed 350 km) (semi-circles)

λi = geomagnetic longitude of the earth projection ofthe ionospheric intersection point (semi-circles)

φi = geomagnetic latitude of the earth projection of the ionospheric intersection point (semi-circles) ψ = earth's central angle between user position and earth projection of ionospheric intersection point (semi-circles)

Table B-15. Elements of coordinate systems

$A = \left(\sqrt{A}\right)^2$	Semi-major axis
$n_0 = \sqrt{\dfrac{\mu}{A^3}}$	Computed mean motion
$t_k = t - t_{oe}$	Time from ephemeris reference epoch*
$n = n_0 + \Delta n$	Corrected mean motion
$M_k = M_0 + nt_k$	Mean anomaly
$M_k = E_k - e \sin E_k$	Kepler's equation for eccentric anomaly (may be solved by iteration)
$v_k = \tan^{-1}\left\{\dfrac{\text{sen } v_k}{\cos v_k}\right\} = \tan^{-1}\left\{\dfrac{\sqrt{1-e^2}\,\text{sen } E_k/(1 - e\cos E_k)}{(\cos E_k - e)/(1 - e\cos E_k)}\right\}$	True anomaly
$E_k = \cos^{-1}\left\{\dfrac{e + \cos v_k}{1 + e\cos v_k}\right\}$	Eccentric anomaly
$\phi_k = v_k + \omega$	Argument of latitude
	Second Harmonic Perturbations
$\delta u_k = C_{us} \sin 2\phi_k + C_{uc} \cos 2\phi_k$	Argument of latitude correction
$\delta r_k = C_{rc} \sin 2\phi_k + C_{rs} \sin 2\phi_k$	Radius correction
$\delta i_k = C_{ic} \cos 2\phi_k + C_{is} \sin 2\phi_k$	Inclination correction
$u_k = \phi_k + \delta u_k$	Corrected argument of latitude
$r_k = A(1 - e\cos E_k) + \delta r_k$	Corrected radius
$i_k = i_0 + \delta i_k + (\text{iDOT})t_k$	Corrected inclination
$\left.\begin{array}{l} x'_k = r_k \cos u_k \\ y'_k = r_k \text{sen } u_k \end{array}\right\}$	Positions in orbital plane
$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)t_k - \dot{\Omega}_e t_{oe}$	Corrected longitude of ascending node
$\left.\begin{array}{l} x_k = x'_k \cos \Omega_k - y'_k \cos i_k \text{ sen } \Omega_k \\ y_k = x'_k \text{ sen } \Omega_k - y'_k \cos i_k \cos \Omega_k \\ z_k = y'_k \text{ sen } i_k \end{array}\right\}$	Earth-centred, earth-fixed coordinates

* t is GPS system time at time of transmission, i.e. GPS time corrected for transit time (range/speed of light). Furthermore, t_k is the actual total time difference between the time t and the epoch time t_{oe}, and must account for beginning or end-of-week crossovers. That is, if t_k is greater than 302 400 seconds, subtract 604 800 seconds from t_k. If t_k is less than −302 400 seconds, add 604 800 seconds to t_k.

3.1.3 AIRCRAFT ELEMENTS

3.1.3.1GNSS (GPS)RECEIVER

3.1.3.1.1 *Satellite exclusion*. The receiver shall exclude any satellite designated unhealthy by the GPS satellite ephemeris health flag.

3.1.3.1.2 *Satellite tracking*. The receiver shall provide the capability to continuously track a minimum of four satellites and generate a position solution based upon those measurements.

3.1.3.1.3 *Doppler shift.* The receiver shall be able to compensate for dynamic Doppler shift effects on nominal SPS signal carrier phase and C/A code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.1.3.1.4 *Resistance to interference*. The receiver shall meet the requirements for resistance to interference as specified in Chapter 3, 3.7.

3.1.3.1.5 *Application of clock and ephemeris data*. The receiver shall ensure that it is using the correct ephemeris and clock data before providing any position solution. The receiver shall monitor the IODC and IODE values, and to update ephemeris and clock data based upon a detected change in one or both of these values. The SPS receiver shall use clock and ephemeris data with corresponding IODC and IODE values for a given satellite.

3.1.4 TIME

GPS time shall be referenced to a UTC (as maintained by the U.S. Naval Observatory) zero time-point defined as midnight on the night of 5 January 1980/morning of 6 January 1980. The largest unit used in stating GPS time shall be 1 week, defined as 604 800 seconds. The GPS time scale shall be maintained to be within 1 microsecond of UTC (Modulo 1 second) after correction for the integer number of leap seconds difference. The navigation data shall contain the requisite data for relating GPS time to UTC.

3.2 Global navigation satellite system (GLONASS) channel of standard accuracy (CSA) (L1)

Note.— In this section the term GLONASS refers to all satellites in the constellation. Standards relating only to GLONASS-M satellites are qualified accordingly.

3.2.1 NON-AIRCRAFT ELEMENTS

3.2.1.1 RFCHARACTERISTICS

3.2.1.1.1 *Carrier frequencies*. The nominal values of L1 carrier frequencies shall be as defined by the following expressions:

$$f_{k1} = f_{01} + k\Delta f_1$$

where

k = –7, …, 0, 1, …, 6 are carrier numbers (frequency channels) of the signals transmitted by GLONASS satellites in the L1 sub-band;

f01 = 1 602 MHz; and
Δf1 = 0.5625 MHz.

Carrier frequencies shall be coherently derived from a common on-board time/frequency standard. The nominal value of frequency, as observed on the ground, shall be equal to 5.0 MHz. The carrier frequency of a GLONASS satellite shall be within ±2 × 10–11relative to its nominal value fk.

Note 1.— The nominal values of carrier frequencies for carrier numbers k are given in Table B-16.

Note 2.— For GLONASS-M satellites, the L2 channel of standard accuracy (CSA) navigation signals will occupy the 1 242.9375 – 1 251.6875 MHz ±0.511 MHz bandwidth as defined by the following expressions:

$$f_{k2} = f_{02} + k\Delta f_2,$$

$$f_{02} = 1\ 246 \text{ MHz};\ \Delta f_2 = 0.4375 \text{ MHz}.$$

For any given value of k the ratio of carrier frequencies of L1 and L2 sub-bands will be equal to:

$$\frac{f_{k2}}{f_{k1}} = \frac{7}{9}$$

Table B-16. L1 carrier frequencies

Carrier number	$H^A{}_n$ (see 3.2.1.3.4)	Nominal value of frequency in L1 sub-band (MHz)
06	6	1 605.3750
05	5	1 604.8125
4	4	1 604.2500
3	3	1 603.6875
2	2	1 603.1250
1	1	1 602.5625
0	0	1 602.0000
–1	31	1 601.4375
–2	30	1 600.8750
–3	29	1 600.3125
–4	28	1 599.7500
–5	27	1 599.1875
–6	26	1 598.6250
–7	25	1 598.0625

3.2.1.1.2 *Carrier phase noise.* The phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth provides the accuracy of carrier phase tracking not worse than 0.1 radian (1 sigma).

3.2.1.1.3 *GLONASS pseudo-random code generation.* The pseudo-random ranging code shall be a 511-bit sequence that is sampled at the output of the seventh stage of a 9-stage shift register. The initialisation vector to generate this sequence shall be "111111111". The generating polynomial that corresponds to the 9-stage shift register shall be:

G(x) = 1 + x5 + x9.

3.2.1.1.4 *Spurious emissions*. The power of the transmitted RF signal beyond the GLONASS allocated bandwidth shall not be more than –40 dB relative to the power of the unmodulated carrier.

Note 1.— GLONASS satellites launched during 1998 to 2005 and beyond use filters limiting out-of-band emissions to the harmful interference limit contained in Recommendation ITU-R RA.769 for the 1 660 – 1 670 MHz band.

Note 2.— GLONASS satellites launched beyond 2005 use filters limiting out-of-band emissions to the harmful interference limit contained in Recommendation ITU-R RA.769 for the 1 610.6 – 1 613.8 MHz and 1 660 – 1 670 MHz bands.

3.2.1.1.5 Correlation loss. The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 0.8 dB.

Note.— The loss in signal power is the difference between the broadcast power in a 1.022 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with1-chip correlator spacing and a 1.022 MHz bandwidth.

3.2.1.2 DATA STRUCTURE

3.2.1.2.1 *General*. The navigation message shall be transmitted as a pattern of digital data which are coded by Hamming code and transformed into relative code. Structurally, the data pattern shall be generated as continuously repeating superframes. The superframe shall consist of the frames and the frames shall consist of the strings. The boundaries of strings, frames and superframes of navigation messages from different GLONASS satellites shall be synchronized within 2 milliseconds.

3.2.1.2.2 *Superframe structure*. The superframe shall have a 2.5-minute duration and shall consist of 5 frames. Within each superframe a total content of non-immediate information (almanac for 24 GLONASS satellites) shall be transmitted.

Note.— Superframe structure with indication of frame numbers in the superframe and string numbers in the frames is shown in Figure B-7.

3.2.1.2.3 *Frame structure.* Each frame shall have a 30-second duration and shall consist of 15 strings. Within each frame the total content of immediate information (ephemeris and time parameters) for given satellite and a part of nonimmediate information (almanac) shall be transmitted. The frames 1 through 4 shall contain the part of almanac for 20 satellites (5 satellites per frame) and frame 5 shall contain the remainder of almanac for 4 satellites. The almanac for onesatellite shall occupy two strings.

Note.— Frame structures are shown in Figures B-8 and B-9.

3.2.1.2.4 *String structure.* Each string shall have a 2-second duration and shall contain binary chips of data and time mark. During the last 0.3 second within this 2-second interval (at the end of each string) the time mark shall be transmitted. The time mark (shortened pseudo-random sequence) shall consist of 30 chips with a time duration for each chip of 10 milliseconds and having the following sequence:

1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0.

During the first 1.7 seconds within this 2-second interval (in the beginning of each string) 85 bits of data (each data bit of a 20 milliseconds duration) shall be transmitted in bi-binary format. The numbers of bits in the string shall be increased from right to left. Along with information bits (bit positions 9 through 84) the check bits of Hamming code (KX) (bit positions 1 through 8) shall be transmitted. The Hamming code shall have a code length of 4. The data of one string shall be separated from the data of adjacent strings by time mark (MB). The words of the data shall be registered by MSB ahead. In each string bit position, 85 shall be an idle chip ("0") and be transmitted first.

3.2.1.2.4.1 *Strings 1 through 4.* The information contained in strings 1 through4 of each frame shall correspond to the satellite from which it is transmitted. This information shall not be changed within the superframe.

3.2.1.2.4.2 *Strings 5 through 15.* Strings 5 through 15 of each frame shall contain GLONASS almanac for 4 or 5 satellites. The information contained in the fifth stringshall be repeated in each frame of the superframe.

Note.— String structure is given in Figure B-10.

3.2.1.3DATA CONTENT

3.2.1.3.1 Ephemeris and time parameters. The ephemeris and time parameters shall be as follows:

m = the string numberwithin the frame;

tk = the time referenced to the beginning of the frame within the current day. It is calculated according to the satellite time scale. The integer number of hours elapsed since the beginning of the current day is registered in the 5 MSBs. The integer number of minutes elapsed since the beginning of the current hour is registered in the next 6 bits. The number of 30-second intervals elapsed since the beginning of the current minute is registered in the one LSB. The beginning of the day according to the satellite time scale coincides with the beginning of the recurrent superframe;

tb = the time interval within the current day according to UTC(SU) + 03 hours 00 min. The immediate data transmitted within the frame are referred to the middle of tb. Duration of the time interval and therefore the maximum value of tb depends on the value of the flag P1;

γn(tb) = the relative deviation of predicted carrier frequency value of n-satellite from the nominal value at the instant tb, i.e.

$$\gamma_n(t_b) = \frac{f_n(t_b) - f_{Hn}}{f_{Hn}},$$

f_{Hn}

where

$f_n(t_b)$	=	the forecast frequency of n-satellite clocks at an instant t_b;
f_{Hn}	=	the nominal value of frequency of n-satellite clocks;
$\tau_n(t_b)$	=	the correction to the n-satellite time t_n relative to GLONASS time t_c at an instant t_b, i.e. $\tau_n(t_b) = t_c(t_b) - t_n(t_b)$;
$x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$	=	the coordinates of n-satellite in PZ-90 coordinate system at an instant t_b;
$\dot{x}_n(t_b)$, $\dot{y}_n(t_b)$, $\dot{z}_n(t_b)$	=	the velocity vector components of n-satellite in PZ-90 coordinate system at an instant t_b;
$\ddot{x}_n(t_b)$, $\ddot{y}_n(t_b)$, $\ddot{z}_n(t_b)$	=	the acceleration components of n-satellite in PZ-90 coordinate system at an instant t_b, which are caused by effect of sun and moon;

E_n	=	an indication of the "age" of the immediate information, i.e. a time interval elapsed since the instant of its calculation (uploading) until the instant t_b for n-satellite;
B_n	=	the health flag. Values greater than 3 indicate the fact of malfunction of given satellite;
P1	=	a flag indicating the time interval between the current and previous value of the t_b parameters in minutes as shown:

P1	Time interval between adjacent values of t_b in minutes
0	0
1	30
10	45
11	60

P2	=	a flag indicating whether the value of t_b is odd or even. A value of "1" indicates a 30-minute interval of service information transmit (t_b = 1, 3, 5 …), a value of "0" indicates a 60-minute interval of service information transmit (t_b = 2, 6, 10 …);
P3	=	a flag indicating the number of satellites for which an almanac is transmitted within a given frame. "1" corresponds to 5 satellites and "0" corresponds to 4 satellites; and
$\Delta\tau_n$	=	the time difference between the navigation RF signal transmitted in L2 sub-band and navigation RF signal transmitted in L1 sub-band by given satellite:

$$\Delta\tau_n = t_{f2} - t_{f1}$$

where t_{f1}, t_{f2} are the equipment delays in L1 and L2 sub-bands respectively, expressed in units of time.

3.2.1.3.2 *Ephemeris and time parameters*. The ephemeris and time parameters shall be as indicated in Table B-17. For the words for which numeric values may be positive or negative, the MSB shall be the sign bit. The chip "0" shall correspond to the "+" sign and the chip "1" shall correspond to the "–" sign.

3.2.1.3.3 *Arrangement of the ephemeris and time parameters.* Arrangements of the ephemeris and time parameters within a frame shall be as indicated in Table B-18.

3.2.1.3.4 *Almanac parameters.* The almanac parameters shall be as follows:

A = an index showing relation of this parameter with the almanac;

$M^A{}_n$ = an index of the modification of n^A-satellite: "00" indicates GLONASS satellite, and "01" indicates GLONASS-M satellite;

τ_c = the GLONASS time scale correction to UTC(SU) time. The correction τ_c is given at the instant of day N^A;

N^A = the calendar day number within the 4-year period beginning since the leap year. The correction τ_c and other almanac data (almanac of orbits and almanac of phases) relate to this day number;

n^A = the slot number occupied by n-satellite;

$H^A{}_n$ = the channel number of a carrier frequency of n^A-satellite (Table B-16);

$\lambda^A{}_n$ = the longitude of the first (within the N^A-day) ascending node of n^A-satellite orbit in PZ-90 coordinate system;

$t_\lambda{}^A{}_n$ = the time of the first ascending node passage of n^A-satellite within N^A-day;

Table B-17. Ephemeris and time parameters

Parameter	Number of bits	Scale factor (LSB)	Effective range	Units
m	4	1		dimensionless
	5	1	0 to 23	hours
t_k	6	1	0 to 59	minutes
	1	30	0 or 30	seconds
t_b	7	15	15...1 425	minutes
$\gamma_n(t_b)$	11	2^{-40}	$\pm 2^{-30}$	dimensionless
$\tau_n(t_b)$	22	2^{-30}	$\pm 2^{-9}$	seconds
$x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$	27	2^{-11}	$\pm 2.7 \times 10^4$	km
$\dot{x}_n(t_b)$, $\dot{y}_n(t_b)$, $\dot{z}_n(t_b)$	24	2^{-20}	± 4.3	km/second
$\ddot{x}_n(t_b)$, $\ddot{y}_n(t_b)$, $\ddot{z}_n(t_b)$	5	2^{-30}	$\pm 6.2 \times 10^{-9}$	km/second^2
E_n	5	1	0 to 31	days
B_n	3	1	0 to 7	dimensionless
P1	2	—	as detailed in 3.2.1.3.1	—
P2	1	1	0; 1	dimensionless
P3	1	1	0; 1	dimensionless
$\Delta\tau_n$	5	2^{-30}	$\pm 13.97 \times 10^{-9}$	seconds

Table B-18. Arrangements of the ephemeris and time parameters within the frame

Parameter	Number of bits	String number within the frame	Bit number within the frame
m	4	1...15	81 – 84
t_k	12	1	65 – 76
t_b	7	2	70 – 76
$\gamma_n(t_b)$	11	3	69 – 79
$\tau_n(t_b)$	22	4	59 – 80
$x_n(t_b)$	27	1	9 – 35
$y_n(t_b)$	27	2	9 – 35
$z_n(t_b)$	27	3	9 – 35
$\dot{x}_n(t_b)$	24	1	41 – 64
$\dot{y}_n(t_b)$	24	2	41 – 64
$\dot{z}_n(t_b)$	24	3	41 – 64
$\ddot{x}_n(t_b)$	5	1	36 – 40
$\ddot{y}_n(t_b)$	5	2	36 – 40
$\ddot{z}_n(t_b)$	5	3	36 – 40
E_n	5	4	49 – 53
B_n	3	2	78 – 80
P1	2	1	77 – 78
P2	1	2	77
P3	1	3	80
$\Delta\tau_n$	5	4	54 – 58

Δi^A_n = the correction to the mean value of inclination of n^A-satellite at instant of $t_\lambda{}^A{}_n$ (mean value of inclination is equal to 63 degrees);

ΔT^A_n = the correction to the mean value of Draconian period of the n^A-satellite at the instant of $t_\lambda{}^A{}_n$ (mean value of Draconian period T is equal to 43 200 seconds);

$\Delta\dot{T}^A_n$ = the rate of change of Draconian period of n^A-satellite;

ε^A_n = the eccentricity of n^A-satellite at instant of $t_\lambda{}^A{}_n$;

ω^A_n = the argument of perigee of n^A-satellite at the instant of $t_\lambda{}^A{}_n$;

τ^A_n = the coarse value of n^A-satellite time correction to GLONASS time at instant of $t_\lambda{}^A{}_n$;

C^A_n = a generalized "unhealthy flag" of n^A-satellite at instant of almanac upload almanac of orbits and phases. When $C_n = 0$, this indicates that n-satellite is non-operational. When $C_n = 1$, this indicates that n-satellite is operational.

3.2.1.3.5 Partition and coding of almanac parameters. The GLONASS almanac, transmitted within the superframe, shall be partitioned over the superframe, as indicated in Table B-19. The numeric values of almanac parameters shall be positive or negative. The MSB shall be the sign bit, the chip "0" shall correspond to the "+" sign, and the chip "1" shall correspond to the "–" sign. The almanac parameters shall be coded as indicated in Table B-20.

3.2.1.3.6 Arrangement of the almanac parameters. Arrangement of the almanac words within the frame shall be as indicated in Table B-21.

3.2.1.4 CONTENT AND STRUCTURE OF ADDITIONAL DATA TRANSMITTED BY GLONASS-MSATELLITES

3.2.1.4.1 Letter designation of additional data. In addition to the GLONASS data, GLONASS-M satellites shall transmit the following additional data as indicated in Table B-17-A:

n — an index of the satellite transmitting the given navigation signal: it corresponds to a slot number within GLONASS constellation;

ln — health flag for n-th satellite: "0" indicates the n-th satellite is healthy, "1" indicates the malfunction of the n-th satellite;

B1 — coefficient to determine ΔUT1: it is equal to the difference between UT1 and UTC at the beginning of the day (NA), expressed in seconds;

B2 — coefficient to determine ΔUT1: it is equal to the daily change of the difference ΔUT1 (expressed in seconds for a mean sun day).

These coefficients shall be used to transform between UTC(SU) and UT1:

$$\Delta UT1 = UTC(SU) - UT1,$$

where

UT1 — Universal Time referenced to the Mean Greenwich Meridian (taking account of Pole motion),

UTC(SU) — Coordinated Universal Time of the Russian Federation State Standard,

$$\Delta UT1 = B1 + B2 \times (N_T - N^A),$$

KP — notification of a forthcoming leap second correction of UTC (±1 s) as shown:

KP	UTC second correction data
00	No UTC correction at the end of the current quarter
01	UTC correction by plus 1 s at the end of the current quarter
11	UTC correction by minus 1 s at the end of the current quarter

Note.— GLONASS system timescale correction is usually performed once a year at midnight 00 hours 00 minutes 00 seconds in accordance with the early notification of the International Time Bureau (BIH/BIPM) at the end of a quarter:

from 31 December to 1 January —first quarter,

from 31 March to 1 April —second quarter,

from 30 June to 1 July —third quarter,

from 30 September to 1 October —fourth quarter.

NT — current date, calendar number of the day within the four-year interval starting from 1 January in a leap year;

Note.— An example of NTtransformation into the common form of current data information (dd/mm/yy) is presented in Attachment D, 4.2.7.1.

N4 — four-year interval number starting from 1996;

FT — a parameter that provides the predicted satellite user range accuracy at time tb. Coding is as indicated in Table B-17-B;

M — type of satellite transmitting the navigation signal. 00refers to a GLONASS satellite; 01 refers to a GLONASS-M satellite;

P4 — flag to show that updated ephemeris parameters are present. "1" indicates thatan updated ephemeris or frequency/time parameters have been uploaded by the control segment;

Note.— Updated ephemeris or frequency/time information is transmitted in the next interval after the end of the current interval tb.

P — technological parameter of control segment indicating the satellite operation mode in respect of time parameters:

00 — τc parameter relayed from control segment, τGPS parameter relayed from control segment;

01 — τc parameter relayed from control segment, τGPS parameter calculated on-board the GLONASS-M satellite;

10 — τc parameter calculated on-board the GLONASS-M satellite; τGPS parameter relayed from control segment;

11 — τc parameter calculated on-board the GLONASS-M satellite; τGPS parameter calculated on-board the GLONASS-M satellite;

τGPS — correction to GPS time relative to GLONASS time:

$$T_{GPS} - T_{GL} = \Delta T + \tau_{GPS},$$

where

ΔT is the integer part, and τGPS is the fractional part of the difference between the system timescales expressed in seconds.

Note.— The integer part ΔT is determined from the GPS navigation message by the user receiver.

M^A_n — type of satellite n^A: coding "00" indicates a GLONASS satellite, coding "01" indicates a GLONASS-M satellite.

3.2.1.4.2 Additional data parameters. Additional data parameters are defined in Tables B-17-A to B-18-A.

3.2.1.4.3 Location of additional data words within GLONASS-M navigation message. The required location of additional data words within the GLONASS-M navigation message is defined in Table B-18-A.

Table B-17-A. Additional data parameters

Parameter	No. of bits	Scale factor (LSB)	Effective range	Units
n	5	1	0 to 31	Dimensionless
l_n	1	1	0; 1	Dimensionless
B1	11	2^{-10}	±0.9	seconds
B2	10	2^{-16}	$(-4.5 \text{ to } 3.5) \times 10^{-3}$	s/mean sun day
KP	2	1	0 to 3	Dimensionless
N_T	11	1	0 to 1 461	days
N_4	5	1	1 to 31	four-year interval
F_T	4		See table B-17-B	
M	2	1	0 to 3	Dimensionless
P4	1	1	0; 1	Dimensionless
P	2	1	00,01,10,11	Dimensionless
τ_{GPS}	22	2^{-30}	$\pm 1.9 \times 10^{-3}$	seconds
M^A_n	2	1	0 to 3	Dimensionless

Table B-17-B. FT word coding

F_T value	Pseudorange accuracy, 1 sigma (m)
0	1
1	2
2	2.5
3	4
4	5
5	7
6	10
7	12
8	14
9	16
10	32
11	64
12	128
13	256
14	512
15	Not used

Table B-18-A. Location of additional data words within the GLONASS-M navigation message

Word	Number of bits	String number within the superframe	Bit number within the string
n	5	4, 19, 34, 49, 64	11 – 15
l_n	1	5, 7, 9, 11, 13, 15, 20, 22, 24, 26, 28, 30, 35, 37, 39, 41, 43, 45, 50, 52, 54, 56, 58, 60, 65, 67, 69, 71, 73, 75	9
		3, 18, 33, 48, 63	65
B1	11	74 (within the superframe)	70 – 80
B2	10	74 (within the superframe)	60 – 69
KP	2	74 (within the superframe)	58 – 59
N_T	11	4, 19, 34, 49, 64	16 – 26
N_4	5	5, 20, 35, 50, 65	32 – 36
F_T	4	4, 19, 34, 49, 64	30 – 33
M	2	4, 19, 34, 49, 64	9 – 10
P4	1	4, 19, 34, 49, 64	34
P	2	3, 18, 33, 48, 63	66 – 67
τ_{GPS}	22	5, 20, 35, 50, 65	10 – 31
M^A_n	2	6, 8, 10, 12, 14	78 – 79

Table B-19. Almanac partition within the superframe

Frame number within the superframe	Satellite numbers, for which almanac is transmitted within given frame
1	1 to 5
2	6 to 10
3	11 to 15
4	16 to 20
5	21 to 24

Table B-20. Almanac parameters coding

Parameter	Number of bits	Scale factor (LSB)	Effective range	Units
$M^A{}_n$	2	1	0 to 3	dimensionless
τ_c	28	2^{-27}	±1	seconds
N^A	11	1	1 to 1 461	days
n^A	5	1	1 to 24	dimensionless
$H^A{}_n$	5	1	0 to 31	dimensionless
$\lambda^A{}_n$	21	2^{-20}	±1	semi-circles
$t_\lambda{}^A{}_n$	21	2^{-5}	0 to 44 100	seconds
$\Delta i^A{}_n$	18	2^{-20}	±0.067	semi-circles
$\Delta T^A{}_n$	22	2^{-9}	$\pm 3.6 \times 10^3$	seconds/revolution
$\Delta \dot{T}^A{}_n$	7	2^{-14}	$\pm 2^{-8}$	seconds/revolution^2
$\varepsilon^A{}_n$	15	2^{-20}	0 to 0.03	dimensionless
$\omega^A{}_n$	16	2^{-15}	±1	semi-circles
$t_\tau{}^A{}_n$	10	2^{-18}	$\pm 1.9 \times 10^{-3}$	seconds
$C^A{}_n$	1	1	0 to 1	dimensionless

Table B-21. Arrangement of almanac parameters within the frame

Parameter	Number of bits	String number within the frame	Bit number within the string
M^A_n	2	6, 8, 10, 12, 14	78 – 79
τ_c	28	5	42 – 69
N^A	11	5	70 – 80
n^A	5	6, 8, 10, 12, 14	73 – 77
H^A_n	5	7, 9, 11, 13, 15	10 – 14
λ^A_n	21	6, 8, 10, 12, 14	42 – 62
$t_{\lambda}{}^A_n$	21	7, 9, 11, 13, 15	44 – 64
Δi^A_n	18	6, 8, 10, 12, 14	24 – 41
ΔT^A_n	22	7, 9, 11, 13, 15	22 – 43
$\Delta \dot{T}^A_n$	7	7, 9, 11, 13, 15	15 – 21
ε^A_n	15	6, 8, 10, 12, 14	9 – 23
ω^A_n	16	7, 9, 11, 13, 15	65 – 80
$t_{\tau}{}^A_n$	10	6, 8, 10, 12, 14	63 – 72
C^A_n	1	6, 8, 10, 12, 14	80

Note.— String numbers of the first four frames within superframe are given. There are no almanac parameters in 14th and 15th strings of 5th frame.

3.2.2 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters that are not transmitted, but are used by either or both non-aircraft and aircraft elements, and that define terms applied to determine the navigation solution and its integrity.

Table B-22. Paritychecking algorithm

b85, b84, …, b10, b9 are the data bits (position 9 to 85 in the string);

β1, β2, ..., ß8 are the check bits of the Hamming code (positions 1 to 8 in the string);

$c_1, c_2, \ldots, c_7, c_\Sigma$ are the checksums generated using the following:

$c_1 = \beta \oplus [\Sigma_i\, b_i]_{mod\ 2}$

i = 9, 10, 12, 13, 15, 17, 19, 20, 22, 24, 26, 28, 30, 32, 34, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84.

$c_2 = \beta_2 \oplus [\Sigma_j\, b_j]_{mod\ 2}$

j = 9, 11, 12, 14, 15, 18, 19, 21, 22, 25, 26, 29, 30, 33, 34, 36, 37, 40, 41, 44, 45, 48, 49, 52, 53, 56, 57, 60, 61, 64, 65, 67, 68, 71, 72, 75, 76, 79, 80, 83, 84.

$c_3 = \beta_3 \oplus [\Sigma_k\, b_k\,]_{mod\ 2}$

k = 10, 11, 12, 16, 17, 18, 19, 23, 24, 25, 26, 31, 32, 33, 34, 38, 39, 40, 41, 46, 47, 48, 49, 54, 55, 56, 57, 62, 63, 64, 65, 69, 70, 71, 72, 77, 78, 79, 80, 85.

$c_4 = \beta_4 \oplus [\Sigma_l\, b_l]_{mod\ 2}$

l = 13, 14, 15, 16, 17, 18, 19, 27, 28, 29, 30, 31, 32, 33, 34, 42, 43, 44, 45, 46, 47, 48, 49, 58, 59, 60, 61, 62, 63, 64, 65, 73, 74, 75, 76, 77, 78, 79, 80.

$c_5 = \beta_5 \oplus [\Sigma_m\, b_m\,]_{mod\ 2}$

m = 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 81, 82, 83, 84, 85.

$c_6 = \beta_6 \oplus [\Sigma_n\, b_n]_{mod\ 2}$

n = 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65.

$c_7 = \beta_7 \oplus [\Sigma_p\, b_p]_{mod\ 2}$

p = 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85.

$c_\Sigma = [\Sigma\, \beta_q]_{mod\ 2} \oplus [\Sigma\, b_r]_{mod\ 2}$

q = 1, 2, 3, 4, 5, 6, 7, 8

r = 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85.

3.2.2.1 Parity checking algorithm for data verification. The algorithm shown in Table B-22 and as detailed below is used to detect and correct an error of 1 bit within the string and to detect an error of 2 or more bits within a string.

3.2.2.1.1 Each string includes the 85 data bits where the 77 MSBs are data chips (b85, b84, …, b10, b9), and the 8 LSBs are the check bits of Hamming code length of 4 (β8, β7, …, β2, β1).

3.2.2.1.2 To correct 1-bit errors within the string the following checksums are generated: (c1, c2, …, c7), and to detect 2-bit errors (or more-even-number-of-bits errors) a checksum $c\Sigma$ is generated, as shown in Table B-22. The following is used for correcting single errors and detecting multiple errors:

a) A string is considered correct if all checksums ($c1$, ..., $c7$, and $c\Sigma$) are equal to "0", or if only one of the checksums ($c1$, ..., $c7$) is equal to "1" and $c\Sigma$ is equal to "1".

b) If two or more of the checksums ($c1$, ..., $c7$) are equal to "1" and $c\Sigma$ is equal to "1", then character "bicor" is corrected to the opposite character in the following bit position:

"icor" = c7 c6 c5 c4 c3 c2 c1+ 8 – K, provided that "icor" ≤85,

where "c7 c6 c5 c4 c3 c2 c1" is a binary number generated from the checksums (c1, ..., c7) with c1being the LSB and c7 being the MSB. K is the ordinal number of the most significant checksum not equal to "0".

If icor> 85, then there is an odd number of multiple errors, and the data shall be rejected.

c) If at least one of the checksums ($c1$, ..., $c7$) is equal to "1" and $c\Sigma$ is equal to "0", or if all checksums ($c1$, ..., $c7$) are equal to "0" but $c\Sigma$ is equal to "1", then there are multiple errors and the data shall be rejected.

3.2.2.2.1 GLONASS system time is determined as:

$$t_{GLONASS} = t_k + \tau_n(t_b) - \gamma_n(t_b)\,(t_k - t_b)$$

where t_k, $\tau_n(t_b)$, $\gamma_n(t_b)$ are parameters described in 3.2.1.3.1.

3.2.2.2.2 GLONASS time is related to National Time Service of Russia (UTC(SU)) time as indicated below:

$$t_{UTC(SU)} = t_{GLONASS} + \tau_c - 03 \text{ hours } 00 \text{ minutes}$$

where

τ_c is a parameter described in 3.2.1.3.4 and

03 hours 00 minutes is continuous time shift caused by difference between Moscow time and Greenwich time.

3.2.2.3 SATELLITE POSITION

3.2.2.3.1 The current satellite position is defined using ephemeris parameters from GLONASS navigation, as indicated and in Table B-17.

3.2.2.3.2 Recalculation of ephemeris from instant tb to instant ti within the interval $(|\tau_i| = |t_i - t_b| \le 15 \text{ minutes})$ is performed using a technique of numeric integration of differential equations describing the motion of the satellites. In the right-hand parts of these equations the accelerations are determined using the gravitational constant μ and the second zonal harmonic of the geopotential J20 which defines polar flattening of the earth, and accelerations due to luni-solar perturbation are taken into account. The equations are integrated in the PZ-90 (3.2.5) coordinate system by applying the Runge-Kutta technique of fourth order, as indicated below:

$$\frac{dx}{dt} = Vx$$

$$\frac{dy}{dt} = Vy$$

$$\frac{dz}{dt} = Vz$$

$$\frac{dV_x}{dt} = -\frac{\mu}{r^3}x - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}x\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 x + 2\omega V_y + \ddot{x}$$

$$\frac{dV_y}{dt} = -\frac{\mu}{r^3}y - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}y\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 y + 2\omega V_x + \ddot{y}$$

$$\frac{dV_z}{dt} = -\frac{\mu}{r^3}z - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}z\left(1 - \frac{5z^2}{r^2}\right) + \ddot{z}$$

where

r = $\sqrt{x^2+y^2+z^2}$;
μ = earth's universal gravitational constant ($398\,600.44 \times 10^9$ m^3/s^2);
a_e = major semi-axis (6 378 136 m);
J^2_0 = second zonal harmonic of the geopotential ($1\,082\,625.7 \times 10^{-9}$); and
ω = earth's rotation rate (7.292115×10^{-5} radians/s).

Coordinates $x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$, and velocity vector components $\dot{x}_n(t_b) = V_x$, $\dot{y}_n(t_b) = V_y$, $\dot{z}_n(t_b) = V_z$ are initial conditions for the integration. Accelerations due to luni-solar perturbation $\ddot{x}_n(t_b)$, $\ddot{y}_n(t_b)$, $\ddot{z}_n(t_b)$ are constant on the integration interval ±15 minutes.

3.2.3 AIRCRAFT ELEMENTS

3.2.3.1 GNSS (GLONASS)RECEIVER

3.2.3.1.1 *Satellite exclusion.* The receiver shall exclude any satellite designated unhealthy in the GLONASS navigation message.

3.2.3.1.2 *Satellite tracking.* The receiver shall provide the capability to continuously track a minimum of four satellites and generate a position solution based upon those measurements.

3.2.3.1.3 *Doppler shift*. The receiver shall be able to compensate for dynamic Doppler shift effects on nominal GLONASS signal carrier phase and standard code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.2.3.1.4 *Resistance to interference*. The receiver shall meet the requirements for resistance to interference as specified in 3.7.

3.2.3.1.4.1 *Intrasystem interference*. When receiving a navigation signal with frequency channel k = n, the interference created by a navigation signal with frequency channel number k = n – 1 or k = n + 1 shall not be more than –48 dBc with respect to the minimum specified satellite power at the surface of the earth provided that the satellites transmitting these signals are simultaneously located in user's visibility zone.

Note.— The intrasystem interference is the intercorrelation properties of the ranging pseudo-random signal with regard to frequency division multiple access.

3.2.3.1.5 *Application of clock and ephemeris data*. The receiver shall ensure that it is using the correct ephemeris and clock data before providing any position solution.

3.2.3.1.6 Leap second correction.Upon GLONASS time leap secondcorrection (see 3.2.1.3.1, tb) the GLONASS receiver shall be capable of:

a) generating a smooth and valid series of pseudo-range measurements; and

b) resynchronizing the data string time mark without loss of signal tracking.

3.2.3.1.6.1 After GLONASS time leap second correction the GLONASS receiver shall utilize the UTC time as follows:

a) utilize the old (prior to the correction) UTC time together with the old ephemeris (transmitted before 00 hours 00 minutes 00 seconds UTC); and

b) utilize the updated UTC time together with the new ephemeris (transmitted after 00 hours 00 minutes 00 seconds UTC).

3.2.4 TIME

3.2.4.1 For the GLONASS-M satellites, the navigation message shall contain the data necessary to relate UTC(SU) time to UT1. GLONASS time shall be maintained to be within 1 millisecond of UTC(SU) time after correction for the integer number of hours due to GLONASS control segment specific features:

$| t_{GLONASS} – (UTC + 03 \text{ hours } 00 \text{ minutes}) | < 1 \text{ ms}$

The navigation data shall contain the requisite data to relate GLONASS time to UTC time (as maintained by the National Time Service of Russia, UTC (SU)) within 1 microsecond.

Note 1.— The timescales of GLONASS satellites are periodically compared with central synchronizer time. Corrections to the timescales of GLONASS satellites relative to GLONASS time and UTC(SU) time are computed at the GLONASS ground-based control complex and uploaded to the satellites twice per day.

Note 2.— There is no integer-second difference between GLONASS time and UTC time. The GLONASS timescale is periodically corrected to integer number of seconds simultaneously with UTC corrections which are performed according to the Bureau International de l'Heure notification (leap second correction). These corrections are performed at 00 hours 00 minutes 00 seconds UTC time at midnight at the end of a quarter of the year. Upon the GLONASS leap second correction the time mark within navigation message changes its position (in a continuous timescale) to become synchronized with 2-second epochs of corrected UTC timescale. GLONASS users are notified in advance on these planned corrections. For the GLONASS-M satellites, notification of these corrections is provided to users via the navigation message parameter KP.

3.2.4.2 Accuracy of mutual satellite timescales synchronization shall be 20 nanoseconds (1 sigma) for GLONASS satellites and 8 nanoseconds (1 sigma) for GLONASS-M satellites.

3.2.4.3 The correction to GPS time relative to GLONASS time (or difference between these timescales) broadcast by the GLONASS-M satellites, τ_{GPS}, shall not exceed 30 nanoseconds (1 sigma).

Note.— The accuracy of τGPS(30 ns) is determined with reference to the GPS SPS coarse acquisition signal and may be refined upon completion of trials of the GLONASS system using GLONASS-M satellites.

3.2.5 COORDINATE SYSTEM

3.2.5.1 PZ-90 (Parameters of common terrestrial ellipsoid and gravitational field of the earth 1990). The GLONASS broadcast ephemeris shall describe a position of transmitting antenna phase centre of a given satellite in the PZ-90 earth centred earth-fixed reference frame.

3.2.5.2 Conversion between PZ-90 and WGS-84.The following conversion parameters shall be used to obtain position coordinates in WGS-84 from position coordinates in PZ-90 (Version 2):

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS-84} = \begin{bmatrix} -0.36 \\ +0.08 \\ +0.18 \end{bmatrix} + \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{PZ-90}$$

Note.— X, Y and Z are expressed in metres.

3.2.5.2.1 The conversion error shall not exceed 0.1 metres (1 sigma) along each coordinate axis.

3.3 Combined use of GPS and GLONASS

3.3.1 AIRCRAFT ELEMENTS

3.3.1.1 Combined GNSS receiver. The combined GNSS receiver shall process signals from GPS and GLONASS in accordance with the requirements specified in 3.1.3.1, GPS (GNSS) receiver, and 3.2.3.1, GLONASS (GNSS) receiver.

3.3.1.1.1 Resistance to interference. The combined GNSS receiver shall meet the individual requirements for GPS and GLONASS as specified in 3.7.

3.3.1.2 Antenna(e). GPS and GLONASS signals shall be received through one or more antennae.

Note.— Performance characteristics of GNSS receiver antennae are defined in 3.8.

3.3.1.3 Conversion between coordinate systems. Position information provided by a combined GPS and GLONASS receiver shall be expressed in WGS-84 earth coordinates. The GLONASS satellite position, obtained in PZ-90 coordinate frame, shall be converted to account for the differences between WGS-84 and PZ-90, as defined in 3.2.5.2.

3.3.1.4 GPS/GLONASS time. When combining measurements from GLONASS and GPS, the difference between GLONASS time and GPS time shall be taken into account.

3.4 Aircraft-based augmentation system (ABAS)

Note.— Guidance on ABAS is given in Attachment D, section 5.

3.5 Satellite-based augmentation system (SBAS)

3.5.1 GENERAL

Note.— Parameters in this section are defined in WGS-84.

3.5.2 RFCHARACTERISTICS

3.5.2.1 Carrier frequency stability. The short-term stability of the carrier frequency (square root of the Allan Variance) at the output of the satellite transmit antenna shall be better than 5 × 10–11over 1 to 10 seconds.

3.5.2.2 Carrier phase noise. The phase noise spectral density of the unmodulated carrier shall be such that a phase

locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian (1 sigma).

3.5.2.3 Spurious emissions. Spurious emissions shall be at least 40 dB below the unmodulated carrier power over all frequencies.

3.5.2.4 Code/carrier frequency coherence. The short-term (less than 10 seconds) fractional frequency difference between the code phase rate and the carrier frequency shall be less than 5 × 10–11(standard deviation). Over the long term (less than 100 seconds), the difference between the change in the broadcast code phase, converted to carrier cycles by multiplying the number of code chips by 1 540, and the change in the broadcast carrier phase, in cycles, shall be within one carrier cycle (standard deviation).

Note.— This applies to the output of the satellite transmit antenna and does not include code/carrier divergence due to ionospheric refraction in the downlink propagation path.

3.5.2.5 Correlation loss. The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 1 dB.

Note.— The loss in signal power is the difference between the broadcast power in a 2.046 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with1-chip correlator spacing and a 2.046 MHz bandwidth.

3.5.2.6 Maximum code phase deviation. The maximum uncorrected code phase of the broadcast signal shall not deviate from the equivalent SBAS network time (SNT) by more than ±2–20seconds.

3.5.2.7 Code/data coherence. Each 2-millisecond symbol shall be synchronous with every other code epoch.

3.5.2.8 Message synchronization. The leading edge of the first symbol that depends on the first bit of the current message shall be broadcast from the SBAS satellite synchronous with a 1-second epoch of SNT.

3.5.2.9 Convolutional encoding. A 250-bit-per-second data stream shall be encoded at a rate of 2 symbols per bit using a convolutional code with a constraint length of 7 to yield 500 symbols per second. The convolutional encoder logic arrangement shall be as illustrated in Figure B-11 with the G3 output selected for the first half of each 4-millisecond data bit period.

3.5.2.10 Pseudo-random noise (PRN) codes. Each PRN code shall be a 1 023-bit Gold code which is itself the Modulo-2 addition of two 1 023-bit linear patterns, G1 and G2i. The G2i sequence shall be formed by delaying the G2 sequence by the associated integer number of chips as illustrated in Table B-23. Each of the G1 and G2 sequences shall be defined as the output of stage 10 of a 10-stage shift register, where the input to the shift register is the Modulo-2 addition of the following stages of the shift register:

a) G1: stages 3 and 10; and

b) G2: stages 2, 3, 6, 8, 9 and 10.

The initial state for the G1 and G2 shift registers shall be "1111111111".

Table B-23. SBAS PRN codes

PRN code number	G2 delay (chips)	First 10 SBAS chips (Leftmost bit represents first transmitted chip, binary)
120	145	110111001
121	175	101011110
122	52	1101001000
123	21	1101100101
124	237	1110000
125	235	111000001
126	886	1011
127	657	1000110000
128	634	10100101
129	762	101010111
130	355	1100011110
131	1 012	1010010110
132	176	1010101111
133	603	100110
134	130	1000111001
135	359	101110001
136	595	1000011111
137	68	111111000
138	386	1011010111

3.5.3 DATA STRUCTURE

3.5.3.1 Format summary. All messages shall consist of a message type identifier, a preamble, a data field and a cyclic redundancy check as illustrated in Figure B-12.

3.5.3.2 Preamble. The preamble shall consist of the sequence of bits "01010011 10011010 11000110", distributed over three successive blocks. The start of every other 24-bit preamble shall be synchronous with a 6-second GPS subframe epoch.

3.5.3.3 Message type identifier. The message type identifier shall be a 6-bit value identifying the message type (Types 0 to 63) as defined in Table B-24. The message type identifier shall be transmitted MSB first.

3.5.3.4 Data field. The data field shall be 212 bits as defined in 3.5.6. Each data field parameter shall be transmitted MSB first.

3.5.3.5 Cyclic redundancy check (CRC). The SBAS message CRC code shall be calculated in accordance with 3.9.

3.5.3.5.1 The length of the CRC code shall be k = 24 bits.

3.5.3.5.2 The CRC generator polynomial shall be:

$$G(x) = x^{24} + x^{23} + x^{18} + x^{17} + x^{14} + x^{11} + x^{10} + x^{7} + x^{6} + x^{5} + x^{4} + x^{3} + x + 1$$

Table B-24. Broadcast message types

Message type	Contents
0	"Do Not Use" (SBAS test mode)
1	PRN mask
2 to 5	Fast corrections
6	Integrity information
7	Fast correction degradation factor
8	Spare
9	GEO ranging function parameters
10	Degradation parameters
11	Spare
12	SBAS network time/UTC offset parameters
13 to 16	Spare
17	GEO satellite almanacs
18	Ionospheric grid point masks
19 to 23	Spare
24	Mixed fast/long-term satellite error corrections
25	Long-term satellite error corrections
26	Ionospheric delay corrections
27	SBAS service message
28	Clock-ephemeris covariance matrix
29 to 61	Spare
62	Reserved
63	Null message

3.5.3.5.3 The CRC information field, M(x), shall be:

$$M(x) = \sum_{i=1}^{226} m_i x^{226-i} = m_1 x^{225} + m_2 x^{224} + \cdots + m_{226} x^0$$

3.5.3.5.4 M(x) shall be formed from the 8-bit SBAS message preamble, 6-bit message type identifier, and 212-bit data field. Bits shall be arranged in the order transmitted from the SBAS satellite, such that m1corresponds to the first transmitted bit of the preamble, and m226corresponds to bit 212 of the data field.

3.5.3.5.5 The CRC code r-bits shall be ordered such that r1is the first bit transmitted and r24 is the last bit transmitted.

3.5.4 DATA CONTENT

3.5.4.1 *PRN mask parameters.* PRN mask parameters shall be as follows:

PRN code number: a number that uniquely identifies the satellite PRN code and related assignments as shown in Table B-25.

PRN mask: 210 PRN mask values that correspond to satellite PRN code numbers. The mask shall set up to 51 of the 210 PRN mask values.

Note.— The first transmitted bit of the PRN mask corresponds to PRN code number 1.

Table B-25. PRN code number assignments

PRN code number	Assignment
1 – 37	GPS
38 – 61	GLONASS slot number plus 37
62 – 119	Spare
120 – 138	SBAS
139 – 210	Spare

PRN mask value:a bit in the PRN mask indicating whether data are provided for the associated satellite PRN code number (1 to 210).

Coding: 0 = data not provided
1 = data provided

PRN mask number: the sequence number (1 to 51) of the mask values set in the PRN mask.

Note.— The PRN mask number is "1" for the lowest satellite PRN number for which the PRN mask value is "1".

Issue of data – PRN (IODP): an indicator that associates the correction data with a PRN mask.

Note.— Parameters are broadcast in the following messages:

a) PRN mask (consisting of 210 PRN mask values) in Type 1 message;

b) PRN mask number in Type 24, 25 and 28 messages;

c) PRN code number in Type 17 message; and

d) IODP in Type 1 to 5, 7, 24, 25 and 28 messages.

3.5.4.2 *Geostationary orbit (GEO) ranging function parameters.* GEO ranging function parameters shall be as follows:

$t_{0,GEO}$: the reference time for the GEO ranging function data, expressed as the time after midnight of the current day.

$[X_G Y_G Z_G]$: the position of the GEO at time t0,GEO.

$[\dot{X}_G \dot{Y}_G \dot{Z}_G]$: the velocity of the GEO at time t0,GEO.

$[\ddot{X}_G \ddot{Y}_G \ddot{Z}_G]$: the acceleration of the GEO at time t0,GEO.

aGf0:the time offset of the GEO clock with respect to SNT, defined at t0,GEO.

aGf1:the drift rate of the GEO clock with respect to SNT.

User range accuracy (URA):an indicator of the root-mean-square ranging error, excluding atmospheric effects, as described in Table B-26.

Note.— All parameters are broadcast in Type 9 message.

Table B-26. User range accuracy

URA	Accuracy (rms)
0	2 m
1	2.8 m
2	4 m
3	5.7 m
4	8 m
5	11.3 m
6	16 m
7	32 m
8	64 m
9	128 m
10	256 m
11	512 m
12	1 024 m
13	2 048 m
14	4 096 m
15	"Do Not Use"

3.5.4.3 GEO almanac parameters. GEO almanac parameters shall be as follows:

PRN code number:see 3.5.4.1.

Health and status: an indication of the functions provided by the SBAS. The service provider identifiers are shown in

Table B-27.

Coding:	Bit 0 (LSB)	Ranging	On (0)	Off (1)
	Bit 1	Precision corrections	On (0)	Off (1)
	Bit 2	Satellite status and basic corrections	On (0)	Off (1)
	Bits 3	Spare		
	Bits 4 to 7	Service provider identifier		

Note.— A service provider ID of 14 is used for GBAS and is not applicable to SBAS.

$[X_{G,A} Y_{G,A} Z_{G,A}]$:the position of the GEO at time $t_{almanac}$.

$[\dot{X}_{G,A} \dot{Y}_{G,A} \dot{Z}_{G,A}]$:the velocity of the GEO at time $t_{almanac}$.

$t_{almanac}$- the reference time for the GEO almanac data, expressed as the time after midnight of the current day.

Note.— All parameters are broadcast in Type 17 message.

3.5.4.4 SATELLITE CORRECTION BROADCAST PARAMETERS

3.5.4.4.1 Long-term correction parameters shall be as follows:

Issue of data (IODi): an indicator that associates the long-term corrections for the ith satellite with the ephemeris data broadcast by that satellite.

Note 1.— For GPS, the IODimatches the IODE and 8 LSBs of the IODC (3.1.1.3.1.4 and 3.1.1.3.2.2).

Note 2.— For GLONASS, the IODiindicates a period of time that GLONASS data are to be used with SBAS data. It consists of two fields as shown in Table B-28.

Δxi: for satellite i, the ephemeris correction for the x axis.

δyi: for satellite i, the ephemeris correction for the y axis.

δzi: for satellite i, the ephemeris correction for the z axis.

δai,f0: for satellite i, the ephemeris time correction.

δ˙ xi: for satellite i, ephemeris velocity correction for x axis.

δ˙ yi: for satellite i, ephemeris velocity correction for y axis.

δ˙ zi: for satellite i, ephemeris velocity correction for z axis.

δai,f1: for satellite i, rate of change of the ephemeris time correction.

ti, LT: the time of applicability of the parameters δxi, δyi, δzi, δai,f0, δx˙i, δy˙i, δz˙I and δai,f1, expressed in seconds after midnight of the current day

Velocity code:an indicator of the message format broadcast (Table B-48 and Table B-49).

Coding: 0 = δx˙i, δy˙i, δz˙I and δai,f1are not broadcast. 1 = δx˙i, δy˙i, δz˙I and δai,f1 are broadcast.

Note.— All parameters are broadcast in Type 24 and 25 messages.

Table B-27. SBAS service provider identifiers

Identifier	Service provider
0	WAAS
1	EGNOS
2	MSAS
3	GAGAN
4	SDCM
5 to 13	Spare
14, 15	Reserved

Table B-28. IODi for GLONASS satellites

MSB	LSB
Validity interval (5 bits)	Latency time (3 bits)

3.5.4.4.2 Fast correction parameters shall be as follows:

Fast correction (FCi): for satellite i, the pseudo-range correction for rapidly varying errors, other than tropospheric or ionospheric errors, to be added to the pseudo-range after application of the long-term correction.

Note.— The user receiver applies separate tropospheric corrections (3.5.8.4.2 and 3.5.8.4.3).

Fast correction type identifier: an indicator (0, 1, 2, 3) of whether the Type 24 message contains the fast correction and integrity data associated with the PRN mask numbers from Type 2, Type 3, Type 4 or Type 5 messages, respectively.

Issue of data-fast correction (IODFj): an indicator that associates UDREIis with fast corrections. The index jshall denote the message type (j = 2 to 5) to which IODFjapplies (the fast correction type identifier +2).

Note.— The fast correction type identifier is broadcast in Type 24 messages. The FCiare broadcast in Type 2 to 5, and Type 24 messages. The IODFjare broadcast in Type 2 to 6, and Type 24 messages.

3.5.4.5 Fast and long-term correction integrity parameters. Fast and long-term correction integrity parameters shall be as follows:

UDREIi: an indicator that defines the σ2i,UDREfor satelliteias described in Table B-29. Model variance of residual clock and ephemeris errors (σ2i,UDRE):the variance of a normal distribution associated with the user differential range errors for satellite iafter application of fast and long-term corrections, excluding atmospheric effects and used in horizontal protection level/vertical protection level computations (3.5.5.6).

Note.— All parameters are broadcast in Type 2 to 6, and Type 24 messages.

3.5.4.6 Ionospheric correction parameters.Ionospheric correction parameters shall be as follows:

IGP mask: a set of 11 ionospheric grid point (IGP) band masks defined in Table B-30.

IGP band mask: a set of IGP mask values which correspond to all IGP locations in one of the 11 IGP bands defined in Table B-30.

Table B-29. Evaluation of UDREI

$UDREI_i$	$\sigma^2_{i,UDRE}$
0	0.0520 m^2
1	0.0924 m^2
2	0.1444 m^2
3	0.2830 m^2
4	0.4678 m^2
5	0.8315 m^2
6	1.2992 m^2
7	1.8709 m^2
8	2.5465 m^2
9	3.3260 m^2
10	5.1968 m^2
11	20.7870 m^2
12	230.9661 m^2
13	2 078.695 m^2
14	"Not Monitored"
15	"Do Not Use"

IGP mask value: a bit indicating whether data are provided within that IGP band for the associated IGP.

Coding: 0 = data are not provided
1 = data are provided

Number of IGP bands: the number of IGP band masks being broadcast. IGP band identifier:the number identifying the ionospheric band as defined in Table B-30. IGP block identifier:the identifier of the IGP block. The IGP blocks are defined by dividing into groups of 15 IGPs the sequence of IGPs within an IGP band mask which have IGP mask values of "1". The IGP blocks are numbered in an order of IGP mask value transmission, starting with "0".

Validity interval (V): the time interval for which the GLONASS ephemeris data are applicable (coded with an offset of 30 s) as described in Table B-31.

Latency time (L): the time interval between the time the last GLONASS ephemeris has been received by the ground segment and the time of transmission of the first bit of the long-term correction message at the GEO(tltc) as described in Table B-32.

IODIk: an indication of when the kth IGP band mask changes.

IGP vertical delay estimate: an estimate of the delay induced for a signal at 1 575.42 MHz if it traversed the ionosphere vertically at the IGP.

Coding: The bit pattern "111111111" indicates "Do Not Use".

GIVEIi: an indicator that defines the σ2i,GIVEas described in Table B-33.

Model variance of residual ionospheric errors (σ2i,GIVE): the variance of a normal distribution associated with the residual ionospheric vertical error at the IGP for an L1 signal.

Note.— All parameters are broadcast in Type 18 and Type 26 messages.

Table B-30. IGP locations and band numbers

IGP location		Transmission order in IGP band mask
Band 0		
180 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	1 – 28
175 W	55S, 50S, 45S, ..., 45N, 50N, 55N	29 – 51
170 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	52 – 78
165 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
160 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
155 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
150 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
145 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 1		
140 W	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 28

IGP location		Transmission order in IGP band mask
135 W	55S, 50S, 45S, ..., 45N, 50N, 55N	29 – 51
130 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	52 – 78
125 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
120 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
115 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
110 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
105 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 2		
100 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
95 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
90 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	51 – 78
85 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
80 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
75 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
70 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
65 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 3		
60 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
55 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
50 W	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 78
45 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
40 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
35 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
30 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
25 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 4		
20 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
15 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
10 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
5 W	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
0	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	101 – 128
5 E	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
10 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
15 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 5		
20 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
25 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50

IGP location		Transmission order in IGP band mask
30 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
35 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
40 E	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 128
45 E	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
50 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
55 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 6		
60 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
65 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
70 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
75 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
80 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
85 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
90 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	151 – 178
95 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 7		
100 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
105 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
110 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
115 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
120 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
125 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
130 E	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	151 – 178
135 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 8		
140 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
145 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
150 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
155 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
160 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
165 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
170 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	151 – 177
175 E	55S, 50S, 45S, ..., 45N, 50N, 55N	178 – 200
Band 9		
60 N	180W, 175W, 170W, …, 165E, 170E, 175E	1 – 72
65 N	180W, 170W, 160W, …, 150E, 160E, 170E	73 – 108
70 N	180W, 170W, 160W, …, 150E, 160E, 170E	109 – 144

IGP location		Transmission order in IGP band mask
75 N	180W, 170W, 160W, …, 150E, 160E, 170E	145 – 180
85 N	180W, 150W, 120W, …, 90E, 120E, 150E	181 – 192
Band 10		
60 S	180W, 175W, 170W, …, 165E, 170E, 175E	1 – 72
65 S	180W, 170W, 160W, …, 150E, 160E, 170E	73 – 108
70 S	180W, 170W, 160W, …, 150E, 160E, 170E	109 – 144
75 S	180W, 170W, 160W, …, 150E, 160E, 170E	145 – 180
85 S	170W, 140W, 110W, …, 100E, 130E, 160E	181 – 192

Table B-31. Validity interval

Data	Bits used	Range of values	Resolution
Validity interval (V)	5	30 s to 960 s	30 s

Table B-32. Latency time

Data	Bits used	Range of values	Resolution
Latency time (L)	3	0 s to 120 s	30 s

Table B-33. Evaluation of GIVEIi

$GIVEI_i$	$\sigma^2_{i,GIVE}$
0	0.0084 m^2
1	0.0333 m^2
2	0.0749 m^2
3	0.1331 m^2
4	0.2079 m^2
5	0.2994 m^2
6	0.4075 m^2
7	0.5322 m^2
8	0.6735 m^2
9	0.8315 m^2
10	1.1974 m^2
11	1.8709 m^2
12	3.3260 m^2
13	20.787 m^2
14	187.0826 m^2
15	"Not Monitored"

3.5.4.7 *Degradation parameters*. Degradation parameters, whenever used, shall be as follows:

Fast correction degradation factor indicator (aii): an indicator of the fast correction degradation factor (ai) for the ithsatellite as described in Table B-34.

Note.— The aii is also used to define the time-out interval for fast corrections, as described in 3.5.8.1.1.

System latency time (tlat): the time interval between the origin of the fast correction degradation and the user differential range estimate indicator (UDREI) reference time.

Brrc: a parameter that bounds the noise and round-off errors when computing the range rate correction degradation as in 3.5.5.6.2.2.

Cltc_lsb: the maximum round-off error due to the resolution of the orbit and clock information.

Cltc_v1: the velocity error bound on the maximum range rate difference ofmissed messages due to clock and orbit rate differences.

Iltc_v1: the update interval for long-term corrections if velocity code = 1 (3.5.4.4.1).

Cltc_v0: a parameter that bounds the difference between two consecutive long-term corrections for satellites with a velocity code = 0.

Iltc_v0: the minimum update interval for long-term messages if velocity code = 0 (3.5.4.4.1).

CGEO_lsb: the maximum round-off error due to the resolution of the orbit and clock information.

CGEO_v: the velocity error bound on the maximum range rate difference of missed messages due to clock and orbit rate differences.

IGEO: the update interval for GEO ranging function messages.

Table B-34. Fast correction degradation factor

Fast correction degradation factor indicator (ai_i)	Fast correction degradation factor (a_i)
0	0.0 mm/s^2
1	0.05 mm/s^2
2	0.09 mm/s^2
3	0.12 mm/s^2
4	0.15 mm/s^2
5	0.20 mm/s^2
6	0.30 mm/s^2
7	0.45 mm/s^2
8	0.60 mm/s^2
9	0.90 mm/s^2
10	1.50 mm/s^2
11	2.10 mm/s^2
12	2.70 mm/s^2
13	3.30 mm/s^2
14	4.60 mm/s^2
15	5.80 mm/s^2

Cer: the bound on the residual error associated with using data beyond the precision approach/approach with vertical guidance time-out.

Ciono_step: the bound on the difference between successive ionospheric grid delay values.

Iiono: the minimum update interval for ionospheric correction messages.

Ciono ramp: the rate of change of the ionospheric corrections.

RSSUDRE: the root-sum-square flag for fast and long-term correction residuals.

Coding: 0 = correction residuals are linearly summed
1 = correction residuals are root-sum-squared

RSSiono: the root-sum-square flag for ionospheric residuals.

Coding: 0 = correction residuals are linearly summed
1 = correction residuals are root-sum-squared

Ccovariance: the term which is used to compensate for quantization effects when using the Type 28 message.

Note 1.— The parameters ai and tlatare broadcast in Type 7 message. All other parameters are broadcast in Type 10 message.

Note 2.— If message Type 28 is not broadcast, Ccovariance is not applicable.

3.5.4.8 Time parameters. Time parameters, whenever used, shall be as follows:

UTC standard identifier: an indication of the UTC reference source as defined in Table B-35.

GPS time-of-week count: the number of seconds that have passed since the transition from the previous GPS week (similar to the GPS parameter in 3.1.1.2.6.1 but with a 1-second resolution).

Table B-35. UTC standard identifier

UTC standard identifier	UTC standard
0	UTC as operated by the Communications Research Laboratory, Tokyo, Japan
1	UTC as operated by the U.S. National Institute of Standards and Technology
2	UTC as operated by the U.S. Naval Observatory
3	UTC as operated by the International Bureau of Weights and Measures
4	Reserved for UTC as operated by a European laboratory
5 to 6	Spare
7	UTC not provided

GPS week number (week count):see 3.1.1.2.6.2.

GLONASS indicator: a flag indicating ifGLONASS time parameters are provided.

Coding: 0 = GLONASS time parameters are not provided
1 = GLONASS time parameters are provided

GLONASS time offset (δai,GLONASS): A parameter that represents the stable partof the offset between the GLONASS time and the SBAS network time.

Note.— If SBAS does not support GLONASS, δai,GLONASS is not applicable.

UTC parameters: A1SNT, A0SNT, t0t, WNt, ΔtLS, WNLSF, DN and ΔtLSFare as described in 3.1.1.3.3.6, with the exception that the SBAS parameters relate SNT to UTC time, rather than GPS time.

Note.— All parameters are broadcast in Type 12 message.

3.5.4.9 Service region parameters. Service region parameters shall be as follows:

Issue of data, service (IODS): an indication of a change of the service provided in the region.

Number of service messages: the number of different Type 27 SBAS service messages being broadcast. (Value is coded with an offset of 1.)

Service message number: a sequential number identifying the message within the currently broadcast set of Type 27 messages (from 1 to number of service messages, coded with an offset of 1).

Number of regions: the number of service regions for which coordinates are broadcast in the message.

Priority code: an indication of a message precedence if two messages define overlapping regions. The message with a higher value of priority code takes precedence. If priority codes are equal, the message with the lower δUDRE takes precedence.

δUDRE indicator-inside: an indication of regional UDRE degradation factor (δUDRE) applicable at locations inside any region defined in the message, in accordance with Table B-36.

δUDRE indicator-outside: an indication of regional UDRE degradation factor (δUDRE) applicable at locations outside all regions defined in all current Type 27 messages, in accordance with Table B-36.

Coordinate latitude: the latitude of one corner of a region.

Coordinate longitude: the longitude of one corner of a region.

Region shape: an indication of whether a region is a triangle or quadrangle.

Coding: 0 = triangle

1 = quadrangle

Note 1.— Coordinate 3 has Coordinate 1 latitude and Coordinate 2 longitude. If region is a quadrangle, Coordinate 4 has Coordinate 2 latitude and Coordinate 1 longitude. Region boundary is formed by joining coordinates in the sequence 1-2-3-1 (triangle) or 1-3-2-4-1 *(quadrangle). Boundary segments have either constant latitude, constant longitude, or constant slope in degrees of latitude per degree of longitude. The change in latitude or longitude along any boundary segment between two coordinates is less than ±180 degrees.*

Note 2.— All parameters are broadcast in Type 27 message.

Table B-36. δUDRE indicator evaluation

δUDRE indicator	δUDRE
0	1
1	1.1
2	1.25
3	1.5
4	2
5	3
6	4
7	5
8	6
9	8
10	10
11	20
12	30
13	40
14	50
15	100

3.5.4.10 Clock-ephemeris covariance matrix parameters. Clock-ephemeris covariance matrix parameters shall be as follows:

PRN mask number: see 3.5.4.1.

Scale exponent: A term to compute the scale factor used tocode the Cholesky factorization elements.

Cholesky factorization elements (Ei,j): Elements of an upper triangle matrix which compresses the information in the clock and ephemeris covariance matrix. These elements are used to compute the user differential range estimate (UDRE) degradation factor (δUDRE) as a function of user position.

3.5.5 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section provides definitions of parameters used by the non-aircraft or aircraft elements that are not transmitted. These parameters, necessary to ensure interoperability of SBAS, are used to determine the navigation solution and its integrity (protection levels).

3.5.5.1 GEOPOSITION AND CLOCK

3.5.5.1.1 GEO position estimate. The estimated position of a GEO at any time tk is:

$$\begin{bmatrix}\hat{X}_G\\ \hat{Y}_G\\ \hat{Z}_G\end{bmatrix} = \begin{bmatrix}X_G\\ Y_G\\ Z_G\end{bmatrix} + \begin{bmatrix}\dot{X}_G\\ \dot{Y}_G\\ \dot{Z}_G\end{bmatrix}(t-t_{0,GEO}) + \frac{1}{2}\begin{bmatrix}\ddot{X}_G\\ \ddot{Y}_G\\ \ddot{Z}_G\end{bmatrix}(t-t_{0,GEO})^2$$

3.5.5.1.2 GEO clock correction. The clock correction for a SBAS GEO satellite iis applied in accordance with the following equation:

t = tG– ΔtG

where

t = SBAS network time;
tG = GEO code phase time at transmission of message; and
ΔtG = GEO code phase offset.

3.5.5.1.2.1 GEO code phase offset (ΔtG) at any time tis:

ΔtG= aGf0+ aGf1(t – t0,GEO)

Where

(t – t0,GEO) is corrected for end-of-day crossover.

3.5.5.2 LONG-TERM CORRECTIONS

3.5.5.2.1 GPS clock correction. The clock correction for a GPS satellite iis applied in accordance with the following equation:

t = tSV,i– [(ΔtSV,i)L1+ δΔtSV,i]

where

t = SBAS network time; t

SV,i = the GPS satellite time at transmission of message;

(ΔtSV,i)L1 = the satellite PRN code phase offset as defined in 3.1.2.2; and

$\delta\Delta t_{SV,i}$ = the code phase offset correction.

3.5.5.2.1.1 The code phase offset correction ($\delta\Delta t_{SV,i}$) for a GPS or SBAS satellite $i$at any time of day $t_k$is:

$$\delta\Delta t_{SV,i}= \delta a_{i,f0}+ \delta a_{i,f1}(t_k- t_{i,LT})$$

3.5.5.2.2 GLONASS clock correction. The clock correction for a GLONASS satellite $i$is applied in accordance with the following equation:

$$t = t_{SV,i} + \tau_n(t_b) - \gamma_n(t_b)(t_{SV,i}- t_b)- \delta\Delta t_{SV,i}$$

where

t = SBAS network

$t_{SV,i}$ = the GLONASS satellite time at transmission of message t_b, $\tau_n(t_b)$, $\gamma_n(t_b)$ = the GLONASS time parameters as defined in 3.2.2.2

$\delta\Delta t_{SV,i}$ = the code phase offset correction

The code phase offset correction $\delta\Delta t_{SV,i}$ for a GLONASS satellite i is:

$$\delta\Delta t_{SV,i} = \delta a_{i,f0}+ \delta a_{i,f1}(t - t_{i,LT}) + \delta a_{i,GLONASS}$$

where

$(t - t_{i,LT})$ is corrected for end-of-day crossover. If the velocity code = 0, then $\delta a_{i,f1} = 0$.

3.5.5.2.3 Satellite position correction. The SBAS-corrected vector for a core satellite constellation(s) or SBAS satellite I at time t is:

$$\begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}_{corrected} = \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} + \begin{bmatrix} \delta x_i \\ \delta y_i \\ \delta z_i \end{bmatrix} + \begin{bmatrix} \delta \dot{x}_i \\ \delta \dot{y}_i \\ \delta \dot{z}_i \end{bmatrix} (t - t_{i,LT})$$

where $(t - t_{i,LT})$ is corrected for end-of-day crossover; and

$[x_i y_i z_i]^T$= the core satellite constellation(s) or SBAS satellite position vector as defined in 3.1.2.3, 3.2.2.3 and 3.5.5.1.1.

If the velocity code = 0, then $[\delta\dot{x}_i \ \delta\dot{y}_i \ \delta\dot{z}_i]^T = [0 \ 0 \ 0]^T$

3.5.5.3 Pseudo-range corrections. The corrected pseudo-range at time tfor satellite I is:

PRi,corrected= PRi+ FCi+ RRCi(t – ti,0f) + ICi+ TCi

where

PRi = the measured pseudo-range after application of the satellite clock correction;

FCi = the fast correction;

RRCi = the range rate correction;

ICi = the ionospheric correction;

TCi = the tropospheric correction (negative value representing the troposphere delay); and

ti,0f = the time of applicability of the most recent fast corrections, which is the start of the epoch of the SNT second that is coincident with the transmission at the SBAS satellite of the first symbol of the message block.

3.5.5.4 Range rate corrections (RRC). The range rate correction for satellite I is:

$$RRC_i = \frac{FC_{i,current} - FC_{i,previous}}{t_{i,0f} - t_{i,0f\_previous}}$$

where

FCi, current = the most recent fast correction;

FCi, previous = a previous fast correction;

ti,0f = the time of applicability of FCi, current; and

ti,0f_previous = the time of applicability of FCi, previous

3.5.5.5 BROADCAST IONOSPHERIC CORRECTIONS

3.5.5.5.1 Location of ionospheric pierce point (IPP). The location of an IPP is defined to be the intersection of the line segment from the receiver to the satellite and an ellipsoid with constant height of350 km above the WGS-84 ellipsoid. This location is defined in WGS-84 latitude (φpp) and longitude (λpp).

3.5.5.5.2 *Ionospheric corrections.* The ionospheric correction for satellite I is:

$$ICi = – Fpp\ \tau vpp$$

where

Fpp = obliquity factor = $\left[1 - \left(\frac{R_e \cos\theta_i}{R_e + h_I}\right)^2\right]^{-\frac{1}{2}}$

τvpp = interpolated vertical ionospheric delay estimate (3.5.5.5.3);

Re = 6 378.1363 km;

θi = elevation angle of satellite i; and

hI= 350 km.

Note.— For GLONASS satellites, the ionospheric correction (ICi) is to be multiplied by the square of the ratio of the GLONASS to the GPS frequencies (fGLONASS/fGPS)2.

3.5.5.5.3 Interpolated vertical ionospheric delay estimate. When four points are used for interpolation, the interpolated vertical ionospheric delay estimate at latitude φpp and longitude λpp is:

$$\tau_{vpp} = \sum_{k=1}^{4} W_k\, \tau_{vk}$$

where

τvk: the broadcast grid point vertical delay values at the kth corner of the IGP grid, as shown in Figure B-13.

W1= xppypp;

W2= (1 – xpp) ypp;

W3= (1 – xpp) (1 – ypp); and

W4= xpp(1 – ypp).

3.5.5.5.3.1 For IPPs between N85° and S85°

$$x_{pp}=\frac{\lambda_{pp}-\lambda_1}{\lambda_2-\lambda_1}$$

$$y_{pp}=\frac{\phi_{pp}-\phi_1}{\phi_2-\phi_1}$$

where

λ1= longitude of IGPs west of IPP;

λ2= longitude of IGPs east of IPP;

φ1= latitude of IGPs south of IPP; and

φ2= latitude of IGPs north of IPP.

Note.— If λ1and λ2cross 180 degrees of longitude, the calculation of xppmust account for the discontinuity in longitude values.

3.5.5.5.3.2 For IPPs north of N85° or south of S85°:

$$y_{pp}=\frac{|\phi_{pp}|-85^\circ}{10^\circ}$$

$$x_{pp}=\frac{\lambda_{pp}-\lambda_3}{90^\circ}\times(1-2\,y_{pp})+y_{pp}$$

where

λ1= longitude of the second IGP to the east of the IPP;

λ2= longitude of the second IGP to the west of the IPP;

λ3= longitude of the closest IGP to the west of the IPP; and

λ4= longitude of the closest IGP to the east of the IPP.

When three points are used for interpolation, the interpolated vertical ionospheric delay estimated is:

3.5.5.5.3.3 For points between S75° and N75°:

$$\tau_{vpp} = \sum_{k=1}^{3} W_k \tau_{vk}$$

where

$W1 = ypp$;

$W2 = 1 - xpp - ypp$; and

$W3 = xpp$.

3.5.5.5.3.4 xpp and ypp are calculated as for four-point interpolation, except that λ1and φ1are always the longitude and latitude of IGP2, and λ2and φ2are the other longitude and latitude. IGP2 is always the vertex opposite the hypotenuse of the triangle defined by the three points, IGP1 has the same longitude as IGP2, and IGP3 has the same latitude as IGP2 (an example is shown in Figure B-14).

3.5.5.5.3.5 For points north of N75° and south of S75°, three-point interpolation is not supported.

3.5.5.5.4 Selection of ionospheric grid points (IGPs). The protocol for the selection of IGPs is:

a) For an IPP between N60° and S60°:

1) if four IGPs that define a 5-degree-by-5-degree cell around the IPP are set to "1" in the IGP mask, they are selected; else,

2) if any three IGPs that define a 5-degree-by-5-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

3) if any four IGPs that define a 10-degree-by-10-degree cell around the IPP are set to"1" in the IGP mask, they are selected; else,

4) if any three IGPs that define a 10-degree-by-10-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

5) an ionospheric correction is not available.

b) For an IPP between N60° and N75° or between S60° and S75°:

1) if four IGPs that define a 5-degree-latitude-by-10-degree longitude cell around the IPP are set to “1” in the IGP mask, they are selected; else,

2) if any three IGPs that define a 5-degree-latitude-by-10-degree longitude triangle that circumscribes the IPP are set to “1” in the IGP mask, they are selected; else,

3) if any four IGPs that define a 10-degree-by-10-degree cell around the IPP are set to“1” in the IGP mask, they are selected; else,

4) if any three IGPs that define a 10-degree-by-10-degree triangle that circumscribes the IPP are set to “1” in the IGP mask, they are selected; else,

5) an ionospheric correction is not available.

c) For an IPP between N75° and N85° or between S75° and S85°:

1) if the two nearest IGPs at 75° and the two nearest IGPs at 85° (separated by 30° longitude if Band 9 or 10 is used, separated by 90° otherwise) are set to “1” in the IGP mask, a 10-degree-by-10-degree cell is created by linearly interpolating between the IGPs at 85° to obtain virtual IGPs at longitudes equal to the longitudes of the IGPs at 75°; else,

2) an ionospheric correction is not available.

d) For an IPP north of N85°:

1) if the four IGPs at N85° latitude and longitudes of W180°, W90°, 0° and E90° are set to “1” in the IGP mask, they are selected; else,

2) an ionospheric correction is not available.

e) For an IPP south of S85°:

1) if the four IGPs at S85° latitude and longitudes of W140°, W50°, E40° and E130° are set to “1” in the IGP mask, they are selected; else,

2) an ionospheric correction is not available.

Note.— This selection is based only on the information provided in the mask, without regard to whether the selected IGPs are monitored, “Not Monitored”, or “Do Not Use”. If any of the *selected IGPs is identified as "Do Not Use", an ionospheric correction is not available. If four IGPs are selected, and one of the four is identified as "Not Monitored", then three-point interpolation is used if the IPP is within the triangular region covered by the three corrections that are provided.*

3.5.5.6 Protection levels. The horizontal protection level (HPL) and the vertical protection level (VPL) are:

$$HPL_{SBAS} = \begin{cases} K_{H,NPA} \times d_{major} & \text{for en-route through non-precision approach (NPA) modes} \\ K_{H,PA} \times d_{major} & \text{for precision approach (PA) and approach with vertical guidance (APV) modes} \end{cases}$$

$$VPL_{SBAS} = K_{V,PA} \times d_V$$

where

$d_V^2 = \sum_{i=1}^{N} s_{v,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the vertical axis;

$$d_{mayor} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}}$$

Where

$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the x axis;

$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the y axis;

$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2$ =covariance of model distribution in the x and y axis;

Where

sx,i = the partial derivative of position error in the x-direction with respect to pseudo-range error on the ith satellite;

sy,i = the partial derivative of position error in the y-direction with respect to pseudo-range error on the ith satellite;

sV,i = the partial derivative of position error in the vertical direction with respect to pseudo-range error on the ith satellite; and

$$\sigma^2_i = \sigma^2_{i,flt} + \sigma^2_{i,UIRE} + \sigma^2_{i,air} + \sigma^2_{i,tropo}.$$

The variances (σ2i,fltand σ2i,UIRE) are defined in 3.5.5.6.2 and 3.5.5.6.3.1. The parameters (σ2i,airand σ2i,tropo) are determined by the aircraft element (3.5.8.4.2 and 3.5.8.4.3).

The x and y axes are defined to be in the local horizontal plane, and the v axis represents local vertical.

For a general least-squares position solution, the projection matrix S is:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \dots & S_{x,N} \\ S_{y,1} & S_{y,2} & \dots & S_{y,N} \\ S_{v,1} & S_{v,2} & \dots & S_{v,N} \\ S_{t,1} & S_{t,2} & \dots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

where

$$G_i = [-\cos El_i \cos Az_i \; -\cos El_i \sin Az_i \; -\sin El_i \; 1] = i^{th} \text{ row of } G;$$

$$W^{-1} = \begin{bmatrix} w_1 & 0 & \dots & 0 \\ 0 & w_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & & \dots & w_i \end{bmatrix};$$

Eli = the elevation angle of the ith ranging source (in degrees);

Azi = the azimuth of the ith ranging source taken counter-clockwise from the x axis in degrees; and

Wi = the inverse weight associated with satellite i= σ2i.

Note 1.— To improve readability, the subscript iwas omitted from the protection matrix's equation.

Note 2.— For an unweighted least-squares solution, the weighting matrix is an identity matrix (wi = 1).

3.5.5.6.1 Definition of K values. The K values are:

$$K_{H,NPA} = 6.18;$$

$$K_{H,PA} = 6.0; \text{ and}$$

$$K_{V,PA} = 5.33.$$

3.5.5.6.2 Definition of fast and long-term correction error model. If fast corrections and long-term correction/GEO ranging parameters are applied, and degradation parameters are applied:

$$\sigma^2_{i,flt} = \begin{cases} [(\sigma_{i,UDRE})(\delta_{UDRE}) + \varepsilon_{fc} + \varepsilon_{rrc} + \varepsilon_{ltc} + \varepsilon_{er}]^2, & \text{si } RSS_{UDRE} = 0 \text{ (Message Type 10)} \\ [(\sigma_{i,UDRE})(\delta_{UDRE})]^2 + \varepsilon^2_{fc} + \varepsilon^2_{rrc} + \varepsilon^2_{ltc} + \varepsilon^2_{er}, & \text{si } RSS_{UDRE} = 1 \text{ (Message Type10)} \end{cases}$$

where

if using message Type 27, δUDRE is a region-specific term as defined in section 3.5.4.9,
if using message Type 28, δUDREis a satellite-specific term as defined in section 3.5.5.6.2.5,
if using neither message, δUDRE= 1.

If fast corrections and long-term corrections/GEO ranging parameters are applied, but degradation parameters are not applied:

$$\sigma^2_{i,flt} = [(\sigma_{i,UDRE})\,(\delta_{UDRE}) + 8m]^2$$

3.5.5.6.2.1 *Fast correction degradation.* The degradation parameter for fast correction data is:

$$\varepsilon_{fc} = \frac{a(t - t_u + t_{lat})^2}{2}$$

where

t = the current time;

tu= (UDREIireference time): if IODFj ≠3, the start time of the SNT 1-second epoch that is coincident with the start of the transmission of the message block that contains the most recent UDREIi data (Type 2 to 6, or Type 24 messages) that matches the IODFjof the fast correction being used. If IODFj= 3, the start time of the epoch of the SNT 1-second epoch that is coincident with the start of transmission of the message that contains the fast correction for the i

thsatellite; and

tlat = (as defined in 3.5.4.7).

Note.— For UDREs broadcast in Type 2 to 5, and Type 24 messages, tuequals the time of applicability of the fast corrections since they are in the same message. For UDREs broadcast in Type 6 message and if the IODF = 3, tualso equals the time of applicability of the fast corrections (t0f). For UDREs broadcast in Type 6 message and IODF ≠3, tuis defined to be the time of transmission of the first bit of Type 6 message at the GEO.

3.5.5.6.2.2 Range rate correction degradation

3.5.5.6.2.2.1 If the RRC = 0, then $\varepsilon_{rrc}= 0$.

3.5.5.6.2.2.2 If the RRC ≠0 and IODF ≠3, the degradation parameter for fast correction data is:

$$\varepsilon_{rrc}=\begin{cases} 0, & \text{si } (IODF_{actual}-IODF_{anterior})MOD3 = 1 \\ \left(\frac{aI_{fc}}{4}+\frac{B_{rrc}}{\Delta t}\right)(t-t_{0f}), & \text{si } (IODF_{actual}-IODF_{anterior})MOD3 \neq 1 \end{cases}$$

3.5.5.6.2.2.3 If RRC ≠0 and IODF = 3, the degradation parameter for range rate data is:

$$\varepsilon_{rrc}=\begin{cases} 0, & \text{si } \left|\Delta t-\frac{I_{fc}}{2}\right| = 0 \\ \left(\frac{a\left|\Delta t-\frac{I_{fc}}{2}\right|}{2}+\frac{B_{rrc}}{\Delta t}\right)(t-t_{0f}), & \text{si } \left|\Delta t-\frac{I_{fc}}{2}\right| \neq 0 \end{cases}$$

where

t= the current time;

IODFcurrent = IODF associated with most recent fast correction;

IODFprevious = IODF associated with previous fast correction;

Δt = ti,0f– ti,0f_previous; and

Ifc = the user time-out interval for fast corrections.

3.5.5.6.2.3 Long-term correction degradation

3.5.5.6.2.3.1 Core satellite constellation(s)

3.5.5.6.2.3.1.1 For velocity code = 1, the degradation parameter for long-term corrections of satellite I is:

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{i,LT} < t < t_{i,LT} + I_{ltc\_v1} \\ C_{ltc\_lsb} + C_{ltc\_v1} \max\left(0, t_{i,LT} - t, t - t_{i,LT} - I_{ltc\_v1}\right), & \text{otherwise} \end{cases}$$

3.5.5.6.2.3.1.2 For velocity code = 0, the degradation parameter for long-term corrections is:

$$\varepsilon_{ltc} = C_{ltc\_v0} \left[\frac{t - t_{ltc}}{I_{lt\text{-}v0}} \right]$$

where

t= the current time;

tltc = the time of transmission of the first bit of the long-term correction message at the GEO; and

[x] = the greatest integer less than x.

3.5.5.6.2.3.2 *GEO satellites*. The degradation parameter for long-term corrections is:

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{0,GEO} < t < t_{0,GEO} + I_{GEO} \\ C_{geo\_lsb} + C_{geo\_v} \max\left(0, t_{0,GEO} - t, t - t_{0,GEO} - I_{geo}\right), & \text{otherwise} \end{cases}$$

where t = the current time.

Note.— When long-term corrections are applied to a GEO satellite, the long-term correction degradation is applied and the GEO navigation message degradation is not applied

3.5.5.6.2.4 Degradation for en-route through non-precision approach

$$\varepsilon_{er} = \begin{cases} 0, & \text{if neither fast nor long-term corrections have timed out for precision approach/approach with vertical guidance} \\ C_{er}, & \text{if fast or long-term corrections have timed out for precision approach/approach with vertical guidance} \end{cases}$$

3.5.5.6.2.5 UDRE degradation factor calculated with message Type 28 data. The δUDRE is:

$$\delta_{UDRE} = \sqrt{I^T \cdot C \cdot I} + \varepsilon_c$$

where

$$I = \begin{bmatrix} i_x \\ i_y \\ i_z \\ 1 \end{bmatrix},$$

$\begin{bmatrix} i_x \\ i_y \\ i_z \end{bmatrix}$ = the unit vector from the user to the satellite in the WGS-84 ECEF coordinate frame

$C = R^T \cdot R$

$\varepsilon_C = C_{covariance} \cdot SF$

$SF = 2^{scale\ exponent-5}$

$R = E \cdot SF$

$$E = \begin{bmatrix} E_{1,1} & E_{1,2} & E_{1,3} & E_{1,4} \\ 0 & E_{2,2} & E_{2,3} & E_{2,4} \\ 0 & 0 & E_{3,3} & E_{3,4} \\ 0 & 0 & 0 & E_{4,4} \end{bmatrix}$$

3.5.5.6.3 Definition of ionospheric correction error model

3.5.5.6.3.1 Broadcast ionospheric corrections. If SBAS-based ionospheric corrections are applied, σ2UIREis:

$$\sigma^2_{UIRE} = F^2_{pp} \times \sigma^2_{UIVE}$$

Where

Fpp = (as defined in 3.5.5.5.2);

$\sigma^2_{UIVE} = \sum_{n=1}^{4} W_n \cdot \sigma^2_{n,ionogrid}$ o $\sigma^2_{UIVE} = \sum_{n=1}^{3} W_n \cdot \sigma^2_{n,ionogrid}$

using the same ionospheric pierce point weights (Wn) and grid points selected for the ionospheric correction (3.5.5.5). For each grid point:

$$\sigma^2_{i,ionogrid} = \begin{cases} (\sigma_{GIVE} + \varepsilon_{iono})^2, & \text{si } RSS_{iono} = 0 \text{ (Type 10 message)} \\ \sigma^2_{GIVE} + \varepsilon^2_{iono}, & \text{si } RSS_{iono} = 1 \text{ (Type 10 message)} \end{cases}$$

Where

$$\varepsilon_{iono} = C_{iono\_step}\left[\frac{t - t_{iono}}{I_{iono}}\right] + C_{iono\_ramp}(t - t_{iono});$$

t= the current time;

t*iono*= the time of transmission of the first bit of the ionospheric correction message at the GEO; and

[x] = the greatest integer less than x.

Note.— For GLONASS satellites, both σGIVEand σIONO parameters are to be multiplied by the square of the ratio of the GLONASS to the GPS frequencies (fGLONASS/fGPS)2.

3.5.5.6.3.2 Ionospheric corrections. If SBAS-based ionospheric corrections are not applied, σ2UIRE is:

$$\sigma^2_{UIRE} = MAX\left\{\left(\frac{T_{iono}}{5}\right)^2, \left(F_{pp} \cdot \tau_{vert}\right)^2\right\}$$

Where

T_{iono} = the ionospheric delay estimated by the chosen model (GPS correction or other model);
F_{pp} = (as defined in 3.5.5.5.2);

$$\tau_{vert} = \begin{cases} 9 \text{ m}, & 0 \le |\phi_{pp}| \le 20 \\ 4.5 \text{ m}, & 20 < |\phi_{pp}| \le 55; y \\ 6 \text{ m}, & 55 < |\phi_{pp}| \end{cases}$$

ϕ_{pp} = latitude of the ionospheric pierce point.

3.5.5.6.3.3 *GLONASS clock.* The degradation parameter for GLONASS clock correction is:

$$\varepsilon_{GLONASS\_CLOCK} = C_{GLONASS\_CLOCK} \cdot [t - t_{GLONASS\_CLOCK}]$$

where

t = the current time tGLONASS_CLOCK = the time of transmission of the first bit of the timing message (MT12) at the GEO

[sc] = the greatest integer less than sc.

Note 1.— For non-GLONASS satellites εGLONASS_CLOCK= 0.

Note 2.— CGLONASS_CLOCK= 0.00833 cm/s.

3.5.6 MESSAGE TABLES

Each SBAS message shall be coded in accordance with the corresponding message format defined in Tables B-37 through B-53. All signed parameters in these tables shall be represented in two's complement, with the sign bit occupying the MSB.

Note.— The range for the signed parameters is smaller than indicated, as the maximum positive value is constrained to be one value less (the indicated value minus the resolution).

Table B-37. Type 0 "Do Not Use" message

Data content	Bits used	Range of values	Resolution
Spare	212	—	—

Table B-38. Type 1 PRN mask message

Data content	Bits used	Range of values	Resolution
For each of 210 PRN code numbers			
Mask value	1	0 or 1	1
IODP	2	0 to 3	1

Note.— All parameters are defined in 3.5.4.1.

Table B-39. Types 2 to 5 fast correction message

Data content	Bits used	Range of values	Resolution
$IODF_i$	2	0 to 3	1
IODP	2	0 to 3	1
For 13 slots			
Fast correction (FC_i)	12	±256.000 m	0.125 m
For 13 slots			
$UDREI_i$	4	(see Table B-29)	(see Table B-29)

Notes.—
1. The parameters $IODF_j$ and FC_i are defined in 3.5.4.4.2.
2. The parameter IODP is defined in 3.5.4.1.
3. The parameter $UDREI_i$ is defined in 3.5.4.5.

Table B-40. Type 6 integrity message

Data content	Bits used	Range of values	Resolution
$IODF_2$	2	0 to 3	1
$IODF_3$	2	0 to 3	1
$IODF_4$	2	0 to 3	1
$IODF_5$	2	0 to 3	1
For 51 satellites (ordered by PRN mask number)			
$UDREI_i$	4	(see Table B-29)	(see Table B-29)

Notes.—
1. The parameters $IODF_j$ are defined in 3.5.4.4.2.
2. The parameter $UDREI_i$ is defined in 3.5.4.5.

Table B-41. Type 7 fast correction degradation factor message

Data content	Bits used	Range of values	Resolution
System latency (t_{lat})	4	0 to 15 s	1 s
IODP	2	0 to 3	1
Spare	2	—	—
For 51 satellites (ordered by PRN mask number)			
Degradation factor indicator (ai_i)	4	(see Table B-34)	(see Table B-34)

Notes.—
1. The parameters t_{lat} and ai_i are defined in 3.5.4.7.
2. The parameter IODP is defined in 3.5.4.1.

Table B-42. Type 9 ranging function message

Data content	Bits used	Range of values	Resolution
Reserved	8	—	—
$t_{0,GEO}$	13	0 to 86 384 s	16 s
URA	4	(see Table B-26)	(see Table B-26)
X_G	30	±42 949 673 m	0.08 m
Y_G	30	±42 949 673 m	0.08 m
Z_G	25	±6 710 886.4 m	0.4 m
$\dot{X}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Y}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Z}_G$	18	±524.288 m/s	0.004 m/s
$\ddot{X}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Y}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Z}_G$	10	±0.032 m/s^2	0.0000625 m/s^2
a_{Gf0}	12	$\pm 0.9537 \times 10^{-6}$ s	2^{-31} s
a_{Gf1}	8	$\pm 1.1642 \times 10^{-10}$ s/s	2^{-40} s/s

Note.— All parameters are defined in 3.5.4.2.

Table B-43. Type 10 degradation parameter message

Data content	Bits used	Range of values	Resolution
B_{rrc}	10	0 to 2.046 m	0.002 m
$C_{ltc\ lsb}$	10	0 to 2.046 m	0.002 m
$C_{ltc\ v1}$	10	0 to 0.05115 m/s	0.00005 m/s
$I_{ltc\ v1}$	9	0 to 511 s	1 s
$C_{ltc\ v0}$	10	0 to 2.046 m	0.002 m
$I_{ltc\ v0}$	9	0 to 511 s	1 s
$C_{geo\ lsb}$	10	0 to 0.5115 m	0.0005 m
$C_{geo\ v}$	10	0 to 0.05115 m/s	0.00005 m/s
I_{geo}	9	0 to 511 s	1 s
C_{er}	6	0 to 31.5 m	0.5 m
$C_{iono\ step}$	10	0 to 1.023 m	0.001 m
I_{iono}	9	0 to 511 s	1 s
$C_{iono\ ramp}$	10	0 to 0.005115 m/s	0.000005 m/s
RSS_{UDRE}	1	0 or 1	1
RSS_{iono}	1	0 or 1	1
$C_{covariance}$	7	0 to 12.7	0.1
Spare	81	—	—

Note.— All parameters are defined in 3.5.4.7.

Table B-44. Type 12 SBAS network time/UTC message

Data content	Bits used	Range of values	Resolution
A_{1SNT}	24	$\pm 7.45 \times 10^{-9}$ s/s	2^{-50} s/s
A_{0SNT}	32	±1 s	2^{-30} s
t_{0t}	8	0 to 602 112 s	4 096 s
WN_t	8	0 to 255 weeks	1 week
Δt_{LS}	8	±128 s	1 s
WN_{LSF}	8	0 to 255 weeks	1 week
DN	8	1 to 7 days	1 day
Δt_{LSF}	8	±128 s	1 s
UTC standard identifier	3	(see Table B-35)	(see Table B-35)
GPS time-of-week (TOW)	20	0 to 604 799 s	1 s
GPS week number (WN)	10	0 to 1 023 weeks	1 week
GLONASS indicator	1	0 or 1	1
$\delta a_{i,\, GLONASS}$ (Note 2)	24	$\pm 2.0 \cdot 10^{-8}$ s	$2.0 \cdot 10^{-31}$ s
Spare	50	—	—

Notes.—
1. *All parameters are defined in 3.5.4.8.*
2. *Applies only if SBAS sends GLONASS timing information in message Type 12 (see 3.5.7.4.4, Timing data).*

Table B-45. Type 17 GEO almanac message

Data content	Bits used	Range of values	Resolution
For each of 3 satellites			
Reserved	2	0	—
PRN code number	8	0 to 210	1
Health and status	8	—	—
$X_{G,A}$	15	±42 598 400 m	2 600 m
$Y_{G,A}$	15	±42 598 400 m	2 600 m
$Z_{G,A}$	9	±6 656 000 m	26 000 m
$\dot{X}_{G,A}$	3	±40 m/s	10 m/s
$\dot{Y}_{G,A}$	3	±40 m/s	10 m/s
$\dot{Z}_{G,A}$	4	±480 m/s	60 m/s
$t_{almanac}$ (applies to all three satellites)	11	0 to 86 336 s	64 s

Note.— All parameters are defined in 3.5.4.3.

Table B-46. Type 18 IGP mask message

Data content	Bits used	Range of values	Resolution
Number of IGP bands	4	0 to 11	1
IGP band identifier	4	0 to 10	1
Issue of data — ionosphere ($IODI_k$)	2	0 to 3	1
For 201 IGPs			
IGP mask value	1	0 or 1	1
Spare	1	—	—

Note.— All parameters are defined in 3.5.4.6.

Table B-47. Type 24 mixed fast/long-term satellite error correction message

Data content	Bits used	Range of values	Resolution
For 6 slots			
Fast correction (FC_i)	12	±256.000 m	0.125 m
For 6 slots			
$UDREI_i$	4	(see Table B-31)	(see Table B-31)
IODP	2	0 to 3	1
Fast correction type identifier	2	0 to 3	1
$IODF_j$	2	0 to 3	1
Spare	4	—	—
Type 25 half-message	106	—	—

Notes.—
1. *The parameters fast correction type identifier, $IODF_j$, and FC_i are defined in 3.5.4.4.2.*
2. *The parameter IODP is defined in 3.5.4.1.*
3. *The parameter $UDREI_i$ is defined in 3.5.4.5.*
4. *The long-term satellite error correction message is divided into two half-messages. The half message for a velocity code = 0 is defined in Table B-48. The half message for a velocity code = 1 is defined in Table B-49.*

Table B-48. Type 25 long-term satellite error correction half message (VELOCITY CODE = 0)

Data content	Bits used	Range of values	Resolution
Velocity Code = 0	1	0	1
For 2 Satellites			
PRN mask number	6	0 to 51	1
Issue of data (IOD_i)	8	0 to 255	1
δx_i	9	±32 m	0.125 m
δy_i	9	±32 m	0.125 m
δz_i	9	±32 m	0.125 m
$\delta a_{i,f0}$	10	$\pm 2^{-22}$ s	2^{-31} s
IODP	2	0 to 3	1
Spare	1	—	—

Notes.—

1. The parameters PRN mask number and IODP are defined in 3.5.4.1.

2. All other parameters are defined in 3.5.4.4.1.

Table B-49. Type 25 long-term satellite error correction half message (VELOCITY CODE = 1)

Data content	Bits used	Range of values	Resolution
For 1 Satellite			
Velocity Code = 1	1	1	1
PRN mask number	6	0 to 51	1
Issue of data (IOD_i)	8	0 to 255	1
δx_i	11	±128 m	0.125 m
δy_i	11	±128 m	0.125 m
δz_i	11	±128 m	0.125 m
$\delta a_{i,f0}$	11	$\pm 2^{-21}$ s	2^{-31} s
$\delta \dot{x}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta \dot{y}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta \dot{z}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta a_{i,f1}$	8	$\pm 2^{-32}$ s/s	2^{-39} s/s
Time-of-applicability ($t_{i,LT}$)	13	0 to 86 384 s	16 s
IODP	2	0 to 3	1

Notes.—

1. The parameters PRN mask number and IODP are defined in 3.5.4.1.

2. All other parameters are defined in 3.5.4.4.1.

Table B-50. Type 26 ionospheric delay message

Data content	Bits used	Range of values	Resolution
IGP band identifier	4	0 to 10	1
IGP block identifier	4	0 to 13	1
For each of 15 grid points			
IGP vertical delay estimate	9	0 to 63.875 m	0.125 m
Grid ionospheric vertical error indicator ($GIVEI_i$)	4	(see Table B-33)	(see Table B-33)
$IODI_k$	2	0 to 3	1
Spare	7	—	—

Note.— All parameters are defined in 3.5.4.6.

Table B-51. Type 27 SBAS service message

Data content	Bits used	Range of values	Resolution
Issue of data, service (IODS)	3	0 to 7	1
Number of service messages	3	1 to 8	1
Service message number	3	1 to 8	1
Number of regions	3	0 to 5	1
Priority code	2	0 to 3	1
δUDRE indicator-inside	4	0 to 15	1
δUDRE indicator-outside	4	0 to 15	1
For each of 5 regions			
Coordinate 1 latitude	8	±90°	1°
Coordinate 1 longitude	9	±180°	1°
Coordinate 2 latitude	8	±90°	1°
Coordinate 2 longitude	9	±180°	1°
Region shape	1	—	—
Spare	15	—	—

Note.— All parameters are defined in 3.5.4.9.

Table B-52. Type 63 null message

Data content	Bits used	Range of values	Resolution
Spare	212	—	—

Table B-53. Type 28 clock-ephemeris covariance matrix

Data content	Bits used	Range of values	Resolution
IODP	2	0 to 3	1
For two satellites			
PRN mask number	6	0 to 51	1
Scale exponent	3	0 to 7	1
$E_{1,1}$	9	0 to 511	1
$E_{2,2}$	9	0 to 511	1
$E_{3,3}$	9	0 to 511	1
$E_{4,4}$	9	0 to 511	1
$E_{1,2}$	10	±512	1
$E_{1,3}$	10	±512	1
$E_{1,4}$	10	±512	1
$E_{2,3}$	10	±512	1
$E_{2,4}$	10	±512	1
$E_{3,4}$	10	±512	1

Notes.—
1. The parameters PRN mask number and IODP are defined in 3.5.4.1.
2. All other parameters are defined in 3.5.4.10.

3.5.7 NON-AIRCRAFT ELEMENTS

Note 1.— Depending on the level of service offered by a particular SBAS, different functions can be implemented as described in Chapter 3, 3.7.3.4.2.

Note 2.— The parameters that are referred to in this section are defined in 3.5.4.

3.5.7.1 GENERAL

3.5.7.1.1 *Required data and broadcast intervals*. SBAS shall broadcast the data required for the supported functions as shown in Table B-54. If the SBAS broadcasts data that are not required for a particular function, the requirements for that data supporting other functions shall apply. The maximum interval between broadcasts for all data of each data type provided shall be as defined in Table B-54.

3.5.7.1.2 *SBAS radio frequency monitoring*. The SBAS shall monitor the SBAS satellite parameters shown in

Table B-55 and take the indicated action.

Note.— SBAS may broadcast null messages (Type 63 messages) in each time slot for which no other data are broadcast.

3.5.7.1.3 *"Do Not Use"*. SBAS shall broadcast a "Do Not Use" message(Type 0 message) when necessary to inform users not to use the SBAS satellite ranging function and its broadcast data.

3.5.7.1.4 *Almanac data.* SBAS shall broadcast almanac data for SBAS satellites (defined in 3.5.4.3) with error less than 150 km (81 NM) of the true satellite position. Unused almanac slots in Type 17 messages shall be coded with a PRN code number of "0". The health and status shall indicate satellite status and the service provider as defined in 3.5.4.3.

3.5.7.1.5 **Recommendation**.— SBAS should broadcast almanac data for all SBAS satellites, regardless of the service provider.

3.5.7.2 *Ranging function*. If an SBAS provides a ranging function, it shall comply with the requirements contained in this section in addition to the requirements of 3.5.7.1.

3.5.7.2.1 Performance requirements

Note.— See Chapter 3, 3.7.3.4.2.1.

3.5.7.2.2 *Ranging function data.* SBAS shall broadcast ranging function data such that the SBAS satellite position error projected on the line-of-sight to any user in the satellite footprint is less than 256 metres. Each SBAS satellite shall broadcast a URA representing an estimate of the standard deviation of the ranging errors referenced to SNT.

3.5.7.3 *GNSS satellite status function.* If an SBAS provides a satellite status function, it shall also comply with the requirements contained in this section.

3.5.7.3.1 *Performance of satellite status functions.* Given any valid combination of active data, the probability of a horizontal error exceeding the HPLSBAS(as defined in 3.5.5.6) for longer than 8 consecutive seconds shall be less than 10–7in any hour, assuming a user with zero latency.

Note.— Active data is defined to be data that have not timed out per 3.5.8.1.1. This requirement includes core satellite constellation(s) and SBAS failures.

3.5.7.3.2 *PRN mask and Issue of data — PRN (IODP).* SBAS shall broadcast a PRN mask and IODP (Type 1 message). The PRN mask values shall indicate whether or not data are being provided for each GNSS satellite. The IODP shall change when there is a change in the PRN mask. The change of IODP in Type 1 messages shall occur before the IODP changes in any other message. The IODP in Type 2 to 5, 7, 24 and 25 messages shall equal the IODP broadcast in the PRN mask message (Type 1 message) used to designate the satellites for which data are provided in that message.

Table B-54. Data broadcast intervals and supported functions

Data type	Maximum broadcast interval	Ranging	GNSS satellite status	Basic differential correction	Precise differential correction	Associated message types
Clock-Ephemeris covariance matrix	120 s					28
SBAS in test mode	6 s					0
PRN mask	120 s		R	R	R	1
UDREI	6 s		R*	R	R	2 to 6, 24
Fast corrections	$I_{fc}/2$ (see Note 4)		R*	R	R	2 to 5, 24
Long-term corrections	120 s		R*	R	R	24, 25
GEO ranging function data	120 s	R				9
Fast correction degradation	120 s		R*	R	R	7
Degradation parameters	120 s				R	10
Ionospheric grid mask	300 s				R	18
Ionospheric corrections, GIVEI	300 s				R	26
Timing data	300 s	R (see Note 3)	R (see Note 3)	R (see Note 3)	R (see Note 3)	12
Almanac data	300 s	R	R	R	R	17
Service level	300 s					27

Notes.—
1. "R" indicates that the data must be broadcast to support the function.
2. "R" indicates special coding as described in 3.5.7.3.3.*
3. Type 12 messages are only required if data are provided for GLONASS satellites.
4. I_{fc} refers to the PA/APV time-out interval for fast corrections, as defined in Table B-57.

Table B-55. SBAS radio frequency monitoring

Parameter	Reference	Alarm limit	Required action
Signal power level	Chapter 3, 3.7.3.4.4.3	minimum = −161 dBW maximum = −153 dBW (Note 2)	Minimum: cease ranging function (Note 1). Maximum: cease broadcast.
Modulation	Chapter 3, 3.7.3.4.4.5	monitor for waveform distortion	Cease ranging function (Note 1).
SNT-to-GPS time	Chapter 3, 3.7.3.4.5	N/A (Note 3)	Cease ranging function unless URA reflects error.
Carrier frequency stability	3.5.2.1	N/A (Note 3)	Cease ranging function unless σ^2_{UDRE} and URA reflect error.
Code/frequency coherence	3.5.2.4	N/A (Note 3)	Cease ranging function unless σ^2_{UDRE} and URA reflect error.
Maximum code phase deviation	3.5.2.6	N/A (Notes 2 and 3)	Cease ranging function unless σ^2_{UDRE} and URA reflect error.
Convolutional encoding	3.5.2.9	all transmit messages are erroneous	Cease broadcast.

Notes.—
1. *Ceasing the ranging function is accomplished by broadcasting a URA and σ^2_{UDRE} of "Do Not Use" for that SBAS satellite.*
2. *These parameters can be monitored by their impact on the received signal quality (C/N_0 impact), since that is the impact on the user.*
3. *Alarm limits are not specified because the induced error is acceptable, provided it is represented in the σ^2_{UDRE} and URA parameters. If the error cannot be represented, the ranging function must cease.*

3.5.7.3.2.1 *Recommendation.—* When the PRN mask is changed, SBAS should repeat the Type 1 message several times before referencing it in other messages to ensure that users receive the new mask.

3.5.7.3.3 *Integrity data.* If SBAS does not provide the basic differential correction function, it shall transmit fast corrections, long-term corrections and fast correction degradation parameters coded to zero for all visible satellites indicated in the PRN mask.

3.5.7.3.3.1 If SBAS does not provide the basic differential correction function, SBAS shall indicate that the satellite is unhealthy ("Do Not Use") if the pseudo-range error exceeds 150 metres.

3.5.7.3.3.2 If SBAS does not provide the basic differential correction function, SBAS shall indicate that the satellite is "Not Monitored" if the pseudo-range error cannot be determined.

3.5.7.3.3.3 If SBAS does not provide the basic differential correction function, SBAS shall transmit a UDREIiof 13 if the satellite is not “Do Not Use” or “Not Monitored”.

3.5.7.3.3.4 The IODFj parameter in Type 2 to 5, 6 or 24 messages shall be equal to 3.

3.5.7.4 Basic differential correction function. If an SBAS provides a basic differential correction function, it shall comply with the requirements contained in this section in addition to the GNSS satellite status function requirements defined in 3.5.7.3.

3.5.7.4.1 Performance of basic differential correction function. Given any valid combination of active data, the probability of a horizontal error exceeding the HPLSBAS(as defined in 3.5.5.6) for longer than 8 consecutive seconds shall be less than 10–7in any hour, assuming a user with zero latency.

Note.— Active data is defined to be data that has not timed out per 3.5.8.1.1. This requirement includes core satellite constellation(s) and SBAS failures.

3.5.7.4.2 Long-term corrections. Except for SBAS satellites from the same service provider, SBAS shall determine and broadcast long-term corrections for each visible GNSS satellite (see Note) indicated in the PRN mask (PRN mask value equal to “1”). The long-term corrections shall be such that the core satellite constellation(s) satellite position error projected on the line-of-sight to any user in the satellite footprint after application of these long-term corrections is less than 256 metres. For each GLONASS satellite, SBAS shall translate satellite coordinates into WGS-84 as defined in 3.5.5.2 prior to determining the long-term corrections. For each GPS satellite, the broadcast IOD shall match both the GPS IODE and 8 LSBs of IODC associated with the clock and ephemeris data used to compute the corrections (3.1.1.3.1.4 and 3.1.1.3.2.2). Upon transmission of a new ephemeris by a GPS satellite, SBAS shall continue touse the old ephemeris to determine the fast and long-term error corrections for at least 2 minutes and not more than4 minutes. For each GLONASS satellite, SBAS shall compute and broadcast an IOD that consists of a latency and a validity interval as defined in 3.5.4.4.1.

Note.— The criteria for satellite visibility include the locations of reference stations and the achieved mask angle at those locations.

3.5.7.4.2.1 **Recommendation.—** To ensure accurate range rate corrections, SBAS should minimize discontinuities in the satellite ephemerides after application of long-term corrections.

3.5.7.4.3 *Fast corrections*. SBAS shall determine fast corrections for each visible GNSS satellite indicated in the PRN mask (PRN mask value equal to "1"). Unless the IODF = 3, each time any fast correction data in Type j (j = 2, 3, 4 or 5) message changes, the IODFj shall sequence "0, 1, 2, 0, ...".

Note.— If there is an alarm condition, the IODFj may equal 3 (see 3.5.7.4.5).

3.5.7.4.4 Timing data. If data are provided for GLONASS, SBAS shall broadcast the timing message (Type 12 message) including GLONASS time offset as defined in Table B-44.

3.5.7.4.5 Integrity data. For each satellite for which corrections are provided, SBAS shall broadcast integrity data (UDREIi and, optionally, Type 27 or 28 message data to calculate δUDRE) such that the integrity requirement in 3.5.7.4.1 is met. If the fast corrections or long-term corrections exceed their coding range, SBAS shall indicate that the satellite is unhealthy ("Do Not Use"). If σ2i,UDRE cannot be determined, SBAS shall indicate that the satellite is "Not Monitored".

If Type 6 message is used to broadcast σ2i,UDRE, then:

a) the IODFj shall match the IODFj for the fast corrections received in Type j message to which the σ2i,UDRE apply; or

b) the IODFj shall equal 3 if the σ2i,UDRE apply to all valid fast corrections received in Type j message which have not timed out.

3.5.7.4.6 *Degradation data*. SBAS shall broadcast degradation parameters (Type 7 message) to indicate the applicable time out interval for fast corrections and ensure that the integrity requirement in 3.5.7.4.1 is met.

3.5.7.5 *Precise differential correction function.* If SBAS provides a precise differential correction function, it shall comply with the requirements contained in this section in addition to the basic differential correction function requirements in 3.5.7.4.

3.5.7.5.1 *Performance of precise differential correction function.* Given any valid combination of active data, the probability of an out-of-tolerance condition for longer than the relevant time-to-alert shall be less than 2 × 10–7during any approach, assuming a user with zero latency. The time-to-alert shall be 5.2 seconds for an SBAS that supports precision approach or APV-II operations, and 8 seconds for an SBAS that supports APV-I operations. An out-of-tolerance condition shall be defined as a horizontal error exceeding the HPL_{SBAS} or a vertical error exceeding the VPL_{SBAS}(as defined in 3.5.5.6). When an out-of-tolerance condition is detected, the resulting alert message (broadcast in a Type 2 to 5 and 6, 24, 26 or 27 messages) shall be repeated three times after the initial notification of the alert condition for a total of four times in 4 seconds.

Note 1.— Active data is defined to be data that has not timed out per 3.5.8.1.1. This requirement includes core satellite constellation(s) and SBAS failures.

Note 2.— Subsequent messages can be transmitted at the normal update rate.

3.5.7.5.2 *Ionospheric grid point (IGP) mask*. SBAS shall broadcast an IGP mask and IODIk(up to 11 Type 18 messages, corresponding to the 11 IGP bands). The IGP mask values shall indicate whether or not data are being provided for each IGP. If IGP Band 9 is used, then the IGP mask values for IGPs north of 55°N in Bands 0 through 8 shall be set to "0". If IGP Band 10 is used, then the IGP mask values for IGPs south of 55°S in Bands 0 through 8 shall be set to "0". The IODIk shall change when there is a change of IGP mask values in the k_{th} band. The new IGP mask shall be broadcast in a Type 18 message before it is referenced in a related Type 26 message. The IODIk in Type 26 message shall equal the IODIk broadcast in the IGP mask message (Type 18 message) used to designate the IGPs for which data are provided in that message.

3.5.7.5.2.1 **Recommendation.—** When the IGP mask is changed, SBAS should repeat the Type 18 message several times before referencing it in a Type 26 message to ensure that users receive the new mask. The same IODIk should be used for all bands.

3.5.7.5.3 *Ionospheric corrections*. SBAS shall broadcast ionospheric corrections for the IGPs designated in the IGP mask (IGP mask values equal to "1").

3.5.7.5.4 Ionospheric integrity data. For each IGP for which corrections are provided, SBAS shall broadcast GIVEI data such that the integrity requirement in 3.5.7.5.1 is met. If the ionospheric correction or σ2i,GIVEexceed their coding range, SBAS shall indicate the status "Do Not Use" (designated in the correction data, 3.5.4.6) for the IGP. If σ2i, GIVEcannot be determined, SBAS shall indicate that the IGP is "Not Monitored" (designated in the GIVEI coding).

3.5.7.5.5 *Degradation data*. SBAS shall broadcast degradation parameters (Type 10 message) such that the integrity requirement in 3.5.7.5.1 is met.

3.5.7.6OPTIONAL FUNCTIONS

3.5.7.6.1 *Timing data*. If UTC time parameters are broadcast, they shall be as defined in 3.5.4.8 (Type 12 message).

3.5.7.6.2 *Service indication*. If service indication data are broadcast, they shall be as defined in 3.5.4.9 (Type 27 message) and Type 28 messages shall not be broadcast. The IODS in all Type 27 messages shall increment when there is a change in any Type 27 message data.

3.5.7.6.3 *Clock-ephemeris covariance matrix*. If clock-ephemeris covariance matrix data are broadcast, they shall be broadcast for all monitored satellites as defined in 3.5.4.10 (Type 28 message) and Type 27 messages shall not be broadcast.

3.5.7.7MONITORING

3.5.7.7.1 *SBAS radio frequency monitoring*. The SBAS shall monitor the SBAS satellite parameters shown in Table B-55 and take the indicated action.

Note.— In addition to the radio frequency monitoring requirements in this section, it will be necessary to make special provisions to monitor pseudo-range acceleration specified in Chapter 3, 3.7.3.4.2.1.5, and carrier phase noise specified in 3.5.2.2 and correlation loss in 3.5.2.5, unless analysis and testing shows that these parameters cannot exceed the stated limits.

3.5.7.7.2 *Data monitoring*. SBAS shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers with the tracking performance defined in Attachment D, 8.11.

3.5.7.7.2.1 The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo range corrections.

3.5.7.7.2.2 The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the Early-Late discriminator function as defined in Attachment D, 8.11.

3.5.7.7.2.3 The monitor action shall be to set UDRE to “Do Not Use” for the satellite.

3.5.7.7.2.4 SBAS shall monitor all active data that can be used by any user within the service area.

3.5.7.7.2.5 SBAS shall raise an alarm within 5.2 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for precision approach or APV II (3.5.7.5.1).

3.5.7.7.2.6 SBAS shall raise an alarm within 8 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for en-route through APV I (3.5.7.4.1).

Note.— The monitoring applies to all failure conditions, including failures in core satellite constellation(s) or SBAS satellites. This monitoring assumes that the aircraft element complies with the requirements of RTCA/DO-229C, except as superseded by 3.5.8 and Attachment D, 8.11.

3.5.7.8 Robustness to core satellite constellation(s) failures. Upon occurrence of a core satellite constellation(s) satellite anomaly, SBAS shall continue to operate normally using the available healthy satellite signals that can be tracked.

3.5.8 AIRCRAFT ELEMENTS

Note 1.— The parameters that are referred to in this section are defined in 3.5.4.

Note 2.— Some of the requirements of this section may not apply to equipment that integrates additional navigation sensors, such as equipment that integrates SBAS with inertial navigation sensors.

3.5.8.1 *SBAS-capable GNSS receiver.* Except as specifically noted, the SBAS-capable GNSS receiver shall process the signals of the SBAS and meet the requirements specified in 3.1.3.1 (GPS receiver) and/or 3.2.3.1 (GLONASS receiver).

Pseudo-range measurements for each satellite shall be smoothed using carrier measurements and a smoothing filter which deviates less than 0.1 metre within 200 seconds after initialization, relative to the steady-state response of the filter defined in

3.6.5.1 in the presence of drift between the code phase and integrated carrier phase of up to 0.01 metre per second.

3.5.8.1.1 Conditions for use of data. The receiver shall use data from an SBAS message only if the CRC of this message has been verified. Reception of a Type 0 message from an SBAS satellite shall result in deselection of that satellite and all data from that satellite shall be discarded for at least 1 minute. For GPS satellites, the receiver shall apply long-term corrections only if the IOD matches boththe IODE and 8 least significant bits of the IODC. For GLONASS satellites, the receiver shall apply long-term corrections only if the time of reception (tr) of the GLONASS ephemeris is inside the following IOD validity interval, as defined in 3.5.4.4.1:

$$t_{LT} - L - V \leq t_r \leq t_{LT} - L$$

Note 1.— For SBAS satellites, there is no mechanism that links GEO ranging function data (Type 9 message) and long term corrections.

Note 2.— This requirement does not imply that the receiver has to stop tracking the SBAS satellite.

3.5.8.1.1.1 The receiver shall use integrity or correction data only if the IODP associated with that data matches the IODP associated with the PRN mask.

3.5.8.1.1.2 The receiver shall use SBAS-provided ionospheric data (IGP vertical delay estimate and GIVEIi) only if the IODIk associated with that data in a Type 26 message matches the IODIk associated with the relevant IGP band mask transmitted in a Type 18 message.

3.5.8.1.1.3 The receiver shall use the most recently received integrity data for which the IODFj equals 3 or the IODFj matches the IODFj associated with the fast correction data being applied (if corrections are provided).

3.5.8.1.1.4 The receiver shall apply any regional degradation to the σ2i, UDRE as defined by a Type 27 service message. If a Type 27 message with a new IODS indicates a higher δUDRE for the user location, the higher δUDRE shall be applied immediately. A lower δUDRE in a new Type 27 message shall not be applied until the complete set of messages with the new IODS has been received.

3.5.8.1.1.5 The receiver shall apply satellite-specific degradation to the σi,UDRE2

as defined by a Type 28 clockephemeris covariance matrix message. The δUDRE derived from a Type 28 message shall be applied immediately.

3.5.8.1.1.6 In the event of a loss of four successive SBAS messages, the receiver shall no longer support SBAS-based precision approach or APV operations.

3.5.8.1.1.7 The receiver shall not use a broadcast data parameter after it has timed out as defined in Table B-56.

Table B-56. Data time-out intervals

Data	Associated message types	En-route, terminal, NPA time-out	Precision approach, APV time-out
Clock-ephemeris covariance matrix	28	360	240
SBAS in test mode	0	N/A	N/A
PRN mask	1	600 s	600 s
UDREI	2 to 6, 24	18 s	12 s
Fast corrections	2 to 5, 24	(see Table B-57)	(see Table B-57)
Long-term corrections	24, 25	360 s	240 s
GEO ranging function data	9	360 s	240 s
Fast correction degradation	7	360 s	240 s
Degradation parameters	10	360 s	240 s
Ionospheric grid mask	18	1 200 s	1 200 s
Ionospheric corrections, GIVEI	26	600 s	600 s
Timing data	12	86 400 s	86 400 s
GLONASS time offset	12	600 s	600 s
Almanac data	17	None	None
Service level	27	86 400 s	86 400 s

Note.— The time-out intervals are defined from the end of the reception of a message.

Table B-57. Fast correction time-out interval evaluation

Fast correction degradation factor indicator (ai_i)	NPA time-out interval for fast corrections (I_{fc})	PA/APV time-out interval for fast corrections (I_{fc})
0	180 s	120 s
1	180 s	120 s
2	153 s	102 s
3	135 s	90 s
4	135 s	90 s
5	117 s	78 s
6	99 s	66 s
7	81 s	54 s
8	63 s	42 s
9	45 s	30 s
10	45 s	30 s
11	27 s	18 s
12	27 s	18 s
13	27 s	18 s
14	18 s	12 s
15	18 s	12 s

3.5.8.1.1.8 The receiver shall not use a fast correction if Δt for the associated RRC exceeds the time-out interval for fast corrections, or if the age of the RRC exceeds $8\Delta t$.

3.5.8.1.1.9 The calculation of the RRC shall be reinitialized if a "Do Not Use" or "Not Monitored" indication is received for that satellite.

3.5.8.1.1.10 For SBAS-based precision approach or APV operations, the receiver shall only use satellites with elevation angles at or above 5 degrees.

3.5.8.1.1.11 The receiver shall no longer support SBAS-based precision approach or APV operation using a particular satellite if the UDREIireceived is greater than or equal to 12.

3.5.8.2RANGING FUNCTION

3.5.8.2.1 Precision approach and APV operations. The root-mean-square (1 sigma)of the total airborne error contribution to the error in a corrected pseudo-range for an SBAS satellite at the minimum received signal power level (Chapter 3, 3.7.3.4.4.3) under the worst interference environment as defined in 3.7 shall be less than or equal to 1.8 metres, excluding multipath effects, tropospheric and ionospheric residual errors.

Note.— The aircraft element will bound the errors caused by multipath and troposphere (3.5.8.4.1). For the purpose of predicting service, the multipath error is assumed to be less than 0.6 metres (1 sigma).

3.5.8.2.2 Departure, en-route, terminal, and non-precision approach operations. The root-mean-square (1 sigma) of the total airborne contribution to the error in a corrected pseudo-range for an SBAS satellite at the minimum received signal power level (Chapter 3, 3.7.3.4.4.3) under the worst interference environment as defined in 3.7 shall be less than or equal to 5 metres, excluding multipath, tropospheric and ionospheric errors.

3.5.8.2.3 SBAS satellite position

3.5.8.2.3.1 *Position computation*. The receiver shall decode Type 9 message and determine the code phase offset and position (XG, YG, ZG) of the SBAS satellite.

3.5.8.2.3.2 SBAS satellite identification. The receiver shall discriminate between SBAS satellites.

Note.— This requirement applies to false acquisition of a satellite due to cross-correlation.

3.5.8.2.4 Almanac data

3.5.8.2.4.1 **Recommendation.—** The almanac data provided by the SBAS should be used for acquisition.

Note.— Health and status information is provided in the GEO almanac data to support acquisition, but need not be used as a condition for use of that satellite.

3.5.8.3 GNSS satellite status function. The receiver shall exclude satellites from the position solution if they are identified as "Do Not Use" by SBAS. If SBAS-provided integrity is used, the receiver shall not be required to exclude GPS satellites based on the GPS-provided ephemeris health flag as required in 3.1.3.1.1 or to exclude GLONASS satellites based on GLONASS-provided ephemeris health flag as required in 3.2.3.1.1.

Note 1.— In the case of a satellite designated unhealthy by the core satellite constellation(s) health flag, SBAS may be able to broadcast ephemeris and clock corrections that will allow the user to continue using the satellite.

Note 2.— If satellites identified as "Not Monitored" by SBAS are used in the position solution, integrity is not provided by SBAS. ABAS or GBAS may be used to provide integrity, if available.

3.5.8.4BASIC AND PRECISE DIFFERENTIAL FUNCTIONS

3.5.8.4.1 *Core satellite constellation(s) ranging accuracy*. The root-mean-square (1 sigma) of the total airborne contribution to the error in a corrected pseudo-range for a GPS satellite at the minimum received signal power level (Chapter 3, 3.7.3.1.5.4) under the worst interference environment as defined in 3.7 shall be less than or equal to 0.4 metres, excluding multipath effects, tropospheric and ionospheric residual errors. The RMS of the total airborne contribution to the error in a corrected pseudo-range for a GLONASS satellite at the minimum received signal power level (Chapter 3, 3.2.5.4) under the worst interference environment as defined in 3.7 shall be less than or equal to 0.8 metres, excluding multipath effects, tropospheric and ionospheric residual errors.

3.5.8.4.2 Precision approach and APV operations

3.5.8.4.2.1 The receiver shall compute and apply long-term corrections, fast corrections, range rate corrections and the broadcast ionospheric corrections. For GLONASS satellites, the ionospheric corrections received from the SBAS shall be multiplied by the square of the ratio of GLONASS to GPS frequencies (fGLONASS/fGPS)2.

3.5.8.4.2.2 The receiver shall use a weighted-least-squares position solution.

3.5.8.4.2.3 The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a 1 sigma deviation less than 0.07 metres.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment D, 6.7.3.

3.5.8.4.2.4 The receiver shall compute and apply horizontal and vertical protection levels defined in 3.5.5.6. In this computation, σ_{tropo} shall be

$$\frac{1}{\sqrt{0{,}002+\mathrm{sen}^2(\theta_i)}} \times 0{,}12 \text{ m}$$

where θi is the elevation angle of the ith satellite.

In addition, σ_{air} shall satisfy the condition that a normal distribution with zero mean and a standard deviation equal to σ_{air} bounds the error distribution for residual aircraft pseudo-range errors as follows:

$$\int_{y}^{\infty} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where

fn(x) = probability density function of the residual aircraft pseudo-range error and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}} dt$$

Note.— The standard allowance for airborne multipath defined in 3.6.5.5.1 may be used to bound the multipath errors.

3.5.8.4.2.5 For precision approach and APV operations, the service provider ID broadcast Type 17 message shall be identical to the service provider ID in the FAS data block, except if ID equals 15 in the FAS data block.

Note.— For SBAS, FAS data blocks are stored in airborne databases. The format of the data for validation of a cyclic redundancy check is shown in Attachment D, 6.6. It differs from the GBAS FAS data block in 3.6.4.5 in that it contains the SBAS HAL and VAL for the particular approach procedure. For approaches conducted using SBAS pseudo-range corrections, the service provider ID in the FAS data block is the same as the service provider ID broadcast as part of the health and status information in Type 17 message. If the service provider ID in the FAS data block equals 15, then any service provider can be used. If the service provider ID in the FAS data block equals 14, then SBAS precise differential corrections cannot be used for the approach.

3.5.8.4.3 Departure, en-route, terminal, and non-precision approach operations

3.5.8.4.3.1 The receiver shall compute and apply long-term corrections, fast corrections and range rate corrections.

3.5.8.4.3.2 The receiver shall compute and apply ionospheric corrections.

Note.— Two methods of computing ionospheric corrections are provided in 3.1.2.4 and 3.5.5.5.2.

3.5.8.4.3.3 The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a standard deviation less than 0.07 metres.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment D, 6.7.3.

3.5.8.4.3.4 The receiver shall compute and apply horizontal and vertical protection levels as defined in 3.5.5.6. In this computation, s_{tropo} shall be:

$$\frac{1}{\sqrt{0{,}002+\mathrm{sen}^2(\theta_i)}}\times 0.12\ \mathrm{m}$$

where θi is the elevation angle of the ith satellite.

In addition, σ_{air} shall satisfy the condition that a normal distribution with zero mean and standard deviation equal to σ_{air} bounds the error distribution for residual aircraft pseudo-range errors as follows:

$$\int_{y}^{\infty} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where

fn(x) = probability density function of the residual aircraft pseudo-range error and

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_{x}^{\infty} e^{-\frac{t^2}{2}} dt$$

Note.— The standard allowance for airborne multipath defined in 3.6.5.5.1 may be used to bound the multipath errors.

3.5.8.4.4 Recommendation.— For departure, en-route, terminal, and non-precision approach operations, the receiver should use the broadcast ionospheric corrections, when available, and a tropospheric model with performance equal to that specified in 3.5.8.4.3.

3.5.9 INTERFACE BETWEEN SBAS

Note.— Guidance material on the interface between different SBAS service providers is given in Attachment D, 6.3.

3.6 Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

Note.— In this section, except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.

3.6.1 GENERAL

The GBAS shall consist of a ground subsystem and an aircraft subsystem. The GBAS ground subsystem shall provide data and corrections for the GNSS ranging signals over a digital VHF data broadcast to the aircraft subsystem. The GRAS ground subsystem shall consist of one or more GBAS ground subsystems.

Note.— Guidance material is provided in Attachment D, 7.1.

3.6.2 RFCHARACTERISTICS

3.6.2.1 *Carrier frequency stability*. The carrier frequency of the data broadcast shall be maintained within ±0.0002 per cent of the assigned frequency.

3.6.2.2 *Bit-to-phase-change encoding.* GBAS messages shall be assembled into symbols, each consisting of 3 consecutive message bits. The end of the message shall be padded by 1 or 2 fill bits if necessary to form the last 3-bit symbol of the message. Symbols shall be converted to D8PSK carrier phase shifts (Δφk) in accordance with Table B-58.

Note.— The carrier phase for the k_{th} symbol (φk) is given by: φk= φk-1+ Δφk.. The D8PSK signal may be produced as shown in Figure B-19 by combining two quadrature RF signals which are independently suppressed-carrier amplitude modulated by base band filtered impulses. A positive increase in Δφk represents a counterclockwise rotation in the complex I-Q plane of Figure B-19.

3.6.2.3 *Modulation wave form and pulse shaping filters*. The output of differential phase encoder shall be filtered by a pulse shaping filter whose output, s(t), is described as follows:

$$s(t)=\sum_{k=-\infty}^{k=\infty} e^{j\phi_k}\, h\,(t-kT)$$

where

h = the impulse response of the raised cosine filter;

φk = (as defined in 3.6.2.2);

t = time; and

T = the duration of each symbol = 1/10 500 second.

This pulse shaping filter shall have a nominal complex frequency response of a raised-cosine filter with α= 0.6. The time response, h(t), and frequency response, H(f), of the base band filters shall be as follows:

$$h(t)=\frac{\text{sen}\left(\frac{\pi t}{T}\right)\cos\left(\frac{\pi\alpha t}{T}\right)}{\frac{\pi t}{T}\left[1-\left(\frac{2\alpha t}{T}\right)^2\right]}$$

$$
H(f)=\begin{cases} 1 & \text{for} \quad 0 \le f < \dfrac{1-\alpha}{2T} \\ \dfrac{1-\operatorname{sen}\left(\dfrac{\pi}{2\alpha}(2fT-1)\right)}{2} & \text{for} \quad \dfrac{1-\alpha}{2T} \le f \le \dfrac{1+\alpha}{2T} \\ 0 & \text{for} \quad f > \dfrac{1+\alpha}{2T} \end{cases}
$$

The output s(t) of the pulse shaping filter shall modulate the carrier.

3.6.2.4 *Error vector magnitude*. The error vector magnitude of the transmitted signal shall be less than 6.5 per cent root-mean-square (1 sigma).

3.6.2.5 RF data rate. The symbol rate shall be 10 500 symbols per second ±0.005 per cent, resulting in a nominal bit rate of 31 500 bits per second.

Table B-58. Data encoding

Message bits			Symbol phase shift
I_{3k-2}	I_{3k-1}	I_{3k}	$\Delta\phi_k$
0	0	0	0π/4
0	0	1	1π/4
0	1	1	2π/4
0	1	0	3π/4
1	1	0	4π/4
1	1	1	5π/4
1	0	1	6π/4
1	0	0	7π/4

Note.— I_j is the j^{th} bit of the burst to be transmitted, where I_1 is the first bit of the training sequence.

3.6.2.6 *Emissions in unassigned time slots.* Under all operating conditions, the maximum power over a 25 kHz channel bandwidth, centred on the assigned frequency, when measured over any unassigned time slot, shall not exceed –105 dBc referenced to the authorized transmitter power.

Note. – If the authorized transmitter power is higher than 150 W, the –105 dBc may not protect reception of emissions in a slot assigned to another desired transmitter for receivers within 200 metres from the undesired transmitting antenna.

3.6.3 DATA STRUCTURE

3.6.3.1 TRANSMITTER TIMING

3.6.3.1.1 *Data broadcast timing structure*. The time division multiple access (TDMA) timing structure shall be based on frames and time slots. Each frame shall be 500 milliseconds in duration. There shall be 2 such frames contained in each 1-second UTC epoch. The first of these frames shall start at the beginning of the UTC epoch and the second frame shall start 0.5 seconds after the beginning of the UTC epoch. The frame shall be time division multiplexed such that it shall consist of 8 individual time slots (A to H) of 62.5-millisecond duration.

3.6.3.1.2 *Bursts.* Each assigned time slot shall contain at most 1 burst. To initiate the use of a time slot, the GBAS shall broadcast a burst in that time slot in each of 5 consecutive frames. For each time slot in use, the ground subsystem shall broadcast a burst in at least 1 frame of every 5 consecutive frames.

Note 1.— Bursts contain one or more messages and may be of variable length up to the maximum allowed within the slot as required by 3.6.3.2.

Note 2.— During time slot initiation, the airborne receiver may not receive the first 4 bursts.

3.6.3.1.3 Timing budget for bursts

3.6.3.1.3.1 Each burst shall be contained in a 62.5-millisecond time slot.

3.6.3.1.3.2 The beginning of the burst shall occur 95.2 microseconds after the beginning of the time slot with a tolerance of ±95.2 microseconds.

3.6.3.1.3.3 For GBAS/E equipment, the start of the synchronization and ambiguity resolution portion of the burst, transmitted with horizontal polarization (HPOL), shall occur within 10 microseconds of the start of the burst transmitted with vertical polarization (VPOL).

Note.— Table B-59 illustrates the burst timing.

3.6.3.1.4 *Ramp-up and transmitter power stabilization*. The transmitter shall ramp up to 90 per cent of the steady-state power level within 190.5 microseconds after the beginning of the burst (2 symbols). The transmitter shall stabilize at the steady-state power within 476.2 microseconds after the beginning of the burst (5 symbols).

Note.— The transmitter power stabilization period may be used by the aircraft receiver to settle its automatic gain control.

3.6.3.1.5 *Ramp-down.* After the final information symbol is transmitted in an assigned time slot, the transmitter output power level shall decrease to at least 30 dB below the steady-state power within 285.7 microseconds (3 symbols).

3.6.3.2 *Burst organization and coding*. Each burst shall consist of the data elements shown in Table B-60. Encoding of the messages shall follow the sequence: application data formatting, training sequence forward error correction (FEC) generation, application FEC generation and bit scrambling.

3.6.3.2.1 *Synchronization and ambiguity resolution*. The synchronization and ambiguity resolution field shall consist of the 48-bit sequence shown below, with the rightmost bit transmitted first:

010 001 111 101 111 110 001 100 011 101 100 000 011 110 010 000

Table B-59. Burst timing

Event	Nominal event duration	Nominal percentage of steady-state power
Ramp-up	190.5 μs	0% to 90%
Transmitter power stabilization	285.7 μs	90% to 100%
Synchronization and ambiguity resolution	1 523.8 μs	100%
Transmission of scrambled data	58 761.9 μs	100%
Ramp-down	285.7 μs (Note 1)	100% to 0%

Notes.—

1. *Event duration indicated for transmission of scrambled data is for maximum application data length of 1 776 bits, 2 fill bits and nominal symbol duration.*

2. *These timing requirements provide a propagation guard time of 1 259 microseconds, allowing for a one-way propagation range of approximately 370 km (200 NM).*

3. *Where bursts from a GBAS broadcast antenna can be received at a range more than 370 km (200 NM) greater than the range from another broadcast antenna using the next adjacent slot, a longer guard time is required to avoid loss of both bursts. To provide a longer guard time, it is necessary to limit the application data length of the first burst to 1 744 bits. This allows a difference in propagation ranges of up to 692 km (372 NM) without conflict.*

Table B-60. Burst data content

Element	Data content	Number of bits
Beginning of burst	all zeros	15
Power stabilization		
Synchronization and ambiguity resolution	3.6.3.2.1	48
Scrambled data:	3.6.3.3	
station slot identifier (SSID)	3.6.3.3.1	3
transmission length	3.6.3.3.2	17
training sequence FEC	3.6.3.3.3	5
application data	3.6.3.3.4	up to 1 776
application FEC	3.6.3.3.5	48
fill bits (Note)	3.6.2.2	0 to 2

Note.— Data scrambling of the fill bits is optional (3.6.3.3.6).

3.6.3.3SCRAMBLED DATA CONTENT

3.6.3.3.1 *Station slot identifier (SSID).* The SSID shall be a numeric value corresponding to the letter designation A to H of the first time slot assigned to the GBAS ground subsystem, where slot A is represented by 0, B by 1, C by 2, … and H by 7. The identifier is transmitted LSB first.

3.6.3.3.2 *Transmission length.* The transmission length shall indicate the total number of bits in both application data and application FEC. The transmission length is transmitted LSB first.

3.6.3.3.3 *Training sequence FEC.* The training sequence FEC shall be computed over the SSID and transmission length fields, using a (25, 20) block code, in accordance with the following equation:

$$[P_1, \ldots, P_5] = [SSID_1, \ldots, SSID_3, TL_1, \ldots, TL_{17}]\, H^T$$

Pn = the nth bit of the training sequence FEC (P1shall be transmitted first);

SSIDn= the nth bit of the station slot identifier (SSID1= LSB);

TLn= the nth bit in the transmission length (TL1= LSB); and

H^T = the transpose of the parity matrix, defined below:

$$H^T = \begin{bmatrix} 0&0&0&0&0&0&0&0&1&1&1&1&1&1&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1&1&0&0&0&0&1&1&1&1&1&1&1&1 \\ 1&1&0&0&0&1&1&1&0&0&1&1&0&0&0&0&1&1&1&1 \\ 1&1&0&1&1&0&1&1&0&1&0&1&0&0&1&1&0&0&1&1 \\ 0&1&1&0&1&0&0&1&1&1&1&0&0&1&0&1&0&1&0&1 \end{bmatrix}^T$$

Note.— This code is capable of correcting all single bit errors and detecting 75 of 300 possible double bit errors.

3.6.3.3.4 *Application data.* The application data shall consist of one or more message blocks, as defined in 3.6.3.4. The message blocks shall be mapped directly into the application data with no additional overhead of intervening layers.

3.6.3.3.5 *Application FEC.* The application FEC shall be calculated using the application data by means of a systematic, fixed-length, Reed-Solomon (R-S) (255, 249) code.

3.6.3.3.5.1 The field-defining primitive, p(x), of the R-S code shall be

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

3.6.3.3.5.2 The generator polynomial of the R-S code, g(x), shall be:

$$g(x)=\prod_{i=120}^{125}(x-\alpha^i)= x^6 + \alpha^{176}x^5 + \alpha^{186}x^4 + \alpha^{244}x^3 + \alpha^{176}x^2 + \alpha^{156}x + \alpha^{225}$$

where αis a root of p(x) used for construction of the Galois Field of size 28,GF(256), and αi is the ith primitive element in GF(256).

3.6.3.3.5.3 In generating the application FEC, the data tobe encoded, m(x), shall be grouped into 8-bit R-S symbols. All data fields in the message blocks that define the application data shall be ordered such as specified in Tables B-61 and B-62, and in the message tables in 3.6.6. However, since the R-S code is a block code, application data blocks shorter than 249 bytes (1 992 bits) shall be extended to 249 bytes by virtual fill bits set to zero and appended to the application data. These virtual fill bits shall not be transferred to the bit scrambler. The data to be encoded, m(x), shall be defined by:

$$m(x) = a_{248}x^{248} + a_{247}x^{247} + ... + a_{248\text{-length}+1}\, x^{248\text{-length}+1} + a_{248\text{-length}}\, x^{248\text{-length}} + ... + a_1x+a_0$$

where

length represents the number of 8-bit bytes in the application data block;

a248represents the message block identifier, with the rightmost bit defined as the LSB and the first bit of the application data sent to the bit scrambler;

a248-length+1represents the last byte of the message block CRC, with the leftmost bit defined as the MSB and the last bit of the application data sent to the bit scrambler; and

a248-length, ..., a1, a0are the virtual fill bits (if any).

3.6.3.3.5.4 The 6 R-S check symbols (bi) shall be defined as the coefficients of the remainder resulting from dividing the message polynomial x6 m(x) by the generator polynomial g(x):

$$b(x)=\sum_{i=0}^{5} b_i x^i + b_5x^5+b_4x^4+b_3x^3+b_2x^2+b_1x^1+b_0 = [x^6m(x)] \bmod g(x)$$

3.6.3.3.5.5 The 8-bit R-S check symbols shall be appended to the application data. Each 8-bit R-S check symbol shall be transmitted MSB first from b0to b5, i.e. the first application FEC bit transferred to the bit scrambler shall be the MSB of b0and the last application FEC bit transferred to the bit scrambler shall be the LSB of b5.

Note 1.— This R-S code is capable of correcting up to 3 symbol errors.

Note 2.— The order of the transmitted 8-bit R-S check symbols of the appended application FEC differs from the VHF data link (VDL) Mode 2. Moreover, for VDL Mode 2 each R-S check symbol is transmitted LSB first.

Note 3.— Example results of application FEC encoding are given in Attachment D, 7.15.

Table B-61. Format of a GBAS message block

Message block	Bits
Message block header	48
Message	up to 1 696
CRC	32

Table B-62. Format of message block header

Data field	Bits
Message block identifier	8
GBAS ID	24
Message type identifier	8
Message length	8

3.6.3.3.6 Bit scrambling

3.6.3.3.6.1 The output of a pseudo-noise scrambler with a 15-stage generator register shall be exclusive OR'ed with the burst data starting with the SSID and ending with the application FEC. Bit scrambling of the fill bits is optional and the set value of the fill bits is optional.

Note.— The fill bits are not used by the aircraft receiver and their values have no impact on the system.

3.6.3.3.6.2 The polynomial for the register taps of the scrambler shall be 1 + x + x15. The register content shall be rotated at the rate of one shift per bit. The initial status of the register, prior to the first SSID bit of each burst, shall be "11010010 1011 001", with the leftmost bit in the first stage of the register. The first output bit of the scrambler shall be sampled prior to the first register shift.

Note.— A diagram of the bit scrambler is given in Attachment D, 7.4.

3.6.3.4 *Message block format.* The message blocks shall consist of a message block header, a message and a 32-bit CRC. Table B-61 shows the construction of the message block. All signed parameters shall be two's complement numbers and all unsigned parameters shall be unsigned fixed point numbers. The scaling of the data shall be as shown in the message tables in 3.6.6. All data fields in the message block shall be transmitted in the order specified in the message tables, with the LSB of each field transmitted first.

Note.— All binary representations reading left to right are MSB to LSB.

3.6.3.4.1 Message block header. The message block header shall consist of a message block identifier, a GBAS identifier (ID), a message type identifier and a message length, as shown in Table B-62. Message block identifier: the 8-bit identifier for the operating mode of the GBAS message block.

Coding: 1010 1010 = normal GBAS message
1111 1111 = test GBAS message
All other values are reserved.

GBAS ID:the four-character GBAS identification to differentiate between GBAS ground subsystems.

Coding: Each character is coded using bits b1 through b6 of its International Alphabet No. 5 (IA-5) representation. For each character, bit b1is transmitted first and six bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 “space” are used. The rightmost character is transmitted first. For a three-character GBAS ID, the rightmost (first transmitted) character shall be IA-5 “space”.

Note.— The GBAS ID is normally identical to the location indicator at the nearest airport. Assignment of GBAS IDs will be coordinated as appropriate to avoid conflicts.

Message type identifier: the numeric label identifying the content of the message (Table B-63).

Message length: the length of the message in 8-bit bytes including the 6-byte message block header, the message and the 4-byte message CRC code.

3.6.3.4.2 Cyclic redundancy check (CRC). The GBAS message CRC shall be calculated in accordance with 3.9.

3.6.3.4.2.1 The length of the CRC code shall be k = 32 bits.

3.6.3.4.2.2 The CRC generator polynomial shall be:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} + x^{3} + x + 1$$

3.6.3.4.2.3 The CRC information field, M(x), shall be:

$$M(x)=\sum_{i=1}^{n} m_i x^{n-i} + m_1 x^{n-1} + m_2 x^{n-2} + \ldots + m_n x^0$$

3.6.3.4.2.4 M(x) shall be formed from the 48-bit GBAS message block header and all bits of the variable-length message, excluding the CRC. Bits shall be arranged in the order transmitted, such that m1corresponds to the first transmitted bit of the message block header, and m_n corresponds to the last transmitted bit of the (n-48) message bits.

3.6.3.4.2.5 The CRC shall be ordered such that r1is the first bit transmitted and r32is the last bit transmitted.

3.6.4 DATA CONTENT

3.6.4.1 *Message types.* The message types that can be transmitted by GBAS shall be as in Table B-63.

3.6.4.2 TYPE 1MESSAGE – PSEUDO-RANGE CORRECTIONS

3.6.4.2.1 The Type 1 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70). The message shall contain three sections:

a) message information (time of validity, additional message flag, number of measurements and the measurement type);

b) low-frequency information (ephemeris decorrelation parameter, satellite ephemeris CRC and satellite availability information); and

c) satellite data measurement blocks.

Note.— Transmission of the low-frequency data for SBAS ranging sources is optional.

3.6.4.2.2 Each Type 1 message shall include ephemeris decorrelation parameter, ephemeris CRC and source availability duration parameters for one satellite ranging source. The ephemeris decorrelation parameter, ephemeris CRC and source availability duration shall apply to the first ranging source in the message.

3.6.4.2.3 Pseudo-range correction parameters shall be as follows:

Modified Z-count: the indication of the time of applicability for all the parameters in the message.

Coding: the modified Z-count resets on the hour (xx:00), 20 minutes past the hour

(xx:20) and 40 minutes past the hour (xx:40) referenced to GPS time.

Additional message flag: an identification of whether the set of measurement blocks in a single frame for a particular measurement type is contained in a single Type 1 message or a linked pair of messages.

Coding: 0 = All measurement blocks for a particular measurement type are contained in one Type 1 message.

1 = This is the first transmitted message of a linked pair of Type 1 messages that together contain the set of all measurement blocks for a particular

measurement type.
2= Spare
3= This is the second transmitted message of a linked pairof Type 1 messages that together contain the set of all measurement blocks for a particular measurement type.

Note.— When a linked pair of Type 1 messages is used for a particular measurement type, the number of measurements and low-frequency data are computed separately for each of the two individual messages.

Number of measurements: the number of measurement blocks in the message.

Measurement type: the type of ranging signal from which the corrections have been computed.

Table B-63. GBAS VHF data broadcast messages

Message type identifier	Message name
0	Spare
1	Pseudo-range corrections
2	GBAS-related data
3	Null message
4	Final approach segment (FAS) data
5	Predicted ranging source availability
6	Reserved
7	Reserved for national applications
8	Reserved for test applications
9 to 100	Spare
101	GRAS pseudo-range corrections
102 to 255	Spare

Note.— See 3.6.6 for message formats.

Coding: 0 = C/A or CSA code L1
1 = reserved
2 = reserved
3 = reserved
4 to 7 = spare

Ephemeris decorrelation parameter(P): a parameter that characterizes the impact of residual ephemeris errors due to decorrelation for the first measurement block in the message.

For a SBAS geostationary satellite, the ephemeris decorrelation parameter, if transmitted, shall be coded as all zeros.

For GBAS ground subsystems that do not broadcast the additional data block 1 in the Type 2 message, the ephemeris decorrelation parameter shall be coded as all zeros.

Ephemeris CRC: the CRC computed with the ephemeris data used to determine corrections for the first measurement block in the message. The ephemeris CRC for core satellite constellation(s) ranging sources shall be calculated in accordance with 3.9. The length of the CRC code shall be k = 16 bits. The CRC generator polynomial shall be:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The CRC information field, M(x), for a given satellite shall be:

$$M(x)= \sum_{i=1}^{n} m_i\, x^{n-1} + m_1 x^{n-1} + m_2 x^{n-2} + \ldots + m_n x^0$$

For a GPS satellite, M(x) shall be of length n = 576 bits. M(x) for a GPS satellite shall be calculated using the first 24 bits from each of words 3 to S10 of subframes 1, 2 and 3 of the data transmission from that satellite, ANDed with the GPS satellite ephemeris mask of Table B-64. M(x) shall be arranged in the order that bytes are transmitted by the GPS satellite, but with each byte ordered LSB first, such that m1corresponds to bit 68 of subframe 1, and m576 corresponds to bit 287 of subframe 3.

Note.— M(x) for a GPS satellite does not include word 1 (TLM) or word 2 (HOW), which start each subframe, or the 6 parity bits at the end of each word.

For a GLONASS satellite, M(x) shall be of length n = 340 bits. M(x) for a GLONASS satellite shall be calculated using strings 1, 2, 3 and 4 of the data transmission from thatsatellite, ANDed with the GLONASS satellite ephemeris mask of Table B-65. Bits shall be arranged in transmission order such that m1corresponds to bit 85 of string 1, and m340corresponds to bit 1 of string 4.

For a SBAS geostationary satellite, the ephemeris CRC, if transmitted shall be coded as all zeros.

The CRC shall be transmitted in the order r9, r10, r11...., r16, r1, r2, r3...r8, where ri is the ith coefficient of the remainder R(x) as defined in 3.9.

Source availability duration: the predicted duration for which corrections for the ranging source are expected to remain available, relative to the modified Z-count for the first measurement block.

Coding: 1111 1110 = The duration is greater than or equal to 2 540 seconds.
1111 1111 = Prediction of source availability duration is not provided by this ground subsystem.

3.6.4.2.4 The measurement block parameters shall be as follows:

Ranging source ID: the identity of the ranging source to which subsequent measurement block data are applicable.

Table B-64. GPS satellite ephemeris mask

Subframe 1:	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Word 3	0000 0000	0000 0000	0000 0011	Word 4	0000 0000	0000 0000	0000 0000
Word 5	0000 0000	0000 0000	0000 0000	Word 6	0000 0000	0000 0000	0000 0000
Word 7	0000 0000	0000 0000	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	1111 1100
Subframe 2:	**Byte 1**	**Byte 2**	**Byte 3**		**Byte 1**	**Byte 2**	**Byte 3**
Word 3	1111 1111	1111 1111	1111 1111	Word 4	1111 1111	1111 1111	1111 1111
Word 5	1111 1111	1111 1111	1111 1111	Word 6	1111 1111	1111 1111	1111 1111
Word 7	1111 1111	1111 1111	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	0000 0000
Subframe 3:	**Byte 1**	**Byte 2**	**Byte 3**		**Byte 1**	**Byte 2**	**Byte 3**
Word 3	1111 1111	1111 1111	1111 1111	Word 4	1111 1111	1111 1111	1111 1111
Word 5	1111 1111	1111 1111	1111 1111	Word 6	1111 1111	1111 1111	1111 1111
Word 7	1111 1111	1111 1111	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	1111 1100

Table B-65. GLONASS satellite ephemeris mask

String 1:
0 0000 0000 0000 0000 0000 1111 1111 1111 1111 1111 1111 1111
1111 1111 1111 1111 1111 1111 1111 0000 0000
String 2:
0 0000 0000 0000 0000 0000 1111 1111 1111 1111 1111 1111 1111
1111 1111 1111 1111 1111 1111 1111 0000 0000
String 3:
0 0000 0111 1111 1111 0000 1111 1111 1111 1111 1111 1111 1111
1111 1111 1111 1111 1111 1111 1111 0000 0000
String 4:
0 0000 1111 1111 1111 1111 1111 1100 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000 0000

Coding: 1 to 36 = GPS satellite IDs (PRN)
37 = reserved
38 to 61 = GLONASS satellite IDs (slot number plus 37) 62 to 119 = spare
120 to 138 = SBAS satellite IDs (PRN) 139 to 255 = spare

Issue of data (IOD):The issue of data associated with the ephemeris data used to determine pseudo-range and range rate corrections.

Coding: for GPS, IOD = GPS IODE parameter (3.1.1.3.2.2)
for GLONASS, IOD = GLONASS "tb" parameter (see 3.2.1.3.1)
for SBAS, IOD = 1111 1111

Note.— For GLONASS insert 0 in the MSB of the IOD.

Pseudo-range correction (PRC): the correction to the ranging source pseudo-range.

Range rate correction (RRC): the rate of change of the pseudo-range correction.

σ_{pr_gnd}: the standard deviation of a normal distribution associated with the signal-in-space contribution of the pseudo-range error at the GBAS reference point (3.6.5.5.1, 3.6.5.5.2 and 3.6.7.2.2.4).

Coding: 1111 1111 = Ranging source correction invalid.

B1 through B4: are the integrity parameters associated with the pseudo-range corrections provided in the same measurement block. For the i_{th} ranging source these parameters correspond to Bi, 1through Bi ,4(3.6.5.5.1.2, 3.6.5.5.2.2 and 3.6.7.2.2.4). The indices "1-4" correspond to the same physical reference receiver for every frame transmitted from a given ground subsystem during continuous operation.

Coding: 1000 0000 = Reference receiver was not used to compute the pseudo-range correction.

Note.— Some airborne receivers may expect a static correspondence of the reference receivers to the indices for short service interruptions. However, the B-value indices may be reassigned after the ground subsystem has been out of service for an extended period of time, such as for maintenance.

3.6.4.3 *Type 2 message — GBAS-related data*. Type 2 message shall identify the location of the GBAS reference point at which the corrections provided by the GBAS apply and shall give other GBAS-related data (Table B-71). GBAS-related

data parameters shall be as follows:

Note.— Additional data blocks may be included in the Type 2 message. Additional data block 1 and additional data block 2 are defined. In the future, other additional data blocks may be defined. Data blocks 2 through 255 are variable length and may be appended to the message after additional data block 1 in any order.

GBAS reference receivers: the number of GNSS reference receivers installed in this GBAS ground subsystem.

Coding: 0 = GBAS installed with 2 reference receivers
1 = GBAS installed with 3 reference receivers 2 = GBAS installed with 4 reference receivers 3 = The number of GNSS reference receivers installed in this GBAS ground subsystem is not applicable

Ground accuracy designator letter: the letter designator indicating the minimum signal-in-space accuracy performance provided by GBAS(3.6.7.1.1).

Coding: 0 = accuracy designation A
1 = accuracy designation B
2 = accuracy designation C
3 = spare

GBAS continuity/integrity designator (GCID):numeric designator indicating the operational status of the GBAS.

Coding: 0 = spare
1 = GCID 1
2 = GCID 2
3 = GCID 3
4 = GCID 4
5 = spare
6 = spare
7 = unhealthy

Note 1.— The values of GCID 2, 3 and 4 are specified in order to ensure compatibility of equipment with future GBAS.

Note 2.— The value of GCID 7 indicates that a precision approach or APV cannot be initiated.

Local magnetic variation:the published magnetic variation at the GBAS reference point.

Coding: Positive value denotes east variation (clockwise from true north), Negative value denotes west variation (counterclockwise from true north)
100 0000 0000 = Precision approach procedures supported by this GBAS are published based on true bearing.

Note.— Local magnetic variation is chosen to be consistent with procedure design and is updated during magnetic epoch years.

$\sigma_{vert\_iono\_gradient}$: the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation (3.6.5.4).

Refractivity index (Nr): the nominal tropospheric refractivity index used to calibrate the tropospheric correction associated with the GBAS ground subsystem (3.6.5.3).

Coding: This field is coded as two's complement number with an offset of +400. A value of zero in this field indicates a refractivity index of 400.

Scale height (ho): a scale factor used to calibrate the tropospheric correction and residual tropospheric uncertainty associated with the GBAS ground subsystem (3.6.5.3).

Refractivity uncertainty (σn): the standard deviation of a normal distribution associated with the residual tropospheric uncertainty (3.6.5.3).

Latitude: the latitude of the GBAS reference point defined in arc seconds.

Coding: Positive value denotes north latitude.
Negative value denotes south latitude.

Longitude: the longitude of the GBAS reference point defined in arc seconds.

Coding: Positive value denotes east longitude.
Negative value denotes west longitude.

Reference point height: the height of the GBAS reference point above the WGS-84 ellipsoid.

3.6.4.3.1 *Additional data block 1 parameters*. Additional data block 1 parameters shall be as follows:

REFERENCE STATION DATA SELECTOR (RSDS): the numerical identifier that is used to select the GBAS ground subsystem.

Note.— The RSDS is different from every other RSDS and every reference path data selector (RPDS) broadcast on the same frequency by every GBAS ground subsystem within the broadcast region.

Coding: 1111 1111 = GBAS positioning service is not provided

MAXIMUM USE DISTANCE (Dmax): the maximum distance (slant range) from the GBAS reference point for which the integrity is assured.

Note.— This parameter does not indicate a distance within which VHF data broadcast field strength requirements are met.

Coding: 0 = No distance limitation

GPS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e\_POS,GPS}$)*:* the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources or that do not provide the GBAS positioning service, this parameter shall be coded as all zeros.

GPS EPHEMERIS MISSED DETECTION PARAMETER, Category I Precision Approach and APV ($K_{md\_e,GPS}$)*:* the multiplier for computation of the ephemeris error position bound for Category I precision approach and APV derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e,\_POS,GLONASS}$): the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources or that do not provide positioning service, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, Category I Precision Approach and APV ($K_{md\_e\_GLONASS}$): the multiplier for computation of the ephemeris error position bound for Category I precision approach and APV derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources, this parameter shall be coded as all zeros.

3.6.4.3.2Additional data blocks. For additional data blocks other than additional data block 1, the parameters for each data block shall be as follows:

ADDITIONAL DATA BLOCK LENGTH: the number of bytes in the additional data block, including the additional data block length and additional data block number fields.

ADDITIONAL DATA BLOCK NUMBER: the numerical identifier of the type of additional data block.

Coding: 0 to 1 = reserved
2 = additional data block 2, GRAS broadcast stations
3 = reserved for future services supporting Category II/III operations
4 = additional data block 4, VDB authentication parameters
5 to 255 = spare

ADDITIONAL DATA PARAMETERS: the set of data defined in accordance with the additional data block number.

3.6.4.3.2.1GRAS broadcast stations

Parameters for additional data block 2 shall include data for one or more broadcast stations as follows (Table B-65A):

CHANNEL NUMBER: the channel number, as defined in 3.6.5.7, associated with a GBAS broadcast station.

Note.— The channel number in this field refers to a frequency and an RSDS.

ΔLATITUDE: the difference of latitude of a GBAS broadcast station, measured from the latitude provided in the latitude parameter of Type 2 message.

Coding: Positive value denotes that the GBAS broadcast station is north of the GBAS reference point.
Negative value denotes that the GBAS broadcast station is south of the GBAS reference point.

ΔLONGITUDE: the difference of longitude of a GBAS broadcast station, measured from the longitude provided in the longitude parameter of Type 2 message.

Coding: Positive value denotes that the GBAS broadcast station is east of the GBAS reference point.
Negative value denotes that the GBAS broadcast station is west of the GBAS reference point.

Note.— Guidance material concerning additional data block 2 is provided in Attachment D, 7.17.

Table B-65A. GRAS broadcast station data

Data content	Bits used	Range of values	Resolution
Channel number	16	20001 to 39999	1
ΔLatitude	8	±25.4°	0.2°
ΔLongitude	8	±25.4°	0.2°

3.6.4.3.2.2VDB authentication parameters

Additional data block 4 includes information needed to support VDB authentication protocols (Table B-65B).

Slot group definition: This 8-bit field indicates which of the 8 slots (A-H) are assigned for use by the ground station. The field is transmitted LSB first. The LSB corresponds to slot A, the next bit to slot B, and so on. A “1” in the bit position indicates the slot is assigned to the ground station. A “0” indicates the slot is not assigned to the ground station.

Table B-65B. VDB authentication parameters

Data content	Bits used	Range of values	Resolution
Slot group definition	8	—	—

TYPE 3MESSAGE — NULL MESSAGE

3.6.4.4.1 The Type 3 message is a variable length "null message" which is intended to be used by ground subsystems that support the authentication protocols (see section 3.6.7.4).

3.6.4.4.2 The parameters for the Type 3 message shall be as follows:

Filler: a sequence of bits alternating between "1" and "0" with a length in bytes that is 10 less than the value in the message length field in the message header.

3.6.4.5 *Type 4 message — Final approach segment (FAS).* Type 4 message shall contain one or more sets of FAS data, each defining a single precision approach (Table B-72). Each

Type 4 message data set shall include the following:

Data set length: the number of bytes in the data set. The data set includes the data set length field and the associated FAS data block, FAS vertical alert limit (FASVAL)/approach status and FAS lateral alert limit (FASLAL)/approach status fields.

FAS data block: the set of parameters to identify a single precision approach or APV and define its associated approach path.

Coding: See 3.6.4.5.1 and Table B-66.

Note.— Guidance material for FAS path definition is contained in Attachment D, 7.11.

FASVAL/approach status: the value of the parameter FASVAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use vertical deviations.

Note.— The range and resolution of values for FASVAL depend upon the approach performance designator in the associated FAS data block.

FASLAL/approach status: the value of the parameter FASLAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use approach.

3.6.4.5.1 *FAS data block*. The FAS data block shall contain the parameters that define a single precision approach or APV. The FAS path is a line in space defined by the landing threshold point/fictitious threshold point (LTP/FTP), flight path alignment point (FPAP), threshold crossing height (TCH) and glide path angle (GPA). The local level plane for the approach is a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). Local vertical for the approach is normal to the WGS-84 ellipsoid at the LTP/FTP. The glide path intercept point (GPIP) is where the final approach path intercepts the local level plane. FAS data block parameters shall be as follows:

Operation type: straight-in approach procedure or other operation types.

Coding: 0 = straight-in approach procedure
1 to 15 = spare

SBAS service provider ID: indicates the service provider associated with this FAS data block.

Coding: See Table B-27.
14 = FAS data block is to be used with GBAS only.
15 = FAS data block can be used with any SBAS service provider.

Note.— This parameter is not used for approaches conducted using GBAS or GRAS pseudo-range corrections.

Table B-66. Final approach segment (FAS) data block

Data content	Bits used	Range of values	Resolution
Operation type	4	0 to 15	1
SBAS provider ID	4	0 to 15	1
Airport ID	32	—	—
Runway number	6	1 to 36	1
Runway letter	2	—	—
Approach performance designator	3	0 to 7	1
Route indicator	5	—	—
Reference path data selector	8	0 to 48	1
Reference path identifier	32	—	—
LTP/FTP latitude	32	±90.0°	0.0005 arcsec
LTP/FTP longitude	32	±180.0°	0.0005 arcsec
LTP/FTP height	16	−512.0 to 6 041.5 m	0.1 m
ΔFPAP latitude	24	±1.0°	0.0005 arcsec
ΔFPAP longitude	24	±1.0°	0.0005 arcsec
Approach TCH (Note)	15	0 to 1 638.35 m or 0 to 3 276.7 ft	0.05 m or 0.1 ft
Approach TCH units selector	1	—	—
GPA	16	0 to 90.0°	0.01°
Course width	8	80 to 143.75 m	0.25 m
ΔLength offset	8	0 to 2 032 m	8 m
Final approach segment CRC	32	—	—

Note.— Information can be provided in either feet or metres as indicated by the approach TCH unit selector.

Airport ID: the three- or four-letter designator used to designate an airport.

Coding: Each character is coded using the lower 6 bits of its IA-5 representation. For each character, bi is transmitted first, and 2 zero bits are appended after b6,so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character istransmitted first. For a three-character airport ID, the rightmost (first transmitted) character shall be IA-5 "space".

Runway number: the approach runway number.

Coding: 1 to 36 = runway number

Note.— For heliport and point-in-space operations, the runway number value is the integer nearest to one tenth of the final approach course, except when that integer is zero, in which case the runway number is 36.

Runway letter: the one-letter designator used, as necessary, to differentiate between parallel runways.

Coding: 0 = no letter
1 = R (right)
2 = C (centre)

3 = L (left)

Approach performance designator: the general information about the approach design.

Coding: 0 = APV
1 = Category I
2 = reserved for Category II
3 = reserved for Category III
4 to 7 = spare

Note.— Some airborne equipment designed for Category I performance is insensitive to the value of the APD. It is intended that airborne equipment designed for Category I performance accepts APD values of at least 1-4 as valid to accommodate future extensions to higher performance types using the same FAS data block.

Route indicator: the one-letter identifier used to differentiate between multiple approaches to the same runway end.

Coding: The letter is coded using bits b1 through b5of its IA-5 representation. Bit b1 is transmitted first. Only upper case letters, excluding "I" and "O", or IA-5 "space" are used.

Reference path data selector (RPDS): the numeric identifier that is used to select the FAS data block (desired approach).

Note.— The RPDS for a given FAS data block is different from every other RPDS and every reference station data selector (RSDS) broadcast on the same frequency by every GBAS within the broadcast region.

Reference path identifier (RPI): the three or four alphanumeric characters used to uniquely designate the reference path.

Coding: Each character is coded using bits b1through b6of its IA-5 representation. For each character, b1is transmitted first, and 2 zero bits are appended after b6so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character reference path identifier, the rightmost (first transmitted) character shall be IA-5 "space".

Note.— The LTP/FTP is a point over which the FAS path passes at a relative height specified by the TCH. LTP is normally located at the intersection of the runway centre line and the threshold.

LTP/FTP latitude: the latitude of the LTP/FTP point in arc seconds.

Coding: Positive value denotes north latitude.
Negative value denotes south latitude.

LTP/FTP longitude: the longitude of the LTP/FTP point in arc seconds.

Coding: Positive value denotes east longitude.
Negative value denotes west longitude.

LTP/FTP height: the height of the LTP/FTP above the WGS-84 ellipsoid.

Coding: This field is coded as an unsigned fixed-point number with an offset of –512 metres. A value of zero in this field

places the LTP/FTP 512 metresbelow the earth ellipsoid.

Note.— The FPAP is a point at the same height as the LTP/FTP that is used to define the alignment of the approach. The origin of angular deviations in the lateral direction is defined to be 305 metres (1000 ft) beyond the FPAP along the lateral FAS path. For an approach aligned with the runway, the FPAP is at or beyond the stop end of the runway.

ΔFPAP latitude: the difference of latitude of the runwayFPAP from the LTP/FTP in arc seconds.

Coding: Positive value denotes the FPAP latitude north of LTP/FTP latitude.
Negative value denotes the FPAP latitude south of the LTP/FTP latitude.

ΔFPAP longitude: the difference of longitude of the runway FPAP from the LTP/FTP in arc seconds.

Coding: Positive value indicates the FPAP longitude east of LTP/FTP longitude.
Negative value indicates the FPAP longitude west of LTP/FTP longitude.

Approach TCH: the height of the FAS path above the LTP/FTP defined in either feet or metres as indicated by the TCH units selector.

Approach TCH units selector: the units used to describe the TCH.

Coding: 0 = feet
1 = metres

Glide path angle (GPA): the angle of the FAS path with respect to the horizontal plane tangent to the WGS-84 ellipsoid at the LTP/FTP.

Course width: the lateral displacement from the path defined by the FAS at the LTP/FTP at which full-scale deflection of a course deviation indicator is attained.

Coding: This field is coded as an unsigned fixed-point number with an offset of 80 metres. A value of zero in this field indicates a course width of 80 metres at the LTP/FTP.

ΔLength offset: the distance from the stop end of the runway to the FPAP.

Coding: 1111 1111 = not provided

Final approach segment CRC: the 32-bit CRC appended to the end of each FAS data block in order to ensure approach data integrity. The 32-bit final approach segment CRC shall be calculated in accordance with 3.9. The length of the CRC code shall be k = 32 bits.

The CRC generator polynomial shall be:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} + x^{3} + x + 1$$

The CRC information field, M(x), shall be:

$$M(x)=\sum_{i=1}^{272} m_i x^{272-i} + m_1x^{271} + m_2x^{272} + \ldots + m_{272}x^0$$

M(x) shall be formed from all bits of the associated FAS data block, excluding the CRC. Bits shall be arranged in the order transmitted, such that m1corresponds to the LSB of the operation type field, and m272corresponds to the MSB of the Δlength offset field. The CRC shall be ordered such that r1is the LSB and r32is the MSB.

3.6.4.6 Type 5 message — predicted ranging source availability. When used, the Type 5 message shall contain rising and setting information for the currently visible or soon to be visible ranging sources. Predicted ranging source availability parameters shall be as follows:

Modified Z-count: indicates the time of applicability of the parameters in this message.

Coding: Same as modified Z-count field in Type 1 message (3.6.4.2).

Number of impacted sources: the number of sources for which duration information applicable to all approaches is provided

Coding: 0 = Only specified obstructed approaches have limitations.
1 to 31 = The number of ranging sources impacted.

Ranging source ID: as for Type 1 message (3.6.4.2).

Source availability sense: indicates whether the ranging source will become available or cease to be available.

Coding: 0 = Differential corrections will soon cease to be provided for the associated ranging source.
1 = Differential corrections will soon start to be provided for the associated ranging source.

Source availability duration: the predicted minimum ranging source availability duration relative to the modified Z-count.

Coding: 111 1111 = The duration is greater than or equal to 1 270 seconds.

Number of obstructed approaches: the number of approaches for which the corrections will be reduced due to approach unique constellation masking.

Reference path data selector: an indication of the FAS data block to which the source availability data applies (3.6.4.5.1).

Number of impacted sources for this approach: the number of sources for which duration information applicable only to this approach is provided.

3.6.4.7 TYPE 6 MESSAGE

Note.— Type 6 message is reserved for future use to provide the information required for Category II/III precision approaches.

3.6.4.8 TYPE 7 MESSAGE

Note.— Type 7 message is reserved for national applications.

3.6.4.9 TYPE 8 MESSAGE

Note.— Type 8 message is reserved for local and regional test applications.

3.6.4.10 TYPE 101 MESSAGE — GRASPSEUDO-RANGE CORRECTIONS

3.6.4.10.1 The Type 101 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70A). The message shall contain three sections:

a) message information (time of validity, additional message flag, number of measurements and the measurement type);

b) low-frequency information (ephemeris decorrelation parameter, satellite ephemeris CRC and satellite availability information); and

c) satellite data measurement blocks.

3.6.4.10.2 Each Type 101 message shall include ephemeris decorrelation parameter, ephemeris CRC and source availability duration parameters for one satellite ranging source. The ephemeris decorrelation parameter, ephemeris CRC and source availability duration shall apply to the first ranging source in the message.

3.6.4.10.3 Pseudo-range correction parameters shall be as follows:

Modified Z-count: as defined in 3.6.4.2.3.

Additional message flag: as defined in 3.6.4.2.3 except applicable to Type 101 messages.

Number of measurements: as defined in 3.6.4.2.3.

Measurement type: as defined in 3.6.4.2.3.

Ephemeris decorrelation parameter (P): as defined in 3.6.4.2.3.

Ephemeris CRC: as defined in 3.6.4.2.3.

Source availability duration: as defined in 3.6.4.2.3.

Number of B parameters: an indication of whether the B parameters are included in the measurement block for each ranging source.

Coding: 0 = B parameters are not included

1 = 4 B parameters per measurement block

3.6.4.10.4 The measurement block parameters shall be as follows:

Ranging source ID: as defined in 3.6.4.2.4.

Issue of data (IOD): as defined in 3.6.4.2.4.

Pseudo-range correction (PRC): as defined in 3.6.4.2.4.

Range rate correction (RRC): as defined in 3.6.4.2.4.

σpr_gnd: as defined in 3.6.4.2.4, with the exception of the range of values and resolution.

B1 through B4: as defined in 3.6.4.2.4.

Note.— Inclusion of the B parameters in the measurement block is optional for Type 101 messages.

3.6.5 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters that are not transmitted, but are used by either or both non-aircraft and aircraft elements, and that define terms applied to determine the navigation solution and its integrity.

3.6.5.1 *Measured and carrier smoothed pseudo-range.* The broadcast correction is applicable to carrier smoothed code pseudo-range measurements that have not had the satellite broadcast troposphere and ionosphere corrections applied to them.

The carrier smoothing is defined by the following filter:

$$P_{CSCn} = \alpha P + (1 - \alpha)\left(P_{CSC_{n-1}} + \frac{\lambda}{2\pi}(\phi_n - \phi_{n-1})\right)$$

where

P_{CSCn}= the smoothed pseudo-range;
P_{CSCn-1} = the previous smoothed pseudo-range;

P = the raw pseudo-range measurement where the raw pseudo-range measurements are obtained from a carrier driven code loop, first order or higher and with a one-sided noise bandwidth greater than or equal to 0.125 Hz;
λ= the L1 wavelength;
φ_n = the carrier phase;
φ_{n-1} = the previous carrier phase; and
α = the filter weighting function equal to the sample interval divided by the time constant of 100 seconds, except as specified in 3.6.8.3.5.1 for airborne equipment.

3.6.5.2 *Corrected pseudo-range*. The corrected pseudo-range for a given satellite at time *t* is:

$$PR_{corrected} = P_{CSC} + PRC + RRC \times (t - tz\text{-count}) + TC + c \times (\Delta t_{sv})_{L1}$$

where

P_{CSC} = the smoothed pseudo-range (defined in 3.6.5.1);
PRC = the pseudo-range correction (defined in 3.6.4.2);
RRC = the pseudo-range correction rate (defined in 3.6.4.2);
t = the current time;
tz-count = the time of applicability derived from the modified Z-count (defined in 3.6.4.2);
TC = the tropospheric correction (defined in 3.6.5.3); and
c and $(\Delta t_{sv})_{L1}$ are as defined in 3.1.2.2 for GPS satellites.

3.6.5.3 TROPOSPHERIC DELAY

3.6.5.3.1 The tropospheric correction for a given satellite is:

$$TC = N_r h_0 \frac{10^{-6}}{\sqrt{0.002 + \text{sen}^2(El_i)}}(1 - e^{-\Delta h/h_0})$$

where

N_r = refractivity index from the Type 2 message (3.6.4.3);

Δh = height of the aircraft above the GBAS reference point;

El_i = elevation angle of the i_{th} satellite; and

h_0 = troposphere scale height from the Type 2 message.

3.6.5.3.2 The residual tropospheric uncertainty is:

$$\sigma_{tropo} = \sigma_n h_0 \frac{10^{-6}}{\sqrt{0.002 + sen^2(El_i)}}(1 - e^{-\Delta h/h_0})$$

where σ_n = the refractivity uncertainty from the Type 2 message (3.6.4.3).

3.6.5.4 *Residual ionospheric uncertainty.* The residual ionospheric uncertainty for a given satellite is:

$$\sigma_{iono} = F_{pp} \times \sigma_{vert\_iono\_gradient} \times (x_{air} + 2 \times \tau \times v_{air})$$

where

F_{pp} = the vertical-to-slant obliquity factor for a given satellite (3.5.5.5.2);

$\sigma_{vert\_iono\_gradient}$ = (as defined in 3.6.4.3);

x_{air} = the distance (slant range) in metres between current aircraft location and the GBAS reference point indicated in the Type 2 message;

τ = 100 seconds (time constant used in 3.6.5.1); and

v_{air} = the aircraft horizontal approach velocity (metres per second).

3.6.5.5 PROTECTION LEVELS

3.6.5.5.1 *Category I precision approach and APV*. The signal-in-space vertical and lateral protection levels (VPL and LPL) are upper confidence bounds on the error in the position relative to the GBAS reference point defined as:

$$VPL = MAX\{VPL_{HO}, VPL_{H1}\}$$

$$LPL = MAX\{LPL_{HO}, LPL_{H1}\}$$

3.6.5.5.1.1 Normal measurement conditions

3.6.5.5.1.1.1 The vertical protection level (VPLH0) and lateral protection level (LPLH0), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$VPL_{H0} = K_{ffmd} \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$LPL_{H0} = K_{ffmd} \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where

K_{ffmd} = the multiplier derived from the probability of fault-free missed detection;

$s\_vert_i = s_{v,i} + s_{x,i} \times \tan(GPA)$;

$s\_lat_i = s_{y,i}$;

$s_{x,i}$ = the partial derivative of position error in the x-direction with respect to pseudo-range error on the i_{th} satellite;

$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the i_{th} satellite;

$s_{v,i}$ = the partial derivative of position error in the vertical direction with respect to pseudo-range error on the i_{th} satellite;

GPA = the glide path angle for the final approach path (3.6.4.5.1);

N = the number of ranging sources used in the position solution; and

i = the ranging source index for ranging sources used in the position solution.

Note.— The coordinate reference frame is defined such that x is along track positive forward, y is cross track positive left in the local level tangent plane and v is the positive up and orthogonal to x and y.

3.6.5.5.1.1.2 For a general-least-squares position solution, the projection matrix S is defined as:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \cdots & S_{x,N} \\ S_{y,1} & S_{y,2} & \cdots & S_{y,N} \\ S_{v,1} & S_{v,2} & \cdots & S_{v,N} \\ S_{t,1} & S_{t,2} & \cdots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

Where

$G_i \;=\; [-\cos El_i \cos Az_i \; -\cos El_i \sin Az_i \; -\sin El_i \; 1] = i^{th}$ row of G; and

$$W = \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_N^2 \end{bmatrix}^{-1}$$

where

$$\sigma_i^2 = \sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i};$$

$\sigma_{pr\_gnd,i} = \sigma_{pr\_gnd}$ for the ith ranging source (3.6.4.2);

$\sigma_{tropo,i}$ = the residual tropospheric uncertainty for the ith ranging source (3.6.5.3);

$\sigma_{iono,i}$ = the residual ionospheric delay (due to spatial decorrelation) uncertainty for the ith ranging source (3.6.5.4); and

$\sigma_{pr\_air,i} = \sqrt{\sigma^2_{receiver}(El_i) + \sigma^2_{multipath}(El_i)}$ the standard deviation of the aircraft contribution to the corrected pseudo-range error for the ith ranging source. The total aircraft contribution includes the receiver contribution (3.6.8.2.1) and a standard allowance for airframe multipath;

where

$\sigma_{multipath}(El_i) \;=\; 0.13 + 0.53e^{-El_i/10\,deg}$ the standard model for the contribution of airframe multipath (in metres);

El_i = the elevation angle for the ith ranging source (in degrees); and

Az_i = the azimuth for the ith ranging source taken counterclockwise for the x axis (in degrees).

Note.— To improve readability, the subscript I was omitted from the projection matrix's equation.

3.6.5.5.1.2 *Faulted measurement conditions*. When the Type 101 message is broadcast without B parameter blocks, the values for VPLH1 and LPLH1 are defined as zero. Otherwise, the vertical protection level (VPLH1) and lateral protection level

(LPLH1), assuming that a latent fault exists in one, and only one reference receiver, are:

$$VPLH1 = \max [VPL_j]$$

$$LPLH1 = \max [LPL_j]$$

where VPL_j and LPL_j for j = 1 to 4 are

$$VPL_j = |B\_vert_j| + K_{md}\,\sigma_{vert,H1} \text{ and}$$
$$LPL_j = |B\_lat_j| + K_{md}\,\sigma_{lat,H1}$$

And;

$$B\_vert_j = \sum_{i=1}^{N}(s\_vert_i \times B_{i,j});$$

$$B\_lat_j = \sum_{i=1}^{N}(s\_lat_i \times B_{i,j});$$

$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the jth reference receiver measurement for the ithranging source;

K_{md} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted;

$$\sigma^2_{vert,H1} = \sum_{i=1}^{N} (s\_vert_i^2 \times \sigma\_H1_i^2);$$

$$\sigma^2_{lat,H1} = \sum_{i=1}^{N} (s\_lat_i^2 \times \sigma\_H1_i^2);$$

$$\sigma\_H1^2_i = \left(\frac{M_i}{U_i}\right) \sigma^2_{pr\_gnd,i} + \sigma^2_{pr\_air,i} + \sigma^2_{tropo,i} + \sigma^2_{iono,i};$$

M_i = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source (indicated by the B values); and

U_i = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source, excluding the jth reference receiver.

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.1.3 *Definition of K multipliers for Category I precision approach and APV*. The multipliers are given in Table B-67.

Table B-67. K-multipliers for Category I precision approach and APV

	M_i			
Multiplier	1 (Note)	2	3	4
K_{ffmd}	6.86	5.762	5.81	5.847
K_{md}	Not used	2.935	2.898	2.878

Note.— For APV I approaches supported by Type 101 messages broadcast without the B parameter block.

3.6.5.5.2 *GBAS positioning service*. The signal-in-space horizontal protection level is an upper confidence bound on the horizontal error in the position relative to the GBAS reference point defined as:

$$HPL = MAX\{HPL_{H0}, HPL_{H1}\}$$

3.6.5.5.2.1 *Normal measurements conditions*. The horizontal protection level (HPLH0), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$HPL_{H0} = K_{ffmd,\ POS}\, d_{major}$$

where

$$d_{mayor} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}}$$

$$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2$$

$$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2$$

$$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2$$

sx,i = the partial derivative of position error in the x-direction with respect to pseudo-range error on the ith satellite

$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the ith satellite

$K_{ffmd,POS}$ = the multiplier derived from the probability of fault-free missed detection

N = the number of ranging sources used in the position solution

i = the ranging source index for ranging sources used in the position solution

σ_i = the pseudo-range error term as defined in 3.6.5.5.1.1

Note.— For the GBAS positioning service, the x and y axes define an arbitrary orthogonal basis in the horizontal plane.

3.6.5.5.2.2 When the Type 101 message is broadcast without B parameter blocks, the value for HPLH1is defined as zero. Otherwise, the horizontal protection level (HPLH1), assuming that a latent fault exists in one and only one reference receiver, is:

$$HPL_{H1} = \max\,[HPL_j]$$

where HPLj for j = 1 to 4 is:

$$HPL_j = |B\_horz_j| + K_{md\_POS}\, d_{major,H1}$$

And;

$$B\_horz_j = \sqrt{\left(\sum_{i=1}^{N} S_{x,i}B_{i,j}\right)^2 + \left(\sum_{i=1}^{N} S_{y,i}B_{i,j}\right)^2}$$

$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the jth reference receiver measurement for the ith ranging source.

K_{md_POS} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted.

$$d_{mayor,H1} = \sqrt{\frac{d\_H1_x^2 + d\_H1_y^2}{2} + \sqrt{\left(\frac{d\_H1_x^2 - d\_H1_y^2}{2}\right)^2 + d\_H1_{xy}^2}}$$

$$d\_H1_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma\_H1_i^2$$

$$d\_H1_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma\_H1_i^2$$

$$d\_H1_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma\_H1_i^2$$

Note.— For the GBAS positioning service, the x and y axes define an arbitrary orthogonal basis in the horizontal plane.

$$\sigma\_H1_i^2 = \left(\frac{M_i}{U_i}\right) \sigma_{pr\_gnd,i}^2 + \sigma_{pr\_air,i}^2 + \sigma_{tropo,i}^2 + \sigma_{iono,i}^2$$

Mi = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source (indicated by the B values).

Ui = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source, excluding the jth reference receiver.

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.2.3 *Definition of K multipliers for GBAS positioning service*. The multiplier Kffmd_POS is equal to 10.0 and the multiplier Kmd_POS, is equal to 5.3.

3.6.5.6 ALERT LIMITS

Note.— Guidance concerning the calculation of alert limits, including approaches associated with channel numbers 40 000 to 99 999, is provided in Attachment D, 7.13.

3.6.5.6.1 Category I precision approach alert limits. The alert limits are defined in Tables B-68 and B-69. For aircraft positions at which the lateral deviation exceeds twice the deviation at which full-scale lateral deflection of a course deviation indicator is achieved, or vertical deviation exceeds twice the deviation at which full-scale fly-down deflection of a course deviation indicator is achieved, both the lateral and vertical alert limits are set to the maximum values given in the tables.

Table B-68. Category I lateral alert limit

Horizontal distance of aircraft position from the LTP/FTP as translated along the final approach path (metres)	Lateral alert limit (metres)
291 < D ≤ 873	FASLAL
873 < D ≤ 7 500	0.0044D (m) + FASLAL – 3.85
D > 7 500	FASLAL + 29.15

Table B-69. Category I vertical alert limit

Height above LTP/FTP of aircraft position translated onto the final approach path (feet)	Vertical alert limit (metres)
100 < H ≤ 200	FASVAL
200 < H ≤ 1 340	0.02925H (ft) + FASVAL – 5.85
H > 1 340	FASVAL + 33.35

3.6.5.6.2 *APV alert limits.* The alert limits are equal tothe FASLAL and FASVAL for approaches with channel numbers in the range of 20 001 to 39 999. For approaches with channel numbers in the range 40 000 to 99 999, the alert limits are stored in the on-board database.

3.6.5.7 *Channel number*. Each GBAS approach transmitted from the ground subsystem is associated with a channel number in the range of 20 001 to 39 999. If provided, the GBAS positioning service is associated with a separate channel number in the range of 20 001 to 39 999. The channel number is given by:

Channel number = 20 000 + 40(F – 108.0) + 411(S)

where

F = the data broadcast frequency (MHz)
S = RPDS or RSDS

and

RPDS = the reference path data selector for the FAS data block (as defined in 3.6.4.5.1)
RSDS = the reference station data selector for the GBAS ground subsystem (as defined in 3.6.4.3.1)

For channel numbers transmitted in the additional data block 2 ofType 2 message (as defined in 3.6.4.3.2.1), only RSDS are used.

Note 1.— When the FAS is not broadcast for an APV, the GBAS approach is associated *with a channel number in the range 40 000 to 99 999.*

Note 2.— Guidance material concerning channel number selection is provided in Attachment D, 7.7.

3.6.5.8 EPHEMERIS ERROR POSITION BOUND

Note.— Ephemeris error position bounds are computed only for core satellite constellation ranging sources used in the position solution (j index) and not for other types of ranging sources (SBAS satellites or pseudolites) that are not subject to undetected ephemeris failures. However, the calculations of these position bounds use information from all ranging sources used in the position solution (i index).

3.6.5.8.1 Category I precision approach and APV. The vertical and lateral ephemeris error position bounds are defined as:

$$VEB = \underset{j}{MAX}\{VEB_j\}$$

$$LEB = \underset{J}{MAX}\{LEB_j\}$$

The vertical and lateral ephemeris error position bounds for the jth core satellite constellation ranging source used in the position solution are given by:

$$VEB_j = \left|s\_vert_j\right| x_{air} P_j + K_{md\_e,j} \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$LEB_j = \left|s\_lat_j\right| x_{air} P_j + K_{md\_e,j} \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where:

s_verti or j   is defined in 3.6.5.5.1.1

s_lati or j   is defined in 3.6.5.5.1.1

x_{air} is defined in 3.6.5.4 N is the number of ranging sources used in the position solution

σ_i is defined in 3.6.5.5.1.1

P_j is the broadcast ephemeris decorrelation parameter for the jth ranging source

$K_{md\_e,j}$ is the broadcast ephemeris missed detection multiplier for Category I precision approach and APV associated with the satellite constellation for the jth ranging source ($K_{md\_e,GPS}$ or $K_{md\_e,GLONASS}$)

3.6.5.8.2 *GBAS positioning service*. The horizontal ephemeris error position bound is defined as:

$$HEB = \underset{j}{MAX}\{HEB_j\}$$

The horizontal ephemeris error position bound for the jth core satellite constellation ranging source used in the position solution is given by:

$$HEB_j = |s_{horz,j}| x_{air} P_j + K_{md\_e\_POS} d_{mayor}$$

where:

$S_{horz,j}^2 = S_{xj}^2 + S_{yj}^2$

$s_{x,j}$ is as defined in 3.6.5.5.2.1

$s_{y,j}$ is as defined in 3.6.5.5.2.1

x_{air} is defined in 3.6.5.4

P_j is the broadcast ephemeris decorrelation parameter for the jth ranging source

$K_{md\_e\_POS}$ is the broadcast ephemeris missed detection multiplier for the GBAS positioning service associated with the satellite constellation for the jth ranging source ($K_{md\_e\_POS,GPS}$ or $K_{md\_e\_POS,GLONASS}$)

d_{major} is as defined in 3.6.5.5.2.1

3.6.6 MESSAGE TABLES

Each GBAS message shall be coded in accordance with the corresponding message format defined in Tables B-70 through B-73.

Note.— Message type structure is defined in 3.6.4.1

Table B-70. Type 1 pseudo-range corrections message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Additional message flag	2	0 to 3	1
Number of measurements (N)	5	0 to 18	1
Measurement type	3	0 to 7	1
Ephemeris decorrelation parameter (P)	8	0 to 1.275 × 10^{-3} m/m	5 × 10^{-6} m/m
Ephemeris CRC	16	—	—
Source availability duration	8	0 to 2 540 s	10 s
For N measurement blocks			
Ranging source ID	8	1 to 255	1
Issue of data (IOD)	8	0 to 255	1
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m
B_1	8	±6.35 m	0.05 m
B_2	8	±6.35 m	0.05 m
B_3	8	±6.35 m	0.05 m
B_4	8	±6.35 m	0.05 m

Table B-70A. Type 101 GRAS pseudo-range corrections message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Additional message flag	2	0 to 3	1
Number of measurements (N)	5	0 to 18	1
Measurement type	3	0 to 7	1
Ephemeris decorrelation parameter (P)	8	0 to 1.275 × 10^{-3} m/m	5 × 10^{-6} m/m
Ephemeris CRC	16	—	—
Source availability duration	8	0 to 2540 s	10 s
Number of B parameters	1	0 or 4	—
Spare	7	—	—
For N measurement blocks			
Ranging source ID	8	1 to 255	1
Issue of data (IOD)	8	0 to 255	1
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s
σ_{pr_gnd}	8	0 to 50.8 m	0.2 m
B parameter block (if provided)			
B_1	8	±25.4 m	0.2 m
B_2	8	±25.4 m	0.2 m
B_3	8	±25.4 m	0.2 m
B_4	8	±25.4 m	0.2 m

Table B-71A. Type 2 GBAS-related data message

Data content	Bits used	Range of values	Resolution
GBAS reference receivers	2	2 to 4	—
Ground accuracy designator letter	2	—	—
Spare	1	—	—
GBAS continuity/integrity designator	3	0 to 7	1
Local magnetic variation	11	±180°	0.25°
Spare	5	—	—
$\sigma_{vert\ iono\ gradient}$	8	0 to 25.5 × 10^{-6} m/m	0.1 × 10^{-6} m/m
Refractivity index	8	16 to 781	3
Scale height	8	0 to 25 500 m	100 m
Refractivity uncertainty	8	0 to 255	1
Latitude	32	±90.0°	0.0005 arcsec
Longitude	32	±180.0°	0.0005 arcsec
GBAS reference point height	24	±83 886.07 m	0.01 m
Additional data block 1 (if provided)			
Reference station data selector	8	0 to 48	1
Maximum use distance (D_{max})	8	2 to 510 km	2 km
$K_{md\ e\ POS,GPS}$	8	0 to 12.75	0.05
$K_{md\ e,GPS}$	8	0 to 12.75	0.05
$K_{md\ e\ POS,GLONASS}$	8	0 to 12.75	0.05
$K_{md\ e,GLONASS}$	8	0 to 12.75	0.05
Additional data block 2 (if provided)			
Additional data block length	8	2 to 255	1
Additional data block number	8	2 to 255	1
Additional data parameters	Variable	—	—

Table B-71B. Type 3 null message

Data content	Bits used	Range of values	Resolution
Filler	Variable (Note)	N/A	N/A

Note.— The number of bytes in the filler field is 10 less than the message length field in the message header as defined in section 3.6.3.4

Table B-72. Type 4 FAS data message

Data content	Bits used	Range of values	Resolution
For N data sets			
Data set length	8	2 to 212	1 byte
FAS data block	304	—	—
FAS vertical alert limit/approach status	8		
(1) when associated approach performance designator indicates APV-I (APD coded as 0)		0 to 50.8 m	0.2 m
(2) when associated approach performance designator does not indicate APV-I (APD not coded as 0)		0 to 25.4 m	0.1 m
FAS lateral alert limit/approach status	8	0 to 50.8 m	0.2 m

Table B-73. Type 5 predicted ranging source availability message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Spare	2	—	—
Number of impacted sources (N)	8	0 to 31	1
For N impacted sources			
Ranging source ID	8	1 to 255	1
Source availability sense	1	—	—
Source availability duration	7	0 to 1 270 s	10 s
Number of obstructed approaches (A)	8	0 to 255	1
For A obstructed approaches			
Reference path data selector	8	0 to 48	—
Number of impacted sources for this approach (N_A)	8	1 to 31	1
For N_A impacted ranging sources for this approach			
Ranging source ID	8	1 to 255	1
Source availability sense	1	—	—
Source availability duration	7	0 to 1 270 s	10 s

3.6.7 NON-AIRCRAFT ELEMENTS

3.6.7.1 *PERFORMANCE*

3.6.7.1.1 *Accuracy*

3.6.7.1.1.1 The root-mean-square (RMS) (1 sigma) of the ground subsystem contribution to the corrected pseudo-range accuracy for GPS and GLONASS satellites shall be:

$$RMS_{pr\_gnd} \leq \sqrt{\frac{(a_0 + a_1 e^{-\theta_n/\theta_0})^2}{M} + (a_2)^2}$$

where

M = the number of GNSS reference receivers, as indicated in the Type 2 message parameter (3.6.4.3), or, when this parameter is coded to indicate "not applicable", the value of M is defined as 1;

n = nth ranging source;

θn = elevation angle for the nth ranging source; and

a0, a1, a2, and θ0 = parameters defined in Tables B-74 and B-75 for each of the defined ground accuracy designators (GADs).

Note 1.— The GBAS ground subsystem accuracy requirement is determined by the GAD letter and the number of installed reference receivers.

Note 2.— The ground subsystem contribution to the corrected pseudo-range error specified by the curves defined in Tables B-74 and B-75 and the contribution to the SBAS satellites do not include aircraft noise and aircraft multipath.

Table B-74. GBAS — GPS accuracy requirement parameters

Ground accuracy designator letter	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)	a_2 (metres)
A	≥ 5	0.5	1.65	14.3	0.08
B	≥ 5	0.16	1.07	15.5	0.08
C	> 35	0.15	0.84	15.5	0.04
	5 to 35	0.24	0	—	0.04

Table B-75. GBAS — GLONASS accuracy requirement parameters

Ground accuracy designator letter	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)	a_2 (metres)
A	≥ 5	1.58	5.18	14.3	0.078
B	≥ 5	0.3	2.12	15.5	0.078
C	> 35	0.3	1.68	15.5	0.042
	5 to 35	0.48	0	—	0.042

3.6.7.1.1.2 The RMS of the ground subsystem contribution to the corrected pseudo-range accuracy for SBAS satellites shall be:

$$RMS_{pr\_gnd} \leq \frac{1.8}{\sqrt{M}} \text{(metres)}$$

where M is as defined in 3.6.7.1.1.1.

Note.— GAD classifications for SBAS ranging sources are under development.

3.6.7.1.2 Integrity

3.6.7.1.2.1 GBAS ground subsystem integrity risk

3.6.7.1.2.1.1 *Category I precision approach and APV*. For a GBAS ground subsystem that provides the Category I precision approach or APV, the integrity risk shall be less than 1.5 × 10–7per approach.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.1) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.2.6 and the integrity risk associated with the monitoring in 3.6.7.3.

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft, results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the CategoryI precision approach or APV protection level and, if additional data block 1 is broadcast, the ephemeris error position bound.

3.6.7.1.2.1.1.1 The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast.

Note.— The time-to-alert above is the time between the onset of the out-of-tolerance lateral or vertical relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition.

3.6.7.1.2.1.1.2 The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 5.5 seconds when Type 101 messages are broadcast.

3.6.7.1.2.1.1.3 For Category I precision approach, the value FASLAL for each FAS block, as defined in the FAS lateral alert limit field of the Type 4 message shall be no greater than 40 metres, and the value FASVAL for each FAS block, as defined in the FAS vertical alert limit field of the Type 4 message, shall be no greater than 10 metres.

3.6.7.1.2.1.1.4 For APV, the value FASLAL and FASVAL shall be no greater than the lateral and vertical alert limits given in Annex 10, Volume I, 3.7.2.4.

3.6.7.1.2.1.2 GBAS positioning service. For GBAS ground subsystem that provides the GBAS positioning service, integrity risk shall be less than 9.9 × 10–8 per hour.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.2) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.2.6 and the integrity risk associated with the monitoring in 3.6.7.3.

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft, results in an out-of-tolerance horizontal relative position error without annunciation for a period longer than the maximum time-to alert. An out-of-tolerance horizontal relative position error is defined as an error that exceeds both the horizontal protection level and the horizontal ephemeris error position bound.

3.6.7.1.2.1.2.1 The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast and less than or equal to 5.5 seconds when Type 101 messages are broadcast.

Note.— The time-to-alert above is the time between the onset of the out-of-tolerance horizontal relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition.

3.6.7.1.2.2 Protection level integrity risk

3.6.7.1.2.2.1 For a GBAS ground subsystem that provides the Category I precision approach or APV, the protection level integrity risk shall be less than 5 × 10–8per approach.

Note.— The Category I precision approach and APV protection level integrity risk is the integrity risk due to undetected errors in position relative to the GBAS reference point greater than the associated protection levels under the two following conditions:

a) normal measurement conditions defined in 3.6.5.5.1.1; and

b) faulted measurement conditions defined in 3.6.5.5.1.2.

3.6.7.1.2.2.2 For a GBAS ground subsystem that provides the positioning service, protection level integrity risk shall be less than 10–9 per hour.

Note.— The GBAS positioning service protection level integrity risk is the integrity risk due to undetected errors in the horizontal position relative to the GBAS reference point greater than the GBAS positioning service protection level under the two following conditions:

a) normal measurement conditions defined in 3.6.5.5.2.1; and

b) faulted measurement conditions defined in 3.6.5.5.2.2.

3.6.7.1.3 Continuity of service

3.6.7.1.3.1 *Continuity of service for Category I precision approach and APV*. The GBAS ground subsystem continuity of service shall be greater than or equal to 1 – 8.0 × 10–6 per 15 seconds.

Note.— The GBAS ground subsystem continuity of service is the average probability per 15-second period that the VHF data broadcast transmits data in tolerance, VHF data broadcast field strength is within the specified range and the protection levels are lower than the alert limits, including configuration changes that occur due to the space segment. This continuity of service requirement is the entire allocation of the signal-in-space continuity requirement from Chapter 3, Table 3.7.2.4-1, and therefore all continuity risks included in that requirement must be accounted for by the ground subsystem provider.

3.6.7.1.3.2 Continuity of service for positioning service

Note.— For GBAS ground subsystems that provide the GBAS positioning service, there may be additional continuity requirements depending on the intended operations.

3.6.7.2 FUNCTIONAL REQUIREMENTS

3.6.7.2.1 General

3.6.7.2.1.1 Data broadcast rates

3.6.7.2.1.1.1 A GBAS ground subsystem that supports Category I precision approach or APV-II shall broadcast Type 1 messages. A GBAS ground subsystem that does not support Category I precision approach or APV-II shall broadcast either Type 1 or Type 101 messages. A GBAS ground subsystem shall not broadcast both Type 1 and Type 101 messages.

Note.— Guidance material concerning usage of the Type 101 message is provided in Attachment D, 7.18.

3.6.7.2.1.1.2 Each GBAS ground subsystem shall broadcast Type 2 messages.

3.6.7.2.1.1.3 Each GBAS ground subsystem shall broadcast FAS blocks in Type 4 messages for all Category I precision approaches supported by that GBAS ground subsystem. If a GBAS ground subsystem supports APV and does not broadcast FAS blocks for the corresponding approaches, it shall broadcast additional data block 1 in the Type 2 message.

Note.— FAS blocks for APV procedures may be held within a database on board the aircraft. Broadcasting additional data block 1 allows the airborne receiver to select the GBAS ground subsystem that supports the approach procedures in the airborne database. FAS blocks may also be broadcast to support operations by aircraft without an airborne database. These procedures use different channel numbers as described in Attachment D, 7.7.

3.6.7.2.1.1.4 When the Type 5 message is used, the ground subsystem shall broadcast the Type 5 message at a rate in accordance with Table B-76.

Note.— When the standard 5 degree mask is not adequate to describe satellite visibility at either the ground subsystem antennas or at an aircraft during a specific approach, the Type5 message may be used to broadcast additional information to the aircraft.

3.6.7.2.1.1.5 *Data broadcast rates.* For all message types required to be broadcast, messages meeting the field strength requirements of Chapter 3, 3.7.3.5.4.4.1.2 and 3.7.3.5.4.4.2.2 and the minimum rates shown in Table B-76 shall be provided at every point within the coverage. The total message broadcast rates from all antenna systems of the ground subsystem combined shall not exceed the maximum rates shown in Table B-76.

Note.— Guidance material concerning the use of multiple antenna systems is provided in Attachment D, 7.12.4.

Table B-76. GBAS VHF data broadcast rates

Message type	Minimum broadcast rate	Maximum broadcast rate
1 or 101	For each measurement type: All measurement blocks once per frame (Note)	For each measurement type: All measurement blocks once per slot
2	Once per 20 consecutive frames	Once per frame
4	All FAS blocks once per 20 consecutive frames	All FAS blocks once per frame
5	All impacted sources once per 20 consecutive frames	All impacted sources once per 5 consecutive frames

Note.— One Type 1 or Type 101 message or two Type 1 or Type 101 messages that are linked using the additional message flag described in 3.6.4.2.

3.6.7.2.1.2 *Message block identifier*. The MBI shall be set to either normal or test according to the coding given in 3.6.3.4.1.

3.6.7.2.1.3 *VDB authentication*

Note. – This section is reserved for forward compatibility with future authentication functions.

3.6.7.2.2 *Pseudo-range corrections*

3.6.7.2.2.1 Message latency. The time between the time indicated by the modified Z-count and the last bit of the broadcast Type 1 or Type 101 message shall not exceed 0.5 seconds.

3.6.7.2.2.2 *Low-frequency data*. Except during an ephemeris change, the first ranging source in the message shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 10 seconds. During an ephemeris change, the first ranging source shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 27 seconds. When new ephemeris data are received from a core satellite constellation's ranging source, the ground subsystem shall use the previous ephemeris data from each satellite until the new ephemeris data have been continuously received for at least 2 minutes but shall make a transition to the new ephemeris data before 3 minutes have passed. When this transition is made to using the new ephemeris data for a given ranging source, the ground subsystem shall broadcast the new ephemeris CRC for all occurrences of thatranging source in the low-frequency information of Type 1 or Type 101 message in the next 3 consecutive frames. For a given ranging source, the ground subsystem shall continue to transmit data corresponding to the previous ephemeris data until the new CRC ephemeris is transmitted in the low-frequency data of Type 1 or Type 101 message (see Note). If the ephemeris CRC changes and the IOD does not, the ground subsystem shall consider the ranging source invalid.

Note.— The delay before the ephemeris transition allow sufficient time for the aircraft subsystem to collect new ephemeris data.

3.6.7.2.2.2.1 **Recommendation**.— The ephemeris decorrelation parameter and the ephemeris CRC for each core satellite constellation's ranging source should be broadcast as frequently as possible.

3.6.7.2.2.3 **Broadcast pseudo-range correction**. Each broadcast pseudo-range correction shall be determined by combining the pseudo-range correction estimates for the relevant ranging source calculated from each of the reference receivers. For each satellite, the measurements used in this combination shall be obtained from the same ephemeris data. The corrections shall be based on smoothed code pseudo-range measurements for each satellite using the carrier measurement from a smoothing filter in accordance with 3.6.5.1.

3.6.7.2.2.4 *Broadcast signal-in-space integrity parameters*. The ground subsystem shall provide σpr_gnd and B parameters for each pseudo-range correction in Type 1 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied. The ground subsystem shall provide σpr_gnd and, if necessary, B parameters for each pseudo-range correction in Type 101 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

Note.— Broadcast of the B parameters are optional for Type 101 messages. Guidance material regarding the B parameters in Type 101 messages is contained in Attachment D, 7.5.11.

3.6.7.2.2.5 **Recommendation**.—Reference receiver measurements should be monitored. Faulted measurements or failed reference receivers should not be used to compute the pseudo-range corrections.

3.6.7.2.2.6 *Repeated transmission of Type 1 or Type 101 messages.* For a given measurement type and within a given frame, all broadcasts of Type 1 or Type 101 messages or linked pairs from all GBAS broadcast stations that share a common GBAS identification, shall have identical data content.

3.6.7.2.2.7 *Issue of data*. The GBAS ground subsystem shall set the IOD field in each ranging source measurement block to be the IOD value received from the ranging source that corresponds to the ephemeris data used to compute the pseudo-range correction.

3.6.7.2.2.8 *Application of signal error models*. Ionospheric and tropospheric corrections shall not be applied to the pseudo-ranges used to calculate the pseudo-range corrections.

3.6.7.2.2.9 *Linked pair of Type 1 or Type 101 messages*. If a linked pair of Type 1 or Type 101 messages is transmitted then,

a) the two messages shall have the same modified Z-count;

b) the minimum number of pseudo-range corrections in each message shall be one;

c) the measurement block for a given satellite shall not be broadcast more than once in a linked pair of messages;

d) the two messages shall be broadcast in different time slots; and

e) the order of the B values in the two messages shall be the same.

3.6.7.2.2.10 *Modified Z-count update*. The modified Z-count for Type 1 or Type 101 messages of a given measurement type shall advance every frame.

3.6.7.2.2.11 Ephemeris decorrelation parameters

3.6.7.2.2.11.1 *Category I precision approach and APV*. For ground subsystems that broadcast the additional data block 1 in the Type 2 message, the ground subsystem shall broadcast the ephemeris decorrelation parameter for each core satellite constellation ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.1 is met.

3.6.7.2.2.11.2 *GBAS positioning service.* For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris decorrelation parameter for each core satellite constellation's ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.2 is met.

3.6.7.2.3 GBAS-related data

3.6.7.2.3.1 *Tropospheric delay parameters*. The ground subsystem shall broadcast a refractivity index, scale height, and refractivity uncertainty in a Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.2 *GCID indication.* If the ground subsystem meets the requirements of 3.6.7.1.2.1.1, 3.6.7.1.2.2.1 and 3.6.7.1.3.1 the GCID shall be set to 1 otherwise it shall be set to 7.

3.6.7.2.3.3 *GBAS reference antenna phase centre position accuracy.* For each GBAS reference receiver, the reference antenna phase centre position error shall be less than 8 cm relative to the GBAS reference point.

3.6.7.2.3.4 **Recommendation**.— GBAS reference point survey accuracy. The survey error of the GBAS reference point, relative to WGS-84, should be less than 0.25 m vertical and 1 m horizontal.

Note.— Relevant guidance material is given in Attachment D, 7.16.

3.6.7.2.3.5 *Ionospheric uncertainty estimate parameter*. The ground subsystem shall broadcast an ionospheric delay gradient parameter in the Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.6 For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris error position bound parameters using additional data block 1 in the Type 2 message.

3.6.7.2.3.7 **Recommendation**.— All ground subsystems should broadcast the ephemeris error position bound parameters using additional data block 1 in the Type 2 message.

3.6.7.2.3.8 For ground subsystems that broadcast additional data block 1 in the Type 2 message, the following requirements shall apply:

3.6.7.2.3.8.1 *Maximum use distance.* The ground subsystem shall provide the distance (Dmax) from the GBAS reference point that defines a volume within which the ground subsystem integrity risk in 3.6.7.1.2.1 and the protection level integrity risk in 3.6.7.1.2.2 are met.

3.6.7.2.3.8.2 *Ephemeris missed detection parameters*. The ground subsystem shall broadcast the ephemeris missed detection parameters for each core satellite constellation such thatthe ground subsystem integrity risk of 3.6.7.1.2.1 is met.

3.6.7.2.3.8.3 *GBAS positioning service indication*. If the ground subsystem does not meet the requirements of 3.6.7.1.2.1.2 and 3.6.7.1.2.2.2, the ground subsystem shall indicate using the RSDS parameter that the GBAS positioning service is not provided.

3.6.7.2.3.9 If the VHF data broadcast is transmitted at more than one frequency within the GRAS service area, each GBAS broadcast station within the GRAS ground subsystem shall broadcast additional data blocks 1 and 2.

3.6.7.2.3.9.1 **Recommendation**.— The VHF data broadcast should include additional data block 2 parameters to identify channel numbers and locations of adjacent and nearby GBAS broadcast stations within the GRAS ground subsystem.

Note.— This facilitates the transition from one GBAS broadcast station to other GBAS broadcast stations in the GRAS ground subsystem.

3.6.7.2.4 Final approach segment data

3.6.7.2.4.1 *FAS data points accuracy*. The relative survey error between the FAS data points and the GBAS reference point shall be less than 0.25 metres vertical and 0.40 metres horizontal.

3.6.7.2.4.2 *SBAS FAS data points accuracy*. For use with SBAS, the survey error of all the FAS data points, relative to WGS-84, shall be less than 0.25 metres vertical and 1 metre horizontal.

3.6.7.2.4.3 **Recommendation**.— The final approach segment CRC should be assigned at the time of procedure design, and kept as an integral part of the FAS data block from that time onward.

3.6.7.2.4.4 **Recommendation**.— The GBAS should allow the capability to set the FASVAL and FASLAL for any FAS data block to “1111 1111” to limit the approach to lateral only or to indicate that the approach must not be used, respectively.

3.6.7.2.5 Predicted ranging source availability data

Note.— Ranging source availability data are optional for Category I and APV and may be required for possible future operations.

3.6.7.2.6 *Integrity monitoring for GNSS ranging sources*. The ground subsystem shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers complying with the tracking constraints in Attachment D, 8.11. The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo-range corrections. The monitor time-to-alert shall comply with 3.6.7.1.2. The monitor action shall be to set σpr_gnd to the bit pattern "1111 1111" for the satellite or to exclude the satellite from the Type 1 or Type 101 message. The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the Early-Late discriminator function as described in Attachment D, 8.11.

3.6.7.3MONITORING

3.6.7.3.1 RF monitoring

3.6.7.3.1.1 *VHF data broadcast monitoring*. The data broadcast transmissions shall be monitored. The transmission of the data shall cease within 0.5 seconds in case of continuous disagreement during any 3-second period between the transmitted application data and the application data derived or stored by the monitoring system prior to transmission.

3.6.7.3.1.2 TDMA slot monitoring. The risk that the ground subsystem transmits a signal in an unassigned slot and fails to detect an out-of-slot transmission, which exceeds that allowed in 3.6.2.6, within 1 second, shall be less than 1 × 10–7 in any 30-second period. If out-of-slot transmissions are detected, the ground subsystem shall terminate all data broadcast transmissions within 0.5 seconds.

3.6.7.3.1.3 *VDB transmitter power monitor*. The probability that the horizontally or elliptically polarized signal's transmitted power increases by more than 3 dB from the nominal power for more than 1 second shall be less than 2.0 × 10–7 in any 30-second period.

Note.— The vertical component is only monitored for GBAS/E equipment.

3.6.7.3.2 Data monitoring

3.6.7.3.2.1 *Broadcast quality monitor*. The ground subsystem monitoring shall comply with the time-to-alert requirements given in 3.6.7.1.2.1. The monitoring action shall be one of the following:

a) to broadcast Type 1 or Type 101 messages with no measurement blocks; or

b) to broadcast Type 1 or Type 101 messages with the opr_gnd, I field set to indicate the ranging source is invalid for every ranging source included in the previously transmitted frame; or

c) to terminate the data broadcast.

Note.— Monitoring actions a) and b) are preferred to c) if the particular failure mode permits such a response, because actions a) and b) typically have a reduced signal-in-space time-to-alert.

3.6.7.4 FUNCTIONAL REQUIREMENTS FOR AUTHENTICATION PROTOCOLS

3.6.7.4.1 Functional requirements for ground subsystems that support authentication

3.6.7.4.1.1 The ground system shall broadcast the additional data block 4 with the Type 2 message with the slot group definition field coded to indicate which slots are assigned to the ground station.

3.6.7.4.1.2 The ground subsystem shall broadcast every Type 2 message in the slot that corresponds to the SSID coding for the ground subsystem. Slot A is represented by SSID = 0, B by 1, C by 2, and H by 7.

3.6.7.4.1.3 *Assigned slot occupancy*. The ground subsystem shall transmit messages such that 87 per cent or more of every assigned slot is occupied. If necessary, Type 3 messages will be used to fill unused space in any assigned time slot.

3.6.7.4.1.4 *Reference path identifier coding*. Every reference path identifier included in every final approach segment data block broadcast by the ground station via the Type 4 messages shall have the first letter selected to indicate the SSID ofthe ground station in accordance with the following coding.

Coding: A = SSID of 0
X = SSID of 1
Z = SSID of 2
J = SSID of 3
C = SSID of 4
V = SSID of 5
P = SSID of 6
T = SSID of 7

3.6.7.4.2 Functional requirements for ground subsystems that do not support authentication

3.6.7.4.2.1 *Reference path indicator coding.* Characters in this set: {A X Z J C V P T} shall not be used as the first character of the reference path identifier included in any FAS block broadcast by the ground station via the Type 4 messages.

3.6.8 *AIRCRAFT ELEMENTS*

3.6.8.1 *GNSS receiver*. The GBAS-capable GNSS receiver shall process signals of GBAS in accordance with the requirements specified in this section as well as with requirements in 3.1.3.1 and/or 3.2.3.1 and/or 3.5.8.1.

3.6.8.2PERFORMANCE REQUIREMENTS

3.6.8.2.1 GBAS aircraft receiver accuracy

3.6.8.2.1.1 The RMS of the total aircraft receiver contribution to the error for GPS and GLONASS shall be:

$$RMS_{pr\_air}(\theta_n) \leq a_0 + a_1 \times e^{-(\theta_n/\theta_0)}$$

where

n = the nth ranging source;

θn = the elevation angle for the nth ranging source; and

a0, a1, and θ0= as defined in Table B-77 for GPS and Table B-78 for GLONASS.

3.6.8.2.1.2 The RMS of the total aircraft receiver contribution to the error for SBAS satellites shall be as defined in 3.5.8.2.1 for each of the defined aircraft accuracy designators.

Note.— The aircraft receiver contribution does not include the measurement error induced by airframe multipath.

Table B-77. Aircraft GPS receiver accuracy requirement

Aircraft accuracy designator	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)
A	≥5	0.15	0.43	6.9
B	≥5	0.11	0.13	4

Table B-78. Aircraft GLONASS receiver accuracy requirement

Aircraft accuracy designator	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)
A	≥5	0.39	0.9	5.7
B	≥5	0.105	0.25	5.5

3.6.8.2.2 VHF data broadcast receiver performance

3.6.8.2.2.1 *VHF data broadcast tuning range*. The VHF data broadcast receiver shall be capable of tuning frequencies in the range of 108.000 – 117.975 MHz in increments of 25 kHz.

3.6.8.2.2.2 *VHF data broadcast capture range.* The VHF data broadcast receiver shall be capable of acquiring and maintaining lock on signals within ±418 Hz of the nominal assigned frequency.

Note.— The frequency stability of the GBAS ground subsystem, and the worst-case doppler shift due to the motion of the aircraft, are reflected in the above requirement. The dynamic range of the automatic frequency control should also consider the frequency-stability error budget of the aircraft VHF data broadcast receiver.

3.6.8.2.2.3 VHF data broadcast sensitivity, range and message failure rate. The VHF data broadcast receiver shall achieve a message failure rate less than or equal to one failed message per 1 000 full-length (222 bytes) application data messages, while operating over a range from –87 dBm to –1 dBm, provided that the variation in the average received signal power between successive bursts in a given time slot does not exceed 40 dB. Failed messages include those lost by the VHF data broadcast receiver system or which do not pass the CRC after application of the FEC.

Note.— Aircraft VHF data broadcast receiving antenna can be horizontally or vertically polarized. Due to the difference in the signal strength of horizontally and vertically polarized components of the broadcast signal, the total aircraft implementation loss is limited to 15 dB for horizontally polarized receiving antennas and 11 dB for vertically polarized receiving antennas.

3.6.8.2.2.4 *VHF data broadcast time slot decoding*. The VHF data broadcast receiver shall meet the requirements of 3.6.8.2.2.3 for all Type 1, 2 and 4 messages from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

Note.— Other GBAS transmissions may include: a) messages other than Type 1, 2 and 4 with the same SSID, and b) messages with different SSIDs.

3.6.8.2.2.4.1 *Decoding of Type 101 messages*. A VHF data broadcast receiver capable of receiving Type 101 messages, shall meet the requirements of 3.6.8.2.2.3 for all Type 101 messages from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

3.6.8.2.2.5 Co-channel rejection

3.6.8.2.2.5.1 *VHF data broadcast as the undesired signal source.* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VHF data broadcast signal that is either:

a) assigned to the same time slot(s) and 26 dB below the desired VHF data broadcast signal power or lower; or

b) assigned different time slot(s) and whose power is up to 15 dBm at the receiver input.

3.6.8.2.2.5.2 *VOR as the undesired signal*. The VHF data broadcast receiver shall meet the requirements specified in

3.6.8.2.2.3 in the presence of an undesired co-channel VOR signal that is 26 dB below the desired VHF data broadcast signal power.

3.6.8.2.2.6 *Adjacent channel rejection*

3.6.8.2.2.6.1 *First adjacent 25 kHz channels (±25 kHz).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 25 kHz on either side of the desired channel that is either:

a) 18 dB above the desired signal power when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) equal in power when the undesired signal is VOR.

3.6.8.2.2.6.2 *Second adjacent 25 kHz channels (±50 kHz).* The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 50 kHz on either side of the desired channel that is either:

a) 43 dB above the desired signal power when the undesired signal is another VHF data broadcast source assigned to the same time slot(s); or

b) 34 dB above the desired signal power when the undesired signal is VOR.

3.6.8.2.2.6.3 Third and beyond adjacent 25 kHz channels (±75 kHz or more). The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 75 kHz or more on either side of the desired channel that is either:

a) 46 dB above the desired signal power when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b) 46 dB above the desired signal power when the undesired signal is VOR.

3.6.8.2.2.7 *Rejection of off-channel signals from sources inside the 108.000 – 117.975 MHz band.* With no on-channel VHF data broadcast signal present, the VHF data broadcast receiver shall not output data from an undesired VHF data broadcast signal on any other assignable channel.

3.6.8.2.2.8 *Rejection of signals from sources outside the 108.000 – 117.975 MHz band*

3.6.8.2.2.8.1 *VHF data broadcast interference immunity*. The VHF data broadcast receivershall meet the requirements specified in 3.6.8.2.2.3 in the presence of one or more signals having the frequency and total interference levels specified inTable B-79.

3.6.8.2.2.8.2 **Desensitization.** The VHF data broadcast receiver shall meet the requirements specifiedin 3.6.8.2.2.3 in the presence of VHF FM broadcast signals with signal levels shown in Tables B-80 and B-81.

Table B-79. Maximum levels of undesired signals

Frequency	Maximum level of undesired signals at the receiver input (dBm)
50 kHz up to 88 MHz	–13
88 MHz – 107.900 MHz	(see 3.6.8.2.2.8.2)
108.000 MHz – 117.975 MHz	excluded
118.000 MHz	–44
118.025 MHz	–41
118.050 MHz up to 1 660.5 MHz	–13

Notes.—

1. *The relationship is linear between single adjacent points designated by the above frequencies.*

2. *These interference immunity requirements may not be adequate to ensure compatibility between VHF data broadcast receivers and VHF communication systems, particularly for aircraft that use the vertically polarized component of the VHF data broadcast. Without coordination between COM and NAV frequencies assignments or respect of a guard band at the top end of the 112 – 117.975 MHz band, the maximum levels quoted at the lowest COM VHF channels (118.000, 118.00833, 118.01666, 118.025, 118.03333, 118.04166, 118.05) may be exceeded at the input of the VDB receivers. In that case, some means to attenuate the COM signals at the input of the VDB receivers (e.g. antenna separation) will have to be implemented. The final compatibility will have to be assured when equipment is installed on the aircraft.*

Table B-80. Desensitization frequency and power requirements that apply for VDB frequencies from 108.025 to 111.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dBm)
88 MHz ≤ f ≤ 102 MHz	15
104 MHz	10
106 MHz	5
107.9 MHz	–10

Notes.—

1. *The relationship is linear between single adjacent points designated by the above frequencies.*

2. *This desensitization requirement is not applied for FM carriers above 107.7 MHz and VDB channels at 108.025 or 108.050 MHz. See Attachment D, 7.2.1.2.2.*

Table B-81. Desensitization frequency and power requirements that apply for VDB frequencies from 112.000 to 117.975 MHz

Frequency	Maximum level of undesired signals at the receiver input (dBm)
88 MHz ≤ f ≤ 104 MHz	15
106 MHz	10
107 MHz	5
107.9 MHz	0

Note.— The relationship is linear between single adjacent points designated by the above frequencies.

3.6.8.2.2.8.3 VHF data broadcast FM intermodulation immunity. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of interference from two-signal, third-order intermodulation products of two VHF FM broadcast signals having levels in accordance with the following:

$$2N1 + N2 + 72 \leq 0$$

for VHF FM sound broadcasting signals in the range 107.7 – 108.0 MHz and

$$2N_1 + N_2 + 3\left(24 - 20\log\frac{\Delta f}{0.4}\right) \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDB frequency.

N1 and N2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VHF data broadcast receiver input.

Neither level shall exceed the desensitization criteria set forth in 3.6.8.2.2.8.2.

Δf = 108.1 – f1, where f1is the frequency of N1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

Note.– The FM intermodulation immunity requirements are not applied to a VHF data broadcast channel operating below 108.1 MHz, hence frequencies below 108.1 MHz are not intended for general assignments. Additional information is provided in Attachment D, 7.2.1.2.

3.6.8.3AIRCRAFT FUNCTIONAL REQUIREMENTS

3.6.8.3.1 Conditions for use of data

3.6.8.3.1.1 The receiver shall use data from a GBAS message only if the CRC of that message has been verified.

3.6.8.3.1.2 The receiver shall use message data only if the message block identifier is set to the bit pattern "1010 1010".

3.6.8.3.1.2.1 *GBAS message processing capability*. The GBAS receiver shall at a minimum process GBAS message types in accordance with Table B-82.

Table B-82. Airborne equipment message type processing

Airborne equipment designed performance	Minimum message types processed
APV-I	MT 1 or 101, MT 2 (including ADB 1 and 2 if provided)
APV-II	MT 1, MT 2 (including ADB 1 and 2 if provided), MT 4
Category I	MT 1, MT 2 (including ADB 1 if provided), MT 4

3.6.8.3.1.2.2 *Airborne processing for forward compatibility*

Note.— Provisions have been made to enable future expansion of the GBAS Standards to support new capabilities. New message types may be defined, new additional data blocks for message Type 2 may be defined and new data blocks defining reference paths for inclusion within message Type 4 may be defined. To facilitate these future expansions, all equipment should be designed to properly ignore all data types that are not recognized.

3.6.8.3.1.2.2.1 *Processing of unknown message types*. The existence of messages unknown to the airborne receiver shall not prevent correct processing of the required messages.

3.6.8.3.1.2.2.2 *Processing of unknown Type 2 extended data blocks*. The existence of message Type 2 additional data blocks unknown to the airborne receiver shall not prevent correct processing of the required messages.

3.6.8.3.1.2.2.3 *Processing of unknown Type 4 data blocks*. The existence of message Type 4 data blocks unknown to the airborne receiver shall not prevent correct processing of the required messages.

Note.— While the current SARPs include only one definition of a data block for inclusion within a Type 4 message, future GBAS Standards may include other reference path definitions.

3.6.8.3.1.3 The receiver shall use only ranging source measurement blocks with matching modified Z-counts.

3.6.8.3.1.4 If Dmaxis broadcast by the ground subsystem, the receiver shall only apply pseudo-range corrections when the distance to the GBAS reference point is less than Dmax.

3.6.8.3.1.5 The receiver shall only apply pseudo-range corrections from the most recently received set of corrections for a given measurement type. If the number of measurement fields in the most recently received Type 1 or Type 101 message indicates that there are no measurement blocks, then the receiver shall not apply GBAS corrections for that measurement type.

3.6.8.3.1.6 The receiver shall exclude from the differential navigation solution any ranging sources for which σpr_gndis set to the bit pattern "1111 1111".

3.6.8.3.1.7 The receiver shall only use a ranging source in the differential navigation solution if the time of applicability indicated by the modified Z-count in the Type 1 or Type 101 message containing the ephemeris decorrelation parameter for that ranging source is less than 120 seconds old.

3.6.8.3.1.8 Conditions for use of data to support Category I precision approach and APV

3.6.8.3.1.8.1 During the final stages of a Category I or APV approach, the receiver shall use only measurement blocks from Type 1 or Type 101 messages that were received within the last 3.5 seconds.

3.6.8.3.1.8.2 The receiver shall use message data from a GBASground subsystem for Category I precision approach or

APV guidance only if the GCID indicates 1, 2, 3 or 4 prior to initiating the final stages of an approach.

3.6.8.3.1.8.3 The receiver shall ignore any changes in GCID during the final stages of an approach.

3.6.8.3.1.8.4 The receiver shall not provide approach vertical guidance based on a particular FAS data block transmitted in a Type 4 message if the FASVAL received prior to initiating the final stages of the approach is set to “1111

1111”.

3.6.8.3.1.8.5 The receiver shall not provide approach guidance based on a particular FAS data block transmitted in a Type 4 message if the FASLAL received prior to initiating the final stages of the approach is set to “1111 1111”.

3.6.8.3.1.8.6 Changes in the values of FASLAL and FASVAL data transmitted in a Type 4 message during the final stages of an approach shall be ignored by the receiver.

3.6.8.3.1.8.7 The receiver shall use FAS data only if the FAS CRC for that data has been verified.

3.6.8.3.1.8.8 The receiver shall only use messages for which the GBAS ID (in the message block header) matches the GBAS ID in the header of the Type 4 message which contains the selected FAS data or the Type 2 message which contains the selected RSDS.

3.6.8.3.1.8.9 Use of FAS data

3.6.8.3.1.8.9.1 The receiver shall use the Type 4 messages to determine the FAS for precision approach.

3.6.8.3.1.8.9.2 The receiver shall use the Type 4 messages to determine the FAS for APV associated with a channel number between 20 001 and 39 999.

3.6.8.3.1.8.9.3 The receiver shall use the FAS held within the on-board database for APV associated with a channel number between 40 000 and 99 999.

3.6.8.3.1.8.10 When the GBAS ground subsystem does not broadcast the Type 4 message and the selected FAS data are available to the receiver from an airborne database, the receiver shall only use messages from the intended GBAS ground subsystem.

3.6.8.3.1.9 Conditions for use of data to provide the GBAS positioning service

3.6.8.3.1.9.1 The receiver shall only use measurement blocks from Type 1 messages that were received within the last 7.5 seconds.

3.6.8.3.1.9.2 The receiver shall only use measurement blocks from Type 101 messages that were received within the last 5 seconds.

3.6.8.3.1.9.3 The receiver shall only use message data if a Type 2 message containing additional data block 1 has been received and the RSDS parameter in this block indicates that the GBAS positioning service is provided.

3.6.8.3.1.9.4 The receiver shall only use messages for which the GBAS ID (in the message block header) matches the GBAS ID in the header of the Type 2 message which contains the selected RSDS.

3.6.8.3.2 Integrity

3.6.8.3.2.1 *Bounding of aircraft errors.* For each satellite used in the navigation solution, the receiver shall compute a $\sigma_{receiver}$ such that a normal distribution with zero mean and a standard deviation equal to $\sigma_{receiver}$ bounds the receiver contribution to the corrected pseudo-range error as follows:

$$\int_{y}^{\infty} f(x)\,dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f(x)\,dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where

f(x) = probability density function of the residual aircraft pseudo-range error and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}}\,dt$$

3.6.8.3.2.2 *Use of GBAS integrity parameters*. The aircraft element shall compute and apply the vertical, lateral and horizontal protection levels described in 3.6.5.5 using the GBAS broadcast σpr_gnd, σN, h0, σvert_iono_gradient, and B parameters as well as the σpr_airparameter. If a Bi,j parameter is set to the bit pattern "1000 0000" indicating that the measurement is not available, the aircraft element shall assume that Bi,j has a value of zero. For Category I precision approach and APV, the aircraft element shall verify that the computed vertical and lateral protection levels are smaller than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

3.6.8.3.3 *Use of satellite ephemeris data*

3.6.8.3.3.1 *IOD check*. The receiver shall only use satellites for which the IOD broadcast by GBAS in the Type 1 or Type 101 message matches the core satellite constellation IOD for the clock and ephemeris data used by the receiver.

3.6.8.3.3.2 *CRC check*. The receiver shall compute the ephemeris CRC for each core satellite constellation's ranging source used in the position solution. The computed CRC shall be validated against the ephemeris CRC broadcast in the Type 1 or Type 101 messages within one second of receiving a new broadcast CRC. The receiver shall immediately cease using any satellite for which the computed and broadcast CRC values fail to match.

Note.— During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the broadcast ephemeris CRC for that satellite.

3.6.8.3.3.3 *Ephemeris error position bounds*

3.6.8.3.3.3.1 Ephemeris error position bounds for Category I precision approach and APV. If the ground subsystem provides additional data block 1 in the Type 2 messages, the aircraft element shall compute the ephemeris error position bounds defined in 3.6.5.8.1 for each core satellite constellation's ranging source used in the position solution within 1s of receiving the necessary broadcast parameters. The aircraft element shall exclude from the position solution satellites for which the computed vertical or lateral ephemeris error position bounds (VEBj or LEBj) are larger than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

Note.— During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the necessary broadcast parameters for that satellite to compute the ephemeris error position bounds.

3.6.8.3.3.3.2 *Ephemeris error position bound for the GBAS positioning service.* The aircraft element shall compute and apply the horizontal ephemeris error position bound (HEBj) defined in 3.6.5.8.2 for each core satellite constellation's ranging source used in the position solution.

3.6.8.3.4 *Message loss*

3.6.8.3.4.1 For Category I precision approach, the receiver shall provide an appropriate alert if no Type 1 or Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.2 For APV, the receiver shall provide an appropriate alert if no Type 1 and no Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.3 For the GBAS positioning service using Type 1 messages, the receiver shall provide an appropriate alert if no Type 1 message was received during the last 7.5 seconds.

3.6.8.3.4.4 For the GBAS positioning service using Type 101 messages, the receiver shall provide an appropriate alert if no Type 101 message was received during the last 5 seconds.

3.6.8.3.5 *Airborne pseudo-range measurements*

3.6.8.3.5.1 Carrier smoothing for airborne equipment. Airborne equipment shall utilize the standard 100-second carrier smoothing of code phase measurements defined in 3.6.5.1. During the first 100 seconds after filter start-up, the value of αshall be either:

a) a constant equal to the sample interval divided by 100 seconds; or

b) a variable quantity defined by the sample interval divided by the time in seconds since filter start-up.

3.7 *Resistance to interference*

3.7.1 *PERFORMANCE OBJECTIVES*

Note 1.— For un augmented GPS and GLONASS receivers the resistance to interference is measured with respect to the following performance parameters:

	GPS	*GLONASS*
Tracking error (1 sigma)	*0.4 m*	*0.8 m*

Note 2.— This tracking error neither includes contributions due to signal propagation such as multipath, tropospheric and ionospheric effects nor ephemeris and GPS and GLONASS satellite clock errors.

Note 3.— For SBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.5.8.2.1 and 3.5.8.4.1.

Note 4.— For GBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.6.7.1.1 and 3.6.8.2.1.

Note 5.— The signal levels specified in this section are defined at the antenna port. Assumed maximum aircraft antenna gain in the lower hemisphere is –10 dBic.

Note 6.— The performance requirements are to be met in the interference environments defined below for various phases of flight.

3.7.2 *CONTINUOUS WAVE (CW)INTERFERENCE*

3.7.2.1 *GPSAND SBASRECEIVERS*

3.7.2.1.1 GPS and SBAS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-83 and shown in Figure B-15 and with a desired signal level of –164.5 dBW at the antenna port.

3.7.2.1.2 GPS and SBAS receivers used for non-precision approach shall meet the performance objectives with interference thresholds 3 dB less than specified in Table B-83. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the interference thresholds shall be 6 dB less than those specified in Table B-83.

Table B-83. CW interference thresholds for GPS and SBAS receivers

Frequency range f_i of the interference signal	Interference thresholds for receivers used for precision approach phase of flight
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ 1 525 MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 525 MHz < $f_i \leq$ 1 565.42 MHz	Linearly decreasing from –42 dBW to –150.5 dBW
1 565.42 MHz < $f_i \leq$ 1 585.42 MHz	–150.5 dBW
1 585.42 MHz < $f_i \leq$ 1 610 MHz	Linearly increasing from –150.5 dBW to –60 dBW
1 610 MHz < $f_i \leq$ 1 618 MHz	Linearly increasing from –60 dBW to –42 dBW*
1 618 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 610 MHz < $f_i \leq$ 1 626.5 MHz	Linearly increasing from –60 dBW to –22 dBW**
1 626.5 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
$f_i >$ 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there is on-board satellite communications.

3.7.2.2GLONASSRECEIVERS

3.7.2.2.1 GLONASS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-84 and shown in Figure B-16 and with a desired signal level of –165.5 dBW at the antenna port.

Table B-84. Interference threshold for GLONASS receivers

Frequency range f_i of the interference signal	Interference thresholds for receivers used for precision approach phase of flight
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ 1 562.15625 MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 562.15625 MHz < $f_i \leq$ 1 583.65625 MHz	Linearly decreasing from –42 dBW to –80 dBW
1 583.65625 MHz < $f_i \leq$ 1 592.9525 MHz	Linearly decreasing from –80 dBW to –149 dBW
1 592.9525 MHz < $f_i \leq$ 1 609.36 MHz	–149 dBW
1 609.36 MHz < $f_i \leq$ 1 613.65625 MHz	Linearly increasing from –149 dBW to –80 dBW
1 613.65625 MHz < $f_i \leq$ 1 635.15625 MHz	Linearly increasing from –80 dBW to –42 dBW*
1 613.65625 MHz < $f_i \leq$ 1 626.15625 MHz	Linearly increasing from –80 dBW to –22 dBW**
1 635.15625 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 626.15625 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
$f_i >$ 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there is on-board satellite communications.

3.7.2.2.2 GLONASS receivers used for non-precision approach shall meet the performance objectives with interference thresholds 3 dB less than specified in Table B-84. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GLONASS signals prior to steady-state navigation, the interference thresholds shall be 6 dB less than those specified in Table B-84.

3.7.3 BAND-LIMITED NOISE-LIKE INTERFERENCE

3.7.3.1 *GPSAND SBASRECEIVERS*

3.7.3.1.1 After steady-state navigation has been established, GPS and SBAS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with noise like interfering signals present in the frequency range of 1 575.42 MHz ±Bwi/2 and with power levels at the antenna port equal to the interference thresholds specified in Table B-85 and Figure B-17 and with the desired signal level of –164.5 dBW at the antenna port.

Note.— Bwi is the equivalent noise bandwidth of the interference signal.

3.7.3.1.2 GPS and SBAS receivers used for non-precision approach shall meet their performance objectives with interference thresholds for band-limited noise-like signals 3 dB less than specified in Table B-85. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the interference thresholds for band-limited noise-like signals shall be 6 dB less than those specified in Table B-85.

3.7.3.2 GLONASSRECEIVERS

3.7.3.2.1 After steady-state navigation has been established, GLONASS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives while receiving noise-like interfering signals in the frequency band fk±Bwi/2, with power levels at the antenna port equal to the interference thresholds defined in Table B-86 and with a desired signal level of –165.5 dBW at the antenna port.

Note.— fkis the centre frequency of a GLONASS channel with fk= 1 602 MHz + k ×0.6525 MHz and k = –7 to +13 as defined in Table B-16 and Bwiis the equivalent noise bandwidth of the interference signal.

3.7.3.2.2 GLONASS receivers used for non-precision approach shall meet their performance objectives with interference thresholds for band-limited noise-like signals 3 dB less than specified in Table B-85. For terminal area and en route steady-state navigation operations, and for initial acquisition of the GLONASS signals prior to steady-state navigation, the interference thresholds for band-limited noise-like signals shall be 6 dB less than those specified in Table B-86.

Note.— For the approach phase of flight it is assumed that the receiver operates in tracking mode and acquires no new satellites.

3.7.3.3 *Pulsed interference*. After steady-state navigation has been established, the receiver shall meet the performance objectives while receiving pulsed interference signals with characteristics according to Table B-87 where the interference threshold is defined at the antenna port.

3.7.3.4 SBAS and GBAS receivers shall not output misleading information in the presence of interference including interference levels above those specified in 3.7.

Note.— Guidance material on this requirement is given in Attachment D, 10.6.

3.8 GNSS aircraft satellite receiver antenna

3.8.1 Antenna coverage. The GNSS antenna shall meet the performance requirements for the reception of GNSS satellite signals from 0 to 360 degrees in azimuth and from 0 to 90 degrees in elevation relative to the horizontal plane of anaircraft in level flight.

3.8.2 *Antenna gain.* The minimum antenna gain shall not be less than that shown in Table B-88 for the specified elevation angle above the horizon. The maximum antenna gain shall not exceed +4 dBic for elevation angles above 5 degrees.

3.8.3 *Polarization.* The GNSS antenna polarization shall be right-hand circular (clockwise with respect to the direction of propagation).

3.9 Cyclic redundancy check

Each CRC shall be calculated as the remainder, R(x), of the Modulo-2 division of two binary polynomials as follows:

$$\left\{\frac{[x^k M(x)]}{G(x)}\right\}_{\text{mod } 2} = Q(x) + \frac{R(x)}{G(x)}$$

where

k = the number of bits in the particular CRC;
M(x) = the information field, which consists of the data items to be protected by the particular CRC represented as a polynomial;
G(x) = the generator polynomial specified for the particular CRC;
Q(x) = the quotient of the division; and
R(x) = the remainder of the division, contains the CRC:

$$R(x) = \sum_{i=1}^{k} r_i x^{k-i} = r_1 x^{k-1} + r_2 x^{k-2} + \dots + r_k x^0$$

Table B-85. Interference threshold for band-limited noise-like interference to GPS and SBAS receivers used for precision approach

Interference bandwidth	Interference threshold
0 Hz < Bw_i ≤ 700 Hz	−150.5 dBW
700 Hz < Bw_i ≤ 10 kHz	−150.5 + 6 $\log_{10}$(BW/700) dBW
10 kHz < Bw_i ≤ 100 kHz	−143.5 + 3 $\log_{10}$(BW/10000) dBW
100 kHz < Bw_i ≤ 1 MHz	−140.5 dBW
1 MHz < Bw_i ≤ 20 MHz	Linearly increasing from −140.5 to −127.5 dBW*
20 MHz < Bw_i ≤ 30 MHz	Linearly increasing from −127.5 to −121.1 dBW*
30 MHz < Bw_i ≤ 40 MHz	Linearly increasing from −121.1 to −119.5 dBW*
40 MHz < Bw_i	−119.5 dBW*

* The interference threshold is not to exceed −140.5 dBW/MHz in the frequency range 1 575.42 ±10 MHz.

Table B-86. Interference threshold for band-limited noise-like interference to GLONASS receivers used for precision approach

Interference bandwidth	Interference threshold
0 Hz < Bw_i ≤ 1 kHz	−149 dBW
1 kHz < Bw_i ≤ 10 kHz	Linearly increasing from −149 to −143 dBW
10 kHz < Bw_i ≤ 0.5 MHz	−143 dBW
0.5 MHz < Bw_i ≤ 10 MHz	Linearly increasing from −143 to −130 dBW
10 MHz < Bw_i	−130 dBW

Table B-87. Interference thresholds for pulsed interference

	GPS and SBAS	GLONASS
Frequency range	1 575.42 MHz ± 10 MHz	1 592.9525 MHz to 1 609.36 MHz
Interference threshold (Pulse peak power)	−20 dBW	−20 dBW
Pulse width	≤125 µs	≤250 µs
Pulse duty cycle	≤1%	≤1%

Table B-88. Minimum antenna gain — GPS, GLONASS and SBAS

Elevation angle degrees	Minimum gain dBic
0	−7
5	−5.5
10	−4
15 to 90	−2.5

Note.— The –5.5 dBic gain at 5 degrees elevation angle is appropriate for an L1 antenna. A higher gain may be required in the future for GNSS signals in the L5/E5 band.

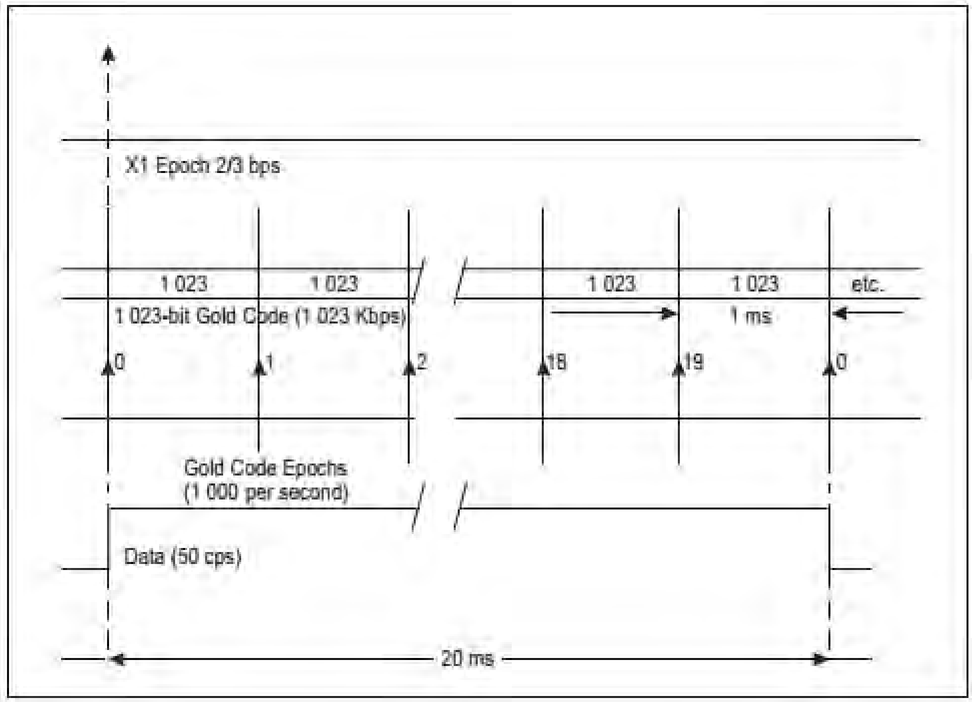


Figure B-1. C/A code timing relationships

SUBFRAME 1	TLM	HOW	GPS week number, SV accuracy and health
SUBFRAME 2	TLM	HOW	Ephemeris parameters
SUBFRAME 3	TLM	HOW	Ephemeris parameters
SUBFRAME 4 (25 pages)	TLM	HOW	Almanac and health for satellites 25–32, special messages, satellite configuration, flags, ionospheric and UTC
SUBFRAME 5 (25 pages)	TLM	HOW	Almanac and health for satellites 1–24 and almanac reference time and GPS week number

Figure B-2. Frame structur

Preamble								Reserved																Parity					
1	0	0	0	1	0	1	1	MSB														LSB							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Figure B-3. TLM word format

Figure B-4. HOW format

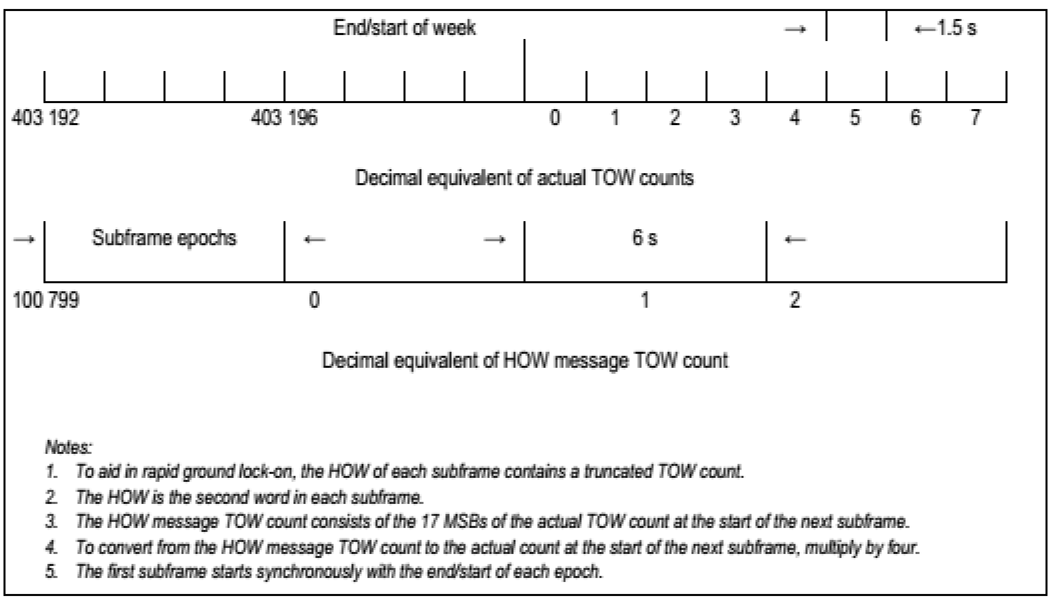


Figure B-5. Time line relationship of HOW

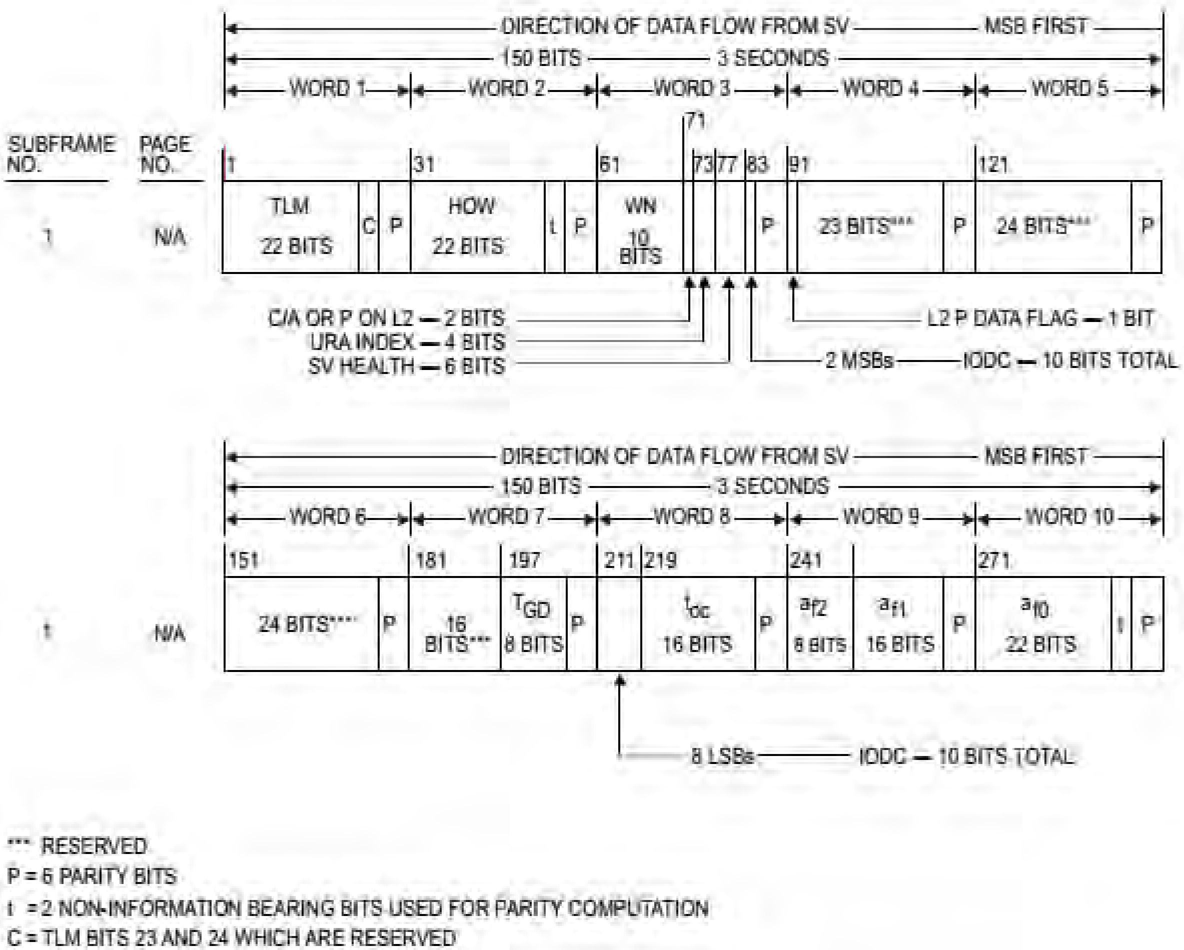


Figure B-6. Data format (1 of 11)

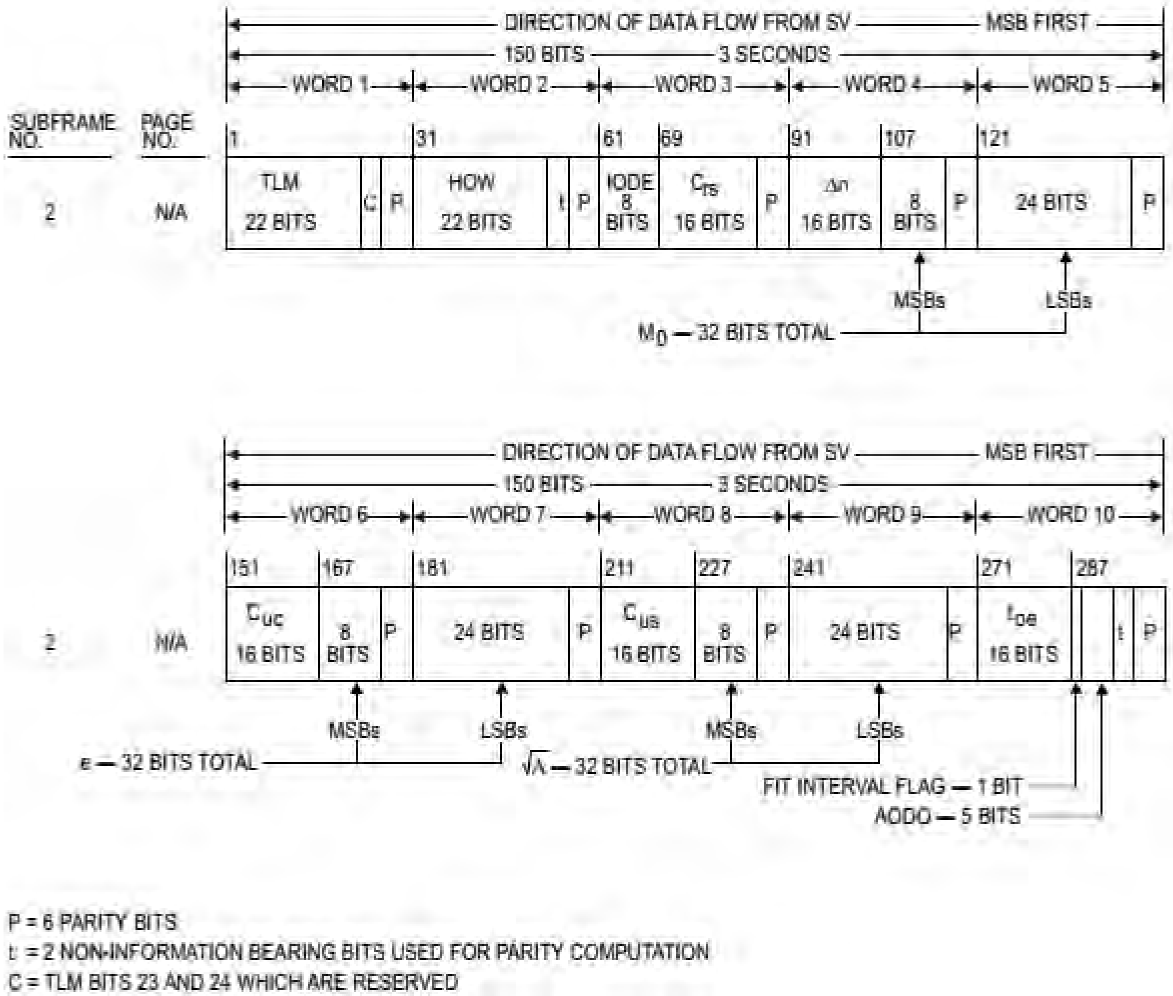


Figure B-6. Data format (2 of 11)

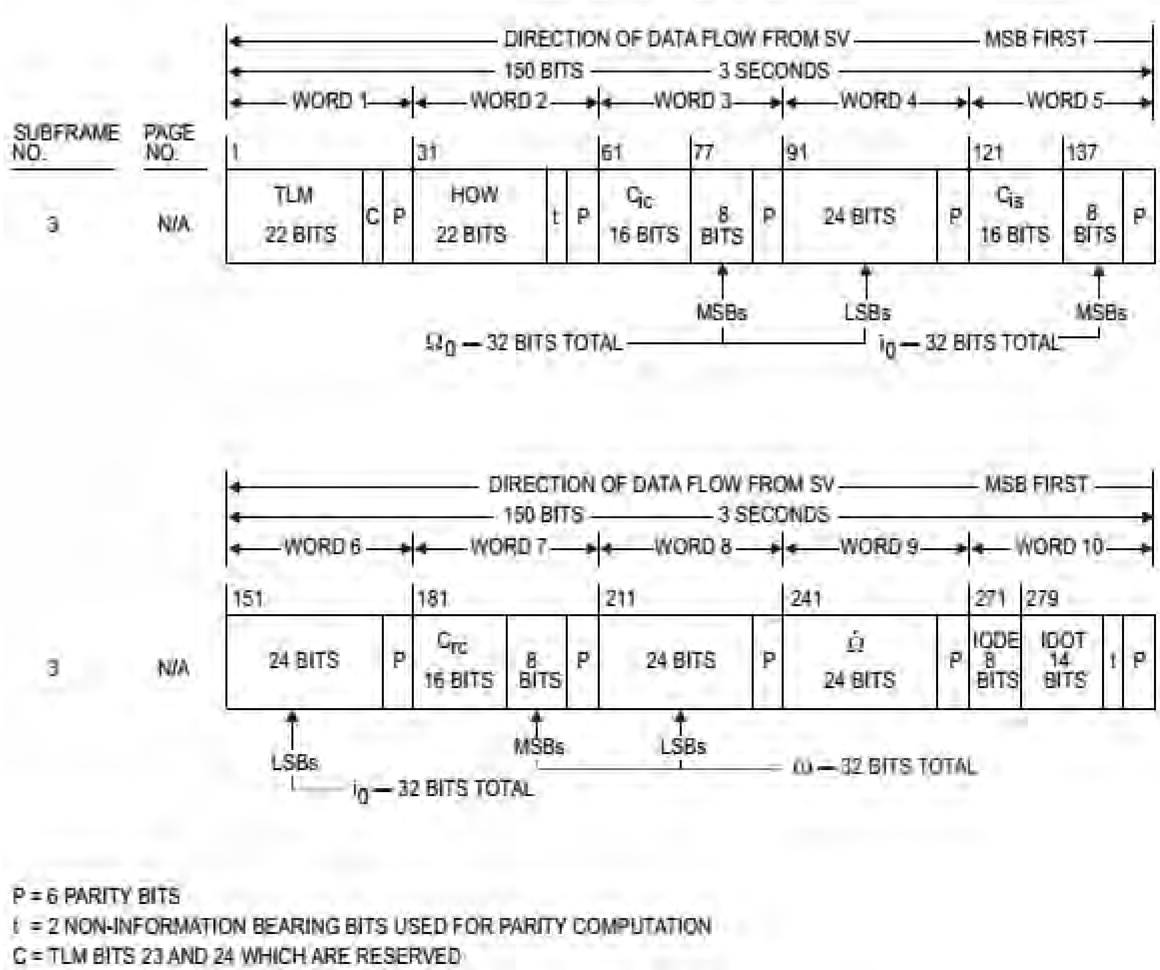
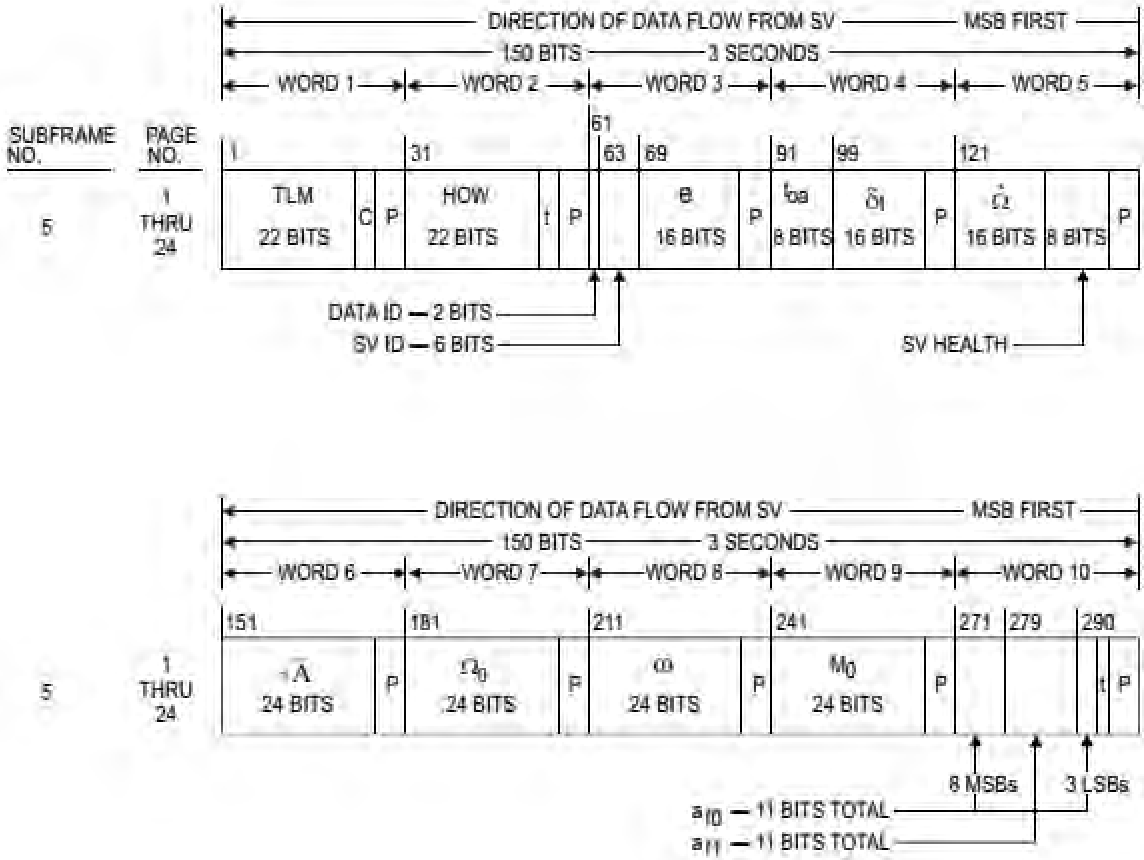


Figure B-6. Data format (3 of 11)



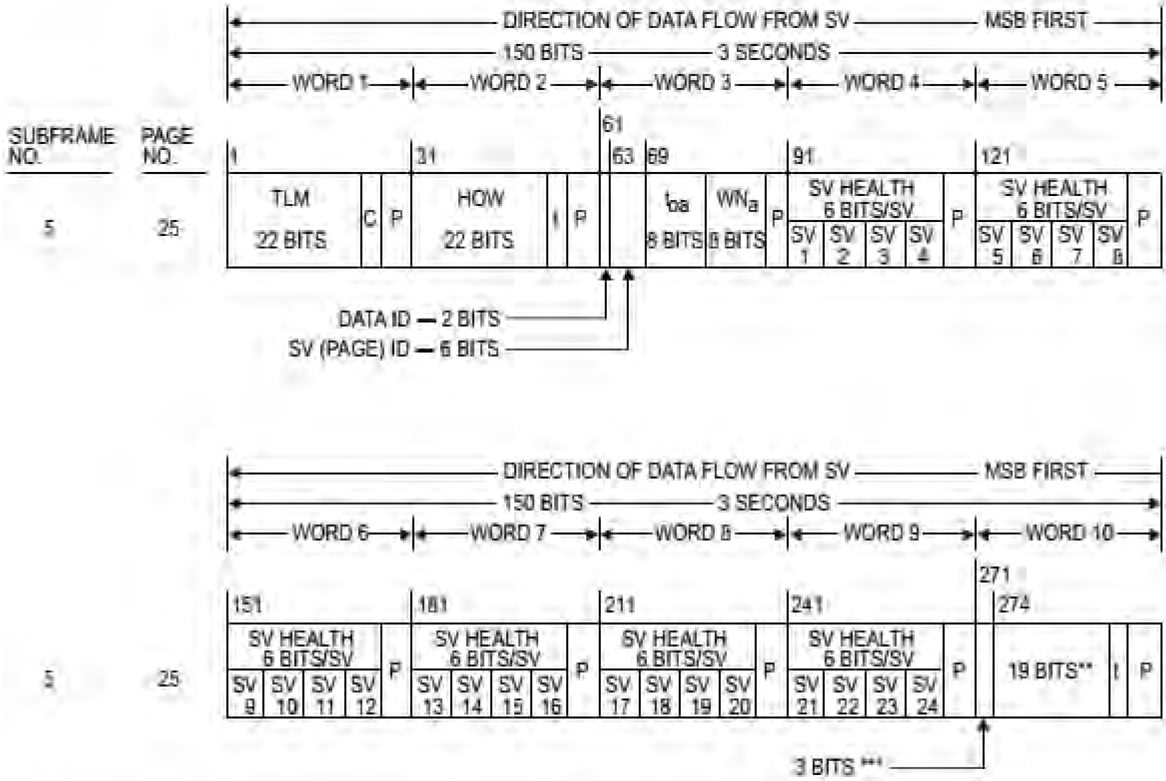
P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Note.— Pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 have the same format as pages 1 through 24 of subframe 5.

Figure B-6. Data format (4 of 11)



** RESERVED FOR SYSTEM USE

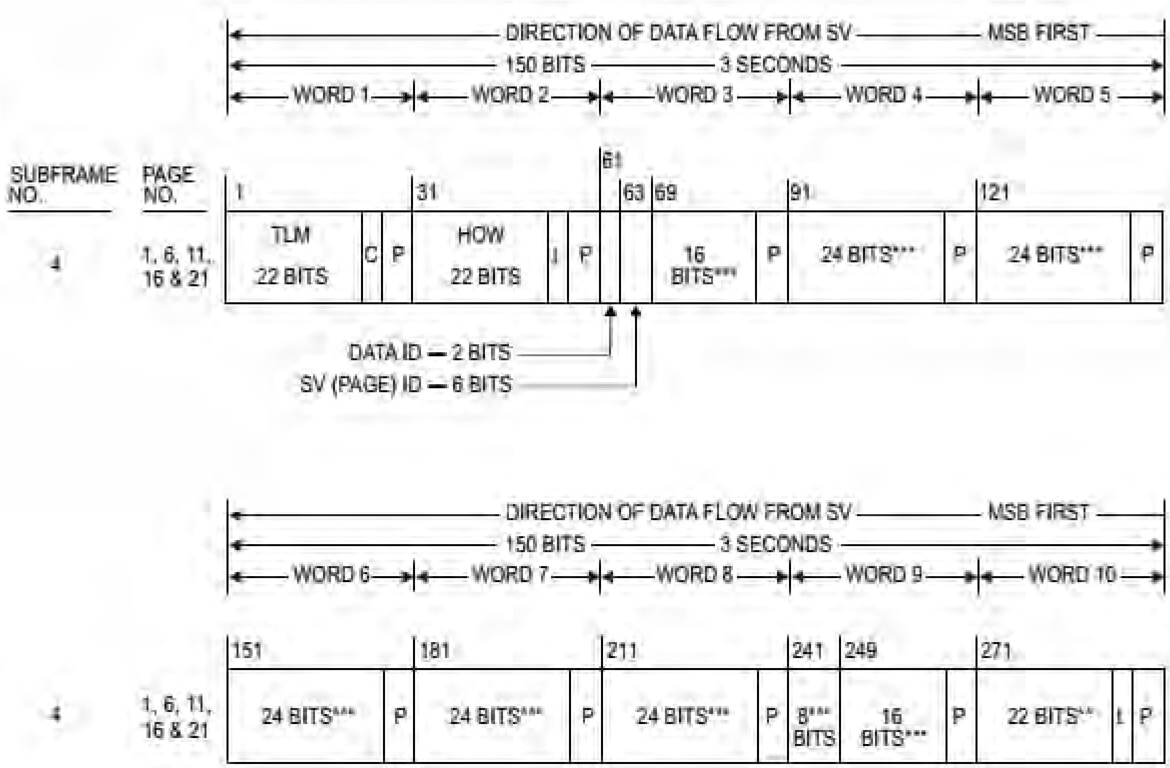
*** RESERVED

P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

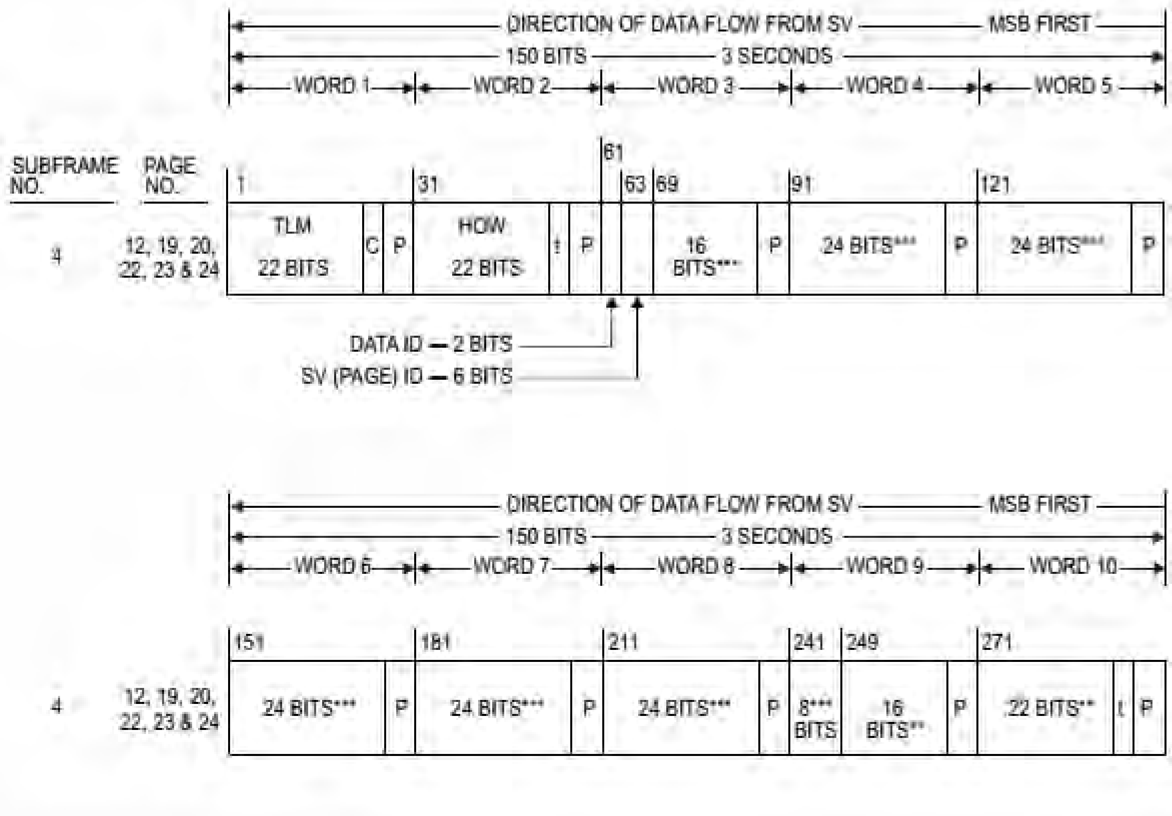
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (5 of 11)



** RESERVED FOR SYSTEM USE
*** RESERVED
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (6 of 11)



** RESERVED FOR SYSTEM USE
*** RESERVED
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (7 of 11)

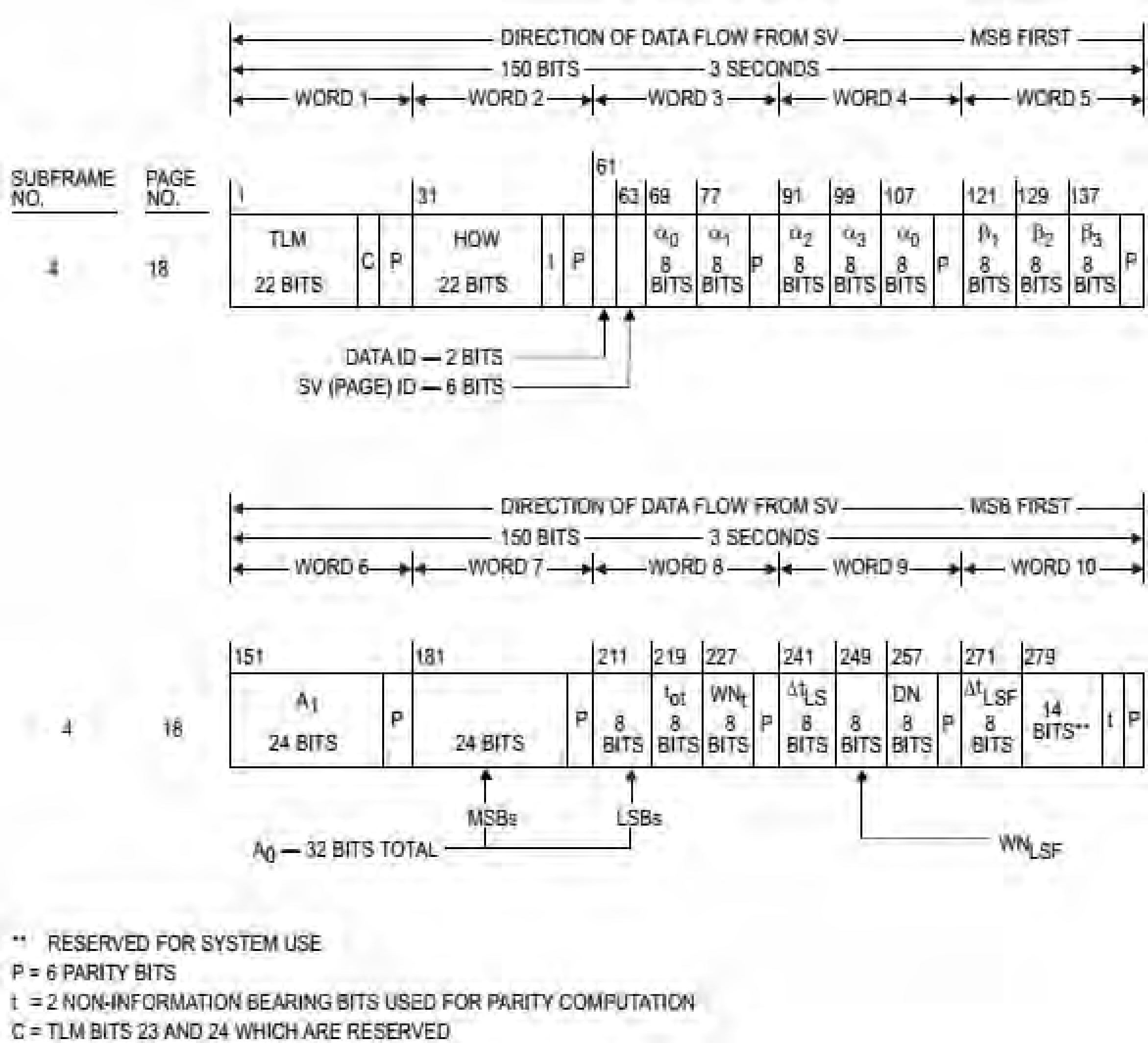


Figure B-6. Data format (8 of 11)

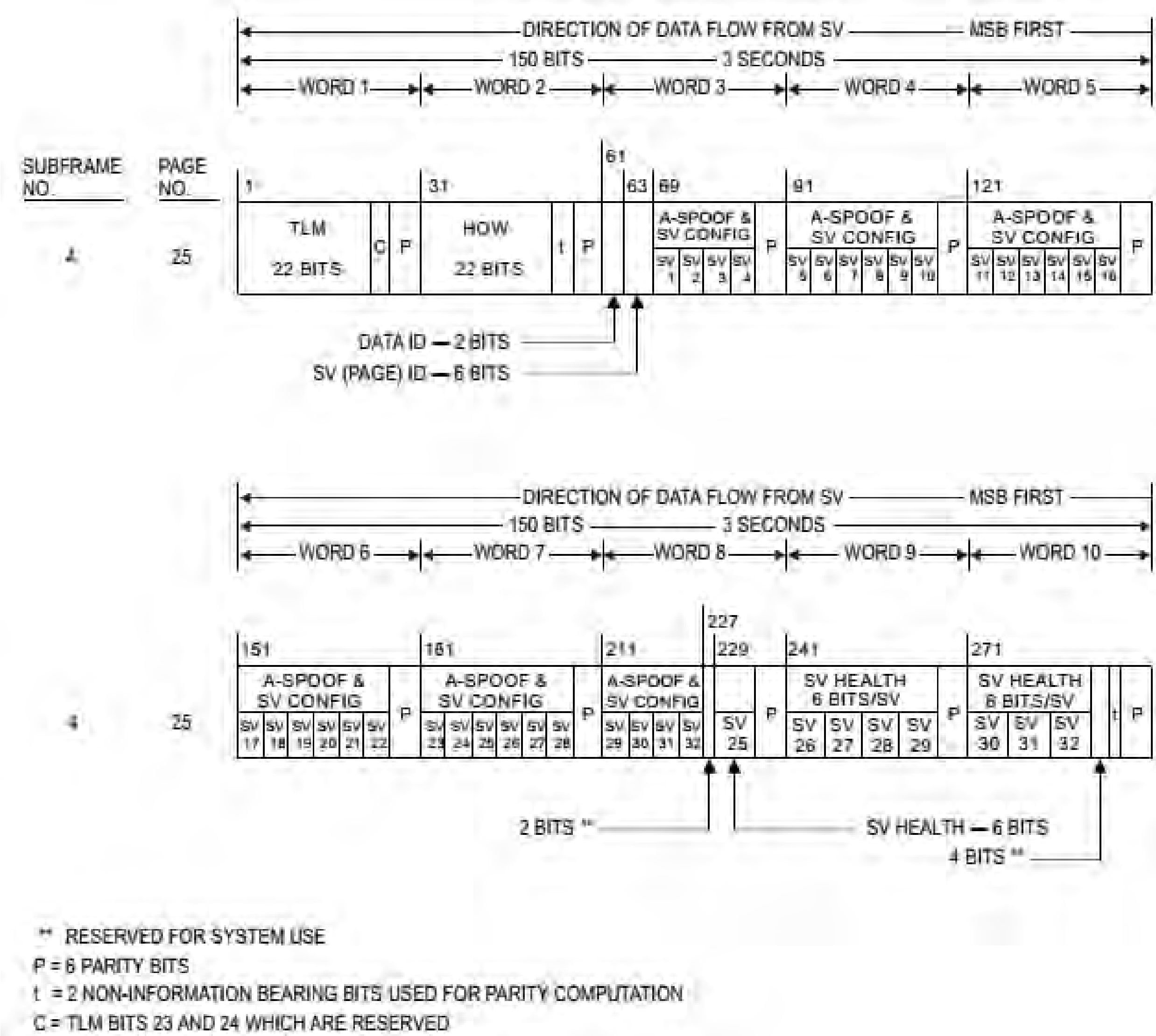


Figure B-6. Data format (9 of 11)

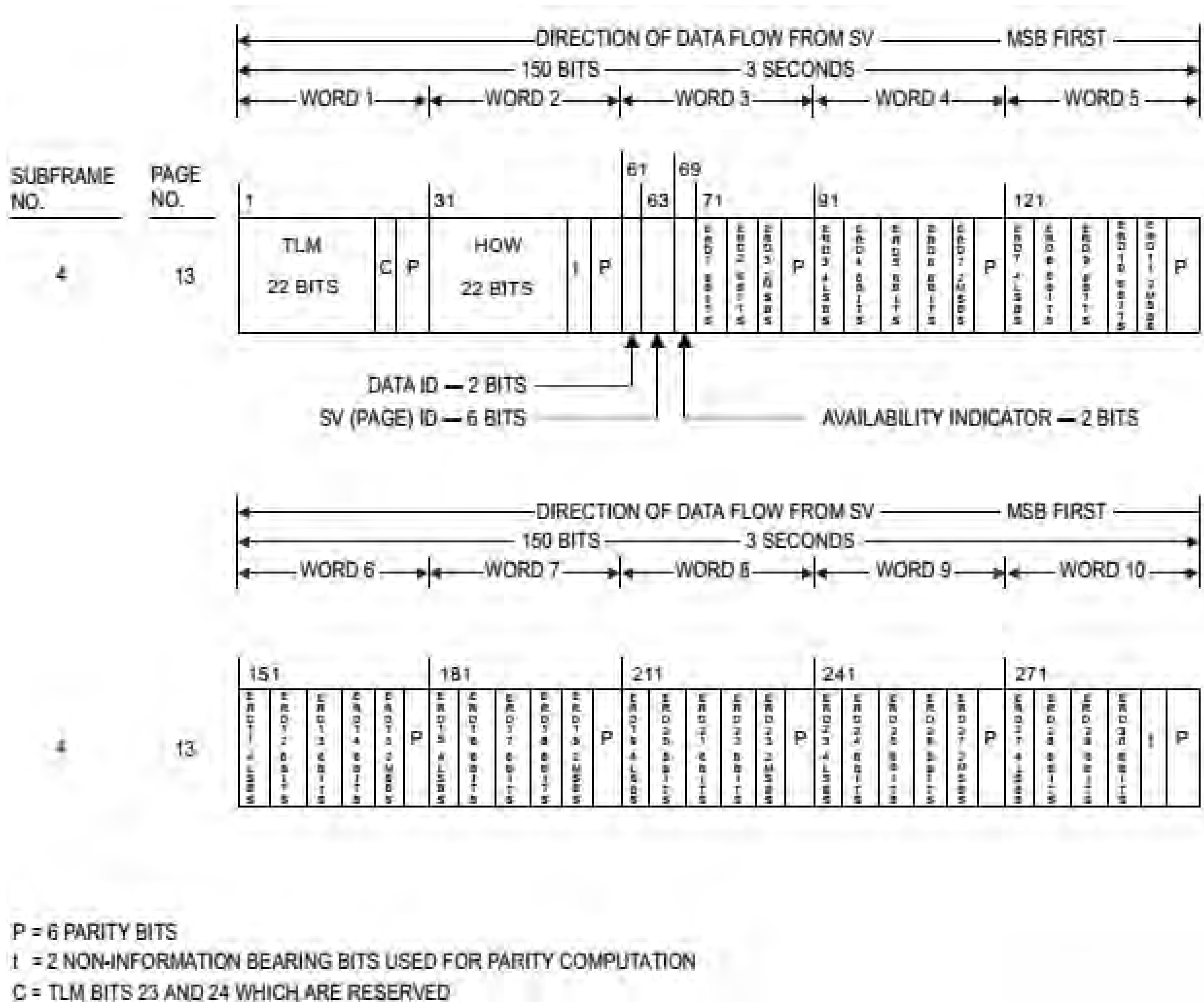
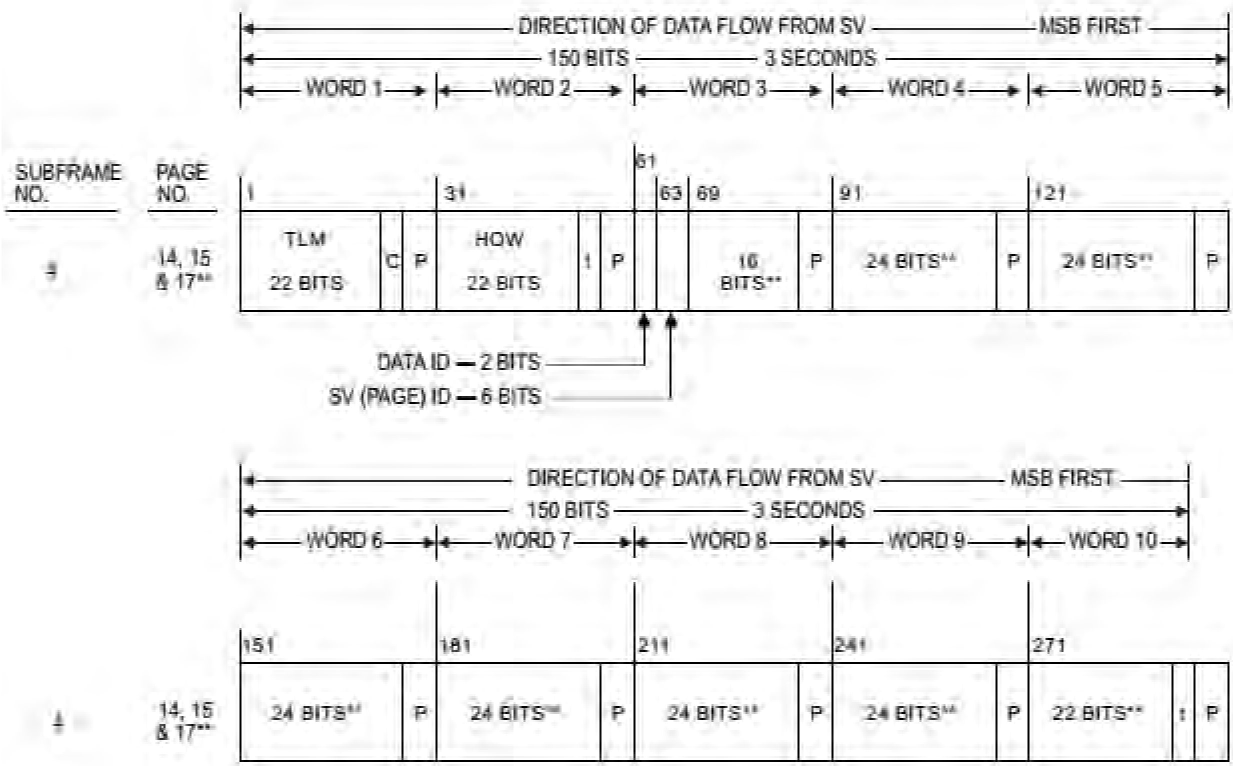


Figure B-6. Data format (10 of 11)



** THE INDICATED PORTIONS OF WORDS 3 THROUGH 10 OF PAGES 14 AND 15 ARE RESERVED FOR SYSTEM USE, WHILE THOSE OF PAGE 17 ARE RESERVED FOR SPECIAL MESSAGES

P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6. Data format (11 of 11)

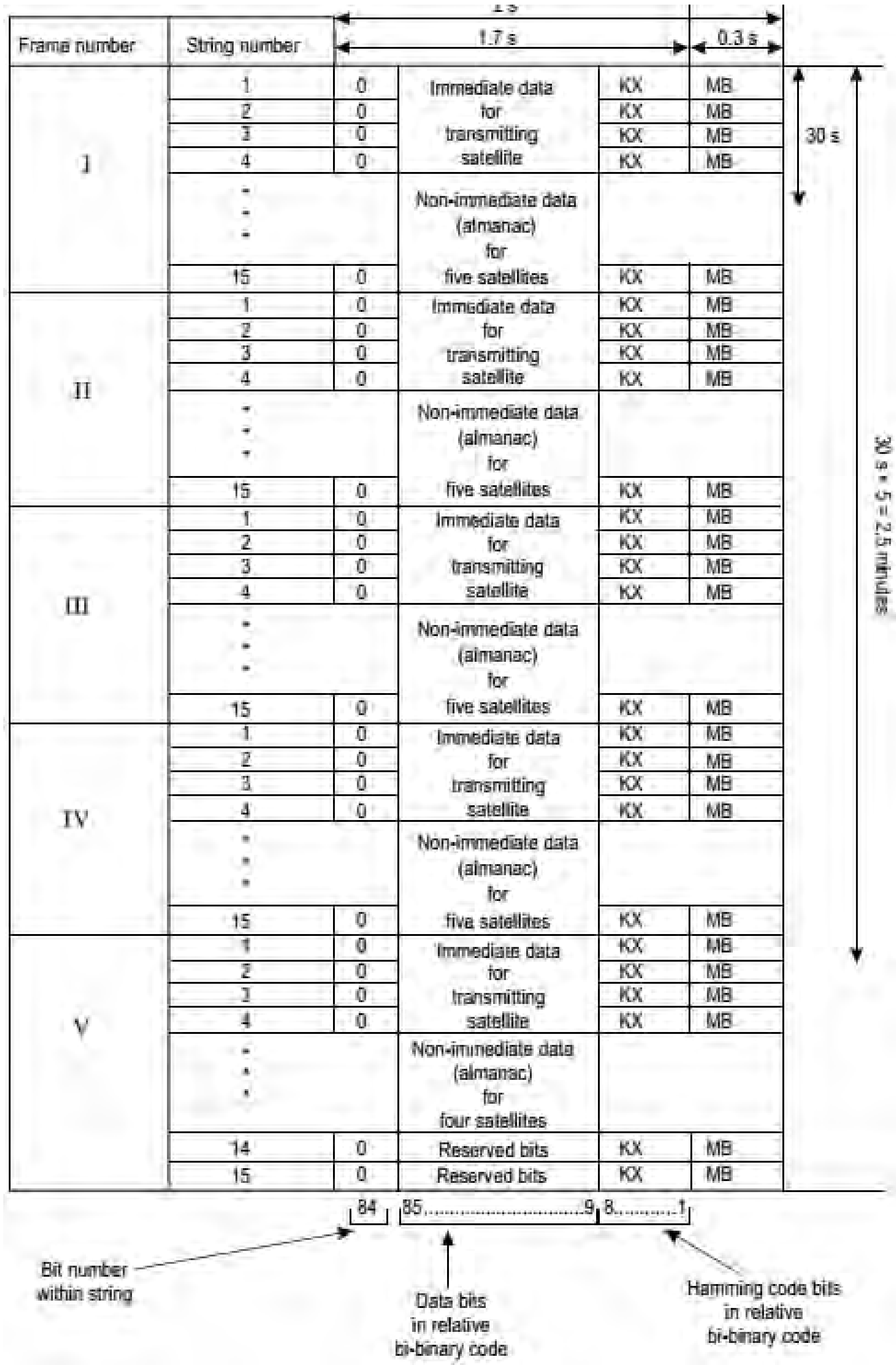
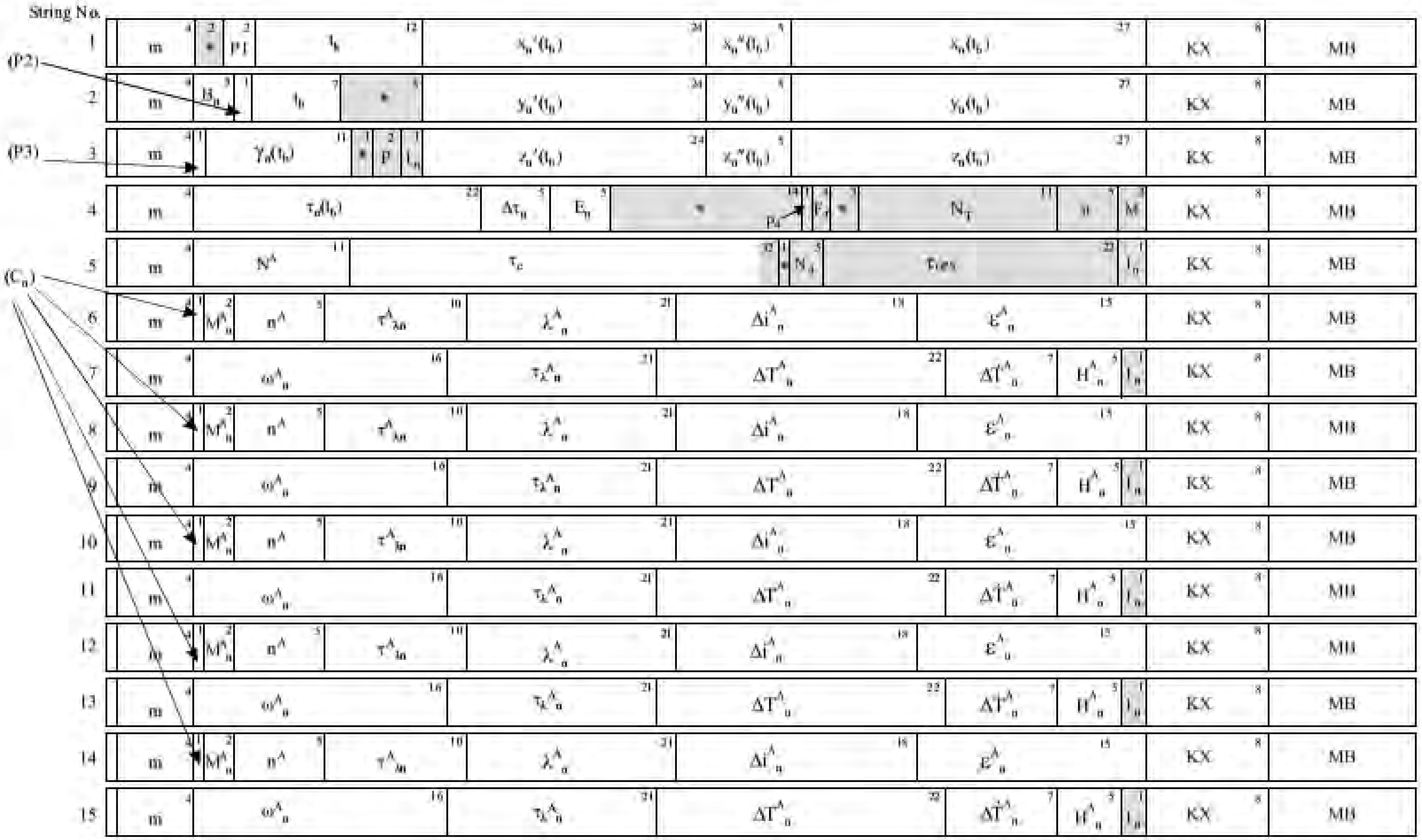


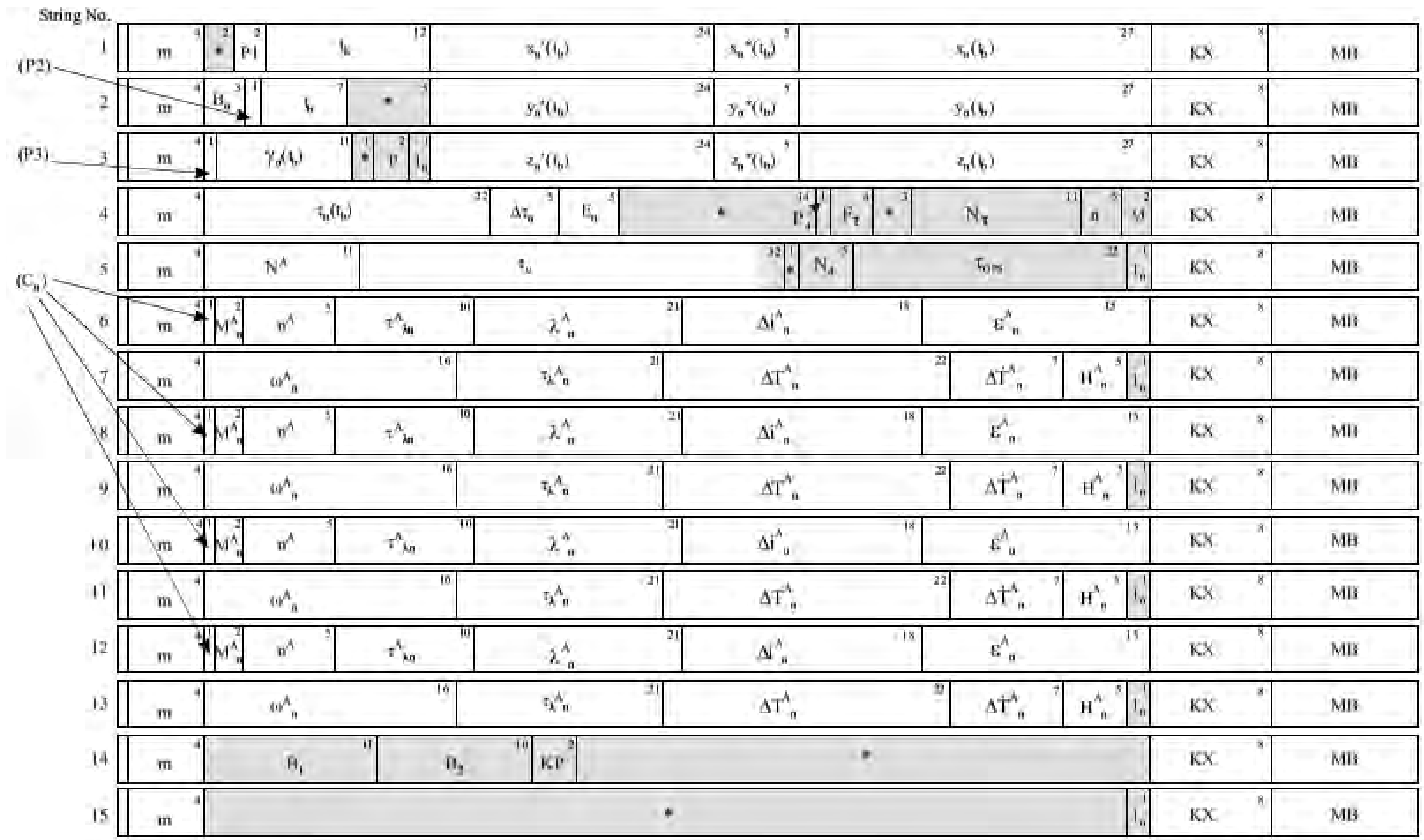
Figure B-7. Superframe structure



* Reserved bits within frame

Note.— Data content, definitions and explanations of parameters are given in 3.2.1.3 and 3.2.1.4. Additional data transmitted by GLONASS-M are highlighted in this figure.

Figure B-8. Frame structure (frames 1 to 4)



* Reserved bits within frame

Note.— Data content, definitions and explanations of parameters are given in 3.2.1.3 and 3.2.1.4. Additional data transmitted by GLONASS-M are highlighted in this figure.

Figure B-9. Frame structure (frame 5)

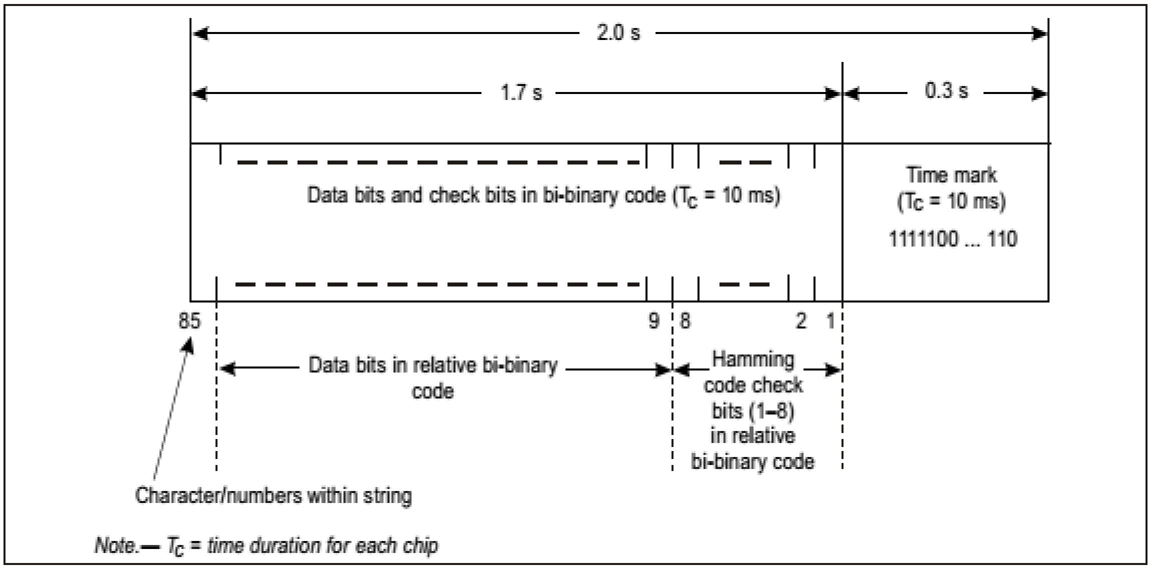


Figure B-10. Data string structure

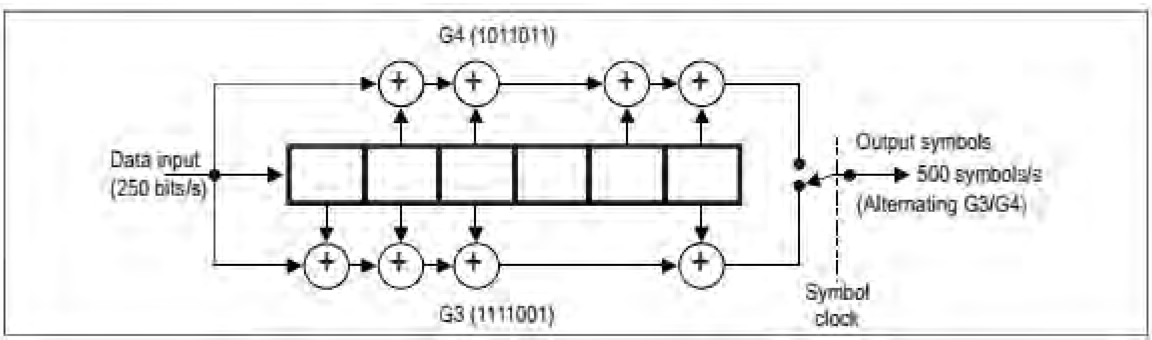


Figure B-11. Convolutional encoding

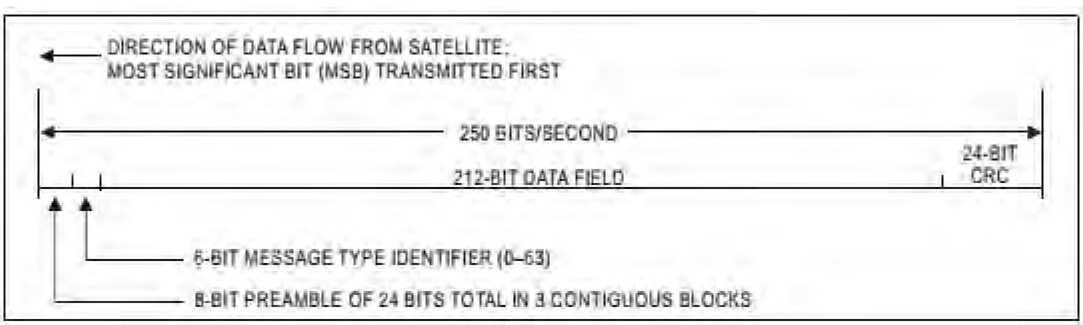


Figure B-12. Data block format

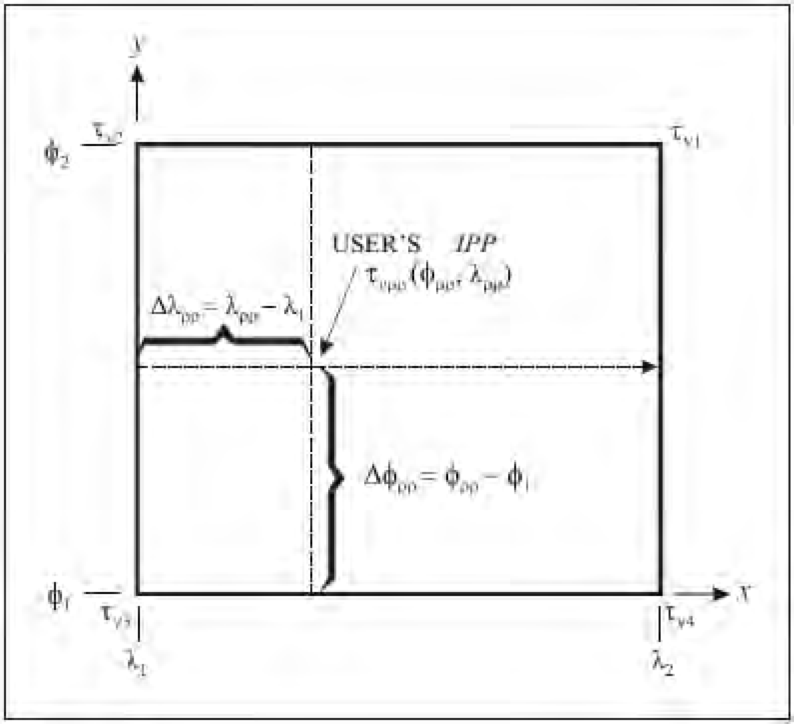


Figure B-13. IGP numbering convention (four IGPs)

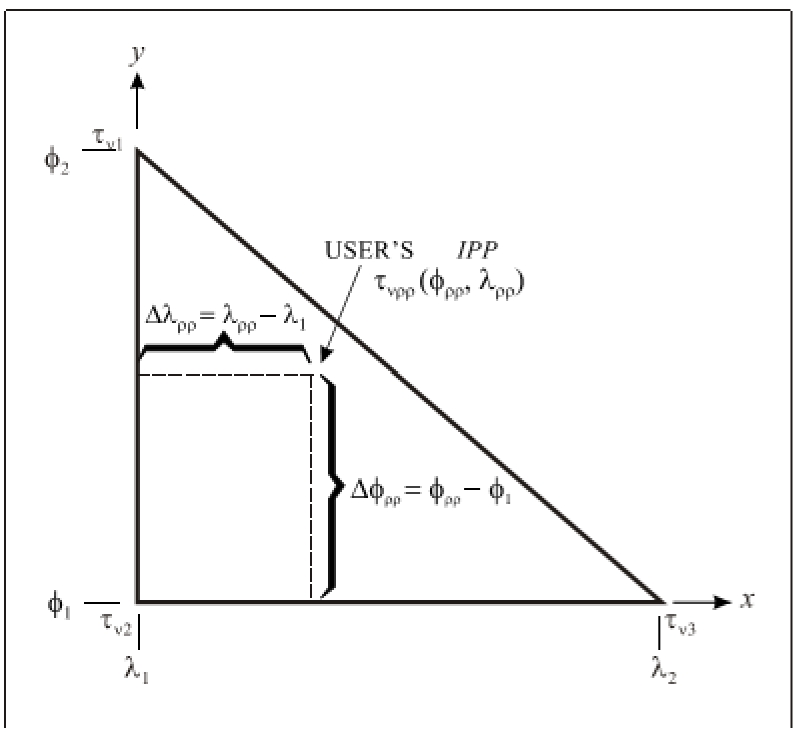


Figure B-14. IGP numbering convention (three IGPs)

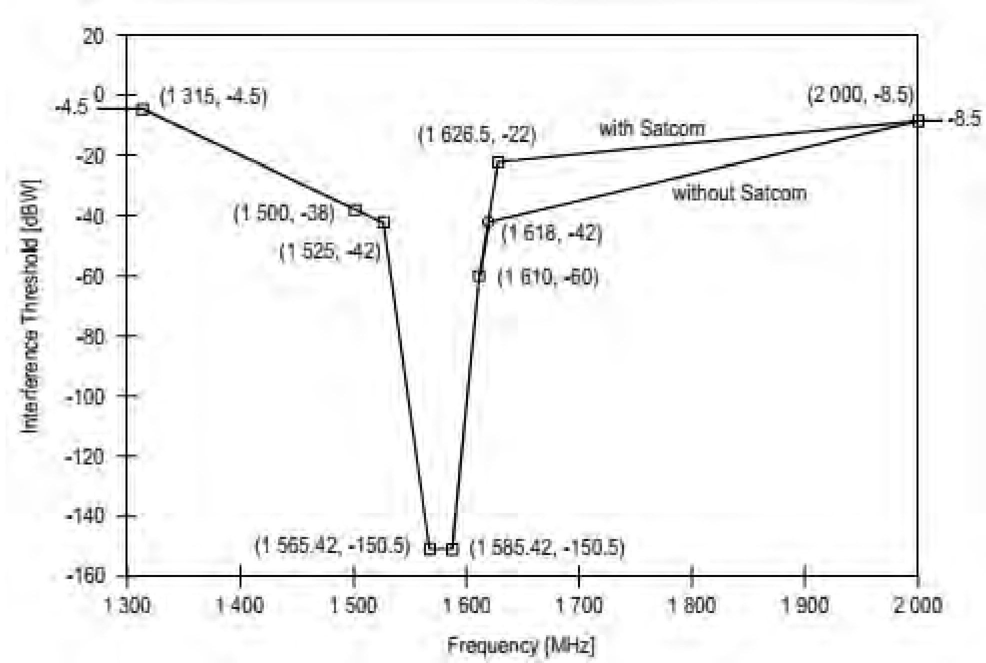


Figure B-15. CW interference thresholds for GPS and SBAS receivers used for precision approach

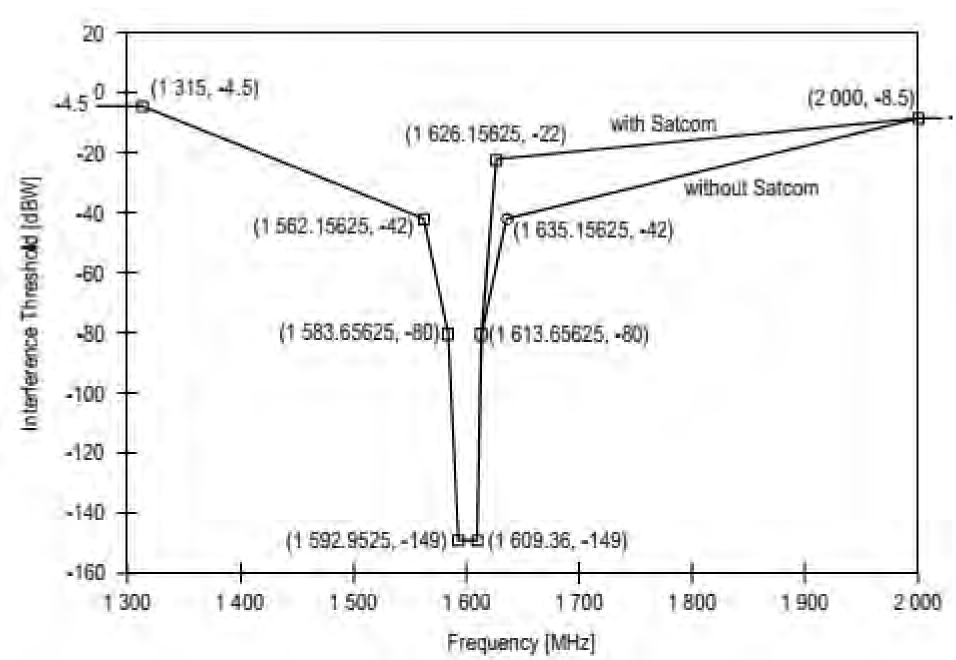


Figure B-16. CW interference thresholds for GLONASS receivers used for precision approach

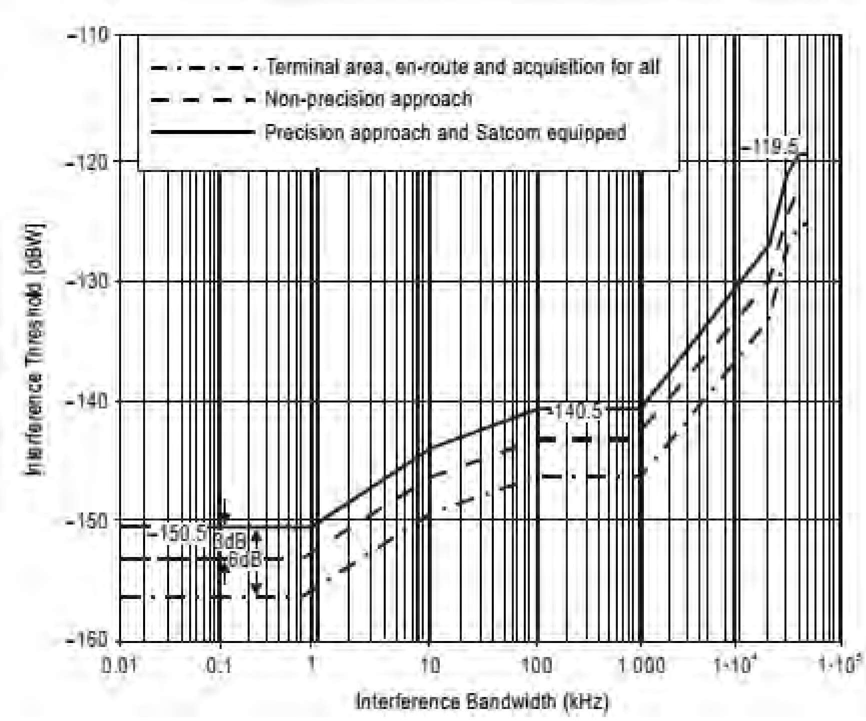


Figure B-17. Interference thresholds versus bandwidth for GPS and SBAS receivers

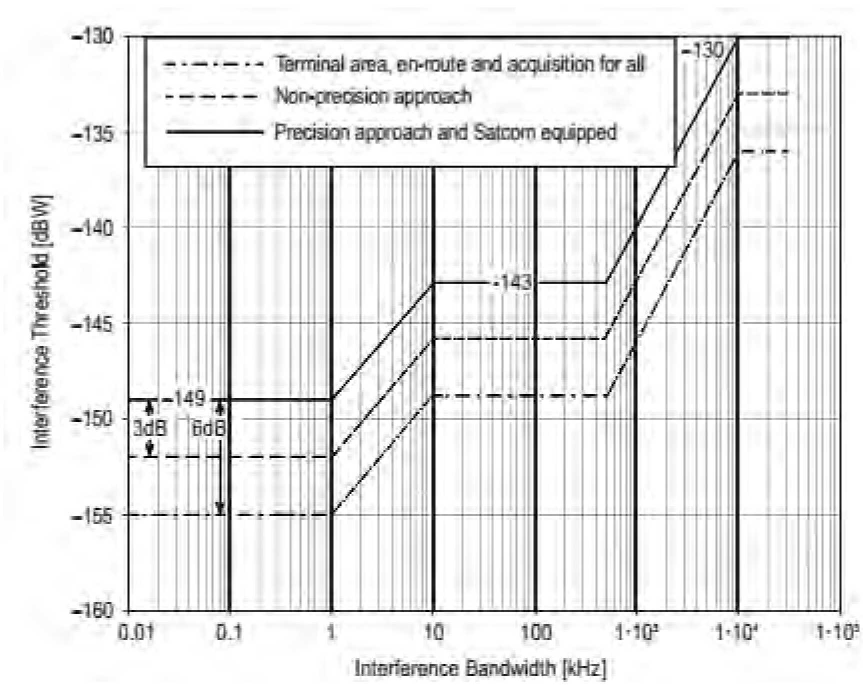


Figure B-18. Interference thresholds versus bandwidth for GLONASS

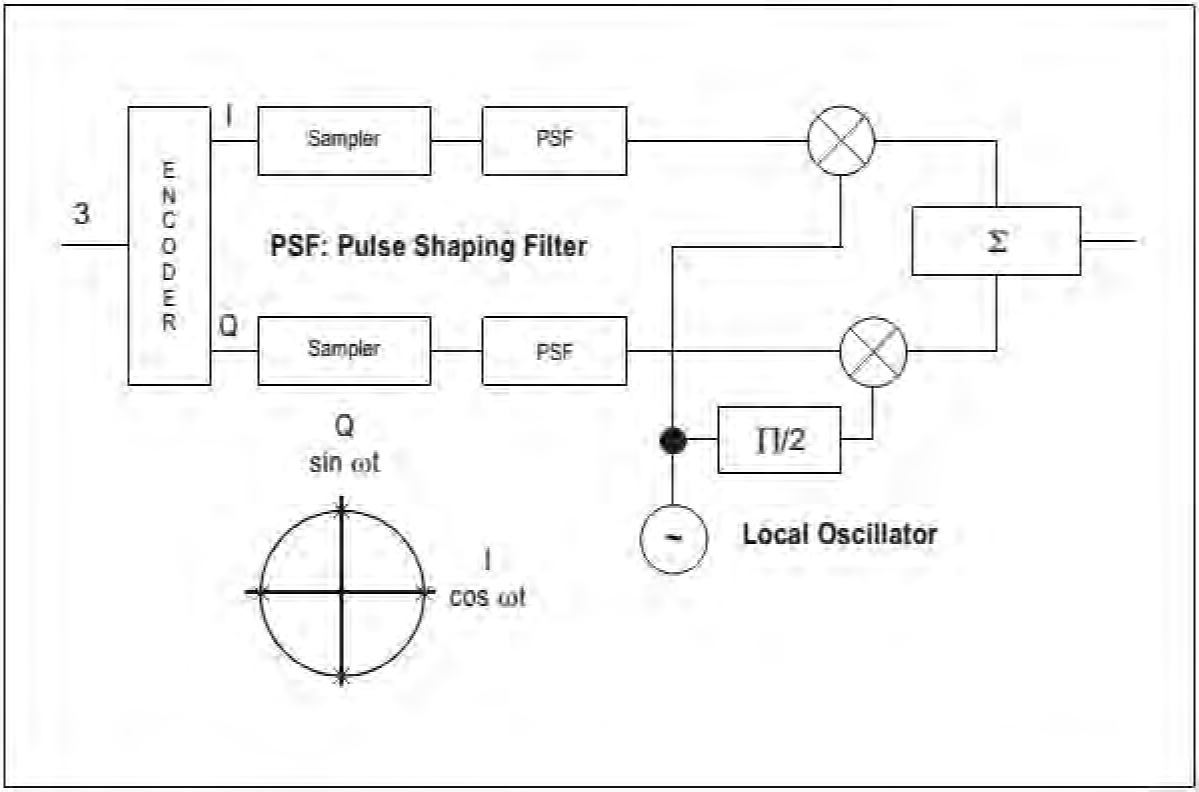
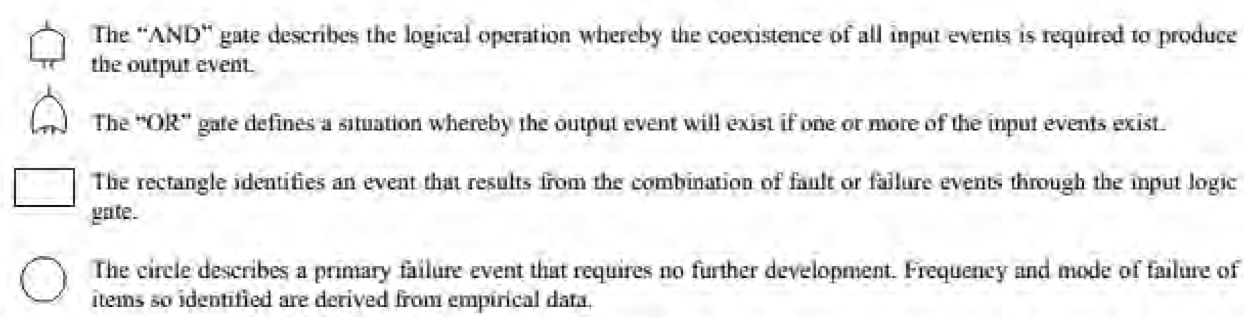


Figure B-19. Example data modulation

ATTACHMENT A. DETERMINATION OF INTEGRITY AND CONTINUITY OF SERVICE OBJECTIVES USING THE RISK TREE METHOD

1. The risk tree method is a graphical method of expressing the logical relationship between a particular failure condition and the causes or failures leading to this condition. It is an application of fault tree analysis being used in the aerospace industry.

1.1 The method employs a set of logic symbols to show the relationship between the various causes of failure. The following symbols are used in this guidance material.



1.2 The method gives a visual representation of sequences and combinations of events leading to the top failure event. The method can also be used to determine the probability of the top event occurring, provided that the probabilities of the individual events are known or can be estimated. In the case of simple fault trees probabilities can be directly calculated, but care must be taken if the primary failure events are not independent, i.e. if failure events are common to more than one path.

1.3 In this guidance material the acceptable probability of the top level event occurring is determined by the risk allocation and the fault tree is used to further partition the risk into integrity and continuity of service risks. Therefore, the term "risk tree" is used rather than "fault tree".

2. *A generic risk tree for aircraft landing operations is given in Figure A-1.* The top event for this tree is taken to be the loss of the aircraft due to a failure of the non-aircraft guidance system. The causes of this event are either an integrity failure of the primary non-aircraft guidance equipment or a continuity of service (COS) failure of the non-aircraft guidance system (i.e. both the primary system and any secondary system used to support a discontinued approach/missed approach). The primary non-aircraft

guidance system is considered to have a number of elements, 1 to N, for example azimuth, elevation and DME/P in the case of MLS. The secondary guidance system may be an alternative non-aircraft system, or in some cases an aircraft navigation system such as an inertial reference system.

2.1 The following probabilities can be defined:

Pa = Probability of aircraft loss due to a failure of the non-aircraft guidance system.

Pb = Probability of aircraft loss due to primary guidance integrity failure.

Pc = Probability of aircraft loss due to COS failure.

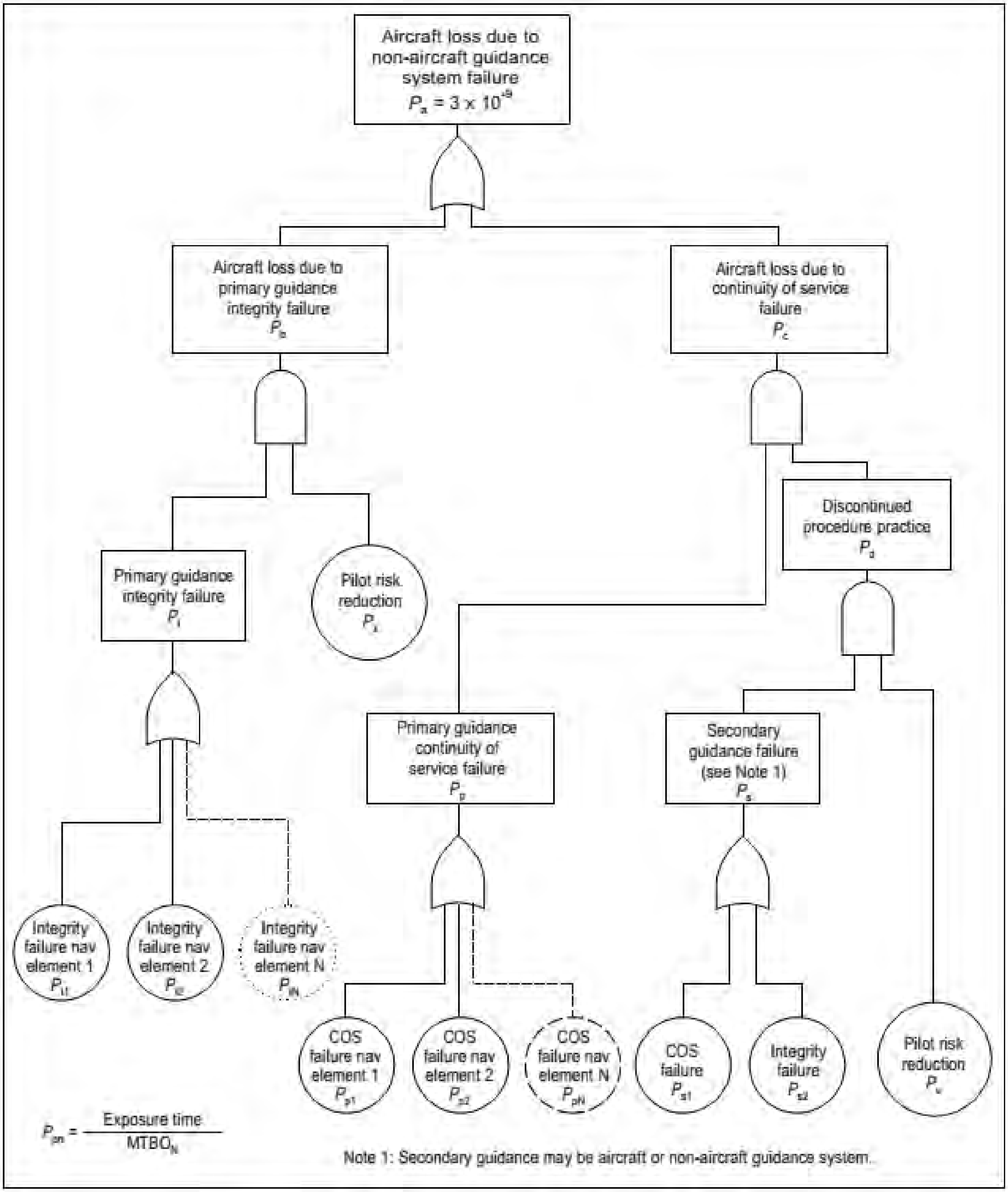


Figure A-1. Generic risk tree

Px = Probability that the pilot is unable to detect and intervene successfully following a primary guidance integrity failure. This risk reduction factor is only relevant in those cases where an integrity failure of the guidance system may be detected by the pilot, e.g. at decision height in a Category I ILS approach.

Pp = Probability of primary guidance COS failure.

Pd = Probability of aircraft loss during a discontinued approach/missed approach procedure.

Pi = Probability of primary guidance integrity failure.

PiN = Probability of integrity failure in Nav element N.

PpN = Probability of COS failure in Nav element N.

Ps = Probability of aircraft loss during a discontinued approach/missed approach with secondary guidance.

Ps1 = Probability of secondary guidance COS failure.

Ps2 = Probability of secondary guidance integrity failure.

Pu = Probability that the pilot is unable to intervene successfully following primary guidance COS failure with no secondary guidance available.

Where:

$$P_a = P_b + P_c$$

$$P_b = P_i \times P_x$$

$$P_i = P_{i1} + P_{i2} + \dots P_{iN}$$

$$P_c = P_p \times P_d$$

$$P_p = P_{p1} + P_{p2} + \dots P_{pN}$$

$$P_d = P_s \times P_u$$

$$P_s = P_{s1} + P_{s2}$$

2.2 The acceptable probability of the top event, Pa, can be determined by partitioning the global risk factor for the approach and landing operation to the various classes of accident. Using this method an acceptable value for Pa of 3 × 10–9has been determined. This is consistent with the smallest probability that can be assigned to each ground navigation element, which is 1 × 10–9 (normally divided equally between integrity and COS failures).

2.3 The risk analysis above assumes no equipment design errors.

3. *Example of the use of the risk tree — MLS Category III basic operations (Figure A-2).*

3.1 In this case there are only two navigation elements involved (e.g. azimuth and elevation). It is assumed that no secondary guidance is available following a COS failure of the primary guidance, the normal procedure being to maintain heading and climb.

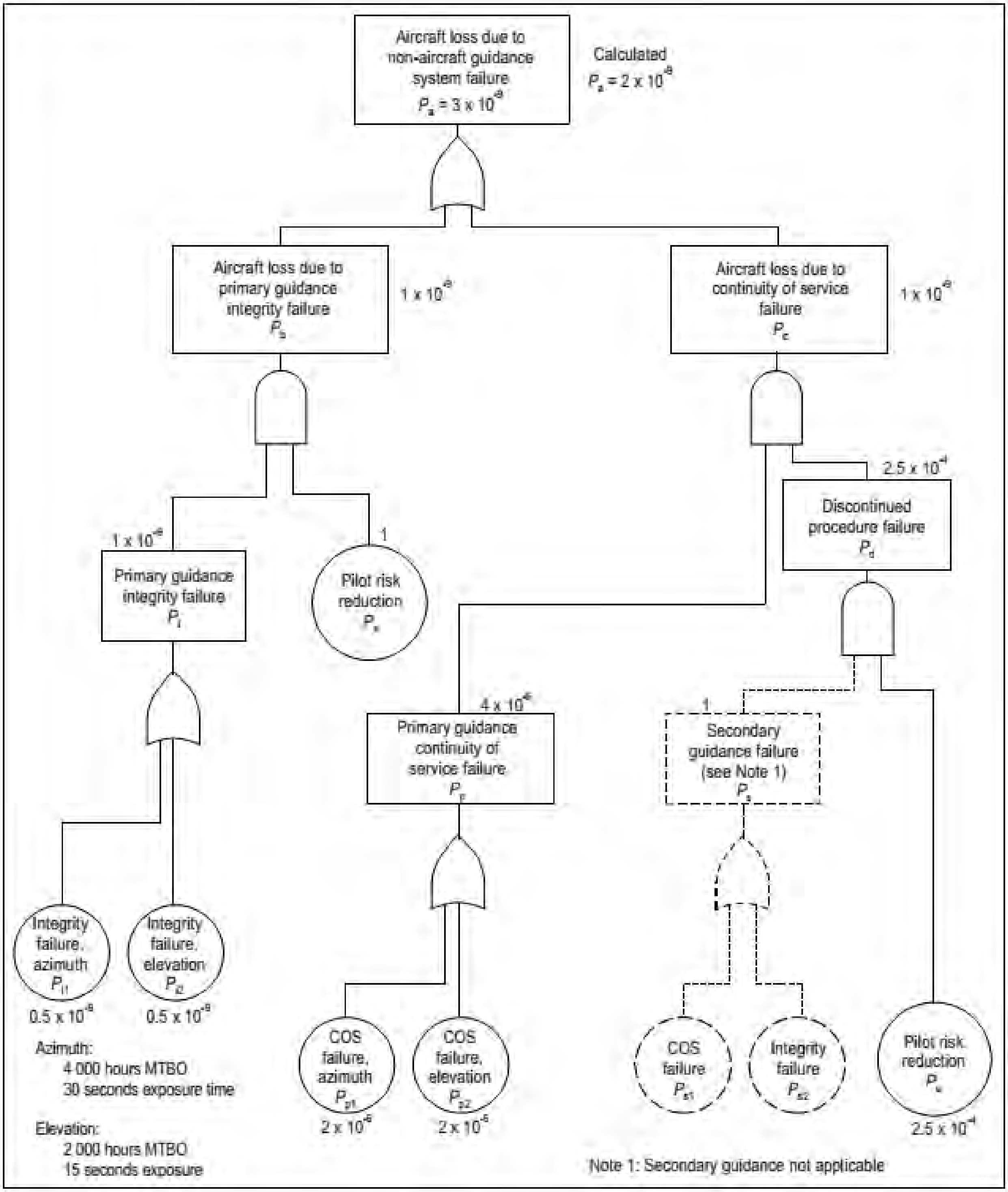


Figure A-2. MLS Category III landing risk tree

$$P_{i1} = P_{i2} = 0.5 \times 10^{-9}$$

$$P_{p1} = P_{p2} = 2 \times 10^{-6}$$

Note.— These figures are from Attachment G, Table G-15, Level 4 and assume exposure times of 30and 15 seconds, and MTBOs of 4 000 and 2 000 hours for the azimuth and elevation elements respectively.

$P_s = 1.0$

Note.— Since there is no guided discontinued approach/missed approach procedure using secondary guidance, the probability of an accident during the procedure is taken to be 1.

$P_x = 1.0$

Note.— It is assumed in this example that in a Category III operation the pilot is unable to intervene in the event of an integrity failure in the ground system. The risk reduction factor is therefore equal to 1.

$P_u = 2.5 \text{ x } 10^{-4}$

Note.— The pilot risk reduction factor is estimated at 1 in 4 000 based on a study of accidents to aircraft conducting approaches to land using ground guidance systems. This is the risk reduction factor assumed due to pilot intervention following a continuity of service failure.

Therefore:

$P_i = 1 \times 10^{-9}$

$P_p = 4 \times 10^{-6}$

$P_d = 2.5 \times 10^{-4}$

$P_c = 4 \times 10^{-6} \times 2.5 \times 10^{-4} = 1 \times 10^{-9}$

$P_b = 1 \times 10^{-9} \times 1$

and:

calculated $P_a = 2 \times 10^{-9}$.

3.2 There is therefore a margin of 1×10^{-9} on the generic requirement.

4. Application of the risk tree to an MLS/RNAV approach in an obstacle rich environment (Figure A-3).

4.1 In this case there are three navigation elements (i.e. azimuth, elevation and DME/P) and all are assumed to meet the integrity and COS requirements for Level 4 azimuth equipment; i.e integrity = 1 – 0.5 × 10–9and MTBO = 4 000 hours.

$P_{i1} = P_{i2} = P_{i3} = 0.5 \times 10^{-9}$

$P_x = 1.0$

Note.— It is assumed that the pilot is unable to intervene in the event of an integrity failure in the ground system.

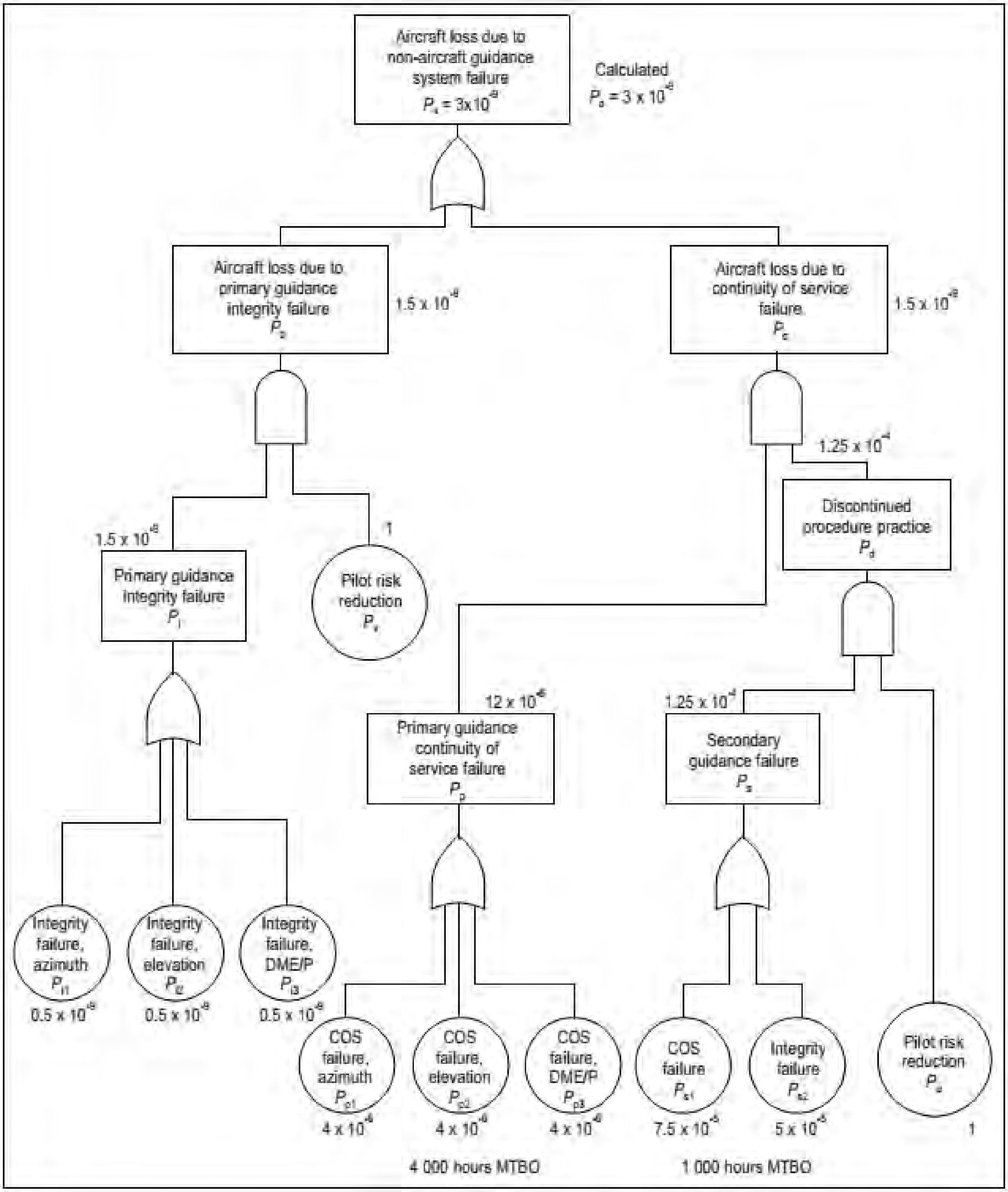


Figure A-3. MLS/RNAV obstacle rich risk tree

$P_{p1} = P_{p2} = P_{p3} = 4 \times 10^{-6}$

Note.— This assumes an obstacle exposure time (OET) of 60 seconds, and an MTBO of 4 000 for all ground elements.

$P_u = 1.0$

Note.— It is assumed that an unguided discontinued approach/missed approach procedure is unacceptable. The probability of an accident during such a procedure is therefore taken to be 1.

$P_{s1} = 7.5 \times 10^{-5}$

4.2 In the case of an MLS/RNAV procedure in an obstacle rich environment, it is assumed that secondary guidance will be essential to execute a safe discontinued approach/missed approach procedure during the period of exposure to the obstacles.

$P_{s1} = 7.5 \times 10^{-5}$

Note.— This is the probability of a COS failure of the secondary guidance ground equipment. It is assumed here that the secondary guidance system has a MTBO of 1 000 hours and that the exposure time is 270 seconds. The exposure time to a failure of the secondary guidance is dependent on the point in the procedure at which the availability of secondary guidance is confirmed. Assuming that this would be prior to the commencement of the MLS/RNAV procedure, and that the pilot would not be required to reconfirm the availability of secondary guidance before commencing the critical obstacle rich part of the procedure, the exposure time could be several minutes.

$P_{s2} = 5 \times 10^{-5}$

Note.— This is the integrity required by the secondary guidance system.

Therefore:

$P_i = 1.5 \times 10^{-9}$

$P_b = 1.5 \times 10^{-9}$

$P_p = 12 \times 10^{-6}$

$P_s = 7.5 \times 10^{-5} + 5 \times 10^{-5} = 1.25 \times 10^{-4}$

$P_d = 1.25 \times 10^{-4}$

$P_c = 12 \times 10^{-6} \times 1.25 \times 10^{-4} = 1.5 \times 10^{-9}$

and:

calculated $P_a = 3 \times 10^{-9}$, as required

Note.— For obstacle exposure times greater than 60 seconds, it will be necessary to either increase the MTBOs of the primary guidance or to increase the risk reduction factor due to the secondary guidance. For example, if the exposure time is increased to 90 seconds, the MTBOs of the primary guidance must be increased to 6 000 hours or the MTBO of the secondary guidance increased to 2 250 hours. There are clearly trade-offs between the reliability of the primary guidance, the exposure time, and the reliability and integrity of the secondary guidance. The risk tree method can be used to examine individual MLS/RNAV procedures and determine the appropriate reliability and integrity requirements for the primary and secondary guidance.

ATTACHMENT B. STRATEGY FOR INTRODUCTION AND APPLICATION OF NON-VISUAL AIDS TO APPROACH AND LANDING

(see Chapter 2, 2.1)

1. Introduction

1.1 Various elements have an influence on all weather operations in terms of safety, efficiency and flexibility. The evolution of new techniques requires a flexible approach to the concept of all weather operations to obtain full benefits of technical development. To create this flexibility a strategy enables, through identification of its objectives and thoughts behind the strategy, incorporation of new technical developments or ideas into this strategy. The strategy does not assume a rapid transition to a single globally established system or selection of systems to support approach and landing operations.

1.2 The strategy addresses the application of non-visual aids to approach and landing with vertical guidance (APV) and precision approach and landing operations.

2. Objectives of strategy

The strategy must:

a) maintain at least the current safety level of all weather operations;

b) retain at least the existing level or planned improved level of service;

c) maintain global interoperability;

d) provide regional flexibility based on coordinated regional planning;

e) be applicable until at least the year 2020; and

f) take account of economic, operational and technical issues.

3. Considerations

3.1 General

The following considerations are based on the assumption that the operational requirement and the required commitment are available and the required effort is applied.

3.2 ILS-related considerations

a) There is a risk that ILS Category II or III operations cannot be safely sustained at specific locations;

b) Annex 10, Volume I, Chapter 3, 3.1.4 contains interference immunity performance standards for ILS receivers;

c) expansion of ILS is limited by channel availability (40 channels);

d) many aging ILS ground installations will need to be replaced; and

e) in most areas of the world, ILS can be maintained in the foreseeable future.

3.3 MLS-related considerations

a) MLS Category I is operational;

b) Category II capable ground equipment is certified. Ground and airborne Category IIIB equipment certification is in progress and is scheduled to be completed in the 2004-2005 time frame; and

c) MLS implementation is planned at specific locations to improve runway utilization in low visibility conditions.

3.4 GNSS-related considerations

a) Standards and Recommended Practices (SARPs) are in place for GNSS with augmentation to support APV and Category I precision approach;

b) SARPs for ground-based regional augmentation system (GRAS) for APV operations are under development;

c) GNSS with satellite-based augmentation system (SBAS) for APV operations is operational in some regions of the world;

d) GNSS with ground-based augmentation system (GBAS) for Category I precision approach operations is expected to be operational by 2006;

e) it is not expected that an internationally accepted GNSS with augmentation as required may be available for Category II and III operations before the 2010-2015 time frame;

f) technical and operational issues associated with GNSS approach, landing and departure operations must be solved in a timely manner; and

g) institutional issues associated with GNSS approach, landing and departure operations must be solved in a timely manner.

3.5 Multi-modal airborne approach and landing capability considerations

To enable this strategy, a multi-modal airborne approach and landing capability is necessary and is expected to be available.

3.6 Other considerations

a) There is an increasing demand for Category II and III operations;

b) GNSS can potentially offer unique operational benefits for low-visibility operations, including new procedures, flexible siting requirements and provision of airport surface guidance;

c) only the three standard systems (ILS, MLS and GNSS with augmentation as required) are considered to play a major role in supporting all weather operations. The use of head-up displays in conjunction with enhanced and/or synthetic vision systems may provide operational benefits;

d) a consequence of the global strategy is that there will not be a rapid transition from ILS to new systems such as GNSS or MLS. It is therefore essential for the implementation of the strategy that the radio frequency spectrum used by all of these systems be adequately protected;

e) to the extent practical, a transition directly from ILS to GNSS is preferable. In some States, however, it may not be possible to make this transition without losing the current level of Category II or III operations;

f) as long as some users of a given runway continue to rely on ILS, the potential operational benefits resulting from the introduction of new landing systems may be limited by the constraints of mixed-system operations;

g) APV operations may be conducted using GNSS with augmentation as required or barometric vertical guidance, and GNSS with ABAS or DME/DME RNAV lateral guidance; and

h) APV operations provide enhanced safety and generally lower operational minima as compared to non-precision approaches.

4. Strategy

Based on the considerations above, the need to consult aircraft operators and international organizations, and to ensure safety, efficiency and cost-effectiveness of the proposed solutions, the global strategy is to:

a) continue ILS operations to the highest level of service as long as operationally acceptable and economically beneficial so as to ensure that airport access is not denied to aircraft solely equipped with ILS;

b) implement MLS where operationally required and economically beneficial;

c) implement GNSS with augmentation (i.e. ABAS, SBAS, GBAS) as required for APV and Category I operations where operationally required and economically beneficial, while ensuring that the issues associated with ionospheric propagation in the equatorial regions are duly addressed and resolved;

d) promote the development and use of a multi-modal airborne approach and landing capability;

e) promote the use of APV operations, particularly those using GNSS vertical guidance, to enhance safety and accessibility;

f) identify and resolve operational and technical feasibility issues for GNSS with ground-based augmentation system (GBAS) to support Category II and III operations. Implement GNSS for Category II and III operations where operationally required and economically beneficial; and

g) enable each region to develop an implementation strategy for these systems in line with the global strategy.

ATTACHMENT C. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE STANDARDS AND RECOMMENDED PRACTICES FOR ILS, VOR, PAR, 75 MHz MARKER BEACONS (EN-ROUTE), NDB AND DME

1. Introduction

The material in this Attachment is intended for guidance and clarification purposes and is not to be considered as part of the specifications or as part of the Standards and Recommended Practices contained in Volume I.

For the clarity of understanding of the text that follows and to facilitate the ready exchange of thoughts on closely associated concepts, the following definitions are included.

Definitions relating to the Instrument Landing System (ILS)

Note.— The terms given here are in most cases capable of use either without prefix or in association with the prefix "indicated". Such usages are intended to convey the following meanings:

No prefix: *the achieved characteristics of an element or concept.*

The prefix "indicated": *the achieved characteristics of an element or concept, as indicated on a receiver (i.e. including the errors of the receiving installation).*

Localizer system	ILS glide path system
Indicated course line. The locus of points in any horizontal plane at which the receiver indicator deflection is zero.	
Indicated course sector. A sector in any horizontal plane containing the indicated course line in which the receiver indicator deflection remains within full-scale values.	
Localizer course bend. A course bend is an aberration of the localizer course line with respect to its nominal position.	***ILS glide path bend.*** An ILS glide path bend is an aberration of the ILS glide path with respect to its nominal position.

2. Material concerning ILS installations

2.1 Operational objectives, design and maintenance objectives, and definition of course structure for Facility Performance Categories

2.1.1 The Facility Performance Categories defined in Chapter 3, 3.1.1 have operational objectives as follows:

Category I operation: A precision instrument approach and landing with a decision height not lower than 60 m (200 ft) and with either a visibility not less than 800 m or a runway visual range not less than 550 m.

Category II operation: A precision instrument approach and landing with a decision height lower than 60 m (200 ft) but not lower than 30 m (100 ft), and a runway visual range not less than 300 m.

Category IIIA operation: A precision instrument approach and landing with:

a) a decision height lower than 30 m (100 ft), or no decision height; and

b) a runway visual range not less than 175 m.

Category IIIB operation: A precision instrument approach and landing with:

a) a decision height lower than 15 m (50 ft), or no decision height; and

b) a runway visual range less than 175 m but not less than 50 m.

Category IIIC operation: A precision instrument approach and landing with no decision height and no runway visual range limitations.

2.1.2 *Capabilities*. Relevant to these objectives will be the type of aircraft using the ILS and the capabilities of the aircraft flight guidance system(s). Modern aircraft fitted with equipment of appropriate design are assumed in these objectives. In practice, however, operational capabilities may extend beyond the specific objectives given at 2.1.1.

2.1.2.1 *Equipage for additional objectives.* The availability of fail-passive and fail-operational flight guidance systems in conjunction with an ILS ground system which provides adequate guidance with an appropriate level of continuity of service and integrity for the particular case can permit the attainment of operational objectives which do not coincide with those described at 2.1.1.

2.1.2.2 *Advanced operations*. For modern aircraft fitted with automatic approach and landing systems, the routine use of such systems is being encouraged by aircraft operating agencies in conditions where the progress of the approach can be visually monitored by the flight crew. For example, such operations may be conducted on Facility Performance Category I — ILS where the guidance quality and coverage exceeds basic requirements given at Chapter 3, 3.1.3.4.1 and extends down to the runway.

2.1.2.3 *ILS classification system*. In order to fully exploit the potential benefits of modern aircraft automatic flight control systems, there is a related need for a method of describing ground-based ILS more completely than can be achieved by reference solely to the Facility Performance Category. This is achieved by the ILS classification system using the three designated characters. It provides a description of those performance aspects which are required to be known from an operations viewpoint in order to decide the operational applications which a specific ILS could support.

2.1.2.4 The ILS classification scheme provides a means to make known the additional capabilities that may be available from a particular ILS ground facility, beyond those associated with the facilities defined in Chapter 3, 3.1.1. These additional capabilities can be exploited in order to permit operational use according to 2.1.2.1 and 2.1.2.2 to be approved down to and below the values stated in the operational objectives described in 2.1.1.

2.1.2.5 An example of the classification system is presented in 2.14.3.

Note.— The following guidance material is intended to assist States when they are evaluating the acceptability of ILS localizer courses and glide paths having bends. Although, by definition, course bends and glide path bends are related to the nominal positions of the localizer course and glide path respectively, the evaluation of high frequency aberrations is based on the deviations from the mean course or path. The material in 2.1.5 and Figure C-2 regarding the evaluation of bends indicates how the bends relate to the mean position of the course and path. Aircraft recordings will normally be in this form.

2.1.3 *Course bends*. Localizer course bends should be evaluated in terms of the course structure specified in Chapter 3,

3.1.3.4. With regard to landing and rollout in Category III conditions, this course structure is based on the desire to provideadequate guidance for manual and/or automatic operations along the runway in low visibility conditions. With regard to

Category I performance in the approach phase, this course structure is based on the desire to restrict aircraft deviations, due to course bends (95 per cent probability basis) at the 30 m (100 ft) height, to lateral displacement of less than 10 m (30 ft). With regard to Categories II and III performance in the approach phase, this course structure is based on the desire to restrict aircraft deviations due to course bends (95 per cent probability basis) in the region between ILS Point B and the ILS reference datum (Category II facilities) or Point D (Category III facilities), to less than 2 degrees of roll and pitch attitude and to lateral displacement of less than 5 m (15 ft).

Note 1.— Course bends are unacceptable when they preclude an aircraft under normal conditions from reaching the decision height in a stable attitude and at a position, within acceptable limits of displacement from the course line, from which a safe landing can be effected. Automatic and semi-automatic coupling is affected to a greater degree than manual coupling by the presence of bends. Excessive control activity after the aircraft has settled on an approach may preclude it from satisfactorily completing an approach or landing. Additionally, when automatic coupling is used, there may be an operational requirement to continue the approach below the decision height. Aircraft guidance can be satisfied if the specification for course structure in Chapter 3, 3.1.3.4, is met.

Note 2.— Bends or other irregularities that are not acceptable will normally be ascertained by flight tests in stable air conditions requiring precision flight check techniques.

2.1.4 *ILS glide path bends*. Bends should be evaluated in terms of the ILS glide path structure specified in Chapter 3,

3.1.5.4. With regard to Category I performance, this glide path structure is based on the desire to restrict aircraft deviations due to glide path bends (95 per cent probability basis) at the 30 m (100 ft) height, to vertical displacements of less than 3 m(10 ft). With regard to Categories II and III performance, this glide path structure is based on the desire to restrict aircraft deviations due to path bends (95 per cent probability basis) at the 15 m (50 ft) height, to less than 2 degrees of roll and pitch attitude and to vertical displacements of less than 1.2 m (4 ft).

Note 1.— Path bends are unacceptable when they preclude an aircraft under normal conditions from reaching the decision height in a stable attitude and at a position, within acceptable limits of displacement from the ILS glide path, from which a safe landing can be effected. Automatic and semi-automatic coupling is affected to a greater degree than manual coupling by the presence of bends. Additionally, when automatic coupling is used, there may be an operational *requirement to continue the approach below the decision height. Aircraft guidance can be satisfied if the specification for ILS glide path structure in Chapter 3, 3.1.5.4, is met.*

Note 2.— Bends or other irregularities that are not acceptable will normally be ascertained by precision flight tests, supplemented as necessary by special ground measurements.

2.1.5 Application of localizer course/glide path bend amplitude Standard. In applying the specification for localizer course structure (Chapter 3, 3.1.3.4) and ILS glide path structure (Chapter 3, 3.1.5.4), the following criteria should be employed:

— Figure C-1 shows the relationship between the maximum (95 per cent probability) localizer course/glide path bend amplitudes and distances from the runway threshold that have been specified for Categories I, II and III performance.

— If the bend amplitudes are to be evaluated in any region of the approach, the flight recordings, corrected for aircraft angular position error, should be analysed for a time interval of plus or minus 20 seconds about the midpoint of the region to be evaluated. The foregoing is based on an aircraft ground speed of 195 km/h (105 knots) plus or minus 9 km/h (5 knots).

The 95 per cent maximum amplitude specification is the allowable percentage of total time interval in which the course/path bend amplitude must be less than the amount specified in Figure C-1 for the region being evaluated. Figure C-2 presents a typical example of the method that can be employed to evaluate the course/path bend amplitude at a particular facility. If the sum of the time intervals t1, t2, t3, where the given specification is exceeded, is equal to or less than 5 per cent of the total time T, the region that is being evaluated is acceptable. Therefore:

$$100 \quad \frac{T - [(t_1 + t_2 + \ldots)]}{T} \geq 95\%$$

Analysis of ILS glide path bends should be made using as a datum the mean glide path and not the downward extended straight line. The extent of curvature is governed by the offset displacement of the ground equipment glide path antenna system, the distance of this antenna system from the threshold, and the relative heights of the ground along the final approach route and at the glide path site (see 2.4).

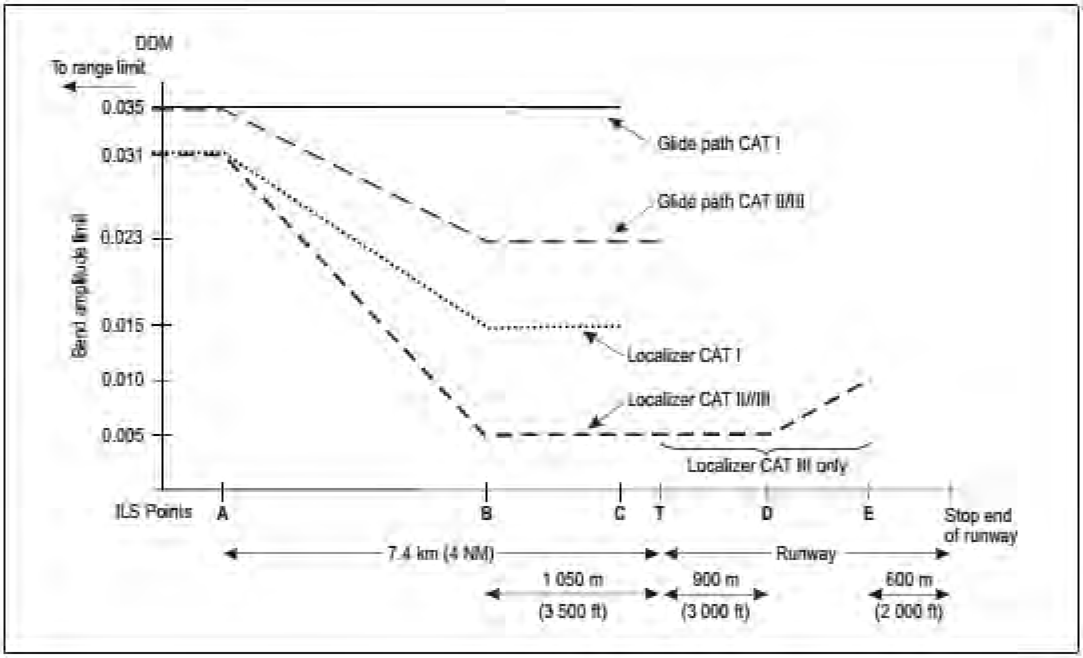


Figure C-1. Localizer course and glide path bend amplitude limits

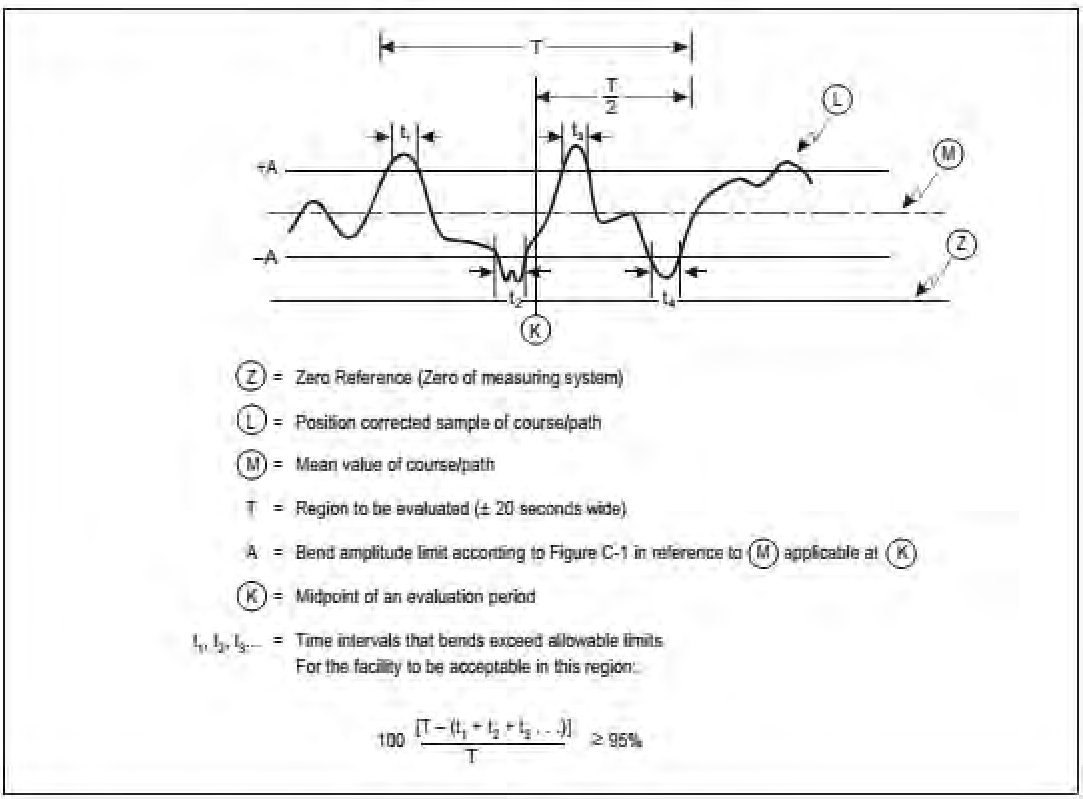


Figure C-2. Evaluation of course/path bend amplitude

2.1.6 *Measurements filter*. Owing to the complex frequency components present in the ILS beam bend structures, measured values of beam bends are dependent on the frequency response of the airborne receiving and recording equipment. It is intended that beam bend measurements be obtained by using a low-pass filter corner frequency (radians per second) for the receiver DDM output circuits and associated recording equipment of V/92.6, where Vis the velocity in km/h of the aircraft or ground vehicle as appropriate.

2.1.7 *Monitor systems.* Available evidence indicates that performance stability within the limits defined in Chapter 3, 3.1.3.6, 3.1.3.7 and 3.1.5.6, i.e. well within the monitor limit, can readily be achieved.

2.1.7.1 The choice of monitor limits is based on judgement, backed by knowledge of the safety requirements for the category of operation. However, the specifications of such monitoring limits do not indicate the magnitude of the normal day-to-day variations in performance which result from setting-up errors and equipment drift. It is necessary to investigate and take corrective action if the day-to-day performance frequently drifts beyond the limits specified in Chapter 3, 3.1.3.6, 3.1.3.7 and 3.1.5.6. The causes of such drifts should be eliminated:

a) to reduce greatly the possibility of critical signal parameters hovering near the specified monitor limits;

b) to ensure a high continuity of ILS service.

2.1.7.2 Following are some general guidelines for the design, operation and maintenance of monitor systems to meet the requirements in Chapter 3, 3.1.3.11 and 3.1.5.7.

1) Great care should be exercised to ensure that monitor systems respond to all those variations of the ground facility which adversely affect the operation of the airborne system during ILS approach.

2) Monitor systems should not react to local conditions which do not affect the navigational information as seen by airborne systems.

3) Drifts of the monitor system equipment should not appreciably reduce or increase the monitoring limits specified.

4) Special care must be taken in the design and operation of the monitor system with the aim of ensuring that the navigational components will be removed or radiation cease in the event of a failure of the monitor system itself.

5) Some monitors rely on devices which sample the signal in the vicinity of the transmitter antenna system. Experience has shown that such monitor systems require special attention in the following aspects:

a) where large-aperture antenna systems are used, it is often not possible to place the monitor sensors in such a position that the phase relationship observed in the far field on the course exists at the sensing point. Nevertheless, the monitor system should also detect antenna and associated feeder system changes which significantly affect the course in the far field;

b) changes in effective ground level caused by snow, flooding, etc., may affect glide path monitor systems, and the actual course in space differently, particularly when reliance is placed on the ground plane to form the desired glide path pattern;

c) attention should be paid to other causes which may disturb the monitor sensing of the radiated signal, such as icing and birds;

d) in a system where monitoring signals are used in a feedback loop to correct variations of the corresponding equipment, special care should be taken that extraneous influence and changes in the monitor system itself do not cause course or ILS glide path variations outside the specified limits without alarming the monitor.

6) One possible form of monitor is an integral monitor in which the contribution of each transmitting antenna element to the far-field course signal is measured at the antenna system. Experience has shown that such monitoring systems, properly designed, can give a close correlation between the monitor indication and the radiated signal in the far field. This type of monitor, in certain circumstances, overcomes the problem outlined in 5) a), b) and c).

2.1.7.3 It will be realized that the DDM measured at any one point in space is a function of displacement sensitivity and the position of the course line or ILS glide path. This should be taken into account in the design and operation of monitor systems.

2.1.8 *Radiation by ILS localizers not in operational use*. Severe interference with operational ILS localizer signals has been experienced in aircraft carrying out approaches to low levels at runways equipped with localizer facilities serving the reciprocal direction to the approach. Interference in aircraft overflying this localizer antenna system is caused by cross modulation due to signals radiated from the reciprocal approach localizer. Such interference, in the case of low level operations, could seriously affect approach or landing, and may prejudice safety. Chapter 3, 3.1.2.7, 3.1.2.7.1 and 3.1.2.7.2 specify the conditions under which radiation by localizers not in operational use may be permitted.

2.1.9 ILS multipath interference

Note.— This guidance material does not consider how new large aircraft impact the sizes of critical and sensitive areas. It is being updated to consider the effect on the critical and sensitive areas of such aircraft, and of the considerable changes in airport and operational environment since the first development of the material. States are urged to use caution in applying the examples described below, as they do not consider several factors that impact quality of signal-in-space.

2.1.9.1 The occurrence of interference to ILS signals is dependent on the total environment around the ILS antennas, and the antenna characteristics. Any large reflecting objects, including vehicles or fixed objects such as structures within the radiated signal coverage, will potentially cause multipath interference to the ILS course and path structure. The location and size of the reflecting fixed objects and structures in conjunction with the directional qualities of the antennas will determine the static course or path structure quality whether Category I,II or III. Movable objects can degrade this structure to the extent that it becomes unacceptable. The areas within which this degradable interference is possible need to be defined and recognized. For the purposes of developing protective zoning criteria, these areas can be divided into two types, i.e. critical areas and sensitive areas:

a) the ILS critical area is an area of defined dimensions about the localizer and glide path antennas where vehicles, including aircraft, are excluded during all ILS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the ILS signal-in-space;

b) the ILS sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations. The sensitive area is protected against interference caused by large moving objects outside the critical area but still normally within the airfield boundary.

Note 1.— The objective of defining critical and sensitive areas is to afford adequate protection to the ILS. The manner in which the terminology is applied may vary between States. In some States, the term "critical area" is also used to describe the area that is referred to herein as the sensitive area.

Note 2.— It is expected that at sites, where ILS and MLS are to be collocated, the MLS might be located within ILS critical areas in accordance with guidance material in Attachment G, 4.1.

2.1.9.2 Typical examples of critical and sensitive areas that need to be protected are shown in Figures C-3A, C-3B, C-4A and C-4B. To protect the critical area, it is necessary to normally prohibit all entry of vehicles and the taxiing or parking of aircraft within this area during all ILS operations. The critical area determined for each localizer and glide path should be clearly designated. Suitable signal devices may need to be provided at taxiways and roadways which penetrate the critical area to restrict the entry of vehicles and aircraft. With respect to sensitive areas, it may be necessary to exclude some or all moving traffic depending on interference potential and category of operation. It would be advisable to have the aerodrome boundaries include all the sensitive areas so that adequate control can be exercised over all moving traffic to prevent unacceptable interference to the ILS signals. If these areas fall outside the aerodrome boundaries, it is essential that the cooperation of appropriate authorities be obtained to ensure adequate control. Operational procedures need to be developed for the protection of sensitive areas.

2.1.9.3 The size of the sensitive area depends on a number of factors including the type of ILS antenna, the topography, and the size and orientation of man-made objects, including large aircraft and vehicles. Modern designs of localizer and glide path antennas can be very effective in reducing the disturbance possibilities and hence the extent of the sensitive areas. Because of the greater potential of the larger types of aircraft for disturbing ILS signals, the sensitive areas for these aircraft extend a considerable distance beyond the critical areas. The problem is aggravated by increased traffic density on the ground.

2.1.9.3.1 In the case of the localizer, any large objects illuminated by the main directional radiation of the antenna must be considered as possible sources of unacceptable signal interference. This will include aircraft on the runway and on some taxiways. The dimensions of the sensitive areas required to protect Category I, II and III operations will vary, the largest being required for Category III. Only the least disturbance can be tolerated for Category III, but an out-of-tolerance course along the runway surface would have no effect on Category I or II operations. If the course structure is already marginal due to static multipath effects, less additional interference will cause an unacceptable signal. In such cases a larger-size sensitive area may have to be recognized.

2.1.9.3.2 In the case of the glide path, experience has shown that any object penetrating a surface above the reflection plane of the glide path antenna and within azimuth coverage of the antenna must be considered as a source of signal interference. The angle of the surface above the horizontal plane of the antenna is dependent on the type of glide path antenna array in use at the time. Very large aircraft, when parked or taxiing within several thousand feet of the glide path antenna and directly between it and the approach path, will usually cause serious disturbance to the glide path signal. On the other hand, the effect of small aircraft beyond a few hundred feet of the glide path antenna has been shown to be negligible.

2.1.9.3.3 Experience has shown that the major features affecting the reflection and diffraction of the ILS signal to produce multipath interference are the height and orientation of the vertical surfaces of aircraft and vehicles. The maximum height of vertical surface likely to be encountered must be established, together with the "worst case" orientation. This is because certain orientations can cause out-of-tolerance localizer or glide path deviations at greater distances than parallel or perpendicular orientations.

2.1.9.4 Computer or model techniques can be employed to calculate the probable location, magnitude and duration of ILS disturbances caused by objects, whether by structures or by aircraft of various sizes and orientation at different locations.

Issues involved with these techniques include the following:

a) computerized mathematical models are in general use and are applied by personnel with a wide variety of experience levels. However, engineering knowledge of and judgement about the appropriate assumptions and limitations are required when applying such models to specific multipath environments. ILS performance information relative to this subject should normally be made available by the ILS equipment manufacturer;

b) where an ILS has been installed and found satisfactory, computers and simulation techniques can be employed to predict the probable extent of ILS disturbance which may arise as a result of proposed new construction. Wherever possible, the results of such computer-aided simulation should be validated by direct comparison with actual flight measurements of the results of new construction; and

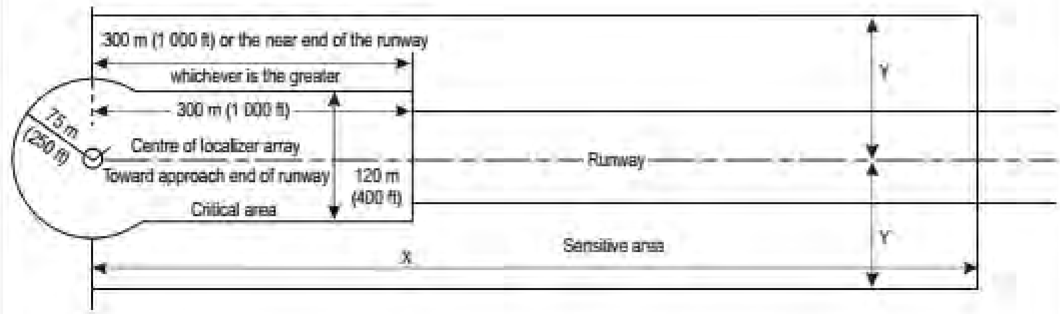
c) taking into account the maximum allowable multipath degradation of the signal due to aircraft on the ground, the corresponding minimum sensitive area limits can be determined. Models have been used to determine the critical and sensitive areas in Figures C-3A, C-3B, C-4A and C-4B, by taking into account the maximum allowable multipath degradation of ILS signals due to aircraft on the ground. The factors that affect the size and shape of the critical and sensitive areas include: aircraft types likely to cause interference, antenna aperture and type (log periodic dipole/dipole, etc.), type of clearance signals (single/dual frequency), category of operations proposed, runway length, and static bends caused by existing structures. Such use of models should involve their validation, which includes spot check comparison of computed results with actual field demonstration data on parked aircraft interference to the ILS signal.

2.1.9.5 Control of critical areas and the designation of sensitive areas on the airport proper may still not be sufficient to protect an ILS from multipath effects caused by large, fixed ground structures. This is particularly significant when considering the size of new buildings being erected for larger new aircraft and other purposes. Structures outside the boundaries of the airport may also cause difficulty to the ILS course quality, even though they meet restrictions with regard to obstruction heights.

2.1.9.5.1 Should the environment of an airport in terms of large fixed objects such as tall buildings cause the structure of the localizer and/or glide path to be near the tolerance limits for the category of operation, much larger sensitive areas may need to be established. This is because the effect of moving objects, which the sensitive areas are designed to protect the ILS against, has to be added to the static beam bends caused by fixed objects. However, direct addition of the maximum bend amplitudes is not considered appropriate and a root sum square combination is felt to be more realistic. Examples are as follows:

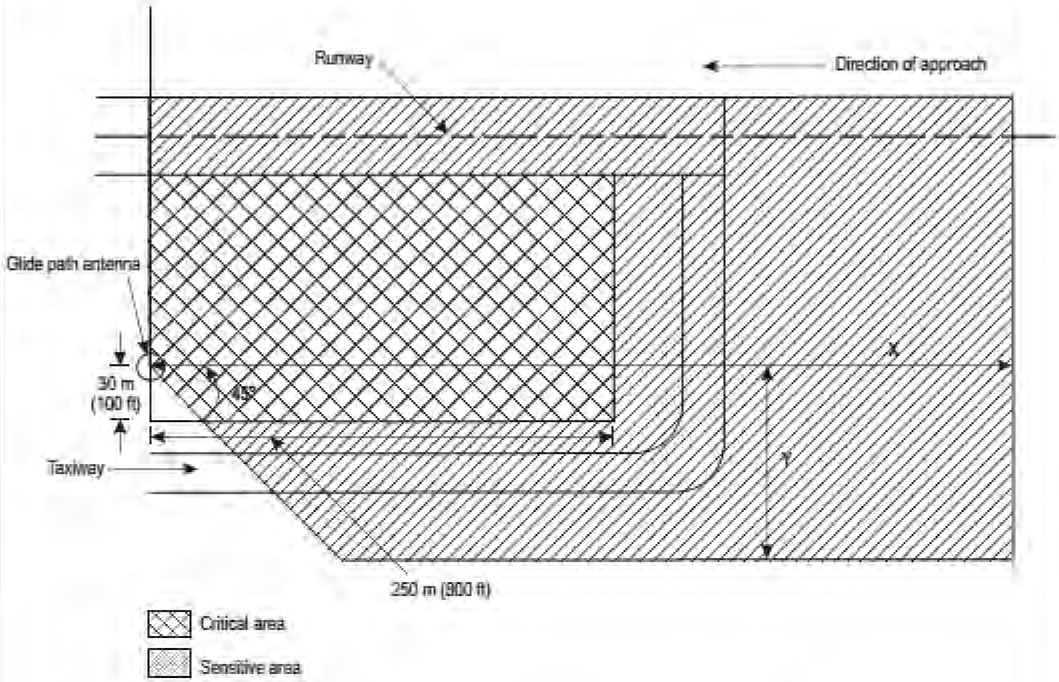
a) localizer course bends due to static objects equals plus or minus 1½µA. Limit plus or minus 5µA. Therefore allowance for moving objects to define localizer sensitive area is

$$\sqrt{5^2 - 1.5^2} = 4.77\mu A$$



		Example 1	*Example 2*	*Example 3*
Aircraft type		B-747	B-747	B-727
Localizer antenna aperture		Typically 27 m (90 ft) (Directional dual frequency, 14 elements)	Typically 16 m (50 ft) (Semi-directional, 8 elements)	Typically 16 m (50 ft) (Semi-directional, 8 elements)
Sensitive area (X, Y)				
Category I	X	600 m (2 000 ft)	600 m (2 000 ft)	300 m (1 000 ft)
	Y	60 m (200 ft)	110 m (350 ft)	60 m (200 ft)
Category II	X	1 220 m (4 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)
Category III	X	2 750 m (9 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)

Figure C-3A. Typical localizer critical and sensitive areas dimension variations for a 3 000 m (10 000 ft) runway



		Example 1	Example 2	Example 3
Aircraft type		B-747	B-727	small & medium*
Category I	X	915 m (3 000 ft)	730 m (2 400 ft)	250 m (800 ft)
	Y	60 m (200 ft)	30 m (100 ft)	30 m (100 ft)
Category II/III	X	975 m (3 200 ft)	825 m (2 700 ft)	250 m (800 ft)
	Y	90 m (300 ft)	60 m (200 ft)	30 m (100 ft)

* Small and medium aircraft here are considered as those having both a length less than 18 m (60 ft) and a height less than 6 m (20 ft).

Note.— *In some cases the sensitive areas may be extended beyond the opposite side of the runway.*

Figure C-3B. Typical glide path critical and sensitive areas dimension variations

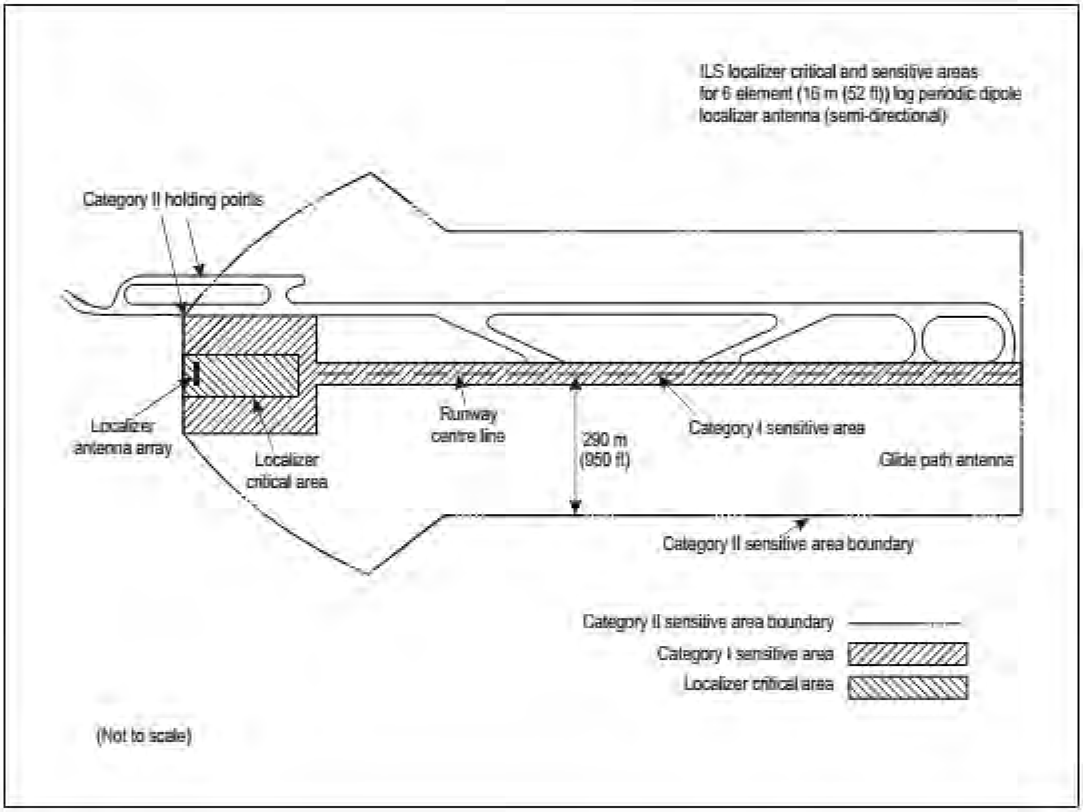


Figure C-4A. Example of critical and sensitive area application at specific sites with B-747 aircraft interference

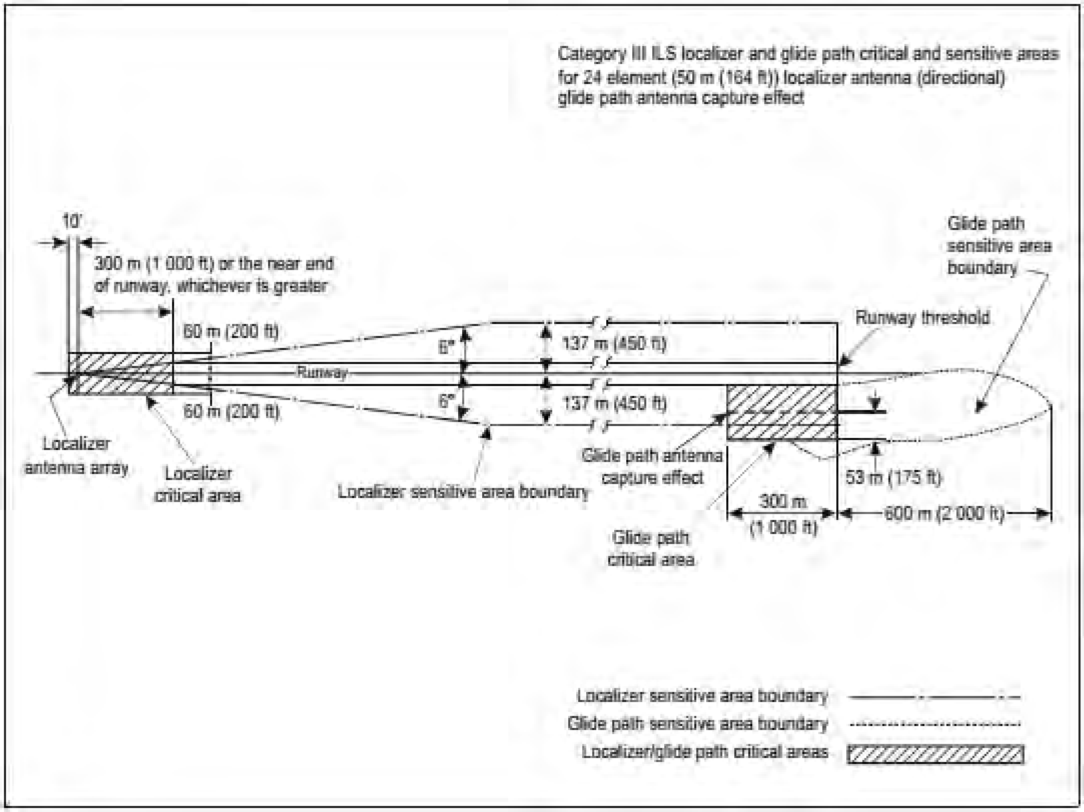


Figure C-4B. Example of critical and sensitive area application at specific sites with B-747 aircraft interference

b) localizer course bends due to static objects equals plus or minus 4μA. Limit plus or minus 5μA. Therefore allowance for moving objects to define localizer sensitive area is

In case b) the sensitive area would be larger, thus keeping interfering objects further away from the runway so that they produce 3μ A or less distortion of the localizer beam. The same principle is applied to the glide path sensitive area.

2.1.10 Reducing localizer bends and areas with insufficient difference in depth of modulation (DDM)

2.1.10.1 Introduction. Owing to site effects at certain locations, it is not always possible to produce, with simple standard ILS installations, localizer courses that are sufficiently free from troublesome bends or irregularities. If this is the case, it is highly preferable to use two radio frequency carriers to provide the standard coverage and signal characteristics. Additional guidance on two radio frequency carrier coverage is provided in 2.7. If standard coverage requirements still cannot be met, reducing radiation in the direction of objects and accepting an increase of the lower vertical coverage boundaries as permitted in Chapter 3, 3.1.3.3.1 may be employed.

2.1.10.2 Reducing standard localizer coverage. When using the coverage reduction option defined in Chapter 3,

3.1.3.3.1, care needs to be taken to ensure that the reduced coverage volume is consistent with the minimum altitudes published for the instrument approach procedure. Additionally, normal vectoring operations should not be terminated and a clearance to intercept the localizer should not be issued until within the promulgated coverage area. This is sometimes referred to as the operational service volume.

2.1.10.2.1 Operational considerations from an air traffic management perspective. Instrument approach procedures must be designed to take into account any reduction in localizer coverage permitted by the Standard in Chapter 3, 3.1.3.3.1. This can be done either by ensuring that the procedure remains within localizer coverage or by providing alternative means to navigate. Consequently, a significant portion (3.7 km (2 NM) minimum) of the initial segment must be within localizer coverage. Localizer coverage needs to be available sufficiently in advance of the area where controllers usually give the approach or intercept clearance to permit pilots to verify the Morse code identification (IDENT).

2.1.10.2.2 Operational considerations from a pilot/aircraft perspective. For aircraft equipped with automatic flight control systems (AFCS), localizer coverage needs to be available prior to the activation of the AFCS intercept mode (manual or automatic flight) and sufficiently in advance of the area where controllers usually give the approach or intercept clearance to permit checking the IDENT signal. When flying manually or when using an AFCS, pilots normally check the IDENT of the ILS facility and then wait to arm the mode enabling localizer intercept turn initiation and capture until after receiving the approach or intercept clearance. Ideally, additional aids (if included in the approach procedure) should permit a determination of the relationship between the aircraft position and the localizer front course line by the pilot.

2.2 ILS airborne receiving equipment

2.2.1 To ensure that the required operational objectives are achieved, it is necessary for the airborne receiving equipment to meet defined performance standards.

Note.— The relevant minimum operational performance standards for ILS receivers are detailed in RTCA DO-195 (1986) and EUROCAE ED-46B (including Amendments Nos. 1 and 2) for the localizer, in RTCA DO-143 (1970) and EUROCAE 1/WG 7/70 for the marker beacon, and in RTCA DO-192 (1986) and EUROCAE ED-47B (including Amendment No. 1) for the glide path receivers.

2.2.2 Immunity performance of ILS localizer receiving systems to interference from VHF FM broadcast signals

2.2.2.1 With reference to Note 2 of 3.1.4.2, Chapter 3, the immunity performance defined there must be measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results and to facilitate their subsequent approval. Tests have shown that FM interference signals may affect both course guidance and flag current, and their effects vary depending on the DDM of the wanted signal which is applied. Additional information can be found in ITU Recommendation ITU-R SM.1140, Test procedures for measuring receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–118 MHz.

Note.— ITU Recommendation ITU-R SM.1140 can be found in the Manual on Testing of Radio Navigation Aids(Doc8071), Volume I.

2.2.2.2 Commonly agreed methodology and formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Chapter 3, 3.1.4. The formulae provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R SM.1009-1, Compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–137 MHz.

Note.— ITU Recommendation ITU-R SM.1009-1 can be found in Doc 8071, Volume I.

2.2.3 Localizer and glide path antenna polarization

2.2.3.1 Over the localizer and glide path frequency bands, respectively, the reception of vertically polarized signals from the forward direction with respect to the localizer and glide path antenna should be at least 10 dB below the reception of horizontally polarized signals from the same direction.

2.3 Alarm conditions for ILS airborne equipment

2.3.1 Ideally, a receiver alarm system such as a visual flag should warn a pilot of any unacceptable malfunctioning conditions which might arise within either the ground or airborne equipments. The extent to which such an ideal may be satisfied is specified below.

2.3.2 The alarm system is actuated by the sum of two modulation depths and, therefore, the removal of the ILS course modulation components from the radiated carrier should result in the actuation of the alarm.

2.3.3 The alarm system should indicate to the pilot and to any other airborne system which may be utilizing the localizer and glide path data, the existence of any of the following conditions:

a) the absence of any RF signal as well as the absence of simultaneous 90 Hz and 150 Hz modulation;

b) the percentage modulation of either the 90 Hz or 150 Hz signal reduction to zero with the other maintained at its normal 20 per cent and 40 per cent modulation respectively for the localizer and glide path;

Note.— It is expected that the localizer alarm occur when either the 90 Hz or 150 Hz modulation is reduced to 10 per cent with the other maintained at its normal 20 per cent. It is expected that the glide path alarm occur when either the 90 Hz or 150 Hz modulation is reduced to 20 per cent with the other maintained at its normal 40 per cent.

2.3.3.1 The alarm indication should be easily discernible and visible under all normal flight deck conditions. If a flag is used, it should be as large as practicable commensurate with the display.

2.4 Guidance for the siting, elevation, adjustment and coverage of glide path equipment

2.4.1 Lateral placement. The lateral placement of the glide path antenna system with respect to the runway centre line is normally not less than 120 m (400 ft).In deciding the lateral placement of the glide path antenna, account should be taken of the appropriate provisions of Annex 14with regard to obstacle clearance surfaces and objects on strips for runways.

2.4.2 ILS glide path curvature. In many cases, the ILS glide path is formed as a conic surface originating at the glide path aerial system. Owing to the lateral placement of the origin of this conic surface from the runway centre line, the locus of the glide path in the vertical plane along the runway centre line is a hyperbola. Curvature of the glide path occurs in the threshold region and progressively increases until touchdown. To limit the amount of curvature, the glide path antenna should not be located at an excessive lateral distance from the runway centre line.

2.4.3 Procedure design. Chapter 3, 3.1.5.1 provides Standards and Recommended Practices for the glide path angle and the height of the ILS reference datum. The longitudinal position of the glide path antenna with respect to the runway threshold is established in order to provide the selected glide path angle and desired ILS reference datum height for the precision approach procedure designed for that runway. The precision approach procedure design may be modified to meet obstacle clearance requirements or to account for technical siting constraints for the glide path antenna (for example, crossing runways or taxiways). The procedure designer will take into account the acceptable glide path angle, threshold crossing height and runway length available as they relate to the type of aircraft expected to use the precision approach procedure.

2.4.4 Longitudinal placement. Assuming that the reflecting surface in the beam forming area can be approximated by a planar surface with appropriate lateral and longitudinal slopes, the required longitudinal position of the glide path antenna is then a function of the ILS reference datum above the runway threshold and of the projection of the glide path reflection plane along the runway centre line. This situation is described pictorially in Figure C-5. In this figure, the line OP is defined by the intersection between the glide path reflection plane and the vertical plane along the runway centre line, and point O is at the same longitudinal distance from the threshold as the glide path antenna. Depending on the height and orientation of the reflection plane, point O may be above or below the runway surface. For a planar reflecting surface, the longitudinal position of the glide path antenna is then calculated as follows:

$$D = \frac{H + Y}{\tan(\theta) + \tan(\alpha)}$$

where

D = the horizontal distance between O and P (equivalent to the longitudinal distance from the glide path antenna to the runway threshold);

H = the nominal height of the ILS reference datum above the runway threshold;

Y = the vertical height of the runway threshold above P';

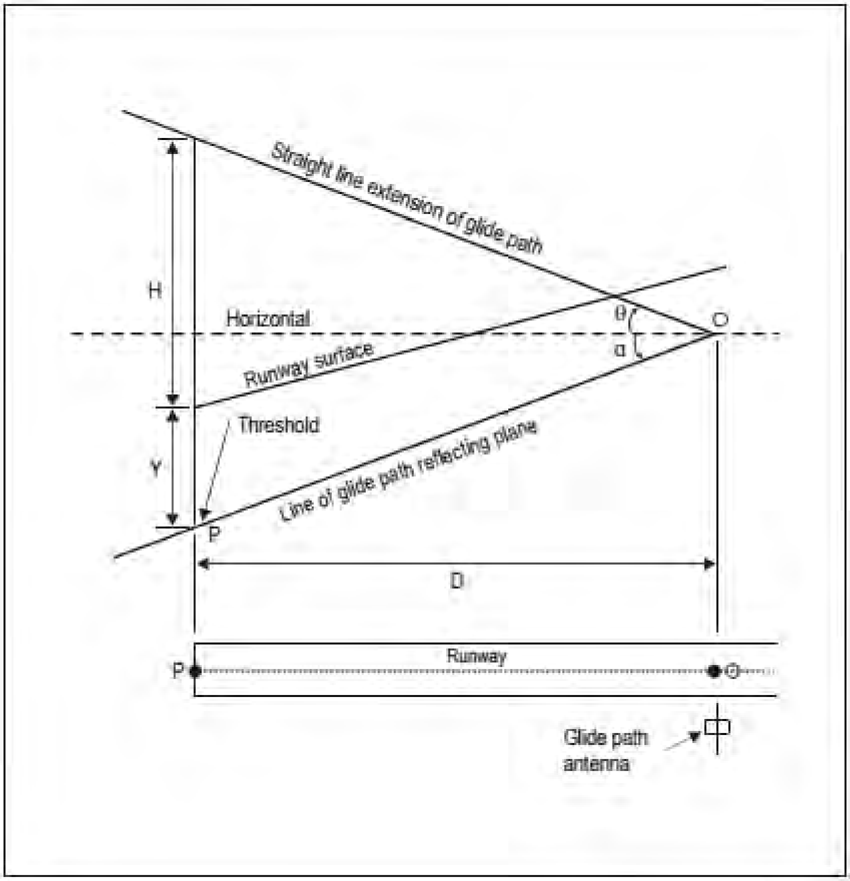


Figure C-5. Glide path siting for sloping runway

θ = the nominal ILS glide path angle;

α = the longitudinal downslope of the glide path reflection plane.

Note.— In the above formula a is to be taken as positive in the case of a downslope from the antenna towards the threshold. Y is taken as positive if the threshold is above the reflection plane intersection line.

2.4.5 The foregoing guidance material is based on the approximation of the reflecting surface by an appropriately oriented plane. Actual siting characteristics, such as significant lateral slope or an irregular rather than planar reflection surface, may require a more rigorous approach if the design goal for the height of the ILS reference datum is to be closely met. In challenging cases, mathematical modelling predictions of the effects of the siting conditions may be appropriate.

2.4.6 Typically, the glide path has some irregularities. The mean ILS glide path angle can be ascertained only by flight tests; the mean observed position of that part of the glide path between ILS Points A and B being represented as a straight line, and the ILS glide path angle being the angle measured between that straight line and its vertical projection on the horizontal plane.

2.4.7 It is important to recognize that the effect of glide path irregularities if averaged within the region between the middle marker and the threshold will likely tend to project a reference datum which is actually different from the ILS reference datum. This reference datum, defined here as the achieved ILS reference datum, is considered to be of important operational significance. The achieved ILS reference datum can only be ascertained by flight check, i.e. the mean observed position of that portion of the glide path typically between points 1 830 m (6 000 ft) and 300 m (1 000 ft) from the threshold being represented as a straight line and extended to touchdown. The point at which this extended straight line meets the line drawn vertically through the threshold at the runway centre line is the achieved ILS reference datum.

Note.— Further guidance on the measurement of the glide path angle and the achieved ILS reference datum is given in Doc 8071.

2.4.8 To reduce multipath interference to Category III glide paths and to reduce siting requirements and sensitive areas at these sites, it is desirable that the signals forming the horizontal radiation pattern from the Category III — ILS glide path antenna system be reduced to as low a value as practicable outside the azimuth coverage limits specified in Chapter 3, 3.1.5.3.

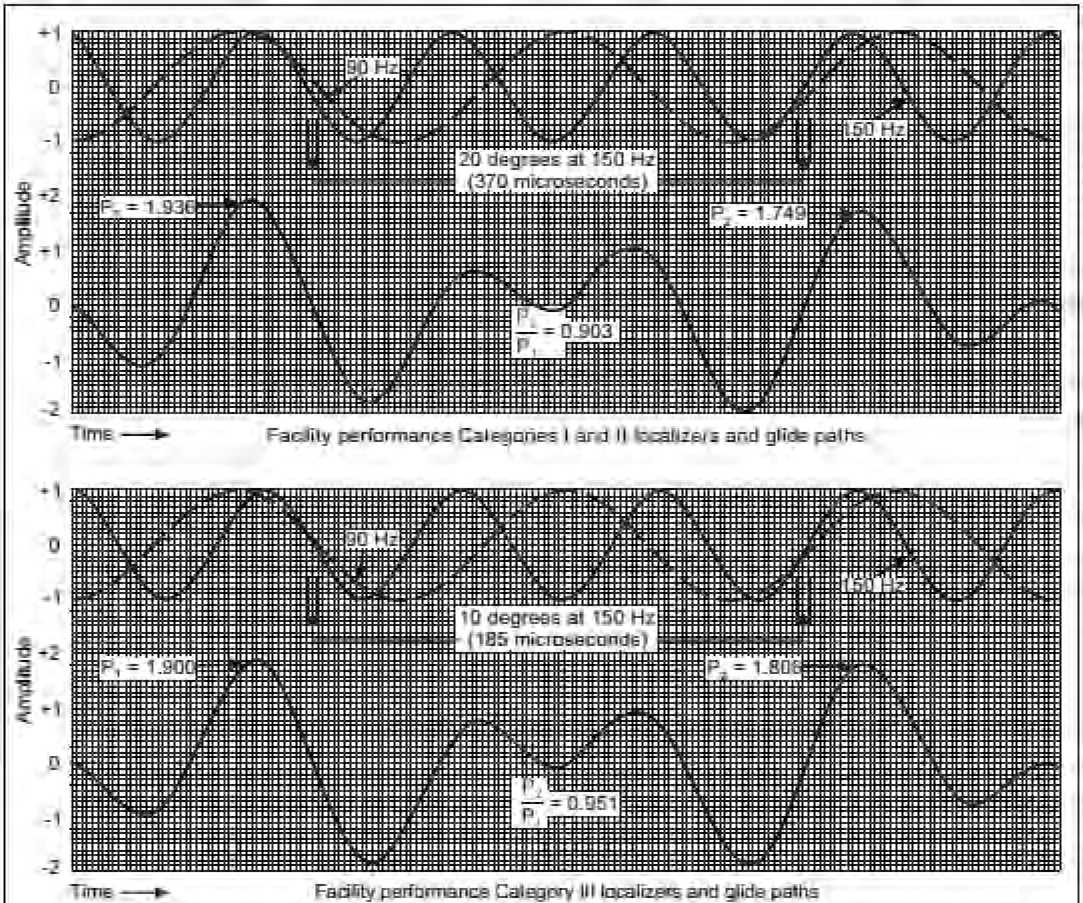
Another acceptable method is to rotate in azimuth the glide path antennas away from multipath sources thus reducing the amount of radiated signals at specific angles while still maintaining the azimuth coverage limits.

2.4.9 Chapter 3, 3.1.5.3.1 indicates the glide path coverage to be provided to allow satisfactory operation of a typical aircraft installation. The operational procedures promulgated for a facility must be compatible with the lower limit of this coverage. It is usual for descents to be made to the intercept altitude and for the approach to continue at this altitude until a fly-down signal is received. In certain circumstances a cross-check of position may not be available at this point. Automatic flight control systems will normally start the descent whenever a fly-up signal has decreased to less than about 10 microamperes.

2.4.10 The objective is, therefore, to provide a fly-up signal prior to intercepting the glide path. Although under normal conditions, approach procedures will be accomplished in such a way that glide path signals will not be used below 0.45 θ, or beyond 18.5 km (10 NM) from the runway, it is desirable that misleading guidance information should not be radiated in this area. Where procedures are such that the glide path guidance may be used below 0.45 θ, adequate precautions must be taken to guard against the radiation of misleading guidance information below 0.45 θ, under both normal conditions and during a malfunction, thus preventing the final descent being initiated at an incorrect point on the approach. Some precautions which can be employed to guard against the radiation of misleading guidance include the radiation of a supplementary clearance signal such as provided for in Chapter 3, 3.1.5.2.1, the provision of a separate clearance monitor and appropriate ground inspection and setting-up procedures.

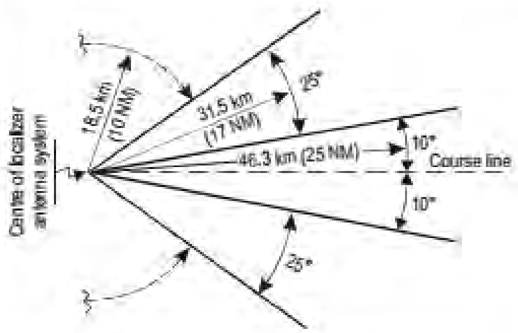
2.4.11 To achieve satisfactory monitor protection against below-path out-of-tolerance DDM, depending on the antenna system used, the displacement sensitivity monitor as required in Chapter 3, 3.1.5.7.1 e) may not be adequate to serve also as a clearance monitor. In some systems, e.g. those using multi-element arrays without supplementary clearance, a slight deterioration of certain antenna signals can cause serious degradation of the clearance with no change or only insignificant changes within the glide path sector as seen by the deviation sensitivity monitor. It is important to ensure that monitor alarm is achieved for any or all possible deteriorated antenna and radiated signal conditions, which may lead to a reduction of clearance to 0.175 DDM or less in the below-path clearance coverage.

2.5 Diagrams (Figures C-6 to C-12 illustrate certain of the Standards contained in Chapter 3)

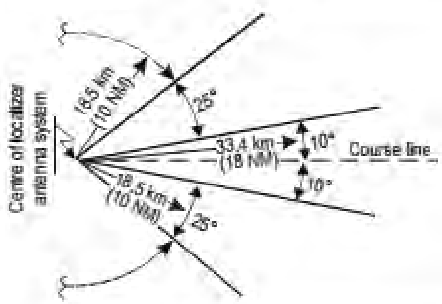


The accompanying graphs illustrate a method that can be used to measure the relative phase relationship between the 90 Hz and 150 Hz tones. The upper portion of each graph shows the individual waveforms and their relationship at the limit of phase differences allowed by Chapter 3, 3.1.3.5.3.3 and 3.1.5.5.3. The lower portion shows the combined waveforms as would be seen on an oscilloscope. By taking the ratio of P_2 and P_1, which gives a value equal to or less than unity, it is possible to determine if the phasing is within tolerance. For Categories I and II ILS the ratio should be greater than 0.903 and for Category III the ratio should be greater than 0.951.

Figure C-6. ILS wave forms illustrating relative audio phasing of the 90 Hz and 150 Hz tones



When topographical features dictate or operational requirements and alternative navigation facilities permit, the following coverage may be provided:



Note.— If coverage as prescribed in Chapter 3, 3.1.3.3.1 is required outside the plus or minus 35-degree sector, this is provided to 18.5 km (10 NM), as indicated by the broken arc above.

Figure C-7A. Localizer coverage with respect to azimuth

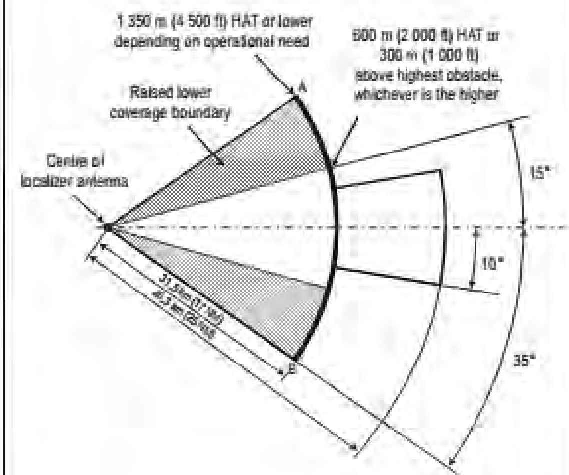
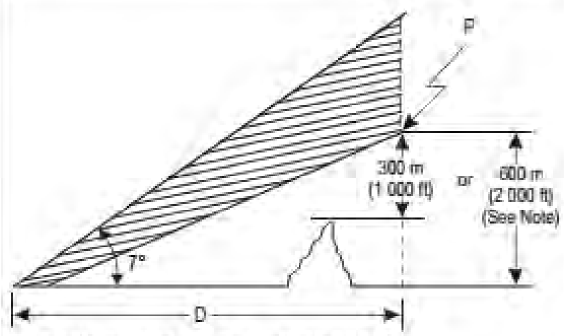


Figure C-7B. Reduced localizer coverage with respect to azimuth



D = Distances and azimuths specified in 3.1.3.3.1

Note.— The point P is either 600 m (2 000 ft) above the elevation of the threshold, or 300 m (1 000 ft) above the elevation of the highest point within the intermediate and final approach areas, whichever is the higher.

Figure C-8A. Localizer coverage with respect to elevation

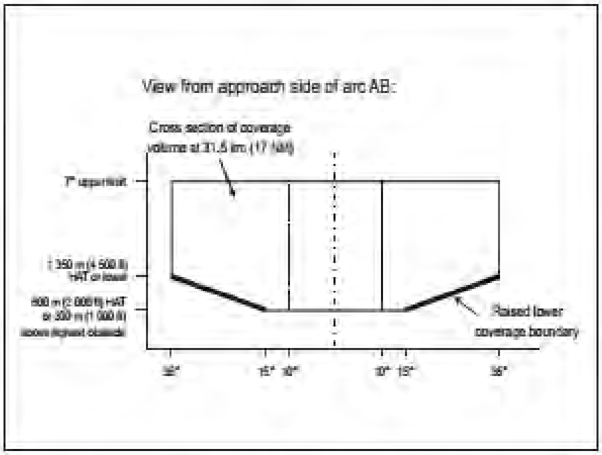


Figure C-8B. Reduced localizer coverage with respect to elevation

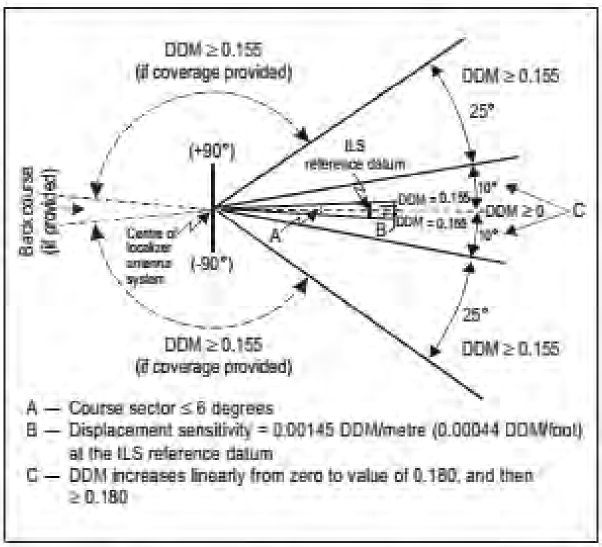


Figure 9. Difference in depth of modulation and displacement sensitivity

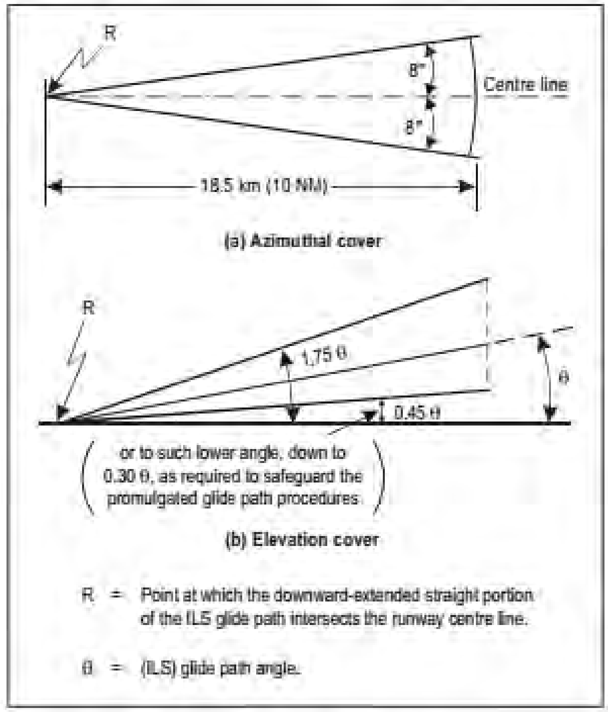


Figure 10. Glide path coverage

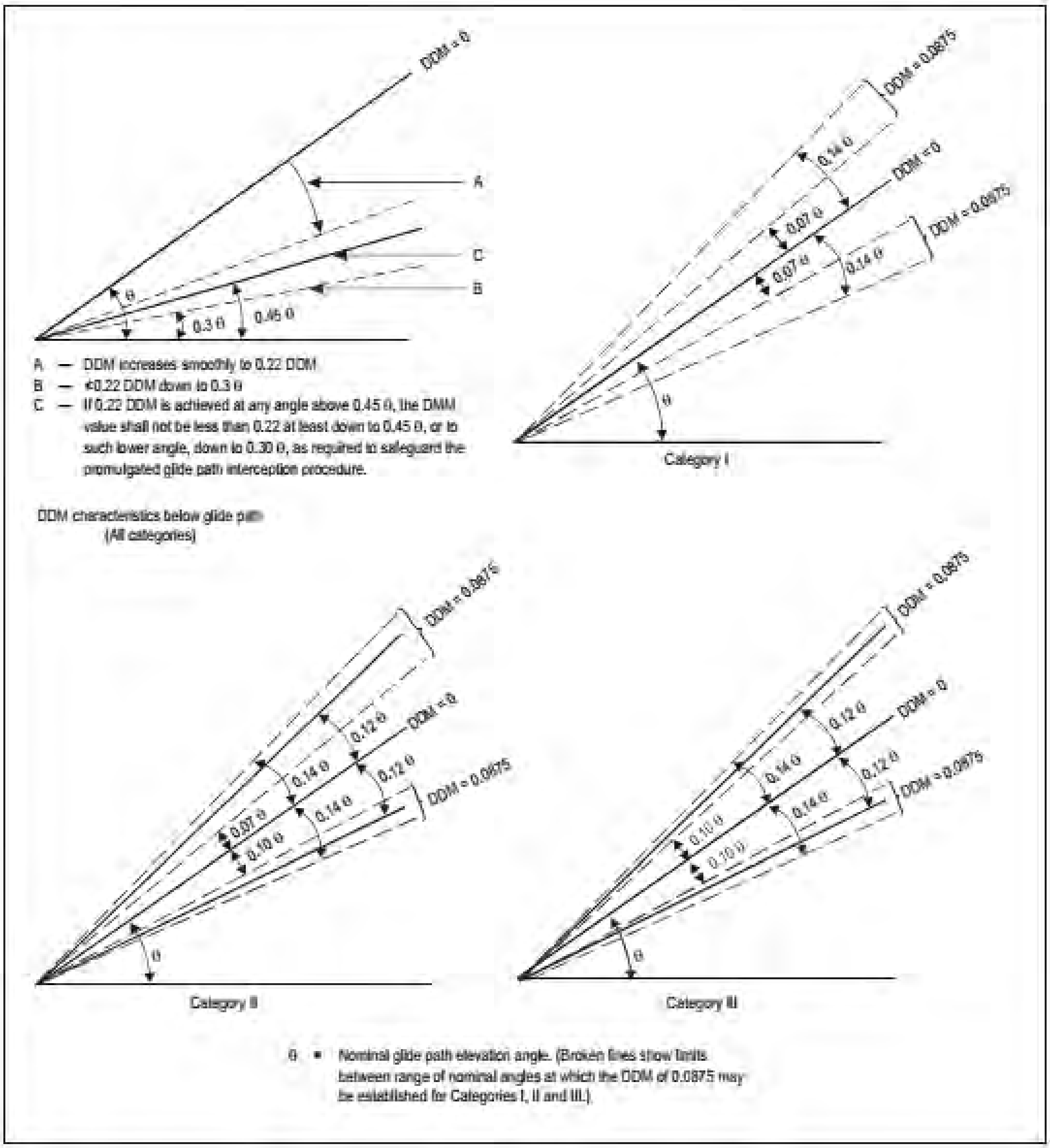
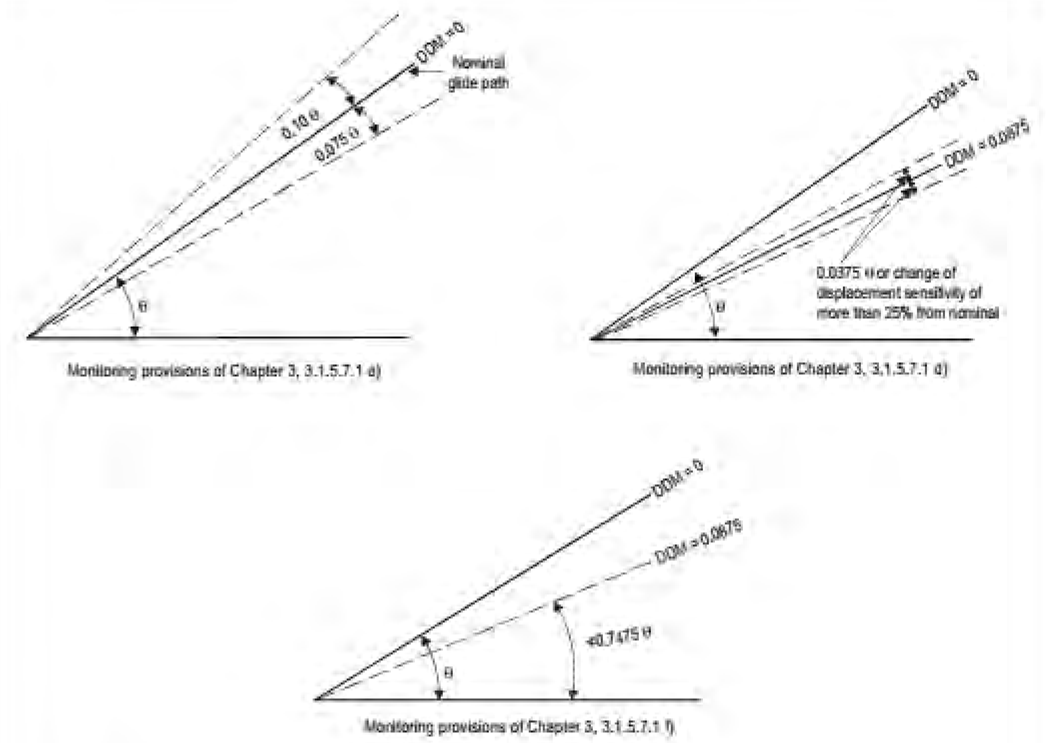


Figure C-11. Glide path — difference in depth of modulation



Note.— The broken lines represent the permissible limits of deviation before monitoring action is required.

Figure C-12. Glide path monitoring provisions

2.6 Deployment of ILS frequencies

2.6.1 In using the figures listed in Table C-1, it must be noted that these are related to ensuring freedom from interference to a point at the protection height and at the limit of service distance of the ILS in the direction of the front beam. If there is an operational requirement for back beam use, the criteria would also be applied to a similar point in the back beam direction. Frequency planning will therefore need to take into account the localizer azimuthal alignment. It is to be noted that the criteria must be applied in respect of each localizer installation, in the sense that while of two localizers, the first may not cause interference to the use of the second, nevertheless the second may cause interference to the use of the first.

2.6.2 The figures listed in Table C-1 are based on providing an environment within which the airborne receivers can operate correctly.

2.6.2.1 ILS localizer receivers

2.6.2.1.1 In order to protect receivers designed for 50 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

2.6.2.1.2 In order to protect receivers designed for 100 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

2.6.2.2 ILS glide path receivers

2.6.2.2.1 In order to protect receivers designed for 150 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;

c) an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

Table C-1. Required distance separations

	Frequency separation	Minimum separation between second facility and the protection point of the first facility km (NM)		
		List A	List B	List C
Localizer	Co-channel	148 (80)	148 (80)	148 (80)
	50 kHz	—	37 (20)	9 (5)
	100 kHz	65 (35)	9 (5)	0
	150 kHz	—	0	0
	200 kHz	11 (6)	0	0
Glide path	Co-channel	93 (50)	93 (50)	93 (50)
	150 kHz	—	20 (11)	2 (1)
	300 kHz	46 (25)	2 (1)	0
	450 kHz	—	0	0
	600 kHz	9 (5)	0	0

List A refers to the use of localizer receivers designed for 200 kHz channel spacing coupled with glide path receivers designed for 600 kHz channel spacing and applicable only in regions where the density of facilities is low.

List B refers to the use of localizer receivers designed for 100 kHz channel spacing coupled with glide path receivers designed for 300 kHz channel spacing.

List C refers to the use of localizer receivers designed for 50 kHz channel spacing coupled with glide path receivers designed for 150 kHz channel spacing.

Note 1.— The above figures are based on the assumption of protection points for the localizer at 46 km (25 NM) distance and 1 900 m (6 250 ft) height and for the ILS glide path at 18.5 km (10 NM) distance and 760 m (2 500 ft) height.

Note 2.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS and VOR facilities in a manner which will preclude the possibility of airborne receiver error due to overloading by high unwanted signal levels when the aircraft is in the initial and final approach phases.

Note 3.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS glide path facilities in a manner which will preclude the possibility of erroneous glide path indications due to reception of adjacent channel signals when the desired signal ceases to radiate for any reason while the aircraft is in the final approach phase.

2.6.2.2.2 In order to protect receivers designed for 300 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, does not exceed the desired signal (0 dB signal ratio);

c) an undesired glide path signal, 300 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;

d) an undesired glide path signal, 450 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

2.6.3 The calculations are based on the assumption that the protection afforded to the wanted signal against interference from the unwanted signal is 20 dB. This corresponds to a disturbance of not more than 15 microamperes at the limit of the service distance of ILS.

2.6.4 In so far as the wanted and unwanted carriers may produce a heterodyne note, the protection ratio ensures that the instrumentation is not affected. However, in cases where a voice facility is used, the heterodyne note may interfere with this facility.

2.6.5 In general, when international use of ILS systems is confined to the pairings listed in Chapter 3, 3.1.6.1.1, the criteria are such that, provided they are met for the localizer element, the glide path element is automatically covered. At certain congested locations, where it is necessary to make assignments in both the first ten and the second ten sequence pairings, it may be necessary to select certain pairings out of sequence in order to meet the minimum geographical separation in 2.6.6.

Example: Referring to Chapter 3, 3.1.6.1.1, it will be noted that ILS Sequence Number 2 pairs the localizer frequency of 109.9 MHz with glide path frequency 333.8 MHz. Sequence Numbers 12 and 19, however, although providing wide frequency separation from Sequence Number 2 in the case of the localizers, assign frequencies of 334.1 MHz and 333.5 MHz, respectively, for the glide paths, both being first adjacent channels (300 kHz spacing) to the Sequence Number 2 glide path channel. If selection of ILS channels is confined to either the first ten or the second ten pairings, then the minimum glide path frequency separation will be 600 kHz.

2.6.6 Table of required distance separations(see Table C-1)

2.6.7 The application of the figures given in Table C-1 will only be correct within the limitations set by the assumptions which include that facilities are essentially non-directional in character, that they have similar radiated powers, that the field strength is approximately proportional to the angle of elevation for angles up to 10 degrees, and that the aircraft antenna is essentially omnidirectional in character. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves, taking into account the particular directivity factors, radiated power characteristics and the operational requirements as to coverage. Where reduced separation distances are determined by taking into account directivity, etc., flight measurements at the ILS protection point and at all points on the approach path should be made wherever possible to ensure that a protection ratio of at least 20 dB is achieved in practice.

2.7 Localizers and glide paths achieving coverage with two radio frequency carriers

2.7.1 Localizer and glide path facilities may achieve their coverage requirements by using two radiation field patterns, commonly known as the "course" and "clearance" patterns, transmitted using separate carrier frequencies spaced within the frequency channel. The course field pattern gives accurate course and displacement indications; the clearance field pattern provides displacement indications at angles beyond the limits of the course field pattern. Discrimination between signals is obtained in airborne receivers by the stronger signal capturing the receiver. Effectiveness of capture depends on the type of detector used but, in general, if the ratio of the two signals is of the order of 10 dB or more, the smaller signal does not cause significantly large errors in demodulated output. For optimum performance within the front course sector, the following guidance material should be applied in the operation of two carrier frequency localizer systems.

2.7.2 The localizer should be designed and maintained so that the ratio of the two radiated signals-in-space within the front course sector does not fall below 10 dB. Particular attention should be directed to the vertical lobe structure produced by the two antenna systems which may be different in height and separated in distance, thus resulting in changes in ratio of signal strengths during approach.

2.7.3 Due to the 6 dB allowance for the receiver pass-band filter ripple, localizer receiver response variations can occur as the clearance frequency is displaced from the course frequency. To minimize this effect, particularly for Category III operations, the course-to-clearance signal ratio needs to be increased from 10 dB to 16 dB.

2.7.4 To minimize further the risk of errors if the ratio of the two radiated signals falls below 10 dB within the front course sector, the difference in alignment of the radiation field patterns of the two signals should be kept as minimal as practicable.

2.7.5 Glide paths which employ two carriers are used to form a composite radiation field pattern on the same radio frequency channel. Special configurations of antennas and the distribution of antenna currents and phasing may permit siting of glide path facilities at locations with particular terrain conditions which may otherwise cause difficulty to a single frequency system. At such sites, an improvement is obtained by reducing the low angle radiation. The second carrier is employed to provide coverage in the region below the glide path.

2.7.6 Monitoring dual frequency systems. The dual frequency monitoring requirements in Chapter 3, 3.1.3.11.2 e) and 3.1.5.7.1 c) specify monitor action for a power output of less than 80 per cent of normal, except that reductions can be accepted to 50 per cent of normal if certain performance requirements are met.

2.7.6.1 Monitoring the course and clearance transmitters for a 20 per cent reduction in power (approximately –1 dB) can be challenging if environmental and other effects such as large ambient temperature variations exist at the site. For example, temperature variations cause normal transmitter power output to vary and coaxial cable insertion losses to change. Even assuming no failure occurs in the transmitting system, the alarm limit occasionally may be exceeded, and this in turn may compromise continuity.

2.7.6.2 The alternative of monitoring at power reductions of up to 50 per cent appears very attractive, but must be used cautiously. Monitoring each transmitter independently at a 50 per cent reduction can allow a large change from the nominal power ratio between the two transmitters if uncorrelated failures occur. This in turn may compromise the capture effect in the receiver, thus increasing structure errors or reducing clearance indications.

2.7.6.3 One solution is to use a monitoring scheme that limits the difference between the power output of the transmitters to approximately 1 dB (i.e. 80 per cent), while allowing both to decrease up to 3 dB (i.e. 50 per cent) if they change together. This method provides a greater tolerance for common mode effects such as cable loss changes due to temperature, and therefore increases continuity of service.

2.8 Integrity and continuity of service — ILS ground equipment

2.8.1 Introduction

2.8.1.1 This material is intended to provide clarification of the integrity and continuity of service objectives of ILS localizer and glide path ground equipment and to provide guidance on engineering design and system characteristics of this equipment. Integrity is needed to ensure that an aircraft on approach will have a low probability of receiving false guidance; continuity of service is needed to ensure that an aircraft in the final stages of approach will have a low probability of being deprived of a guidance signal.

Integrity and continuity of service are both key safety factors during the critical phase of approach and landing. The integrity and continuity of service must of necessity be known from an operational viewpoint in order to decide the operational application which an ILS could support.

2.8.1.2 It is generally accepted, irrespective of the operational objective, that the average rate of a fatal accident during landing, due to failures or shortcomings in the whole system, comprising the ground equipment, the aircraft and the pilot, should not exceed 1×10^{-7}. This criterion is frequently referred to as the global risk factor.

2.8.1.3 In the case of Category I operations, responsibility for assuring that the above objective is not exceeded is vested more or less completely in the pilot. In Category III operations, the same objective is required but must now be inherent in the whole system. In this context it is of the utmost importance to endeavour to achieve the highest level of integrity and continuity of service of the ground equipment.

2.8.1.4 The requirements for integrity and high continuity of service require highly reliable systems to minimize the probability of failure which may affect any characteristic of the total signal-in-space. It is suggested that States endeavour to achieve reliability with as large a margin as is technically and economically reasonable. Reliability of equipment is governed by basic construction and operating environment. Equipment design should employ the most suitable engineering techniques, materials and components, and rigorous inspection should be applied in manufacture. Equipment should be operated in environmental conditions appropriate tothe manufacturers' design criteria.

2.8.2 Achievement and retention of integrity service levels

2.8.2.1 An integrity failure can occur if radiation of a signal which is outside specified tolerances is either unrecognized by the monitoring equipment or the control circuits fail to remove the faulty signal. Such a failure might constitute a hazard if it results in a gross error.

2.8.2.2 Clearly not all integrity failures are hazardous in all phases of the approach. For example, during the critical stages of the approach, undetected failures producing gross errors in course width or course line shifts are of special significance whereas an undetected change of modulation depth, or loss of localizer and glide slope clearance and localizer identification would not necessarily produce a hazardous situation. The criterion in assessing which failure modes are relevant must however include all those deleterious fault conditions which are not unquestionably obvious to the automatic flight system or pilot.

2.8.2.3 The highest order of protection is required against the risk of undetected failures in the monitoring and associated control system. This would be achieved by careful design to reduce the probability of such occurrences to a low level and provide fail-safe operations compliant with the Standards of Chapter 3, 3.1.3.11.4 and 3.1.5.7.4, and by carrying out maintenance checks on the monitor system performance at intervals which are determined by a design analysis.

2.8.2.4 A design analysis can be used to calculate the level of integrity of the system in any one landing. The following formula applies to certain types of ILS and provides an example of the determination of system integrity, I, from a calculation of the probability of transmission of undetected erroneous radiation, P.

(1) $I = 1 - P$

$$P = \frac{T_1 T_2}{\alpha_1 \alpha_2 M_1 M_2} \text{ when } T_1 < T_2$$

where

I = integrity

P = the probability of a concurrent failure in transmitter and monitor systems resulting in erroneous undetected radiation

M_1 = transmitter mean time between failures (MTBF)

M_2 = MTBF of the monitoring and associated control system

$\frac{1}{\alpha_1}$ = ratio of the rate of failure in the transmitter resulting in the radiation of an erroneous signal to the rate of all transmitter failures

$\frac{1}{\alpha_2}$ = ratio of the rate of failure in the monitoring and associated control system resulting in inability to detect an erroneous signal to the rate of all monitoring and associated control system failures

T_1 = period of time (in hours) between transmitter checks

T_2 = period of time (in hours) between checks on the monitoring and associated control system

When T1 ≥ T2 the monitor system check may also be considered a transmitter check. In this case, therefore T1= T2 and the formula would be:

(2) $$P = \frac{T_2^2}{\alpha_1 \alpha_2 M_1 M_2}$$

2.8.2.5 Since the probability of occurrence of an unsafe failure within the monitoring or control equipment is extremely remote, to establish the required integrity level with a high degree of confidence would necessitate an evaluation period many times that needed to establish the equipment MTBF. Such a protracted period is unacceptable and therefore the required integrity level can only be predicted by rigorous design analysis of the equipment.

2.8.2.6 Protection of the integrity of the signal-in-space against degradation which can arise from extraneous radio interference falling within the ILS frequency band or from re-radiation of ILS signals must also be considered. Measures to prevent the latter by critical and sensitive area protection are given in general terms at 2.1.9. With regard to radio interference it may be necessary to confirm periodically that the level of interference does not constitute a hazard.

2.8.2.7 In general, monitoring equipment design is based on the principle of continuously monitoring the radiated signals-in-space at specific points within the coverage volume to ensure their compliance with the Standards specified at Chapter 3, 3.1.3.11 and 3.1.5.7. Although such monitoring provides to some extent an indication that the signal-in-space at all other points in the coverage volume is similarly within tolerance, this is largely inferred. It is essential therefore to carryout rigorous flight and ground inspections at periodic intervals to ensure the integrity of the signal-in-space throughout the coverage volume.

2.8.3 Achievement and retention of continuity of service levels

2.8.3.1 A design analysis should be used to predict the MTBF and continuity of service of the ILS equipment. Before assignment of a level of continuity of service and introduction into Category II or III service, however, the mean time between outages (MTBO) of the ILS should be confirmed by evaluation in an operational environment. In this evaluation, an outage is defined as any unanticipated cessation of signal-in-space. This evaluation takes into account the impact of operational factors, i.e. airport environment, inclement weather conditions, power availability, quality and frequency of maintenance. MTBO is related to MTBF, but is not equivalent, as some equipment failures, such as a failure of a transmitter resulting in the immediate transfer to a standby transmitter may not necessarily result in an outage. For continuity of service Level 2, 3 or 4, the evaluation period should be sufficient to determine achievement of the required level with a high degree of confidence. One method to demonstrate that continuity standards are met is the sequential test method. If this method is used, the following considerations apply:

a) the minimum acceptable confidence level is 60 per cent. To achieve the confidence level of 60 per cent, the evaluation period has to be longer than the required MTBO hours as stated in Table C-2. Typically, these minimal evaluation periods for new and subsequent installations are for Level 2, 1 600 operating hours, for Level 3, 3 200 hours and for Level 4, 6 400 hours. To assess the seasonal influence of the environment, a minimal evaluation period of one year is typically required for a new type of installation in a particular environment. It may be possible to reduce this period in cases where the operating environment is well controlled and similar to other proven installations. Where several identical systems are being operated under similar conditions, it may be possible to base the assessment on the cumulative operating hours of all the systems; this will result in a reduced evaluation period. Once a higher confidence level is obtained for a type of installation, subsequent installation of the same type of equipment under similar operational and environmental conditions may follow shorter evaluation periods;

b) during the evaluation period, it should be decided for each outage if it is caused by a design failure or if it is caused by a failure of a component due to its normal failure rate. Design failures are, for instance, operating components beyond their specification (overheating, overcurrent, overvoltage, etc. conditions). These design failures should be dealt with such that the operating condition is brought back to the normal operating condition of the component or that the component is replaced with a part suitable for the operating conditions. If the design failure is treated in this way, the evaluation may continue and this outage is not counted, assuming that there is a high probability that this design failure will not occur again. The same applies to outages due to any causes which can be mitigated by permanent changes to the operating conditions.

2.8.3.2 An assigned continuity of service level should not be subject to frequent change. A suitable method to assess the behaviour of a particular installation is to keep the records and calculate the average MTBO over the last five to eight failures of the equipment. This weighs the MTBO for continuity of service purposes to be more relevant to the next approach, rather than computing MTBO over the lifetime of the equipment. If continuity of service deteriorates, the assigned designation should be reduced until improvements in performance can be effected.

2.8.3.3 Additional detailed guidance. Several States have published continuity of service policies and procedures. The following documents may be consulted for additional guidance and details:

a) European Guidance Material on Continuity of Service Evaluation in Support of the Certification of ILS & MLS Ground Systems, EUR DOC 012; and

b) Instrument Landing System Continuity of Service Requirements and Procedures, Order 6750.57, United States Federal Aviation Administration.

2.8.4 The following configuration is an example of a redundant equipment arrangement that is likely to meet the objectives for integrity and continuity of service Levels 3 and 4. The localizer and glide path facilities each consist of two continuously operating transmitters, one connected to the antenna and the standby connected to a dummy load. With these transmitters is associated a monitor system performing the following functions:

a) confirming proper operation within the specified limits of the main transmitter and antenna system by means of majority voting among redundant monitors;

b) confirming operation of the standby equipment.

2.8.4.1 Whenever the monitor system rejects one of the equipments the facility continuity of service level will be reduced because the probability of cessation of signal consequent on failure of other equipment will be increased. This change of performance must be automatically indicated at remote locations.

2.8.4.2 An identical monitoring arrangement to the localizer is used for the glide path facility.

2.8.4.3 To reduce mutual interference between the main and standby transmitters any stray radiation from the latter is at least 50 dB below the carrier level of the main transmitter measured at the antenna system.

2.8.4.4 In the above example, the equipment would include provision to facilitate monitoring system checks at intervals specified by the manufacturer, consequent to the design analysis, to ensure attainment of the required integrity level. Such checks, which can be manual or automatic, provide the means to verify correct operation of the monitoring system including the control circuitry and changeover switching system. The advantage of adopting an automatic monitor integrity test is that no interruption to the operational service provided by the localizer or glide path is necessary. It is important when using this technique to ensure that the total duration of the check cycle is short enough not to exceed the total period specified in Chapter 3, 3.1.3.11.3 or 3.1.5.7.3.

2.8.4.5 Interruption of facility operation due to primary power failures is avoided by the provision of suitable standby supplies, such as batteries or "no-break" generators. Under these conditions, the facility should be capable of continuing in operation over the period when an aircraft may be in the critical stages of the approach. Therefore the standby supply should have adequate capacity to sustain service for at least two minutes.

2.8.4.6 Warnings of failures of critical parts of the system, such as the failure of the primary power supply, must be given at the designated control points.

2.8.4.7 In order to reduce failure of equipment that may be operating near its monitor tolerance limits, it is useful for the monitor system to include provision to generate a pre-alarm warning signal to the designated control point when the monitored parameters reach a limit equal to a value in the order of 75 per cent of the monitor alarm limit.

2.8.4.8 An equipment arrangement similar to that at 2.8.4, but with no transmitter redundancy, would normally be expected to achieve the objectives for continuity of service Level 2.

2.8.5 Guidance relating to localizer far field monitors is given below.

2.8.5.1 Far field monitors are provided to monitor course alignment but may also be used to monitor course sensitivity. A far field monitor operates independently from integral and near field monitors. Its primary purpose is to protect against the risk of erroneous setting-up of the localizer, or faults in the near field or integral monitors. In addition, the far field monitor system will enhance the ability of the combined monitor system to respond to the effects of physical modification of the radiating elements or variations in the ground reflection characteristics. Moreover, multipath effects and runway area disturbances not seen by near field and integral monitors, and some occurrences of radio interferences may be substantially monitored by using a far field monitoring system built around a suitable receiver(s), installed under the approach path.

2.8.5.2 A far field monitor is generally considered essential for Category III operations, while for Category II it is generally considered to be desirable. Also for Category I installations, a far field monitor has proved to be a valuable tool to supplement the conventional monitor system.

2.8.5.3 The signal received by the far field monitor will suffer short-term interference effects caused by aircraft movements on or in the vicinity of the runway and experience has shown that it is not practical to use the far field monitor as an executive monitor. When used as a passive monitor, means must be adopted to minimize such temporary interference effects and to reduce the occurrence of nuisance downgrade indications; some methods of achieving this are covered in

2.8.5.4. The response of the far field monitor to interference effects offers the possibility of indicating to the air traffic control point when temporary disturbance of the localizer signal is present. However, experience has shown that disturbances due to aircraft movements may be present along the runway, including the touchdown zone, and not always be observed at the far field monitor. It must not be assumed, therefore, that a far field monitor can provide comprehensive surveillance of aircraft movements on the runway.

2.8.5.3.1 Additional possible applications of the far field monitor are as follows:

a) it can be a useful maintenance aid to verify course and/or course deviation sensitivity in lieu of a portable far field monitor;

b) it may be used to provide a continuous recording of far field signal performance showing the quality of the far field signal and the extent of signal disturbance.

2.8.5.4 Possible methods of reducing the occurrence of nuisance downgrade indications include:

a) incorporation of a time delay within the system adjustable from 30 to 240 seconds;

b) the use of a validation technique to ensure that only indications not affected by transitory disturbances are transmitted to the control system;

c) use of low pass filtering.

2.8.5.5 A typical far field monitor consists of an antenna, VHF receiver and associated monitoring units which provide indications of DDM, modulation sum, and RF signal level. The receiving antenna is usually of a directional type to minimize unwanted interference and should be at the greatest height compatible with obstacle clearance limits. For course line monitoring, the antenna is usually positioned along the extended runway centre line. Where it is desired to also monitor displacement sensitivity, an additional receiver and monitor are installed with antenna suitably positioned to one side of the extended runway centre line. Some systems utilize a number of spatially separated antennas.

2.9 Localizer and glide path displacement sensitivities

2.9.1 Although certain localizer and glide path alignment and displacement sensitivities are specified in relation to the ILS reference datum, it is not intended to imply that measurement of these parameters must be made at this datum.

2.9.2 Localizer monitor system limits and adjustment and maintenance limits given in Chapter 3, 3.1.3.7 and 3.1.3.11 are stated as percentage changes of displacement sensitivity. This concept, which replaces specifications of angular width in earlier editions, has been introduced because the response of aircraft guidance systems is directly related to displacement sensitivity. It will be noted that angular width is inversely proportional to displacement sensitivity.

2.10 Siting of ILS markers

2.10.1 Considerations of interference between inner and middle markers, and the minimum operationally acceptable time interval between inner and middle marker light indications, will limit the maximum height marked by the inner marker to a height on the ILS glide path of the order of 37 m (120 ft) above threshold for markers sited within present tolerances in Annex 10. A study of the individual site will determine the maximum height which can be marked, noting that with a typical airborne marker receiver a separation period of the order of 3 seconds at an aircraft speed of 140 kt between middle and inner marker light indications is the minimum operationally acceptable time interval.

2.10.2 In the case of ILS installations serving closely spaced parallel runways, e.g. 500 m (1 650 ft) apart, special measures are needed to ensure satisfactory operation of the marker beacons. Some States have found it practical to employ a common outer marker for both ILS installations. However, special provisions, e.g. modified field patterns, are needed in the case of the middle markers if mutual interference is to be avoided, and especially in cases where the thresholds are displaced longitudinally from one another.

2.11 Use of DME as an alternative to ILS marker beacons

2.11.1 When DME is used as an alternative to ILS marker beacons, the DME should be located on the airport so that the zero range indication will be a point near the runway.

If the DME associated with ILS uses a zero range offset, this facility has to be excluded from RNAV solutions.

2.11.2 In order to reduce the triangulation error, the DME should be sited to ensure a small angle (e.g. less than 20 degrees) between the approach path and the direction to the DME at the points where the distance information is required.

2.11.3 The use of DME as an alternative to the middle marker beacon assumes a DME system accuracy of 0.37 km (0.2 NM) or better and a resolution of the airborne indication such as to allow this accuracy to be attained.

2.11.4 While it is not specifically required that DME be frequency paired with the localizer when it is used as an alternative for the outer marker, frequency pairing is preferred wherever DME is used with ILS to simplify pilot operation and to enable aircraft with two ILS receivers to use both receivers on the ILS channel.

2.11.5 When the DME is frequency paired with the localizer, the DME transponder identification should be obtained by the "associated" signal from the frequency-paired localizer.

2.12 The use of supplementary sources of orientation guidance in association with ILS

2.12.1 Aircraft beginning an ILS approach may be assisted by guidance information provided by other ground referenced facilities such as VORs, surveillance radar or, where these facilities cannot be provided, by a locator beacon.

2.12.2 When not provided by existing terminal or en-route facilities, a VOR, suitably sited, will provide efficient transition to the ILS. To achieve this purpose the VOR may be sited on the localizer course or at a position some distance from the localizer course provided that a radial will intersect the localizer course at an angle which will allow smooth transitions in the case of auto coupling. The distance between the VOR site and the desired point of interception must be recognized when determining the accuracy of the interception and the airspace available to provide for tracking errors.

2.12.3 Where it is impracticable to provide a suitably sited VOR, a compass locator or an NDB can assist transition to the ILS. The facility should be sited on the localizer course at a suitable distance from the threshold to provide for optimum transition.

2.13 The use of Facility Performance

Category I — ILS for automatic approaches and landings in visibility conditions permitting visual monitoring of the operation by the pilot

2.13.1 Facility Performance Category I — ILS installations of suitable quality can be used, in combination with aircraft flight control systems of types not relying solely on the guidance information derived from the ILS sensors, for automatic approaches and automatic landings in visibility conditions permitting visual monitoring of the operation by the pilot.

2.13.2 To assist aircraft operating agencies with the initial appraisal of the suitability of individual ILS installations for such operations, provider States are encouraged to promulgate:

a) the differences in any respect from Chapter 3, 3.1;

b) the extent of compliance with the provisions in Chapter 3, 3.1.3.4 and 3.1.5.4, regarding localizer and glide path beam structure; and

c) the height of the ILS reference datum above the threshold.

2.13.3 To avoid interference which might prevent the completion of an automatic approach and landing, it is necessary that local arrangements be made to protect, to the extent practicable, the ILS critical and sensitive areas.

2.14 ILS classification — supplementary ILS description method with objective to facilitate operational utilization

2.14.1 The classification system given below, in conjunction with the current facility performance categories, is intended to provide a more comprehensive method of describing an ILS.

2.14.2 The ILS classification is defined by using three characters as follows:

a) I, II or III: this character indicates conformance to Facility Performance Category in Chapter 3, 3.1.3 and 3.1.5.

b) A, B, C, T, D or E: this character defines the ILS points to which the localizer structure conforms to the course

structure given at Chapter 3, 3.1.3.4.2, except the letter T, which designates the runway threshold. The points are defined in Chapter 3, 3.1.1.

c) 1, 2, 3 or 4: this number indicates the level of integrity and continuity of service given in Table C-2.

Note.— In relation to specific ILS operations it is intended that the level of integrity and continuity of service would typically be associated as follows:

1) Level 2 is the performance objective for ILS equipment used to support low visibility operations when ILS guidance for position information in the landing phase is supplemented by visual cues. This level is a recommended objective for equipment supporting Category I operations;

2) Level 3 is the performance objective for ILS equipment used to support operations which place a high degree of reliance on ILS guidance for positioning through touchdown. This level is a required objective for equipment supporting Category II and IIIA operations; and

3) Level 4 is the performance objective for ILS equipment used to support operations which place a high degree of reliance on ILS guidance throughout touchdown and rollout. This level basically relates to the needs of the full range of Category III operations.

2.14.3 As an example, a Facility Performance Category II — ILS which meets the localizer course structure criteria appropriate to a Facility Performance Category III — ILS down to ILS point "D" and conforms to the integrity and continuity of service objectives of Level 3 would be described as class II/D/3.

2.14.4 ILS classes are appropriate only to the ground ILS element. Consideration of operational categories must also include additional factors such as operator capability, critical and sensitive area protection, procedural criteria and ancillary aids, such as transmissometers and lights.

Table C-2. Integrity and continuity of service objectives

Level	Localizer or glide path		
	Integrity	Continuity of service	MTBO (hours)
1		Not demonstrated, or less than required for Level 2	
2	$1 - 10^{-7}$ in any one landing	$1 - 4 \times 10^{-6}$ in any period of 15 seconds	1 000
3	$1 - 0.5 \times 10^{-9}$ in any one landing	$1 - 2 \times 10^{-6}$ in any period of 15 seconds	2 000
4	$1 - 0.5 \times 10^{-9}$ in any one landing	$1 - 2 \times 10^{-6}$ in any period of 30 seconds (localizer) 15 seconds (glide path)	4 000 (localizer) 2 000 (glide path)

Note.— For currently installed systems, in the event that the Level 2 integrity value is not available or cannot be readily calculated, it is necessary to at least perform a detailed analysis of the integrity to assure proper monitor fail-safe operation.

2.15 ILS carrier frequency and phase modulation

2.15.1 In addition to the desired 90 Hz and 150 Hz AM modulation of the ILS RF carriers, undesired frequency modulation (FM) and/or phase modulation (PM) may exist. This undesired modulation can cause centring errors in ILS receivers due to slope detection by ripple in the intermediate frequency (IF) filter pass-band.

2.15.2 For this to occur, the translated RF carrier frequency must fall on an IF frequency where the pass-band has a high slope. The slope converts the undesired 90 Hz and 150 Hz frequency changes to AM of the same frequencies. Similarly, any difference in FM deviation between the undesired 90 Hz and 150 Hz components is converted to DDM, which in turn produces an offset in the receiver. The mechanism is identical for PM as for FM, since PM causes a change in frequency equal to the change in phase (radians) multiplied by the modulating frequency.

2.15.3 The effect of the undesired FM and/or PM is summed by vector addition to the desired AM. The detected FM is either in phase or anti-phase with the AM according to whether the pass-band slope at the carrier's IF is positive or negative. The detected PM is in quadrature with the AM, and may also be positive or negative according to the pass-band slope.

2.15.4 Undesired FM and/or PM from frequencies other than 90 Hz and 150 Hz, but which pass through the 90 Hz and 150 Hz tone filters of the receiver, can also cause changes to the desired 90 Hz and 150 Hz AM modulation of the ILS RF carrier, resulting in a DDM offset error in the receiver. Thus, it is essential that when measuring undesired FM and PM levels, audio band-pass filters with a pass-band at least as wide as that of the tone filters of ILS receivers be used. These filters are typically inserted in commercial modulation meter test equipment between the demodulation and metering circuits, to ensure that only spectral components of interest to ILS applications are measured. To standardize such measurements, the filter characteristics are recommended as shown below:

Frequency (Hz)	*90 Hz band-pass filter attenuation, dB*	*150 Hz band-pass filter attenuation, dB*
≤45	–10	–16
85	–0.5	(no specification)
90	0	–14
95	–0.5	(no specification)
142	(no specification)	–0.5
150	–14	0
158	(no specification)	–0.5
≥300	–16	–10

2.15.5 The preferred maximum limits, as shown below, are derived from ILS receiver centring error limits specified in EUROCAE documents ED-46B and ED-47B, based on the worst-case-to-date observed correlation between undesired modulation levels and centring errors:

Facility type	*90 Hz peak deviation, FM Hz/PM radians (Note 1)*	*150 Hz peak deviation, FM Hz/PM radians (Note 2)*	*Deviation difference, Hz (Note 3)*
Localizer, Cat I	135/1.5	135/0.9	45
Localizer, Cat II	60/0.66	60/0.4	20
Localizer, Cat III	45/0.5	45/0.3	15
Glide path, Cat I	150/1.66	150/1.0	50
Glide path, Cat II or III	90/1.0	90/0.6	30

Note 1.— This column applies to the peak frequency or phase deviation as measured with the 90 Hz tone filter specified in 2.15.4.

Note 2.— This column applies to the peak frequency or phase deviation as measured with the 150 Hz tone filter specified in 2.15.4.

Note 3.— This column applies to the difference in peak frequency deviation between the separate measurements of the undesired 90 Hz FM (or equivalent PM) and the 150 Hz FM (or equivalent PM) obtained with the filters specified in the table in 2.15.4. The equivalent deviation for 90 Hz and 150 Hz measured PM values is calculated by multiplying each peak PM measurement in radians by its corresponding modulating frequency in Hz.

3. Material concerning VOR/DVOR

3.1 Guidance relating to VOR/DVOR equivalent isotropically radiated power (EIRP) and coverage

Note.— Unless specifically mentioned, all guidance material provided below applies to VOR and DVOR signals.

3.1.1 The field strength specified at Chapter 3, 3.3.4.2, is based on the following consideration:

Airborne receiver sensitivity	−117 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+7 dB
Power required at antenna	−110 dBW

The power required of minus 110 dBW is obtained at 118 MHz with a power density of minus 107 dBW/m2; minus 107 dBW/m2 is equivalent to 90 microvolts per metre, i.e. plus 39 dB referenced to 1 microvolt per metre.

Note.— The power density for the case of an isotropic antenna may be computed in the following manner:

where

Pd = power density in dBW/m2;

Pa = power at receiving point in dBW;

λ= wavelength in metres.

3.1.2 The necessary EIRP to achieve a field strength of 90 microvolts per metre (minus 107 dBW/m2) is given in

Figure C-13. The field strength is directly proportional to the antenna elevation pattern. The actual radiation patterns of the antennas depend on a number of factors such as height of the antenna phase centre above ground level (AGL), surface roughness, terrain form and conductivity of ground and counterpoise. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, a conservative value has been provided. Whenever more precise system data are available, a more precise estimation of range is permissible. Further guidance may be found in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

3.2 Guidance in respect of siting of VOR

3.2.1 VOR is susceptible to multipath interference from surrounding terrain, buildings, trees and power lines. The effect of this should therefore be considered when selecting a site for a new facility, and when considering the acceptability of proposed developments in the vicinity of established sites. Doppler VOR is more resistant to multipath interference than conventional VOR and may be used to provide acceptable performance on more challenging multipath sites.

Note.— Guidance on siting of VOR is given in documents EUROCAE ED-52 (including Amendment No. 1), United States Federal Aviation Administration Order 6820.10 and ICAO EUR DOC 015 (First Edition).

3.2.2 The impact of wind farm developments on VOR is an increasing problem in many States due to the growth of interest in alternative energy sources. The impact of wind farms on VOR is difficult to assess for several reasons, including:

a) the cumulative effect of a group of turbines may be unacceptable even though the effect of each of the turbines may be acceptable individually;

b) worst-case errors may be experienced when the turbine blades are stationary (due to either high or low wind speeds). The actual error is a function of the orientation of the turbine and position of the turbine blades when stationary;

c) worst-case errors are likely to be experienced at the limit of coverage and at low elevation angles; and

d) it is unlikely that the worst-case errors can be confirmed by flight inspections due to the factors listed above.

3.2.3 Computer simulations can be used to assess the effect of wind farms on VOR using worst-case assumptions, as outlined above.

3.3 [Reserved]

3.4 Criteria for geographical separation of VOR type facilities

3.4.1 In using the figures listed in Table C-3, it must be noted that these are derived from the agreed formulae in respect of specific altitudes. In application of the figures, regional meetings would only afford protection to the extent of the operationally required altitude and distance and, by use of the formulae, criteria can be calculated for any distance or altitude.

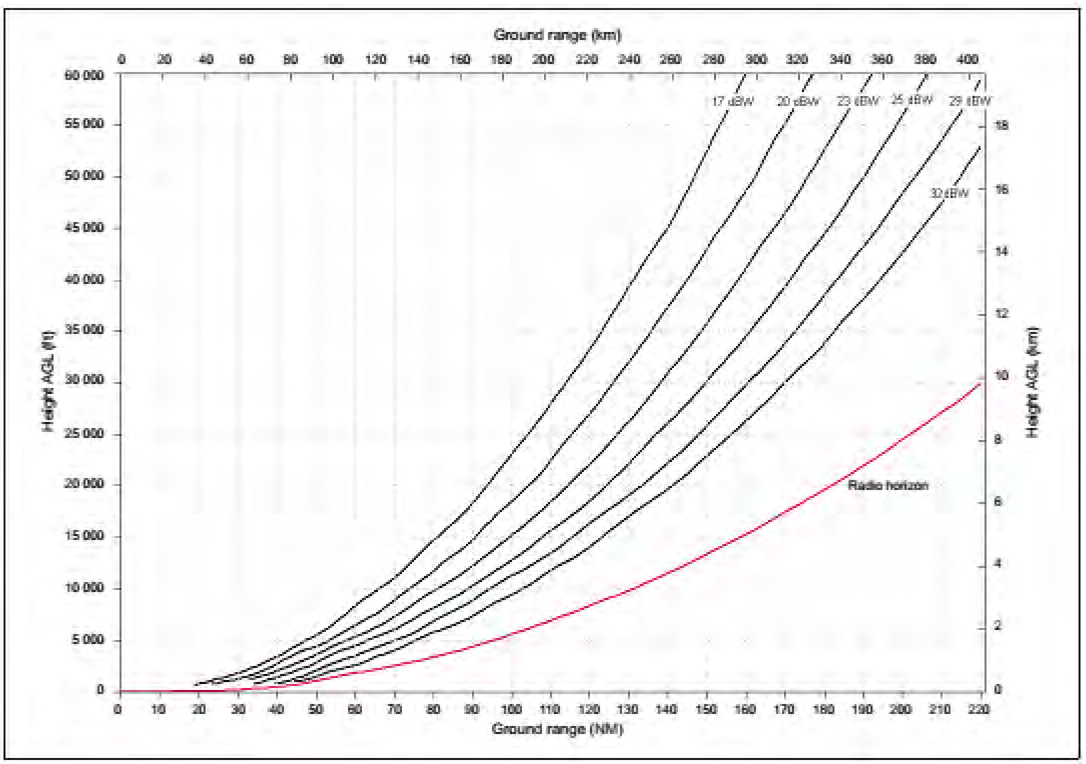


Figure C-13. Necessary EIRP to achieve a field strength of 90 microvolts per metre (–107 dBW/m2) as a function of height aboveand distance from the VOR/DVOR

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.

Note 2.— The guidance provided assumes that the VOR/DVOR counterpoise height above ground level (AGL) that defines the antenna pattern is at 3 m (10 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.

Note 3.— The transmitted power required to achieve an EIRP value as shown depends upon transmitting antenna gain and cable losses. As an example, an EIRP of 25 dBW can be achieved by a VOR with an output power of 100 W, a cable loss of 1 dB and an antenna gain of 6 dBi.

3.4.2 The figures listed are calculated on the assumption that the effective adjacent channel rejection of the airborne receiver is better than 60 dB down at the next assignable channel.

3.4.3 The calculations are based on the assumption that the protection against interference afforded to the wanted signal from the unwanted signal is 20 dB, corresponding to a bearing error of less than 1 degree due to the unwanted signal.

3.4.4 It is recognized that, in the case of adjacent channel operation, there isa small region in the vicinity of a VOR facility, in which interference may be caused to an aircraft using another VOR facility. However, the width of this region is so small that the duration of the interference would be negligible and, in any case, it is probable that the aircraft would change its usage from one facility to the other.

3.4.5 The agreed formulae for calculating the geographical separations are as follows (nautical miles may be substituted for kilometres):

A — minimum geographical separation (co-channel):

either $2\,D_1 + \frac{20-K}{S}$ km

where $D_1 > D_2 + \frac{K}{S}$

or $2\,D_2 + \frac{20+K}{S}$ km

where $D_1 < D_2 + \frac{K}{S}$

B — geographical separation (adjacent channel):

collocation case

$$< \frac{40 - K}{S}$$

non-collocated case

$$> 2D_1 - \frac{40 + K}{S}\ km$$

$$\text{where } D_1 > D_2 + \frac{K}{S}$$

or $$2D_2 - \frac{40 - K}{S}\ km$$

$$\text{where } D_1 < D_2 + \frac{K}{S}$$

C – geographical separation (adjacent channel)
(receivers designed for 100 kHz channel spacing in a 50 kHz channel spacing environment)

If receivers having an effective adjacent channel rejection of no better than 26 dB are used(e.g. a 100 kHz receiver used in a50 kHz environment), a figure of 6 should be substituted for the figure of 40 in the above adjacent channel formulae. In this instance, the geographical collocation formula should not be used as the protection afforded may be marginal.

This leads to the following formula:

$$> 2D_1 + \frac{6 + K}{S}\ km$$

$$\text{where } D_1 > D_2 + \frac{K}{S}$$

or $$2D_2 - \frac{6 - K}{S}\ km$$

$$\text{where } D_1 < D_2 + \frac{K}{S}$$

Table C-3. Values of geographical separation distances for co-channel operation

		VOR facilities of equal effective radiated power		VOR facilities which differ in effective radiated power by 6 dB				VOR facilities which differ in effective radiated power by 12 dB			
		Minimum geographical separation between facilities is $2D_1 + \frac{20}{S}$ *if* $D_1 > D_2$ or $2D_2 + \frac{20}{S}$ *if* $D_2 > D_1$		Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ *if* $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ *if* $D_1 < D_2 + \frac{K}{S}$				Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ *if* $D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ *if* $D_1 < D_2 + \frac{K}{S}$			
Altitude m (ft)	S dB/km (NM)	K dB	$\frac{20}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)
1	2	3	4	5	6	7	8	9	10	11	12
1 200 (4 000)	0.32 (0.60)	0	61 (33)	6	19 (10)	43 (23)	80 (43)	12	37 (20)	24 (13)	98 (53)
3 000 (10 000)	0.23 (0.43)	0	87 (47)	6	26 (14)	61 (33)	113 (61)	12	52 (28)	35 (19)	137 (74)
4 500 (15 000)	0.18 (0.34)	0	109 (59)	6	33 (18)	76 (41)	143 (77)	12	67 (36)	44 (24)	174 (94)
6 000 (20 000)	0.15 (0.29)	0	128 (69)	6	39 (21)	89 (48)	167 (90)	12	78 (42)	52 (28)	206 (110)
7 500 (25 000)	0.13 (0.25)	0	148 (80)	6	44 (24)	104 (56)	193 (104)	12	89 (48)	59 (32)	237 (128)
9 000 (30 000)	0.12 (0.23)	0	161 (87)	6	48 (26)	113 (61)	209 (113)	12	96 (52)	65 (35)	258 (139)
12 000 (40 000)	0.10 (0.19)	0	195 (105)	6	59 (32)	135 (73)	254 (137)	12	119 (64)	78 (42)	311 (168)
18 000 (60 000)	0.09 (0.17)	0	219 (118)	6	65 (35)	154 (83)	284 (153)	12	130 (70)	87 (47)	348 (188)

Note.— S, K and the sign of K are defined in 3.4.5.

In the above formulae:

D1, D2 = service distances required of the two facilities (km).

K = the ratio (dB) by which the effective radiated power of the facility providing D1coverage exceeds that of the facility providing D2coverage.

Note.– If the facility providing D2is of higher effective radiated power, then "K" will have a negative value.

S = slope of the curve showing field strength against distance for constant altitude (dB/km).

3.4.6 The figures listed in Table C-3 are based on providing an environment within which the airborne receivers can operate correctly.

3.4.6.1 In order to protect VOR receivers designed for 50 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

3.4.6.2 In order to protect VOR receivers designed for 100 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

3.4.7 Use of the figures given in 3.4.6 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. The assumptions include that the change of field strength with distance (Factor "S") at various altitudes of reception is only valid for angles of elevation at the VOR of up to about 5 degrees, but above the radio line of sight. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves.

3.4.8 The deployment of 50 kHz channel spacing requires conformity with Chapter 3, 3.3.2.2 and 3.3.5.7 and Annex 10, Volume V, Chapter 4, 4.2.4. Where, due to special circumstances it is essential during the initial conversion period from 100 kHz channel spacing to 50 kHz channel spacing to take account of nearby VOR facilities that do not conform with Chapter 3, 3.3.2.2 and 3.3.5.7 and Annex 10, Volume V, Chapter 4, 4.2.4, greater geographical separation between these and the new facilities utilizing 50 kHz channel spacing will be required to ensure a bearing error of less than one degree due to the unwanted signal. On the assumption that the sideband levels of the 9 960 Hz harmonic of the radiated signal of such facilities do not exceed the following levels:

9 960 Hz 0	dB reference
2nd harmonic	–20 dB
3rd harmonic	–30 dB
4th harmonic and above	–40 dB

the separation formulae at 3.4.5 should be applied as follows:

a) where only receivers designed for 50 kHz channel spacing need to be protected, the value of 40 should be replaced by 20 in the formula at B — non-collocated case;

b) where it is necessary to protect receivers designed for 100 kHz channel spacing, the co-channel formula at A — co channel case, should be applied for the range of altitudes for which protection is required.

3.4.9 When DME/N facilities and VOR facilities are intended to operate in association with each other, as outlined in Chapter 3, 3.5.3.3.4, and have a common service volume, both the co-channel and adjacent channel geographical separation distances required by the DME are satisfied by the separation distances of the VOR as computed in this section, provided the distance between VOR and DME does not exceed 600 m (2 000 ft). A potential interference situation may also occur with the implementation of DME "Y" channels since interference between two DME ground stations spaced 63 MHz apart could occur when transmitting and receiving on the same frequency (e.g. transmissions from channel 17 Y could interfere with reception on channels 80 X and 80 Y). To obviate any ground receiver desensitization due to this interference, a minimum ground separation distance of 18.5 km (10 NM) between facilities is necessary.

3.5 Criteria for geographical separation of VOR/ILS facilities

3.5.1 In using the figures of 3.5.3.1 and 3.5.3.2, it is to be borne in mind that the following assumptions have been made:

a) that the localizer receiver characteristic is as shown in 2.6.2, and the VOR receiver characteristic as shown in 3.4.2;

b) that the protection ratio for the ILS system and the VOR system is 20 dB as in 2.6.4 and 3.4.3, respectively;

c) that the protection point for ILS is at a service distance of 46.25 km (25 NM) measured along the line of use, and at an altitude of 1 900 m (6 250 ft).

Note.— With the advent of highly directional ILS localizer antenna arrays, the most critical protection point will not be along the extended runway centre line. Directive antennas result in critical protection points at maximum distance, either plus or minus 10 degrees or plus or minus 35 degrees off the runway centre line. Protection of these points should be examined during the frequency assignment process.

3.5.2 Although international VOR and ILS facilities will not appear on the same frequency, it may occur that an international VOR facility may share temporarily the same frequency as, and on a comparable basis with, a national ILS facility. For this reason, guidance is given as to the geographical separation required not only for a VOR and an ILS facility separated by 50 kHz or 100 kHz, but also for co-channel usage.

3.5.3 Because of the differing characteristics of use of the two equipments, the criteria for minimum geographical separation of VOR/ILS to avoid harmful interference are stated separately for each facility where relevant.

3.5.3.1 Co-channel case

a) Protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 148 km (80 NM)

from the ILS protection point.

b) On the assumption that a VOR having an ERP of 17 dBW (50 W) is to be protected to a service distance of 46.25 km (25 NM) and an altitude of 3 000 m (10 000 ft), protection of the VOR system requires that the ILS be at least 148 km (80 NM) from the VOR.

c) If protection of the VOR is required to, say, 92.5 km (50 NM) and 6 000 m (20 000 ft), the ILS is to be at least 250 km (135 NM) from the VOR.

3.5.3.2 Adjacent channel case. Protection of the VOR system is effectively obtained without geographical separation of the facilities. However, in the case of:

a) a localizer receiver designed for 100 kHz channel spacing and used in an area where navaid assignments are spaced at 100 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 9.3 km (5 NM) from the ILS protection point;

b) a localizer receiver designed for 100 kHz channel spacing and used in an area where assignments are spaced at 50 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 79.6 km (43 NM) from the ILS protection point.

3.5.4 Use of the figures given in 3.5.3 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves.

3.5.5 Protection of the ILS system from VOR interference is necessary where a VOR facility is located near an ILS approach path. In such circumstances, to avoid disturbance of the ILS receiver output due to possible cross modulation effects, suitable frequency separation between the ILS and VOR channel frequencies should be used. The frequency separation will be dependent upon the ratio of the VOR and ILS field densities, and the characteristics of the airborne installation.

3.6 Receiving function

3.6.1 *Sensitivity*. After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function should be such as to provide on a high percentage of occasions theaccuracy of output specified in 3.6.2, with a signal having a field strength of 90 microvolts per metre or minus 107 dBW/m2.

3.6.2 *Accuracy*. The error contribution of the airborne installation should not exceed plus or minus 3 degrees with a 95 per cent probability.

Note 1.— The assessment of the error contribution of the receiver will need to take account of:

1) the tolerance of the modulation components of the ground VOR facility as defined in Chapter 3, 3.3.5;

2) variation in signal level and carrier frequency of the ground VOR facility;

3) the effects of unwanted VOR and ILS signals.

Note 2.— The airborne VOR installation is not considered to include any special elements which may be provided for the processing of VOR information in the aircraft and which may introduce errors of their own (e.g. radio magnetic indicator (RMI).).

3.6.3 Flag alarm operation. Ideally, the flag alarm should warn a pilot of any unacceptable malfunctioning conditions which might arise within either the ground or airborne equipments. The extent to which such an ideal might be satisfied is specified below.

3.6.3.1 The flag alarm movement is actuated by the sum of two currents which are derived from the 30 Hz and 9 960 Hz elements of the VOR bearing component signal and, therefore, the removal of these elements from the radiated carrier results in the appearance of the flags. Since the VOR ground monitor interrupts the bearing components when any unacceptable condition prevails on the ground, there will be an immediate indication within an aircraft when the system is unusable.

3.6.3.2 The flag alarm movement current is also dependent upon the AGC characteristics of the airborne equipment and any subsequent gain following the receiver's second detector. Thus, if with a correctly adjusted airborne receiver the flagis just out of view when receiving a VOR signal conforming to the modulation characteristics specified in Chapter 3, 3.3.5, the flags will again become visible in the event of a decrease in the receiver's overall gain characteristics.

Note.— Certain types of receivers employ warning indications other than mechanical flags to perform the functions described here.

3.6.4 VOR receiver susceptibility to VOR and localizer signals

3.6.4.1 The receiver design should provide correct operation in the following environment:

a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB (during bench testing of the receiver, in this first adjacent channel case, the undesired signal is varied over the frequency range of the combined ground station (plus or minus 9 kHz) and receiver frequency tolerance);

c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;

d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

Note 1.— It is recognized that not all receivers currently meet requirement b); however, all future equipments are designed to meet this requirement.

Note 2.— In some States, a smaller ground station tolerance is used.

3.6.5 Immunity performance of VOR receiving systems to interference from VHF FM broadcast signals

3.6.5.1 With reference to Chapter 3, 3.3.8, the immunity performance defined therein must be measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results and to facilitate their subsequent approval. Additional information can be found in ITU Recommendation ITU-R SM.1140, Test procedures for measuring aeronautical receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–118 MHz.

Note.— Receiver test procedures are also given in the VOR receiver MOPS (RTCA DO-196, and EUROCAE ED-22B).

3.6.5.2 Commonly agreed formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Chapter 3,3.3.8. The formulae provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R IS.1009-1, Compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–137 MHz.

3.7 VOR system accuracy

Note.— Guidance material on the determination of VOR system performance values is also contained in Annex 11, Attachment A.

3.7.1 *Purpose*. The following guidance material is intended to assist in the use of VOR systems. It is not intended to represent lateral separation standards or minimum obstacle clearances, although it may of course provide a starting point in their determination. The setting of separation standards or minimum obstacle clearances will necessarily take account of many factors not covered by the following material.

3.7.1.1 There is, however, a need to indicate a system use accuracy figure for the guidance of States planning VOR systems.

3.7.2 *Explanation of terms*. The following terms are used with the meanings indicated:

a) *VOR radial signal error.* The difference between the nominal magnetic bearing to a point of measurement from the VOR ground station and the bearing indicated by the VOR signal at that same point. The VOR radial signal error is made up of certain stable elements, such as course displacement error and most site and terrain effect errors, and certain random variable errors. The VOR radial signal error is associated with the ground station only and excludes other error factors, such as airborne equipment errors and pilotage element.

b) *VOR radial variability error*. That part of the VOR radial signal error which can be expected to vary about the essentially constant remainder. The radial variability error is the sum of the variable errors.

c) *VOR radial displacement error*. That part of the VOR radial signal error which is stable and may be considered as fixed for long periods of time.

d) *VOR airborne equipment error*. That error attributable to the inability of the equipment in the aircraft to translate correctly the bearing information contained in the radial signal. This error includes the contributions of the airborne receiver and the instrumentation used to present the information to the pilot.

e) *VOR aggregate error*. The difference between the magnetic bearing to a point of measurement from the VOR ground station and the bearing indicated by airborne VOR equipment of stated accuracy. More simply put, this is the error in the information presented to the pilot, taking into account not only the ground station and propagation path errors, but also the error contributed by the airborne VOR receiver and its instrumentation. The entire VOR radial signal error, both fixed and variable, is used.

f) *VOR pilotage element*. The error in the use of VOR navigation attributable to the fact that the pilot cannot or does not keep the aircraft precisely at the centre of the VOR radial or bearing indicated by the equipment.

g) *VOR system use error*. The square root of the sum of the squares (RSS) of VOR aggregate error and the pilotage element. This combination may be used to determine the probability of an aircraft remaining within specified limits when using VOR.

3.7.3 Calculation of VOR system use accuracy

3.7.3.1 The VOR system use accuracy is derived by considering the following error elements:

a) *VOR radial signal error(Eg).* This element consists of the radial displacement error and the radial variability error. It is determined by considering such factors as fixed radial displacement, monitoring, polarization effects, terrain effects and environment changes.

b) *VOR airborne equipment error(Ea*). This element embraces all factors in the airborne VOR system which introduces errors (errors resulting from the use of compass information in some VOR displays are not included).

c) *VOR pilotage element(Ep*). The value taken for this element is that used in PANS-OPS (Doc 8168) for pilot tolerance.

Note.— A measurement error also exists, but in a generalized discussion of errors may be considered to be absorbed in the other error values.

3.7.3.2 Since the errors in a), b), and c), when considered on a system basis (not any one radial) are independent variables, they may be combined on a root-sum-square method(RSS) when the same probability level is given to each element. For the purpose of this material, each element is considered to have a 95 per cent probability.

Therefore, the following formulae are derived:

VOR aggregate error = $\sqrt{Eg^2 + Ea^2}$

VOR system use error = $\sqrt{Eg^2 + Ea^2 + Ep^2}$

3.7.3.3 The following examples will derive only the VOR system use error but calculations can also be made to determine VOR aggregate error, if desired. By use of these formulae, the impact on the system of improvement or degradation of one of more error elements can be assessed.

Note.— All figures for VOR radial signal error are related to radials for which no restrictions are published.

3.7.3.4 Subject to the qualifications indicated in 3.7.1, it is considered that a VOR system use accuracy of plus or minus 5 degrees on a 95 per cent probability basis is a suitable figure for use by States planning the application of the VOR system (see, however, 3.7.3.5). This figure corresponds to the following component errors:

VOR radial signal error:

plus or minus 3° (95 per cent probability), a value readily achieved in practice.

VOR airborne equipment error:

plus or minus 3°(95 per cent probability), system characteristics value (see 3.6.2).

VOR pilotage element:

plus or minus 2.5°(95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

3.7.3.5 While the figure of plus or minus 5 degrees on a 95 per cent probability basis is a useful figure based on broad practical experience and used by many States, it must be noted that this figure may be achieved only if the error elements which make it up remain within certain tolerances. It is clear that, if the errors attributable to the VOR system elements are larger than the amounts noted, the resulting VOR system use error will also be larger. Conversely, where any or all of the VOR system error elements are smaller than those used in the above computation, the resulting VOR system use error will also be smaller.

3.7.3.6 The following examples, also derived from practical experience, provide additional planning guidance for States:

A.— VOR radial signal error:

plus or minus 3.5°(95 per cent probability), used by some States as the total ground system error.

VOR airborne equipment error:

plus or minus 4.2°(95 per cent probability), recognized in some States as the minimum performance figure for some

classes of operations.

VOR pilotage element:

plus or minus 2.5°(95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

Calculated VOR system use accuracy:

plus or minus 6°(95 per cent probability).

B. — VOR radial signal error:

plus or minus 1.7°(95 per cent probability), based on extensive flight measurements conducted in one State on a large number of VORs.

VOR airborne equipment error:

plus or minus 2.7°(95 per cent probability), achieved in many airline operations.

VOR pilotage element:

plus or minus 2.5°(95 per cent probability), in accordance with PANS-OPS (see also 3.7.3.8).

Calculated VOR system use accuracy:

plus or minus 4°(95 per cent probability).

3.7.3.7 More realistic application of the VOR system may be achieved by assessing the errors as they actually exist in particular circumstances, rather than by using all-embracing generalizations which may give unduly optimistic or pessimistic results. In individual applications, it may be possible to utilize a system use accuracy value less than plus or minus 5 degrees if one or more of the error elements are smaller than the values used to compute the plus or minus 5 degrees. Conversely, a system use accuracy value greater than plus or minus 5 degrees will be necessary where it is known that radials are of poor quality or significant site errors exist, or for other reasons. However, in addition to this advice a warning is also essential regarding the use of lower values of individual elements in the system (for example, the radial signal error) on the assumption that an overall improvement in system accuracy will occur. There is considerable evidence that this may not be the case in some circumstances and that lower system accuracy values should not be applied without other confirmation (e.g. by radar observation) that an actual improvement in overall performance is being achieved.

3.7.3.8 It is to be noted that in angular systems such as the VOR, the pilotage element error, expressed in angular terms, will be greater as the aircraft nears the point source. Thus, while ground system and airborne error contributions, expressed in angular terms, are for all practical purposes constant at all ranges, it is necessary when considering the overall system use accuracy figures to take into account the larger pilotage element error occurring when the aircraft is near the VOR. However, these larger pilotage element errors do not result in large lateral deviations from course when near the facility.

3.8 Changeover points for VORs

Guidance on the establishment of changeover points on ATS routes defined by VORs is contained in Annex 11, Attachment A.

4. Precision approach radar system

Figures C-14 to C-18 illustrate certain of the Standards contained in Chapter 3, 3.2.

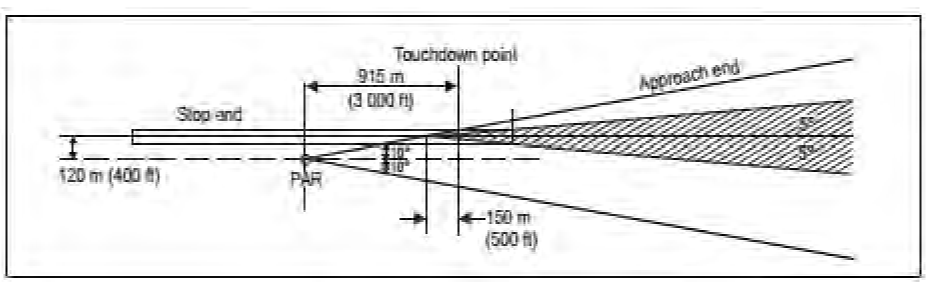


Figure C-14. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

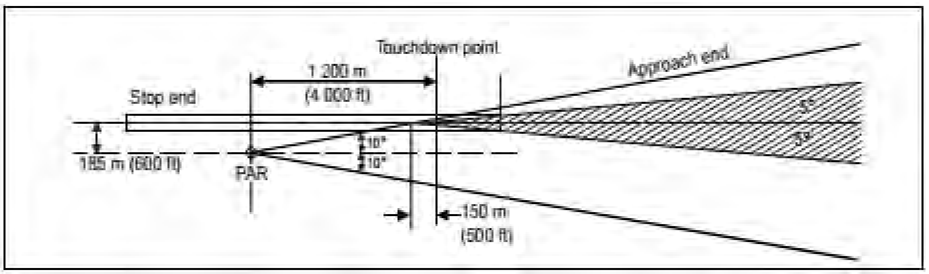


Figure C-15. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan plus or minus 10 degrees on QDR of runway

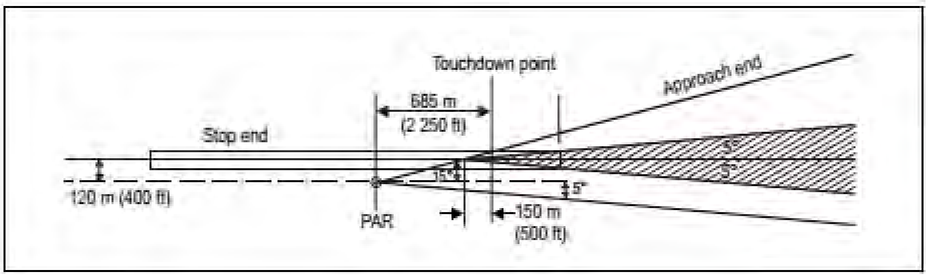


Figure C-16. Minimum set-back of PAR with respect to touchdown for offset of 120 m (400 ft) when aligned to scan 5 degrees and 15 degrees on QDR of runway

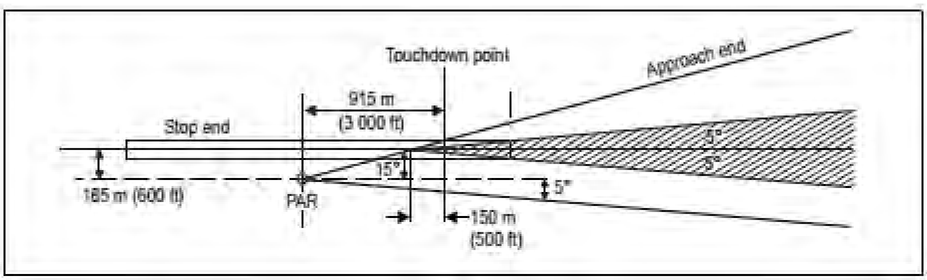


Figure C-17. Minimum set-back of PAR with respect to touchdown for offset of 185 m (600 ft) when aligned to scan 5 degrees and 15 degrees on QDR of runway

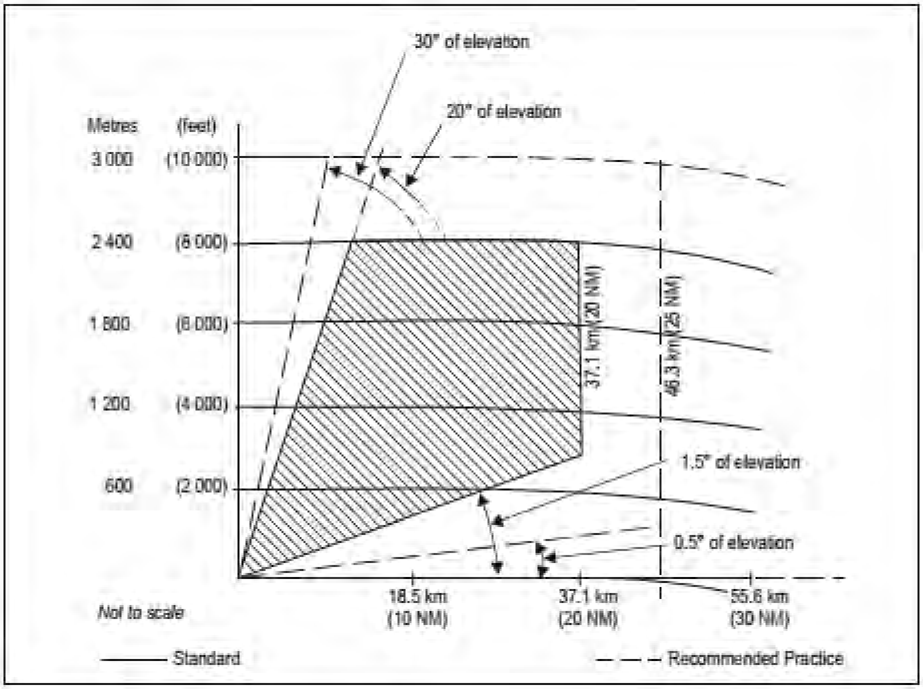


Figure C-18. SRE of precision approach radar system — vertical coverage on a 15 m^2 echoing area aircraft

5. Specification for 75 MHz marker beacons (en-route)

5.1 Marker beacon antenna arrays

5.1.1 *General*. The following describes types of marker antenna arrays that are frequently used in current practice. These types are the simplest forms meeting normal requirements; in special cases, arrays having a better performance (see Note to 5.1.4) may be required.

5.1.2 Z marker beacons

a) *Radiating system*. A radiating system consisting of two horizontal dipole arrays crossed at right angles, each comprising two co-linear half-wave radiating elements with centres spaced approximately a half wavelength apart and mounted one-quarter wavelength above the counterpoise. The currents in the dipoles and their respective elements are adjusted so that:

1) the current in one set of dipole arrays relative to that in the other set is equal but differs in time phase by 90 degrees;

2) the currents in the radiating elements of a particular dipole array are equal and in time phase.

b) *Counterpoise.* A square counterpoise with minimum dimensions of 9 m × 9 m, usually elevated about 1.8 m (6 ft) above the ground and, if fabricated from wire mesh, with the dimension of the mesh not exceeding 7.5 cm × 7.5 cm.

5.1.3 Fan marker beacons for use only at low altitudes (low power fan marker beacons).A radiating system capable of providing the field strengths indicated in Chapter 3, 3.1.7.3.2.

5.1.4 Fan marker beacons for general use (high power fan marker beacons)

a) *Radiating system*. A radiating system consisting of four horizontal co-linear half-wave (approximate) radiating elements mounted approximately one-quarter wavelength above the counterpoise. The current in each of the antenna elements should be in phase and should have a current ratio of 1:3:3:1.

Note.— The current distribution between elements and their height above the counterpoise may be altered to provide patterns for specific operational requirements. Improved vertical patterns for certain operational needs may be achieved by adjusting the height of the dipole arrays above the counterpoise to a value of one-quarter wavelength or greater, but less than a half wavelength.

b) *Counterpoise*. A rectangular counterpoise with minimum dimensions of 6 m × 12 m, usually elevated about 1.8 m (6 ft) above the ground and, if fabricated from wire mesh, with the dimension of the mesh not exceeding 7.5 cm × 7.5 cm.

5.2 Identification coding for fan marker beacons associated with a four-course radio range

5.2.1 Fan marker beacons located on the legs of a four-course radio range do not normally require an identification signal relating to a particular geographic location, but only a signal that will indicate the leg with which they are associated.

5.2.2 In the case of a four-course radio range having not more than one marker on any leg, it is current practice to identify a marker by a single dash if on the leg bearing true north or nearest to north in a clockwise direction (east), and toidentify a marker on other legs by two, three or four dashes according to whether the leg with which it is associated is the second, third or fourth leg from north in a clockwise direction. Where more than one fan marker beacon is associated with one leg of a four-course radio range, the marker nearest to the station is identified by dashes only, the next nearest by two dots preceding the dashes, and the third by three dots preceding the dashes, and so on.

Note.— In certain special circumstances, the above coding system may lead to ambiguities due to two markers associated with the legs of different but overlapping radio ranges being geographically close together. In such cases, it is desirable to use a distinctive identification coding with one of the marker beacons.

6. Material concerning NDB

6.1 Guidance material on NDB field strength requirements in latitudes between 30°N and 30°S

6.1.1 In order to obtain a satisfactory service within the rated coverage of an NDB located in latitudes between 30°N and 30°S, a minimum value of field strength of 120 microvolts per metre would be required, except where practical experience in the operation of NDBs over several years has revealed that a minimum field strength of 70 microvolts per metre would be adequate to meet all the operational needs. In some specific areas, field strength values considerably in excess of 120 microvolts per metre would be required. Such areas are:

a) Indonesia and Papua New Guinea, Myanmar, Malay Peninsula, Thailand, Lao People's Democratic Republic, Democratic Kampuchea, Viet Nam and Northern Australia;

b) Caribbean and northern parts of South America;

c) Central and South Central Africa.

6.1.2 The field strength of 120 microvolts per metre is based upon practical experience to date and is a compromise between what is technically desirable and what it is economically possible to provide.

6.2 Guidance material on meaning and application of rated and effective coverage

6.2.1 Rated coverage

6.2.1.1 The rated coverage as defined in Chapter 3, 3.4.1, is a means of designating actual NDB performance, in a measurable way, which is dependent on the frequency, the radiated power, and the conductivity of the path between the NDB and a point on the boundary where the minimum value of field strength is specified.

6.2.1.2 The rated coverage has been found to be a useful means of facilitating regional planning and, in some instances, may be related to effective coverage.

6.2.1.3 The application of rated coverage to frequency planning is governed by the following criteria:

6.2.1.3.1 Frequencies should be deployed having regard to the rated coverage of the NDBs concerned, so that the ratio of the signal strength of any NDB at the boundary of its rated coverage to the total field strength due to co-channel stations and adjacent channel stations (with an appropriate allowance for the selectivity characteristics of a typical airborne receiver) is not less than 15 dB by day.

6.2.1.3.2 The figures set forth in Attachment B to Volume V of Annex 10 should be applied, as appropriate, in determining the allowance to be made for the attenuation of adjacent channel signals.

6.2.1.4 It follows from the application of rated coverage to frequency deployment planning that, unless otherwise specified, protection against harmful interference can only be ensured within the rated coverage of an NDB and, then, only if the radiated power of the NDBs is adjusted to provide within reasonably close limits the field strength required at the limit of the rated coverage. In areas where the density of NDBs is high, any NDB providing a signal at the limit of its rated coverage materially in excess of that agreed in the region concerned will give rise, in general, to harmful interference within the rated coverages of cochannel or adjacent channel NDBs in the area concerned, and will limit the number of NDBs which can be installed in the region within the available spectrum. It is important, therefore, that increases in radiated power beyond that necessary to provide the rated coverage, particularly at night when sky wave propagation may give rise to interference over long distances, should not be made without coordination with the authorities of the other stations likely to be affected (see Chapter 3, 3.4.3).

6.2.1.5 Frequency planning is considerably facilitated if a common value of minimum field strength within the desired coverage is used.

6.2.1.6 Extensive experience has shown that in relatively low noise level areas, such as Europe, the figure of 70 microvolts per metre is satisfactory.

6.2.1.6.1 Experience has also shown that the figure of 120 microvolts per metre is generally satisfactory for higher noise level areas but will be inadequate in areas of very high noise. In such areas, the information given in 6.3 may be used for general guidance.

6.2.2 Relationship to effective coverage

6.2.2.1 *Rated coverage may have a close correlation to effective coverage under the following conditions*:

a) when the minimum field strength within the rated coverage is such that, for most of the time, it exceeds the field strength due to atmospheric and other noise sufficiently to ensure that the latter will not distort the information presented in the aircraft to the extent that it is unusable;

b) when the ratio of the strength of the wanted signal to that of interfering signals exceeds the minimum required value at all points within the coverage, in order to ensure that interfering signals will also not distort the information presented in the aircraft to the extent that it is unusable.

6.2.2.2 Since, normally, the lowest signal within the coverage will occur at its boundary, these conditions imply that at the boundary the field strength should be such that its ratio to atmospheric noise levels would ensure usable indications in the aircraft for most of the time and that, in respect of the boundary value, overall planning should ensure that the ratio of its value to that of interfering signals exceeds the required value for most of the time.

6.2.2.3 Although the value of 70 microvolts per metre used for frequency deployment has been found successful in Europe (i.e. north of 30°latitude) in giving coverage values which closely approximate to effective coverage most of the time, experience is too limited to prove the suitability of the 120 microvolts per metre value for general application in areas of high noise. It is to be expected that rated coverages in high noise based on a boundary value of 120 microvolts per metre will, on many occasions, be substantially greater than the effective coverage achieved. In such areas, in order to secure a better correlation between rated coverage and an average of the achieved effective coverage, it may be advisable to choose a boundary value based more closely on the proportionality of noise in that area to the noise in areas where a boundary value has been satisfactorily established (e.g. Europe), or to determine an appropriate value from a statistical examination of achieved effective coverages in respect of an NDB in the area of known performance.

6.2.2.4 It is important to appreciate, however, that minimum values of field strength based on a simple comparison of noise levels in different areas may be insufficient, because factors such as the frequency of occurrence of noise, its character and effect on the airborne receiver and the nature of the air operation involved may all modify ratios determined in this way.

6.2.2.5 Values of diurnal and seasonal noise in various parts of the world have been published in Report 322 of the former CCIR of the ITU.

6.2.2.5.1 Correlation of these values to actual local conditions and the derivation of required signal-to-noise ratios for effective operational use of ADF equipment is not yet fully established.

6.2.3 Effective coverage

6.2.3.1 Effective coverage as defined in Chapter 3, 3.4.1, is the area surrounding an NDB, within which useful information to the operator concerned can be obtained at a particular time. It is, therefore, a measure of NDB performance under prevailing conditions.

6.2.3.2 The effective coverage is limited by the ratio of the strength of the steady (non-fading) signal received from the NDB to the total noise intercepted by the ADF receiver. When this ratio falls below a limiting value, useful bearings cannot be obtained. It should also be noted that the effective coverage of an NDB may in some cases be limited to the range of the usable identification signal.

6.2.3.3 The strength of signal received from the NDB is governed by:

a) the power supplied to the antenna of the NDB;

b) the radiation efficiency of the antenna, which varies according to the height of the antenna and other characteristics of the radiating system;

c) the conductivity of the path between the NDB and the receiver, which may vary considerably as between one site and another, and is always less over land than over seawater;

d) the operating radio frequency.

6.2.3.4 The noise admitted by the receiver depends on:

a) the bandwidth of the receiver;

b) the level of atmospheric noise, which varies according to the geographical area concerned, with the time of day and the season of the year, and which may reach very high levels during local thunderstorms;

c) the level of the interference produced by other radio emissions on the same or on adjacent frequencies, which is governed to a large extent by the NDB density in the area concerned and the effectiveness of regional planning;

d) the level of noise due to electrical noise in the aircraft or to industrial noise (generated by electric motors, etc.), when the coverage of the NDB extends over industrial areas.

6.2.3.4.1 It has to be noted that the effect of noise depends on characteristics of the ADF receiver and the associated equipment, and also on the nature of the noise (e.g. steady noise, impulsive noise).

6.2.3.5 A further factor which limits the effective coverage of an NDB is present at night when interaction occurs between components of the signal which are propagated respectively in the horizontal plane (ground wave propagation) and by reflection from the ionosphere (sky wave propagation). When there is interaction between these components, which arrive at the ADF receiver with a difference of phase, bearing errors are introduced (night effect).

6.2.3.6 It will thus be seen that the effective coverage of an NDB depends on so many factors, some of which are variable, that it is impossible to specify the effective coverage of an NDB in any simple manner. The effective coverage of any NDB, in fact, varies according to the time of day and the season of the year.

6.2.3.6.1 Hence any attempt to specify an effective coverage, which would be obtainable at any time throughout the day or throughout the year, would result either in a figure for coverage which would be so small (since this would be the coverage obtained under the worst conditions of atmospheric noise, etc.) as to give quite a misleading picture of the effectiveness of the NDB, or would involve such high power and costly antenna systems (to provide the required coverage under the worst conditions), that the installation of such an NDB would usually be precluded by considerations of initial and operating costs. No specific formula can be given in determining what rated coverage would be equivalent to a desired effective coverage and the relation must be assessed regionally.

6.2.3.7 Those concerned with the operational aspects of NDB coverage will normally consider requirements in terms of a desired operational coverage and, in regional planning, it will usually be necessary to interpret such requirements in terms of a rated coverage from which may be derived the essential characteristics of the NDB required and which will also define the area to be protected against harmful interference. No specific formula can be given in determining what rated coverage would be equivalent to a desired operational coverage and the relation must be assessed regionally.

6.2.3.8 Some States have recorded data on NDBs and their effective coverage; and collection of similar information would be a practical way of obtaining an assessment of effective coverage in terms of rated coverage of facilities in a given area. This information would also be useful for future regional planning. In order to reduce the number of factors involved in assessing effective coverage, it would be desirable to establish criteria for determining the limit of useful coverage in terms of the reaction of the bearing indicator. The data referred to previously, together with measurements of actual field strength within the coverage of the NDB, would also permit determination of the effectiveness of existing installations and provide a guide to improvements that may be necessary to achieve a desired effective coverage.

6.3 Coverage of NDBs

6.3.1 Introduction

6.3.1.1 The following studies have been based on the latest propagation and noise data available to the ITU. They are included in this Attachment as general guidance in respect of NDB planning. Attention is called particularly to the assumptions made.

6.3.1.2 When applying the material, the validity of the assumptions in respect of the particular conditions under consideration should be carefully examined and, in particular, it should be noted that the assumed signal-to-noise ratios require considerable further study before they can be accepted as representative of the ratios limiting useful reception.

6.3.2 Assumptions

1. Operating frequency — 300 kHz.
Reference is made, however, where appropriate, to frequencies of 200 kHz and 400 kHz.

2. a) Average soil conductivity:
($\sigma = 10^{-13}$ e.m.u.)

b) Average seawater conductivity:
($\sigma = 4.10^{-11}$ e.m.u.)

3. The level of atmospheric noise (RMS) which is likely to prevail: 1) by day, 2) by night, over land masses, within the belts of latitude mentioned. [The values of expected noise have been derived from Recommendation ITU-R P.372-6 and have been taken as the average noise by day and by night during equinox periods, i.e. the values which are likely to be exceeded 20–25 per cent of the year.]

4. Input powers to the antenna of the NDB of:
a) 5 kW
b) 1 kW
c) 500 W
d) 100 W
e) 50 W
f) 10 W

5. The following average values of radiation efficiencies of antennas, i.e. the ratio of:

$$\left[\frac{\text{Radiated power}}{\text{Input power to antenna}}\right]$$

	Input power to antenna	*Radiation efficiency of antenna*
a)	5 kW	20% (–7 dB)
b)	5 kW	10% (–10 dB)
c)	1 kW	8% (–11 dB)
d)	500 W	5% (–13 dB)
e)	100 W	3% (–15 dB)
f)	50 W	2% (–17 dB)
g)	10 W	1% (–20 dB)
h)	10 W	0.3% (–25 dB)

i) The figure for a) is included because it is possible to realize this efficiency by the use of a more elaborate antenna system than is usually employed.

ii) The figure for h) is included because many low power NDBsuse very inefficient antennas.

6. An admittance band of the ADF receiver of 6 kHz.

7. Required ratios of signal-(median) to-noise (RMS) of:

a) 15 dB by day;

b) 15 dB by night.

6.3.3 Results of studies

A. – Minimum field strengths required at the boundary of the rated coverage:

Latitude	*By day for 15 dB S/N ratio*	*By night for 15 dB S/N ratio*
5°N – 5°S	320 μV/m (+50 dB)	900 μV/m (+59 dB)
5° – 15°N&S	85 μV/m (+39 dB)	700 μV/m (+57 dB)
15° – 25°N&S	40 μV/m (+32 dB)	320 μV/m (+50 dB)
25° – 35°N&S	18★μV/m (+25 dB)	120 μV/m (+42 dB)
>35°N&S	18★μV/m (+25 dB)	50 μV/m (+35 dB)

A star shown against a figure indicates that a higher value of field strength — probably 2 or 3 times the values shown (plus 6 to plus 10 dB) — may be necessary in the presence of high aircraft noise and/or industrial noise.

B.— Coverage of NDBs (expressed in terms of the radius of a circle, in kilometres, with the NDB at the centre) which may be expected under the assumptions made:

1) By day, over land, and for 15 dB S/N ratio at the boundary of the coverage:

	Input power to antenna			
Latitude	*(a) 5 kW*	*(b) 5 kW*	*(c) 1 kW*	*(d) 500 W*
5°N – 5°S	320	300	170	120
5° – 15°N&S	510	470	320	250
15° – 25°N&S	>600	600	450	350
25° – 35°N&S	>600★	>600★	600★	500★
>35°N&S	>600★	>600★	>600★	500★

Latitude	*Input power to antenna* (e) 100 W	(f) 50 W	(g) 10 W	(h) 10 W
5°N – 5°S	50	30	10	<10
5° – 15°N&S	150	90	40	10
15° – 25°N&S	220	160	70	45
25° – 35°N&S	330★	250★	130★	80★
>35°N&S	330★	250★	130★	100★

2) By night, over land, and for 15 dB S/N ratioat the boundary of the coverage:

Latitude	*Input power to antenna* (a) 5 kW	(b) 5 kW	(c) 1 kW	(d) 500 W
5°N – 5°S	190	150	85	50
5° – 15°N&S	210	180	110	70
15° – 25°N&S	320	300	170	120
25° – 35°N&S	390	390	280	200
>35°N&S	390	390	390	310

Latitude	*Input power to antenna* (e) 100 W	(f) 50 W	(g) 10 W	(h) 10 W
5°N – 5°S	20	<10	<10	<10
5° – 15°N&S	25	15	<10	<10
15° – 25°N&S	50	30	10	<10
25° – 35°N&S	100	70	25	15
>35°N&S	180	120	50	30

6.3.3.1 In all of the above tables, it has to be noted that:

a) the distances are given in kilometres, in accordance with ITU practice;

b) the figures in the final columns, with the heading 10 W, are calculated on the assumption that the low power NDB uses a very inefficient antenna (see 6.3.2, assumption 5 h));

c) a star shown against a figure indicates that the coverage may be limitedby aircraft and industrial noises.

6.3.3.2 It has also to be noted that:

a) if a frequency of 200 kHz were used in place of 300 kHz, this would not appreciably affect the coverage of low power short range NDBs, but the coverage of the higher power, longer range beacons (for example, those with a range of 150 km or more) would be increased, as compared with those shown in the tables, by about 20 per cent;

b) if a frequency of 400 kHz were used in place of 300 kHz this would not appreciably affect the coverage of low power short range NDBs, but the coverage of the higher power, longer range beacons (for example, those with a range of 150 km or more) would be decreased, as compared with those shown in the tables, by about 25 per cent;

c) use of an ADF receiver with a narrower band would, other things being equal, provide wider coverage for the same radiated power of the NDB or, for the same coverage, an improved effective signal-to-noise ratio. For example, if an admittance band of 1 kHz instead of 6 kHz were used, the coverage might be increased by as much as 30 per cent for the same radiated power or, alternatively, the effective signal-noise ratio might be increased by as much as 8 dB;

d) if a sector of the coverage of an NDB is over seawater, a greater coverage may be expected within that sector due to:

1) better ground wave propagation over seawater than over land;

2) the noise level, which is highest over land, often drops fairly steeply with increasing distance from the land. It might be assumed, therefore, that the distances shown in the tables could be increased by about 30 per cent by day, and by about 20 per cent by night, when the path is over seawater;

e) if, however, the beacon is sited on an island remote from land masses (for example, in mid-Pacific or mid-Atlantic, but not in the Caribbean), the coverage of the beacon is likely to be much greater, particularly in tropical latitudes, than is indicated in the tables; and in such cases figures for coverage similar to those shown for latitudes more than 35°N and S may be assumed for all latitudes, due to the much lower level of atmospheric noise which prevails in mid-ocean as compared with that experienced over, or in proximity to, land masses.

6.3.4 Limitation of coverage of a beacon at night due to “night effect”.

a) The distances, at night, at which the ground wave and sky wave components of the received field are likely to be equal are as follows:

Frequency	*Over land*	*Over sea*
200 kHz	500 km	550 km
300 kHz	390 km	520 km
400 kHz	310 km	500 km

b) The distances, at night, at which the ground wave component of the received field is likely to exceed the sky wave component by 10 dB are as follows:

Frequency	*Over land*	*Over sea*
200 kHz	300 km	320 km
300 kHz	230 km	300 km
400 kHz	200 km	280 km

c) It is, therefore, unlikely that reliable bearings can be obtained, at night, due to interaction of the two components of the received field, at much greater distances than those shown in 6.3.4 b). These distances are independent of the power of the NDB.

d) It has to be noted, moreover, that, while with overland paths of good conductivity, night effect will only be serious at somewhat greater distances than those indicated over paths of poor conductivity, night effect may become pronounced at much shorter ranges. This will also depend to some extent upon the characteristics of the radiation system.

6.4 Considerations affecting operations of NDBs

6.4.1 Depth of modulation

6.4.1.1 In specifying that the depth of modulation should be maintained as near to 95 per cent as is practicable, it must be noted that, at the frequencies used for NDBs, the small antennas generally in use can affect the effective modulation depth of the NDB system due to attenuation of the sidebands.

6.4.1.2 At this order of frequency, the antennas are normally only a small fraction of a wavelength long; they are therefore highly reactive and tend to have a high Q.

6.4.1.3 The effect is illustrated in Figure C-19, which was compiled from measurements made by one State. The modulating frequency in these measurements was 1 020 Hz. If a lower modulating frequency were used, the effect would be less.

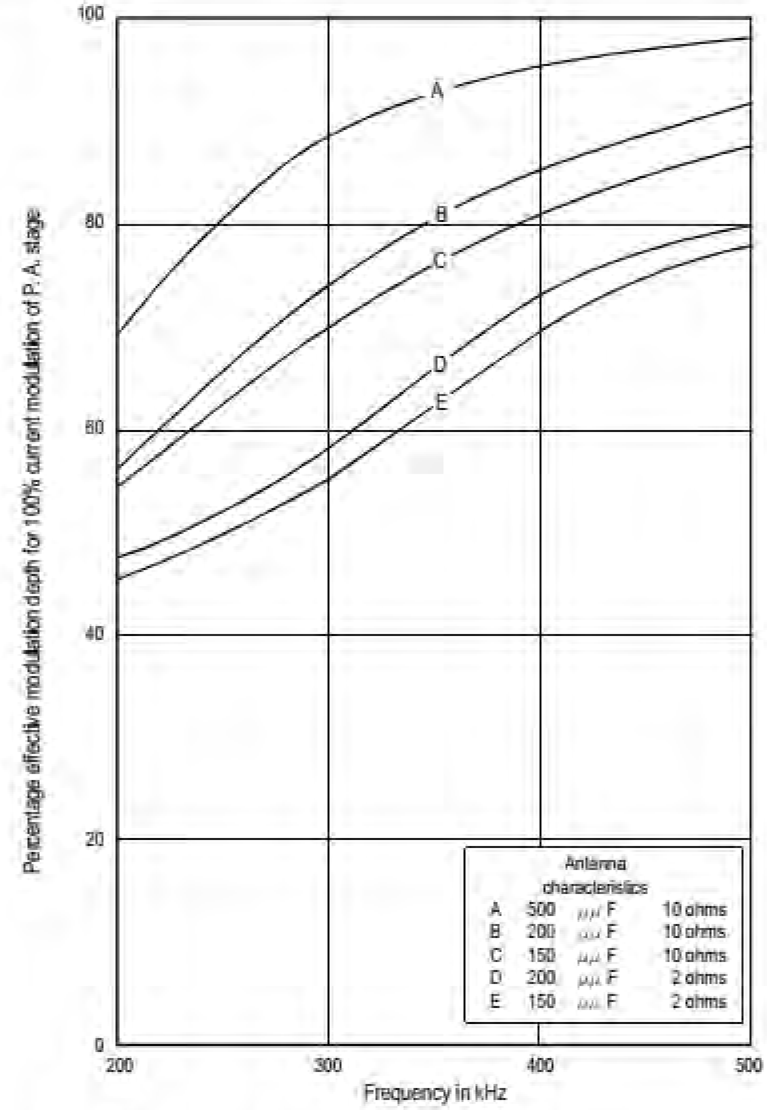
6.4.1.4 In order to reduce the attenuation, attempts should be made to reduce the Q of the antenna. This can be done in two ways, by increasing either its capacity or resistance.

6.4.1.5 Inserting additional resistance in an antenna wastes power, whereas increasing the capacity does not. Additionally, the effect of increasing the capacity is to reduce the voltage across the system and hence to reduce the insulation problems.

6.4.1.6 For these reasons, it is considered desirable to increase antenna capacity by the use of a top load as, for example, in the so-called umbrella top capacity.

6.4.2 Earth systems

Frequency planning is done on the assumption that the field strength will be maintained at the correct value. If the earth resistance is high (i.e. an insufficient earth system), not only will the radiation efficiency be low but the power radiated will be sensitive to changes in climatic conditions and other factors affecting the earth loss. In all cases, the earth system needs to be the best possible, taking into account all local circumstances.



Note.— The modulating frequency in these measurements was 1 020 Hz.

Figure C-19. The effect of antenna Q on the depth of modulation of the radiated signal

6.5 Considerations affecting the choice of the modulating frequency for NON/A2A NDBs

Recognition of the fact that modern narrow band ADF receivers have improved selectivity characteristics requires consideration of the fact that, in so far as attenuation of the audio sidebands by these receivers results in a reduction of the effective depth of modulation of the signal, the distance at which satisfactory identification is obtained is consequently reduced. In such circumstances, it is considered that 400 Hz would provide a better identification service than 1 020 Hz. There is some evidence, however, that under conditions of high atmospheric noise, the higher frequency of 1 020 Hz may provide a more easily readable signal.

7. Material concerning DME

7.1 Guidance material concerning both DME/N and DME/P

7.1.1 System efficiency

7.1.1.1 System efficiency is the combined effect of down-link garble, ground transponder dead time, up-link garble, and interrogator signal processor efficiency. Since each of these efficiency components are statistically independent, they can be computed individually and then combined to yield the system efficiency. The effect of a single component is defined as the percentage ratio of valid replies processed by the interrogator in response to its own interrogations assuming all other components are not present. The system efficiency is then the product of the individual components.

7.1.1.2 In computing system efficiency, the number of missing replies as well as the accuracy of the range measurement made with the received replies should be considered. Missing replies may result from signal interference due to garble or from interrogations being received at the transponder during a dead time period. Replies which contain significant errors large enough to be rejected by the interrogator signal processing also should be treated as missing replies when computing the efficiency component.

7.1.1.3 The interference rate due to garble is dependent upon the channel assignment plan, traffic loading, and the ground transponder and interrogator receiver bandwidths. Because the FA mode has a wider receiver bandwidth than the IA mode, it is more susceptible to interference. These factors were accommodated in the DME/P system definition and normally do not require special consideration by the operating authority.

7.1.2 Down-link garble

Down-link garble occurs when valid interrogations at the ground transponder are interfered with by coincident interrogations from other aircraft and results in loss of signal or errors in time-of-arrival measurement. This undesired air-toground loading is a function of the number of interrogating aircraft in the vicinity of the serving transponder and the corresponding distribution of interrogation frequencies and signal amplitudes received at the transponder.

Note.— Transponder to transponder garbling is controlled by the channel assignment authorities.

7.1.3 Up-link garble

Up-link garble occurs when valid replies at the interrogator are interfered with by other transponders and results in loss of signal or errors in pulse time-of-arrival measurement. The garble can be interference from any transponder whose frequency is within the bandwidth of the interrogator, including those on the same frequency, but with different pulse coding. This undesired ground-to-air loading is a function of the number of transponders in the vicinity of the interrogator and the corresponding distribution of reply frequencies and signal amplitudes received at the interrogator.

7.1.4 Interrogator processor efficiency

The interrogator signal processor efficiency is the ratio of the number of replies processed by the interrogator to the number of interrogations in the absence of garble and transponder dead time effects. This efficiency depends on the reply pulse threshold level and the receiver noise level.

7.1.5 Relationship between aircraft served and transmission rate

7.1.5.1 Specification of the maximum transponder transmission rate establishes the maximum average transmitter power level. Chapter 3, 3.5.4.1.5.5 recommends that the transponder have a transmission rate capability of 2 700 pulse pairs per second if 100 aircraft are to be served. This represents typical transponder loading arising from 100 aircraft. To determine the actual transmission rate capability that should be accommodated at a given facility during peak traffic conditions requires that the maximum number of interrogators be estimated. To compute the interrogation loading on the transponder, the following should be considered:

a) the number of aircraft that constitutes the peak traffic load;

b) the number of interrogators in use on each aircraft;

c) the distribution of operating modes of the interrogators in use (e.g. search, initial approach, final approach, ground

test);

d) the appropriate pulse repetition frequency as given in Chapter 3, 3.5.3.4.

7.1.5.2 Given the interrogation loading which results from the peak traffic as well as the reply efficiency of the transponder in the presence of this load, the resulting reply rate can be computed, thereby establishing the required transmitter capability. This reply rate is the level that, when exceeded, results in a reduction in receiver sensitivity (as specified in Chapter 3, 3.5.4.2.4) in order to maintain the reply rate at or below this maximum level.

7.1.6 *Siting of DME associated with ILS or MLS*

7.1.6.1 The DME should, where possible, provide to the pilot an indicated zero range at touchdown in order to satisfy current operational requirements.

7.1.6.2 The optimum site for a DME transponder is dependent upon a number of technical and operational factors. DME/N may be installed with ILS or MLS where operational requirements permit. DME/P, which provides higher accuracy and coverage throughout the entire runway region, is required to support the more flexible and advanced operations that are available with MLS.

7.1.6.3 In the case of DME/N, the provision of zero range indication may be achieved by siting the transponder as close as possible to the point at which zero range indication is required. Alternatively, the transponder time delay can be adjusted to permit aircraft interrogators to indicate zero range at a specified distance from the DME antenna. When the indicated DME zero range has a reference other than the DME antenna, consideration should be given to publishing this information.

7.1.6.4 In the case of DME/P, in order to meet accuracy and coverage requirements, particularly in the runway region, it is recommended that the DME/P be sited as closely as possible to the MLS azimuth facility, consistent with obstacle clearance criteria. For aircraft equipped with a full MLS capability, the desired zero range indication can then be obtained by utilizing MLS basic data. Note that the DME/P transponder time delay must not be adjusted for this purpose.

7.1.6.5 It is desirable that all users obtain indicated zero range at touchdown irrespective of the airborne equipment fitted. This would necessitate location of the DME/P abeam the runway at the touchdown point. In this case accuracy requirements for DME/P would not be met on the runway. It must be noted that MLS Basic Data Word 3 only permits the coding of DME/P coordinates within certain limits.

7.1.6.6 If an MLS/DME/P and an ILS/DME/N serve the same runway, an aircraft equipped with a minimum MLS capability can have a zero range indication at the MLS approach azimuth site when operating on MLS and a zero range indication at the touchdown point when operating on ILS. As this is considered to be operationally unacceptable, specifically from an ATC point of view, and if ILS/MLS/DME frequency tripling to prevent the relocation of the DME/N is not possible, the implementation of DME/P is to be postponed until the DME/N is withdrawn.

7.1.6.7 The nominal location of the zero range indication provided by a DME/N interrogator needs to be published.

7.1.6.8 In considering DME sites, it is also necessary to take into account technical factors such as runway length, profile, local terrain and transponder antenna height to assure adequate signal levels in the vicinity of the threshold and along the runway, and also to assure the required coverage volume (circular or sector). Care is also to be taken that where distance information is required in the runway region, the selected site is not likely to cause the interrogator to lose track due to excessive rate of change of velocity (i.e. the lateral offset of the DME antenna must be chosen with care).

7.1.7 *Geographical separation criteria*

7.1.7.1 In order to allow consideration of actual antenna designs, equipment characteristics, and service volumes, the signal ratios needed to assure interference-free operation of the various facilities operating on DME channels are provided in 7.1.8 and 7.1.9. Given these ratios, the geographical separations of facilities may be readily evaluated by accounting for power losses over the propagation paths.

7.1.8 *Desired to undesired (D/U) signal ratios at the airborne receiver*

7.1.8.1 Table C-4 indicates the necessary D/U signal ratios needed to protect the desired transponder reply signal at an airborne receiver from the various co-frequency/adjacent frequency, same code/different code, undesired transponder reply signal combinations that may exist. The prerequisite for any calculation using the provided ratios is that the required minimum power density of the desired DME is met throughout the operationally published coverage volume. For initial assignments, the D/U ratios necessary to protect airborne equipment with 6-microsecond decoder rejection should be used. In making an assignment, each facility must be treated as the desired source with the other acting as the undesired. If both satisfy their unique D/U requirement, then the channel assignment may be made.

7.1.8.2 *Accordingly, DME channel assignments depend upon the following:*

a) *For co-channel assignments:* This condition occurs when both the desired and undesired signals operate on a channel (W, X, Y or Z) that is co-frequency, same code. The D/U signal ratio should be at least 8 dB throughout the service volume.

b) *For co-frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel. A similar Y channel and a Z channel combination also applies.

c) *For first adjacent frequency, same code assignments*: This condition occurs when both the desired and undesired facilities are of W, X, Y or Z type.

d) *For first adjacent frequency, different code assignments*: This condition occurs when one facility operates on an X channel with the other on a W channel, but with a frequency offset of 1 MHz between transponder reply frequencies. A similar Y channel and a Z channel combination also applies.

Table C-4. Protection ratio D/U (dB)

Type of assignment	A	B
Co-frequency:		
Same pulse code	8	8
Different pulse code	8	−42
First adjacent frequency:		
Same pulse code	$-(P_u - 1)$	−42
Different pulse code	$-(P_u + 7)$	−75
Second adjacent frequency:		
Same pulse code	$-(P_u + 19)$	−75
Different pulse code	$-(P_u + 27)$	−75

Note 1.— The D/U ratios in column A protect those DME/N interrogators operating on X or Y channels. Column A applies to decoder rejection of 6 microseconds.

Note 2.— The D/U ratios in column B protect those DME/N or DME/P interrogators utilizing discrimination in conformance with 3.5.5.3.4.2 and 3.5.5.3.4.3 of Chapter 3 and providing a decoder rejection conforming to 3.5.5.3.5 of Chapter 3.

Note 3.— P_u is the peak effective radiated power of the undesired signal in dBW.

Note 4.— The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the EIRP of the undesired facility.

Note 5.— In assessing adjacent channel protection, the magnitude of D/U ratio in column A should not exceed the magnitude of the value in column B.

e) *For second adjacent frequency, same or different code assignments*: The second adjacent frequency combinations generally need not be frequency protected. However, special attention should be given to Note 4 of Table C-4, especially if the undesired facility is a DME/P transponder.

7.1.9 *Special considerations for DME Y and Z channel assignments*

The channel assignment plan for DME is such that the transponder reply frequency for each Y or Z channel is the same as the interrogation frequency of another DME channel. Where the reply frequency of one DME matches the interrogation frequency of a second DME, the two transponders should be separated by a distance greater than the radio horizon distance between them. The radio horizon distance is calculated taking into account the elevations of the two transponder antennas.

7.1.10 *Special considerations for DME/P associated with ILS*

7.1.10.1 For those runways where it is intended to install DME associated with ILS and where early MLS/RNAV operations are planned, installation of DME/P is preferred.

7.1.10.2 When it is intended to use the DME/P ranging information throughout the terminal area, interrogation pulse pairs with the correct spacing and nominal frequency must trigger the transponder if the peak power density at the transponder antenna is at least minus 93 dBW/m2. This sensitivity level is based on the values contained in Chapter 3, 3.5.4.2.3.1and it is applied to DME/P IA mode, where at this level DME/P IA mode is intended to comply with DME/N reply efficiency and at least DME/N accuracy.

7.1.11 Considerations for the universal access transceiver (UAT)

7.1.11.1 Frequency planning criteria to ensure compatibility between DME and the UAT are contained in Part II of the Manual on the Universal Access Transceiver (UAT)(Doc 9861).

7.2 Guidance material concerning DME/N only

7.2.1 *Coverage of DME/N*

7.2.1.1 Whether a particular installation can provide the required frequency, protected coverage volume can be determined by using Figure C-20. The propagation loss for paths without obstructions uses the IF-77 propagation model.

7.2.1.2 Whenever a DME that provides coverage using either a directional or bi-directional DME antenna, the antenna pattern in azimuth and elevation has to be taken into account to achieve the full benefit of the reduced separation requirements outside the antennas main lobe. The actual radiation patterns of the antennas depend on a number of factors, including height of the antenna phase centre, height of the DME counterpoise above ground level (AGL), terrain surface roughness, terrain form, site elevation above mean sea level (MSL), and conductivity of ground and counterpoise. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the equivalent isotropically radiated power (EIRP). Conversely, practical experience has shown, that under favourable siting conditions, and under the less pessimistic conditions often found in actual service, satisfactory system operation is achieved with a lower EIRP. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, the values in Figure C-20 are recommended.

Note.— Further guidance may be found in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

7.2.2 *EIRP of DME/N facilities*

7.2.2.1 The power density figure prescribed in Chapter 3, 3.5.4.1.5.2 is based on the following example:

Airborne receiver sensitivity	–120 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+9 dB
Power required at antenna	–111 dBW

Minus 111 dBW at the antenna corresponds to minus 89 dBW/ m2at the mid-band frequency.

7.2.2.2 Nominal values of the necessary EIRP to achieve a power density of minus 89 dBW/m2 are given in Figure C-20. For coverage under difficult terrain and siting conditions it may be necessary to make appropriate increases in the EIRP. Conversely, under favourable siting conditions, the stated power density may be achieved with a lower EIRP.

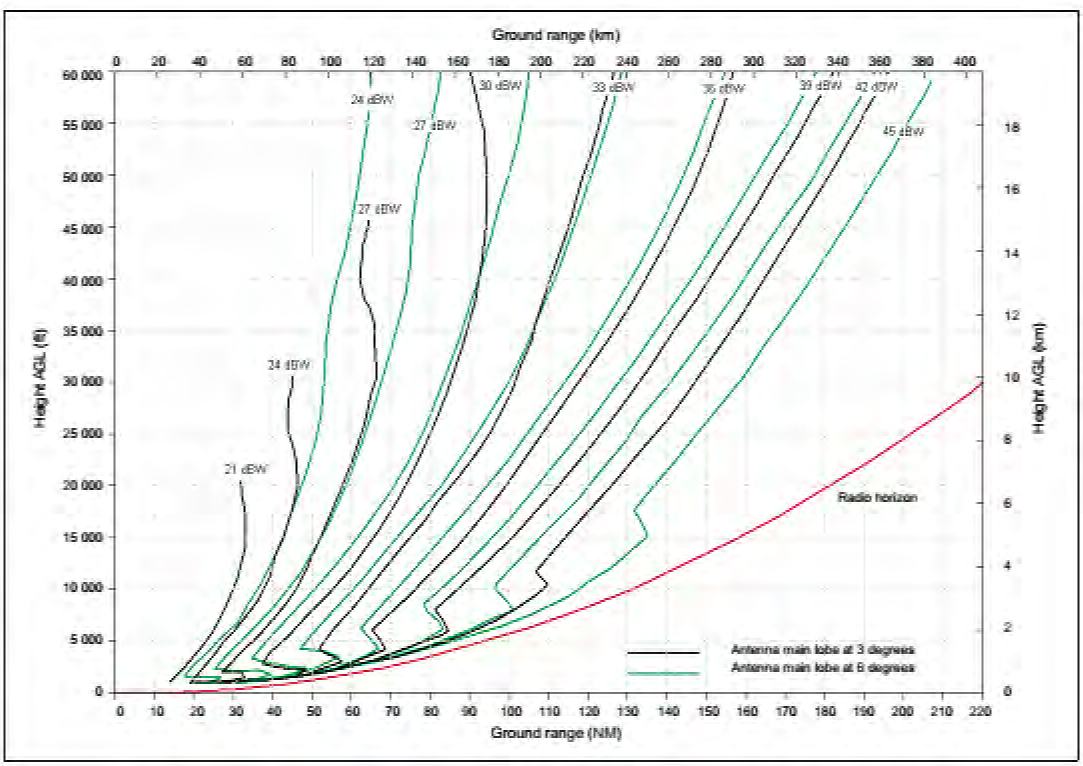


Figure C-20. Necessary EIRP to achieve a power density of –89 dBW/m2 as a function of height above and distance from the DME

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.

Note 2.— The radio horizon in Figure C-20 is for a DME antenna located 5 m (17 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.

Note 3.— If the antenna is located significantly higher than the assumed reference antenna, the radio horizon and power density will increase.

7.2.3 *DME-DME RNAV*

7.2.3.1 There is an increasing use of DME to support area navigation (RNAV) operations. Although the use of DME to support RNAV operations does not impose any additional technical requirements on the DME system, it does raise some additional issues compared with the traditional use of DME with VOR to support conventional operations. These are examined briefly below.

7.2.3.2 DME/DME positioning is based on the aircraft RNAV system triangulating position from multiple DME ranges from DME facility locations in the aircraft database. The resulting accuracy of the position solution depends on the range to the DMEs and their relative geometry. Some additional measures are therefore necessary to ensure that the DME infrastructure is adequate to support the RNAV operation, i.e. that sufficient DMEs are available and that their location provides adequate geometry to meet the accuracy requirements. For approach and departure procedures, it is also necessary to confirm that there is adequate signal strength and that there are no false locks or unlocks due to multipath. When ensuring there are sufficient DMEs, it is also important to identify any critical DMEs (i.e. those which must be operational for the necessary performance to be assured).

7.2.3.3 Errors in published DME facility locations will result in RNAV position errors. It is therefore important that DME positions are correctly surveyed and that adequate procedures are in place to ensure that the location data are correctly published. For DME facilities collocated with VOR, the DME position should be separately surveyed and published if the separation distance exceeds 30 m (100 ft).

Note.— Standards for data quality and publication of DME location information are given in Annex 15 — Aeronautical Information Services.

7.2.3.4 When using DME to support RNAV, scanning DME aircraft receivers usually do not check the DME identification. As a consequence, removing the identification of a

DME during tests and maintenance operations does not guarantee that the signals will not be used operationally. Maintenance actions that may provide misleading information should be minimized.

Note 1.— Further guidance on flight inspection of DME-DME RNAV procedures is given in Doc 8071.

Note 2.— Further guidance on navigation infrastructure assessment to support RNAV procedures is given in EUROCONTROL-GUID-0114 (available at http://www.eurocontrol.int/eatm /public/standard_page/gr_lib.html) and on the performance-based navigation (PBN) page of the ICAO website at http://www.icao.int/pbn.

7.3 Guidance material concerning DME/P only

7.3.1 *DME/P system description*

7.3.1.1 The DME/P is an integral element of the microwave landing system described in Chapter 3, 3.11. The DME/P signal format defines two operating modes, initial approach (IA) and final approach (FA). The IA mode is compatible and interoperable with DME/N and is designed to provide improved accuracies for the initial stages of approach and landing. The FA mode provides substantially improved accuracy in the final approach area. Both modes are combined into a single DME/P ground facility and the system characteristics are such that DME/N and DME/P functions can be combined in a single interrogator. The IA and FA modes are identified by pulse codes which are specified in Chapter 3, 3.5.4.4. In the MLS approach sector, the DME/P coverage is at least 41 km (22 NM) from the ground transponder. It is intended that the interrogator does not operate in the FA mode at ranges greater than 13 km (7 NM) from the transponder site, although the transition from the IA mode may begin at 15 km (8 NM) from the transponder. These figures were selected on the assumption that the transponder is installed beyond the stop end of the runway at a distance of approximately 3 600 m (2 NM) from the threshold.

7.3.1.2 A major potential cause of accuracy degradation encountered in the final phases of the approach and landing operation is multipath (signal reflection) interference. DME/P FA mode minimizes these effects by using wideband signal processing of pulses having fast rise time leading edges, and by measuring the time of arrival at a low point on the received pulse where it has not been significantly corrupted by multipath. This is in contrast to the slower rise time pulses and higher thresholding at the 50 per cent level used in DME/N.

7.3.1.3 Because the FA mode is used at ranges less than 13 km (7 NM), the transmitter can provide an adequate signal level to meet the required accuracy without the fast rise time pulse violating the transponder pulse spectrum requirements. Use of the 50 per cent threshold and a narrow receiver bandwidth in the IA mode permits an adequate but less demanding performance to the coverage limits. The transponder determines the interrogation mode in use by the interrogation code in order to time the reply delay from the proper measurement reference. The IA mode is interoperable with DME/N permitting a DME/N interrogator to be used with a DME/P transponder to obtain at least the accuracy with a DME/N transponder. Similarly, a DME/P interrogator may be used with a DME/N transponder.

7.3.2 *DME/P system accuracy requirements*

7.3.2.1 DME/P accuracy requirements

7.3.2.1.1 When considering the DME/P accuracy requirement, the operations that can be performed in the service volume of the final approach mode tend to fall into one of two groups. This has led to two accuracy standards being defined for the final approach mode:

a) accuracy standard 1:this is the least demanding and is designed to cater for most CTOL operations;

b) accuracy standard 2:this gives improved accuracy that may be necessary for VTOL and STOL operations, CTOL flare manoeuvres using MLS flare elevation guidance and CTOL high-speed turnoffs.

7.3.2.1.2 Table C-5 shows applications of DME and typical accuracy requirements. This will assist in selecting the appropriate accuracy standard to meet the operational requirement. The calculations are based on a distance of 1 768 m (5 800 ft) between the DME antenna and the runway threshold. The following paragraphs refer to Table C-5.

7.3.2.1.3 It is intended that the DME/P accuracy approximately corresponds to the azimuth function PFE at a distance of 37 km (20 NM) from the MLS reference datum both along the extended runway centre line and at an azimuth angle of 40 degrees. The CMN is the linear equivalent of the plus or minus 0.1 degree CMN specified for the azimuth angle function.

7.3.2.1.4 PFE corresponds to azimuth angular error; CMN is approximately the linear equivalent of the plus or minus 0.1 degree CMN specified for the azimuth angle system.

7.3.2.1.5 The plus or minus 30 m (100 ft) PFE corresponds to a plus or minus 1.5 m (5 ft) vertical error for a 3-degree elevation angle.

7.3.2.1.6 Flare initiation begins in the vicinity of the MLS approach reference datum; MLS elevation and DME/P provide vertical guidance for automatic landing when the terrain in front of the runway threshold is uneven.

7.3.2.1.7 Sensitivity modification or autopilot gain scheduling requirements are not strongly dependent on accuracy.

Table C-5.

Function	Typical distance from the threshold	PFE (95% probability)	CMN (95% probability)
Approach (7.3.2.1.3)			
— extended runway centre line	37 km (20 NM)	±250 m (±820 ft)	±68 m (±223 ft)
— at 40° azimuth	37 km (20 NM)	±375 m (±1 230 ft)	±68 m (±223 ft)
Approach (7.3.2.1.4)			
— extended runway centre line	9 km (5 NM)	±85 m (±279 ft)	±34 m (±111 ft)
— at 40° azimuth	9 km (5 NM)	±127 m (±417 ft)	±34 m (±111 ft)
Marker replacement			
— outer marker	9 km (5 NM)	±800 m (±2 625 ft)	not applicable
— middle marker	1 060 m (0.57 NM)	±400 m (±1 312 ft)	not applicable
30 m decision height determination (100 ft)	556 m (0.3 NM)	±30 m (±100 ft)	not applicable
(7.3.2.1.5)	556 m (0.3 NM)	±15 m (±50 ft)	not applicable
— 3° glide path (CTOL)			
— 6° glide path (STOL)			
Flare initiation over uneven terrain (7.3.2.1.6)			
— 3° glide path (CTOL)	0	±30 m (±100 ft)	±18 m (±60 ft)
— 6° glide path (STOL)	0	±12 m (±40 ft)	±12 m (±40 ft)
Sensitivity modifications (7.3.2.1.7) (autopilot gain scheduling)	37 km (20 NM) to 0	±250 m (±820 ft)	not applicable
Flare manoeuvre with MLS flare elevation (7.3.2.1.8)			
— CTOL	0	±30 m (±100 ft)	±12 m (±40 ft)
— STOL	0	±12 m (±40 ft)	±12 m (±40 ft)
Long flare alert (7.3.2.1.9)	Runway region	±30 m (±100 ft)	not applicable
CTOL high speed roll-out/turnoffs (7.3.2.1.10)	Runway region	±12 m (±40 ft)	±30 m (±100 ft)
Departure climb and missed approach	0 to 9 km (5 NM)	±100 m (±328 ft)	±68 m (±223 ft)
VTOL approaches (7.3.2.1.11)	925 m (0.5 NM) to 0	±12 m (±40 ft)	±12 m (±40 ft)
Coordinate translations (7.3.2.1.12)	—	±12 m to ±30 m (±40 ft to ±100 ft)	±12 m (±40 ft)

7.3.2.1.8 It is intended that this specification applies when vertical guidance and sink rate for automatic landing are derived from the MLS flare elevation and the DME/P.

Note.— Although the standard has been developed to provide for MLS flare elevation function, this function is not implemented and is not intended for future implementation.

7.3.2.1.9 It indicates to the pilot if the aircraft is landing beyond the touchdown region.

7.3.2.1.10 The roll-out accuracy requirement reflects system growth potential. In this application the roll-out PFE would be dictated by the possible need to optimize roll-out deceleration and turnoff so as to decrease runway utilization time.

7.3.2.1.11 It is intended to assure the pilot that the aircraft is over the landing pad before descending.

7.3.2.1.12 It may be desirable to translate the MLS coordinates from one origin to another when the antennas are not installed in accordance with Chapter 3, 3.11.5.2.6 or 3.11.5.3.5. The figures in the table are typical of a VTOL application; actual values will depend on the geometry of the installation.

7.3.3 *DME/P error budgets*

Example error budgets for DME/P accuracy standards 1 and 2 are shown in Table C-6. If the specified error components are not individually exceeded in practice, it can be expected that the overall system performance, as specified in Chapter 3,

3.5.3.1.4, will be achieved. A garbling contribution to the system error is computed by taking the root sum square (RSS) of the errors obtained in the specified down-link environment with those obtained in the specified up-link environment and removing, on an RSS basis, the error obtained in a non-garbling environment.

Table C-6. Example of DME/P error budget

Error source	Error component	FA mode Standard 1		FA mode Standard 2		IA mode	
		PFE m (ft)	CMN m (ft)	PFE m (ft)	CMN m (ft)	PFE m (ft)	CMN m (ft)
Instrumentation	Transponder	±10 (±33)	±8 (±26)	±5 (±16)	±5 (±16)	±15 (±50)	±10 (±33)
	Interrogator	±15 (±50)	±10 (±33)	±7 (±23)	±7 (±23)	±30 (±100)	±15 (±50)
Site related	Down-link specular multipath	±10 (±33)	±8 (±26)	±3 (±10)	±3 (±10)	±37 (±121)	±20 (±66)
	Up-link specular multipath	±10 (±33)	±8 (±26)	±3 (±10)	±3 (±10)	±37 (±121)	±20 (±66)
	Non-specular (diffuse) multipath	±3 (±10)	±3 (±10)	±3 (±10)	±3 (±10)	±3 (±10)	±3 (±10)
	Garble	±6 (±20)	±6 (±20)	±6 (±20)	±6 (±20)	±6 (±20)	±6 (±20)

Note 1.— The figures for "non-specular multipath" and for "garble" are the totals of the up-link and down-link components.

Note 2.— PFE contains both bias and time varying components. In the above table the time varying components and most site related errors are assumed to be essentially statistically independent. The bias components may not conform to any particular statistical distribution.

In considering these error budgets, caution is to be exercised when combining the individual components in any particular mathematical manner.

Note 3.— The transmitter wave form is assumed to have a 1 200 nanosecond rise time.

7.3.4 *System implementation*

7.3.4.1 While the DME/P may be implemented in various ways, the instrumental and propagation errors assumed are typical of those obtainable with equipment designs which provide internal time delay drift compensation and which establish timing reference points by thresholding on the leading edge of the first pulse of a pulse pair using the following techniques:

a) *IA mode*. A conventional technique which thresholds at the 50 per cent amplitude point;

b) *FA mode*. A delay-attenuate-and-compare (DAC) technique which thresholds between the 5 per cent and 30 per cent amplitude points.

7.3.4.2 Accuracy standard 1 can be achieved using a delay of 100 nanoseconds and an attenuation of 5 to 6 dB. It is also required that the threshold amplitude point of both the delayed pulse and the attenuated pulse lie within the partial rise time region.

7.3.4.3 The example above does not preclude time of arrival measurement techniques other than the DAC from being used, but it is necessary in any case that threshold measurements take place during the pulse partial rise time.

7.3.5 *DME/P interrogator signal processing*

7.3.5.1 During acquisition

a) The interrogator acquires and validates the signal within 2 seconds before transitioning to track mode even in the presence of squitter and random pulse pairs from adjacent channels, which result in a 50 per cent system efficiency.

b) After loss of the acquired signal in either the IA or FA mode, the interrogator provides a warning output within 1 second, during which time the guidance information continues to be displayed. After loss of signal, the interrogator returns to the search condition in the IA mode in order to re-establish track.

7.3.5.2 During track

When track is established, the receiver output consists of valid guidance information before removing the warning. The validation process continues to operate as long as the interrogator is in track. The interrogator remains in track as long as the system efficiency is 50 per cent or greater. While in track, the receiver provides protection against short duration, large amplitude erroneous signals.

7.3.5.3 Range date filter

The accuracy specifications in Chapter 3, 3.5.3.1.4, as well as the error budgets discussed in 7.3.3, assume that the higher frequency noise contributions are limited by a low pass filter with a corner frequency of qw as specified in Figure C-21. Depending upon the user's application, additional filtering for noise reduction can be used provided that the induced phase delay and amplitude variation do not adversely affect the aircraft flight control system's dynamic response. The following sections recommend additional features which should be incorporated into the data filter.

7.3.5.4 Velocity memory

The data filter may require a velocity memory in order to achieve the specified accuracies in Chapter 3, 3.5.3.1.4 with a system efficiency of 50 per cent. It should be noted that low system efficiencies can occur in the IA mode during identification transmissions.

7.3.5.5 Outlier rejection

Range estimates which are significantly different from previous filtered range estimates, because they cannot be the result of aircraft motion, should be assumed to be in error. Such data should be rejected at the input to the data filter.

7.3.6 *DME/P error measurement methods*

7.3.6.1 System errors

7.3.6.1.1 The DME/P system accuracies are specified in Chapter 3, 3.5.4.1.4 in terms of path following error (PFE) and control motion noise (CMN). These parameters describe the interaction of the DME/P guidance signal with the aircraft in terms directly related to aircraft position errors and flight control system design.

7.3.6.1.2 For the purposes of determining compliance with the accuracy standard, the PFE and CMN components are evaluated over any T second interval (where T = 40 seconds in the IA mode and 10 seconds in the FA mode) of the flight error record taken within the DME/P coverage limits. The 95 per cent probability requirement is interpreted to be satisfied if the PFE and CMN components do not exceed the specified error limits for a total period that is more than 5 per cent of the evaluation time interval. This is illustrated in Figure C-21. To evaluate the PFE and CMN components of the DME/P guidance data, the true aircraft position, as determined by a suitable position reference, is subtracted from the guidance data to form an error signal. This error signal is then filtered by the PFE and CMN filters, where the outputs provide suitable estimates of the PFE and CMN components, respectively. These filters are defined in Figure C-21.

7.3.6.1.3 These filters can be utilized to determine the transponder instrumentation error components specified in Chapter 3, 3.5.4.5.3 and 3.5.4.5.4. Similarly, the interrogator instrumentation error components, specified in Chapter 3, 3.5.5.4, can be determined.

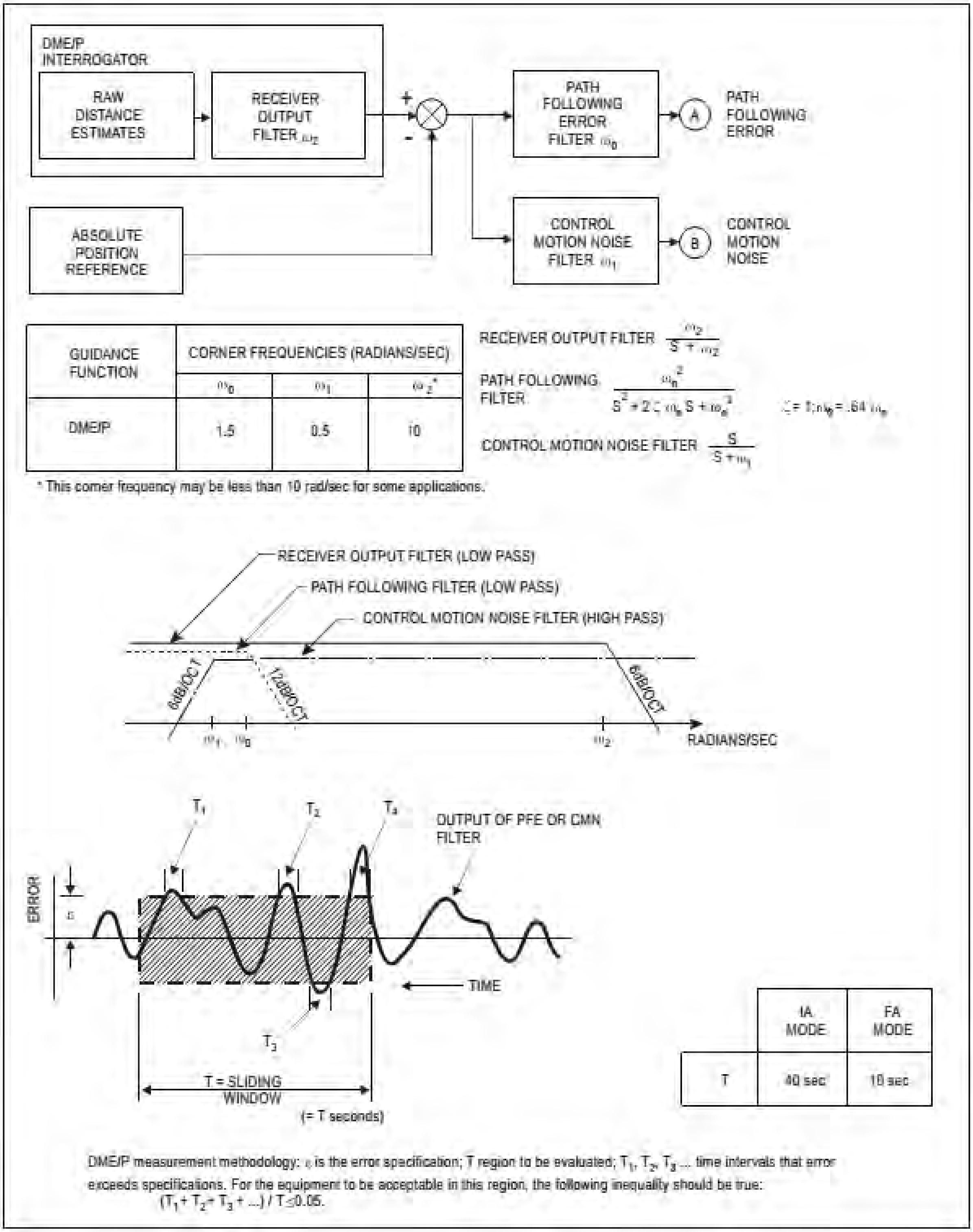


Figure C-21

7.3.7 *Multipath effects*

7.3.7.1 Under the multipath conditions likely to exist, the accuracy specifications of the DME/P assume that the performance is not degraded beyond a certain limit and that this degradation is equally applied to both interrogator and transponder receiver.

7.3.7.2 To ensure that the equipment is working according to the specifications, the following should apply to FA mode operation of the system:

a) if a signal of sufficient power to make thermal noise contributions insignificant is applied to the receivers, a second signal delayed between 0 and 350 nanoseconds with respect to the first, with an amplitude 3 dB or more below the first and with a scalloping frequency between 0.05 and 200 Hz should not produce errors in the receiver output of more than plus or minus 100 nanoseconds (15 m);

b) for delays more than 350 nanoseconds the error contribution will be reduced considerably. A typical value will be plus or minus 7 nanoseconds (1 m).

7.3.7.3 The airborne DME antenna should be located so as to preclude antenna gain reductions in the forward direction with the aircraft in the landing configuration. Any such antenna gain reductions could enhance the multipath error component when the aircraft is on approach and landing phases when highest DME accuracies are required.

7.3.8 *DME/P power budget*

7.3.8.1 Tables C-7 and C-8 are an example of CTOL air-to-ground and ground-to-air power budgets. The permitted peak ERP value is based on a pulse shape which meets the spectral constraints in Chapter 3, 3.5.4.1.3 e).

Table C-7. CTOL ground-to-air power budget

Power budget items	41 km (22 NM)	13 km (7 NM)	Ref. datum	Roll-out
Peak effective radiated power, dBm	55	55	55	55
Ground multipath loss, dB	−5	−3	−4	−17
Antenna pattern loss, dB	−4	−2	−5	−5
Path loss, dB	−125	−115	−107	−103
Monitor loss, dB	−1	−1	−1	−1
Polarization and rain loss, dB	−1	−1	0	0
Received signal at aircraft, dBm	−81	−67	−62	−71
Power density at aircraft, dBW/m²	−89	−75	−70	−79
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	−4	−4	−4	−4
Received signal at interrogator, dBm	−85	−71	−66	−75
Receiver noise video, dBm				
(Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		−103	−103	−103
IF BW: 0.8 MHz	−109			
Signal-to-noise ratio (video), dB	24	32	37	28

Table C-8. CTOL air-to-ground power budget

Power budget items	41 km (22 NM)	13 km (7 NM)	Ref. datum	Roll-out
Interrogator transmitter power, dBm	57	57	57	57
Aircraft antenna gain, dB	0	0	0	0
Aircraft cable loss, dB	−4	−4	−4	−4
Peak effective radiated power, dBm	53	53	53	53
Ground multipath loss, dB	−5	−3	−4	−17
Path loss, dB	−125	−115	−107	−103
Polarization and rain loss, dB	−1	−1	0	0
Received signal at transponder antenna, dBm	−78	−66	−58	−67
Ground antenna gain, dB	8	8	8	8
Pattern loss, dB	−4	−2	−5	−5
Cable loss, dB	−3	−3	−3	−3
Received signal at transponder, dBm	−77	−63	−58	−67
Receiver noise video, dBm				
(Noise factor (NF) = 9 dB)				
IF BW: 3.5 MHz		−106	−106	−106
IF BW: 0.8 MHz	−112			
Signal-to-noise ratio (video), dB	35	43	48	39

7.3.8.2 In the power budget calculations, it is assumed that the aircraft antenna is not shielded by the aircraft structure including the landing gear when extended.

7.3.8.3 The video power signal-to-noise ratio is related to the IF power signal-to-noise ratio in the following manner:

$$S/N\ (\text{video}) = S/N\ (\text{IF}) + 10 \log \frac{\text{IF noise bandwidth}}{\text{video noise bandwidth}}$$

Note 1.— The distances are measured from the transponder antenna.

Note 2.— Frequency dependent parameters were calculated for 1 088 MHz.

7.3.9 *DME/P monitor time delay measurement*

The required time delay measurement can be accomplished by measuring the output of a PFE filter and making a control decision within 1 second. However, since the transponder PFE is a slowly varying error component, an equivalent measurement is to average the unfiltered time delay samples for 1 second.

8. Material concerning power supply switch-over times

8.1 Power supply switch-over times for ground-based radio aids used in the vicinity of aerodromes

The power supply switch-over times for radio navigation aids and ground elements of communications systems are dependent on the type of runway and aircraft operations to be supported. Table C-9 indicates representative switch-over times which may be met by power supply systems currently available.

Table C-9. Power supply switch-over times for ground-based radio aids used at aerodromes

Type of runway	Aids requiring power	Maximum switch-over times (seconds)
Instrument approach	SRE	15
	VOR	15
	NDB	15
	D/F facility	15
Precision approach, Category I	ILS localizer	10
	ILS glide path	10
	ILS middle marker	10
	ILS outer marker	10
	PAR	10
Precision approach, Category II	ILS localizer	0
	ILS glide path	0
	ILS inner marker	1
	ILS middle marker	1
	ILS outer marker	10
Precision approach, Category III	(same as Category II)	

ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

1. Definitions

Bi-binary. Bi-binary is known as "Manchester Encoding". It is sometimes referred to as "Differential Manchester Encoding". Using this system, it is the transition of the edge that determines the bit.

Chip. A single digital bit of the output of a pseudo-random bit sequence.

Gold code. A class of unique codes used by GPS, which exhibit bounded cross-correlation and off-peak auto-correlation values.

Selective availability (SA).A set of techniques for denying the full accuracy and selecting the level of positioning, velocity and time accuracy of GPS available to users of the standard positioning service signal.

Note.— GPS SA was discontinued at midnight on 1 May 2000.

2. General

Standards and Recommended Practices for GNSS contain provisions for the elements identified in Chapter 3, 3.7.2.2. Additional implementation guidance is provided in the Global Navigation Satellite System (GNSS) Manual (Doc 9849).

Note.— Except where specifically annotated, GBAS guidance material applies to GRAS.

3. Navigation system performance requirements

3.1 Introduction

3.1.1 Navigation system performance requirements are defined in the Performance-based Navigation (PBN) Manual (Doc 9613) for a single aircraft and for the total system which includes the signal-in-space, the airborne equipment and the ability of the aircraft to fly the desired trajectory. These total system requirements were used as a starting point to derive GNSS signal-in-space performance requirements. In the case of GNSS, degraded configurations which may affect multiple aircraft are to be considered. Therefore, certain signal-in-space performance requirements are more stringent to take into account multiple aircraft use of the system.

3.1.2 Two types of approach and landing operations with vertical guidance (APV), APV-I and APV-II, use vertical guidance relative to a glide path, but the facility or navigation system may not satisfy all of the requirements associated with precision approach. These operations combine the lateral performance equal to that of an ILS Category I localizer with different levels of vertical guidance. Both APV-I and APV-II provide access benefits relative to a non-precision approach, and the service that is provided depends on the operational requirements and the SBAS infrastructure. APV-I and APV-II exceed the requirements (lateral and vertical) for current RNAV approaches using barometric altimetry, and the relevant onboard equipment will therefore be suitable for the conduct of barometric VNAV APV and RNAV non-precision approaches.

3.2.1 GNSS position error is the difference between the estimated position and the actual position. For an estimated position at a specific location, the probability should be at least 95 per cent that the position error is within the accuracy requirement.

3.2.2 Stationary, ground-based systems such as VOR and ILS have relatively repeatable error characteristics, so that performance can be measured for a short period of time (e.g. during flight inspection) and it is assumed that the system accuracy does not change after the test. However, GNSS errors change over time. The orbiting of satellites and the error characteristics of GNSS result in position errors that can change over a period of hours. In addition, the accuracy itself (the error bound with 95 per cent probability) changes due to different satellite geometries. Since it is not possible to continually measure system accuracy, the implementation of GNSS demands increased reliance on analysis and characterization of errors. Assessment based on measurements within a sliding time window is not suitable for GNSS.

3.2.3 The error for many GNSS architectures changes slowly over time, due to filtering in the augmentation systems and in the user receiver. This results in a small number of independent samples in periods of several minutes. This issue is very important for precision approach applications, because it implies that there is a 5 per cent probability that the position error can exceed the required accuracy for an entire approach. However, due to the changing accuracy described in 3.2.2, this probability is usually much lower.

3.2.4 The 95 per cent accuracy requirement is defined to ensure pilot acceptance, since it represents the errors that will typically be experienced. The GNSS accuracy requirement is to be met for the worst-case geometry under which the system

is declared to be available. Statistical or probabilistic credit is not taken for the underlying probability of particular ranging signal geometry.

3.2.5 Therefore, GNSS accuracy is specified as a probability for each and every sample, rather than as a percentage of samples in a particular measurement interval. For a large set of independent samples, at least 95 per cent of the samples should be within the accuracy requirements in Chapter 3, Table 3.7.2.4-1. Data is scaled to the worst-case geometry in order to eliminate the variability in system accuracy that is caused by the geometry of the orbiting satellites.

3.2.6 An example of how this concept can be applied is the use of GPS to support performance required for nonprecision approach operations. Assume that the system is intended to support non-precision approaches when the horizontal dilution of precision (HDOP) is less than or equal to 6. To demonstrate this performance, samples should be taken over a long period of time (e.g. 24 hours). The measured position error g for each sample i is denoted gi. This error is scaled to the worst-case geometry as 6 × gi/HDOP. Ninety-five per cent of the scaled errors must be less than 220 m for the system to comply with the non-precision accuracy requirement under worst-case geometry conditions. The total number of samples collected must be sufficient for the result to be statistically representative, taking into account the decorrelation time of the errors.

3.2.7 A range of vertical accuracy values is specified for Category I precision approach operations which bounds the different values that may support an equivalent operation to ILS. A number of values have been derived by different groups, using different interpretations of the ILS standards. The lowest value from these derivations was adopted as a conservative value for GNSS; this is the minimum value given for the range. Because this value is conservative, and because GNSS error characteristics are different from ILS, it may be possible to achieve Category I operations using larger values of accuracy within the range. The larger values would result in increased availability for the operation. The maximum value in the range has been proposed as a suitable value, subject to validation.

3.2.8 The GPS SPS position error (Chapter 3, 3.7.3.1.1.1) accounts for the contribution of the space and control segment to position errors (satellite clock and ephemeris errors) only; it does not include the contributions of ionospheric and tropospheric delay model errors, errors due to multipath effects, and receiver measurement noise errors (Attachment D, 4.1.2). These errors are addressed in the receiver standards. The user positioning error at the output of ABAS-capable equipment is mainly driven by the GNSS receiver used.

3.2.8.1 For Basic GNSS receivers, the receiver qualification standards require demonstration of user positioning accuracy in the presence of interference and a model of selective availability (SA) to be less than 100 m (95 per cent of time) horizontally and 156 m (95 per cent of time) vertically. The receiver standards do not require that a Basic GNSS receiver applies the ionospheric correction described in Appendix B, 3.1.2.4.

Note.— The term "Basic GNSS receiver" designates the GNSS avionics that at least meet the requirements for a GPS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-208 as amended by United States Federal Aviation Administration (FAA) TSO-C129A, or EUROCAE ED-72A (or equivalent).

3.2.8.2 Since the discontinuation of SA, the representative user positioning accuracy of GPS has been conservatively estimated to be as shown in Table D-0. The numbers provided assume that the worst two satellites of a nominal 24 GPS satellite constellation are out of service. In addition, a 7 m (1 σ) ionospheric delay model error, a 0.25 m (1 σ) residual tropospheric delay error, and a 0.80 m (1 σ) receiver noise error are assumed. After discontinuation of SA (Attachment D, 1.), the dominant pseudo-range error for users ofthe GPS Standard Positioning Service is the ionospheric error that remains after application of the ionospheric corrections. This error is also highly variable and depends on conditions such as user geomagnetic latitude, level of solar activity (i.e. point of the solar cycle that applies), level of ionospheric activity (i.e. whether there is a magnetic storm, or not), elevation angle of the pseudo-range measurement, season of the year, and time of day. The ionospheric delay model error assumption reflected in Table D-0 is generally conservative; however, conditions can be found under which the assumed 7 m (1 σ) error during solar maximum would be inadequate.

Table D-0. GPS user positioning accuracy

	GPS user positioning accuracy 95% of time, global average
Horizontal position error	33 m (108 ft)
Vertical position error	73 m (240 ft)

3.2.9 SBAS and GBAS receivers will be more accurate, and their accuracy will be characterized in real time by the receiver using standard error models, as described in Chapter 3, 3.5, for SBAS and Chapter 3, 3.6, for GBAS.

Note 1.—The term "SBAS receiver" designates the GNSS avionics that at least meet the requirements for an SBAS receiver as outlined in Annex 10, VolumeI and the specifications of RTCA/DO-229C, as amended by United States FAA TSO-C145A/TSO-C146A (or equivalent).

Note 2.—The term "GBAS receiver" designates the GNSS avionics that at least meet the requirements for a GBAS receiver as outlined in Annex 10, VolumeI and the specifications of RTCA/DO-253A, as amended by United States FAA TSO-C161 and TSO-C162 (or equivalent).

3.3 Integrity

3.3.1 Integrity is a measure of the trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation (or phase of flight).

3.3.2 To ensure that the position error is acceptable, an alert limit is defined that represents the largest position error allowable for a safe operation. The position error cannot exceed this alert limit without annunciation. This is analogous to ILS in that the system can degrade so that the error is larger than the 95th percentile but within the monitor limit.

3.3.3 The integrity requirement of the navigation system for a single aircraft to support en-route, terminal, initial approach, non-precision approach and departure is assumed to be 1 – 1 × 10–5 per hour.

3.3.4 For satellite-based navigation systems, the signal-in-space in the en-route environment simultaneously serves a large number of aircraft over a large area, and the impact of a system integrity failure on the air traffic management system will be greater than with traditional navigation aids. The performance requirements in Chapter 3, Table 3.7.2.4-1, are therefore more demanding.

3.3.5 For APV and precision approach operations, integrity requirements for GNSS signal-in-space requirements of Chapter 3, Table 3.7.2.4-1, were selected to be consistent with ILS requirements.

3.3.6 Alert limits for typical operations are provided in Note 2 to Table 3.7.2.4-1. A range of alert limits is specified for precision approach operations, reflecting potential differences in system design that may affect the operation. In ILS, monitor thresholds for key signal parameters are standardized, and the monitors themselves have very low measurement noise on the parameter that is being monitored. With differential GNSS, some system monitors have comparably large measurement noise uncertainty whose impact must be considered on the intended operation. In all cases, the effect of the alert limit is to restrict the satellite-user geometry to one where the monitor performance (typically in the pseudo range domain) is acceptable when translated into the position domain.

3.3.7 The smallest precision approach vertical alert limit (VAL) value (10 m (33 ft)) was derived based on the monitor performance of ILS as it could affect the glide slope at a nominal decision altitude of 60 m (200 ft) above the runway threshold. By applying this alert limit, the GNSS error, under faulted conditions, can be directly compared to an ILS error under faulted conditions, such that the GNSS errors are less than or equal to the ILS errors. For those faulted conditions with comparably large measurement noise in GNSS, this results in monitor thresholds are more stringent than ILS.

3.3.8 The largest precision approach VAL value (35 m (115 ft)) was derived to ensure obstacle clearance equivalent to ILS for those error conditions which can be modelled as a bias during the final approach, taking into account that the aircraft decision altitude is independently derived from barometric pressure. An assessment has been conducted of the worst-case effect of a latent bias error equal to the alert limit of 35 m (115 ft), concluding that adequate obstacle clearance protection is provided on the approach and missed approach (considering the decision altitude would be reached early or late, using an independent barometric altimeter). It is important to recognize that this assessment only addressed obstacle clearance and is limited to those error conditions which can be modelled as bias errors. Analysis has shown 35 m (115 ft) bias high and low conditions can be tolerated up to the approach speed category (Categories A through D) glide path angle limits in the Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS, Doc 8168) without impinging on the ILS obstacle clearance surfaces.

3.3.9 Since the analysis of a 35 m (115 ft) VAL is limited in scope, a system-level safety analysis should be completed before using any value greater than 10 m (33 ft) for a specific system design. The safety analysis should consider obstacle clearance criteria and risk of collision due to navigation error, and the risk of unsafe landing due to navigation error, given the system design characteristics and operational environment (such as the type of aircraft conducting the approach and the supporting airport infrastructure). With respect to the collision risk, it is sufficient to confirm that the assumptions identified in 3.3.8 are valid for the use of a 35 m (115 ft) VAL. With respect to an unsafe landing, the principal mitigation for a navigation error is pilot intervention during the visual segment. Limited operational trials, in conjunction with operational expertise, have indicated that navigation errors of less than 15 m (50 ft) consistently result in acceptable touchdown performance. For errors larger than 15 m (50 ft), there can be a significant increase in the flight crew workload and potentially a significant reduction in the safety margin, particularly for errors that shift the point where the aircraft reaches the decision altitude closer to the runway threshold where the flight crew may attempt to land with an unusually high rate of descent. The hazard severity of this event is major (see the Safety Management Manual (SMM) (Doc 9859)). One acceptable means to manage the risks in the visual segment is for the system to comply with the following criteria:

a) the fault-free accuracy is equivalent to ILS. This includes system 95 per cent vertical navigation system error (NSE) less than 4 m (13 ft), and a fault-free system vertical NSE exceeding 10 m (33 ft) with a probability less than 10-7 foreach location where the operation is tobe approved. This assessment is performed over all environmental and operational conditions under which the service is declared available;

b) under system failure conditions, the system design is such that the probability of an error greater than 15 m (50 ft) is lower than 10-5, so that the likelihood of occurrence is remote. The fault conditions to be taken into account are those affecting either the core constellations or the GNSS augmentation under consideration. This probability is to be understood as the combination of the occurrence probability of a given failure with the probability of detection for applicable monitor(s). Typically, the probability of a single fault is large enough that a monitor is required to satisfy this condition.

3.3.10 For GBAS, a technical provision has been made to broadcast the alert limit to aircraft. GBAS standards require the alert limit of 10 m (33 ft). For SBAS, technical provisions have been made to specify the alert limit through an updatable database (see Attachment C).

3.3.11 The approach integrity requirements apply in any one landing and require a fail-safe design. If the specific risk on a given approach is known to exceed this requirement, the operation should not be conducted. One of the objectives of the design process is to identify specific risks that could cause misleading information and to mitigate those risks through redundancy or monitoring to achieve a fail-safe design. For example, the ground system may need redundant correction processors and to be capable of shutting down automatically if that redundancy is not available due to a processor fault.

3.3.12 A unique aspect of GNSS is the time-varying performance caused by changes in the core satellite geometry. A means to account for this variation is included in the SBAS and GBAS protocols through the protection level equations, which provide a means to inhibit use of the system if the specific integrity risk is too high.

3.3.13 GNSS performance can also vary across the service volume as a result of the geometry of visible core constellation satellites. Spatial variations in system performance can further be accentuated when the ground system operates in a degraded mode following the failure of system components such as monitoring stations or communication links. The risk due to spatial variations in system performance should be reflected in the protection level equations, i.e. the broadcast corrections.

3.3.14 GNSS augmentations are also subject to several atmospheric effects, particularly due to the ionosphere. Spatial and temporal variations in the ionosphere can cause local or regional ionospheric delay errors that cannot be corrected within the SBAS or GBAS architectures due to the definition of the message protocols. Such events are rare and their likelihood varies by region, but they are not expected to be negligible. The resulting errors can be of sufficient magnitude to cause misleading information and should be mitigated in the system design through accounting for their effects in the broadcast parameters (e.g. σiono_vert in GBAS), and monitoring for excessive conditions where the broadcast parameters are not adequate. The likelihood of encountering such events should be considered when developing any system monitor.

3.3.15 Another environmental effect that should be accounted for in the ground system design is the errors due to multipath at the ground reference receivers, which depend on the physical environment of monitoring station antennas as well as on satellite elevations and times in track.

3.4 Continuity of service

3.4.1 Continuity of service of a system is the capability of the system to perform its function without unscheduled interruptions during the intended operation.

3.4.2 *En-route*

3.4.2.1 For en-route operations, continuity of service relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity throughout the intended operation, assuming that it was available at the start of the operation. The occurrence of navigation system alerts, either due to rare fault-free performance or to failures, constitute continuity failures. Since the durations of these operations are variable, the continuity requirement is specified as a probability on a per-hour basis.

3.4.2.2 The navigation system continuity requirement for a single aircraft is 1 – 1 × 10–4per hour. However, for satellite based systems, the signal-in-space may serve a large number of aircraft over a large area. The continuity requirements in Chapter 3, Table 3.7.2.4-1, represent reliability requirements for the GNSS signal-in-space, i.e. they derive mean time between outage (MTBO) requirements for the GNSS elements.

3.4.2.3 A range of values is given in Chapter 3, Table 3.7.2.4-1, for the signal-in-space continuity requirement for en-route operations. The lower value is the minimum continuity for which a system is considered to be practical. It is appropriate for areas with low traffic density and airspace complexity. In such areas, the impact of a navigation system failure is limited to a small number of aircraft, and there is, therefore, no need to increase the continuity requirement significantly beyond the single aircraft requirement (1 – 1 ×10–4per hour). The highest value given (i.e. 1 – 1 ×10–8 per hour) is suitable for areas with high traffic density and airspace complexity, where a failure will affect a large number of aircraft. This value is appropriate for navigation systems where there is a high degree of reliance on the system for navigation and possibly for dependent surveillance. The value is sufficiently high for the scenario based on a low probability of a system failure during the life of the system. Intermediate values of continuity (e.g. 1 – 1 ×10–6per hour) are considered to be appropriate for areas of high traffic density and complexity where there is a high degree of reliance on the navigation system but in which mitigation for navigation system failures is possible. Such mitigation may be through the use of alternative navigation means or the use of ATC surveillance and intervention to maintain separation standards. The values of continuity performance are determined by airspace needs to support navigation where GNSS has either replaced the existing navigation aid infrastructure or where no infrastructure previously existed.

3.4.3 *Approach and landing*

3.4.3.1 For approach and landing operations, continuity of service relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity during the approach and landing, given that it was available at the start of the operation. In particular, this means that loss of continuity events that can be predicted and for which NOTAMs have been issued do not have to be taken into account when establishing compliance of a given system design against the SARPs continuity requirement. The occurrence of navigation system alerts, either due to rare fault-free performance or to failures, constitutes a loss of continuity event. In this case, the continuity requirement is stated as a probability for a short exposure time.

3.4.3.2 The continuity requirements for approach and landing operations represent only the allocation of the requirement between the aircraft receiver and the non-aircraft elements of the system. In this case, no increase in the requirement is considered necessary to deal with multiple aircraft use of the system. The continuity value is normally related only to the risk associated with a missed approach and each aircraft can be considered to be independent. However, in some cases, it may be necessary to increase the continuity values since a system failure has to be correlated between both runways (e.g. the use of a common system for approaches to closely-spaced parallel runways).

3.4.3.3 For GNSS-based APV and Category I approaches, missed approach is considered a normal operation, since it occurs whenever the aircraft descends to the decision altitude for the approach and the pilot is unable to continue with visual reference. The continuity requirement for these operations applies to the average risk (over time) of loss of service, normalized to a 15-second exposure time. Therefore, the specific risk of loss of continuity for a given approach could exceed the average requirement without necessarily affecting the safety of the service provided or the approach. A safety assessment performed for one system led to the conclusion that, in the circumstances specified in the assessment, continuing to provide the service was safer than withholding it.

3.4.3.4 For those areas where the system design does not meet the average continuity risk specified in the SARPs, it is still possible to publish procedures. However, specific operational mitigations should be put in place to cope with the reduced continuity expected. For example, flight planning may not be authorized based on a GNSS navigation means with such a high average continuity risk.

3.5 Availability

3.5.1 The availability of GNSS is characterized by the portion of time the system is to be used for navigation during which reliable navigation information is presented to the crew, autopilot, or other system managing the flight of the aircraft.

3.5.2 When establishing the availability requirements for GNSS, the desired level of service to be supported should be considered. If the satellite navigation service is intended to replace an existing en-route navigation aid infrastructure, the availability of the GNSS should be commensurate with the availability provided by the existing infrastructure. An assessment of the operational impact of a degradation in service should be conducted.

3.5.3 Where GNSS availability is low, it is still possible to use the satellite navigation service by restricting the

navigation operating times to those periods when it is predicted to be available. This is possible in the case of GNSS since unavailability due to insufficient satellite geometry is repeatable. Under such restrictions, there remains only a continuity risk associated with the failure of necessary system components between the time the prediction is made and the time the operation is conducted.

3.5.4 *En-route*

3.5.4.1 Specific availability requirements for an area or operation should be based upon:

a) traffic density and complexity;

b) alternate navigation aids;

c) primary/secondary surveillance coverage;

d) air traffic and pilot procedures; and

e) duration of outages.

3.5.4.2 For this reason, the GNSS SARPs specify a range of values for availability requirements. The requirements support GNSS sole-means operations in airspace with various levels of traffic and complexity. The lower end of the range is only sufficient for providing sole means of navigation in a low traffic density and complexity airspace.

3.5.4.3 While augmentations can reduce the dependency of the GNSS on a particular core element, they do not provide usable service without the core elements. The requirement for the availability of a particular augmentation in an area should account for potential degradation in the GNSS core elements (i.e. the minimum constellation of core elements (number and diversity of satellites) that is expected). Operational procedures should be developed in case such a degraded configuration occurs.

3.5.5 *Approach*

3.5.5.1 Specific requirements for an area should be based upon:

a) traffic density and complexity;

b) procedures for filing and conducting an approach to an alternate airport;

c) navigation system to be used for an alternate airport;

d) air traffic and pilot procedures;

e) duration of outages; and

f) geographic extent of outages.

3.5.5.2 When developing operating procedures for GNSS approach systems, the duration of an outage and its impact

on the alternate airport should be considered. Although GNSS outages can occur which affect many approaches, the approach

service can be restored without any maintenance because of the orbiting of the satellites.

3.5.6 Determining GNSS availability

The availability of GNSS is complicated by the movement of satellites relative to a coverage area under consideration and the

potentially long time needed to restore a satellite in the event of a failure. Accurately measuring the availability would require

many years to allow for a measurement period longer than the MTBF and repair times. The availability of GNSS should be determined through design, analysis and modelling, rather than measurement. The availability model should account for the

ionospheric, tropospheric and receiver error models used bythe receiver to verify integrity (e.g. HPL, LPL and VPL

calculations). The availability specified in Chapter 3, 3.7.2.4, applies to the design availability.

Note.— Additional guidance material pertaining to reliability and availability of radio communications and navigation

aids is contained in Attachment F.

4. GNSS core elements

4.1 GPS

Note.— Additional information concerning GPS can be found in the Global Positioning System Standard Positioning Service — Performance Standard, October 2001, and Interface Control Document (ICD)-GPS-200C.

4.1.1 The performance standard is based upon the assumption that a representative standard positioning service (SPS) receiver is used. A representative receiver has the following characteristics: designed in accordance with ICD-GPS-200C; uses a 5-degree masking angle; accomplishes satellite position and geometric range computations in the most current realization of the World Geodetic System 1984 (WGS-84) Earth-Centred, Earth-Fixed (ECEF) coordinate system; generates a position and time solution from data broadcast by all satellites in view; compensates for dynamic Doppler shift effects on nominal SPS ranging signal carrier phase and C/A code measurements; excludes GPS unhealthy satellites from the position solution; uses up-to-date and internally consistent ephemeris and clock data for all satellites it is using in its position solution; and loses track in the event that a GPS satellite stops transmitting C/A code. The time transfer accuracy applies to a stationary receiver operating at a surveyed location. A 12-channel receiver will meet performance requirements specified in Chapter 3,

3.7.3.1.1.1 and 3.7.3.1.2. A receiver that is able to track four satellites only (Appendix B, 3.1.3.1.2) will not get the full accuracy and availability performance.

4.1.2 *Accuracy.* The accuracy is measured with a representative receiver and a measurement interval of 24 hours for any point within the coverage area. The positioning and timing accuracy are for the signal-in-space (SIS) only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath. The accuracy is derived based on the worst two of 24 satellites being removed from the constellation and a 6-metre constellation RMS SIS user range error (URE).

4.1.3 *Range domain accuracy.* Range domain accuracy is conditioned by the satellite indicating a healthy status and transmitting C/A code and does not account for satellite failures outside of the normal operating characteristics. Range domain accuracy limits can be exceeded during satellite failures or anomalies while uploading data to the satellite. Exceedance of the range error limit constitutes a major service failure as described in 4.1.6. The range rate error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The range acceleration error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The root-mean-square range error accuracy is the average of the RMS URE of all satellites over any 24-hour interval for any point within the coverage area. Under nominal conditions, all satellites are maintained to the same standards, so it is appropriate for availability modelling purposes to assume that all satellites have a 6-metre RMS SIS URE. The standards are restricted to range domain errors allocated to space and control segments.

4.1.4 *Availability*. Availability is the percentage of time over any 24-hour interval that the predicted 95 per cent positioning error (due to space and control segment errors) is less than its threshold, for any point within the coverage area. It is based on a 36-metre horizontal 95 per cent threshold; a 77-metre vertical 95 per cent threshold; using a representative receiver; and operating within the coverage area over any 24-hour interval. The service availability assumes the worst combination of two satellites out of service.

4.1.4.1 *Relationship to augmentation availability*. The availability of ABAS, GBAS and SBAS does not directly relate to the GPS availability defined in Chapter 3, 3.7.3.1.2. States and operators must evaluate the availability of the augmented system by comparing the augmented performance to the requirements. Availability analysis is based on an assumed satellite constellation and the probability of having a given number of satellites. Twenty-four operational satellites are available on orbit with 0.95 probability (averaged over any day), where a satellite is defined to be operational if it is capable of, but is not necessarily transmitting, a usable ranging signal. At least

21satellites in the 24 nominal plane/slot positions must be set healthy and must be transmitting a navigation signal with 0.98 probability (yearly averaged).

4.1.5 *Reliability.* Reliability is the percentage of time over a specified time interval that the instantaneous SPS SIS URE is maintained within the range error limit, at any given point within the coverage area, for all healthy GPS satellites. The reliability standard is based on a measurement interval of one year and the average of daily values within the coverage area. The single point average reliability assumes that the total service failure time of 18 hours will be over that particular point (3 failures each lasting 6 hours).

4.1.6 *Major service failure*. A major service failure is defined to be a condition over a time interval during which a healthy GPS satellite's ranging signal error (excluding atmospheric and receiver errors) exceeds the range error limit. As defined in Chapter 3, 3.7.3.1.1.3 a), the range error limit is the larger of:

a) 30 m; or

b) 4.42 times the URA, not to exceed 150 m.

4.1.7 Coverage. The SPS supports the terrestrial coverage area, which is from the surface of the earth up to an altitude of 3 000 km.

4.2 GLONASS

Note.— Additional information concerning GLONASS can be found in the GLONASS Interface Control Document published by Scientific Coordination Information Center, Russian Federation Ministry of Defence, Moscow.

4.2.1 *Assumptions.* The performance standard is based upon the assumption that a representative channel of standard accuracy (CSA) receiver is used. A representative receiver has the following characteristics: designed in accordance with GLONASS ICD; uses a 5-degree masking angle; accomplishes satellite position and geometric range computations in the most current realization of the PZ-90 and uses PZ-90 – WGS-84 transformation parameters as indicated in Appendix B, 3.2.5.2; generates a position and time solution from data broadcast by all satellites in view; compensates for dynamic Doppler shift effects on nominal CSA ranging signal carrier phase and standard accuracy signal measurements; excludes GLONASS unhealthy satellites from the position solution; uses up-to-date and internally consistent ephemeris and clock data for all satellites it is using in its position solution; and loses track in the event that a

GLONASS satellite stops transmitting standard accuracy code. The time transfer accuracy applies to a stationary receiver operating at a surveyed location.

4.2.2 *Accuracy*. Accuracy is measured with a representative receiver and a measurement interval of 24 hours for any point within the coverage area. The positioning and timing accuracy are for the signal-in-space (SIS) only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath. The accuracy is derived based on the worst two of 24 satellites being removed from the constellation and a 6-metre constellation RMS SIS user range error (URE).

4.2.3 *Range domain accuracy*. Range domain accuracy is conditioned by the satellite indicating a healthy status and transmitting standard accuracy code and does not account for satellite failures outside of the normal operating characteristics. Range domain accuracy limits can be exceeded during satellite failures or anomalies while uploading data to the satellite. Exceeding the range error limit constitutes a major service failure as described in 4.2.6. The range rate error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The range acceleration error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The root-mean-square range error accuracy is the average of the RMS URE of all satellites over any 24-hour interval for any point within the coverage area. Under nominal conditions, all satellites are maintained to the same standards, so it is appropriate for availability modelling purposes to assume that all satellites have a 6-metre RMS SIS URE. The standards are restricted to range domain errors allocated to space and control segments.

4.2.4 *Availability.* Availability is the percentage of time over any 24-hour interval that the predicted 95 per cent positioning error (due to space and control segment errors) is less than its threshold, for any point within the coverage area. It is based on a 12-metre (40-foot) horizontal 95 per cent threshold and a 25-metre (80-foot) vertical 95 per cent threshold, using a representative receiver and operating within the coverage area over any 24-hour interval. The service availability assumes the worst combination of two satellites out of service.

4.2.4.1 *Relationship to augmentation availability.* The availability of ABAS, GBAS and SBAS does not directly relate to the GLONASS availability defined in Chapter 3, 3.7.3.2.2. Availability analysis is based on an assumed satellite constellation and the probability of having a given number of satellites. Twenty-four operational satellites are available in orbit with 0.95 probability (averaged over any day), where a satellite is defined to be operational if it is capable of, but is not necessarily transmitting, a usable ranging signal. At least 21satellites in the 24 nominal plane/slot positions must be set healthy and must be transmitting a navigation signal with 0.98 probability (yearly averaged).

4.2.5 *Reliability.* Reliability is the percentage of time over a specified time interval that the instantaneous CSA SIS URE is maintained within the range error limit, at any given point within the coverage area, for all healthy GLONASS satellites. The reliability standard is based on a measurement interval of one year and the average of daily values within the coverage area. The single point average reliability assumes that the total service failure time of 18 hours will be over that particular point (3 failures each lasting 6 hours).

4.2.6 *Major service failure*. A major service failure is defined as a condition over a time interval during which a healthy GLONASS satellite's ranging signal error (excluding atmospheric and receiver errors) exceeds the range error limit of 18 m (60 ft) (as defined in Chapter 3, 3.7.3.2.1.3 a)) and/or failures in radio frequency characteristics of the CSA ranging signal, navigation message structure or navigation message contents that deteriorate the CSA receiver's ranging signal reception or processing capabilities.

4.2.7 *Coverage.* The GLONASS CSA supports the terrestrial coverage area, which is from the surface of the earth up to an altitude of 2 000 km.

4.2.8 *GLONASS time*. GLONASS time is generated based on GLONASS Central Synchronizer time. Daily instability of the Central Synchronizer hydrogen clock is not worse than 5 ×10–14. The difference between GLONASS time and UTC(SU) is within 1 millisecond. The navigation message contains the requisite data to relate GLONASS time to UTC(SU) within 0.7 microsecond.

4.2.8.1 *Transformation of GLONASS-M current data information into common form.* A satellite navigation message contains current data information in NT parameter. It could be transformed into the common form by the following algorithm:

a) Current year number J in the four-year interval is calculated:

If $1 \leq N_T \leq 366$; $J = 1$;
If $367 \leq N_T \leq 731$; $J = 2$;
If $732 \leq N_T \leq 1096$; $J = 3$;
If $1097 \leq N_T \leq 1461$; $J = 4$.

b) Current year in common form is calculated by the following formula:

Y = 1996 + 4 (N4– 1) + (J – 1).

c) Current day and month (dd/mm) are extracted from the reference table stored in user equipment ROM. The table interrelates NT parameter and common form dates.

4.2.9 GLONASS coordinate system. The GLONASS coordinate system is PZ-90 as described in Parameters of Earth,1990 (PZ-90), published by the Topographic Service, Russian Federation Ministry of Defence, Moscow.

4.2.9.1 PZ-90 parameters include fundamental geodetic constants, dimensions of the common terrestrial ellipsoid, the characteristics of the gravitational field of the earth, and the elements of the Krasovsky ellipsoid (coordinate system 1942) orientation relative to the common terrestrial ellipsoid.

4.2.9.2 By definition, the coordinate system PZ-90 is a geocentric Cartesian space system whose origin is located at the centre of the earth's body. The Z-axis is directed to the Conventional Terrestrial Pole as recommended by the International Earth Rotation Service. The X-axis is directed to the point of intersection of the earth's equatorial plane and zero meridian established by the Bureau International de l'Heure. The Y-axis completes the right-handed coordinate system.

4.3 Dilution of precision

Dilution of precision (DOP) factors express how ranging accuracy is scaled by a geometry effect to yield position accuracy. The optimal geometry (i.e. the lowest DOP values) for four satellites is achieved when three satellites are equally spaced on the horizon, at minimum elevation angle, and one satellite is directly overhead. The geometry can be said to "dilute" the range domain accuracy by the DOP factor.

4.4 GNSS receiver

4.4.1 The failures caused by the receiver can have two consequences on navigation system performance which are the interruption of the information provided to the user or the output of misleading information. Neither of these events are accounted for in the signal-in-space requirement.

4.4.2 The nominal error of the GNSS aircraft element is determined by receiver noise, interference, and multipath and tropospheric model residual errors. Specific receiver noise requirements for both the SBAS airborne receiver and the GBAS airborne receiver include the effect of any interference below the protection mask specified in Appendix

B, 3.7. The required performance has been demonstrated by receivers that apply narrow correlator spacing or code smoothing techniques.

5. Aircraft-based augmentation system (ABAS)

5.1 ABAS augments and/or integrates the information obtained from GNSS elements with information available on board the aircraft in order to ensure operation according to the values specified in Chapter 3, 3.7.2.4.

5.2 ABAS includes processing schemes that provide:

a) integrity monitoring for the position solution using redundant information (e.g. multiple range measurements). The monitoring scheme generally consists of two functions: fault detection and fault exclusion. The goal of fault detection is to detect the presence of a positioning failure. Upon detection, proper fault exclusion determines and excludes the source of the failure (without necessarily identifying the individual source causing the problem), thereby allowing GNSS navigation to continue without interruption. There are two general classes of integrity monitoring: receiver autonomous integrity monitoring (RAIM), which uses GNSS information exclusively, and aircraft autonomous integrity monitoring (AAIM), which uses information from additional on-board sensors (e.g. barometric altimeter, clock and inertial navigation system (INS));

b) continuity aiding for the position solution using information of alternative sources, such as INS, barometric altimetry and external clocks;

c) availability aiding for the position solution (analogous to the continuity aiding); and

d) accuracy aiding through estimation of remaining errors in determined ranges.

5.3 Non-GNSS information can be integrated with GNSS information in two ways:

a) integrated within the GNSS solution algorithm (an example is the modelling of altimetry data as an additional satellite measurement); and

b) external to the basic GNSS position calculation (an example is a comparison of the altimetry data for consistency with the vertical GNSS solution with a flagraised whenever the comparison fails).

5.4 Each scheme has specific advantages and disadvantages, and it is not possible to present a description of all potential integration options with specific numerical values of the achieved performance. The same applies to the situation when several GNSS elements are combined (e.g. GPS and GLONASS).

6. Satellite-based augmentation system (SBAS)

6.1 An SBAS is made up of three distinct elements:

a) the ground infrastructure;

b) the SBAS satellites; and

c) the SBAS airborne receiver.

6.1.1 The ground infrastructure includes the monitoring and processing stations that receive the data from the navigation satellites and compute integrity, corrections and ranging data which form the SBAS signal-in-space. The SBAS satellites relay the data relayed from the ground infrastructure to the SBAS airborne receivers that determine position and time information using core satellite constellation(s) and SBAS satellites. The SBAS airborne receivers acquire the ranging and correction data and apply these data to determine the integrity and improve the accuracy of the derived position.

6.1.2 The SBAS ground network measures the pseudo-range between the ranging source and an SBAS receiver at the known locations and provides separate corrections for ranging source ephemeris errors, clock errors and ionospheric errors.

The user applies a tropospheric delay model.

6.1.3 The ranging source ephemeris error and slow moving clock error are the primary bases for the long-term correction. The ranging source clock error is adjusted for the long-term correction and tropospheric error and is the primary basis for the fast correction. The ionospheric errors among many ranging sources are combined into vertical ionospheric errors at predetermined ionospheric grid points. These errors are the primary bases for ionospheric corrections.

6.2 SBAS coverage area and service areas

6.2.1 It is important to distinguish between the coverage area and service areas for an SBAS. A coverage area comprises one or more service areas, each capable of supporting operations based on some or all of the SBAS functions defined in Chapter 3, 3.7.3.4.2. These functions can be related to the operations that are supported as follows:

a) Ranging: SBAS provides a ranging source for use with other augmentation(s) (ABAS, GBAS or other SBAS);

b) Satellite status and basic differential corrections: SBAS provides en-route, terminal, and non-precision approach service. Different operations (e.g. performance-based navigation operations) may be supported in different service areas;

c) Precise differential corrections: SBAS provides APV and precision approach service (i.e. APV-I, APV-II and precision approach may be supported in different service areas).

6.2.2 Satellite-based augmentation services are provided by the Wide Area Augmentation System (WAAS) (North America), the European Geostationary Navigation Overlay Service (EGNOS) (Europe and Africa) and the Multifunction Transport Satellite (MTSAT) Satellite-based Augmentation System (MSAS) (Japan). The GPS-aided Geo-augmented Navigation (GAGAN) (India) and the System of Differential Correction and Monitoring (SDCM) (Russia) are also under development to provide these services.

6.2.3 An SBAS may provide accurate and reliable service outside the defined service area(s). The ranging, satellite status and basic differential corrections functions are usable throughout the entire coverage area. The performance of these functions may be technically adequate to support en-route, terminal and non-precision approach operations by providing monitoring and integrity data for core satellite constellations and/or SBAS satellites. The only potential for integrity to be compromised is if there is a satellite ephemeris error that can not be observed by the SBAS ground network while it creates an unacceptable error outside the service area. For alert limits of 0.3 NM specified for non-precision approach and greater, this is very unlikely.

6.2.4 Each State is responsible for defining SBAS service areas and approving SBAS-based operations within its airspace. In some cases, States will field SBAS ground infrastructure linked to an existing SBAS. This would be required to achieve APV or precision approach performance. In other cases, States may simply approve service areas and SBAS-based operations using available SBAS signals. In either case, each State is responsible for ensuring that SBAS meets the requirements of Chapter 3, 3.7.2.4, within its airspace, and that appropriate operational status reporting and NOTAMs are provided for its airspace.

6.2.5 Before approving SBAS-based operations, a State must determine that the proposed operations are adequately supported by one or more SBASs. This determination should focus on the practicality of using SBAS signals, taking into account the relative location of the SBAS ground network. This could involve working with the State(s) or organization(s) responsible for operating the SBASs. For an airspace located relatively far from an SBAS ground network, the number of visible satellites for which that SBAS provides status and basic corrections would be reduced. Since SBAS receivers are able to use data from two SBASs simultaneously, and to use autonomous fault detection and exclusion when necessary, availability may still be sufficient for approval of operations.

6.2.6 Before publishing procedures based on SBAS signals, a State is expected to provide a status monitoring and NOTAM system. To determine the effect of a system element failure on service, a mathematical service volume model is to be used. The State can either obtain the model from the SBAS operator or develop its own model. Using the current and forecast status data of the basic system elements, and the locations where the State has approved operations, the model would identify airspace and airports where service outages are expected, and it could be used to originate NOTAMs. The system element status data (current and forecast)required for the model could be obtained via a bilateral arrangement with the SBAS service provider, or via connection to a real time “broadcast” of the data if the SBAS service provider chooses to provide data in this way.

6.2.7 Participating States or regions will coordinate through ICAO to ensure that SBAS provides seamless global coverage, taking into account that aircraft equipped to use the signal could suffer operational restrictions in the event that a State or region does not approve the use of one or more of the SBAS signals in its airspace. In such an event, the pilot may have to deselect GNSS altogether since the aircraft equipment may not allow de selection of all SBAS or a particular SBAS.

6.2.8 As the SBAS geostationary orbit satellite coverages (footprints) overlap, there will be interface issues among the SBASs. As a minimum, the SBAS airborne receivers must be able to operate within the coverage of any SBAS. It is possible for an SBAS provider to monitor and send integrity and correction data for a geostationary orbit satellite that belongs to another SBAS service provider. This improves availability by adding ranging sources. This improvement does not require any interconnection between SBAS systems and should be accomplished by all SBAS service providers.

6.2.9 Other levels of integration can be implemented using a unique connection between the SBAS networks (e.g. separate satellite communication). In this case, SBASs can exchange either raw satellite measurements from one or more reference stations or processed data (corrections or integrity data) from their master stations. This information can be used to improve system robustness and accuracy through data averaging, or integrity through a cross check mechanism. Availability will also be improved within the service areas, and the technical performance will meet the GNSS SARPs throughout the entire coverage (i.e. monitoring of satellites ephemeris would be improved). Finally, SBAS control and status data could be exchanged to improve system maintenance.

6.3 Integrity

6.3.1 The provisions for integrity are complex, as some attributes are determined within the SBAS ground network and transmitted in the signal-in-space, while other attributes are determined within the SBAS equipment on the aircraft. For the satellite status and basic corrections functions, an error uncertainty for the ephemeris and clock corrections is determined by the SBAS ground network. This uncertainty is modelled by the variance of a zero-mean, normal distribution that describes the user differential range error (UDRE) for each ranging source after application of fast and long-term corrections and excluding atmospheric effects and receiver errors.

6.3.2 For the precise differential function, an error uncertainty for the ionospheric correction is determined. This uncertainty is modelled by the variance of a zero-mean, normal distribution that describes the L1 residual user ionospheric range error (UIRE) for each ranging source after application of ionospheric corrections. This variance is determined from an ionospheric model using the broadcast grid ionospheric vertical error (GIVE).

6.3.3 There is a finite probability that an SBAS receiver would not receive an SBAS message. In order to continue navigation in that case, the SBAS broadcasts degradation parameters in the signal-in-space. These parameters are used in a number of mathematical models that characterize the additional residual error from both basic and precise differential corrections induced by using old but active data. These models are used to modify the UDRE variance and the UIRE variance as appropriate.

6.3.4 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. The horizontal protection level (HPL) provides a bound on the horizontal position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. If the computed HPL exceeds the horizontal alert limit

(HAL) for a particular operation, SBAS integrity is not adequate to support that operation. The same is true for precision approach and APV operations, if the VPL exceeds the vertical alert limit (VAL).

6.3.5 One of the most challenging tasks for an SBAS provider is to determine UDRE and GIVE variances so that the protection level integrity requirements are met without having an impact on availability. The performance of an individual SBAS depends on the network configuration, geographical extent and density, the type and quality of measurements used and the algorithms used to process the data. General methods for determining the model variance are described in Section 14.

6.3.6 Residual clock and ephemeris error (σ_{UDRE}). The residual clock error is well characterized by a zero-mean, normal distribution since there are many receivers that contribute to this error. The residual ephemeris error depends upon theuser location. For the precise differential function, the SBAS provider will ensure that the residual error for all users within a defined service area is reflected in the σ_{UDRE}. For the basic differential function, the residual ephemeris error should be evaluated and may be determined to be negligible.

6.3.7 Vertical ionospheric error (σ_{GIVE}). The residual ionospheric error is well represented by a zero-mean, normal distribution since there are many receivers that contribute to the ionospheric estimate. Errors come from the measurement noise, the ionospheric model and the spatial decorrelation of the ionosphere. The position error caused by ionospheric error ismitigated by the positive correlation of the ionosphere itself.In addition, the residual ionospheric error distribution has truncated tails, i.e. the ionosphere cannot create a negative delay, and has a maximum delay.

6.3.8 Aircraft element errors. The combined multipath and receiver contribution is bounded as described in Section 14. This error can be divided into multipath and receiver contribution as defined in Appendix B, 3.6.5.5.1, and the standard model for multipath may be used. The receiver contribution can be taken from the accuracy requirement (Appendix B, 3.5.8.2 and 3.5.8.4.1) and extrapolated to typical signal conditions. Specifically, the aircraft can be assumed to have $\sigma^2_{air} = \sigma^2_{receiver} + \sigma^2_{multipath}$, where it is assumed that $\sigma_{receiver}$ is defined by the RMS pr_airspecified for GBAS Airborne Accuracy Designator A equipment, and $\sigma_{multipath}$ is defined in Appendix B, 3.6.5.5.1. The aircraft contribution to multipath includes the effects of reflections from the aircraft itself. Multipath errors resulting from reflections from other objects are not included. If experience indicates that these errors are not negligible, they must be accounted for operationally.

6.3.9 Tropospheric error. The receiver must use a model to correct for tropospheric effects. The residual error of the model is constrained by the maximum bias and variance defined in Appendix B, 3.5.8.4.2 and 3.5.8.4.3. The effects of this mean must be accounted for by the ground subsystem. The airborne user applies a specified model for the residual tropospheric error (σ_{tropo}).

6.4 RF characteristics

6.4.1 *Minimum GEO signal power level.* The minimum aircraft equipment (e.g. RTCA/DO-229D) is required to operate with a minimum signal strength of –164 dBW at the input of the receiver in the presence of non-RNSS interference (Appendix B, 3.7) and an aggregate RNSS noise density of –173 dBm/Hz. In the presence of interference, receivers may not have reliable tracking performance for an input signal strength below –164 dBW (e.g. with GEO satellites placed in orbit prior to 2014). A GEO that delivers a signal power below –164 dBW at the output of the standard receiving antenna at 5-degree elevation on the ground can be used to ensure signal tracking in a service area contained in a coverage area defined by a minimum elevation angle that is greater than 5 degrees (e.g. 10 degrees). In this case, advantage is taken from the gain characteristic of the standard antenna to perform a trade-off between the GEO signal power and the size of the service area in which a trackable signal needs to be ensured. When planning for the introduction of new operations based on SBAS, States are expected to conduct an assessment of the signal power level as compared to the level interference from RNSS and nonRNSS sources. If the outcome of this analysis indicates that the level of interference is adequate to operate, then operations can be authorized.

6.4.2 *SBAS network time*. SBAS network time is a time reference maintained by SBAS for the purpose of defining corrections. When using corrections, the user's solution for time is relative to the SBAS network time rather than core satellite constellation system time. If corrections are not applied, the position solution will be relative to a composite core satellite constellation/SBAS network time depending on the satellites used and the resulting accuracy will be affected by the difference among them.

6.4.3 *SBAS convolutional encoding.* Information on the convolutional coding and decoding of SBAS messages can be found in RTCA/DO-229C, Appendix A.

6.4.4 *Message timing*. The users' convolutional decoders will introduce a fixed delay that depends on their respective algorithms (usually 5 constraint lengths, or 35 bits), for which they must compensate to determine SBAS network time (SNT) from the received signal.

6.4.5 *SBAS signal characteristics.* Differences between the relative phase and group delay characteristics of SBAS signals, as compared to GPS signals, can create a relative range bias error in the receiver tracking algorithms. The SBAS service provider is expected to account for this error, as it affects receivers with tracking characteristics within the tracking constraints in Attachment D, 8.11. For GEOs for which the on-board RF filter characteristics have been published in RTCA/DO229D, Appendix T, the SBAS service providers are expected to ensure that the UDREs bound the residual errors including the maximum range bias errors specified in RTCA/DO229D. For other GEOs, the SBAS service providers are expected to work with equipment manufacturers in order to determine, through analysis, the maximum range bias errors that can be expected from existing receivers when they process these specific GEOs. This effect can be minimized by ensuring that the GEOs have a wide bandwidth and small group delay across the pass-band.

6.4.6 SBAS pseudo-random noise (PRN) codes. RTCA/DO-229D, Appendix A, provides two methods for SBAS PRN code generation.

6.5 SBAS data characteristics

6.5.1 *SBAS messages*. Due to the limited bandwidth, SBAS data is encoded in messages that are designed to minimize the required data throughput. RTCA/DO-229D, Appendix A, provides detailed specifications for SBAS messages.

6.5.2 *Data broadcast intervals*. The maximum broadcast intervals between SBAS messages are specified in Appendix B, Table B-54. These intervals are such that a user entering the SBAS service broadcast area is able to output a corrected position along with SBAS-provided integrity information in a reasonable time. For en-route, terminal and NPA operations, all needed data will be received within 2 minutes, whereas for precision approach operations, it will take a maximum of 5 minutes. The maximum intervals between broadcasts do not warrant a particular level of accuracy performance as defined in Chapter 3, Table 3.7.2.4-1. In order to ensure a given accuracy performance, each service provider will adopt a set of broadcast intervals taking into account different parameters such as the type of constellations (e.g. GPS with SA, GPS without SA) or the ionospheric activity.

6.5.3 *Time-to-alert.* Figure D-2 provides explanatory material for the allocation of the total time-to-alert defined in Chapter 3, Table 3.7.2.4-1. The time-to-alert requirements in Appendix B, 3.5.7.3.1, 3.5.7.4.1 and 3.5.7.5.1 (corresponding to the GNSS satellite status, basic differential correction and precise differential correction functions, respectively) include both the ground and space allocations shown in Figure D-2.

6.5.4 Tropospheric function. Because tropospheric refraction is a local phenomenon, users will compute their own tropospheric delay corrections. A tropospheric delay estimate for precision approach is described in RTCA/DO-229C, although other models can be used.

6.5.5 Multipath considerations. Multipath is one of the largest contributors to positioning errors for SBAS affecting both ground and airborne elements. For SBAS ground elements, emphasis should be placed on reducing or mitigating the effects of multipath as much as possible so that the signal-in-space uncertainties will be small. Many mitigation techniques have been studied from both theoretical and experimental perspectives. The best approach for implementing SBAS reference stations with minimal multipath errors is to:

a) ensure that an antenna with multipath reduction features is chosen;

b) consider the use of ground plane techniques;

c) ensure that the antenna is placed in a location with low multipath effects; and

d) use multipath-reducing receiver hardware and processing techniques.

6.5.6 *GLONASS issue of data*. Since the existing GLONASS design does not provide a uniquely defined identifier for sets of ephemeris and clock data, SBAS will use a specific mechanism to avoid any ambiguity in the application of the broadcast corrections. This mechanism is explained in Figure D-3. The definitions of the latency time and validity interval along with the associated coding requirements can be found in Appendix B, section 3.5.4. The user can apply the long-term corrections received only if the set of GLONASS ephemeris and clock data used on board have been received within the validity interval.

6.6 SBAS final approach segment (FAS) data block

6.6.1 The SBAS final approach segment (FAS) data block for a particular approach procedure is as shown in Table D-1. It is the same as the GBAS FAS data block defined in Appendix B, section 3.6.4.5, with the exception that the SBAS FAS data block also contains the HAL and VAL to be used for the approach procedure as described in 6.3.4.

6.6.2 FAS data blocks for SBAS and some GBAS approaches are held within a common on-board database supporting both SBAS and GBAS. Within this database, channel assignments must be unique for each approach and coordinated withcivil authorities. States are responsible for providing the FAS data for incorporation into the database. The FAS block for a particular approach procedure is described in Appendix B, 3.6.4.5.1 and Table B-66.

Table D-1. SBAS FAS data block

Data content	Bits used	Range of values	Resolution
Operation type	4	0 to 15	1
SBAS provider ID	4	0 to 15	1
Airport ID	32	–	–
Runway number	6	1 to 36	1
Runway letter	2	–	–
Approach performance designator	3	0 to 7	1
Route indicator	5	–	–
Reference path data selector	8	0 to 48	1
Reference path identifier	32	–	–
LTP/FTP latitude	32	± 90.0°	0.0005 arcsec
LTP/FTP longitude	32	± 180.0°	0.0005 arcsec
LTP/FTP height	16	–512.0 to 6 041.5 m	0.1 m
ΔFPAP latitude	24	± 1.0°	0.0005 arcsec
ΔFPAP longitude	24	± 1.0°	0.0005 arcsec
Approach threshold crossing height (TCH) (Note 1)	15	0 to 1 638.35 m (0 to 3 276.7 ft)	0.05 m (0.1 ft)
Approach TCH units selector	1	–	–
Glide path angle (GPA)	16	0 to 90.0°	0.01°
Course width at threshold	8	80.0 to 143.75 m	0.25 m
ΔLength offset	8	0 to 2 032 m	8 m
Horizontal alert limit (HAL)	8	0 to 50.8 m	0.2 m
Vertical alert limit (VAL) (Note 2)	8	0 to 50.8 m	0.2 m
Final approach segment CRC	32	–	–

Note 1.— Information can be provided in either feet or metres as indicated by the approach TCH unit sector.

Note 2.— VAL of 0 indicates that the vertical deviations are not to be used (i.e. a lateral guidance only approach).

7. Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

Note.— In this section, except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.

7.1 System description

7.1.1 GBAS consists of ground and aircraft elements. A GBAS ground subsystem typically includes a single active VDB transmitter and broadcast antenna, referred to as a broadcast station, and multiple reference receivers. A GBAS ground subsystem may include multiple VDB transmitters and antennas that share a single common GBAS identification (GBAS ID) and frequency as well as broadcast identical data. The GBAS ground subsystem can support all the aircraft subsystems within its coverage providing the aircraft with approach data, corrections and integrity information for GNSS satellites in view. All international aircraft supporting APV should maintain approach data within a database on board the aircraft. The Type 4 message must be broadcast when the ground subsystem supports Category I precision approaches. The Type 4 message must also be broadcast when the ground subsystem supports APV approaches if the approach data is not required by the State to be maintained in the on-board database.

Note.— Allocation of performance requirements between the GBAS subsystems and allocation methodology can be found in RTCA/DO-245, Minimum Aviation System Performance Standards for the Global Positioning System/Local Area Augmentation System (GPS/LAAS). Minimum Operational Performance Standards for GRAS airborne equipment are under development by RTCA.

7.1.2 GBAS ground subsystems provide two services: the approach service and the GBAS positioning service. The approach service provides deviation guidance for FASs in Category I precision approach, APV, and NPA within the operational coverage area. The GBAS positioning service provides horizontal position information to support RNAV operations within the service area. The two services are also distinguished by different performance requirements associated with the particular operations supported (see Table 3.7.2.4-1) including different integrity requirements as discussed in 7.5.1.

7.1.3 A primary distinguishing feature for GBAS ground subsystem configurations is whether additional ephemeris error position bound parameters are broadcast. This feature is required for the positioning service, but is optional for approach services. If the additional ephemeris error position bound parameters are not broadcast, the ground subsystem is responsible for assuring the integrity of ranging source ephemeris data without reliance on the aircraft calculating and applying the ephemeris boundas discussed in 7.5.9.

7.1.4 GBAS. There are multiple configurations possible of GBAS ground subsystems conforming to the GNSS

Standards, such as:

a) configuration that supports Category I precision approach only;

b) a configuration that supports Category I precision approach and APV, and also broadcasts the additional ephemeris error position bound parameters;

c) a configuration that supports Category I precision approach, APV, and the GBAS positioning service, while also broadcasting the ephemeris error position bound parameters referred to in b); and

d) a configuration that supports APV and the GBAS positioning service, and is used within a GRAS.

7.1.5 GRAS configurations. From a user perspective, a GRAS ground subsystem consists of one or more GBAS ground subsystems (as described in 7.1.1 through 7.1.4), each with a unique GBAS identification, providing the positioning service and APV where required. By using multiple GBAS broadcast stations, and by broadcasting the Type 101 message, GRAS is able to support en-route operations via the GBAS positioning service, while also supporting terminal, departure, and APV operations over a larger coverage region than that typically supported by GBAS. In some GRAS applications, the corrections broadcast in the Type 101 message may be computed using data obtained from a network of reference receivers distributed in the coverage region. This permits detection and mitigation of measurement errors and receiver faults.

7.1.6 VDB transmission path diversity. All broadcast stations of a GBAS ground subsystem broadcast identical data with the same GBAS identification on a common frequency. The airborne receiver need not and cannot distinguish between messages received from different broadcast stations of the same GBAS ground subsystem. When within coverage of two such broadcast stations, the receiver will receive and process duplicate copies of messages in different time division multiple access (TDMA) time slots.

7.1.7 Interoperability of the GBAS ground and aircraft elements compatible with RTCA/DO-253A is addressed in Appendix B, 3.6.8.1. GBAS receivers compliant with RTCA/DO-253A will not be compatible with GRAS ground subsystems broadcasting Type 101 messages. However, GRAS and GBAS receivers compliant with RTCA GRAS MOPS, will be compatible with GBAS ground subsystems. SARPs-compliant GBAS receivers may not be able to decode the FAS data correctly for APV transmitted from GBAS ground subsystems. These receivers will apply the FASLAL and FASVAL as if conducting a Category I precision approach. Relevant operational restrictions have to apply to ensure the safety of the operation.

7.1.8 The GBAS VDB transmits with either horizontal or elliptical polarization (GBAS/H or GBAS/E). This allows service providers to tailor the broadcast to their operational requirements and user community.

7.1.9 The majority of aircraft will be equipped with a horizontally-polarized VDB receiving antenna, which can be used to receive the VDB from both GBAS/H and GBAS/E equipment. A subset of aircraft will be equipped with a vertically polarized antenna due to installation limitations or economic considerations. These aircraft are not compatible with GBAS/H equipment and are, therefore, limited to GBAS-based operations supported by GBAS/E.

7.1.10 GBAS service providers must publish the signal polarization (GBAS/H or GBAS/E), for each GBAS facility in the aeronautical information publication (AIP). Aircraft operators that use vertically polarized receiving antenna will haveto take this information into account when managing flight operations, including flight planning and contingency procedures.

7.2 RF characteristics

7.2.1 Frequency coordination

7.2.1.1 Performance factors

7.2.1.1.1 The geographical separation between a candidate GBAS station, a candidate VOR station and existing VOR or GBAS installations must consider the following factors:

a) the coverage volume, minimum field strength and effective radiated power (ERP) of the candidate GBAS including the GBAS positioning service, if provided. The minimum requirements for coverage and field strength are found in

Chapter 3, 3.7.3.5.3 and 3.7.3.5.4.4, respectively. The ERP is determined from these requirements;

b) the coverage volume, minimum field strength and ERP of the surrounding VOR and GBAS stations including the GBAS positioning service, if provided. Specifications for coverage and field strength for VOR are found in Chapter 3, 3.3, and respective guidance material is provided in Attachment C;

c) the performance of VDB receivers, including co-channel and adjacent channel rejection, and immunity to desensitization and intermodulation products from FM broadcast signals. These requirements are found in Appendix B, 3.6.8.2.2;

d) the performance of VOR receivers, including co-channel and adjacent channel rejection of VDB signals. Since existing VOR receivers were not specifically designed to reject VDB transmissions, desired-to-undesired (D/U) signal ratios for co-channel and adjacent channel rejection of the VDB were determined empirically. Table D-2 summarizes the assumed signal ratios based upon empirical performance of numerous VOR receivers designed for 50 kHz channel spacing;

e) for areas/regions of frequency congestion, a precise determination of separation may be required using the appropriate criteria;

Table D-2. Assumed [D/U]required signal ratios to protect VOR from GBAS VDB

Frequency offset	$[D/U]_{required}$ ratio to protect VOR receivers (dB)
Co-channel	26
$\lvert f_{VOR} - f_{VDB} \rvert = 25$ kHz	0
$\lvert f_{VOR} - f_{VDB} \rvert = 50$ kHz	−34
$\lvert f_{VOR} - f_{VDB} \rvert = 75$ kHz	−46
$\lvert f_{VOR} - f_{VDB} \rvert = 100$ kHz	−65

f) that between GBAS installations RPDS and RSDS numbers are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. The requirement is found in Appendix B, 3.6.4.3.1;

g) that between GBAS installations within radio range of a particular GBAS ground subsystem the reference path identifier is assigned to be unique. The requirement is found in Appendix B, 3.6.4.5.1; and

h) the four-character GBAS ID to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Appendix B, 3.6.3.4.1.

7.2.1.1.2 Nominal link budgets for VDB are shown in Table D-3. The first example in Table D-3 assumes a user receiver height of 3 000 m (10 000 ft) MSL and a transmit antenna designed to suppress ground illumination in order to limit the fading losses to a maximum of 10 dB at coverage edge. In the case of GBAS/E equipment, the 10 dB also includes any effects of signal loss due to interference between the horizontal and vertical components. The second example in Table D-3 provides a link budget for longer range positioning service. It is for a user receiver height sufficient to maintain radio line-of sight with a multi-path limiting transmitting antenna. No margin is given for fading as it is assumed that the receiver is at low elevation angles of radiation and generally free from significant null for the distances shown in the table (greater than 50 NM).

7.2.1.2 *FM immunity*

7.2.1.2.1 Once a candidate frequency is identified for which the GBAS and VOR separation criteria are satisfied, compatibility with FM transmissions must be determined. This is to be accomplished using the methodology applied when determining FM compatibility with VOR. If FM broadcast violates this criterion, an alternative candidate frequency has to be considered.

7.2.1.2.2 The desensitization is not applied for FM carriers above 107.7 MHz and VDB channels at 108.050 MHz because the off-channel component of such high-level emissions from FM stations above 107.7 MHz will interfere with GBAS VDB operations on 108.025 and 108.050 MHz, hence those assignments will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate interference in the VDB receiver.

7.2.1.2.3 The FM intermodulation immunity requirements are not applied to a VDB channel operating below 108.1 MHz, hence assignments below 108.1 MHz will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate intermodulation products in the VDB receiver.

7.2.1.3 Geographic separation methodologies

7.2.1.3.1 The methodologies below may be used to determine the required GBAS-to-GBAS and GBAS-to-VOR geographical separation. They rely on preserving the minimum desired-to-undesired signal ratio. [D/U]*required* is defined as the signal ratio intended to protect the desired signal from co-channel or adjacent channel interference from an undesired transmission. [D/U]*required* values required for protection of a GBAS receiver from undesired GBAS or VOR signals are defined in Appendix B, 3.6.8.2.2.5 and 3.6.8.2.2.6. [D/U]*required* values intended for protection of a VOR receiver from GBAS VDB transmissions as shown in Table D-2 are not defined in SARPs and represent the assumed values based on test results.

7.2.1.3.2 Geographic separation is constrained by preserving [D/U]*required* at the edge of the desired signal coverage where the desired signal power is derived from the minimum field strength requirements in Chapter 3. This desired signal level, converted to dBm, is denoted PD, min. The allowed signal power of the undesired signal (PU,allowed) is:

$$P_{Uallowed}(dBm) = (P_{D,min}\ (dBm) - [D/U]_{required}\ (dB))$$

where

TxU is the effective radiated power of the undesired transmitter; and

L is the transmission loss of the undesired transmitter, including free-space path loss, atmospheric and ground effects.
This loss depends upon the distance between the undesired transmitter and the edge of the desired signal coverage.

To ensure D/U*required* is satisfied, Pu ≤DU*allowed*. The constraint for assigning a channel is therefore:

$$P_U(dBm) = (Tx_U\ (dBm) - L\ (dB))$$

7.2.1.3.3 The transmission loss can be obtained from standard propagation models published in ITU-R Recommendation P.528-2 or from free-space attenuation until the radio horizon and then a constant 0.5 dB/NM attenuation factor. These two methodologies result in slightly different geographical separation for co-channel and first adjacent channels, and identical separation as soon as the second adjacent channel is considered. The free-space propagation approximation is applied in this guidance material.

7.2.1.4 Example of GBAS/GBAS geographical separation criteria

7.2.1.4.1 For GBAS VDB co-channel transmissions assigned to the same time slot, the parameters for horizontal polarization are:

D/U = 26 dB (Appendix B, 3.6.8.2.2.5.1);

$P_{D,min}$ = –72 dBm (equivalent to 215 microvolts per metre, Chapter 3, 3.7.3.5.4.4); and

T_{xU} = 47 dBm (example link budget, Table D-3);

$$L \geq (47 + 26 - (-72)) = 145 \text{ dB}.$$

7.2.1.4.2 The geographic separation for co-channel, co-slot GBAS VDB assignments is obtained by determining the distance at which the transmission loss equals 145 dB for receiver altitude of 3 000 m (10 000 ft) above that of the GBAS VDB transmitter antenna. This distance is 318 km (172 NM) using the free-space attenuation approximation and assuming a negligible transmitter antenna height. The minimum required geographical separation can then be determined by adding this distance to the nominal distance between the edge of coverage and the GBAS transmitter 43 km (23 NM). This results in a co-channel, co-slot reuse distance of 361 km (195 NM).

7.2.1.5 *Guidelines on GBAS/GBAS geographical separation criteria*. Using the methodology described above, typical geographic separation criteria can be defined for GBAS to GBAS and GBAS to VOR. The resulting GBAS/GBAS minimum required geographical separation criteria are summarized in Table D-4.

Note.— Geographical separation criteria between the GBAS transmitters providing the GBAS positioning service are under development. A conservative value corresponding to the radio horizon may be used as an interim value for separation between co-frequency, adjacent time slot transmitters to ensure time slots do not overlap.

7.2.1.6 *Guidelines on GBAS/VOR geographical separation criteria.* The GBAS/VOR minimum geographical separation criteria are summarized in Table D-5 based upon the same methodology and the nominal VOR coverage volumes in Attachment C.

Table D-3. Nominal VDB link budget

VDB link elements				
For approach service	Vertical component at coverage edge		Horizontal component at coverage edge	
Required receiver sensitivity (dBm)	−87		−87	
Maximum aircraft implementation loss (dB)	11		15	
Power level after aircraft antenna (dBm)	−76		−72	
Operating margin (dB)	3		3	
Fade margin (dB)	10		10	
Free space path loss (dB) at 43 km (23 NM)	106		106	
Nominal effective radiated power (ERP) (dBm)	43		47	
For longer range and low radiation angle associated with positioning service	Vertical component		Horizontal component	
Required receiver sensitivity (dBm)	−87		−87	
Maximum aircraft implementation loss (dB)	11		15	
Power level after aircraft antenna (dBm)	−76		−72	
Operating margin (dB)	3		3	
Fade margin (dB)	0		0	
Nominal ERP (dBm)				
Range (km (NM)) / Free space loss (dB)	ERP (dBm)	ERP (W)	ERP (dBm)	ERP (W)
93 (50) / 113	39.9	10	43.9	25
185 (100) / 119	45.9	39	49.9	98
278 (150) / 122	49.4	87	53.4	219
390 (200) / 125	51.9	155	55.9	389

Notes.—

1. *In this table ERP is referenced to an isotropic antenna model.*
2. *It is possible, with an appropriately sited multipath limiting VDB transmitting antenna with an ERP sufficient to meet the field strength requirements for approach service and considering local topographical limitations, to also satisfy the field strength requirements such that positioning service can be supported at the ranges in this table.*
3. *Actual aircraft implementation loss (including antenna gain, mismatch loss, cable loss, etc.) and actual receiver sensitivity may be balanced to achieve the expected link budget. For example, if the aircraft implementation loss for the horizontal component is 19 dB, the receiver sensitivity must exceed the minimum requirement and achieve -91 dBm to satisfy the nominal link budget.*

Note 1.— When determining the geographical separation between VOR and GBAS, VOR as the desired signal is generally the constraining case due to the greater protected altitude of the VOR coverage region.

Note 2.— Reduced geographical separation requirements can be Pobtained using standard propagation models defined in ITU-R Recommendation P.528-2.

7.2.2 The geographical separation criteria for GBAS/ILS and GBAS/VHF communications are under development.

7.2.3 Compatibility with ILS. Until compatibility criteria are developed for GBAS VDB and ILS, VDB cannot be assigned to channels below 112.025 MHz. If there is an ILS with a high assigned frequency at the same airport as a VDB with a frequency near 112 MHz, it is necessary to consider ILS and VDB compatibility. Considerations for assignment of

VDB channels include the frequency separation between the ILS and the VDB, the distance separation between the ILS coverage area and the VDB, the VDB and ILS field strengths, and the VDB and ILS sensitivity. For GBAS equipment with transmitter power of up to 150 W (GBAS/E, 100 W for horizontal component and 50 W for vertical component) or 100 W (GBAS/H), the 16th channel (and beyond) will be below –106 dBm at a distance of 200 m from the VDB transmitter, including allowing for a +5 dB positive reflection. This –106 dBm figure assumes a –86 dBm localizer signal at the ILS receiver input and a minimum 20 dB signal-to-noise ratio.

7.2.4 Compatibility with VHF communications. For GBAS VDB assignments above 116.400 MHz, it is necessary to consider VHF communications and GBAS VDB compatibility. Considerations for assignment of these VDB channels include the frequency separation between the VHF communication and the VDB, the distance separation between the transmitters and coverage areas, the field strengths, the polarization of the VDB signal, and the VDB and VHF sensitivity. Both aircraft and ground VHF communication equipment are to be considered. For GBAS/E equipment with a transmitter maximum power of up to 150 W (100 W for horizontal component and 50 W for vertical component), the 64th channel (and beyond) will be below –120 dBm at a distance of 200 m from the VDB transmitter including allowing for a +5 dB positive reflection. For GBAS/H equipment with a transmitter maximum power of 100 W, the 32nd channel (and beyond) will be below –120 dBm at a distance of 200 m from the VDB transmitter including allowing for a +5 dB positive reflection, and a 10 dB polarization isolation. It must be noted that due to differences in the VDB and VDL transmitter masks, separate analysis must be performed to ensure VDL does not interfere with the VDB.

Table D-4. Typical GBAS/GBAS frequency assignment criteria

Channel of undesired VDB in the same time slots	Path loss (dB)	Minimum required geographical separation for Tx_U = 47 dBm and $P_{D,min}$ = –72 dBm in km (NM)
Cochannel	145	361 (195)
1st adjacent channel (±25 kHz)	101	67 (36)
2nd adjacent channel (±50 kHz)	76	44 (24)
3rd adjacent channel (±75 kHz)	73	No restriction
4th adjacent channel (±100 kHz)	73	No restriction

Note.— No geographic transmitter restrictions are expected between co-frequency, adjacent time slots provided the undesired VDB transmitting antenna is located at least 200 m from areas where the desired signal is at minimum field strength.

Table D-5. Minimum required geographical separation for a VOR coverage (12 000 m (40 000 ft) level)

Channel of undesired GBAS VDB	Path loss (dB)	VOR coverage radius		
		342 km (185 NM)	300 km (162 NM)	167 km (90 NM)
Co-channel	152	892 km (481 NM)	850 km (458 NM)	717 km (386 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 25 kHz	126	774 km (418 NM)	732 km (395 NM)	599 km (323 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 50 kHz	92	351 km (189 NM)	309 km (166 NM)	176 km (94 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 75 kHz	80	344 km (186 NM)	302 km (163 NM)	169 km (91 NM)
$\lvert f_{Desired} - f_{Undesired} \rvert$ = 100 kHz	61	No restriction	No restriction	No restriction

Note.— Calculations are based on reference frequency of 112 MHz and assume GBAS Tx_U = 47 dBm and VOR $P_{D,min}$ = –79 dBm.

7.2.5 For a GBAS ground subsystem that only transmits a horizontally-polarized signal, the requirement to achieve the power associated with the minimum sensitivity is directly satisfied through the field strength requirement. For a GBAS ground subsystem that transmits an elliptically-polarized component, the ideal phase offset between HPOL and VPOL components is 90 degrees. In order to ensure that an appropriate received power is maintained throughout the GBAS coverage volume during normal aircraft manoeuvres, transmitting equipment should be designed to radiate HPOL and VPOL signal components with an RF phase offset of 90 degrees. This phase offset should be consistent over time and environmental conditions. Deviations from the nominal 90 degrees must be accounted for in the system design and link budget, so that any fading due to polarization loss does not jeopardize the minimum receiver sensitivity. System qualification and flight inspection procedures will take into account an allowable variation in phase offset consistent with maintaining the appropriate signal level throughout the GBAS coverage volume. One method of ensuring both horizontal and vertical field strength is to use a single VDB antenna that transmits an elliptically-polarized signal, and flight inspect the effective fieldstrength of the vertical and horizontal signals in the coverage volume.

7.3 Coverage

7.3.1 The GBAS coverage to support approach services is depicted in Figure D-4. When the additional ephemeris error position bound parameters are broadcast, differential corrections may only be used within the Maximum Use Distance (Dmax) defined in the Type 2 message. Where practical, it is operationally advantageous to provide valid guidance along the visual segment of an approach.

7.3.2 The coverage required to support the GBAS positioning service is dependent upon the specific operations intended. The optimal coverage for this service is intended to be omnidirectional in order to support operations using the GBAS positioning service that are performed outside of the precision approach coverage volume. Each State is responsible for defining a service area for the GBAS positioning service and ensuring that the requirements of Chapter 3, 3.7.2.4 are satisfied. When making this determination, the characteristics of the fault-free GNSS receiver should be considered, including the reversion to ABAS-based integrity in the event of loss of GBAS positioning service.

7.3.3 The limit on the use of the GBAS positioning service information is given by the Maximum Use Distance (Dmax), which defines the range within which the required integrity is assured and differential corrections can be used for either the positioning service or precision approach. Dmax however does not delineate the coverage area where field strength requirements specified in Chapter 3, 3.7.3.5.4.4 are met nor matches this area. Accordingly, operations based on the GBAS positioning service can be predicated only in the coverage area(s) (where the field strength requirements are satisfied) within the Dmax range.

7.3.4 As the desired coverage area of a GBAS positioning service may be greater than that which can be provided by a single GBAS broadcast station, a network of GBAS broadcast stations can be used to provide the coverage. These stations can broadcast on a single frequency and use different time slots (8 available) in neighbouring stations to avoid interference or they can broadcast on different frequencies. Figure D-4A details how the use of different time slots will allow a single frequency to be used without interference subject to guard time considerations noted under Table B-59. For a network based on different VHF frequencies, guidance material in 7.17 should be considered.

7.4 Data structure

A bit scrambler/descrambler is shown in Figure D-5.

Note.— Additional information on the data structure of the VHF data broadcast is given in RTCA/DO-246B, GNSS Based Precision Approach Local Area Augmentation System (LAAS) — Signal-in-Space Interface Control Document (ICD).

7.5 Integrity

7.5.1 Different levels of integrity are specified for precision approach operations and operations based on the GBAS positioning service. The signal-in-space integrity risk for Category I is 2 × 10-7per approach. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service have to also meet the signal-in-space integrity risk requirement specified for terminal area operations, which is 1 × 10-7/hour (Chapter 3, Table 3.7.2.4-1). Therefore additional measures are necessary to support these more stringent requirements for positioning service. The signal-in-space integrity risk is allocated between the ground subsystem integrity risk and the protection level integrity risk. The ground subsystem integrity risk allocation covers failures in the ground subsystem as well as core constellation and SBAS failures such as signal quality failures and ephemeris failures. The protection level integrity risk allocation covers rare fault free performance risks and the case of failures in one of the reference receiver measurements. In both cases the protection level equations ensure that the effects of the satellite geometry used by the aircraft receiver are taken into account. This is described in more detail in the following paragraphs.

7.5.2 The GBAS ground subsystem defines a corrected pseudo-range error uncertainty for the error relative to the GBAS reference point (σ_{pr_gnd}) and the errors resulting from vertical (σ_{tropo}) and horizontal (σ_{iono}) spatial decorrelation. These uncertainties are modelled by the variances of zero-mean, normal distributions which describe these errors for each ranging source.

7.5.3 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. General methods for determining that the model variance is adequate to guarantee the protection level integrity risk are described in Section 14. The lateral protection level (LPL) provides a bound on the lateral position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. For Category I precision approach and APV, if the computed LPL exceeds the lateral alert limit (LAL) or the VPL exceeds the vertical alert limit (VAL), integrity is not adequate to support the operation. For the positioning service the alert limits are not defined in the standards, with only the horizontal protection level and ephemeris error position bounds required to be computed and applied. The alert limits will be determined based on the operation being conducted. The aircraft will apply the computed protection level and ephemeris bounds by verifying they are smaller than the alert limits. Two protection levels are defined, one to address the condition when all reference receivers are fault-free (H0– Normal Measurement Conditions), and one to address the condition when one of the reference receivers contains failed measurements (H1– Faulted Measurement Conditions). Additionally an ephemeris error position bound provides a bound on the position error due to failures in ranging source ephemeris. For Category I precision approach and APV, a lateral error bound (LEB) and a vertical error bound (VEB) are defined. For the positioning service a horizontal ephemeris error bound (HEB) is defined.

7.5.4 Ground system contribution to corrected pseudo-range error (σ_{pr_gnd}). Error sources that contribute to this error include receiver noise, multipath, and errors in the calibration of the antenna phase centre. Receiver noise has a zero-mean, normally distributed error, while the multipath and antenna phase centre calibration can result in a small mean error.

7.5.5 *Residual tropospheric errors*. Tropospheric parameters are broadcast in Type 2 messages to model the effects of the troposphere, when the aircraft is at a different height than the GBAS reference point. This error can be well-characterized by a zero-mean, normal distribution.

7.5.6 *Residual ionospheric errors.* An ionospheric parameter is broadcast in Type 2 messages to model the effects of the ionosphere between the GBAS reference point and the aircraft. This error can be well-characterized by a zero-mean, normal distribution.

7.5.7 *Aircraft receiver contribution to corrected pseudo-range error.* The receiver contribution is bounded as described in Section 14. The maximum contribution, used for analysis by the GBAS provider, can be taken from the accuracy requirement, where it is assumed that $\sigma_{receiver}$ equals $RMS_{pr_air}$for GBAS Airborne Accuracy Designator A equipment.

7.5.8 *Airframe multipath error.* The error contribution from airframe multipath is defined in Appendix B, 3.6.5.5.1. Multipath errors resulting from reflections from other objects are not included. If experience indicates that these errors are not negligible, they must be accounted for operationally or through inflation of the parameters broadcast by the ground (e.g. σ_{pr_gnd}).

7.5.9 Ephemeris error uncertainty. Pseudo-range errors resulting from ephemeris errors (defined as a discrepancy between the true satellite position and the satellite position determined from the broadcast data) are spatially decorrelated and will therefore be different for receivers indifferent locations. When users are relatively close to the GBAS reference point, the residual differential error due to ephemeris errors will besmall and both the corrections and uncertainty parameters σ_{pr_gnd}sent by the ground subsystem will be valid to correct the raw measurements and compute the protection levels. For users further away from the GBAS reference point, protection against ephemeris failures can be ensured in two different ways:

a) the ground subsystem does not transmit the additional ephemeris error position bound parameters. In this case, the ground subsystem is responsible for assuring integrity in case of satellite ephemeris failures without reliance on the aircraft calculating and applying the ephemeris bound. This may impose a restriction on the distance between the GBAS reference point and the decision altitude/height depending upon the ground subsystem means of detecting ranging source ephemeris failures. One means of detection is to use satellite integrity information broadcast by SBAS; and

b) the ground subsystem transmits the additional ephemeris error position bound parameters which enable the airborne receiver to compute an ephemeris error bound. These parameters are: coefficients used in the ephemeris error position bound equations (Kmd_e_(), where the subscript () means either “GPS”, “GLONASS”, “POS, GPS” or “POS, GLONASS”), the maximum use distance for the differential corrections (Dmax), and the ephemeris decorrelation parameters (P). The ephemeris decorrelation parameter (P) in the Type 1 or Type 101 message characterizes the residual error as a function of distance between the GBAS reference point and the aircraft. The value of P is expressed in m/m. The values of P are determined by the ground subsystem for each satellite. One of the main factors influencing the values of P is the ground subsystem monitor design. The quality of the ground monitor will be characterized by the smallest ephemeris error (or minimum detectable error (MDE)) that it can detect. The relationship between the P parameter and the MDE for a particular satellite can be approximated by Pi = MDEi/Riwhere Riis the smallest of the predicted ranges from the ground subsystem reference receiver antenna(s) for the period of validity of Pi. Being dependent on satellite geometry, the P parameters values are slowly varying. However, it is not a requirement for the ground subsystem to dynamically vary P. Static P parameters could be sent if they properly ensure integrity. In this latter case, the availability would be slightly degraded. Generally, as MDE becomes smaller, overall GBAS availability improves.

7.5.10 *Ephemeris error/failure monitoring*. There are several types of monitoring approaches for detecting ephemeris errors/failures. They include:

a) *Long baseline*. This requires the ground subsystem to use receivers separated by large distances to detect ephemeris errors that are not observable by a single receiver. Longer baselines translate to better performance in MDE;

b) *SBAS*. Since SBAS augmentation provides monitoring of satellite performance, including ephemeris data, integrity information broadcast by SBAS can be used as an indication of ephemeris validity. SBAS uses ground subsystem receivers installed over very long baselines, therefore this provides optimum performance for ephemeris monitoring and thus achieves small MDEs; and

c) *Ephemeris data monitoring*. This approach involves comparing the broadcast ephemeris over consecutive satellite orbits. There is an assumption that the only threat of failure is due to a failure in ephemeris upload from the constellation ground control network. Failures due to uncommanded satellite manoeuvres must be sufficiently improbable to ensure that this approach provides the required integrity.

7.5.10.1 The monitor design (for example, its achieved MDE) is to be based upon the integrity risk requirements and the failure model the monitor is intended to protect against. A bound on the GPS ephemeris failure rate can be determined from the reliability requirements defined in Chapter 3, 3.7.3.1.3, since such an ephemeris error would constitute a major service failure.

7.5.10.2 The GLONASS control segment monitors the ephemeris and time parameters, and in case of any abnormal situation it starts to input the new and correct navigation message. The ephemeris and time parameter failures do not exceed 70 m of range errors. The failure rate of GLONASS satellite including the ephemeris and time parameter failures does not exceed 4 ×10-5per satellite per hour.

7.5.11 A typical GBAS ground subsystem processes measurements from 2 to4 reference receivers installed in the immediate vicinity of the reference point. The aircraft receiver is protected against a large error or fault condition in a single reference receiver by computing and applying the B parameters from the Type 1 or Type 101 message to compare data from the various reference receivers. Alternative system architectures with sufficiently high redundancy in reference receiver measurements may employ processing algorithms capable of identifying a large error or fault in one of the receivers. This may apply for a GRAS network with receivers distributed over a wide area and with sufficient density of ionospheric pierce points to separate receiver errors from ionospheric effects. The integrity can then be achieved using only the protection levels for normal measurement conditions (VPLH0and LPLH0), with appropriate values for Kffmd and σpr_gnd. This can be achieved using the Type 101 message with the B parameters excluded.

7.6 Continuity of service

7.6.1 Ground continuity and integrity designator. The ground continuity and integrity designator (GCID) provides a classification of GBAS ground subsystems. The ground subsystem meets the requirements of Category I precision approach or APV when GCID is set to 1. GCID 2, 3 and 4 are intended to support future operations with requirements that are more stringent than Category I operations. The GCID is intended to be an indication of ground subsystem status to be used when an aircraft selects an approach. It is not intended to replace or supplement an instantaneous integrity indication communicatedin a Type 1 or Type 101 message. GCID does not provide any indication of the ground subsystem capability to support the GBAS positioning service.

7.6.2 Ground subsystem continuity of service. GBAS ground subsystems are required to meet the continuity specified in Appendix B to Chapter 3, 3.6.7.1.3 in order to support Category I precision approach and APV. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service should support the minimum continuity required for terminal area operations, which is 1–10–4/hour (Chapter 3, Table 3.7.2.4-1). When the Category I precision approach or APV required continuity (1–8 × 10–6/15 seconds) is converted to a per hour value it does not meet the 1–10–4/hour minimum continuity requirement. Therefore, additional measures are necessary to meet the continuity required for other operations. One method of showing compliance with this requirement is to assume that airborne implementation uses both GBAS and ABAS to provide redundancy and that ABAS provides sufficient accuracy for the intended operation.

7.7 GBAS channel selection

7.7.1 Channel numbers are used in GBAS to facilitate an interface between aircraft equipment and the signal-in-space that is consistent with interfaces for ILS and MLS. The cockpit integration and crew interface for GBAS may be based on entry of the 5-digit channel number. An interface based on approach selection through a flight management function similar to current practice with ILS is also possible. The GBAS channel number may be stored in an on-board navigation database as part of a named approach. The approach may be selected by name and the channel number can automatically be provided to the equipment that must select the appropriate GBAS approach data from the broadcast data. Similarly, the use of the GBAS positioning service may be based on the selection of a 5-digit channel number. This facilitates conducting operations other than the approaches defined by the FAS data. To facilitate frequency tuning, the GBAS channel numbers for neighbouring GBAS ground subsystems supporting positioning service may be provided in the Type 2 message additional data block 2.

7.7.2 A channel number in the range from 20 001 to 39 999 is assigned when the FAS data are broadcast in the Type 4 message. A channel number in the range from 40 000 to 99 999 is assigned when the FAS data associated with an APV are obtained from the on-board database.

7.8 Reference path data selector and reference station data selector

A mapping scheme provides a unique assignment of a channel number to each GBAS approach. The channel number consists of five numeric characters in the range 20001 to 39 999. The channel number enables the GBAS airborne subsystem to tune to the correct frequency and select the final approach segment (FAS) data block that defines the desired approach. The correct FAS data block is selected by the reference path data selector (RPDS), which is included as part of the FAS definition data in a Type 4 message. Table D-6 shows examples of the relationship between the channel number, frequency and RPDS.

The same mapping scheme applies to selection of the positioning service through the reference station data selector (RSDS).

The RSDS is broadcast in the Type 2 message and allows the selection of a unique GBAS ground subsystem that provides the positioning service. For GBAS ground subsystems that do not provide the positioning service and broadcast the additional ephemeris data, the RSDS is coded with a value of 255. All RPDS and RSDS broadcast by a ground subsystem must be unique on the broadcast frequency within radio range of the signal. The RSDS value must not be the same as any of the broadcast RPDS values.

7.9 Assignment of RPDS and RSDS by service provider

RPDS and RSDS assignments are to be controlled to avoid duplicate use of channel numbers within the protection region for the data broadcast frequency. Therefore, the GBAS service provider has to ensure that an RPDS and RSDS are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. Assignments of RPDS and RSDS are to be managed along with assignments of frequency and time slots for the VHF data broadcast.

Table D-6. Channel assignment examples

Channel number (N)	Frequency in MHz (F)	Reference path data selector (RPDS) or Reference station data selector (RSDS)
20 001	108.025	0
20 002	108.05	0
20 003	108.075	0
....	....	....
20 397	117.925	0
20 398	117.95	0
20 412 (Note)	108.025	1
20 413	108.05	1
....	....	....

Note.— Channels between 20 398 and 20 412 are not assignable because the channel algorithm maps them to frequencies outside the range of 108.025 MHz and 117.950 MHz. A similar "gap" in the channel assignments occurs at each RPDS transition.

7.10 GBAS identification

The GBAS identification (ID) is used to uniquely identify a GBAS ground subsystem broadcasting on a given frequency within the coverage region of the GBAS. The aircraft will navigate using data broadcast from one or more GBAS broadcast stations of a single GBAS ground subsystem (as identified by a common GBAS identification).

7.11 Final approach segment (FAS) path

7.11.1 FAS path is a line in space defined by the landing threshold point/fictitious threshold point (LTP/FTP), flight path alignment point (FPAP), threshold crossing height (TCH) and glide path angle (GPA). These parameters are determined

from data provided in a FAS data block within a Type 4 message or in the on-board database. The relationship between these parameters and the FAS path is illustrated in Figure D-6.

7.11.1.1 FAS data blocks for SBAS and some GBAS approaches are held within a common onboard database supporting both SBAS and GBAS. States are responsible for providing the FAS data to support APV procedures when the Type 4 message is not broadcast. These data comprise the parameters contained within the FAS block, the RSDS, and associated broadcast frequency. The FAS block for a particular approach procedure is described in Appendix B, 3.6.4.5.1 and Table B-66.

7.11.2 FAS path definition

7.11.2.1 Lateral orientation. The LTP/FTP is typically at or near the runway threshold. However, to satisfy operational needs or physical constraints, the LTP/FTP may not be at the threshold. The FPAP is used in conjunction with the LTP/FTP to define the lateral reference plane for the approach. For a straight-in approach aligned with the runway, the FPAP will be at or beyond the stop end of the runway. The FPAP is not placed before the stop end of the runway.

7.11.2.2 *ΔLength offset*. The Δlength offset defines the distance from the end of the runway to the FPAP. This parameter is provided to enable the aircraft equipment to compute the distance to the end of the runway. If the Δlength offset is not set to appropriately indicate the end of the runway relative to the FPAP, the service provider should ensure the parameter is coded as "not provided".

7.11.2.3 Vertical orientation. Local vertical for the approach is defined as normal to the WGS-84 ellipsoid at the LTP/FTP and may differ significantly from the local gravity vector. The local level plane for the approach is defined as a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). The datum crossing point (DCP) is a point at a height defined by TCH above the LTP/FTP. The FAS path is defined as a line with an angle (defined by the GPA) relative to the local level plane passing through the DCP. The GPIP is the point where the final approach path intercepts the local level plane. The GPIP may actually be above or below the runway surface depending on the curvature of the runway.

7.11.3 "ILS look-alike" deviation computations. For compatibility with existing aircraft designs, it is desirable for aircraft equipment to output guidance information in the form of deviations relative to a desired flight path defined by the FAS path. The Type 4 message includes parameters that support the computation of deviations that are consistent with typical ILS installations.

7.11.3.1 Lateral deviation definition. Figure D-6 illustrates the relationship between the FPAP and the origin of the lateral angular deviations. The course width parameter and FPAP are used to define the origin and sensitivity of the lateral deviations. By adjusting the location of the FPAP and the value of the course width, the course width and sensitivity of a GBAS can be set to the desired values. They may be set to match the course width and sensitivity of an existing ILS or MLS. This may be necessary, for example, for compatibility with existing visual landing aids.

7.11.3.1.1 Lateral deviation reference. The lateral deviation reference plane is the plane that includes the LTP/FTP, FPAP and a vector normal to the WGS-84 ellipsoid at the

LTP/FTP. The rectilinear lateral deviation is the distance of the computed aircraft position from the lateral deviation reference plane. The angular lateral deviation is a corresponding angulardisplacement referenced to the GBAS azimuth reference point (GARP). The GARP is defined to be beyond the FPAP along the procedure centre line by a fixed offset value of 305 m (1 000 ft).

7.11.3.1.2 *Lateral displacement sensitivity.* The lateral displacement sensitivity is determined by the aircraft equipment from the course width provided in the FAS data block. The service provider is responsible for setting the course width parameter to a value that results in the appropriate angle for full scale deflection (i.e. 0.155 DDM or 150 µA) taking into account any operational constraints.

7.11.3.2 Vertical deviations. Vertical deviations are computed by the aircraft equipment with respect to a GBAS elevation reference point (GERP). The GERP may be at the GPIPor laterally offset from the GPIP by a fixed GERP offset value of 150 m. Use of the offset GERP allows the glide path deviations to produce the same hyperbolic effects that are normal characteristics of ILS and MLS (below200 ft). The decision to offset the GERP or not is made by the aircraft equipment in accordance with requirements driven by compatibility with existing aircraft systems. Service providers should be aware that users may compute vertical deviations using a GERP which is placed at either location. Sensitivity of vertical deviations is set automatically in the aircraft equipment asa function of the GPA. The specified relationship between GPA and the full scale deflection (FSD) of the vertical deviation sensitivity is: FSD = 0.25*GPA. The value 0.25 is the same as forMLS (Attachment G, 7.4.1.2) and differs slightly from the nominal value of 0.24 recommended for ILS (Chapter 3, section 3.1.5.6.2). However, the value specified is well within the tolerances recommended for ILS (0.2 to 0.28). Therefore the resulting sensitivity is equivalent to the glide path displacement sensitivity provided by a typical ILS.

7.11.4 *Approaches not aligned with the runway.* Some operations may require the definition of a FAS path that is not aligned with the runway centre line as illustrated in Figure D-7. For approaches not aligned with the runway, the LTP/FTP may or may not lie on the extended runway centre line. For this type of approach Δlength offset is not meaningful and should be set to “not provided”.

7.11.5 *SBAS service provider.* A common format is used for FAS data blocks to be used by both GBAS and SBAS. The SBAS service provider ID field identifies which SBAS system(s) may be used by an aircraft that is using the FAS data during an approach. The GBAS service provider may inhibit use of the FAS data in conjunction with any SBAS service. For precision approaches based on GBAS this field is not used, and it can be ignored by aircraft GBAS equipment.

7.11.6 Approach identifier. The service provider is responsible for assigning the approach identifier for each approach. The approach identification should be unique within a large geographical area. Approach identifications for multiple runways at a given aerodrome should be chosen to reduce the potential for confusion and misidentification. The approach identification should appear on the published charts that describe the approach. The first letter of the approach identifier is used in the authentication protocols for GBAS. Ground stations that support the authentication protocols must encode the first character of the identifier for all approaches supported from the set of letters {A X Z J C V P T} as described in Appendix B, section 3.6.7.4.1.4. This enables airborne equipment (that supports the authentication protocols) to determine which slots are assigned to the ground station and therefore to subsequently ignore reception of data broadcast in slots not assigned to the selected ground station. For ground stations that do not support the authentication protocols, the first character of the approach identifier may be assigned any character except those in the set {A X Z J C V P T}.

7.12 Airport siting considerations

7.12.1 The installation of a GBAS ground subsystem involves special considerations in choosing prospective sites for the reference receiver antennas and the VDB antenna(s). In planning antenna siting, Annex 14 obstacle limitation requirements must be met.

7.12.2 Locating reference receiver antennas. The site should be selected in an area free of obstructions, so as to permit the reception of satellite signals at elevation angles as low as possible. In general, anything masking GNSS satellites at elevation angles higher than 5 degrees will degrade system availability.

7.12.2.1 The antennas for the reference receivers should be designed and sited to limit multipath signals that interfere with the desired signal. Mounting antennas close to a ground plane reduces long-delay multipath resulting from reflections below the antenna. Mounting height should be sufficient to prevent the antenna being covered by snow, or being interfered with by maintenance personnel or ground traffic. The antenna should be sited so that any metal structures, such as air vents, pipes and other antennas are outside the near-field effects of the antenna.

7.12.2.2 Besides the magnitude of the multipath error at each reference receiver antenna location, the degree of correlation must also be considered. Reference receiver antennas should be located in places that provide independent multipath environments.

7.12.2.3 The installation of each antenna should include a mounting that will not flex in winds or under ice loads. Reference receiver antennas should be located in an area where access is controlled. Traffic may contribute to error due to multipath or obstruct view of satellites from the antennas.

7.12.3 Locating the VDB antenna. The VDB antenna should be located so that an unobstructed line-of-sight exists from the antenna to any point within the coverage volume for each supported FAS. Consideration should also be given to ensuring the minimum transmitter-to-receiver separation so that the maximum field strength is not exceeded. In order to provide the required coverage for multiple FASs at a given airport, and in order to allow flexibility in VBD antenna siting, the actual coverage volume around the transmitter antenna may need to be considerably larger than that required for a single FAS. The ability to provide this coverage is dependent on the VDB antenna location with respect to the runway and the height of the VDB antenna. Generally speaking, increased antenna height may be needed to provide adequate signal strength to users at low altitudes, but may also result in unacceptable multipath nulls within the desired coverage volume. A suitable antenna height trade-off must be made based on analysis, to ensure the signal strength requirements are met within the entire volume. Consideration should also be given to the effect of terrain features and buildings on the multipath environment.

7.12.4 Use of multiple transmit antennas to improve VDB coverage. For some GBAS installations, constraints on antenna location, local terrain or obstacles may result in ground multipath and/or signal blockage that make it difficult to provide the specified field strength at all points within the coverage area. Some GBAS ground facilities may make use of one or more additional antenna systems, sited to provide signal path diversity such that collectively they meet the coverage requirements.

7.12.4.1 Whenever multiple antenna systems are used, the antenna sequence and message scheduling must be arranged to provide broadcasts at all points within the coverage area that adhere to the specified minimum and maximum data broadcast rates and field strengths, without exceeding the receiver’s ability to adapt to transmission-to-transmission variations in signal strength in a given slot. To avoid receiver processing issues concerning lost or duplicated messages, all transmissions of the Type 1 or Type

101 message, or linked pair of Type 1 or Type 101 messages for a given measurement type within a single frame need to provide identical data content.

7.12.4.2 One example of the use of multiple antennas is a facility with two antennas installed at the same location but at different heights above the ground plane. The heights of the antennas are chosen so that the pattern from one antenna fills the nulls in the pattern of the other antenna that result from reflections from the ground plane. The GBAS ground subsystem alternates broadcasts between the two antennas, using one or two assigned slots of each frame for each antenna. Type 1 or Type 101 messages are broadcast once per frame, per antenna. This allows for reception of one or two Type 1 or Type 101 messages per frame, depending on whether the user is located within the null of one of the antenna patterns. Type 2 and 4 messages are broadcast from the first antenna in one frame, then from the second antenna in the next frame. This allows for reception of one each of the Type 2 and 4 messages per one or two frames, depending on the user location.

7.13 Definition of lateral and vertical alert limits

7.13.1 The lateral and vertical alert limits for Category I precision approach are computed as defined in Appendix B, Tables B-68 and B-69. In these computations the parameters D and H have the meaning shown in Figure D-8.

7.13.2 The vertical alert limit for Category I precision approach is scaled from a height of 60 m (200 ft) above the LTP/FTP. For a procedure designed with a decision height of more than 60 m (200 ft), the VAL at that decision height will be larger than the broadcast FASVAL.

7.13.3 The lateral and vertical alert limits for APV procedures associated with channel numbers 40 001 to 99 999 are computed in the same manner as for APV procedures using SBAS as given in Attachment D, 3.2.8.

7.14 Monitoring and maintenance actions

7.14.1 Specific monitoring requirements or built-in tests may be necessary and should be determined by individual States. Since the VDB signal is critical to the operation of the GBAS broadcast station, any failure of the VDB to successfully transmit a usable signal within the assigned slots and over the entire coverage area is to be corrected as soon aspossible. Therefore, it is recommended that the following conditions be used as a guide for implementing a VDB monitor:

a) *Power.* A significant drop in power is to be detected within 3 seconds.

b) *Loss of message type.* The failure to transmit any scheduled message type(s). This could be based on the failure to transmit a unique message type in succession, or a combination of different message types.

c) *Loss of all message types*. The failure to transmit any message type for a period equal to or greater than 3 seconds will be detected.

7.14.2 Upon detection of a failure, and in the absence ofa backup transmitter, termination of the VDB service should be considered if the signal cannot be used reliably within the coverage area to the extent that aircraft operations could be significantly impacted. Appropriate actions in operational procedures are to be considered to mitigate the event of the signal being removed from service. These would include dispatching maintenance specialists to service the GBAS VDB or special ATC procedures. Additionally, maintenance actions should be taken when possible for all built-in test failures to prevent loss of GBAS service.

7.15 Examples of VDB messages

7.15.1 Examples of the coding of VDB messages are provided in Tables D-7 through D-10. The examples illustrate the coding of the various application parameters, including the cyclic redundancy check (CRC) and forward error correction (FEC) parameters, and the results of bit scrambling and D8PSK symbol coding. The engineering values for the message parameters in these tables illustrate the message coding process, but are not necessarily representative of realistic values.

7.15.2 Table D-7 provides an example of a Type 1 VDB message. The additional message flag field is coded to indicate that this is the first of two Type 1 messages to be broadcast within the same frame. This is done for illustration purposes; a second Type 1 message is not typically required, except to allow broadcast of more ranging source corrections than can be accommodated in a single message.

7.15.3 Table D-7A provides an example of a Type 101 VDB message. The additional message flag field is coded to indicate that this is the first of two Type 101 messages to be broadcast within the same frame. This is done for illustration purposes; a second Type 101 message is not typically required, except to allow broadcast of more ranging source corrections than can be accommodated in a single message.

7.15.4 Table D-8 provides examples of a Type 1 VDB message and a Type 2 VDB message coded within a single burst (i.e. two messages to be broadcast within a single transmission slot). The additional message flag field of the Type 1 message is coded to indicate that it is the second of two Type 1 messages to be broadcast within the same frame. The Type 2 message includes additional data block 1. Table D-8A provides an example of Type 1 and Type 2 messages with additional data blocks 1 and 2.

7.15.4.1 Table D-8B provides an example of Type 2 messages with additional data blocks 1 and 4 coded within a single burst with a Type 3 message that is used to fill the rest of the time slot.

7.15.5 Table D-9 provides an example of a Type 4 message containing two FAS data blocks.

7.15.6 Table D-10 provides an example of a Type 5 message. In this example, source availability durations common to all approaches are provided for two ranging sources. Additionally, source availability durations for two individual approaches are provided: the first approach has two impacted ranging sources and the second approach has one impacted ranging source. The Type 2 message includes additional data block 1.

7.16 GBAS survey accuracy

The standards for the survey accuracy for NAVAIDs are contained in Annex 14 — Aerodromes. In addition, the Manual of the World Geodetic System 1984 (WGS-84)(Doc 9674) provides guidance on the establishment of a network of survey control stations at each aerodrome and how to use the network to establish WGS-84 coordinates. Until specific requirements are developed for GBAS, the Annex 14 survey accuracy requirements for NAVAIDs located at the aerodrome apply to GBAS. The recommendation contained in Appendix B to Chapter 3, 3.6.7.2.3.4, for the survey accuracy of the GBAS reference point is intended to further reduce the error in the WGS-84 position calculated by an airborne user of the GBAS positioning service to a value smaller than that established by the requirements of Appendix B to Chapter 3, 3.6.7.2.4.1 and 3.6.7.2.4.2, in the GBAS standards and to enhance survey accuracy compared to that specified in Annex 14. The integrity of all aeronautical data used for GBAS is to be consistent with the integrity requirements in Chapter 3, Table 3.7.2.4-1.

7.17 Type 2 message additional data blocks

7.17.1 The Type 2 message contains data related to the GBAS facility such as the GBAS reference point location, the GBAS continuity and integrity designator (GCID) and other pertinent configuration information. A method for adding new data to the Type 2 message has been devised to allow GBAS to evolve to support additional service types. The method is through the definition of new additional data blocks that are appended to the Type 2 message. In the future, more additional data blocks may be defined. Data blocks 2 through 255 have variable length and may be appended to the message after additional data block 1 in any order.

7.17.2 Type 2 message additional data block 1 contains information related to spatial decorrelation of errors and information needed to support selection of the GBAS positioning service (when provided by a given ground station).

7.17.3 Type 2 message additional data block 2 data may be used in GRAS to enable the GRAS airborne subsystem to switch between GBAS broadcast stations, particularly if the GBAS broadcast stations utilize different frequencies. Additional data block 2 identifies the channel numbers and locations of the GBAS broadcast station currently being received and other adjacent or nearby GBAS broadcast stations.

7.17.4 Type 2 message additional data block 3 is reserved for future use.

7.17.5 Type 2 message additional data block 4 contains information necessary for a ground station that supports the authentication protocols. It includes a single parameter which indicates which slots are assigned to the ground station for VDB transmissions. Airborne equipment that supports the authentication protocols will not use data unless it is transmitted in the slots indicated by the slot group definition field in the MT 2 ADB 4.

Table D-7. Example of a Type 1 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	E	100
Transmission length (bits)	17	0 to 1 824 bits	1 bit	536	000 0000 1000 0110 00
Training sequence FEC	5	—	—	—	0000 1
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 1 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	61	0011 1101
Message (Type 1 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	1st of pair	01
Number of measurements	5	0 to 18	1	4	0 0100
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 $\times 10^{-3}$m/m	5×10^{-6}m/m	1×10^{-4}	0001 0100
Ephemeris CRC	16	—	—	—	0000 0000 0000 0000
Source availability duration	8	0 to 2 540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	2	0000 0010
Issue of data (IOD)	8	0 to 255	1	255	1111 1111
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	−0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	0.98 m	0011 0001
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B_3	8	±6.35 m	0.05 m	−0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Measurement Block 2					
Ranging source ID	8	1 to 255	1	4	0000 0100
Issue of data (IOD)	8	0 to 255	1	126	0111 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	−1.0 m	1111 1111 1001 1100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	+0.2 m/s	0000 0000 1100 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	0.34 m	0001 0001
B_1	8	±6.35 m	0.05 m	+0.20 m	0000 0100
B_2	8	±6.35 m	0.05 m	+0.30 m	0000 0110
B_3	8	±6.35 m	0.05 m	−0.50 m	1111 0110
B_4	8	±6.35 m	0.05 m	Not used	1000 0000

Table D-7A. Example of a Type 101 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3			E	100
Transmission length (bits)	17	0 to 1824 bits	1 bit	416	00000000110100000
Training sequence FEC	5				11011
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 101 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8,101	1	101	0110 0101
Message length	8	10 to 222 bytes	1 byte	46	0010 1110
Message (Type 101 example)					
Modified Z-count	14	0 to 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	1st of pair	01
Number of measurements	5	0 to 18	1	4	0 0100
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 × 10^{-3}m/m	5 × 10^{-6}m/m	0.115 × 10^{-3}m/m	0001 0111
Ephemeris CRC	16			0	0000 0000 0000 0000
Source availability duration	8	0 to 2540 s	10 s	Not provided	1111 1111
Number of B parameters	1	0 to 1	1	0	0
Spare	7			0	000 0000
Measurement Block 1					
Ranging source ID	8	1 to 255	1	2	0000 0010
Issue of data (IOD)	8	0 to 255	1	255	1111 1111
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+3.56 m	0000 0001 0110 0100
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.011 m/s	1111 1111 1111 0101
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	9.8 m	0011 0001
Measurement Block 2					
Ranging source ID	8	1 to 255	1	4	0000 0100
Issue of data (IOD)	8	0 to 255	1	126	0111 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	-1.0 m	1111 1111 1001 1100
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	+0.002 m/s	0000 0000 0000 0010
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	3.4 m	0001 0001
Measurement Block 3					
Ranging source ID	8	1 to 255	1	12	0000 1100
Issue of data (IOD)	8	0 to 255	1	222	1101 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+4.11 m	0000 0001 1001 1011
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.029 m/s	1111 1111 1110 0011
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	10.2 m	0011 0011

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Measurement Block 4					
Ranging source ID	8	1 to 255	1	23	0001 0111
Issue of data (IOD)	8	0 to 255	1	80	0101 0000
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	-2.41 m	1111 1111 0000 1111
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.096 m/s	1111 1111 1010 0000
σ_{pr_gnd}	8	0 to 50.8 m	0.2 m	1.6 m	0000 1000
Message Block CRC	32				1000 1000 1001 1111 0111 1000 0000 0100
APPLICATION FEC	48				1100 1100 1110 0110 1111 0110 1100 1110 1101 0110 0110 0010
Input to the bit scrambling (Note 2)	0 41 60 1B 55 73 A4 A8 A6 74 17 C2 20 E8 00 00 FF 00 40 FF 26 80 AF FF 8C 20 7E 39 FF 40 00 88 30 7B D9 80 C7 FF CC E8 0A F0 FF 05 FF 10 20 1E F9 11 46 6B 73 6F 67 33				
Output from the bit scrambling (Note 3)	0 67 57 93 1F 6C BC 83 79 EE C2 1B 12 34 46 D0 09 C1 09 FC 3A 84 80 0F E6 9F 18 6D 77 8E 1E 60 19 1B BA FF BC AB 68 26 7B E7 BC CE FA 0B D3 C4 43 C8 E0 B6 FA 42 84 A1				
Fill bits	0 to 2			0	
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650105 06345463 57026113 51374661 15123376 12066670 44776307 04225000 02735027 73373152 13230100 04706272 74137202 47724524 12715704 15442724 01101677 44571303 66447212 222				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.*

Table D-8. Example of Type 1 and Type 2 VDB messages in a single burst

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	E	10 0
Transmission length (bits)	17	0 to 1 824 bits	1 bit	544	000 0000 1000 1000 00
Training sequence FEC	5	—	—	—	0000 0
APPLICATION DATA					
Message Block 1 (Type 1 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 1 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	2nd of pair	11
Number of measurements	5	0 to 18	1	1	0 0001
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 × 10^{-3} m/m	5 × 10^{-6} m/m	0 (SBAS)	0000 0000
Ephemeris CRC	16	—	—	0	0000 0000 0000 0000
Source availability duration	8	0 to 2 540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	122	0111 1010
Issue of data (IOD)	8	0 to 255	1	2	0000 0010
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	1.96 m	0110 0010
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B_3	8	±6.35 m	0.05 m	–0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block 1 CRC	32	—	—	—	1011 0101 1101 0000 1011 1100 0101 0010
Message Block 2 (Type 2 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	34	0010 0010
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2	—	—	B	01
Spare	1	—	—	0	0

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
GBAS continuity/integrity designator	3	0 to 7	1	1	001
Local magnetic variation	11	±180°	0.25°	58° E	000 1110 1000
Spare	5	—	—	0	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 × 10^{-6} m/m	0.1 × 10^{-6} m/m	0	0000 0000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	45°40'32" N	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005 arcsec	93°25'13"W	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	±83 886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference Station Data Selector	8	0 to 48	1	5	0000 0101
Maximum Use Distance (D_{max})	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Message Block 2 CRC	32	—	—	—	0101 1101 0111 0110 0010 0011 0001 1110
Application FEC	48				1110 1000 0100 0101 0011 1011 0011 1011 0100 0001 0101 0010
Input to the bit scrambling (Note 2)	0 41 10 00 55 30 CA 10 80 38 17 C3 80 00 00 00 FF 5E 40 26 00 1C FF 46 40 C0 DF 01 4A 3D 0B AD 55 30 CA 10 40 44 A4 17 00 00 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 78 C4 6E BA 4A 82 DC DC A2 17				
Output from the bit scrambling (Note 3)	0 67 27 88 1F 2F D2 3B 5F A2 C2 1A B2 DC 46 D0 09 9F 09 25 1C 18 D0 B6 2A 7F B9 55 C2 F3 15 45 7C 50 A9 6F 3B 10 00 D9 71 17 DC 4B 2D 1B 7B 83 72 D4 F7 CA 62 C8 D9 12 25 5E 13 2E 13 E0 42 44 37 45 68 29 5A B9 55 65				
Fill bits	0 to 2	—	—	1	0
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650105 67443352 35201160 30501336 62023576 12066670 74007653 30010255 31031274 26172772 76236442 41177201 35131033 33421734 42751235 60342057 66270254 17431214 03421036 70316613 46567433 66547730 34732201 40607506 014444				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5 π/4 radians), relative to the phase of the first symbol.*

Table D-8A. Example of Type 1 and Type 2 VDB messages with additional data blocks 1 and 2

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3			E	100
Transmission length (bits)	17	0 to 1824 bits	1 bit	592	00000001001010000
Training sequence FEC	5				10110
APPLICATION DATA					
Message Block 1 (Type 1 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 1 example)					
Modified Z-count	14	0 to 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	2nd of pair	11
Number of measurements	5	0 to 18	1	1	0 0001
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275×10^{-3} m/m	5×10^{-6} m/m	0 (SBAS)	0000 0000
Ephemeris CRC	16			0	0000 0000 0000 0000
Source availability duration	8	0 to 2540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	122	0111 1010
Issue of data (IOD)	8	0 to 255	1	2	0000 0010
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+2.09 m	0000 0000 1101 0001
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	1.96 m	0110 0010
B1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B3	8	±6.35 m	0.05 m	–0.25 m	1111 1011
B4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block 1 CRC	32				00110010 10100100 11001011 00110000
Message Block 2 (Type 2 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	40	0010 1000
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2			B	01
Spare	1			0	0

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
GBAS continuity/integrity designator	3	0 to 7	1	1	001
Local magnetic variation	11	±180°	0.25°	58° E	000 1110 1000
Spare	5			0	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5×10^{-6}m/m	0.1×10^{-6}m/m	0	0000 0000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	45°40'32" N	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005 arcsec	93°25'13" W	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	±83 886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference Station Data Selector	8	0 to 48	1	5	0000 0101
Maximum Use Distance (Dmax)	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Additional Data Blocks					
Additional Data Block Length	8	2 to 255	1	6	0000 0110
Additional Data Block Number	8	2 to 255	1	2	0000 0010
Additional Data Block 2					
Channel Number	16	20001 to 39999	1	25001	0110 0001 1010 1001
ΔLatitude	8	±25.4°	0.2°	5.2	0001 1010
ΔLongitude	8	±25.4°	0.2°	–3.4	1110 1111
Message Block 2 CRC	32				11100000 01110010 00011101 00100100
Application FEC	48				1110 0010 0101 1100 0000 1111 1010 1011 0011 0100 0100 0000
Input to the bit scrambling (Note 2)		0 42 90 0D 55 73 A4 A8 80 38 17 C3 80 00 00 00 FF 5E 40 8B 00 1C FF 46 40 C0 DF 01 0C D3 25 4C 55 73 A4 A8 40 14 A4 17 00 00 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 60 40 95 86 58 F7 24 B8 4E 07 02 2C D5 F0 3A 47			
Output from the bit scrambling (Note 3)		0 64 A7 85 1F 6C BC 83 5F A2 C2 1A B2 DC 46 D0 09 9F 09 88 1C 18 D0 B6 2A 7F B9 55 84 1D 3B A4 7C 13 C7 D7 3B 40 00 D9 71 17 DC 4B 2D 1B 7B 83 72 D4 F7 CA 62 C8 D9 12 25 5E 13 2E 13 E0 5A C0 CC 79 7A 5C A2 DD B9 75 B6 95 64 52 78 3F			
Fill bits	0 to 2			1	0
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 4)		00000035 11204546 31650107 56336574 60137224 74145772 26467132 56422234 30443700 05565722 06506741 73647332 27242654 63345227 31575333 33421734 42751235 60342057 66270254 17431214 03421036 70316613 46567433 62077121 37275607 55315167 17135031 34423411 274444			

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.*

Table D-8B. Example of a Type 2 message containing data blocks 1 and 4

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15	—	—	—	000 0000 0000 0000
Synchronization and ambiguity resolution	48	—	—	—	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier	3	—	—	E	100
Transmission length	17	0 to 1824 bits	1 bit	1704	0 0000 0110 1010 1000
Training sequence FEC	5	—	—	—	01000
APPLICATION DATA					
Message Block 1 (Type 2 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	000010 000101 001100 001100
Message type identifier	8	1 to 101	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	37	0010 0101
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2	—	—	B	01
Spare	1	—	—	—	0
GBAS continuity/integrity designator	3	0 to 7	1	2	010
Local magnetic variation	11	±180°	0.25°	E58.0°	000 1110 1000
Spare	5	—	—	—	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 x 10^{-6} m/m	0.1 x 10^{-6} m/m	4 x 10^{-6}	0010 1000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	N45° 40' 32" (+164432")	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005 arcsec	W93° 25' 13" (-336313")	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	±83 886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference station data selector	8	0 to 48	1	5	0000 0101
Maximum use distance (D_{max})	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e\ C,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e\ C,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Additional Data Block 4					
Additional data block length	8	3	1 byte	3	0000 0011
Additional data block number	8	4	1	4	0000 0100
Slot group definition	8	—	—	E	0011 0000
Message Block 1 CRC	32	—	—	—	1100 0101 1110 0000 0010 0110 1100 1011

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Message Block 2 (Type 3 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	000010 000101 001100 001100
Message type identifier	8	1 to 101	1	3	0000 0011
Message length	8	N/A	1 byte	170	1010 1010
Message (Type 3 example)					
Filler	1280	—	—	—	1010 1010 ...... 1010 1010
Message Block 2 CRC	32	—	—	—	1001 0000 1110 1100 1101 1001 1011 1010
Application FEC	48	—	—	—	0000 1000 0010 0011 1100 1011 1101 0000 1101 0110 1011 0101
Input to the bit scrambling (Note 2)	0 45 58 02 55 30 CA 10 40 A4 A2 17 00 14 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 C0 20 0C D3 64 07 A3 55 30 CA 10 C0 55 5D 9B 37 09 AD 6B 0B D3 C4 10				
Output from the bit scrambling (Note 3)	0 63 6F 8A 1F 2F D2 3B 9F 3E 77 CE 32 C8 D9 50 DE C1 C1 5A D4 09 7E E7 81 5A 5C D4 28 56 00 CE 29 60 A3 5F 77 87 C0 C9 D2 42 73 01 15 DB A6 8F EF 8C F3 88 DC 78 B6 C7 D0 93 58 5D 46 B5 6F D5 0C AA 77 FE D3 30 A2 27 E1 EC E4 F7 17 2D AD F4 0B 29 82 04 61 96 E4 50 E9 58 FA B8 C0 38 99 C7 BB 6C 3D 09 CA 7B 7E C2 CF 60 8D 18 75 B9 2B C5 FC 94 C8 57 79 52 C5 5F 6A B2 FF DF 33 4D DD 74 B5 28 2A 06 01 91 9B A4 43 E9 63 05 1D 95 B4 54 29 56 05 51 95 5B AA BC 00 36 66 2E EE 0F 0E 72 71 21 25 E5 EB 14 FD A8 CB F8 83 38 62 39 1E 3A 4E 3E 8E 30 71 D9 24 BA 17 C1 AC 9B F7 BC D3 C8 A3 78 1D 39 B5 C4 2B 69 FD 04 CA 68 81 07 9A 64 8F 6B 39 7D 2A 34 D0 6F EA				
Fill bits	0 to 2	—	—	2	00
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650102 46331130 13067746 52605627 35467122 62533573 77100603 75554273 01666461 41203311 42111340 14733657 27302663 77076361 44301001 17175104 35263707 43007132 40135774 07012022 52546153 57425454 25413051 54022547 01622754 12302141 24615265 50476225 56622615 23311312 51275055 11132570 45242065 63665236 04052447 35155017 73303745 61650521 06765616 04756006 16264736 30530735 02426407 53610061 12111501 04147002 72512117 74672621 42254251 12533720 37475054 44460104 57516674 46523401 22503075 25125742 03431633 22607072 37230050 35463673 43300570 12353363 77140357 42715724 03470633 30354042 67720645 27225703 50111005 40736127 14021742 36572477 13042222 2				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *In this example, fill bits are not scrambled.*
4. *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.*

Table D-9. Example of a Type 4 message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				010 0011 1110 1111 1100 0110 0011 1011 0000 0011 1100 1000 0
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	D	01 1
Transmission length (bits)	17	0 to 1 824 bits	1 bit	784	000 0000 1100 0100 00
Training sequence FEC	5	—	—	—	0000 0
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 4 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	CMJ	0000 1100 1101 0010 1010 0000
Message type identifier	8	1 to 8	1	4	0000 0100
Message length	8	10 to 222 bytes	1 byte	92	0101 1100
Message (Type 4 example)					
FAS Data Set 1					
Data set length	8	2 to 212	1 byte	41	0010 1001
FAS Data Block 1					
Operation type	4	0 to 15	1	0	0000
SBAS service provider	4	0 to 15	1	15	1111
Airport ID	32	—	—	LFBO	0000 1100 0000 0110 0000 0010 0000 1111
Runway number	6	1 to 36	1	15	00 1111
Runway letter	2	—	—	R	01
Approach performance designator	3	0 to 7	1	CAT 1	001
Route indicator	5	—	—	C	0001 1
Reference path data selector (RPDS)	8	0 to 48	1	3	0000 0011
Reference path identifier	32	—	—	GTBS	0000 0111 0001 0100 0000 0010 0001 0011
LTP/FTP latitude	32	±90.0°	0.0005 arcsec	43.6441075°N	0001 0010 1011 1010 1110 0010 1000 0110
LTP/FTP longitude	32	±180.0°	0.0005 arcsec	1.345940°E	0000 0000 1001 0011 1101 1110 1001 0000
LTP/FTP height	16	–512.0 to 6 041.5 m	0.1 m	197.3	0001 1011 1011 0101
ΔFPAP latitude	24	±1°	0.0005 arcsec	–0.025145°	1111 1101 0011 1100 1100 1100
ΔFPAP longitude	24	±1°	0.0005 arcsec	0.026175°	0000 0010 1110 0000 0010 1100
Approach threshold crossing height (TCH)	15	0 to 1 638.35 m (0 to 3 276.7 ft)	0.05 m (0.1 ft)	17.05 m	000 0001 0101 0101
Approach TCH units selector	1	0 = ft; 1 = m	—	metres	1
Glide path angle (GPA)	16	0 to 90°	0.01°	3°	0000 0001 0010 1100
Course width	8	80.0 to 143.75 m	0.25 m	105	0110 0100
ΔLength offset	8	0 to 2 032 m	8 m	0	0000 0000
FAS Data Block 1 CRC	32	—	—	—	1010 0010 1010 0101 1010 1000 0100 1101
FASVAL/Approach status	8	0 to 25.4	0.1 m	10	0110 0100
FASLAL/Approach status	8	0 to 50.8	0.2 m	40	1100 1000
FAS Data Set 2					
Data set length	8	2 to 212	1 byte	41	0010 1001

Table D-10. Example of a Type 5 message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	D	01 1
Transmission length (bits)	17	0 to 1 824 bits	1 bit	272	000 0000 0100 0100 00
Training sequence FEC	5	—	—	—	0001 1
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 5 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	CMJ	0000 1100 1101 0010 1010 0000
Message type identifier	8	1 to 8	1	5	0000 0101
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 5 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Spare	2	—	—	—	00
Number of impacted sources (N)	8	0 to 31	1	2	0000 0010
First impacted source					
Ranging source ID	8	1 to 255	1	4	0000 0100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	50 s	0000 101
Second impacted source					
Ranging source ID	8	1 to 255	1	3	0000 0011
Source availability sense	1	—	—	Will start	1
Source availability duration	7	0 to 1 270 s	10 s	200 s	0010 100
Number of obstructed approaches (A)	8	0 to 255	1	2	0000 0010
First obstructed approach					
Reference path data selector (RPDS)	8	0 to 48	1	21	0001 0101
Number of impacted sources for first obstructed approach (N_A)	8	1 to 31	1	2	0000 0010
First impacted ranging source of first obstructed approach					
Ranging source ID	8	1 to 255	1	12	0000 1100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	250 s	0011 001
Second impacted ranging source of first obstructed approach					
Ranging source ID	8	1 to 255	1	14	0000 1110
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	1 000 s	1100 100
Second obstructed approach					
Reference path data selector (RPDS)	8	0 to 48	1	14	0000 1110
Number of impacted sources for second obstructed approach (N_A)	8	1 to 31	1	1	0000 0001

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
First impacted ranging source of second obstructed approach					
Ranging source ID	8	1 to 255	1	12	0000 1100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	220 s	0010 110
Message Block CRC	32	—	—	—	1101 1011 0010 1111 0001 0010 0000 1001
APPLICATION FEC	48	—	—	—	0011 1110 1011 1010 0001 1110 0101 0110 1100 1011 0101 1011
Input to the bit scrambling (Note 2)	1 82 20 18 55 05 4B 30 A0 38 17 C0 40 20 50 C0 94 40 A8 40 30 4C 70 13 70 80 30 34 90 48 F4 DB DA D3 6A 78 5D 7C				
Output from the bit scrambling	1 A4 17 90 1F 1A 53 1B 7F A2 C2 19 72 FC 16 10 62 81 E1 43 2C 48 5F E3 1A 3F 56 60 18 86 EA 33 F3 B3 09 07 26 28				
Fill bits	0 to 2	—	—	0	
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 3)	00000035112045463165043220566605510676024161244773634632207001032240066013321241662311636437771101731157430232344514664444 4				

Notes.—

1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *Symbols are represented by their differential phase with respect to the first symbol of the message, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians) relative to the first symbol.*

7.18 Type 101 message

Type 101 message is an alternative to Type 1 message developed to fit the specific needs of GRAS systems. The primary difference in the contents and application of these two message types is two-fold: (a) Type 101 message has a larger available range for σpr_gnd values and (b) ground subsystem time-to-alert is larger for a system broadcasting Type 101 messages. The first condition would typically occur in a system where a broadcast station covers a large area, such that decorrelation errorsincrease the upper limit of the pseudo-range correction errors. The second condition may be typical for systems where a central master station processes data from multiple receivers dispersed over a large area.

8. Signal quality monitor (SQM) design

8.1 The objective of the signal quality monitor (SQM) is to detect satellite signal anomalies in order to prevent aircraft receivers from using misleading information (MI). MI is an undetected aircraft pseudo-range differential error greater than the maximum error (MERR) that can be tolerated. These large pseudo-range errors are due to C/A code correlation peak distortion caused by satellite payload failures. If the reference receiver used to create the differential corrections and the aircraft receiver have different measurement mechanizations (i.e. receiver bandwidth and tracking loop correlator spacing), the signal distortion affects them differently. The SQM must protect the aircraft receiver in cases when mechanizations are not similar. SQM performance is further defined by the probability of detecting a satellite failure and the probability of incorrectly annunciating a satellite failure.

8.2 The signal effects that might cause a GBAS or SBAS to output MI can be categorized into three different effects on the correlation function as follows:

a) *Dead zones*: If the correlation function loses its peak, the receiver's discriminator function will include a flat spot or dead zone. If the reference receiver and aircraft receiver settle in different portions of this dead zone, MI can result.

b) *False peaks*: If the reference receiver and aircraft receiver lock to different peaks, MI could exist.

c) Distortions: If the correlation peak is misshapen, an aircraft that uses a correlator spacing other than the one used by the reference receivers may experience MI.

8.3 The threat model proposed for use in assessment of SQM has three parts that can create the three correlation peak pathologies listed above.

8.4 Threat Model A consists of the normal C/A code signal except that all the positive chips have a falling edge that leads or lags relative to the correct end-time for that chip. This threat model is associated with a failure in the navigation data unit (NDU), the digital partition of a GPS or GLONASS satellite.

8.4.1 Threat Model A for GPS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in fractions of a chip. The range for this parameter is $-0.12 \leq \Delta \leq 0.12$. Threat Model A for GLONASS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in fractions of a chip. The range for this parameter is $-0.11 \leq \Delta \leq 0.11$.

8.4.2 Within this range, threat Model A generates the dead zones described above. (Waveforms with lead need not be tested, because their correlation functions are simply advances of the correlation functions for lag; hence, the MI threat is identical.)

8.5 Threat Model B introduces amplitude modulation and models degradations in the analog section of the GPS or GLONASS satellite. More specifically, it consists of the output from a second order system when the nominal C/A code baseband signal is the input. Threat Model B assumes that the degraded satellite subsystem can be described as a linear system dominated by a pair of complex conjugate poles. These poles are located at $\sigma \pm j2\pi f_d$, where σ is the damping factor in 10^6 nepers/second and fd is the resonant frequency with units of 10^6 cycles/second.

8.5.1 The unit step response of a second order system is given by:

$$e(t) = \begin{cases} 0 & t \leq 0 \\ 1 - \exp(-\sigma t)\left[\cos\omega_d t + \frac{\sigma}{\omega_d}\sin\omega_d t\right] & t \geq 0 \end{cases}$$

where $\omega_d = 2\pi f_d$.

8.5.2 Threat Model B for GPS corresponding to second order anomalies uses the following ranges for the parameters Δ, f_d and σ:

$$\Delta = 0;\ 4 \leq f_d \leq 17;\ \text{and}\ 0.8 \leq \sigma \leq 8.8.$$

Threat Model B for GLONASS corresponding to second order anomalies uses the following ranges for the parameters defined above:

$$\Delta = 0;\ 10 \leq f_d \leq 20;\ \text{and}\ 2 \leq \sigma \leq 8.$$

8.5.3 Within these parameter ranges, threat Model B generates distortions of the correlation peak as well as false peaks.

8.6 Threat Model C introduces both lead/lag and amplitude modulation. Specifically, it consists of outputs from a second order system when the C/A code signal at the input suffers from lead or lag. This waveform is a combination of the two effects described above.

8.6.1 Threat Model C for GPS includes parameters Δ, fdand σ with the following ranges:

$$-0.12 \leq \Delta \leq 0.12;\ 7.3 \leq f_d \leq 13;\ \text{and}\ 0.8 \leq \sigma \leq 8.8.$$

Threat Model C for GLONASS includes parameters Δ, fd and σ with the following ranges:

$$-0.11 \leq \Delta \leq 0.11;\ 10 \leq f_d \leq 20;\ \text{and}\ 2 \leq \sigma \leq 8.$$

8.6.2 Within these parameter ranges, threat Model C generates dead zones, distortions of the correlation peak and false peaks.

8.7 Unlike GPS and GLONASS, the SBAS signal is commissioned and controlled by the service provider. Moreover, the service provider also monitors the quality of the signal from the SBAS. To this end, the threat model will be specified and published by the service provider for each SBAS satellite. The SBAS SQM will be designed to protect all avionics that comply with Table D-12. Publication of the threat model is required for those cases where a service provider chooses to allow the SBAS ranging signal from a neighbouring service provider to be used for precision approach by SBAS or GBAS.

In these cases, the service provider will monitor the SBAS ranging signal from the neighbouring satellite.

8.8 In order to analyse the performance of a particular monitor design, the monitor limit must be defined and set to protect individual satellite pseudo-range error relative to the protection level, with an allocation of the ground subsystem integrity risk. The maximum tolerable error (denoted as MERR) for each ranging source *i* can be defined in GBAS as:

$$\text{MERR} = K_{ffmd}\sigma_{pr\_gnd,i}$$ and

$$\text{MERR}=K_{V,PA}\sqrt{\sigma^2_{i,UDRE} + \min\{\sigma^2_{i,UIRE}\}}$$

for SBAS APV and precision approach where min $\{\sigma^2_{i,UIRE}\}$ is the minimum possible value for any user. MERR is evaluated at the output of a fault-free user receiver and varies with satellite elevation angle and ground subsystem performance.

8.9 The SQM is designed to limit the UDRE to values below the MERR in the case of a satellite anomaly. Typically, the SQM measures various correlation peak values and generates spacing and ratio metrics that characterize correlation peak distortion. Figure D-9 illustrates typical points at the top of a fault-free, unfiltered correlation peak.

8.9.1 A correlator pair is used for tracking. All other correlator values are measured with respect to this tracking pair.

8.9.2 Two types of test metrics are formed: early-minus-late metrics (D) that are indicative of tracking errors caused by peak distortion, and amplitude ratio metrics (R) that measure slope and are indicative of peak flatness or close-in, multiple peaks.

8.9.3 It is necessary that the SQM has a precorrelation bandwidth that is sufficiently wide to measure the narrow spacing metrics, so as not to cause significant peak distortion itself and not to mask the anomalies caused by the satellite failure. Typically, the SQM receiver must have a precorrelation bandwidth of at least 16 MHz for GPS and at least 15 MHz for GLONASS.

8.9.4 The test metrics are smoothed using low-pass digital filters. The time constant of these filters are to be shorter than those used jointly (and standardized at 100 seconds) by the reference receivers for deriving differential corrections and by the aircraft receiver for smoothing pseudo-range measurements (using carrier smoothing). The smooth metrics are then compared to thresholds. If any one of the thresholds is exceeded, an alarm is generated for that satellite.

8.9.5 The thresholds used to derive performance are defined as minimum detectable errors (MDEs) and minimum detectable ratios (MDRs). Fault-free false detection probability and missed detection probability are used to derive MDEs and MDRs. The noise in metrics (D) and (R), as denoted $\sigma_{D,test}$ and $\sigma_{R,test}$ below, is dominated by multipath errors. Note that the metric test can also have a mean value (μtest) caused by SQM receiver filter distortion. Threshold tests must also account for the mean values.

8.9.6 The MDE and MDR values used in the SQM performance simulations are calculated based on the following equations:

$$MDE = (K_{ffd} + K_{md})\ \sigma_{D,test} \text{ and}$$
$$MDR = (K_{ffd} + K_{md})\ \sigma_{R,test}$$

where

Kffd= 5.26 is a typical fault-free detection multiplier representing a false detection probability of 1.5 ×10–7per test;

Kmd= 3.09 is a typical missed detection multiplier representing a missed detection probability of 10–3per test;

σD,test is the standard deviation of measured values of difference test metric D; and

σR,test is the standard deviation of measured values of ratio test metric R.

8.9.7 If multiple independent SQM receivers are used to detect the failures, the sigma values can be reduced by the square root of the number of independent monitors.

8.9.8 A failure is declared if

$$| D,test - \mu_{D,test} | \geq MDE \text{ or}$$
$$| R,test - \mu_{R,test} | \geq MDR$$

for any of the tests performed, where μX,testis the mean value of the test X that accounts for fault-free SQM receiver filter distortion, as well as correlation peak distortion peculiar to the specific C/A code PRN. (Not all C/A code correlation peaks have the same slope. In a simulation environment, however, this PRN distortion can be ignored, and a perfect correlation peak can be used, except for simulated filter distortion.)

8.10 The standard deviations of the test statistics, σD,test and σR,test can be determined via data collection on a multicorrelator receiver in the expected operating environment. The data collection receiver utilizes a single tracking pair of correlators and additional correlation function measurement points which are slaved to this tracking pair, as illustrated in Figure D-9. Data is collected and smoothed for all available measurement points in order to compute the metrics. The standard deviation of these metrics define σD,test. It is also possible to compute these one sigma test statistics if a multipath model of the installation environment is available.

8.10.1 The resulting σD,test is highly dependent on the multipath environment in which the data are collected. The deviation due to multipath can be an order of magnitude greater than that which would result from noise even at minimum carrier-to-noise level. This aspect illustrates the importance ofthe antenna design and siting criteria which are the primary factors in determining the level of multipath that will enter the receiver. Reducing multipath will significantly decrease the resulting MDEs and thus improve the SQM capabilities.

8.10.2 Mean values μD,test and μR,test, on the other hand, are determined in a relatively error-free environment, such as through the use of GPS and GLONASS signal simulator as input. These mean values model the nominal SQM receiver's filter distortion of the autocorrelation peak, including the effects of distortion due to adjacent minor autocorrelation peaks.The mean values can differ for the various PRNs based on these properties.

8.10.3 The presence of nominal signal deformation biases may cause the distribution of the monitor detectors to have non-zero mean. These biases can be observed by averaging measurements taken from a real-world data collection. Note that the nominal biases may depend on elevation and they typically change slowly over time.

8.11 In order for the ground monitor to protect users against the different threat models described above, it is necessary to assume that aircraft receivers have specific characteristics. If no such constraints were assumed, the complexity of the ground monitor would be unnecessarily high. Evolution in the technology may lead to improved detection capability in the aircraft receiver and may alleviate the current constraints.

8.11.1 For double-delta correlators, the aircraft receiver tracks the strongest correlation peak over the full code sequence for every ranging source used in the navigation solution.

8.11.2 For double-delta correlators, the precorrelation filter rolls off by at least 30 dB per octave in the transition band. For GBAS receivers, the resulting attenuation in the stop band is required to be greater than or equal to 50 dB (relative to the peak gain in the pass band).

8.11.3 The following parameters are used to describe the tracking performance specific to each type of satellite:

a) the instantaneous correlator spacing is defined as the spacing between a particular set of early and late samples of the correlation function;

b) the average correlator spacing is defined as a one-second average of the instantaneous correlator spacing. The average applies over any one-second time frame;

c) the discriminator Δis based upon an average of early-minus-late samples with spacings inside the specified range, or is of the type Δ= 2Δd1– Δ2d1, with both d1 and 2d1in the specified range. Either a coherent or non-coherent discriminator is used;

d) the differential group delay applies to the entire aircraft system prior to the correlator, including the antenna. The differential group delay is defined as:

$$\left|\frac{d\phi}{d\omega}(f_c) - \frac{d\phi}{d\omega}(f)\right|$$

where

fc is the precorrelation band pass filter centre frequency;

f is any frequency within the 3dB bandwidth of the precorrelation filter;

φ is the combined phase response of precorrelation band pass filter and antenna; and

ω is equal to $2\pi f$.

8.11.4 For aircraft receivers using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of theinstallation, the correlator spacing and the differential groupdelay are within the ranges defined in Table D-11.

8.11.5 For aircraft receivers using early-late correlators and tracking GLONASS satellites, the precorrelation bandwidth of the installation, the correlator spacing, and the differential group delay are within the ranges as defined in Table D-12.

8.11.6 For aircraft receivers using double-delta correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Tables D-13A and D-13B.

8.11.7 For aircraft receivers using the early-late or double-delta correlators and tracking SBAS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-14.

9. Status monitoring and NOTAM

9.1 System status

9.1.1 Degradation of GBAS usually has local effects and affects mainly approach operations. System degradation of GBAS is to be distributed as approach-related information.

9.1.2 Degradation of core satellite constellation(s) or SBAS usually has not only local effects, but additional consequences for a wider area, and may directly affect en-route operations. System degradation of these elements is to be distributed as area-related information. An example is a satellite failure.

9.1.3 Degradation of GRAS may have local effects and/or wide area effects. Therefore, if the degradation has only local effects, GRAS system degradation information is to be distributed in accordance with 9.1.1. If the degradation has wide area effects, GRAS system degradation information is to be distributed in accordance with 9.1.2.

9.1.4 Information is to be distributed to indicate the inability of GNSS to support a defined operation. For example, GPS/SBAS may not support a precision approach operation on a particular approach. This information can be generated automatically or manually based upon models of system performance.

Table D-11. GPS tracking constraints for early-late correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	2 < BW ≤ 7 MHz	0.045 – 1.1	0.04 – 1.2	≤ 600 ns
2	7 < BW ≤ 16 MHz	0.045 – 0.21	0.04 – 0.235	≤ 150 ns
3	16 < BW ≤ 20 MHz	0.045 – 0.12	0.04 – 0.15	≤ 150 ns
4	20 < BW ≤ 24 MHz	0.08 – 0.12	0.07 – 0.13	≤ 150 ns

Table D-12. GLONASS tracking constraints for early-late correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing range (chips)	Instantaneous correlator spacing range (chips)	Differential group delay
1	7 < BW ≤ 9 MHz	0.05 – 1.0	0.045 – 1.1	≤100 ns
2	9 < BW ≤ 15 MHz	0.05 – 0.2	0.045 – 0.22	≤ 100 ns
3	15 < BW ≤ 18 MHz	0.05 – 0.1	0.045 – 0.11	≤ 100 ns

Table D-13A. GPS tracking constraints for GRAS and SBAS airborne receivers with double-delta correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (X) (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	(–50 × X) + 12 < BW ≤ 7 MHz	0.1 – 0.2	0.09 – 0.22	≤ 600 ns
	2 < BW ≤ 7 MHz	0.2 – 0.6	0.18 – 0.65	
2	(–50 × X) + 12 < BW ≤ (40 × X) + 11.2 MHz	0.045 – 0.07	0.04 – 0.077	≤ 150 ns
	(–50 × X) + 12 < BW ≤ 14 MHz	0.07 – 0.1	0.062 – 0.11	
	7 < BW ≤ 14 MHz	0.1 – 0.24	0.09 – 0.26	
3	14 < BW ≤ 16 MHz	0.07 – 0.24	0.06 – 0.26	≤ 150 ns

Table D-13B. GPS tracking constraints for GBAS airborne receivers with double-delta correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing range (X) (chips)	Instantaneous correlator spacing range (chips)	Differential group delay
1	(–50 × X) + 12 < BW ≤ 7 MHz	0.1 – 0.2	0.09 – 0.22	≤ 600 ns
	2 < BW ≤ 7 MHz	0.2 – 0.6	0.18 – 0.65	
2	(–50 × X) + 12 < BW ≤ (133.33 × X) + 2.667 MHz	0.07 – 0.085	0.063 – 0.094	≤ 150 ns
	(–50 × X) + 12 < BW ≤ 14 MHz	0.085 – 0.1	0.077 – 0.11	
	7 < BW ≤ 14 MHz	0.1 – 0.24	0.09 – 0.26	
3	14 < BW ≤ 16 MHz	0.1 – 0.24	0.09 – 0.26	≤ 150 ns
	(133.33 × X) + 2.667 < BW ≤ 16 MHz	0.085 – 0.1	0.077 – 0.11	

Table D-14. SBAS ranging function tracking constraints

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	2 < BW ≤ 7 MHz	0.045 – 1.1	0.04 – 1.2	≤ 600 ns
2	7 < BW ≤ 20 MHz	0.045 – 1.1	0.04 – 1.2	≤ 150 ns

9.2 Information on type of degradation

The following information is to be distributed:

a) non-availability of service;

b) downgrade of service, if applicable; and

c) time and expected duration of degradation.

9.3 Timing of notification

For scheduled events, notification should be given to the NOTAM authority at least 72 hours prior to the event. For unscheduled events, notification to the NOTAM authority should be given within 15 minutes. Notification should be given for events of 15-minute, or longer, duration.

10. Interference

10.1 Potential for interference

Satellite radio navigation systems such as GPS and GLONASS feature relatively weak received signal power, meaning that an interference signal could cause loss of service. In order to maintain service, it will be necessary to ensure that the maximum interference levels specified in the SARPs are not exceeded.

10.2 Specification of the interference threshold at the antenna port

The indications of the interference threshold levels are referenced to the antenna port. In this context, the term "antenna port" means the interface between the antenna and the GNSS receiver where the satellite signal power corresponds to the nominal minimum received signal power of –164.5dBW for GPS and –165.5 dBW for GLONASS. Due to the reduced distance from potential interference sources, GNSS receivers that are used for the approach phase of flight must have a higher interference threshold than receivers that are only used for en-route navigation.

10.3 In-band interference sources

A potential source of in-band harmful interference is Fixed Service operation in certain States. There is a primary allocation to the fixed service for point-to-point microwave links in certain States in the frequency band used by GPS and GLONASS.

10.4 Out-of-band interference sources

Potential sources of out-of-band interference include harmonics and spurious emissions of aeronautical VHF and UHF transmitters. Out-of-band noise, discrete spurious products and intermodulation products from radio and TV broadcasts can also cause interference problems.

10.5 Aircraft generated sources

10.5.1 The potential for harmful interference to GPS and GLONASS on an aircraft depends on the type of aircraft, its size and the transmitting equipment installed. The GNSS antenna location should take into account the possibility of onboard interference (mainly SATCOM).

10.5.2 GNSS receivers that are used on board aircraft with SATCOM equipment must have a higher interference threshold in the frequency range between 1 610 MHz and 1

626.5 MHz than receivers on board aircraft without SATCOM equipment. Therefore, specifications for the interference threshold discriminate between both cases.

Note.— Limits for radiated SATCOM aircraft earth stations are given in Annex 10, Volume III, Part I, Chapter 4, 4.2.3.5.

10.5.3 The principal mitigation techniques for on-board interference include shielding, filtering, receiver design techniques, and, especially on larger aircraft, physical separation of antennas, transmitters and cabling. Receiver design techniques include the use of adaptive filters and interference cancellation techniques that mitigate against narrow in-band interference. Antenna design techniques include adaptive null steering antennas that reduce the antenna gain in the direction of interference sources without reducing the signal power from satellites.

10.6 Integrity in the presence of interference

The requirement that SBAS and GBAS receivers do not output misleading information in the presence of interference is intended to prevent the output of misleading information under unintentional interference scenarios that could arise. It is notintended to specifically address intentional interference. While it is impossible to completely verify this requirement throughtesting, an acceptable means of compliance can be found in the appropriate receiver Minimum Operational Performance Standards published by RTCA and EUROCAE.

11. Recording of GNSS parameters

11.1 In order to be able to conduct post-incident/accident investigations (Chapter 2, 2.1.4.2 and 2.1.4.3), it is necessary to record GNSS information both for the augmentation system and for the appropriate GNSS core system constellation used for the operation. The parameters to be recorded are dependent on the type of operation, augmentation system and core elements used. All parameters available to users within a given service area should be recorded at representative locations in the service area.

11.2 The objective is not to provide independent assurance that the GNSS is functioning correctly, nor is it to provide another level of system monitoring for anomalous performance or input data for a NOTAM process. The recording system need not be independent of the GNSS service and may be delegated to other States or entities. In order to enable future reconstruction of position, velocity and time indications provided by specific GNSS configurations, it is recommended to log data continuously, generally at a 1 Hz rate.

11.3 For GNSS core systems the following monitored items should be recorded for all satellites in view:

a) observed satellite carrier-to-noise density (C/N0);

b) observed satellite raw pseudo-range code and carrier phase measurements;

c) broadcast satellite navigation messages, for all satellites in view; and

d) relevant recording receiver status information.

11.4 For SBAS the following monitored items should be recorded for all geostationary satellites in view in addition to the GNSS core system monitored items listed above:

a) observed geostationary satellite carrier-to-noise density (C/N0);

b) observed geostationary satellite raw pseudo-range code and carrier phase measurements;

c) broadcast SBAS data messages; and

d) relevant receiver status information.

11.5 For GBAS the following monitored items should be recorded in addition to the GNSS core system and SBAS monitored items listed above (where appropriate):

a) VDB power level;

b) VDB status information; and

c) broadcast GBAS data messages.

12. GNSS performance assessment

The data described in Section 11 may also support periodic confirmation of GNSS performance in the service area.

13. GNSS and database

Note.— Provisions relating to aeronautical data are contained in Annex 11, Chapter 2, and Annex 15, Chapter 3.

13.1 The database is to be current with respect to the effective AIRAC cycle, which generally means that a current database be loaded into the system approximately every 28 days. Operating with out-of-date navigation databases has to be avoided.

13.2 In certain situations, operations using an expired database can be conducted safely by implementing a process and/or using procedures to ensure that the required data is correct. These processes and/or procedures need prior approval by the State.

13.2.1 These procedures should be based on one of the following methods:

a) require the crew to check, prior to the operation, critical database information against current published information. (This method increases workload and would not be practical for all applications.); or

b) waive the requirement for a current database and frequent checks by the crew of the database information. This waiver can only be applied to very specific cases where aircraft are operated in a strictly limited geographical area and where that area is controlled by a single regulatory agency or multiple agencies that coordinate this process; or

c) use another approved method that ensures an equivalent level of safety.

14. Modelling of residual errors

14.1 Application of the integrity requirements for SBAS and GBAS requires that a model distribution be used to characterize the error characteristics in the pseudo-range. The HPL/LPL and VPL models (see 7.5.3) are constructed based on models of the individual error components (in the pseudo-range domain) that are independent, zero-mean, normal distributions. The relationship between this model and the true error distribution must be defined.

14.2 One method of ensuring that the protection level risk requirements are met is to define the model variance (σ2), such that the cumulative error distribution satisfies the conditions:

$$\int_{y}^{\infty} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \left(\frac{y}{\sigma}\right) \geq 0 \text{ and}$$

where

f(x) = probability density function of the residual aircraft pseudo-range error; and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}} dt.$$

14.3 This method can be directly applied when the error components have zero-mean, symmetrical and unimodal probability density functions. This is the case for the receiver contribution to corrected pseudo-range error, since the aircraft element is not subjected to low-frequency residual multipath errors.

14.4 This method can be extended to address non-zero-mean, residual errors by inflating the model variance to compensate for the possible effect of the mean in the position domain.

14.5 Verification of the pseudo-range error models must consider a number of factors including:

a) the nature of the error components;

b) the sample size required for confidence in the data collection and estimation of each distribution;

c) the correlation time of the errors; and

d) the sensitivity of each distribution to geographic location and time.

Figure D-1. Reserved

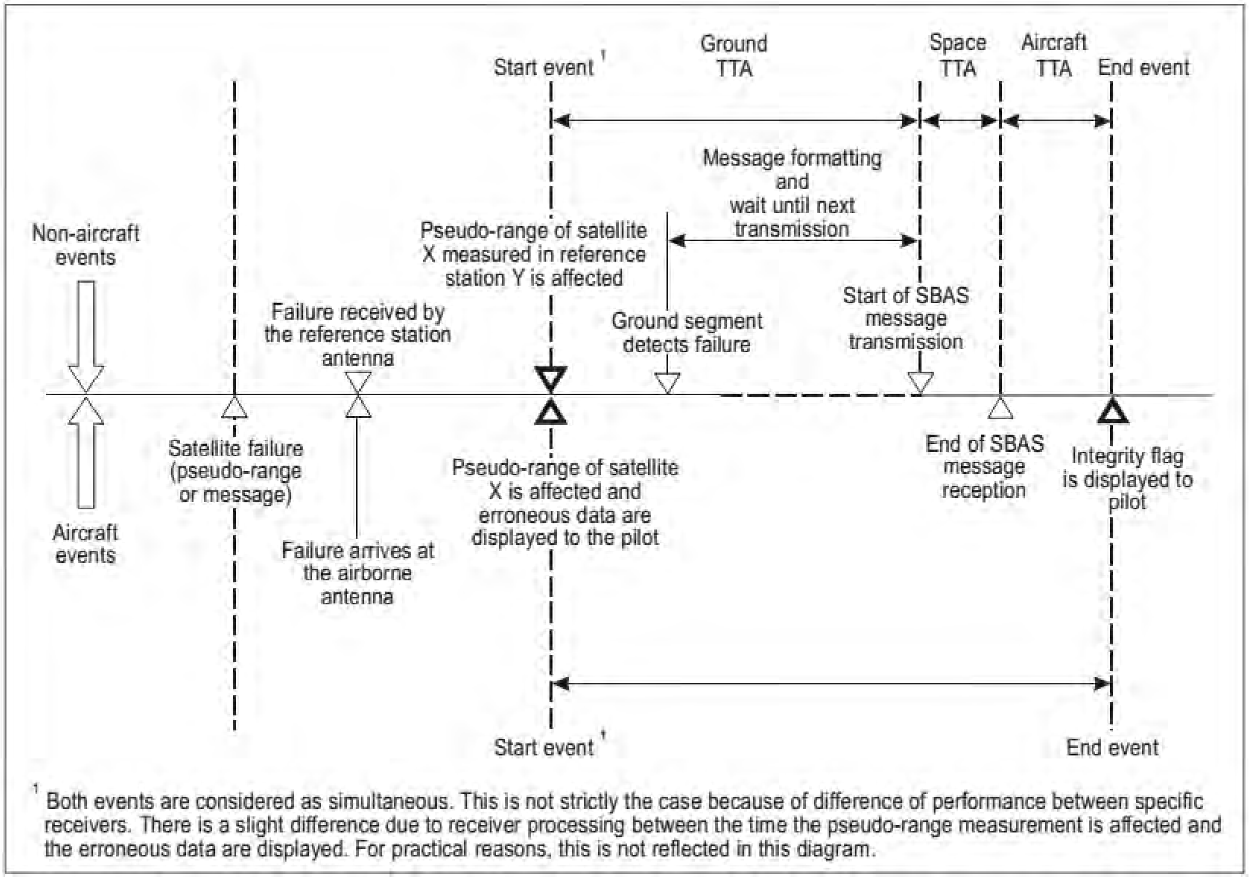


Figure D-2. SBAS time-to-alert

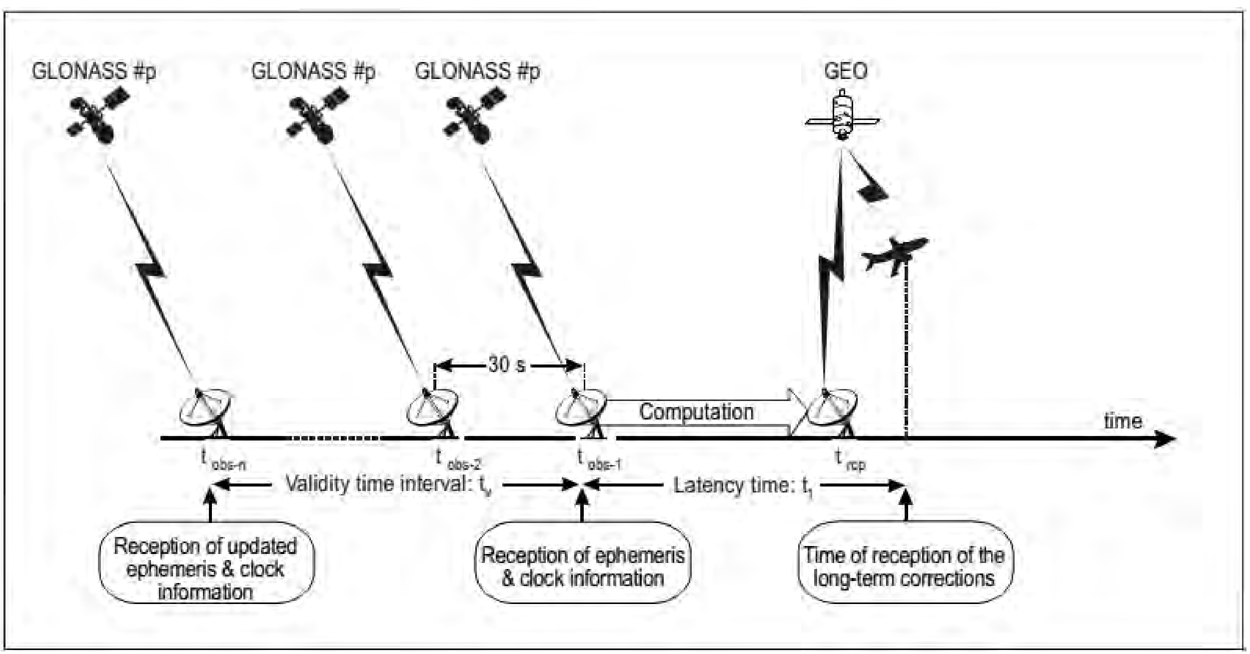
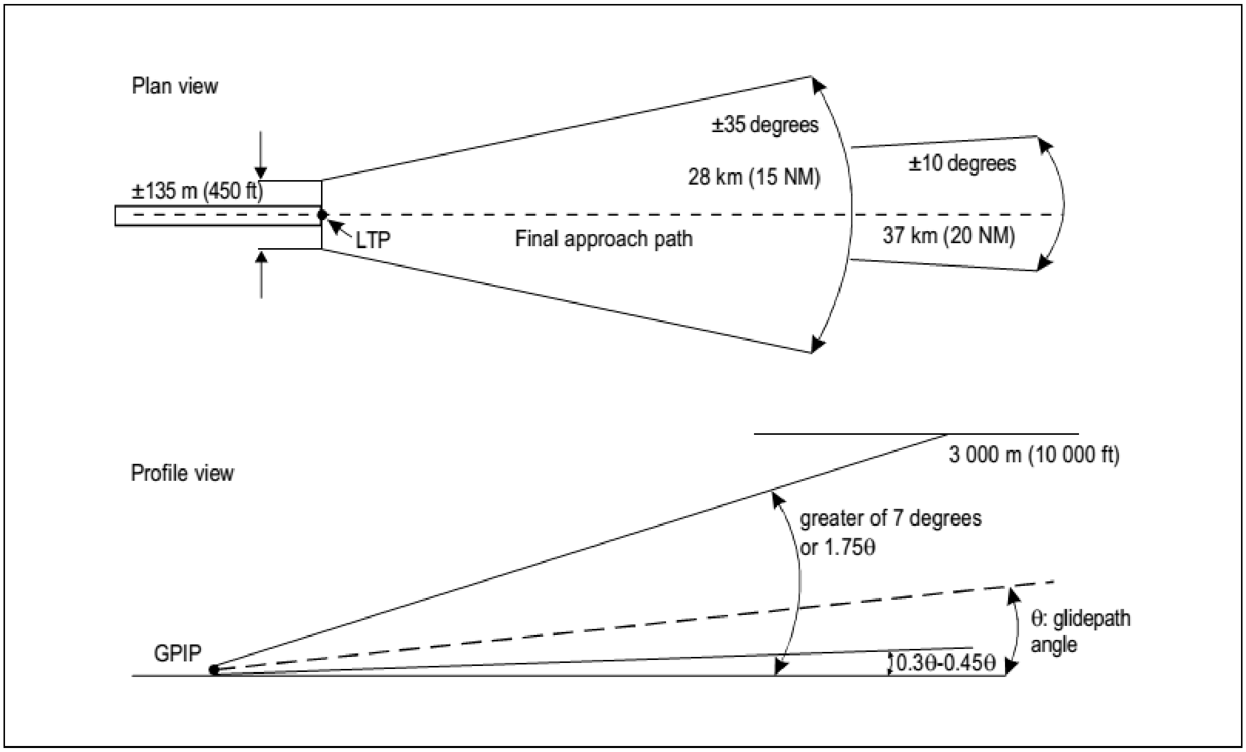


Figure D-3. GLONASS time



GPIP — glide path intersection point
LTP — landing threshold point

Figure D-4. Minimum GBAS coverage

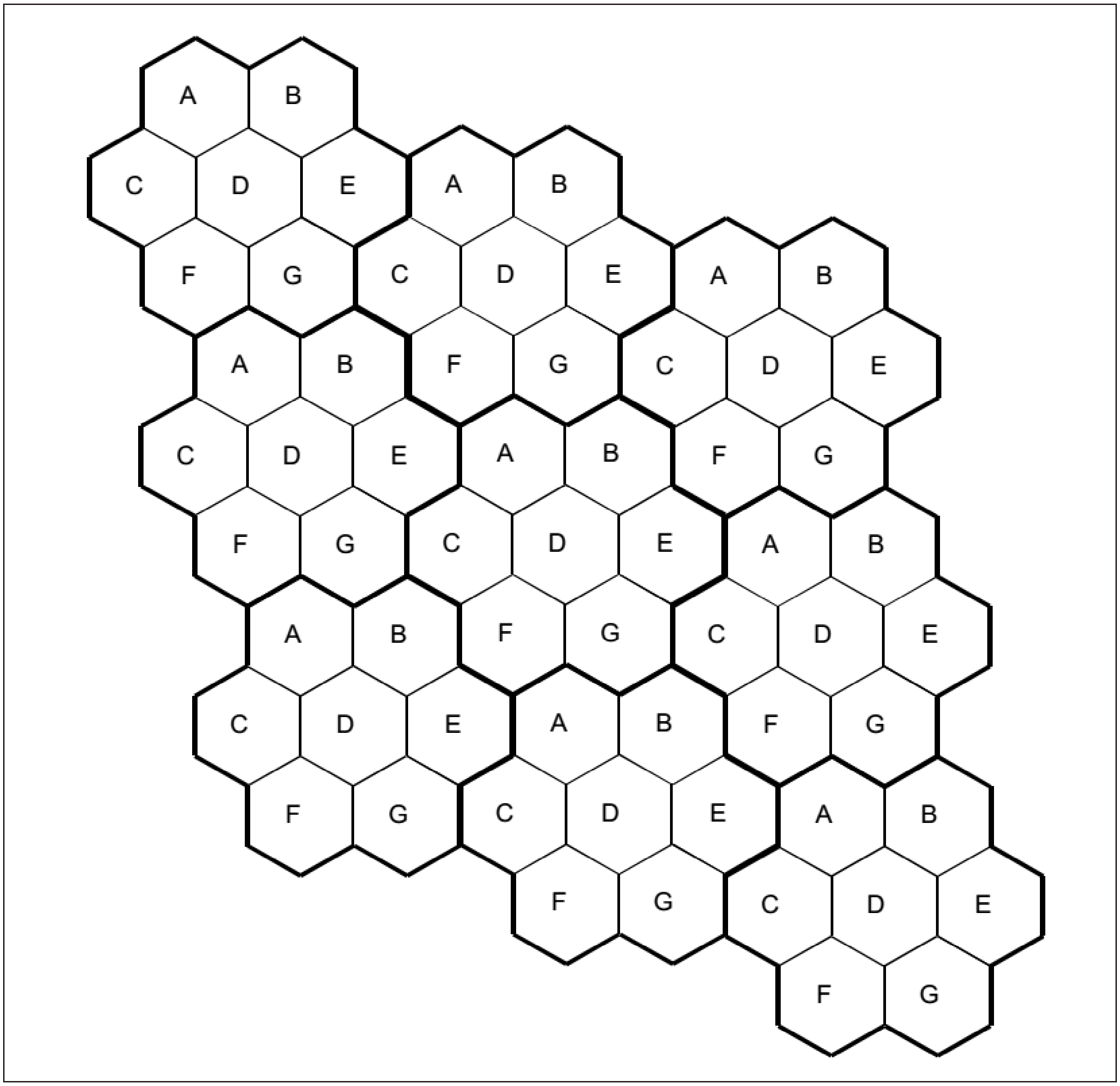


Figure D-4A. Single frequency GRAS VHF networking using multiple time slots

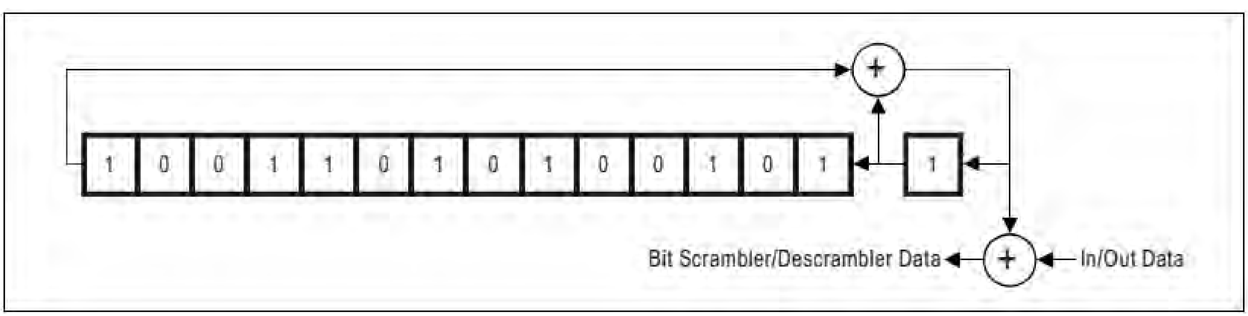
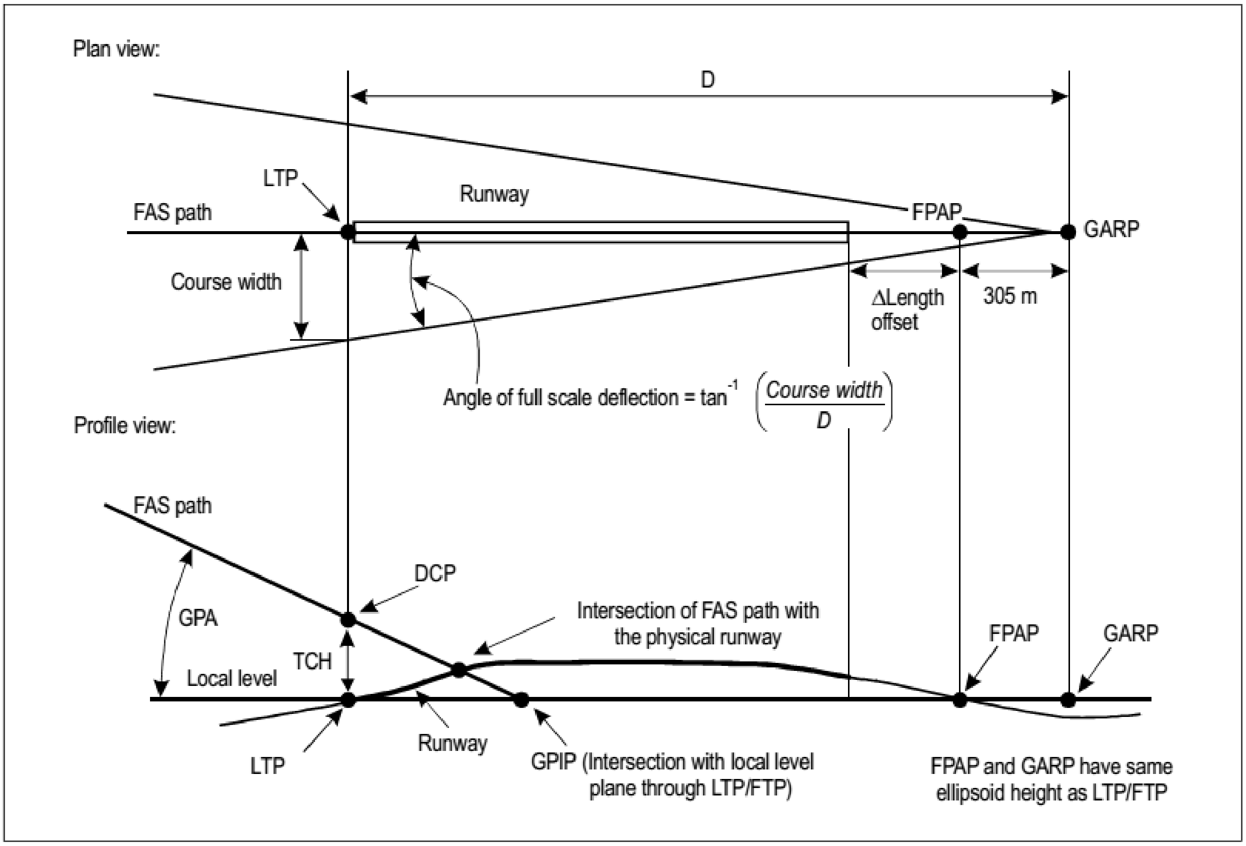
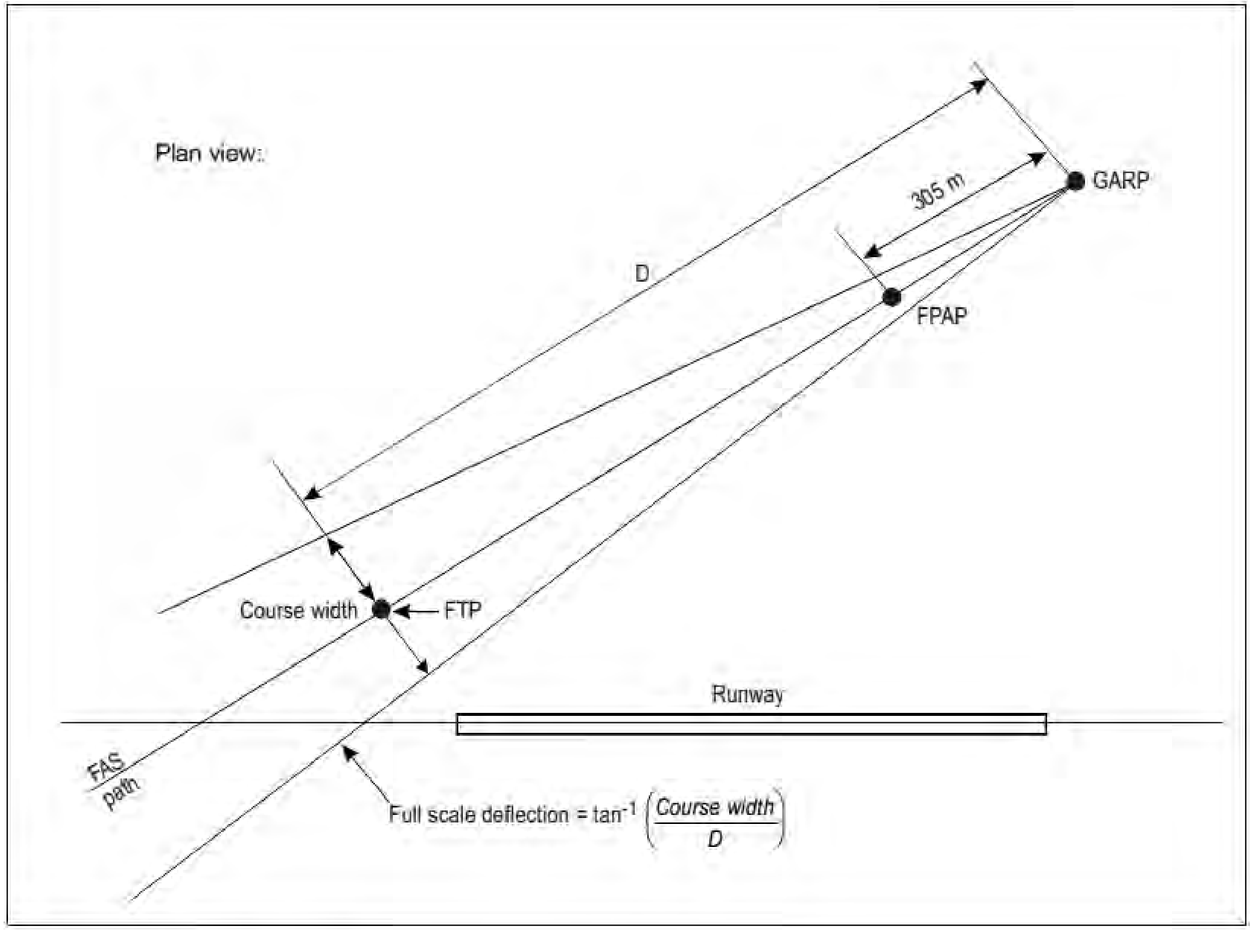


Figure D-5. Bit scrambler/descrambler



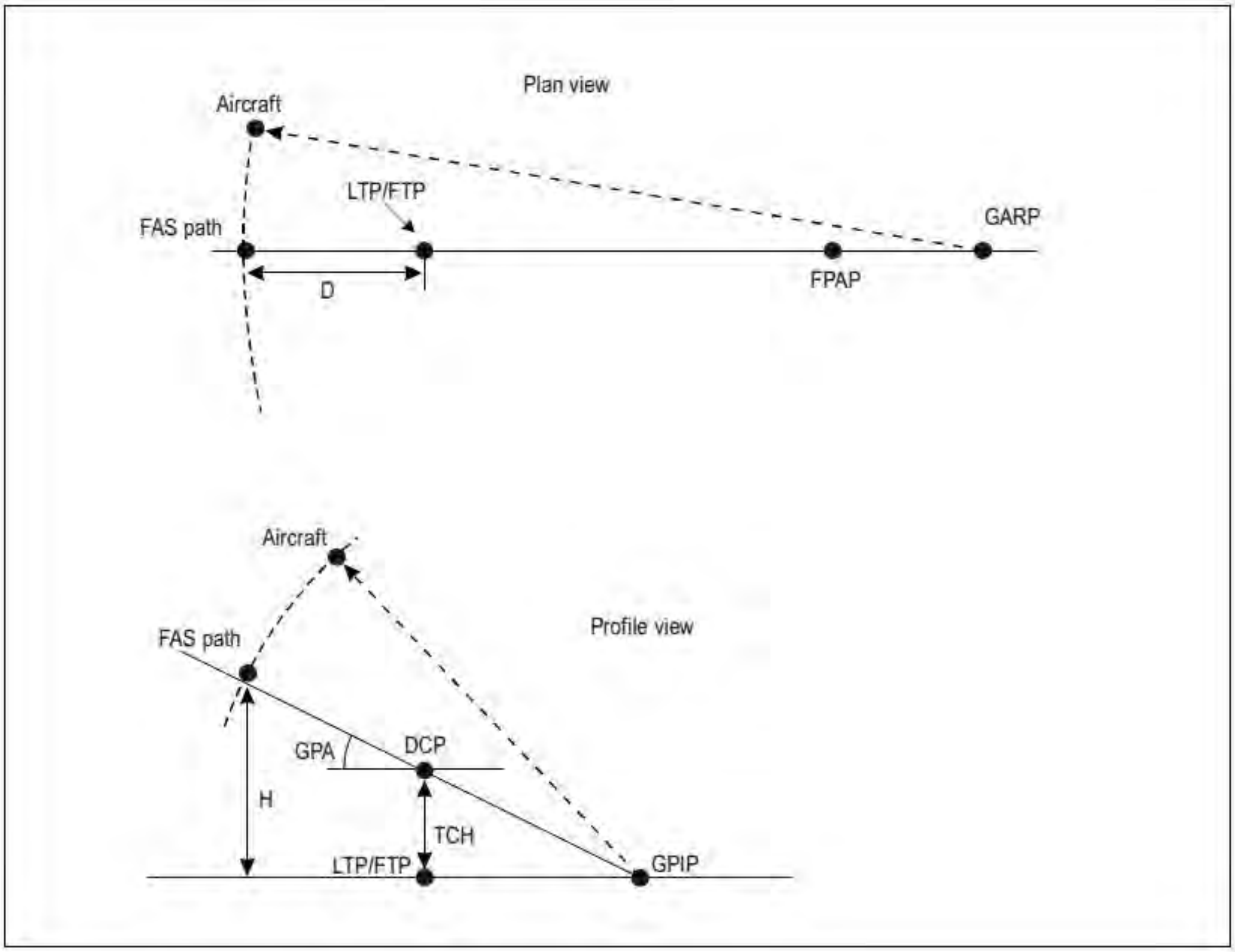
DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point (see Figure D-7)
GARP — GBAS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-6. FAS path definition



FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point
GARP — GBAS azimuth reference point

Figure D-7. FAS path definition for approaches not aligned with the runway



DCP — datum crossing point
FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point (see Figure D-7)
GARP — GBAS azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-8. Definition of D and H parameters in alert limit computations

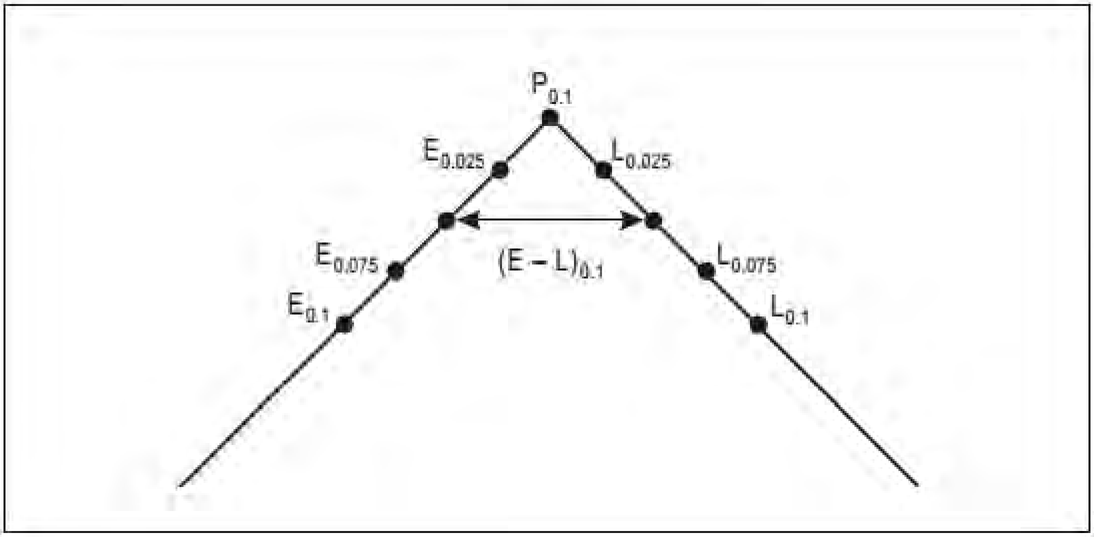


Figure D-9. "Close-in" correlation peak and measured correlator values

ATTACHMENT E. GUIDANCE MATERIAL ON THE PRE-FLIGHT CHECKING OF VOR AIRBORNE EQUIPMENT

1. Specification for a VOR airborne equipment test facility (VOT)

1.1 Introduction

For the guidance of States wishing to provide a test signal for the pre-flight checking of VOR airborne equipment, suggested characteristics for a VOR airborne equipment test facility (VOT) are given hereafter.

1.2 General

1.2.1 The VOT must be designed to provide signals that will permit satisfactory operation of a typical VOR aircraft installation in those areas of the aerodrome where pre-flight checking is convenient and desirable.

1.2.2 The VOT must be constructed and adjusted so that the VOR bearing indicator in the aircraft will indicate zero degrees "FROM" when the receiver has not departed from calibration. This indication remains constant irrespective of the aircraft's angular position with respect to the VOT within the intended coverage.

1.2.3 In view of the manner in which use is made of a VOT, there is no fundamental need for its duplication at any one site.

1.2.4 The VOT is required to radiate a radio frequency carrier with which are associated two separate 30 Hz modulations. The characteristics of these modulations should be identical with the reference phase and variable phase signals associated with VOR. The phases of these modulations should be independent of azimuth and should be coincident with each other at all times.

1.3 Radio frequency

The VOT should operate in the band 108 to 117.975 MHz on an appropriate VOR channel selected so as not to interfere with any VHF navigation or communication services. The highest assignable frequency is 117.95 MHz. The frequency tolerance of the radio frequency carrier should be plus or minus 0.005 per cent, except as specified in Chapter 3, 3.3.2.2 and 3.3.2.3.

1.4 Polarization and accuracy

1.4.1 The emission from the VOT should be horizontally polarized.

1.4.2 The accuracy of the "bearing" information conveyed by the radiation from the VOT should be plus or minus 1 degree.

Note.— Since the two modulations on the radio frequency carrier are in phase coincidence at all times, the vestigial vertically polarized energy will have no effect on the accuracy of the facility.

1.5 Coverage

1.5.1 Coverage requirements, and hence the power which must be radiated, will necessarily depend to a considerable extent on local circumstances. For some installations, a small fraction of 1 W will suffice while in other cases, particularly if two or more closely adjacent aerodromes are to be served by a single test facility, several watts of radio frequency energy may need to be emitted.

1.5.2 Where there is a need to protect co-channel VORs, VOTs and ILS localizers from VOT interference, the radio emission must be limited to that required to provide satisfactory operation and to ensure that interference with other co-channel assignments does not occur.

1.6 Modulation

1.6.1 The radio frequency carrier as observed at any point in space should be amplitude modulated by two signals as follows:

a) a subcarrier of 9 960 Hz of constant amplitude, frequency modulated at 30 Hz and having a deviation ratio of 16 plus or minus 1 (i.e. 15 to 17);

b) 30 Hz.

1.6.2 The depth of modulation due to the 9 960 Hz and the 30 Hz signals should be within the limits of 28 per cent for each component.

1.6.3 The signal which frequency modulates the 9 960 Hz subcarrier and the signal which amplitude modulates the radio frequency carrier should both be maintained at 30 Hz within plus or minus 1 per cent.

1.6.4 The frequency of the 9 960 Hz subcarrier should be maintained within plus or minus 1 per cent.

1.6.5 The percentage of amplitude modulation on the 9 960 Hz subcarrier present at the output of the transmitter should not be greater than 5 per cent.

1.7 Identification

1.7.1 The VOT should transmit a 1 020 Hz identification signal. The identification code for a VOT installation should be selected by the competent authority so as to be unmistakably distinctive as to the test function and, if necessary, as to the location.

Note.— In one State, when the VOT coverage is confined to a single aerodrome, the identification consists of a continuous series of dots.

1.7.2 The depth to which the radio frequency carrier is modulated by the identification signal should be approximately 10 per cent.

1.8 Monitoring

1.8.1 Basically, there is no need for continuous automatic monitoring of VOT provided the relative phase of the AM and FM 30 Hz components are mechanically locked and facilities exist for periodic inspection and remote supervision of the state of the VOT.

1.8.2 Provision of automatic monitoring can double the cost of a VOT installation and, consequently, many competent

authorities are likely to employ only remote supervision at a control point. However, where, in the light of the operational use to be made of a VOT, a State decides to provide automatic monitoring, the monitor should transmit a warning to a control point and cause a cessation of transmission if either of the following deviations from established conditions arises:

a) a change in excess of 1 degree at the monitor site of the “bearing” information transmitted by the VOT;

b) a reduction of 50 per cent in the signal level of the 9 960 Hz or 30 Hz signals at the monitor. Failure of the monitor should automatically cause a cessation of transmission.

2. Selection and use of VOR aerodrome check-points

2.1 General

2.1.1 When a VOR is suitably located in relationship to an aerodrome, the pre-flight checking of an aircraft VOR installation can be facilitated by the provision of suitably calibrated and marked check-points at convenient parts of the aerodrome.

2.1.2 In view of the wide variation in circumstances encountered, it is not practicable to establish any standard requirements or practices for the selection of VOR aerodrome check-points. However, States wishing to provide this facility should be guided by the following considerations in selecting the points to be used.

2.2 Siting requirements for check-points

2.2.1 The signal strength of the nearby VOR has to be sufficient to ensure satisfactory operation of a typical aircraft VOR installation. In particular, full flag action (no flag showing) must be ensured.

2.2.2 The check-points should, within the limits of operating convenience, be located away from buildings or other reflecting objects (fixed or moving) which are likely to degrade the accuracy or stability of the VOR signal.

2.2.3 The observed VOR bearing at any selected point should ideally be within plus or minus 1.5 degrees of the bearing accurately determined by survey or chart plotting.

Note.— The figure of plus or minus 1.5 degrees has no direct operational significance in that the observed bearing becomes the published bearing; however, where a larger difference is observed, there is some possibility of poor stability.

2.2.4 The VOR information at a selected point should be used operationally only if found to be consistently within plus or minus 2 degrees of the published bearing. The stability of the VOR information at a selected point should be checked periodically with a calibrated receiver to ensure that the plus or minus 2-degree tolerance is satisfied, irrespective of the orientation of the VOR receiving antenna.

Note.— The tolerance of plus or minus 2 degrees relates to the consistency of the information at the selected point and includes a small tolerance for the accuracy of the calibrated VOR receiver used in checking the point. The 2-degree figure does not relate to any figure for acceptance or rejection of an aircraft VOR installation, this being a matter for determination by Administrations and users in the light of the operation to be performed.

2.2.5 Check-points which can satisfy the foregoing requirements should be selected in consultation with the operators concerned. Provision of check-points in holding bays, at runway ends and in maintenance and loading areas, is usually desirable.

2.3 Marking of VOR check-points

Each VOR check-point must be distinctively marked. This marking must include the VOR bearing which a pilot would observe on the aircraft instrument if the VOR installation were operating correctly.

2.4 Use of VOR check-points

The accuracy with which a pilot must position the aircraft with respect to a check-point will depend on the distance from the VOR station. In cases where the VOR is relatively close to a check-point, particular care must be taken to place the aircraft's VOR receiving antenna directly over the check-point.

ATTACHMENT F. GUIDANCE MATERIALCONCERNING RELIABILITY AND AVAILABILITYOF RADIOCOMMUNICATIONS AND NAVIGATION AIDS

1. Introduction and fundamental concepts

This Attachment is intended to provide guidance material which Member States may find helpful in providing the degree of facility reliability and availability consistent with their operational requirement. The material in this Attachment is intended for guidance and clarification purposes, and is not to be considered as part of the Standards and Recommended Practices contained in this Annex.

1.1 Definitions

Facility availability. The ratio of actual operating time to specified operating time.

Facility failure. Any unanticipated occurrence which gives rise to an operationally significant period during which a facility does not provide service within the specified tolerances.

Facility reliability. The probability that the ground installation operates within the specified tolerances.

Note.— This definition refers to the probability that the facility will operate for a specified period of time.

Mean time between failures (MTBF). The actual operating time of a facility divided by the total number of failures of the facility during that period of time.

Note.— The operating time is in general chosen so as to include at least five, and preferably more, facility failures in order to give a reasonable measure of confidence in the figure derived.

Signal reliability. The probability that a signal-in-space of specified characteristics is available to the aircraft.

Note.— This definition refers to the probability that the signal is present for a specified period of time.

1.2 Facility reliability

1.2.1 Reliability is achieved by a combination of factors. These factors are variable and may be individually adjusted for an integrated approach that is optimum for, and consistent with, the needs and conditions of a particular environment. For example, one may compensate to some extent for low reliability by providing increased maintenance staffing and/or equipment redundancy. Similarly, low levels of skill among maintenance personnel may be offset by providing equipment of high reliability.

1.2.2 The following formula expresses facility reliability as a percentage:

$$R = 100\ e^{-t/m}$$

where:

R = reliability (probability that the facility will be operative within the specified tolerances for a time t, also referred to as probability of survival, Ps);

e = base of natural logarithms;

t = time period of interest;

m = mean time between facility failures.

It may be seen that reliability increases as mean time between failures (MTBF) increases. For a high degree of reliability, andfor operationally significant values of t, we must have a large MTBF; thus, MTBF is another more convenient way of expressing reliability.

1.2.3 Experimental evidence indicates that the above formula is true for the majority of electronic equipments where the failures follow a Poisson distribution. It will not be applicable during the early life of an equipment when there is a relatively large number of premature failures of individual components; neither will it be true when the equipment is nearing the end of its useful life.

1.2.4 At many facility types utilizing conventional equipment, MTBF values of 1 000 hours or more have been consistently achieved. To indicate the significance of a 1 000-hour MTBF, the corresponding 24-hour reliability is approximately 97.5 per cent (i.e. the likelihood of facility failure during a 24-hour period is about 2.5 per cent).

1.2.5 Figure F-1 shows the probability of facility survival, Ps, after a time period, t, for various values of MTBF.

Note.— It is significant that the probability of surviving a period of time equal to the MTBF is only 0.37 (37 per cent); thus, it is not assumed that the MTBF is a failure-free period.

1.2.6 It may be seen that adjustment of MTBF will produce the desired degree of reliability. Factors which affect MTBF and hence facility reliability are:

a) inherent equipment reliability;

b) degree and type of redundancy;

c) reliability of the serving utilities such as power and telephone or control lines;

d) degree and quality of maintenance;

e) environmental factors such as temperature and humidity.

1.3 Facility availability

1.3.1 Availability, as a percentage, may be expressed in terms of the ratio of actual operating time divided by specified operating time taken over a long period. Symbolically,

$$A = \frac{\text{Actual time operating (100)}}{\text{Specified operating time}}$$

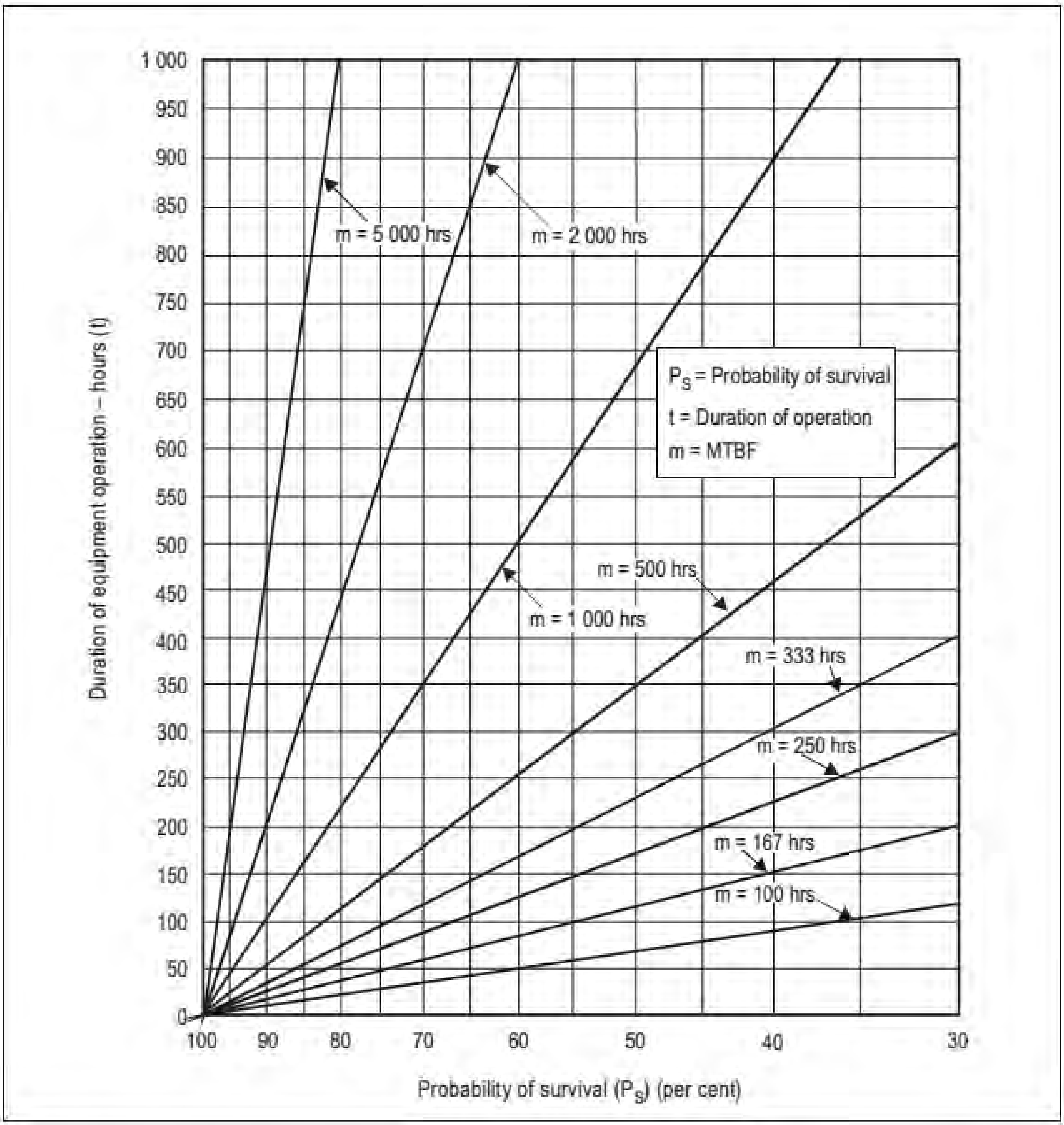


Figure F-1. Plot of $P_s = 100\ e^{-t/m}$

For example, if a facility was operating normally for a total of 700 hours during a 720-hour month, the availability for that month would be 97.2 per cent.

1.3.2 Factors important in providing a high degree of facility availability are:

a) facility reliability;

b) quick response of maintenance personnel to failures;

c) adequate training of maintenance personnel;

d) equipment designs providing good component accessibility and maintainability;

e) efficient logistic support;

f) provision of adequate test equipment;

g) standby equipment and/or utilities.

2. Practical aspects of reliability and availability

2.1 Measurement of reliability and availability

2.1.1 *Reliability.* The value that is obtained for MTBF in practice must of necessity be an estimate since themeasurement will have to be made over a finite period of time. Measurement of MTBF over finite periods of time will enable Administrations to determine variations in the reliability of their facilities.

2.1.2 *Availability*. This is also important in that it provides an indication of the degree to which a facility (or group of facilities) is available to the users. Availability is directly related to the efficiency achieved in restoring facilities to normal service.

2.1.3 The basic quantities and manner of their measurement are indicated in Figure F-2. This figure is not intended to represent a typical situation which would normally involve a larger number of inoperative periods during the specified operating time. It should also be recognized that to obtain the most meaningful values for reliability and availability the specified operating time over which measurements are made should be as long as practicable.

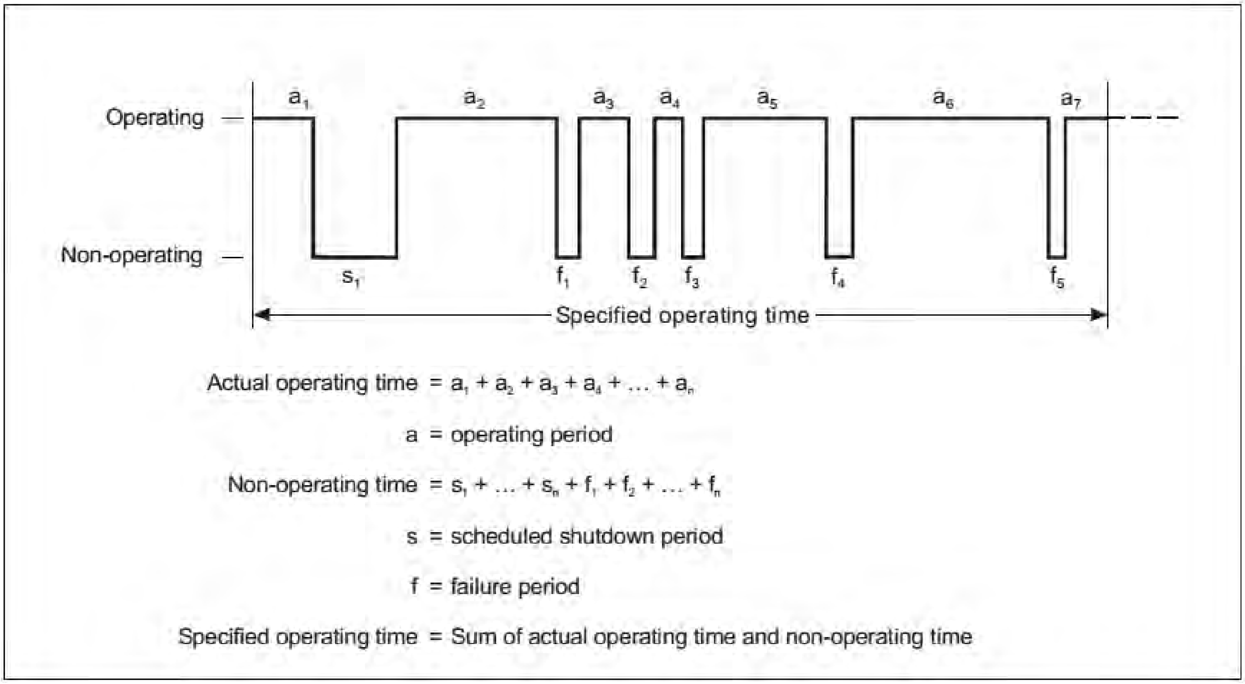


Figure F-2. Evaluation of facility availability and reliability

2.1.4 Using the quantities illustrated in Figure F-2, which includes one scheduled shutdown period and five failure periods, one may calculate mean time between failures (MTBF) and availability (A) as follows:

Let:

$a_1 + a_2 + a_3 + a_4 + a_5 + a_6 + a_7$	=	5 540	hours
s_1	=	20	hours
f_1	=	2½	hours
f_2	=	6¼	hours
f_3	=	3¾	hours
f_4	=	5	hours
f_5	=	2½	hours
Specified operating time	=	5 580	hours

$$\text{MTBF} = \frac{\text{Actual operating time}}{\text{Number of failures}}$$

$$= \frac{\sum_{i=1}^{7} a_1}{5}$$

$$= \frac{5\ 540}{5\ 580} \times 100 = 99.3 \text{ per cent}$$

ATTACHMENT G. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OFTHE MLS STANDARDS AND RECOMMENDED PRACTICES

1. Definitions
(see also Chapter 3, 3.11.1)

Dynamic side-lobe level. The level that is exceeded 3 per cent of the time by the scanning antenna far field radiation pattern exclusive of the main beam as measured at the function scan rate using a 26 kHz beam envelope video filter. The 3 per cent level is determined by the ratio of the side-lobe duration which exceeds the specified level to the total scan duration.

Effective side-lobe level. That level of scanning beam side lobe which in a specified multipath environment results in a particular guidance angle error.

MLS point D. A point 2.5 m (8 ft) above the runway centre line and 900 m (3 000 ft) from the threshold in the direction of the azimuth antenna.

MLS point E. A point 2.5 m (8 ft) above the runway centre line and 600 m (2 000 ft) from the stop end of the runway in the direction of the threshold.

Standard receiver. The airborne receiver model assumed in partitioning the MLS error budgets. The salient characteristics are: (1) signal processing based on the measurement of beam centres; (2) negligible centring error; (3) control motion noise (CMN) less than or equal to the values contained in Chapter 3, 3.11.6.1.1.2; (4) a 26 kHz bandwidth 2-pole low pass beam envelope filter; and (5) angle data output filtering by a single pole, low pass filter with a corner frequency of 10 radians per second.

2. Signal-in-space characteristics — angle and data functions

2.1 Signal format organization

2.1.1 The signal format is based on time-division multiplexing wherein each angle guidance function is transmitted in sequence and all are transmitted on the same radio frequency. The angle information is derived by measuring the time difference between the successive passes of highly directive, unmodulated fan beams. Functions may be transmitted in any order. Recommended time slots are provided for the approach azimuth, approach elevation, flare, and back azimuth angle functions. Preceding each scanning beam and data transmission is a preamble which is radiated throughout the coverage volume by a sector antenna. The preamble identifies the next scan function and also synchronizes the airborne receiver signal processing circuits and logic.

2.1.2 In addition to the angle scan function, there are basic and auxiliary data functions, each with its own preamble, which are also transmitted from the sector antennas. The preamble permits each function to be recognized and processed independently. Consequently, functions can be added to or deleted from the ground configurations without affecting the operation of the receiver. The codes used in the preamble and data functions are modulated by differential phase shift keying (DPSK).

2.1.2.1 ***DPSK data signal characteristics.*** The DPSK data are transmitted by differential phase modulation of the radio frequency carrier with relative phase states of 0 or 180 degrees. The DPSK data signal has the following characteristics:

data rate — 15.625 kHz
bit length — 64 microseconds
logic "0" — no phase transition
logic "1" — phase transition

2.1.3 Examples of the angle function organization and timing are shown in Figures G-1 and G-2.*

2.1.4 The sequences of angle guidance and data transmissions shown in Figures G-3A, G-3B and G-3C have been demonstrated to provide sufficient freedom from synchronous interference.

2.1.4.1 The structure of these sequences is intended to provide sufficient randomization to preclude synchronous interference such as may be caused by propeller rotation effects.

2.1.4.2 The sequence pair shown in Figure G-3A accommodates the transmission of all functions. Any function not required may be deleted so long as the remaining functions are transmitted in the designated time positions.

2.1.4.3 The sequence pair shown in Figure G-3B accommodates the high rate approach azimuth function. Any function not required may be deleted so long as the remaining functions are transmitted in the designated time positions.

* All figures are located at the end of the Attachment.

2.1.4.4 Figure G-3C shows the complete time multiplex transmission cycle which may be composed of the sequence pairs from Figure G-3A or from Figure G-3B. The open time periods between sequences can be used for the transmission of auxiliary data words as indicated. Basic data words also may be transmitted in any open time period.

2.1.4.5 Sufficient time is available in the cycle shown for the transmission of the basic data and the auxiliary data defined in words A1-A4, B1-B39, B40-B45 and B55, provided that data are also transmitted during unused time slots or slots devoted for data words within the sequences.

2.1.4.6 More efficient sequences may be designed by adjusting the timing within the sequences and the inter-sequence gaps to allow the transmission of additional auxiliary data words. Such sequences must be designed to provide equivalent freedom from synchronous interference as the sequences shown in Figures G-3A, G-3B and G-3C. Frequency domain analysis techniques may be utilized to demonstrate that alternative sequences are sufficiently randomized.

2.2 Angle guidance parameters

2.2.1 The angle guidance parameters that define the MLS angle measurement process are specified in Chapter 3, 3.11.4.5. Two additional parameters that are useful in visualizing the operation of the system are the mid scan time (Tm) and the pause time. They may be derived from the Chapter 3 specifications and are shown for reference in the following table.

Signal format midscan and pause times

(see Figure G-2)

Function	*Midscan*[1] *time,* T_m *(µs)*	*Pause time (µs)*
Approach azimuth	7 972	600
High rate approach azimuth	5 972	600
Back azimuth	5 972	600
Approach elevation	2 518	400
Flare elevation	2 368	800

1 Measured from the receiver reference time (see Appendix A, Table A-1).

2.2.2 *Function timing accuracy*. Because of the inaccuracy in the determination of the reference time of the Barker code, and because the transmitter circuits smooth the phase or amplitude during phase transitions of the DPSK modulation, it is not possible to determine the timing of the signal with an accuracy better than 2 microseconds from the signal-in-space. It is therefore necessary to measure the timing accuracy specified in Chapter 3, 3.11.4.3.4 on the ground equipment. Suitable test points should be provided in the ground equipment.

2.3 Azimuth guidance functions

2.3.1 *Scanning conventions.* Figure G-4 shows the approach azimuth and back azimuth scanning conventions.

2.3.2 *Coverage requirements*. Figures G-5 and G-6 illustrate the azimuth coverage requirements specified in Chapter 3, 3.11.5.2.2.

2.3.2.1 When the approach or back azimuth antenna sites are necessarily offset from the runway centre line, the following factors should be considered:

a) coverage requirements throughout the runway region;

b) accuracy requirements at the applicable reference datum;

c) approach azimuth to back azimuth transition; and

d) potential disturbances due to moving vehicles, aircraft or airport structures.

2.3.2.2 An offset azimuth antenna is normally adjusted such that the zero-degree azimuth is either parallel to the runway centre line or intersects the centre line extended at an operationally preferred point for the intended application. The alignment of the zero-degree azimuth with respect to the runway centre line is transmitted on the auxiliary data.

2.3.3 *High rate approach azimuth*. Where the approach proportional guidance sector is plus or minus 40 degrees or less, it is possible to use a higher scanning rate for the azimuth function. The high rate approach azimuth function is available to offset the increase in CMN caused by large beam width antennas (e.g. 3 degrees). Reducing the CMN provides two benefits:

1) angle guidance signal-in-space power density requirements can be reduced; and 2) dynamic side-lobe level requirements can be relaxed.

2.3.3.1 In general, this function will reduce the CMN caused by wide bandwidth, uncorrelated sources such as diffuse multipath or receiver thermal noise by a factor of $\sqrt{1/3}$ relative to the basic 13 Hz function rate. However, the full reduction of power density by $\sqrt{1/3}$ cannot be realized for all ground antenna beam widths because of the requirement to provide sufficient power density for signal acquisition on a single scan basis. The power required for DPSK transmissions may be such that no economies are realized in the ground equipment transmitters by using the higher data rate (see Table G-1).*

2.3.3.2 However, with respect to the CMN performance, the full benefit of the increased data rate can be realized. For example, at the minimum signal levels shown in Table G-2, the azimuth CMN can be reduced from 0.10 degree to 0.06 degree for the 1-degree and the 2-degree beamwidth antennas.

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* All tables are located at the end of the Attachment

2.3.4 Clearance

2.3.4.1 Where used, clearance pulses are transmitted adjacent to the scanning beam signals at the edges of proportional guidance sector as shown in the timing diagram in Figure G-7. The proportional guidance sector boundary is established at one beamwidth inside the scan start/stop angles, such that the transition between scanning beam and clearance signals occurs outside the proportional guidance sector. Examples of composite wave forms which may occur during transition are shown in Figure G-8.

2.3.4.2 When clearance guidance is provided in conjunction with a narrow beamwidth (e.g. one degree) scanning antenna, the scanning beam antenna is to radiate for 15 microseconds while stationary at the scan start/stop angles.

2.3.4.3 At some locations it may be difficult to satisfy the amplitude criteria of Chapter 3, 3.11.6.2.5.2, because of clearance signal reflections. At these locations the scan sector may be extended.

2.3.4.4 Care is to be taken with respect to the fly-right/fly-left clearance convention change when approaching azimuth stations in an opposite direction (e.g. approach towards the back azimuth antenna).

2.3.5 *Approach azimuth monitoring.* The intention of monitoring is to guarantee the guidance integrity appropriate for the promulgated approach procedure. It is not intended that all azimuth angles be monitored independently, but that at least one approach azimuth, normally aligned with the extended runway centre line, be monitored and that adequate means be provided to ensure that the performance and integrity of the other azimuth angles are maintained.

2.3.6 *Lower coverage limit determination*. When the threshold is not in line of sight of the approach azimuth antenna, the height of the lower limit of the approach azimuth coverage in the runway region is determined by simulation and/or field measurements. The lower limit of the azimuth coverage to be published is the height above the runway surface that satisfies the accuracy requirements in Chapter 3, 3.11.4.9.4 as determined by field measurements.

2.3.6.1 If operations require coverage below the coverage limits obtainable from 2.3.6, the azimuth antenna can be offset from the runway centre line and moved toward the runway threshold to cover the touchdown region. The airborne installation must use the azimuth guidance, precision distance and siting coordinates of the ground equipment to compute the centre line approach.

2.3.6.2 The landing minima obtainable from a computed centre line approach are, among other things, a function of the combined reliability and integrity of the MLS approach azimuth, DME/P transponder and airborne equipment.

2.4 Elevation guidance functions

2.4.1 *Scanning conventions*. Figure G-9 shows the approach elevation scanning conventions.

2.4.2 *Coverage requirements*. Figures G-10A and G-10B illustrate the elevation requirements specified in Chapter 3, 3.11.5.3.2.

2.4.3 *Elevation monitoring*. The intention of monitoring is to guarantee the guidance integrity appropriate for the promulgated approach procedure. It is not intended that all elevation angles be monitored independently, but that at least one,normally the minimum glide path, be monitored, and that adequate means be provided to ensure that the performance and integrity of the other elevation angles are maintained.

2.5 Accuracy

2.5.1 General

2.5.1.1 System accuracy is specified in Chapter 3, in terms of the path following error (PFE), path following noise (PFN), and control motion noise (CMN). These parameters are intended to describe the interaction of the angle guidance signal with the aircraft in terms which can be directly related to aircraft guidance errors and the flight control system design.

2.5.1.2 The system PFE is the difference between the airborne receiver angle measurement and the true position angle of the aircraft. The guidance signal is distorted by ground and airborne equipment errors and errors due to propagation effects. To assess the suitability of the signal-in-space for aircraft guidance, these errors are viewed in the pertinent frequency region. The PFE includes the mean course error and the PFN.

2.5.2 MLS measurement methodology

2.5.2.1 The PFE, PFN and CMN are evaluated by using the filters defined in Figure G-11. The filter characteristics are based on a wide range of existing aircraft response properties and are considered adequate for foreseeable aircraft designs as well.

2.5.2.2 While the term "PFE" suggests the difference between a desired flight path and the actual flight path taken by an aircraft following the guidance signal, in practice, this error is evaluated by instructing the flight inspection pilot to fly a desired MLS azimuth and recording the difference between the airborne equipment output guidance indication from the PFE filter and the corresponding aircraft position measurement as determined by a suitable position reference. A similar technique using the appropriate filter determines the CMN.

2.5.2.3 *Error evaluation*. The PFE estimates are obtained at the output of the PFE filter (test point A in Figure G-11). The CMN estimates are obtained at the output of the CMN filter (test point B in Figure G-11). Filter corner frequencies are shown in Figure G-11.

2.5.2.3.1 The PFE and CMN for approach azimuth or for back azimuth are evaluated over any 40-second interval of the flight error record taken within the coverage limits (i.e. T= 40 in Figure G-12). The PFE and CMN for approach elevation are evaluated over any 10-second interval of the flight error record taken within the coverage limits (i.e. T= 10 in Figure G-12).

2.5.2.3.2 The 95 per cent probability requirement is interpreted to be met if the PFE or CMN does not exceed the specified error limits for more than 5 per centof the evaluation interval (see Figure G-12).

2.5.2.3.3 An alternative flight inspection procedure can be used which does not rely on an absolute reference. In this procedure, only the fluctuating components of the flight record produced at the output of the PFE filter are measured and compared with the PFN standard. The average value of the PFE is assumed to not exceed the mean course alignment specified during the flight inspection period. Therefore, the mean course alignment is added to the PFN measurement for comparison with the specified system PFE. The CMN may be similarly evaluated without accounting for the mean course alignment.

2.5.2.4 *Ground and airborne instrumentation errors.* The instrumentation error induced by the ground and airborne equipment may be determined by measurements taken in an environment which is free from reflected signals or other propagation anomalies which can cause beam envelope perturbations.

2.5.2.4.1 First, the instrumentation errors associated with the standard airborne receiver are determined using a bench test instrument, and the centring error is adjusted to zero. Airborne equipment errors can be measured by recording 40 seconds of data using a standard bench test set. The data can then be divided into four 10-second intervals. The average of each interval is considered to be the PFE while twice the square root of its associated variance is the CMN.

Note.— The receiver output may be evaluated using the PFE and CMN filters, if desired.

2.5.2.4.2 Second, this standard receiver is used to measure the total system instrumentation error by operating the ground equipment on an antenna range or in some other reflection-free environment. Since the receiver centring error has been made negligible, the measured PFE can be attributed to the ground equipment. The ground equipment CMN is obtained by subtracting the known standard receiver CMN variance from the CMN variance of the measurement. The average error over a 10-second measurement interval is considered to be the PFE, while twice the square root of the differential variances is considered to be the instrumental CMN.

2.6 Power density

2.6.1 General

2.6.1.1 Three criteria establish the angle power budgets:

a) angle single-scan acquisition requires a 14-dB signal-to-noise ratio (SNR) as measured at the beam envelope filter (i.e. the video SNR);

b) the angle CMN must be maintained within specified limits;

c) the DPSK transmissions must have a detection probability at the extremes of coverage of at least 72 per cent.

2.6.1.2 The source of CMN at 37 km (20 NM) is primarily internal receiver thermal noise. The noise induced error (dθ) can be estimated by:

$$d\theta = \frac{\theta_{BW}}{2\left(\sqrt{SNR}\sqrt{g}\right)}$$

$$g = \frac{\text{Function sample rate}}{2\ (\text{Filter noise bandwidth right})}$$

where θBWis the antenna beamwidth in degrees and gis the ratio of the function sample rate to the noise bandwidth of the receiver output filter. For a single pole filter, the noise bandwidth is π/2 times the 3 dB bandwidth. This expression reflects the CMN dependence upon ground antenna beamwidth and sample rate.

2.6.2 System power budget

2.6.2.1 The system power budget is presented in Table G-1. The power density specified in Chapter 3, 3.11.4.10.1, is related to the signal power specified in Table G-1 at the aircraft antenna by the relation:

Power into isotropic antenna (dBm) = Power density (dBW/m2) – 5.5

2.6.2.2 The angle function measurement assumes a 26-kHz beam envelope filter bandwidth. The video (SNR) given in 2.6.1 is related to the intermediate frequency (IF) SNR by:

$$\text{SNR (Video)} = \text{SNR (IF)} + \\ +10\log\left[\frac{\text{IF noise bandwidth}}{\text{Video noise bandwidth}}\right]$$

2.6.2.3 The DPSK preamble function analysis assumes: 1) a carrier reconstruction phase lock loop airborne receiver implementation; and 2) that the receiver preamble decoder rejects all preambles which do not satisfy the Barker code or fail the preamble parity check.

2.6.2.4 Items a) through e) in Table G-1 are functions of the aircraft position or weather, and thus have been assumed to be random events. That is, they will simultaneously reach their worst-case values only on rare occasions. Therefore, these losses are viewed as random variables and are root-sum-squared to obtain the loss component.

2.6.2.5 To support auto land operations, power densities higher than those specified for the approach azimuth angle signals in Chapter 3, 3.11.4.10.1 are required at the lower coverage limit above the runway surface to limit the CMN to 0.04 degree. Normally, this additional power density will exist as a natural consequence of using the same transmitter to provide the scanning beam and DPSK signals and considering other power margins such as the available aircraft antenna gain, propagation losses, coverage losses at wide angles and rain losses which can be, at least partially, discounted in the runway region (see Table G-1).

2.6.3 Multipath relative power density

2.6.3.1 Fixed or mobile obstacles around the MLS ground transmitting antennas may create reflections which are known as multipath. The reflections are affecting all MLS transmissions (DPSK, angle guidance signals, out-of-coverage indication signals and clearance pulses). Relative levels between the direct guidance signal (coding the correct guidance signal) and the reflected signals are used by the MLS angular receiver to acquire and track the correct signals. These relative levels therefore have to be within given and known tolerances to allow correct receiver performances. The MOPS for MLS Airborne Receiving Equipment, EUROCAE ED-36B document, contains the MLS receivers' minimum operational performance specifications ensuring correct performances against the multipath environment, as specified in Chapter 3, 3.11.4.10.3.

2.6.3.2 The four-decibel minimum ratio in Chapter 3, 3.11.4.10.3.1 and 3.11.4.10.3.3, guarantees a valid acquisition by the receiver. Lower ratios may delay signal acquisition or create false acquisition and tracking of multipath signals.

2.6.3.3 The maximum one-second duration in Chapter 3, 3.11.4.10.3.1 and 3.11.4.10.3.3, will ensure that the correct guidance information will continue to be output by the receiver without alert and will therefore not cause loss of service. This duration has to be assessed using approaching aircraft minimum ground speed.

2.6.3.4 Accuracy requirements will limit the level and duration of azimuth multipath coding angles within a narrow sector around centre line (i.e. +/-4°) as the scanning beam shape depicted in Chapter 3, 3.11.5.2.1.3, will be affected. The periodic ground and flight checks will show whether the error contribution from static multipath is compatible with the accuracy requirements. Critical and sensitive areas protection procedures will ensure that dynamic multipath error contribution will not degrade the overall accuracy beyond accuracy requirements.

2.6.3.5 For elevation guidance, signal-in-space degradation by multipath at lower height is not anticipated.

2.6.4 *Airborne power budget*

2.6.4.1 Table G-2 provides an example of an airborne power budget used in developing the power density standards.

2.7 Data applications

2.7.1 *Basic data*. The basic data defined in Chapter 3, 3.11.4.8.2.1 are provided to enable airborne receivers to process scanning beam information for various ground equipment configurations and to adjust outputs so they are meaningful to the pilot or airborne system. Data functions are also used to provide additional information (e.g. station identification and equipment status) to the pilot or airborne system.

2.7.2 *Auxiliary data*

2.7.2.1 The auxiliary data defined in Chapter 3, 3.11.4.8.3.1 and 3.11.4.8.3.2 are provided to digitally uplink the following types of information:

a) *Data describing ground equipment siting geometry.* These are transmitted in words A1-A4 and in some of the words B40-B54.

b) *Data to support MLS/RNAV operations*. These are transmitted in words B1-B39.

c) *Operational information data.* These are transmitted in words B55-B64.

2.7.2.2 The rates of transmission of auxiliary data words are based on the following criteria:

a) Data that are required to be decoded within six seconds upon entering the MLS coverage volume should be transmitted with a maximum time between transmissions of 1 second (see 7.3.3.1.1).

b) Data that are required for an intended operation but are not required to be decoded within six seconds should be transmitted with a maximum time between transmissions of2 seconds. This rate will allow the generation of a warning upon loss of data within 6 seconds.

c) Operational information data should be transmitted with a maximum time between transmissions of 10 seconds. This will allow the generation of a warning upon loss of data within 30 seconds.

2.7.3 *Application of MLS/RNAV data words B1 through B39*

2.7.3.1 The data contained in auxiliary data words B1-B39 are designed to allow MLS/RNAV operations to be supported utilizing only the data contained within the MLS data words. In order to support computed centre line approaches to both the primary and secondary runways, curved approaches and departures, and missed approaches, these data include information on procedure type (approach or departure), procedure name, runway and way-points.

2.7.3.2 The data transmitted by approach azimuth and back azimuth are segregated. This means, for example, that each will have a separate cyclic redundancy check (CRC) and be decoded independently by the airborne equipment. Data for a given MLS/RNAV procedure are transmitted in the coverage where the procedure begins. Normally this means that approach and missed approach data would be transmitted by approach azimuth and departure data would be transmitted by back azimuth equipment. However, way-points belonging to approaches, missed approaches or departures could be transmitted in either the azimuth or the back azimuth coverage. For example, a departure may be initiated in approach azimuth coverage, therefore that data would be transmitted by approach azimuth. If the procedure begins in a common coverage region the associated data can be transmitted in only one region, except where otherwise dictated by operational requirements.

2.7.3.3 The procedures are defined by a series of way-points. The way-points are specified in a cartesian coordinate system with X, Y and Z coordinates whose origin is at the MLS datum point. The coordinate system is illustrated in Figure G-13.

2.7.3.4 The segments between way-points are either straight or curved. Curved segments are defined as the arc joining two way-points, as illustrated in Figure G-14. The arc of the circle is always tangent to the preceding and following segments, straight or circular. Final approach segments and segments pointing to the initial way-point of an approach procedure or extending from the last flown way-point of a departure or missed approach procedure are always straight. They are extensions to straight segments or tangents to circular segments. These straight segments would not necessarily require a way-point at the edge of the coverage, thus way-points could be saved.

2.7.3.5 For any procedure type the coding starts with the way-point farthest from the threshold and ends with the waypoint nearest to the runway. All way-points for approach procedures must be coded before any missed approach way-points or departure way-points. This rule simplifies the decoding by segregating the way-points belonging to the approaches from the others. Several procedures can share one or more way-points. When this is the case it is feasible to transmit this information only once. The shared way-points must be the final ones for approach procedures and the initial ones for missed approach and departure procedures. Approaches, missed approaches and departures can share data provided the data are transmitted in the same coverage sector. When way-points are shared with a procedure previously defined in the database this is indicated by a way-point index following a way-point. The way-point index gives the location in the database of the first shared way-point.

2.7.3.6 The way-point index is the value representing the sequential order in which the way-points are listed in the database. It is used in the coding to indicate where the way-points for a procedure are located. A way-point index of zero in the procedure descriptor indicates that this is a computed centre line application where no way-points are provided.

2.7.3.7 Although way-points are defined by X, Y and Z coordinates, in a variety of cases not all coordinates have to be transmitted. Way-points located on the primary runway centre line have a Y coordinate equal to zero. The corresponding field defining this value can be omitted by setting the "Y coordinate follows" bit to ZERO.

2.7.3.8 Whenever the Z coordinate is not necessary for path construction, data can be saved by not transmitting this value. This is indicated by setting the "Z coordinate follows" bit to ZERO. This may apply to initial way-points preceding the final approach fix where guidance is based on altimetry and not on a computed MLS vertical position. It may also apply to way-points located on a constant gradient between way-points for which the Z value is defined. In this case, the airborne equipment would compute the Z coordinate assuming a constant gradient. Missed approach and departure way-points located in back azimuth coverage are also candidates for deleting the Z coordinate, since vertical guidance is not available. For the back azimuth application, the Z coordinate may be transmitted for use by the airborne equipment to resolve the horizontal position of the aircraft. This allows for a reduction of the lateral errors introduced in the conversion from the slant range and conical back azimuth angle to X-Y coordinates.

2.7.3.9 The 3-bit field following the way-point coordinates contains the next segment/field identifier. This data item indicates whether the next segment of the procedure is straight or curved, whether the current way-point is the last one defined for the procedure, and whether to link the procedure to a missed approach or a shared portion of another procedure identified by a missed approach index or next way-point index. It also indicates whether a data field for threshold crossing height or virtual azimuth to way-point distance is appended to the way-point definition.

2.7.3.9.1 Some typical applications of the identifiers in Appendix A, Table A-17 are listed below. This list is not all inclusive:

a) identifiers 0 and 1 are used when the next way-point in the procedure is not a shared way-point, or is a shared waypoint coded for the first time;

b) identifiers 2 and 3 are used to refer to the next way-points in the procedure that are already coded and shared with another procedure. The coding of these way-points is not repeated but the index allows the connection of the procedure to the shared way-points of the other procedure;

c) identifiers 4 and 5 are used in the next-to-last way-point for procedures ending or beginning on the primary runway. The last way-point is the threshold. For this way-point only, the threshold crossing height is specified since the exact location of the threshold with respect to the MLS datum is given in the auxiliary A words. Identifier 4 is used when the MLS/RNAV missed approach guidance is not required, and identifier 5 is used when a "missed approach index" follows;

d) identifiers 6 and 7 are used for the final way-point of any procedure except as noted inc) above. For the primary runway these identifiers are used if there is a need to fully specify the X, Y and Z coordinates of the last way-point. These identifiers are also used for secondary runways and helipads. Identifier 6 is used when no missed approach is following and identifier 7 when a missed approach follows; and

e) identifiers 5 and 7 do not apply to missed approaches and departures.

2.7.3.10 Following the convention for other MLS basic and auxiliary data, all digital data encoded in the database are transmitted with the least significant bit first and the sign bit is transmitted as the most significant bit, with a ONE indicating a negative value. It is noted that the auxiliary data word addresses used to indicate the last approach azimuth database word and the first back azimuth database word are transmitted with the most significant bit first.

2.7.4 Example application of MLS/RNAV data words

2.7.4.1 The following paragraphs provide an example of the data assignment process for MLS/RNAV data words contained in auxiliary data words B1-B39. A sample set of approach and departure procedures is provided and the process by which the various way-points and associated procedure characteristics are interpreted and formatted for transmission is described.

2.7.4.2 Table G-3 depicts a set of sample approach, missed approach, and departure procedures for two hypothetical runways. Table G-4 contains way-point data for the sample procedures indicated in Table G-3 and illustrated in Figure G-15.

2.7.4.3 Prior to inserting the procedures data into the structure of B1-B39, the characteristics of the MLS/RNAV data must be understood in order to optimally use the available number of data words. In the data set of Tables G-3 and G-4, the following specific characteristics can be noted: procedures KASEL and NELSO share the same way-points No. 1 (WP 1) and No. 2 (WP 2); procedures KASEL and NELSO link to a missed approach procedure; procedure SEMOR is a secondary runway approach; procedure LAWSO is a departure procedure and will be transmitted in back azimuth coverage; all waypoints outside of the precision final approach fix (PFAF) will not require the Z coordinate to be transmitted; the Y coordinate will not have to be transmitted for several way-points that are located on the extended primary runway centre line.

2.7.4.4 Data word B1 specified in Appendix A, Table A-15, defines the structure of the MLS/RNAV data to be transmitted in the approach azimuth coverage sector. This word also contains the approach azimuth CRC code. The number of procedures to be transmitted in the approach azimuth sector is 3. This can be determined from Table G-3. The data word address with the last approach azimuth MLS/RNAV data word is determined after the complete set is inserted into the format. In this case, the address of the last word is B11. The CRC code is calculated as described in Note 3 to Table A-15. Words B42 and B43 are not transmitted so that the relevant bits are set to ZERO. Word A4 is transmitted so that the relevant bit is set to ONE. The coding for data word B1 is shown in Table G-5.

2.7.4.5 Data word B39 specified in Appendix A, Table A-15 defines the structure of the MLS/RNAV data to be transmitted in the back azimuth coverage sector. This word also contains the back azimuth CRC code. The number of procedures to be transmitted in the back azimuth sector is 1.The data word address with the first back azimuth MLS/RNAV data word is determined after the complete set is inserted into the format. In this case the address of the first word is B36. The CRC code is calculated as described in Note 3 to Table A-15. Word B43 is not transmitted so that bit is set to ZERO. The back azimuth map/CRC indicator bit is set to ONE to indicate that this is a map/CRC word. The coding for data word B39 is shown in Table G-5.

2.7.4.6 Procedure descriptor words specified in Appendix A, Table A-15 are defined for all approach and departure procedures. Missed approach procedures are linked to approach procedures in the data format and hence do not require a procedure descriptor. Procedure descriptor words for the sample data set are shown in Table G-6. It is noted that the procedure descriptor data words cannot be fully defined until the completion of the actual assignment of the way-point data due to the need for a "first way-point index" associated with each procedure. This item is the first way-point for the procedure sequence. The index is generated as indicated in 2.7.3.6. It is noted that the "validity indicator" of a procedure name (see Table G-4) is the version number of the procedure and is a value from 1 to 9.

2.7.4.7 The way-point data assignment process is in accordance with Appendix A, Tables A-15, 16 and 17. Table G-7 represents the assignment of the sample data set. The preambles, addresses and parity bits have been left out of the table. Starting with the data word immediately after the approach procedure descriptor words, the first way-point of the first procedure is assigned. For the sample data set, it means that data word B5 is the first word with way-point data. The next step is to insert the data into the appropriate format. The procedures data always commence with the X coordinate of the initial way-point. The structure of the database allows for individual data items to overlap between auxiliary data words. For example, the first 14 bits of the X coordinate of WP 3 of procedure KASEL are transmitted in word B5. The final bit is transmitted in word B6.

2.7.4.7.1 Because of the bit weight of the way-point coordinate least significant bit, the coded way-point coordinate must be rounded. It is desirable to achieve a result as close as possible to the actual way-point coordinate value. Such rounding is normally performed by adding to the actual value half the weight of the LSB then performing integer division on the result. For example, the X coordinate of WP 2 of procedure KASEL is 6 556 m (actual). The coded binary value should be 2 561 since,

$$Integer\left[\frac{\left(|\,6\,556\,|+\frac{2.56}{2}\right)}{2.56}\right] = 2\,561$$

For negative numbers the sign bit should be carried through the calculation.

2.7.4.8 After the X coordinate is the "Y coordinate follows" bit. This bit would be set to zero, and the Y coordinate would not be transmitted as shown in Table G-7 for KASEL

WP 2 and WP 1. As shown in KASEL WP 3, the Y coordinate is needed and is transmitted after the “Y coordinate follows” bit.

2.7.4.9 Depending on the coding of the “Y coordinate follows” bit, the “Z coordinate follows” bit is coded after the Y coordinate information. For procedure KASEL, WP 4 does not require the Z coordinate since it is prior to the PFAF. The Z coordinate is also not required for WP 2 because there is a constant glide path between WP 3 and WP 1. As shown in KASEL WP 3, the Z coordinate is needed and is transmitted after the “Z coordinate follows” bit.

2.7.4.10 The next segment/field identifier is assigned in accordance with Appendix A, Table A-17. For the identifier following WP 2 in procedure KASEL, the value 5 indicates that the threshold way-point height is transmitted next, followed by the way-point index of the missed approach procedure. For procedure NELSO, since the last two way-points are shared with procedure KASEL the identifier following WP 3 has the value 3, indicating that the index for the next way-point is transmitted next. In this case the index is 3, pointing to WP2 of procedure KASEL. For the missed approach procedure the identifier is set to 6, indicating that this is the last way-point in the procedure. For secondary runway procedure SEMOR the identifier is also set to 6. In this case, however, it indicates that the virtual azimuth to way-point distance follows.

2.7.4.11 Table G-8 shows the assignment of the departure procedure way-points. The departure data start with word B36, the procedure descriptor. The way-points data begin with word B37. Departure data are assigned using the same method as for the approach data.

2.7.4.12 After the database is completely assigned, the CRC values may be calculated using B1-B39 and the other required data items. Table G-9 shows the results of this calculation for the sample data set including the auxiliary A words, basic word B6, and auxiliary words B40-B41.

2.8 Adjacent channel interference considerations

2.8.1 The standard has been structured such that there is at least a 5-dB margin to account for variations in the effective radiated power above the minimum power density specification. The interference specification is based upon worst-case antenna beamwidth combinations, data rate, and undesired interference synchronization.

3. Ground equipment

3.1 Scanning beam shape

3.1.1 The azimuth scanning beam envelope on the antenna bore sight and the elevation scanning beam envelope at the preferred elevation angle, as detected by a standard receiver, has to conform to the limits specified in Figure G-16 under conditions of high SNR and negligible multipath (e.g. during a trial on an antenna range). The –10 dB symmetry relative to accuracy performance is not necessarily expected in the equipment design.

3.2 Scanning beam side lobes

3.2.1 *Performance specification*. The antenna side-lobe design has to satisfy two conditions: 1) the dynamic side-lobe level does not prevent the airborne receiver from acquiring and tracking the main beam. Satisfactory performance cannot be assured if dynamic side lobes persist at levels above –10 dB; 2)the effective side-lobe level is compatible with the system error budget.

3.2.2 The effective side-lobe level (P_{ESL}) is related to the dynamic side-lobe level (P_{DYN}) by:

$$P_{ESL} = K \times P_{DYN}$$

where

Kis a reduction factor which depends upon the antenna implementation. The reduction factor may be dependent upon:

a) a directive antenna element pattern which reduces the multipath signal level relative to the coverage volume;

b) the degree of randomness in the dynamic side lobes.

Note.— The dynamic side lobes are of least concern, if the measured dynamic side-lobe levels are less than the specified effective side-lobe levels.

3.2.3 Lateral multipath reflections from the azimuth antenna side lobes and ground multipath reflections from elevation antenna side lobes can perturb the main beam and induce angular errors. To ensure that the error dθ generated by the antenna side lobes is within the propagation error budgets, the required effective side-lobe level ESL can be estimated using:

$$P_{ESL} = \frac{d\theta}{\theta_{BW} P_R P_{MA}}$$

Where

P_R is the multipath obstacle reflection coefficient, θ_{BW} is the ground antenna beamwidth and PMA is the motion averaging factor.

Note.— A -25 dB P_{ESL} will generally satisfy the propagation error budget in a complex propagation environment.

3.2.4 The motion averaging factor depends on the specific multipath geometry, the aircraft velocity, the function data rate and the output filter bandwidth. For combinations of multipath geometry and aircraft velocity such that the multipath scalloping frequency is greater than 1.6 Hz, the motion factor is:

$$P_{MA} = \sqrt{\frac{2\ (\text{output filter noise bandwidth})}{\text{Function data rate}}}$$

3.2.5 This factor can be further reduced at higher multipath scalloping frequencies where the multipath-induced beam distortions are uncorrelated within the time interval between the TO and FRO scans.

3.3 Approach elevation antenna pattern

3.3.1 If required to limit multipath effects, the horizontal radiation pattern of the approach elevation antenna gradually de-emphasizes the signal away from the antenna boresight. Typically the horizontal pattern of the approach elevation antenna is to be reduced by 3 dB at 20 degrees off the boresight and by 6 dB at 40 degrees. Depending on the actual multipath conditions, the horizontal radiation pattern may require more or less de-emphasis.

3.4 Approach/back azimuth channels

3.4.1 When a runway has MLS installed for both approach directions, the equipment not in use for the approach may be operated as a back azimuth. If it is desired to assign different channels to each runway direction, necessarily the azimuth units will be operated on different frequencies depending on the mode of operation — approach or back azimuth. Care must be taken in the channel assignments so that the two frequencies are close enough to avoid any mechanical adjustment of the azimuth antenna vertical pattern when the approach direction is reversed.

3.4.2 The frequency separation should be limited such that the loss in pattern gain for back azimuth (from the optimum approach value) can be accommodated by the transmitter power margins shown in Table G-1 for the back azimuth function.

4. Siting considerations

4.1 MLS/ILS collocation

4.1.1 *MLS elevation antenna*

4.1.1.1 *Introduction*

4.1.1.1.1 When collocating an MLS elevation antenna with an ILS glide path, a series of decisions will have to be made to determine an elevation antenna location. Siting criteria have been developed based on minimizing the effects of MLS elevation equipment on the ILS glide path signal. This criteria along with signal-in-space, operational, critical areas, and obstacle clearance considerations will influence the final location of the elevation antenna.

4.1.1.1.2 The purpose is to start with a general region for siting the elevation antenna and then to reduce this region to an optimum location for a particular facility. This goal is achieved by stepping through a series of factors and considerations. This decision-making process is shown as a logic flow diagram in Figure G-17. These guidelines are not intended to be an all-inclusive MLS siting manual, but only to provide additional guidance when MLS collocation with ILS is required.

4.1.1.1.3 Referring to Figure G-17, the section number corresponds to one of the three siting geometries, that is 4.1.1.2 for "siting the elevation antenna between the glide path and runway", etc. The numbers in each block reference the specific paragraph in the supporting text for Figure G-17. This paragraph provides a more detailed description of the factor(s) to be considered for that step.

4.1.1.1.4 The two general regions for siting the elevation antenna are shown in Figure G-18. Depending on the location of the glide path, either one region or the other may not exist. In addition, these regions must already satisfy signal-in-space criteria prior to their consideration.

4.1.1.2 Siting the elevation antenna between the glide path and the runway

4.1.1.2.1 The setback for the elevation antenna is dependent upon the MLS approach reference datum (ARD) height. The MLS ARD must satisfy the criteria stated in Chapter 3, 3.11.4.9.1. The elevation antenna setback can be determined by the equation (see Figure G-19):

$$SB = \frac{ARDH - RPCH}{\tan\theta} \geq \frac{15 - RPCH}{\tan\theta}$$

Where:

all distances are in metres;

SB is the setback distance of the elevation antenna phase centre from the runway threshold, parallel to the runway centre line;

RPCH is the relative phase centre height of the elevation antenna compared to the runway surface at threshold. (This includes the elevation antenna phase centre height and the difference in terrain elevation between the threshold and the elevation antenna site.);

ARDH is the desired MLS approach reference datum height; and

θ is the minimum glide path.

4.1.1.2.2 The conical coordinate system of the elevation antenna and its offset from centre line will cause the minimum glide path elevation guidance to be above the approach reference datum. Considering the recommendation of Chapter 3, 3.11.5.3.5.2.2 this offset should be limited by the following equation:

$$(OS)^2 + (SB)^2 \leq \left[\frac{(18 - RPCH)}{\tan\theta}\right]^2$$

Where:

all distances are in metres; and

OS is the offset distance between the elevation antenna phase centre and the vertical plane containing the runway centre line (see Figure G-19).

4.1.1.2.3 Furthermore, the MLS ARD should be coincident with the ILS reference datum within one metre as stated in Chapter 3, 3.11.5.3.5.3. This is given in the following equation:

$$\frac{RDH - 1 - RPCH}{\tan\theta} \leq SB \leq \frac{RDH + 1 - RPCH}{\tan\theta}$$

Where:

all distances are in metres; and

RDH is the height of the ILS reference datum.

4.1.1.2.4 To determine the diagonal boundary for Region 1 of Figure G-18 two factors need to be considered. The first factor is that the elevation antenna must not penetrate the region through which the Fresnel zone for the ILS glide path migrates during an approach. In general, this requirement can be achieved by siting the elevation antenna to the runway side of the diagonal line between the glide path antenna mast and the runway centre line at threshold. The value for φin Figure G-18 is dependent on the location of the glide path antenna mast relative to centre line at threshold. The second factor is to minimize lateral penetration of the glide path antenna pattern (see 4.1.1.3.2). However, for this elevation antenna region satisfying the second factor is preferable but not essential.

4.1.1.2.5 After determining the acceptable range of elevation antenna locations based on the above criteria, the minimum elevation antenna offset is determined by the obstacle limitation requirements in Annex 14, Chapter 4.

4.1.1.2.6 When possible the elevation antenna location is to be adjusted to minimize the effects of the elevation antenna critical area on flight operations. Furthermore, it may be desirable to choose the elevation antenna location in a way which maximizes the union of the MLS elevation critical area and the ILS glide path critical area. This union will minimize any enlargement of the combined critical areas. Due to the necessity to site the elevation antenna in front of the glide path, the elevation antenna will normally have to be sited in the glide path critical area. For elevation antenna critical areas see Section 4.3. For a description of the glide path critical area see Attachment C, Section 2.1.10.

4.1.1.2.7 Once the site for the elevation antenna has been identified, a location for the elevation antenna monitor must be found. The elevation signal is to be monitored as stated in 2.4.3. The height of the elevation field monitor is dependent onthe use of integral monitoring of the minimum glide path and obstacle clearance criteria. The following considerations may be helpful in determining a monitor location:

a) It is desirable to have the field monitor as close to the far field as practical to minimize near field effects on the monitor. However, this distance is to be limited to avoid false alarms due to vehicle and aircraft traffic between the field monitor and the antenna.

b) It is desirable to minimize blockage and distortion of the elevation signal by the monitor in the final approach region. This may be achieved if the monitor location is offset up to 30 degrees from the elevation antenna boresight and at distances from 40 m (130 ft) to 80 m (260 ft) depending on particular equipment designs.

c) The field monitor offset from the antenna boresight is to be limited to maintain the appropriate monitor sensitivity to mechanical stability. It is not intended that the field monitor offset will exceed 30 degrees from the elevation antenna boresight.

d) The elevation field monitor is to be sited to avoid affecting, or being affected by, the ILS glide path field monitor.

4.1.1.3 Siting the elevation antenna at a greater offset than the glide path

4.1.1.3.1 When siting the elevation antenna at offsets of 130 m (430 ft) to 180 m (590 ft) from runway centre line, the conical effect on the achieved approach reference datum height becomes more prominent. Depending on the facility, the elevation antenna setback may have to be adjusted to satisfy the criteria discussed in 4.1.1.2.1, 4.1.1.2.2 and 4.1.1.2.3.

4.1.1.3.2 When siting the elevation antenna at an offset from runway centre line greater than that of the resident glide path, the elevation antenna should not penetrate the lateral pattern of the glide path. The value of Φin Figure G-18 is dependent on the type of glide path antenna present and the physical characteristics of the elevation equipment. In general, "Φ" denotes the –10 dB point in the glide path antenna lateral pattern. The –10 dB value may be relaxed to –4 dB, particularly for capture-effect glide path antennas, subject to verification of glide path signal quality.

4.1.1.3.3 After determining the acceptable range of elevation antenna locations based on the above criteria, this location may have to be bounded further to satisfy obstacle limitation requirements in Annex 14, particularly taxiway-to-obstacle separation criteria.

4.1.1.4 *Alternatives*

4.1.1.4.1 If collocation of the elevation antenna with the glide path cannot readily be achieved, an alternative is to site the elevation antenna on the opposite side of the runway.

4.1.2 *MLS azimuth antenna*

4.1.2.1 *Introduction*

4.1.2.1.1 When collocating the MLS azimuth antenna with the ILS localizer, one will have to make a series of decisions which will determine the azimuth antenna location. Siting criteria have been developed based on minimizing the effects of the MLS azimuth antenna equipment on the ILS localizer signal and vice versa. The criteria developed along with signal-in-space, operation, critical areas, and obstacle clearance considerations will influence the final location of the azimuth antenna. Since the presence of a humped runway or approach lighting system may require an increase in the azimuth antenna phase centre height (PCH), these factors must be considered when applying any of the following criteria.

4.1.2.1.2 The purpose is to start with a general region for siting the azimuth antenna and then reduce this region to an optimum location for a particular facility. This goal is achieved by stepping through a list of considerations shown as a logicflow diagram in Figure G-20.

4.1.2.1.3 Referring to Figure G-20, the section numbers refer to one of the four siting geometries (i.e. 4.1.2.2 corresponds to “azimuth antenna sited ahead of the localizer antenna”, etc.). The numbers in each box reference a specific

paragraph in the supporting text for Figure G-20. This paragraph provides a more detailed description of the factors to be

considered for that step.

4.1.2.1.4 The general regions for siting the azimuth antenna are shown in Figure G-21.

4.1.2.2 *Azimuth antenna sited ahead of localizer antenna*

4.1.2.2.1 The azimuth antenna is to be symmetrically sited on the localizer course line at least 30 m (100 ft) ahead of the localizer antenna array. The limit for the maximum distance (variable "X" in Figure G-21) is determined by the requirement to satisfy the obstacle limitation requirements set forth in Annex 14 for both the azimuth antenna structure and azimuth monitor. This is the preferred location for the azimuth antenna. However, factors such as the presence of a localizer near field monitor may require the location of the azimuth antenna to be modified. The azimuth antenna cannot be sited such that it blocks line-of-sight between the localizer antenna and the localizer field monitor. Due to line-of-sight blockage of the ILS ground check point by the azimuth station, the ILS ground check points may have to be reassessed.

4.1.2.2.2 It is desirable to collocate the DME/P antenna with azimuth antenna whenever possible. However, if the DME/P antenna cannot be collocated with the azimuth antenna due to violation of obstacle limitation requirements, one may consider an offset DME/P site or selecting an alternate collocation configuration (see Attachment C, Section 7.1.6 and Section 5 below).

4.1.2.2.3 When possible, the azimuth antenna location can be adjusted to minimize the effect of the azimuth antenna critical area on flight operations. In addition, it may be desirable to maximize the union of azimuth and localizer critical areas. Due to the necessity to collocate the azimuth antenna in close proximity to the localizer antenna, normally one of the antennas will have to be sited in the critical area of the other antenna. For the azimuth antenna critical area, see 4.3. For the localizer critical areas see Attachment C, Section 2.1.10.

4.1.2.2.4 After a suitable site for the azimuth antenna has been determined, a location for the azimuth antenna field monitor must be found. The azimuth antenna should be monitored as stated in 2.3.5. The preferred location for the field monitor is on the extended runway centre line. However, the monitor pole can be a source of azimuth signal degradation. Therefore, if this monitor location causes unacceptable signal degradation or unsatisfactory monitoring capabilities due to the presence of light lane structures, ILS localizer, etc., an alternate field monitor location may be desirable. This second procedure is only recommended if integral monitoring of the approach radial is available. The following considerations may be helpful in determining a monitor location:

a) It is desirable to have the field monitor as close to the far field as practical to minimize near field effects on the monitor. However, this distance should be limited to avoid false alarms due to vehicle and aircraft traffic between the monitor and azimuth antenna.

b) It is desirable to minimize blockage and distortion of the azimuth signal by the field monitor in the final approach region. The field monitor should be sited as far below the azimuth antenna phase centre as practical.

c) The field monitor offset from the antenna boresight should be limited to maintain the appropriate monitor sensitivity to mechanical stability.

d) The azimuth antenna field monitor should be sited to avoid affecting, or being affected by, the localizer monitor.

4.1.2.3 Azimuth antenna sited behind ILS localizer

4.1.2.3.1 The distance between the localizer and the MLS azimuth antenna will depend on obstacle limitation requirements, availability of real estate, presence of a localizer back course, and the desirability of collocating the DME/P antenna with the azimuth antenna. If a localizer back course is being utilized, a distance of at least 30 m (100 ft) between the azimuth and localizer antennas is preferred, and the azimuth antenna must be symmetrically sited on the localizer course centre line. For localizer antennas with a high front-to-back power ratio, it may be possible to reduce the 30 m (100 ft) separation. Once the distance between the azimuth and localizer antennas is known, Figure G-22 can be used to determine the height of the azimuth antenna phase centre relative to the localizer antenna array. To ensure that the azimuth guidance errors due to signal scattering by the ILS localizer remain insignificant (≤0.03 degree) throughout the azimuth coverage volume, point "W" (Figure G-22) is typically selected to determine the value for variable "X" of Figure G-22. If selection of that point results in an azimuth antenna siting which violates obstacle clearance requirements or a tower-mounted installation that is notfeasible, the following actions may be considered:

a) knowing the specific localizer and azimuth equipment involved, an analysis may be performed to determine the height of the azimuth antenna phase centre. Generally, it is recommended that the azimuth antenna phase centre height be selected so that the errors due to signal scattering from the localizer are limited to 0.03 degree. However, that allocation may be increased after considering the contribution from other error sources such as ground and airborne equipment errors, side lobe reflections from buildings, ground reflections, and errors due to interfering aircraft (see Table G-10); and

b) a point on the line W – WN(Figure G-22) may be selected to determine the value for variable “X”. It is preferred that the point selected be as close to point “W” as practical and it must be operationally acceptable for the procedure concerned. Since the error allocation used in the development of this criteria represents a small portion of the total propagation error budget, the azimuth signal might meet the accuracy requirement even below the plane which contains the point selected and the azimuth antenna phase centre. The point to which acceptable azimuth signal exists along the minimum glide path angle may be determined by flight measurements.

4.1.2.3.2 If a localizer near field monitor is present on the extended runway centre line, adjustment of the azimuth antenna phase centre height (PCH) or the localizer monitor height may be required to minimize the effects of the localizer monitor pole on the azimuth signal. However, it is expected that as long as the monitor pole is at or lower than the localizer antenna element height no further adjustment due to the presence of the monitor pole will be required.

4.1.2.4 *Integrated azimuth and localizer configuration*

4.1.2.4.1 *Azimuth antenna integrated under the localizer array*

4.1.2.4.1.1 The first consideration for this configuration is to determine the height of the obstacle clearance surface at the localizer array. The vertical distance between the ground and the obstacle clearance surface at this point should be at least equal to the azimuth antenna height, including the pedestal, plus the required vertical spacing between the top of the azimuth antenna and the localizer antenna element. If this condition is not observed an alternate collocation configuration has to be considered.

4.1.2.4.1.2 Experimental results, from a 24-element log-period localizer, indicate that the vertical spacing between the top of the azimuth antenna and the bottom of the localizer antenna elements has to be at least 0.5 m (1.6 ft) with a spacing ofgreater than 0.7 m (2.3 ft) being preferred. For localizers with elements having relatively higher coupling, increased vertical spacing is preferred.

4.1.2.4.2 *Azimuth antenna integrated within the localizer array*

4.1.2.4.2.1 For this configuration it may not be necessary to consider the height of the obstacle clearance surface since the azimuth antenna is usually lower than the existing localizer antenna. When integrating the azimuth antenna, some modifications at the localizer antenna are required which may influence the localizer signal-in-space. However, effects depend very much on the type of localizer.

4.1.2.4.2.2 Experimental results, from a two-frequency localizer using dipole antennas, indicate that it is possible to compensate these effects by minor on-site modifications at the localizer antenna. The feasibility of this integrated configuration has to be confirmed for each type of localizer.

4.1.2.4.3 If an ILS near field monitor is present, it is necessary to determine the increase in azimuth antenna phase centre height or decrease in the localizer monitor height required to minimize the effects of the monitor pole on the azimuth signal. In general, satisfactory results may be obtained by siting the azimuth antenna phase centre approximately 0.3 m (1 ft) above the monitor pole. This value is dependent on the localizer monitor design and location.

4.1.2.5 *Offset azimuth*

4.1.2.5.1 At some sites where ILS and MLS are to be collocated, it may be found impossible because of physical restrictions to locate the MLS azimuth antenna in front of or back of the ILS localizer antenna or to integrate it with the ILSlocalizer antenna. At those sites an advantageous solution could be to offset the MLS and DME/P antennas. The siting information contained in auxiliary data would enable computation in the aircraft of an MLS centre line approach.

4.1.2.5.2 For this collocation configuration, the preferred siting is with the azimuth antenna radome in the localizer array plane (Area 1 of Figure G-21). A minimum distance of 3 m (10 ft) between the azimuth equipment and the localizer array (end element) is preferable.

4.1.2.5.3 If siting the azimuth antenna abeam the localizer is not practical, the azimuth antenna may be sited behind the localizer array plane (Area 2 of Figure G-21). The azimuth antenna offset has to provide at least a 3 m (10 ft) distance and prohibit penetration of the azimuth proportional guidance region by the localizer array.

4.1.2.5.4 If siting the azimuth antenna ahead of the localizer array plane is required, degradation of the localizer signalmay result. The region where the least effect of the azimuth equipment on the localizer signal is expected is shown in Area 3 of Figure G-21. The azimuth antenna location can be verified using an azimuth equipment mock-up.

4.2 *MLS siting within an approach lighting system*

4.2.1 The presence of an approach lighting system serving the opposite end approach will affect the siting of an MLS azimuth antenna. Factors to be considered in proper siting are coverage requirements (see 2.3.2), the need to avoid visual blockage of lights, obstacle limitation requirements, and azimuth signal multipath from the light structures.

4.2.2 These criteria are applicable for typical installations where the approach lights are mounted at essentially a constant height or rise with increasing distance from the runway.

4.2.3 The following guidance is based on MLS siting within existing lighting system structures. It may be more practical to use light structures which do not affect the signal-in-space if these are available.

4.2.4 If the location of an MLS azimuth antenna on extended runway centre line 60 m (200 ft) beyond the far end of the approach lighting system is not possible or practical, it may be sited within the light plane boundaries given the following criteria:

a) in the horizontal plane, the antenna is to be sited on extended runway centre line not closer than 300 m to the runway stop end and as far as possible from the nearest light position toward runway stop end. (This places the back of the azimuth equipment against a light position.)

b) the siting of the azimuth station is to be such that the shadowing of the lights of the approach lighting system is minimized, particularly within decision height boundaries. The azimuth station should not shadow any light(s) other than that located in a centre part of a cross bar or a centre line barrette (see Annex 14, Volume I, Attachment A, Section 11.3 for further guidance).

4.2.4.1 If the spacing between adjacent light stations is 30 m (100 ft) or more, the phase centre should be at least 0.3 m (1 ft) above light centre line of the closest light station toward runway stop end. This could be relaxed to 0.15 m (0.5 ft), if necessary, if the site is otherwise free of significant multipath problems. This may require the use of an elevated azimuth station.

4.2.4.2 If the spacing between adjacent light stations is less than 30 m (100 ft), the phase centre should be at least 0.6 m (2 ft) above light centre line of the closest light station toward runway stop end.

4.3 Critical and sensitive areas

4.3.1 The occurrence of interference to MLS signals is dependent on the reflection and shadowing environment around the MLS antennas and the antenna beamwidths. Vehicles and fixed objects within 1.7 beamwidths of the receiver location are considered "in-beam" and will cause main lobe multipath interference to the MLS guidance signals. Typically, the ground equipment beamwidths are chosen such that no azimuth in-beam reflections exist along the final approach course and no elevation in-beam multipath exists along the commissioned glide paths. However, movable objects may enter the in-beam multipath regions and cause interfering reflections to or shadowing of the guidance signals to the extent that the quality becomes unacceptable. The areas within which vehicles can cause degraded performance need to be defined and recognized. For the purpose of developing protective zoning criteria, these areas can be divided into two types, i.e. critical areas and sensitive areas:

a) The MLS critical area is an area of defined dimensions about the azimuth and elevation antennas where vehicles, including aircraft, are excluded during all MLS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the guidance signals.

b) The MLS sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the MLS signals during MLS operations. The sensitive area provides protection against interference caused by large objects outside the critical area but still normally within the airfield boundary.

Note 1.— Where disturbance to the guidance signal can occur only at some height above the ground the terms "critical volume" or "sensitive volume" are used.

Note 2.— The objective of defining critical and sensitive areas is to afford adequate protection of the MLS guidance signals. The manner in which the terminology is applied may vary between States. In some States, the term "critical area" is also used to describe the area that is referred to herein as the sensitive area.

4.3.2 Typical examples of critical and sensitive areas that need to be protected are shown in Figure G-23 and Figure G-24. The tabled values associated with Figure G-23 and Figure G-24 apply to approach procedures with elevation angles of three degrees or higher. To assure the signal quality, it is necessary normally to prohibit all entry of vehicles and the taxiing or parking of aircraft within this area during all MLS operations. The critical area determined for each azimuth and elevation antenna should be clearly designated. Suitable signal devices may need to be provided at taxiways and roadways which penetrate the critical area in order to restrict the entry of vehicles and aircraft.

4.3.3 Computer modelling techniques can be employed to calculate the magnitude and duration of signal disturbances caused by structures or by aircraft of various sizes and orientation at differing locations. Typically, the parameters required to operate such a model are the antenna beamwidths and the size, location and orientation of reflecting and shadowing objects. Taking into account the maximum allowable multipath degradation of the signal due to aircraft on the ground, the corresponding critical and sensitive areas can be determined. Such a method has been used in developing Figures G-23 and G-24, after validation of computer models which included comparisons at selected points of computed results with actual field and flight data on parked aircraft interference to the MLS guidance signals.

4.3.4 Control of critical areas and the designation of sensitive areas on the airport proper generally will be sufficient to protect MLS signals from multipath effects caused by large, fixed ground structures. This is particularly significant when considering the size of new buildings. Structures outside the boundaries of the airport generally will not cause difficulty to the MLS signal quality as long as the structures meet obstacle limitation criteria.

4.3.5 The boundary of the protected zone (i.e. the combined critical and sensitive areas) is defined such that interference caused by aircraft and vehicles outside that boundary will not cause errors in excess of typical allowances for propagation effects. The derivation of error allowances to protect centre line approach profiles, as shown in Tables G-10 and G-11 for a “clean” and “complex” propagation environment, proceed as follows. Allowances for equipment errors are subtracted (on a root sum square basis (RSS)) from the system error limits at the approach reference datum (ARD) and the resulting balance of the error budget is available for propagation anomalies. The ground reflection is accommodated at both clean and complex sites, while in complex environments, a margin is reserved to accommodate additional error sources such as support structure vibration, diffracted signals from, for example, approach lighting system (ALS) lights and supports or more intense lateral reflections. Finally, 70 per cent of the remaining error balance is allocated to define the protected zone boundary. Thus, error balances are available to define protected zone boundaries for the extreme cases of a very clean propagation environment with only ground reflections and for a very complex environment with several significant sources of propagation errors.

4.3.6 The MLS critical areas are smaller than the ILS critical areas. Where MLS antennas are located in close proximity to the ILS antennas, the ILS critical areas in most cases will protect the MLS for similar approach paths.

Note.— A reduction of the MLS critical and sensitive areas may be obtained by measurements or analysis which consider the specific environment. It is recommended that samples be taken at least every 15 m (50 ft).

4.3.7 *Azimuth*. For an azimuth antenna supporting an aligned approach along the zero degree azimuth, the region between the azimuth antenna and runway stop end is to be designated as a critical area. The sensitive area of Figure G-23A provides additional signal protection when low visibility landing operations are in progress. In general, the azimuth sensitive area will fall within the runway boundaries such that adequate control can be exercised over all moving traffic to prevent unacceptable interference to the MLS signals. In developing the sensitive area lengths of Table G-12A, it was assumed that the landed B-727 (or B-747) type aircraft has cleared the runway before the landing aircraft reaches a height of 90 m (300 ft) (or 180 m (600 ft) for B-747)). That assumption resulted from consideration of the following factors:

a) 5.6 km (3 NM) separation behind B-747 size aircraft;

b) 3.7 km (2 NM) separation behind B-727 size aircraft;

c) runway occupancy time for the landing aircraft is 30 seconds; and

d) approaching aircraft speed is approximately 220 km/hr (2 NM/min).

4.3.7.1 For an approach azimuth equipment that supports aircraft guidance on the runway surface, an additional sensitive area has to be protected. Due to the low level of power density received by an aircraft on the ground, with the receiving antenna at the lower limit of the coverage, the relative power density of the azimuth beam diffracted by the fin trailing edge of an aircraft leaving or approaching the runway can be significant and create in-beam multipath effects. Typicalsurfaces in which no aircraft fin should be present are described in Figure G-23B. There are angular sectors starting from the azimuth antenna, with a semi-width of 1.7 beamwidth centred on the runway centre line. The semi-width is limited at a value given in Table G-12E for an azimuth antenna phase centre 1.4 m (4.6 ft) above a flat runway. In case the power density received onthe ground is different from what is expected from propagation above a flat ground, some corrections should be applied. It has been determined, for example, that if the actual power density 2.5 m (8 ft) above the runway is 6 dB higher (due for example to azimuth antenna phase centre two times higher), the sensitive area semi-width can be reduced by 6 m (20 ft) (or increased if the power density is 6 dB lower).

4.3.7.2 For an azimuth antenna supporting an offset approach, the critical and sensitive areas will depend on the azimuth antenna location and the approach track orientation relative to the zero degree azimuth. The critical area extends for at least 300 m (1 000 ft) in front of the azimuth antenna. To avoid shadowing while landing operations are in progress, additional protection is to be provided in the form of a sensitive area. Table G-12B gives sensitive area length for use with an offset azimuth installation. When a procedure is along an azimuth other than the zero degree azimuth, the plan view definition has to take into account beam spreading. Figure G-25 shows typical examples.

Note.— This guidance material also applies to an azimuth antenna providing the back azimuth function.

4.3.7.3 *Critical and sensitive areas for the computed centre line approach*. Figure G-26 provides a general illustration of the areas to be protected from uncontrolled movement of ground traffic. The exact shape of that area will depend on the azimuth antenna location, azimuth to threshold distance, decision height, type of aircraft operating at the facility, and the multipath environment.

4.3.7.3.1 In determining the area to be protected, the following steps are appropriate:

a) determine the direction of line AG (Figure G-26) from the azimuth antenna (point A) to the nearest point to the runway centre line where guidance is required (point G);

b) locate point C on line AG at a distance from the azimuth antenna found by entering Table G-12C or G-12D with azimuth to threshold distance, size of the largest aircraft on ground and height of point G on the minimum glide path;

c) line AB has the same length as line AC and lines AC and AB are angularly separated by an amount for in-beam multipath (1.7 beamwidth) and a value for flight path deviation allowance to account for deviations of the approaching aircraft about the nominal approach track;

d) determine the direction of line AF from the azimuth antenna to point F at a height of 300 m (1 000 ft) on the minimum glide path;

e) determine the direction of line AD which is angularly separated by 1.7 BW from line AF;

f) the length of line AD is taken from Table G-12C or G-12D with information on the height of point F; and

g) the area to be protected is bounded by the polygon ABCD.

4.3.7.3.2 Typically, the areas of polygon ABCD in Figure G-26 within at least the first 300 m (1 000 ft) or 600 m (2 000 ft) of the azimuth antenna are to be designated, respectively, as a critical area where B-727 or B-747 size aircraft areoperating. The balance of the region is designated as a sensitive area. Where possible, the azimuth antenna is to be offset to the runway side away from that of active taxiways. At facilities where the azimuth antenna is set back less than 300 m (1 000 ft) or located ahead of the runway stop end, a detailed analysis and consideration of the airport layout may support reductions of the area to be protected.

4.3.7.4 *Critical and sensitive areas for MLS/RNAV procedures*. For MLS/RNAV approach procedures, the critical and sensitive areas will require expansion to protect against in-beam multipath in the sectors used. These expanded areas protect approach procedures which are not possible with ILS. The length of the area to be protected depends on the operational minimum height surface selected from Table G-13. Information for determining the area to be protected is given in Figure G-27. For a wide range of profiles, simulation indicated that, where B-727 size aircraft are operating, adequate protection would be afforded if the first 300 m (1 000 ft) of the protected area is designated as a critical area and the remainder as a sensitive area. For B-747 size aircraft, the corresponding length is 600 m (2 000 ft). For higher approach profiles, the length derived from Table G-13 or an equation therein may be less than these values; in this case the entire expanded area is to be designated as a critical area. Increased flexibility may be obtained by performing an analysis considering the specific approach profile and airport environment.

4.3.8 *Elevation*. The elevation critical area to be protected results from the critical volume shown in Figure G-24. Normally no sensitive area is defined for the elevation antenna. As the lower surface of the critical volume normally is well above ground level, aircraft may hold near the elevation antenna as long as the lower boundary of the critical volume is not penetrated.

4.3.8.1 For normal siting of a 1.0 degree beamwidth elevation antenna and flat ground, the fuselage of most aircraft types will fit under the profile lower surface of the critical volume of Figure G-24.

4.3.8.2 For a 1.5 degree beamwidth elevation antenna, limited penetration of the profile lower surface of the critical volume of Figure G-24 by an aircraft fuselage may be tolerated by defining the lower part of the critical volume between 1.5 degrees and 1.7 beamwidth below the minimum glide path assensitive volume. At sites performing well within tolerance, aircraft may hold in front of the antenna provided:

a) the separation angle between the glide path and the top of the aircraft fuselage is at least 1.5 degrees;

b) the aircraft tail fin does not penetrate the lower surface of the critical volume; and

c) the fuselage is at right angle to the centre line.

4.3.8.3 For MLS/RNAV approach procedures, the plan view of the elevation critical area will require expansion to ensure the elevation signal quality along the nominal approach track (Figure G-28). These expanded areas protect approach procedures which are not possible with ILS. The characteristics of the profile view (Figure G-24) remain unchanged, noting that the lower boundary is referenced to the nominal approach track. This guidance material covers a wide range of profiles. Increased flexibility may be obtained by performing an analysis considering the specific approach profile and airport environment.

5. Operational considerations on siting of DME ground equipment

5.1 The DME equipment should, whenever possible, provide indicated zero range to the pilot at the touchdown point in order to satisfy current operational requirements.

5.1.1 When DME/P is installed with the MLS, indicated zero range referenced to the MLS datum point may be obtained by airborne equipment utilizing coordinate information from the MLS data. DME zero range should be referenced to the DME/P site.

6. Interrelationship of ground equipment monitor and control actions

6.1 The interrelationship of monitor and control actions is considered necessary to ensure that aircraft do not receive incomplete guidance which could jeopardize safety, but at the same time continue to receive valid guidance which may safely be utilized in the event of certain functions ceasing to radiate.

Note.— The interrelationship of ground equipment monitor and control actions is presented in Table G-14.

7. Airborne equipment

7.1 General

7.1.1 The airborne equipment parameters and tolerances included in this section are intended to enable an interpretation of the Standards contained in Chapter 3, 3.11 and include allowances, where appropriate, for:

a) variation of the ground equipment parameters within the limits defined in Chapter 3, 3.11;

b) aircraft manoeuvres, speeds and attitudes normally encountered within the coverage volume.

Note 1.— The airborne equipment includes the aircraft antenna(s), the airborne receiver, the pilot interface equipment and the necessary interconnections.

Note 2.— Detailed "Minimum Performance Specifications" for MLS avionics have been compiled and coordinated by the European Organization for Civil Aviation Electronics (EUROCAE) and RTCA Inc. ICAO periodically provides to Contracting States current lists of the publications of these organizations in accordance with Recommendations 3/18(a) and 6/7(a) of the Seventh Air Navigation Conference.

7.1.2 *Function decoding*

7.1.2.1 The airborne equipment is to be capable of decoding and processing the approach azimuth, high rate approach azimuth, back azimuth, and approach elevation functions, and data required for the intended operation.

7.1.2.2 In addition, the receiver utilizes techniques to prevent function processing resulting from the presence of function preambles embedded within the data fields of basic and auxiliary data words and scanning beam side lobe radiation. One technique to accomplish this is to decode all function preambles. Following the decode of a preamble, the detection and decoding of all function preambles is then disabled for a period of time corresponding to the length of the function.

7.1.2.3 Range information is decoded independently.

7.1.3 The receiver decodes the full range of angles permitted by the signal format for each function. The guidance angle is determined by measuring the time interval between the received envelopes of the TO and FRO scans. The decoded angle is related to this time interval by the equation given in Chapter 3, 3.11.4.5.

7.1.4 The receiver is capable of normal processing of each radiated function without regard to the position of the function in the transmitted sequences.

7.1.5 If the MLS approach azimuth and back azimuth information is presented on the selector and/or flight instruments, it is to be displayed in magnetic degrees. Receivers in the automatic mode display the relevant information transmitted by the ground station as part of the basic data word 4.

7.1.6 The receiver has the capability for both manual and automatic selection of approach track, elevation angle and back azimuth radial when provided. When in automatic mode, the selection is made as follows.

7.1.6.1 Approach azimuth— select the angular reciprocal of the approach azimuth magnetic orientation in basic data word 4.

7.1.6.2 *Elevation angle*— select the minimum glide path in basic data word 2.

7.1.6.3 *Back azimuth*— select the angle of the back azimuth magnetic orientation in basic data word 4.

Note.— The receiver indicates when deviation is referenced to the back azimuth signal.

7.1.7 The MLS airborne receiver system must have an integrity compatible with the overall integrity of MLS which is at least $1 - 1 \times 10^{-7}$ in any one landing.

7.1.8 For airborne equipment used in MLS/RNAV operations the capability is to be provided to unambiguously display the procedure selected.

7.2 Radio frequency response

7.2.1 Acceptance bandwidth

7.2.1.1 The receiver should meet acquisition and performance requirements when the received signal frequency is

offset by up to plus or minus 12 kHz from the normal channel centre frequency. This figure considers possible ground

transmitter offsets of plus or minus 10 kHz and Doppler shifts of plus or minus 2 kHz. The receiver should decode all

functions independently of the different frequency offsets of one function relative to another.

7.2.2 Selectivity

7.2.2.1 When the receiver is tuned to an inoperative channel and an unwanted MLS signal of a level 33 dB above that

specified in Chapter 3, 3.11.4.10.1 for the approach azimuth DPSK is transmitted on any one of the remaining channels, the

receiver should not acquire the signal.

7.2.3 In-channel spurious response

7.2.3.1 The receiver performance specified in Chapter 3,3.11.6, should be met when, in addition, interference on the

same channel is received at a level not exceeding that specified in Chapter 3, 3.11.4.1.4.

7.2.4 Interference from out-of-band transmissions

7.2.4.1 The receiver performance inChapter 3, 3.11.6 is to be met when, in addition, interference from undesired

signals is received at a level not exceeding –124.5 dBW/m

2

at the MLS receiver antenna.

7.3 Signal processing

7.3.1 Acquisition

7.3.1.1 The receiver should, in the presence of an input guidance signal which conforms to the requirements of

Chapter 3, 3.11.4, acquire and validate the guidance signal before transitioning to the track mode within two seconds along

the critical portion of the approach and within six seconds at the limits of coverage.

7.3.1.2 Approach or high-rate approach azimuth guidance acquisitions are not allowed below 60 m (200 ft).

Note.— Acquisition below 60 m (200 ft) may lead to acquisition of false guidance, as the multipath signal level may be above direct signal level. Aircraft power loss or pilot tuning are potential causes of acquisition below 60 m (200 ft). Technical or operational measures should be taken to prevent such acquisition.

7.3.2 *Tracking*

7.3.2.1 While tracking, the receiver should provide protection against short duration (less than one second) large amplitude spurious signals. When track is established, the receiver should output valid guidance information before removing the warning. During track mode, the validation process should continue to operate.

7.3.2.2 After loss of the tracked signal for more than one second, the receiver should provide a warning signal. Within the one-second interval, the guidance information should remain at the last output value.

Note 1.— A validated guidance signal is one that satisfies the following criteria:

a) the correct function identification is decoded;

b) the preamble timing signal is decoded;

c) the "TO" and "FRO" scanning beams or left/right clearance signals are present and symmetrically located with respect to the midpoint time; and

d) the detected beamwidth is from 25 to 250 microseconds.

Note 2.— Guidance signal validation also requires that the receiver repeatedly confirm that the signal being acquired or tracked is the largest signal for at least one second.

7.3.2.3 The aircraft should be on the runway centre line or on the selected azimuth angle at 60 m (200 ft) and the receiver has to be in tracking mode. Below that height, the receiver should keep tracking the approach azimuth or high rate approach azimuth signal as far as this signal is coding an angle within a narrow sector centred onthe runway centre line or onthe selected azimuth angle even if other signals are up to 10 dB higher than the tracked signal.

7.3.3 *Data functions*

7.3.3.1 Data acquisition. Performance in the airborne acquisition of data provided on either the basic or auxiliary data function is broken into two items: the time allowed to acquire the data and the probability of an undetected error in the acquired data.

7.3.3.1.1 At the minimum signal power density, the time to acquire basic data word 2 which is transmitted at a rate of 6.25 Hz does not exceed two seconds on a 95 per cent probability basis. The time to acquire data that are transmitted at a rate of 1 Hz does not exceed 6 seconds on a 95 per cent probability basis.

7.3.3.1.2 In the acquisition process, the receiver decodes the appropriate data words and applies certain tests to ensure that the probability of undetected errors does not exceed 1 × 10–6at the minimum signal power density for those data requiring this level of integrity. The recommended performance specifications for undetected errors may require additional airborne processing of the data beyond simple decoding. For example, these may be achieved by processing multiple samples of the same data words.

7.3.3.1.3 If the receiver does not acquire data required for the intended operation, a suitable warning is to be provided.

7.3.3.1.4 At the minimum signal power density the time to acquire all data words required to support MLS/ RNAV operations (auxiliary data words B1-B41, A1/B42, A2, A3, A4/B43 and basic data word 6) must not exceed 20 seconds on a 95 per cent probability basis. The MLS/RNAV equipment has to ensure that the probability of undetected errors for this block of data does not exceed 0.5×10^{-9}. This performance assumes a 2 dB improvement in signal to noise. This may be achieved through reduced cable loss, margin or improved receiver sensitivity (see the airborne power budget given in Table G-2). Additionally, with signal levels above this, the acquisition time is intended to be less than 20 seconds.

7.3.3.2 Data validation. After acquisition of data, the receiver repeatedly confirms that the data being received are the same as the acquired data. The receiver decodes several consecutive and identical data different from that previously acquired before taking action to accept the new decoded data.

7.3.3.2.1 For data required to support MLS/RNAV operations, the airborne equipment applies the cyclic redundancy check (CRC) to the data to ensure sufficient integrity has been achieved. Data that continue to be received continue to be validated. The MLS/RNAV equipment does not accept a new block of data to be used until it is validated with the CRC.

7.3.3.3 *Data loss*. Within 6 seconds after the loss of basic data or auxiliary data that is transmitted with a maximum interval of 2 seconds or less, the receiver provides a suitable warning and removes the existing data. Within 30 seconds after the loss of auxiliary data other than that referred to above, the receiver provides a suitable warning.

7.3.3.3.1 For data required to support MLS/RNAV operations, the airborne equipment does not remove existing data

following validation except under the conditions described in 7.3.3.2.1. An MLS/RNAV data block that has been validated by the CRC is not removed until a new data block has been received with a different ground equipment identification in basic data word 6, a new MLS channel is selected, or power is removed. Additionally the data block is not removed when transitioning to back azimuth coverage.

7.3.4 *Multipath performance*

7.3.4.1 Where the radiated signal power density is high enough to cause the airborne equipment thermal noise contribution to be insignificant, the following specifications should apply for scalloping frequencies between 0.05 Hz and 999 Hz.

7.3.4.1.1 *In-beam multipath*. Multipath signals coded less than two beamwidths from the direct signal and with amplitudes of 3 dB or more below the direct signal should not degrade the angle guidance accuracy output by more than plus or minus 0.5 beamwidth (peak error). The receiver should not lose track when such conditions occur.

7.3.4.1.2 Out-of-beam multipath. Multipath signals coded 2 beamwidths or more from the direct signal and with amplitudes of 3 dB or more below the direct signal should not degrade the angle guidance accuracy by more than plus or minus 0.02 beamwidth. For azimuth signals, and within a narrow sector around the centre line or around the selected azimuth angle, multipath signals with amplitudes of up to 10 dB above the direct signal and not distorting the direct beam shape as specified in Chapter 3, 3.11.5.2.1.3, should not degrade the angle guidance accuracy by more than plus or minus 0.02 beamwidth. The receiver should not lose track when such conditions occur.

7.3.5 *Clearance*

7.3.5.1 The airborne equipment should provide clearance guidance information whenever the antenna is in the presence of a valid clearance guidance signal.

7.3.5.2 When the decoded angle indication is outside the proportional guidance sector defined in Appendix A, Table A-7, the MLS guidance signal should be interpreted as clearance guidance.

7.3.5.3 When clearance pulses are transmitted, the receiver shall be able to process the range of pulse envelope shapes that may appear in the transition between clearance and scanning beam signals. A particular pulse envelope is dependent on the receiver position, scanning antenna beamwidth, and the relative phase and amplitude ratios of the clearance and scanning beam signals as shown in Figure G-8. The receiver is also required to process rapid changes of indicated angle of the order of 1.5 degrees (peak amplitude) when outside the proportional guidance limits.

7.3.5.4 In receivers with the capability to select or display azimuth angle guidance information greater than plus or minus 10 degrees, the proportional coverage limits in basic data must be decoded and used to preclude use of erroneous guidance.

7.4 Control and output

7.4.1 *Approach azimuth and approach elevation deviation scale factor*

7.4.1.1 *Approach azimuth.* When the approach azimuth deviation information is intended to have the same sensitivity characteristics as ILS, it is a function of the “approach azimuth antenna to threshold distance”, as supplied by the basic data, in accordance with the following table:

Approach azimuth antenna to threshold distance (ATT)	Nominal course width
0 – 400 m	± 3.6 degrees
500 – 1 900 m	± 3.0 degrees
2 000 – 4 100 m	$\pm \arctan\left(\frac{105}{ATT}\right)$ degrees
4 200 – 6 300 m	± 1.5 degrees

7.4.1.2 Approach elevation. The deviation information is a continuous function of the manually or automatically selected elevation angle (Θ) in accordance with the formula Θ/4 = half a nominal glide path width, so that glide path widths are nominally in accordance with the following examples:

Selected elevation angle (degrees)	Nominal glide path width (degrees)
3	± 0.75
7.5	± 1.875

Note.— These sensitivity characteristics are applicable to elevation angles up to 7.5 degrees.

7.4.2 *Angle data output filter characteristics*

7.4.2.1 *Phase lags*. To assure proper autopilot interface, the receiver output filter, for sinusoidal input frequencies, does not include phase lags which exceed:

a) 4 degrees from 0.0 to 0.5 rad/s for the azimuth function; and

b) 6.5 degrees from 0.0 to 1.0 rad/s and 10 degrees at 1.5 rad/s for the elevation function.

7.4.3 *Minimum glide path*. When there is capability of selecting the approach elevation angle, a suitable warning is to be issued if the selected angle is lower than the minimum glide path as provided in basic data word 2.

7.4.4 *Status bits*. A suitable warning is to be provided when the function status bits in acquired basic data indicate that the respective function is not being radiated or is being radiated in test mode.

7.5 Use of back azimuth guidance for missed approaches and departures

7.5.1 *Usable back azimuth angles*

7.5.1.1 Flight test results indicated that back azimuth angles of up to ±30 degrees from the runway centre line can be used for navigation guidance for missed approaches and departures. With appropriate interception techniques, larger angle offsets might be acceptable up to the flyable limits of back azimuth coverage. Departure guidance can utilize the back azimuth signal for centre line guidance throughout the take-off roll and initial departure. It is intended that a turn to intercept the back azimuth is initiated at an operationally acceptable altitude, and the prescribed procedure is protected according to appropriate obstacle clearance criteria.

7.5.2 Back azimuth deviation scale

7.5.2.1 The scaling of back azimuth deviations must be sufficient to support back azimuth departures and missed approaches not aligned with the approach azimuth, as well as missed approach and departure tracks aligned with the approach azimuth. Deviation scaling effects are most pronounced when manoeuvring to intercept a back azimuth. Very sensitive

scaling will cause lateral overshoots and limit flyability of the signal, whereas very insensitive scaling will result in the large

consumption of airspace. A nominal coursewidth sensitivity of ±6 degrees provides for an acceptable interception of back

azimuth during missed approach and departure.

7.5.3 Approach azimuth to back azimuth switching

7.5.3.1 Following initiation of a missed approach using back azimuth guidance, the guidance must switch from

approach azimuth to back azimuth. The switching, either automatically or manually, from approach azimuth to back azimuth

guidance is intended to provide continuous flyable guidance throughout the missed approach sequence. Switching is not expected to occur until the aircraft receives a validated back azimuth signal, but it is intended to occur before the approach

azimuth guidance becomes too sensitive to fly. Switching based onloss of approach azimuth may not occur until the aircraft

is very close to the approach azimuth antenna resulting in unflyable guidance. Switching based only on loss of elevation

guidance may occur prior to the aircraft receiving a valid back azimuth signal. However, switching might be based on loss of

elevation guidance once the back azimuth signal has been validated. Automatic switching at or near the mid-point between

azimuth antennas will provide a method which results in continuous guidance during the transition. The mid-point switching

methodology may require the use of DME information by the MLS receiver. Precautions are to be taken so that approach to

back azimuth switching does not automatically occur unless a missed approach has been initiated.

8. Operations at the limits of and outside the promulgated MLS coverage sectors

8.1 The limits of the azimuth proportional guidance sectors are transmitted in basic data words 1 and 5. These limits do not indicate the maximum flyable MLS approach and back azimuth angles which will normally be at some angle inside these limits. For example, for an approach azimuth providing a proportional guidance sector of ±40 degrees, flyable MLS approach azimuth angles with a full course width of ±3 degrees will exist to approximately ±37 degrees. For a back azimuth, flyable back azimuth angles with full course width will exist to within 6 degrees of the proportional guidance sector limits.

8.2 The basic MLS antenna designs should preclude the generation of unwanted signals outside coverage. Under some unusual siting conditions, MLS signals might be reflected into regions outside the promulgated coverage with sufficient strength to cause erroneous guidance information to be presented by the receiver. As in current procedure the implementing authority would specify operational procedures based on the use of other navaids to bring the aircraft into landing system coverage without transiting the area of concern or may publish advisories which alert pilots to the condition. In addition, theMLS signal format permits the use of two techniques to further reduce the probability of encountering erratic flag activity.

8.2.1 If the undesired MLS signals are reflections and if operational conditions permit, the coverage sector can be adjusted (increased or decreased) such that, at the receiver, either the direct signal is greater than any reflection or the reflector is not illuminated. This technique is referred to as coverage control.

8.2.2 Out-of-coverage indication signals can be transmitted into the out-of-coverage sectors for use in the receiver to ensure a flag whenever an undesired angle guidance signal is present. This is accomplished by transmitting an out-of coverage indication signal into the region which is greater in magnitude than the undesired guidance signal.

8.3 If it is operationally required to confirm the selected MLS channel outside the promulgated coverage sectors of the MLS, it is intended that this confirmation be derived from the identification of the associated DME. MLS status information is not available outside the promulgated MLS coverage sectors.

9. Separation criteria in terms of signal ratios and propagation losses

9.1 Geographical separation

9.1.1 The separation criteria are provided in 9.2 and 9.3 as desired signal-to-noise ratios and when combined with appropriate propagation losses allow evaluation of MLS C-Band frequency assignments as regards on-channel and adjacent channel interference. When selecting frequencies for MLS facilities, a similar criteria for the DME/P element or an associated DME/N as provided in Attachment C to this Part need to be considered.

9.2 Co-frequency requirements

9.2.1 Co-frequency MLS channel assignments should be made to preclude the acquisition of DPSK preambles of an undesired co-channel facility. The required level of the undesired signal is less than minus 120 dBm, which is 2 dB below a sensitive MLS airborne system, as shown below:

—	receiver sensitivity	=	–112 dBm
—	margin for aircraft antenna gain above minimum	=	–6 dBm
			–118 dBm

Considering the system power budget in Table G-1, which shows the minimum signal level at the aircraft is required to be at least minus 95 dBm, the minus 120 dBm requirement is achieved by placing the undesired co-channel at a geographic separation which exceeds the radio horizon distance at any point in the promulgated coverage sector of the desired facility.

Note.— The DPSK signal requires more protection than the scanning beam so that by limiting the undesired co-channel signal to minus 120 dBm, interference from the scanning beam is negligible.

9.3 Adjacent frequency requirements

9.3.1 Considering the absence of requirements on transmitter spectrum characteristics for the first and second adjacent channels, the ground stations operating at these frequencies should be placed at a geographical separation that exceeds the radio horizon distance at any point in the promulgated coverage sector of the desired facility.

Note.— Where for specific reasons (for example, ILS/MLS/DME pairing channels) the first or second adjacent channels need to be assigned, a less conservative method to assure receiver protection is to guarantee that the minimum SNR values as quoted in 3.11.6.1.4 are available at any point in the promulgated coverage sector of the desired facility while the undesired facility is transmitting.

9.3.2 For the third and subsequent adjacent channels, the ground stations operating at these frequencies should be placed at a geographical separation which guarantees that the minimum SNR values as quoted in Chapter 3, 3.11.6.1.4 are available at any point in the promulgated coverage sector of the desired facility while undesired facilities are transmitting.

9.3.2.1 If there is no undesired MLS transmission situated at less than 4 800 m from any point of the promulgated coverage, the –94.5 dBW/m^2 maximum power of Chapter 3, 3.11.4.1.4.2 compared to the minimum power density of Chapter 3, 3.11.4.10.1 assures that the SNR minimum values will be met. No constraints are anticipated.

9.3.2.2 If there is an undesired MLS transmission situated at less than 4 800 m from a point of the promulgated coverage, the maximum power produced by this transmission and measured, during transmission time for angle and data signals, in a 150 kHz band centred on the desired nominal frequency has to be assessed taking into account the frequency separation, spectrum performances and antenna pattern of the transmitter and the appropriate propagation losses. This maximum power has then to be compared to the desired angle and data level to check that the minimum SNR values defined in 3.11.6.1.4 are met. If not, another channel offering a larger frequency separation has to be assigned in order to reduce this maximum undesired power taking benefit of the spectrum characteristic of the transmitter.

9.4 Development of frequency planning criteria

9.4.1 The controlling factor when developing adjacent channel frequency planning criteria is the radiated spectrum from the MLS ground station. When developing frequency planning criteria for the third adjacent channel and above, ideally, the radiated spectrum output of individual MLS ground stations should be considered. However it may be possible in a geographic region to use a generic MLS transmitter mark which meets the requirements of that region.

10. Material concerning MLS installations at special locations

10.1 MLS facility performance throughout the coverage volume

10.1.1 It is recognized that at some locations the requirements for MLS specified in Chapter 3, 3.11 cannot be met throughout the whole volume of coverage due to environmental effects on the signal. It is expected that at such locations the requirements of Chapter 3, 3.11 are to be met at least in the guidance sector for all published instrument procedures to a defined point beyond which the MLS guidance is not used for intended operations. To assist appropriate authorities with the initial appraisal of the suitability of such individual MLS installations for the intended operations, relevant coverage restrictions need to be promulgated.

11. Integrity and continuity of service — MLS ground equipment

11.1 Introduction

11.1.1 This material is intended to provide description of the integrity and continuity of service objectives of MLS ground equipment and to provide guidance on engineering design and system characteristics of this equipment. The integrity and continuity of service must of necessity be known from an operational viewpoint in order to decide the operational application which an MLS could support.

11.1.2 It is generally accepted, irrespective of the operational objective, that the average rate of a fatal accident during landing, due to failures or shortcomings in the whole system, comprising the ground equipment, the aircraft and the pilot, should not exceed 1 × 10–7. This criterion is frequently referred to as the global risk factor.

11.1.3 In the case of Category I operations, while minimum standards of accuracy and integrity are required during the early stages of landing, most of the responsibility for assuring that the above objective is not exceeded is vested in the pilot. In Category III operations, the same objective is required but must now be inherent in the whole system. In this context it is of the utmost importance to endeavour to achieve the highest level of integrity and continuity of service of the ground equipment. Integrity is needed to ensure that an aircraft on approach will have a low probability of receiving false guidance; continuity of service is needed to ensure that an aircraft in the final stages of approach will have a low probability of beingdeprived of a guidance signal.

11.1.4 It is seen that various operational requirements correspond to varied objectives of integrity and continuity of service. Table G-15 identifies and describes four levels of integrity and continuity of service that are applicable for basic procedures where DME is not a critical element.

11.2 Achievement and retention of integrity and continuity of service levels

11.2.1 An integrity failure can occur if radiation of a signal which is outside specified tolerances or which is incorrect (in the case of digital data) is either unrecognized by the monitoring equipment or the control circuits fail to remove the faulty signal. Such a failure might constitute a hazard if it results in a gross error.

11.2.2 Clearly not all integrity failures are hazardous in all phases of the approach. For example, during the critical stages of the approach, undetected failures producing significant path following error (PFE) are of special significance whereas an undetected loss of clearance or identification signals would not necessarily produce a hazardous situation. The criterion in assessing which failure modes are relevant must however include all those deleterious fault conditions which are not unquestionably obvious to the automatic flight system or pilot.

11.2.3 It is especially important that monitors be designed to provide fail-safe operation through compliance with the Standards of Chapter 3, 3.11.5.2.3 and 3.11.5.3.3. This often requires a rigorous design analysis. Monitor failures otherwise may permit the radiation of erroneous signals. Some of the possible conditions which might constitute a hazard in operational performance Categories II and III are:

a) an undetected fault causing a significant increase in PFE as seen by an approaching aircraft;

b) an undetected error in the minimum glide path, transmitted in basic data word 2;

c) an undetected error in the TDM synchronization resulting in overlap; and

d) loss of power that increases CMN to unacceptable limits.

11.2.4 The highest order of protection is required against the risk of undetected failures in the monitoring and associated control system. This would be achieved by careful design to reduce the probability of such occurrences to a low level and by carrying out periodic checks on the monitor system performance at intervals which are determined by the design analysis. Such an analysis can be used to calculate the level of integrity of the system in any one landing. The following formula can be applied to certain types of MLS and provides an example of the determination of system integrity, I, from a calculation of the probability of transmission of undetected erroneous radiation, P.

$$I = 1 - P$$

$$P = \frac{T^2}{\alpha_1 \alpha_2 M_1 M_2}$$

Where:

I = integrity;

P = the probability of a concurrent failure in transmitter and monitor systems resulting in undetected erroneous radiation;

M_1 = transmitter mean time between failure (MTBF)

M_2 = MTBF of the monitoring and associated control system;

$\frac{1}{\alpha_1}$ = ratio of the rate of failure in the transmitter resulting in the radiation of an erroneous signal to the rate of all transmitter failures;

$\frac{1}{\alpha_2}$ = ratio of the rate of failure in the monitoring and associated control system resulting in inability to detect an erroneous signal to the rate of all monitoring and associated control system failures; and

T = period of time (in hours) between checks on the monitoring and associated control system.

This example formula would be applicable to a non-redundant monitor design in which a single value of T applies to all elements of the monitoring and associated control system.

11.2.5 With regard to integrity, since the probability of occurrence of an unsafe failure within the monitoring or control equipment is extremely remote, to establish the required integrity level with a high degree of confidence would necessitate an evaluation period many times that needed to establish the equipment MTBF. Such a protracted period is unacceptable and therefore the required integrity level can only be predicted by rigorous design analysis of the equipment. However, a degree of confidence in the analysis can be achieved by demonstration of independence between the transmitter and monitor functions. The predicted performances of the transmitter and monitor can then be evaluated independently, resulting in more feasible evaluation periods.

11.2.6 The MTBF and continuity of service of equipment is governed by basic construction characteristics and by the operating environment. The basic construction characteristics include the failure rate of the components of the equipment and the physical relationship of the components. Failure rate (1/MTBF) and continuity of service are not always directly related because not all equipment failures will necessarily result in an outage, e.g. an event such as a failure of a transmitter resulting in the immediate transfer to a standby transmitter. The manufacturer is expected to provide the details of the design to allow the MTBF and the continuity of service to be calculated. Equipment design has to employ the most suitable engineering techniques, materials, and components, and rigorous inspection should be applied during manufacture. It is essential to ensure that equipment is operated within the environmental conditions specified by the manufacturer.

11.2.7 The design continuity of service is expected to exceed that given in 12.4 by as large a margin as is feasible. The reasons for that are as follows:

a) the MTBF experienced in an operational environment is often worse than that determined by the design calculations due to the impact of operational factors;

b) the continuity of service objectives given in 12.4 are minimum values to be achieved in an operational environment.
Any improvement in performance above these values enhances the overall safety of the landing operation;

c) a margin between the continuity of service objective and that achieved is required in order to reduce the chance of falsely rejecting the suitability of an equipment for a particular level of service due to statistical uncertainty.

Note.— The Level 3 and 4 continuity of service values include a factor that accounts for the pilot's capability to avoid a fatal accident in the event of a loss of guidance. It is particularly desirable to reduce this factor to the maximum extent practical by achieving the best possible continuity of service for Level 3 and 4 equipment.

11.2.8 Experience has shown that there is often a difference between the calculated continuity of service and that experienced in an operational environment both because the performance of the equipment may be different from the calculated value and because of the impact of operational factors, i.e. airport environment, inclement weather conditions, power availability, quality and frequency of maintenance, etc. For these reasons, it is recommended that the equipment MTBF and continuity of service be confirmed by evaluation in an operational environment. Continuity of service may be evaluated by means of mean time between outages, where an outage is defined as any unanticipated cessation of signal-in-space. It is calculated by dividing total facility up-time by the number of operational failures. For integrity and continuity of service Levels 2, 3 or 4, the evaluation period is to be sufficient to determine achievement of the required level with a high degree of confidence. To determine whether the performance record of an individual equipment justifies its assignment to Levels 2, 3 or 4 requires judicious consideration of such factors as:

a) the performance record and experience of system use established over a suitable period of time;

b) the average achieved MTBO established for this type of equipment; and

c) the trend of the failure rates.

11.2.9 The minimum acceptable confidence level for acceptance/rejection is 60 per cent. Depending on the service

level of the MLS, this may result in different evaluation periods. To assess the influence of the airport environment, a minimal evaluation period of one year is typically required for a new type of installation at that particular airport. It may be possible to reduce this period in cases where the operating environment is well controlled and similar to other proven installations. Subsequent installation of the same type of equipment under similar operational and environmental conditions may follow different evaluation periods. Typically, these minimal periods for subsequent installations are for Level 2, 1 600 hours, for Level 3, 3 200 hours and for Level 4, at least 6 400 hours. Where several identical systems are being operated under similar conditions, it may be possible to base the assessment on the cumulative operating hours of all the systems. This will result in a reduced evaluation period.

11.2.10 During the evaluation period it should be decided for each outage if it is caused by a design failure or if it is caused by a failure of a component due to its normal failure rate. Design failures are, for instance, operating components beyond their specification (overheating, overcurrent, overvoltage, etc., conditions). These design failures should be dealt with such that the operating condition is brought back to the normal operating condition of the component or that the component is replaced with a part suitable for the operating conditions. If the design failure is treated in this way, the evaluation may continue and this outage is not counted, assuming that there is a high probability that this design failure will not occur again. The same applies to outages due to any causes which can be mitigated by permanent changes to the operating conditions.

11.2.11 A suitable method to assess the behaviour of a particular installation is to keep the records and calculate the average MTBO over the last five to eight failures of the equipment. A typical record of this method is given in Figures G-35A and G-35B.

11.2.12 During the equipment evaluation, and subsequent to its introduction into operational service, records have to be maintained of all equipment failures or outages to confirm retention of the desired continuity of service.

Note.— If an equipment requires redundant or standby units to achieve the required continuity of service, an arrangement such as that described in 11.3.4 is required to assure that the standby equipment is available when needed.

11.3 Additional considerations concerning continuity of service and integrity

11.3.1 The stringent requirement for integrity and continuity of service essential for Category III operations requires equipment having adequate assurance against failures. Reliability of the ground equipment must be very high, so as to ensure that safety during the critical phase of approach and landing is not impaired by a ground equipment failure when the aircraft is at such a height or attitude that it is unable to take safe corrective action. A high probability of performance within the specified limits has to be ensured. Facility reliability in terms of MTBF clearly has to be related on a system basis to the probability of failure which may affect any characteristic of the total signal-in-space.

11.3.2 The following configuration is an example of a redundant equipment arrangement that is likely to meet the objectives for integrity and continuity of service Levels 3 and 4. The azimuth facility consists of two transmitters and an associated monitor system performing the following functions:

a) monitoring of operation within the specified limits of the main transmitter and antenna system by means of majority voting among redundant monitors; and

b) monitoring the standby equipment.

11.3.2.1 Whenever the monitor system rejects one of the equipments the facility continuity of service level will be reduced because the probability of cessation of signal consequent on failure of other equipment will be increased. The change of performance must be automatically indicated at remote locations.

11.3.2.2 An identical monitoring arrangement to the azimuth is used for the elevation facility.

11.3.3 In the above example, the equipment would include provision to facilitate monitoring system checks at intervals specified by the manufacturer, consequent to his design analysis, to ensure attainment of the required integrity level. Such checks, which can be manual or automatic, provide the means to verify correct operation of the monitoring system including the control circuitry and changeover switching system. It is desirable to perform these checks in such a way that there is no interruption to operational service. The advantage of implementing an automatic monitor integrity test is that it can be accomplished more frequently, thereby achieving a higher level of integrity.

11.3.4 Interruption of facility operation due to primary power failures is avoided by the provision of suitable standby supplies, such as batteries or “no-break” generators. Under these conditions, the facility should be capable of continuing in operation over the period when an aircraft may be in the critical stages of the approach. Therefore the standby supply should have adequate capacity to sustain service for at least two minutes.

11.3.5 Warnings of failures of critical parts of the system, such as the failure of the primary power supply, must be given at the designated control points if the failure affects operational use.

11.3.6 In order to reduce failure of equipment that may be operating near its monitor tolerance limits, it is useful for the monitor system to include provision to generate a pre-alarm warning signal to the designated control point when the monitored parameters reach a limit equal to a value on the order of 75 per cent of the monitor alarm limit.

11.3.7 Protection of the integrity of the signal-in-space against degradation, which can arise from extraneous electromagnetic interference falling within the MLS frequency band or from reradiation of MLS signals, must be considered.

11.3.8 A field monitor can provide additional protection by providing a warning against exceeding path following error limits due to physical movement of the MLS antenna or by protecting against faults in the integral monitor.

11.3.9 In general, monitoring equipment design is based on the principle of continuously monitoring the radiated signals-in-space at specific points within the coverage volume to ensure their compliance with the Standards specified at Chapter 3, 3.11.5.2.3 and 3.11.5.3.3. Although such monitoring provides to some extent an indication that the signal-in-space at all other points in the coverage volume is similarly within tolerance, this is largely inferred. It is essential therefore to carry out rigorous inspections at periodic intervals to ensure the integrity of the signal-in-space throughout the coverage volume.

11.3.10 An equipment arrangement similar to that at 11.3.2, but with no transmitter redundancy, and the application of the guidance outlined in 11.3.5, 11.3.6, 11.3.7, 11.3.8, and 11.3.9, would normally be expected to achieve the objectives for integrity and continuity of service for level 2.

12. Classification of MLS approach azimuth, elevation and DME ground facilities

12.1 The classification system as described in the following paragraphs, is intended to identify in a concise way essential information to be used by instrument procedure designers, operators and air traffic services regarding the performance of a particular MLS installation. The information is to be published in the aeronautical information publication (AIP).

12.2 The information concerning MLS facility performance should comprise:

a) the limits of the azimuth proportional guidance sector;

b) the vertical guidance limit;

c) the availability of the guidance signal along the runway; and

d) the reliability of the guidance signal (azimuth, elevation and DME).

12.3 The classification system, containing information of a particular MLS facility, is defined using the following formats:

a) *Azimuth proportional guidance sector limits*. This field identifies for a particular MLS the azimuth proportional guidance sector limits as defined in basic data word 1. Two values separated by a colon (XX:YY) indicate the sector limits as seen from the approach direction; the first value being the sector limit left of the zero degree azimuth and the second value being the sector limit right of the zero degree azimuth.

b) *Vertical guidance limit.* This field, located directly after the azimuth limit (format: XX:YY/ZZ m (or XX:YY/ ZZ ft)), represents the minimum height (in metres or feet) above threshold on the final approach segment along the minimum glide path (MGP) to which the system conforms to the signal characteristics specified in Chapter 3, 3.11.

c) *Runway guidance*. The character D or E (as defined in Section 1 of Attachment G) represents the point to which the azimuth guidance along the runway conforms to the signal characteristics specified in Chapter 3, 3.11 (format: XX:YY/ZZ/E). If the guidance signal along the runway does not conform to the above-mentioned characteristics, then a dash (—) is used in the format.

d) *Reliability of the guidance signal*. The character 1, 2, 3 or 4 indicates the level of integrity and continuity of service of the guidance signal (Table G-15). The character A, which is placed after the Level 3 or 4 designation, indicates that the elevation and DME/P objectives are equivalent to the azimuth objectives in accordance with Note 6 of Table G-15 (format: XX:YY/ZZ/E/4).

Note 1.— Where DME is not required for the intended MLS operations, there is no need to include DME/P reliability in MLS classification.

Note 2.— Where an improved elevation and/or DME/P reliability is required according to Note 6 of Table G-15 for the intended MLS/RNAV operations, the improved elevation and/or DME/P reliability is to be included in the MLS classification.

12.3.1 Any degradation of the signal below Annex 10 Standards, or below previously published performance, should be promulgated by the appropriate authority (Chapter 2, 2.1.2 and Section 10 above).

12.4 Table G-15 gives continuity of service and integrity objectives for MLS basic and MLS/RNAV operations.

Note.— In relation to specific MLS operations it is intended that the level of integrity and continuity of service would typically be associated as follows:

1) Level 2 is the performance objective for MLS equipment used to support low visibility operations when guidance for position information in the landing phase is supplemented by visual cues. This level is a recommended objective for equipment supporting Category I operations;

2) Level 3 is the performance objective for MLS equipment used to support operations which place a high degree of reliance on MLS guidance for positioning through touchdown. This level is a required objective for equipment supporting Category II and IIIA operations; and

3) Level 4 is the performance objective for MLS equipment used to support operations which place a high degree of reliance on MLS guidance throughout touchdown and roll-out. This level basically relates to the needs of the full range of Category III operations.

12.5 The following example of MLS facility classification:

40:30/50 ft/E/4A

denotes a system with:

a) a proportional guidance sector of 40 degrees left and 30 degrees right of the zero-degree azimuth;

b) vertical guidance down to 50 ft above threshold;

c) roll-out guidance to MLS point E; and

d) integrity and continuity of service Level 4 with elevation and DME/P objectives equivalent to azimuth.

13. Computed centre line approaches

13.1 General

13.1.1 Computed centre line approaches considered below are based on a computed path along a runway centre line where the azimuth antenna is not sited on the extended runway centre line. The simplest form of a computed centre line approach is one in which the nominal track is parallel to the zero-degree azimuth. In order to conduct MLS/RNAV operation, a greater capability than that available in the basic MLS receiver is required.

13.1.2 Computed centre line approaches to the MLS primary runway are conducted to the runway whose relationship to the MLS ground equipment is identified in the auxiliary data words.

13.1.3 When the final segment is contained in the MLS coverage volume, computed centre line approaches can be conducted along a straight final segment on a descent gradient down to the decision height (DH). Computed centre line approaches may result in decision heights that are above decision heights achievable with aligned MLS approaches.

13.2 Computed centre line approach error budget

13.2.1 RTCA (RTCA/DO-198) has described a total system error budget for MLS area navigation (RNAV) equipment.
This error budget includes contributions due to:

a) ground system performance;

b) airborne sensor performance;

c) ground system geometry effects;

d) MLS/RNAV computer computational error; and

e) flight technical error (FTE).

13.2.2 The composite of the above errors with the exclusion of FTE is referred to as total position error. Within 3.7 km (2 NM) of the MLS approach reference datum the permissible total lateral position error for MLS/RNAV equipment at a position 60 m (200 ft) above the MLS datum point on a 3-degree elevation angle and a runway length of 3 000 m (10 000 ft), is 15 m (50 ft) (see the note below). Similarly, the permissible total vertical position error is 3.7 m (12 ft) at the same position. A portion of the total position error budget has been reserved for the MLS/RNAV computer performance (computational error). Within 3.7 km (2 NM) of the MLS approach reference datum, the portion of the error budget reserved for computational error is ±0.6 m (2 ft) both laterally and vertically. The results presented in 13.5 are dependent on meeting this computational accuracy requirement.

13.2.3 Using root sum square methodology the permissible total lateral position error, exclusive of MLS/RNAV computer performance, is slightly less than ±15 m (50 ft). Similarly, the permissible total vertical position error, exclusive of computational error is slightly less than ±3.7 m (12 ft). Hence, the combined error due to ground system performance, airborne sensor performance and ground system geometry effects is not expected to exceed ±15 m (50 ft) laterally and 3.7 m (12 ft) vertically at the described location. Using this information and assumptions about ground and airborne sensor performance, the maximum permissible azimuth and elevation antenna offsets (geometry effects) from the runway centre line can be obtained.

13.2.4 The CMN does not exceed ±7.3m (24 ft) laterally and ±1.9 m (6.3 ft) vertically, or the linear equivalent of ±0.1 degree, whichever is less. The linear values are based on nominal antenna sitings (azimuth antenna to threshold distance of 3 300 m (11 000 ft) and datum point to threshold distance of 230 m (760 ft)), with a 3-degree elevation angle. Within 3.7 km (2 NM) of the MLS approach reference datum, the portion of the CMN budget reserved for computational error is 1.1 m (3.5 ft) laterally and 0.6 m (2.0 ft) vertically.

Note.— All errors represent 95 percentile errors.

13.3 Siting and accuracy considerations

13.3.1 Theoretical and operational analysis has shown that several factors will impact the amount of azimuth antenna lateral offset that can be permitted and still obtain lateral and vertical position accuracy identified in 13.2.

13.3.2 Distance between azimuth and elevation antennas

13.3.2.1 For a given azimuth antenna offset, a short azimuth to elevation distance results in relatively large azimuth angles at positions near the approach reference datum. As a result, the error contribution from the DME is large, and the lateral accuracy may degrade unacceptably. At a runway where a large azimuth antenna offset and a short azimuth to elevation distance exist, use of DME/P rather than DME/N may be required to achieve the required lateral accuracy.

13.3.3 *Azimuth accuracy*

13.3.3.1 The azimuth antenna offset limits presented in 13.5 are based on the ±6 m (20 ft) azimuth path following error accuracy specification (see Chapter 3, 3.11.4.9.4). The recommended ±4 m (13.5 ft) azimuth accuracy specification would permit larger azimuth antenna offsets and still obtain required computed position accuracy at DH. Azimuth angle accuracy is assumed to degrade in accordance with Chapter 3, 3.11.4.9.

13.3.4 *DME accuracy*

13.3.4.1 Smaller errors in position determination result when DME/P equipment is used and the final approach segment is contained within 9.3 km (5 NM) of the MLS approach reference datum. There are two DME/P final approach mode accuracy standards in this region. Resulting azimuth antenna offset values when using DME/P as presented in 13.5, are based on final approach mode Standard 1 accuracy. Larger azimuth antenna offset values may be permissible if DME/P equipment meeting final approach mode Standard 2 accuracy is used. DME/P final approach mode Standard 1 ranging accuracy is assumed to degrade in accordance with Chapter 3, 3.5.3.1.3.4 and Table B. DME/N is assumed to degrade in accordance with Chapter 3, 3.5.3.1.3.2.

13.3.5 *Use of elevation information in the lateral position computation*

13.3.5.1 Generally, lateral position computation that excludes elevation information will be sufficient for computed centre line approaches to the primary runway. If elevation information is not used in lateral computation, the lateral error increases. This error increases with azimuth angle, height and decreasing range. Permissible azimuth antenna offsets presented in 13.5 are reduced if elevation information is not used in the lateral computation. Elevation angle accuracy is assumed to degrade in accordance with Chapter 3, 3.11.4.9.

13.4 Equipment considerations

13.4.1 Performance of airborne sensors, MLS ground equipment and MLS/RNAV avionics implementation influence the range of application of computed centre line approaches. Information presented in 13.5 is based on the following equipment considerations.

13.4.2 *Airborne sensors*

13.4.2.1 It is assumed the receiver will decode all auxiliary data words required for MLS computed centre line approaches unless the information contained in the data words is available from other avionics sources with the same accuracy and integrity as required for auxiliary data. Digital MLS angle data and range data are needed for computing lateral and vertical position. Angle data quantization is 0.01 degrees. Range quantization is 2.0 m (0.001 NM).

13.4.3 *RNAV computations*

13.4.3.1 No assumption is made about where the RNAV position computations are made. A portion of the computed centre line approach error budget has been reserved for computation error. This permits flexible algorithm implementation.

13.4.4 *Permissible azimuth antenna offset calculation techniques*

13.4.4.1 RTCA (RTCA/DO-198, Appendix D) has identified several different position determination algorithms. Different algorithms can handle different ground equipment configurations. The algorithm designed to handle any ground equipment geometry is the RTCA case 12 algorithm. Permissible antenna offset values were obtained using Monte Carlo simulation techniques. The results were also obtained using a direct analytical method. The analytical method uses geometric transformations of the maximum MLS angle and range errors to determine system performance. The Monte Carlo technique through the emulation of an MLS/RNAV system is a statistical method used to determine system performance.

13.4.4.2 *Possible restriction in position determination.* Depending on ground equipment geometry a region of possible multiple solutions to the position determination algorithm may exist. This region of multiple solutions is dependent on the locations of the elevation antenna and DME transponder relative to the runway and computed approach path. The most pronounced effect occurs when the DME transponder lies in the region between the approach path DH point and the elevation antenna. The position ambiguities can be resolved when the DME transponder is located behind the elevation antenna when viewed from the approach direction. When the DME transponder is located in front of the elevation antenna it may not be possible to resolve the position ambiguity.

13.4.5 *Ground equipment geometry*

13.4.5.1 The nominal ground equipment geometry in terms of the relative position of the ground components is depicted in Figure G-29. The DME/P transponder is assumed to be collocated with the approach azimuth antenna. When DME/P ground equipment is not available, the DME/N transponder is assumed to be located between the MLS approach azimuth and elevation antennas.

13.4.5.2 Because of the relatively large error induced by the DME/N, the location of the DME/N transponder has no significant influence on the calculated permissible azimuth antenna offset. This permits DME/N siting over a large area between the azimuth and elevation antennas. Similarly, the offset of the elevation antenna will have little effect.

13.5 Permissible approach azimuth antenna offset positions for computed centre line approaches to the primary runway

13.5.1 *DME results*

13.5.1.1 The maximum azimuth offset represents, for a given set of conditions, the largest offset that does not exceed the computed centre line approach error budget identified in 13.2. DME/P results are presented as a function of the azimuth to elevation distance. The permissible azimuth antenna offsets with DME/P are presented in Figure G-30.

13.5.1.2 For a given azimuth to elevation distance, the azimuth antenna can be sited any place in the shaded area and the resulting computed centre line approach meet requirements of 13.2.

13.5.1.3 Results were obtained when DME/N ranging accuracies are used. These results are presented in Figure G-31.

13.6 Low visibility approaches

13.6.1 *Possible applications*

13.6.1.1 The possibility of low visibility computed centre line applications may be limited to operations on the primary instrument runway because of the geometry considerations involved in achieving adequate accuracy. Primary instrument runway applications where computed centre line capability would be useful are those where the azimuth is offset from the runway centre line due to a severe siting restriction. There may be such azimuth offset applications where low visibility operations would be considered beneficial.

13.6.1.2 The expected airborne implementation for such low visibility computed centre line approaches would use noncomputed elevation guidance (assuming the elevation ground antenna is sited normally) and lateral guidance derived from a combination of azimuth (including MLS siting data contained in the basic and auxiliary data functions) and range from the DME/P transponder.

13.6.2 *Airborne system performance*

13.6.2.1 Safety-critical software associated with the guidance function for non-computed low visibility approaches mainly involves the MLS receiver. For computed centre line approaches, the DME interrogator and the navigation computations must also be considered. The safety-critical software for these functions will have to be designed, developed, documented and evaluated.

13.6.2.2 The necessary algorithms are relatively simple and do not pose any certification difficulty. However, experience with flight management system (FMS) computers indicates that it would be difficult to certify a safety-critical function implemented within an existing FMS. Current FMS architectures are not partitioned to allow separate certification of different functions to different levels of criticality and the size and complexity of an FMS precludes safety-critical certification of the entire FMS computer. Consequently, alternatives to FMS implementation can be considered for computed centre line capability intended for low visibility applications (e.g. incorporation within the autopilot or within the MLS receiver). These alternatives would provide output guidance with the same output characteristics as a normal straight-in approach.

13.6.3 *Ground system performance*

13.6.3.1 Based on the implementation assumed in 13.3.5, elevation guidance would be used in exactly the same manner as for basic MLS approaches. Consequently, the elevation ground equipment integrity and continuity of service objectives would remain unchanged from those already given in Table G-15. For lateral guidance, the integrity and continuity of service objectives given in Table G-15 for azimuth would apply to the azimuth and DME combined, resulting in objectives for both that are more stringent than those needed for basic MLS operations. However, a low visibility computed centre line operation to a 30 m (100 ft) DH may be achieved by the use of ground equipment meeting the level 4 objectives contained in Table G-15.

13.6.4 Accuracy

13.6.4.1 MLS/RNAV will support computed paths to Category I decision heights for the primary runway given siting limitations as identified in Figure G-30. In addition, under certain conditions MLS/RNAV may provide sufficient accuracy to support Category II and III approaches. In order to accomplish this, the airborne implementation is as stated in 13.6.1.2.

13.6.4.2 The error budgets for Category II and III procedures are the following. For Category III, the lateral accuracy requirements are the same as the MLS approach azimuth accuracies specified at the approach reference datum. These requirements are ±6 m (20 ft) for PFE and ±3.2 m (10.5 ft) for CMN (Chapter 3, 3.11.4.9.4). For Category II the lateral requirements are obtained by splaying the allowed Category III values from the approach reference datum out to the Category II decision height of 30 m (100 ft). The equations used to compute these values (in metres) are:

$$PFE = 6 \times \frac{(D_{AZ-ARD} + R)}{D_{AZ-ARD}}$$

$$CMN = 3.2 \times \frac{(D_{AZ-ARD} + R)}{D_{AZ-ARD}}$$

$$R = \frac{DH_{CatII} - DH_{CatIII}}{\tan \theta}$$

Where:

D_{AZ-ARD} = distance between approach azimuth antenna and approach reference datum (threshold)

R = distance between $DH_{Cat\ II}$ and $DH_{Cat\ III}$

θ = elevation angle

As an example, for a 3 000 m (10 000 ft) runway and a 3-degree elevation with an approach azimuth setback of 300 m (1 000 ft), a Category III decision height of 15 m (50 ft) and a Category II decision height of 30 m (100 ft), the following values are obtained:

D_{AZ-ARD} = 3 300 m

R = 286 m

$PFE_{DH\ Cat\ II}$ = 6.5 m (21.3 ft)

$CMN_{DH\ Cat\ II}$ = 3.5 m (11.5 ft)

13.6.4.3 The computed centre line capability down to Category II decision height will not necessarily support auto land operations as the guidance may not be provided down to the runway and in the runway region. Also, the more stringent error tolerances for Category II/III will result in more constraints in antenna siting than for Category I. Primarily this will constrain the lateral offset of the approach azimuth from runway centre line.

13.7 Computed centre line approaches to parallel secondary runways

13.7.1 A secondary runway as defined here is a runway that has a different geometric relationship than the one contained in the auxiliary data A words. Computed centre line approaches to a parallel secondary runway are approaches along a computed path on the extended runway centre line which is not aligned with an MLS azimuth radial and/or elevation angle but is parallel to the primary runway centre line.

13.7.2 The material in this section provides guidance on permissible runway geometries for computed centre line approaches to a parallel secondary runway to decision heights of 60 m (200 ft). The material in this section is based on the theoretical application of MLS and DME/P (Standard 1) SARPs. The error budget used is the conservative error budget identified in 13.2, and relaxations of this error budget are described in 13.7.6.1.

13.7.3 *Runway geometry considerations*

13.7.3.1 Figure G-32 presents the runway and equipment geometry. The secondary runway location is established laterally with the use of runway spacing in metres. Negative values represent secondary runway locations left of the primary runway. The longitudinal position of the secondary runway threshold is referred to as threshold stagger relative to the primary runway. Negative values represent threshold stagger forward of the primary runway threshold.

13.7.4 *Large runway spacing considerations*

13.7.4.1 Additional considerations are necessary for computed centre line approaches to widely spaced parallel runways. These considerations include:

a) adequate signal coverage to DH for some parallel runway geometries may require the use of an elevation antenna with more than ±40 degrees of horizontal coverage;

b) the critical areas around the MLS antennas may have to be increased for these operations; and

c) these operations require the use of elevation guidance below the primary runway minimum glide path.

13.7.5 *Runway geometry*

13.7.5.1 Figure G-33 shows permitted runway spacings and threshold staggers for the secondary runway. It represents results for a 3 000 m (10 000 ft) primary runway. The geometrics change marginally with primary runway length. The shaded area represents results obtained using existing MLS and DME/P (Standard 1) SARPs and the error budget identified in 13.2. To use Figure G-33, enter the values for secondary runway spacing and threshold stagger. If the resulting point lies within theshaded area a computed centre line approach to a 60 m (200 ft) DH on a 3-degree elevation is possible.

Note.— The circular region near the 1 200 m runway threshold stagger is due to the upper limit of elevation guidance used. This region is not expected to present any practical operational limitations.

13.7.6 Extensions to the runway geometries

13.7.6.1 Flight and ground tests have shown that the shaded area can be expanded with the following additional considerations:

a) an angular expansion is possible by utilizing existing elevation guidance outside the minimum specified azimuth proportional guidance sector. Elevation guidance for this angular expansion must be verified; and

b) a radial expansion is possible with a slight relaxation of the vertical error budget to 4.9 m (16 ft). This relaxation is still very conservative and equates to 66 per cent ofthe equivalent ILS error budget (7 m (24.1 ft)).

13.7.6.2 An example of the use of Figure G-33 is presented by point A. Using the foregoing expansions, a computed centre line approach to a secondary runway is possible for a –1 400 m runway spacing and +200 m threshold stagger.

14. Application of Table G-15 service level objectives for MLS/RNAV operations

14.1 MLS/RNAV procedures discussed below can be conducted with ground equipment meeting integrity and continuity of service objectives identified in Table G-

15. Many of these operations may be accomplished with MLS ground equipment meeting Level 2 objectives only. Further a majority of the procedures may not require positive guidance during the discontinued approach/missed approach procedure. Where procedural means cannot provide the required obstacle clearance along an unguided discontinued approach/missed approach, some form of secondary guidance will be required. The accuracy requirements of the secondary guidance system will be determined by the nature of the obstacle-rich environment.

14.1.1 In those rare cases where an MLS/RNAV procedure is in an obstacle-rich environment, the calculated obstacle exposure time (OET) may require a higher level of equipment type than that required for landing.

14.1.2 *Determination of critical segments*

14.1.2.1 The following terms are used to determine the length of the critical segments of an MLS/RNAV procedure.

Obstacle-rich environment. An environment where it is not possible to construct an unguided discontinued approach/missed approach using procedural means. Secondary guidance will be required to achieve a climb to minimum sector altitude.

Critical segment. A segment where an unguided discontinued approach/missed approach would expose the aircraft to an obstacle.

Obstacle exposure time (OET). The time interval required to fly the critical segment of an MLS/RNAV procedure. This time is used to establish the required level of service of the non-aircraft guidance equipment.

14.1.2.2 In order to determine OET the following procedure can be followed (see Figure G-34):

a) determine if there is an obstacle-rich environment by aligning the unguided discontinued approach/missed approach surface with any potential heading that may be used during an unguided discontinued approach/missed approach from the MLS/RNAV procedure;

b) determine whether there is a procedural means for avoiding the obstacle without the need for secondary guidance;

and

c) determine the OET as the period of time during which the obstacle is within the unguided discontinued approach/ missed approach surface, while there is no procedural means for avoiding the obstacle.

14.2 Computed centre line operations

14.2.1 When conducted to the primary runway, these operations require the airborne system to compute lateral guidance only. Vertical guidance is provided by the elevation function directly. The airborne equipment providing the lateral guidance must have the same integrity as the MLS receiver is required to have for basic MLS operations being conducted to an equivalent decision height. Computed centre line operations conducted to a decision height below a Category I decision height require that the DME have an accuracy, integrity and continuity of service level applicable to the type of operation.

14.2.2 When conducted to a parallel secondary runway these operations require the airborne system to compute both lateral and vertical guidance. Decision heights may be limited by the MLS signal coverage and computed guidance accuracy achievable.

14.2.3 MLS ground equipment meeting Level 2 service objectives may be sufficient for computed centre line operations when:

a) the operation is conducted to Category I decision heights or higher; and

b) reference path construction and computed lateral and vertical guidance by the airborne equipment meets the same level of integrity as the MLS receiver for a basic MLS operation.

14.2.4 When computed centre line operations are conducted below Category I decision heights, the service level of the MLS ground equipment must be commensurate with the decision height used. Identically the airborne equipment providing computed guidance must have the same integrity as the basic receiver would have to conduct MLS basic operations to an equivalent decision height.

14.3 MLS curved path procedures

14.3.1 These procedures must be examined carefully to determine the level of service needed for the ground equipment. With MLS curved path operations the most stringent requirement for integrity and continuity of service may be based on a portion of the flight path prior to decision height. In these situations, the integrity and continuity of service objectives of the MLS ground equipment cannot be predicated solely on the category of the landing. For operations where the obstacle clearance requirements place a high degree of reliance on guidance accuracy, the ground equipment integrity and continuity of service objectives can be determined using the risk tree method described in Attachment A. The following requirements must also be considered:

a) airborne equipment must have the capability of reference path construction and computed vertical and lateral guidance with positive control in the turns; and

b) airborne integrity and continuity of service must be consistent with the degree of reliance on the guidance accuracy necessary to safely execute the procedure.

15. Application of simplified MLS configurations

15.1 While SARPs for basic and expanded MLS configurations state a single signal-in-space standard, a simplified MLS configuration is defined in Chapter 3, 3.11.3.4 to permit the use of MLS in support of performance-based navigation operations.

15.2 Relaxed coverage, accuracy, and monitor limits do not exceed those specified in Chapter 3, 3.1 for a Facility Performance Category I ILS. Such a simplified MLS configuration is capable of supporting Category I operations with significant reductions in size of azimuth and elevation antennas. Further reductions in equipment complexity can be achieved as the CMN requirement is waived for applications in support of approach and landing operations which do not require autopilot coupling.

15.3 The simplified MLS is compatible with the basic and expanded MLS configurations.

Table G-1. System power budget

(±40° azimuth coverage; 0–20° vertical coverage; 37 km (20 NM) range)

Power budget items (Note 1)	Approach azimuth function					Elevation function			Back azimuth function			
			Angle BW				Angle BW			Angle BW		
	DPSK	Clearance	1°	2°	3° (Note 2)	DPSK	1°	2°	DPSK	1°	2°	3°
Signal required at aircraft (dBm)	–95.0	–93.5	–91.2	–85.2	–81.7	–95.0	–93.5	–90.0	–95.0	–93.5	–88.2	–84.7
Propagation loss (dB) (Notes 3, 4)	139.0	139.0	139.0	139.0	139.0	138.1	138.1	138.1	133.9	133.9	133.9	133.9
Probabilistic losses (dB):												
a) Polarization	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
b) Rain	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.3	1.3	1.3	1.3
c) Atmospheric	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
d) Horizontal multipath	3.0	3.0	0.5	0.5	0.5	3.0	–	–	3.0	0.5	0.5	0.5
e) Vertical multipath	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0
Root – sum – square (RSS) total a) through e) (dB)	4.3	4.3	3.1	3.1	3.1	4.3	2.5	2.5	3.9	2.5	2.5	2.5
Horizontal and vertical pattern loss (dB)	–	1.0	2.0	2.0	2.0	–	6.0	6.0	–	2.0	2.0	2.0
Monitor margin (dB)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Antenna gain (dB) (Note 5)	–	–13.3	–23.0	–20.0	–18.0	–	–20.8	–17.8	–	–23.0	–20.0	–18.0
Net power gain at coverage extremes (dB)	–7.3	–	–	–	–	–7.3	–	–	–7.3	–	–	–
Required transmitter power (dBm)	42.5	39.0	31.4	40.4	41.1	41.6	33.8	40.3	37.1	23.4	31.7	37.2
Example 20 watt transmitter (dBm)	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Transmitter power margin (dB)	0.5	4.0	11.6	2.6	1.9	1.4	9.2	2.7	5.9	19.6	11.3	5.8

NOTES.—

1. Losses and antenna gains are representative values.
2. High data rate for 3° azimuth beamwidth will reduce required transmitter power by 4.8 dB.
3. Distance to azimuth antenna taken as 41.7 km (22.5 NM).
4. Distance to back azimuth antenna taken as 23.1 km (12.5 nautical miles).
5. The required transmitter power can be reduced by using higher efficiency antennas.

Table G-2. Airborne power budget

Power budget items	DPSK	Clearance	Approach azimuth function Angle BW 1°	2°	3°	3° (Note 1)	Elevation function Angle BW 1°	2°	Back azimuth function Angle BW 1°	2°	3°
IF SNR (dB) required for:											
a) 72% decode rate	5.0	—	—	—	—	—	—	—	—	—	—
b) 0.1° CMN (Note 2)	—	—	8.8	14.8	18.3	13.5	—	10.0	—	11.8	15.3
c) Acquisition	—	6.5	—	—	—	—	6.5	—	6.5	—	—
Noise power in 150 kHz IF bandwidth (dBm)	–122.0	–122.0	–122.0	–122.0	–122.0	–122.0	–122.0	–122.0	–122.0	–122.0	–122.0
Signal power required at IF (dBm)	–117.0	–115.5	–113.2	–107.2	–103.7	–108.5	–115.5	–112.0	–115.5	–110.2	–106.7
Noise figure (dB)	11	11	11	11	11	11	11	11	11	11	11
Cable loss (Note 3) (dB)	5	5	5	5	5	5	5	5	5	5	5
Airborne antenna gain (dBi)	0	0	0	0	0	0	0	0	0	0	0
Margin (dB)	6	6	6	6	6	6	6	6	6	6	6
Signal required at aircraft (dBm)	–95.0	–93.5	–91.2	–85.2	–81.7	–86.5	–93.5	–90.0	–93.5	–88.2	–84.7

NOTES.—

1. High rate approach azimuth function.
2. 0.2° CMN for the back azimuth function.
3. Provides for either front or rear antenna cable losses in typical installations. Additional losses (up to 11 dB) may be accommodated by air carrier class avionics.

Table G-3. Sample RNAV procedures for MLS installation on Runway 23R
(see Figure G-15)

Procedure name	Procedure type	Runway	Missed approach	Number of way-points	AAZ or BAZ
KASEL-1-A	Approach	23R	Yes	4	AAZ
NELSO-1-B	Approach	23R	Yes	3	AAZ
N/A	Missed approach	23R	N/A	2	AAZ
SEMOR-1-C	Approach	26 (Note)	No	2	AAZ
LAWSO-6-D	Departure	23R	N/A	3	BAZ

Note.— Runway 26 is a secondary runway. The virtual azimuth to way-point distance is 3 000 m.

Table G-4. Sample way-point information for MLS/RNAV procedures

Basic indicator	Validity indicator	Route indicator	Way-point number	X (metres)	Y (metres)	Z (metres)	Notes
KASEL	1	A	4	8 200	–9 094	N/A	No Z
			3	9 954	–5 336	789	PFAF
			2	6 556	0	344	No Z, No Y
			1	259	0	16.8 (Note)	Threshold
NELSO	1	B	3	9 742	6 499	819	PFAF
			2	6 556	0	344	Shared with KASEL
			1	259	0	16.8 (Note)	Shared with KASEL
N/A (missed approach)	N/A	N/A	2	–7 408	0	N/A	No Z, No Y
			1	0	0	N/A	No Z, No Y
SEMOR	1	C	2	5 567	–5 276	346	PFAF
			1	159	–2 401	16	Threshold
LAWSO	6	D	3	–8 018	3 057	N/A	No Z
			2	–4 964	0	N/A	No Z, No Y
			1	0	0	N/A	No Z, No Y

Note.— This value is the threshold crossing height, referenced to ground level at threshold. The height of the threshold with respect to the MLS datum point is given in auxiliary word A2.

Table G-5. Example of B1 and B39 data word assignments

Data word title	Data word	Bit numbers	Data item	Value	Coding
Approach azimuth map/CRC	B1	I_{21-24}	Number of procedure descriptors	3	1100
		I_{25-30}	Last approach azimuth database word	11	001011 (Note 2)
		I_{31-62}	CRC code	See Table G-9	
		I_{63}	Word B42 transmitted	No	0
		I_{64}	Word A4 transmitted	Yes	1
		I_{65}	Word B43 transmitted	No	0
		I_{66-69}	Spare	zeros	0000
Back azimuth map/CRC (Note 3)	B39	I_{21-24}	Number of procedure descriptors	1	1000
		I_{25-30}	First back azimuth database word	36	100100 (Note 2)
		I_{31-62}	CRC code	See Table G-9	
		I_{63}	Word B43 transmitted	No	0
		I_{64-68}	Spare	zeros	00000
		I_{69}	Back azimuth map/CRC indicator	map/CRC	1

NOTES.—

1. Bit coding is indicated with the lower bit number on the left.
2. Data word addresses are as defined in Table A-9, Appendix A with the most significant bit first.
3. Facility without back azimuth database may employ all words up to B39 for the approach azimuth database.

Table G-6. Example of procedure descriptor word assignments

Data item	Bit numbers	Procedure descriptor data words							
		KASEL		NELSO		SEMOR		LAWSO	
		B2		B3		B4		B36	
		Value	Coded	Value	Coded	Value	Coded	Value	Coded
Basic indicator (first character)	I_{21}-I_{25}	K	11010	N	01110	S	11001	L	00110
Second character	I_{26}-I_{30}	A	10000	E	10100	E	10100	A	10000
Third character	I_{31}-I_{35}	S	11001	L	00110	M	10110	W	11101
Fourth character	I_{36}-I_{40}	E	10100	S	11001	O	11110	S	11001
Fifth character	I_{41}-I_{45}	L	00110	O	11110	R	01001	O	11110
Validity indicator	I_{46}-I_{49}	1	1000	1	1000	1	1000	6	0110
Route indicator	I_{50}-I_{54}	A	10000	B	01000	C	11000	D	00100
Runway number	I_{55}-I_{60}	23	111010	23	111010	26	010110	23	111010
Runway letter	I_{61}-I_{62}	R	10	R	10	–	00	R	10
Procedure type	I_{63}	APP	0	APP	0	APP	0	DEP	1
First way-point index	I_{64}-I_{69}	1	100000	4	001000	5	101000	1	100000

Note.— Bit coding is indicated with the lower bit number on the left.

Table G-7. Example of way-point assignments for MLS/RNAV approach procedures

Procedure name	Data word	Bit numbers	Data item	Value	Value	WP Index
KASEL	B5	$I_{21\text{-}35}$	WP 4 – X coordinate	8 200 m	110000010011000	1
		I_{36}	Y coordinate follows	Yes	1	
		$I_{37\text{-}51}$	WP 4 – Y coordinate	–9 094 m	000001111011001	
		I_{52}	Z coordinate follows	No	0	
		$I_{53\text{-}55}$	Next segment/field identifier	straight = 0	000	
		$I_{56\text{-}69}$	WP 3 – X coordinate (first 14 bits)	9 954 m	00001100111100	2
	B6	I_{21}	WP 3 – X coordinate (last bit)		0	
		I_{22}	Y coordinate follows	Yes	1	
		$I_{23\text{-}37}$	WP 3 – Y coordinate	–5 336 m	001001000001001	
		I_{38}	Z coordinate follows	Yes	1	
		$I_{39\text{-}51}$	WP 3 – Z coordinate	789 m	1001111011000	
		$I_{52\text{-}54}$	Next segment field/identifier	curved = 1	100	
		$I_{55\text{-}69}$	WP 2 – X coordinate	6 556 m	100000000101000	3
	B7	I_{21}	Y coordinate follows	No	0	
		I_{22}	Z coordinate follows	Yes	1	
		$I_{23\text{-}35}$	WP 2 – Z coordinate	344 m	0011110110000	
		$I_{36\text{-}38}$	Next segment/field identifier	5	101	
		$I_{39\text{-}44}$	Threshold way-point height	16.8 m	010001	
		$I_{45\text{-}50}$	Missed approach index	7	111000	
NELSO		$I_{51\text{-}65}$	WP 3 – X coordinate	9 742 m	101110110111000	4
		I_{66}	Y coordinate follows	Yes	1	
		$I_{67\text{-}69}$	WP 3 – Y coordinate (first 3 bits)	6 499 m	110	
	B8	$I_{21\text{-}32}$	WP 3 – Y coordinate (last 12 bits)		101111001000	
		I_{33}	Z coordinate follows	Yes	1	
		$I_{34\text{-}46}$	WP 3 – Z coordinate	819 m	1110100111000	
		$I_{47\text{-}49}$	Next segment/field identifier	shared = 3	110	
		$I_{50\text{-}55}$	Next way-point index	3	110000	
SEMOR		$I_{56\text{-}69}$	WP 2 – X coordinate (first 14 bits)	5 567 m	11111110000100	5
	B9	I_{21}	WP 2 – X coordinate (last bit)		0	
		I_{22}	Y coordinate follows	Yes	1	
		$I_{23\text{-}37}$	WP 2 – Y coordinate	–5 276 m	101100000001001	
		I_{38}	Z coordinate follows	Yes	1	
		$I_{39\text{-}51}$	WP 2 – Z coordinate	346 m	0111110110000	
		$I_{52\text{-}54}$	Next segment/field identifier	straight = 0	000	
		$I_{55\text{-}69}$	WP 1 – X coordinate	159 m	011111000000000	6
	B10	I_{21}	Y coordinate follows	Yes	1	
		$I_{22\text{-}36}$	WP 1 – Y coordinate	–2 401 m	010101011100001	
		I_{37}	Z coordinate follows	Yes	1	

Procedure name	Data word	Bit numbers	Data item	Value	Value	WP Index
		$I_{38\text{-}50}$	WP 1 – Z coordinate	16 m	0010111000000	
		$I_{51\text{-}53}$	Next segment/field identifier	6	011	
		$I_{54\text{-}59}$	Virtual azimuth distance	3 000 m	011110	
Missed Approach		$I_{60\text{-}69}$	WP 2 – X coordinate (first 10 bits)	–7 408 m	0111001011	7
	B11	$I_{21\text{-}25}$	WP 2 – X coordinate (last 5 bits)		01001	
		I_{26}	Y coordinate follows	No	0	
		I_{27}	Z coordinate follows	No	0	
		$I_{28\text{-}30}$	Next segment/field identifier	straight = 0	000	
		$I_{31\text{-}45}$	WP 1 – X coordinate	0	000000000000000	8
		I_{46}	Y coordinate follows	No	0	
		I_{47}	Z coordinate follows	No	0	
		$I_{48\text{-}50}$	Next segment/field identifier	6	011	
		$I_{51\text{-}69}$	Spare	zeros	000...000	

Note.— Bit coding is indicated with the lower bit number on the left.

Table G-8. Example MLS/RNAV departure way-point assignments

Procedure name	Data word	Bit numbers	Data item	Value	Coding	WP Index
LAWSO	B37	I_{21-35}	WP 3 – X coordinate	–8 018 m	001111000011001	1
		I_{36}	Y coordinate follows	Yes	1	
		I_{37-51}	WP 3 – Y coordinate	3 057 m	010101010010000	
		I_{52}	Z coordinate follows	No	0	
		I_{53-55}	Next segment/field identifier	curved = 1	100	
		I_{56-69}	WP 2 – X coordinate (first 14 bits)	–4 964 m	11001001111000	2
	B38	I_{21}	WP 2 – X coordinate (last bit)		1	
		I_{22}	Y coordinate follows	No	0	
		I_{23}	Z coordinate follows	No	0	
		I_{24-26}	Next segment/field identifier	straight = 0	000	
		I_{27-41}	WP 1 – X coordinate	0	000000000000000	3
		I_{42}	Y coordinate follows	No	0	
		I_{43}	Z coordinate follows	No	0	
		I_{44-46}	Next segment/field identifier	Last WP = 6	011	
		I_{47-69}	Spare	zeros	000...000	

Note.— Bit coding is indicated with the lower bit number on the left.

Table G-9. Example of complete MLS/RNAV database

	Bit position															
	1	2			3		4			5		6			7	
Word	3456	7890	1234	5678	9012	3456	7890	1234	5678	9012	3456	7890	1234	5678	9012	3456
A1	0000	0111	0011	0010	0101	1101	1001	1000	0010	0110	0010	0100	0000	0000	0000	0100
A2	0000	1010	0011	0010	0111	0000	0010	0111	1001	1000	0000	0000	0110	0000	0001	1010
A3	0000	1101	0011	0010	0001	0111	0110	0110	0011	0000	0100	0110	0111	0000	0111	1101
A4	0001	0011	0011	0010	0111	0000	0010	0000	0000	0000	0001	0000	0000	0000	0110	1000
B1	0000	0111	1100	0010	1100	0111	0100	0011	1111	0000	0001	1001	0001	0000	0010	0111
B2	0000	1010	1101	0100	0011	0011	0100	0011	0100	0100	0011	1010	1001	0000	0111	1001
B3	0000	1101	0111	0101	0000	1101	1001	1111	0100	0010	0011	1010	1000	0100	0000	1101
B4	0001	0011	1100	1101	0010	1101	1110	0100	1100	0110	0001	0110	0001	0100	0011	1110
B5	0001	0100	1100	0001	0011	0001	0000	0111	1011	0010	0000	0001	1001	1110	0000	0001
B6	0001	1001	0100	1001	0000	0100	1110	0111	1011	0001	0010	0000	0001	0100	0011	0000
B7	0001	1110	0100	1111	0110	0001	0101	0001	1110	0010	1110	1101	1100	0111	0110	1001
B8	0010	0010	1011	1100	1000	1111	0100	1110	0011	0110	0001	1111	1100	0010	0000	0011
B9	0010	0101	0110	1100	0000	0100	1101	1111	0110	0000	0001	1111	0000	0000	0101	0110
B10	0010	1000	1010	1010	1110	0001	1001	0111	0000	0001	1011	1100	1110	0101	1110	0100
B11	0010	1111	0100	1000	0000	0000	0000	0000	0000	1100	0000	0000	0000	0000	0110	0100
B36	1001	0001	0011	0100	0011	1011	1001	1111	0011	0001	0011	1010	1011	0000	0010	0101
B37	1001	0110	0011	1100	0011	0011	0101	0101	0010	0000	1001	1001	0011	1100	0100	0000
B38	1001	1011	1000	0000	0000	0000	0000	0000	1100	0000	0000	0000	0000	0000	0001	1101
B39	1001	1100	1000	1001	0010	1011	0010	0001	1000	1011	1111	0010	0000	0000	1010	1001
B40	1010	0000	0111	0011	0110	0110	0110	1000	0101	0110	0101	0010	0010	1010	0110	1001
B41	1010	0111	1100	0000	0000	0110	1101	1001	0111	0000	0000	0000	0000	0000	0001	1111
B44	1011	0011	1110	1010	0101	1000	0100	1010	0000	1110	1110	1000	1000	0000	0001	1011
B45	1011	0100	1111	1001	0000	0000	0000	1101	0010	0100	0000	0000	0010	1111	0000	0011
BDW6	0011	0011	1000	1000	0011											

Note.— Preamble bits I_1 to I_{12} are not shown.

Table G-10. Error allocations for MLS azimuth critical and sensitive area development

(distances are in metres (feet); error values are in degrees)

	Azimuth to threshold distance metres (feet)							
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 360 (11 000)	3 660 (12 000)	3 960 (13 000)
Antenna beamwidth	2°	2°	2°	2°	2°	1°	1°	1°
a) System budget for PFN = 3.5 m (11.5 ft)	0.1098	0.0941	0.0824	0.0732	0.0659	0.0599	0.0549	0.0507
b) Ground equipment error allowance	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120
c) Ground reflection allowance	0.0400	0.0400	0.0400	0.0400	0.0400	0.0200	0.0200	0.0200
d) Clean site error allocation $\left[d = \sqrt{a^2 - b^2 - c^2}\right]$	0.1016	0.0844	0.0710	0.0601	0.0510	0.0552	0.0497	0.0450
e) ALS/monitor pole allowance	0.0300	0.0300	0.0300	0.0300	0.0300	0.0150	0.0150	0.0150
f) Complex site error allocation $\left[f = \sqrt{d^2 - e^2}\right]$	0.0970	0.0788	0.0643	0.0521	0.0412	0.0531	0.0474	0.0424
g) 70 per cent complex site error allocation	0.0679	0.0552	0.0450	0.0365	0.0288	0.0372	0.0332	0.0297
a) System budget for CMN = 3.2 m (10.5 ft)	0.1003	0.0859	0.0752	0.0668	0.0602	0.0547	0.0501	0.0463
b) Ground equipment error allowance	0.0315	0.0270	0.0236	0.0210	0.0189	0.0172	0.0158	0.0145
c) Airborne equipment error allowance	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
d) Allowance for structure vibration	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320
e) Clean/complex site error allocation $\left[e = \sqrt{a^2 - b^2 - c^2 - d^2}\right]$	0.0884	0.0735	0.0620	0.0527	0.0449	0.0380	0.0319	0.0261
f) 70 per cent complex site error allocation	0.0619	0.0515	0.0434	0.0369	0.0314	0.0266	0.0223	0.0183

Table G-11. Error allocations for MLS elevation critical area development
(all allocation values are in degrees)

Antenna beamwidth		1.5°	1.0°
a)	System budget for PFN = 0.4 m (1.3 ft)	0.083	0.083
b)	Ground equipment error allowance	0.010	0.010
c)	Sidelobe reflections allowance	0.055	0.037
d)	Clean site error allocation $\left[d = \sqrt{a^2 - b^2 - c^2}\right]$	0.061	0.073
e)	Vertical diffractions (field monitors)	0.030	0.030
f)	Lateral reflections allowance	0.031	0.043
g)	Complex site error allocation $\left[g = \sqrt{d^2 - e^2 - f^2}\right]$	0.043	0.051
h)	70% complex site error allocation	0.030	0.036
a)	System budget for CMN = 0.3 m (1.0 ft)	0.064	0.064
b)	Ground equipment error allowance	0.032	0.032
c)	Airborne equipment error allowance	0.010	0.010
d)	Sidelobe reflections allowance	0.015	0.010
e)	Allowance for structure vibration	0.010	0.010
f)	Clean/complex site error allocation $\left[f = \sqrt{a^2 - b^2 - c^2 - d^2 - e^2}\right]$	0.052	0.053
g)	70% complex site error allocation	0.036	0.037

Table G-12A. Typical azimuth sensitive area lengths
(aligned approach along zero degree azimuth, see 4.3.7)
(distances are in metres (feet); values in both units have been rounded)

Azimuth to threshold distance	2.0° beamwidth					1.0° beamwidth		
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 350 (11 000)	3 660 (12 000)	3 960 (13 000)
B-747, clean site	490 (1 600)	520 (1 700)	580 (1 900)	610 (2 000)	640 (2 100)	670 (2 200)	700 (2 300)	700 (2 300)
B-727, clean site	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	460 (1 500)	490 (1 600)
B-747, complex site	490 (1 600)	550 (1 800)	580 (1 900)	640 (2 100)	700 (2 300)	730 (2 400)	760 (2 500)	820 (2 700)
B-727, complex site	300 (1 000)	300 (1 000)	300 (1 000)	460 (1 500)	550 (1 800)	460 (1 500)	490 (1 600)	550 (1 800)

Table G-12B. Typical azimuth sensitive area lengths
(offset approach, see 4.3.7.1)
(distances are in metres (feet); values in both units have been rounded)

Azimuth to threshold distance	2.0° beamwidth					1.0° beamwidth		
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 350 (11 000)	3 660 (12 000)	3 960 (13 000)
B-747, clean site	640 (2 100)	730 (2 400)	790 (2 600)	880 (2 900)	880 (2 900)	920 (3 000)	940 (3 100)	1 010 (3 300)
B-727, clean site	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	490 (1 600)	550 (1 800)
B-747, complex site	670 (2 200)	760 (2 500)	820 (2 700)	880 (2 900)	1 010 (3 300)	980 (3 200)	1 070 (3 500)	1 130 (3 700)
B-727, complex site	300 (1 000)	300 (1 000)	330 (1 100)	460 (1 500)	550 (1 800)	490 (1 600)	520 (1 700)	550 (1 800)

Table G-12C. Typical azimuth sensitive area lengths (computed centre line approach, see 4.3.7.2, clean sites)

(distances are in metres (feet); values in both units have been rounded)

Azimuth to threshold distance	2.0° beamwidth					1.0° beamwidth		
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 350 (11 000)	3 660 (12 000)	3 960 (13 000)
B-727, clean site								
Height: 300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)
75 (250)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	490 (1 600)	550 (1 800)
60 (200)	300 (1 000)	300 (1 000)	300 (1 000)	460 (1 500)	490 (1 600)	610 (2 000)	610 (2 000)	670 (2 200)
45 (150)	300 (1 000)	300 (1 000)	490 (1 600)	550 (1 800)	610 (2 000)	670 (2 200)	760 (2 500)	820 (2 700)
30 (100)	300 (1 000)	520 (1 700)	610 (2 000)	700 (2 300)	820 (2 700)	920 (3 000)	980 (3 200)	1 100 (3 600)
15 (50)	610 (2 000)	730 (2 400)	880 (2 900)	1 010 (3 300)	1 070 (3 500)	1 100 (3 600)	1 040 (3 400)	1 190 (3 900)
B-747, clean site								
300 (1 000)	430 (1 400)	460 (1 500)	490 (1 600)	520 (1 700)	520 (1 700)	550 (1 800)	580 (1 900)	610 (2 000)
75 (250)	640 (2 100)	730 (2 400)	790 (2 600)	850 (2 800)	880 (2 900)	920 (3 000)	940 (3 100)	1 010 (3 300)
60 (200)	700 (2 300)	790 (2 600)	820 (2 700)	920 (3 000)	940 (3 100)	940 (3 100)	1 010 (3 300)	1 010 (3 300)
45 (150)	760 (2 500)	820 (2 700)	920 (3 000)	1 010 (3 300)	1 070 (3 500)	1 070 (3 500)	1 190 (3 900)	1 400 (4 600)
30 (100)	850 (2 800)	960 (3 100)	1 100 (3 600)	1 250 (4 100)	1 400 (4 600)	1 550 (5 100)	1 710 (5 600)	1 890 (6 200)
15 (50)	1 070 (3 500)	1 340 (4 400)	1 580 (5 200)	1 830 (6 000)	1 980 (6 500)	2 040 (6 700)	2 070 (6 800)	2 070 (6 800)

Table G-12D. Typical azimuth sensitive area lengths (computed centre line approach, see 4.3.7.2, complex sites)

(distances are in metres (feet); values in both units have been rounded)

Azimuth to threshold distance	2.0° beamwidth					1.0° beamwidth		
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 350 (11 000)	3 660 (12 000)	3 960 (13 000)
B-727, complex site								
Height: 300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)	300 (1 000)
300 (1 000)	300 (1 000)	300 (1 000)	330 (1 100)	460 (1 500)	550 (1 800)	490 (1 600)	520 (1 700)	550 (1 800)
300 (1 000)	300 (1 000)	330 (1 100)	330 (1 100)	490 (1 600)	550 (1 800)	580 (1 900)	610 (2 000)	730 (2 400)
330 (1 100)	330 (1 100)	330 (1 100)	490 (1 600)	550 (1 800)	670 (2 200)	700 (2 300)	790 (2 600)	880 (2 900)
330 (1 100)	330 (1 100)	550 (1 800)	640 (2 100)	730 (2 400)	1 010 (3 300)	940 (3 100)	1 040 (3 400)	1 160 (3 800)
640 (2 100)	640 (2 100)	790 (2 600)	940 (3 100)	1 070 (3 500)	1 250 (4 100)	1 250 (4 100)	1 280 (4 200)	1 430 (4 700)
B-747, clean site								
300 (1 000)	430 (1 400)	460 (1 500)	490 (1 600)	520 (1 700)	670 (2 200)	550 (1 800)	580 (1 900)	610 (2 000)
75 (250)	670 (2 200)	760 (2 500)	820 (2 700)	880 (2 900)	1 010 (3 300)	980 (3 200)	1 070 (3 500)	1 130 (3 700)
60 (200)	730 (2 400)	820 (2 700)	920 (3 000)	1 010 (3 300)	1 130 (3 700)	1 040 (3 400)	1 070 (3 500)	1 220 (4 000)
45 (150)	820 (2 700)	880 (2 900)	980 (3 200)	1 100 (3 600)	1 220 (4 000)	1 100 (3 600)	1 190 (3 900)	1 430 (4 700)
30 (100)	920 (3 000)	1 010 (3 300)	1 130 (3 700)	1 280 (4 200)	1 430 (4 700)	1 580 (5 200)	1 770 (5 800)	1 950 (6 400)
15 (50)	1 100 (3 600)	1 370 (4 500)	1 620 (5 300)	1 830 (6 000)	2 130 (7 000)	2 230 (7 300)	2 350 (7 700)	2 380 (7 800)

Table G-12E. Typical azimuth sensitive area semi-width to protect roll-out guidance (see 4.3.7)

(distances are in metres (feet))

Azimuth to threshold distance	2.0°beamwidth					1.0°beamwidth		
	1 830 (6 000)	2 140 (7 000)	2 440 (8 000)	2 750 (9 000)	3 050 (10 000)	3 350 (11 000)	3 660 (12 000)	3 960 (13 000)
Clean/complex site	38 (123)	48 (157)	59 (193)	70 (230)	83 (271)	54 (177)	62 (202)	69 (227)

Table G-13. Minimum height surface angle and related protected coverage volume lengths for MLS/RNAV approach procedures

Protected coverage volume length L[m(ft)] PCH = 2.0 m	Minimum height surface angle (degrees), θ	
	B-727	B-747
300 (1 000)	1.81	3.49
450 (1 500)	1.23	2.36
600 (2 000)	0.95	1.79
750 (2 500)	0.77	1.44
900 (3 000)	N/A	1.21

The following equation can be used to determine the minimum height surface angle (Θ) in respect to an azimuth antenna phase centre for arbitrary protected coverage volume length "L".

$$\theta = \tan^{-1}\left[\frac{TFH + \frac{\sqrt{\lambda(L)}}{4} - PCH}{L}\right]$$

where:

TFH = tail fin height;
PCH = phase centre height of MLS antenna;
λ = MLS wave length.

Note.— TFH equals 10.4 m for B-727 and 19.3 m for B-747, and λ is 0.06 m. PCH and L must be in metres if TFH and λ are in metres.

Table G-14. Interrelationship of ground equipment monitor and control action

Sub-system failure	Resultant action						
	Approach azimuth	Approach elevation	Back azimuth	Basic data radiated into approach azimuth coverage	Basic data radiated into back azimuth coverage	Auxiliary data	DME/N or DME/P
Approach azimuth	*	*		+		+	
Approach elevation		*					
Back azimuth			*		+		
Basic data radiated into approach azimuth coverage	*	*		*		+	
Basic data radiated into back azimuth coverage			*		*		
Auxiliary data	+	+		+		*	
DME/N or DME/P							*

* Indicates radiation should cease.
\+ Indicates radiation may continue when operationally required.

Table G-15. Continuity of service and integrity objectives for MLS basic and MLS/RNAV operations

Level	Azimuth or elevation			DME/P (Note 6)		
	Integrity in any one landing	Continuity of service	MTBO (hours)	Integrity in any one landing (Note 4)	Continuity of service	MTBO (hours)
1	Not demonstrated, but designed to meet the Level 2 requirements (Note 3)					
2	$1 - 1 \times 10^{-7}$	$1 - 4 \times 10^{-6}$ (15 s)	1 000	$1 - 1 \times 10^{-7}$	$1 - 4 \times 10^{-6}$ (15 s)	1 000
3	$1 - 0.5 \times 10^{-9}$	$1 - 2 \times 10^{-6}$ (15 s)	2 000	$1 - 1 \times 10^{-7}$	$1 - 4 \times 10^{-6}$ (15 s)	1 000
4 (Note 5)	$1 - 0.5 \times 10^{-9}$	$1 - 2 \times 10^{-6}$ (30 s Az) (15 s El) (Note 6)	4 000 Az 2 000 El (Note 6)	$1 - 1 \times 10^{-7}$	$1 - 4 \times 10^{-6}$ (15 s)	1 000

NOTES.—

1. Data word continuity of service and integrity are included in the specified values of the angle function for each level of service.
2. Back azimuth is not required for basic operations.
3. It is intended that all equipments meet at least Level 2 requirements.
4. If DME/N is used with MLS the figures may be reduced to $1 - 1 \times 10^{-5}$.
5. The Level 4 exposure times are based on experience with ILS and are consistent with existing operational capabilities. As experience is gained with MLS, and enhanced operational capabilities are proposed, it may be necessary to adjust these values.
6. MLS/RNAV procedures may require the Level 3 and 4 integrity, continuity of service and MTBO objectives of the elevation, DME/P and, if used, back azimuth to be equivalent to the approach azimuth equipment.

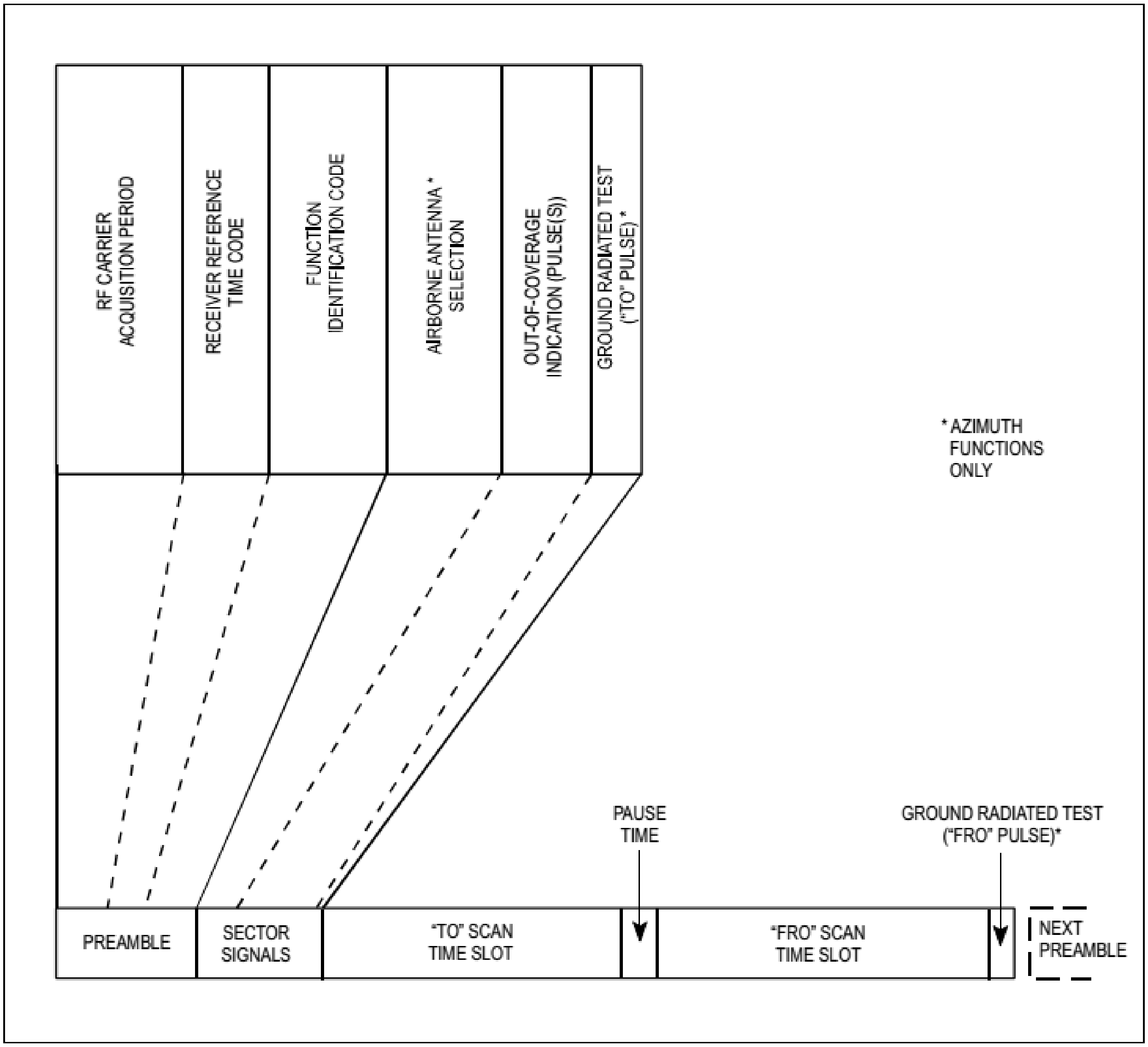


Figure G-1. Angle function organization

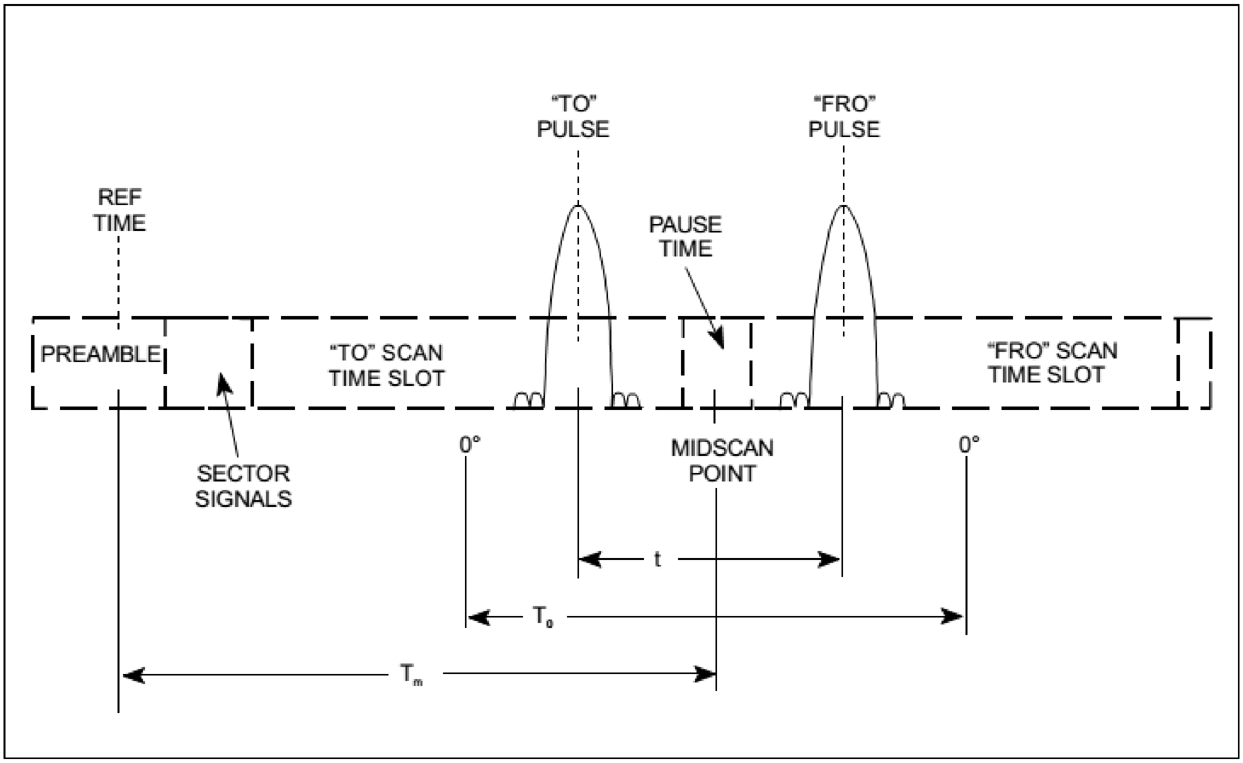
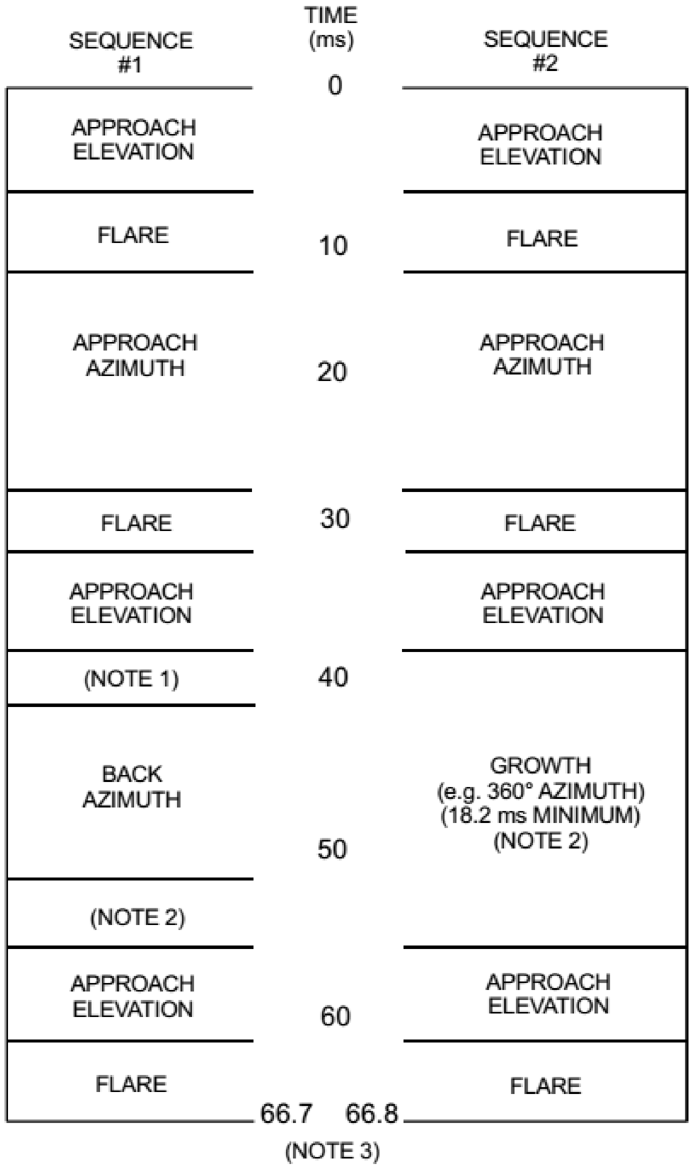


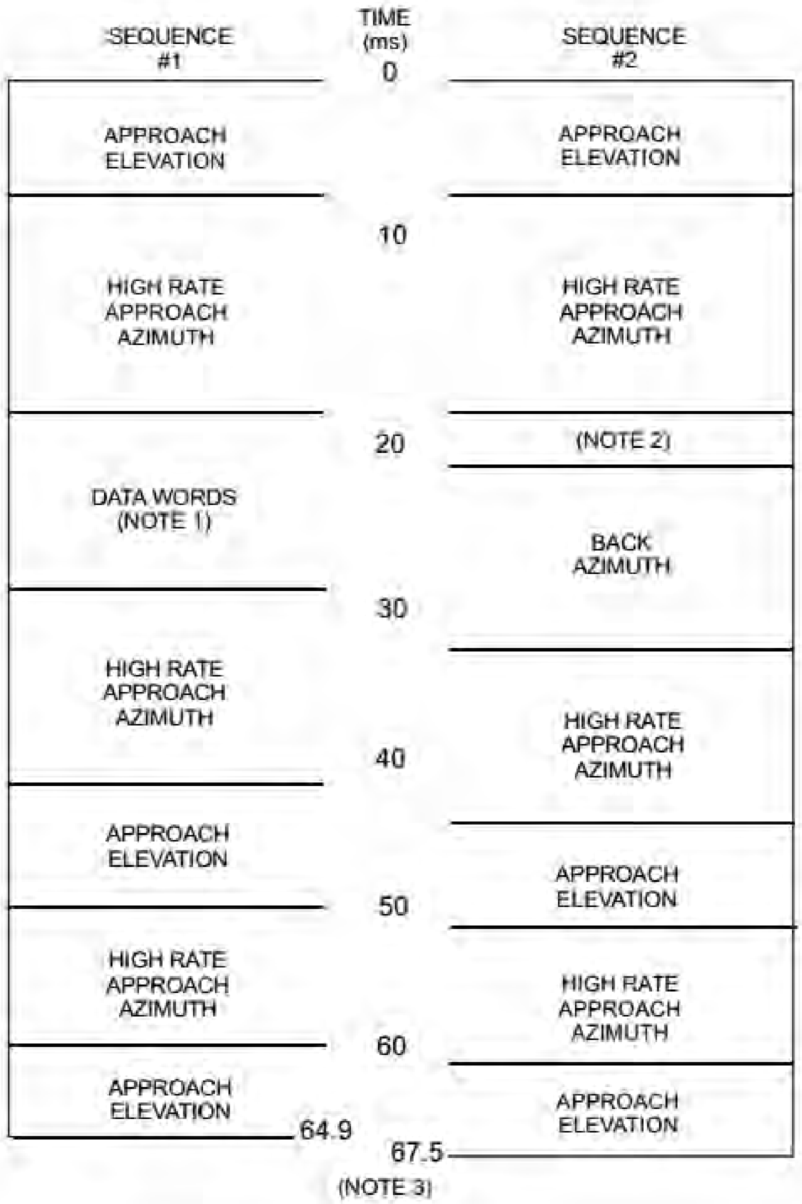
Figure G-2. Angle scan timing parameters



Notes:

1. When back azimuth is provided, basic data word 2 must be transmitted only in this position.
2. Data words may be transmitted in any open time periods.
3. The total time duration of sequence #1 plus sequence #2 must not exceed 134 ms.

Figure G-3A. Transmission sequence pair which provides for all MLS angle guidance functions



Notes:

1. Data words may be transmitted in any open time periods.
2. When back azimuth is provided, basic data word 2 must be transmitted only in this position.
3. The total time duration of sequence #1 plus sequence #2 must not exceed 134 ms.

Figure G-3B. Transmission sequence pair which provides for the MLS high rate approach azimuth angle guidance function

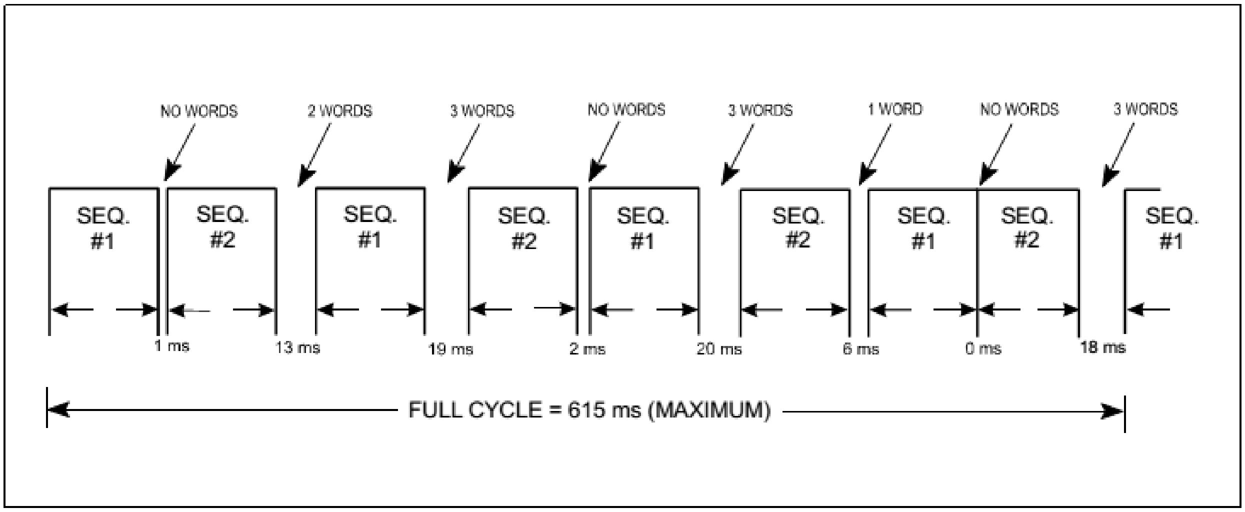


Figure G-3C. Complete multiplex transmission cycle showing open time periods available for data words

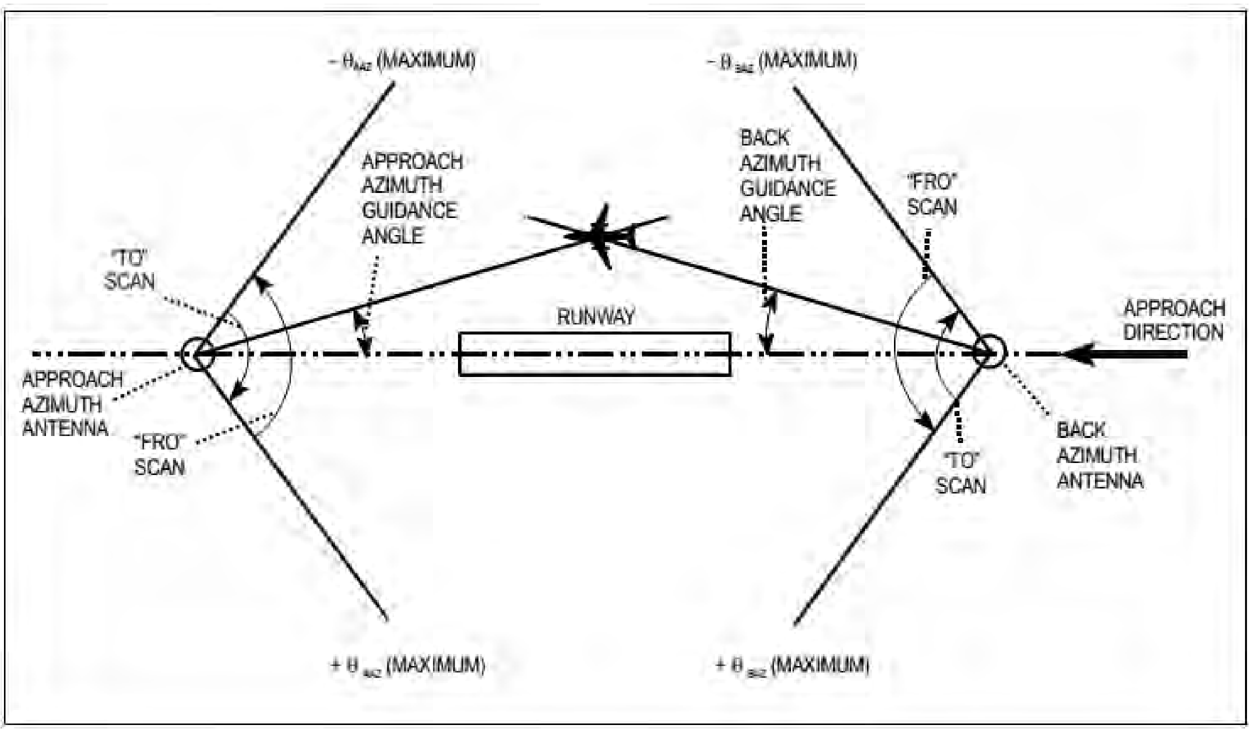


Figure G-4. Scanning conventions for azimuth guidance functions

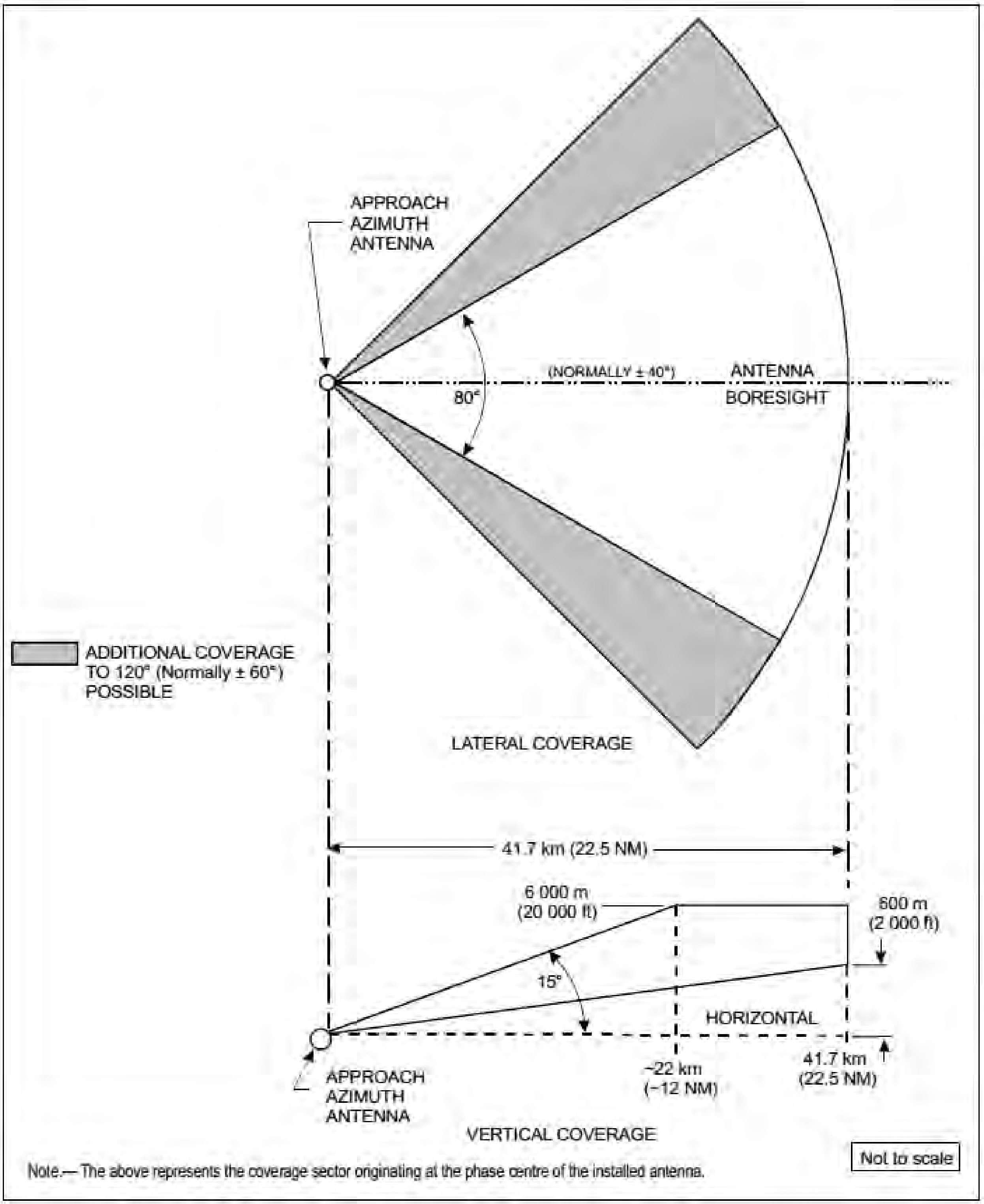


Figure G-5A. Approach azimuth region coverage

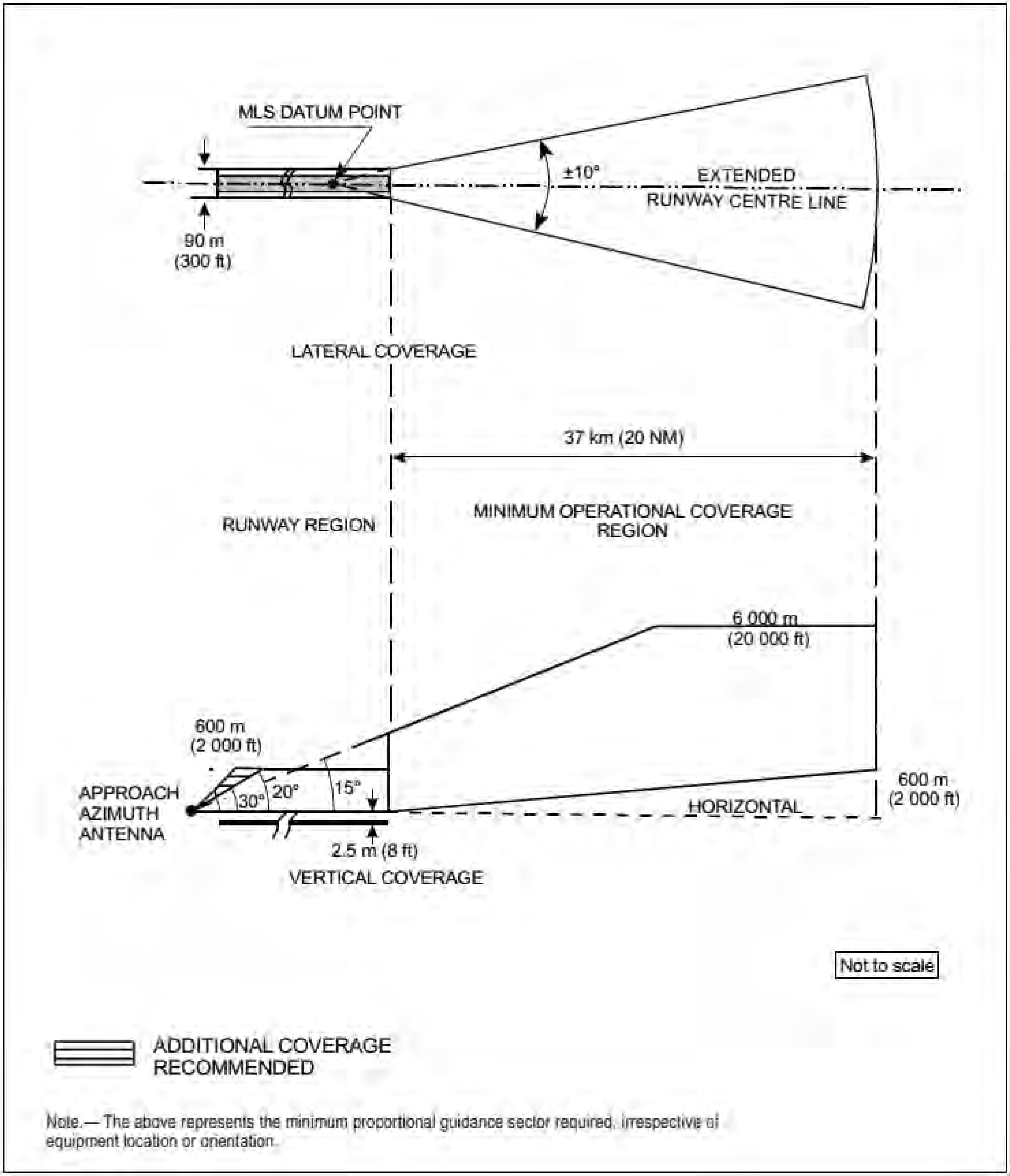


Figure G-5B. Azimuth runway region coverage and minimum operational coverage region

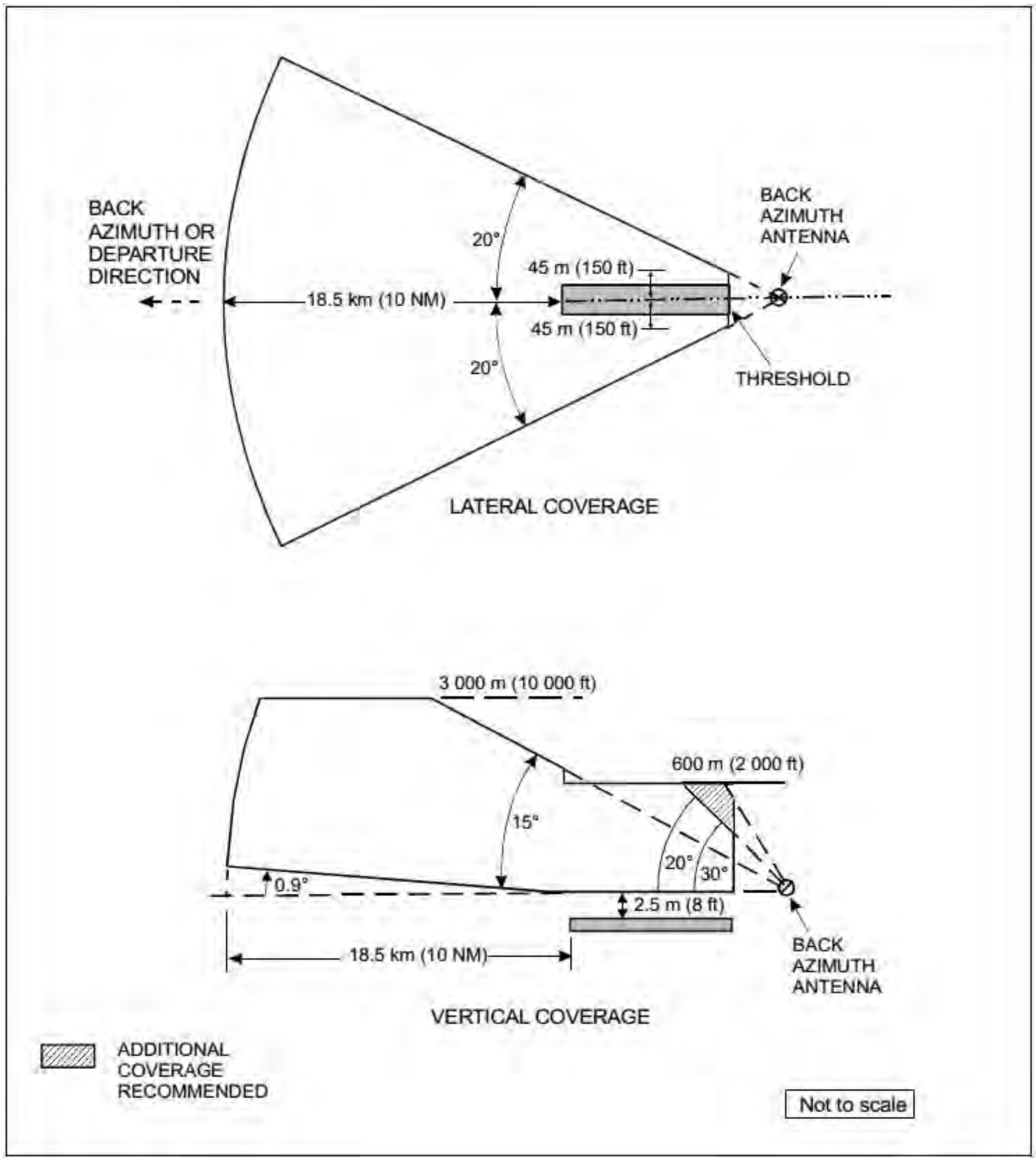


Figure G-6. Back azimuth region coverage

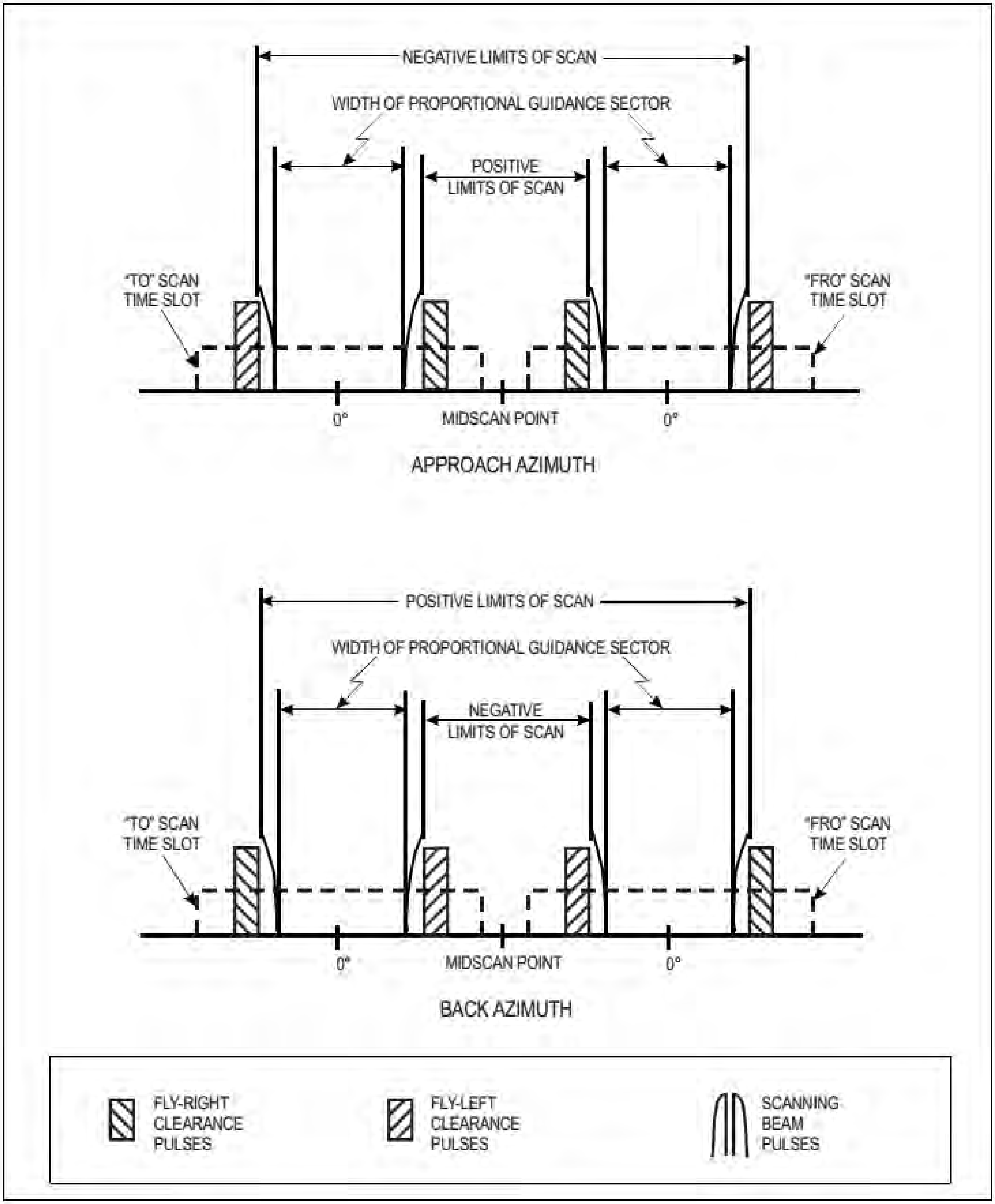


Figure G-7. Clearance pulse conventions for azimuth functions

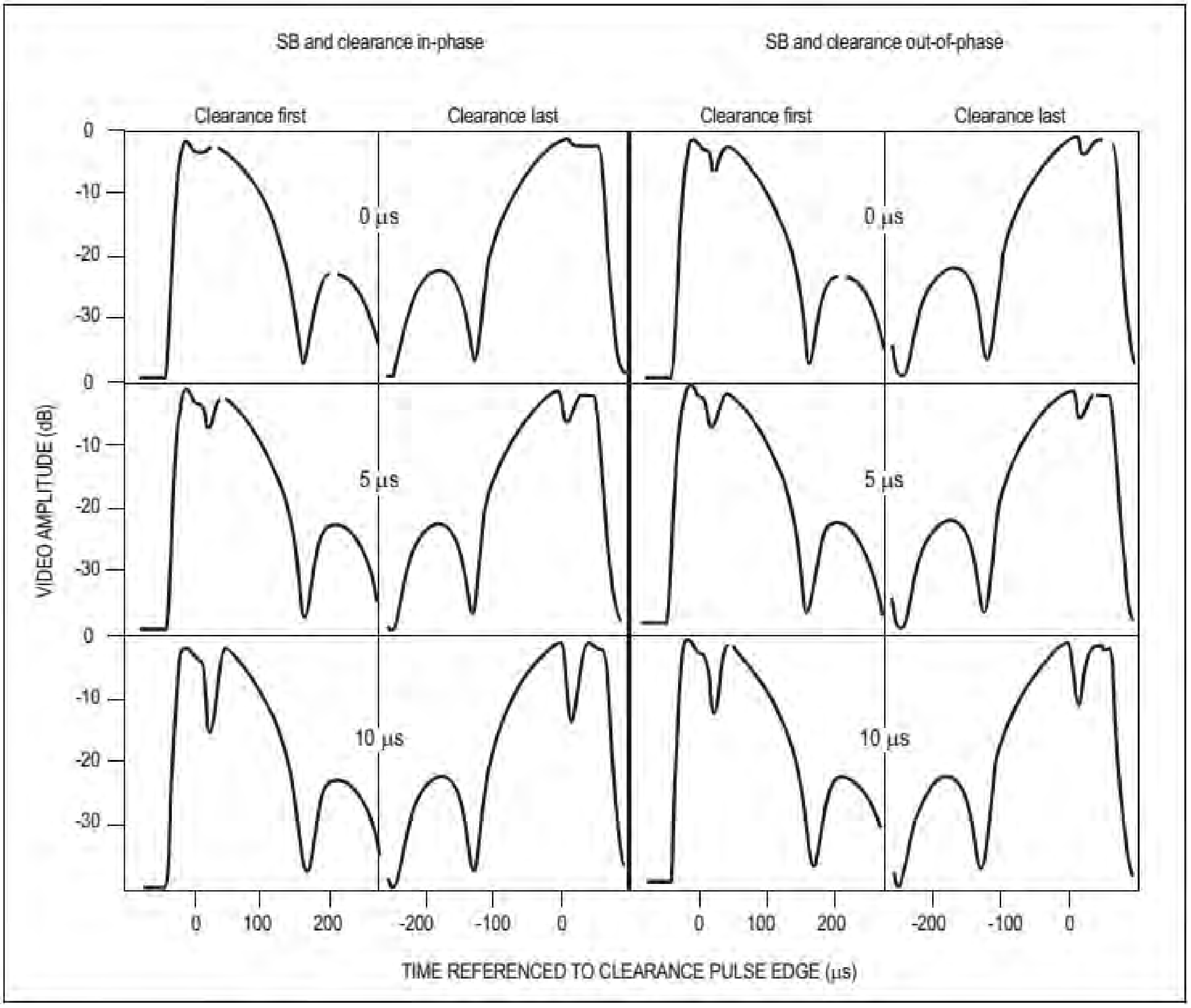


Figure G-8. Examples of received video waveforms in SB/clearance transition region for switching times of 0, 5 and 10 microseconds

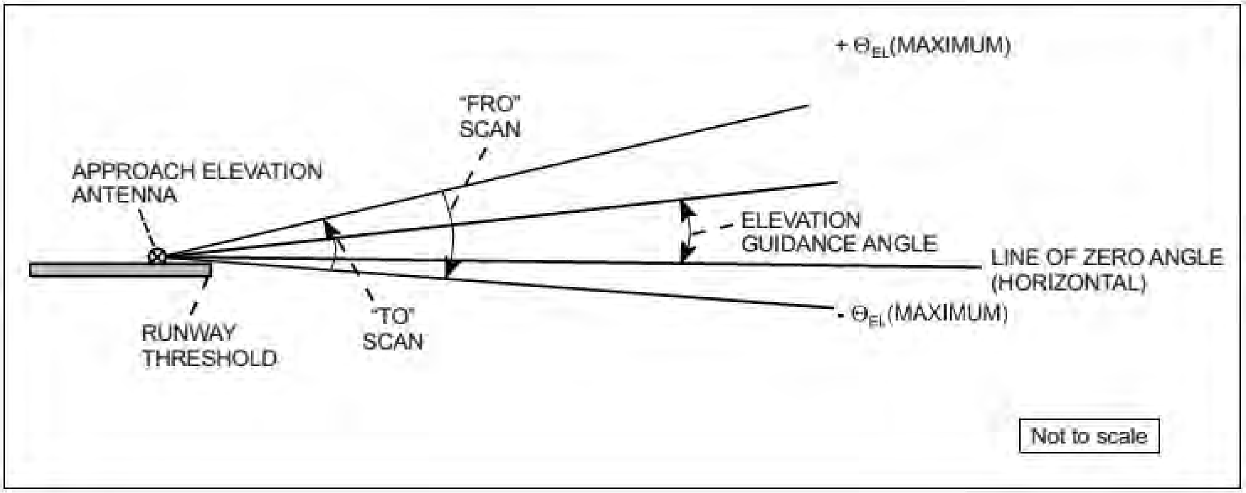


Figure G-9. Scanning conventions for approach elevation function

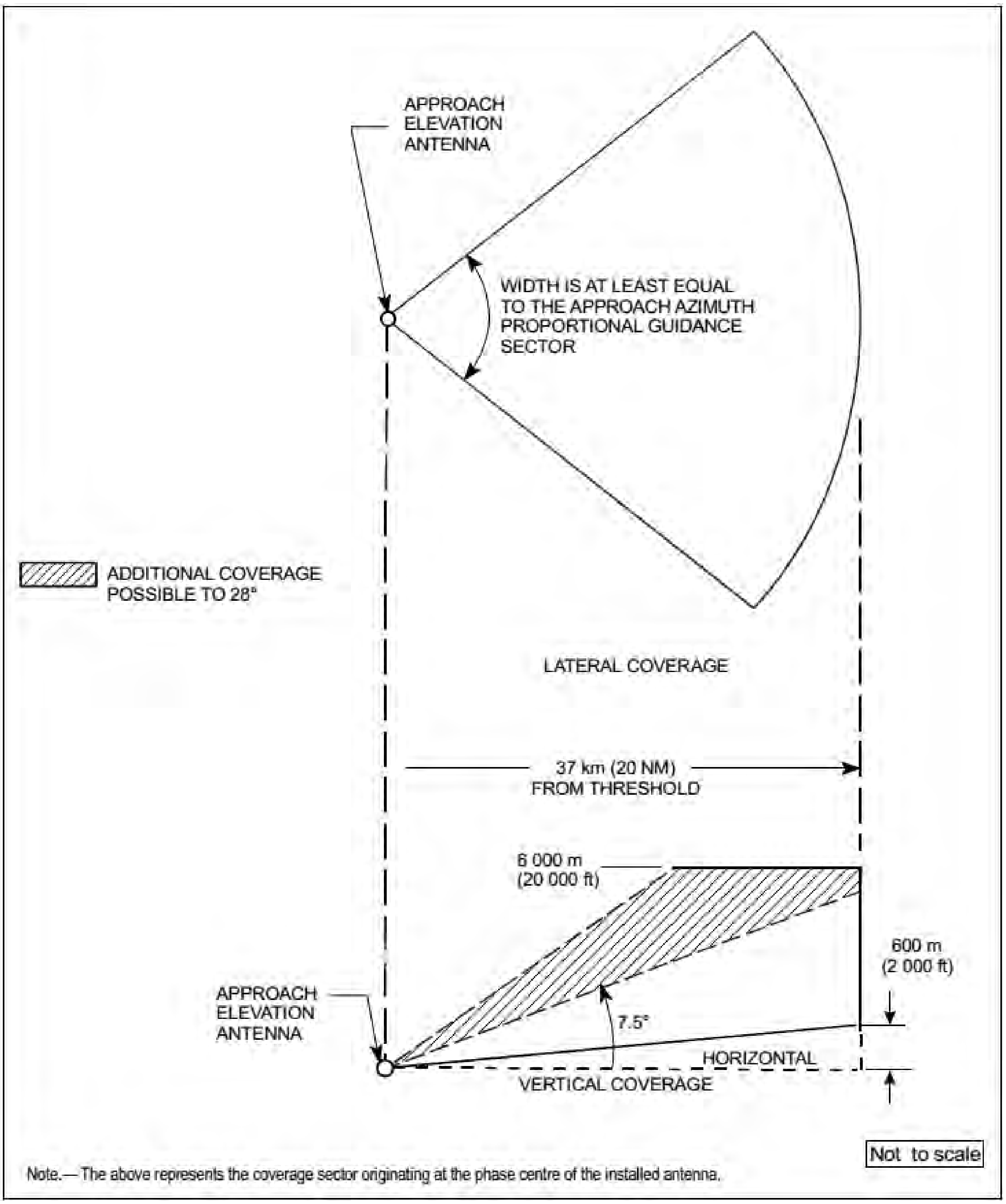


Figure G-10A. Elevation approach region coverage

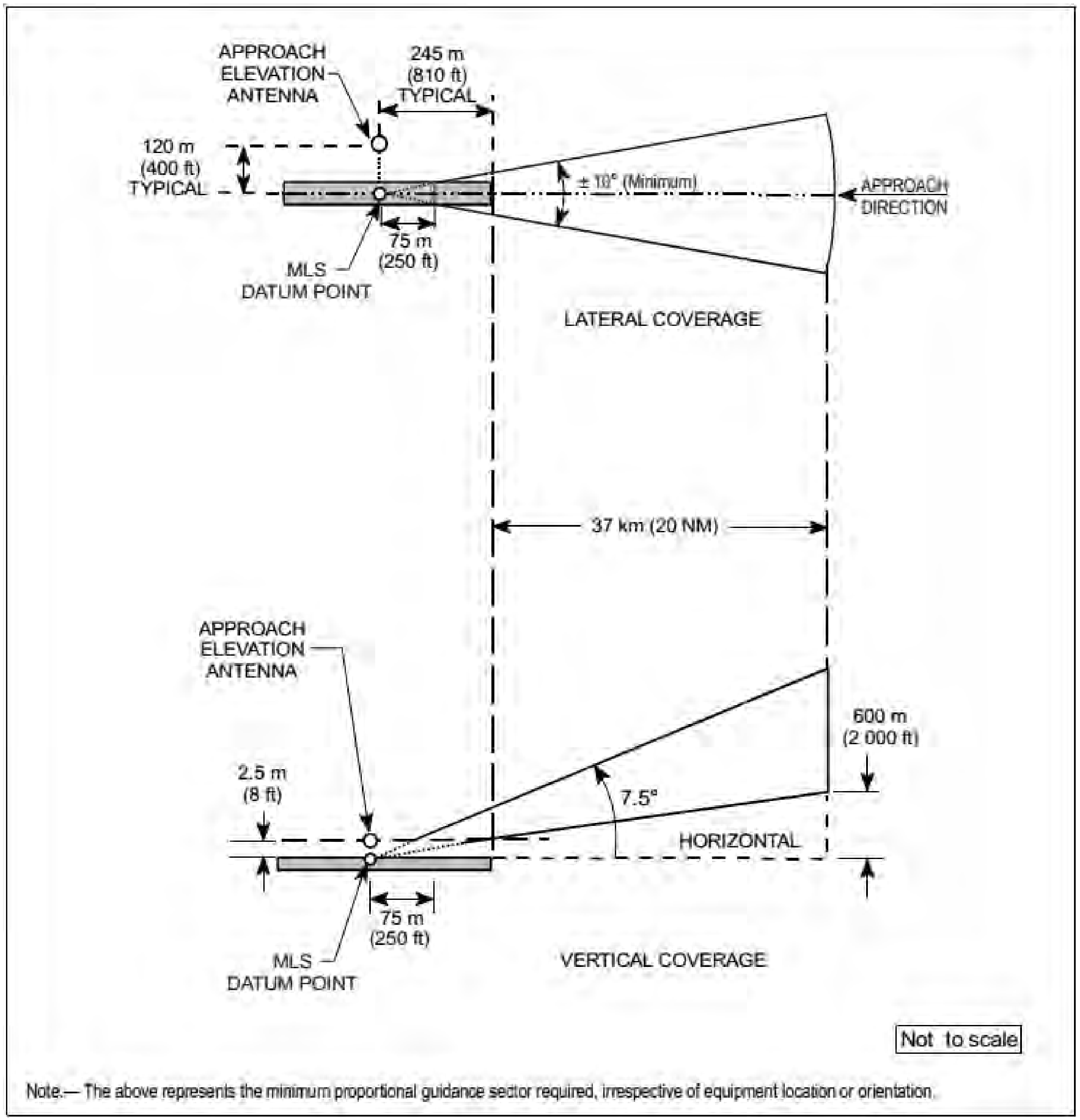
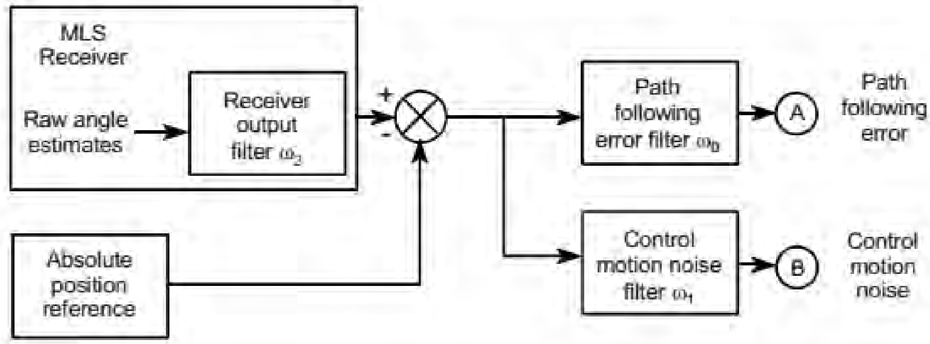


Figure G-10B. Elevation minimum operational coverage



Guidance function	Corner frequencies (Radians/sec)		
	ω_0	ω_1	ω_2
Approach azimuth	0.5	0.3	10
Approach elevation	1.5	0.5	10
DME//P	1.5	0.5	10

Receiver output filter $$\frac{\omega_2}{S + \omega_2}$$

Path following filter $$\frac{\omega_n^2}{S^2 + 2\zeta\omega_n S + \omega_n^2}$$ $\zeta = 1$, $\omega_0 = 0.64\ \omega_n$

Control motion noise filter $$\frac{S}{S + \omega_1}$$ $S = j\omega$

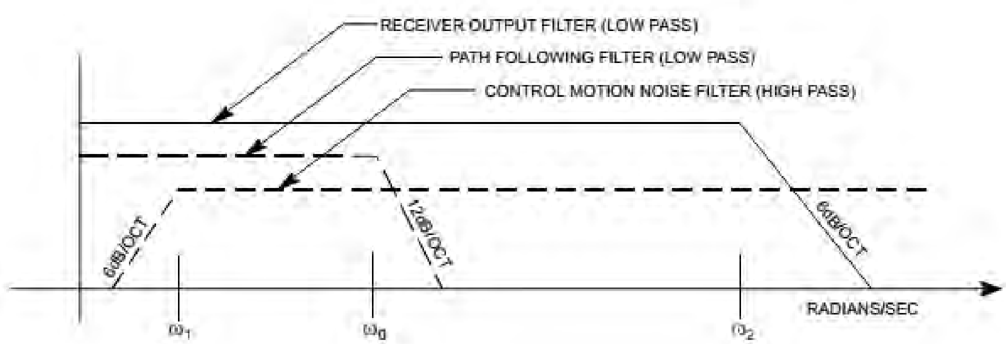


Figure G-11. Filter configurations and corner frequencies

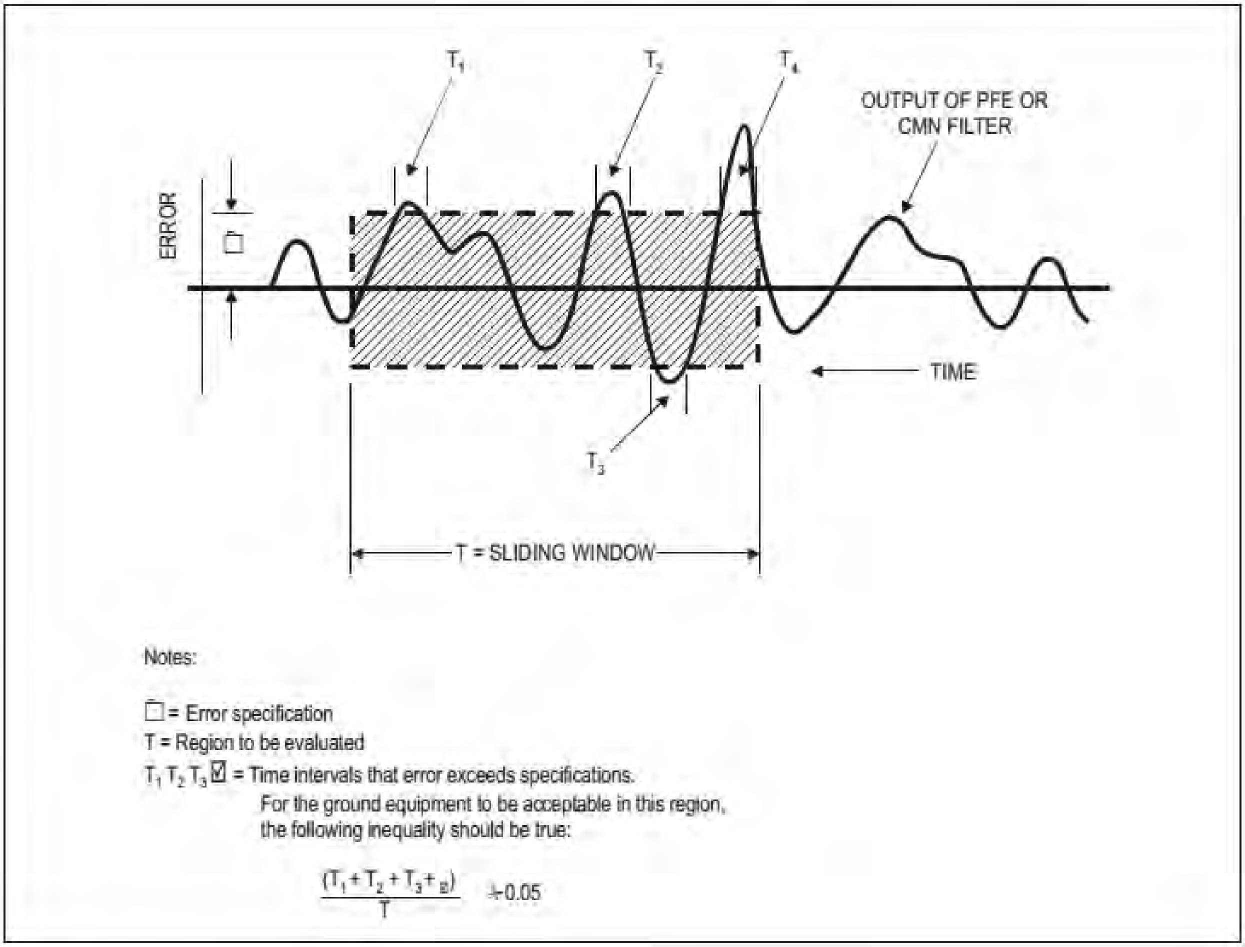


Figure G-12. MLS measurement methodology

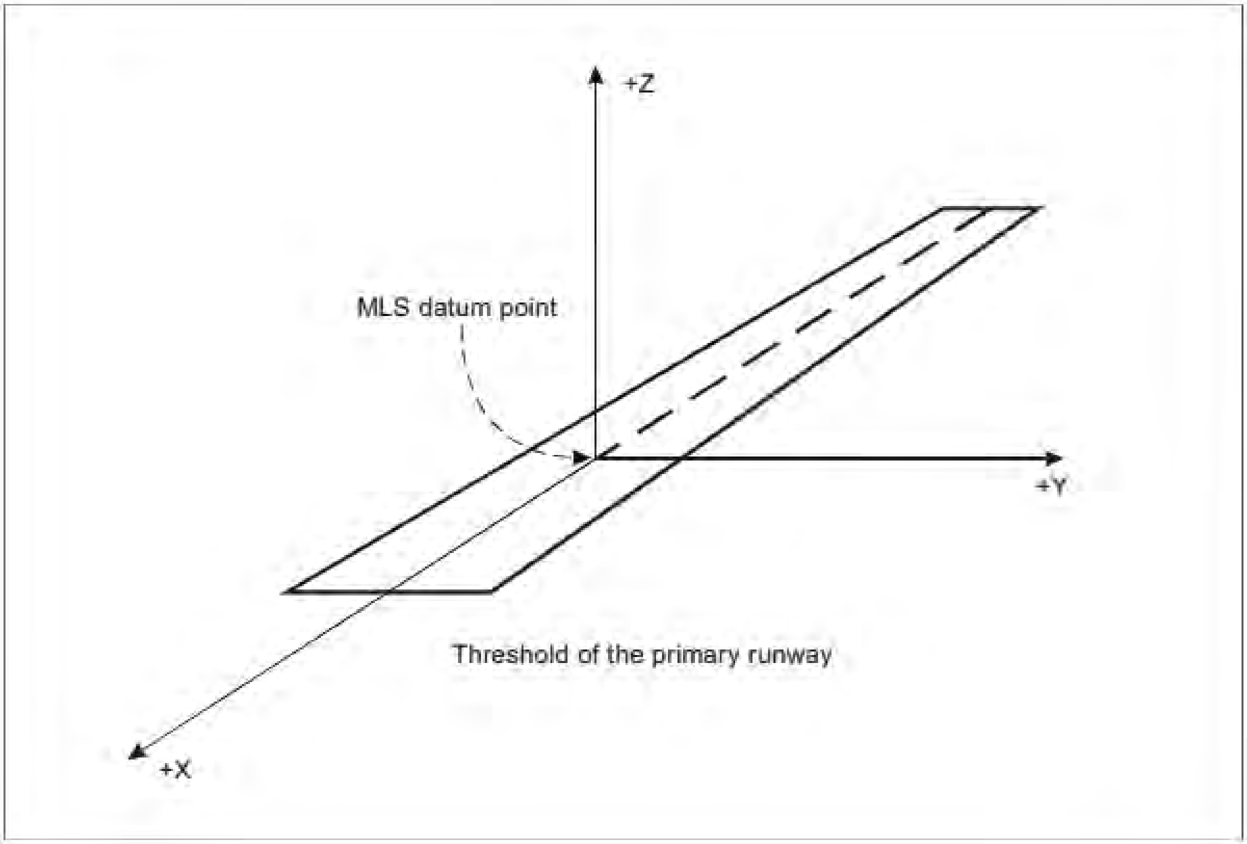


Figure G-13. MLS/RNAV way-point coordinate system

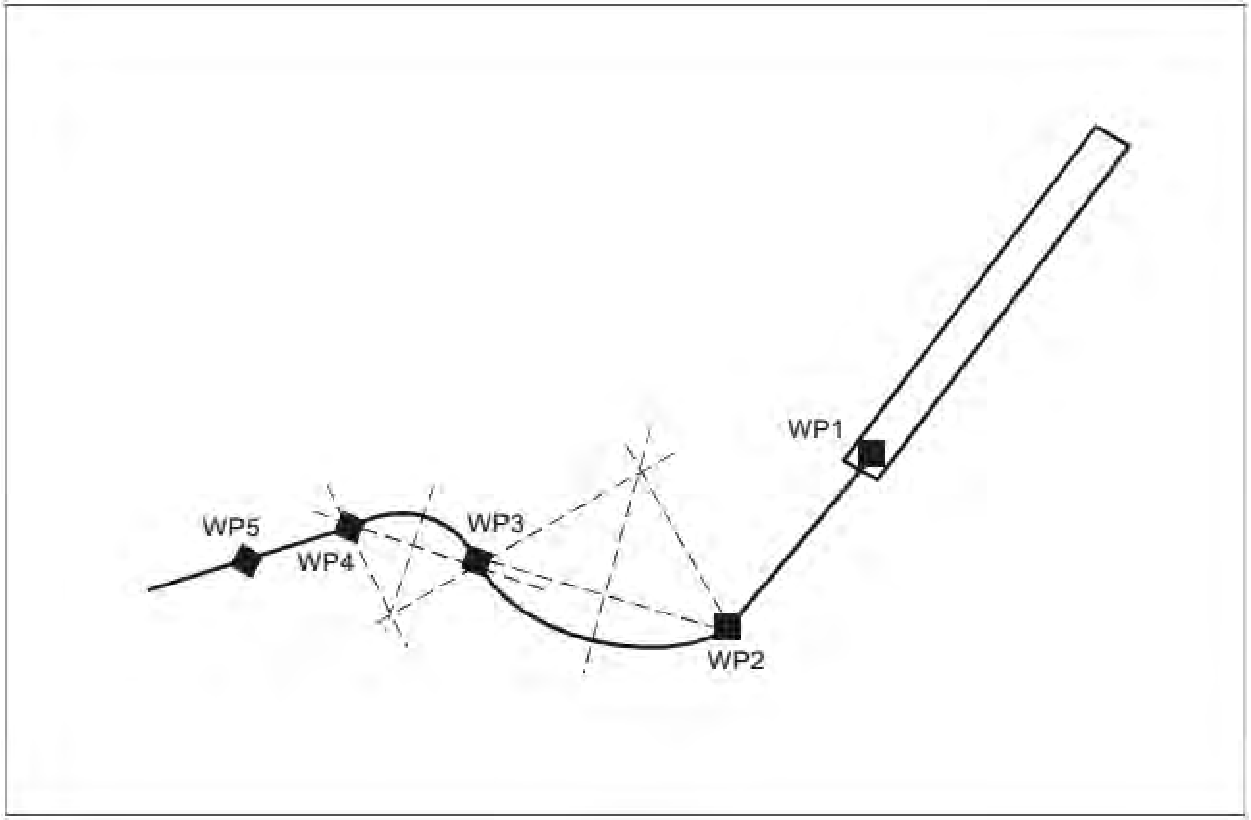


Figure G-14. Definition of curved segments

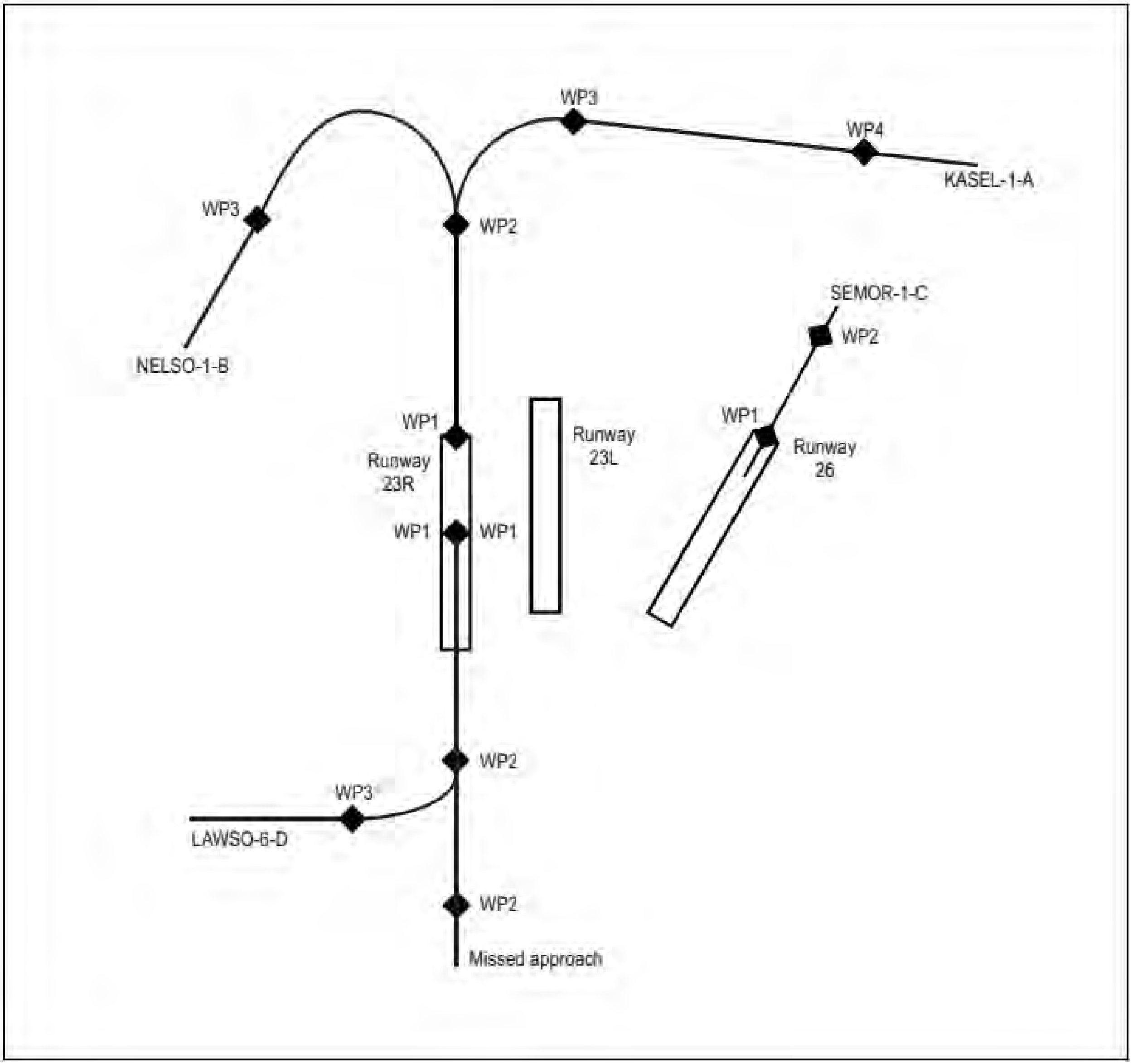


Figure G-15. Diagram of sample MLS/RNAV procedures

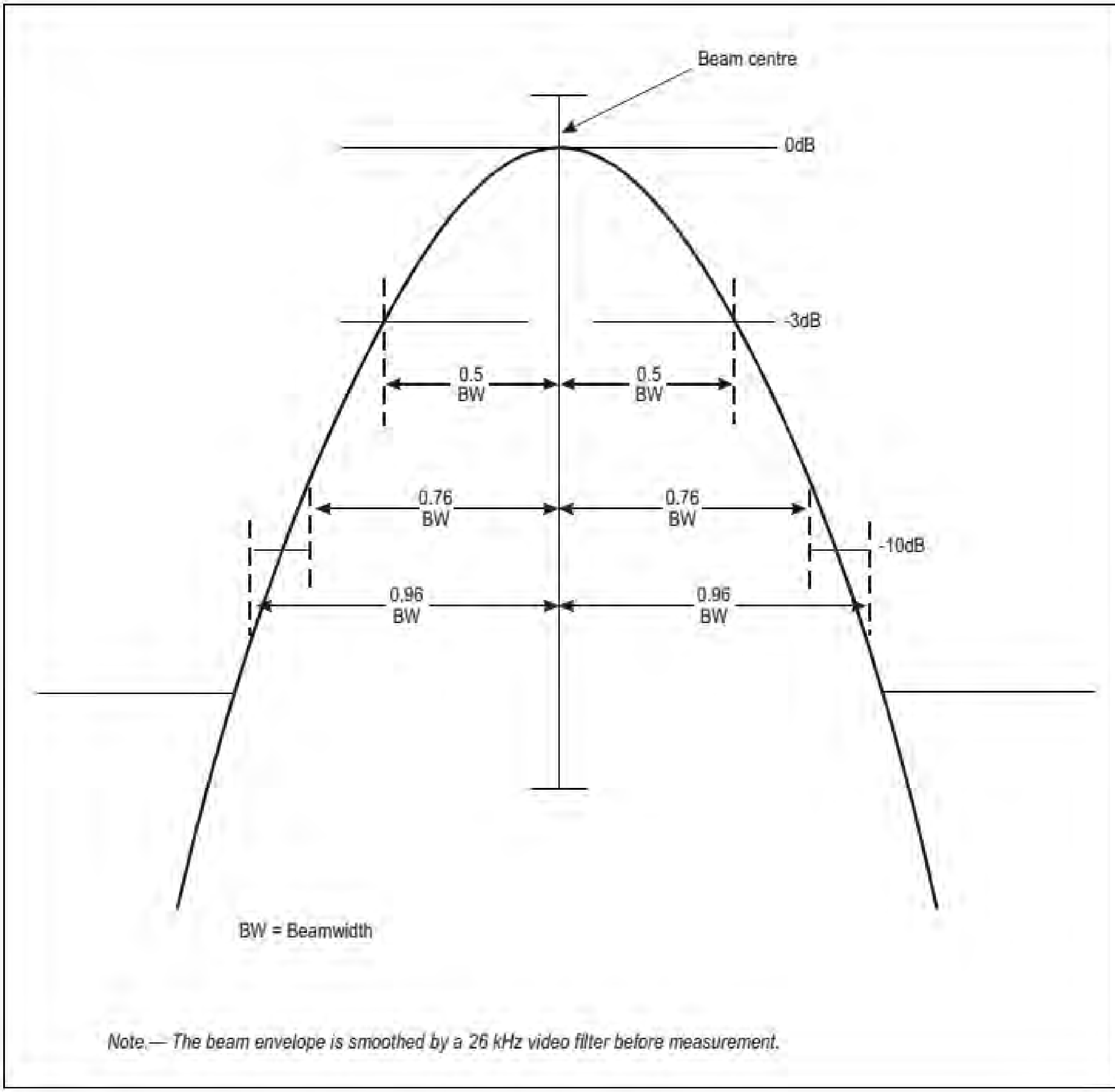


Figure G-16. Far field dynamic signal-in-space

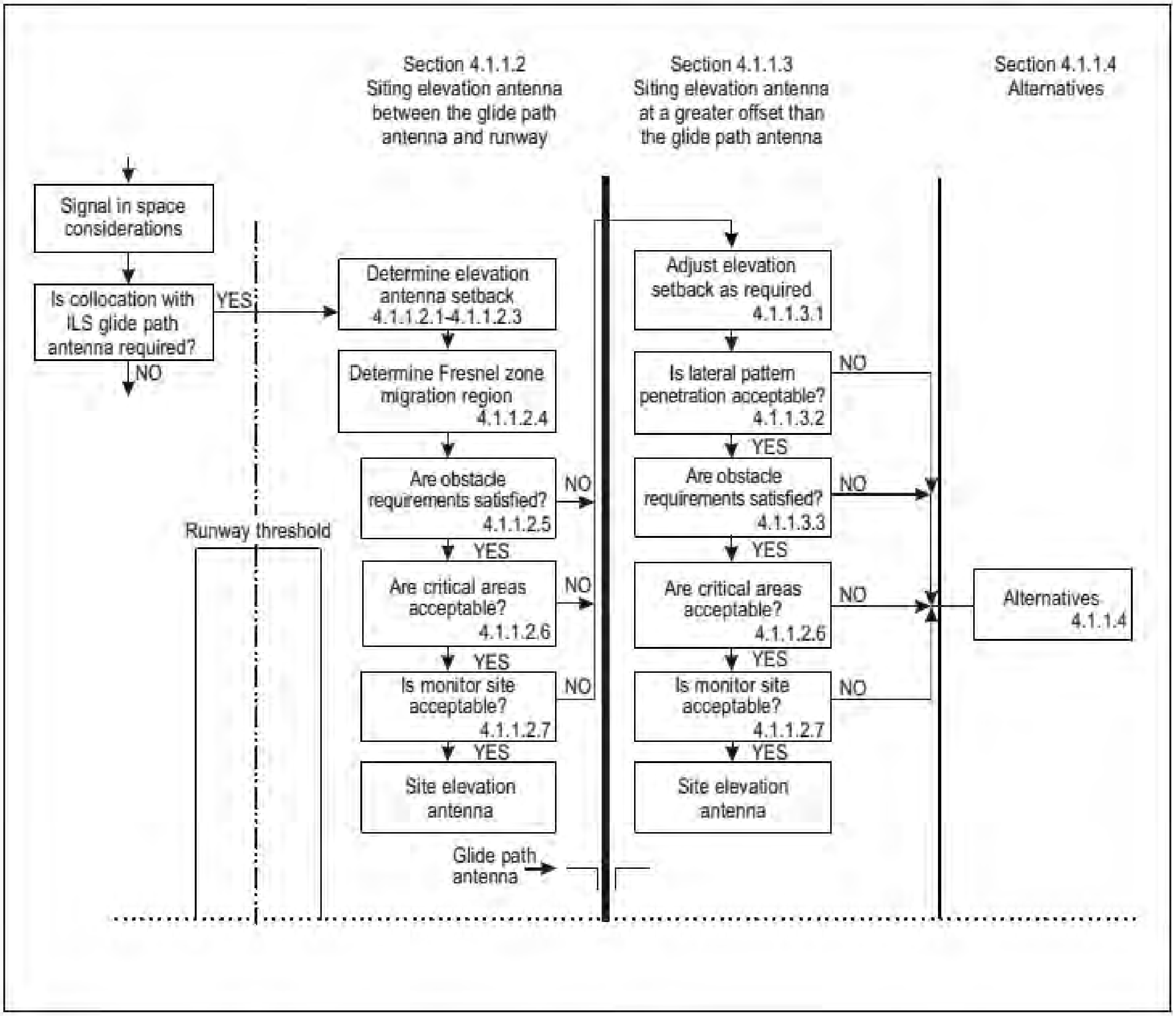


Figure G-17. Elevation/glide path logic flow diagram

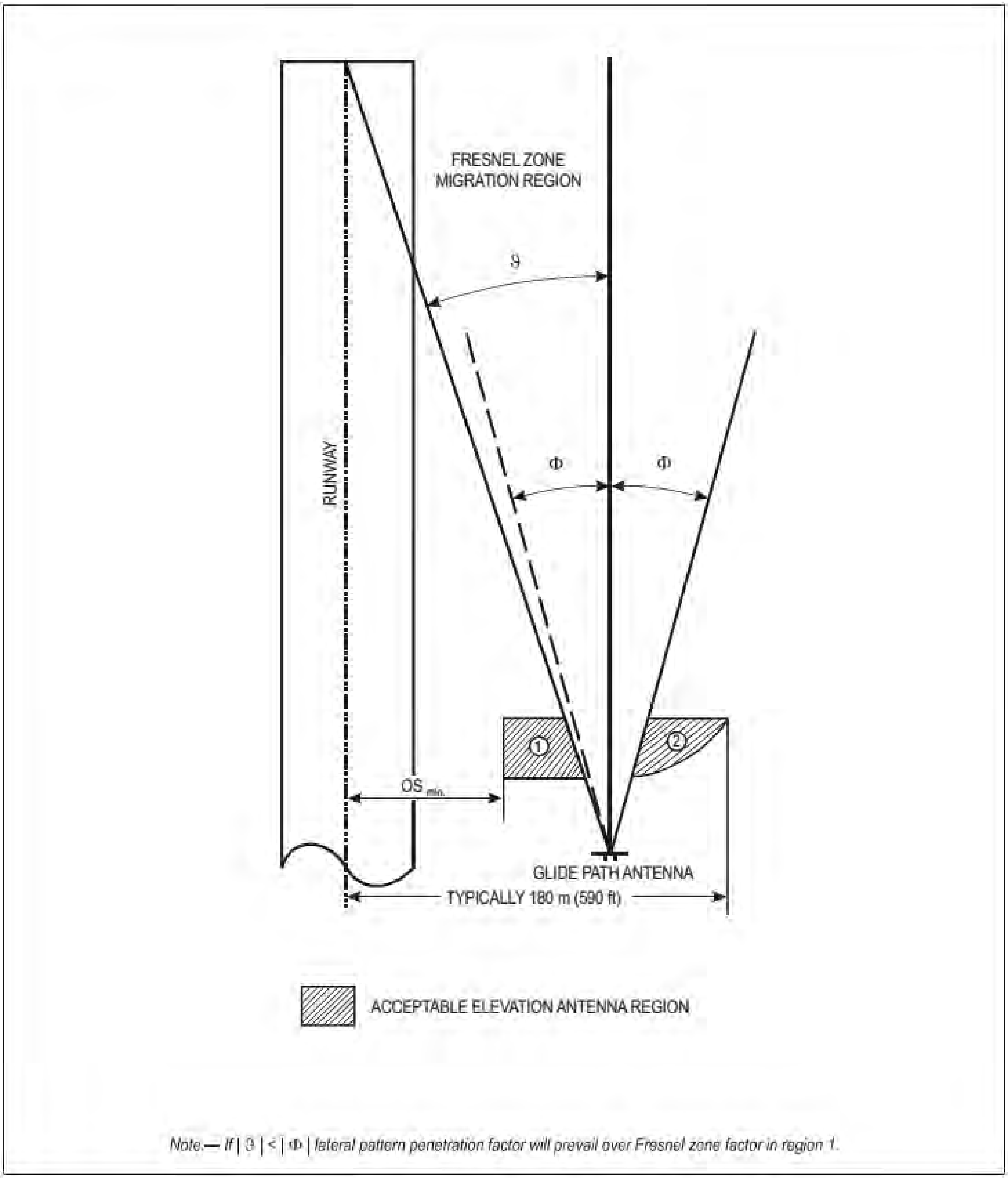


Figure G-18. Elevation antenna regions for collocation with ILS (3° minimum glide path)

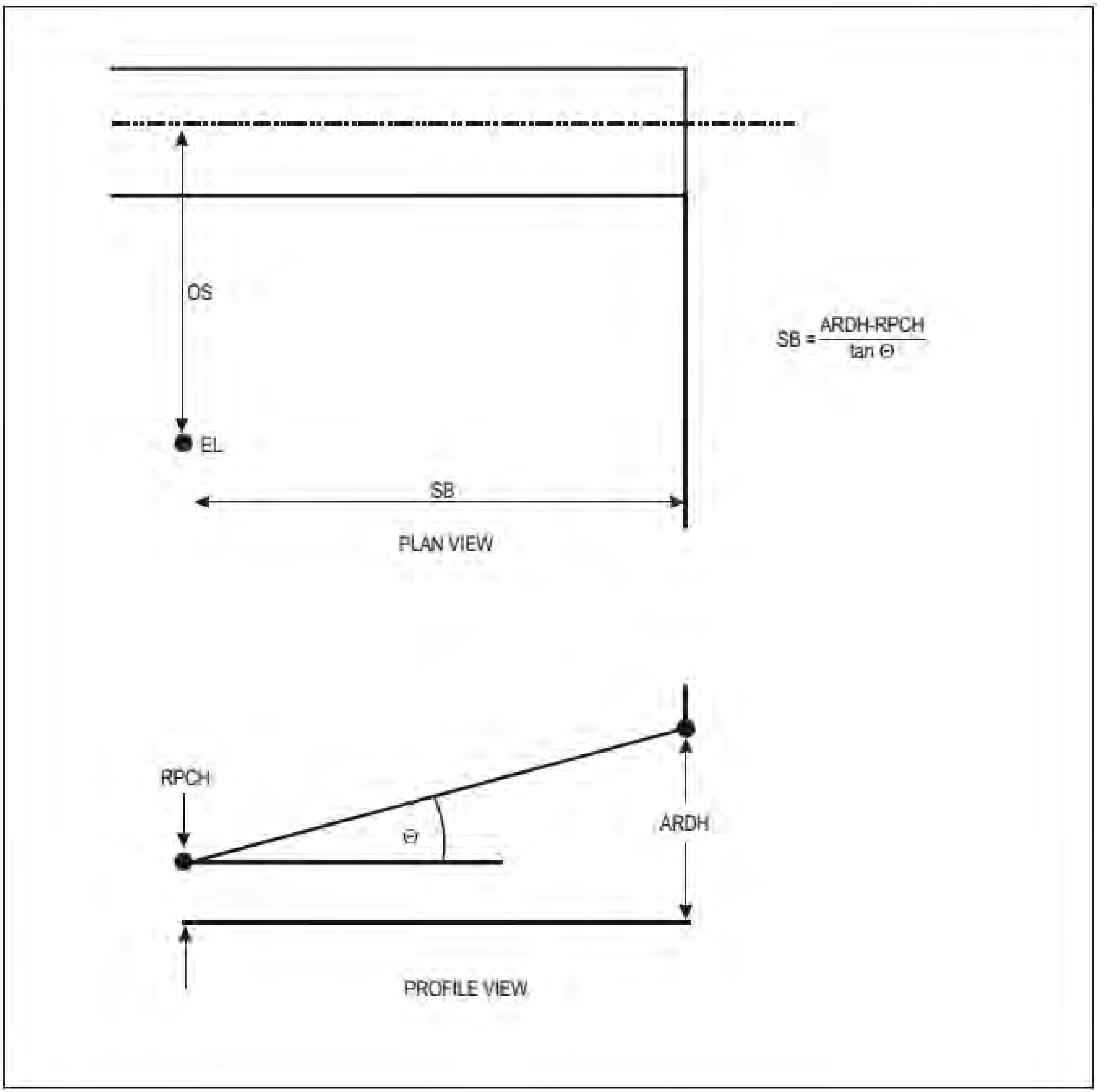


Figure G-19. Elevation siting parameters

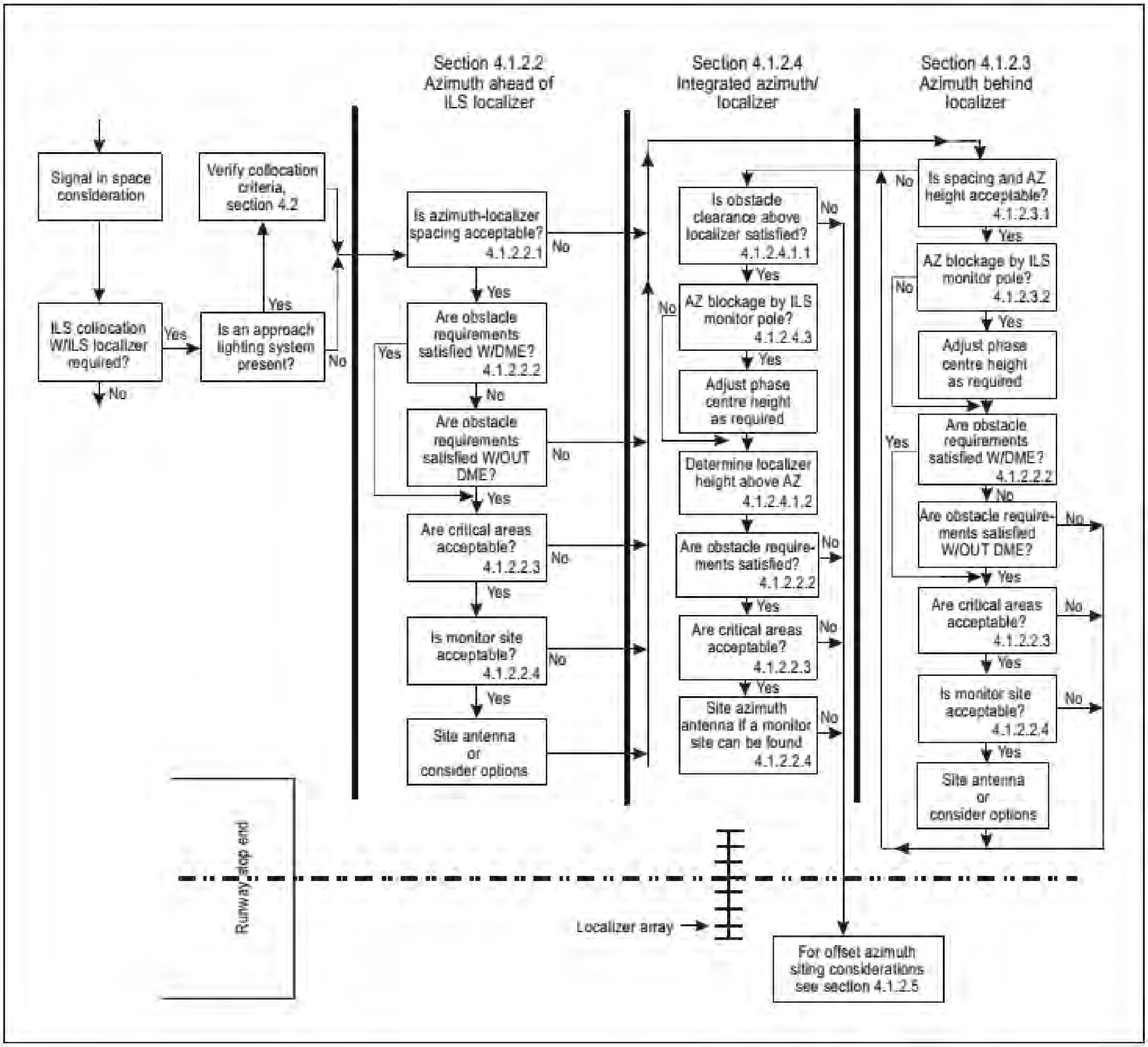


Figure G-20. Azimuth/localizer logic flow diagram

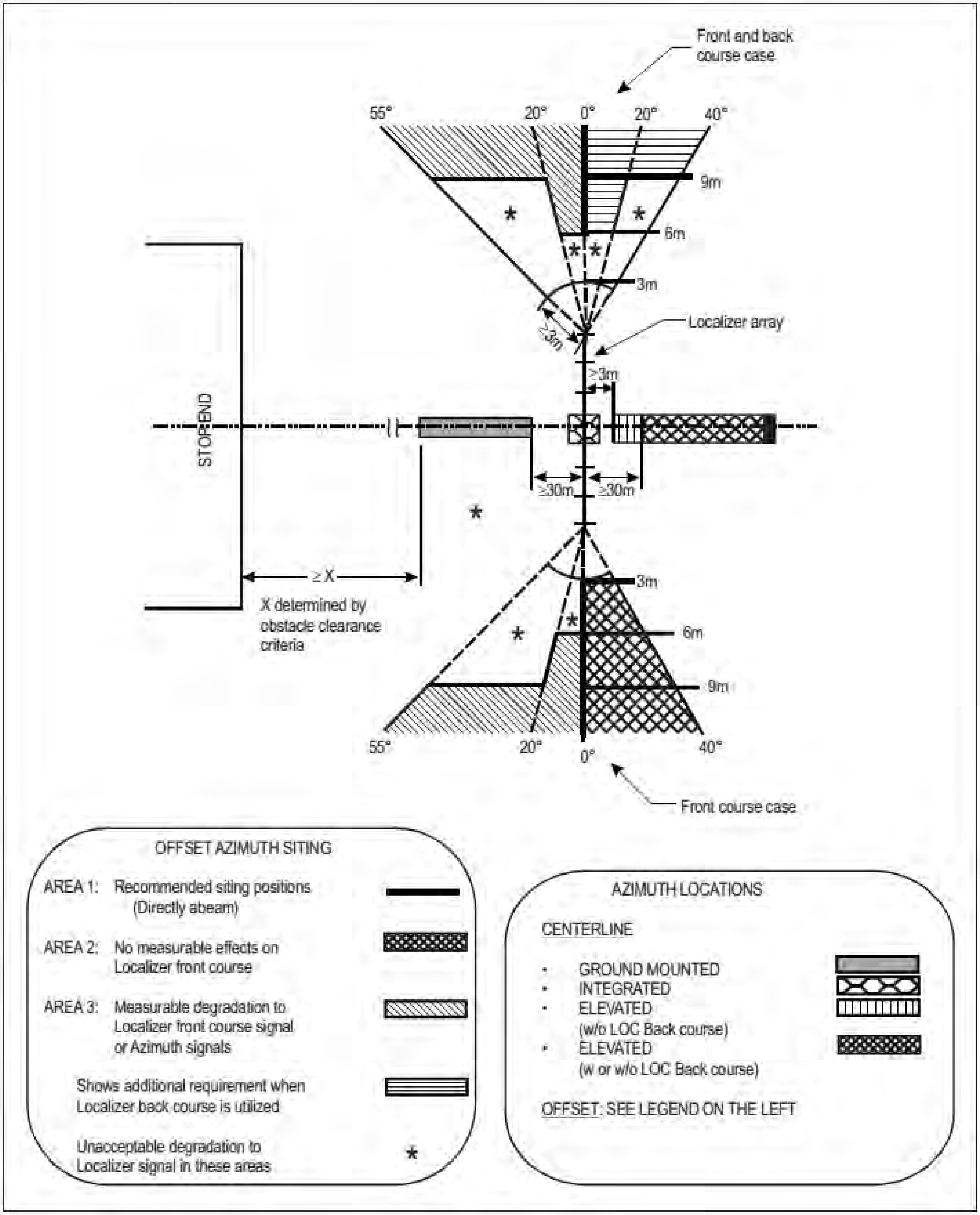


Figure G-21. Azimuth antenna regions for collocation with ILS

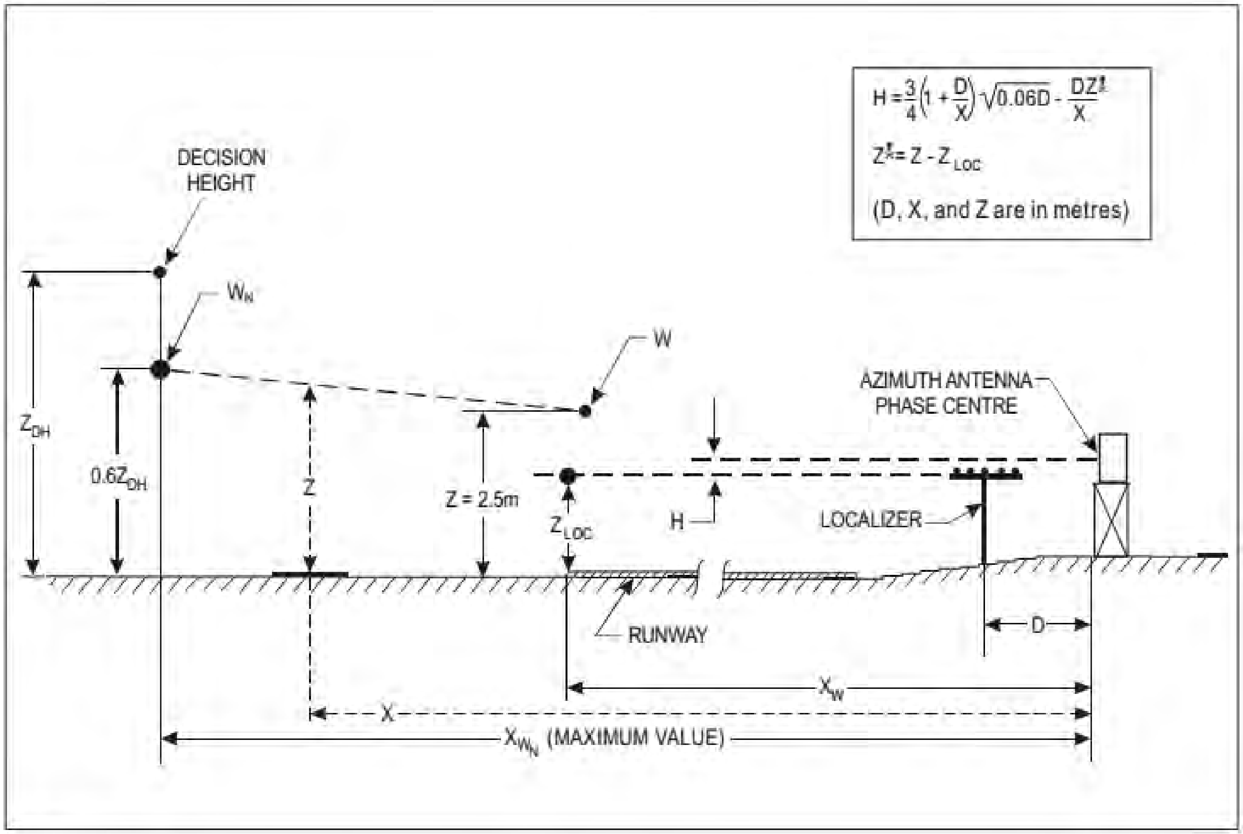
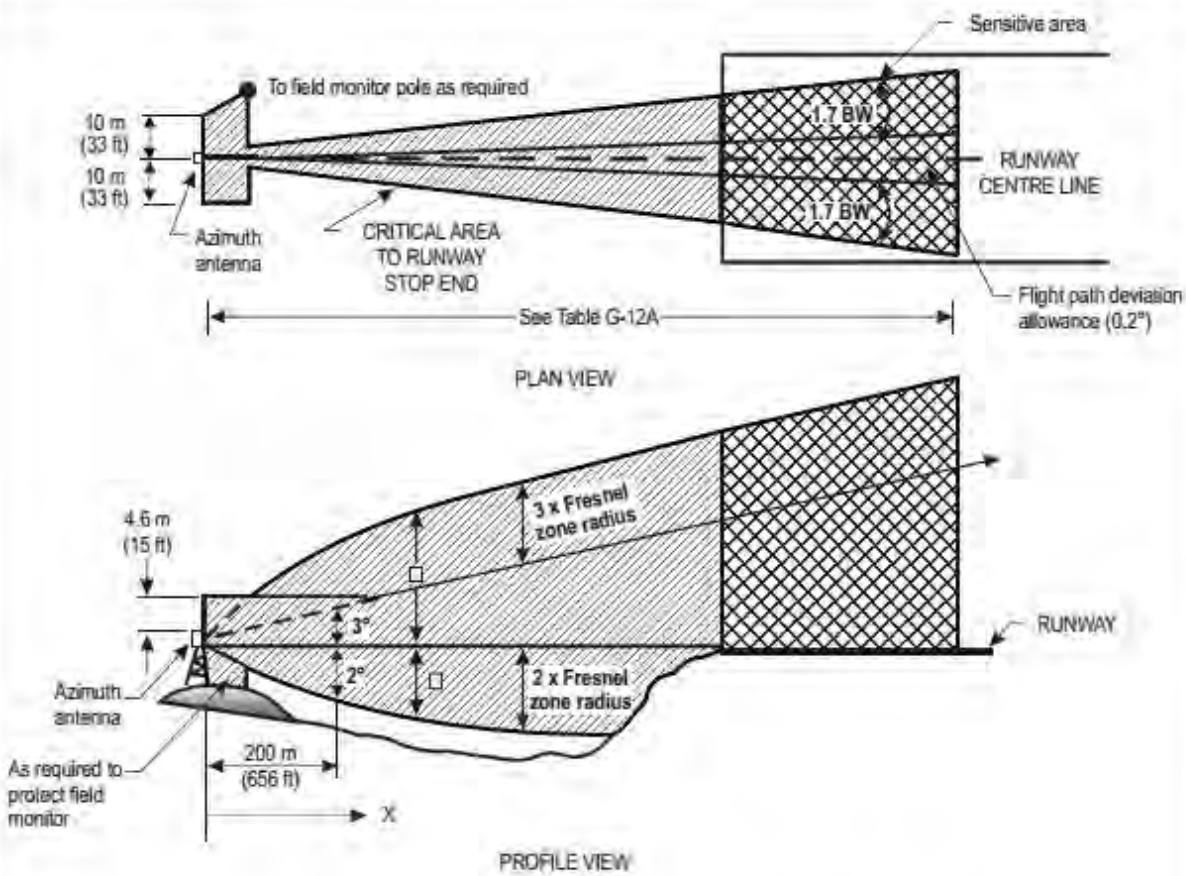


Figure G-22. Azimuth phase centre height requirement when siting an azimuth antenna behind an ILS localizer



VALUE FOR α and β

* X m (ft)	** α m (ft)	** β m (ft)
30 (100)	1.1 (3.5)	5.7 (18.6)
75 (250)	2.7 (8.7)	10.5 (34.3)
150 (500)	5.3 (17.5)	17.1 (56.2)
225 (750)	7.5 (24.5)	23.2 (76.0)
300 (1 000)	8.6 (28.3)	28.9 (94.8)

Where:

$\alpha = 0.035\,X \qquad X < 200$ m

$\alpha = 2\sqrt{0.06\,X} \qquad X > 200$ m

$\beta = X \tan 3° + 3\sqrt{0.06\,X}$

* MEASURED HORIZONTALLY FROM AZIMUTH ANTENNA

** MEASURED VERTICALLY FROM BOTTOM OF AZIMUTH ANTENNA APERTURE

BW = BEAMWIDTH

Figure G-23A. Typical azimuth critical and sensitive areas

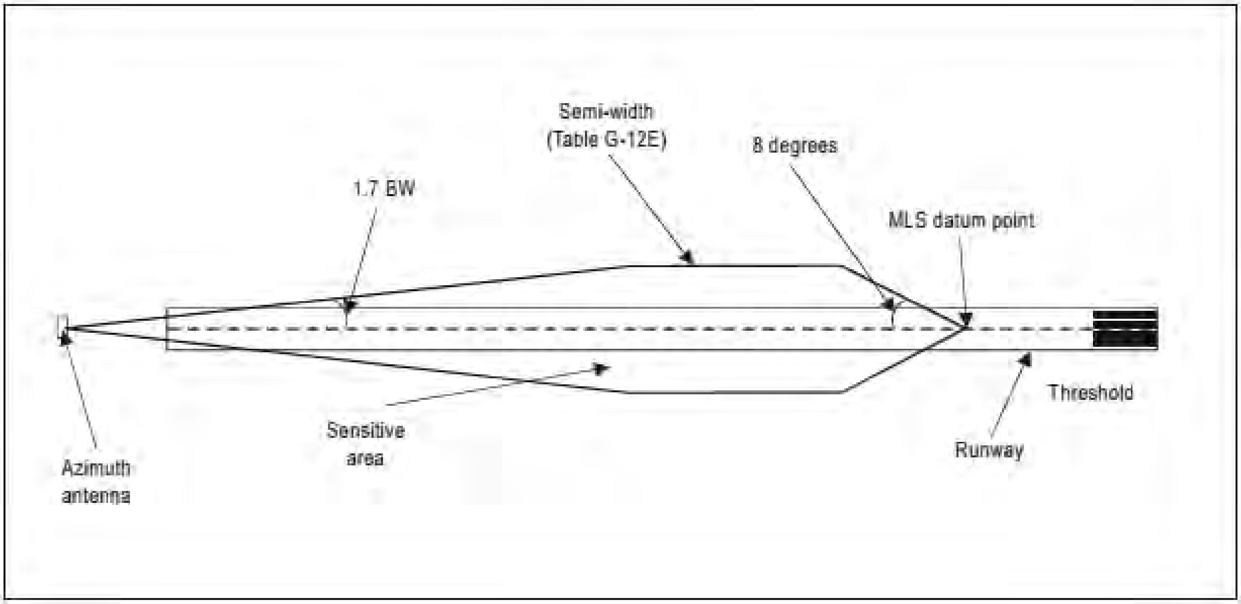
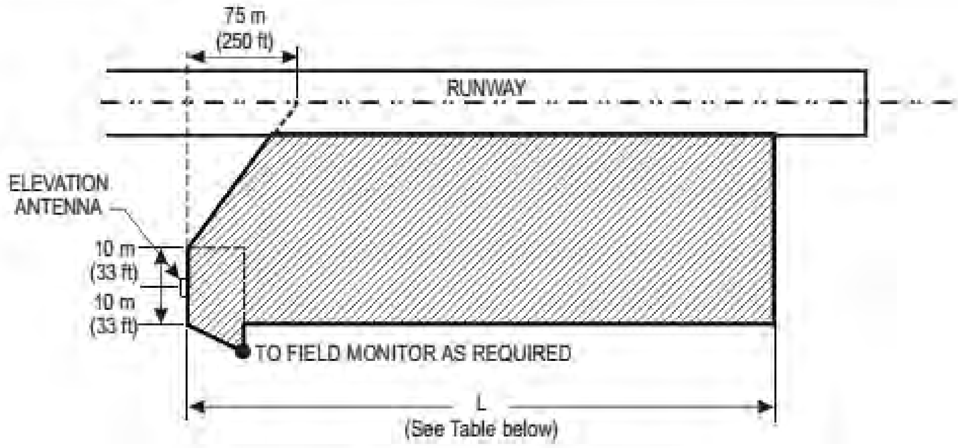
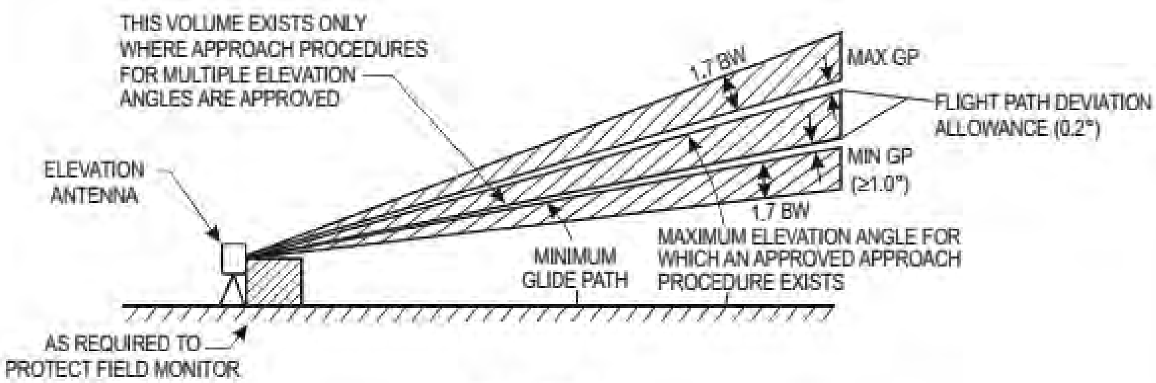


Figure G-23B. Typical azimuth sensitive area to protect roll-out guidance



BEAMWIDTH	CLEAN SITE		COMPLEX SITE	
	B-747	B-727	B-747	B-727
1.0°	320 m (1 050 ft)	170 m (560 ft)	385 m (1 260 ft)	180 m (600 ft)
1.5°	400 m (1 310 ft)	250 m (820 ft)	565 m (1 860 ft)	300 m (990 ft)

PLAN VIEW



PROFILE VIEW

Figure G-24. Typical elevation critical and sensitive areas/volume

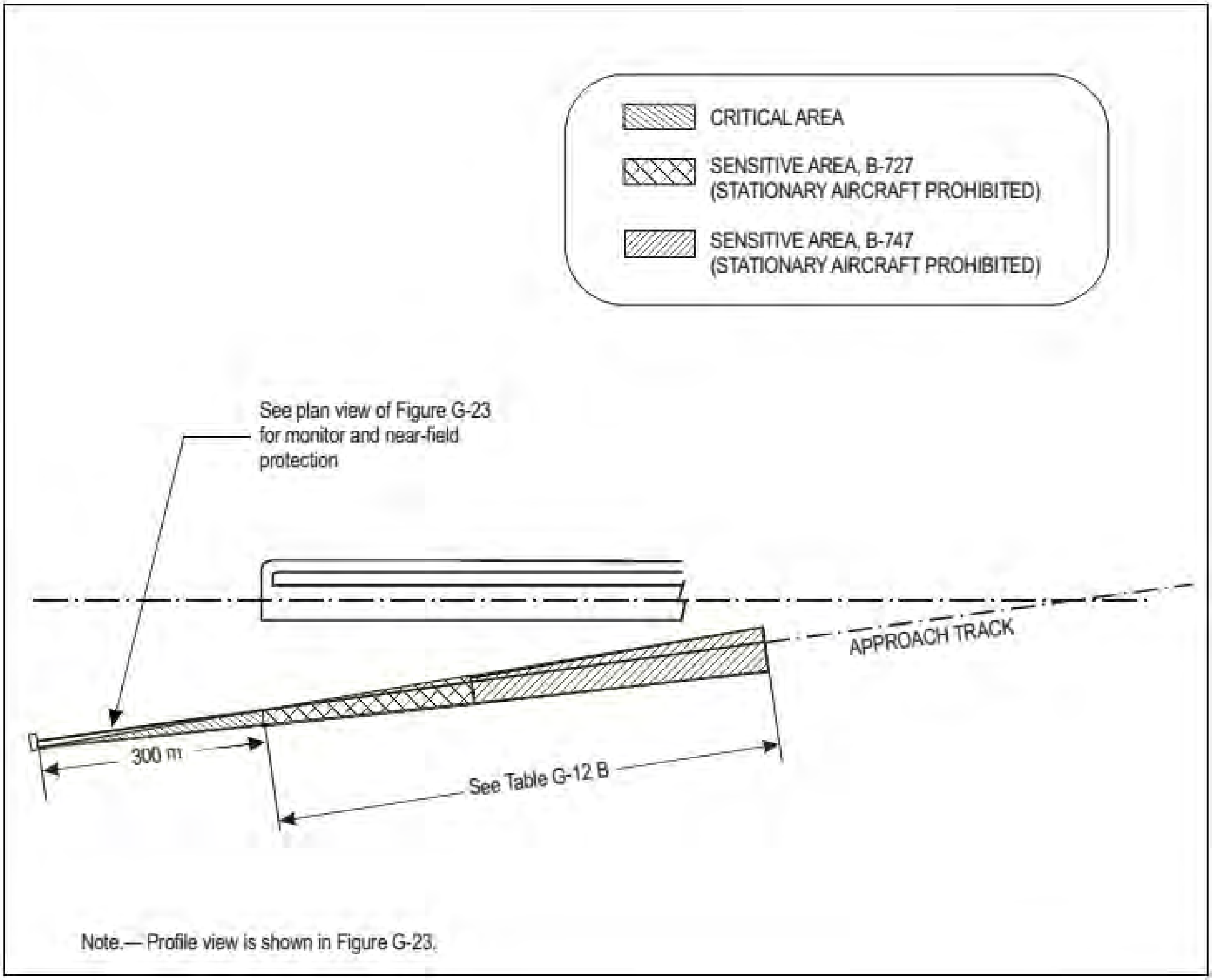


Figure G-25. Typical azimuth critical and sensitive areas for offset azimuth installation

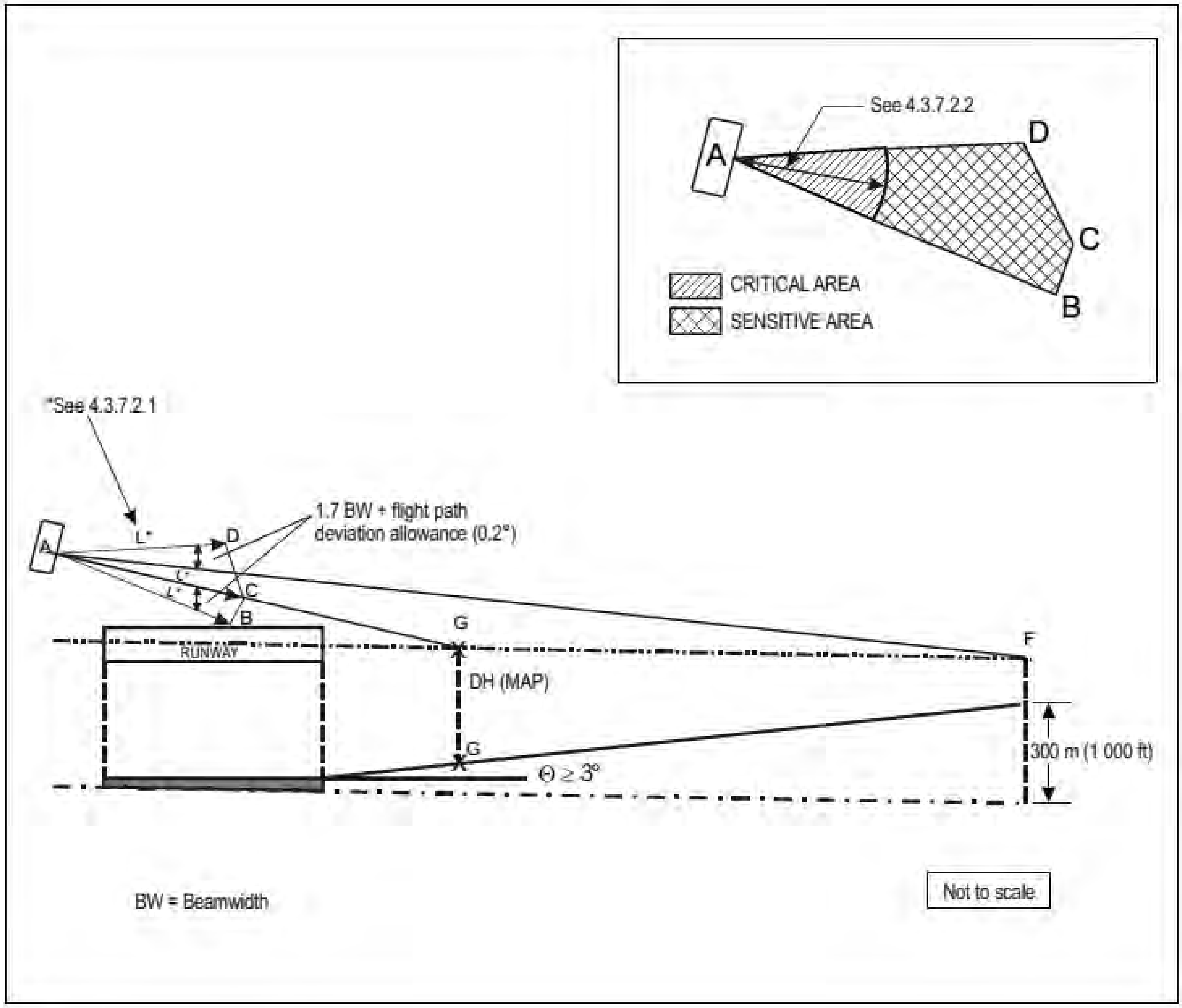


Figure G-26. Typical azimuth critical and sensitive areas/volume for the computed centre line procedure

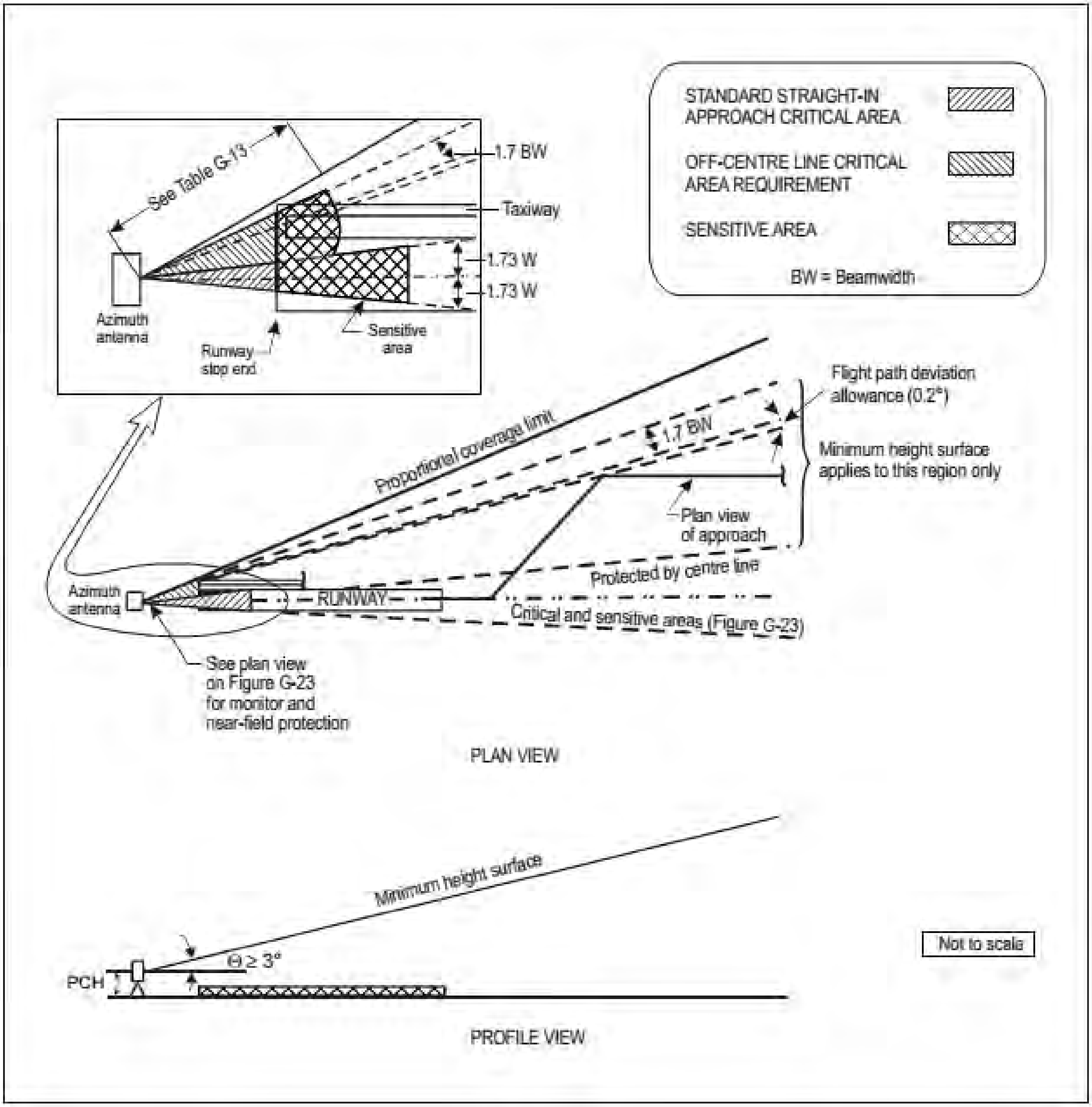


Figure G-27. Typical extension of azimuth critical and sensitive areas for segmented and curved approaches

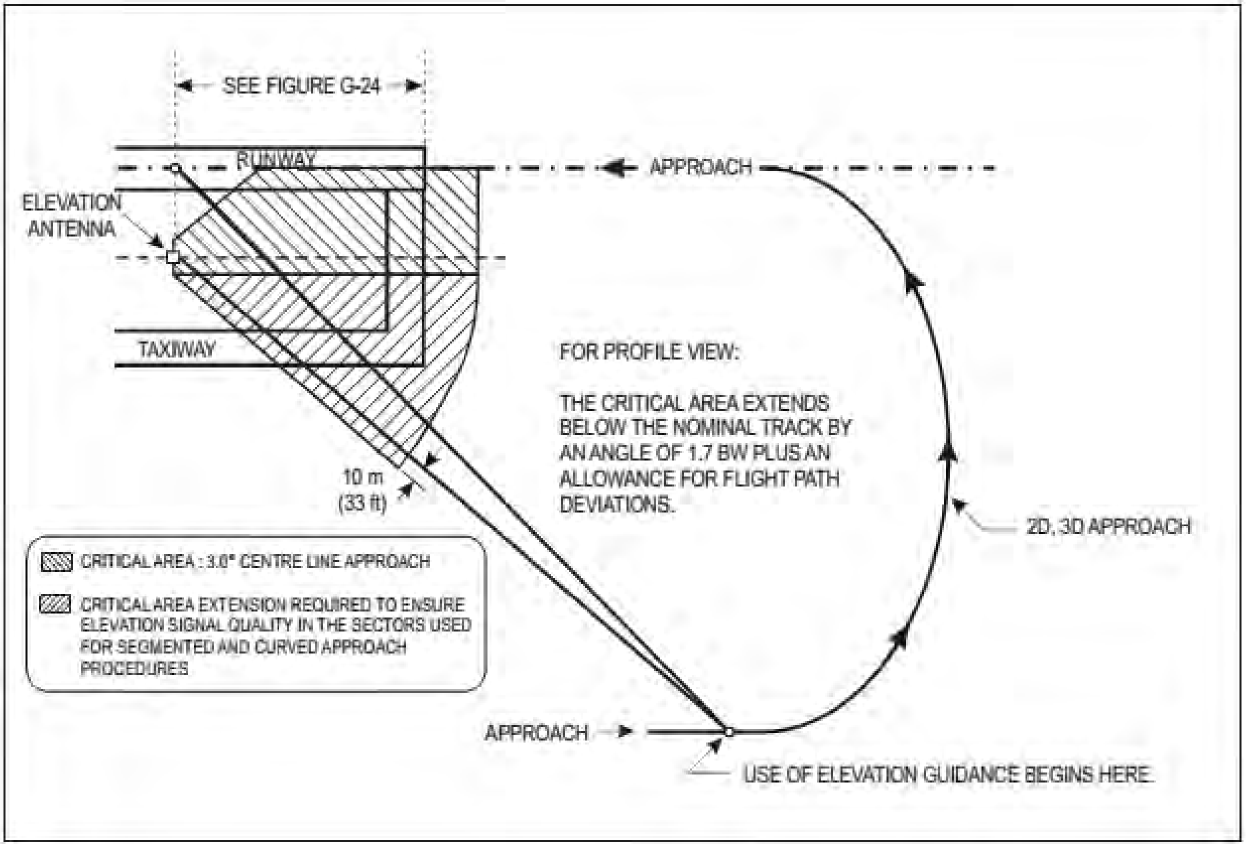


Figure G-28. Typical extension of the elevation critical area for segmented and curved approach procedures

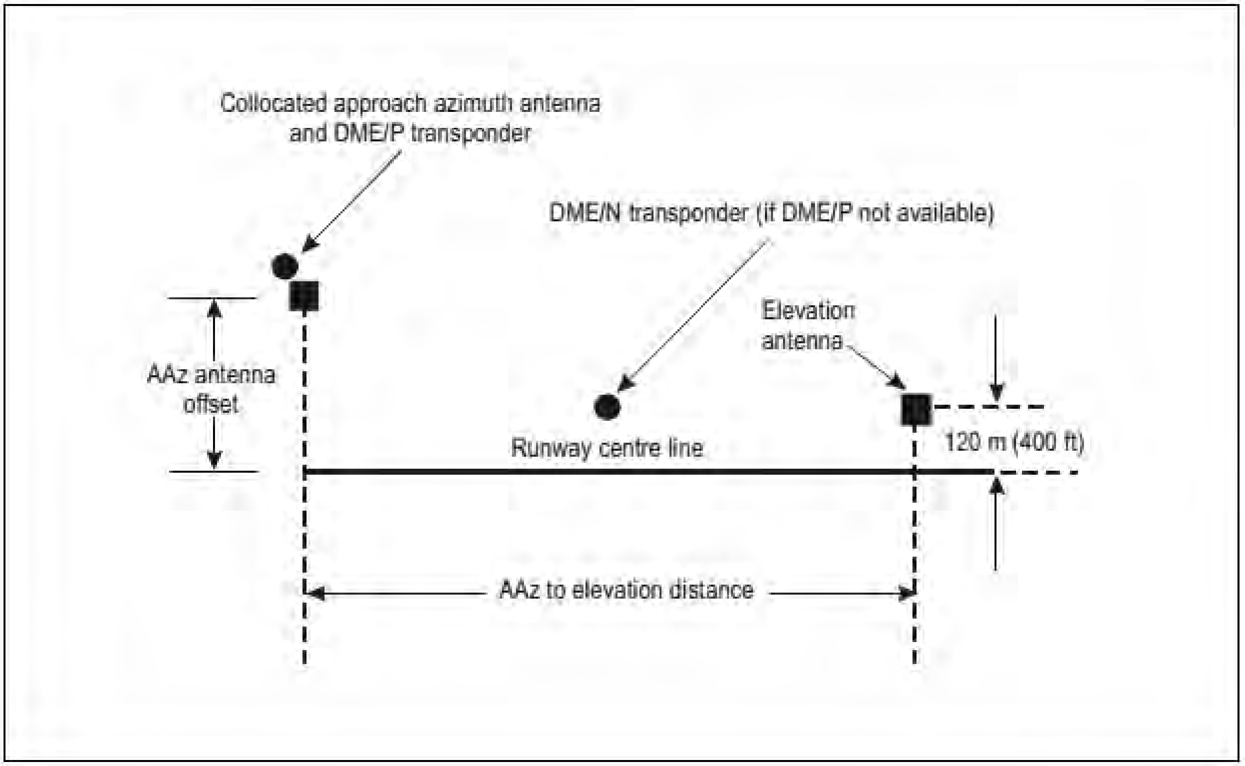


Figure G-29. Ground equipment geometry for computed centre line approaches

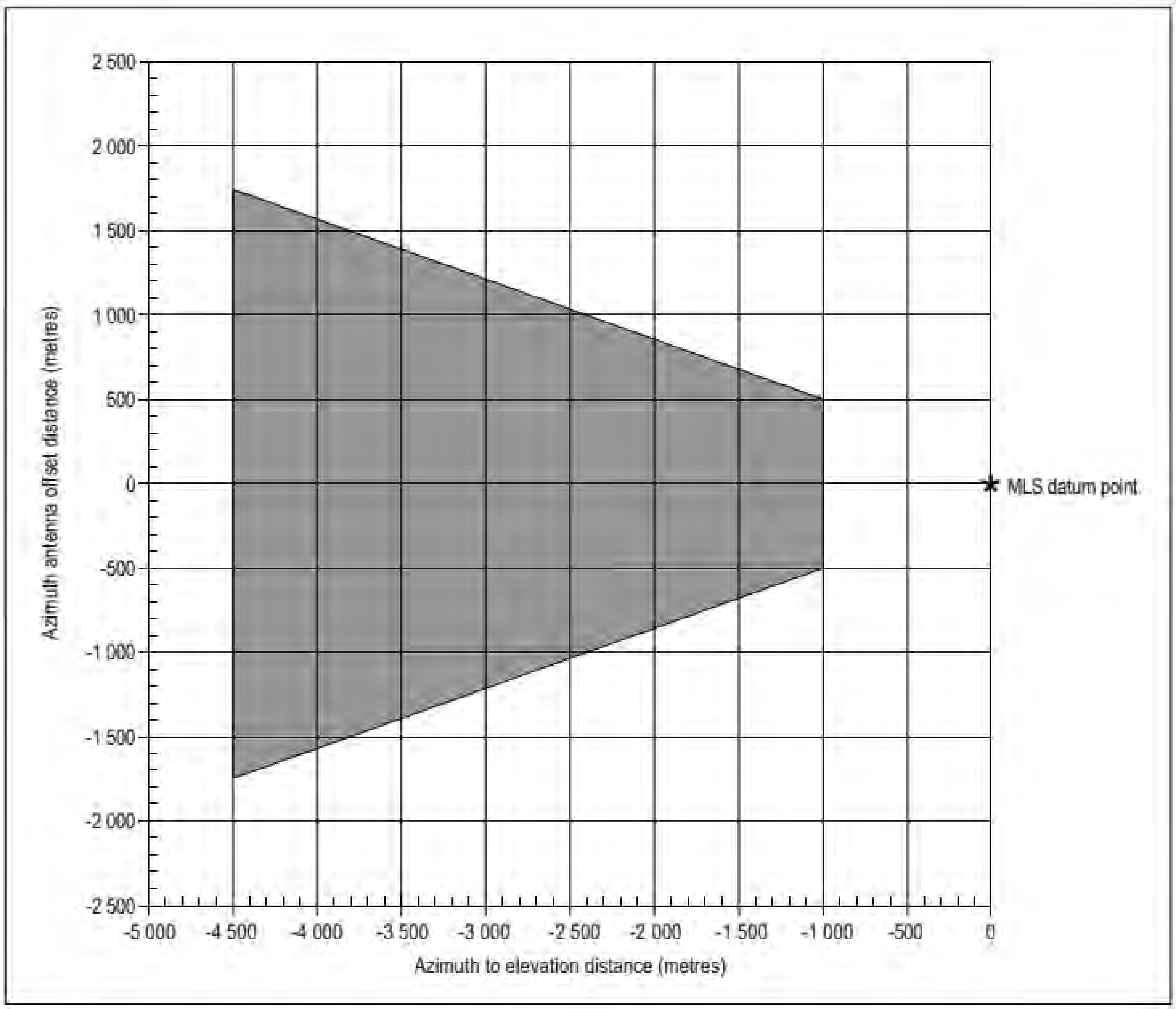


Figure G-30. Permissible azimuth antenna offsets for computed centre line approaches with DME/P (Standard 1) ranging

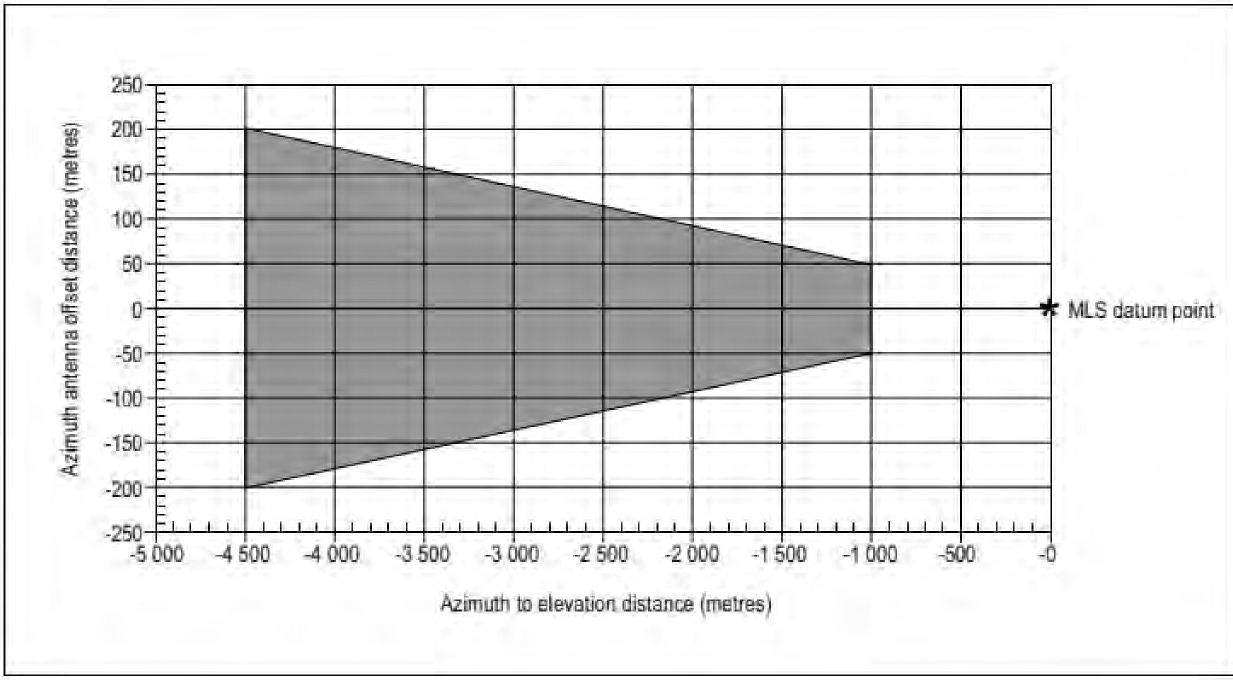
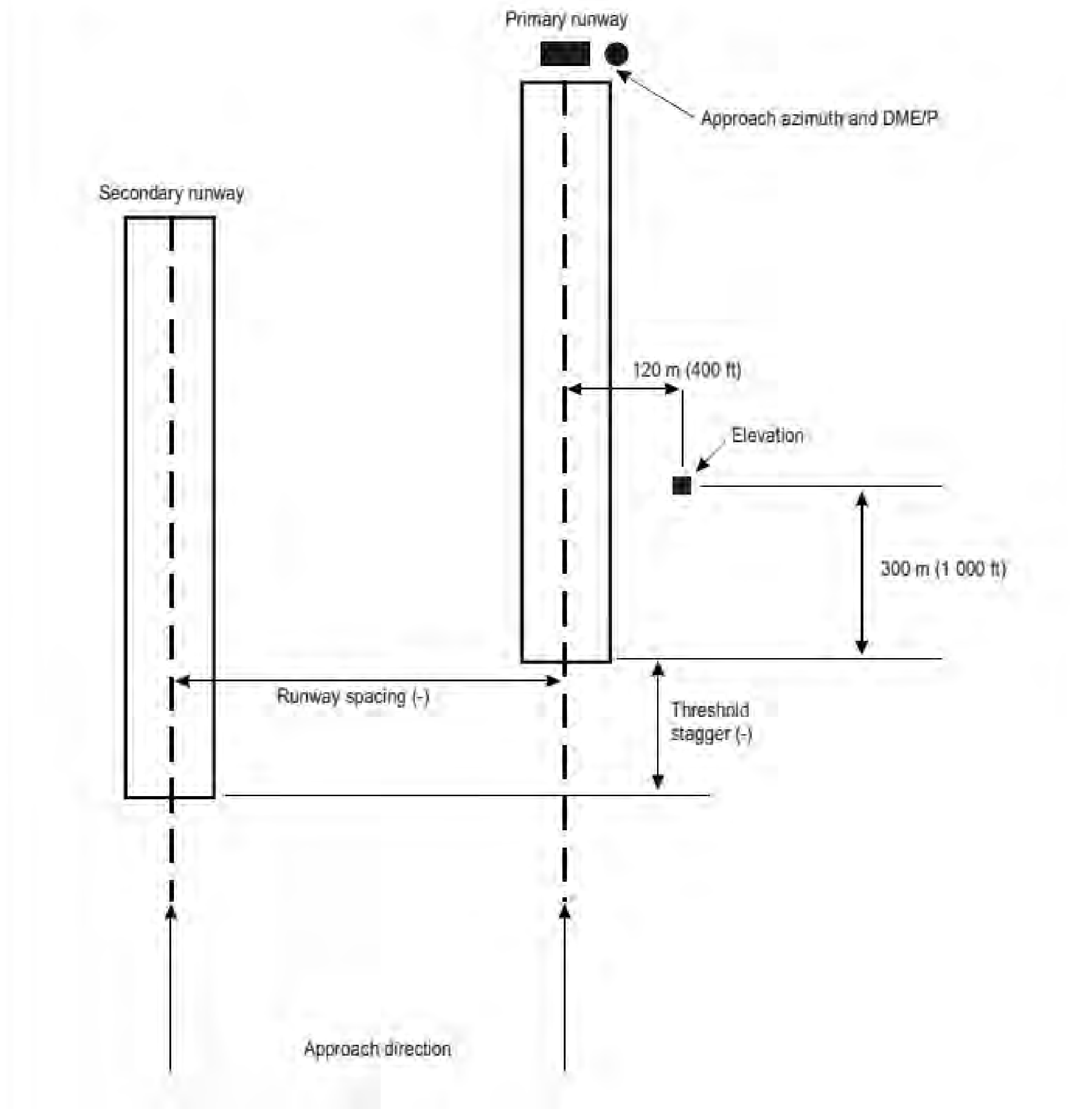
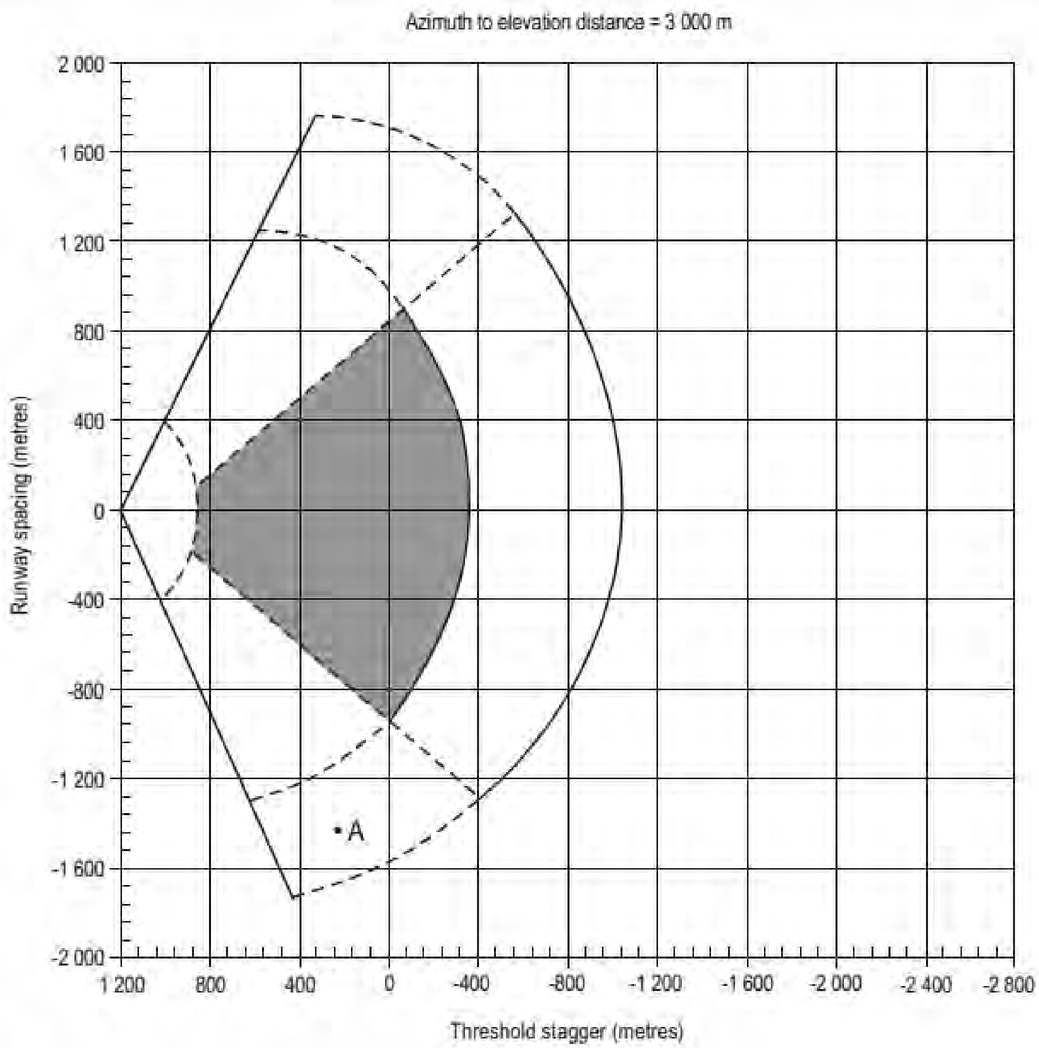


Figure G-31. Permissible azimuth antenna offsets for computed centre line approaches with DME/N ranging



Note.— The position shown for the elevation antenna is defined by typical values that are used to compute the data shown in Figure G-33.

Figure G-32. Runway and equipment geometry for computed centre line approaches to parallel secondary runways



Notes:

1. The radial boundary is dependent on elevation antenna performance.
2. Point A represents the example described in 13.7.6.

Figure G-33. Permissible runway geometries for computed centre line approaches to parallel secondary runways

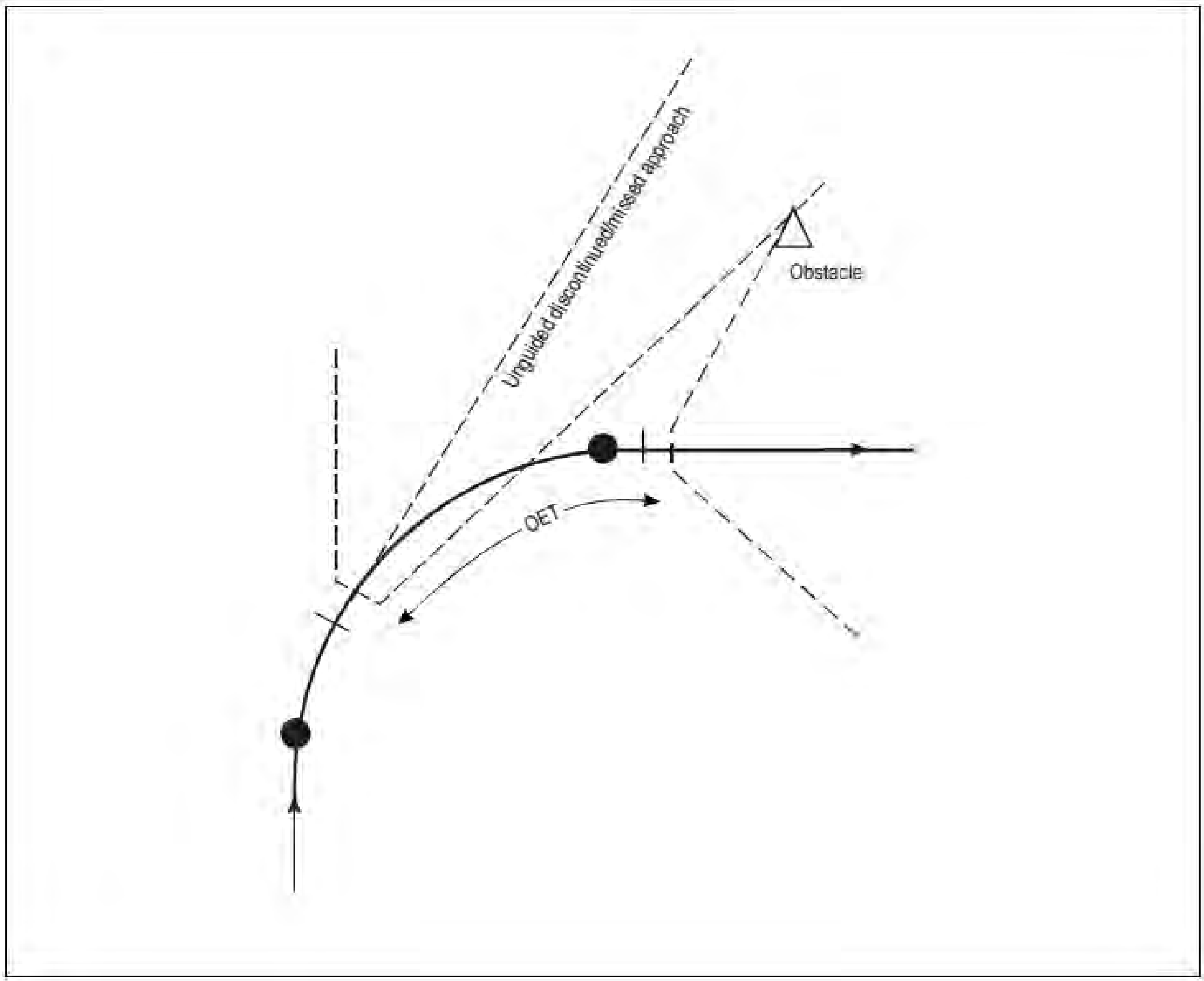


Figure G-34. Determination of obstacle exposure time (OET)

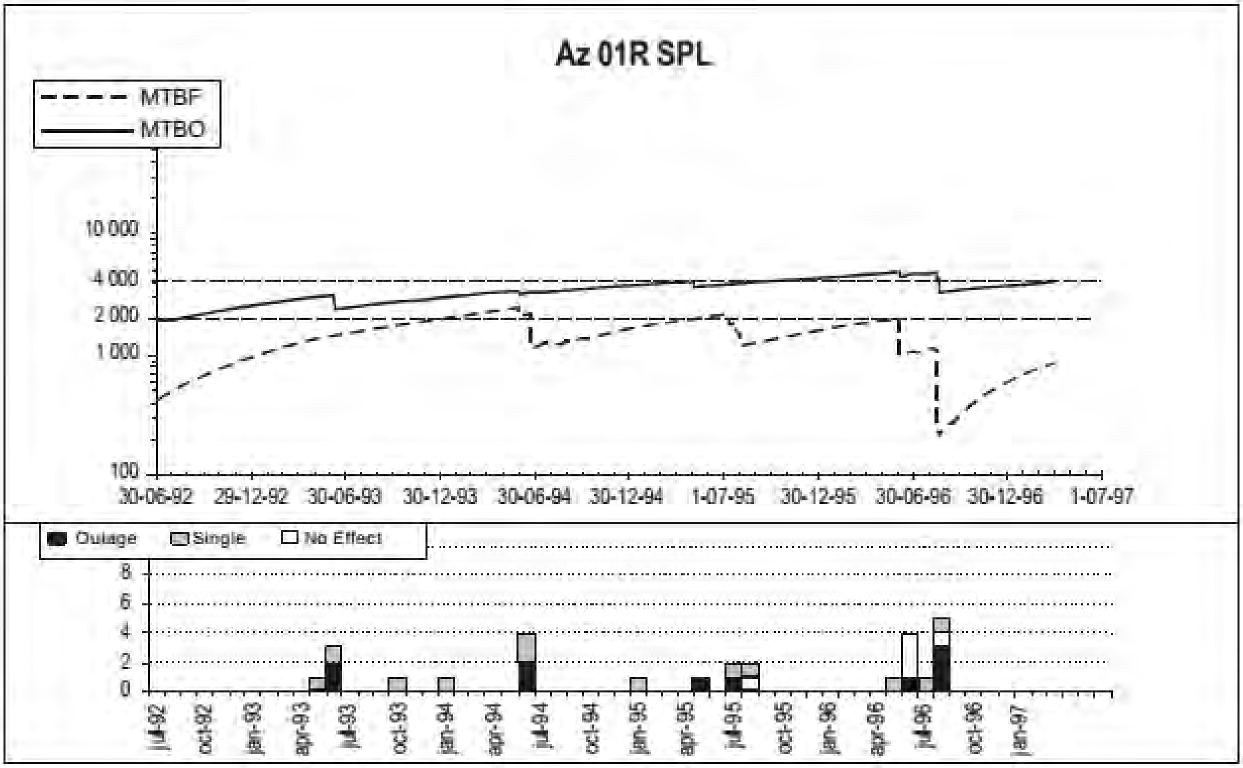


Figure G-35A. Example outage record for MLS azimuth facility

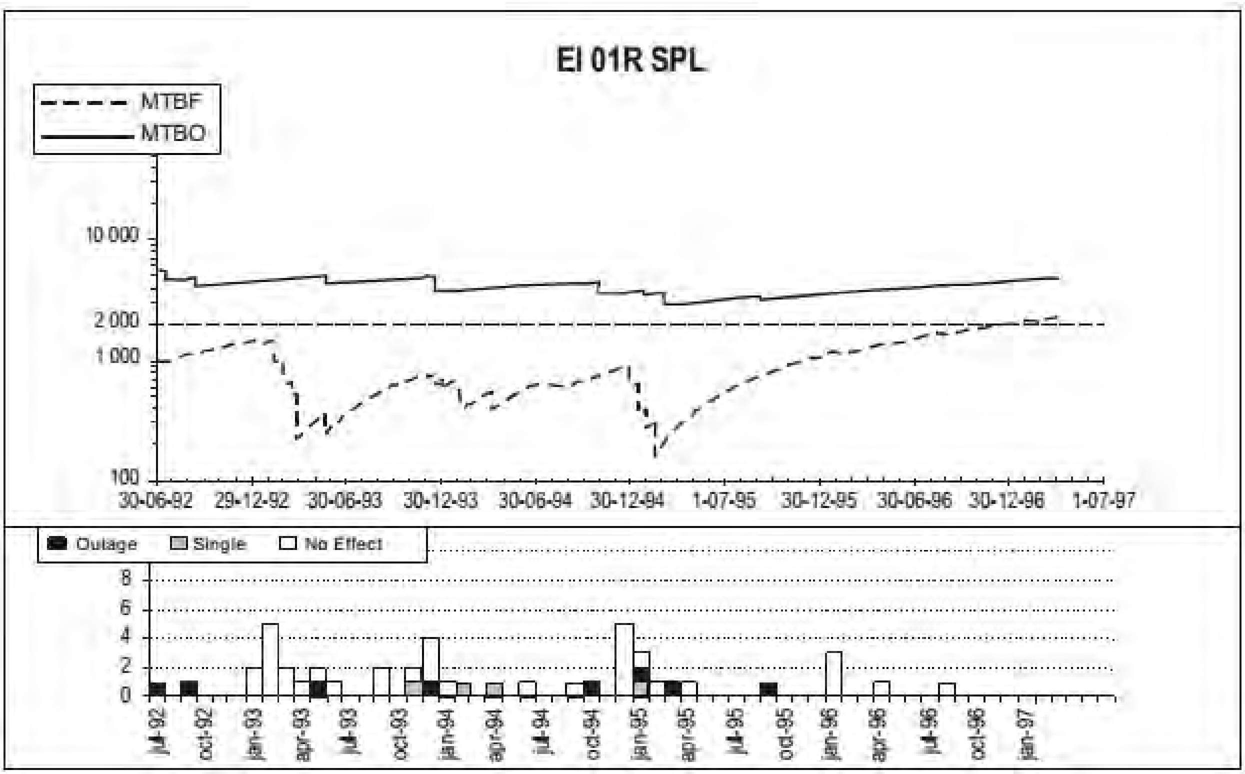


Figure G-35B. Example outage record for MLS elevation facility

ANNEX 10 — VOLUME II
COMMUNICATION PROCEDURES

Introduction

The object of the international aeronautical telecommunication service is to ensure the telecommunications and radio aids to air navigation necessary for the safety, regularity and efficiency of international air navigation. Procedures for the International Aeronautical Telecommunication Service are herein set forth for worldwide use. It is recognized that Supplementary Procedures may be required in certain cases in order to meet particular requirements of the ICAO Regions. Any Supplementary Procedure recommended for this purpose must be a requirement peculiar to the region and must not be contained in, nor conflict with, any worldwide Procedure of ICAO.

Where appropriate, specific ITU Radio Regulations have been paraphrased in this document. Users of these Procedures should note that the Radio Regulations Annex of the International Telecommunications Convention is all embracing in character and, therefore, should be applied in all pertinent cases. All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union.

The Communication Procedures are to be used in conjunction with the Abbreviations and Codes of Doc 8400 and with such other codes and abbreviations as may be approved by ICAO for use in communications. Volume II contains a number of provisions relating to the exchange of information which were developed primarily for low modulation rates utilizing the coded character sets of International Alphabets Nos. 2 and 3. Provisions for International Alphabet No. 5 (IA-5) for use at medium and higher signalling rates are contained in Annex 10, Volume III.

CHAPTER 1. DEFINITIONS

When the following terms are used in this publication, they have the meaning prescribed in this chapter:

Note 1.— A list of additional specialized communication terms and their definitions is contained in Attachment A.

Note 2.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radiocommunication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies(Doc 9718).

1.1 Services

Aeronautical broadcasting service. A broadcasting service intended for the transmission of information relating to air navigation.

Aeronautical fixed service (AFS). A telecommunication service between specified fixed points provided primarily for the safety of air navigation and for the regular, efficient and economical operation of air services.

Aeronautical fixed telecommunication network (AFTN). A worldwide system of aeronautical fixed circuits provided, as part of the aeronautical fixed service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics.

Aeronautical mobile service (RR S1.32). A mobile service between aeronautical stations and aircraft stations, or between aircraft stations, in which survival craft stations may participate; emergency position-indicating radio beacon stations may also participate in this service on designated distress and emergency frequencies.

Aeronautical mobile (R)* service (RR S1.33). An aeronautical mobile service reserved for communications relating to safety and regularity of flight, primarily along national or international civil air routes.

Aeronautical mobile-satellite service (RR S1.35). A mobile satellite service in which mobile earth stations are located on board aircraft; survival craft stations and emergency position-indicating radio beacon stations may also participate in this service.

Aeronautical mobile-satellite (R)* service (RR S1.36).An aeronautical mobile-satellite service reserved for communications relating to safety and regularity of flights, primarily along national or international civil air routes.

Aeronautical radio navigation service (RR S1.46).A radio navigation service intended for the benefit and for the safe operation of aircraft.

Note. – *The following Radio Regulations are quoted for purposes of reference and/or clarity in understanding of the above definition of the aeronautical radio navigation service:*

> RR S1.10 Radio navigation: *Radiodetermination used for the purpose of navigation, including obstruction warning*.

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* route

RR S1.9 Radio determination: The determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves.

Aeronautical telecommunication service. A telecommunication service provided for any aeronautical purpose.

International telecommunication service. A telecommunication service between offices or stations of different States, or between mobile stations which are not in the same State, or are subject to different States.

1.2 Stations

Aerodrome control radio station. A station providing radiocommunication between an aerodrome control tower and aircraft or mobile aeronautical stations.

Aeronautical fixed station. A station in the aeronautical fixed service.

Aeronautical station (RR S1.81). A land station in the aeronautical mobile service. In certain instances, an aeronautical station may be located, for example, on board ship or on a platform at sea.

Aeronautical telecommunication station. A station in the aeronautical telecommunication service.

AFTN communication centre. An AFTN station whose primary function is the relay or retransmission of AFTN traffic from (or to) a number of other AFTN stations connected to it.

AFTN destination station. An AFTN station to which messages and/or digital data are addressed for processing for delivery to the addressee.

AFTN origin station. An AFTN station where messages and/or digital data are accepted for transmission over the AFTN.

AFTN station. A station forming part of the aeronautical fixed telecommunication network (AFTN) and operating as such under the authority or control of a State.

Air-ground control radio station. An aeronautical telecommunication station having primary responsibility for handling communications pertaining to the operation and control of aircraft in a given area.

Aircraft station (RR S1.83). A mobile station in the aeronautical mobile service, other than a survival craft station, located on board an aircraft.

Communication centre. An aeronautical fixed station which relays or retransmits telecommunication traffic from (or to) a number of other aeronautical fixed stations directly connected to it.

Mobile surface station. A station in the aeronautical telecommunication service, other than an aircraft station, intended to be used while in motion or during halts at unspecified points.

Network station. An aeronautical station forming part of a radiotelephony network.

Radio direction finding (RR S1.12). Radiodetermination using the reception of radio waves for the purpose of determining the direction of a station or object.

Radio direction-finding station (RR S1.91). A radiodetermination station using radio direction finding.

Note.— The aeronautical application of radio direction finding is in the aeronautical radio navigation service.

Regular station. A station selected from those forming an enroute air-ground radiotelephony network to communicate with or to intercept communications from aircraft in normal conditions.

Tributary station. An aeronautical fixed station that may receive or transmit messages and/or digital data but which does not relay except for the purpose of serving similar stations connected through it to a communication centre.

1.3 Communication methods

Air-ground communication. Two-way communication between aircraft and stations or locations on the surface of the earth.

Air-to-ground communication. One-way communication from aircraft to stations or locations on the surface of the earth.

Blind transmission. A transmission from one station to another station in circumstances where two-way communication cannot be established but where it is believed that the called station is able to receive the transmission.

Broadcast. A transmission of information relating to air navigation that is not addressed to a specific station or stations.

Duplex. A method in which telecommunication between two stations can take place in both directions simultaneously.

Ground-to-air communication. One-way communication from stations or locations on the surface of the earth to aircraft.

Inter pilot air-to-air communication. Two-way communication on the designated air-to-air channel to enable aircraft engaged in flights over remote and oceanic areas out of range of VHF ground stations to exchange necessary operational information and to facilitate the resolution of operational problems.

Non-network communications. Radiotelephony communications conducted by a station of the aeronautical mobile service, other than those conducted as part of a radiotelephony network.

Radiotelephony network. A group of radiotelephony aeronautical stations which operate on and guard frequencies from the same family and which support each other in a defined manner to ensure maximum dependability of air-ground communications and dissemination of air-ground traffic.

Readback. A procedure whereby the receiving station repeats a received message or an appropriate part thereof back to the transmitting station so as to obtain confirmation of correct reception.

Simplex. A method in which telecommunication between two stations takes place in one direction at a time.

Telecommunication (RR S1.3). Any transmission, emission, or reception of signs, signals, writing, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems.

1.4 Direction finding

Homing. The procedure of using the direction-finding equipment of one radio station with the emission of another radio station, where at least one of the stations is mobile, and whereby the mobile station proceeds continuously towards the other station.

Radio bearing. The angle between the apparent direction of a definite source of emission of electro-magnetic waves and a reference direction, as determined at a radio direction finding station. A true radio bearing is one for which the reference direction is that of true North. A magnetic radio bearing is one for which the reference direction is that of magnetic North.

1.5 Teletypewriter systems

Automatic relay installation. A teletypewriter installation where automatic equipment is used to transfer messages from incoming to outgoing circuits.

Note.— This term covers both fully automatic and semiautomatic installations.

Fully automatic relay installation. A teletypewriter installation where interpretation of the relaying responsibility in respect of an incoming message and the resultant setting up of the connections required to effect the appropriate retransmissions is carried out automatically, as well as all other normal operations of relay, thus obviating the need for operator intervention, except for supervisory purposes.

Message field. An assigned area of a message containing specified elements of data.

Semi-automatic relay installation. A teletypewriter installation where interpretation of the relaying responsibility in respect of an incoming message and the resultant setting-up of the connections required to effect the appropriate retransmissions require the intervention of an operator but where all other normal operations of relay are carried out automatically.

Teletypewriter tape. A tape on which signals are recorded in the 5-unit Start-Stop code by completely severed perforations (Chad Type) or by partially severed perforations (Chadless Type) for transmission over teletypewriter circuits.

"Torn-tape" relay installation. A teletypewriter installation where messages are received and relayed in teletypewriter tape form and where all operations of relay are performed as the result of operator intervention.

1.6 Agencies

Aeronautical telecommunication agency. An agency responsible for operating a station or stations in the aeronautical telecommunication service.

Aircraft operating agency. The person, organization or enterprise engaged in, or offering to engage in, an aircraft operation.

1.7 Frequencies

Primary frequency. The radiotelephony frequency assigned to an aircraft as a first choice for air-ground communication in a radiotelephony network.

Secondary frequency. The radiotelephony frequency assigned to an aircraft as a second choice for air-ground communication in a radiotelephony network.

1.8 Data link communications

Controller-pilot data link communications (CPDLC). A means of communication between controller and pilot, using data link for ATC communications.

Current data authority. The designated ground system through which a CPDLC dialogue between a pilot and a controller currently responsible for the flight is permitted to take place.

Downstream data authority. A designated ground system, different from the current data authority, through which the pilot can contact an appropriate ATC unit for the purposes of receiving a downstream clearance.

Next data authority. The ground system so designated by the current data authority through which an onward transfer of communications and control can take place.

1.9 Miscellaneous

Aeronautical fixed circuit. A circuit forming part of the aeronautical fixed service (AFS).

Aeronautical fixed telecommunication network circuit. A circuit forming part of the aeronautical fixed telecommunication network (AFTN).

Aeronautical telecommunication log. A record of the activities of an aeronautical telecommunication station.

Air-report. A report from an aircraft in flight prepared in conformity with requirements for position, and operational and/or meteorological reporting.

Note.— Details of the AIREP form are given in PANS-ATM (Doc 4444).

Altitude. The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).

ATS direct speech circuit. An aeronautical fixed service (AFS) telephone circuit, for direct exchange of information between air traffic services (ATS) units.

Automatic telecommunication log. A record of the activities of an aeronautical telecommunication station recorded by electrical or mechanical means.

Flight level. A surface of constant atmospheric pressure which is related to a specific pressure datum, 1 013.2 hectopascals (hPa), and is separated from other such surfaces by specific pressure intervals.

Note 1.— A pressure type altimeter calibrated in accordance with the standard atmosphere:

a) when set to a QNH altimeter setting, will indicate altitude;

b) when set to a QFE altimeter setting, will indicate height above the QFE reference datum;

c) when set to a pressure 1 013.2 hPa, may be used to indicate flight levels.

Note 2.— The terms "height" and "altitude", used in

Note 1 above, indicate altimetric rather than geometric heights and altitudes.

Frequency channel. A continuous portion of the frequency spectrum appropriate for a transmission utilizing a specified class of emission.

Note.— The classification of emissions and information relevant to the portion of the frequency spectrum appropriate for a given type of transmission (bandwidths) is specified in the ITU Radio Regulations, Article S2 and Appendix S1.

Height. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

Human performance. Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations.

Location indicator. A four-letter code group formulated in accordance with rules prescribed by ICAO and assigned to the location of an aeronautical fixed station.

Meteorological operational channel. A channel of the aeronautical fixed service (AFS), for the exchange of aeronautical meteorological information.

Meteorological operational telecommunication network. An integrated system of meteorological operational channels, as part of the aeronautical fixed service (AFS), for the exchange of aeronautical meteorological information between the aeronautical fixed stations within the network.

Note.— "Integrated" is to be interpreted as a mode of operation necessary to ensure that the information can be transmitted and received by the stations within the network in accordance with pre-established schedules.

NOTAM. A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

Operational control communications. Communications required for the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of a flight.

Note.— Such communications are normally required for the exchange of messages between aircraft and aircraft operating agencies.

Route segment. A route or portion of route usually flown without an intermediate stop.

Routing Directory. A list in a communication centre indicating for each addressee the outgoing circuit to be used.

SNOWTAM. A special series NOTAM notifying the presence or removal of hazardous conditions due to snow, ice, slush or standing water associated with snow, slush and ice on the movement area, by means of a specific format.

CHAPTER 2. ADMINISTRATIVE PROVISIONS RELATING TO THE INTERNATIONAL AERONAUTICAL TELECOMMUNICATION SERVICE

2.1 Division of service

The international aeronautical telecommunication service shall be divided into four parts:

1) aeronautical fixed service;

2) aeronautical mobile service;

3) aeronautical radio navigation service;

4) aeronautical broadcasting service.

2.2 Telecommunication — Access

All aeronautical telecommunication stations, including end systems and intermediate systems of the aeronautical telecommunication network (ATN), shall be protected from unauthorized direct or remote access.

2.3 Hours of service

2.3.1 The Competent Authority shall give notification of the normal hours of service of stations and offices of the international aeronautical telecommunication service under its control to the aeronautical telecommunication agencies designated to receive this information by other Administrations concerned.

2.3.2 Whenever necessary and practicable, the Competent Authority shall give notification of any change in the normal hours of service, before such a change is effected, to the aeronautical telecommunication agencies designated to receive this information by other Administrations concerned. Such changes shall also, whenever necessary, be promulgated in NOTAM.

2.3.3 If a station of the international aeronautical telecommunication service, or an aircraft operating agency, requests a change in the hours of service of another station, such change shall be requested as soon as possible after the need for change is known. The station or aircraft operating agency requesting the change shall be informed of the result of its request as soon as possible.

2.4 Supervision

2.4.1 Each State shall designate the authority responsible for ensuring that the international aeronautical telecommunication service is conducted in accordance with the Procedures in this Annex.

2.4.2 **Recommendation**. – *Occasional infringements of the Procedures contained herein, when not serious, should be dealt with by direct communication between the parties immediately interested either by correspondence or by personal contact.*

2.4.3 When a station commits serious or repeated infringements, representations relating to them shall be made to the authority designated in 2.4.1 of the State to which the station belongs by the authority which detects them.

2.4.4 **Recommendation**.— *The authorities designated in 2.4.1 should exchange information regarding the performance of systems of communication, radio navigation, operation and maintenance, unusual transmission phenomena, etc*.

2.5 Superfluous transmissions

Each State shall ensure that there is no wilful transmission of unnecessary or anonymous signals, messages or data by any station within that State.

2.6 Interference

Before authorizing tests and experiments in any station, each Administration, in order to avoid harmful interference, shall prescribe the taking of all possible precautions, such as the choice of frequency and of time, and the reduction or, if possible, the suppression of radiation. Any harmful interference resulting from tests and experiments shall be eliminated as soon as possible.

CHAPTER 3. GENERAL PROCEDURES FOR THE

INTERNATIONAL AERONAUTICAL TELECOMMUNICATION SERVICE

3.1 General

The procedures outlined in this chapter are general in character and shall be applied where appropriate to the other chapters contained in this Volume.

Note.— Detailed procedures, with special application to the service concerned, are contained in Chapters 4, 5, 6, 7 and 8.

3.2 Extensions of service and closing down of stations

3.2.1 Stations of the international aeronautical telecommunication service shall extend their normal hours of service as required to provide for traffic necessary for flight operation.

3.2.2 Before closing down, a station shall notify its intention to all other stations with which it is in direct communication, confirm that an extension of service is not required and advise the time of re-opening if other than its normal hours of service.

3.2.3 When it is working regularly in a network on a common circuit, a station shall notify its intention of closing down either to the control station, if any, or to all stations in the network. It shall continue watch for two minutes and may then close down if it has received no call during this period.

3.2.4 Stations with other than continuous hours of operation, engaged in, or expected to become engaged in distress, urgency, unlawful interference, or interception traffic, shall extend their normal hours of service to provide the required support to those communications.

3.3 Acceptance, transmission and delivery of messages

3.3.1 Only those messages coming within the categories specified in 4.4.1.1 shall be accepted for transmission by the aeronautical telecommunication service.

3.3.1.1 The responsibility for determining the acceptability of a message shall rest with the station where the message is filed for transmission.

3.3.1.2 Once a message is deemed acceptable, it shall be transmitted, relayed and (or) delivered in accordance with the priority classification and without discrimination or undue delay.

3.3.1.3 **Recommendation**.— *The authority in control of any station through which a message is relayed, should make representations at a later date to the authority in control of the accepting station regarding any message which is considered unacceptable.*

3.3.2 Only messages for stations forming part of the aeronautical telecommunication service shall be accepted for transmission, except where special arrangements have been made with the telecommunication authority concerned.

3.3.2.1 Acceptance as a single message of a message intended for two or more addresses, whether at the same station or at different stations, shall be permitted subject, however, to the provisions prescribed in 4.4.3.1.2.3.

3.3.3 Messages handled for aircraft operating agencies shall be accepted only when handed in to the telecommunication station in the form prescribed herein and by an authorized representative of that agency, or when received from that agency over an authorized circuit.

3.3.4 For each station of the aeronautical telecommunication service from which messages are delivered to one or more aircraft operating agencies, a single office for each aircraft operating agency shall be designated by agreement between the aeronautical telecommunication agency and the aircraft operating agency concerned.

3.3.5 Stations of the international aeronautical telecommunication service shall be responsible for delivery of messages to addressee(s) located within the boundaries of the aerodrome(s) served by that station and beyond those boundaries only to such addressee(s) as may be agreed by special arrangements with the Administrations concerned.

3.3.6 Messages shall be delivered in the form of a written record, or other permanent means as prescribed by authorities.

3.3.6.1 **Recommendation**. – *In cases where telephone or loudspeaker systems are used without recording facilities for the delivery of messages, a written copy should be provided, as confirmation of delivery, as soon as possible.*

3.3.7 Messages originated in the aeronautical mobile service by an aircraft in flight and which require transmission over the aeronautical fixed telecommunication network to effect delivery, shall be reprocessed by the aeronautical telecommunication station into the message format prescribed in 4.4.2 prior to transmission on the AFTN.

3.3.7.1 Messages originated in the aeronautical mobile service by an aircraft in flight and which require transmission over the aeronautical fixed service, other than on AFTN circuits, shall also be reprocessed by the aeronautical telecommunication station into the format prescribed in 4.4.2 except where, subject to the provisions of 3.3.5, prior and other arrangements have been made between the aeronautical telecommunication agency and the aircraft operating agency concerned for predetermined distribution of messages from aircraft.

3.3.7.2 Messages (including air-reports) without specific address containing meteorological information received from an aircraft in flight shall be forwarded without delay to the meteorological office associated with the point of reception.

3.3.7.3 Messages (including air-reports) without specific address containing air traffic services information from aircraft in flight shall be forwarded without delay to the air traffic services unit associated with the communication station receiving the message.

3.3.7.4 PANS.— When recording the text of air-reports in AIREP form, the data conventions approved by ICAO for this purpose shall be used wherever possible.

Note.— Provisions relating to the composition, including data conventions, of air-reports and to the order and form in which the elements of such reports are transmitted by the aircraft stations and recorded and retransmitted by the aeronautical stations, are contained in the PANS-ATM (Doc 4444).

3.3.7.5 PANS.— When air-reports in AIREP form are to be retransmitted by telegraphy (including teletypewriting), the text transmitted shall be as recorded in compliance with 3.3.7.4.

3.4 Time system

3.4.1 Universal Co-ordinated Time (UTC) shall be used by all stations in the aeronautical telecommunication service. Midnight shall be designated as 2400 for the end of the day and 0000 for the beginning of the day.

3.4.2 A date-time group shall consist of six figures, the first two figures representing the date of the month and the last four figures the hours and minutes in UTC.

3.5 Record of communications

3.5.1 General

3.5.1.1 A telecommunication log, written or automatic, shall be maintained in each station of the aeronautical telecommunication service except that an aircraft station, when using radiotelephony in direct communication with an aeronautical station, need not maintain a telecommunication log.

Note.— The telecommunication log will serve as a protection, should the operator's watch activities be investigated. It may be required as legal evidence.

3.5.1.1.1 **Recommendation.—** Aeronautical stations should record messages at the time of their receipt, except that, if during an emergency the continued manual recording would result in delays in communication, the recording of messages, may be temporarily interrupted and completed at the earliest opportunity.

Note.— In the case of radiotelephony operation it would be desirable if voice recording were provided for use during interruption in manual recording.

3.5.1.1.2 **Recommendation**.— When a record is maintained in an aircraft station, either in a radiotelephone log or elsewhere, concerning distress communications, harmful interference, or interruption to communications, such a record should be associated with information concerning the time and the position, and altitude of the aircraft.

3.5.1.2 In written logs, entries shall be made only by operators on duty except that other persons having knowledge of facts pertinent to the entries may certify in the log the accuracy of operators' entries.

3.5.1.3 All entries shall be complete, clear, correct and intelligible. Superfluous marks or notations shall not be made in the log.

3.5.1.4 In written logs, any necessary correction in the log shall be made only by the person making the initial entry. The correction shall be accomplished by drawing or typing a single line through the incorrect entry, initialling same, recording the time and date of correction. The correct entry shall be made on the next line after the last entry.

3.5.1.5 Telecommunication logs, written or automatic, shall be retained for a period of at least thirty days. When logs are pertinent to inquiries or investigations they shall be retained for longer periods until it is evident that they will be no longer required.

3.5.1.6 The following information shall be entered in written logs:

a) the name of the agency operating the station;

b) the identification of the station;

c) the date;

d) the time of opening and closing the station;

e) the signature of each operator, with the time the operator assumes and relinquishes a watch;

f) the frequencies being guarded and type of watch (continuous or scheduled) being maintained on each frequency;

g) except at intermediate mechanical relay stations where the provisions of this paragraph need not be complied with, a record of each communication, test transmission, or attempted communication showing text of communication, time communication completed, station(s) communicated with, and frequency used. The text of the communication may be omitted from the log when copies of the messages handled are available and form part of the log;

h) all distress communications and action thereon;

i) a brief description of communication conditions and difficulties, including harmful interference. Such entries should include, whenever practicable, the time at which interference was experienced, the character, radio frequency and identification of the interfering signal;

j) a brief description of interruption to communications due to equipment failure or other troubles, giving the duration of the interruption and action taken;

k) such additional information as may be considered by the operator to be of value as a part of the record of the station’s operations.

3.6 Establishment of radiocommunication

3.6.1 All stations shall answer calls directed to them by other stations in the aeronautical telecommunication service and shall exchange communications on request.

3.6.2 All stations shall radiate the minimum power necessary to ensure a satisfactory service.

3.7 Use of abbreviations and codes

3.7.1 Abbreviations and codes shall be used in the international aeronautical telecommunication service whenever they are appropriate and their use will shorten or otherwise facilitate communication.

3.7.1.1 Where abbreviations and codes other than those

approved by ICAO are contained in the text of messages, the originator shall, if so required by the aeronautical telecommunication station accepting the message for transmission, make available to that station a decode for the abbreviations and codes used.

Note.— The use of ICAO approved abbreviations and codes wherever appropriate — for example, those contained in PANS-ABC (Doc 8400) — obviates the need for application of the provisions of 3.7.1.1.

3.8 Cancellation of messages

Messages shall be cancelled by a telecommunication station only when cancellation is authorized by the message originator.

CHAPTER 4. AERONAUTICAL FIXED SERVICE (AFS)

4.1 General

4.1.1 The aeronautical fixed service shall comprise the following systems and applications that are used for ground-ground (i.e. point-to-point and/or point-to-multipoint) communications in the international aeronautical telecommunication service:

a) ATS direct speech circuits and networks;

b) meteorological operational circuits, networks and broadcast systems;

c) the aeronautical fixed telecommunications network (AFTN);

d) the common ICAO data interchange network (CIDIN);

e) the air traffic services (ATS) message handling services; and

f) the inter-centre communications (ICC).

Note 1.— Provisions relating to ATS direct speech communications are contained in 4.2.

Note 2.— Provisions relating to meteorological operational channels and meteorological operational telecommunication networks are contained in 4.3.

Note 3.— The AFTN provides a store-and-forward messaging service for the conveyance of text messages in ITA-2 or IA-5 format, using character-oriented procedures. Provisions relating to the AFTN are contained in 4.4.

Note 4.— The CIDIN provides a common transport service for the conveyance of binary or text application messages, in support of the AFTN and OPMET applications. Procedural provisions relating to the CIDIN are contained in 4.5.

Note 5.— The ATS (air traffic services) message handling services (ATSMHS) application allows ATS messages to be exchanged between service users over the aeronautical telecommunication network (ATN) internet communication service (ICS). Procedural provisions relating to ATS message handling services are contained in 4.6.

Note 6.— The inter-centre communications applications enable the exchange of information between air traffic service units over the aeronautical telecommunication network (ATN) internet communication service (ICS), in support of notification, coordination, transfer of *control, flight planning, airspace management and air traffic flow management. Procedural provisions relating to inter-centre communications are contained in 4.7.*

Note 7.— The aeronautical telecommunication network through its ATSMHS and ICC applications enable the transition of existing AFTN and CIDIN users and systems into the ATN architecture.

4.1.2 Material permitted in AFS messages

Note.— The provisions contained in 4.1.2 do not apply to ATS voice communications.

4.1.2.1 The following characters are allowed in text messages:

Letters: ABCDEFGHIJKLMNOPQRSTUVWXYZ

Figures:1 2 3 4 5 6 7 8 9 0

Other signs:

- - (hyphen)
- ? (question mark)
- : (colon)
- ((open bracket)
-) (close bracket)
- . (full stop, period, or decimal point)
- , (comma)
- ’ (apostrophe)
- = (double hyphen or equal sign)
- / (oblique)
- + (plus sign)

Characters other than those listed above shall not be used in messages unless absolutely necessary for understanding of the text. When used, they shall be spelled out in full.

4.1.2.2 For the exchange of messages over the teletypewriter circuits, the following signals of the International Telegraph Alphabet No. 2 (ITA-2) shall be permitted:

signals nos. 1 to 3 — in letter and in figure case;

signal no. 4 — in letter case only;

signal no. 5 — in letter and in figure case;

signals nos. 6 to 8 — in letter case only;

signal no. 9 — in letter and in figure case;

signal no. 10 — in letter case only; and

signals nos. 11 to 31 — in letter and figure case.

Note 1.— "Letter case" and "figure case" are to be understood as the shift condition in which the equipment associated with the channel was positioned prior to the reception of the signal.

Note 2.— When using any of the above signals, account is to be taken of, amongst others, the provisions of 4.4.5.3.

Note 3.— The foregoing provisions of 4.1.2.2 are not intended to prevent the use of:

a) figure case of signals nos. 6, 7 and 8 after bilateral agreements between States having telecommunication stations directly connected to each other;

b) figure case of signal no. 10 as the priority alarm (see 4.4.4.3); and

c) figure case of signal no. 4 for operational purposes only and not as part of a message.

4.1.2.3 For the exchange of messages over the teletypewriter circuits, the following characters of International Alphabet No. 5 (IA-5) shall be permitted:

— characters 0/1 to 0/3, 0/7 — in the priority alarm (see 4.4.15.2.2.5), 0/10, 0/11 — in the ending sequence (see 4.4.15.3.12.1), 0/13;

— characters 2/0, 2/7 to 2/9, 2/11 to 2/15;

— characters 3/0 to 3/10, 3/13, 3/15;

— characters 4/1 to 4/15;

— characters 5/0 to 5/10; and

— character 7/15.

Note.— The foregoing provisions of 4.1.2.3 are not intended to prevent the use of the full IA-5 after agreement between the Administrations concerned.

4.1.2.4 Roman numerals shall not be employed. If the originator of a message wishes the addressee to be informed that roman figures are intended, the arabic figure or figures shall be written and preceded by the word ROMAN.

4.1.2.5 Messages using the ITA-2 code shall not contain:

1) any uninterrupted sequence of signals nos. 26, 3, 26 and

3 (letter case and figure case) in this order, other than the one in the heading as prescribed in 4.4.2.1.1; and

2) any uninterrupted sequence of four times signal no. 14 (letter case and figure case) other than the one in the ending as prescribed in 4.4.6.1.

4.1.2.6 Messages using IA-5 shall not contain:

1) character 0/1 (SOH) other than the one in the heading as prescribed in 4.4.15.1.1 a);

2) character 0/2 (STX) other than the one in the origin line as prescribed in 4.4.15.2.2.7;

3) character 0/3 (ETX) other than the one in the ending as prescribed in 4.4.15.3.12.1;

4) any uninterrupted sequence of characters 5/10, 4/3, 5/10, 4/3 in this order (ZCZC);

5) any uninterrupted sequence of characters 2/11, 3/10, 2/11, 3/10 in this order (+:+:);

6) any uninterrupted sequence of four times character 4/14 (NNNN); and

7) any uninterrupted sequence of four times character 2/12 (,,,,).

4.1.2.7 The text of messages shall be drafted in plain language or in abbreviations and codes, as prescribed in 3.7. The originator shall avoid the use of plain language when reduction in the length of the text by appropriate abbreviations and codes is practicable.

Words and phrases which are not essential, such as expressions of politeness, shall not be used.

4.1.2.8 If the originator of a message wishes alignment functions [<≡] to be transmitted at specific places in the text part of such message (see4.4.5.3 and 4.4.15.3.6), the sequence [<≡] shall be written on each of those places.

4.2 ATS direct speech circuits

Note.— Provisions relating to ATS direct speech communications are contained in Chapter 6 of Annex 11.

4.3 Meteorological operational channels and meteorological operational telecommunication networks

Meteorological operational channel procedures and meteorological operational communication network procedures shall be compatible with aeronautical fixed telecommunications network (AFTN) procedures.

Note.— "Compatible" is to be interpreted as a mode of operation ensuring that the information exchanged over the meteorological operational channels also can be exchanged over the aeronautical fixed telecommunication network without harmful effect on the operation of the aeronautical fixed telecommunication network and vice versa.

4.4 Aeronautical fixed telecommunication network (AFTN)

4.4.1 General

4.4.1.1 **Categories of messages.** Subject to the provisions of 3.3, the following categories of message shall be handled by the aeronautical fixed telecommunication network:

a) distress messages;

b) urgency messages;

c) flight safety messages;

d) meteorological messages;

e) flight regularity messages;

f) aeronautical information services (AIS) messages;

g) aeronautical administrative messages;

h) service messages.

4.4.1.1.1 *Distress messages (priority indicator SS).* This message category shall comprise those messages sent by mobile stations reporting that they are threatened by grave and imminent danger and all other messages relative to the immediate assistance required by the mobile station in distress.

4.4.1.1.2 *Urgency messages (priority indicator DD).* This category shall comprise messages concerning the safety of a ship, aircraft or other vehicles, or of some person on board or within sight.

4.4.1.1.3 Flight safety messages (priority indicator FF) shall comprise:

a) movement and control messages as defined in PANS-ATM (Doc 4444), Chapter 11;

b) messages originated by an aircraft operating agency of immediate concern to aircraft in flight or preparing to depart;

c) meteorological messages restricted to SIGMET information, special air-reports, AIRMET messages, volcanic ash and tropical cyclone advisory information and amended forecasts.

4.4.1.1.4 Meteorological messages (priority indicator GG) shall comprise:

a) messages concerning forecasts, e.g. terminal aerodrome forecasts (TAFs), area and route forecasts;

b) messages concerning observations and reports, e.g. METAR, SPECI.

4.4.1.1.5 Flight regularity messages (priority indicator GG) shall comprise:

a) aircraft load messages required for weight and balance computation;

b) messages concerning changes in aircraft operating schedules;

c) messages concerning aircraft servicing;

d) messages concerning changes in collective requirements for passengers, crew and cargo covered by deviation from normal operating schedules;

e) messages concerning non-routine landings;

f) messages concerning pre-flight arrangements for air navigation services and operational servicing for non-scheduled aircraft operations, e.g. overflight clearance requests;

g) messages originated by aircraft operating agencies reporting an aircraft arrival or departure;

h) messages concerning parts and materials urgently required for the operation of aircraft.

4.4.1.1.6 Aeronautical information services (AIS) messages (priority indicator GG) shall comprise:

a) messages concerning NOTAMs;

b) messages concerning SNOWTAMs.

4.4.1.1.7 Aeronautical administrative messages (priority indicator KK) shall comprise:

a) messages regarding the operation or maintenance of facilities provided for the safety or regularity of aircraft operations;

b) messages concerning the functioning of aeronautical telecommunication services;

c) messages exchanged between civil aviation authorities relating to aeronautical services.

4.4.1.1.8 Messages requesting information shall take the same priority indicator as the category of message being requested except where a higher priority is warranted for flight safety.

4.4.1.1.9 Service messages (priority indicator as appropriate).This category shall comprise messages originated by aeronautical fixed stations to obtain information or verification concerning other messages which appear to have been transmitted incorrectly by the aeronautical fixed service, confirming channel-sequence numbers, etc.

4.4.1.1.9.1 Service messages shall be prepared in the format prescribed in 4.4.2 or 4.4.15. In applying the provisions of 4.4.3.1.2 or 4.4.15.2.1.3 to service messages addressed to an aeronautical fixed station identified only by a location indicator, this indicator shall be immediately followed by the ICAO three-letter designator YFY, followed by an appropriate 8th letter.

4.4.1.1.9.2 Service messages shall be assigned the appropriate priority indicator.

4.4.1.1.9.2.1 **Recommendation.—** *When service messages refer to messages previously transmitted, the priority indicator assigned should be that used for the message(s) to which they refer.*

4.4.1.1.9.3 Service messages correcting errors in transmission shall be addressed to all the addressees that will have received the incorrect transmission.

4.4.1.1.9.4 A reply to a service message shall be addressed to the station which originated the initial service message.

4.4.1.1.9.5 **Recommendation.—** *The text of all service messages should be as concise as possible.*

4.4.1.1.9.6 A service message, other than one acknowledging receipt of SS messages, shall be further identified by the use of the abbreviation SVC as the first item in the text.

4.4.1.1.9.7 When a service message refers to a message previously handled, reference to the previous message shall be made by use of the appropriate transmission identification (see 4.4.2.1.1 b) and 4.4.15.1.1 b)) or the filing time and originator indicator groups (see4.4.4 and 4.4.15.2.2) identifying the reference message.

4.4.1.2 Order of priority

4.4.1.2.1 The order of priority for the transmission of messages in the aeronautical fixed telecommunication network shall be as follows:

Transmission priority	Priority indicator
1	SS
2	DD FF
3	GG KK

4.4.1.2.2 **Recommendation**.— *Messages having the same priority indicator should be transmitted in the order in which they are received for transmission.*

4.4.1.3 Routing of messages

4.4.1.3.1 All communications shall be routed by the most expeditious route available to effect delivery to the addressee.

4.4.1.3.2 Predetermined diversion routing arrangements shall be made, when necessary, to expedite the movement of communication traffic. Each communication centre shall have the appropriate diversion routing lists, agreed to by the Administration(s) operating the communication centres affected and shall use them when necessary.

4.4.1.3.2.1 **Recommendation**.— Diversion routing should be initiated:

1) in a fully automatic communication centre:

a) immediately after detection of the circuit outage, when the traffic is to be diverted via a fully automatic communication centre;

b) within a 10-minute period after detection of the circuit outage, when the traffic is to be diverted via a non-fully automatic communication centre;

2) in a non-fully automatic communication centre within a 10-minute period after detection of the circuit outage.

Service message notification of the diversion requirement should be provided where no bilateral or multilateral prearranged agreements exist.

4.4.1.3.3 As soon as it is apparent that it will be impossible to dispose of traffic over the aeronautical fixed service within a reasonable period, and when the traffic is held at the station where it was filed, the originator shall be consulted regarding further action to be taken, unless:

a) otherwise agreed between the station concerned and the originator; or

b) arrangements exist whereby delayed traffic is automatically diverted to commercial telecommunication services without reference to the originator.

Note.— The expression "reasonable period" means a period of time such that it seems probable that the traffic will not be delivered to the addressee within any fixed transit period applicable to *the category of traffic concerned, or, alternatively, any predetermined period agreed between originators and the telecommunication station concerned.*

4.4.1.4 *Supervision of message traffic*

4.4.1.4.1 *Continuity of message traffic*. The receiving station shall check the transmission identification of incoming transmissions to ensure the correct sequence of channel sequence numbers of all messages received over that channel.

4.4.1.4.1.1 When the receiving station detects that one or more channel-sequence numbers are missing, it shall send a complete service message (see4.4.1.1.9) to the previous station rejecting receipt of any message that may have been transmitted with such missing number(s). The text of this service message shall comprise the signal QTA, the procedure signal MIS followed by one or more missing transmission identification (see4.4.2.1.1.3 and 4.4.15.1.1.4) and the end of-text signal (see4.4.5.6 and 4.4.15.3.12).

Note.— The following examples illustrate application of the above-mentioned procedure. In example 2) the hyphen (-) separator is understood to mean "through" in plain language.

1) when one channel-sequence number is missing:

SVC→QTA→MIS→ABC↑123↓<≡

2) when several channel-sequence numbers are missing:

SVC→QTA→MIS→ABC↑123-126↓<≡

4.4.1.4.1.1.1 When the provisions of 4.4.1.4.1.1 are applied, the station notified of the missing message(s) condition by the service message shall reassume its responsibility for transmission of the message (or messages) that it had previously transmitted with the transmission identification concerned, and shall retransmit that message (or those messages) with a new (correct in sequence) transmission identification. The receiving station shall synchronize such that the next expected channel-sequence number is the last received channel-sequence number plus one.

4.4.1.4.1.2 **Recommendation**.— *When the receiving station detects that a message has a channel sequence number less than that expected, it should advise the previous station using a service message with a text comprising:*

1) the abbreviation SVC;

2) the procedure signal LR followed by the transmission identification of the received message;

3) the procedure signal EXP followed by the transmission identification expected;

4) the end-of-text signal.

Note.— The following example illustrates application of the above-mentioned procedure:

SVC→LR→ABC↑123→↓EXP→ABC↑135↓<≡

4.4.1.4.1.2.1 **Recommendation**.— *When the provisions of 4.4.1.4.1.2 are applied, the station receiving the out-of sequence message should synchronize such that the next expected channel-sequence number is the last received channel-sequence number plus one. The previous station should check its outgoing channel-sequence numbers and, if necessary, correct the sequence.*

4.4.1.4.2 *Misrouted messages*

Note.— A message is considered to have been misrouted when it contains no relaying instructions, expressed or implied, on which the receiving station can take action.

4.4.1.4.2.1 When the receiving station detects that a message has been misrouted to it, it shall either:

1) send a service message (see4.4.1.1.9) to the previous station rejecting receipt of the misrouted message; or

2) itself assume responsibility for transmission of the message to all addressee indicators.

Note.— The procedure of 1) is preferable at stations using "torn-tape" relay methods or a semi-automatic relay technique with continuous tape. The procedure of 2) may be preferred at stations using fully automatic relay methods or a semi-automatic relay technique without continuous tape.

4.4.1.4.2.2 When the provisions of 4.4.1.4.2.1, 1) are applied, the text of the service message shall comprise the abbreviation SVC, the signal QTA, the procedure signal MSR followed by the transmission identification (see4.4.2.1.1.3 and 4.4.15.1.1.4) of the misrouted message and the end-of-text signal (see4.4.5.6 and 4.4.15.3.12).

Note.— The following example illustrates application of the above-mentioned procedure:

SVC→QTA→MSR→ABC↑123↓<≡

4.4.1.4.2.3 When, as a result of the provisions of 4.4.1.4.2.2, a sending station is notified of the misrouted message condition by service message, it shall reassume its responsibility for the message and shall retransmit as necessary on the correct outgoing channel or channels.

4.4.1.4.3 When a circuit becomes interrupted and alternative facilities exist, the last channel-sequence numbers sent and received shall be exchanged between the stations concerned. Such exchanges shall take the form of complete service messages (see4.4.1.1.9) with the text comprising the abbreviation SVC, the procedure signals LR and LS followed by the transmission identifications of the relevant messages and the end-of-text signal (see4.4.5.6 and 4.4.15.3.12).

Note. — The following example illustrates application of the above-mentioned procedure:

SVC→LR→ABC↑123↓→LS→BAC↑321↓<≡

4.4.1.5 *Failure of communications*

4.4.1.5.1 Should communication on any fixed service circuit fail, the station concerned shall attempt to re-establish contact as soon as possible.

4.4.1.5.2 **Recommendation**. — *If contact cannot be re-established within a reasonable period on the normal fixed service circuit, an appropriate alternative circuit should be used. If possible, attempts should be made to establish communication on any authorized fixed service circuit available.*

4.4.1.5.2.1 If these attempts fail, use of any available air-ground frequency shall be permitted only as an exceptional and temporary measure when no interference to aircraft in flight is ensured.

4.4.1.5.2.2 Where a radio circuit fails due to signal fadeout or adverse propagation conditions, a receiving watch shall be maintained on the regular fixed service frequency normally in use. In order to re-establish contact on this frequency as soon as possible there shall be transmitted:

a) the procedure signal DE;

b) the identification of the transmitting station transmitted three times;

c) the alignment function [<≡];

d) the letters RY repeated without separation for three lines of page copy;

e) the alignment function [<≡];

f) end-of-message signal (NNNN).

The foregoing sequence shall be repeated as required.

4.4.1.5.2.3 A station experiencing a circuit or equipment failure shall promptly notify other stations with which it is in direct communication if the failure will affect traffic routing by those stations. Restoration to normal shall also be notified to the same stations.

4.4.1.5.3 Where diverted traffic will not be accepted automatically or where a predetermined diversion routing has not been agreed, a temporary diversion routing shall be established by the exchange of service messages. The text of such service messages shall comprise:

1) the abbreviation SVC;

2) the procedure signal QSP;

3) if required, the procedure signal RQ, NO or CNL to request, refuse or cancel a diversion;

4) identification of the routing areas, States, territories, locations, or stations for which the diversion applies;

5) the end-of-text signal.

Note.— The following examples illustrate application of the above-mentioned procedures:

a) to request a diversion:

SVC→QSP→RQ→C→K→BG→BI↓<≡

b) to accept a diversion:

SVC→QSP→C→K→BG→BI↓<≡

c) to refuse a diversion:

SVC→QSP→NO→C→K→BG→BI↓<≡

d) to cancel a diversion:

SVC→QSP→CNL→C→K→BG→BI↓<≡

4.4.1.6 Long-term retention of AFTN traffic records

4.4.1.6.1 Copies of all messages, in their entirety, transmitted by an AFTN origin station shall be retained for a period of at least 30 days.

Note.— The AFTN origin station, although responsible for ensuring that AFTN traffic is recorded, is not necessarily the unit where the records are made and retained. By local agreement the State concerned may permit the originators to perform those functions.

4.4.1.6.2 AFTN destination stations shall retain, for a period of at least 30 days, a record containing the information necessary to identify all messages received and the action taken thereon.

Note.— The provision for identification of messages mentioned in 4.4.1.6.2 may be obtained by recording the heading, address and origin parts of messages.

4.4.1.6.3 **Recommendation.**— *AFTN communication centres should retain, for a period of at least 30 days, a record containing the information necessary to identify all messages relayed or retransmitted and the action taken thereon*.

Note 1.— The provision for identification of messages mentioned in 4.4.1.6.3 may be obtained by recording the heading, address and origin parts of messages.

Note 2.— Provisions relating to short-term retention of AFTN traffic records in AFTN communication centres are contained in 4.4.1.7.

4.4.1.7 Short-term retention of AFTN traffic records

4.4.1.7.1 Except as provided in 4.4.1.7.2, AFTN communication centres shall retain, for a period of at least one hour, a copy of all messages, in their entirety, retransmitted or relayed by that communication centre.

4.4.1.8 Test procedures on AFTN channels

4.4.1.8.1 **Recommendation**.— *Test messages transmitted on AFTN channels for the purpose of testing and repairing lines should consist of the following:*

1) the start-of-message signal;

2) the procedure signal QJH;

3) the originator indicator;

4) three page-copy lines of the sequence of characters RY in ITA-2 or U(5/5) *(2/10) in IA-5; and

5) the end-of-message signal.

4.4.2 Message format — International Telegraph Alphabet No. 2 (ITA-2)

All messages, other than those prescribed in 4.4.1.8 and

4.4.9.3, shall comprise the components specified in 4.4.2.1 to 4.4.6.1 inclusive.

Note 1.— An illustration of the ITA-2 message format is given in Figure 4-1.

Note 2.— In the subsequent Standards relative to message format the following symbols have been used in making reference to the functions assigned to certain signals in the International Telegraph Alphabet No. 2 (see Volume III, Part I, 8.2.1 and Table 8-1):

Symbol	Signification
<	CARRIAGE RETURN (signal no. 27)
≡	LINE FEED (signal no. 28)
↓	LETTER SHIFT (signal no. 29)
↑	FIGURE SHIFT (signal no. 30)
→	SPACE (signal no. 31)

4.4.2.1 Heading

4.4.2.1.1 The heading shall comprise:

a) start-of-message signal, the characters ZCZC;

b) transmission identification comprising:

1) circuit identification;

2) channel-sequence number.

c) additional service information (if necessary) comprising:

1) one SPACE;

2) no more than ten characters.

d) spacing signal.

4.4.2.1.1.1 The circuit identification shall consist of three letters selected and assigned by the transmitting station; the first letter identifying the transmitting, the second letter the receiving end of the circuit and the third letter to identify the channel; where there is only one channel between the transmitting and receiving stations, channel letter A shall be assigned; where more than one channel between stations is provided, the channels shall be identified as A, B, C, etc. in respective order.

4.4.2.1.1.2 Three-digit channel-sequence numbers from 001 to 000 (representing 1 000) shall be assigned sequentially by telecommunication stations to all messages transmitted directly from one station to another. A separate series of these numbers shall be assigned for each channel and a new series shall be started daily at 0000 hours.

4.4.2.1.1.2.1 **Recommendation.—** The use of the 4-digit channel-sequence number, to preclude duplication of the same numbers during the 24-hour period, is permitted subject to agreement between the authorities responsible for the operation of the circuit.

4.4.2.1.1.3 The transmission identification shall be sent over the circuit in the following sequence:

a) SPACE [→];

b) transmitting-terminal letter;

c) receiving-terminal letter;

d) channel-identification letter;

e) FIGURE SHIFT [↑];

f) channel-sequence number (3 digits).

Message part		Component of the message part	Element of the component	Teletypewriter signal
HEADING (*see* 4.4.2.1)		Start-of-Message Signal	—	**ZCZC**
		Transmission Identification	a) One SPACE b) Transmitting-terminal letter c) Receiving-terminal letter d) Channel-identification letter e) One FIGURE SHIFT f) Channel-sequence number (3 digits) (*Example:* NRA062)	→ ... ↑ ...
		(*If necessary*) Additional Service Indication	a) One SPACE b) No more than 10 characters (*Example:* 270930)	
		Spacing Signal	Five SPACES One LETTER SHIFT	→→→→→↓
ADDRESS (*see* 4.4.3)	THE PERMANENT PART OF A MESSAGE	Alignment Function	One CARRIAGE RETURN, one LINE FEED	<≡
		Priority Indicator	The relevant 2-letter group	...
		Addressee Indicator(s)	One SPACE / An 8-letter group — given in sequence for each addressee (*Example:* →**EGLLZRZX**→**EDLLYKYX**→**EGLLACAM**)	
		Alignment Function(s)	One CARRIAGE RETURN, one LINE FEED	<≡
ORIGIN (*see* 4.4.4)		Filing Time	One FIGURE SHIFT The 6-digit date-time group specifying when the message was filed for transmission One LETTER SHIFT	↑ ...... ↓
		Originator Indicator	One SPACE The 8-letter group identifying the message originator	→ ......
		Priority Alarm (*used only in teletypewriter operation for Distress Messages*)	One FIGURE SHIFT Five Signal No. 10 of Telegraph Alphabet No. 2 One LETTER SHIFT	↑ Attention ↓ Signal(s)
		Optional Heading Information	a) One SPACE b) Additional data not to exceed the remainder of the line. See 4.4.4.4.	
		Alignment Function	One CARRIAGE RETURN, one LINE FEED	<≡
TEXT (*see* 4.4.5)		Beginning of the Text	Specific identification of Addressee(s) (*if necessary*) *with* each followed by one CARRIAGE RETURN, one LINE FEED (*if necessary*) The English word FROM (*if necessary*) (*see* 4.4.5.2.3) Specific identification of Originator (*if necessary*) The English word STOP followed by one CARRIAGE RETURN, one LINE FEED (*if necessary*) (*see* 4.4.5.2.3); *and/or* Originator's reference (*if used*)	
		Message Text	Message Text with one CARRIAGE RETURN, one LINE FEED at the end of each printed line of the Text except for the last one (*see* 4.4.5.3)	
		Confirmation (*if necessary*)	a) One CARRIAGE RETURN, one LINE FEED b) The abbreviation CFM followed by the portion of the Text being confirmed	
		Correction (*if necessary*)	a) One CARRIAGE RETURN, one LINE FEED b) The abbreviation COR followed by the correction of an error made in the preceding Text	
		End-of-Text Signal	a) One LETTER SHIFT b) One CARRIAGE RETURN, one LINE FEED	↓<≡
ENDING (*see* 4.4.6)		Page-Feed Sequence	Seven LINE FEEDS	≡≡≡≡≡≡≡
		End-of-Message Signal	Four of the letter case of N (Signal No. 14)	NNNN
		Message-Separation Signal (*used only on message traffic transmitted to a "torn-tape" station*)	Twelve LETTER SHIFTS	↓↓↓↓↓↓↓↓↓↓↓↓
		Tape Feed (*see* 4.4.7)	Additional LETTER SHIFTS will appear at this point in instances where prior arrangements have been made for tape-feed transmissions to be employed on an incoming circuit (*see* 4.4.7).	

Legend: ↑ FIGURE SHIFT (*Signal No. 30*) ≡ LINE FEED (*Signal No. 28*) ↓ LETTER SHIFT (*Signal No. 29*)
→ SPACE (*Signal No. 31*) < CARRIAGE RETURN (*Signal No. 27*)

Figure 4-1. Message format ITA-2

(the above illustrates the teletypewriter message format prescribed in 4.4.2 to 4.4.9.1 inclusive)

4.4.2.1.2 In teletypewriter operation, the spacing signal, consisting of 5 SPACES [→→→→→] followed by 1 LETTER SHIFT [↓], shall be transmitted immediately following the transmission identification prescribed in 4.4.2.1.1.3.

Note.— The examples appearing below illustrate the application of the transmission identification Standard (see 4.4.2.1.1 b) and 4.4.2.1.1.3):

Tape	Page-copy
→GLB↑039→→→→→↓	GLB039

(This indicates the 39th message of the day transmitted on Channel B of the circuit from Station G to Station L.)

4.4.2.1.3 Optional service information shall be permitted to be inserted following the transmission identification subject to agreement between the authorities responsible for the operation of the circuit. Such additional service information shall be preceded by a SPACE followed by not more than ten characters and shall not contain any alignment functions.

4.4.2.1.4 **Recommendation.—** *To avoid any misinterpretation of the diversion indicator especially when considering the possibility of a partly mutilated heading, the sequence of two consecutive signals no. 22 (in the letter case or in the figure case) should not appear in any other component of the heading.*

4.4.3 Address

4.4.3.1 The address shall comprise:

a) alignment function [<≡];

b) priority indicator;

c) addressee indicator(s);

d) alignment function [<≡].

4.4.3.1.1 The priority indicator shall consist of the appropriate two-letter group assigned by the originator in accordance with the following:

Priority

Message category	Priority indicator
distress messages (see4.4.1.1.1)	SS
urgency messages (see4.4.1.1.2)	DD
flight safety messages (see4.4.1.1.3).	FF
meteorological messages (see4.4.1.1.4)	GG
flight regularity messages (see4.4.1.1.5)	GG
aeronautical information services messages (see4.4.1.1.6)	GG
aeronautical administrative messages (see4.4.1.1.7).	KK
service messages (see4.4.1.1.9)	(as appropriate)

4.4.3.1.2 An addressee indicator, which shall be immediately preceded by a SPACE, except when it is the first address indicator of the second or third line of address shall comprise:

a) the four-letter location indicator of the place of destination;

b) the three-letter designator identifying the organization/ function (aeronautical authority, service or aircraft operating agency) addressed;

c) an additional letter, which shall represent a department, division or process within the organization/function addressed. The letter X shall be used to complete the address when explicit identification is not required.

Note 1.— The four-letter location indicators are listed in Doc 7910 — Location Indicators.

Note 2.— The three-letter designators are listed in Doc 8585 — Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services.

4.4.3.1.2.1 Where a message is to be addressed to an organization that has not been allocated an ICAO three-letter designator of the type prescribed in 4.4.3.1.2, the location indicator of the place of destination shall be followed by the ICAO three-letter designator YYY (or the ICAO three-letter designator YXY in the case of a military service or organization). The name of the addressee organization shall then be included in the first item of the text of the message. The eighth position letter following the ICAO three-letter designator YYY or YXY shall be the filler letter X.

4.4.3.1.2.2 Where a message is to be addressed to an aircraft in flight and, therefore, requires handling over the AFTN for part of its routing before retransmission over the aeronautical mobile service, the location indicator of the aeronautical station which is to relay the message to the aircraft shall be followed by the ICAO three-letter designator ZZZ. The identification of the aircraft shall then be included in the first item of the text of the message. The eighth position letter following the ICAO three-letter designator ZZZ shall be the filler letter X.

Note.— The following examples illustrate application of the Standards in 4.4.3.1.2.1 and 4.4.3.1.2.2:

1) addressee indicators (possible types):

LGATZTZX	*aerodrome control tower (ZTZ) at LGAT*
LGATYMYF	*section (F) of the Meteorological Office (YMY) at LGAT*
LGATKLMN	*department (N) of the aircraft operating agency KLM (KLM) at LGAT*
LGATYYYX	*the aircraft operating agency whose name appears in the beginning of the message text and whose office location is served by LGAT*
LGATZZZX	*the aeronautical station (LGAT) is required to relay this message in the aeronautical mobile service to the aircraft whose identification appears in the beginning of the message text.*
2) YYY ICAO	*three-letter designator:*

Example of a message addressed to (say) “Penguin Airlines” at NCRG by the PHNL office of the same aircraft operating agency. The Heading and Ending of the message are not shown in this example of teletypewriter page-copy form.

(Address) *GG NCRGYYYX*
(Origin) *311521 PHNLYYYX*
(Text) *AIR PENGUIN FLIGHT 801*

CANCELLED

3) ZZZ ICAO *three-letter designator:*

Example of a message addressed to aircraft GABCD via aeronautical station NZAA from Area Control Centre at NZZC. The Heading and Ending of the message are not shown in this example of teletypewriter page-copy form.

(Address) *FF NZAAZZZX*
(Origin) *031451 NZZCZQZX*
(Text) *GABCD CLR DES 5000FT HK NDB*

4.4.3.1.2.3 The complete address shall be restricted to three lines of page-printing copy and, except as provided in 4.4.14, a separate addressee indicator shall be used for each addressee whether at the same or at different locations.

4.4.3.1.2.3.1 Where messages are offered in page-copy form for transmission and contain more addressee indicators than can be accommodated on three lines of a page-copy, such message shall be converted, before transmission, into two or more messages, each of which shall conform with the provisions of 4.4.3.1.2.3. During such conversion, the addressee indicators shall, in so far as practicable, be positioned in the sequence which will ensure that the minimum number of retransmissions will be required at subsequent communication centres.

4.4.3.1.2.3.2 On teletypewriter circuits, the completion of each line of addressee indicator groups in the address of a message shall be immediately followed by the alignment function [<≡].

4.4.4 Origin

The origin shall comprise:

a) filing time;

b) originator indicator;

c) priority alarm (when necessary);

d) optional heading field;

e) alignment function [<≡].

4.4.4.1 The filing time shall comprise the 6-digit date-time group indicating the date and time of filing the message for transmission (see3.4.2); in teletypewriter operation, the filing time shall be followed by one LETTER SHIFT [↓].

4.4.4.2 An originator indicator, which shall be immediately preceded by a SPACE, shall comprise:

a) the four-letter location indicator of the place at which the message is originated;

b) the three-letter designator identifying the organization/ function (aeronautical authority, service or aircraft operating agency) which originated the message;

c) an additional letter which shall represent a department, division or process within the organization/function of the originator. The letter X shall be used to complete the address when explicit identification is not required.

4.4.4.2.1 Where a message is originated by an organization that has not been allocated an ICAO three-letter designator of the type prescribed in 4.4.4.2 b), the location indicator of the place at which the message is originated shall be followed immediately by the ICAO three-letter designator YYY followed by the filler letter X (or the ICAO three-letter designator YXY followed by the filler letter X in the case of a military service or organization). The name of the organization (or military service) shall then be included in the first item in the text of the message.

4.4.4.2.2 Where a message originated by an aircraft in flight requires handling on the AFTN for part of its routing before delivery, the originator indicator shall comprise the location indicator of the aeronautical station responsible for transferring the message to the AFTN, followed immediately by the ICAO three-letter designator ZZZ followed by the filler letter X. The identification of the aircraft shall then be included in the first item in the text of the message.

4.4.4.2.3 Messages relayed over the AFTN that have been originated in other networks shall use a valid AFTN originator indicator that has been agreed for use by the relay or gateway function linking the AFTN with the external network.

Note.— The following illustrates the application of 4.4.4.2.2 procedure as it would appear with a message from aircraft KLM153 addressed to the Area Control Centre at CZEG, the message being handled via aeronautical station CYCB. The heading and ending of the message are not shown in this example of teletypewriter page-copy form:

(Address)	*FF CZEGZRZX*
(Origin)	*031821 CYCBZZZX*
(Text)	*KLM153 [remainder of text as received from aircraft]*

4.4.4.3 The priority alarm shall be used only for distress messages. When used, it shall consist of the following, in the order stated:

a) FIGURE SHIFT [↑];

b) FIVE transmissions of signal no. 10 (figure case);

c) LETTER SHIFT [↓].

Note 1.— The figure case of signal no. 10 of the International Telegraph Alphabet No. 2 generally corresponds to the figure case of J of teletypewriter equipment in use on aeronautical fixed service circuits.

Note 2.— Use of the priority alarm will actuate a bel (attention) signal at the receiving teletypewriter station, other than at those fully automatic stations which may provide a similar alarm on receipt of priority indicator SS, thereby alerting supervisory personnel at relay centres and operator at tributary stations, so that immediate attention may be given to the message.

4.4.4.4 The inclusion of optional data in the origin line shall be permitted provided a total of 69 characters is not exceeded and subject to agreement between the authorities concerned. The presence of the optional data field shall be indicated by one occurrence of the SPACE character immediately preceding optional data.

4.4.4.4.1 **Recommendation.—** *When additional addressing information in a message needs to be exchanged between source and destination addresses, it should be conveyed in the optional data field (ODF), using the following specific format:*

a) characters one and full stop (1.) to indicate the parameter code for the additional address function;

b) three modifier characters, followed by an equal sign [=] and the assigned 8-character ICAO address; and

c) the character hyphen (-) to terminate the additional address parameter field.

4.4.4.4.1.1 **Recommendation.—** *When a separate address for service messages or inquiries is different from the originator indicator, the modifier SVC should be used.*

4.4.4.5 The origin line shall be concluded by an alignment function [<≡].

4.4.5 Text

4.4.5.1 The text of messages shall be drafted in accordance with 4.1.2.

4.4.5.2 When an originator's reference is used, it shall appear at the beginning of the text, except as provided in 4.4.5.2.1 and 4.4.5.2.2.

4.4.5.2.1 When the ICAO three-letter designators YXY, YYY or ZZZ comprise the second element of the addressee indicator (see4.4.3.1.2.1 and 4.4.3.1.2.2) and it, therefore, becomes necessary to identify in the text the specific addressee of the message, such identification group will precede the originator's reference (if used) and become the first item of the text.

4.4.5.2.2 When the ICAO three-letter designators YXY, YYY or ZZZ comprise the second element of the originator indicator (see4.4.4.2.1 and 4.4.4.2.2) and it thus becomes necessary to identify in the text the name of the organization (or military service), or the aircraft, which originated the message, such identification shall be inserted in the first item of the text of the message.

4.4.5.2.3 When applying the provisions of 4.4.5.2.1 and 4.4.5.2.2 to messages where the ICAO three-letter designator(s) YXY, YYY or ZZZ is (are) used to refer to two or more different organizations (or military services), the sequence of further identification in the text shall correspond to the complete sequence used in the address and origin of the message. In such instance, each addressee identification shall be followed immediately by an alignment function. The name of the (YXY, YYY or ZZZ) organization originating the message shall then be preceded with "FROM". "STOP" followed by an alignment function shall then be included in the text at the end of these identifications to precede the remainder of the text wording.

4.4.5.3 An alignment function [<≡] shall be transmitted at the end of each printed line of the text except for the last (see4.4.5.6).

4.4.5.4 When it is desired to confirm a portion of the text of a message in teletypewriter operation, such confirmation shall be separated from the last text group by an alignment function [<≡], and shall be indicated by the abbreviation CFM followed by the portion being confirmed.

4.4.5.5 When it is discovered that an error has been made in the text, the correction shall be separated from the last text group or confirmation, if any, by an alignment function [<≡] in the case of teletypewriter circuits. This shall be followed by the abbreviation COR and the correction.

4.4.5.5.1 Stations shall make all indicated corrections on the page-copy prior to local delivery.

4.4.5.6 At the end of the text the following end-of-text signal shall be transmitted:

1 LETTER SHIFT [↓], alignment function [<≡].

4.4.5.7 The text of the messages entered by the AFTN origin station shall not exceed 1 800 characters in length.

Note 1.— Where it is desired that a communication with a text exceeding 1 800 characters be transmitted over the aeronautical fixed telecommunication network, 4.4.5.7 requires that such a communication be entered by the AFTN origin station in the form of separate messages, each text of which does not exceed 1 800 characters. Guidance material for forming separate messages from a single long message is given in Attachment B to Volume II.

Note 2.— The character count includes all printing and non-printing characters in the message from, but not including, the alignment function preceding the beginning of the text to, but not including, the end-of-text signal.

4.4.6 Ending

4.4.6.1 The ending shall comprise:

a) the page-feed sequence consisting of 7 LINE FEEDS [≡≡≡≡≡≡≡];

Note.— This, together with the 1 LINE FEED of the preceding alignment function, will provide sufficient separation between messages when appearing in page copy form.

b) the end-of-message signal, consisting of the letter N (letter case of signal no. 14), appearing FOUR times in undivided sequence.

Note.— This component, transmitted intact from the moment of the first transmission of the message until ultimate delivery, is required so that connections set up for cross-office transmission, at a semi-automatic or fully automatic relay installation, can be cleared for following message traffic.

And in addition, on message traffic transmitted to "torn-tape" relay stations only:

c) the message-separation signal, consisting of a LETTER SHIFT [↓] transmitted 12 times in uninterrupted sequence.

Note 1.— Nothing but letter shifts are to be transmitted in message traffic between the end-of-message signal of one message and the start-of-message signal of the next.

Note 2.— The following illustrates the procedures specified in 4.4.2 to 4.4.6.1 inclusive for a message in page-copy form:

(Heading)	**ZCZC LPA183*
(Address)	*GG LGGGZRZX LGATKLMW*
(Origin)	*201838 EGLLKLMW*
(Text)	*As required*
(Ending)	*(Page feed)* *NNNN***

**Note 2A.— If this message had been one of a series and there had been no manual paper-feed action between messages by the operator attending the receiving page teletypewriter, the "NNNN" of the preceding message would have appeared here.*

***Note 2B.— In the circumstances described in Note 2A, the heading of the next message received would be printed on page-copy at this position.*

Note 2C.— In actual station practice, messages would be separated on page-copy by tearing through the page-feed sequence. The end-of-message signal would then appear to have become a *component part of the next message. This apparent misplacement is, however, unlikely to give rise to any misunderstanding on the part of communicators or addressees since, in practice, the end-of-message signal has no significance on page-copy.*

4.4.6.2 AFTN messages entered by the AFTN origin station shall not exceed 2 100 characters in length.

Note.— The character count includes all printing and non-printing characters in the message from and including the start-of-message signal (ZCZC) to and including the end-of message signal (NNNN).

4.4.7 Tape feed

4.4.7.1 **Recommendation.—** *In "torn-tape" installations, and in "semi-automatic" installations using continuous tape technique, when signals additional to those prescribed in 4.4.6.1 are required to ensure that the tape is adequately advanced from the reperforator at the receiving stations, when the ending of one message is not followed immediately by the start-of-message signal of another message, local arrangements should be made at the receiving station to avoid the need for transmission of these signals by the transmitting station.*

Note.— In "torn-tape" stations, a facility is normally necessary whereby the tape can be fed from the receiving reperforator to an extent that permits the receiving operator to tear through the message-separation signal at the correct point, on occasions when the operator is ready to tear the tape but there has been no following message to cause this tape feed to take place. In semi-automatic stations using continuous-tape techniques, a similar process may be necessary in similar circumstances to advance the tape to an extent that permits the end-of-message signal to reach the transmitter.

4.4.7.1.1 When the provisions of 4.4.7.1 cannot be applied, arrangements shall be made with the transmitting station for the latter to send, at the end of a single message, or following the last message of a series, an agreed number of LETTER SHIFTS [↓] in addition to the components prescribed in 4.4.6.

4.4.8 Stripped address

When applying the provisions of 4.4.3 or 4.4.15.2.1, an AFTN communication centre shall omit from the address all the addressee indicators not required for:

a) onward transmission by the AFTN communication centre to which the message is transmitted;

b) local delivery to the addressee(s) by the AFTN destination station;

c) onward transmission or local delivery by the aggregate of stations on a multi-point circuit.

4.4.9 Teletypewriter operating procedure — general

4.4.9.1 End-of-line functions

4.4.9.1.1 A single line of page-copy shall not contain more than a total of 69 characters and/or spaces.

4.4.9.1.2 One CARRIAGE RETURN [<] and one LINE FEED IMPULSES [≡] shall be transmitted between each printed page-line of the text of a message.

4.4.9.2 *Duration of transmissions*. For simplex circuits, the transmission of a series of messages in a single transmission shall not continue for longer than approximately five minutes. Action shall be taken to deliver or relay each message correctly received without waiting for the end of the series.

4.4.9.3 *Channel-check transmissions*. Except as provided in 4.4.9.3.3 and 4.4.9.3.5 the following periodic transmissions shall be sent on teletypewriter circuits:

1) heading (see4.4.2.1.1);

2) alignment function [<≡];

3) the procedure signal CH;

4) alignment function [<≡];

5) end-of-message signal [NNNN];

6) message-separation signal [↓↓↓↓↓↓↓↓↓↓↓↓] (if required).

The receiving station shall then check the transmission identification of this incoming transmission to ensure its correct sequence in respect of all messages received over that incoming channel.

Note.— Application of this procedure provides some measure of assurance that channel continuity is maintained.

4.4.9.3.1 **Recommendation.—** *Where a circuit is unoccupied, the transmission specified in 4.4.9.3 should be sent at H + 00, H + 20, H + 40.*

4.4.9.3.2 If a periodic channel check transmission is not received within a tolerance agreed for that channel, a station shall send a service message to the station from which the transmission was expected. The text of this service message shall comprise:

1) the abbreviation SVC;

2) the procedure signal MIS;

3) the procedure signal CH;

4) (optionally) the time at which the transmission was expected;

5) the procedure signal LR;

6) the transmission identification of the last message received;

7) the end-of-text signal.

Note.— The following example illustrates application of the above-mentioned procedure:

SVC→MIS→CH→[↑1220↓→]LR→ABC↑123↓<≡

4.4.9.3.3 When a teletypewriter channel is equipped with a system of controlled circuit protocol, and following agreement between the Administrations responsible, the transmission specified in 4.4.9.3 shall not be made.

4.4.9.3.4 *Channel-check transmissions and station radio identifications*. In order to satisfy the requirements of ITU regarding periodic transmission of the station radio identification, those AFTN stations using radio teletypewriter channels may combine the station radio identification transmission with the channel-check transmission specified in

4.4.9.3. In this case the combined transmission shall be sent as follows:

1) heading (see4.4.2.1.1);

2) alignment function [<≡];

3) the procedure signal CH;

4) alignment function [<≡];

5) the procedure signal DE followed by one SPACE [→] and the assigned ITU radio call sign;

6) alignment function [<≡];

7) end-of-message signal [NNNN];

8) message-separation signal [↓↓↓↓↓↓↓↓↓↓↓↓] (if required).

Note.— Application of this format will permit this special transmission to be handled by fully automatic switching centres without the intervention of supervisory personnel.

4.4.9.3.4.1 Recommendation.— When multichannel radioteletypewriter circuits are used (e.g. MET and AFTN) the station radio call sign transmission should be sent on only one channel of the circuit. The channel chosen should be the one which is the most convenient for this purpose with the identification transmission being sent in conformance with the format used on that channel. When an AFTN channel is chosen the identification transmission should be combined with the channel-check transmission.

4.4.9.3.5 When a teletypewriter circuit is associated with Automatic Error Correction (ARQ) equipment, and following agreement between the Administrations responsible, the transmissions specified in 4.4.9.3 need not be made: however stations employing radioteletypewriter channels on the AFTN for which the station radio identification is required, shall comply with the provisions of 4.4.9.3.4.

Note.— The foregoing is not to be interpreted as implying any ICAO requirement necessitating the installation of Automatic Error Correction (ARQ) equipment on international aeronautical fixed circuits.

4.4.10 Normal teletypewriter transmission procedures

4.4.10.1 Messages shall be transmitted in accordance with predetermined responsibility for onward relay as agreed between the Administrations responsible for the operation of directly connected stations (see also4.4.1.3 and 4.4.1.5.2.3).

4.4.10.1.1 Arising from the responsibility agreements established under the provisions of4.4.10.1, each station of the AFTN shall employ and, subject to the provisions of 4.4.10.1.1.1, adhere to a Routing Directory which consists of the Routing List.

4.4.10.1.1.1 When an incoming message contains only identical location indicators in the lines-following-the-heading the receiving station shall accept responsibility for further relay. If possible such relay shall be effected on the normal outgoing circuit to the place of destination of the message; if it is not possible to use the normal circuit, an appropriate alternative outgoing circuit shall be used. When neither of these facilities is in operation, the message shall not be retransmitted over the circuit from which it was received, without prior service message (see4.4.1.1.9) notification of this action being given to the station that had made the previous transmission.

4.4.10.1.1.2 **Recommendation**. – *An AFTN message originator not capable of handling service messages should agree with the AFTN centre it is connected to on a method of exchanging service messages.*

Note.— A method of specifying service address in the optional data field is shown in4.4.4.4.2 and 4.4.4.4.2.1.

4.4.10.1.2 *Form of transmission – teletypewriter operation*. All transmissions shall comprise in the following order (see Figure 4-2).

4.4.10.1.2.1 *Starting pulse.* When the receiving station uses equipment fitted with a time-switch to stop the teletypewriter machine motor when the channel is idle, a 20-30 millisecond SPACING IMPULSE shall be transmitted when the channel has been at rest for 30 seconds or more and at least 1.5 seconds shall be permitted to elapse before the transmission of the heading.

Note 1.— This is equivalent to the transmission of a LETTER SHIFT [↓], followed by a pause (i.e. a continuous MARKING IMPULSE) of at least 1.37 seconds.

Note 2.— Application of this procedure will allow the receiving equipment to reach synchronization before transmission of the heading is commenced.

4.4.10.1.3 *Message format.* All messages shall be prepared in accordance with the provisions of 4.4.2 (ITA-2 format) or 4.4.15 (IA-5 format).

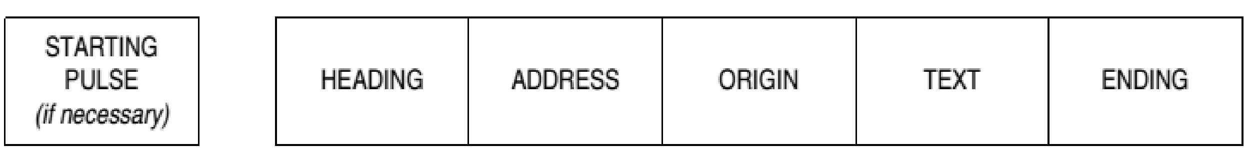

Figure 4-2. Form of transmission — teletypewriter operation (see 4.4.10.1.2)

4.4.10.1.3.1 **Recommendation.**— *The Heading Line, with the exception of the SOH character, should be omitted on circuits employing one of the data link control procedures contained in 8.6.3 and 8.6.4 of Annex 10, Volume III.*

4.4.10.1.4 Reprocessing procedures

4.4.10.1.4.1 A message requiring retransmission shall have its previous heading deleted by the station which received such message for relay. The retransmission shall commence with the new heading using the transmission identification for the outgoing channel.

4.4.10.1.4.1.1 When applying the provisions of 4.4.10.1.4.1, transmission of the address part of the message shall commence at some point during the 5 SPACES, 1 LETTER SHIFT [→→→→→↓] immediately preceding the first alignment function [<≡].

4.4.10.1.4.1.2 At tributary and "torn-tape" relay stations not equipped with automatic numbering machine devices and hence where it is necessary for a small number of additional teletypewriter characters to be perforated on a tape before the start-of-message signal to preclude risk of mutilation of the latter signal during retransmission, such additional characters, as required, shall consist of LETTER SHIFTS [↓]. Subsequent transmission on the outgoing channel shall then commence at a point as close as practicable to the start-of-message signal.

4.4.10.1.4.1.3 At stations where the heading of a message is originated by automatic equipment at the point of and time of transmission on the outgoing channel, but where preparation of the other parts of a message is by the perforation of a tape and where, therefore, it is necessary for a small number of additional teletypewriter characters to be perforated before the alignment function [<≡] at the commencement of the address so as to preclude risk of mutilation of this alignment function, such additional characters, as required, shall consist of LETTER SHIFTS [↓] or SPACES [→]. Subsequent transmission on the outgoing channel shall then commence at a point as close as practicable to the first alignment function [<≡] of the message.

4.4.10.1.4.2 At a "torn-tape" station the incoming tapes shall be torn at a position in the message-separation signal component (see4.4.6.1 and 4.4.7.1) so that the preceding end of-message signal remains intact.

4.4.10.1.4.2.1 Following application of the provisions of 4.4.10.1.4.2 the shortened (i.e. less than 12 LETTER SHIFTS [↓]) message-separation signal remaining on the message tape shall be deleted, if necessary by electronic methods, before retransmission to an automatic relay installation. If the retransmission is to another “torn-tape” station then:

1) the shortened message-separation signal shall be reformed to a complete [↓↓↓↓↓↓↓↓↓↓↓↓] signal by transmission of the necessary number of additional LETTER SHIFTS [↓]; or

2) the shortened message-separation signal remaining on the tape shall be removed and a new and complete message-separation signal shall be added to the message in the process of retransmission in accordance with the provisions of 4.4.6.1 c).

4.4.10.1.5 When possible in “torn-tape” or semiautomatic installations, a correct tape shall be obtained prior to onward relay; when tape is illegible or mutilated the station shall not relay the message unless good judgement indicates that this is not likely to result in malfunctioning of equipment at subsequent relay stations.

4.4.10.1.6 *Acknowledgement of receipt of messages*. In teletypewriter operation and except as provided in 4.4.10.1.6.1, a receiving station shall not transmit acknowledgement of receipt of incoming messages. In lieu thereof the provisions of 4.4.1.4.1 shall be applied.

4.4.10.1.6.1 The receipt of distress messages (priority SS — see4.4.1.1.1) shall be individually acknowledged by the AFTN destination station sending a service message (see 4.4.1.1.9) to the AFTN origin station. Such acknowledgement of receipt shall take the format of a complete message addressed to the AFTN origin station, shall be assigned priority indicator SS and the associated priority alarm (see 4.4.4.3) and shall have a text comprising:

1) the procedure signal R;

2) the origin (see4.4.4), without priority alarm, or optional heading information of the message being acknowledged;

3) the end-of-text signal [↓<≡].

Note.— The following example illustrates the application of 4.4.10.1.6.1 procedure:

Heading *(see 4.4.2.1.1)*
<≡SS→LECBZRZX<≡
↑121322↓→EGLLYFYX (Priority Alarm) <≡
R→↑121319↓→LECBZRZX↓<≡

Ending *(see 4.4.6)*

4.4.10.1.7 In cases where an addressee of a multi-address message requests a repetition of the message from the origin station, the origin station shall address the repeat of the message only to the addressee requesting the repeat. Under these conditions the procedure signal DUPE shall not be included.

4.4.11 Action on mutilated or improperly formatted messages detected in teletypewriter relay stations

4.4.11.1 If, before retransmission is commenced, a relay station detects that a message has been mutilated or improperly formatted at some point ahead of the end-of-message signal, and it has reason to believe that this mutilation had occurred before the message had been received by the previous station, it shall send a service message (see4.4.1.1.9) to the originator as identified by the originator indicator in the origin of the mutilated or improperly formatted message, requesting repetition of the incorrectly received message.

Note 1.— The following example illustrates a typical text of a service message in which the foregoing procedure has been applied in respect of a mutilated message having as its origin “141335 CYULACAX”:

SVC→QTA→RPT→↑141335↓→CYULACAX↓<≡

Note 2.— This circumstance of detection of a mutilation may only be possible at “torn-tape” relay stations.

4.4.11.2 When the provisions of 4.4.11.1 are applied, the originator as identified by the originator indicator in the origin of the mutilated message shall reassume responsibility for the mutilated message, and shall comply with the provisions of 4.4.11.3.

4.4.11.3 Following application of the provisions of 4.4.11.2, the following reprocessing shall be accomplished before the unmutilated version of the message is transmitted for the second time towards the same addressee or addressees:

1) *insert* a new heading;

2) *remove* the ending of the message (see4.4.6.1);

3) *insert* in lieu thereof the procedure signal DUPE, preceded by at least 1 LETTER SHIFT [↓] and followed by 1 CARRIAGE RETURN, 8 LINE FEEDS, end-of-message signal and, if necessary (see4.4.6 and 4.4.7), the LETTER SHIFTS [↓] of the message-separation signal and tape feed.

Note.— The example appearing in Figure 4-3 illustrates the application of this procedure.

4.4.11.4 If, before retransmission is commenced, a relay station detects that one or more messages have been mutilated at some point ahead of the end-of-message signal, and it has reason to believe that this mutilation had occurred during or subsequent to its transmission from the previous station, it shall send a service message (see4.4.1.1.9) to the previous station rejecting the mutilated transmission and requesting a repetition of the incorrectly received message (or messages).

Note 1.— The following examples illustrate application of the above-mentioned procedure. In example 2) the hyphen (-) separator is understood to mean "through" in plain language.

1) in respect of a single mutilated message:

SVC→QTA→RPT→ABC↑123↓<≡

2) in respect of several mutilated messages:

SVC→QTA→RPT→ABC↑123-126↓<≡

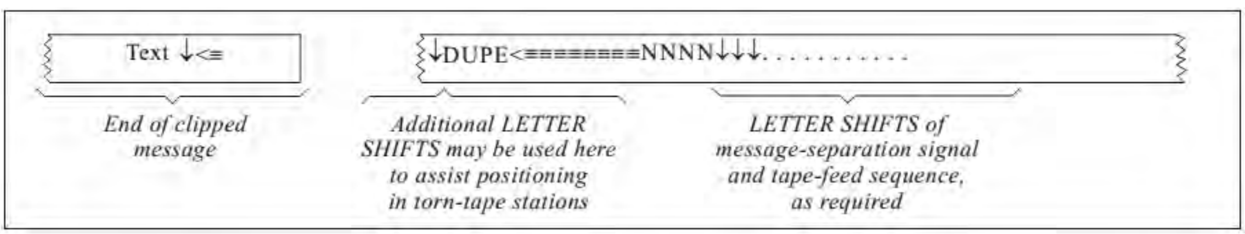

Figure 4-3. Example of application of 4.4.11.3 procedure

Note 2.— This circumstance of detection of a mutilation may only be possible at "torn-tape" relay stations.

4.4.11.5 When the provisions of 4.4.11.4 are applied, the station receiving the service message shall reassume responsibility for the referenced message. It shall then retransmit the unmutilated copy of the referenced message with a new (i.e. correct in sequence) transmission identification (see4.4.2.1.1 b)). If that station is not in possession of an unmutilated copy of the original message, it shall take the action prescribed in 4.4.11.1.

4.4.11.6 If, before retransmission is commenced, a relay station detects that a received message has a recognizable but mutilated end-of-message signal, it shall, where necessary, repair this mutilation before retransmission.

Note.— This circumstance of detection of a mutilation may only be possible at "torn-tape" relay stations and the action prescribed will be essential where messages are being transmitted to a semi-automatic or fully automatic station.

4.4.11.7 If, during retransmission of a message, a relay station detects that the message has been mutilated at some point ahead of the end-of-message signal and is able to take action before a correct end-of-message signal has been transmitted, it shall:

1) cancel the transmission by inserting into the channel the sequence
↓<≡QTA→QTA↓<≡followed by a complete ending (see4.4.6);

2) reassume responsibility for the message;

3) comply with the provisions of 4.4.11.1 or 4.4.11.4 as appropriate.

Note.— This circumstance of detection of a mutilation may only be possible at "torn-tape" relay stations or at semiautomatic stations using continuous-tape.

4.4.11.8 If, after a message has been transmitted *in toto*, a station detects that the text or the origin of the message was mutilated or incomplete, it shall transmit to all addressees concerned a service message with the following text, if an unmutilated copy of the message is available in the station:

SVC CORRECTION *(the origin of the incorrect message)*
STOP *(followed by the correct text).*

Note.— This circumstance of detection of a mutilation or incomplete message may only be possible at "torn-tape" relay stations or at semi-automatic stations using continuous-tape.

4.4.11.9 If, after transmission of the text of a message, a relay station detects that the message has an obviously mutilated end-of-message signal, it shall insert a proper end-of-message signal into the channel.

Note.— This circumstance of detection of a mutilation may only be possible at "torn-tape" relay stations or at semiautomatic stations using continuous-tape.

4.4.11.10 If, after transmission of the text material of a message, a relay station can detect that there is no complete end-of-message signal, but has no practicable means of discovering whether the irregularity has affected only the end-of-message signal or whether it may have also caused part of the original text to have been lost, it shall insert into the channel the following:

1) ↓<≡CHECK≡TEXT≡
NEW→ENDING→ADDED→

2) its own station identification;

3) ↓<≡

4) a proper ending as prescribed in 4.4.6.1.

Note 1.— On tape copy, this insertion will appear as follows:

↓<≡CHECK≡TEXT≡
NEW→ENDING→ADDED→LOWWYFYX↓<≡≡≡≡≡≡≡≡NNNN↓↓↓. . .

Note 2.— On page copy, this insertion will appear as follows:

CHECK
TEXT
NEW ENDING ADDED LOWWYFYXNNNN

Note 3.— The staggered presentation on copy is prescribed to ensure that the attention of the addressee is drawn immediately to the insertion.

Note 4.— The FIGURE SHIFT[↑] is included to ensure proper functioning where First Line Monitoring Equipment is used, where the presence of the FIGURE SHIFT in the origin is used to cause disconnection of this equipment and where the missing part of the message includes this FIGURE SHIFT.

Note 5.— This circumstance of detection of a mutilation may only be relevant to fully automatic stations or stations using semi-automatic methods without continuous-tape.

4.4.11.11 **Recommendation**.— *Relay stations applying the procedural provisions of 4.4.11.9 or 4.4.11.10 should, if practicable, ensure that the appropriate material therein prescribed is* *inserted prior to the transmission of a complete start-of-message signal associated with any following message.*

4.4.11.12 If a relay station detects that a message was received with a completely mutilated address line, it shall send a service message to the previous station rejecting the mutilated transmission.

4.4.11.12.1 The text of this service message shall comprise:

1) the abbreviation SVC;

2) the procedure signal QTA;

3) the procedure signal ADS;

4) the transmission identification of the message rejected;

5) the indication CORRUPT;

6) the end-of-text signal.

Note.— The following example illustrates application of the above-mentioned procedure:

SVC→QTA→ADS→ABC↑123↓→CORRUPT↓<≡

4.4.11.12.2 The station receiving such a service message shall reassume responsibility for the referenced message, and shall retransmit the message with a corrected address line, and a new transmission identification.

4.4.11.13 If a relay station detects a received message with an invalid (i.e. length other than 8 letters) or unknown addressee indicator, it shall relay the message to those valid addresses for which it has relay responsibility using the stripped address procedure (see4.4.8).

4.4.11.13.1 In addition, except as in 4.4.11.13.3, the station shall send a service message to the previous station requesting correction of the error. The text of this service message shall comprise:

1) the abbreviation SVC;

2) the procedure signal ADS;

3) the transmission identification of the message in error;

4) an alignment function;

5) the first address line of the message as received;

6) an alignment function;

7) either:

a) for an invalid addressee indicator: the indication CHECK;

b) for an unknown addressee indicator: the indication UNKNOWN;

8) the invalid or unknown addressee indicator(s);

9) the end-of-text signal.

Note.— The following examples illustrate the application of the procedure of 4.4.11.13.1:

a) for an invalid addressee indicator:

SVC→ADS→ABC↑123↓<≡GG→EGLLACAX→EGPKYTYX→CYAAYFYX→
CYQXAFX<≡CHECK→CYQXAFX↓<≡

b) for an unknown addressee indicator:

SVC→ADS→ABC↑123↓<≡GG→EGLLACAX→EGEHYTYX→CYAAYFYX→CYQXACA
X<≡UNKNOWN→EGEHYTYX↓<≡

4.4.11.13.2 A station receiving a service message as prescribed in 4.4.11.13.1 shall, if a correct addressee indicator is available, repeat the message to that addressee only using the stripped address procedure (see4.4.8) or, if a correct addressee indicator is not available, act as prescribed in 4.4.11.13.1.

4.4.11.13.3 Where the procedure of 4.4.11.13 is applied in the case of an unknown addressee indicator, and if the origin of the message is without fault, the station shall send a service message to the originator. The text of this service message shall comprise:

1) the abbreviation SVC;

2) the procedure signal ADS;

3) the origin of the message in error;

4) an alignment function;

5) the first address line of the message as received;

6) an alignment function;

7) the indication UNKNOWN;

8) the unknown addressee indicator(s);

9) the end-of-text signal.

Note. — The following example illustrates application of the above-mentioned procedure:

SVC→ADS→↑141335↓→CYULACAX<≡
GG→EGLLACAX→EGEHYTYX→CYAAYFYX→
CYQXACAX<≡UNKNOWN→EGEHYTYX↓<≡

4.4.11.13.4 A station receiving such a service message shall obtain a correct addressee indicator and shall repeat the message to the addressee using the stripped address procedure (see4.4.8).

4.4.11.14 When the first relay station detects that a message was received with a mutilated origin line or without any origin, it shall:

a) stop processing the message;

b) send a service message to the station from which the message was received.

4.4.11.14.1 The text of this service message shall comprise:

1) the abbreviation SVC;

2) the procedure signal QTA;

3) the procedure signal OGN;

4) the transmission identification of the message rejected;

5) the indication CORRUPT;

6) the end-of-text signal.

Note.— The following example illustrates application of the above-mentioned procedure:

SVC→QTA→OGN→ABC↑123↓→CORRUPT↓<≡

4.4.11.14.2 The station receiving a service message as prescribed in 4.4.11.14.1 shall reassume responsibility for the referenced message and shall retransmit the message with a correct origin line and a new transmission identification.

Note.— When applying the provisions of 4.4.11.14, the minimum requirements for processing the origin of AFTN messages are:

1) the date-time group consisting of six numeric characters;

2) the originator indicator consisting of eight alpha characters.

4.4.11.15 When the first relay station detects that a message was received with an incorrect originator indicator, it shall:

a) stop processing the message; and

b) send a service message to the station from which the message was received.

4.4.11.15.1 The text of the service message shall comprise:

1) the abbreviation SVC;

2) the procedure signal QTA;

3) the procedure signal OGN;

4) the transmission identification of the message rejected;

5) the indicator INCORRECT; and

6) the end-of-text signal.

Note.— The following ITA-2 example illustrates application of the above-mentioned procedure:

SVC→QTA→OGN→ABC↑123↓→INCORRECT↓<≡

4.4.11.15.2 The station receiving a service message as prescribed in 4.4.11.15.1 shall resume responsibility for the referenced message and shall retransmit the message with a correct originator indicator and, if applicable, a new transmission identification.

Note.— When applying the provisions of 4.4.11.15 the relay centre requirement is as a minimum the first character of the originator indicator verified as the first character of the location indicator of the place at which the message is originated.

4.4.12 Correction of errors during tape preparation

4.4.12.1 Messages for which tapes are prepared at the origin station shall not be allowed to flow into the AFTN with known uncorrected errors.

4.4.12.2 Errors made ahead of the text of a message shall be corrected by discarding the incorrect tape and preparing a new one.

4.4.12.3 Where possible, errors made in the text of a message shall be corrected by back-spacing the tape and eliminating the error by operation of the LETTERS [↓] key over the undesired portion.

4.4.12.4 Where the action of 4.4.12.3 is not possible, correction to the text shall be made immediately after the error by making the error sign (→E→E→E→), transmitting the last correct word or group and then continuing with the tape preparation.

4.4.12.5 Where neither the action of 4.4.12.3 nor the action of 4.4.12.4 is possible because the error in the text is not noticed until later in the preparation process (but before the end-of-message signal has been added) the station shall comply with the provisions of 4.4.5.5.

4.4.12.6 The ending must be typed without error.

4.4.13 Correction of errors during message origination in cases where the message is flowing into the AFTN during preparation

4.4.13.1 Messages flowing into the AFTN during preparation shall not be terminated with an end-of-message signal if they contain known uncorrected errors.

4.4.13.2 Where an error is made, in this circumstance, in any part of the message which precedes the text, the unfinished message shall be cancelled by sending the sequence

↓<≡QTA→QTA↓<≡ followed by a complete ending (see 4.4.6).

4.4.13.3 Errors made in the text and noticed immediately shall be corrected by making the error sign (→E→E→E→), transmitting the last correct word or group and then continuing with the message.

4.4.13.4 In cases where errors are made in the text and not noticed until later in the origination process, the station shall comply with the provisions of 4.4.5.5.

4.4.13.5 In cases where it becomes obvious, during the origination of the text, that the message should be cancelled, the station shall take the action described in 4.4.13.2.

4.4.14 Predetermined distribution system for AFTN messages

4.4.14.1 When it has been agreed between the Administrations concerned to make use of a predetermined distribution system for AFTN messages, the system described below shall be used.

4.4.14.2 The Predetermined Distribution Addressee Indicator (PDAI) shall be constructed as follows:

a) The first and second letters:

The first two letters of the Location Indicator of the communications centre of the State which has agreed to implement the system and which receives messages over a circuit for which it has a predetermined routing responsibility;

b) The third and fourth letters:

The letters ZZ, indicating a requirement for special distribution;

c) The fifth, sixth and seventh letters:

1) The fifth, sixth and seventh letters taken from the series A to Z and denoting the national and/or international distribution list(s) to be used by the receiving AFTN centre;

2) “N” and “S”, as the fifth letter, are reserved for NOTAM and SNOWTAM respectively (see Appendix 5 to Annex 15);

d) The eighth letter: Either the filler letter "X" or a letter taken from the series A to Z to further define the national and/or international distribution list(s) to be used by the receiving AFTN centre.

Note 1.— To avoid conflict with the AFTN start-of-message signal, combinations with ZC or CZ will not be used.

Note 2.— To avoid conflict with the AFTN end-of message signal, combinations with NN will not be used.

4.4.14.3 *PANS.— Predetermined Distribution Addressee Indicators (PDAIs) should be used whenever possible on AFTN messages between States which have agreed to make use of the predetermined distribution system.*

4.4.14.4 AFTN messages carrying Predetermined Distribution Addressee Indicators allocated by the State receiving the message shall be routed to the addressees listed on the associated list of Addressee Indicators described in 4.4.14.5.

4.4.14.5 States shall send their list of selected Predetermined Distribution Addressee Indicators together with the associated lists of Addressee Indicators to:

a) the States from which they will receive AFTN messages for predetermined distribution, to assure correct routing; and

b) the States which will originate AFTN messages for predetermined distribution to facilitate the treatment of requests for retransmission and to assist originators in using the Predetermined Distribution Addressee Indicators correctly.

4.4.14.5.1 The list of Addressee Indicators associated with a Predetermined Distribution Addressee Indicator shall include either:

a) Addressee Indicators for national distribution; or

b) Addressee Indicators for international distribution; or

c) Predetermined Distribution Addressee Indicators for international distribution; or

d) any combination of a), b) and c).

4.4.15 Message format — International Alphabet No. 5 (IA-5)

When it has been agreed between the Administrations concerned to use International Alphabet No. 5 (IA-5) the format described in 4.4.15 through 4.4.15.3 shall be used. It shall be the responsibility of Administrations using IA-5 to accommodate adjacent AFTN stations employing ITA-2 code in the format described in 4.4.2. All messages, other than those prescribed in 4.4.1.8 and 4.4.9.3 shall comprise the components specified in 4.4.15.1 to 4.4.15.6 inclusive.

Note 1.— An illustration of the IA-5 message format is given in Figure 4-4.

Note 2.— In the subsequent standards relative to message format the following symbols have been used in making reference to the functions assigned to certain signals in IA-5. (See Volume III, Part I, 8.6.1 and Tables 8-2 and 8-3.)

Symbol	Signification
<	CARRIAGE RETURN (character position 0/13)
≡	LINE FEED (character position 0/10)
→	SPACE (character position 2/0).

4.4.15.1 Heading

4.4.15.1.1 The heading shall comprise:

a) start-of-heading (SOH) character 0/1;

b) transmission identification comprising:

1) circuit or link identification;

2) channel-sequence number;

c) additional service information (if necessary) comprising:

1) one SPACE;

2) no more than 10 characters.

4.4.15.1.1.1 On point-to-point circuits or links, the identification shall consist of three letters selected and assigned by the transmitting station; the first letter identifying the transmitting, the second letter the receiving end of the circuit, and the third letter the channel. Where only one channel exists, the letter A shall be assigned. Where more than one channel between stations is provided, the channels shall be identified as A, B, C, etc., in respective order. On multipoint channels, the identification shall consist of three letters selected and assigned by the circuit control or master station.

4.4.15.1.1.2 Except as provided in 4.4.15.1.1.3 three-digit channel-sequence numbers from 001 to 000 (representing 1 000) shall be assigned sequentially by telecommunication stations to all messages transmitted directly from one station to another. A separate series of these numbers shall be assigned for each channel and a new series shall be started daily at 0000 hours.

4.4.15.1.1.3 **Recommendation.—** *The expansion of the channel-sequence number to preclude duplication of the same numbers during the 24-hour period should be permitted subject to agreement between the Authorities responsible for the operation of the circuit.*

4.4.15.1.1.4 The transmission identification shall be sent over the circuit in the following sequence:

a) transmitting-terminal letter;

b) receiving-terminal letter;

c) channel-identification letter;

d) channel-sequence number.

4.4.15.1.1.5 Additional service information shall be permitted to be inserted following the transmission identification subject to agreement between the Authorities responsible for the operation of the circuit. Such additional service information shall be preceded by a SPACE (→) followed by not more than 10 characters inserted into the heading of message immediately following the last digit of the channel-sequence number and shall not contain any alignment functions. When no such additional service information is added the information in 4.4.15.1.1.4 shall be followed immediately by that of 4.4.15.2.

4.4.15.2 *Address*

4.4.15.2.1 The address shall comprise:

a) alignment function [<≡];

b) priority indicator;

c) addressee indicator(s);

d) alignment function [<≡].

4.4.15.2.1.1 The priority indicator shall consist of the appropriate two-letter group assigned by the originator in accordance with the following:

Message part		*Component of the message part*	*Elements of the component*	*Teletypewriter character*
THE HEADING	HEADING LINE (see 4.4.15.1.1)	Start-of-Heading Character	One Character (0/1)	SOH
		Transmission Identification	a) Transmitting-terminal letter b) Receiving-terminal letter c) Channel-identification letter d) Channel-sequence number (*Example:* NRA062)	......
		(*If necessary*) Additional Service Indication	a) One SPACE b) No more than the remainder of the line (*Example:* 270930)	→
	ADDRESS (see 4.4.15.2.1)	Alignment Function	One CARRIAGE RETURN, one LINE FEED	<≡
		Priority Indicator	The relevant 2-letter group	--
		Addressee Indicator(s)	One SPACE An 8-letter group given in sequence for each addressee (*Example:* **EGLLZRZX→EGLLYKYX→EGLLACAD)**	
		Alignment Function(s)	One CARRIAGE RETURN, one LINE FEED	<≡
	ORIGIN (see 4.4.15.2.2)	Filing Time	6-digit date-time group specifying when the message was filed for transmission	......
		Originator Indicator	a) One SPACE b) 8-letter group identifying the message originator	→......
		Priority Alarm (*used only in teletypewriter operation for Distress Messages*)	Five characters (0/7)(BEL)	
		Optional Heading Information	a) One SPACE b) Additional data not to exceed the remainder of the line. See 4.4.15.2.2.6.	
		Alignment Function	One CARRIAGE RETURN, one LINE FEED	<≡
		Start-of-Text Character	One character (0/2)	STX
TEXT (see 4.4.15.3)		Beginning of the Text	Specific identification of Addressee(s) (*If necessary*) *with* each followed by one CARRIAGE RETURN, one LINE FEED (*if necessary*) The English word FROM (*if necessary*)(see 4.4.15.3.5) Specific identification of Originator (*if necessary*) The English word STOP followed by one CARRIAGE RETURN, one LINE FEED (*if necessary*) (see 4.4.15.3.5) *and/or* Originator's reference (*if used*)	
		Message Text	Message Text with one CARRIAGE RETURN, one LINE FEED at the end of each printed line of the Text except for the last one (see 4.4.15.3.6)	
		Confirmation (*if necessary*)	a) One CARRIAGE RETURN, one LINE FEED b) The abbreviation CFM followed by the portion of the Text being confirmed.	
		Correction (*if necessary*)	a) One CARRIAGE RETURN, one LINE FEED b) The abbreviation COR followed by the correction of an error made in the preceding Text	
ENDING (see 4.4.15.3.12.1)		Alignment Function	One CARRIAGE RETURN, one LINE FEED	<≡
		Page-feed Sequence	One character (0/11)	VT
		End-of-Text character	One character (0/3)	ETX

Figure 4-4. Message format International Alphabet No. 5 (IA-5)

(the above illustrates the teletypewriter message format described in 4.4.15)

Priority indicator	*Message category*
SS	distress messages
DD	urgency messages (see4.4.1.1.2)
FF	flight safety messages (see4.4.1.1.3)
GG	meteorological messages (see4.4.1.1.4)
GG	flight regularity messages (see4.4.1.1.5)
GG	aeronautical information services messages (see4.4.1.1.6)
KK	aeronautical administrative messages (see 4.4.1.1.7)
as appropriate	service messages (see4.4.1.1.9)

4.4.15.2.1.2 The order of priority shall be the same as specified in 4.4.1.2.

4.4.15.2.1.3 An addressee indicator, which shall be immediately preceded by a SPACE, except when it is the first address indicator of the second or third line of addresses, shall comprise:

a) the four-letter location indicator of the place of destination;

b) the three-letter designator identifying the organization/function (aeronautical authority, service or aircraft operating agency) addressed;

c) an additional letter, which shall represent a department, division or process within the organization/function addressed. The letter X shall be used to complete the address when explicit identification is not required.

4.4.15.2.1.3.1 Where a message is to be addressed to an organization that has not been allocated an ICAO three-letter designator of the type prescribed in 4.4.15.2.1.3 the location indicator of the place of destination shall be followed by the ICAO three-letter designator YYY (or the ICAO three-letter designator YXY in the case of a military service or organization). The name of the addressee organization shall then be included in the first item in the text of the message. The eighth position letter following the ICAO three-letter designator YYY or YXY shall be the filler letter X.

4.4.15.2.1.3.2 Where a message is to be addressed to a aircraft in flight and, therefore, requires handling over the AFTN for part of its routing before retransmission over the Aeronautical Mobile Service, the location indicator of the aeronautical station which is to relay the message to the aircraft shall be followed by the ICAO three-letter designator ZZZ. The identification of the aircraft shall then be included in the first item of the text of the message. The eighth position letter following the ICAO three-letter designator ZZZ shall be the filler letter X.

4.4.15.2.1.4 The complete address shall be restricted to three lines of page-printing copy, and, except as provided in 4.4.16, a separate addressee indicator shall be used for each addressee whether at the same or different locations.

4.4.15.2.1.5 The completion of the addressee indicator group(s) in the address of a message shall be immediately followed by the alignment function.

4.4.15.2.1.6 Where messages are offered in page-copy form for transmission and contain more addressee indicators than can be accommodated on three lines of a page copy, such messages shall be converted, before transmission, into two or more messages, each of which shall conform with the provisions of 4.4.15.2.1.5. During such conversion, the addressee indicators shall, in so far as practicable, be positioned in the sequence which will ensure that the minimum number of retransmissions will be required at subsequent communication centres.

4.4.15.2.2 *Origin*

The origin shall comprise:

a) filing time;

b) originator indicator;

c) priority alarm (when necessary);

d) optional heading information;

e) alignment function [<≡];

f) start-of-text character, character 0/2 (STX).

4.4.15.2.2.1 The filing time shall comprise the 6-digit date-time group indicating the date and time of filing the message for transmission (see3.4.2).

4.4.15.2.2.2 The originator indicator, which shall be immediately preceded by a SPACE, shall comprise:

a) the four-letter location indicator of the place at which the message is originated;

b) the three-letter designator identifying the organization/function (aeronautical authority, service or aircraft operating agency) which originated the message;

c) an additional letter which shall represent a department, division or process within the organization/function of the originator. The letter X shall be used to complete the address when explicit identification is not required.

4.4.15.2.2.3 Where a message is originated by an organization that has not been allocated an ICAO three-letter designator of the type prescribed in 4.4.15.2.2.2, the location indicator of the place at which the message is originated shall be followed immediately by the ICAO three-letter designator YYY followed by the filler letter X (or the ICAO three-letter designator YXY followed by the filler letter X in the case of a military service or organization). The name of the organization (or military service) shall then be included in the first item in the text of the message.

4.4.15.2.2.3.1 Messages relayed over the AFTN that have been originated in other networks shall use a valid AFTN originator indicator that has been agreed for use by the relay or gateway function linking the AFTN with the external network.

4.4.15.2.2.4 Where a message originated by an aircraft in flight requires handling on the AFTN for part of its routing before delivery, the originator indicator shall comprise the location indicator of the aeronautical station responsible for transferring the message to the AFTN, followed immediately by the ICAO three-letter designator ZZZ followed by the filler letter X. The identification of the aircraft shall then be included in the first item in the text of the message.

4.4.15.2.2.5 The priority alarm shall be used only for distress messages. When used it shall consist of five successive BEL (0/7) characters.

Note.— Use of the priority alarm will actuate a bell (attention) signal at the receiving teletypewriter station, other than at those fully automatic stations which may provide a similar alarm on receipt of priority indicator SS, thereby alerting supervisory personnel at relay centres and operators at tributary stations, so that immediate attention may be given to the message.

4.4.15.2.2.6 The inclusion of optional data in the origin line shall be permitted provided a total of 69 characters is not exceeded and subject to agreement between the Administrations concerned. The presence of the optional data field shall be indicated by one occurrence of the SPACE character immediately preceding optional data.

4.4.15.2.2.6.1 **Recommendation**.— *When additional addressing information in a message needs to be exchanged between source and destination addresses, it should be conveyed in the optional data field (ODF), using the following specific format:*

a) characters one and full stop (1.) to indicate the parameter code for the additional address function;

b) three modifier characters, followed by an equal sign (=) and the assigned 8-character ICAO address; and

c) the character hyphen (-) to terminate the additional address parameter field.

4.4.15.2.2.6.1.1 **Recommendation**.— When a separate address for service messages or inquiries is different from the originator indicator, the modifier SVC should be used 4.4.15.2.2.7 The origin line shall be concluded by an alignment function [<≡] and the start-of-text (STX) (0/2) character.

4.4.15.3 Text

4.4.15.3.1 The text of messages shall be drafted in accordance with 4.1.2 and shall consist of all data between STX and ETX.

Note.— When message texts do not require conversion to the ITA-2 code and format and do not conflict with ICAO message types or formats in PANS-ATM (Doc 4444), Administrations may make full use of the characters available in International Alphabet No. 5 (IA-5).

4.4.15.3.2 When an originator's reference is used, it shall appear at the beginning of the text, except as provided in 4.4.15.3.3 and 4.4.15.3.4.

4.4.15.3.3 When the ICAO three-letter designators YXY, YYY or ZZZ comprise the second element of the addressee indicator (see4.4.15.2.1.3.1 and 4.4.15.2.1.3.2) and it, therefore, becomes necessary to identify in the text the specific addressee of the message, such identification group shall precede the originator's reference (if used) and become the first item of the text.

4.4.15.3.4 When the ICAO three-letter designators YXY, YYY or ZZZ comprise the second element of the originator indicator (see4.4.15.2.2.3 and 4.4.15.2.2.4) and it thus becomes necessary to identify in the text the name of the organization (or military service) or the aircraft which originated the message, such identification shall be inserted in the first item of the text of the message.

4.4.15.3.5 When applying the provisions of 4.4.15.3.3 and 4.4.15.3.4 to messages where the ICAO three-letter designator(s) YXY, YYY, ZZZ refer to two or more different organizations (or military services), the sequence of further identification in the text shall correspond to the complete sequence used in the address and originator indicator of the message. In such instance, each addressee identification shall be followed immediately by an alignment function. The name of the (YXY, YYY or ZZZ) organization originating the message shall then be preceded with "FROM". "STOP" followed by an alignment function shall then be included in the text at the end of this identification and preceding the remainder of text.

4.4.15.3.6 An alignment function shall be transmitted at the end of each printed line of the text. When it is desired to confirm a portion of the text of a message in teletypewriter operation, such confirmation shall be separated from the last text group by an alignment function [<≡], and shall be indicated by the abbreviation CFM followed by the portion being confirmed.

4.4.15.3.7 Where messages are prepared off-line, e.g. by preparation of a paper tape, errors in the text shall be corrected by backspacing and replacing the character in error by character DEL (7/15).

4.4.15.3.8 Corrections to textual errors made in on-line operations shall be corrected by inserting →E→E→E→ following the error, then retyping the last correct word (or group).

4.4.15.3.9 When it is not discovered until later in the origination process that an error has been made in the text, the correction shall be separated from the last text group, or confirmation, if any, by an alignment function [<≡]. This shall be followed by the abbreviation COR and the correction.

4.4.15.3.10 Stations shall make all indicated corrections on the page-copy prior to local delivery or a transfer to a manually operated circuit.

4.4.15.3.11 The text of messages entered by the AFTN origin station shall not exceed 1 800 characters in length. AFTN messages exceeding 1 800 characters shall be entered by the AFTN origin station in the form of separate messages. Guidance material for forming separate messages from a single long message is given in Attachment B to Volume II. When messages or data are transmitted only on medium or high speed circuits the text may be increased to a length that exceeds 1 800 characters as long as performance characteristics of the network or link are not diminished and subject to agreement between the Administrations concerned.

Note.— The character count includes all printing and nonprinting characters in the text from, but not including, the start-of-text signal to, but not including, the first alignment function of the ending.

4.4.15.3.12 *Ending*

4.4.15.3.12.1 The ending of a message shall comprise the following in the order stated:

a) an alignment [<≡] function following the last line of text;

b) page-feed character, character 0/11 (VT);

c) end-of-text character 0/3 (ETX).

4.4.15.3.12.1.1 **Recommendation**.— *Station terminal equipment (page printers) on the International Alphabet Number 5 (IA-5) shall be provided with a capability to generate sufficient line feed functions for local station use upon the reception of a VERTICAL TAB character (0/11).*

4.4.15.3.12.1.2 **Recommendation.**— *When the message does not transit ITA-2 portions of the AFTN, or where Administrations have made provisions to add automatically the second carriage return before transmission to an ITA-2 circuit, one carriage return in the alignment function and end-of-line function should be permitted subject to agreement between the Administrations concerned.*

4.4.15.3.12.1.3 Messages entered by the AFTN origin station shall not exceed 2 100 characters in length.

Note.— The character count includes all printing and nonprinting characters in the message from and including the start-of-heading character (SOH) to and including the end-of-text character.

4.4.15.4 Except as provided in4.4.15.5 to 4.4.15.6 and 4.4.16, the procedures of 4.4.8 and 4.4.9 to 4.4.13 shall be used for messages using IA-5 code.

4.4.15.5 Channel-check transmissions. In the case where continuous control of channel condition is not provided the following periodic transmissions shall be sent on teletypewriter circuits:

1) heading line (see4.4.15.1.1);

S
2) alignment function T;
X
3) the procedure signal CH;
E
4) alignment function T.
X

The receiving station shall then check the transmission identification of this incoming transmission to ensure its correct sequence in respect of all messages received over that incoming channel.

Note.— Application of this procedure provides some measure of assurance that channel continuity is maintained; however, a continuously controlled channel is much more preferable in that data integrity can also be improved.

4.4.15.5.1 **Recommendation.—** *Where a circuit is unoccupied and uncontrolled, the transmission identified in 4.4.15.5 should be sent at H + 00, H + 20, H + 40.*

4.4.15.6 The receipt of distress messages (priority indicator SS, see4.4.1.1.1) shall be individually acknowledged by the AFTN destination station by sending a service message (see4.4.1.1.9) to the AFTN origin station. Such acknowledgement of receipt shall take the format of a complete message addressed to the AFTN origin station, shall be assigned priority indicator SS and the associated priority alarm (see4.4.15.2.2.5), and shall have a text comprising:

1) the procedure signal R;

2) the origin line (see4.4.15.2.2) without priority alarm, or optional heading information of the message being acknowledged;

3) the ending (see4.4.15.3.12.1).

Note.— The following example illustrates the application of the 4.4.15.6 procedures:
Heading (see4.4.15.1.1)
<≡SS →LECBZRZX <≡
121322 →EGLLYFYX (Priority Alarm) <≡
S
TR →121319 →LECBZRZX <≡

X

Ending (see4.4.15.3.12.1).

4.4.16 Action taken on mutilated messages in IA-5 detected in computerized AFTN relay stations

4.4.16.1 On channels employing continuous control the mutilation detection and subsequent recovery shall be a function of the link control procedures and shall not require the subsequent sending of service or CHECK TEXT NEW ENDING ADDED messages.

4.4.16.2 On channels not employing continuous control the relay station shall employ the following procedures:

4.4.16.2.1 If, during the reception of a message a relay station detects that the message has been mutilated at some point ahead of the end-of-text character, it shall:

1) cancel the onward routing responsibility for the message;

2) send a service message to the transmitting station requesting a retransmission.

Note.— The following example illustrates a typical text of a service message in which the foregoing procedure has been applied in respect of a mutilated message:

SVC→QTA→RPT→ABC 123 (ending — see4.4.15.3.12.1)

4.4.16.2.2 When the provisions of 4.4.16.2.1 are applied, the station receiving the service message shall reassume responsibility for the referenced message with a new (i.e. correct in sequence) transmission identification (see 4.4.15.2.1). If that station is not in possession of an unmutilated copy of the original message, it shall send a message to the originator as identified by the originator indicator in the origin of the mutilated message, requesting repetition of the incorrectly received message.

Note.— The following example illustrates a typical text of a service message in which the foregoing procedure has been applied in respect of a mutilated message having as its origin “141335 CYULACAX”:

SVC→QTA→RPT→141335→CYULACAX
(ending — see4.4.15.3.12.1)

4.4.16.3 If, after transmission of the text material of a message, a relay station can detect that there is no complete end-of-text character, but has no practical means of discovering whether the irregularity has affected only the end-of-text character, or whether it has also caused part of the original text to have been lost, it shall insert into the channel the following:

1) <≡CHECK≡TEXT≡
NEW→ENDING→ADDED

2) its own station identification;

3) (ending — see4.4.15.3.12.1).

4.4.17 Transfer of AFTN messages over code and byte independent circuits and networks

When AFTN messages are transferred across code and byte independent circuits and networks of the AFS, the following shall apply.

4.4.17.1 Except as provided in 4.4.17.3 the heading line of the message shall be omitted. The message shall start with an alignment function followed by the address.

4.4.17.2 The message shall end with a complete ending.

4.4.17.3 **Recommendation.—** *For the purposes of technical supervision, entry centres should be permitted to insert additional data preceding the first alignment function and/or following the ending of the message. Such data may be disregarded by the receiving station.*

4.4.17.3.1 When the provisions of 4.4.17.3 are applied, the data added shall not include either carriage return or line feed characters or any of the combinations listed in 4.1.2.4.

4.5 Common ICAO Data Interchange Network (CIDIN)

Note 1.— The common ICAO data interchange network (CIDIN), which comprises application entities and communication services for ground-ground message exchange, makes use of protocols based on the International Telegraph and Telephone Consultative Committee (CCITT) X.25 Recommendation to provide code and byte-independent communication facilities.

Note 2.— The principal goals of the CIDIN are to improve the AFTN and to support large message transmission and more demanding applications, such as operational meteorological information (OPMET), between two or multiple ground systems.

Note 3.— Details of CIDIN communication procedures, as implemented in Europe, are shown in the EUR CIDIN Manual.

4.6 ATS Message Handling Services (ATSMHS)

The ATS message service of the ATS (air traffic services) message handling service (ATSMHS) application shall be used to exchange ATS messages between users over the aeronautical telecommunication network (ATN) internet.

Note 1.— The ATS message service comprised in the ATS message handling service application aims at providing generic message services over the ATN internet communication service (ICS). It may, in turn, be used as a communication system by user-applications communicating over the ATN. This may be achieved, for example, by means of application programme interfaces to the ATS message service.

Note 2.— The detailed specification of the ATS message handling service application is included in the Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN) (Doc 9705), Sub-volume III.

Note 3.— The ATS message service is provided by the implementation over the ATN internet communication service of the message handling systems specified in ISO/IEC (International Organization for Standardization/International Electrotechnical Commission) 10021 and ITU-T (International Telecommunication Union — Telecommunication Standardization Sector) X.400 and complemented by the additional requirements specified in the Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN) (Doc 9705). The two sets of documents, the ISO/IEC MOTIS (Message-Oriented Text Interchange System) International Standards and the ITU-T X.400 Series of Recommendations (1988 or later) are, in principle, aligned with each other. However, there are a small number of differences. In the above-mentioned document, reference is made to the relevant ISO International Standards and International Standardized Profiles (ISP), where applicable. Where necessary, e.g. for reasons of interworking or to point out differences, reference is also made to the relevant X.400 Recommendations.

Note 4.— The following types of ATN end systems performing ATS message handling services are defined in the Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN)(Doc 9705), Sub-volume III:

1) an ATS message server;

2) an ATS message user agent;

3) an AFTN/AMHS gateway (aeronautical fixed telecommunication network/ATS message handling system); and

4) a CIDIN/AMHS gateway (common ICAO data interchange network/ATS message handling system). Connections may be established over the internet communications service between any pair constituted of these ATN end systems (see Table 4-1).

Table 4-1. Communications between ATN end systems implementing ATS message handling services

ATN End System 1	ATN End System 2
ATS Message Server	ATS Message Server
ATS Message Server	AFTN/AMHS Gateway
ATS Message Server	CIDIN/AMHS Gateway
ATS Message Server	ATS Message User Agent
AFTN/AMHS Gateway	AFTN/AMHS Gateway
CIDIN/AMHS Gateway	CIDIN/AMHS Gateway
CIDIN/AMHS Gateway	AFTN/AMHS Gateway

4.7 Inter-Centre Communications (ICC)

The inter-centre communications (ICC) applications set shall be used to exchange ATS messages between air traffic service users over the ATN internet.

Note 1.— The ICC applications set enables the exchange of information in support of the following operational services:

a) flight notification;

b) flight coordination;

c) transfer of control and communications;

d) flight planning;

e) airspace management; and

f) air traffic flow management.

Note 2.— The first of the applications developed for the ICC set is the ATS interfacility data communication (AIDC).

Note 3.— The AIDC application exchanges information between ATS units (ATSUs) for support of critical air traffic control (ATC) functions, such as notification of flights approaching a flight information region (FIR) boundary, coordination of boundary conditions and transfer of control and communications authority.

Note 4.— The detailed specification of the AIDC application is included in the Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN) (Doc 9705), Sub-volume III.

Note 5.— The AIDC application is strictly an ATC application for exchanging tactical control information between ATS units. It does not support the exchange of information with other offices or facilities.

Note 6.— The AIDC application supports the following operational services:

a) flight notification;

b) flight coordination;

c) transfer of executive control;

d) transfer of communications; and

e) transfer of general information (flight-related data or free text messages, i.e. unstructured).

CHAPTER 5. AERONAUTICAL MOBILE SERVICE — VOICE COMMUNICATIONS

5.1 General

Note.— For the purposes of these provisions, the communication procedures applicable to the aeronautical mobile service, as appropriate, also apply to the aeronautical mobile satellite service.

5.1.1 In all communications the highest standard of discipline shall be observed at all times.

5.1.1.1 ICAO standardized phraseology shall be used in all situations for which it has been specified. Only when standardized phraseology cannot serve an intended transmission, plain language shall be used.

Note.— Detailed language proficiency requirements appear in the Appendix to Annex 1.

5.1.1.2 The transmission of messages, other than those specified in 5.1.8, on aeronautical mobile frequencies when the aeronautical fixed services are able to serve the intended purpose, shall be avoided.

5.1.1.3 **Recommendation**.— *In all communications, the consequences of human performance which could affect the accurate reception and comprehension of messages should be taken into consideration.*

Note.— Guidance material on human performance can be found in the Human Factors Training Manual (Doc 9683).

5.1.2 Where it is necessary for an aircraft station to send signals for testing or adjustment which are liable to interfere with the working of a neighbouring aeronautical station, the consent of the station shall be obtained before such signals are sent. Such transmissions shall be kept to a minimum.

5.1.3 When it is necessary for a station in the aeronautical mobile service to make test signals, either for the adjustment of a transmitter before making a call or for the adjustment of a receiver, such signals shall not continue for more than 10 seconds and shall be composed of spoken numerals (ONE, TWO, THREE, etc.) in radiotelephony, followed by the radio call sign of the station transmitting the test signals. Such transmissions shall be kept to a minimum.

5.1.4 Except as otherwise provided, the responsibility of establishing communication shall rest with the station having traffic to transmit.

Note.— In certain cases when SELCAL is used the procedures respecting the establishment of communications are contained in 5.2.4.

5.1.5 **Recommendation**.— *After a call has been made to the aeronautical station, a period of at least 10 seconds should elapse before a second call is made. This should eliminate unnecessary transmissions while the aeronautical station is getting ready to reply to the initial call.*

5.1.6 When an aeronautical station is called simultaneously by several aircraft stations, the aeronautical station shall decide the order in which aircraft shall communicate.

5.1.7 In communications between aircraft stations, the duration of communication shall be controlled by the aircraft station which is receiving, subject to the intervention of an aeronautical station. If such communications take place on an ATS frequency, prior permission of the aeronautical station shall be obtained. Such requests for permission are not required for brief exchanges.

5.1.8 Categories of messages

The categories of messages handled by the aeronautical mobile service and the order of priority in the establishment of communications and the transmission of messages shall be in accordance with the following table.

Message category and Radiotelephony order of priority signal

a) Distress calls, distress messages and distress traffic MAYDAY

b) Urgency messages, including PAN, PAN messages preceded by the or PAN, PAN medical transports signal MEDICAL

c) Communications relating to direction finding —

d) Flight safety messages —

e) Meteorological messages —

f) Flight regularity messages —

Note 1.— Messages concerning acts of unlawful interference constitute a case of exceptional circumstances which may preclude the use of recognized communication procedures used to determine message category and priority.

Note 2.— A NOTAM may qualify for any of the categories or priorities c) to f) inclusive. The decision as to which priority will depend on the contents of the NOTAM and its importance to the aircraft concerned.

5.1.8.1 Distress messages and distress traffic shall be handled in accordance with the provisions of 5.3.

5.1.8.2 Urgency messages and urgency traffic, including messages preceded by the medical transports signal, shall be handled in accordance with the provisions of 5.3.

Note.— The term "medical transports" is defined in the 1949 Geneva Conventions and Additional Protocols (see also RR S33 Section III) and refers to "any means of transportation by land, water, or air, whether military or civilian, permanent or temporary, assigned exclusively to medical transportation and under the control of a competent authority of a Party to the conflict".

5.1.8.3 Communications relating to direction finding shall be handled in accordance with Chapter 6.

5.1.8.4 Flight safety messages shall comprise the following:

1) movement and control messages [see PANS-ATM (Doc 4444)];

2) messages originated by an aircraft operating agency or by an aircraft, of immediate concern to an aircraft in flight;

3) meteorological advice of immediate concern to an aircraft in flight or about to depart (individually communicated or for broadcast);

4) other messages concerning aircraft in flight or about to depart.

5.1.8.5 Meteorological messages shall comprise meteorological information to or from aircraft, other than those in 5.1.8.4, 3).

5.1.8.6 Flight regularity messages shall comprise the following:

1) messages regarding the operation or maintenance of facilities essential for the safety or regularity of aircraft operation;

2) messages concerning the servicing of aircraft;

3) instructions to aircraft operating agency representatives concerning changes in requirements for passengers and crew caused by unavoidable deviations from normal operating schedules. Individual requirements of passengers or crew shall not be admissible in this type of message;

4) messages concerning non-routine landings to be made by the aircraft;

5) messages concerning aircraft parts and materials urgently required;

6) messages concerning changes in aircraft operating schedules.

5.1.8.6.1 Air traffic services units using direct pilot controller communication channels shall only be required to handle flight regularity messages provided this can be achieved without interference with their primary role and no other channels are available for the handling of such messages.

Note.— The messages at 5.1.8.4, 2) and 5.1.8.6, 1) to 6) typify some of the operational control communications defined in Chapter 1.

5.1.8.7 **Recommendation**.— *Messages having the same priority should, in general, be transmitted in the order in which they are received for transmission*.

5.1.8.8 Interpilot air-to-air communication shall comprise messages related to any matter affecting safety and regularity of flight. The category and priority of these messages shall be determined on the basis of their content in accordance with 5.1.8.

5.1.9 Cancellation of messages

5.1.9.1 Incomplete transmissions. If a message has not been completely transmitted when instructions to cancel are received, the station transmitting the message shall instruct the receiving station to disregard the incomplete transmission. This shall be effected in radiotelephony by use of an appropriate phrase.

5.1.9.2 *Complete transmissions*

Recommendation.— *When a completed message transmission is being held pending correction and the receiving station is to be informed to take no forwarding action, or when delivery or onward relay cannot be accomplished, transmission should be cancelled. This should be effected in radiotelephony by the use of an appropriate phrase.*

5.1.9.3 The station cancelling a transmission shall be responsible for any further action required.

5.2 Radiotelephony procedures

Note.— When Selective Calling (SELCAL) equipment is used certain of the following procedures are superseded by those contained in 5.2.4.

5.2.1 General

5.2.1.1 PANS.— When a controller or pilot communicates via voice, the response should be via voice. Except as provided by 8.2.12.1, when a controller or pilot communicates via CPDLC, the response should be via CPDLC.

5.2.1.2 *Language to be used*

5.2.1.2.1 The air-ground radiotelephony communications shall be conducted in the language normally used by the station on the ground or in the English language.

Note 1.— The language normally used by the station on the ground may not necessarily be the language of the State in which it is located. A common language may be agreed upon regionally as a requirement for stations on the ground in that region.

Note 2.— The level of language proficiency required for aeronautical radiotelephony communications is specified in the Appendix to Annex 1.

5.2.1.2.2 The English language shall be available, on request from any aircraft station, at all stations on the ground serving designated airports and routes used by international air services.

5.2.1.2.3 The languages available at a given station on the ground shall form part of the Aeronautical Information Publications and other published aeronautical information concerning such facilities.

5.2.1.3 *Word spelling in radiotelephony*. When proper names, service abbreviations and words of which the spelling is doubtful are spelled out in radiotelephony the alphabet in Figure 5-1 shall be used.

Note 1.— The pronunciation of the words in the alphabet as well as numbers may vary according to the language habits of the speakers. In order to eliminate wide variations in pronunciation, posters illustrating the desired pronunciation are available from ICAO.

Note 2.— The Spelling Alphabet specified in 5.2.1.3 is also prescribed for use in the Maritime Mobile Service (ITU Radio Regulations, Appendix S14).

5.2.1.4 *Transmission of numbers in radiotelephony*

5.2.1.4.1 *Transmission of numbers*

5.2.1.4.1.1 All numbers, except as prescribed in 5.2.1.4.1.2, shall be transmitted by pronouncing each digit separately.

Note.— The following examples illustrate the application of this procedure (see 5.2.1.4.3.1 for pronunciation).

aircraft call signs	*transmitted as*
CCA 238	Air China **two three eight**
OAL 242	Olympic **two four two**
flight levels	*transmitted as*
FL 180	flight level **one eight zero**
FL 200	flight level **two zero zero**
headings	*transmitted as*
100 degrees	heading **one zero zero**
080 degrees	heading **zero eight zero**
wind direction and speed	*transmitted as*
200 degrees 70 knots	wind two **zero zero degrees seven zero** knots
160 degrees 18 knots gusting 30 knots	wind **one six zero** degrees **one eight knots** gusting three **zero knots**
transponder codes	*transmitted as*
2 400	squawk **two four zero zero**

4 203	squawk **four two zero three**
runway	*transmitted as*
27	runway **two seven**
30	runway **three zero**
altimeter setting	*transmitted as*
1 010	QNH **one zero one zero**
1 000	QNH **one zero zero zero**

5.2.1.4.1.2 All numbers used in the transmission of altitude, cloud height, visibility and runway visual range (RVR) information, which contain whole hundreds and whole thousands, shall be transmitted by pronouncing each digit in the number of hundreds or thousands followed by the word HUNDRED or THOUSAND as appropriate. Combinations of thousands and whole hundreds shall be transmitted by pronouncing each digit in the number of thousands followed by the word THOUSAND followed by the number of hundreds followed by the word HUNDRED.

Note.— The following examples illustrate the application of this procedure (see5.2.1.4.3.1 for pronunciation).

Letter	*Word*	*Approximate pronunciation*	
		International Phonetic Convention	*Latin alphabet representation*
A	**Alfa**	'ælfa	AL FAH
B	**Bravo**	'bra:'vo	BRAH VOH
C	**Charlie**	'tʃɑ:li *or* 'ʃɑ:li	CHAR LEE *or* SHAR LEE
D	**Delta**	'deltɑ	DELL TAH
E	**Echo**	'eko	ECK OH
F	**Foxtrot**	'fɔkstrɔt	FOKS TROT
G	**Golf**	gʌlf	GOLF
H	**Hotel**	ho:'tel	HO TELL
I	**India**	'indi·ɑ	IN DEE AH
J	**Juliett**	'dʒu:li·'et	JEW LEE ETT
K	**Kilo**	'ki:lo	KEY LOH
L	**Lima**	'li:mɑ	LEE MAH
M	**Mike**	mɑik	MIKE
N	**November**	no'vembə	NO VEM BER
O	**Oscar**	'ɔskɑ	OSS CAH
P	**Papa**	pə'pɑ	PAH PAH
Q	**Quebec**	ke'bek	KEH BECK
R	**Romeo**	'ro:mi·o	ROW ME OH
S	**Sierra**	si'erɑ	SEE AIR RAH
T	**Tango**	'tængo	TANG GO
U	**Uniform**	'ju:nifɔ:m *or* 'u:nifɔrm	YOU NEE FORM *or* OO NEE FORM
V	**Victor**	'viktɑ	VIK TAH
W	**Whiskey**	'wiski	WISS KEY
X	**X-ray**	'eks'rei	ECKS RAY
Y	**Yankee**	'jænki	YANG KEY
Z	**Zulu**	'zu:lu:	ZOO LOO

Note.— In the approximate representation using the Latin alphabet, syllables to be emphasized are underlined.

Note 1.— The pronunciation of the words in the alphabet may vary according to the language habits of the speakers. In order to eliminate wide variations in pronunciation, posters illustrating the desired pronunciation are available from ICAO.

Note 2.— The Spelling Alphabet specified in 5.2.1.3 is also prescribed for use in the Maritime Mobile Service (ITU Radio Regulations, Appendix S14).

Figure 5-1. The Radiotelephony Spelling Alphabet (see 5.2.1.3)

altitude	*transmitted as*
800	**eight hundred**
3 400	**three thousand four hundred**
12 000	**one two thousand**
cloud height	*transmitted as*
2 200	**two thousand two hundred**
4 300	**four thousand three hundred**
visibility	*transmitted as*
1 000	visibility **one thousand**
700	visibility **seven hundred**
runway visual range	*transmitted as*
600	RVR **six hundred**
1 700	RVR **one thousand seven hundred**

5.2.1.4.1.3 Numbers containing a decimal point shall be transmitted as prescribed in 5.2.1.4.1.1 with the decimal point in appropriate sequence being indicated by the word DECIMAL.

Note 1.— The following examples illustrate the application of this procedure:

Number	*Transmitted as*
100.3	ONE ZERO ZERO DECIMAL THREE
38 143.9	THREE EIGHT ONE FOUR THREE DECIMAL NINE

Note 2.— For identification of VHF frequencies the number of digits used after the decimal point are determined on the basis of the channel spacing (5.2.1.7.3.4.3 refers to frequencies separated by 25 kHz, 5.2.1.7.3.4.4 refers to frequencies separated by 8.33 kHz).

Note 3.— The channelling/frequency pairing relationship for 8.33 kHz and 25 kHz is found in Table 4-1 (bis), Volume V.

5.2.1.4.1.4 **PANS.—** *When transmitting time, only the minutes of the hour should normally be required. Each digit should be pronounced separately. However, the hour should be included when any possibility of confusion is likely to result.*

Note.— The following example illustrates the application of this procedure when applying the provisions of 5.2.1.2.2:

Time	Statement
0920 (9:20 A.M.)	TOO ZE-RO Or ZE-RO NIN-er TOO ZE-RO
1643 (4:43 P.M.)	FOW-er TREE Or WUN SIX FOW-er TREE

5.2.1.4.2 *Verification of numbers*

5.2.1.4.2.1 When it is desired to verify the accurate reception of numbers the person transmitting the message shall request the person receiving the message to read back the numbers.

5.2.1.4.3 Pronunciation of numbers

5.2.1.4.3.1 When the language used for communication is English, numbers shall be transmitted using the following pronunciation:

Numeral or numeral element	*Pronunciation*
0	ZE-RO
1	WUN
2	TOO
3	TREE
4	FOW-er
5	FIFE
6	SIX
7	SEV-en
8	AIT
9	NIN-er

Decimal	DAY-SEE-MAL
Hundred	HUN- dred
Thousand	TOU- SAND

Note.— The syllables printed in capital letters in the above list are to be stressed; for example, the two syllables in ZE-RO are given equal emphasis, whereas the first syllable of FOW-er is given primary emphasis.

5.2.1.5 *Transmitting technique*

5.2.1.5.1 **PANS.—** *Each written message should be read prior to commencement of transmission in order to eliminate unnecessary delays in communications.*

5.2.1.5.2 Transmissions shall be conducted concisely in a normal conversational tone.

Note.– See the language proficiency requirements in the Appendix to Annex 1.

5.2.1.5.3 **PANS**.— *Speech transmitting technique should be such that the highest possible intelligibility is incorporated in each transmission. Fulfilment of this aim requires that air crew and ground personnel should:*

a) *enunciate each word clearly and distinctly;*

b) maintain an even rate of speech not exceeding 100 words per minute. When a message is transmitted to an aircraft and its contents need to be recorded the speaking rate should be at a slower rate to allow for the writing process. A slight pause preceding and following numerals makes them easier to understand;

c) maintain the speaking volume at a constant level;

d) be familiar with the microphone operating techniques particularly in relation to the maintenance of a constant distance from the microphone if a modulator with a constant level is not used;

e) suspend speech temporarily if it becomes necessary to turn the head away from the microphone.

5.2.1.5.4 **Recommendation**.– *Speech transmitting technique should be adapted to the prevailing communications conditions*.

5.2.1.5.5 **PANS**.— *Messages accepted for transmission should be transmitted in plain language or ICAO phraseologies without altering the sense of the message in any way. Approved ICAO* *abbreviations contained in the text of the message to be transmitted to aircraft should normally be converted into the unabbreviated words or phrases which these abbreviations represent in the language used, except for those which, owing to frequent and common practice, are generally understood by aeronautical personnel.*

Note.— The abbreviations which constitute the exceptions mentioned in 5.2.1.5.5 are specifically identified in the abbreviation encode sections of the PANS-ABC (Doc 8400).

5.2.1.5.6 **PANS.—** *To expedite communication, the use of phonetic spelling should be dispensed with, if there is no risk of this affecting correct reception and intelligibility of the message.*

5.2.1.5.7 **PANS.—** *The transmission of long messages should be interrupted momentarily from time to time to permit the transmitting operator to confirm that the frequency in use is clear and, if necessary, to permit the receiving operator to request repetition of parts not received.*

5.2.1.5.8 The following words and phrases shall be used in radiotelephony communications as appropriate and shall have the meaning ascribed hereunder:

Phrase	Meaning
ACKNOWLEDGE	"Let me know that you have received and understood this message."
AFFIRM	"Yes."
APPROVED	"Permission for proposed action granted."
BREAK	"I hereby indicate the separation between portions of the message." (To be used where there is no clear distinction between the text and other portions of the message.)
BREAK BREAK	"I hereby indicate the separation between messages transmitted to different aircraft in a very busy environment."
CANCEL	"Annul the previously transmitted clearance."
CHECK	"Examine a system or procedure." (Not to be used in any other context. No answer is normally expected.)
CLEARED	"Authorized to proceed under the conditions specified."

CONFIRM	"I request verification of: (clearance, instruction, action, information)."
CONTACT	"Establish communications with..."
CORRECT	"True" or "Accurate".
CORRECTION	"An error has been made in this transmission (or message indicated). The correct version is..."
DISREGARD	"Ignore."
HOW DO YOU	"What is the readability of my trans READ mission?" (see5.2.1.8.4.)
I SAY AGAIN	"I repeat for clarity or emphasis."
MAINTAIN	"Continue in accordance with the condition(s) specified" or in its literal sense, e.g. "Maintain VFR".
MONITOR	"Listen out on (frequency)."
NEGATIVE	"No" or "Permission not granted" or "That is not correct" or "Not capable".
OVER	"My transmission is ended, and I expect a response from you."

Note.— Not normally used in VHF communications. OUT "This exchange of transmissions is ended and no response is expected."

Note.— Not normally used in VHF communications.

READ BACK	"Repeat all, or the specified part, of this message back to me exactly as received."
RECLEARED	"A change has been made to your last clearance and this new clearance supersedes your previous clearance or part thereof."
REPORT	"Pass me the following information..."

REQUEST	"I should like to know..." or "I wish to obtain..."
ROGER	"I have received all of your last transmission."
	Note.— Under no circumstances to be used in reply to a question requiring
"READ BACK"	or a direct answer in the affirmative (AFFIRM) or negative (NEGATIVE).
SAY AGAIN	"Repeat all, or the following part, of your last transmission."
SPEAK SLOWER	"Reduce your rate of speech."
	Note.— For normal rate of speech, see 5.2.1.5.3 b).
STANDBY	"Wait and I will call you."
	Note.— The caller would normally re-establish contact if the delay is lengthy. STANDBY is not an approval or denial.
UNABLE	"I cannot comply with your request, instruction, or clearance."
	Note.— UNABLE is normally followed by a reason.
WILCO	*(Abbreviation for "will comply".)* "I understand your message and will comply with it."
WORDS TWICE	a) As a request: "Communication is difficult. Please send every word, or group of words, twice."
	b) As information: "Since communication is difficult, every word, or group of words, in this message will be sent twice."

5.2.1.6 *Composition of messages*

5.2.1.6.1 Messages handled entirely by the aeronautical mobile service shall comprise the following parts in the order stated:

a) call indicating the addressee and the originator (see5.2.1.7.3);

b) text (see5.2.1.6.2.1.1).

Note. – The following examples illustrate the application of this procedure:

(call) NEW YORK RADIO SWISSAIR ONE ONE ZERO

(text) REQUEST SELCAL CHECK or

(call) SWISSAIR ONE ONE ZERO NEW YORK RADIO

(text)CONTACT SAN JUAN ON FIVE SIX

5.2.1.6.2 Messages requiring handling by the AFTN for part of their routing and similarly messages which are not handled in accordance with predetermined distribution arrangements (see3.3.7.1) shall be composed as follows:

5.2.1.6.2.1 When originated in an aircraft:

1) call (see5.2.1.7.3);

2) the word FOR;

3) the name of the organization addressed;

4) the name of the station of destination;

5) the text.

5.2.1.6.2.1.1 The text shall be as short as practicable to convey the necessary information; full use shall be made of ICAO phraseologies.

Note. – The following example illustrates the application of this procedure:

(call) BOSTON RADIO SWISSAIR ONE TWO EIGHT

(address) FOR SWISSAIR BOSTON

(text) NUMBER ONE ENGINE CHANGE REQUIRED

5.2.1.6.2.2 When addressed to an aircraft.When a

message, prepared in accordance with 4.4.2, is retransmitted

by an aeronautical station to an aircraft in flight, the heading and address of the AFTN message format shall be omitted

during the retransmission on the aeronautical mobile service.

5.2.1.6.2.2.1 When the provisions of 5.2.1.6.2.2 are applied, the aeronautical mobile service message transmission shall comprise:

a) the text [incorporating any corrections (COR) contained in the AFTN message];

b) the word FROM;

c) the name of the originating organization and its location (taken from the origin section of the AFTN message).

5.2.1.6.2.2.2 **PANS**. – *When the text of a message to be transmitted by an aeronautical station to an aircraft in flight contains approved ICAO abbreviations, these abbreviations should normally be converted during the transmission of the message into the unabbreviated words or phrases which the abbreviations represent in the language used, except for those which, owing to frequent or common practice, are generally understood by aeronautical personnel.*

Note.– *The abbreviations which constitute the exceptions mentioned in 5.2.1.6.2.2.2 are specifically identified in the abbreviations encode sections of the PANS-ABC (Doc 8400).*

5.2.1.7 *Calling*

5.2.1.7.1 *Radiotelephony call signs for aeronautical stations*

Note.– *The formation of call signs as specified in ITU Radio Regulations S19 Section III and Section VII.*

5.2.1.7.1.1 Aeronautical stations in the aeronautical mobile service shall be identified by:

a) the name of the location; and

b) the unit or service available.

5.2.1.7.1.2 The unit or service shall be identified in accordance with the table below except that the name of the location or the unit/service may be omitted provided satisfactory communication has been established.

Unit/service available	*Call sign suffix*
area control centre	CONTROL

approach control	APPROACH
approach control radar arrivals	ARRIVAL
approach control radar departures	DEPARTURE
aerodrome control	TOWER
surface movement control	GROUND
radar (in general)	RADAR
precision approach radar	PRECISION
direction-finding station	HOMER
flight information service	INFORMATION
clearance delivery	DELIVERY
apron control	APRON
company dispatch	DISPATCH
aeronautical station	RADIO

5.2.1.7.2 Radiotelephony call signs for aircraft

5.2.1.7.2.*1 Full call signs*

5.2.1.7.2.1.1 An aircraft radiotelephony call sign shall be one of the following types:

Type a) — the characters corresponding to the registration marking of the aircraft; or

Type b) — the telephony designator of the aircraft operating agency, followed by the last four characters of the registration marking of the aircraft;

Type c) — the telephony designator of the aircraft operating agency, followed by the flight identification.

Note 1.— The name of the aircraft manufacturer or of the aircraft model may be used as a radiotelephony prefix to the Type a) call sign (see Table 5-1).

Note 2.— The telephony designators referred to in Types b) and c) are contained in Doc 8585 — Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services.

Note 3.— Any of the foregoing call signs may be inserted in field 7 of the ICAO flight plan as the aircraft identification.

Instructions on the completion of the flight plan form are contained in PANS-ATM, Doc 4444.

5.2.1.7.2.2 *Abbreviated call signs*

5.2.1.7.2.2.1 The aircraft radiotelephony call signs shown in 5.2.1.7.2.1.1, with the exception of Type c), may be abbreviated in the circumstances prescribed in 5.2.1.7.3.3.1.

Abbreviated call signs shall be in the following form:

Type a) — the first character of the registration and at least the last two characters of the call sign;

Type b) — the telephony designator of the aircraft operating agency, followed by at least the last two characters of the call sign;

Table 5-1. Examples of full call signs and abbreviated call signs
(see5.2.1.7.2.1 and 5.2.1.7.2.2)

		Type a)		*Type b)*	*Type c)*
Full call sign	N 57826	*CESSNA FABCD	*CITATION FABCD	VARIG PVMA	SCANDINAVIAN 937
Abbreviated call sign	N26 or N826	CESSNA CD or CESSNA BCD	CITATION CD or CITATION BCD	VARIG MA or VARIG VMA	(no abbreviated form)

* Examples illustrate the application of Note 1 to 5.2.1.7.2.1.1.

Type c) — no abbreviated form.

Note.— Either the name of the aircraft manufacturer or of the aircraft model may be used in place of the first character in Type a).

5.2.1.7.3 *Radiotelephony procedures*

5.2.1.7.3.1 An aircraft shall not change the type of its radiotelephony call sign during flight, except temporarily on the instruction of an air traffic control unit in the interests of safety.

5.2.1.7.3.1.1 Except for reasons of safety no transmission shall be directed to an aircraft during take-off, during the last part of the final approach or during the landing roll.

5.2.1.7.3.2 *Establishment of radiotelephony communications*

5.2.1.7.3.2.1 Full radiotelephony call signs shall always be used when establishing communication. The calling procedure of an aircraft establishing communication shall be in accordance with Table 5-2.

5.2.1.7.3.2.2 **PANS**.— *Stations having a requirement to transmit information to all stations likely to intercept should preface such transmission by the general call ALL STATIONS, followed by the identification of the calling station.*

Note.— No reply is expected to such general calls unless individual stations are subsequently called to acknowledge receipt.

5.2.1.7.3.2.3 The reply to the above calls shall be in accordance with Table 5-3. The use of the calling aeronautical station's call sign followed by the answering aeronautical station's call sign shall be considered the invitation to proceed with transmission by the station calling.

5.2.1.7.3.2.4 **PANS**.— *When a station is called but is uncertain of the identification of the calling station, it should reply by transmitting the following:*

STATION CALLING . . . (station called) SAY AGAIN YOUR CALL SIGN

Note.— The following example illustrates the application ofthis procedure:

(CAIRO station replying)

STATION CALLING CAIRO (pause) SAY AGAIN YOUR CALL SIGN

5.2.1.7.3.2.5 Communications shall commence with a call and a reply when it is desired to establish contact, except that, when it is certain that the station called will receive the call, the calling station may transmit the message, without waiting for a reply from the station called.

5.2.1.7.3.2.6 Interpilot air-to-air communication shall be established on the air-to-air channel 123.45 MHz by either a directed call to a specific aircraft station or a general call, taking into account conditions pertaining to use of this channel.

Note.— For conditions on use of air-to-air channels see Annex 10, Volume V, 4.1.3.2.1,also Volume II, 5.2.2.1.1.4.

5.2.1.7.3.2.6.1 **PANS**.— *As the aircraft may be guarding more than one frequency, the initial call should include the distinctive channel identification "INTERPILOT".*

Note. – *The following examples illustrate the application of this calling procedure.*

CLIPPER 123 — SABENA 901 — INTERPILOT — DO YOU READ or

ANY AIRCRAFT VICINITY OF 30 NORTH 160 EAST — JAPANAIR 401 — INTERPILOT — OVER

Table 5-2. **Radiotelephony calling procedure***(*see5.2.1.7.3.2.1)*

	Type a)	*Type b)*	*Type c)*
Designation of the station called	NEW YORK RADIO	NEW YORK RADIO	NEW YORK RADIO
Designation of the station calling	GABCD**	SPEEDBIRD ABCD**	AEROFLOT 321**

* *In certain cases where the call is initiated by the aeronautical station, the call may be effected by transmission of coded tone signals.*

** *With the exception of the telephony designators and the type of aircraft, each character in the call sign shall be spoken separately. When individual letters are spelled out, the radiotelephony spelling alphabet prescribed in 5.2.1.3 shall be used. Numbers are to be spoken in accordance with 5.2.1.4.*

Table 5-3. **Radiotelephony reply procedure** *(see 5.2.1.7.3.2.3)*

	Type a)	*Type b)*	*Type c)*
Designation of the station called	GABCD*	SPEEDBIRD ABCD*	AEROFLOT 321*
Designation of the answering station	NEW YORK RADIO	NEW YORK RADIO	NEW YORK RADIO

* *With the exception of the telephony designators and the type of aircraft, each character in the call sign shall be spoken separately. When individual letters are spelled out, the radiotelephony spelling alphabet prescribed in 5.2.1.3 shall be used. Numbers are to be spoken in accordance with 5.2.1.4.*

5.2.1.7.3.3 *Subsequent radiotelephony communications*

5.2.1.7.3.3.1 Abbreviated radiotelephony call signs, as prescribed in 5.2.1.7.2.2, shall be used only after satisfactory communication has been established and provided that no confusion is likely to arise. An aircraft station shall use its abbreviated call sign only after it has been addressed in this manner by the aeronautical station.

5.2.1.7.3.3.2 After contact has been established, continuous two-way communication shall be permitted without further identification or call until termination of the contact.

5.2.1.7.3.3.3 In order to avoid any possible confusion, when issuing ATC clearances and reading back such clearances, controllers and pilots shall always add the call sign of the aircraft to which the clearance applies.

5.2.1.7.3.4 *Indication of transmitting channel*

5.2.1.7.3.4.1 **PANS.**— *As the aeronautical station operator generally guards more than one frequency, the call should be followed by an indication of the frequency used, unless other suitable means of identifying the frequency are known to exist.*

5.2.1.7.3.4.2 **PANS**.— *When no confusion is likely to arise, only the first two digits of the High Frequency (in kHz) need be used to identify the transmitting channel.*

Note.— The following example illustrates the application of this procedure:

(PAA 325 calling Kingston on 8 871 kHz)

KINGSTON CLIPPER THREE TWO FIVE — ON EIGHT EIGHT

5.2.1.7.3.4.3 **PANS.**— *Except as specified in 5.2.1.7.3.4.4 all six digits of the numerical designator should be used to identify the transmitting channel in VHF radiotelephony communications, except in the case of both the fifth and sixth digits being zeros, in which case only the first four digits should be used.*

Note 1.— The following examples illustrate the application of the procedure in 5.2.1.7.3.4.3:

Channel	Transmitted as
118.000	ONE ONE EIGHT DECIMAL ZERO
118.005	ONE ONE EIGHT DECIMAL ZERO ZERO FIVE
118.010	ONE ONE EIGHT DECIMAL ZERO ONE ZERO
118.025	ONE ONE EIGHT DECIMAL ZERO TWO FIVE
118.050	ONE ONE EIGHT DECIMAL ZERO FIVE ZERO
118.100	ONE ONE EIGHT DECIMAL ONE

Note 2.— Caution must be exercised with respect to the indication of transmitting channels in VHF radiotelephony communications when all six digits of the numerical designator are used in airspace where communication channels are separated by 25 kHz, because on aircraft installations with a channel separation capability of 25 kHz or more, it is only possible to select the first five digits of the numerical designator on the radio management panel.

Note 3.— The numerical designator corresponds to the channel identification in Annex 10, Volume V, Table 4-1 (bis).

5.2.1.7.3.4.4 **PANS**. – *In airspace where all VHF voice communications channels are separated by 25 kHz or more and the use of six digits as in 5.2.1.7.3.4.3 is not substantiated by the operational requirement determined by the appropriate authorities, the first five digits of the numerical designator should be used, except in the case of both the fifth and sixth digits being zeros, in which case only the first four digits should be used.*

Note 1.– The following examples illustrate the application of the procedure in 5.2.1.7.3.4.4 and the associated settings of the aircraft radio management panel for communication equipment with channel separation capabilities of 25 kHz and 8.33/25 kHz:

Channel	*Transmitted as*	*Radio management panel setting for communication equipment with*	
		25 kHz (5 digits)	8.33/ 25 kHz (6 digits)
118.000	ONE ONE EIGHT DECIMAL ZERO	118.00	118.000
118.025	ONE ONE EIGHT DECIMAL ZERO TWO	118.02	118.025
118.050	ONE ONE EIGHT DECIMAL ZERO FIVE	118.05	118.050
118.075	ONE ONE EIGHT DECIMAL ZERO SEVEN	118.07	118.075
118.100	ONE ONE EIGHT DECIMAL ONE	118.10	118.100

Note 2.– Caution must be exercised with respect to the indication of transmitting channels in VHF radiotelephony communications when five digits of the numerical designator are used in airspace where aircraft are also operated with channel separation capabilities of 8.33/25 kHz. On aircraft installations with a channel separation capability of 8.33 kHz and more, it is possible to select six digits on the radio management panel. It should therefore be ensured that the fifth and sixth digits are set to 25 kHz channels (see Note 1).

Note 3.– The numerical designator corresponds to the channel identification in Annex 10, Volume V, Table 4-1 (bis).

5.2.1.8 Test procedures

5.2.1.8.1 **PANS**.— *The form of test transmissions should be as follows:*

a) the identification of the station being called;

b) the aircraft identification;

c) the words "RADIO CHECK";

d) the frequency being used.

5.2.1.8.2 **PANS**. – *The reply to a test transmission should be as follows:*

a) the identification of the aircraft;

b) the identification of the aeronautical station replying;

c) information regarding the readability of the aircraft transmission.

5.2.1.8.3 **PANS.**— *The test transmission and reply thereto should be recorded at the aeronautical station.*

5.2.1.8.4 **PANS**. – *When the tests are made, the following readability scale should be used:*

Readability Scale
1 Unreadable
2 Readable now and then
3 Readable but with difficulty
4 Readable
5 Perfectly readable

5.2.1.9 *Exchange of communications*

5.2.1.9.1 Communications shall be concise and unambiguous, using standard phraseology whenever available.

5.2.1.9.1.1 **Recommendation**.— *Abbreviated procedures should only be used after initial contact has been established and where no confusion is likely to arise.*

5.2.1.9.2 *Acknowledgement of receipt*. The receiving operator shall make certain that the message has been received correctly before acknowledging receipt.

Note.– Acknowledgement of receipt is not to be confused with acknowledgement of intercept in radiotelephony network operations.

5.2.1.9.2.1 When transmitted by an aircraft station, the acknowledgement of receipt of a message shall comprise the call sign of that aircraft.

5.2.1.9.2.2 **PANS**.— *An aircraft station should acknowledge receipt of important air traffic control messages or parts thereof by reading them back and terminating the readback by its radio call sign.*

Note 1.— Air traffic control clearances, instructions and information requiring readback are specified in PANS-ATM (Doc 4444).

Note 2.— The following example illustrates the application of this procedure:

(ATC clearance by network station to an aircraft)

Station:
TWA NINE SIX THREE MADRID

Aircraft:
MADRID TWA NINE SIX THREE

Station:
TWA NINE SIX THREE MADRID — ATC CLEARS
TWA NINE SIX THREE TO DESCEND TO NINE
THOUSAND FEET

Aircraft (acknowledging):
CLEARED TO DESCEND TO NINE THOUSAND
FEET — TWA NINE SIX THREE

Station (denoting accuracy of readback):
MADRID

5.2.1.9.2.3 When acknowledgement of receipt is transmitted by an aeronautical station:

1)*to an aircraft station*: it shall comprise the call sign of the aircraft, followed if considered necessary by the call sign of the aeronautical station;

2)*to another aeronautical station:* it shall comprise the call sign of the aeronautical station that is acknowledging receipt.

5.2.1.9.2.3.1 **PANS.**— *An aeronautical station should acknowledge position reports and other flight progress reports by reading back the report and terminating the read back by its* *call sign, except that the read back procedure may be suspended temporarily whenever it will alleviate congestion on the communication channel.*

5.2.1.9.2.4 **PANS**. – *It is permissible for verification for the receiving station to read back the message as an additional acknowledgement of receipt. In such instances, the station to which the information is read back should acknowledge the correctness of read back by transmitting its call sign.*

5.2.1.9.2.5 **PANS**. – *If both position report and other information – such as weather reports – are received in the same message, the information should be acknowledged with the words such as "WEATHER RECEIVED" after the position report has been read back, except when intercept of the information is required by other network stations. Other messages should be acknowledged, the aeronautical station transmitting its call sign only.*

5.2.1.9.3 End of conversation. A radiotelephone conversation shall be terminated by the receiving station using its own call sign.

5.2.1.9.4 *Corrections and repetitions*

5.2.1.9.4.1 When an error has been made in transmission, the word "CORRECTION" shall be spoken, the last correct group or phrase repeated, and then the correct version transmitted.

5.2.1.9.4.2 If a correction can best be made by repeating the entire message, the operator shall use the phrase "CORRECTION, I SAY AGAIN" before transmitting the message a second time.

5.2.1.9.4.3 **Recommendation.** – *When an operator transmitting a message considers that reception is likely to be difficult, he should transmit the important elements of the message twice.*

5.2.1.9.4.4 If the receiving operator is in doubt as to the correctness of the message received, he shall request repetition either in full or in part.

5.2.1.9.4.5 If repetition of an entire message is required, the words "SAY AGAIN" shall be spoken. If repetition of a portion of a message is required, the operator shall state: "SAY AGAIN ALL BEFORE...(first word satisfactorily received)"; or "SAY AGAIN...(word before missing portion) TO...(word after missing portion)"; or "SAY AGAIN ALL AFTER...(last word satisfactorily received)".

5.2.1.9.4.6 **Recommendation**. – *Specific items should be requested, as appropriate, such as "SAY AGAIN ALTIMETER", "SAY AGAIN WIND".*

5.2.1.9.4.7 If, in checking the correctness of a read back, an operator notices incorrect items, he shall transmit the words “NEGATIVE I SAY AGAIN” at the conclusion of the readback followed by the correct version of the items concerned.

5.2.1.9.5 *“Operations normal” reports*

PANS.— *When “operations normal” reports are transmitted by aircraft, they should consist of the prescribed call followed by the words “OPERATIONS NORMAL”.*

5.2.2 *Establishment and assurance of communications*

5.2.2.1 *Communications watch/Hours of service*

5.2.2.1.1 During flight, aircraft stations shall maintain watch as required by the appropriate Authority and shall not cease watch, except for reasons of safety, without informing the aeronautical station(s) concerned.

5.2.2.1.1.1 Aircraft on long over-water flights, or on flights over designated areas over which the carriage of an emergency locator transmitter (ELT) is required, shall continuously guard the VHF emergency frequency 121.5 MHz, except for those periods when aircraft are carrying out communications on other VHF channels or when airborne equipment limitations or cockpit duties do not permit simultaneous guarding of two channels.

5.2.2.1.1.2 Aircraft shall continuously guard the VHF emergency frequency 121.5 MHz in areas or over routes where the possibility of interception of aircraft or other hazardous situations exist, and a requirement has been established by the appropriate authority.

5.2.2.1.1.3 **Recommendation**.— *Aircraft on flights other than those specified in 5.2.2.1.1.1 and 5.2.2.1.1.2 should guard the emergency frequency 121.5 MHz to the extent possible.*

5.2.2.1.1.4 The user of the air-to-air VHF communications channel shall ensure that adequate watch is maintained on designated ATS frequencies, the frequency of the aeronautical emergency channel, and any other mandatory watch frequencies.

5.2.2.1.2 Aeronautical stations shall maintain watch as required by the appropriate Authority.

5.2.2.1.3 Aeronautical stations shall maintain a continuous listening watch on VHF emergency channel 121.5 MHz during the hours of service of the units at which it is installed.

Note.— See Annex 10, Volume V, 4.1.3.1.1 for provisions related to the utilization of 121.5 MHz at aeronautical stations.

5.2.2.1.4 When it is necessary for an aircraft station or aeronautical station to suspend operation for any reason, it shall, if possible, so inform other stations concerned, giving the time at which it is expected that operation will be resumed. When operation is resumed, other stations concerned shall be so informed.

5.2.2.1.4.1 When it is necessary to suspend operation beyond the time specified in the original notice, a revised time of resumption of operation shall, if possible, be transmitted at or near the time first specified.

5.2.2.1.5 **Recommendation**.— *When two or more ATS frequencies are being used by a controller, consideration should be given to providing facilities to allow ATS and aircraft transmissions on any of the frequencies to be simultaneously retransmitted on the other frequencies in use thus permitting aircraft stations within range to hear all transmissions to and from the controller.*

5.2.2.2 *Principles of network operation (HF communications)*

5.2.2.2.1 **PANS.—** *The aeronautical stations of a radiotelephony network should assist each other in accordance with the following network principles, in order to provide the air-ground communication service required of the network by aircraft flying on the air routes for which the network is responsible.*

5.2.2.2.2 **PANS**.— *When the network comprises a large number of stations, network communications for flights on any individual route segment should be provided by selected stations, termed "regular stations" for that segment.*

Note 1.— The selection of stations to act as regular stations for a particular route segment will, where necessary, be undertaken by regional or local agreement, after consultation, if necessary, between the States responsible for the network.

Note 2.— In principle, the regular stations will be those serving the locations immediately concerned with flights on that route segment, i.e. points of take-off and landing, appropriate flight information centres or area control centres and, in some cases, additional suitably located stations required to complete the communication coverage or for intercept purposes.

Note 3.— In selecting the regular stations, account will be taken of the propagation characteristics of the frequencies used.

5.2.2.2.3 **PANS.—** *In areas or on routes where radio conditions, length of flights or distance between aeronautical stations require additional measures to ensure continuity of air-ground communication throughout the route segment, the regular stations should share between them a responsibility of primary guard whereby each station will provide the primary guard for that portion of the flight during which the messages from the aircraft can be handled most effectively by that station.*

5.2.2.2.4 **PANS.** – *During its tenure of primary guard, each regular station should, among other things:*

a) be responsible for designating suitable primary and secondary frequencies for its communications with the aircraft;

b) receive all position reports and handle other messages from and to the aircraft essential to the safe conduct of the flight;

c) be responsible for the action required in case of failure of communications (see5.2.2.7.2).

5.2.2.2.5 **PANS**.— *The transfer of primary guard from one station to the next will normally take place at the time of the traversing of flight information region or control area boundaries, this guard being provided at any time, as far as possible, by the station serving the flight information centre or area control centre in whose area the aircraft is flying. However, where communication conditions so demand, a station may be required to retain primary guard beyond such geographical boundaries or release its guard before the aircraft reaches the boundary, if appreciable improvement in air-ground communication can be effected thereby*.

5.2.2.3 *Frequencies to be used*

5.2.2.3.1 Aircraft stations shall operate on the appropriate radio frequencies.

5.2.2.3.1.1 The air-ground control radio station shall designate the frequency(ies) to be used under normal conditions by aircraft stations operating under its control.

5.2.2.3.1.2 **PANS.—** *In network operation, the initial designation of primary and secondary frequencies should be made by the network station with which the aircraft makes pre-flight check or its initial contact after take-off. This station should also ensure that other network stations are advised, as required, of the frequency(ies) designated*.

5.2.2.3.2 **Recommendation**.— *An aeronautical station, when designating frequencies in accordance with 5.2.2.3.1.1 or 5.2.2.3.1.2, should take into account the appropriate propagation data and distance over which communications are required.*

5.2.2.3.3 **Recommendation**.— *If a frequency designated by an aeronautical station proves to be unsuitable, the aircraft station should suggest an alternative frequency.*

5.2.2.3.4 **PANS.**— When, notwithstanding the provisions of 5.1.1, air-ground frequencies are used for the exchange between network stations of messages essential for coordination and cooperation between the stations, such communication should, so far as possible, be effected over network frequencies not being used at that time for the bulk of the air-ground traffic. In all cases, the communication with aircraft stations should take priority over the inter-ground station communications.

5.2.2.4 *Establishment of communications*

5.2.2.4.1 Aircraft stations shall, if possible, communicate directly with the air-ground control radio station appropriate to the area in which the aircraft are flying. If unable to do so, aircraft stations shall use any relay means available and appropriate to transmit messages to the air-ground control radio station.

5.2.2.4.2 When normal communications from an aeronautical station to an aircraft station cannot be established, the aeronautical station shall use any relay means available and appropriate to transmit messages to the aircraft station. If these efforts fail, the originator shall be advised in accordance with procedures prescribed by the appropriate Authority.

5.2.2.4.3 **PANS**.— *When, in network operation, communication between an aircraft station and a regular station has not been established after calls on the primary and secondary frequencies, aid should be rendered by one of the other regular stations for that flight, either by calling the attention of the station first called or, in the case of a call made by an aircraft station, by answering the call and taking the traffic.*

5.2.2.4.3.1 **PANS**.— *Other stations of the network should render assistance by taking similar action only if attempts to establish communications by the regular stations have proved unsuccessful.*

5.2.2.4.4 **PANS**.— *The provisions of 5.2.2.4.3 and 5.2.2.4.3.1 should also be applied:*

a) on request of the air traffic services unit concerned;

b) when an expected communication from an aircraft has not been received within a time period such that the occurrence of a communication failure is suspected.

Note.— A specific time period may be prescribed by the appropriate ATS Authority.

5.2.2.5 *Transfer of HF communications*

5.2.2.5.1 **PANS.**— *An aircraft station should be advised by the appropriate aeronautical station to transfer from one radio frequency or network to another. In the absence of such advice, the aircraft station should notify the appropriate aeronautical station before such transfer takes place.*

5.2.2.5.2 **PANS**.— *In the case of transfer from one network to another, the transfer should preferably take place while the aircraft is in communication with a station operating in both networks to ensure continuity of communications. If, however, the change of network must take place concurrently with the transfer of communication to another network station, the transfer should be coordinated by the two network stations prior to advising or authorizing the frequency change. The aircraft should also be advised of the primary and secondary frequencies to be used after the transfer.*

5.2.2.5.3 An aircraft station which has transferred communications watch from one radio frequency to another shall, when so required by the appropriate ATS Authority, inform the aeronautical station concerned that communications watch has been established on the new frequency.

5.2.2.5.4 **PANS.**— *When entering a network after takeoff, an aircraft station should transmit its take-off time or time over the last check-point, to the appropriate regular station.*

5.2.2.5.5 **PANS.**— *When entering a new network, an aircraft station should transmit the time over the last checkpoint, or of its last reported position, to the appropriate regular station.*

5.2.2.5.6 **PANS.**— *Before leaving the network, an aircraft station should in all cases advise the appropriate regular station of its intention to do so by transmitting one of the following phrases, as appropriate:*

a) when transferring to a pilot-to-controller channel:
Aircraft: CHANGING TO. . . (air traffic services unit concerned)

b) after landing:
Aircraft: LANDED. . . (location) . . . (time)

5.2.2.6 *Transfer of VHF communications*

5.2.2.6.1 An aircraft shall be advised by the appropriate aeronautical station to transfer from one radio frequency to another in accordance with agreed procedures. In the absence of such advice, the aircraft station shall notify the appropriate aeronautical station before such a transfer takes place.

5.2.2.6.2 When establishing initial contact on, or when leaving, a VHF frequency, an aircraft station shall transmit such information as may be prescribed by the appropriate Authority.

5.2.2.7 *Voice communications failure*

5.2.2.7.1 *Air-ground*

5.2.2.7.1.1 When an aircraft station fails to establish contact with the appropriate aeronautical station on the designated channel, it shall attempt to establish contact on the previous channel used and, if not successful, on another channel appropriate to the route. If these attempts fail, the aircraft station shall attempt to establish communication with the appropriate aeronautical station, other aeronautical stationsor other aircraft using all available means and advise the aeronautical station that contact on the assigned channel could not be established. In addition, an aircraft operating within a network shall monitor the appropriate VHF channel for calls from nearby aircraft.

5.2.2.7.1.2 If the attempts specified under 5.2.2.7.1.1 fail, the aircraft station shall transmit its message twice on the designated channel(s), preceded by the phrase "TRANSMITTING BLIND" and, if necessary, include the addressee(s) for which the message is intended.

5.2.2.7.1.2.1 **PANS.** – *In network operation, a message which is transmitted blind should be transmitted twice on both primary and secondary channels. Before changing channel, the aircraft station should announce the channel to which it is changing.*

5.2.2.7.1.3 *Receiver failure*

5.2.2.7.1.3.1 When an aircraft station is unable to establish communication due to receiver failure, it shall transmit reports at the scheduled times, or positions, on the channel in use, preceded by the phrase "TRANSMITTING BLIND DUE TO RECEIVER FAILURE". The aircraft station shall transmit the intended message, following this by a complete repetition. During this procedure, the aircraft shall also advise the time of its next intended transmission.

5.2.2.7.1.3.2 An aircraft which is provided with air traffic control or advisory service shall, in addition to complying with 5.2.2.7.1.3.1, transmit information regarding the intention of the pilot-in-command with respect to the continuation of the flight of the aircraft.

5.2.2.7.1.3.3 When an aircraft is unable to establish communication due to airborne equipment failure it shall, when so equipped, select the appropriate SSR code to indicate radio failure.

Note.— General rules which are applicable in the event of communications failure are contained in Annex 2 to the Convention.

5.2.2.7.2 *Ground-to-air*

5.2.2.7.2.1 When an aeronautical station has been unable to establish contact with an aircraft station after calls on the frequencies on which the aircraft is believed to be listening, it shall:

a) request other aeronautical stations to render assistance by calling the aircraft and relaying traffic, if necessary;

b) request aircraft on the route to attempt to establish communication with the aircraft and relay traffic, if necessary.

5.2.2.7.2.2 The provisions of 5.2.2.7.2.1 shall also be applied:

a) on request of the air traffic services unit concerned;

b) when an expected communication from an aircraft has not been received within a time period such that the occurrence of a communication failure is suspected.

Note.— A specific time period may be prescribed by the appropriate ATS Authority.

5.2.2.7.2.3 **Recommendation**.— *If the attempts specified in 5.2.2.7.2.1 fail, the aeronautical station should transmit messages addressed to the aircraft, other than messages containing air traffic control clearances, by blind transmission on the frequency(ies) on which the aircraft is believed to be listening.*

5.2.2.7.2.4 Blind transmission of air traffic control clearances shall not be made to aircraft, except at the specific request of the originator.

5.2.2.7.3 *Notification of communications failure*. The air-ground control radio station shall notify the appropriate air traffic services unit and the aircraft operating agency, as soon as possible, of any failure in air-ground communication.

5.2.3 *HF message handling*

5.2.3.1 *General*

5.2.3.1.1 **PANS**.— *When operating within a network, an aircraft station should, in principle, whenever communications conditions so permit, transmit its messages to the stations of the network from which they can be most readily delivered to their ultimate destinations. In particular, aircraft reports required by air traffic services should be transmitted to the network station serving the flight information centre or area control centre in whose area the aircraft is flying. Conversely, messages to aircraft in flight should, whenever possible, be transmitted directly to the aircraft by the network station serving the location of the originator.*

Note.— Exceptionally, an aircraft may need to communicate with an aeronautical station outside the network appropriate to its particular route segment. This is permissible, provided it can be done without interrupting the continuous watch with the communication network appropriate to the route segment, when such watch is required by the appropriate ATS Authority, and provided it does not cause undue interference with the operation of other aeronautical stations.

5.2.3.1.2 **PANS.**— *Messages passed from an aircraft to a network station should, whenever possible, be intercepted and acknowledged by other stations of the network, which serve locations where the information is also required.*

Note 1.— Determination of the arrangements for dissemination of air-ground messages without address will be a matter for multilateral or local agreement.

Note 2.— In principle, the number of stations required to intercept are to be kept to a minimum consistent with the operational requirement.

5.2.3.1.2.1 **PANS**.— *Acknowledgement of intercept should be made immediately after the acknowledgement of receipt by the station to which the message was passed.*

5.2.3.1.2.2 **PANS**.— *Acknowledgement of an intercept message should be made by transmitting the radio call sign of the station having intercepted the message, followed by the word ROGER, if desired, and the call sign of the station having transmitted the message.*

5.2.3.1.2.3 **PANS.**— *In the absence of acknowledgement of intercept within one minute, the station accepting the message from the aircraft should forward it, normally over the aeronautical fixed service, to the station(s) which have failed to acknowledge intercept.*

5.2.3.1.2.3.1 **PANS**.— *If, in abnormal circumstances, forwarding is necessary using the air-ground channels, the provisions of 5.2.2.3.4 should be observed.*

5.2.3.1.2.4 **PANS.**— *When such forwarding is done over the aeronautical fixed telecommunication network, the messages should be addressed to the network station(s) concerned.*

5.2.3.1.2.5 **PANS.**— *The station(s) to which the messages have been forwarded should carry out local distribution of them in the same way as if they had been received directly from the aircraft over the air-ground channel.*

5.2.3.1.2.6 The aeronautical station receiving an air report or a message containing meteorological information transmitted by an aircraft in flight shall forward the message without delay:

1) to the air traffic services unit and meteorological offices associated with the station;

2) to the aircraft operating agency concerned or its representative when that agency has made a specific request to receive such messages.

5.2.3.1.3 **PANS**.— *The provisions of 5.2.3.1.2 should also be applied, if practicable, in non-network operation.*

5.2.3.1.4 **Recommendation**.— *When a message addressed to an aircraft in flight is received by the aeronautical station included in the address, and when that station is not able to establish communication with the aircraft to which the message is addressed, the message should be forwarded to those aeronautical stations on the route which may be able to establish communication with the aircraft.*

Note.— This does not preclude the transmission by the forwarding aeronautical station, of the original message to the aircraft addressed, if the forwarding station is later able to communicate with that aircraft.

5.2.3.1.4.1 **Recommendation**.— *If the aeronautical station to which the message is addressed is unable to dispose of the message in accordance with 5.2.3.1.4, the station of origin should be advised.*

5.2.3.1.4.2 The aeronautical station forwarding the message shall amend the address thereof, by substituting for its own location indicator the location indicator of the aeronautical station to which the message is being forwarded.

5.2.3.2 *Transmission of ATS messages to aircraft*

5.2.3.2.1 **PANS**.— *If it is not possible to deliver an ATS message to the aircraft within the time specified by ATS, the aeronautical station should notify the originator. Thereafter, it should take no further action with respect to this message unless specifically instructed by ATS.*

5.2.3.2.2 **PANS.**— *If delivery of an ATS message is uncertain because of inability to secure an acknowledgement, the aeronautical station should assume that the message has not been received by the aircraft and should advise the originator immediately that, although the message has been transmitted, it has not been acknowledged.*

5.2.3.2.3 **PANS**.— *The aeronautical station, having received the message from ATS, should not delegate to another station the responsibility for delivery of the message to the aircraft. However, in case of communication difficulties, other stations should assist, when requested, in relaying the message to the aircraft. In this case, the station having received the message from ATS should obtain without delay definite assurance that the aircraft has correctly acknowledged the message.*

5.2.3.3 *Recording of air-ground communications on teletypewriter*

5.2.3.3.1 **PANS**.— *When recording on teletypewriter, the following procedure should be used:*

a) each line should begin at the left margin;

b) a new line should be used for each transmission;

c) each communication should contain some or all of the following items in the order shown:

1) call sign of the calling station;

2) text of the message;

3) call sign of the station called or the receiving station, followed by the appropriate abbreviation to indicate “Received”, “Read back”, or “No reply heard”;

4) call sign of station(s) acknowledging intercept followed by appropriate abbreviation to indicate “Received”;

5) designation of frequency used;

6) time in UTC of the communication;

d) missing parts of the message text should be indicated by typing the three periods (space . space . space . space) or three letters M (space M space M space M space);

e) correction of typing errors should be made by keyboard manipulation (space E space E space E space), followed by the correct information. Errors detected after the completion of the entry should be corrected after the last entry, using the abbreviation COR, followed by the correct information.

5.2.4 *SELCAL procedures*

Note.— The procedures contained in 5.2.4 are applicable when SELCAL is used and replace certain of the procedures related to calling contained in 5.2.1.

5.2.4.1 *General*

5.2.4.1.1 **PANS**.— *With the selective calling system known as SELCAL, the voice calling is replaced by the transmission of coded tones to the aircraft over the radiotelephony channels. A single selective call consists of a combination of four pre-selected audio tones whose transmission requires approximately 2 seconds. The tones are generated in the aeronautical station coder and are received by a decoder connected to the audio output of the airborne receiver. Receipt of the assigned tone code (SELCAL code) activates a cockpit call system in the form of light and/or chime signals.*

Note.— Due to the limited number of SELCAL codes, similar code assignments to multiple aircraft may be expected.

Therefore, the use of correct radiotelephony (RTF) procedures contained in this chapter is emphasized when establishing communications via SELCAL.

5.2.4.1.2 **PANS.**— *SELCAL should be utilized by suitably equipped stations for ground-to-air selective calling on the en-route HF and VHF radio channels.*

5.2.4.1.3 **PANS**.— *On aircraft equipped with SELCAL, the pilot is still able to keep a conventional listening watch if required.*

5.2.4.2 *Notification to aeronautical stations of aircraft SELCAL codes*

5.2.4.2.1 **PANS.**— *It is the responsibility of the aircraft operating agency and the aircraft to ensure that all aeronautical stations, with which the aircraft would normally communicate during a particular flight, know the SELCAL code associated with its radiotelephony call sign.*

5.2.4.2.2 **PANS.**— *When practicable, the aircraft operating agency should disseminate to all aeronautical stations concerned, at regular intervals, a list of SELCAL codes assigned to its aircraft or flights.*

5.2.4.2.3 **PANS.**— *The aircraft should:*

a) include the SELCAL code in the flight plan submitted to the appropriate air traffic services unit; and

b) ensure that the HF aeronautical station has the correct SELCAL code information by establishing communications temporarily with the HF aeronautical station while still within VHF coverage.

Note.— Provisions regarding completion of the flight plan are set forth in the PANS-ATM (Doc 4444).

5.2.4.3 *Pre-flight check*

5.2.4.3.1 ***PANS.***— *The aircraft station should contact the appropriate aeronautical station and request a pre-flight SELCAL check and, if necessary, give its SELCAL code.*

5.2.4.3.2 **PANS.**— *When primary and secondary frequencies are assigned, a SELCAL check should normally be made first on the secondary frequency and then on the primary frequency. The aircraft station would then be ready for continued communication on the primary frequency.*

5.2.4.3.3 **PANS.**— *Should the pre-flight check reveal that either the ground or airborne SELCAL installation is inoperative, the aircraft should maintain a continuous listening watch on its subsequent flight until SELCAL again becomes available.*

5.2.4.4 *Establishment of communications*

5.2.4.4.1 **PANS**.— *When an aeronautical station initiates a call by SELCAL, the aircraft replies with its radio call sign, followed by the phrase "GO AHEAD".*

5.2.4.5 *En-route procedures*

5.2.4.5.1 **PANS**.— *Aircraft stations should ensure that the appropriate aeronautical station(s) are aware that SELCAL watch is being established or maintained.*

5.2.4.5.2 **PANS.**— *When so prescribed on the basis of regional air navigation agreements, calls for scheduled reports from aircraft may be initiated by an aeronautical station by means of SELCAL.*

5.2.4.5.3 **PANS.**— *Once SELCAL watch has been established by a particular aircraft station, aeronautical stations should employ SELCAL whenever they require to call aircraft.*

5.2.4.5.4 **PANS**.— *In the event the SELCAL signal remains unanswered after two calls on the primary frequency and two calls on the secondary frequency, the aeronautical station should revert to voice calling.*

5.2.4.5.5 **PANS.**— *Stations in a network should keep each other immediately advised when malfunctioning occurs in a SELCAL installation on the ground or in the air. Likewise, the aircraft should ensure that the aeronautical stations concerned with its flight are immediately made aware of any malfunctioning of its SELCAL installation, and that voice calling is necessary.*

5.2.4.5.6 **PANS**.– *All stations should be advised when the SELCAL installation is again functioning normally.*

5.2.4.6 *SELCAL code assignment to aircraft*

5.2.4.6.1 **PANS**.– *In principle, the SELCAL code in the aircraft should be associated with the radiotelephony call sign, i.e. where the flight number (service number) is employed in the radio call sign, the SELCAL code in the aircraft should be listed against the flight number. In all other cases, the SELCAL code in the aircraft should be listed against the aircraft registration.*

Note.— The use of aircraft radio call signs, consisting of the airline abbreviation followed by the flight service number, is increasing among aircraft operators throughout the world. The SELCAL equipment in aircraft should, therefore, be of a type which permits a particular code being associated with a particular flight number, i.e. equipment which is capable of adjustment in code combinations. At this stage, however, many aircraft still carry SELCAL equipment of the single code type, and it will not be possible for aircraft with such equipment to satisfy the principle set out above. This should not militate against use of the flight number type of radio call sign by an aircraft so equipped if it wishes to apply this type of call sign, but it is essential when a single code airborne equipment is used in conjunction with a flight number type radio call sign that the ground stations be advised in connection with each flight of the SELCAL code available in the aircraft.

5.3 Distress and urgency radiotelephony communication procedures

5.3.1 *General*

Note.— The distress and urgency procedures contained in 5.3 relate to the use of radiotelephony. The provisions of Article S30 and Appendix S13 of the ITU Radio Regulations are generally applicable, except that S30.9 permits other procedures to be employed where special arrangements between governments exist, and are also applicable to radiotelephony communications between aircraft stations and stations in the maritime mobile service.

5.3.1.1 Distress and urgency traffic shall comprise all radiotelephony messages relative to the distress and urgency conditions respectively. Distress and urgency conditions are defined as:

a) *Distress:* a condition of being threatened by serious and/or imminent danger and of requiring immediate assistance.

b)*Urgency*: a condition concerning the safety of an aircraft or other vehicle, or of some person on board or within sight, but which does not require immediate assistance.

5.3.1.2 The radiotelephony distress signal MAYDAY and the radiotelephony urgency signal PAN PAN shall be used at the commencement of the first distress and urgency communication respectively.

5.3.1.2.1 At the commencement of any subsequent communication in distress and urgency traffic, it shall be permissible to use the radiotelephony distress and urgency signals.

5.3.1.3 The originator of messages addressed to an aircraft in distress or urgency condition shall restrict to the minimum the number and volume and content of such messages as required by the condition.

5.3.1.4 If no acknowledgement of the distress or urgency message is made by the station addressed by the aircraft, other stations shall render assistance, as prescribed in 5.3.2.2 and 5.3.3.2 respectively.

Note.— "Other stations" is intended to refer to any other station which has received the distress or urgency message and has become aware that it has not been acknowledged by the station addressed.

5.3.1.5 Distress and urgency traffic shall normally be maintained on the frequency on which such traffic was initiated until it is considered that better assistance can be provided by transferring that traffic to another frequency.

Note.— 121.5 MHz or alternative available VHF or HF frequencies may be used as appropriate.

5.3.1.6 In cases of distress and urgency communications, in general, the transmissions by radiotelephony shall be made slowly and distinctly, each word being clearly pronounced to facilitate transcription.

5.3.2 Radiotelephony distress communications

5.3.2.1 *Action by the aircraft in distress*

5.3.2.1.1 In addition to being preceded by the radiotelephony distress signal MAYDAY (see5.3.1.2), preferably spoken three times, the distress message to be sent by an aircraft in distress shall:

a) be on the air-ground frequency in use at the time;

b) consist of as many as possible of the following elements spoken distinctly and, if possible, in the following order:

1) name of the station addressed (time and circumstances permitting);

2) the identification of the aircraft;

3) the nature of the distress condition;

4) intention of the person in command;

5) present position, level (i.e. flight level, altitude, etc., as appropriate) and heading.

Note 1.— The foregoing provisions may be supplemented by the following measures:

a) the distress message of an aircraft in distress being made on the emergency frequency 121.5 MHz or another aeronautical mobile frequency, if considered necessary or desirable. Not all aeronautical stations maintain a continuous guard on the emergency frequency;

b) the distress message of an aircraft in distress being broadcast, if time and circumstances make this course preferable;

c) the aircraft transmitting on the maritime mobile service radiotelephony calling frequencies;

d) the aircraft using any means at its disposal to attract attention and make known its conditions (including the activation of the appropriate SSR mode and code);

e) any station taking any means at its disposal to assist an aircraft in distress;

f) any variation on the elements listed under 5.3.2.1.1 b), when the transmitting station is not itself in distress, provided that such circumstance is clearly stated in the distress message.

Note 2.— The station addressed will normally be that station communicating with the aircraft or in whose area of responsibility the aircraft is operating.

5.3.2.2 Action by the station addressed or first station acknowledging the distress message

5.3.2.2.1 The station addressed by aircraft in distress, or first station acknowledging the distress message, shall:

a) immediately acknowledge the distress message;

b) take control of the communications or specifically and clearly transfer that responsibility, advising the aircraft if a transfer is made;

c) take immediate action to ensure that all necessary information is made available, as soon as possible, to:

1) the ATS unit concerned;

2) the aircraft operating agency concerned, or its representative, in accordance with pre-established arrangements;

Note.— The requirement to inform the aircraft operating agency concerned does not have priority over any other action which involves the safety of the flight in distress, or of any other flight in the area, or which might affect the progress of expected flights in the area.

d) warn other stations, as appropriate, in order to prevent the transfer of traffic to the frequency of the distress communication.

5.3.2.3 *Imposition of silence*

5.3.2.3.1 The station in distress, or the station in control of distress traffic, shall be permitted to impose silence, either on all stations of the mobile service in the area or on any station which interferes with the distress traffic. It shall address these instructions "to all stations", or to one station only, according to circumstances. In either case, it shall use:

— STOP TRANSMITTING;

— the radiotelephony distress signal MAYDAY.

5.3.2.3.2 The use of the signals specified in 5.3.2.3.1 shall be reserved for the aircraft station in distress and for the station controlling the distress traffic.

5.3.2.4 *Action by all other stations*

5.3.2.4.1 The distress communications have absolute priority over all other communications, and a station aware of them shall not transmit on the frequency concerned, unless:

a) the distress is cancelled or the distress traffic is terminated;

b) all distress traffic has been transferred to other frequencies;

c) the station controlling communications gives permission;

d) it has itself to render assistance.

5.3.2.4.2 Any station which has knowledge of distress traffic, and which cannot itself assist the station in distress, shall nevertheless continue listening to such traffic until it is evident that assistance is being provided.

5.3.2.5 *Termination of distress communications and of silence*

5.3.2.5.1 When an aircraft is no longer in distress, it shall transmit a message cancelling the distress condition.

5.3.2.5.2 When the station which has controlled the distress communication traffic becomes aware that the distress condition is ended, it shall take immediate action to ensure that this information is made available, as soon as possible, to:

1) the ATS unit concerned;

2) the aircraft operating agency concerned, or its representative, in accordance with pre-established arrangements.

5.3.2.5.3 The distress communication and silence conditions shall be terminated by transmitting a message, including the words "DISTRESS TRAFFIC ENDED", on the frequency or frequencies being used for the distress traffic. This message shall be originated only by the station controlling the communications when, after the reception of the message prescribed in 5.3.2.5.1, it is authorized to do so by the appropriate authority.

5.3.3 Radiotelephony urgency communications

5.3.3.1 *Action by the aircraft reporting an urgency condition except as indicated in 5.3.3.4*

5.3.3.1.1 In addition to being preceded by the radiotelephony urgency signal PAN PAN (see5.3.1.2), preferably spoken three times and each word of the group pronounced as the French word "panne", the urgency message to be sent by an aircraft reporting an urgency condition shall:

a) be on the air-ground frequency in use at the time;

b) consist of as many as required of the following elements spoken distinctly and, if possible, in the following order:

1) the name of the station addressed;

2) the identification of the aircraft;

3) the nature of the urgency condition;

4) the intention of the person in command;

5) present position, level (i.e. flight level, altitude, etc., as appropriate) and heading;

6) any other useful information.

Note 1.— The foregoing provisions of 5.3.3.1.1 are not intended to prevent an aircraft broadcasting an urgency message, if time and circumstances make this course preferable.

Note 2. – The station addressed will normally be that station communicating with the aircraft or in whose area of responsibility the aircraft is operating.

5.3.3.2 *Action by the station addressed or first station acknowledging the urgency message*

5.3.3.2.1 The station addressed by an aircraft reporting an urgency condition, or first station acknowledging the urgency message, shall:

a) acknowledge the urgency message;

b) take immediate action to ensure that all necessary information is made available, as soon as possible, to:

1) the ATS unit concerned;

2) the aircraft operating agency concerned, or its representative, in accordance with pre-established arrangements;

Note. – The requirement to inform the aircraft operating agency concerned does not have priority over any other action which involves the safety of the flight in distress, or of any other flight in the area, or which might affect the progress of expected flights in the area.

c) if necessary, exercise control of communications.

5.3.3.3 *Action by all other stations*

5.3.3.3.1 The urgency communications have priority over all other communications, except distress, and all stations shall take care not to interfere with the transmission of urgency traffic.

5.3.3.4 *Action by an aircraft used for medical transports*

5.3.3.4.1 The use of the signal described in 5.3.3.4.2 shall indicate that the message which follows concerns a protected medical transport pursuant to the 1949 Geneva Conventions and Additional Protocols.

5.3.3.4.2 For the purpose of announcing and identifying aircraft used for medical transports, a transmission of the radiotelephony urgency signal PAN PAN, preferably spoken three times, and each word of the group pronounced as the French word “panne”, shall be followed by the radiotelephony signal for medical transports MAY-DEE-CAL, pronounced as in the French “médical”. The use of the signals described above indicates that the message which follows concerns a protected medical transport. The message shall convey the following data:

a) the call sign or other recognized means of identification of the medical transports;

b) position of the medical transports;

c) number and type of medical transports;

d) intended route;

e) estimated time en route and of departure and arrival, as appropriate; and

f) any other information such as flight altitude, radio frequencies guarded, languages used, and secondary surveillance radar modes and codes.

5.3.3.5 *Action by the station addressed or by other stations receiving a medical transports message*

5.3.3.5.1 The provisions of 5.3.3.2 and 5.3.3.3 shall apply as appropriate to stations receiving a medical transports message.

5.4 Communications related to acts of unlawful interference

The station addressed by an aircraft being subjected to an act of unlawful interference, or first station acknowledging a call from such aircraft, shall render all possible assistance, including notification of appropriate ATS units as well as any other station, agency or person in a position to facilitate the flight.

CHAPTER 6. AERONAUTICAL RADIO NAVIGATION SERVICE

6.1 General

6.1.1 The aeronautical radio navigation service shall comprise all types and systems of radio navigation aids in the international aeronautical service.

6.1.2 An aeronautical radio navigation aid which is not in continuous operation shall, if practicable, be put into operation on receipt of a request from an aircraft, any controlling authority on the ground, or an authorized representative of an aircraft operating agency.

6.1.2.1 **Recommendation**.— *Requests from aircraft should be made to the aeronautical station concerned on the air-ground frequency normally in use.*

6.1.3 Arrangements shall be made for the local aeronautical information service unit to receive without delay essential information about changes in the operational status of non-visual aids as required for pre-flight briefing and dissemination in accordance with the provisions of Annex 15.

6.2 Direction finding

Introductory Notes

1) Direction-finding stations work either singly or in groups of two or more stations under the direction of a main direction-finding station.

2) A direction-finding station working alone can only determine the direction of an aircraft in relation to itself.

6.2.1 **Recommendation.—** *A direction-finding station working alone should give the following, as requested:*

1) true bearing of the aircraft, using the appropriate phrase;

2) true heading to be steered by the aircraft, with no wind, to head for the direction-finding station using the appropriate phrase;

3) magnetic bearing of the aircraft, using the appropriate phrase;

4) magnetic heading to be steered by the aircraft with no wind to make for the station, using the appropriate phrase.

6.2.2 **Recommendation**.— *When direction-finding stations work as a network to determine the position of an aircraft, the bearings taken by each station should be sent immediately to the station controlling the direction-finding network to enable the position of the aircraft to be determined.*

6.2.2.1 **Recommendation**.— *The station controlling the network should, on request, give the aircraft its position in one of the following ways:*

1) position in relation to a point of reference or in latitude and longitude, using the appropriate phrase;

2) true bearing of the aircraft in relation to the direction finding station or other specified point, using the appropriate phrase, and its distance from the direction finding station or point, using the appropriate phrase;

3) magnetic heading to steer with no wind, to make for the direction-finding station or other specified point using the appropriate phrase, and its distance from the direction-finding station or point, using the appropriate phrase.

6.2.3 Aircraft stations shall normally make requests for bearings, courses or positions, to the aeronautical station responsible, or to the station controlling the direction-finding network.

6.2.4 To request a bearing, heading or position, the aircraft station shall call the aeronautical station or the direction-finding control station on the listening frequency. The aircraft shall then specify the type of service that is desired by the use of the appropriate phrase.

6.2.5 As soon as the direction-finding station or group of stations is ready, the station originally called by the aircraft station shall where necessary request transmission for direction-finding service and, if necessary, indicate the frequency to be used by the aircraft station, the number of times the transmission should be repeated, the duration of the transmission required or any special transmission requirement.

6.2.5.1 In radiotelephony, an aircraft station which requests a bearing shall end the transmission by repeating its call sign. If the transmission has been too short for the direction-finding station to obtain a bearing, the aircraft shall give a longer transmission for two periods of approximately ten seconds, or alternatively provide such other signals as may be requested by the direction-finding station.

Note.— Certain types of VHF/DF stations require the provision of a modulated signal (voice transmission) in order to take a bearing.

6.2.6 When a direction-finding station is not satisfied with its observation, it shall request the aircraft station to repeat the transmission.

6.2.7 When a heading or bearing has been requested, the direction-finding station shall advise the aircraft station in the following form:

1) the appropriate phrase;

2) bearing or heading in degrees in relation to the direction-finding station, sent as three figures;

3) class of bearing;

4) time of observation, if necessary.

6.2.8 When a position has been requested, the direction finding control station, after plotting all simultaneous observations, shall determine the observed position of the aircraft and shall advise the aircraft station in the following form:

1) the appropriate phrase;

2) the position;

3) class of position;

4) time of observation.

6.2.9 As soon as the aircraft station has received the bearing, heading or position, it shall repeat back the message for confirmation or correction.

6.2.10 When positions are given by bearing or heading and distance from a known point other than the station making the report, the reference point shall be an aerodrome, prominent town or geographic feature. An aerodrome shall be given in preference to other places. When a large city or town is used as a reference place, the bearing or heading, and the distance given shall be measured from its centre.

6.2.11 When the position is expressed in latitude and longitude, groups of figures for degrees and minutes shall be used followed by the letter N or S for latitude and the letter E or W for longitude, respectively. In radiotelephony the words NORTH, SOUTH, EAST or WEST shall be used.

6.2.12 According to the estimate by the direction-finding station of the accuracy of the observations, bearings and positions shall be classified as follows:

Bearings:

Class A — accurate within plus or minus 2 degrees;

Class B — accurate within plus or minus 5 degrees;

Class C — accurate within plus or minus 10 degrees;

Class D — accuracy less than Class C.

Positions:

Class A — accurate within 9.3 km (5 NM);

Class B — accurate within 37 km (20 NM);

Class C — accurate within 92 km (50 NM);

Class D — accuracy less than Class C.

6.2.13 Direction-finding stations shall have authority to refuse to give bearings, heading or positions when conditions are unsatisfactory or when bearings do not fall within the calibrated limits of the station, stating the reason at the time of refusal.

CHAPTER 7. AERONAUTICAL BROADCASTING SERVICE

7.1 General

7.1.1 Broadcast material

The text of broadcast material shall be prepared by the originator in the form desired for transmission.

7.1.2 Frequencies and schedules

7.1.2.1 Broadcasts shall be made on specified frequencies and at specified times.

7.1.2.2 Schedules and frequencies of all broadcasts shall be publicized in appropriate documents. Any change in frequencies or times shall be publicized by NOTAM at least two weeks in advance of the change.* Additionally, any such change shall, if practicable, be announced on all regular broadcasts for 48 hours preceding the change and shall be transmitted once at the beginning and once at the end of each broadcast.

*Note.— This does not prevent an emergency change of frequency when required in circumstances which do not permit the promulgation of a NOTAM at least two weeks in advance of the change.

7.1.2.3 Scheduled broadcasts (other than sequential collective type broadcasts), shall be started at the scheduled time by the general call. If a broadcast must be delayed, a short notice shall be transmitted at the scheduled time advising recipients to "stand by" and stating the approximate number of minutes of delay.

7.1.2.3.1 After definite advice has been given to stand by for a certain period, the broadcast shall not be started until the end of the standby period.

7.1.2.4 Where broadcasts are conducted on a time allotment basis, transmission shall be terminated by each station promptly at the end of the allotted time period whether or not transmission of all material has been completed.

7.1.2.4.1 In sequential collective type broadcasts each station shall be ready to commence its broadcasts at the designated time. If for any reason a station does not commence its broadcast at the designated time, the station immediately following in sequence shall wait and then commence its broadcast at its own designated time.

7.1.3 Interruption of service

In the event of interruption of service at the station responsible for a broadcast, the broadcast shall, if possible, be made by another station until normal service is resumed. If this is not possible, and the broadcast is of the type intended for interception by fixed stations, the stations which are required to copy the broadcasts shall continue to listen on the specified frequencies until normal service is resumed.

7.2 **Radiotelephone broadcast procedures**

7.2.1 Broadcast technique

7.2.1.1 Transmissions by radiotelephone shall be as natural, short and concise as practicable consistent with clarity.

7.2.1.2 Rate of speech on radiotelephone broadcasts shall not exceed 100 words per minute.

7.2.2 Preamble of the general call

The preamble of each radiotelephone broadcast shall consist of the general call, station name, and optionally the time of broadcast (UTC).

Note.— The following example illustrates the application of this procedure:

(general call)	*ALL STATIONS*
(the words THIS IS)	*THIS IS*
(station name)	*NEW YORK RADIO*
(time of broadcast)	*TIME, ZERO ZERO FOUR FIVE*

CHAPTER 8. AERONAUTICALMOBILE SERVICE — DATA LINK COMMUNICATIONS

8.1 General

Note 1.— While the provisions of Chapter 8 are based primarily on the use of controller-pilot data link communications (CPDLC), the provisions of 8.1 would apply to other data link applications, where applicable, including Data link—flight information services (e.g. D-ATIS, DVOLMET, etc.).

Note 2.— For the purposes of these provisions, the communication procedures applicable to the aeronautical mobile service, as appropriate, also apply to the aeronautical mobile satellite service.

8.1.1 Composition of data link messages

8.1.1.1 The text of messages shall be composed in standard message format (e.g. CPDLC message set), in plain language or in abbreviations and codes, as prescribed in 3.7. Plain language shall be avoided when the length of the text can be reduced by using appropriate abbreviations and codes. Nonessential words and phrases, such as expressions of politeness, shall not be used.

8.1.1.2 The following characters are allowed in the composition of messages:

Letters: ABCDEFGHIJKLMNOPQRSTUVWXYZ
(upper case only)

Figures: 1 2 3 4 5 6 7 8 9 0

Other signs:
- - (hyphen)
- ? (question mark)
- : (colon)
- ((open bracket)
-) (close bracket)
- . (full stop, period, or decimal point)
- , (comma)
- ’ (apostrophe)
- = (double hyphen or equal sign)
- / (oblique)
- + (plus sign)

and the space character.

Characters other than those listed above shall not be used in messages.

8.1.1.3 Roman numerals shall not be employed. If the originator of a message wishes the addressee to be informed that Roman figures are intended, the Arabic figure or figures shall be written and preceded by the word ROMAN.

8.1.2 Display of data link messages

8.1.2.1 Ground and airborne systems shall allow for messages to be appropriately displayed, printed when required, and stored in a manner that permits timely and convenient retrieval should such action be necessary.

8.1.2.2 Whenever textual presentation is required, the English language shall be displayed as a minimum.

8.2 **CPDLC procedures**

Note.— The CPDLC message set referred to in this section can be found in the PANS-ATM, Appendix 5.

8.2.1 In all communications the highest standard of discipline shall be observed at all times.

8.2.1.1 **Recommendation.—***Consequences of human performance, which could affect the accurate reception and comprehension of messages, should be taken into consideration when composing a message.*

Note.— Guidance material on human performance can be found in the Human Factors Training Manual (Doc 9683) and Human Factors Guidelines for Air Traffic Management (ATM) Systems (Doc 9758).

8.2.2 Ground and airborne systems shall provide controllers and pilots with the capability to review and validate any operational messages they send.

8.2.3 Ground and airborne systems shall provide controllers and pilots with the capability to review, validate and when applicable, acknowledge any operational messages they receive.

8.2.4 The controller shall be provided with the capability to respond to messages, including emergencies, to issue clearances, instructions and advisories, and to request and provide information, as appropriate.

8.2.5 The pilot shall be provided with the capability to respond to messages, to request clearances and information, to report information, and to declare or cancel an emergency.

8.2.6 The pilot and the controller shall be provided with the capability to exchange messages which do not conform to defined formats (i.e. free text messages).

8.2.7 Unless specified by the appropriate ATS authority, voice read-back of CPDLC messages shall not be required.

8.2.8 Establishment of CPDLC

8.2.8.1 The controller and the pilot shall be informed when CPDLC has been successfully established.

8.2.8.2 **PANS**.— *CPDLC shall be established in sufficient time to ensure that the aircraft is communicating with the appropriate ATC unit.*

8.2.8.3 The controller and pilot shall be informed when CPDLC is available for operational use, at initial establishment, as well as on resumption of CPDLC after a failure.

8.2.8.4 The pilot shall be able to identify the air traffic control unit providing the air traffic control service at any time while the service is being provided.

8.2.8.5 When the airborne system detects that CPDLC is available for operational use, it shall send the CPDLC downlink message element CURRENT DATA AUTHORITY.

8.2.8.6 Airborne-initiated CPDLC

8.2.8.6.1 **PANS**.— *When an ATC unit receives an unexpected request for CPDLC from an aircraft, the circumstances leading to the request shall be obtained from the aircraft to determine further action*.

8.2.8.6.2 **PANS**.— *When the ATC unit rejects a request for CPDLC, it shall provide the pilot with the reason for the rejection using an appropriate CPDLC message.*

8.2.8.7 ATC unit-initiated CPDLC

8.2.8.7.1 An ATC unit shall only establish CPDLC with an aircraft if the aircraft has no CPDLC link established, or when authorized by the ATC unit currently having CPDLC established with the aircraft.

8.2.8.7.2 When a request for CPDLC is rejected by an aircraft, the reason for the rejection shall be provided using CPDLC downlink message element NOT CURRENT DATA AUTHORITY or message element NOT AUTHORIZED NEXT DATA AUTHORITY, as appropriate. Local procedures shall dictate whether the reason for rejection is presented to the controller. No other reasons for airborne rejection of ATC unitinitiation of CPDLC shall be permitted.

8.2.9 Exchange of operational CPDLC messages

8.2.9.1 Controllers and pilots shall construct CPDLC messages using the defined message set, a free text message or a combination of both.

8.2.9.1.1 **PANS**. — *When CPDLC is being used, and the intent of the message is included in the CPDLC message set contained in the PANS-ATM, Appendix 5, the associated message shall be used.*

8.2.9.1.2 **PANS**.— *Except as provided by 8.2.12.1, when a controller or pilot communicates via CPDLC, the response should be via CPDLC. When a controller or pilot communicates via voice, the response should be via voice.*

8.2.9.1.3 **PANS**.— *Whenever a correction to a message sent via CPDLC is deemed necessary or the contents of a message needs to be clarified, the controller or pilot shall use the most appropriate means available for issuing the correct details or for providing clarification.*

Note.— The following procedures may be applied by the controller, in terms of correcting clearances, instructions or information, or by a pilot, in terms of correcting a reply to an uplink message or correcting previously advised requests or information.

8.2.9.1.3.1 **PANS**.— *When voice communications are used to correct a CPDLC message for which no operational response has yet been received, the controller's or pilot's transmission shall be prefaced by the phrase: "DISREGARD CPDLC (message type) MESSAGE, BREAK" — followed by the correct clearance, instruction, information or request.*

Note.— It is possible that, at the time the voice communicated clarification is transmitted, the CPDLC message being referred to has not yet reached the recipient, or has reached the recipient but has not been acted upon, or has reached the recipient and has been acted upon.

8.2.9.1.3.2 **PANS**.— *When referring to and identifying the CPDLC message to be disregarded, caution should be exercised in its phrasing so as to avoid any ambiguity with the issuance of the accompanying corrected clearance, instruction, information or request.*

Note.— For example, if SAS445, maintaining FL290, had been instructed via CPDLC to climb to FL350, and the controller needs to correct the clearance utilizing voice communications, the following phrase might be used:

SAS445 DISREGARD CPDLC CLIMB CLEARANCE MESSAGE, BREAK, CLIMB TO FL310.

8.2.9.1.3.3 **PANS**.— *If a CPDLC message that requires an operational response is subsequently negotiated via voice, an appropriate CPDLC message closure response shall be sent to ensure proper synchronization of the CPDLC dialogue. This could be achieved either by explicitly instructing the recipient of the message via voice to close the dialogue or by allowing the system to automatically close the dialogue.*

8.2.9.2 The composition of a CPDLC message shall not exceed five message elements, only two of which may contain the route clearance variable.

8.2.9.2.1 **PANS.**— *The use of long messages or messages with multiple clearance elements, multiple clearance request elements or messages with a combination of clearances and information should be avoided where possible.*

Note.— Guidance material on the development of local operating procedures and CPDLC good operating technique can be found in the Human Factors Guidelines for Air Traffic Management (ATM) Systems(Doc 9758).

8.2.9.3 CPDLC ground systems and airborne systems shall be capable of using the CPDLC message urgency and alert attributes to alter presentations in order to draw attention to higher priority messages.

Note.— Message attributes dictate certain message handling requirements for the CPDLC user receiving a message. Each CPDLC message has three attributes: urgency, alert and response attributes. When a message contains multiple message elements, the highest precedence message element attribute type becomes the attribute type for the entire message.

8.2.9.3.1 The urgency attribute shall delineate the queuing requirements for received messages that are displayed to the end-user. Urgency types are presented in Table 8-1.

8.2.9.3.2 The alert attribute shall delineate the type of alerting required upon message receipt. Alert types are presented in Table 8-2.

8.2.9.3.3 The response attribute shall delineate valid responses for a given message element. Response types are presented in Table 8-3 for uplink messages and Table 8-4 for downlink messages.

8.2.9.3.3.1 **PANS**.— *When a multi-element message requires a response, and the response is in the form of a single message element, the response shall apply to all message elements.*

Note.— For example, a multi-element message containing CLIMB TO FL310 MAINTAIN MACH.84, a WILCO response applies to, and indicates compliance with, both elements of the message.

8.2.9.3.3.2 **PANS.**— *When a single message element clearance or any part of a multi-element clearance message cannot be complied with, the pilot shall send an UNABLE response for the whole message.*

8.2.9.3.3.3 **PANS**.— *The controller shall respond with an UNABLE message that applies to all elements of the request when no element(s) of a single or multi-element clearance request can be approved. The current clearance(s) shall not be restated.*

8.2.9.3.3.4 **PANS**.— *When a multi-element clearance request can only be partially accommodated, the controller shall respond with an UNABLE message applying to all the message elements of the request and, if appropriate, include a reason and/or information on when a clearance may be expected.*

Table 8-1. Urgency Attribute (Uplink and Downlink)

Type	*Description*	*Precedence*
D	Distress	1
U	Urgent	2
N	Normal	3
L	Low	4

Table 8-2. Alert Attribute (Uplink and Downlink)

Type	*Description*	*Precedence*
H	High	1
M	Medium	2
L	Low	3
N	No alerting required	4

Table 8-3. Response Attribute (Uplink)

Type	*Response required*	*Valid responses*	*Precedence*
W/U	Yes	WILCO, UNABLE, STANDBY, NOT CURRENT DATA AUTHORITY, NOT AUTHORIZED NEXT DATA AUTHORITY, LOGICAL ACKNOWLEDGEMENT (only if required), ERROR	1
A/N	Yes	AFFIRM, NEGATIVE, STANDBY, NOT CURRENT DATA AUTHORITY, NOT AUTHORIZED NEXT DATA AUTHORITY, LOGICAL ACKNOWLEDGEMENT (only if required), ERROR	2
R	Yes	ROGER, UNABLE, STANDBY, NOT CURRENT DATA AUTHORITY, NOT AUTHORIZED NEXT DATA AUTHORITY, LOGICAL ACKNOWLEDGEMENT (only if required), ERROR	3
Y	Yes	Any CPDLC downlink message, LOGICAL ACKNOWLEDGEMENT (only if required)	4
N	No, unless logical acknowledgement required	LOGICAL ACKNOWLEDGEMENT (only if required), NOT CURRENT DATA AUTHORITY, NOT AUTHORIZED NEXT DATA AUTHORITY, ERROR	5

Table 8-4. Response Attribute (Downlink)

Type	*Response required*	*Valid responses*	*Precedence*
Y	Yes	Any CPDLC uplink message, LOGICAL ACKNOWLEDGEMENT (only if required)	1
N	No, unless logical acknowledgement required	LOGICAL ACKNOWLEDGEMENT (only if required), SERVICE UNAVAILABLE, FLIGHT PLAN NOT HELD, ERROR	2

Note.— A separate CPDLC message (or messages) may subsequently be transmitted to respond to those elements that can be accommodated.

8.2.9.3.3.5 **PANS**.— *When all elements of a single or multi-element clearance request can be accommodated, the controller shall respond with clearances corresponding to each element of the request. This response should be a single uplink message.*

Note.— For example, while messages containing multi element clearance requests are to be avoided, a multi-element downlink message containing the indicated message elements:

REQUEST CLEARANCE YQM YYG YYT YQX
TRACK X EINN EDDF
REQUEST CLIMB TO FL350
REQUEST MACH 0.84

could be responded to with

CLEARED YQM YYG YYT YQX TRACK X EINN
EDDF
CLIMB TO FL350
REPORT MAINTAINING
CROSS YYG AT OR AFTER 1150
NO SPEED RESTRICTION.

8.2.9.3.3.6 **PANS.**— *When a CPDLC message contains more than one message element and the response attribute for the message is Y, when utilized, the single response message shall contain the corresponding number of replies in the same order.*

Note.— For example, a multi-element uplink message containing

CONFIRM SQUAWK
WHEN CAN YOU ACCEPT FL410

could be responded to with

SQUAWKING 5525
WE CAN ACCEPT FL410 AT 1636Z

8.2.9.4 When a ground or airborne system generates the CPDLC message ERROR, the reason for the error shall be included in the message.

8.2.9.5 The appropriate ATS authority shall select those message elements contained in PANS-ATM, Appendix 5 that support operations in their airspace. Should an ATS authority choose to select a subset of the message elements, and a received message does not belong to this subset, the ATC unit shall respond by uplinking the message element SERVICE U N AVA I L A BL E .

Note.— Further processing of the received message is not required.

8.2.9.5.1 **Recommendation**.—*Only the uplink messages appropriate to a particular control sector's operations should be provided to the controller.*

Note.— The CPDLC message set contained in PANS-ATM, Appendix 5 was developed to encompass different air traffic management environments.

8.2.9.5.2 When considered necessary by the appropriate ATS authority, additional pre-formatted free text messages shall be made available to the controller for those occasions where the CPDLC message set contained in the PANS-ATM does not provide for specific requirements. In such cases, a list of pre-formatted free text messages shall be established by the appropriate ATS authority, in consultation with operators and other ATS authorities that may be concerned.

8.2.9.5.3 Information concerning CPDLC message element subsets utilized and, if applicable, any additional preformatted free text messages, shall be published in aeronautical information publications.

8.2.9.6 Transfer of CPDLC

Note.— Details on CPDLC transfer can be found in the Manual of Air Traffic Services Data Link Applications (Doc 9694).

8.2.9.6.1 **PANS**.— *When CPDLC is transferred, the transfer of voice communications and CPDLC shall commence concurrently.*

8.2.9.6.2 **PANS**.— *When an aircraft is transferred from an ATC unit where CPDLC is available to an ATC unit where CPDLC is not available, CPDLC termination shall commence concurrent with the transfer of voice communications.*

8.2.9.6.3 When a transfer of CPDLC results in a change of data authority, and there are still messages for which the closure response has not been received (i.e. messages outstanding), the controller transferring the CPDLC shall be informed.

8.2.9.6.3.1 If the controller needs to transfer the aircraft without replying to any downlink message(s) outstanding, the system shall have the capability to automatically send the appropriate closure response message(s). In such cases, the contents of any automatically sent closure response message(s) shall be promulgated in local instructions.

8.2.9.6.3.2 When the controller decides to transfer the aircraft without receiving pilot responses to any uplink message(s) outstanding, the ground system shall have the capability to automatically end the dialogue for each message prior to the transfer.

8.2.9.6.3.2.1 **PANS.**— *The controller should revert to voice communications to clarify any ambiguity associated with the message(s) outstanding.*

8.2.9.6.4 When a transfer of CPDLC does not result in a change of data authority, and there are still messages outstanding, these messages shall either be forwarded to the appropriate controller or shall be closed in accordance with local instructions and, if necessary, letters of agreement.

8.2.10 Display of CPDLC messages

Recommendation.—*ATC units utilizing a CPDLC message contained in the PANS-ATM should display the associated text pertaining to that message as presented in the PANS-ATM, Appendix 5.*

8.2.11 Free text messages

PANS.— *The use of free text messages by controllers or pilots, other than pre-formatted free text messages referred to in paragraph 8.2.9.5.2, should be avoided.*

Note.— Whilst it is recognized that non-routine and emergency situations may necessitate the use of free text, particularly when voice communication has failed, the avoidance of utilizing free text messages is intended to reduce the possibility of misinterpretation and ambiguity.

8.2.12 Emergencies, hazards and equipment failure procedures

8.2.12.1 **PANS.**— *When a CPDLC emergency message is received, the controller shall acknowledge receipt of the message by the most efficient means available.*

8.2.12.2 **PANS**.— *When responding via CPDLC to a report indicating unlawful interference, uplink message ROGER 7500shall be used.*

8.2.12.3 **PANS**.— *When responding via CPDLC to all other emergency or urgency messages, uplink message ROGER shall be used.*

8.2.12.4 When a CPDLC message requires a logical acknowledgement and/or an operational response, and such a response is not received, the pilot or controller, as appropriate, shall be alerted.

8.2.12.5 *Failure of CPDLC*

Note.— Action to be taken in the event of the failure of a single CPDLC message is covered in 8.2.12.7.

8.2.12.5.1 **Recommendation**.—*A CPDLC failure should be detected in a timely manner.*

8.2.12.5.2 The controller and pilot shall be alerted to a failure of CPDLC as soon as a failure has been detected.

8.2.12.5.3 **PANS**.— *When a controller or pilot is alerted that CPDLC has failed, and the controller or pilot needs to communicate prior to CPDLC being restored, the controller or pilot should revert to voice, if possible, and preface the information with the phrase:*

CPDLC FAILURE.

8.2.12.5.4 **PANS**.— *Controllers having a requirement to transmit information concerning a complete CPDLC ground system failure to all stations likely to intercept should preface such a transmission by the general call ALL STATIONS CPDLC FAILURE, followed by the identification of the calling station.*

Note.— No reply is expected to such general calls unless individual stations are subsequently called to acknowledge receipt.

8.2.12.5.5 **PANS.—** *When CPDLC fails and communications revert to voice, all CPDLC messages outstanding should be considered not delivered and the entire dialogue involving the messages outstanding should be recommenced by voice.*

8.2.12.5.6 **PANS**.— *When CPDLC fails but is restored prior to a need to revert to voice communications, all messages outstanding should be considered not delivered and the entire dialogue involving the messages outstanding should be recommenced via CPDLC.*

8.2.12.6 *Intentional shutdown of CPDLC*

8.2.12.6.1 When a system shutdown of the communications network or the CPDLC ground system is planned, a NOTAM shall be published to inform all affected parties of the shutdown period and if necessary, the details of the voice communication frequencies to be used.

8.2.12.6.2 Aircraft currently in communication with the ATC unit shall be informed by voice or CPDLC of any imminent loss of CPDLC service.

8.2.12.6.3 The controller and pilot shall be provided with the capability to abort CPDLC.

8.2.12.7 *Failure of a single CPDLC message*

PANS.— *When a controller or pilot is alerted that a single CPDLC message has failed, the controller or pilot shall take one of the following actions, as appropriate:*

a) via voice, confirm the actions that will be undertaken with respect to the related dialogue, prefacing the information with the phrase:

CPDLC MESSAGE FAILURE;

b) via CPDLC, reissue the CPDLC message that failed.

8.2.12.8 *Discontinuation of the use of CPDLC pilot requests*

8.2.12.8.1 **PANS**.— When a controller requires all stations or a specific flight to avoid sending CPDLC requests for a limited period of time, the following phrase shall be used:

((call sign) or ALL STATIONS) STOP SENDING CPDLC REQUESTS [UNTIL ADVISED] [(reason)]

Note.— Under these circumstances, CPDLC remains available for the pilot to, if necessary, respond to messages, report information, and declare and cancel an emergency.

8.2.12.8.2 **PANS**.— The resumption of the normal use of CPDLC shall be advised by using the following phrase:

((call sign) or ALL STATIONS) RESUME NORMAL CPDLC OPERATIONS

8.2.13 Where the testing of CPDLC with an aircraft could affect the air traffic services being provided to the aircraft, coordination shall be effected prior to such testing.

. 8.2.14 Downstream clearance delivery service

8.2.14.1 The appropriate ATS authority shall determine whether an ATC unit supports downstream clearance delivery service.

8.2.14.2 Establishment of downstream

8.2.14.2 clearance delivery service

8.2.14.2.1 Downstream clearance delivery service shall only be initiated by the airborne system. The initiation shall indicate that this communication is only to receive a downstream clearance.

8.2.14.2.2 When an ATC unit rejects a request for downstream clearance delivery service, it shall provide the pilot with the reason for the rejection using the CPDLC message SERVICE UNAVAILABLE.

8.2.14.3 *Operation of downstream clearance delivery service*

8.2.14.3.1 The controller and pilot shall be informed when downstream clearance delivery service is available for operational communication.

8.2.14.3.2 The controller and pilot shall be informed of the failure of downstream clearance delivery service.

8.2.14.3.3 The CPDLC message elements that are permitted for downstream clearance delivery service shall be established by regional air navigation agreement.

8.2.14.3.4 A clearance request issued as a downstream clearance request shall be clearly identifiable as such to the controller.

8.2.14.3.5 A clearance issued as a downstream clearance shall be clearly identifiable as such to the pilot.

8.2.14.4 *Termination of downstream clearance delivery service*

8.2.14.4.1 Termination of downstream clearance delivery service shall only be initiated by the airborne system.

8.2.14.4.2 Downstream clearance delivery service with an ATC unit shall be terminated whenever the downstream data authority becomes the current data authority.

ATTACHMENTS TO ANNEX 10 — VOLUME II

Attachment A to Volume II —

LIST OF SPECIALIZED COM TERMS AND THEIR DEFINITIONS RELATED TO AERONAUTICAL TELECOMMUNICATIONS PLANNING

On 25 March 1964 the Council at the 11th Meeting of its Fifty-first Session approved the following list of specialized communication terms and their definitions for general use within ICAO. The Council further requested States to use the terms in the approved manner in particular in correspondence with ICAO, in working papers presented by them to ICAO meetings and in any other appropriate texts. Those terms which are marked with an asterisk are already used and defined in the main body of Annex 10 while the remaining terms were selected as terms in general use by aeronautical telecommunications people but having caused difficulty at some ICAO meetings or having resulted in the development of conflicting definitions by different meetings.

1. For general use

*__Aeronautical telecommunication agency__. An agency responsible for operating a station or stations in the aeronautical telecommunication service.

*__Aeronautical telecommunication service__. A telecommunication service provided for any aeronautical purpose.

*__Aeronautical telecommunication station__. A station in the aeronautical telecommunication service.

*__Aircraft operating agency__. The person, organization or enterprise engaged in, or offering to engage in, an aircraft operation.

*__Double channel simplex__. Simplex using two frequency channels one in each direction.

Note.— This method was sometimes referred to as cross band.

*__Duplex__. A method in which telecommunication between two stations can take place in both directions simultaneously.

*__Frequency channel__. A continuous portion of the frequency spectrum appropriate for a transmission utilizing a specified class of emission. Note.— The classification of emissions and information relevant to the portion of the frequency spectrum appropriate for a given type of transmission (bandwidths) are specified in the ITU Radio Regulations, Article S2 and Appendix S1.

*__International telecommunication service.__ A telecommunication service between offices or stations of different States, or between mobile stations which are not in the same State, or are subject to different States.

*__Offset frequency simplex__. A variation of single channel simplex wherein telecommunication between two stations is effected by using in each direction frequencies that are intentionally slightly different but contained within a portion of the spectrum allotted for the operation.

*__Simplex__. A method in which telecommunication between two stations takes place in one direction at a time.

Note.— In application to the aeronautical mobile service this method may be subdivided as follows:

a) single channel simplex;

b) double channel simplex;

c) offset frequency simplex.

*__Single channel simplex.__ Simplex using the same frequency channel in each direction.

2. For use in aeronautical fixed service planning

*__Aeronautical fixed service (AFS__). A telecommunication service between specified fixed points provided primarily for the safety of air navigation and for the regular, efficient and economical operation of air services.

*__Aeronautical fixed telecommunication network (AFTN).__A worldwide system of aeronautical fixed circuits provided as part of the aeronautical fixed service, for the exchange of messages and/or digital data between aeronautical fixed stations having the same or compatible communications characteristics.

*__AFTN communication centre__. An AFTN station whose primary function is the relay or retransmission of AFTN traffic from (or to) a number of other AFTN stations connected to it.

*__AFTN destination station.__ An AFTN station to which messages are addressed for local delivery to the addressee.

AFTN entry-exit points. Centres through which AFTN traffic entering and leaving an ICAO Air Navigation Region should flow.

*__AFTN group__. Three or more radio stations in the aeronautical fixed telecommunications network exchanging communications on the same radio frequency.

*__AFTN origin station__. An AFTN station where messages are handed in for transmission over the AFTN.

*__AFTN station__. A station forming part of the aeronautical fixed telecommunication network (AFTN) and operating as such under the authority or control of a State.

*__Automatic relay installation__. A teletypewriter installation where automatic equipment is used to transfer messages from incoming to outgoing circuits.

Note.— This term covers both fully automatic and semiautomatic installations.

Channel. A single means of direct fixed service communication between two points.

Circuit. A communication system which includes all the direct AFTN channels between two points.

*__Communication centre__. An aeronautical fixed station which relays or retransmits telecommunication traffic from (or to) a number of other aeronautical fixed stations directly connected to it.

*__Fully automatic relay installation__. A teletypewriter installation where interpretation of the relaying responsibility in respect of an incoming message and the resultant setting-up of the connections required to effect the appropriate retransmissions is carried out automatically, as well as all other normal operations of relay, thus obviating the need for operator intervention, except for supervisory purposes.

*__Incoming circuit responsibility list__. A list, for each incoming circuit of a communication centre, of the location indicators for which relay responsibilities are to be accepted in respect of messages arriving on that circuit.

*__Location indicator__. A four-letter code group formulated in accordance with rules prescribed by ICAO and assigned to the location of an aeronautical fixed station.

Relay time. The relay time of a COM centre is the elapsed time between the instant that a message has been completely received at that centre and the instant that it has been completely retransmitted on an outgoing circuit.

Route (AFTN). The path followed by a particular channel of a circuit.

Routing (AFTN). The chosen itinerary to be followed by messages on the AFTN between acceptance and delivery.

*__Routing Directory__. A list in a communication centre indicating for each addressee the outgoing circuit to be used.

*__Routing List__. A list in a communication centre indicating for each addressee the outgoing circuit to be used.

*__Semi-automatic relay installation__. A teletypewriter installation where interpretation of the relaying responsibility in respect of an incoming message and the resultant setting-up of the connections required to effect the appropriate retransmissions require the intervention of an operator but where all other normal operations of relay are carried out automatically.

*"__Torn-tape" relay installation__. A teletypewriter installation where messages are received and relayed in teletypewriter tape form and where all operations of relay are performed as the result of operator intervention.

Transit time. The elapsed time between the instant of filing a message with an AFTN station for transmission on the network, and the instant that it is made available to the addressee.

*__Tributary station__. An aeronautical fixed station that may receive or transmit messages and/or digital data but which does not relay except for the purpose of serving similar stations connected through it to a communication centre.

3. For use in aeronautical

mobile service planning

***Aerodrome control radio station**. A station providing radiocommunication between an aerodrome control tower and aircraft or mobile aeronautical stations.

***Aeronautical mobile service**. A mobile service between aeronautical stations and aircraft stations, or between aircraft stations, in which survival craft stations may participate; emergency position-indicating radio beacon stations may also participate in this service on designated distress and emergency frequencies.

***Aeronautical station.** A land station in the aeronautical mobile service. In certain instances, an aeronautical station may be placed on board a ship or an earth satellite.

***Aircraft station**. A mobile station in the aeronautical mobile service, other than a survival craft station, located on board an aircraft.

***Air-ground communication**. Two-way communication between aircraft and stations or locations on the surface of the earth.

***Air-ground control radio station.** An aeronautical telecommunication station having primary responsibility for handling communications pertaining to the operation and control of aircraft in a given area.

***Air-to-ground communication**. One-way communication from aircraft to stations or locations on the surface of the earth.

***Alternative means of communication.** A means of communication provided with equal status, and in addition to the primary means.

General purpose system (GP). Air-ground radiotelephony facilities providing for all categories of traffic listed in 5.1.8.

Note.— In this system communication is normally indirect, i.e. exchanged through the intermediary of a third person.

***Ground-to-air communication.** One-way communication from stations or locations on the surface of the earth to aircraft.

***Non-network communications**. Radiotelephony communications conducted by a station of the aeronautical mobile service, other than those conducted as part of a radiotelephony network.

*__Operational control communications__. Communications required for the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of a flight.

Note.— Such communications are normally required for the exchange of messages between aircraft and aircraft operating agencies.

"Pilot-controller" system. Air-ground radiotelephony facilities implemented primarily to provide a means of direct communication between pilots and controllers.

*__Primary means of communication__. The means of communication to be adopted normally by aircraft and ground stations as a first choice where alternative means of communication exists.

*__Radiotelephony network__. A group of radiotelephony aeronautical stations which operate on and guard frequencies from the same family and which support each other in a defined manner to ensure maximum dependability of airground communications and dissemination of air-ground traffic.

*__Regular station__. A station selected from those forming an enroute air-ground radiotelephony network to communicate with or to intercept communications from aircraft in normal conditions.

Attachment B to Volume II —

GUIDANCE MATERIAL FOR THE TRANSMISSION OF LONG MESSAGES ON THE AFTN

1. **Introduction**

The requirement for the transmission of separate messages over the AFTN when a text exceeding 1 800 characters is encountered is detailed in 4.4.5.7 and 4.4.15.3.11. When messages have to be divided into two or more parts, the following procedure should be applied.

2. **Procedure**

Each message part should carry the same address and origin with the sequence of each part indicated on the last line of text as follows:

(End of first message)	/ / END PART 01 / /
(End of second message)	/ / END PART 02 / /
... etc. ...	
(End of last message)	/ / END PART XX/XX / /

Note.— The following example illustrates the application of the above procedure, for a three-part message. The message part sequence information is included in the text character count.

a) *First message:*

(Address)	GG EGLLYMYX
(Origin)	102030 KWBCYMYX
(Text)	text
	/ / END PART 01 / /
(Ending)	NNNN

b) *Second message:*

(Address)	GG EGLLYMYX
(Origin)	102030 KWBCYMYX
(Text)	text continued
	/ / END PART 02 / /
(Ending)	NNNN

c) *Third and last message:*

(Address)	GG EGLLYMYX
(Origin)	102030 KWBCYMYX
(Text)	remainder of text
	/ / END PART 03/03 / /
(Ending)	NNNN

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue or the Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services(PANS) are approved by the Council for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

PART I — DIGITAL DATA COMMUNICATION SYSTEMS
CHAPTER 1. DEFINITIONS

Note 1.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radiocommunication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

Note 2.— This Part of Annex 10 includes Standards and Recommended Practices for certain forms of equipment for communication systems. While the Contracting State will determine the necessity for specific installations in accordance with the conditions prescribed in the relevant Standard or Recommended Practice, review of the need for specific installation and the formulation of ICAO opinion and recommendations to Contracting States concerned, is carried out periodically by Council, ordinarily on the basis of recommendations of Regional Air Navigation Meetings (Doc 8144,Directives to Regional Air Navigation Meetings and Rules of Procedure for their Conduct).

Note 3.— This chapter contains general definitions relevant to communication systems. Definitions specific to each of the systems included in this volume are contained in the relevant chapters.

Note 4.— Material on secondary power supply and guidance material concerning reliability and availability for communication systems is contained in Annex 10, Volume I, 2.9 and Volume I, Attachment F, respectively.

Aeronautical administrative communications (AAC). Communications necessary for the exchange of aeronautical administrative messages.

Aeronautical operational control (AOC). Communication required for the exercise of authority over the initiation, continuation, diversion or termination of flight for safety, regularity and efficiency reasons.

Aeronautical telecommunication network (ATN). A global internetwork architecture that allows ground, air-ground and avionic data subnetworks to exchange digital data for the safety of air navigation and for the regular, efficient and economic operation of air traffic services.

Aircraft address. A unique combination of twenty-four bits available for assignment to an aircraft for the purpose of airground communications, navigation and surveillance.

Aircraft earth station (AES). A mobile earth station in the aeronautical mobile-satellite service located on board an aircraft (see also "GES").

Air traffic service. A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Automatic dependent surveillance — contract (ADS-C). A means by which the terms of an ADS-C agreement will be exchanged between the ground system and the aircraft, via a data link, specifying under what conditions ADS-C reports would be initiated, and what data would be contained in the reports.

Automatic terminal information service (ATIS). The automatic provision of current, routine information to arriving and departing aircraft throughout 24 hours or a specified portion thereof.

Data link-automatic terminal information service (D-ATIS). The provision of ATIS via data link.

Voice-automatic terminal information service (Voice-ATIS). The provision of ATIS by means of continuous and repetitive voice broadcasts.

Bit error rate (BER). The number of bit errors in a sample divided by the total number of bits in the sample, generally averaged over many such samples.

Carrier-to-multipath ratio (C/M). The ratio of the carrier power received directly, i.e. without reflection, to the multipath power, i.e. carrier power received via reflection.

Carrier-to-noise density ratio (C/No). The ratio of the total carrier power to the average noise power in a 1 Hz bandwidth, usually expressed in dBHz.

Channel rate. The rate at which bits are transmitted over the RF channel. These bits include those bits used for framing and error correction, as well as the information bits. For burst transmission, the channel rate refers to the instantaneous burst rate over the period of the burst.

Channel rate accuracy. This is relative accuracy of the clock to which the transmitted channel bits are synchronized. For example, at a channel rate of 1.2 kbits/s, maximum error of one part in 106 implies the maximum allowed error in the clock is ±1.2 × 10-3Hz.

Circuit mode. A configuration of the communications network which gives the appearance to the application of a dedicated transmission path.

Controller pilot data link communications (CPDLC). A means of communication between controller and pilot, using data link for ATC communications.

Data link flight information services (D-FIS). The provision of FIS via data link.

Doppler shift. The frequency shift observed at a receiver due to any relative motion between transmitter and receiver.

End-to-end. Pertaining or relating to an entire communication path, typically from (1) the interface between the information source and the communication system at the transmitting end to (2) the interface between the communication system and the information user or processor or application at the receiving end.

End-user. An ultimate source and/or consumer of information.

Energy per symbol to noise density ratio (Es/No). The ratio of the average energy transmitted per channel symbol to the average noise power in a 1 Hz bandwidth, usually expressed in dB. For A-BPSK and A-QPSK, one channel symbol refers to one channel bit.

Equivalent isotropically radiated power (e.i.r.p.). The product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).

Flight information service (FIS). A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights.

Forward error correction (FEC). The process of adding redundant information to the transmitted signal in a manner which allows correction, at the receiver, of errors incurred in the transmission.

Gain-to-noise temperature ratio. The ratio, usually expressed in dB/K, of the antenna gain to the noise at the receiver output of the antenna subsystem. The noise is expressed as the temperature that a 1 ohm resistor must be raised to produce the same noise power density.

Ground earth station (GES). An earth station in the fixed satellite service, or, in some cases, in the aeronautical mobile-satellite service, located at a specified fixed point on land to provide a feeder link for the aeronautical mobile satellite service.

Note.— This definition is used in the ITU's Radio Regulations under the term "aeronautical earth station". The definition herein as "GES" for use in the SARPs is to clearly distinguish it from an aircraft earth station (AES), which is a mobile station on an aircraft.

Mode S subnetwork. A means of performing an interchange of digital data through the use of secondary surveillance radar (SSR) Mode S interrogators and transponders in accordance with defined protocols.

Point-to-point. Pertaining or relating to the interconnection of two devices, particularly end-user instruments. A communication path of service intended to connect two discrete end-users; as distinguished from broadcast or multipoint service.

Slotted aloha. A random access strategy whereby multiple users access the same communications channel independently, but each communication must be confined to a fixed time slot. The same timing slot structure is known to all users, but there is no other coordination between the users.

Time division multiple access (TDMA). A multiple access scheme based on time-shared use of an RF channel employing:

(1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to interact with a master control station to mediate access to the channel.

Time division multiplex (TDM). A channel sharing strategy in which packets of information from the same source but with different destinations are sequenced in time on the same channel.

Transit delay. In packet data systems, the elapsed time between a request to transmit an assembled data packet and an indication at the receiving end that the corresponding packet has been received and is ready to be used or forwarded.

VHF digital link (VDL). A constituent mobile subnetwork of the aeronautical telecommunication network (ATN), operating in the aeronautical mobile VHF frequency band. In addition, the VDL may provide non-ATN functions such as, for instance, digitized voice.

CHAPTER 2. GENERAL

[to be developed]

CHAPTER 3. AERONAUTICAL TELECOMMUNICATION NETWORK

Note 1.— Detailed technical specifications for ATN/OSI applications are contained in the Manual on Detailed Technical Specifications for the Aeronautical Telecommunication Network (ATN) using ISO/OSI Standards and Protocols(Doc 9880) and in the Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN) (Doc 9705).

Note 2.— Detailed technical specifications for ATN/IPS applications are contained in the Manual for the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocols(Doc 9896) (available electronically on the ICAO-Net).

3.1 DEFINITIONS

Application entity (AE). An AE represents a set of ISO/OSI communication capabilities of a particular application process (see ISO/IEC 9545 for further details).

ATN security services. A set of information security provisions allowing the receiving end system or intermediate system to unambiguously identify (i.e. authenticate) the source of the received information and to verify the integrity of that information.

ATS interfacility data communication (AIDC). Automated data exchange between air traffic services units in support of flight notification, flight coordination, transfer of control and transfer of communication.

ATS message handling service (ATSMHS). An ATN application consisting of procedures used to exchange ATS messages in store-and-forward mode over the ATN such that the conveyance of an ATS message is in general not correlated with the conveyance of another ATS message by the service provider.

ATS message handling system (AMHS). The set of computing and communication resources implemented by ATS organizations to provide the ATS message handling service.

Authorized path. A communication path suitable for a given message category.

Data link initiation capability (DLIC). A data link application that provides the ability to exchange addresses, names and version numbers necessary to initiate data link applications (see Doc 4444).

Directory service (DIR). A service, based on the ITU-T X.500 series of recommendations, providing access to and management of structured information relevant to the operation of the ATN and its users.

Required communication performance (RCP). A statement of the performance requirements for operational communication in support of specific ATM functions (see Manual on Required Communication Performance (RCP) (Doc 9869)).

3.2 INTRODUCTION

3.2.1 The ATN is specifically and exclusively intended to provide digital data communications services to air traffic service provider organizations and aircraft operating agencies in support of:

a) air traffic services communications (ATSC) with aircraft;

b) air traffic services communications between ATS units;

c) aeronautical operational control communications (AOC); and

d) aeronautical administrative communications (AAC).

3.3 GENERAL

Note — The Standards and Recommended Practices in sections 3.4 to 3.8 define the minimum required protocols and services that will enable the global implementation of the aeronautical telecommunication network (ATN).

3.3.1 ATN communication services shall support ATN applications.

3.3.2 Requirements for implementation of the ATN shall be made on the basis of regional air navigation agreements.

These agreements shall specify the area in which the communication standards for the ATN/OSI or the ATN/IPS are

applicable.

3.4 GENERAL REQUIREMENTS

3.4.1 The ATN shall either use International Organization for Standardization (ISO) communication standards for open systems interconnection (OSI) or use the Internet Society (ISOC) communications standards for the Internet Protocol Suite (IPS).

Note 1.— ATN/IPS implementation is preferred for ground-ground networks. While ATN/OSI continues to be supported in air-ground networks, particularly when using VDL Mode 2, it is expected that future air-ground implementations will use the ATN/IPS.

Note 2.— Interoperability between interconnecting OSI/IPS networks is expected to be arranged prior to implementation.

Note 3.— Guidance material on interoperability between ATN/OSI and ATN/IPS is contained in Doc 9896.

3.4.2 The AFTN/AMHS gateway shall ensure the interoperability of AFTN and CIDIN stations and networks with the ATN.

3.4.3 An authorized path(s) shall be defined on the basis of a predefined routing policy.

3.4.4 The ATN shall transmit, relay and deliver messages in accordance with the priority classifications and without discrimination or undue delay.

3.4.5 The ATN shall provide means to define data communications that can be carried only over authorized paths for the traffic type and category specified by the user.

3.4.6 The ATN shall provide communication in accordance with the prescribed required communication performance (RCP).

Note.— The Manual on Required Communication Performance (RCP) (Doc 9869) contains the necessary information on RCP.

3.4.7 The ATN shall operate in accordance with the communication priorities defined in Table 3-1[1] and Table 3-2.

3.4.8 The ATN shall enable exchange of application information when one or more authorized paths exist.

3.4.9 The ATN shall notify the appropriate application processes when no authorized path exists.

3.4.10 The ATN shall make provisions for the efficient use of limited bandwidth subnetworks.

3.4.11 **Recommendation**.— *The ATN should enable an aircraft intermediate system (router) to connect to a ground intermediate system (router) via different subnetworks.*

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[1] Tables 3-1 and 3-2 are located at the end of this chapter.

3.4.12 **Recommendation.—** *The ATN should enable an aircraft intermediate system (router) to connect to different ground intermediate systems (routers).*

3.4.13 The ATN shall enable the exchange of address information between applications.

3.4.14 Where the absolute time of day is used within the ATN, it shall be accurate to within 1 second of coordinated universal time (UTC).

Note.— The time accuracy value results in synchronization errors of up to two seconds.

3.5 ATN APPLICATIONS REQUIREMENTS

3.5.1 System applications

Note.— System applications provide services that are necessary for operation of the ATN.

3.5.1.1 The ATN shall support the data link initiation capability (DLIC) applications when air-ground data links are implemented.

Note.— The Manual of Air Traffic Services Data Link Applications (Doc 9694, Part I) defines the data link initiation capability (DLIC) application.

3.5.1.2 The ATN/OSI end-system shall support the following directory services (DIR) application functions when AMHS and/or security protocols are implemented:

a) directory information retrieval; and

b) directory information modification.

3.5.2 Air-ground applications

3.5.2.1 The ATN shall be capable of supporting one or more of the following applications:

a) ADS-C;

b) CPDLC; and

c) FIS (including ATIS and METAR).

Note.— See the Manual of Air Traffic Services Data Link Applications (Doc 9694).

3.5.3 Ground-ground applications

3.5.3.1 The ATN shall be capable of supporting the following applications:

a) ATS interfacility data communication (AIDC); and

b) ATS message handling services applications (ATSMHS).

Note.— See the Manual of Air Traffic Services Data Link Applications (Doc 9694).

3.6 ATN COMMUNICATIONS SERVICE REQUIREMENTS

3.6.1 ATN/IPS upper layer communications service

3.6.1.1 An ATN host[2] shall be capable of supporting the ATN/IPS upper layers including an application layer.

3.6.2 ATN/OSI upper layer communications service

3.6.2.1 An ATN/OSI end-system (ES) shall be capable of supporting the OSI upper layer communications service (ULCS) including session, presentation and application layers.

3.6.3 ATN/IPS communications service

3.6.3.1 An ATN host shall be capable of supporting the ATN/IPS including the:

a) transport layer in accordance with RFC 793 (TCP) and RFC 768 (UDP); and

b) network layer in accordance with RFC 2460 (IPv6).

3.6.3.2 An IPS router shall support the ATN network layer in accordance with RFC 2460 (IPv6) and RFC 4271 (BGP), and RFC 2858 (BGP multiprotocol extensions).

3.6.4 ATN/OSI communications service

3.6.4.1 An ATN/OSI end-system shall be capable of supporting the ATN including the:

a) transport layer in accordance with ISO/IEC 8073 (TP4) and optionally ISO/IEC 8602 (CLTP); and

b) network layer in accordance with ISO/IEC 8473 (CLNP).

3.6.4.2 An ATN intermediate system (IS) shall support the ATN network layer in accordance with ISO/IEC 8473 (CLNP) and ISO/IEC 10747 (IDRP).

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[2] An ATN host is an ATN end-system in OSI terminology; an ATN end-system is an ATN host in IPS terminology.

3.7 ATN NAMING AND ADDRESSING REQUIREMENTS

Note.— The ATN naming and addressing scheme supports the principles of unambiguous identification of intermediate systems (routers) and end-systems (hosts) and provides global address standardization.

3.7.1 The ATN shall provide provisions for unambiguous application identification.

3.7.2 The ATN shall provide provisions for unambiguous addressing.

3.7.3 The ATN shall provide means to unambiguously address all ATN end-systems (hosts) and intermediate systems

(routers).

3.7.4 The ATN addressing and naming plans shall allow States and organizations to assign addresses and names within their own administrative domains.

3.8 ATN SECURITY REQUIREMENTS

3.8.1 The ATN shall make provisions whereby only the controlling ATS unit may provide ATC instructions to aircraft operating in its airspace.

Note.— This is achieved through the current and next data authority aspects of the controller-pilot data link communications (CPDLC) application.

3.8.2 The ATN shall enable the recipient of a message to identify the originator of that message.

3.8.3 ATN end-systems supporting ATN security services shall be capable of authenticating the identity of peer end systems, authenticating the source of messages and ensuring the data integrity of the messages.

Note.— The use of security is the default; however, its implementation is based on local policy.

3.8.4 The ATN services shall be protected against service attacks to a level consistent with the application service requirements.

TABLES FOR CHAPTER 3

Table 3-1. Mapping of ATN communication priorities

Message categories	*ATN application*	*Corresponding protocol priority*	
		Transport layer priority	*Network layer priority*
Network/systems management		0	14
Distress communications		1	13
Urgent communications		2	12
High-priority flight safety messages	CPDLC, ADS-C	3	11
Normal-priority flight safety messages	AIDC, ATIS	4	10
Meteorological communications	METAR	5	9
Flight regularity communications	DLIC, ATSMHS	6	8
Aeronautical information service messages		7	7
Network/systems administration	DIR	8	6
Aeronautical administrative messages		9	5
<unassigned>		10	4
Urgent-priority administrative and U.N. Charter communications		11	3
High-priority administrative and State/Government communications		12	2
Normal-priority administrative communications		13	1
Low-priority administrative communications and aeronautical passenger communications		14	0

Note.— The network layer priorities shown in the table apply only to connectionless network priority and do not apply to subnetwork priority.

Table 3-2. Mapping of ATN network priority to mobile subnetwork priority

Message categories	*ATN network layer priority*	*Corresponding mobile subnetwork priority (see Note 4)*					
		AMSS	*VDL Mode 2*	*VDL Mode 3*	*VDL Mode 4*	*SSR Mode S*	*HFDL*
Network/systems management	14	14	see Note 1	3	14	high	14
Distress communications	13	14	see Note 1	2	13	high	14
Urgent communications	12	14	see Note 1	2	12	high	14
High-priority flight safety messages	11	11	see Note 1	2	11	high	11
Normal-priority flight safety messages	10	11	see Note 1	2	10	high	11
Meteorological communications	9	8	see Note 1	1	9	low	8
Flight regularity communications	8	7	see Note 1	1	8	low	7
Aeronautical information service messages	7	6	see Note 1	0	7	low	6
Network/systems administration	6	5	see Note 1	0	6	low	5
Aeronautical administrative messages	5	5	not allowed	not allowed	not allowed	not allowed	not allowed
<unassigned>	4	unassigned	unassigned	unassigned	unassigned	unassigned	unassigned
Urgent-priority administrative and U.N. Charter communications	3	3	not allowed	not allowed	not allowed	not allowed	not allowed
High-priority administrative and State/Government communications	2	2	not allowed	not allowed	not allowed	not allowed	not allowed
Normal-priority administrative communications	1	1	not allowed	not allowed	not allowed	not allowed	not allowed
Low-priority administrative communications and aeronautical passenger communications	0	0	not allowed	not allowed	not allowed	not allowed	not allowed

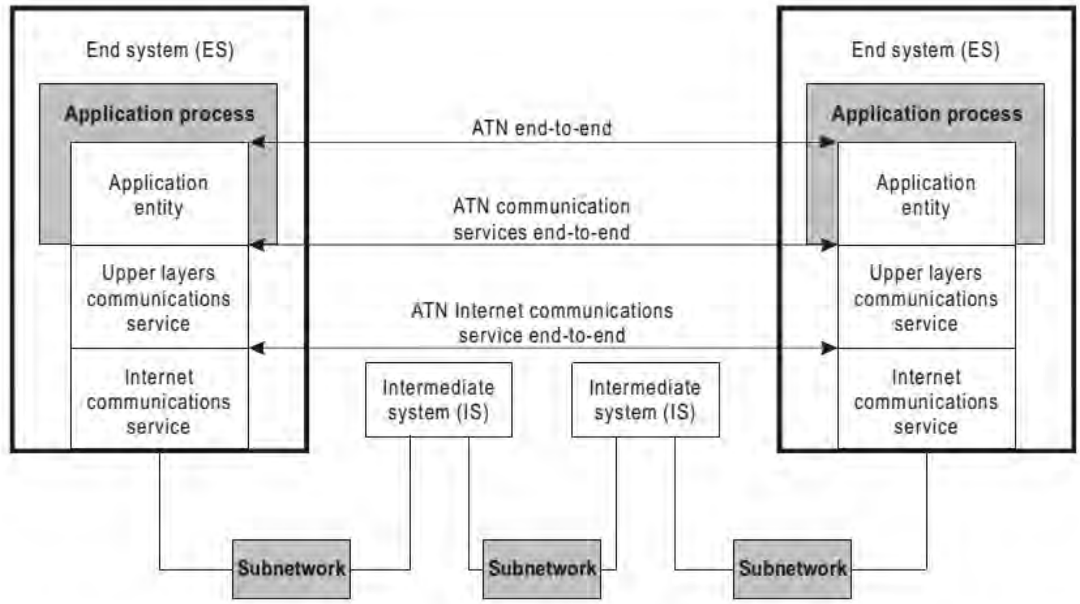
Note 1.— VDL Mode 2 has no specific subnetwork priority mechanisms.

Note 2.— The AMSS SARPs specify mapping of message categories to subnetwork priority without explicitly referencing ATN network layer priority.

Note 3.— The term "not allowed" means that only communications related to safety and regularity of flight are authorized to pass over this subnetwork as defined in the subnetwork SARPs.

Note 4.— Only those mobile subnetworks are listed for which subnetwork SARPs exist and for which explicit support is provided by the ATN boundary intermediate system (BIS) technical provisions.

FIGURE FOR CHAPTER 3



Note 1.— Shading indicates elements outside the scope of these SARPs. User requirements define the interface between the application entity and the user and ensure the functionality and interoperability of the ATN.

Note 2.— The figure represents a simplified model of the ATN and does not depict all of its capabilities (e.g. the store and forward capability which is provided for ATS message handling service).

Note 3.— Various end-to-end points have been defined within the ATN to specify certain end-to-end performance requirements. It may be necessary, however, to define different end-to-end points to facilitate the qualification of implementations to those performance requirements. In such cases, the end-to-end points should be clearly defined and correlated with the end-to-end points shown in the figure.

Note 4.— An IS is a conceptual representation of functionality and does not correspond precisely to a router. A router which implements the system management application requires the protocols of an end system and when using the system management application is also acting as an end system.

Figure 3-1. Conceptual model of the ATN

CHAPTER 4. AERONAUTICALMOBILE-SATELLITE (ROUTE) SERVICE (AMS(R)S)

Note 1.— This chapter contains Standards and Recommended Practices applicable to the use of Aeronautical Mobile Satellite (R) Service communications technologies. The Standards and Recommended Practices in this chapter are service-and performance-oriented and are not tied to a specific technology or technique.

Note 2.— Detailed Technical Specifications of AMS(R)S Systems are contained in the manual on AMS(R)S. This document also provides a detailed description of the AMS(R)S, including details on the Standards and Recommended Practices below.

4.1 DEFINITIONS

Connection establishment delay. Connection establishment delay, as defined in ISO 8348, includes a component, attributable to the called subnetwork (SN) service user, which is the time between the SN-CONNECT indication and the SN-CONNECT response. This user component is due to actions outside the boundaries of the satellite subnetwork and is therefore excluded from the AMS(R)S specifications.

Data transfer delay (95th percentile). The 95th percentile of the statistical distribution of delays for which transit delay is the average.

Data transit delay. In accordance with ISO 8348, the average value of the statistical distribution of data delays. This delay represents the subnetwork delay and does not include the connection establishment delay.

Network (N). The word "network" and its abbreviation "N" in ISO 8348 are replaced by the word "subnetwork" and its abbreviation "SN", respectively, wherever they appear in relation to the subnetwork layer packet data performance.

Residual error rate. The ratio of incorrect, lost and duplicate subnetwork service data units (SNSDUs) to the total number of SNSDUs that were sent.

Spot beam. Satellite antenna directivity whose main lobe encompasses significantly less than the earth's surface that is within line-of-sight view of the satellite. May be designed so as to improve system resource efficiency with respect to geographical distribution of user earth stations.

Subnetwork (SN). See **Network (N).**

Subnetwork service data unit (SNSDU). An amount of subnetwork user data, the identity of which is preserved from one end of a subnetwork connection to the other.

Total voice transfer delay. The elapsed time commencing at the instant that speech is presented to the AES or GES and concluding at the instant that the speech enters the interconnecting network of the counterpart GES or AES. This delay includes vocoder processing time, physical layer delay, RF propagation delay and any other delays within an AMS(R)S subnetwork.

Note.— The following terms used in this chapter are defined in Annex 10 as follows:

- Aeronautical telecommunication network (ATN): Volume III, Chapter 1.
- Aeronautical mobile-satellite (route) service (AMS(R)S): Volume II, Chapter 1.1.
- Aircraft earth station (AES): Volume III, Chapter 1.
- Ground earth station (GES): Volume III, Chapter 1.
- Subnetwork layer: Volume III, Chapter 6.1.

4.2 GENERAL

4.2.1 Any mobile-satellite system intended to provide AMS(R)S shall conform to the requirements of this chapter.

4.2.1.1 An AMS(R)S system shall support packet data service, or voice service, or both.

4.2.2 Requirements for mandatory carriage of AMS(R)S system equipment including the level of system capability shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment. A level of system capability shall include the performance of the AES, the satellite and the GES.

4.2.3 The agreements indicated in 4.2.2 shall provide at least two years' notice of mandatory carriage of airborne systems.

4.2.4 **Recommendation.—** *Civil aviation authorities should coordinate with national authorities and service providers those implementation aspects of an AMS(R)S system that will permit its worldwide interoperability and optimum use, as appropriate.*

4.3 RF CHARACTERISTICS

4.3.1 Frequency bands

Note.— ITU Radio Regulations permit systems providing mobile-satellite service to use the same spectrum as AMS(R)S without requiring such systems to offer safety services. This situation has the potential to reduce the spectrum available for AMS(R)S. It is critical that States consider this issue in frequency planning and in the establishment of national or regional spectrum requirements.

4.3.1.1 When providing AMS(R)S communications, an AMS(R)S system shall operate only in frequency bands which are appropriately allocated to AMS(R)S and protected by the ITU Radio Regulations.

4.3.2 Emissions

4.3.2.1 The total emissions of the AES necessary to meet designed system performance shall be controlled to avoid harmful interference to other systems necessary to support safety and regularity of air navigation, installed on the same or other aircraft.

Note 1.— Harmful interference can result from radiated and/or conducted emissions that include harmonics, discrete spurious, intermodulation product and noise emissions, and are not necessarily limited to the "transmitter on" state.

Note 2.— Protection requirements for GNSS are contained in Annex 10, Volume I.

4.3.2.2 INTERFERENCE TO OTHER AMS(R)SEQUIPMENT

4.3.2.2.1 Emissions from an AMS(R)S system AES shall not cause harmful interference to an AES providing AMS(R)S on a different aircraft.

Note.— One method of complying with 4.3.2.2.1 is by limiting emissions in the operating band of other AMS(R)S equipment to a level consistent with the intersystem interference requirements such as contained in RTCA document DO-215. RTCA and EUROCAE may establish new performance standards for future AMS(R)S which may describe methods of compliance with this requirement.

4.3.3 Susceptibility

4.3.3.1 The AES equipment shall operate properly in an interference environment causing a cumulative relative change in its receiver noise temperature ($\Delta T/T$) of 25 per cent.

4.4 PRIORITY ANDPRE-EMPTIVE ACCESS

4.4.1 Every aircraft earth station and ground earth station shall be designed to ensure that messages transmitted in accordance with Annex 10, Volume II, 5.1.8,including their order of priority, are not delayed by the transmission and/or reception of other types of messages. If necessary, as a means to comply with the above requirement, message types not defined in Annex 10, Volume II, 5.1.8 shall be terminated even without warning, to allow Annex 10, Volume II, 5.1.8 type messages to be transmitted and received.

4.4.2 All AMS(R)S data packets and all AMS(R)S voice calls shall be identified as to their associated priority.

4.4.3 Within the same message category, the system shall provide voice communications priority over data communications.

4.5 SIGNAL ACQUISITION AND TRACKING

4.5.1 The AES, GES and satellites shall properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 1 500 km/h (800 knots) along any heading.

4.5.1.1 **Recommendation.—** *The AES, GES and satellites should properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 2 800 km/h (1 500 knots) along any heading*.

4.5.2 The AES, GES and satellites shall properly acquire and track service link signals when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 0.6 g.

4.5.2.1 **Recommendation.** – *The AES, GES and satellites should properly acquire and track service link signals when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 1.2 g.*

4.6 PERFORMANCE REQUIREMENTS

4.6.1 Designated operational coverage

4.6.1.1 An AMS(R)S system shall provide AMS(R)S throughout its designated operational coverage (DOC).

4.6.2 Failure notification

4.6.2.1 In the event of a service failure, an AMS(R)S system shall provide timely predictions of the time, location and duration of any resultant outages until full service is restored.

Note.— Service outages may, for example, be caused by the failure of a satellite, satellite spot beam, or GES. The geographic areas affected by such outages may be a function of the satellite orbit and system design, and may vary with time.

4.6.2.2 The system shall annunciate a loss of communications capability within 30 seconds of the time when it detects such a loss.

4.6.3 AES requirements

4.6.3.1 The AES shall meet the relevant performance requirements contained in 4.6.4 and 4.6.5 for aircraft in straight and level flight throughout the designated operational coverage of the satellite system.

4.6.3.1.1 **Recommendation.—** *The AES should meet the relevant performance requirements contained in 4.6.4 and 4.6.5 for aircraft attitudes of +20/-5 degrees of pitch and +/-25 degrees of roll throughout the DOC of the satellite system.*

4.6.4 Packet data service performance

4.6.4.1 If the system provides AMS(R)S packet data service, it shall meet the standards of the following subparagraphs.

Note.— System performance standards for packet data service may also befound in RTCA Document DO-270.

4.6.4.1.1 An AMS(R)S system providing a packet data service shall be capable of operating as a constituent mobile subnetwork of the ATN.

Note.— In addition, an AMS(R)S may provide non-ATN data functions.

4.6.4.1.2DELAY PARAMETERS

Note.— The term "highest priority service" denotes the priority which is reserved for distress, urgency and certain infrequent network system management messages. The term "lowest priority service" denotes the priority used for regularity of flight messages. All delay parameters are under peak-hour traffic loading conditions.

4.6.4.1.2.1 *Connection establishment delay*. Connection establishment delay shall not be greater than 70 seconds.

4.6.4.1.2.1.1 **Recommendation**.— *Connection establishment delay should not be greater than 50 seconds.*

4.6.4.1.2.2 In accordance with ISO 8348, data transit delay values shall be based on a fixed subnetwork service data unit (SNSDU) length of 128 octets. Data transit delays shall be defined as average values.

4.6.4.1.2.3 Data transit delay, from-aircraft, highest priority. From-aircraft data transit delay shall not be greater than 40 seconds for the highest priority data service.

4.6.4.1.2.3.1 **Recommendation.—** *Data transit delay, from-aircraft, highest priority. From-aircraft data transit delay should not be greater than 23 seconds for the highest priority data service.*

4.6.4.1.2.3.2 **Recommendation.**— *Data transit delay, from-aircraft, lowest priority. From-aircraft data transit delay should not be greater than 28 seconds for the lowest priority data service.*

4.6.4.1.2.4 Data transit delay, to-aircraft, highest priority. To-aircraft data transit delay shall not be greater than 12 seconds for the highest priority data service.

4.6.4.1.2.4.1 **Recommendation.**— *Data transit delay, to-aircraft, lowest priority. To-aircraft data transit delay should not be greater than 28 seconds for the lowest priority data service.*

4.6.4.1.2.5 Data transfer delay (95th percentile), from-aircraft, highest priority. From-aircraft data transfer delay (95th percentile), shall not be greater than 80 seconds for the highest priority data service.

4.6.4.1.2.5.1 **Recommendation.**—*Data transfer delay (95th percentile), from-aircraft, highest priority. From-aircraft data transfer delay (95th percentile), should not be greater than 40 seconds for the highest priority data service.*

4.6.4.1.2.5.2 **Recommendation.**—*Data transfer delay (95th percentile), from-aircraft, lowest priority. From-aircraft data transfer delay (95th percentile), should not be greater than 60 seconds for the lowest priority data service.*

4.6.4.1.2.6 Data transfer delay (95th percentile), to-aircraft, highest priority. To-aircraft data transfer delay (95th percentile), shall not be greater than 15 seconds for the highest priority data service.

4.6.4.1.2.6.1 **Recommendation**.—*Data transfer delay (95th percentile), to-aircraft, lowest priority. To-aircraft data transfer delay (95th percentile), should not be greater than 30 seconds for the lowest priority data service.*

4.6.4.1.2.7 *Connection release delay (95th percentile).* The connection release delay (95th percentile) shall not be greater than 30 seconds in either direction.

4.6.4.1.2.7.1 **Recommendation**.—*The connection release delay (95th percentile) should not be greater than 25 seconds in either direction.*

4.6.4.1.3 *INTEGRITY*

4.6.4.1.3.1 Residual error rate, from-aircraft. The residual error rate in the from-aircraft direction shall not be greater than 10-4 per SNSDU.

4.6.4.1.3.1.1 **Recommendation**.—*The residual error rate in the from-aircraft direction should not be greater than 10-6 per SNSDU.*

4.6.4.1.3.2 Residual error rate, to-aircraft. The residual error rate in the to-aircraft direction shall not be greater than 10-6per SNSDU.

4.6.4.1.3.3 *Connection resilience*. The probability of a subnetwork connection (SNC) provider-invoked SNC release shall not be greater than 10-4over any one-hour interval.

Note.— Connection releases resulting from GES-to-GES handover, AES log-off or virtual circuit pre-emption are excluded from this specification.

4.6.4.1.3.4 The probability of an SNC provider-invoked reset shall not be greater than 10-1 over any one-hour interval.

4.6.5 Voice service performance

4.6.5.1 If the system provides AMS(R)S voice service, it shall meet the requirements of the following subparagraphs.

Note.— ICAO is currently considering these provisionsin the light of the introduction of new technologies.

4.6.5.1.1 *CALL PROCESSING DELAY*

4.6.5.1.1.1 *AES origination*. The 95th percentile of the time delay for a GES to present a call origination event to the terrestrial network interworking interface after a call origination event has arrived at the AES interface shall not be greater than 20 seconds.

4.6.5.1.1.2 *GES origination*. The 95th percentile of the time delay for an AES to present a call origination event at its aircraft interface after a call origination event has arrived at the terrestrial network interworking interface shall not be greater than 20 seconds.

4.6.5.1.2 *VOICE QUALITY*

4.6.5.1.2.1 The voice transmission shall provide overall intelligibility performance suitable for the intended operational and ambient noise environment.

4.6.5.1.2.2 The total allowable transfer delay within an AMS(R)S subnetwork shall not be greater than 0.485 seconds.

4.6.5.1.2.3 **Recommendation.—** Due account should be taken of the effects of tandem vocoders and/or other analog/digital conversions.

4.6.5.1.3 *VOICE CAPACITY*

4.6.5.1.3.1 The system shall have sufficient available voice traffic channel resources such that an AES- or GES originated AMS(R)S voice call presented to the system shall experience a probability of blockage of no more than 10-2.

Note.— Available voice traffic channel resources include all pre-emptable resources, including those in use by non AMS(R)S communications.

4.6.6 Security

4.6.6.1 The system shall provide features for the protection of messages in transit from tampering.

4.6.6.2 The system shall provide features for protection against denial of service, degraded performance characteristics, or reduction of system capacity when subjected to external attacks.

Note.— Possible methods of such attack include intentional flooding with spurious messages, intentional corruption of system software or databases, or physical destruction of the support infrastructure.

4.6.6.3 The system shall provide features for protection against unauthorized entry.

Note.— These features are intended to provide protection against spoofing and "phantom controllers".

4.7 SYSTEM INTERFACES

4.7.1 An AMS(R)S system shall allow subnetwork users to address AMS(R)S communications to specific aircraft by means of the ICAO 24-bit aircraft address.

Note.— Provisions on the allocation and assignment of ICAO 24-bit addresses are contained in the Appendix to Chapter 9.

4.7.2 Packet data service interfaces

4.7.2.1 If the system provides AMS(R)S packet data service, it shall provide an interface to the ATN.

Note.— The detailed technical specifications related to provisions of the ATN-compliant subnetwork service are contained in Section 5.2.5 and Section 5.7.2 of Doc 9880 — Manual on Detailed Technical Specifications for the Aeronautical Telecommunication Network (ATN) (in preparation).

4.7.2.2 If the system provides AMS(R)S packet data service, it shall provide a connectivity notification (CN) function.

CHAPTER 5. SSR MODE S AIR-GROUND DATA LINK

Note.— The SSR Mode S air-ground data link is also referred to as the Mode S subnetwork in the context of the aeronautical telecommunication network (ATN).

5.1 DEFINITIONS RELATINGTO THE MODE S SUBNETWORK

Aircraft. The term aircraft may be used to refer to Mode S emitters (e.g. aircraft/vehicles), where appropriate.

Aircraft address. A unique combination of 24 bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

Aircraft data circuit-terminating equipment (ADCE). An aircraft specific data circuit-terminating equipment that is associated with an airborne data link processor (ADLP). It operates a protocol unique to Mode S data link for data transfer between air and ground.

Aircraft data link processor (ADLP). An aircraft-resident processor that is specific to a particular air-ground data link (e.g. Mode S) and which provides channel management, and segments and/or reassembles messages for transfer. It is connected to one side of aircraft elements common to all data link systems and on the other side to the air-ground link itself.

Aircraft/vehicle. May be used to describe either a machine or device capable of atmospheric flight, or a vehicle on the airport surface movement area (i.e. runways and taxiways).

Air-initiated protocol. A procedure initiated by a Mode S aircraft installation for delivering a standard length or extended length downlink message to the ground.

BDS Comm-B Data Selector. The 8-bit BDS code determines the register whose contents are to be transferred in the MB field of a Comm-B reply. It is expressed in two groups of 4 bits each, BDS1 (most significant 4 bits) and BDS2 (least significant 4 bits).

Broadcast. The protocol within the Mode S system that permits uplink messages to be sent to all aircraft in coverage area, and downlink messages to be made available to all interrogators that have the aircraft wishing to send the message under surveillance.

Capability report. Information identifying whether the transponder has a data link capability as reported in the capability (CA) field of an all-call reply or squitter transmission (see "data link capability report").

Close-out. A command from a Mode S interrogator that terminates a Mode S link layer communication transaction.

Cluster of interrogators. Two or more interrogators with the same interrogator identifier (II) code, operating cooperatively to ensure that there is no interference to the required surveillance and data link performance of each of the interrogators, in areas of common coverage.

Comm-A. A 112-bit interrogation containing the 56-bit MA message field. This field is used by the uplink standard length message (SLM) and broadcast protocols.

Comm-B. A 112-bit reply containing the 56-bit MB message field. This field is used by the downlink SLM, ground-initiated and broadcast protocols.

Comm-C. A 112-bit interrogation containing the 80-bit MC message field. This field is used by the uplink extended length message (ELM) protocol.

Comm-D. A 112-bit reply containing the 80-bit MD message field. This field is used by the downlink ELM protocol.

Connection. A logical association between peer-level entities in a communication system.

Data link capability report. Information in a Comm-B reply identifying the complete Mode S communications capabilities of the aircraft installation.

Downlink. A term referring to the transmission of data from an aircraft to the ground. Mode S air-to-ground signals are transmitted on the 1 090 MHz reply frequency channel.

Extended length message (ELM). A series of Comm-C interrogations (uplink ELM) transmitted without the requirement for intervening replies, or a series of Comm-D replies (downlink ELM) transmitted without intervening interrogations.

Uplink ELM (UELM). A term referring to extended length uplink communication by means of 112-bit Mode S Comm-C interrogations, each containing the 80-bit Comm-C message field (MC).

Downlink ELM (DELM). A term referring to extended length downlink communication by means of 112-bit Mode S Comm-D replies, each containing the 80-bit Comm-D message field (MD).

Frame. The basic unit of transfer at the link level. In the context of Mode S subnetwork, a frame can include from one to four Comm-A or Comm-B segments, from two to sixteen Comm-C segments, or from one to sixteen Comm-D segments.

General formatter/manager (GFM). The aircraft function responsible for formatting messages to be inserted in the transponder registers. It is also responsible for detecting and handling error conditions such as the loss of input data.

Ground data circuit-terminating equipment (GDCE). A ground specific data circuit-terminating equipment associated with a ground data link processor (GDLP). It operates a protocol unique to Mode S data link for data transfer between air and ground.

Ground data link processor (GDLP). A ground-resident processor that is specific to a particular air-ground data link (e.g. Mode S), and which provides channel management, and segments and/or reassembles messages for transfer. It is connected on one side (by means of its DCE) to ground elements common to all data link systems, and on the other side to the air-ground link itself.

Ground-initiated Comm-B (GICB). The ground-initiated Comm-B protocol allows the interrogator to extract Comm-B replies containing data from a defined source in the MB field.

Ground-initiated protocol. A procedure initiated by a Mode S interrogator for delivering standard length or extended length messages to a Mode S aircraft installation.

Mode S air-initiated Comm-B (AICB) protocol. A procedure initiated by a Mode S transponder for transmitting a single Comm-B segment from the aircraft installation.

Mode S broadcast protocols. Procedures allowing standard length uplink or downlink messages to be received by more than one transponder or ground interrogator respectively.

Mode S ground-initiated Comm-B (GICB) protocol. A procedure initiated by a Mode S interrogator for eliciting a single Comm-B segment from a Mode S aircraft installation, incorporating the contents of one of 255 Comm-B registers within the Mode S transponder.

Mode S multisite-directed protocol. A procedure to ensure that extraction and close-out of a downlink standard length or extended length message is affected only by the particular Mode S interrogator selected by the aircraft.

Mode S packet. A packet conforming to the Mode S subnetwork standard, designed to minimize the bandwidth required from the air-ground link. ISO 8208 packets may be transformed into Mode S packets and vice-versa.

Mode S specific protocol (MSP). A protocol that provides restricted datagram service within the Mode S subnetwork.

Mode S specific services. A set of communication services provided by the Mode S system which are not available from other air-ground subnetworks, and therefore not interoperable.

Mode S specific services entity (SSE). An entity resident within an XDLP to provide access to the Mode S specific services.

Packet. The basic unit of data transfer among communication devices within the network layer (e.g. an ISO 8208 packet or a Mode S packet).

Segment. A portion of a message that can be accommodated within a single MA/MB field in the case of a standard length message, or MC/MD field in the case of an extended length message. This term is also applied to the Mode S transmissions containing these fields.

Standard length message (SLM). An exchange of digital data using selectively addressed Comm-A interrogations and/or Comm-B replies (see “Comm-A” and “Comm-B”).

Subnetwork. An actual implementation of a data network that employs a homogeneous protocol and addressing plan, and is under the control of a single authority.

Subnetwork management entity (SNME). An entity resident within a GDLP that performs subnetwork management and communicates with peer entities in intermediate or end-systems.

Timeout. The cancellation of a transaction after one of the participating entities has failed to provide a required response within a pre-defined period of time.

Uplink. A term referring to the transmission of data from the ground to an aircraft. Mode S ground-to-air signals are transmitted on the 1 030 MHz interrogation frequency channel.

XDCE. A general term referring to both the ADCE and the GDCE.

XDLP. A general term referring to both the ADLP and the GDLP.

5.2 MODE S CHARACTERISTICS

5.2.1 General provisions

Note 1.— Reference ISO document. When the term "ISO 8208" is referred to in this standard, it means the ISO Standard "Information technology — Data communications — X.25 Packet Layer Protocol for Data Terminal Equipment, Reference Number ISO/IEC 8208: 1990(E)".

Note 2.— The overall architecture of the Mode S subnetwork is presented in the diagram on the following page.

Note 3.— The processing splits into three different paths. The first consists of the processing of switched virtual circuits (SVCs), the second consists of the processing of Mode S specific services, and the third consists of the processing of subnetwork management information. SVCs utilize the reformatting process and the ADCE or GDCE function. Mode S specific services utilize the Mode S specific services entity (SSE) function.

5.2.1.1 **Message categories**. The Mode S subnetwork shall only carry aeronautical communications classified under categories of flight safety and flight regularity as specified in Annex 10, Volume II, Chapter 5, 5.1.8.4 and 5.1.8.6.

5.2.1.2 **Signals in space**. The signal-in-space characteristics of the Mode S subnetwork shall conform to the provisions contained in Annex 10, Volume IV, Chapter 3, 3.1.2.

5.2.1.3 **Code and byte independency**. The Mode S subnetwork shall be capable of code and byte independent transmission of digital data.

5.2.1.4 **Data transfer**. Data shall be conveyed over the Mode S data link in segments using either standard length message (SLM) protocols or extended length message (ELM) protocols as defined in 3.1.2.6.11 and 3.1.2.7 of Annex 10, Volume IV.

Note 1.— An SLM segment is the contents of one 56-bit MA or MB field. An ELM segment is the contents of one 80-bit MC or MD field.

Note 2.— An SLM frame is the contents of up to four linked MA or MB fields. An ELM frame is the contents of 2 to 16 MC or 1 to 16 MD fields.

5.2.1.5 **Bit numbering**. In the description of the data exchange fields, the bits shall be numbered in the order of their transmission, beginning with bit 1. Bit numbers shall continue through the second and higher segments of multi-segment frames. Unless otherwise stated, numerical values encoded by groups (fields) of bits shall be encoded using positive binary notation and the first bit transmitted shall be the most significant bit (MSB) (3.1.2.3.1.3 of Annex 10, Volume IV).

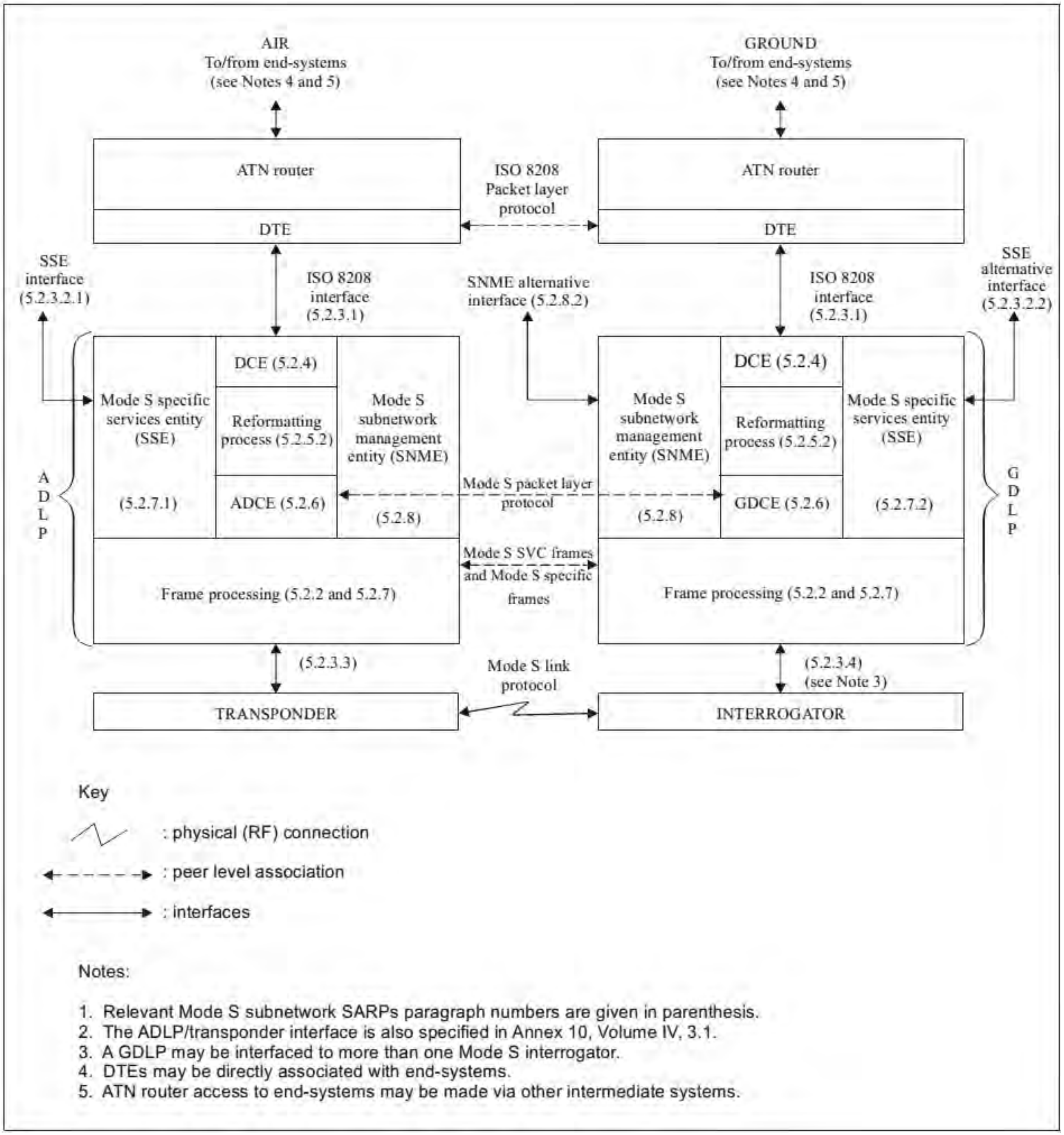
5.2.1.6 **Unassigned bits.** When the length of the data is not sufficient to occupy all bit positions within a message field or subfield, the unassigned bit positions shall be set to 0.

5.2.2 Frames

5.2.2.1 UPLINK FRAMES

5.2.2.1.1 *SLM frame*. An uplink SLM frame shall be composed of up to four selectively addressed Comm-A segments.

Functional elements of the Mode S subnetwork



Note.— Each Comm-A segment (MA field) received by the ADLP is accompanied by the first 32 bits of the interrogation that delivered the segment (3.1.2.10.5.2.1.1 of Annex 10, Volume IV). Within these 32 bits is the 16-bit special designator (SD) field (3.1.2.6.1.4 of Annex 10, Volume IV).

5.2.2.1.1.1 *SD field.* When the designator identification (DI) field (bits 14-16) has a code value of 1 or 7, the special designator (SD) field (bits 17-32) of each Comm-A interrogation shall be used to obtain the interrogator identifier subfield (IIS, bits 17-20) and the linked Comm -A subfield (LAS, bits 30-32). The action to be taken shall depend on the value of LAS. The contents of LA Sand IIS shall be retained and shall be associated with the Comm-A message segment for use in assembling the frame as indicated below. All fields other than the LASfield shall be as defined in 3.1.2 of Annex 10, Volume IV.

Note. – The SD field structure is shown in Figure 5-1[3].

5.2.2.1.1.2 *LAS coding*. The 3-bit LASsubfield shall be coded as follows:

LAS MEANING

0 single segment
1 linked, 1st segment
2 linked, 2nd but not final segment
3 linked, 3rd but not final segment
4 linked, 4th and final segment
5 linked, 2nd and final segment
6 linked, 3rd and final segment
7 unassigned

5.2.2.1.1.3 *Single segment SLM frame*. If LAS= 0, the data in the MA field shall be considered a complete frame and shall be made available for further processing.

5.2.2.1.1.4 *Multiple segment SLM frame*. The ADLP shall accept and assemble linked 56-bit Comm-A segments associated with all sixteen possible interrogator identifier (II) codes. Correct linking of Comm-A segments shall be achieved by requiring that all Comm-A segmentshave the same value of IIS. If LAS= 1 through 6, the frame shall consist of two to four Comm-A segments as specified in the following paragraphs.

5.2.2.1.1.4.1 *Initial segment*. If LAS= 1, the MA field shall be assembled as the initial segment of an SLM frame. The initial segment shall be stored until all segments of the frame have been received or the frame is cancelled.

[3] All figures and tables are located at the end of this chapter

5.2.2.1.1.4.2 *Intermediate segment*. If LAS= 2 or 3, the MA field shall be assembled in numerical order as an intermediate segment of the SLM frame. It shall be associatedwith previous segments containing the same value of IIS.

5.2.2.1.1.4.3 *Final segment*. If LAS= 4, 5 or 6, the MA field shall be assembled as the final segment of the SLM frame. It shall be associated with previous segments containing the same value of IIS.

5.2.2.1.1.4.4 *Frame completion*. The frame shall be considered complete and shall be made available for further processing as soon as all segments of the frame have been received.

5.2.2.1.1.4.5 *Frame cancellation*. An incomplete SLM frame shall be cancelled if one or more of the following conditions apply:

a) a new initial segment (LAS= 1) is received with the same value of IIS.In this case, the new initial segment shall be retained as the initial segment of a new SLM frame;

b) the sequence of received LAS codes (after the elimination of duplicates) is not contained in the following list:

1) LAS= 0
2) LAS= 1,5
3) LAS= 1,2,6
4) LAS= 1,6,2
5) LAS= 1,2,3,4
6) LAS= 1,3,2,4
7) LAS= 1,2,4,3
8) LAS= 1,3,4,2
9) LAS= 1,4,2,3
10) LAS= 1,4,3,2

c) Tc seconds have elapsed since the last Comm-A segment with the same value of IIS was received (Table 5-1).

5.2.2.1.1.4.6 *Segment cancellation.* A received segment for an SLM frame shall be discarded if it is an intermediate or final segment and no initial segment has been received with the same value of IIS.

5.2.2.1.1.4.7 *Segment duplication*. If a received segment duplicates a currently received segment number with the same value of IIS, the new segment shall replace the currently received segment.

Note.— The action of the Mode S subnetwork protocols may result in the duplicate delivery of Comm-A segments.

5.2.2.1.2 *ELM frame*. An uplink ELM frame shall consist of from 20 to 160 bytes and shall be transferred from the interrogator to the transponder using the protocol defined in 3.1.2.7 of Annex 10, Volume IV. The first 4 bits of each uplink ELM segment (MC field) shall contain the interrogator identifier (II) code of the Mode S interrogator transmitting the ELM. The ADLP shall check the II code of each segment of a completed uplink ELM. If all of the segments contain the same II code, the II code in each segment shall be deleted and the remaining message bits retained as user data for further processing. If all of the segments do not contain the same II code, the entire uplink ELM shall be discarded.

Note.— An uplink ELM frame consists of two to sixteen associated Comm-C segments, each of which contains the 4-bit II code. Therefore, the capacity for packet transfer is 19 to 152 bytes per uplink ELM frame.

5.2.2.2 DOWNLINK FRAMES

5.2.2.2.1 *SLM frame*. A downlink SLM frame shall be composed of up to 4 Comm-B segments. The MB field of the first Comm-B segment of the frame shall contain a 2-bit linked Comm-B subfield (LBS, bits 1 and 2 of the MB field). This subfield shall be used to control linking of up to four Comm-B segments.

Note.— The LBS uses the first 2-bit positions in the first segment of a multi or single segment downlink SLM frame.

Hence, 54 bits are available for Mode S packet data in the first segment of a downlink SLM frame. The remaining segments of the downlink SLM frame, if any, have 56 bits available.

5.2.2.2.1.1 *LBS coding*. Linking shall be indicated by the coding of the LBS subfield of the MB field of the initial Comm-B segment of the SLM frame.

The coding of LBS shall be as follows:

LBS MEANING

0 single segment
1 initial segment of a two-segment SLM frame
2 initial segment of a three-segment SLM frame
3 initial segment of a four-segment SLM frame

5.2.2.2.1.2 Linking protocol

5.2.2.2.1.2.1 In the Comm-B protocol, the initial segment shall be transmitted using the air-initiated or multisite directed protocols. The LBS field of the initial segment shall indicate to the ground the number of additional segments to be transferred (if any). Before the transmission of the initial segment to the transponder, the remaining segments of the SLM frame (if any) shall be transferred to the transponder for transmission to the interrogator using the ground-initiated Comm-B protocol. These segments shall be accompanied by control codes that cause the segments to be inserted in ground-initiated Comm-B registers 2, 3 or 4, associated respectively with the second, third, or fourth segment of the frame.

5.2.2.2.1.2.2 Close-out of the air-initiated segment that initiated the protocol shall not be performed until all segments have been successfully transferred.

Note.— The linking procedure including the use of the ground-initiated Comm-B protocol is performed by the ADLP.

5.2.2.2.1.3 *Directing SLM frames*. If the SLM frame is to be multisite-directed, the ADLP shall determine the II code of the Mode S interrogator or cluster of interrogators (5.2.8.1.3) that shall receive the SLM frame.

5.2.2.2.2 *ELM FRAME*

Note.— A downlink ELM consists of one to sixteen associated Comm-D segments.

5.2.2.2.2.1 Procedure. Downlink ELM frames shall be used to deliver messages greater than or equal to 28 bytes and shall be formed using the protocol defined in 3.1.2.7 of Annex 10, Volume IV.

5.2.2.2.2.2 *Directing ELM frames.* If the ELM frame is to be multisite-directed, the ADLP shall determine the II code of the Mode S interrogator or cluster of interrogators (5.2.8.1.3) that shall receive the ELM frame.

5.2.2.3 *XDLP frame processing*. Frame processing shall be performed on all Mode S packets (except for the MSP packet) as specified in 5.2.2.3 to 5.2.2.5. Frame processing for Mode S specific services shall be performed as specified in 5.2.7.

5.2.2.3.1 *Packet length*. All packets (including a group of packets multiplexed into a single frame) shall be transferred in a frame consisting of the smallest number of segments needed to accommodate the packet. The user data field shall be an integral multiple of bytes in length. A 4-bit parameter (LV) shall be provided in the Mode S DATA, CALL REQUEST, CALL ACCEPT, CLEAR REQUEST and INTERRUPT packet headers so that during unpacking no additional bytes are added to the user data field. The LV field shall define the number of full bytes used in the last segment of a frame. During LV calculations, the 4-bit II code in the last segment of an uplink ELM message shall be (1) ignored for uplink ELM frames with an odd number of Comm-C segments and (2) counted for uplink ELM frames with an even number of Comm-C segments. The value contained in the LV field shall be ignored if the packet is multiplexed.

Note.— A specific length field is used to define the length of each element of a multiplexed packet. Therefore the LV field value is not used. LV field error handling is described in Tables 5-16 and 5-19.

5.2.2.3.2 *Multiplexing*. When multiplexing multiple Mode S packets into single SLM on ELM frame, the following procedures shall be used. Multiplexing of the packets within the ADLP shall not be applied to packets associated with SVCs of different priorities.

Note.— Multiplexing is not performed on MSP packets.

5.2.2.3.2.1 *Multiplexing optimization*

Recommendation.— *When multiple packets are awaiting transfer to the same XDLP, they should be multiplexed into a single frame in order to optimize throughput, provided that packets associated with SVCs of different priorities are not multiplexed together.*

5.2.2.3.2.2 *Structure*. The structure of the multiplexed packets shall be as follows:

HEADER:6 or 8	LENGTH:8	1ST PACKET:v	LENGTH:8	2ND PACKET:v

Note.— A number in the field signifies the field length in bits; "v" signifies that the field is of variable length.

5.2.2.3.2.2.1 *Multiplexing header*. The header for the multiplexed packets shall be as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2

Where,

Data packet type (DP)= 0
MSP packet type (MP)= 1
Supervisory packet (SP)= 3
Supervisory type (ST)= 2

Note.— See Figure 5-23 for a definition for the field structure used in the multiplexing header.

5.2.2.3.2.2.2 *Length.* This field shall contain the length of the following packet in bytes. Any error detected in a multiplexed DATA packet, such as inconsistency between length as indicated in the LENGTH field and the length of the frame hosting that packet, shall result in the discarding of the packet unless the error can be determined to be limited to the LENGTH field, in which case a REJECT packet with the expected PS value can be sent.

5.2.2.3.2.2.2.1 **Recommendation.**— *For multiplex packets, if the entire packet cannot be de-multiplexed, then the first constituent packet should be treated as a format error, and the remainder should be discarded.*

5.2.2.3.2.3 *Termination. The end of a frame containing a sequence of multiplexed packets shall be determined by one of the following events:*

a) a length field of all zeros; or

b) less than eight bits left in the frame.

5.2.2.3.3 *MODE SCHANNEL SEQUENCE PRESERVATION*

5.2.2.3.3.1 *Application*. In the event that multiple Mode S frames from the same SVC are awaiting transfer to the same XDLP, the following procedure shall be used.

5.2.2.3.3.2 *Procedure*

Note 1.— SLM and ELM transactions can occur independently.

Note 2.— Uplink and downlink transactions can occur independently.

5.2.2.3.3.2.1 *SLM frames*. SLM frames awaiting transfer shall be transmitted in the order received.

5.2.2.3.3.2.2 *ELM frames*. ELM frames awaiting transfer shall be transmitted in the order received.

5.2.2.4 GDLP *FRAME PROCESSING*

5.2.2.4.1 GENERAL PROVISIONS

5.2.2.4.1.1 The GDLP shall determine the data link capability of the ADLP/transponder installation from the data link capability report (5.2.9) before performing any data link activity with that ADLP.

5.2.2.4.1.2 GDLP frame processing shall provide to the interrogator all data for the uplink transmission that are not provided directly by the interrogator.

5.2.2.4.2 *Delivery status*. GDLP frame processing shall accept an indication from the interrogator function that a specified uplink frame that was previously transferred to the interrogator has been successfully delivered over the ground-to-air link.

5.2.2.4.3 *Aircraft address.* GDLP frame processing shall receive from the interrogator along with the data in each downlink SLM or ELM frame, the 24-bit address of the aircraft that transmitted the frame. GDLP frame processing shall be capable of transferring to the interrogator the 24-bit address of the aircraft that is to receive an uplink SLM or ELM frame.

5.2.2.4.4 *Mode S protocol type identification*. GDLP frame processing shall indicate to the interrogator the protocol to be used to transfer the frame: standard length message protocol, extended length message protocol or broadcast protocol.

5.2.2.4.5 *Frame determination*. A Mode S packet (including multiplexed packets but excluding MSP packets) intended for uplink and less than or equal to 28 bytes shall be sent as an SLM frame. A Mode S packet greater than 28 bytes shall be sent as an uplink ELM frame for transponders with ELM capability, using M-bit processing as necessary (5.2.5.1.4.1). If the transponder does not have ELM capability, packets greater than 28bytes shall be sent using the M-bit or S-bit (5.2.5.1.4.2) assembly procedures as necessary and multiple SLM frames.

Note.— The Mode S DATA, CALL REQUEST, CALL ACCEPT, CLEAR REQUEST and INTERRUPT packets are the only Mode S packets that use M-bit or S-bit sequencing.

5.2.2.5 ADLP *FRAME PROCESSING*

5.2.2.5.1 *General provisions*. With the possible exception of the last 24 bits (address/parity), ADLP frame processing shall accept from the transponder the entire content of both 56-bit and 112-bit received uplink transmissions, excluding all call and

ACAS interrogations. ADLP frame processing shall provide to the transponder all data for the downlink transmission that is not provided directly by the transponder (5.2.3.3).

5.2.2.5.2 *Delivery status*. ADLP frame processing shall accept an indication from the transponder that a specified downlink frame that was previously transferred to the transponder has been closed out.

5.2.2.5.3 *Interrogator identifier.* ADLP frame processing shall accept from the transponder, along with the data in each uplink SLM and ELM, the interrogator identifier (II) code of the interrogator that transmitted the frame. ADLP frame processing shall transfer to the transponder the II code of the interrogator or cluster of interrogators that shall receive a multisite-directed frame.

5.2.2.5.4 *Mode S protocol type identification.* ADLP frame processing shall indicate to the transponder the protocol to be used to transfer the frame: ground-initiated, air-initiated, broadcast, multisite-directed, standard length or extended length.

5.2.2.5.5 *Frame cancellation*. ADLP frame processing shall be capable of cancelling downlink frames previously transferred to the transponder for transmission but for which a close-out has not been indicated. If more than one frame is stored within the transponder, the cancellation procedure shall be capable of cancelling the stored frames selectively.

5.2.2.5.6 *Frame determination*. A Mode S packet (including multiplexed packets but excluding MSP packets) intended for downlink and less than or equal to 222 bits shall be sent as an SLM frame. A Mode S packet greater than 222 bits shall be sent as a downlink ELM frame for transponders with ELM capability using M-bit processing as necessary (5.2.5.1.4.1). When M-bit processing is used, all ELM frames containing M = 1 shall contain the maximum number of ELM segments that the transponder is capable of transmitting in response to one requesting interrogation (UF = 24) (5.2.9.1). If the transponder does not have ELM capability, packets greater than 222 bits shall be sent using the M-bit or S-bit (5.2.5.1.4.2) assembly procedures and multiple SLM frames.

Note.— The maximum length of a downlink SLM frame is 222bits. This is equal to 28 bytes (7 bytes for 4 Comm-B segments) minus the 2-bit linked Comm-B subfield (5.2.2.2.1.1).

5.2.2.6 *PRIORITY MANAGEMENT*

5.2.2.6.1 *ADLP priority management*. Frames shall be transferred from the ADLP to the transponder in the following order of priority (highest first):

a) Mode S specific services;

b) search requests (5.2.8.1);

c) frames containing only high priority SVC packets; and

d) frames containing only low priority SVC packets.

5.2.2.6.2 GDLP *PRIORITY MANAGEMENT*

Recommendation.— Uplink frames should be transferred in the following order of priority (highest first):

a) Mode S specific services;

b) frames containing at least one Mode S ROUTE packet (5.2.8.1);

c) frames containing at least one high priority SVC packet; and

d) frames containing only low priority SVC packets.

5.2.3 Data exchange interfaces

5.2.3.1 THE DTE ISO 8208INTERFACE

5.2.3.1.1 *General provisions*. The interface between the XDLP and the DTE(s) shall conform to ISO 8208 packet layer protocol (PLP). The XDLP shall support the procedures of the DTE as specified in ISO 8208. As such, the XDLP shall contain a DCE (5.2.4).

5.2.3.1.2 *Physical and link layer requirements for the DTE/DCE interface*. The requirements are:

a) the interface shall be code and byte independent and shall not impose restrictions on the sequence, order, or pattern of the bits transferred within a packet; and

b) the interface shall support the transfer of variable length network layer packets.

5.2.3.1.3 DTE *ADDRESS*

5.2.3.1.3.1 *Ground DTE address*. The ground DTE address shall have a total length of 3 binary coded decimal (BCD) digits, as follows:

X0X1X2

X0 shall be the most significant digit. Ground DTE addresses shall be decimal numbers in the range of 0 through 255 coded in BCD. Assignment of the DTE address shall be a local issue. All DTEs connected to GDLPs having overlapping coverage shall have unique addresses. GDLPs which have a flying time less than Tr (Table 5-1) between their coverage areas shall be regarded as having overlapping coverage.

5.2.3.1.3.2 *Mobile DTE address*. The mobile DTE address shall have a total length of 10 BCD digits, as follows:

X0X1X2X3X4X5X6X7X8X9

X0 shall be the most significant digit. The digits X0to X7shall contain the octal representation of the aircraft address coded in BCD. The digits X8X9shall identify a sub-address for specific DTEs on board an aircraft. This sub-address shall be a decimal number in the range of 0 and 15 coded in BCD. The following sub-address assignments shall be used:

00 ATN router

01 to 15 Unassigned

5.2.3.1.3.3 *Illegal DTE addresses.* DTE addresses outside of the defined ranges or not conforming to the formats for the ground and mobile DTE addresses specified in 5.2.3.1.3.1 and 5.2.3.1.3.2 shall be defined to be illegal DTE addresses. The detection of an illegal DTE address in a CALL REQUEST packet shall lead to a rejection of the call as specified in 5.2.5.1.5.

5.2.3.1.4 PACKET LAYER PROTOCOL REQUIREMENTS OF THE DTE/DCE INTERFACE

5.2.3.1.4.1 *Capabilities*. The interface between the DTE and the DCE shall conform to ISO 8208 with the following capabilities:

a) expedited data delivery, i.e. the use of INTERRUPT packets with a user data field of up to 32 bytes;

b) priority facility (with two levels, 5.2.5.2.1.1.6);

c) fast select (5.2.5.2.1.1.13, 5.2.5.2.1.1.16); and

d) called/calling address extension facility, if required by local conditions (i.e. the XDLP is connected to the DTE via a network protocol that is unable to contain the Mode S address as defined).

Other ISO 8208 facilities and the D-bit and the Q-bit shall not be invoked for transfer over the Mode S packet layer protocol.

5.2.3.1.4.2 Parameter values.The timer and counter parameters for the DTE/DCE interface shall conform to the

default ISO 8208 values.

5.2.3.2 MODE SSPECIFIC SERVICES INTERFACE

Note.— Mode S specific services consist of the broadcast Comm-A and Comm-B, GICB and MSP.

5.2.3.2.1 ADLP

5.2.3.2.1.1 General provisions.The ADLP shall support the accessing ofMode S specific services through the

provision of one or more separate ADLP interfaces for this purpose.

5.2.3.2.1.2 Functional capability.Message and control coding via this interface shall support all of the capabilities

specified in 5.2.7.1.

5.2.3.2.2 GDLP

5.2.3.2.2.1 General provisions.The GDLP shall support the accessing ofMode S specific services through the

provision of a separate GDLP interface for this purpose and/or by providing access to these services through the DTE/DCE

interface.

5.2.3.2.2.2 Functional capability.Message and control coding via this interface shall support all of the capabilities

specified in 5.2.7.2.

5.2.3.3 ADLP/TRANSPONDER INTERFACE

5.2.3.3.1 TRANSPONDER TO ADLP

5.2.3.3.1.1 The ADLP shall accept an indication of protocol type from the transponder in connection with data transferred from the transponder to the ADLP. This shall include the following types of protocols:

a) surveillance interrogation;

b) Comm-A interrogation;

c) Comm-A broadcast interrogation; and

d) uplink ELM.

The ADLP shall also accept the II code of the interrogator used to transmit the surveillance, Comm-A or uplink ELM.

Note. — Transponders will not output all-call and ACAS information on this interface.

5.2.3.3.1.2 The ADLP shall accept control information from the transponder indicating the status of downlink transfers.

This shall include:

a) Comm-B close-out;

b) Comm-B broadcast timeout; and

c) downlink ELM close-out.

5.2.3.3.1.3 The ADLP shall have access to current information defining the communication capability of the Mode S transponder with which it is operating. This information shall be used to generate the data link capability report (5.2.9).

5.2.3.3.2 ADLP *TO TRANSPONDER*

5.2.3.3.2.1 The ADLP shall provide an indication of protocol type to the transponder in connection with data transferred from the ADLP to the transponder. This shall include the following types of protocols:

a) ground-initiated Comm-B;

b) air-initiated Comm-B;

c) multisite-directed Comm-B;

d) Comm-B broadcast;

e) downlink ELM; and

f) multisite-directed downlink ELM.

The ADLP shall also provide the II code for transfer of a multisite-directed Comm-B or downlink ELM and the Comm-B data selector (BDS) code (3.1.2.6.11.2 of Annex 10, Volume IV) for a ground-initiated Comm-B.

5.2.3.3.2.2 The ADLP shall be able to perform frame cancellation as specified in 5.2.2.5.5.

5.2.3.4 GDLP/MODE S *INTERROGATOR INTERFACE*

5.2.3.4.1 INTERROGATOR TO GDLP

5.2.3.4.1.1 The GDLP shall accept an indication of protocol type from the interrogator in connection with data transferred from the interrogator to the GDLP. This shall include the following types of protocols:

a) ground-initiated Comm-B;

b) air-initiated Comm-B;

c) air-initiated Comm-B broadcast; and

d) downlink ELM.

The GDLP shall also accept the BDS code used to identify the ground-initiated Comm-B segment.

5.2.3.4.1.2 The GDLP shall accept control information from the interrogator indicating the status of uplink transfers

and the status of the addressed Mode S aircraft.

5.2.3.4.2 GDLP to interrogator.The GDLP shall provide an indication of protocol type to the interrogator in

connection with data transferred from the GDLP to the interrogator. This shall include the following types of protocols:

a) Comm-A interrogation;

b) Comm-A broadcast interrogation;

c) uplink ELM; and

d) ground-initiated Comm-B request.

The GDLP shall also provide the BDS codefor the ground-initiated Comm-B protocol.

5.2.4 DCE operation

Note.— The DCE process within the XDLP acts as a peer process to the DTE. The DCE supports the operations of the DTE with the capability specified in 5.2.3.1.4. The following requirements do not specify format definitions and flow control on the DTE/DCE interface. The specifications and definitions in ISO 8208 apply for these cases.

5.2.4.1 *State transitions*. The DCE shall operate as a state machine. Upon entering a state, the DCE shall perform the actions specified in Table 5-2. State transitions and additional action(s) shall be as specified in Table 5-3 through Table 5-12.

Note.— The next state transition (if any) that occurs when the DCE receives a packet from the DTE is specified by Table 5-3 through Table 5-8. These tables are organized according to the hierarchy illustrated in Figure 5-2. The same transitions are defined in Table 5-9 through Table 5-12 when the DCE receives a packet from the XDCE (via the reformatting process).

5.2.4.2 DISPOSITION OF PACKETS

5.2.4.2.1 Upon receipt of a packet from the DTE, the packet shall be forwarded or not forwarded to the XDCE (via the reformatting process) according to the parenthetical instructions contained in Tables 5-3 to 5-8. If no parenthetical instruction is listed or if the parenthetical instruction indicates "do not forward", the packet shall be discarded.

5.2.4.2.2 Upon receipt of a packet from the XDCE (via the reformatting process), the packet shall be forwarded or not forwarded to the DTE according to the parenthetical instructions contained in Tables 5-9 to 5-12. If no parenthetical instruction is listed or if the parenthetical instruction indicates "do not forward", the packet shall be discarded.

5.2.5 Mode S packet layer processing

5.2.5.1 GENERAL REQUIREMENTS

5.2.5.1.1 *BUFFER REQUIREMENTS*

5.2.5.1.1.1 *ADLP buffer requirements*

5.2.5.1.1.1.1 The following requirements apply to the entire ADLP and shall be interpreted as necessary for each of the main processes (DCE, reformatting, ADCE, frame processing and SSE).

5.2.5.1.1.1.2 The ADLP shall be capable of maintaining sufficient buffer space for fifteen SVCs:

a) maintain sufficient buffer space to hold fifteen Mode S subnetwork packets of 152 bytes each in the uplink direction

per SVC for a transponder with uplink ELM capability or 28 bytes otherwise;

b) maintain sufficient buffer space tohold fifteen Mode S subnetwork packets of 160 bytes each in the downlink

direction per SVC for a transponder with downlink ELM capability or 28 bytes otherwise;

c) maintain sufficientbuffer space for two Mode S subnetwork INTERRUPT packets of 35 bytes each (user data field

plus control information), one ineach direction, for each SVC;

d) maintain sufficient resequencing buffer space for storing thirty-one Mode S subnetwork packets of152 bytes each in

the uplink direction per SVC for a transponder with uplink ELM capability or 28 bytes otherwise; and

e) maintain sufficient buffer space for the temporary storage of at least one Mode S packet of 160 bytes undergoing

M-bit or S-bit processing in each direction per SVC.

5.2.5.1.1.1.3 The ADLP shall be capable of maintaining a buffer of 1 600 bytes in each direction to be shared among

all MSPs.

5.2.5.1.1.2 GDLP buffer requirements

5.2.5.1.1.2.1 Recommendation.— The GDLP should be capable of maintaining sufficient buffer space for an average of 4 SVCs for each Mode S aircraft in the coverage area of the interrogators connected to it, assuming all aircraft have ELM

capability.

Note.— Additional buffer space may be required if DTEs associated with end-systems are supported.

5.2.5.1.2 CHANNEL NUMBER POOLS

5.2.5.1.2.1 The XDLP shall maintain several SVC channel number pools; the DTE/DCE (ISO 8208) interface uses one

set. Its organization, structure and use shall be as defined in the ISO 8208 standard. The other channel pools shall be used on

the ADCE/GDCE interface.

5.2.5.1.2.2 The GDLP shall manage a pool of temporary channel numbers in the range of 1 to 3, for each ground

DTE/ADLP pair. Mode S CALL REQUEST packets generated by the GDLP shall contain the ground DTE address and a

temporary channel number allocated fromthe pool of that ground DTE. The GDLP shall not reuse a temporary channel

number allocated to an SVC that is still in the CALL REQUEST state.

Note 1.— The use of temporary channel numbers allows the GDLP to have up to three call requests in process at the

same time for a particular ground DTE and ADLP combination. Italso allows the GDLP or ADLP to clear a channel before

the permanent channel number is assigned.

Note 2.— The ADLP may be in contact with multiple ground DTEs at any one time. All the ground DTEs use temporary

channel numbers ranging from 1 to 3.

5.2.5.1.2.3 The ADLP shall use the ground DTE address to distinguish the temporary channel numbers used by the various ground DTEs. The ADLP shall assign a permanent channel number (in the range of 1 to 15) to all SVCs and shall inform the GDLP of the assigned number by including it in the Mode S CALL REQUEST by ADLP or Mode S CALL

ACCEPT by ADLP packets. The temporary channel number shall be included in the Mode S CALL ACCEPT by ADLP together with the permanent channel number in order to define the association of these channel numbers. The ADLP shall continue to associate the temporary channel number with the permanent channel number of an SVC until the SVC is returned to the READY (p1) state, or else, while in the DATA TRANSFER (p4) state, a Mode S CALL REQUEST by GDLP packetis received bearing the same temporary channel number. A non-zero permanent channel number in the Mode S CLEAR REQUEST by ADLP, CLEAR REQUEST by GDLP, CLEAR CONFIRMATION by ADLP or CLEAR CONFIRMATION by GDLP packet shall indicate that the permanent channel number shall be used and the temporary channel number shall be ignored. In the event that an XDLP is required to send one ofthese packets in the absence of a permanent channel number, the permanent channel number shall be set to zero, which shall indicate to the peer XDLP that the temporary channel number is to be used.

Note.— The use of a zero permanent channel number allows the ADLP to clear an SVC when no permanent channel number is available, and allows the GDLP to do likewise before it has been informed of the permanent channel number.

5.2.5.1.2.4 The channel number used by the DTE/DCE interface and that used by the ADCE/GDCE interface shall be assigned independently. The reformatting process shall maintain an association table between the DTE/DCE and the ADCE/GDCE channel numbers.

5.2.5.1.3 *Receive ready and receive not ready conditions*. The ISO 8208 interface and the ADCE/GDCE interface management procedures shall be independent operations since each system must be able to respond to separate receive ready and receive not ready indications.

5.2.5.1.4 *PROCESSING OF M-BIT AND S-BIT SEQUENCES*

Note.— M-bit processing applies to the sequencing of the DATA packet. S-bit processing applies to the sequencing of Mode S CALL REQUEST, CALL ACCEPT, CLEAR REQUEST and INTERRUPT packets.

5.2.5.1.4.1 *M-bit processing*

Note.— The packet size used on the DTE/DCE interface can be different from that used on the ADCE/GDCE interface.

5.2.5.1.4.1.1 M-bit processing shall be used when DATA packets are reformatted (5.2.5.2). M-bit processing shall utilize the specifications contained in the ISO 8208 standard. The M-bit sequence processing shall apply on a per channel basis. The M-bit set to 1 shall indicate that a user data field continues in the subsequent DATA packet. Subsequent packets in an M-bit sequence shall use the same header format (i.e. the packet format excluding the user data field).

5.2.5.1.4.1.2 If the packet size for the XDCE (5.2.6.4.2) interface is larger than that used on the DTE/DCE interface, packets shall be combined to the extent possible as dictated by the M-bit, when transmitting a Mode S DATA packet. If the packet size is smaller on the XDCE interface than that defined on the DTE/DCE interface, packets shall be fragmented to fit into the smaller Mode S packet using M-bit assembly.

5.2.5.1.4.1.3 A packet shall be combined with subsequent packets if the packet is filled and more packets exist in the M-bit sequence (M-bit = 1). A packet smaller than the maximum packet size defined for this SVC (partial packet) shall only be allowed when the M-bit indicates the end of an M-bit sequence. A received packet smaller than the maximum packet size with M-bit equal to 1 shall cause a reset to be generated as specified in ISO 8208 and the remainder of the sequence should be discarded.

5.2.5.1.4.1.4 **Recommendation**.— *In order to decrease delivery delay, reformatting should be performed on the partial receipt of an M-bit sequence, rather than delay reformatting until the complete M-bit sequence is received.*

5.2.5.1.4.2 *S-bit processing*. S-bit processing shall apply only to Mode S CALL REQUEST, CALL ACCEPT, CLEAR REQUEST and INTERRUPT packets. This processing shall be performed as specified for M-bit processing (5.2.5.1.4.1) except that the packets associated with any S-bit sequence whose reassembly is not completed in Tq seconds (Tables 5-1 and 5-13) shall be discarded (5.2.6.3.6, 5.2.6.4.5.2 and 5.2.6.9), and receipt of a packet shorter than the maximum packet size with S = 1 shall cause the entire S-bit sequence to be treated as a format error in accordance with Table 5-16.

5.2.5.1.5 *MODE SSUBNETWORK ERROR PROCESSING FOR ISO 8208PACKETS*

5.2.5.1.5.1 D-bit.If the XDLP receives a DATA packet with the D-bit set to 1, the XDLP shall send a RESET REQUEST packet to the originating DTE containing a cause code (CC)= 133 and a diagnostic code (DC)= 166. If the D-bit is set to 1 in a CALL REQUEST packet, the D-bit shall be ignored by the XDLP. The D-bit of the corresponding CALL ACCEPT packet shall always be set to 0. The use of CC is optional.

5.2.5.1.5.2 *Q-bit*. If the XDLP receives a DATA packet with the Q-bit set to 1, the XDLP shall send a RESET REQUEST packet to the originating DTE containing CC = 133 and DC= 83. The use of CC is optional.

5.2.5.1.5.3 *Invalid priority*. If the XDLP receives a call request with a connection priority value equal to 2 through 254, the XDLP shall clear the virtual circuit using DC= 66 and CC= 131. The use of CC is optional.

5.2.5.1.5.4 *Unsupported facility*. If the XDLP receives a call request with a request for a facility that it cannot support, the XDLP shall clear the virtual circuit using DC = 65 and C = 131. The use of CC is optional.

5.2.5.1.5.5 *Illegal calling DTE address*. If the XDLP receives a call request with an illegal calling DTE address (5.2.3.1.3.3), the XDLP shall clear the virtual circuit using DC = 68 and CC= 141. The use of CC is optional.

5.2.5.1.5.6 *Illegal called DTE address*. If the XDLP receives a call request with an illegal called DTE address (5.2.3.1.3.3), the XDLP shall clear the virtual circuit using DC = 67 and CC= 141. The use of CC is optional.

5.2.5.2 REFORMATTING PROCESS

Note.— The reformatting process is divided into two subprocesses: uplink formatting and downlink formatting. For the ADLP, the uplink process reformats ModeS packets into ISO 8208 packets and the downlink process reformats ISO 8208 packets into Mode S packets. For the GDLP, the uplink process reformats ISO 8208 packets into Mode S packets and the downlink process reformats Mode S packets into ISO 8208 packets.

5.2.5.2.1 *CALL REQUESTBY ADLP*

5.2.5.2.1.1 *Translation into Mode S packets*

5.2.5.2.1.1.1 *Translated packet format*. Reception by the ADLP reformatting process of an ISO 8208 CALL REQUEST packet from the local DCE shall result in the generation of corresponding Mode S CALL REQUEST by ADLP packet(s) (as determined by S-bit processing (5.2.5.1.4.2)) as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	P:1	FILL:1	SN:6	CH:4	AM:4	AG:8	S:1	FS:2	F:1	LV:4	UD:v

5.2.5.2.1.1.2 Data packet type (DP).This field shall be set to 0.

5.2.5.2.1.1.3 MSP packet type (MP).This field shall be set to 1.

5.2.5.2.1.1.4 Supervisory packet (SP).This field shall be set to 1.

5.2.5.2.1.1.5 Supervisory type (ST).This field shall be set to 0.

5.2.5.2.1.1.6 Priority (P).This field shall be set to 0 for a low priority SVC and to 1 for a high priority SVC. The value for this field shall be obtained from the data transfer field of the priority facility of the ISO 8208 packet, and shall be set to 0 if the ISO 8208 packet does not contain the priority facility or if a priority of 255 is specified. The other fields of the priority facility shall be ignored.

5.2.5.2.1.1.7 *Sequence number (SN).* For a particular SVC, each packet shall be numbered (5.2.6.9.4).

5.2.5.2.1.1.8 *Channel number (CH).* The channel number shall be chosen from the pool of SVC channel numbers available to the ADLP. The pool shall consist of 15 values from 1 through 15. The highest available channel number shall be chosen from the pool. An available channel shall be defined as one in state p1. The correspondence between the channel number used by the Mode S subnetwork and the number used by the DTE/DCE interface shall be maintained while the channel is active.

Note.— Also refer to 5.2.5.1.2 on channel pool management.

5.2.5.2.1.1.9 *Address, mobile (AM).* This address shall be the mobile DTE sub-address (5.2.3.1.3.2) in the range of 0 to 15. The address shall be extracted from the two least significant digits of the calling DTE address contained in the ISO 8208 packet and converted to binary representation.

Note.— The 24-bit aircraft address is transferred within the Mode S link layer.

5.2.5.2.1.1.10 Address, ground (AG).This address shall be the ground DTE address (5.2.3.1.3.1) in the range of 0 to 255. The address shall be extracted from the called DTE address contained in the ISO 8208 packet and converted to binary representation.

5.2.5.2.1.1.11 *Fill field*. The fill field shall be used to align subsequent data fields on byte boundaries. When indicated as “FILL: n”, the fill field shall be set to a length of “n” bits. When indicated as “FILL1: 0 or 6”, the fill field shall be set to a length of 6 bits for a non-multiplexed packet in a downlink SLM frame and 0 bit for all other cases. When indicated as “FILL2: 0 or 2”, the fill field shall be set to a length of 0 bit for a non-multiplexed packet in a downlink SLM frame or for a multiplexing header and 2 bits for all other cases.

5.2.5.2.1.1.12 *S field (S).* A value of 1 shall indicate that the packet is part of an S-bit sequence with more packets in the sequence to follow. A value of 0 shall indicate that the sequence ends with this packet. This field shall be set as specified in 5.2.5.1.4.2.

5.2.5.2.1.1.13 *FS field (FS).* A value of 0 shall indicate that the packet does not contain fast select data. A value of 2 or 3 shall indicate that the packet contains fast select data. A value of 2 shall indicate normal fast select operation. A value of 3 shall indicate fast select with restricted response. An FS value of 1 shall be undefined.

5.2.5.2.1.1.14 *First packet flag (F).* This field shall be set to 0 in the first packet of an S-bit sequence and in a packet that is not part of an S-bit sequence. Otherwise it shall be set to 1.

5.2.5.2.1.1.15 *User data length (LV).*This field shall indicate the number of full bytes used in the last SLM or ELM segment as defined in 5.2.2.3.1.

5.2.5.2.1.1.16 *User data field (UD).* This field shall only be present if optional CALL REQUEST user data (maximum 16 bytes) or fast select user data (maximum 128 bytes) is contained in the ISO 8208 packet. The user data field shall be transferred from ISO 8208 packet unchanged using S-bit processing as specified in 5.2.5.1.4.2.

5.2.5.2.1.2 Translation into ISO 8208 packets

5.2.5.2.1.2.1 *Translation.* Reception by the GDLP reformatting process of a Mode S CALL REQUEST by ADLP packet (or an S-bit sequence of packets) from the GDCE shall result in the generation of a corresponding ISO 8208 CALL REQUEST packet to the local DCE. The translation from the Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.1.1 with the exceptions as specified in 5.2.5.2.1.2.2.

5.2.5.2.1.2.2 *Called DTE, calling DTE address and length fields*. The calling DTE address shall be composed of the aircraft address and the value contained in the AM field of the Mode S packet, converted to BCD (5.2.3.1.3.2). The called DTE address shall be the ground DTE address contained in the AG field of the Mode S packet, converted to BCD. The length field shall be as defined in ISO 8208.

5.2.5.2.2 *CALL REQUEST BY GDLP*

5.2.5.2.2.1 *Translation into Mode S packets*

5.2.5.2.2.1.1 *General*. Reception by the GDLP reformatting process of an ISO 8208 CALL REQUEST packet from the local DCE shall result in the generation of corresponding Mode S CALL REQUEST by GDLP packet(s) (as determined by S-bit processing (5.2.5.1.4.2)) as follows:

DP:1	MP:1	SP:2	ST:2	FILL:2	P:1	FILL:1	SN:6	FILL:2	TC:2	AM:4	AG:8	S:1	FS:2	F:1	LV:4	UD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1.

5.2.5.2.2.1.2 Data packet type (DP).This field shall be set to 0.

5.2.5.2.2.1.3 MSP packet type (MP).This field shall be set to 1.

5.2.5.2.2.1.4 Supervisory packet (SP).This field shall be set to 1.

5.2.5.2.2.1.5 Supervisory type (ST).This field shall be set to 0.

5.2.5.2.2.1.6 Temporary channel number field (TC).This field shall be used to distinguish multiple call requests from a GDLP. The ADLP reformatting process, upon receipt of a temporary channel number, shall assign a channel number from those presently in the READY state, p1.

5.2.5.2.2.1.7 *Address, ground (AG).* This address shall be the ground DTE address (5.2.3.1.3.1) in the range of 0 to 255.

The address shall be extracted from the calling DTE address contained in the ISO 8208 packet and converted to binary representation.

5.2.5.2.2.1.8 *Address, mobile (AM*). This address shall be the mobile DTE sub-address (5.2.3.1.3.2) in the range of 0 to

15. The address shall be extracted from the two least significant digits of the called DTE address contained in the ISO 8208 packet and converted to binary representation.

5.2.5.2.2.2 *Translation into ISO 8208 packets*

5.2.5.2.2.2.1 *Translation*. Reception by the ADLP reformatting process of a Mode S CALL REQUEST by GDLP packet (or an S-bit sequence of packets) from the ADCE shall result in the generation of a corresponding ISO 8208 CALL REQUEST packet to the local DCE. The translation from the Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.2.1 with the exceptions as specified in 5.2.5.2.2.2.2.

5.2.5.2.2.2.2 *Called DTE, calling DTE address and length fields*. The called DTE address shall be composed of the aircraft address and the value contained in the AM field of the Mode S packet, converted to BCD (5.2.3.1.3.2). The calling DTE address shall be the ground DTE address contained in the AG field of the Mode S packet, converted to BCD. The length field shall be as defined in ISO 8208.

5.2.5.2.3 *CALL ACCEPT BY ADLP*

5.2.5.2.3.1 *Translation into Mode S packets*

5.2.5.2.3.1.1 *Translated packet format*. Reception by the ADLP reformatting process of an ISO 8208 CALL ACCEPT packet from the local DCE shall result in the generation of corresponding Mode S CALL ACCEPT by ADLP packet(s) (as determined by S-bit processing(5.2.5.1.4.2)) as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	TC:2	SN:6	CH:4	AM:4	AG:8	S:1	FILL:2	F:1	LV:4	UD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1.

5.2.5.2.3.1.2 Data packet type (DP).This field shall be set to 0.

5.2.5.2.3.1.3 MSP packet type (MP).This field shall be set to 1.

5.2.5.2.3.1.4 Supervisory packet (SP).This field shall be set to 1.

5.2.5.2.3.1.5 Supervisory type (ST).This field shall be set to 1.

5.2.5.2.3.1.6 *Temporary channel number (TC).* The TC value in the originating Mode S CALL REQUEST by GDLP packet shall be returned to the GDLP along with the channel number (CH) assigned by the ADLP.

5.2.5.2.3.1.7 *Channel number (CH*). The field shall be set equal to the channel number assigned by the ADLP as determined during the CALL REQUEST procedures for the Mode S connection.

5.2.5.2.3.1.8 *Address, mobile and address, ground*. The AM and AG values in the originating Mode S CALL REQUEST by GDLP packet shall be returned in these fields. When present, DTE addresses in the ISO 8208 CALL ACCEPT packet shall be ignored.

5.2.5.2.3.2 *Translation into ISO 8208 packets*

5.2.5.2.3.2.1 *Translation*. Reception by the GDLP reformatting process of a Mode S CALL ACCEPT by ADLP packet (or an S-bit sequence of packets) from the GDCE shall result in the generation of a corresponding ISO 8208 CALL ACCEPT packet to the local DCE. The translation from the Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.3.1 with the exceptions as specified in 5.2.5.2.3.2.2.

5.2.5.2.3.2.2 *Called DTE, calling DTE address and length fields*. Where present, the called DTE address shall be composed of the aircraft address and the value contained in the AM field of the Mode S packet, converted to BCD (5.2.3.1.3.2). Where present, the calling DTE address shall be the ground DTE address contained in the AG field of the Mode S packet, converted to BCD. The length field shall be as defined in ISO 8208.

Note.— The called and calling DTE addresses are optional in the corresponding ISO 8208 packet and are not required for correct operation of the Mode S subnetwork.

5.2.5.2.4 *CALL ACCEPTBY GDLP*

5.2.5.2.4.1 *Translation into Mode S packets*

5.2.5.2.4.1.1 *Translated packet format.* Reception by the GDLP reformatting process of an ISO 8208 CALL ACCEPT packet from the local DCE shall result in the generation of corresponding Mode S CALL ACCEPT by GDLP packet(s) (as determined by S-bit processing(5.2.5.1.4.2)) as follows:

DP:1	MP:1	SP:2	ST:2	FILL:2	FILL:2	SN:6	CH:4	AM:4	AG:8	S:1	FILL:2	F:1	LV:4	UD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1.

5.2.5.2.4.1.2 Data packet type (DP).This field shall be set to 0.

5.2.5.2.4.1.3 MSP packet type (MP).This field shall be set to 1.

5.2.5.2.4.1.4 Supervisory packet (SP).This field shall be set to 1.

5.2.5.2.4.1.5 Supervisory type (ST).This field shall be set to 1.

5.2.5.2.4.1.6 *Address, mobile and address, ground*. The AM and AG values in the originating Mode S CALL REQUEST by ADLP packet shall be returned in these fields. When present, DTE addresses in the ISO 8208 CALL ACCEPT packet shall be ignored.

5.2.5.2.4.2 *Translation into ISO 8208 packets*

5.2.5.2.4.2.1 *Translation.* Reception by the ADLP reformatting process of a Mode S CALL ACCEPT by GDLP packet (or an S-bit sequence of packets) from the ADCE shall result in the generation of a corresponding ISO 8208 CALL ACCEPT packet to the local DCE. The translation from the Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.4.1 with the exceptions as specified in 5.2.5.2.4.2.2.

5.2.5.2.4.2.2 *Called DTE, calling DTE address and length fields*. Where present, the calling DTE address shall be composed of the aircraft address and the value contained in the AM field of the Mode S packet, converted to BCD (5.2.3.1.3.2). Where present, the called DTE address shall be the ground DTE address contained in the AG field of the Mode S packet, converted to BCD. The length field shall be as defined in ISO 8208.

Note.— The called and calling DTE addresses are optional in the corresponding ISO 8208 packet and are not required for correct operation of the Mode S subnetwork.

5.2.5.2.5 *CLEAR REQUESTBY ADLP*

5.2.5.2.5.1 *Translation into Mode S packets*

5.2.5.2.5.1.1 *Translated packet format*. Reception by the ADLP reformatting process of an ISO 8208 CLEAR REQUEST packet from the local DCE shall result in the generation of a corresponding Mode S CLEAR REQUEST by ADLP packet(s) (as determined by S-bit processing (5.2.5.1.4.2)) as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	TC:2	SN:6	CH:4	AM:4	AG:8	CC:8	DC:8	S:1	FILL:2	F:1	LV:4	UD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1 and 5.2.5.2.2.

5.2.5.2.5.1.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.2.5.1.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.2.5.1.4 *Supervisory packet (SP).* This field shall be set to 1.

5.2.5.2.5.1.5 *Channel number (CH)*: If a channel number has been allocated during the call acceptance phase, then CH shall be set to that value, otherwise it shall be set to zero.

5.2.5.2.5.1.6 *Temporary channel (TC):* If a channel number has been allocated during the call acceptance phase, then TC shall be set to zero, otherwise it shall be set to the value used in the CALL REQUEST by GDLP.

5.2.5.2.5.1.7 *Supervisory type (ST).* This field shall be set to 2.

5.2.5.2.5.1.8 *Address, ground or address, mobile*. The AG and AM values in the originating Mode S CALL REQUEST by ADLP or CALL REQUEST by GDLP packets shall be returned in these fields. When present, DTE addresses in the ISO 8208 CLEAR REQUEST packet shall be ignored.

5.2.5.2.5.1.9 *Clearing cause (CC) and diagnostic code (DC) fields*. These fields shall be transferred without modification from the ISO 8208 packet to the Mode S packet when the DTE has initiated the clear procedure. If the XDLP has initiated the clear procedure, the clearing cause field and diagnostic field shall be as defined in the state tables for the DCE and XDCE (see also 5.2.6.3.3). The coding and definition of these fields shall be as specified in ISO 8208.

5.2.5.2.5.2 *Translation into ISO 8208 packets*

5.2.5.2.5.2.1 *Translation.* Reception by the GDLP reformatting process of a Mode S CLEAR REQUEST by ADLP packet (or an S-bit sequence of packets) from the local GDCE shall result in the generation of a corresponding ISO 8208 CLEAR REQUEST packet to the local DCE. The translation from the Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.5.1 with the exceptions specified in 5.2.5.2.5.2.2 and 5.2.5.2.5.2.3.

5.2.5.2.5.2.2 *Called DTE, calling DTE and length fields*. These fields shall be omitted in the ISO 8208 CLEAR REQUEST packet.

5.2.5.2.5.2.3 *Clearing cause field.* This field shall be set taking account of 5.2.6.3.3.

5.2.5.2.6 *CLEAR REQUESTBY GDLP*

5.2.5.2.6.1 *Translation into Mode S packets*

5.2.5.2.6.1.1 *Translated packet format.* Reception by the GDLP reformatting process of an ISO 8208 CLEAR REQUEST packet from the local DCE shall result in the generation of corresponding Mode S CLEAR REQUEST by GDLP packet(s) (as determined by S-bit processing (5.2.5.1.4.2)) as follows:

DP:1	MP:1	SP:2	ST:2	FILL:2	TC:2	SN:6	CH:4	AM:4	AG:8	CC:8	DC:8	S:1	FILL:2	F:1	LV:4	UD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1, 5.2.5.2.2 and 5.2.5.2.5.

5.2.5.2.6.1.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.2.6.1.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.2.6.1.4 *Supervisory packet (SP).* This field shall be set to 1.

5.2.5.2.6.1.5 *Channel number (CH):* If a channel number has been allocated during the call acceptance phase, then CH shall be set to that value, otherwise it shall be set to zero.

5.2.5.2.6.1.6 Temporary channel (TC): If a channel number has been allocated during the call acceptance phase, then TC shall be set to zero, otherwise it shall be set to the value used in the CALL REQUEST by GDLP.

5.2.5.2.6.1.7 *Supervisory type (ST).This field shall be set to 2.*

5.2.5.2.6.2 *Translation into ISO 8208 packets*

5.2.5.2.6.2.1 *Translation.* Reception by the ADLP reformatting process of a Mode S CLEAR REQUEST by GDLP packet (or an S-bit sequence of packets) from the local ADCE shall result in the generation of a corresponding ISO 8208 CLEAR REQUEST packet to the local DCE. The translation from the Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.6.1.

5.2.5.2.6.2.2 *Called DTE, calling DTE and length fields*. These fields shall be omitted in the ISO 8208 CLEAR REQUEST packet.

5.2.5.2.7 *DATA*

5.2.5.2.7.1 *Translation into Mode S packets*

5.2.5.2.7.1.1 *Translated packet format*. Reception by the XDLP reformatting process of ISO 8208 DATA packet(s) from the local DCE shall result in the generation of corresponding Mode S DATA packet(s) as determined by M-bit processing (5.2.5.1.4.1), as follows:

DP:1	M:1	SN:6	FILL1:0 or 6	PS:4	PR:4	CH:4	LV:4	UD:v

5.2.5.2.7.1.2 Data packet type (DP).This field shall be set to 1.

5.2.5.2.7.1.3 M field (M).A value of 1 shall indicate that the packet is part of an M-bit sequence with more packets in the sequence to follow. A value of 0 shall indicate that the sequence ends with this packet. The appropriate value shall be placed in the M-bit field of the Mode S packet.

Note.— See 5.2.5.1.4 and ISO 8208 for a complete explanation.

5.2.5.2.7.1.4 Sequence number (SN).The sequence number field shall be set as specified in 5.2.5.2.1.1.7.

5.2.5.2.7.1.5 Packet send sequence number (PS).The packet send sequence number field shall be set as specified in 5.2.6.4.4.

5.2.5.2.7.1.6 *Packet receive sequence number (PR).* The packet receive sequence number field shall be set as specified in 5.2.6.4.4.

5.2.5.2.7.1.7 *Channel number (CH).* The channel number field shall contain the Mode S channel number that corresponds to the incoming ISO 8208 DATA packet channel number.

5.2.5.2.7.1.8 *User data length (LV).* This field shall indicate the number of full bytes used in the last SLM or ELM segment as defined in 5.2.2.3.1.

5.2.5.2.7.1.9 *Fill (FILL1).* This field shall be set as specified in 5.2.5.2.1.1.11.

5.2.5.2.7.1.10 *User data (UD).* The user data shall be transferred from the ISO 8208 packet to the Mode S packet utilizing the M-bit packet assembly processing as required.

5.2.5.2.7.2 *Translation into ISO 8208 packets*. Reception by the XDLP reformatting process of Mode S DATA packet(s) from the local XDCE shall result in the generation of corresponding ISO 8208 DATA packet(s) to the local DCE. The translation from Mode S packet(s) to the ISO 8208 packet(s) shall be the inverse of the processing defined in 5.2.5.2.7.1.

5.2.5.2.8 *INTERRUPT*

5.2.5.2.8.1 *Translation into Mode S packets*

5.2.5.2.8.1.1 *Translated packet format*. Reception by the XDLP reformatting process of an ISO 8208 INTERRUPT packet from the local DCE shall result in the generation of corresponding Mode S INTERRUPT packet(s) (as determined by S-bit processing (5.2.5.1.4.2)) as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	S:1	F:1	SN:6	CH:4	LV:4	UD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1.

5.2.5.2.8.1.2 *Data packet type (DP).*This field shall be set to 0.

5.2.5.2.8.1.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.2.8.1.4 *Supervisory packet (SP).* This field shall be set to 3.

5.2.5.2.8.1.5 *Supervisory type (ST).* This field shall be set to 1.

5.2.5.2.8.1.6 *User data length (LV).* This field shall be set as specified in 5.2.2.3.1.

5.2.5.2.8.1.7 *User data (UD).* The user data shall be transferred from the ISO 8208 packet to the Mode S packet using the S-bit packet reassembly processing as required. The maximum size of the user data field for an INTERRUPT packet shall be 32 bytes.

5.2.5.2.8.2 *Translation into ISO 8208 packets.* Reception by the XDLP reformatting process of Mode S INTERRUPT packet(s) from the local XDCE shall result in the generation of a corresponding ISO 8208 INTERRUPT packet to the local DCE. The translation from the Mode S packet(s) to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.8.1.

5.2.5.2.9 *INTERRUPT CONFIRMATION*

5.2.5.2.9.1 *Translation into Mode S packets*

5.2.5.2.9.1.1 *Translated packet format.* Reception by the XDLP reformatting process of an ISO 8208 INTERRUPT CONFIRMATION packet from the local DCE shall result inthe generation of a corresponding Mode S INTERRUPT CONFIRMATION packet as follows:

DP:1	MP:1	SP:2	ST:2	SS:2	FILL2:0 or 2	SN:6	CH:4	FILL:4

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1.

5.2.5.2.9.1.2 Data packet type (DP).This field shall be set to 0.

5.2.5.2.9.1.3 MSP packet type (MP).This field shall be set to 1.

5.2.5.2.9.1.4 Supervisory packet (SP).This field shall be set to 3.

5.2.5.2.9.1.5 Supervisory type (ST).This field shall be set to 3.

5.2.5.2.9.1.6 Supervisory subset (SS).This field shall be set to 0.

5.2.5.2.9.2 *Translation into ISO 8208 packets.* Reception by the XDLP reformatting process of a Mode S INTERRUPT CONFIRMATION packet from the local XDCE shall result in the generation of a corresponding ISO 8208 INTERRUPT CONFIRMATION packet to the local DCE. The translation from the Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.9.1.

5.2.5.2.10 *RESET REQUEST*

5.2.5.2.10.1 *Translation into Mode S packets*

5.2.5.2.10.1.1 *Translated packet format*. Reception by the XDLP reformatting process of an ISO 8208 RESET REQUEST packet from the local DCE shall result in the generation of a corresponding Mode S RESET REQUEST packet as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	FILL:2	SN:6	CH:4	FILL:4	RC:8	DC:8

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1.

5.2.5.2.10.1.2 Data packet type (DP).This field shall be set to 0.

5.2.5.2.10.1.3 MSP packet type (MP).This field shall be set to 1.

5.2.5.2.10.1.4 Supervisory packet (SP).This field shall be set to 2.

5.2.5.2.10.1.5 Supervisory type (ST).This field shall be set to 2.

5.2.5.2.10.1.6 *Reset cause code (RC) and diagnostic code (DC).* The reset cause and diagnostic codes used in the Mode S RESET REQUEST packet shall be as specified in the ISO 8208 packet when the reset procedure is initiated by the DTE. If the reset procedure originates with the DCE, the DCE state tables shall specify the diagnostic fields coding. In this case, bit 8 of the reset cause field shall be set to 0.

5.2.5.2.10.2 *Translation into ISO 8208 packets.* Reception by the XDLP reformatting process of a Mode S RESET packet from the local XDCE shall result in the generation of a corresponding ISO 8208 RESET packet to the local DCE. The translation from the

Mode S packet to the ISO 8208 packet shall be the inverse of the processing defined in 5.2.5.2.10.1.

5.2.5.2.11 *ISO 8208 RESTART REQUEST to Mode S CLEAR REQUEST*. The receipt of an ISO 8208 RESTART REQUEST from the local DCE shall result in the reformatting process generating a Mode S CLEAR REQUEST by ADLP or Mode S CLEAR REQUEST by GDLP for all SVCs associated with the requesting DTE. The fields of the Mode S CLEAR REQUEST packets shall be set as specified in 5.2.5.2.5 and 5.2.5.2.6.

Note.— There are no restart states in the Mode S packet layer protocol.

5.2.5.3 *PACKETS LOCAL TO THE MODE SSUBNETWORK*

Note.— Packets defined in this section do not result in the generation of an ISO 8208 packet.

5.2.5.3.1 MODE S RECEIVE READY

5.2.5.3.1.1 *Packet format*. The Mode S RECEIVE READY packet arriving from an XDLP is not related to the control of the DTE/DCE interface and shall not cause the generation of an ISO 8208 packet. The format of the packet shall be as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	FILL:2	SN:6	CH:4	PR:4

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1. The packet shall be processed as specified in 5.2.6.5.

5.2.5.3.1.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.3.1.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.3.1.4 *Supervisory packet (SP).* This field shall be set to 2.

5.2.5.3.1.5 *Supervisory type (ST).* This field shall be set to 0.

5.2.5.3.1.6 Packet receive sequence number (PR).This field shall be set as specified in 5.2.6.4.4.

5.2.5.3.2 *MODE S RECEIVE NOT READY*

5.2.5.3.2.1 *Packet format*. The Mode S RECEIVE NOT READY packet arriving from an XDLP is not related to the control of the DTE/DCE interface and shall not cause the generation of an ISO 8208 packet. The format of the packet shall be as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	FILL:2	SN:6	CH:4	PR:4

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1. The packet shall be processed as specified in 5.2.6.6.

5.2.5.3.2.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.3.2.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.3.2.4 *Supervisory packet (SP).* This field shall be set to 2.

5.2.5.3.2.5 *Supervisory type (ST).* This field shall be set to 1.

5.2.5.3.2.6 *Packet receive sequence number (PR).* This field shall be set as specified in 5.2.6.4.4.

5.2.5.3.3 *MODE S ROUTE*

5.2.5.3.3.1 *Packet format*. The format for the packet shall be as follows:

DP:1	MP:1	SP:2	ST:2	OF:1	IN:1	RTL:8	RT:v	ODL:0 or 8	OD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1. The packet shall only be generated by the GDLP. It shall be processed by the ADLP as specified in 5.2.8.1.2 and shall have a maximum size as specified in 5.2.6.4.2.1.

5.2.5.3.3.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.3.3.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.3.3.4 *Supervisory packet (SP).* This field shall be set to 3.

5.2.5.3.3.5 *Supervisory type (ST).* This field shall be set to 0.

5.2.5.3.3.6 *Option flag (OF*). This field shall indicate the presence of the optional data length (ODL) and optional data (OD) fields. OF shall be set to 1 if ODL and OD are present. Otherwise it shall be set to 0.

5.2.5.3.3.7 Initialization bit (IN).This field shall indicate the requirement for subnetwork initialization. It shall be set by the GDLP as specified in 5.2.8.1.2 d).

Note.— Initialization causes the clearing of any open SVCs associated with the DTE addresses contained in the ROUTE packet. This is needed to assure that all channels are closed at acquisition and for initialization following recovery after a GDLP failure.

5.2.5.3.3.8 Route table length (RTL).This field shall indicate the size of the route table, expressed in bytes.

5.2.5.3.3.9 *Route table (RT)*

5.2.5.3.3.9.1 *Contents.* This table shall consist of a variable number of entries each containing information specifying the addition or deletion of entries in the II code-DTE cross-reference table (5.2.8.1.1).

5.2.5.3.3.9.2 *Entries*. Each entry in the route table shall consist of the II code, a list of up to 8 ground DTE addresses, and a flag indicating whether the resulting II code-DTE pairs shall be added or deleted from the II code-DTE cross-reference table. A route table entry shall be coded as follows:

II:4	AD:1	ND:3	DAL:v

5.2.5.3.3.9.3 *Interrogator identifier (II).* This field shall contain the 4-bit II code.

5.2.5.3.3.9.4 *Add/delete flag (AD).* This field shall indicate whether the II code-DTE pairs shall be added (AD = 1) or deleted (AD= 0) from the II code-DTE cross-reference table.

5.2.5.3.3.9.5 *Number of DTE addresses (ND).* This field shall be expressed in binary in the range from 0 to 7 and shall indicate the number of DTE addresses present in DAL minus 1 (in order to allow from 1 to 8 DTE addresses).

5.2.5.3.3.9.6 *DTE address list (DAL).* This list shall consist of up to 8 DTE addresses, expressed in 8-bit binary representation.

5.2.5.3.3.10 *Optional data length (ODL).* This field shall contain the length in bytes of the following OD field.

5.2.5.3.3.11 *Optional data (OD).* This variable length field shall contain optional data.

5.2.5.3.4 *MODE S CLEAR CONFIRMATIONBY ADLP*

5.2.5.3.4.1 *Packet format*. The format for this packet shall be as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	TC:2	SN:6	CH:4	AM:4	AG:8

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1 and

5.2.5.2.5. This packet shall be processed as specified in 5.2.6.3.

5.2.5.3.4.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.3.4.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.3.4.4 *Supervisory packet (SP).* This field shall be set to 1.

5.2.5.3.4.5 *Channel number (CH):* If a channel number has been allocated during the call acceptance phase, then CH shall be set to that value, otherwise it shall be set to zero.

5.2.5.3.4.6 *Temporary channel (TC):* If a channel number has been allocated during the call acceptance phase, then TC shall be set to zero, otherwise it shall be set to the value used in the CALL REQUEST by GDLP.

5.2.5.3.4.7 *Supervisory type (ST).* This field shall be set to 3.

5.2.5.3.5 *MODE S CLEAR CONFIRMATIONBY GDLP*

5.2.5.3.5.1 *Packet format*. The format for this packet shall be as follows:

DP:1	MP:1	SP:2	ST:2	FILL:2	TC:2	SN:6	CH:4	AM:4	AG:8

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1 and

5.2.5.2.6. This packet shall be processed as specified in 5.2.6.3.

5.2.5.3.5.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.3.5.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.3.5.4 *Supervisory packet (SP).* This field shall be set to 1.

5.2.5.3.5.5 *Channel number (CH):* If a channel number has been allocated during the call acceptance phase, then CH shall be set to that value, otherwise it shall be set to zero.

5.2.5.3.5.6 *Temporary channel (TC):* If a channel number has been allocated during the call acceptance phase, then TC shall be set to zero, otherwise it shall be set to the value used in the CALL REQUEST by GDLP.

5.2.5.3.5.7 *Supervisory type (ST).* This field shall be set to 3.

5.2.5.3.6 *MODE S RESET CONFIRMATION*

5.2.5.3.6.1 *Packet format.* The format for this packet shall be as follows:

DP:1	MP:1	SP:2	ST:2	FILL2:0 or 2	FILL:2	SN:6	CH:4	FILL:4

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1. This packet shall be processed asspecified in Table 5-14.

5.2.5.3.6.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.3.6.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.3.6.4 *Supervisory packet (SP).* This field shall be set to 2.

5.2.5.3.6.5 *Supervisory type (ST).* This field shall be set to 3.

5.2.5.3.7 *MODE S REJECT*

5.2.5.3.7.1 *Packet format*. The format for this packet shall be as follows:

DP:1	MP:1	SP:2	ST:2	SS:2	FILL2:0 or 2	SN:6	CH:4	PR:4

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1. This packet shall be processed as specified in 5.2.6.8.

5.2.5.3.7.2 *Data packet type (DP).* This field shall be set to 0.

5.2.5.3.7.3 *MSP packet type (MP).* This field shall be set to 1.

5.2.5.3.7.4 *Supervisory packet (SP).* This field shall be set to 3.

5.2.5.3.7.5 *Supervisory type (ST).* This field shall be set to 3.

5.2.5.3.7.6 *Supervisory subset (SS).* This field shall be set to 1.

5.2.5.3.7.7 *Packet receive sequence number (PR*). This field shall be set as specified in 5.2.6.4.4.

5.2.6 XDCE operation

Note.— The ADCE process within the ADLP acts as a peer process to the GDCE process in the GDLP.

5.2.6.1 *State transitions.* The XDCE shall operate as a state machine. Upon entering a state, the XDCE shall perform the actions specified in Table 5-14. State transition and additional action(s) shall be as specified in Table 5-15 through Table 5-22.

Note 1.— The next state transition (if any) that occurs when the XDCE receives a packet from the peer XDCE is specified by Table 5-15 through Table 5-19. The same transitions are defined in Table 5-20 through Table 5-22 when the XDCE receives a packet from the DCE (via the reformatting process).

Note 2.— The XDCE state hierarchy is the same as for the DCE as presented in Figure 5-2, except that states r2,r3 and p5 are omitted.

5.2.6.2 *DISPOSITION OF PACKETS*

5.2.6.2.1 Upon receipt of a packet from the peer XDCE, the packet shall be forwarded or not forwarded to the DCE (via the reformatting process) according to the parenthetical instructions contained in Tables 5-15 to 5-19. If no parenthetical instruction is listed or if the parenthetical instruction indicates "do not forward" the packet shall be discarded.

5.2.6.2.2 Upon receipt of a packet from the DCE (via the reformatting process), the packet shall be forwarded or not forwarded to the peer XDCE according to the parenthetical instructions contained in Tables 5-20 to 5-22. If no parenthetical instruction is listed or if the parenthetical instruction indicates "do not forward" the packet shall be discarded.

5.2.6.3 SVCCALL SETUP AND CLEAR PROCEDURE

5.2.6.3.1 *Setup procedures*. Upon receipt of a CALL REQUEST from the DCE or peer XDCE, the XDLP shall determine if sufficient resources exist to operate the SVC. This shall include: sufficient buffer space (refer to 5.2.5.1.1 forbuffer requirements) and an available p1 state SVC. Upon acceptance of the CALL REQUEST from the DCE (via the reformatting process), the Mode S CALL REQUEST packet shall be forwarded to frame processing. Upon acceptance of a Mode S CALL REQUEST from the peer XDCE (via frame processing), the Mode S CALL REQUEST shall be sent to the reformatting process.

5.2.6.3.2 *Aborting a call request.* If the DTE and/or the peer XDCE abort a call before they have received a CALL ACCEPT packet, they shall indicate this condition by issuing a CLEAR REQUEST packet. Procedures for handling these cases shall be as specified in Table 5-16 and Table 5-20.

5.2.6.3.3 *VIRTUAL CALL CLEARING*

5.2.6.3.3.1 If the XDCE receives a Mode S CALL REQUEST from the reformatting process that it cannot support, it shall initiate a Mode S CLEAR REQUEST packet that is sent to the DCE (via the reformatting process) for transfer to the DTE (the DCE thus enters the DCE CLEAR REQUEST to DTE state, p7).

5.2.6.3.3.2 If the XDCE receives a Mode S CALL REQUEST packet from the peer XDCE (via frame processing) which it cannot support, it shall enter the state p7.

5.2.6.3.3.3 A means shall be provided to advise the DTE whether an SVC has been cleared due to the action of the peer DTE or due to a problem within the subnetwork itself.

5.2.6.3.3.4 **Recommendation**.— *The requirement of 5.2.6.3.3.3 should be satisfied by setting bit 8 of the cause field to 1 to indicate that the problem originated in the Mode S subnetwork and not in the DTE. The diagnostic and cause codes should be set as follows:*

a) no channel number available, DC = 71, CC = 133;

b) buffer space not available, DC = 71, CC = 133;

c) DTE not operational, DC = 162, CC = 141; and

d) link failure, DC = 225, CC = 137.

5.2.6.3.3.5 If the ADLP receives a Mode S ROUTE packet with the IN bit set to ONE, the ADLP shall perform local initialization by clearing Mode S SVCs associated with the DTE addresses contained in the ROUTE packet. If the GDLP receives a search request (Table 5-23) from an ADLP, the GDLP shall perform local initialization by clearing Mode S SVCs associated with that ADLP. Local initialization shall be accomplished by:

a) releasing all allocated resources associated with these SVCs (including the resequencing buffers);

b) returning these SVCs to the ADCE ready state (p1); and

c) sending Mode S CLEAR REQUEST packets for these SVCs to the DCE (via the reformatting process) for transfer to the DTE.

Note.— This action will allow all ISO 8208 SVCs attached to the Mode S SVCs to be cleared and return to their ready states (p1).

5.2.6.3.4 *Clear confirmation*. When the XDCE receives a Mode S CLEAR CONFIRMATION packet, the remaining allocated resources to manage the SVC shall be released (including the resequencing buffers) and the SVC shall be returned to the p1 state. Mode S CLEAR CONFIRMATION packets shall not be transferred to the reformatting process.

5.2.6.3.5 *Clear collision*. A clear collision occurs at the XDCE when it receives a Mode S CLEAR REQUEST packet from the DCE (via the reformatting process) and then receives a Mode S CLEAR REQUEST packet from the peer XDCE (or vice versa). In this event, the XDCE does not expect to receive a Mode S CLEAR CONFIRMATION packet for this SVC and shall consider the clearing complete.

5.2.6.3.6 *Packet processing.* The XDCE shall treat an S-bit sequence of Mode S CALL REQUEST, CALL ACCEPT and CLEAR REQUEST packets as a single entity.

5.2.6.4 DATA TRANSFER AND INTERRUPT PROCEDURES

5.2.6.4.1 *GENERAL PROVISIONS*

5.2.6.4.1.1 Data transfer and interrupt procedures shall apply independently to each SVC. The contents of the user data field shall be passed transparently to the DCE or to the peer XDCE. Data shall be transferred in the order dictated by the sequence numbers assigned to the data packets.

5.2.6.4.1.2 To transfer DATA packets, the SVC shall be in a FLOW CONTROL READY state (d1).

5.2.6.4.2 *MODE SPACKET SIZE*

5.2.6.4.2.1 The maximum size of Mode S packets shall be 152 bytes in the uplink direction and 160 bytes in the downlink direction for installations that have full uplink and downlink ELM capability. The maximum downlink packet size for level four transponders with less than 16 segment downlink ELM capability shall be 10 bytes times the maximum number of downlink ELM segments that the transponder specifies in its data link capability report. If there is no ELM capability, the maximum Mode S packet size shall be 28 bytes.

5.2.6.4.2.2 The Mode S subnetwork shall allow packets of less than the maximum size to be transferred.

5.2.6.4.3 *FLOW CONTROL WINDOW SIZE*

5.2.6.4.3.1 The flow control window size of the Mode S subnetwork shall be independent of that used on the DTE/DCE interface. The Mode S subnetwork window size shall be 15 packets in the uplink and downlink directions.

5.2.6.4.4 *SVCFLOW CONTROL*

5.2.6.4.4.1 Flow control shall be managed by means of a sequence number for received packets (PR) and one for packets that have been sent (PS). A sequence number (PS) shall be assigned for each Mode S DATA packet generated by the XDLP for each SVC. The first Mode S DATA packet transferred by the XDCE to frame processing when the SVC has just entered the flow control ready state shall be numbered zero. The first Mode S packet received from the peer XDCE after an SVC has just entered the flow control ready state shall be numbered zero. Subsequent packets shall be numbered consecutively.

5.2.6.4.4.2 A source of Mode S DATA packets (the ADCE or GDCE) shall not send (without permission from the receiver) more Mode S DATA packets than would fill the flow control window. The receiver shall give explicit permission to send more packets.

5.2.6.4.4.3 The permission information shall be in the form of the next expected packet sequence number and shall be denoted PR. If a receiver wishes to update the window and it has data to transmit to the sender, a Mode S DATA packet shall be used for information transfer. If the window must be updated and no data are to be sent, a Mode S RECEIVE READY (RR) or Mode S RECEIVE NOT READY (RNR) packet shall be sent. At this point, the “sliding window” shall be moved to begin at the new PR value. The XDCE shall now be authorized to transfer more packets without acknowledgement up to the window limit.

5.2.6.4.4.4 When the sequence number (PS) of the next Mode S DATA packet to be sent is in the range PR ≤PS ≤PR + 14 (modulo 16), the sequence number shall be defined to be “in the window” and the XDCE shall be authorized to transmit the packet.

Otherwise, the sequence number (PS) of the packet shall be defined to be "outside the window" and the XDCE shall not transmit the packet to the peer XDCE.

5.2.6.4.4.5 When the sequence number (PS) of the packet received is next in sequence and within the window, the XDCE shall accept this packet. Receipt of a packet with a PS:

a) outside the window; or

b) out of sequence; or

c) not equal to 0 for the first data packet after entering FLOW CONTROL READY state (d1);

shall be considered an error (5.2.6.8).

5.2.6.4.4.6 The receipt of a Mode S DATA packet with a valid PS number (i.e. the next PS insequence) shall cause the lower window PR to be changed to that PS value plus 1. The packet receive sequence number (PR) shall be conveyed to the originating XDLP by a Mode S DATA, RECEIVE READY, RECEIVE NOT READY, or REJECT packet. A valid PR value shall be transmitted by the XDCE to the peer XDCE after the receipt of 8 packets provided that sufficient buffer space exists to store 15 packets. Incrementing the PR and PS fields shall be performed using modulo 16 arithmetic.

Note.— The loss of a packet which contains the PR value may cause the ADLP/GDLP operations for that SVC to cease.

5.2.6.4.4.7 A copy of a packet shall be retained until the user data has been successfully transferred. Following successful transfer, the PS value shall be updated.

5.2.6.4.4.8 The PR value for user data shall be updated as soon as the required buffer space for the window (as determined by flow control management) is available within the DCE.

5.2.6.4.4.9 Flow control management shall be provided between the DCE and XDCE.

5.2.6.4.5 INTERRUPT PROCEDURES FOR SWITCHED VIRTUAL CIRCUITS

5.2.6.4.5.1 If user data is to be sent via the Mode S subnetwork without following the flow control procedures, the interrupt procedures shall be used. The interrupt procedure shall have no effect on the normal data packet and flow control procedures. An interrupt packet shall be delivered to the DTE (or the transponder or interrogator interface) at or before the point in the stream of data at which the interrupt was generated. The processing of a Mode S INTERRUPT packet shall occur as soon as it is received by the XDCE.

Note.— The use of clear, reset, and restart procedures can cause interrupt data to be lost.

5.2.6.4.5.2 The XDCE shall treat an S-bit sequence of Mode S INTERRUPT packets as a single entity.

5.2.6.4.5.3 Interrupt processing shall have precedence over any other processing for the SVC occurring at the time of the interrupt.

5.2.6.4.5.4 The reception of a Mode S INTERRUPT packet before the previous interrupt of the SVC has been confirmed (by the receipt of a Mode S INTERRUPT CONFIRMATION packet) shall be defined as an error. The error results in a reset (see Table 5-18).

5.2.6.5 RECEIVE READY PROCEDURE

5.2.6.5.1 The Mode S RECEIVE READY packet shall be sent if no Mode S DATA packets (that normally contain the updated PR value) are available for transmittal and it is necessary to transfer the latest PR value. It also shall be sent to terminate a receiver not ready condition.

5.2.6.5.2 Receipt of the Mode S RECEIVE READY packet by the XDCE shall cause the XDCE to update its value of PR for the outgoing SVC. It shall not be taken as a demand for retransmission of packets that have already been transmitted and are still in the window.

5.2.6.5.3 Upon receipt of the Mode S RECEIVE READY packet, the XDCE shall go into the ADLP(GDLP) RECEIVE READY state (g1).

5.2.6.6 RECEIVE NOT READY PROCEDURE

5.2.6.6.1 The Mode S RECEIVE NOT READY packet shall be used to indicate a temporary inability to accept additional DATA packets for the given SVC. The Mode S RNR condition shall be cleared by the receipt of a Mode S RR packet or a Mode S REJECT packet.

5.2.6.6.2 When the XDCE receives a Mode S RECEIVE NOT READY packet from the peer XDCE, it shall update its value of PR for the SVC and stop transmitting Mode S

DATA packets on the SVC to the XDLP. The XDCE shall go into the ADLP(GDLP) RECEIVE NOT READY state (g2).

5.2.6.6.3 The XDCE shall transmit a Mode S RECEIVE NOT READY packet to the peer XDCE if it is unable to receive from the peer XDCE any more Mode S DATA packets on the indicated SVC. Under these conditions, the XDCE shall go into the ADCE(GDCE) RECEIVE NOT READY state (f2).

5.2.6.7 RESET PROCEDURE

5.2.6.7.1 When the XDCE receives a Mode S RESET REQUEST packet from either the peer XDCE or the DCE (via the reformatting process) or due to an error condition performs its own reset, the following actions shall be taken:

a) those Mode S DATA packets that have been transmitted to the peer XDCE shall be removed from the window;

b) those Mode S DATA packets that are not transmitted to the peer XDCE but are contained in an M-bit sequence for which some packets have been transmitted shall be deleted from the queue of DATA packets awaiting transmission;

c) those Mode S DATA packets received from the peer XDCE that are part of an incomplete M-bit sequence shall be

discarded;

d) the lower window edge shall be set to 0 and the next packet sent shall have a sequence number (PS) of 0;

e) any outstanding Mode S INTERRUPT packets to or from the peer XDCE shall be left unconfirmed;

f) any Mode S INTERRUPT packet awaiting transfer shall be discarded;

g) data packets awaiting transfer shall not be discarded (unless they are part of a partially transferred M-bit sequence);

and

h) the transition to d1 shall also include a transition to i1, j1, f 1 and g1.

5.2.6.7.2 The reset procedure shall apply to the DATA TRANSFER state (p4). The error procedure in Table 5-16 shall be followed. In any other state the reset procedure shall be abandoned.

5.2.6.8 REJECT PROCEDURE

5.2.6.8.1 When the XDCE receives a Mode S DATA packet from the peer XDCE with incorrect format or whose packet sequence number (PS) is not within the defined window (Table 5-19) or is out of sequence, it shall discard the received packet and send a Mode S REJECT packet to the peer XDCE via frame processing. The Mode S REJECT packet shall indicate a value of PR for which retransmission of the Mode S DATA packets is to begin. The XDCE shall discard subsequent out-of-sequence Mode S DATA packets whose receipt occurs while the Mode S REJECT packet response is still outstanding.

5.2.6.8.2 When the XDCE receives a Mode S REJECT packet from the peer XDCE, it shall update its lower window value with the new value of PR and begin to (re)transmit packets with a sequence number of PR.

5.2.6.8.3 Reject indications shall not be transferred to the DCE. If the ISO 8208 interface supports the reject procedures, the reject indications occurring on the ISO 8208 interface shall not be transferred between the DCE and the XDCE.

5.2.6.9 PACKET RESEQUENCING AND DUPLICATE SUPPRESSION

Note 1.— If the frames for an SVC include both types (SLM and ELM), the sequence of packets may be lost due to the different delivery times. The order may also be lost if multiple interrogators are used to deliver frames for the same SVC to agiven XDLP. The following procedure will correct for a limited amount of desequencing.

Note 2.— This process serves as an interface between frame processing and the XDCE function.

5.2.6.9.1 *Resequencing*. Resequencing shall be performed independently for the uplink and downlink transfers of each Mode S SVC. The following variables and parameters shall be used: SNRA 6-bit variable indicating the sequence number of a received packet on a specific SVC. It is contained in the SN field of the packet (5.2.5.2.1.1.7).

NESN The next expected sequence number following a series of consecutive sequence numbers.

HSNR The highest value of SNR in the resequencing window.

Tq Resequencing timers (see Tables 5-1 and 5-13) associated with a specific SVC.

All operations involving the sequence number (SN) shall be performed modulo 64.

5.2.6.9.2 *Duplication window*. The range of SNR values between NESN– 32 and NESN –1 inclusive shall be denoted the duplication window.

5.2.6.9.3 *Resequencing window*. The range of SNR values between NESN+ 1 and NESN+ 31 inclusive shall be denoted the resequencing window. Received packets with a sequence number value in this range shall be stored in the resequencing window in sequence number order.

5.2.6.9.4 *TRANSMISSION FUNCTIONS*

5.2.6.9.4.1 For each SVC, the first packet sent to establish a connection (the first Mode S CALL REQUEST or first Mode S CALL ACCEPT packet) shall cause the value of the SN field to be initialized to zero. The value of the SN field shall be incremented after the transmission (or retransmission) of each packet.

5.2.6.9.4.2 The maximum number of unacknowledged sequence numbers shall be 32 consecutive SN numbers. Should this condition be reached, then it shall be treated as an error and the channel cleared.

Note.— A limit on the number of unacknowledged packets is required since the SN field is six bits long and therefore has a maximum of 64 different values before the values repeat.

5.2.6.9.5 *RECEIVE FUNCTIONS*

5.2.6.9.5.1 *Resequencing*. The resequencing algorithm shall maintain the variables HSNR and NESN for each SVC.

NESN shall be initialized to 0 for all SVCs and shall be reset to 0 when the SVC re-enters the channel number pool (5.2.5.1.2).

5.2.6.9.5.2 *Processing of packets within the duplication window*. If a packet is received with a sequence number value within the duplication window, the packet shall be discarded.

5.2.6.9.5.3 *Processing of packets within the resequencing window.* If a packet is received with a sequence number within the resequencing window, it shall be discarded as a duplicate if a packet with the same sequence number has already been received and stored in the resequencing window. Otherwise, the packet shall be stored in the resequencing window. Then, if no Tq timers are running, HSNR shall be set to the value of SNR for this packet and a Tq timer shall be started with its initial value (Tables 5-1 and 5-13). If at least one Tq timer is running, and SNR is not in the window between NESN and HSNR+ 1 inclusive, a new Tq timer shall be started and the value of HSNR shall be updated. If at least one Tq timer is running, and SNR for this packet is equal to HSNR+ 1, the value of HSNR shall be updated.

5.2.6.9.5.4 *Release of packets to the XDCE*. If a packet is received with a sequence number equal to NESN, the following procedure shall be applied:

a) the packet and any packets already stored in the resequencing window up to the next missing sequence number shall be passed to the XDCE;

b) NESNshall be set to 1 + the value of the sequence number of the last packet passed to the XDCE; and

c) the Tqtimer associated with any of the released packets shall be stopped.

5.2.6.9.6 *Tq timer expiration*. If a Tq timer expires, the following procedure shall be applied:

a) NESN shall be incremented until the next missing sequence number is detected after that of the packet associated with the Tq timer that has expired;

b) any stored packets with sequence numbers that are no longer in the resequencing window shall be forwarded to the XDCE except that an incomplete S-bit sequence shall be discarded; and

c) the Tq timer associated with any released packets shall be stopped.

5.2.7 Mode S specific services processing

Mode S specific services shall be processed by an entity in the XDLP termed the Mode S specific services entity (SSE).

Transponder registers shall be used to convey the information specified in Table 5-24. The data structuring of the registers in Table 5-24 shall be implemented in such a way that interoperability is ensured.

Note 1.— The data formats and protocols for messages transferred via Mode S specific services are specified in the Technical Provisions for Mode S Services and Extended Squitter(Doc 9871) (in preparation).

Note 2.— Uniform implementation of the data formats and protocols for messages transferred via Mode S specific services will ensure interoperability.

Note 3.— This section describes the processing of control and message data received from the Mode S specific services interface.

Note 4.— Control data consists of information permitting the determination of, for example, message length, BDS code used to access the data format for a particular register, and aircraft address.

5.2.7.1 ADLP PROCESSING

5.2.7.1.1 *DOWNLINK PROCESSING*

5.2.7.1.1.1 *Specific services capability*. The ADLP shall be capable of receiving control and message data from the Mode S specific services interface(s) and sending delivery notices to this interface. The control data shall be processed to determine the protocol type and the length of the message data. When the message or control data provided at this interface are erroneous (i.e. incomplete, invalid or inconsistent), the ADLP shall discard the message and deliver an error report at theinterface.

Note.— The diagnostic content and error reporting mechanism are a local issue.

5.2.7.1.1.2 *Broadcast processing.* The control and message data shall be used to format the Comm-B broadcast message as specified in 5.2.7.5 and transferred to the transponder.

5.2.7.1.1.3 *GICB processing.* The 8-bit BDS code shall be determined from the control data. The 7-byte register content shall be extracted from the received message data. The register content shall be transferred to the transponder, along with an indication of the specified register number. A request to address one of the air-initiated Comm-B registers or the airborne collision avoidance system (ACAS) active resolution advisories register shall be discarded. The assignment of registers shall be as specified in Table 5-24.

Note.— Provision of the data available in transponder registers 40, 50 and 60 {HEX} has been mandated in some ICAO Regions in support of ATM applications.

5.2.7.1.1.4 *MSP processing*

5.2.7.1.1.4.1 The MSP message length, channel number (M/CH) (5.2.7.3.1.3) and optionally the interrogator identifier (II) code shall be determined from the control data. The MSP message content shall be extracted from the received message data. If the message length is 26 bytes or less, the SSE shall format an air-initiated Comm-B message (5.2.7.1.1.4.2) for transfer to the transponder using the short form MSP packet (5.2.7.3.1). If the message length is 27 to 159 bytes and the transponder has adequate downlink ELM capability, the SSE shall format an ELM message for transfer using the short form MSP packet. If the message length is 27 to 159 bytes and the transponder has a limited downlink ELM capability, the SSE shall format multiple long form MSP packets (5.2.7.3.2) using ELM messages, as required utilizing the L-bit and M/SN fields for association of the packets. If the message length is 27 to 159 bytes and the transponder does not have downlink ELM capability, the SSE shall format multiple long form MSP packets (5.2.7.3.2) using air initiated Comm-B messages, as required utilizing the L-bit and M/SN fields for association of the packets. Different frame types shall never be used in the delivery of an MSP message. Messages longer than 159 bytes shall be discarded. The assignment of downlink MSP channel numbers shall be as specified in Table 5-25.

5.2.7.1.1.4.2 For an MSP, a request to send a packet shall cause the packet to be multisite-directed to the interrogator which II code is specified in control data. If no II code is specified, the packet shall be downlinked using the air-initiated protocol. A message delivery notice for this packet shall be provided to the Mode S specific interface when the corresponding close-out(s) have been received from the transponder. If a close-out has not been received from the transponder in Tz seconds, as specified in Table 5-1, the MSP packet shall be discarded. This shall include the cancellation in the transponder of any frames associated with this packet. A delivery failure notice for this message shall be provided to the Mode S specific services interface.

5.2.7.1.2 *UPLINK PROCESSING*

Note.— This section describes the processing of Mode S specific services messages received from the transponder.

5.2.7.1.2.1 *Specific services capability.* The ADLP shall be capable of receiving Mode S specific services messages from the transponder via frame processing. The ADLP shall be capable of delivering the messages and the associated control data at the specific services interface. When the resources allocated at this interface are insufficient to accommodate the output data, the ADLP shall discard the message and deliver an error report at this interface.

Note.— The diagnostic content and the error reporting mechanism are a local issue.

5.2.7.1.2.2 *Broadcast processing*. If the received message is a broadcast Comm-A, as indicated by control data received over the transponder/ADLP interface, the broadcast ID and user data (5.2.7.5) shall be forwarded to the Mode S specific services interface (5.2.3.2.1) along with the control data that identifies this as a broadcast message. The assignment of uplink broadcast identifier numbers shall be as specified in Table 5-23.

5.2.7.1.2.3 *MSP processing.* If the received message is an MSP, as indicated by the packet format header (5.2.7.3), the user data field of the received MSP packet shall be forwarded to the Mode S specific services interface (5.2.3.2.1) together with the MSP channel number (M/CH), the IIS subfield (5.2.2.1.1.1) together with control data that identifies this as an MSP message. L-bit processing shall be performed as specified in 5.2.7.4. The assignment of uplink MSP channel numbers shall be as specified in Table 5-25.

5.2.7.2 GDLP PROCESSING

5.2.7.2.1 *UPLINK PROCESSING*

5.2.7.2.1.1 *Specific services capability*. The GDLP shall be capable of receiving control and message data from the Mode S specific services interface(s) (5.2.3.2.2) and sending delivery notices to the interface(s). The control data shall be processed to determine the protocol type and the length of the message data.

5.2.7.2.1.2 *Broadcast processing.* The GDLP shall determine the interrogator(s), broadcast azimuths and scan times from the control data and format the broadcast message for transfer to the interrogator(s) as specified in 5.2.7.5.

5.2.7.2.1.3 *GICB processing*. The GDLP shall determine the register numberand the aircraft address from the control data. The aircraft address and BDS code shall be passed to the interrogator as a request for a ground-initiated Comm-B.

5.2.7.2.1.4 *MSP processing*. The GDLP shall extract from the control data the message length, the MSP channel number (M/CH) and the aircraft address, and obtain the message content from the message data. If the message length is 27 bytes or less, the SSE shall format a Comm-A message for transfer to the interrogator using the short form MSP packet (5.2.7.3.1). If the message length is 28 to 151 bytes and the transponder has uplink ELM capability, the SSE shall format an ELM message for transfer to the interrogator using the short form MSP packet. If the message length is 28 to 151 bytes and the transponder does not have uplink ELM capability, the SSE shall format multiple long form MSP packets (5.2.7.3.2) utilizing the L-bit and the M/SN fields for association of the packets. Messages longer than 151 bytes shall be discarded. The interrogator shall provide a delivery notice to the Mode S specific services interface(s) indicating successful or unsuccessfuldelivery, for each uplinked packet.

5.2.7.2.2 *DOWNLINK PROCESSING*

5.2.7.2.2.1 *Specific services capability*. The GDLP shall be capable of receiving Mode S specific services messages from the interrogator via frame processing.

5.2.7.2.2.2 *Broadcast processing*. If the received message is a broadcast Comm-B, as indicated by the interrogator/GDLP interface, the GDLP shall:

a) generate control data indicating the presence of a broadcast message and the 24-bit address of the aircraft from which the message was received;

b) append the 7-byte MB field of the broadcast Comm-B; and

c) forward this data to the Mode S specific services interface(s) (5.2.3.2.2).

5.2.7.2.2.3 *GICB processing*. If the received message is a GICB, as indicated by the interrogator/GDLP interface, the GDLP shall:

a) generate control data indicating the presence of a GICB message, the register number and the 24-bit address of the aircraft from which the message was received;

b) append the 7-byte MB field of the GICB; and

c) forward this data to the Mode S specific services interface(s) (5.2.3.2.2).

5.2.7.2.2.4 *MSP processing*. If the received message is an MSP as indicated by the packet format header (5.2.7.3), the GDLP shall:

a) generate control data indicating the transfer of an MSP, the length of the message, the MSP channel number (M/CH) and the 24-bit address of the aircraft from which the message was received;

b) append the user data field of the received MSP packet; and

c) forward this data to the Mode S specific services interface(s) (5.2.3.2.2).

L-bit processing shall be performed as specified in 5.2.7.4.

5.2.7.3 MSPPACKET FORMATS

5.2.7.3.1 *Short form MSP packet.* The format for this packet shall be as follows:

DP:1	MP:1	M/CH:6	FILL1:0 or 6	UD:v

5.2.7.3.1.1 *Data packet type (DP).* This field shall be set to 0.

5.2.7.3.1.2 *MSP packet type (MP).* This field shall be set to 0.

5.2.7.3.1.3 *MSP channel number (M/CH).* The field shall be set to the channel number derived from the SSE control data.

5.2.7.3.1.4 *Fill field (FILL1:0 or 6).* The fill length shall be 6 bits for a downlink SLM frame. Otherwise the fill length shall be 0.

5.2.7.3.1.5 *User data (UD).* The user data field shall contain message data received from the Mode S specific services interface (5.2.3.2.2).

5.2.7.3.2 *Long form MSP packet.* The format for this packet shall be as follows:

DP:1	MP:1	SP:2	L:1	M/SN:3	FILL2:0 or 2	M/CH:6	UD:v

Fields shown in the packet format and not specified in the following paragraphs shall be set as specified in 5.2.5.2.1 and 5.2.7.3.1.

5.2.7.3.3 *Data packet type (DP).* This field shall be set to 0.

5.2.7.3.3.1 *MSP packet type (MP).* This field shall be set to 1.

5.2.7.3.3.2 *Supervisory packet (SP).* This field shall be set to 0.

5.2.7.3.3.3 L field (L).A value of 1 shall indicate that the packet is part of an L-bit sequence with more packets in the sequence to follow. A value of 0 shall indicate that the sequence ends with this packet.

5.2.7.3.3.4 *MSP sequence number field (M/SN).* This field shall be used to detect duplication in the delivery of L-bit sequences. The first packet in an L-bit sequence shall be assigned a sequence number of 0. Subsequent packets shall be numbered sequentially. A packet received with the same sequence number as the previously received packet shall be discarded.

5.2.7.4 *L-bit processing*. L-bit processing shall be performed only on the long form MSP packet and shall be performed as specified for M-bit processing (5.2.5.1.4.1) except as specified in the following paragraphs.

5.2.7.4.1 Upon receipt of a long form MSP packet, the XDLP shall construct the user data field by:

a) verifying that the packet order is correct using the M/SN field (5.2.7.3.2);

b) assuming that the user data field in the MSP packet is the largest number of integral bytes that is contained within the frame;

c) associating each user data field in an MSP packet received with a previous user data field in an MSP packet that has an L-bit value of 1; and

Note.— Truncation of the user data field is not permitted as this is treated as an error condition.

d) if an error is detected in the processing of an MSP packet, the packet shall be discarded.

5.2.7.4.2 In the processing of an L-bit sequence, the XDLP shall discard any MSP packets that have duplicate M/SN values. The XDLP shall discard the entire L-bit sequence if a long form MSP packet is determined to be missing by use of the M/SN field.

5.2.7.4.3 The packets associated with any L-bit sequence whose reassembly is not completed in Tm seconds (Tables 5-1 and 5-13) shall be discarded.

5.2.7.5 BROADCAST FORMAT

5.2.7.5.1 *Uplink broadcast*. The format of the broadcast Comm-A shall be as follows: The 83-bit uplink broadcast shall be inserted in an uplink Comm-A frame. The MA field of the Comm-A frame shall contain the broadcast identifier specified in Table 5-23 in the first 8 bits, followed by the first 48 user data bits of the broadcast message. The last 27 user data bits of the broadcast message shall be placed in the 27 bits immediately following the UF field of the Comm-A frame.

5.2.7.5.2 *Downlink broadcast.* The format of broadcast Comm-B shall be as follows: The 56-bit downlink broadcast message shall be inserted in the MB field of the broadcast Comm-B. The MB field shall contain the broadcast identifier specified in Table 5-23 in the first 8 bits, followed by the 48 user data bits.

5.2.8 Mode S subnetwork management

5.2.8.1 INTERROGATOR LINK DETERMINATION FUNCTION

Note.— The ADLP interrogator link determination function selects the II code of the Mode S interrogator through which a Mode S subnetwork packet may be routed to the desired destination ground DTE.

5.2.8.1.1 *II code-DTE address correlation*. The ADLP shall construct and manage a Mode S interrogator-data terminal equipment (DTE) cross-reference table whose entries are Mode S interrogator identifier (II) codes and ground DTE addresses associated with the ground ATN routers or other ground DTEs. Each entry of the II code-DTE cross-reference table shall consist of the 4-bit Mode S II code and the 8-bit binary representation of the ground DTE.

Note 1.— Due to the requirement for non-ambiguous addresses, a DTE address also uniquely identifies a GDLP.

Note 2.— An ATN router may have more than one ground DTE address.

5.2.8.1.2 *Protocol.* The following procedures shall be used:

a) when the GDLP initially detects the presence of an aircraft, or detects contact with a currently acquired aircraft through an interrogator with a new II code, the appropriate fields of the DATA LINK CAPABILITY report shall be examined to determine if, and to what level, the aircraft has the capability to participate in a data exchange. After positive determination of data link capability, the GDLP shall uplink one or more Mode S ROUTE packets as specified in 5.2.5.3.3. This information shall relate the Mode S II code with the ground DTE addresses accessible through that interrogator. The ADLP shall update the II code-DTE cross-reference table and then discard the Mode S ROUTE packet(s);

b) a II code-DTE cross-reference table entry shall be deleted when commanded by a Mode S ROUTE packet or when the ADLP recognizes that the transponder has not been selectively interrogated by a Mode S interrogator with a given II code for Ts seconds by monitoring the IIS subfield in Mode S surveillance or Comm-A interrogations (Table 5-1);

c) when the GDLP determines that modification is required to the Mode S interrogator assignment, it shall transfer one or more Mode S ROUTE packets to the ADLP. The update information contained in the Mode S ROUTE packet shall be used by the ADLP to modify its cross-reference table. Additions shall be processed before deletions;

d) when the GDLP sends the initial ROUTE packet after acquisition of a Mode S data link-equipped aircraft, the IN bit shall be set to ONE. This value shall cause the ADLP to perform the procedures as specified in 5.2.6.3.3.3. Otherwise, the IN bit shall be set to ZERO;

e) when the ADLP is initialized (e.g. after a power-up procedure), the ADLP shall issue a search request by sending a broadcast Comm-B message with broadcast identifier equal to 255 (FF16, as specified in Table 5-23) and the remaining 6 bytes unused. On receipt of a search request, a GDLP shall respond with one or more Mode S ROUTE packets, clear all SVCs associated with the ADLP,as specified in 5.2.6.3.3, and discard the search request. This shall cause the ADLP to initialize the II code-DTE cross-reference table; and

f) on receipt of an update request (Table 5-23), a GDLP shall respond with one or more Mode S ROUTE packets and discard the update request. This shall cause the ADLP to update the II code-DTE cross-reference table.

Note.— The update request may be used by the ADLP under exceptional circumstances (e.g. changeover to standby unit) to verify the contents of its II codeDTE cross -reference table.

5.2.8.1.3 *PROCEDURES FOR DOWNLINKING MODE SPACKETS*

5.2.8.1.3.1 When the ADLP has a packet to downlink, the following procedures shall apply:

a) *CALL REQUEST packet.* If the packet to be transferred is a Mode S CALL REQUEST, the ground DTE address field shall be examined and shall be associated with a connected Mode S interrogator using the II code-DTE cross-reference table. The packet shall be downlinked using the multisite-directed protocol. A request to transfer a packet to a DTE address not in the cross-reference table shall result in the action specified in 5.2.6.3.3.1.

b) *Other SVC packets*. For an SVC, a request to send a packet to a ground DTE shall cause the packet to be multisite-directed to the last Mode S interrogator used to successfully transfer (uplink or downlink) a packet to that DTE, provided that this Mode S interrogator is currently in the II code-DTE cross-reference table. Otherwise, an SVC packet shall be downlinked using the multisite-directed protocol to any other Mode S interrogator associated with the specified ground DTE address. Level 5 transponders shall be permitted to use additional interrogators for downlink transfer as indicated in the II code-DTE cross-reference table.

5.2.8.1.3.2 A downlink frame transfer shall be defined to be successful if its Comm-B or ELM close-out is received from the transponder within Tz seconds as specified in Table

5-1. If the attempt is not successful and an SVC packet is to be sent, the II code-DTE cross-reference table shall be examined for another entry with the same called ground DTE address and a different Mode S II code. The procedure shall be retried using the multisite-directed protocol with the new Mode S interrogator. If there are no entries for the required called DTE, or all entries result in a failed attempt, a link failure shall be declared (5.2.8.3.1).

5.2.8.2 SUPPORT FOR THE DTE(S)

5.2.8.2.1 *GDLP connectivity reporting.* The GDLP shall notify the ground DTE(s) of the availability of a Mode S data link-equipped aircraft ("join event"). The GDLP shall also inform the ground DTEs when such an aircraft is no longer in contact via that GDLP ("leave event"). The GDLP shall provide for notification (on request) of all Mode S data link equipped aircraft currently in contact with that GDLP. The notifications shall provide the ground ATN router with the subnetwork point of attachment (SNPA) address of the mobile ATN router, with the position of the aircraft and quality of service as optional parameters. The SNPA of the mobile ATN router shall be the DTE address formed by the aircraft address and a sub-address of 0 (5.2.3.1.3.2).

5.2.8.2.2 *ADLP connectivity reporting*. The ADLP shall notify all aircraft DTEs whenever the last remaining entry for a ground DTE is deleted from the II code-DTE cross-reference table (5.2.8.1.1). This notification shall include the address of this DTE.

5.2.8.2.3 *Communications requirements*. The mechanism for communication of changes in subnetwork connectivity shall be a confirmed service, such as the join/leave events that allow notification of the connectivity status.

5.2.8.3 ERROR PROCEDURES

5.2.8.3.1 *Link failure*. The failure to deliver a packet to the referenced XDLP after an attempt has been made to deliver this packet via all available interrogators shall be declared to be a link level failure. For an SVC, the XDCE shall enter the state p1 and release all resources associated with that channel. This shall include the cancellation in the transponder of any frames associated with this SVC. A Mode S CLEAR REQUEST packet shall be sent to the DCE via the reformatting process and shall be forwarded by the DCE as an ISO 8208 packet to the local DTE as described in 5.2.6.3.3. On the aircraft side, the channel shall not be returned to the ADCE channel pool, i.e. does not return to the state p1, until Tr seconds after the link failure has been declared (Table 5-1).

5.2.8.3.2 *ACTIVE CHANNEL DETERMINATION*

5.2.8.3.2.1 *Procedure for d1 state*. The XDLP shall monitor the activity of all SVCs, not in a READY state (p1). If an SVC is in the (XDCE) FLOW CONTROL READY state (d1) for more than Tx seconds (the active channel timer, Tables 5-1 and 5-13) without sending a Mode S RR, RNR, DATA, or REJECT packet, then:

a) if the last packet sent was a Mode S REJECT packet to which a response has not been received, then the XDLP shall resend that packet;

b) otherwise, the XDLP shall send a Mode S RR or RNR packet as appropriate to the peer XDLP.

5.2.8.3.2.2 *Procedure for other states.* If an XDCE SVC is in the p2, p3, p6, p7, d2 or d3 state for more than Tx seconds, the link failure procedure of 5.2.8.3.1 shall be performed.

5.2.8.3.2.3 Link failure shall be declared if either a failure to deliver, or a failure to receive, keep-alive packets has occurred. In which case the channel shall be cleared.

5.2.9 The data link capability report

The data link capability report shall be as specified in Annex 10, Volume IV, 3.1.2.6.10.2.

5.2.10 System timers

5.2.10.1 The values for timers shall conform to the values given in Tables 5-1 and 5-13.

5.2.10.2 Tolerance for all timers shall be plus or minus one per cent.

5.2.10.3 Resolution for all timers shall be one second.

5.2.11 System requirements

5.2.11.1 *Data integrity*. The maximum bit error rates for data presented at the ADLP/transponder interface or the GDLP/interrogator interface measured at the local DTE/XDLP interface (andvice versa) shall not exceed 10-9 for undetected errors and 10-7for detected errors.

Note.— The maximum error rate includes all errors resulting from data transfers across the interfaces and from XDLP internal operation.

5.2.11.2 TIMING

5.2.11.2.1 *ADLP timing*. ADLP operations shall not take longer than 0.25 seconds for regular traffic and 0.125 seconds for interrupt traffic. This interval shall be defined as follows:

a) *Transponders with downlink ELM capability*. The time that the final bit of a 128-byte data packet is presented to the DCE for downlink transfer to the time that the final bit ofthe first encapsulating frame is available for delivery to the transponder.

b) *Transponders with Comm-B capability.* The time that the final bit of a user data field of 24 bytes is presented to the DCE for downlink transfer to the time that the final bit of the last of the four Comm-B segments that forms the frame encapsulating the user data is available for delivery to the transponder.

c) *Transponders with uplink ELM capability.* The time that the final bit of the last segment of an ELM of 14 Comm-C segments that contains a user data field of 128 bytes is received by the ADLP to the time that the final bit of the corresponding packet is available for delivery to the DTE.

d) Transponders with Comm-A capability.The time that the final bit of the last segment of four linked Comm-A segments that contains a user data field of 25 bytes is received by the ADLP to the time that the final bit of the corresponding packet is available for delivery to the DTE.

5.2.11.2.2 *GDLP TIMING*

Recommendation.— *The total time delay across the GDLP, exclusive of transmission delay, should not be greater than 0.125 seconds.*

5.2.11.3 *Interface rate*. The physical interface between the ADLP and the transponder shall have a minimum bit rate of 100 kilobits per second.

5.3 *DCE AND XDCE STATE TABLES*

5.3.1 State table requirements. The DCE and XDCE shall function as specified in state Tables 5-3 to 5-22. State Tables 5-15 through 5-22 shall be applied to:

a) ADLP state transitions when the XDCE or XDLP terms in parenthesis are omitted; and

b) GDLP state transitions when the terms in parenthesis are used and the XDCE or XDLP preceding them are omitted.

5.3.2 *Diagnostic and cause codes*. The table entries for certain conditions indicate a diagnostic code that shall be included in the packet generated when entering the state indicated. The term, "D= ," shall define the diagnostic code. When "A= DIAG ", the action taken shall be to generate an ISO 8208 DIAGNOSTIC packet and transfer it to the DTE; the diagnostic code indicated shall define the entry in the diagnostic field of the packet. The cause field shall be set as specified in 5.2.6.3.3. The reset cause field shall be set as specified in ISO 8208.

Note 1.— The tables provided below specify state requirements in the following order:

5-3 DCE special cases

5-4 DTE effect on DCE restart states

5-5 DTE effect on DCE call setup and clearing states

5-6 DTE effect on DCE reset states

5-7 DTE effect on DCE interrupt transfer states

5-8 DTE effect on DCE flow control transfer states

5-9 XDCE effect on DCE restart states

5-10 XDCE effect on DCE call setup and clearing states

5-11 XDCE effect on DCE reset states

5-12 XDCE effect on DCE interrupt transfer states

5-15 GDLP (ADLP) effect on ADCE (GDCE) packet layer ready states

5-16 GDLP (ADLP) effect on ADCE (GDCE) call setup and clearing states

5-17 GDLP (ADLP) effect onADCE (GDCE) reset states

5-18 GDLP (ADLP) effect on ADCE (GDCE) interrupt transfer states

5-19 GDLP (ADLP) effect on ADCE (GDCE) flow control transfer states

5-20 DCE effect on ADCE (GDCE)call setup and clearing states

5-21 DCE effect on ADCE (GDCE) reset states

5-22 DCE effect on ADCE (GDCE) interrupt transfer states

Note 2.— All tables specify both ADLP and GDLP actions.

Note 3.— Within the Mode S subnetwork, states p6 and d2 are transient states.

Note 4.— References to "notes" in the state tables refer to table-specific notes that follow each state table.

Note 5.— All diagnostic and cause codes are interpreted as decimal numbers.

Note 6.— An SVC between an ADCE and a GDCE may be identified by a temporary and/or permanent channel number, as defined in 5.2.5.1.2.

5.4 MODE S PACKET FORMATS

5.4.1 *Formats. The Mode S packet formats shall be as specified in Figures 5-3 to 5-22.*

5.4.2 *Significance of control fields. The structure of the format control fields used in Mode S packets shall be as specified in Figure 5-23. The significance of all control fields used in these packet formats shall be as follows:*

Field symbol	Definition
AG Address,	Ground; the 8-bit binary representation of the ground DTE address (5.2.3.1.3.1)
AM Address,	Mobile; the 4-bit binary representation of the last two BCD digits of the mobile DTE address (5.2.3.1.3.2)
CC	Clearing cause as defined in ISO 8208
CH	Channel number (1 to 15)
DC	Diagnostic code as defined in ISO 8208
DP	Data packet type (Figure 5-23)
F	S-bit sequence, first packet flag
FILL	Fill field
FILL1	Has a length of 6 bits for a non-multiplexed packet in a downlink SLM frame; otherwise it is 0 bit
FILL2	Has a length of 0 bit for a non-multiplexed packet in a downlink SLM frame and for a multiplexing header; otherwise it is 2 bits

FIRST PACKET	The contents of the first of the multiplexed packets
FS	Fast select present
IN	Initialization bit
L	"More bit" for long-form MSP packets as specified in 5.2.7.4
LAST PACKET	The contents of the last of the multiplexed packets
LENGTH	The length of a multiplexed packet in bytes expressed as an unsigned binary number
LV	User data field length; number of user bytes as specified in 5.2.2.3.1
M	"More bit" for SVC DATA packets as specified in 5.2.5.1.4.1
M/CH	MSP channel number
MP	MSP packet type (Figure 5-23)
M/SN	Sequence number; the sequence number for the long form MSP packet
OD	Optional data
ODL	Optional data length
OF	Option flag
P	Priority field
PR	Packet receive sequence number
PS	Packet send sequence number
RC	Resetting cause code as defined in ISO 8208
RT	Route table as defined in 5.2.5.3.3.8
RTL	Route table length expressed in bytes
S	"More bit" for CALL REQUEST, CALL ACCEPT, CLEAR REQUEST and INTERRUPT packets as specified in 5.2.5.1.4.2
SN	Sequence number; the sequence number for this packet type

SP	Supervisory packet (Figure 5-23)
SS	Supervisory subset number (Figure 5-23)
ST	Supervisory type (Figure 5-23)
TC	Temporary channel number (1 to 3)
UD	User data field

TABLES FOR CHAPTER 5

Table 5-1. ADLP Mode S subnetwork timers

Timer name	*Timer label*	*Nominal value*	*Reference*
Channel retirement	*Tr*	600 s	5.2.8.3.1
Active channel-ADLP	*Tx*	420 s	5.2.8.3.2
Interrogator interrogation	*Ts*	60 s	5.2.8.1.2
Interrogator link	*Tz*	30 s	5.2.7.1.1.4.2, 5.2.8.1.3.2
Link frame cancellation	*Tc*	60 s	5.2.2.1.1.4.5
L-bit delivery-ADLP	*Tm*	120 s	5.2.7.4.3
Packet resequencing and S-bit delivery	*Tq*	60 s	5.2.6.9

Table 5-2. DCE actions at state transition

DCE state	*State definition*	*Action that shall be taken when entering the state*
*r*1	PACKET LEVEL READY	Return all SVCs to the *p*1 state (see *p*1 state explanation).
*r*2	DTE RESTART REQUEST	Return each SVC to the *p*1 state (see *p*1 state explanation). Issue a RESTART CONFIRMATION to the DTE.
*r*3	DCE RESTART REQUEST	Issue a RESTART REQUEST to the DTE. Unless entered via the *r*2 state, send a RESTART REQUEST to the reformatting process.
*p*1	READY	Release all resources assigned to SVC. Break the correspondence between the DTE/DCE SVC and the ADCE/GDCE SVC (the ADCE/GDCE SVC may not yet be in the *p*1 state).
*p*2	DTE CALL REQUEST	Determine if sufficient resources exist to support request; if so, allocate resources and forward CALL REQUEST packet to reformatting process; if not, enter DCE CLEAR REQUEST to DTE state (*p*7). Determination of resources and allocation is as defined in ISO 8208.
*p*3	DCE CALL REQUEST	Determine if sufficient resources exist to support request; if so allocate resources and forward CALL REQUEST packet to DTE; if not, send a CLEAR REQUEST packet to the reformatting process. Determination of resources and allocation is as defined in ISO 8208.
*p*4	DATA TRANSFER	No action.
*p*5	CALL COLLISION	Reassign outgoing call to another SVC (the DTE in its call collision state ignores the incoming call) and enter the DCE CALL REQUEST state (*p*3) for that new SVC. Enter the *p*2 state to process the CALL REQUEST from the DTE.
*p*6	DTE CLEAR REQUEST	Release all resources assigned to SVC, send a CLEAR CONFIRMATION packet to the DTE and enter *p*1 state.
*p*7	DCE CLEAR REQUEST to DTE	Forward CLEAR REQUEST packet to DTE.
*d*1	FLOW CONTROL READY	No action.
*d*2	DTE RESET REQUEST	Remove DATA packets transmitted to DTE from window; discard any DATA packets that represent partially transmitted M-bit sequences and discard any INTERRUPT packet awaiting transfer to the DTE; reset all window counters to 0; set any timers and retransmission parameters relating to DATA and INTERRUPT transfer to their initial value. Send RESET CONFIRMATION packet to DTE. Return SVC to *d*1 state.
*d*3	DCE RESET REQUEST to DTE	Remove DATA packets transmitted to DTE from window; discard any DATA packets that represent partially transmitted M-bit sequences and discard any INTERRUPT packet awaiting transfer to the DTE; reset all window counters to 0; set any timers and retransmission parameters relating to DATA and INTERRUPT transfer to their initial value. Forward RESET REQUEST packet to DTE.

DCE state	*State definition*	*Action that shall be taken when entering the state*
*i*1	DTE INTERRUPT READY	No action.
*i*2	DTE INTERRUPT SENT	Forward INTERRUPT packet received from DTE to reformatting process.
*j*1	DCE INTERRUPT READY	No action.
*j*2	DCE INTERRUPT SENT	Forward INTERRUPT packet received from reformatting process to DTE.
*f*1	DCE RECEIVE READY	No action.
*f*2	DCE RECEIVE NOT READY	No action.
*g*1	DTE RECEIVE READY	No action.
*g*2	DTE RECEIVE NOT READY	No action.

Table 5-3. DCE special cases

Received from DTE	*DCE special cases* *Any state*
Any packet less than 2 bytes in length (including a valid data link level frame containing no packet)	A=DIAG *D*=38
Any packet with an invalid general format identifier	A=DIAG *D*=40
Any packet with a valid general format identifier and an assigned logical channel identifier (includes a logical channel identifier of 0)	See Table 5-4

Table 5-4. DTE effect on DCE restart states

Packet received from DTE	DCE restart states (see Note 5) PACKET LEVEL READY (see Note 1) *r*1	DTE RESTART REQUEST *r*2	DCE RESTART REQUEST *r*3
Packets having a packet type identifier shorter than 1 byte and logical channel identifier not equal to 0	See Table 5-5	*A=ERROR* *S=r*3 *D*=38 (see Note 4)	*A=DISCARD*
Any packet, except RESTART, REGISTRATION (if supported) with a logical channel identifier of 0	*A=DIAG* *D*=36	*A=DIAG* *D*=36	*A=DIAG* *D*=36
Packet with a packet type identifier which is undefined or not supported by DCE	See Table 5-5	*A=ERROR* *S=r*3 *D*=33 (see Note 4)	*A=DISCARD*
RESTART REQUEST, RESTART CONFIRMATION, or REGISTRATION (if supported) packet with a logical channel identifier unequal to 0	See Table 5-5	*A=ERROR* *S=r*3 *D*=41 (see Note 4)	*A=DISCARD*
RESTART REQUEST	*A=NORMAL* (forward) *S=r*2	*A=DISCARD*	*A=NORMAL* *S=p*1 or *d*1 (see Note 2)
RESTART CONFIRMATION	*A=ERROR* *S=r*3 *D*=17 (see Note 6)	*A=ERROR* *S=r*3 *D*=18 (see Note 4)	*A=NORMAL* *S=p*1 or *d*1 (see Note 2)
RESTART REQUEST OR RESTART CONFIRMATION packet with a format error	*A=DIAG* *D*=38, 39, 81 or 82	*A=DISCARD*	*A=ERROR* *D*=38, 39, 81 or 82
REGISTRATION REQUEST or REGISTRATION CONFIRMATION packets (see Note 3)	*A=NORMAL*	*A=NORMAL*	*A=NORMAL*
REGISTRATION REQUEST or REGISTRATION CONFIRMATION packet with a format error (see Note 3)	*A=DIAG* *D*=38, 39, 81 or 82	*A=ERROR* *S=r*3 *D*=38, 39, 81 or 82 (see Note 4)	*A=ERROR* *D*=38, 39, 81 or 82
Call setup, call clearing, DATA, interrupt, flow control, or reset packet	See Table 5-5	*A=ERROR* *S*=r3 *D*=18	*A=DISCARD*

NOTES:

1. *The Mode S subnetwork has no restart states. Receipt of a RESTART REQUEST causes the DCE to respond with a RESTART CONFIRMATION. The RESTART REQUEST packet is forwarded to the reformatting process, which issues clear requests for all SVCs associated with the DTE. The DCE enters the* r3 *state only as a result of an error detected on the DTE/DCE interface.*
2. *The SVC channels are returned to state* p*1, the permanent virtual circuits (PVC) channels are returned to state* d*1.*
3. *The use of the registration facility is optional on the DTE/DCE interface.*
4. *No action is taken within the Mode S subnetwork.*
5. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared for the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
6. *The error procedure consists of entering the* r3 *state, and sending a RESTART REQUEST to the reformatting process.*

Table 5-5. DTE effect on DCE call setup and clearing states

Packet received from DTE	DCE call setup and clearing states (see Note 5) READY *p*1	DTE CALL REQUEST *p*2	DCE CALL REQUEST *p*3	DATA TRANSFER *p*4	CALL COLLISION *p*5 (see Notes 1 and 4)	DTE CLEAR REQUEST *p*6	DCE CLEAR REQUEST to DTE *p*7
Packets having a packet type identifier shorter than 1 byte	*A=ERROR* *S=p*7 *D*=38	*A=ERROR* *S=p*7 *D*=38 (see Note 2)	*A=ERROR* *S=p*7 *D*=38 (see Note 2)	See Table 5-6	*A=ERROR* *S=p*7 *D*=38 (see Note 2)	*A=ERROR* *S=p*7 *D*=38 (see Note 2)	*A=DISCARD*
Packets having a packet type identifier which is undefined or not supported by DCE	*A=ERROR* *S=p*7 *D*=33	*A=ERROR* *S=p*7 *D*=33 (see Note 2)	*A=ERROR* *S=p*7 *D*=33 (see Note 2)	See Table 5-6	*A=ERROR* *S=p*7 *D*=33 (see Note 2)	*A=ERROR* *S=p*7 *D*=33 (see Note 2)	*A=DISCARD*
RESTART REQUEST, RESTART CONFIRMATION or REGISTRATION packet with logical channel identifier unequal to 0	*A=ERROR* *S=p*7 *D*=41	*A=ERROR* *S=p*7 *D*=41 (see Note 2)	*A=ERROR* *S=p*7 *D*=41 (see Note 2)	See Table 5-6	*A=ERROR* *S=p*7 *D*=41 (see Note 2)	*A=ERROR* *S=p*7 *D*=41 (see Note 2)	*A=DISCARD*
CALL REQUEST	*A=NORMAL* *S=p*2 (forward)	*A=ERROR* *S=p*7 *D*=21 (see Note 2)	*A=NORMAL* *S=p*5	*A=ERROR* *S=p*7 *D*=23 (see Note 2)	*A=ERROR* *S=p*7 *D*=24 (see Note 2)	*A=ERROR* *S=p*7 *D*=25 (see Note 2)	*A=DISCARD*
CALL ACCEPT	*A=ERROR* *S=p*7 *D*=20	*A=ERROR* *S=p*7 *D*=21 (see Note 2)	*A=NORMAL* *S=p*4 (Forward) or *A=ERROR* *S=p*7 *D*=42 (see Notes 2 and 3)	*A=ERROR* *S=p*7 *D*=23 (see Note 2)	*A=ERROR* *S=p*7 *D*=24 (see Notes 2 and 4)	*A=ERROR* *S=p*7 *D*=25 (see Note 2)	*A=DISCARD*
CLEAR REQUEST	*A=NORMAL* *S=p*6	*A=NORMAL* *S=p*6 (forward)	*A=NORMAL* *S=p*6 (forward)	*A=NORMAL* *S=p*6 (forward)	*A=NORMAL* *S=p*6 (forward)	*A=DISCARD*	*A=NORMAL* *S=p*1 (do not forward)
CLEAR CONFIRMATION	*A=ERROR* *S=p*7 *D*=20	*A=ERROR* *S=p*7 *D*=21 (see Note 2)	*A=ERROR* *S=p*7 *D*=22 (see Note 2)	*A=ERROR* *S=p*7 *D*=23 (see Note 2)	*A=ERROR* *S=p*7 *D*=24 (see Note 2)	*A=ERROR* *S=p*7 *D*=25 (see Note 2)	*A=NORMAL* *S=p*1 (do not forward)
DATA, interrupt, flow control or reset packets	*A=ERROR* *S=p*7 *D*=20	*A=ERROR* *S=p*7 *D*=21 (see Note 2)	*A=ERROR* *S=p*7 *D*=22 (see Note 2)	See Table 5-6	*A=ERROR* *S=p*7 *D*=24 (see Note 2)	*A=ERROR* *S=p*7 *D*=25 (see Note 2)	*A=DISCARD*

Packet received from DTE	DCE call setup and clearing states (see Note 5)						
	READY *p*1	DTE CALL REQUEST *p*2	DCE CALL REQUEST *p*3	DATA TRANSFER *p*4	CALL COLLISION *p*5 (see Notes 1 and 4)	DTE CLEAR REQUEST *p*6	DCE CLEAR REQUEST to DTE *p*7

NOTES:

1. *On entering the* p5 *state, the DCE reassigns the outgoing call to the DTE to another channel (no CLEAR REQUEST is issued) and responds to incoming DTE call as appropriate with a CLEAR REQUEST or CALL ACCEPT packet.*
2. *The error procedure consists of performing the actions specified when entering the* p7 *state (including sending a CLEAR REQUEST packet to the DTE) and additionally sending a CLEAR REQUEST packet to the XDCE (via the reformatting process).*
3. *The use of the fast select facility with a restriction on the response prohibits the DTE from sending a CALL ACCEPT packet.*
4. *The DTE in the event of a call collision must discard the CALL REQUEST packet received from the DCE.*
5. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*

Table 5-6. DTE effect on DCE reset states

Packet received from DTE	DCE reset states (see Note 2) FLOW CONTROL READY *d*1	RESET REQUEST by DTE *d*2	DCE RESET REQUEST to DTE *d*3
Packet with a packet type identifier shorter than 1 byte	*A=ERROR* *S=d*3 *D*=38 (see Note 1)	*A=ERROR* *S=d*3 *D*=38 (see Note 1)	*A=DISCARD*
Packet with a packet type identifier which is undefined or not supported by DCE	*A=ERROR* *S=d*3 *D*=33 (see Note 1)	*A=ERROR* *S=d*3 *D*=33 (see Note 1)	*A=DISCARD*
RESTART REQUEST, RESTART CONFIRMATION, or REGISTRATION (if supported) packet with logical channel identifier unequal to 0	*A=ERROR* *S=d*3 *D*=41 (see Note 1)	*A=ERROR* *S=d*3 *D*=41 (see Note 1)	*A=DISCARD*
RESET REQUEST	*A=NORMAL* *S=d*2 (forward)	*A=DISCARD*	*A=NORMAL* *S=d*1 (do not forward)
RESET CONFIRMATION	*A=ERROR* *S=d*3 *D*=27 (see Note 1)	*A=ERROR* *S=d*3 *D*=28 (see Note 1)	*A=NORMAL* *S=d*1 (do not forward)
INTERRUPT packet	See Table 5-7	*A=ERROR* *S=d*3 *D*=28 (see Note 1)	*A=DISCARD*
INTERRUPT CONFIRMATION packet	See Table 5-7	*A=ERROR* *S=d*3 *D*=28 (see Note 1)	*A=DISCARD*
DATA or flow control packet	See Table 5-8	*A=ERROR* *S=d*3 *D*=28 (see Note 1)	*A=DISCARD*
REJECT supported but not subscribed to	*A=ERROR* *S=d*3 *D*=37 (see Note 1)	*A=ERROR* *S=d*3 *D*=37 (see Note 1)	*A=DISCARD*

NOTES:

1. *The error procedure consists of performing the specified actions when entering the* d3 *state (which includes forwarding a RESET REQUEST packet to the DTE) and sending a RESET REQUEST packet to the XDCE (via the formatting function).*
2. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared for the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*

Table 5-7. DTE effect on DCE interrupt transfer states

Packet received from DTE	DTE/DCE interrupt transfer states (see Note 2) DTE INTERRUPT READY *i*1	 DTE INTERRUPT SENT *i*2
INTERRUPT (see Note 1)	*A=NORMAL* *S=i*2 (forward)	*A=ERROR* *S=d*3 *D*=44 (see Note 3)
Packet received from DTE	**DTE/DCE interrupt transfer states (see Note 2) DCE INTERRUPT READY *j*1**	** DCE INTERRUPT SENT *j*2**
INTERRUPT CONFIRMATION (see Note 1)	*A=ERROR* *S=d*3 *D*=43 (see Note 3)	*A=NORMAL* *S=j*1 (forward)

NOTES:

1. *If the packet has a format error, then the error procedure applies (see Note 3). Interrupt packets with user data greater than 32 bytes should be treated as a format error.*
2. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
3. *The error procedure consists of performing the specified actions when entering the* d3 *state (which includes forwarding a RESET REQUEST packet to the DTE) and sending a RESET REQUEST packet to the XDCE (via the reformatting process).*

Table 5-8. DTE effect on DCE flow control transfer states

Packet received from DTE	DCE flow control transfer states (see Notes 2 and 3) DCE RECEIVE READY *f*1	 DCE RECEIVE NOT READY *f*2
DATA packet with less than 4 bytes when using modulo 128 numbering	*A*=*ERROR* *S*=*d*3 *D*=38 (see Note 4)	*A*=*DISCARD*
DATA packet with invalid PR	*A*=*ERROR* *S*=*d*3 *D*=2 (see Note 4)	*A*=*ERROR* *S*=*d*3 *D*=2 (see Note 4)
DATA packet with valid PR but invalid PS or user data field with improper format	*A*=*ERROR* *S*=*d*3 *D*=1 (invalid PS) *D*=39 (UD > max negotiated length) *D*=82 (UD unaligned) (see Note 4)	*A*=*DISCARD* (process PR data)
DATA packet with valid PR with M-bit set to 1 when the user data field is partially full	*A*=*ERROR* *S*=*d*3 *D*=165 (see Note 4)	*A*=*DISCARD* (process PR data)
DATA packet with valid PR, PS and user data field format	*A*=*NORMAL* (forward)	*A*=*DISCARD* (process PR data)
Packet received from DTE	**DCE flow control transfer states (see Notes 2 and 3) DTE RECEIVE READY *g*1**	** DTE RECEIVE NOT READY *g*2**
RR, RNR, or REJECT packet with less than 3 bytes when using modulo 128 numbering (see Note 1)	*A*=*DISCARD*	*A*=*DISCARD*
RR, RNR, or REJECT packet with an invalid PR	*A*=*ERROR* *S*=*d*3 *D*=2 (see Note 4)	*A*=*ERROR* *S*=*d*3 *D*=2 (see Note 4)
RR packet with a valid PR	*A*=*NORMAL*	*A*=*NORMAL* *S*=*g*1
RNR packet with a valid PR	*A*=*NORMAL* *S*=*g*2	*A*=*NORMAL*
REJECT packet with a valid PR	*A*=*NORMAL*	*A*=*NORMAL* *S*=*g*1

NOTES:

1. *The reject procedures are not required.*
2. *The RR, RNR and REJECT procedures are a local DTE/DCE matter and the corresponding packets are not forwarded to the XDCE.*
3. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
4. *The error procedure consists of performing the specified actions when entering the* d3 *state (which includes forwarding a RESET REQUEST packet to the DTE) and sending a RESET REQUEST packet to the XDCE (via the reformatting process).*

Table 5-9. XDCE effect on DCE restart states

Packet received from XDCE	DCE restart states (see Note) PACKET LEVEL READY *r*1	 DTE RESTART REQUEST *r*2	 DCE RESTART REQUEST *r*3
CALL REQUEST	See Table 5-10	Send CLEAR REQUEST to reformatting process with *D*=244	Send CLEAR REQUEST to reformatting process with *D*=244
CALL ACCEPT, CLEAR REQUEST, DATA, INTERRUPT, INTERRUPT CONFIRMATION, RESET REQUEST	See Table 5-10	*A=DISCARD*	*A=DISCARD*

Note.— Table entries are defined as follows: A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*

Table 5-10. XDCE effect on DCE call setup and clearing states

Packet received from XDCE	DCE call setup and clearing states (see Note) READY *p*1	 DTE CALL REQUEST *p*2	 DCE CALL REQUEST *p*3	 DATA TRANSFER *p*4	 CALL COLLISION *p*5	 DTE CLEAR REQUEST *p*6	 DCE CLEAR REQUEST to DTE *p*7
CALL REQUEST	*A=NORMAL* *S=p*3 (forward)	INVALID	INVALID	INVALID	INVALID	INVALID	INVALID
CALL ACCEPT	*A=DISCARD*	*A=NORMAL* *S=p*4 (forward)	INVALID	INVALID	INVALID	*A=DISCARD*	*A=DISCARD*
CLEAR REQUEST	*A=DISCARD*	*A=NORMAL* *S=p*7 (forward)	*A=NORMAL* *S=p*7 (forward)	*A=NORMAL* *S=p*7 (forward)	INVALID	*A=DISCARD*	*A=DISCARD*
DATA, INTERRUPT, INTERRUPT CONFIRMATION, or RESET REQUEST	*A=DISCARD*	INVALID	INVALID	See Table 5-11	INVALID	*A=DISCARD*	*A=DISCARD*

Note.— Table entries are defined as follows: A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*

Table 5-11. XDCE effect on DCE reset states

Packet received from XDCE	DCE reset states (see Note) FLOW CONTROL READY *d*1	DTE RESET REQUEST *d*2	DCE RESET REQUEST to DTE *d*3
RESET REQUEST	*A=NORMAL* *S=d3* (forward)	*A=NORMAL* *S=d1* (forward)	*A=DISCARD*
INTERRUPT	See Table 5-12	*A=DISCARD*	*A=DISCARD*
INTERRUPT CONFIRMATION	See Table 5-12	*A=DISCARD*	INVALID
DATA	*A=NORMAL* (forward)	*A=DISCARD*	*A=DISCARD*

Note.— Table entries are defined as follows: A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*

Table 5-12. XDCE effect on DCE interrupt transfer states

Packet received from XDCE	DCE interrupt transfer states (see Note) DTE INTERRUPT READY *i*1	DTE INTERRUPT SENT *i*2
INTERRUPT CONFIRMATION	INVALID	*A=NORMAL* *S=i1* (forward)
Packet received from XDCE	**DCE interrupt transfer states (see Note) DCE INTERRUPT READY *j*1**	**DCE INTERRUPT SENT *j*2**
INTERRUPT	*A=NORMAL* *S=j2* (forward)	INVALID

Note.— Table entries are defined as follows: A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*

Table 5-13. GDLP Mode S subnetwork timers

Timer name	*Timer label*	*Nominal value*	*Reference*
Active channel-GDLP	*Tx*	300 s	5.2.8.3.2
L-bit delivery-GDLP	*Tm*	120 s	5.2.7.4.3
Packet resequencing and S-bit delivery	*Tq*	60 s	5.2.6.9

Table 5-14. XDCE actions at state transition

XDCE state	*State definition*	*Action that shall be taken when entering the state*
*r*1	PACKET LEVEL READY	Return all SVCs to the *p*1 state.
*p*1	READY	Release all resources assigned to the SVC. Break the correspondence between the ADCE/GDCE SVC and the DTE/DCE SVC (the DTE/DCE SVC may not yet be in a *p*1 state).
*p*2	GDLP(ADLP) CALL REQUEST	Determine if sufficient resources exist to support request; if so allocate resources and forward Mode S CALL REQUEST packet to reformatting process; if not, enter ADCE(GDCE) CLEAR REQUEST to GDLP(ADLP) state (*p*7).
*p*3	ADCE(GDCE) CALL REQUEST	Determine if sufficient resources exist to support request; if so, allocate resources and forward Mode S CALL REQUEST packet to frame processing; if not, send Mode S CLEAR REQUEST to reformatting process and go to state *p*1. Do not forward the Mode S CALL REQUEST to the peer XDCE.
*p*4	DATA TRANSFER	No action.
*p*6	GDLP(ADLP) CLEAR REQUEST	Release all resources, send a Mode S CLEAR CONFIRMATION packet to the peer XDCE and enter the *p*1 state.
*p*7	ADCE(GDCE) CLEAR REQUEST to GDLP(ADLP)	Forward Mode S CLEAR REQUEST packet to the peer XDCE via frame processing.
*d*1	FLOW CONTROL READY	No action.
*d*2	GDLP(ADLP) RESET REQUEST	Remove Mode S DATA packets transmitted to peer XDCE from window; discard any DATA packets that represent partially transmitted M-bit sequences and discard any Mode S INTERRUPT packets awaiting transfer to the peer XDCE; reset all flow control window counters to 0 (5.2.6.7.1). Send Mode S RESET CONFIRMATION packet to the peer XDCE. Return SVC to *d*1 state. Forward Mode S RESET REQUEST packet to reformatting process.
*d*3	ADCE(GDCE) RESET REQUEST to GDLP(ADLP)	Remove Mode S DATA packets transmitted to peer XDCE from window; discard any DATA packets that represent partially transmitted M-bit sequences and discard any Mode S INTERRUPT packets awaiting transfer to the peer XDCE; reset all flow control window counters to 0 (5.2.6.7.1). Forward Mode S RESET REQUEST packet to peer XDCE via frame processing.
*i*1	GDLP(ADLP) INTERRUPT READY	No action.
*i*2	GDLP(ADLP) INTERRUPT SENT	Forward Mode S INTERRUPT packet received from peer XDCE to the reformatting process.
*j*1	ADCE(GDCE) INTERRUPT READY	No action.
*j*2	ADCE(GDCE) INTERRUPT SENT	Forward Mode S INTERRUPT packet received from the reformatting process.
*f*1	ADCE(GDCE) RECEIVE READY	No action.
*f*2	ADCE(GDCE) RECEIVE NOT READY	No action.
*g*1	GDLP(ADLP) RECEIVE READY	No action.
*g*2	GDLP(ADLP) RECEIVE NOT READY	No action.

Table 5-15. GDLP (ADLP) effect on ADCE (GDCE) packet layer ready states

Packet received from GDLP (ADLP) (see Note 2)	ADCE (GDCE) states (see Notes 1 and 3) PACKET LEVEL READY *r*1
CH=0 with no TC present (see Note 4) or CH=0 in a CALL ACCEPT by ADLP packet	*A=DISCARD*
Unassigned packet header	*A=DISCARD*
Call setup, call clearing, DATA, interrupt, flow control, or reset	See Table 5-16

NOTES:

1. *The XDCE state is not necessarily the same state as the DTE/DCE interface.*
2. *All packets from the peer XDLP have been checked for duplication before evaluation as represented by this table.*
3. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
4. *Where CH=0 and a valid TC is present in a CLEAR REQUEST by ADLP or GDLP packet or a CLEAR CONFIRMATION by ADLP or GDLP packet, it is handled as described in 5.2.5.1.2.3 and Table 5-16.*

Table 5-16. GDLP (ADLP) effect on ADCE (GDCE) call setup and clearing states

Packet received from GDLP (ADLP) (see Note 2)	ADCE (GDCE) call setup and clearing States (See Notes 1, 7 and 8) READY *p*1	GDLP (ADLP) CALL REQUEST *p*2	ADCE (GDCE) CALL REQUEST *p*3	DATA TRANSFER *p*4	GDLP (ADLP) CLEAR REQUEST *p*6	ADCE (GDCE) CLEAR REQUEST to GDLP (ADLP) *p*7
Format error (see Note 3)	*A=ERROR* (see Note 10) *S=p*7 *D*=33 (see Note 9)	*A=ERROR* *S=p*7 *D*=33 (see Note 6)	*A=ERROR* *S=p*7 *D*=33 (see Notes 6 and 9)	See Table 5-17	*A=ERROR* *S=p*7 *D*=25 (see Note 6)	*A=DISCARD*
CALL REQUEST	*A=NORMAL* (5.2.6.3.1) *S=p*2 (forward request to DCE)	*A=ERROR* *S=p*7 *D*=21 (see Note 6)	Not applicable (see Note 4)	Not applicable (see Note 4)	*A=ERROR* *S=p*7 *D*=25 (see Note 6)	*A=DISCARD*
CALL ACCEPT	*A=ERROR* *S=p*7 *D*=20 (see Note 10)	*A=ERROR* *S=p*7 *D*=21 (see Note 6)	*A=NORMAL* (5.2.6.3.1) *S=p*4 (forward to DCE), or *A=ERROR* *S=p*7 *D*=42 (see Note 6)	*A=ERROR* *S=p*7 *D*=23 (see Note 6)	*A=ERROR* *S=p*7 *D*=25 (see Note 6)	*A=DISCARD*

Packet received from GDLP (ADLP) (see Note 2)	ADCE (GDCE) call setup and clearing States (See Notes 1, 7 and 8) READY *p1*	GDLP (ADLP) CALL REQUEST *p2*	ADCE (GDCE) CALL REQUEST *p3*	DATA TRANSFER *p4*	GDLP (ADLP) CLEAR REQUEST *p6*	ADCE (GDCE) CLEAR REQUEST to GDLP (ADLP) *p7*
CLEAR REQUEST	*A=NORMAL* (5.2.6.3.3) *S=p6* (do not forward)	*A=NORMAL* (5.2.6.3.3) *S=p6* (forward to DCE)	*A=NORMAL* (5.2.6.3.3) *S=p6* (forward to DCE)	*A=NORMAL* (5.2.6.3.3) *S=p6* (forward to DCE)	*A=DISCARD*	*A=NORMAL* (5.2.6.3.3) *S=p1* (do not forward)
CLEAR CONFIRMATION	*A=ERROR* *S=p7* *D=20* (see Note 10)	*A=ERROR* *S=p7* *D=21* (see Note 6)	*A=ERROR* *S=p7* *D=22* (see Note 6)	*A=ERROR* *S=p7* *D=23* (see Note 6)	*A=ERROR* *S=p7* *D=25* (see Note 6)	*A=NORMAL* (5.2.6.3.3) *S=p1* (do not forward)
DATA, interrupt, flow control or reset packets	*A=ERROR* *S=p7* *D=20* (see Note 10)	*A=ERROR* *S=p7* *D=21* (see Notes 6 and 9)	*A=ERROR* *S=p7* *D=22* (see Notes 5 and 6)	See Table 5-17	*A=ERROR* *S=p7* *D=25* (see Note 6)	*A=DISCARD*

NOTES:

1. *The XDCE is not necessarily in the same state as the DTE/DCE interface.*
2. *All packets from the peer XDLP have been checked for duplication before evaluation as represented by this table.*
3. *A format error may result from an S-bit sequence having a first or intermediate packet shorter than the maximum length, or else from an invalid LV field in a CALL REQUEST, CALL ACCEPT, CLEAR REQUEST or INTERRUPT packet. There are no other detectable Mode S format errors.*
4. *The ADCE assigns all channel numbers used between the ADLP and GDLP, hence call collisions are not possible. When a CALL REQUEST by GDLP packet is received bearing a temporary channel number associated with an SVC in the* p4 *state, the association of the temporary to permanent channel number is broken (5.2.5.1.2.3).*
5. *Not applicable to the GDLP.*
6. *The error procedure consists of performing the actions specified when entering the* p7 *state (including sending a CLEAR REQUEST packet to the peer XDLP) and additionally sending a CLEAR REQUEST packet to the DCE (via the reformatting process).*
7. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
8. *The number in parentheses below an "*A = NORMAL*" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*
9. *An error condition is declared and transfer to the* p7 *state is possible only if the ground DTE address is known unambiguously. Otherwise the action is to discard the packet.*
10. *The error procedure consists of performing the action when entering the* p7 *state (including sending a CLEAR REQUEST packet to the XDLP) but without sending a CLEAR REQUEST packet to the local DCE.*

Table 5-17. GDLP (ADLP) effect on ADCE (GDCE) reset states

Packet received from GDLP (ADLP) (see Note 2)	ADCE (GDCE) reset states (see Notes 1, 4 and 5) FLOW CONTROL READY *d*1	GDLP (ADLP) RESET REQUEST *d*2	ADCE (GDCE) RESET REQUEST to GDLP (ADLP) *d*3
RESET REQUEST	*A=NORMAL* (5.2.6.7) *S=d*2 (forward to DCE)	*A=DISCARD*	*A=NORMAL* (5.2.6.7) *S=d*1 (do not forward)
RESET CONFIRMATION	*A=ERROR* *S=d*3 *D*=27 (see Note 3)	*A=ERROR* *S=d*3 *D*=28 (see Note 3)	*A=NORMAL* (5.2.6.7) *S=d*1 (do not forward)
INTERRUPT	See Table 5-18	*A=ERROR* *S=d*3 *D*=28 (see Note 3)	*A=DISCARD*
INTERRUPT CONFIRMATION	See Table 5-18	*A=ERROR* *S=d*3 *D*=28 (see Note 3)	*A=DISCARD*
DATA or flow control packet	See Table 5-19	*A=ERROR* *S=d*3 *D*=28 (see Note 3)	*A=DISCARD*
Format error (see Note 6)	*A=ERROR* *S=d*3 *D*=33 (see Note 3)	*A=ERROR* *S=d*3 *D*=33 (see Note 3)	*A=DISCARD*

NOTES:

1. *The XDCE is not necessarily in the same state as the DTE/DCE interface.*
2. *All packets from the peer XDLP have been checked for duplication before evaluation as represented by this table.*
3. *The error procedure consists of performing the specified actions when entering the* d3 *state (which includes forwarding a RESET REQUEST packet to the peer XDLP) and sending a RESET REQUEST packet to the DCE (via the formatting function).*
4. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared for the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
5. *The number in parentheses below an "*A = NORMAL*" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*
6. *A format error may result from an S-bit sequence having a first or intermediate packet shorter than the maximum length, or else from an invalid LV field in a CALL REQUEST, CALL ACCEPT, CLEAR REQUEST, or INTERRUPT packet. There are no other detectable Mode S format errors.*

Table 5-18. GDLP (ADLP) effect on ADCE (GDCE) interrupt transfer states

Packet received from GDLP (ADLP) (see Note 2)	ADCE/GDCE interrupt transfer states (see Notes 1, 3 and 4) GDLP (ADLP) INTERRUPT READY *i*1	GDLP (ADLP) INTERRUPT SENT *i*2
INTERRUPT (see Note 6)	*A=NORMAL* (5.2.6.4.5) *S=i2* (forward to DCE)	*A=ERROR* *S=d*3 *D*=44 (see Note 5)
Packet received from GDLP (ADLP) (see Note 2)	**ADCE (GDCE) interrupt transfer states (see Notes 1, 3 and 4) ADCE (GDCE) INTERRUPT READY *j*1**	**ADCE (GDCE) INTERRUPT SENT *j*2**
INTERRUPT CONFIRMATION	*A=ERROR* *S=d*3 *D*=43 (see Note 5)	*A=NORMAL* (5.2.6.4.5) *S=j*1 (forward confirmation to DCE)

NOTES:

1. *The XDCE is not necessarily in the same state as the DTE/DCE interface.*
2. *All packets from the peer XDLP have been checked for duplication before evaluation as represented by this table.*
3. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared for the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
4. *The number in parentheses below an "*A = NORMAL*" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*
5. *The error procedure consists of performing the specified actions when entering the* d3 *state (which includes forwarding a RESET REQUEST packet to the peer XDLP) and sending a RESET REQUEST packet to the DCE (via the reformatting process).*
6. *User data length for INTERRUPT packets greater than 32 bytes, or an out of sequence INTERRUPT packet, are considered as errors.*

Table 5-19. GDLP (ADLP) effect on ADCE (GDCE) flow control transfer states

Packet received from GDLP (ADLP) (see Note 2)	ADCE (GDCE) flow control transfer states (see Notes 1, 6 and 7) ADCE (GDCE) RECEIVE READY *f*1	ADCE (GDCE) RECEIVE NOT READY *f*2
DATA packet with invalid PR (see Note 3)	*A=ERROR* *S=d*3 *D*=2 (see Note 8)	*A=ERROR* *S=d*3 *D*=2 (see Note 8)
DATA packet with valid PR, invalid PS or LV subfield (see Notes 4 and 5)	*A=DISCARD,* but process the PR value and send REJECT packet containing the expected PS value (see Note 5)	*A=DISCARD*, but process the PR value and send REJECT packet containing the expected PS value when busy condition ends

DATA packet with valid PR, PS and LV subfield	*A=NORMAL* (5.2.6.4.4) (forward)	*A=PROCESS*, if possible; or *A=DISCARD*, but process the PR value and send REJECT containing the expected PS value when busy condition ends

Packet received from GDLP (ADLP) (see Note 2)	ADCE (GDCE) flow control transfer states (see Notes 1, 6 and 7) GDLP (ADLP) RECEIVE READY *g*1	 GDLP (ADLP) RECEIVE NOT READY *g*2
RR, RNR, REJECT packet with invalid PR (see Note 3)	*A=ERROR* *S=d*3 *D*=2 (see Note 8)	*A=ERROR* *S=d*3 *D*=2 (see Note 8)
RR with valid PR field (see Note 9)	*A=NORMAL* (5.2.6.5)	*A=NORMAL* (5.2.6.6) *S=g*1
RNR with valid PR value (see Note 9)	*A=NORMAL* (5.2.6.5) *S=g*2	*A=NORMAL* (5.2.6.6)
REJECT with valid PR (see Note 9)	*A=NORMAL* (5.2.6.5)	*A=NORMAL* (5.2.6.6) *S=g*1

NOTES:

1. *The XDCE is not necessarily in the same state as the DTE/DCE interface.*
2. *All packets from the peer XDLP have been checked for duplication before evaluation as represented by this table.*
3. *An invalid PR value is one which is less than the PR value (modulo 16) of the last packet sent by the peer XDLP, or greater than the PS value of the next data packet to be transmitted by the XDLP.*
4. *An invalid PS value is one which is different from the next expected value for PS.*
5. *An invalid LV subfield is one which represents a value that is too large for the size of the segment received. In the event of an LV field error which gives rise to a loss of confidence in the correctness of the other fields in the packet, the packet is discarded without any further action.*
6. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
7. *The number in parentheses below an "*A = NORMAL*" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*
8. *The error procedure consists of performing the specified actions when entering the* d3 *state (which includes forwarding a RESET REQUEST packet to the peer XDLP) and sending a RESET REQUEST packet to the DCE (via the reformatting process).*
9. *RR, RNR, and REJECT packets have no end-to-end significance and are not forwarded to the DCE.*
10. *The receipt of a packet smaller than the maximum packet size with M-bit = 1 will cause a reset to be generated and the remainder of the sequence will be discarded.*

Table 5-20. DCE effect on ADCE (GDCE) call setup and clearing states

Packet received from DCE (see Notes 2 and 4)	ADCE (GDCE) call setup and clearing states (see Notes 1, 7 and 8)					
	READY *p*1	GDLP (ADLP) CALL REQUEST *p2*	ADCE (GDCE) CALL REQUEST *p*3	DATA TRANSFER *p*4	GDLP (ADLP) CLEAR REQUEST *p*6	ADCE (GDCE) to GDLP (ADLP) CLEAR REQUEST *p*7
CALL REQUEST (see Note 6)	*A=NORMAL* (5.2.6.3.1) *S=p*3 (forward)	INVALID (see Note 5)	INVALID (see Note 3)	INVALID (see Note 3)	INVALID (see Note 3)	INVALID (see Note 3)
CALL ACCEPT (see Note 4)	*A=DISCARD*	*A=NORMAL* *S=P*4 (forward)	INVALID (see Note 3)	INVALID (see Note 3)	*A=DISCARD*	*A=DISCARD*
CLEAR REQUEST (see Note 4)	*A=DISCARD*	*A=NORMAL* (5.2.6.3.3) *S=p*7 (forward)	*A=NORMAL* (5.2.6.3.3) *S=p*7 (forward)	*A=NORMAL* (5.2.6.3.3) *S=p*7 (forward)	*A=DISCARD*	*A=DISCARD*
DATA, INTERRUPT or RESET packets (see Note 4)	*A=DISCARD*	INVALID (see Note 3)	INVALID (see Note 3)	See Table 5-21	*A=DISCARD*	*A=DISCARD*

NOTES:

1. *The XDCE is not necessarily in the same state as the DTE/DCE interface.*
2. *This is the DTE packet received via the DCE after all DTE/DCE processing has occurred. Procedures local to the DTE/DCE interface (such as RR, RNR, and REJECT if in effect), do not affect the XDCE directly. All error procedures as documented in ISO 8208 have been performed. Hence certain packets are rejected by the interface and are not represented in this table.*
3. *The DCE in its protocol operation with the DTE will detect this error condition, hence the erroneous packet can be said never to "reach" the XDCE; see also Note 2.*
4. *The channel number for the DTE/DCE need not be the same channel number used for the ADCE/GDCE; a packet from the DTE which contains a channel number is associated with an air/ground channel by means of a previously established cross-reference table. If none exists then the DTE/DCE channel by definition references an air/ground channel in the* p*1 state.*
5. *The ADCE assigns all channel numbers used between the ADLP and GDLP; hence call collisions (denoted* p5 *ISO 8208) are not possible; see also Note 4.*
6. *A CALL REQUEST from the DTE can never be associated with an XDCE channel number which is not in the* p*1 state.*
7. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
8. *The number in parentheses below an "*A = NORMAL*" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Table 5-21. DCE effect on ADCE (GDCE) reset states

Packet received from DCE	ADCE (GDCE) reset states (see Notes 1, 4 and 5) FLOW CONTROL READY *d*1	GDLP (ADLP) RESET REQUEST *d*2	ADCE (GDCE) RESET REQUEST to GDLP (ADLP) *d*3
RESET REQUEST	*A=NORMAL* (5.2.6.7) *S=d*3 (forward)	*A=NORMAL* (5.2.6.7) *S=d*1 (forward)	*A=DISCARD*
RESET CONFIRMATION	INVALID (see Note 3)	INVALID (see Note 3)	INVALID (see Note 3)
INTERRUPT	See Table 5-22	*A=DISCARD*	Hold interrupt until Mode S reset complete
INTERRUPT CONFIRMATION	See Table 5-22	*A=DISCARD*	INVALID (see Note 3)
DATA (see Note 2)	*A=NORMAL* (5.2.6.4) (forward)	*A=DISCARD*	Hold data until Mode S reset complete

NOTES:

1. *The XDCE is not necessarily in the same state as the DTE/DCE interface.*
2. *This is the DTE packet received via the DCE after all DTE/DCE processing has occurred. Procedures local to the DTE/DCE interface (such as RR, RNR, and REJECT if in effect), do not affect the XDCE directly. All error procedures as documented in ISO 8208 have been performed. Hence certain packets are rejected by the interface and are not represented in this table.*
3. *The DCE in its protocol operation with the DTE will detect this error condition, hence the erroneous packet can be said never to "reach" the XDCE; see also Note 2.*
4. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
5. *The number in parentheses below an "*A = NORMAL*" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Table 5-22. DCE effect on ADCE (GDCE) interrupt transfer states

Packet received from DCE (see Note 2)	ADCE (GDCE) interrupt transfer state (see Notes 1, 4 and 5) GDLP (ADLP) INTERRUPT READY *i*1	GDLP (ADLP) INTERRUPT SENT *i*2
INTERRUPT CONFIRMATION	INVALID (See Note 3)	*A=NORMAL* (5.2.6.4.5) *S=i*1 (forward)
Packet received from DCE (see Note 2)	**ADCE (GDCE) interrupt transfer states (see Notes 1, 4 and 5) ADCE (GDCE) INTERRUPT READY *j*1**	**ADCE (GDCE) INTERRUPT SENT *j*2**
INTERRUPT	*A=NORMAL* (5.2.6.4.5) *S=j*2 (forward)	INVALID (see Note 3)

NOTES:

1. *The XDCE is not necessarily in the same state as the DTE/DCE interface.*
2. *This is the DTE packet received via the DCE after all DTE/DCE processing has occurred. Procedures local to the DTE/DCE interface (such as RR, RNR, and REJECT if in effect), do not affect the XDCE directly. All error procedures as documented in ISO 8208 have been performed. Hence certain packets are rejected by the interface and are not represented in this state.*
3. *The DCE in its protocol operation with the DTE will detect this error condition, hence the erroneous packet can be said never to "reach" the XDCE; see also Note 2.*
4. *Table entries are defined as follows:* A = *action to be taken,* S = *the state to be entered,* D = *the diagnostic code to be used in packets generated as a result of this action,* DISCARD *indicates that the received packet is to be cleared from the XDLP buffers, and INVALID indicates that the packet/state combination cannot occur.*
5. *The number in parentheses below an "*A = NORMAL*" table entry is the paragraph number in this document that defines the actions to be taken to perform normal processing on the received packet. If no paragraph number is referenced, the normal processing is defined in the table entry.*

Table 5-23. Broadcast identifier number assignments

Uplink broadcast identifier	*Assignment*
00_{16}	Not valid
01_{16}	Reserved (differential GNSS correction)
30_{16}	Not valid
31_{16}	Reserved for ACAS (RA broadcast)
32_{16}	Reserved for ACAS (ACAS broadcast)
Others	Unassigned
Downlink broadcast identifier	***Assignment***
00_{16}	Not valid
02_{16}	Reserved (traffic information service)
10_{16}	Data link capability report
20_{16}	Aircraft identification
FE_{16}	Update request
FF_{16}	Search request
Others	Unassigned

Table 5-24. Register number assignments

Transponder register No.	*Assignment*
00_{16}	Not valid
01_{16}	Unassigned
02_{16}	Linked Comm-B, segment 2
03_{16}	Linked Comm-B, segment 3
04_{16}	Linked Comm-B, segment 4
05_{16}	Extended squitter airborne position
06_{16}	Extended squitter surface position
07_{16}	Extended squitter status
08_{16}	Extended squitter identification and type
09_{16}	Extended squitter airborne velocity
$0A_{16}$	Extended squitter event-driven information
$0B_{16}$	Air/air information 1 (aircraft state)
$0C_{16}$	Air/air information 2 (aircraft intent)
$0D_{16}$-$0E_{16}$	Reserved for air/air state information
$0F_{16}$	Reserved for ACAS
10_{16}	Data link capability report
11_{16}-16_{16}	Reserved for extension to data link capability reports
17_{16}	Common usage GICB capability report
18_{16}-$1F_{16}$	Mode S specific services capability reports
20_{16}	Aircraft identification
21_{16}	Aircraft and airline registration markings
22_{16}	Antenna positions
23_{16}	Reserved for antenna position
24_{16}	Reserved for aircraft parameters
25_{16}	Aircraft type
26_{16}-$2F_{16}$	Unassigned
30_{16}	ACAS active resolution advisory
31_{16}-$3F_{16}$	Unassigned
40_{16}	Selected vertical intention
41_{16}	Next waypoint identifier
42_{16}	Next waypoint position
43_{16}	Next waypoint information
44_{16}	Meteorological routine air report

Transponder register No.	*Assignment*
45_{16}	Meteorological hazard report
46_{16}	Reserved for flight management system Mode 1
47_{16}	Reserved for flight management system Mode 2
48_{16}	VHF channel report
49_{16}-$4F_{16}$	Unassigned
50_{16}	Track and turn report
51_{16}	Position report coarse
52_{16}	Position report fine
53_{16}	Air-referenced state vector
54_{16}	Waypoint 1
55_{16}	Waypoint 2
56_{16}	Waypoint 3
57_{16}-$5E_{16}$	Unassigned
$5F_{16}$	Quasi-static parameter monitoring
60_{16}	Heading and speed report
61_{16}	Extended squitter emergency/priority status
62_{16}	Reserved for target state and status information
63_{16}	Reserved for extended squitter
64_{16}	Reserved for extended squitter
65_{16}	Aircraft operational status
66_{16}-$6F_{16}$	Reserved for extended squitter
70_{16}-75_{16}	Reserved for future aircraft downlink parameters
76_{16}-$E0_{16}$	Unassigned
$E1_{16}$-$E2_{16}$	Reserved for Mode S BITE
$E3_{16}$	Transponder type/part number
$E4_{16}$	Transponder software revision number
$E5_{16}$	ACAS unit part number
$E6_{16}$	ACAS unit software revision number
$E7_{16}$-$F0_{16}$	Unassigned
$F1_{16}$	Military applications
$F2_{16}$	Military applications
$F3_{16}$-FF_{16}	Unassigned

Note.— In the context of Table 5-24, the term “aircraft” can be understood as “transponder carrying aircraft”, “pseudo-aircraft (e.g. an obstacle)” or “vehicle”.

Table 5-25. MSP channel number assignments

Uplink channel number	*Assignment*
0	Not valid
1	Reserved (specific services management)
2	Reserved (traffic information service)
3	Reserved (ground-to-air alert)
4	Reserved (ground derived position)
5	ACAS sensitivity level control
6	Reserved (ground-to-air service request)
7	Reserved (air-to-ground service response)
8–63	Unassigned
Downlink channel number	*Assignment*
0	Not valid
1	Reserved (specific services management)
2	Unassigned
3	Reserved (data flash)
4	Reserved (position request)
5	Unassigned
6	Reserved (ground-to-air service response)
7	Reserved (air-to-ground service request)
8–63	Unassigned

FIGURES FOR CHAPTER 5

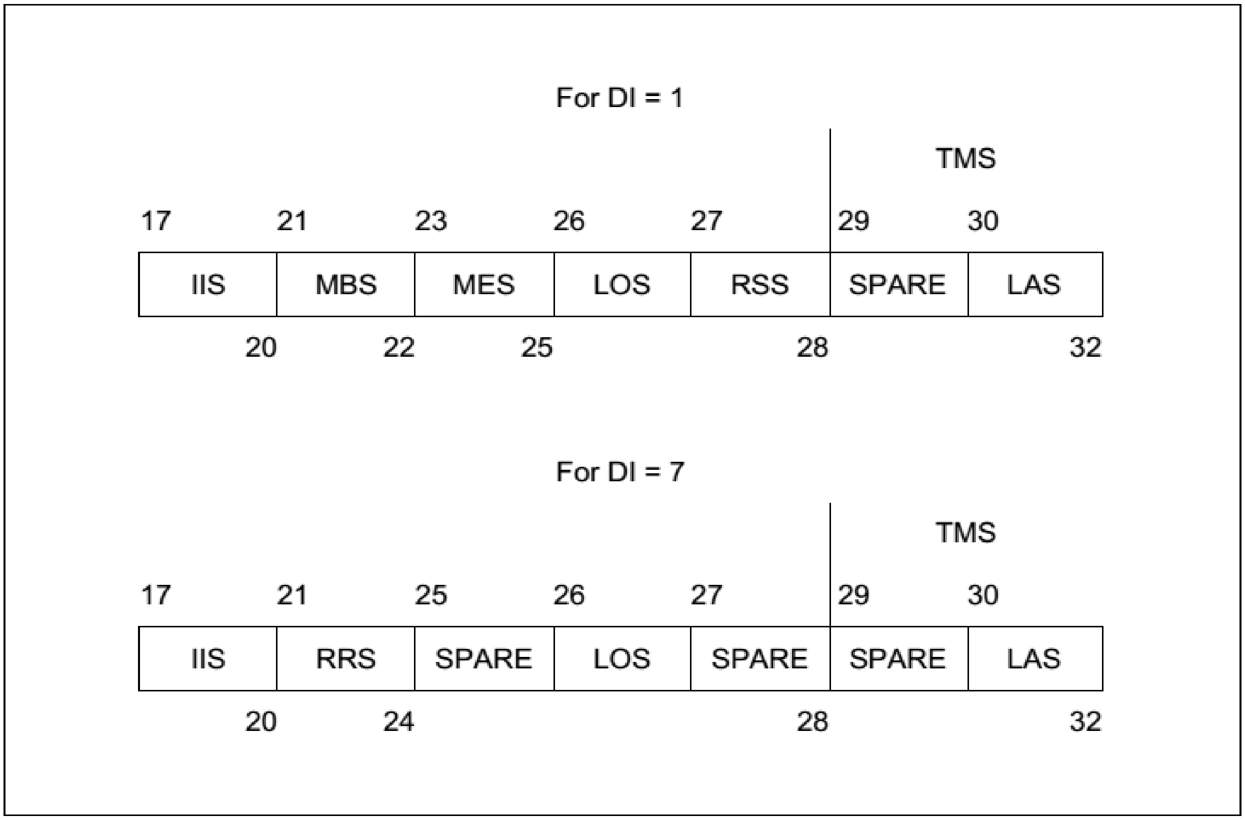
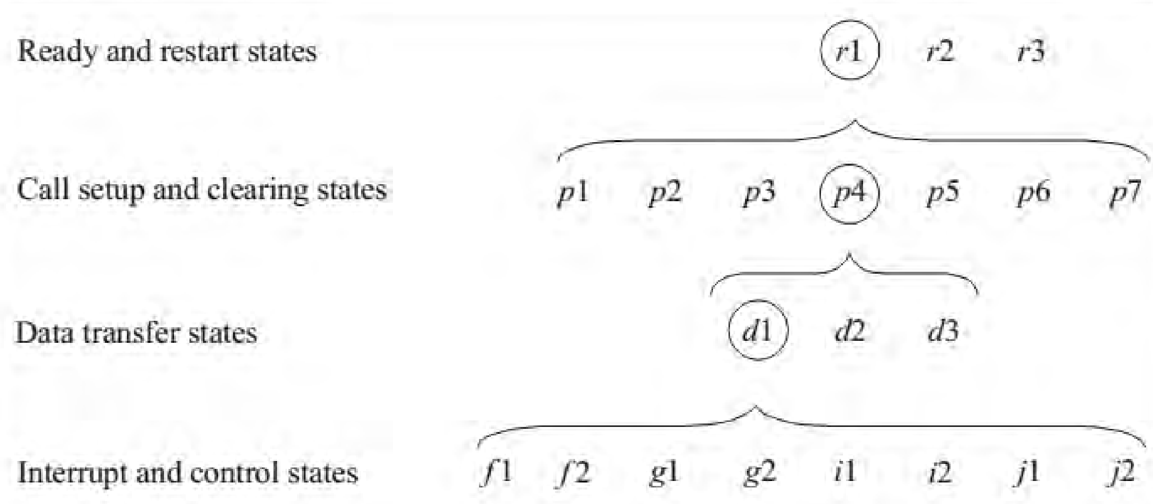


Figure 5-1. The SD field structure



Note.— States r*1,* p*4 and* d*1 (shown circled) are states that provide access to the lower levels of the DCE substate hierarchy.*

Figure 5-2. DCE substate hierarchy

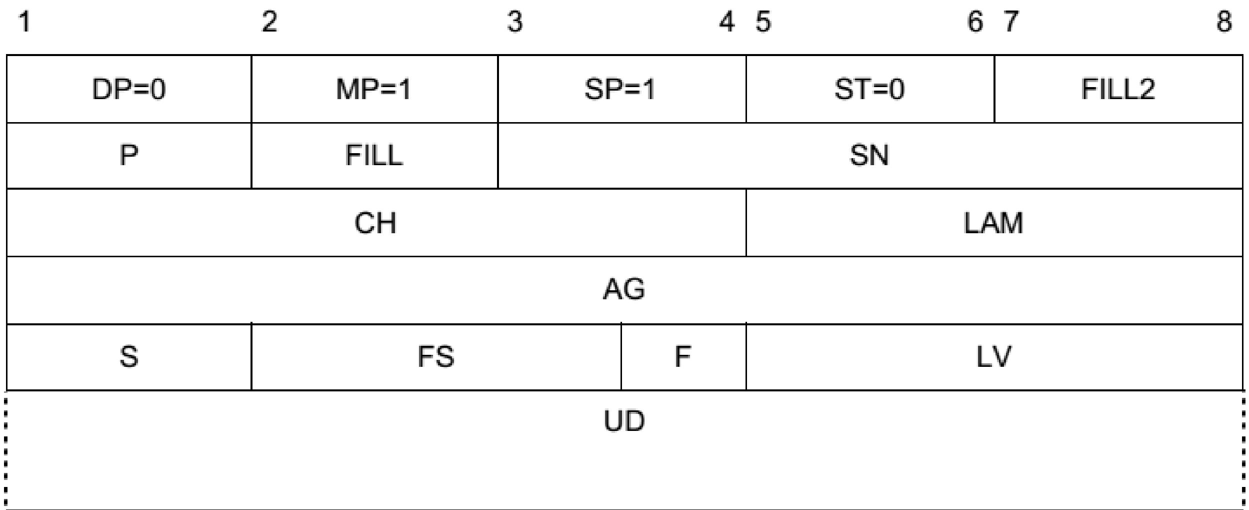


Figure 5-3. CALL REQUEST by ADLP packet

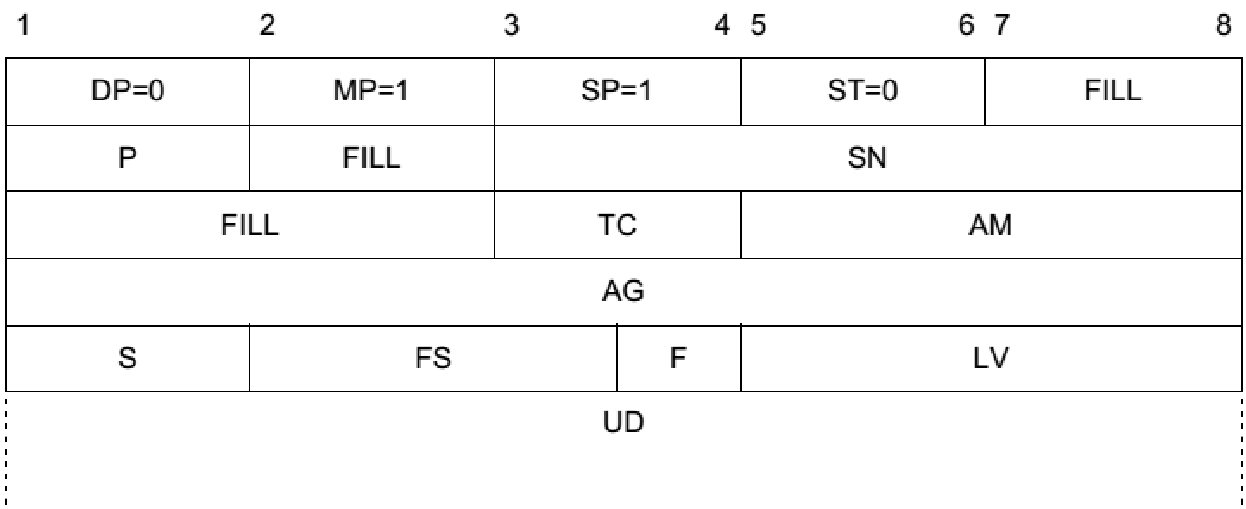


Figure 5-4. CALL REQUEST by GDLP packet

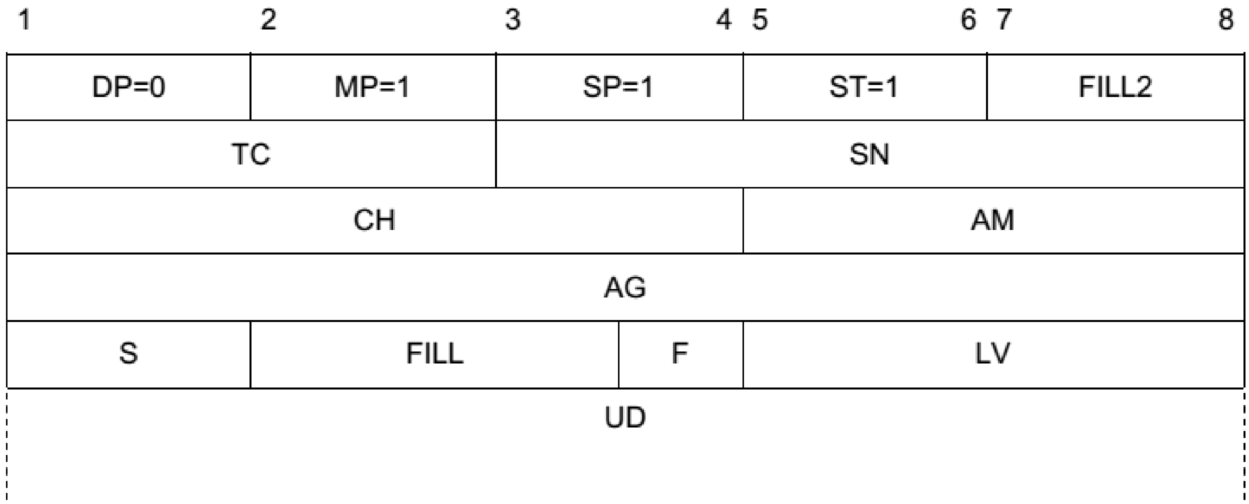


Figure 5-5. CALL ACCEPT by ADLP packet

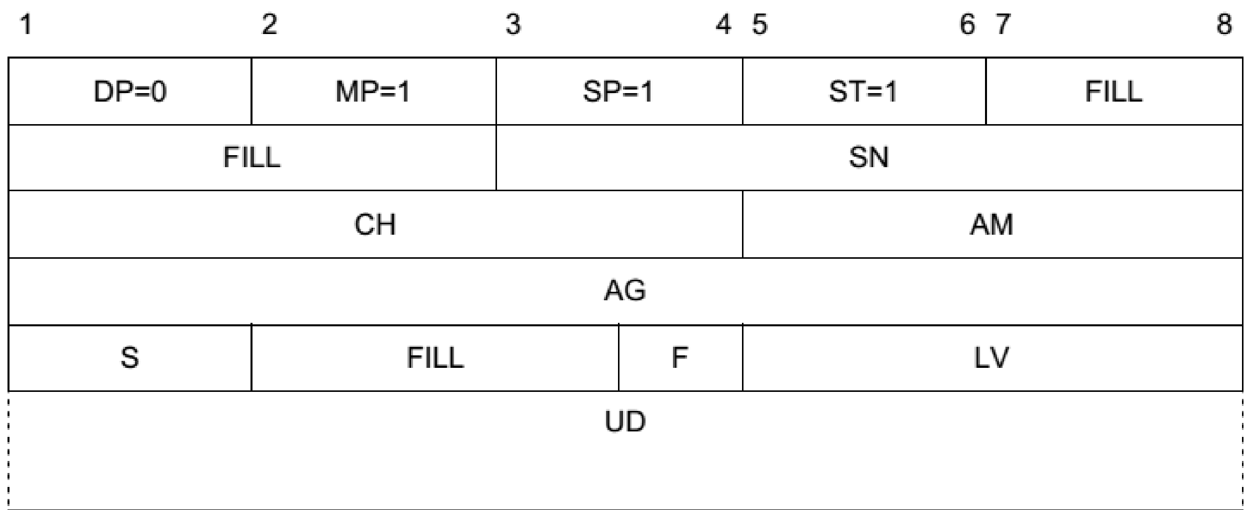


Figure 5-6. CALL ACCEPT by GDLP packet

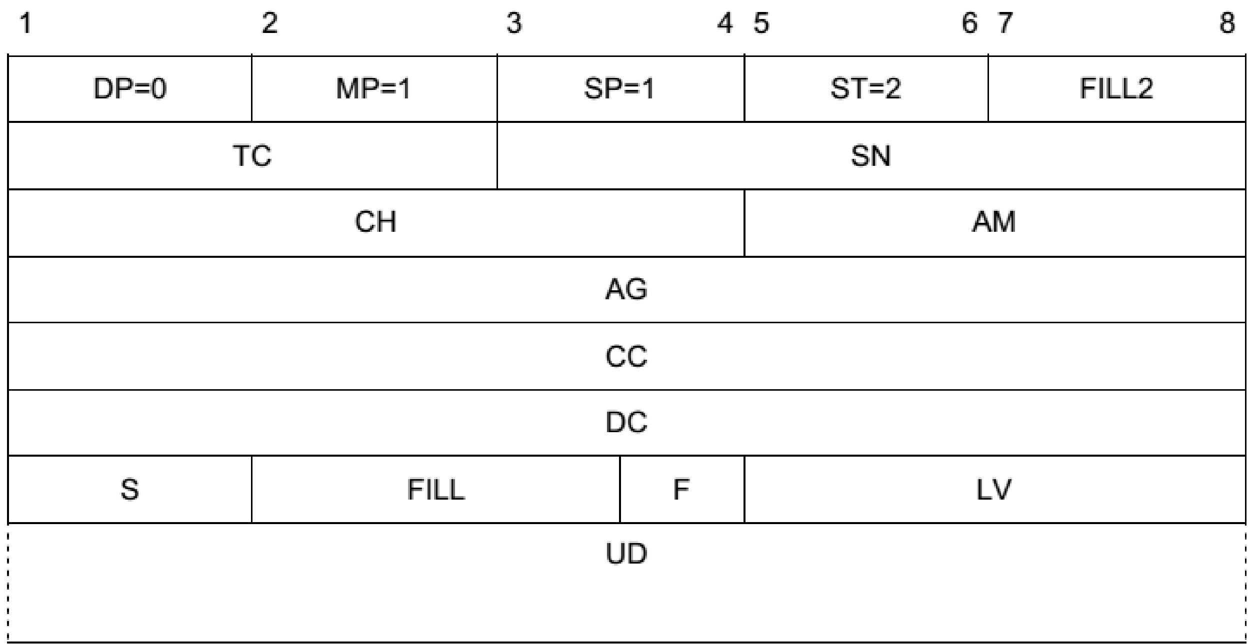


Figure 5-7. CLEAR REQUEST by ADLP packet

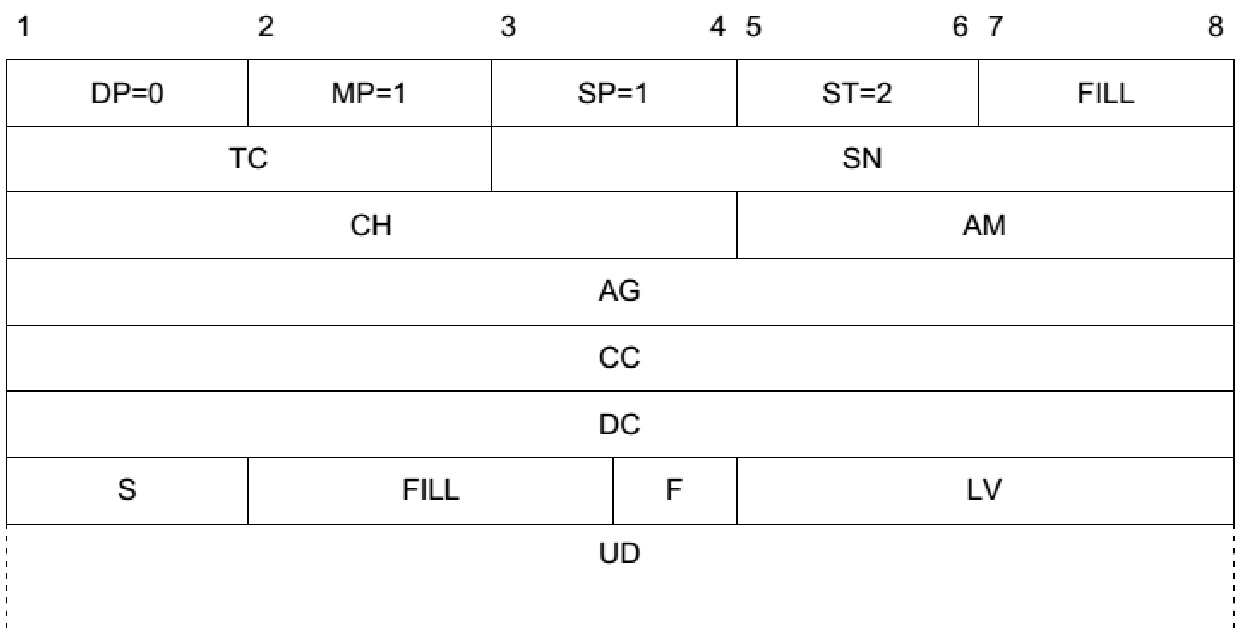


Figure 5-8. CLEAR REQUEST by GDLP packet

<table>
<tr><td colspan="5">1 2 3 4 5 6 7 8</td></tr>
<tr><td>DP=0</td><td>MP=1</td><td>SP=1</td><td>ST=3</td><td>FILL2</td></tr>
<tr><td colspan="2">TC</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">AM</td></tr>
<tr><td colspan="5">AG</td></tr>
</table>

Figure 5-9. CLEAR CONFIRMATION by ADLP packet

<table>
<tr><td colspan="5">1 2 3 4 5 6 7 8</td></tr>
<tr><td>DP=0</td><td>MP=1</td><td>SP=1</td><td>ST=3</td><td>FILL</td></tr>
<tr><td colspan="2">TC</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">AM</td></tr>
<tr><td colspan="5">AG</td></tr>
</table>

Figure 5-10. CLEAR CONFIRMATION by GDLP packet

<table>
<tr><td colspan="5">1 2 3 4 5 6 7 8</td></tr>
<tr><td>DP=1</td><td>M</td><td colspan="3">SN</td></tr>
<tr><td colspan="4">FILL1</td><td></td></tr>
<tr><td colspan="3">PS</td><td colspan="2">PR</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">LV</td></tr>
<tr><td colspan="5">UD</td></tr>
</table>

Figure 5-11. DATA packet

1 2 3 4 5 6 7 8

<table>
<tr><td>DP=0</td><td>MP=1</td><td>SP=3</td><td>ST=1</td><td>FILL2</td></tr>
<tr><td>S</td><td>F</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">LV</td></tr>
<tr><td colspan="5">UD</td></tr>
</table>

Figure 5-12. INTERRUPT packet

1 2 3 4 5 6 7 8

<table>
<tr><td>DP=0</td><td>MP=1</td><td>SP=3</td><td>ST=3</td><td>SS=0</td></tr>
<tr><td colspan="2">FILL2</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">FILL</td></tr>
</table>

Figure 5-13. INTERRUPT CONFIRMATION packet

1 2 3 4 5 6 7 8

<table>
<tr><td>DP=0</td><td>MP=1</td><td>SP=3</td><td>ST=3</td><td>SS=1</td></tr>
<tr><td colspan="2">FILL2</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">PR</td></tr>
</table>

Figure 5-14. REJECT packet

1 2 3 4 5 6 7 8

<table>
<tr><td>DP=0</td><td>MP=1</td><td>SP=2</td><td>ST=0</td><td>FILL2</td></tr>
<tr><td colspan="2">FILL</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">PR</td></tr>
</table>

Figure 5-15. RECEIVE READY packet

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4 5</th><th>6 7 8</th></tr>
<tr><td>DP=0</td><td>MP=1</td><td>SP=2</td><td>ST=1</td><td>FILL2</td></tr>
<tr><td colspan="2">FILL</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">PR</td></tr>
</table>

Figure 5-16. RECEIVE NOT READY packet

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4 5</th><th>6 7 8</th></tr>
<tr><td>DP=0</td><td>MP=1</td><td>SP=2</td><td>ST=2</td><td>FILL2</td></tr>
<tr><td colspan="2">FILL</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">FILL</td></tr>
<tr><td colspan="5">RC</td></tr>
<tr><td colspan="5">DC</td></tr>
</table>

Figure 5-17. RESET REQUEST packet

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4 5</th><th>6 7 8</th></tr>
<tr><td>DP=0</td><td>MP=1</td><td>SP=2</td><td>ST=3</td><td>FILL2</td></tr>
<tr><td colspan="2">FILL</td><td colspan="3">SN</td></tr>
<tr><td colspan="3">CH</td><td colspan="2">FILL</td></tr>
</table>

Figure 5-18. RESET CONFIRMATION packet

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4 5</th><th>6 7</th><th>8</th></tr>
<tr><td>DP=0</td><td>MP=1</td><td>SP=3</td><td>ST=0</td><td>OF</td><td>IN</td></tr>
<tr><td colspan="6">RTL</td></tr>
<tr><td colspan="6">RT</td></tr>
<tr><td colspan="6">ODL</td></tr>
<tr><td colspan="6">OD</td></tr>
</table>

Figure 5-19. ROUTE packet

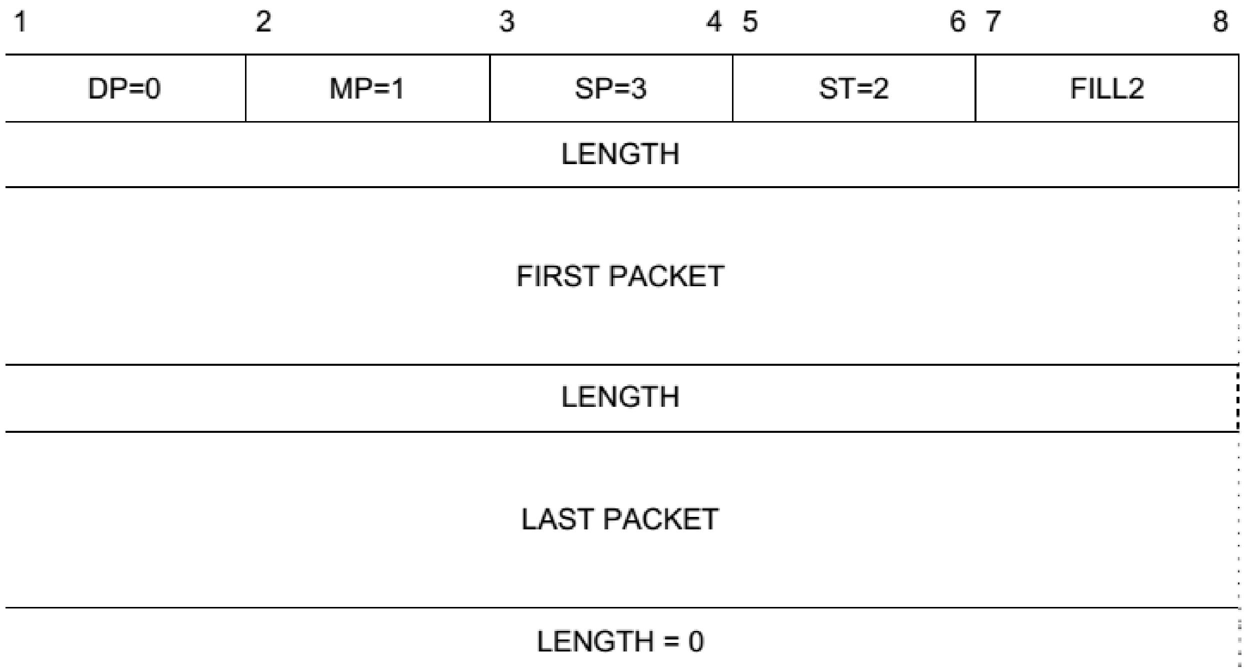


Figure 5-20. MULTIPLEX packet

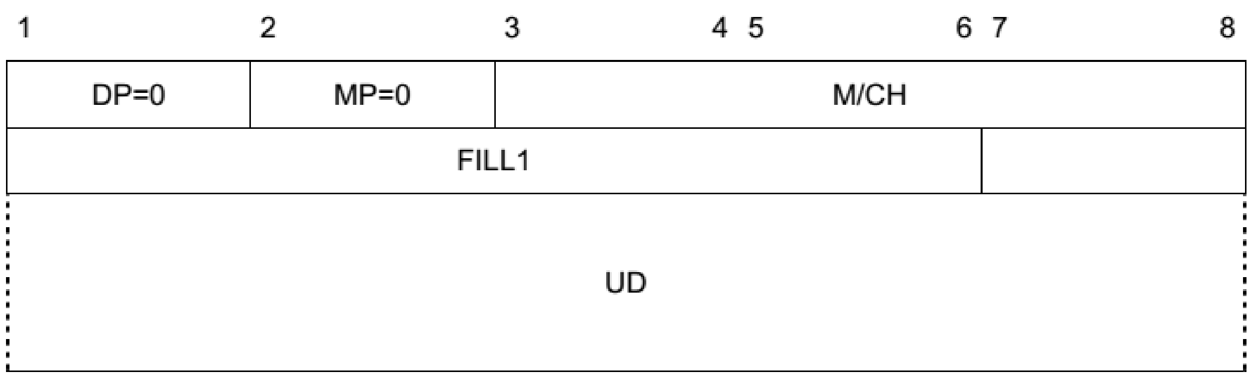


Figure 5-21. SHORT FORM MSP packet

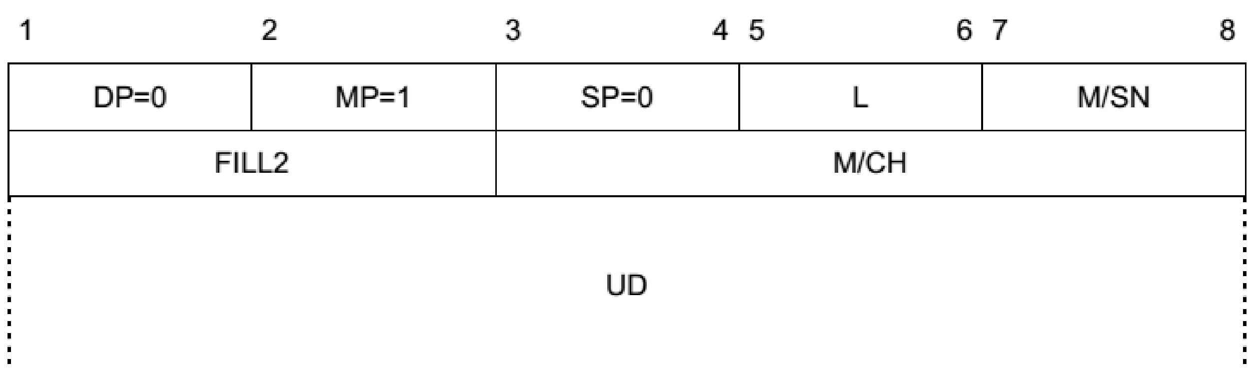
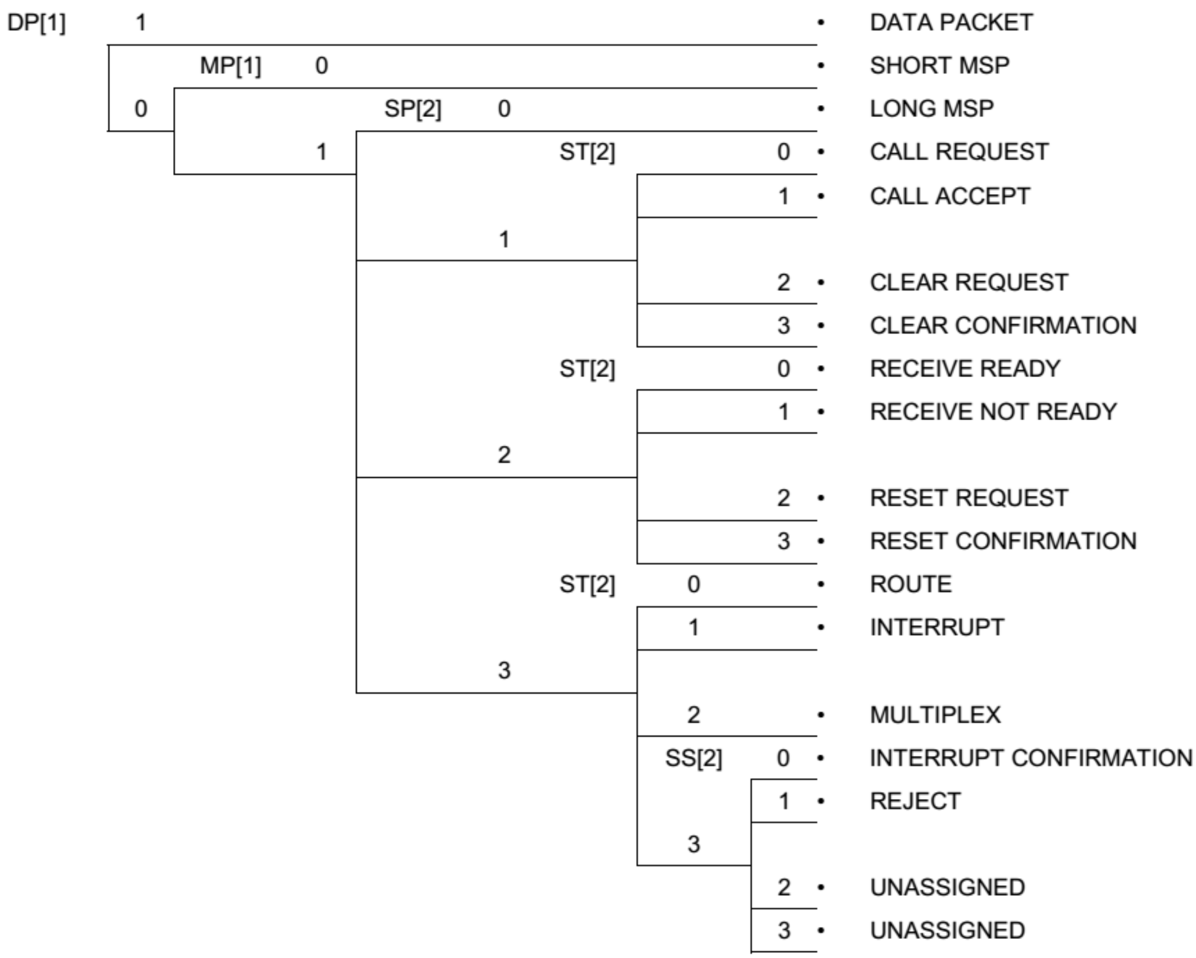


Figure 5-22. LONG FORM MSP packet



LEGEND:

DP = DATA packet type

MP = MSP packet type

SP = SUPERVISORY packet

ST = SUPERVISORY type

SS = SUPERVISORY subset

Figure 5-23. Control fields used in MODE S packets

CHAPTER 6. VHF AIR-GROUND DIGITAL LINK (VDL)

6.1 DEFINITIONS ANDSYSTEM CAPABILITIES

Note 1.— The very high frequency (VHF) digital link (VDL) Mode 2 and the VDL Mode 4 provide data service capabilities. The VDL Mode 3 provides both voice and data service capabilities. The data capability is a constituent mobile subnetwork of the aeronautical telecommunication network (ATN). In addition, the VDL may provide non-ATN functions. Standards and Recommended Practices (SARPs) for the VDL are defined and referenced below.

Note 2.— Additional information on VDL is contained in the Manuals on VHF VDL Mode 2, VDL Mode 3 and VDL Mode 4 Technical Specifications (Docs 9776, 9805 and 9816).

Note 3.— Sections 6.1.2 to 6.8.2 contain Standards and Recommended Practices for VDL Modes 2 and 3. Section 6.9 contains Standards and Recommended Practices for VDL Mode 4.

6.1.1 Definitions

Automatic dependent surveillance-broadcast (ADS-B). A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.

Broadcast. A transmission of information relating to air navigation that is not addressed to a specific station or stations.

Burst. A time-defined, contiguous set of one or more related signal units which may convey user information and protocols, signalling, and any necessary preamble.

Current slot. The slot in which a received transmission begins.

Data circuit-terminating equipment (DCE). A DCE is a network provider equipment used to facilitate communications between DTEs.

Data link entity (DLE). A protocol state machine capable of setting up and managing a single data link connection.

Data link service (DLS) sublayer. The sublayer that resides above the MAC sublayer. For VDL Mode 4, the DLS sublayer resides above the VSS sublayer. The DLS manages the transmit queue, creates and destroys DLEs for connection oriented communications, provides facilities for the LME to manage the DLS, and provides facilities for connectionless communications.

Data terminal equipment (DTE). A DTE is an endpoint of a subnetwork connection.

Extended Golay Code. An error correction code capable of correcting multiple bit errors.

Frame. The link layer frame is composed of a sequence of address, control, FCS and information fields. For VDL Mode 2, these fields are bracketed by opening and closing flag sequences, and a frame may or may not include a variable-length information field.

Gaussian filtered frequency shift keying (GFSK). A continuous-phase, frequency shift keying technique using two tones and a Gaussian pulse shape filter.

Global signalling channel (GSC). A channel available on a worldwide basis which provides for communication control.

Link. A link connects an aircraft DLE and a ground DLE and is uniquely specified by the combination of aircraft DLS address and the ground DLS address. A different subnetwork entity resides above every link endpoint.

Link layer. The layer that lies immediately above the physical layer in the Open Systems Interconnection protocol model. The link layer provides for the reliable transfer of information across the physical media. It is subdivided into the data link sublayer and the media access control sublayer.

Link management entity (LME). A protocol state machine capable of acquiring, establishing and maintaining a connection to a single peer system. An LME establishes data link and subnetwork connections, "hands-off" those connections, and manages the media access control sublayer and physical layer. An aircraft LME tracks how well it can communicate with the ground stations of a single ground system. An aircraft VME instantiates an LME for each ground station that it monitors. Similarly, the ground VME instantiates an LME for each aircraft that it monitors. An LME is deleted when communication with the peer system is no longer viable.

M burst. A management channel data block of bits used in VDL Mode 3. This burst contains signalling information needed for media access and link status monitoring.

Media access control (MAC). The sublayer that acquires the data path and controls the movement of bits over the data path.

Mode 2. A data-only VDL mode that uses D8PSK modulation and a carrier sense multiple access (CSMA) control scheme.

Mode 3. A voice and data VDL mode that uses D8PSK modulation and a TDMA media access control scheme.

Mode 4. A data-only VDL mode using a GFSK modulation scheme and self-organizing time division multiple access (STDMA).

Physical layer. The lowest level layer in the Open Systems Interconnection protocol model. The physical layer is concerned with the transmission of binary information over the physical medium (e.g. VHF radio).

Quality of service. The information relating to data transfer characteristics used by various communication protocols to achieve various levels of performance for network users.

Reed-Solomon code .An error correction code capable of correcting symbol errors. Since symbol errors are collections of bits, these codes provide good burst error correction capabilities.

Self-organizing time division multiple access (STDMA). A multiple access scheme based on time-shared use of a radio frequency (RF) channel employing: (1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to mediate access to these time slots without reliance on a master control station.

Slot. One of a series of consecutive time intervals of equal duration. Each burst transmission starts at the beginning of a slot.

Subnetwork connection. A long-term association between an aircraft DTE and a ground DTE using successive virtual calls to maintain context across link handoff.

Subnetwork dependent convergence function (SNDCF). A function that matches the characteristics and services of a particular subnetwork to those characteristics and services required by the internetwork facility.

Subnetwork entity. In this document, the phrase "ground DCE" will be used for the subnetwork entity in a ground station communicating with an aircraft; the phrase "ground DTE" will be used for the subnetwork entity in a ground router communicating with an aircraft station; and, the phrase "aircraft DTE" will be used for the subnetwork entity in an aircraft communicating with the station. A subnetwork entity is a packet layer entity as defined in ISO 8208.

Subnetwork layer. The layer that establishes, manages and terminates connections across a subnetwork.

System. A VDL-capable entity. A system comprises one or more stations and the associated VDL management entity. A system may either be an aircraft system or a ground system.

Time division multiple access (TDMA). A multiple access scheme based on time-shared use of an RF channel employing:

(1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to interact with a master control station to mediate access to the channel.

User group. A group of ground and/or aircraft stations which share voice and/or data connectivity. For voice communications, all members of a user group can access all communications. For data, communications include point-to-point connectivity for air-to-ground messages, and point-to-point and broadcast connectivity for ground-to-air messages.

VDL management entity (VME). A VDL-specific entity that provides the quality of service requested by the ATN-defined

SN_SME. A VME uses the LMEs (that it creates and destroys) to enquire the quality of service available from peer systems.

VDL Mode 4 burst. A VHF digital link (VDL) Mode 4 burst is composed of a sequence of source address, burst ID, information, slot reservation and frame check sequence (FCS) fields, bracketed by opening and closing flag sequences.

Note.— The start of a burst may occur only at quantized time intervals and this constraint allows the propagation delay between the transmission and reception to be derived.

VDL Mode 4 DLS system. A VDL system that implements the VDL Mode 4 DLS and subnetwork protocols to carry ATN packets or other packets.

VDL Mode 4 specific services (VSS) sublayer. The sublayer that resides above the MAC sublayer and provides VDL Mode 4 specific access protocols including reserved, random and fixed protocols.

VDL station. An aircraft-based or ground-based physicalentity, capable of VDL Mode 2, 3 or 4.

Note.— In the context of this chapter, a VDL station is also referred to as a "station".

Vocoder. A low bit rate voice encoder/decoder.

Voice unit. A device that provides a simplex audio and signalling interface between the user and VDL.

VSS user. A user of the VDL Mode 4 specific services. The VSS user could be higher layers in the VDL Mode 4 SARPs or an external application using VDL Mode 4.

6.1.2 Radio channels and functional channels

6.1.2.1 **Aircraft station radio frequency range.** An aircraft station shall be capable of tuning to any of the channels in the range specified in Section 6.1.4.1 within 100 milliseconds after the receipt of an autotune command. In addition, for VDL Mode 3, an aircraft station shall be able to tune to any channel in the range specified in Section 6.1.4.1 within 100 milliseconds after the receipt of any tuning command.

6.1.2.2 **Ground station radio frequency range**. A ground station shall be capable of operating on its assigned channel within the radio frequency range detailed in 6.1.4.1.

6.1.2.3 **Common signalling channel.** Frequency 136.975MHz shall be reserved as a worldwide common signalling channel (CSC) for VDL Mode 2.

6.1.3 System capabilities

6.1.3.1 **Data transparency.** The VDL system shall provide code-independent, byte-independent transfer of data.

6.1.3.2 **Broadcast**. The VDL system shall provide link layer data broadcast services (Mode 2) and/or voice and data broadcast services (Mode 3). For VDL Mode 3, the data broadcast service shall support network multicasting capability originating from the ground.

6.1.3.3 **Connection management.** The VDL system shall establish and maintain a reliable communications path between the aircraft and the ground system while allowing but not requiring manual intervention.

Note.— In this context "reliable" is defined by the BER requirement specified in 6.3.5.1.

6.1.3.4 **Ground network transition.** A VDL-equipped aircraft shall transition from one ground station to another when circumstances dictate.

6.1.3.5 **Voice capability.** The VDL Mode 3 system shall support a transparent, simplex voice operation based on a "Listen-Before-Push-To-Talk" channel access.

6.1.4 Air-ground VHF digital link communications system characteristics

6.1.4.1 The radio frequencies used shall be selected from the radio frequencies in the band 117.975–137 MHz. The lowest assignable frequency shall be 118.000 MHz, and the highest assignable frequency shall be 136.975 MHz. The separation between assignable frequencies(channel spacing) shall be 25 kHz.

Note.— Volume V specifies that the block of frequencies from 136.9 – 136.975 MHz inclusive is reserved for VHF air-ground digital communications.

6.1.4.2 The design polarization of emissions shall be vertical.

6.2 SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

6.2.1 Ground station transmitting function

6.2.1.1 **Frequency stability**. The radio frequency of VDL ground station equipment operation shall not vary more than plus or minus 0.0002 per cent (2 parts per million) from the assigned frequency.

Note.— The frequency stability for VDL ground stations using DSB-AM modulation is specified in Part II, Chapter 2 for 25 kHz channel spacing.

6.2.2 Power

Recommendation.—The effective radiated power should be such as to provide a field strength of at least 75 microvolts per metre (minus 109 dBW/m2) within the defined operational coverage of the facility, on the basis of free-space propagation.

6.2.3 Spurious emissions

6.2.3.1 Spurious emissions shall be kept at the lowest value which the state of the technique and the nature of the service permit.

Note.— Appendix S3 to the Radio Regulations specifies the levels of spurious emissions to which transmitters must conform.

6.2.4 Adjacent channel emissions

6.2.4.1 The amount of power from a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 0 dBm.

6.2.4.1.1 After 1 January 2002, the amount of power from all new installations of a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 2 dBm.

6.2.4.2 The amount of power from a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 25 dBm and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 52 dBm.

6.2.4.2.1 After 1 January 2002, the amount of power from all new installations of a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 28 dBm.

6.2.4.2.2 After 1 January 2002, the amount of power from all new installations of a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the fourth adjacent channel shall be less than minus 38 dBm, and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 53 dBm.

6.2.4.3 The amount of power from a VDL ground transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 20 dBm.

6.2.4.3.1 After 1 January 2002, the amount of power from all new installations of a VDL ground transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 18 dBm.

6.2.4.4 After 1 January 2005, all VDL ground transmitters shall meet the provisions of 6.2.4.1.1, 6.2.4.2.1, 6.2.4.2.2 and 6.2.4.3.1, subject to the conditions of 6.2.4.5.

6.2.4.5 Requirements of mandatory compliance of the provisions of 6.2.4.4 shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales. The agreements shall provide at least two years' notice of mandatory compliance of ground systems.

6.3 SYSTEM CHARACTERISTICSOF THE AIRCRAFT INSTALLATION

6.3.1 *Frequency stability*. The radio frequency of VDL aircraft equipment shall not vary more than plus or minus 0.0005 per cent (5 parts per million) from the assigned frequency.

6.3.2 *Power*. The effective radiated power shall be such as to provide a field strength of at least 20 microvolts per metre (minus 120 dBW/m2) on the basis of free-space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated.

6.3.3 Spurious emissions

6.3.3.1 Spurious emissions shall be kept at the lowest value which the state of the technique and the nature of the service permit.

Note.— Appendix S3 to the Radio Regulations specifies the levels of spurious emissions to which transmitters must conform.

6.3.4 Adjacent channel emissions

6.3.4.1 The amount of power from a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 0 dBm.

6.3.4.1.1 After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 2 dBm.

6.3.4.2 The amount of power from a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 25 dBm and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 52 dBm.

6.3.4.2.1 After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 28 dBm.

6.3.4.2.2 After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the fourth adjacent channel shall be less than minus 38 dBm, and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 53 dBm.

6.3.4.3 The amount of power from a VDL aircraft transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 20 dBm.

6.3.4.3.1 After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 18 dBm.

6.3.4.4 After 1 January 2005, all VDL aircraft transmitters shall meet the provisions of 6.3.4.1.1, 6.3.4.2.1, 6.3.4.2.2 and 6.3.4.3.1, subject to the conditions of 6.3.4.5.

6.3.4.5 Requirements of mandatory compliance of the provisions of 6.3.4.4 shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales. The agreements shall provide at least two years' notice of mandatory compliance of aircraft systems.

6.3.5 Receiving function

6.3.5.1 *Specified error rate.* The specified error rate for Mode 2 operation shall be the maximum corrected Bit Error Rate (BER) of 1 in 104. The specified error rate for Mode 3 operation shall be the maximum uncorrected BER of 1 in 103. The specified error rate for Mode 4 operation shall be the maximum uncorrected BER of 1 in 104.

Note.— The above physical layer BER requirements are derived from the BER requirement imposed by ATN at the subnetwork interface.

6.3.5.2 *Sensitivity.* The receiving function shall satisfy the specified error rate with a desired signal strength of not more than 20 microvolts per metre (minus 120 dBW/m2).

Note.— The required signal strength at the edge of the service volume takes into account the requirements of the system and signal losses within the system, and considers environmental noise sources.

6.3.5.3 Out-of-band immunity performance. The receiving function shall satisfy the specified error rate with a desired signal field strength of not more than 40 microvolts per metre (minus 114 dBW/m2) and with an undesired DSB-AM D8PSK or GFSK signal on the adjacent or any other assignable channel being at least 40 dB higher than the desired signal.

6.3.5.3.1 After 1 January 2002, the receiving function of all new installations of VDL shall satisfy the specified error rate with a desired signal field strength of not more than

40 microvolts per metre (minus 114 dBW/m2) and with an undesired VHF DSB-AM, D8PSK or GFSK signal at least 60 dB higher than the desired signal on any assignable channel 100 kHz or more away from the assigned channel of the desired signal.

Note.— This level of interference immunity performance provides a receiver performance consistent with the influence of the VDL RF spectrum mask as specified in 6.3.4 with an effective isolation transmitter/receiver isolation of 69 dB. Better transmitter and receiver performance could result in less isolation required. Guidance material on the measurement technique is included in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies(Doc 9718).

6.3.5.3.2 After 1 January 2005, the receiving function of all installations of VDL shall meet the provisions of6.3.5.3.1, subject to the conditions of 6.3.5.3.3.

6.3.5.3.3 Requirements of mandatory compliance of the provisions of 6.3.5.3.2 shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales. The agreement shall provide for at least two years' notice of mandatory compliance of aircraft systems.

6.3.5.4 INTERFERENCE IMMUNITY PERFORMANCE

6.3.5.4.1 The receiving function shall satisfy the specified error rate with a desired field strength of not more than 40 microvolts per metre, and with one or more out-of-band signals, except for VHF FM broadcast signals, having a total level at the receiver input of minus 33 dBm.

Note.— In areas where adjacent higher band signal interference exceeds this specification, a higher immunity requirement will apply.

6.3.5.4.2 The receiving function shall satisfy the specified error rate with a desired field strength of not more than 40 microvolts per metre, and with one or more VHF FM broadcast signals having a total level at the receiver input of minus 5 dBm.

6.4 PHYSICAL LAYER PROTOCOLS AND SERVICES

The aircraft and ground stations shall access the physical medium operating in simplex mode.

6.4.1 Functions

6.4.1.1 The physical layer shall provide the following functions:

a) transmitter and receiver frequency control;

b) digital reception by the receiver;

c) digital transmission by the transmitter; and

d) notification services.

6.4.1.1.1 *Transmitter/receiver frequency control.* The VDL physical layer shall set the transmitter or receiver frequency as commanded by the link management entity (LME).

Note.— The LME is a link layer entity as contained in the Manuals on VDL Mode 2 and VDL Mode 3 Technical Specifications.

6.4.1.1.2 Digital reception by the receiver. The receiver shall decode input signals and forward them to the higher layers for processing.

6.4.1.1.3 *Digital transmission*. The VDL physical layer shall appropriately encode and transmit information received from higher layers over the RF channel.

6.4.2 Modes 2 and 3 common physical layer

6.4.2.1 *Modulation scheme.* Modes 2 and 3 shall use differentially encoded 8 phase shift keying (D8PSK), using a raised cosine filter with α= 0.6 (nominal value). The information to be transmitted shall be differentially encoded with 3 bits per symbol (baud) transmitted as changes in phase rather than absolute phase. The data stream to be transmitted shall be divided into groups of 3 consecutive data bits, least significant bit first. Zeros shall be padded to the end of the transmissions if needed for the final channel symbol.

6.4.2.1.1 *Data encoding*. A binary data stream entering a differential data encoder shall be converted into three separate binary streams X, Y, and Z so that bits 3n form X, bits 3n + 1 form Y, and bits 3n + 2 form Z. The triplet at time k (Xk, Yk, Zk) shall be converted to a change in phase as shown in Table 6-1[4], and the absolute phase Φk is the accumulated series of ΔΦk, that is:

$$\phi_k = \phi_{k-1} + \Delta\phi_k$$

6.4.2.1.2 *Transmitted signal form*. The phase-modulated baseband signal as defined in 6.4.2.1.1 shall excite the pulse shape filter.

$$s(t) = \sum_{k=-\infty}^{+\infty} h(\phi_k, t - kT_s)$$

[4] All tables are located at the end of this chapter

where:

h is the complex impulse response of the pulse shape filter;
k is defined in 6.4.2.1.1;
Φ is defined by the equation in 6.4.2.1.1;
t is time;
Ts is time duration of each symbol.

The output (function of time) of the pulse shape filter (s(t)) shall modulate the carrier frequency. The pulse shape filter shall have a nominal complex frequency response of a raised-cosine filter with α=0.6.

6.4.2.2 *Modulation rate*. The symbol rate shall be 10 500 symbols/second, resulting in a nominal bit rate of 31 500 bits/s. The modulation stability requirements for Modes 2 and 3 are provided in Table 6-2.

6.4.3 Mode 2 specific physical layer

Note.— The Mode 2 specific physical layer specification includes a description of the Mode 2 training sequence, forward error correction (FEC), interleaving, bit scrambling, channel sensing, and physical layer system parameters.

6.4.3.1 To transmit a sequence of frames, a station shall insert the bit numbers and flags (per the data link service description for Mode 2 as contained in the Manual on VDL Mode 2 Technical Specifications), compute the FEC (per 6.4.3.1.2), interleave (per 6.4.3.1.3), prepend the training sequence (per 6.4.3.1.1), carry out bit scrambling (per 6.4.3.1.4) and finally encode and modulate the RF signal (per 6.4.2.1).

6.4.3.1.1 *Training sequence*. Data transmission shall begin with a demodulator training sequence consisting of five segments:

a) transmitter ramp-up and power stabilization;

b) synchronization and ambiguity resolution;

c) reserved symbol;

d) transmission length; and

e) header FEC.

Note.— Immediately after these segments follows an AVLC frame with the format as contained in the data link service description in the Manual on VDL Mode 2 Technical Specifications.

6.4.3.1.1.1 *Transmitter ramp-up and power stabilization.* The purpose of the first segment of the training sequence, called the ramp-up, is to provide for transmitter power stabilization and receiver AGC settling, and it shall immediately precede the first symbol of the unique word. The duration of the ramp-up shall be five symbol periods. The time reference point (t), for the following specification is the centre of the first unique word symbol, a point that occurs half a symbol period after the end of the ramp-up. Conversely stated, the beginning of the ramp-up starts at t = –5.5 symbol periods. The transmitted power shall be less than –40 dBc prior to time t = –5.5 symbol periods. The ramp-up shall provide that at time t = –3.0 symbol periods the transmitted power is 90 per cent of the manufacturer's stated output power or greater (see Figure 6-1[5]). Regardless of the method used to implement (or truncate) the raised cosine filter, the output of the transmitter between times t = –3.0 and t = –0.5 will appear as if '000' symbols were transmitted during the ramp-up period.

Note. 1.— For Mode 3, the timing reference point is the same as the "power reference point".

Note 2.— It is desirable to maximize the time allowed for the AGC settling time. Efforts should be made to have power above 90 per cent of nominal output power at t – 3.5 symbol periods.

6.4.3.1.1.2 Synchronization and ambiguity resolution. The second segment of the training sequence shall consist of the unique word:

000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010

and shall be transmitted from left to right.

6.4.3.1.1.3 Reserved symbol. The third segment of the training sequence shall consist of the single symbol representing 000.

Note.— This field is reserved for future definition.

6.4.3.1.1.4 Transmission length. To allow the receiver to determine the length of the final Reed-Solomon block, the transmitter shall send a 17-bit word, from least significant bit (lsb) to most significant bit (msb), indicating the total number of data bits that follow the header FEC.

Note.— The length does not include those bits transmitted for: the Reed Solomon FEC, extra bits padded to ensure that the inter leaver generates an integral number of 8-bit words, or the extra bits padded to ensure that the data encoder generates an integral number of 3-bit symbols.

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[5] All figures are located at the end of this chapter.

6.4.3.1.1.5 *Header FEC*. To correct bit errors in the header, a (25, 20) block code shall be computed over the reserved symbol and the transmission length segments. The block code shall be transmitted as the fifth segment. The encoder shall accept the header in the bit sequence that is being transmitted. The five parity bits to be transmitted shall be generated using the following equation:

$$[P_1 , \ldots , P_5] = [R_1 , \ldots , R_3 , TL_1 , \ldots , TL_{17}] H^T$$

where:

P is the parity symbol (P1shall be transmitted first);

R is the reserved symbol;

TL is the transmission Length symbol;

T is the matrix transpose function; and

H is the parity matrix defined below:

$$H = \begin{bmatrix} 0&0&0&0&0&0&0&0&1&1&1&1&1&1&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1&1&0&0&0&0&1&1&1&1&1&1&1&1 \\ 1&1&0&0&0&1&1&1&0&0&1&1&0&0&0&0&1&1&1&1 \\ 1&1&0&1&1&0&1&1&0&1&0&1&0&0&1&1&0&0&1&1 \\ 0&1&1&0&1&0&0&1&1&1&1&0&0&1&0&1&0&1&0&1 \end{bmatrix}$$

6.4.3.1.1.6 *Bit transmission order*. The five parity bits of the resultant vector product shall be transmitted from the left bit first.

6.4.3.1.2 *Forward error correction*. In order to improve the effective channel throughput by reducing the number of required retransmissions, FEC shall be applied after the training sequence, regardless of frame boundaries.

6.4.3.1.2.1 *FEC calculation*. The FEC coding shall be accomplished by means of a systematic fixed-length Reed Solomon (RS)(255,249) 28-ary code.

Note 1.— This code is capable of correcting up to three octets for data blocks of 249 octets (1992 bits). Longer transmissions must be divided up into 1992 bit transmissions and shorter transmissions must be extended by virtual fill with trailing zeros. Six RS-check octets are appended for a total block of 255 octets.

The field defining the primitive polynomial of the code shall be as follows:

$$p(x) = (x^8 + x^7 + x^2 + x + 1)$$

The generator polynomial shall be as follows:

$$\prod_{i=120}^{125} (x - \alpha^i)$$

where:

α is a primitive element of GF(256);
GF(256) is a Galois field (GF) of size 256.

Note 2.— The Reed-Solomon codes are described in the Recommendation for Space Data System Standards Telemetry Channel Coding, by the Consultative Committee for Space Data Systems (see the Appendix to this chapter).

6.4.3.1.2.2 *Block lengths*. The six RS-check octets shall be calculated on blocks of 249 octets. Longer transmissions shall be split into blocks of 249 octets, per 6.4.3.1.3. Blocks of shorter length shall be extended to 249 octets by a virtual fill of trailing zeros. The virtual fill shall not be transmitted. Blocks shall be coded according to 6.4.3.1.2.3 through 6.4.3.1.2.3.3.

6.4.3.1.2.3 *No error correction*. For blocks with 2 or fewer non-fill octets, no error correction shall be used.

6.4.3.1.2.3.1 *Single-byte error correction*. For blocks with 3 to 30 non-fill octets, all six RS-check octets shall be generated, but only the first two shall be transmitted. The last four RS-check octets shall be treated as erasures at the decoder.

6.4.3.1.2.3.2 *Two-byte error correction.* For blocks with 31 to 67 non-fill octets, all six RS-check octets shall be generated, but only the first four shall be transmitted. The last two RS-check octets shall be treated as erasures at the decoder.

6.4.3.1.2.3.3 *Three-byte error correction.* For blocks with 68 or more non-fill octets, all six RS-check octets shall be generated and transmitted.

6.4.3.1.3 *Interleaving*. To improve the performance of the FEC, an octet-based table-driven interleaver shall be used.

The interleaver shall create a table having 255 octets per row and c rows, where

$$c = \frac{\textit{transmission length (bits)}}{1992 \textit{ (bits)}}$$

where:

a) the transmission length is as defined in 6.4.3.1.1.5; and

b) c= the smallest integer greater than or equal to the value of the fraction.

After extending the data to an even multiple of 1992 bits, the interleaver shall write the transmission stream into the first 249 octets of each row by taking each consecutive group of eight bits and storing them from the first column to the 249th.

The first bit in each group of eight bits shall be stored in the eighth bit position; the first group of1992 bits shall be stored in the first row, the second group of1992 bits in the second row, etc. After the FEC is computed on each row, the FEC data (or erasures) shall be stored in columns 250 through 255. The interleaver shall then pass the data to the scrambler by reading out column by column, skipping any octet which contains erasures or all fill bits. All of the bits inan octet shall be transmittedfrom bit 8 to bit 1.

On reception, the de-interleaver shall calculate the number of rows and size of the last (potentially partial) row from the length field in the header. It shall only pass valid data bytes to the higher layer.

6.4.3.1.4 *Bit scrambling.* To aid clock recovery and to stabilize the shape of the transmitted spectrum, bit scrambling shall be applied. The pseudo noise (PN) sequence shall be a 15-stage generator (see Figure 6-2) with the characteristic polynomial:

$$X^{15} + X + 1$$

The PN-sequence shall start after the frame synchronization pattern with the initial value 1101 0010 1011 001 with the leftmost bit in the first stage of the register as per Figure 6-2. After processing each bit, the register shall be shifted one bit to the right. For possible encryption in the future this initial value shall be programmed. The sequence shall be added (modulo 2) to the data at the transmit side (scrambling)and to the scrambled data at the receive side (descrambling) per Table 6-3.

Note.— The concept of a PN scrambler is explained in ITU-R Recommendation S.446-4, Annex I, Section 4.3.1, Method 1 (see the Appendix to this chapter).

6.4.3.2 MODE 2 CHANNEL SENSING

6.4.3.2.1 Channel busy to idle detection. When a station receives on-channel power of at least –87 dBm for at least 5 milliseconds, then:

a) with a likelihood of 0.9, it shall continue to consider the channel occupied if the signal level is attenuated to below -92 dBm for less than 1 millisecond; and

b) with a likelihood of 0.9, it shall consider the channel unoccupied if the signal level is attenuated to below –92 dBm for at least 1.5 milliseconds.

Note.— The maximum link throughput available to all users is highly sensitive to the RF channel sense delay (from the time when the channel actually changes state until a station detects and acts on that change) and RF channel seizure delay (from the time when a station decides to transmit until the transmitter is sufficiently ramped up to lock out other stations). Accordingly, it is imperative that all efforts are made to reduce those times as the state-of-the-art advances.

6.4.3.2.2 *Channel idle to busy detection*. With a likelihood of at least 0.9, a station shall consider the channel occupied within 1 millisecond after on-channel power rises to at least –90 dBm.

6.4.3.2.3 **Recommendation**.— *The detection of an occupied channel should occur within 0.5 milliseconds.*

Note.— A higher probability of false alarm is acceptable on the idle to busy detection than the busy to idle detection because of the effects of the two different errors.

6.4.3.3 MODE 2 RECEIVER/TRANSMITTER INTERACTION

6.4.3.3.1 *Receiver to transmitter turnaround time*. A station shall transmit the training sequence such that the centre of the first symbol of the unique word will be transmitted within 1.25 milliseconds after the result of an access attempt is successful (see Figure 6-3). The total frequency change during the transmission of the unique word shall be less than 10 Hz. After transmission of the unique word, the phase acceleration shall be less than 500 Hz per second.

6.4.3.3.2 *Transmitter to receiver turnaround time*. The transmitter power shall be –20 dBc within 2.5 symbol periods of the middle of the final symbol of the burst. The transmitter power leakage when the transmitter is in the "off" state shall be less than –83 dBm. A station shall be capable of receiving and demodulating with nominal performance, an incoming signal within 1.5 milliseconds after transmission of the final information symbol.

Note.— Reference DO-160D section 21, category H for antenna radiated signals.

6.4.3.4 MODE 2PHYSICAL LAYER SYSTEM PARAMETERS

6.4.3.4.1 The physical layer shall implement the system parameters as defined in Table 6-4.

6.4.3.4.1.1 *Parameter P1 (minimum transmission length).* Parameter P1 defines the minimum transmission length that a receiver shall be capable of demodulating without degradation of BER.

6.4.4 Mode 3 specific physical layer

Note.— The Mode 3 specific physical layer specification includes a description of Mode 3 management (M) burst and handoff check message (H) burst uplink, M burst downlink, voice/data (V/D) burst, and bit scrambling.

6.4.4.1 *Management (M) burst and handoff check message (H) burst uplink*. The M uplink burst (as contained in the Manual on VDL Mode 3 Technical Specifications) shall consist of three segments, the training sequence followed by the system data and the transmitter ramp down. The H uplink burst (as contained in the Manual on VDL Mode 3 Technical Specifications) shall consist of three segments, the training sequence followed by the handoff check message and the transmitter ramp down.

6.4.4.1.1 Training sequence. Uplink M burst and H burst training sequences shall consist of two components as follows:

a) transmitter ramp up and power stabilization; and

b) synchronization and ambiguity resolution.

6.4.4.1.1.1 Transmitter ramp-up and power stabilization. This shall be as defined in Section 6.4.3.1.1.1.

6.4.4.1.1.2 Synchronization and ambiguity resolution. The second component of the training sequence shall consist of the synchronization sequence, known as S2*, as follows:

000 001 101 100 110 010 111 100 010 011 101 000 111 000 011 001

and shall be transmitted from left to right.

Note.— The sequence S2 is very closely related to the sequence S2(Section 6.4.4.3.1.2). The 15 phase changes between the 16 symbols of S2* are each exactly 180oout of phase from the 15 phase changes associated with S2 . This relationship can be used to simplify the process of simultaneously searching for both sequences.*

6.4.4.1.2 *System data and handoff check message.* The non-3T configuration (as contained in the Manual on VDL Mode 3 Technical Specifications) system data shall consist of 32 transmitted symbols. The 96 transmitted bits shall include 48 bits of information and 48 parity bits, generated as 4 Golay (24, 12) code words. The 3T configuration as contained in the Manual on VDL Mode 3 Technical Specifications shall consist of 128 transmitted symbols. The 384 transmitted bits shall include 192 bits of information and 192 parity bits, generated as 16 Golay (24, 12) code words. The 3T configuration handoff check message shall consist of 40 transmitted symbols. The 120 transmitted bits shall include 60 bits of information and 60 parity bits, generated as 5 Golay (24,12) code words.

The specific definition of the Golay encoder shall be as follows:

If the 12 bit input bit sequence is written as a row vector x, then the 24 bit output sequence can be written as the row vector y, where y= x G, and the matrix G shall be given by

$$\mathbf{G} = \begin{matrix}
1&1&0&1&0&1&1&1&0&0&0&1&1&0&0&0&0&0&0&0&0&0&0&0\\
0&1&1&1&1&1&0&0&1&0&0&1&0&1&0&0&0&0&0&0&0&0&0&0\\
1&1&1&0&1&0&0&1&0&1&0&1&0&0&1&0&0&0&0&0&0&0&0&0\\
0&1&1&0&0&0&1&1&1&0&1&1&0&0&0&1&0&0&0&0&0&0&0&0\\
1&1&1&0&0&1&1&0&1&1&0&0&0&0&0&0&1&0&0&0&0&0&0&0\\
1&0&1&1&0&0&1&1&0&1&1&0&0&0&0&0&0&1&0&0&0&0&0&0\\
1&0&0&1&1&0&0&1&1&0&1&1&0&0&0&0&0&0&1&0&0&0&0&0\\
0&1&0&1&1&0&1&1&1&1&0&0&0&0&0&0&0&0&0&1&0&0&0&0\\
0&0&1&0&1&1&0&1&1&1&1&0&0&0&0&0&0&0&0&0&1&0&0&0\\
0&0&0&1&0&1&1&0&1&1&1&1&0&0&0&0&0&0&0&0&0&1&0&0\\
1&1&0&1&1&1&0&0&0&1&1&0&0&0&0&0&0&0&0&0&0&0&1&0\\
1&0&1&0&1&1&1&0&0&0&1&1&0&0&0&0&0&0&0&0&0&0&0&1
\end{matrix}$$

Note.— The extended Golay code allows for the correction of any error pattern with 3 or fewer bit errors and the detection of any 4-bit error pattern.

6.4.4.1.3 *Transmitter ramp-down.* The transmitter power shall be –20 dBc within 2.5 symbol periods of the middle of the final symbol of the burst. The transmitter power leakage when the transmitter is in the "off" state shall be less than -83 dBm.

Note.— Reference RTCA/DO-160D section 21, category H for antenna radiated signals.

6.4.4.2 *Management (M) burst downlink*. The M downlink burst (as contained in the Manual on VDL Mode 3 Technical Specifications) shall consist of three segments, the training sequence followed by the system data and the transmitter ramp down.

6.4.4.2.1 *Training sequence.* The M downlink burst training sequence shall consist of two components as follows:

a) transmitter ramp up and power stabilization; and

b) synchronization and ambiguity resolution.

6.4.4.2.1.1 *Transmitter ramp-up and power stabilization*. This shall be as defined in 6.4.4.1.1.1.

6.4.4.2.1.2 *Synchronization and ambiguity resolution*. Three separate synchronization sequences shall be used for this burst type. The standard sequence, known as S1, shall be as follows:

000 111 001 001 010 110 000 011 100 110 011 111 010 101 100 101

and shall be transmitted from left to right. The special sequence used to identify poll responses shall be as defined in 6.4.4.1.1.2.

The special sequence used to identify net entry requests (S1*) shall use the following sequence:

000 001 111 111 100 000 110 101 010 000 101 001 100 011 010 011

and shall be transmitted from left to right.

Note.— The sequence S1 is very closely related to the sequence S1. The 15 phase changes between the 16 symbols of S1* are each exactly 180° out of phase from the 15 phase changes associated with S1 . This relationship can be used to simplify the process of simultaneously searching for both sequences.*

6.4.4.2.2 *System data.* The system data segment shall consist of 16 transmitted symbols. The 48 transmitted bits shall be encoded as 24 bits of system data and 24 bits of parity bits generated as two consecutive (24, 12) Golay code words. The encoding of the (24, 12) Golay code words should be as defined in 6.4.4.1.2.

6.4.4.2.3 *Transmitter ramp-down*. This shall be as defined in 6.4.4.1.3.

6.4.4.3 *Voice or data (V/D) burst*. The V/D burst (as contained in the Manual on VDL Mode 3 Technical Specifications) shall consist of four segments: the training sequence followed by the header, the user information segment and the transmitter ramp down. The same V/D burst format shall be used for both uplink and downlink.

6.4.4.3.1 *Training sequence.* V/D burst training sequence shall consist of two components as follows:

a) transmitter ramp-up and power stabilization; and

b) synchronization and ambiguity resolution.

6.4.4.3.1.1 *Transmitter ramp-up and power stabilization*. This shall be as specified in 6.4.4.1.1.1.

6.4.4.3.1.2 *Synchronization and ambiguity resolution*. The second component of the training sequence shall consist of the synchronization sequence, known as S2, as follows:

000 111 011 010 000 100 001 010 100 101 011 110 001 110 101 111

and shall be transmitted from left to right.

6.4.4.3.2 *Header.* The header segment shall consist of 8 transmitted symbols. The 24 transmitted bits shall be encoded as 12 bits of header information and 12 parity bits, generated as a single (24, 12) Golay code word. The encoding of the (24, 12) Golay code word shall be as defined in 6.4.4.1.2.

6.4.4.3.3 User information. The user information segment shall consist of 192 3-bit symbols. When transmitting voice, FEC shall be applied to the analysis output of the vocoder specified in 6.8. The vocoder shall provide satisfactory performance in a BER environment of 10–3(with a design goal of 10–2). The overall bit rate of the vocoder including FEC is 4 800 bits/s (except when in the truncated mode in which the bit rate is 4 000 bits/s).

6.4.4.3.3.1 When transmitting user data, the 576 bits shall be encoded as a single Reed-Solomon (72, 62) 28–ary code word. For user data input to the Reed-Solomon encoder of length less than 496 bits, input data shall be padded with zeroes at the end to a full length of 496 bits. The field defining the primitive polynomial of the code shall be as described in 6.4.3.1.2.1.

The generator polynomial shall be as follows:

$$\prod_{i=120}^{129} (x-\alpha^i)$$

Note.— The Reed-Solomon (72, 62) code is capable of correcting up to five 28-ary (code word) symbol errors in the received word.

6.4.4.3.4 *Transmitter ramp-down.* This shall be as defined in 6.4.4.1.3.

6.4.4.4 *Interleaving.* There shall be no interleaving in Mode 3 operation.

6.4.4.5 *Bit scrambling*. Under Mode 3 operation, bit scrambling, as specified in 6.4.3.1.4 shall be performed on each burst, starting after the training sequence. The scrambling sequence shall be reinitialized on each burst effectively providing a constant overlay for each of the Mode 3 fixed length bursts.

6.4.4.6 *Receiver/transmitter interaction.* The switching times in this subsection will be defined as the time between the middle of the last information symbol of one burst and the middle of the first symbol of the synchronization sequence of the subsequent burst.

Note.— This nominal time will be shortened by considerations such as the finite width of each symbol due to Nyquist filtering and the ramp up and power stabilization sequence. Such alternative definitions could yield switching times up to 8 symbol periods shorter.

6.4.4.6.1 *Receiver to transmitter switching time*. An aircraft radio shall be capable of switching from reception to transmission within 17 symbol periods. This time can be relaxed to 33 symbol periods for aircraft radios which do not implement functions requiring discrete addressing.

Note 1.— The shortest R/T switching time for an aircraft radio occurs when the reception of an uplink M channel beacon is followed by a V/D transmission in the same slot. In certain instances where aircraft radios do not implement functions requiring discrete addressing, the R/T switching time can be increased since the last two Golay words of the uplink M channel beacon need not be read.

Note 2.— The minimum turnaround time assumes that in configurations 3V1D, 2V1D, and 3T (as contained in Section 5.5.2.4 of the Manual on VDL Mode 3 Technical Specifications), the aircraft radios will be provided with software that will prevent them from transmitting a downlink M channel message in a slot following the reception of a voice message from another aircraft with a long time delay.

6.4.4.6.2 *Transmitter to receiver switching time.* An aircraft radio shall be capable of switching from transmission to reception within 32 symbol periods.

Note.— The worst case T/R switching time for an aircraft radio occurs when it transmits a downlink M channel message and receives a V/D message in the same slot.

6.4.4.7 *Fringe coverage indication*

6.4.4.7.1 **Recommendation**.— *Indication of near edge-of-coverage should be provided to the VDL Mode 3 aircraft.*

6.5 LINK LAYER PROTOCOLS AND SERVICES

6.5.1 General information

6.5.1.1 *Functionality*. The VDL link layer shall provide the following sublayer functions:

a) media access control (MAC) sublayer, which requires the use of the carrier sense multiple access (CSMA) algorithm for Mode 2 or TDMA for Mode 3;

b) a data link service (DLS) sublayer:

1) for Mode 2, the DLS sublayer provides connection-oriented point-to-point links using data link entities (DLE) and connectionless broadcast link over the MAC sublayer; and

2) for Mode 3, the DLS sublayer provides acknowledged connectionless point-to-point and point-to-multipoint links over a MAC sublayer that guarantees sequencing; and

c) a VDL management entity (VME), which establishes and maintains DLEs between the aircraft and the ground-based systems using link management entities (LME).

6.5.1.2 SERVICE

6.5.1.2.1 Connection-oriented. The VDL Mode 2 link layer shall provide a reliable point-to-point service using a connection-oriented DLS sublayer.

6.5.1.2.2 **Connectionless**. The VDL Mode 2 and 3 link layers shall provide an unacknowledged broadcast service using a connectionless DLS sublayer.

6.5.1.2.3 **Acknowledged connectionless**. The VDL Mode 3 link layer shall provide an acknowledged point-to-point service using a connectionless DLS sublayer that relies upon the MAC sublayerto guarantee sequencing.

6.5.2 MAC sublayer

6.5.2.1 The MAC sublayer shall provide for the transparent acquisition of the shared communications path. It makes invisible to the DLS sublayer the way in which supporting communications resources are utilized to achieve this.

Note.— Specific MAC services and procedures for VDL Modes 2 and 3 are contained in the Manuals on VDL Mode 2 and VDL Mode 3 Technical Specifications.

6.5.3 Data link service sublayer

6.5.3.1 For Mode 2, the DLS shall support bit-oriented simplex air-ground communications using the aviation VHF link control (AVLC) protocol.

Note.— Specific data link services, parameters and protocol definitions for VDL Mode 2 are contained in the Manual on VDL Mode 2 Technical Specifications.

6.5.3.2 For Mode 3, the DLS shall support bit-oriented, priority based, simplex air-ground communications using the acknowledged connectionless data link (A-CLDL) protocol.

Note.— Specific data link services, parameters and protocol definitions for VDL Mode 3 are contained in the Manual on VDL Mode 3 Technical Specifications.

6.5.4 VDL management entity

6.5.4.1 *Services.* The VME shall provide link establishment, maintenance and disconnection services as well as support parameter modification. Specific VME services, parameter formats and procedures for Modes 2 and 3 are contained in the Manuals on VDL Mode 2 and Mode 3 Technical Specifications.

6.6 SUBNETWORK LAYER PROTOCOLS AND SERVICES

6.6.1 Architecture for Mode 2

6.6.1.1 The subnetwork layer protocol used across the VHF air-ground subnetwork for VDL Mode 2 is referred to formally as a subnetwork access protocol (SNAcP) and shall conform to ISO 8208, except as contained in the Manual on VDL Mode 2 Technical Specifications. The SNAcP is contained within the Manual on VDL Mode 2 Technical Specifications as the subnetwork protocol. If there are any differences between the Manual on VDL Mode 2 Technical Specifications and the cited specifications, the Manual on VDL Mode 2 Technical Specifications shall have precedence. On the air-ground interface, the aircraft subnetwork entity shall act as a DTE and the ground subnetwork entity shall act as a DCE.

Note.— Specific subnetwork layer protocol access points, services, packet formats, parameters and procedures for VDL Mode 2 are contained in the Manual on VDL Mode 2 Technical Specifications.

6.6.2 Architecture for Mode 3

6.6.2.1 The subnetwork layer used across the VHF air-ground subnetwork for VDL Mode 3 provides the flexibility to simultaneously support multiple subnetwork protocols. The currently defined options are to support ISO 8473 connectionless network protocol and to support ISO 8208, both as contained in the Manual on VDL Mode 3 Technical Specifications. The Manual on VDL Mode 3 Technical Specifications shall have precedence with respect to any differences with the cited specifications. For the ISO 8208 interface, both the air and ground subnetwork entities shall act as DCEs.

Note.— Specific subnetwork layer protocol access points, services, packet formats, parameters and procedures for VDL Mode 3 are contained in the Manual on VDL Mode 3 Technical Specifications.

6.7 THE VDL MOBILE SUBNETWORK DEPENDENT CONVERGENCE FUNCTION (SNDCF)

6.7.1 VDL Mode 2 SNDCF

6.7.1.1 *Introduction.* The VDL Mode 2 mobile SNDCF shall be the standard mobile SNDCF.

6.7.1.2 *New function*. The VDL Mode 2 mobile SNDCF shall support maintaining context (e.g. compression tables) across subnetwork calls. The SNDCF shall use the same context (e.g. compression tables) across all SVCs negotiated to a DTE, when negotiated with the same parameters. The SNDCF shall support at least 2 SVCs sharing a context.

Note 1.— Because handoffs can be expected to reorder packets, certain compression algorithms do not lend themselves to use over VDL Mode 2. Further, implementors of dictionary-based compression algorithms must be sensitive to the problem of updates arriving on either the old or newly established call.

Note 2.— The encoding of the Call User Data field is described in Doc 9705 except with modifications as contained in the Manual on VDL Mode 2 Technical Specifications.

6.7.2 VDL Mode 3 SNDCF

6.7.2.1 The VDL Mode 3 shall support one or more of the defined SNDCFs. The first is the standard ISO 8208 SNDCF as defined in Doc 9705. This is a connection-oriented SNDCF. The second type of SNDCF supported by VDL Mode 3 is denoted frame-based SNDCF. The details of this connectionless oriented SNDCF are contained in the Manual on VDL Mode 3 Technical Specifications, including network layer interface, support for broadcast and unicast network packets, and ATN router support.

Note.— The framed-based SNDCF is termed such because it uses the VDL Mode 3 frames without the need for an additional protocol (viz. ISO 8208 SNDCF) to transfer network packets. The frame-based SNDCF achieves independence from the network protocol by identifying the payload of each frame. Upon receipt of a frame, the payload is examined and control is passed to the protocol identified.

6.8 VOICE UNIT FOR MODE 3

6.8.1 Services

6.8.1.1 The voice unit shall provide for a simplex, "push-to-talk" audio and signalling interface between the user and the VDL. Two separate mutually exclusive voice circuit types shall be supported:

a) Dedicated circuits: This shall provide service to a specific user group on anexclusive basis with no sharing of the circuit with other users outside the group. Access shall be based on a "listen-before-push-to-talk" discipline.

b) Demand assigned circuits: This shall provide voice circuit access which is arbitrated by the ground station in response to an access request received from the aircraft station. This type of operation shall allow dynamic sharing of the channel resource increasing trunking efficiency.

6.8.1.2 *Priority access*. The voice unit operation shall support a priority override access for authorized ground users.

6.8.1.3 *Message source identification*. The voice unit operation shall support notification to the user of the source of a received message (i.e. whether the message originated from an air or ground station).

6.8.1.4 *Coded squelch*. The voice unit shall support a coded squelch operation that offers some degree of rejection of undesired co-channel voice messages based on the burst time of arrival.

6.8.2 Speech encoding, parameters and procedures

6.8.2.1 The VDL Mode 3 shall use the advanced multiband excitation (AMBE) 4.8 kbits/s encoding/decoding algorithm, version number AMBE-ATC-10, developed by Digital Voice Systems, Incorporated (DVSI) for voice communications.

Note 1.— Information on technical characteristics of the 4.8 kbits/s AMBE algorithm is contained in AMBE-ATC-10 Low Level Description, obtainable from DVSI.

Note 2.— The 4.8 kbits/s AMBE encoding/decoding technology described in the document is subject to DVSI patent rights and copyrights. Manufacturers must enter into a license agreement with DVSI prior to obtaining a detailed description of the algorithm before incorporation in equipment operating in the VDL Mode 3 service. By letter to ICAO dated 29 October 1999, DVSI confirmed its commitment to license the technology for the manufacture and sale of aeronautical equipment under reasonable terms and conditions, negotiated on a non-discriminatory basis.

6.8.2.2 Speech encoding definition, voice unit parameters, and procedure descriptions for VDL Mode 3 Voice Unit operation are contained in the Manual on VDL Mode 3 Technical Specifications.

6.9 VDL MODE 4

6.9.1 A Mode 4 station shall conform to the requirements defined in 6.1.2.3, 6.1.4.2, 6.2.1.1, 6.2.3.1, 6.2.4, 6.3.1, 6.3.3.1, 6.3.4, 6.3.5.1, 6.3.5.2, 6.3.5.3, 6.3.5.4.1 and 6.9.

6.9.2 VDL Mode 4 radio channels

6.9.2.1 VDL MODE 4STATION FREQUENCY RANGE

6.9.2.1.1 *Transmitter/receiver tuning range*. A VDL Mode 4 transmitter/receiver shall be capable of tuning to any of the 25 kHz channels from 112 MHz to 137 MHz.

Note.— Operational conditions or certain applications may require the equipment to be operated in a narrower frequency range.

6.9.2.1.2 *Simultaneous reception.* A VDL Mode 4 station shall be capable of receiving two channels simultaneously.

6.9.2.1.3 **Recommendation.** – *A VDL Mode 4 station should be capable of receiving additional channels simultaneously as required by operational services.*

6.9.2.2 GLOBAL SIGNALLING CHANNELS

6.9.2.2.1 VDL Mode 4 stations shall use two assigned frequencies as global signalling channels (GSC), to support user communications and link management functions.

Note.— Additional channels may be defined in a local domain and notified to mobile users by broadcast from ground stations on the GSCs defined above.

6.9.3 System capabilities

6.9.3.1 *ATN compatibility.* The VDL Mode 4 system shall support ATN/IPS-compliant subnetwork services.

Note.— VDL Mode 4 provides a seamless transfer of data between ATN/IPS ground networks and ATN/IPS aircraft networks. Interoperability with ATN/OSI networks, where required, is expected to be arranged prior to implementation. VDL Modes 2 and 3 provide ATN/OSI-compliant subnetworks.

6.9.3.2 *Data transparency*. The VDL Mode 4 system shall provide code-independent, byte-independent transfer of data.

6.9.3.3 *Broadcast.* The VDL Mode 4 system shall provide link layer broadcast services.

6.9.3.4 *Point-to-point.* The VDL Mode 4 system shall provide link layer point-to-point services.

6.9.3.5 *Air-air communications*. The VDL Mode 4 system shall provide air-air communications, without ground support, as well as air-ground communications.

6.9.3.6 *Connection management*. When supporting air-ground operations, the VDL Mode 4 system shall establish and maintain a reliable communications path between the aircraft and the ground system while allowing, but not requiring, manual intervention.

6.9.3.7 *Ground network transition.* A mobile VDL Mode 4 DLS station shall transition from one ground VDL Mode 4 DLS station to another as required.

6.9.3.8 *Derived time capability.* VDL Mode 4 shall provide the capability for deriving time from time-of-arrival measurements of received VDL Mode 4 transmissions whenever externally derived estimates of time are unavailable.

6.9.3.9 *Simplex operations.* Mobile and ground VDL Mode 4 stations shall access the physical medium operating in simplex mode.

6.9.4 Coordination of channel utilization

6.9.4.1 On a regional basis, transmissions shall be scheduled relative to UTC, to ensure efficient use of shared channels and to avoid unintentional slot re-use.

6.9.5 Physical layer protocols and services

Note.— Unless otherwise stated, the requirements defined in this section apply to both mobile and ground stations.

6.9.5.1 FUNCTIONS

6.9.5.1.1 *TRANSMITTED POWER*

6.9.5.1.1.1 *Airborne installation.* The effective radiated power shall be such as to provide a field strength of at least 35 microvolts per metre (minus 114.5 dBW/m2) on the basis of free space propagation, at ranges and altitudes appropriate to the conditions pertaining to the areas over which the aircraft is operated.

6.9.5.1.1.2 *Ground installation*.

Recommendation.—*The effective radiated power should be such as toprovide a field strength of at least 75 microvolts per metre (minus 109 dBW/m2) within the defined operational coverage of the facility, on the basis of free-space propagation*.

6.9.5.1.2 *TRANSMITTER AND RECEIVER FREQUENCY CONTROL*

6.9.5.1.2.1 The VDL Mode 4 physical layer shall set the transmitter or receiver frequency as commanded by the link management entity (LME). Channel selection time shall be less than 13 ms after the receipt of a command from a VSS user.

6.9.5.1.3 *DATA RECEPTION BY RECEIVER*

6.9.5.1.3.1 The receiver shall decode input signals and forward them to the higher layers for processing.

6.9.5.1.4 *DATA TRANSMISSION BY TRANSMITTER*

6.9.5.1.4.1 *Data encoding and transmission*. The physical layer shall encode the data received from the data link layer and transmit it over the RF channel. RF transmission shall take place only when permitted by the MAC.

6.9.5.1.4.2 *Order of transmission*. The transmission shall consist of the following stages in the following order:

a) transmitter power stabilization;

b) bit synchronization;

c) ambiguity resolution and data transmission; and

d) transmitter decay.

Note.— The definitions of the stages are given in Sections 6.9.5.2.3.1 to 6.9.5.2.3.4.

6.9.5.1.4.3 *Automatic transmitter shutdown.* A VDL Mode 4 station shall automatically shut-down power to any final stage amplifier in the event that output power from that amplifier exceeds –30 dBm for more than 1 second. Reset to an operational mode for the affected amplifier shall require a manual operation.

Note.— This is intended to protect the shared channel resource against so-called "stuck transmitters".

6.9.5.1.5 *NOTIFICATION SERVICES*

6.9.5.1.5.1 *Signal quality.* The operational parameters of the equipment shall be monitored at the physical layer. Signal quality analysis shall be performed in the demodulator process and in the receive process.

Note.— Processes that may be evaluated in the demodulator include bit error rate (BER), signal to noise ratio (SNR), and timing jitter. Processes that may be evaluated in the receiver include received signal level and group delay.

6.9.5.1.5.2 *Arrival time.* The arrival time of each received transmission shall be measured with a two-sigma error of 5 microseconds.

6.9.5.1.5.3 **Recommendation**.— *The receiver should be capable of measuring the arrival time within a two-sigma error of 1 microsecond.*

6.9.5.2 PROTOCOL DEFINITION FOR GFSK

6.9.5.2.1 *Modulation scheme*. The modulation scheme shall be GFSK. The first bit transmitted (in the training sequence) shall be a high tone and the transmitted tone shall be toggled before transmitting a 0 (i.e. non-return to zero inverted encoding).

6.9.5.2.2 *Modulation rate*. Binary ones and binary zeros shall be generated with a modulation index of 0.25 ± 0.03 and a BT product of 0.28 ± 0.03, producing data transmission at a bit rate of 19 200 bits/s ± 50 ppm.

6.9.5.2.3 *STAGES OF TRANSMISSION*

6.9.5.2.3.1 *Transmitter power stabilization*. The first segment of the training sequence is the transmitter power stabilization, which shall have a duration of 16 symbol periods. The transmitter power level shall be no less than 90 per cent of the steady state power level at the end of the transmitter power stabilization segment.

6.9.5.2.3.2 *Bit synchronization*. The second segment of the training sequence shall be the 24-bit binary sequence 0101 0101 0101 0101 0101 0101, transmitted from left to right immediately before the start of the data segment.

6.9.5.2.3.3 *Ambiguity resolution and data transmission*. The transmission of the first bit of data shall start 40 bit intervals (approximately 2 083.3 microseconds) ± 1 microsecond after the nominal start of transmission.

Note 1.— This is referenced to emissions at the output of the antenna.

Note 2.— Ambiguity resolution is performed by the link layer.

6.9.5.2.3.4 *Transmitter decay.* The transmitted power level shall decay at least by 20 dB within 300 microseconds after completing a transmission. The transmitter power level shall beless than -90 dBm within 832 microseconds after completing a transmission.

6.9.5.3 CHANNEL SENSING

6.9.5.3.1 *Estimation of noise floor.* A VDL Mode 4 station shall estimate the noise floor based on power measurements of the channel whenever a valid training sequence has not been detected.

6.9.5.3.2 The algorithm used to estimate the noise floor shall be such that the estimated noise floor shall be lower than the maximum power value measured on the channel over the last minute when the channel is regarded as idle.

Note.— The VDL Mode 4 receiver uses an energy sensing algorithm as one of the means to determine the state of the channel (idle or busy). One algorithm that can be used to estimate the noise floor is described in the Manual on VHF Digital Link (VDL) Mode 4 (Doc 9816).

6.9.5.3.3 *Channel idle to busy detection*. A VDL Mode 4 station shall employ the following means to determine the channel idle to busy transition at the physical layer.

6.9.5.3.3.1 *Detection of a training sequence*. The channel shall be declared busy if a VDL Mode 4 station detects a valid training sequence followed by a frame flag.

6.9.5.3.3.2 *Measurement of channel power.* Regardless of the ability of the demodulator to detect a valid training sequence, a VDL Mode 4 station shall consider the channel busy with at least a 95 per cent probability within 1 ms after on channel power rises to the equivalent of at least four times the estimated noise floor for at least 0.5 milliseconds.

6.9.5.3.4 *CHANNEL BUSY TO IDLE DETECTION*

6.9.5.3.4.1 A VDL Mode 4 station shall employ the following means to determine the channel busy to idle transition.

6.9.5.3.4.2 *Measurement of transmission length*. When the training sequence has been detected, the channel busy state shall be held for a period of time at least equal to 5 milliseconds, and subsequently allowed to transition to the idle state based on measurement of channel power.

6.9.5.3.4.3 *Measurement of channel power.* When not otherwise held in the channel busy state, a VDL Mode 4 station shall consider the channel idle with at least a 95 per cent probability if on-channel power falls below the equivalent of twicethe estimated noise floor for at least 0.9 milliseconds.

6.9.5.4 RECEIVER/TRANSMITTER INTERACTION

6.9.5.4.1 *Receiver to transmitter turnaround time.* A VDL Mode 4 station shall be capable of beginning the transmission of the transmitter power stabilization sequence within 16 microseconds after terminating the receiver function.

6.9.5.4.2 *Frequency change during transmission.* The phase acceleration of the carrier from the start of the synchronization sequence to the data end flag shall be less than 300 Hz per second.

6.9.5.4.3 *Transmitter to receiver turnaround time*. A VDL Mode 4 station shall be capable of receiving and demodulating with nominal performance an incoming signal within 1 ms after completing a transmission.

Note.— Nominal performance is defined as a bit error rate (BER) of 10^{-4}.

6.9.5.5 PHYSICAL LAYER SYSTEM PARAMETERS

6.9.5.5.1 *PARAMETER P1 (MINIMUM TRANSMISSION LENGTH)*

6.9.5.5.1.1 A receiver shall be capable of demodulating a transmission of minimum length P1 without degradation of BER.

6.9.5.5.1.2 The value of P1 shall be 19 200 bits.

6.9.5.5.2 *PARAMETER P2 (NOMINAL CO-CHANNEL INTERFERENCE PERFORMANCE)*

6.9.5.5.2.1 The parameter P2 shall be the nominal co-channel interference at which a receiver shall be capable of demodulating without degradation in BER.

6.9.5.5.2.2 The value of P2 shall be 12 dB.

6.9.5.6 FMBROADCAST INTERFERENCE IMMUNITY PERFORMANCE FOR VDL MODE 4RECEIVING SYSTEMS

6.9.5.6.1 A VDL Mode 4 station shall conform to the requirements defined in section 6.3.5.4 when operating in the band 117.975–137 MHz.

6.9.5.6.2 A VDL Mode 4 station shall conform to the requirements defined below when operating in the band 108-117.975 MHz.

6.9.5.6.2.1 The VDL Mode 4 receiving system shall meet the requirements specified in 6.3.5.1 in the presence of two signal, third-order intermodulation products caused by VHF FM broadcast signals having levels in accordance with the following:

$$2N_1 + N_2 + 72 \leq 0$$

for VHF FM sound broadcasting signals in the range 107.7–108.0 MHz

and

$$2N_1 + N_2 + 3\left\{24 - 20\ \log \frac{\Delta f}{0.4}\right\} \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz,

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver,a two-signal, third-order

intermodulation product on the desired VDL Mode 4 frequency.

N1and N2are the levels (dBm) of the two VHF FM sound broadcasting signals at the VDL Mode 4 receiver input. Neither level shall exceed the desensitization criteria set forth in 6.9.5.6.2.2.

Δf = 108.1 – f1, where f1is the frequency of N1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

Note.— The FM intermodulation immunity requirements are not applied to a VDL Mode 4 channel operating below 108.1 MHz, and hence frequencies below 108.1 MHz are not intended for general assignments.

6.9.5.6.2.2 The VDL Mode 4 receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels in accordance with Table 6-5.

6.9.6 Link layer

Note.— Details on link layer functions are contained in the Manual on VHF Digital Link (VDL) Mode 4 (Doc 9816).

6.9.7 Subnetwork layer and SNDCF

Note.— Details on subnetwork layer functions and SNDCF are contained in the Manual on VHF Digital Link (VDL) Mode 4 (Doc 9816).

6.9.8 ADS-B applications

Note.— Details on ADS-B application functions are contained in the Manual on VHF Digital Link (VDL) Mode 4 (Doc 9816).

Table 6-1. Modes 2 and 3 data encoding

X_k	Y_k	Z_k	$\Delta\phi_k$
0	0	0	$0\ \pi / 4$
0	0	1	$1\ \pi / 4$
0	1	1	$2\ \pi / 4$
0	1	0	$3\ \pi / 4$
1	1	0	$4\ \pi / 4$
1	1	1	$5\ \pi / 4$
1	0	1	$6\ \pi / 4$
1	0	0	$7\ \pi / 4$

Table 6-2. Modes 2 and 3 modulation stability

VDL Mode	Aircraft Modulation Stability	Ground Modulation Stability
Mode 2	± 0.0050 per cent	± 0.0050 per cent
Mode 3	± 0.0005 per cent	± 0.0002 per cent

Table 6-3. Scrambler functions

Function	Data in	Data out
scrambling	clean data	scrambled data
descrambling	scrambled data	clean data

Table 6-4. Physical services system parameters

Symbol	Parameter name	Mode 2 value
P1	Minimum transmission length	131071 bits

Table 6-5. VDL Mode 4 operating on frequencies between 112.0–117.975 MHz

Frequency (MHz)	Maximum level of unwanted signal at receiver input (dBm)
88–104	+15
106	+10
107	+5
107.9	0

Note. – The relationship is linear between adjacent points designated by the above frequencies.

FIGURES FOR CHAPTER 6

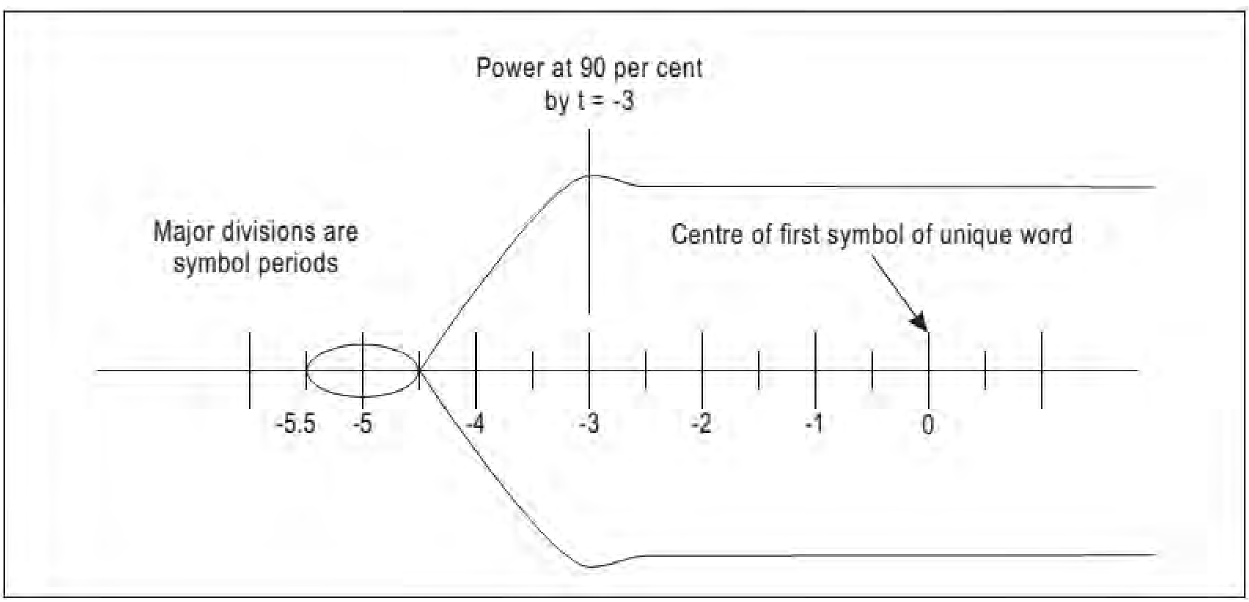

Figure 6-1. Transmitter power stabilization

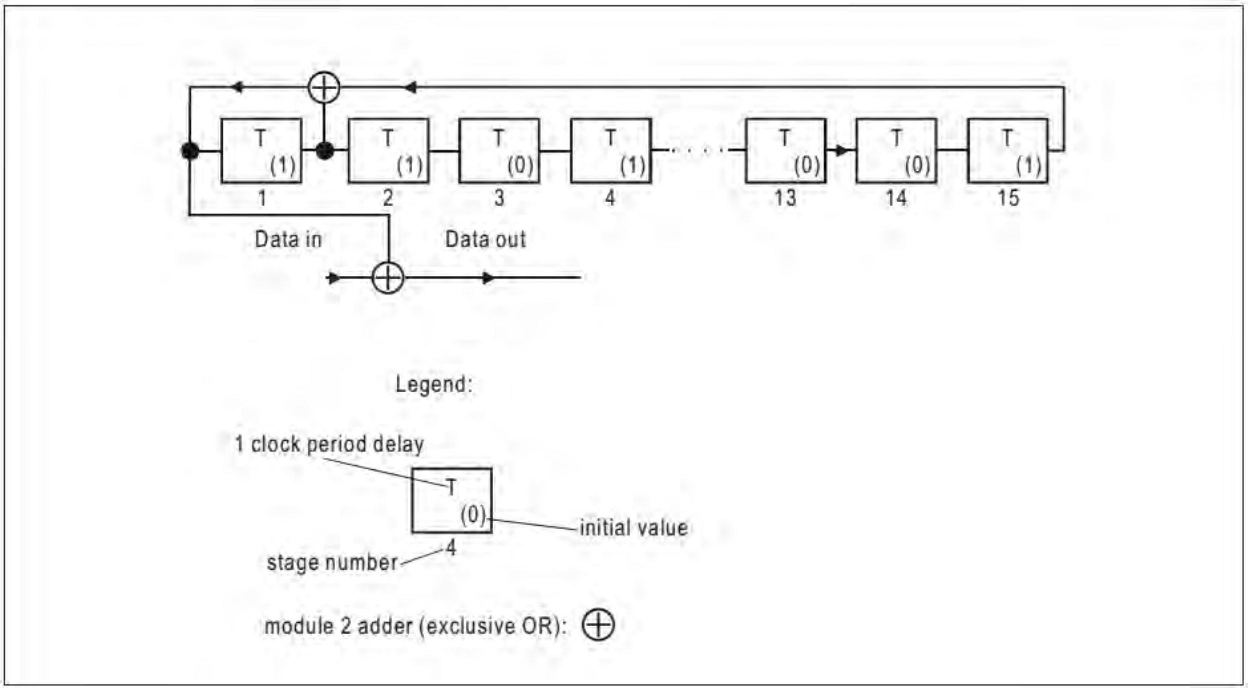

Figure 6-2. PN-generator for bit scrambling sequence

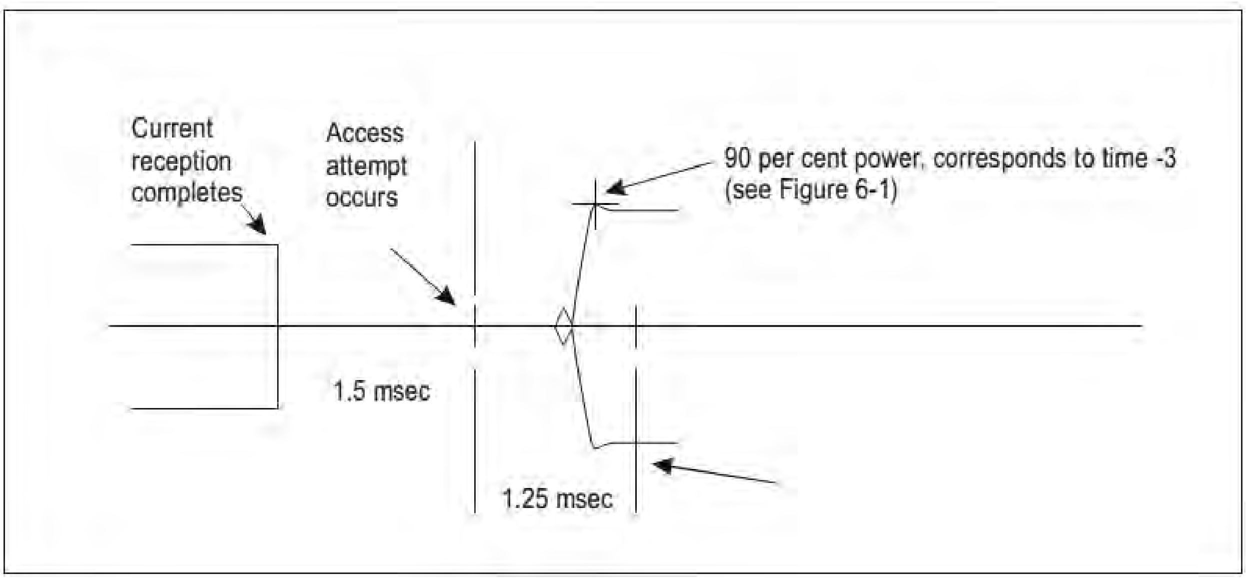

Figure 6-3. Receive to Transmit turnaround time

APPENDIX TO CHAPTER 6

REFERENCES

1. REFERENCES

References to Standards from the International Organization for Standardization (ISO) are as specified (including date published) below. These ISO Standards shall apply to the extent specified in the SARPs.

2. NORMATIVE REFERENCES

These SARPs reference the following ISO documents:

ISO	*Title*	*Date published*
646	*Information technology — ISO 7-bit coded character set for information interchange*	12/91
3309	*HDLC Procedures — Frame Structure, Version 3*	12/93
4335	*HDLC Elements of Procedures*, Version 3	12/93
7498	*OSI Basic Reference Model, Version 1*	11/94
7809	*HDLC Procedures — Consolidation of Classes of Procedures, Version 1*	12/93
8208	*Information Processing Systems — Data Communications — X.25 Packet Level Protocol for Data Terminal Equipment*	3/90 2nd ed.
8885	*HDLC Procedures — General Purpose XID Frame Information Field Content and Format*, Version [1]	12/93
8886.3	*OSI Data Link Service Definition*, Version 3	6/92
10039	*Local Area Networks — MAC Service Definition*, Version 1	6/91

3. BACKGROUND REFERENCES

The following documents are listed as reference material.

Originator	*Title*	*Date published*
ITU-R	Recommendation S.446.4, Annex I	
CCSDS	*Telemetry Channel Coding, Recommendation for Space Data System Standards*, Consultative Committee for Space Date Systems, CCSDS 101.0-B-3, Blue Book	5/92

CHAPTER 7. SUBNETWORK INTERCONNECTION

[to be developed]

CHAPTER 8. AFTN NETWORK

8.1 DEFINITIONS

Data signalling rate. Data signalling rate refers to the passage of information per unit of time, and is expressed in bits/second.
Data signalling rate is given by the formula:

$$\sum_{i=1}^{i=m} \frac{1}{T_i} \log_2 n_i$$

where *m* is the number of parallel channels, T*i* is the minimum interval for the *i*th channel expressed in seconds, n*i* is the number of significant conditions of the modulation in the *i*th channel.

Note 1.—

a) For a single channel (serial transmission) it reduces to(1/T)log2n; with a two-condition modulation(n = 2), it is1/T.

b) For a parallel transmission with equal minimum intervals and equal number of significant conditions on each channel, it ism(1/T)log2n (m(1/T) in case of a two-condition modulation).

Note 2.— In the above definition, the term "parallel channels" is interpreted to mean: channels, each of which carries an integral part of an information unit, e.g. the parallel transmission of bits forming a character. In the case of a circuit comprising a number of channels, each of which carries information "independently", with the sole purpose of increasing the traffic handling capacity, these channels are not to be regarded as parallel channels in the context of this definition.

Degree of standardized test distortion. The degree of distortion of the restitution measured during a specific period of time when the modulation is perfect and corresponds to a specific text.

Effective margin. That margin of an individual apparatus which could be measured under actual operating conditions.

Low modulation rates. Modulation rates up to and including 300 bauds.

Margin. The maximum degree of distortion of the circuit at the end of which the apparatus is situated which is compatible with the correct translation of all the signals which it may possibly receive.

Medium modulation rates. Modulation rates above 300 and up to and including 3 000 bauds.

Modulation rate. The reciprocal of the unit interval measured in seconds. This rate is expressed in bauds.

Note.— Telegraph signals are characterized by intervals of time of duration equal to or longer than the shortest or unit interval. The modulation rate (formerly telegraph speed) is therefore expressed as the inverse of the value of this unit interval.
If, for example, the unit interval is 20 milliseconds, the modulation rate is 50 bauds.

Synchronous operation. Operation in which the time interval between code units is a constant.

8.2 TECHNICAL PROVISIONSRELATING TO TELETYPEWRITER APPARATUS AND CIRCUITS USED IN THE AFTN

8.2.1 In international teletypewriter circuits of the AFTN, using a 5-unit code, the International Telegraph Alphabet No. 2 (see Table 8-1[6]) shall be used only to the extent prescribed in 4.1.2 of Volume II.

8.2.2 **Recommendation.—** *The modulation rate should be determined by bilateral or multilateral agreement between administrations concerned, taking into account primarily traffic volume.*

8.2.3 **Recommendation**.— *The nominal duration of the transmitting cycle should be at least 7.4 units (preferably 7.5),the stop element lasting for at least 1.4 units (preferably 1.5).*

8.2.3.**1 Recommendation**.— *The receiver should be able to translate correctly in service the signals coming from a transmitter with a nominal transmitting cycle of 7 units.*

8.2.4 **Recommendation.—** *Apparatus in service should be maintained and adjusted in such a manner that its net effective margin is never less than 35 per cent.*

8.2.5 **Recommendation.—** *The number of characters which the textual line of the page-printing apparatus may contain should be fixed at 69.*

8.2.6 **Recommendation**.— *In start-stop apparatus fitted with automatic time delay switches, the disconnection of the power supply to the motor should not take place before the lapse of at least 45 seconds after the reception of the last signal.*

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[6] All tables and figures are located at the end of this chapter.

8.2.7 **Recommendation.** – *Arrangements should be made to avoid the mutilation of signals transmitted at the head of a message and received on start-stop reperforating apparatus.*

8.2.7.1 **Recommendation.**— *If the reperforating apparatus is provided with local means for feeding the paper, not more than one mutilated signal should be tolerated.*

8.2.8 **Recommendation**. – *Complete circuits should be so engineered and maintained that their degree of standardized test distortion does not exceed 28 per cent on the standardized text:*

THE QUICK BROWN FOX JUMPS
OVER THE LAZY DOG

or

VOYEZ LE BRICK GEANT QUE
JEXAMINE PRES DU WHARF

8.2.9 **Recommendation.**— *The degree of isochronous distortion on the standardized text of each of the parts of a complete circuit should be as low as possible, and in any case should not exceed 10 per cent.*

8.2.10 **Recommendation**.— *The overall distortion in transmitting equipment used on teletypewriter channels should not exceed 5 per cent.*

8.2.11 **Recommendation**.— *AFTN circuits should be equipped with a system of continuous check of channel condition. Additionally, controlled circuit protocols should be applied.*

8.3 TERMINAL EQUIPMENT ASSOCIATED WITH AERONAUTICAL RADIOTELETYPEWRITER CHANNELS OPERATING IN THE BAND 2.5 – 30 MHz

8.3.1 Selection of type of modulation and code

8.3.1.1 **Recommendation**. – *Frequency shift modulation (F1B) should be employed in radioteletypewriter systems used in the aeronautical fixed service (AFS), except where the characteristics of the independent sideband (ISB) method of operation are of advantage.*

Note.— F1B type of modulation is accomplished by shifting a radio frequency carrier between two frequencies representing "position A" (start signal polarity) and "position Z" (stop signal polarity) of the start-stop 5-unit telegraphic code.

8.3.2 System characteristics

8.3.2.1 **Recommendation**.— The characteristics of signals from radioteletypewriter transmitters utilizing F1B modulation should be as follows:

a)Frequency shift: the lowest possible value.

b) Frequency shift tolerance: within plus or minus 3 per cent of the nominal value of the frequency shift.

c) Polarity: single channel circuits: the higher frequency corresponds to "position A" (start signal polarity).

8.3.2.2 **Recommendation.**— *The variation of the mean between the radio frequencies representing respectively "position A" and "position Z" should not exceed 100 Hz during any two-hour period.*

8.3.2.3 **Recommendation.—** *The overall distortion of the teletypewriter signal, as monitored at the output of the radio transmitter or in its immediate vicinity, should not exceed 10 per cent.*

Note.— Such distortion means the displacement in time of the transitions between elements from their proper positions, expressed as a percentage of unit element time.

8.3.2.4 **Recommendation**.— *Radioteletypewriter receivers concerned withF1B modulation should be capable of operating satisfactorily on signals having the characteristics set out in 8.3.2.1 and 8.3.2.2.*

8.3.2.5 **Recommendation**.— *The characteristics of multichannel transmission of teletypewriter signals over a radio circuit should be established by agreement between the Administrations concerned.*

8.4 CHARACTERISTICS OF INTERREGIONAL AFS CIRCUITS

8.4.1 **Recommendation.**— *Interregional AFS circuits being implemented or upgraded should employ high quality telecommunications service. Modulation rate should take into account traffic volumes expected under both normal and alternate route conditions.*

8.5 TECHNICAL PROVISIONS RELATING TO ATS MESSAGE TRANSMISSION

8.5.1 Interconnection by direct or omnibus channels — low modulation rates — 5-unit code.

Note.— See 8.6 for medium modulation rates.

8.5.1.1 **Recommendation.—** *AFTN techniques (cf. 8.2) should be used.*

8.6 TECHNICAL PROVISIONS RELATING TO INTERNATIONAL GROUND-GROUND DATA INTERCHANGE AT MEDIUM AND HIGHER SIGNALLING RATES

Note.— Throughout this section in the context of coded character sets, the term "unit" means the unit of selective information and is essentially equivalent to the term "bit".

8.6.1 General

8.6.1.1 **Recommendation.** – *In international data interchange of characters, a 7-unit coded character set providing a repertoire of 128 characters and designated as International Alphabet No. 5 (IA-5) should be used. Compatibility with the 5-unit coded character set of International Telegraph Alphabet No. 2 (ITA-2) should be ensured where applicable.*

8.6.1.2 When the provisions of 8.6.1.1 are applied, International Alphabet No. 5 (IA-5) contained in Table 8-2 shall be used.

8.6.1.2.1 The serial transmission of units comprising an individual character of IA-5 shall be with the low order unit (b1) transmitted first.

8.6.1.2.2 **Recommendation.** – *When IA-5 is used, each character should include an additional unit for parity in the eighth level position.*

8.6.1.2.3 When the provisions of 8.6.1.2.2 are applied, the sense of the character parity bit shall produce even parity in links which operate on the start-stop principle, and odd parity in links using end-to-end synchronous operations.

8.6.1.2.4 Character-for-character conversion shall be as listed in Tables 8-3 and 8-4 for all characters which are authorized in the AFTN format for transmission on the AFS in both IA-5 and ITA-2.

8.6.1.2.5 Characters which appear in only one code set, or which are not authorized for transmission on the AFS shall be as depicted in the code conversion tables.

8.6.2 Data transmission characteristics

8.6.2.1 **Recommendation**.— *The data signalling rate should be chosen from among the following:*

1600 bits/s	4 800 bits/s
1 200 bits/s	9 600 bits/s
2 400 bits/s	

8.6.2.2 **Recommendation.**—*The type of transmission for each data signalling rate should be chosen as follows:*

Data signalling rate	Type of transmission
1600 bits/s	Synchronous or asynchronous serial transmission
1 200 bits/s	Synchronous or asynchronous serial transmission
2 400 bits/s	Synchronous serial transmission
4 800 bits/s	Synchronous serial transmission
9 600 bits/s	Synchronous serial transmission

8.6.2.3 **Recommendation**.—*The type of modulation for each data signalling rate should be chosen as follows:*

Data signalling rate	Type of modulation
1600 bits/s	Frequency
1 200 bits/s	Frequency
2 400 bits/s	Phase
4 800 bits/s	Phase
9 600 bits/s	Phase-amplitude

Note.— This recommendation does not necessarily apply to ground-ground extensions of air-ground links used exclusively for the transfer of air-ground data, inasmuch as such circuits may be considered as part of the air-ground link.

8.6.2.4 CHARACTER STRUCTURE ON DATA LINKS

8.6.2.4.1 Character parity shall not be used for error checking on CIDIN links. Parity appended to IA-5 coded characters per 8.6.1.2.2, prior to entry to the CIDIN shall be ignored. For messages exiting the CIDIN, parity shall be generated in accordance with 8.6.1.2.3.

8.6.2.4.2 Characters of less than eight bits in length shall be padded out to eight bits in length before transmission over any octet-based or bit-oriented communications network. The padding bits shall occupy the higher order end of the octet, i.e. bit 8, bit 7 as required, and shall have the binary values 0.

8.6.2.5 When exchanging data over CIDIN links using bit-oriented procedures, the entry centre address, exit centre addresses and destination addresses in the Transport and CIDIN Packet Headers shall be in the IA-5 character set contained in Table 8-2.

8.6.2.6 **Recommendation**.— *When transmitting messages in AFTN format over CIDIN links using bit-oriented procedures, the messages should be in the IA-5 character set contained in Table 8-2.*

8.6.3 Ground-ground character-oriented data link control procedures

Note.— The provisions of this section pertain to ground-ground data interchange applications using IA-5 prescribed by 8.6.1 and which employ the ten transmission control characters (SOH, STX, ETX, EOT, ENQ, ACK, DLE, NAK, SYN, and ETB) for data link control, over synchronous or asynchronous transmission facilities.

8.6.3.1 *Descriptions*. The following descriptions shall apply to data link applications contained in this section:

a) A master station is that station which has control of the data link at a given instant.

b) A slave station is one that has been selected to receive a transmission from the master station.

c) A control station is the single station on a multipoint link that is permitted to assume master status and deliver messages to one or more individually selected (non-control) tributary stations, or it is permitted to assign temporary master status to any of the other tributary stations.

8.6.3.2 MESSAGE COMPOSITION

a) A transmission shall consist of characters from IA-5 transmitted in accordance with 8.6.1.2.2 and shall be either an information message or a supervisory sequence.

b) An information message used for the exchange of data shall take one of the following forms:

1)	S		E B
	T	---TEXT---	T C
	X		X C

2)	S		E B
	T	---TEXT---	T C
	X		B C

3)	S		S		E B
	O	---HEADING---	T	---TEXT---	T C
	H		X		X C

4)	S		S		E B
	O	---HEADING---	T	---TEXT---	T C
	H		X		B C

5)	S		E B
	O	---HEADING---	T C
	H		B C

B

Note 1.— C is a block check character (BCC).

C

Note 2.— In formats 2), 4), and 5) above which end with ETB, some continuation is required.

c) A supervisory sequence shall be composed of either a single transmission control character (EOT, ENQ, ACK or NAK) or a single transmission control (ENQ) preceded by a prefix of up to 15 non-control characters, or the character DLE used in conjunction with other graphic and control characters to provide additional communication control functions.

8.6.3.3 Three system categories are specified in terms of their respective circuit characteristics, terminal configurations, and message transfer procedures as follows:

System category A: two-way alternate, multipoint allowing either centralized or non-centralized operation and single or multiple message-oriented information transfers without replies (but with delivery verification).

System category B: two-way simultaneous, point-to-point employing message associated blocking and modulo 8 numbering of blocks and acknowledgements.

System category C: two-way alternate, multipoint allowing only centralized (computer-to-terminal) operation, single or multiple message transfers with replies.

8.6.3.3.1 In addition to the characteristics prescribed in the paragraphs that follow for both system categories A and B, other parameters that shall be accounted for in order to ensure viable, operationally reliable communications include:

a) the number of SYN characters required to establish and maintain synchronization;

Note.— Normally the transmitting station sends three contiguous SYN characters and the receiving station detects at least two before any action is taken.

b) the values of system time-outs for such functions as “idle line” and “no response” as well as the number of automatic retries that are to be attempted before manual intervention is signalled;

c) the composition of prefixes within a 15 character maximum.

Note.— By agreement between the administrations concerned, it is permissible for supervisory signals to contain a station identification prefix using characters selected from columns 4 through 7 of IA-5.

8.6.3.3.2 **Recommendation.—** *For multipoint implementations designed to permit only centralized (computer-to-terminal) operations, the provisions of 8.6.3.7 should be employed.*

8.6.3.4 BLOCK CHECK CHARACTER

8.6.3.4.1 Both system category A and B shall utilize a block check character to determine the validity of a transmission.

8.6.3.4.2 The block check character shall be composed of 7 bits plus a parity bit.

8.6.3.4.3 Each of the first 7 bits of the block check character shall be the modulo 2 binary sum of every element in the same bit 1 to bit 7 column of the successive characters of the transmitted block.

8.6.3.4.4 The longitudinal parity of each column of the block, including the block check character, shall be even.

8.6.3.4.5 The sense of the parity bit of the block check character shall be the same asfor the information characters (see 8.6.1.2.3).

8.6.3.4.6 *SUMMATION*

8.6.3.4.6.1 The summation to obtain the block check character shall be started by the first appearance of either SOH (start of heading) or STX (start of text).

8.6.3.4.6.2 The starting character shall not be included in the summation.

8.6.3.4.6.3 If an STX character appears after the summation has been started by SOH, then the STX character shall be included in the summation as if it were a text character.

8.6.3.4.6.4 With the exception of SYN (synchronous idle), all the characters which are transmitted after the start of the block check summation shall be included in the summation, including the ETB (end of transmission/block) or ETX (end of text) control character which signals that the following character is the block check character.

8.6.3.4.7 No character, SYN or otherwise, shall be inserted between the ETB or ETX character and the block check character.

8.6.3.5 DESCRIPTION OF SYSTEM CATEGORY A

System category A is one in which a number of stations are connected by a multipoint link and one station is permanently designated as the control station which monitors the link at all times to ensure orderly operation.

8.6.3.5.1 *LINK ESTABLISHMENT PROCEDURE*

8.6.3.5.1.1 To establish the link for transmission, the control station shall either:

a) poll one of the tributary stations to assign it master status; or

b) assume master status and select one or more tributary (slave) stations to receive a transmission.

8.6.3.5.1.2 Polling shall be accomplished by the control station sending a polling supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

8.6.3.5.1.3 A tributary station detecting its assigned polling supervisory sequence shall assume master status and respond in one of two ways:

a) if the station has a message to send, it shall initiate a selection supervisory sequence as described in 8.6.3.5.1.5;

b) if the station has no message to send, it shall send EOT, and master status shall revert to the control station.

8.6.3.5.1.4 If the control station detects an invalid or no response resulting from a poll, it shall terminate by sending EOT prior to resuming polling or selection.

8.6.3.5.1.5 Selection shall be accomplished by the designated master station sending a selection supervisory sequence consisting of a prefix identifying a single station and ending in ENQ.

8.6.3.5.1.6 A station detecting its assigned selection supervisory sequence shall assume slave status and send one of two replies:

a) if the station is ready to receive, it shall send a prefix followed by ACK. Upon detecting this reply, the master station

shall either select another station or proceed with message transfer;

b) if the station is not ready to receive, it shall send a prefix followed by NAK and thereby relinquish slave status. If

the master station receives NAK, or no reply, it shall either select another or the same tributary station or terminate;

c) it shall be permissible for N retries ($N \geq 0$) to be made to select a station for which NAK, an invalid reply, or no response has been received.

8.6.3.5.1.7 If one or more stations have been selected and have properly responded with ACK, the master station shall proceed with message transfer.

8.6.3.5.2 *MESSAGE TRANSFER PROCEDURE*

8.6.3.5.2.1 The master station shall send a message or series of messages, with or without headings to the selected slave station(s).

8.6.3.5.2.2 The transmission of a message shall:

a) begin with:

– SOH if the message has a heading,
– STX if the message has no heading;

b) be continuous, ending with ETX, immediately followed by a block check character (BCC).

8.6.3.5.2.3 After transmitting one or more messages, the master station shall verify successful delivery at each selected slave station.

8.6.3.5.3 DELIVERY VERIFICATION PROCEDURE

8.6.3.5.3.1 The master station shall send a delivery verification supervisory sequence consisting of a prefix identifying a single slave station and ending in ENQ.

8.6.3.5.3.2 A slave station detecting its assigned delivery verification supervisory sequence shall send one of two replies:

a) if the slave station properly received all of the transmission, it shall send an optional prefix followed by ACK;

b) if the slave station did not receive all of the transmission properly, it shall send an optional prefix followed by NAK.

8.6.3.5.3.3 If the master station receives no reply or an invalid reply, it shall request a reply from the same or another slave station until all selected stations have been properly accounted for.

8.6.3.5.3.4 If the master station receives a negative reply (NAK) or, after N ≥0 repeat attempts, no reply, it shall repeat that transmission to the appropriate slave stations at a later opportunity.

8.6.3.5.3.5 After all messages have been sent and delivery verified, the master station shall proceed with link termination.

8.6.3.5.4 *LINK TERMINATION PROCEDURE*

8.6.3.5.4.1 The terminate function, negating the master or slave status of all stations and returning master status to the control station, shall be accomplished by the master station transmitting EOT.

8.6.3.6 DESCRIPTION OF SYSTEM CATEGORY B

System category B is one in which two stations are on a point-to-point, full-duplex link and each station has the capability tomaintain concurrent master and slave status, i.e. master status on its transmit side and slave status on its receive side and both stations can transmit simultaneously.

8.6.3.6.1 *LINK ESTABLISHMENT PROCEDURE*

8.6.3.6.1.1 To establish the link for message transfers (from the calling to the called station), the calling station shall request the identity of the called station by sending an identification supervisory sequence consisting of a DLE character followed by a colon character, an optional prefix, and ENQ.

8.6.3.6.1.2 The called station, upon detecting ENQ, shall send one of two replies:

a) if ready to receive, it shall send a sequence consisting of a DLE followed bya colon, a prefix which includes its identity and ended by ACK0 (see 8.6.3.6.2.5). This establishes the link for message transfers from the calling to the called station;

b) if not ready to receive, it shall send the above sequence with the ACK0 replaced by NAK.

8.6.3.6.1.3 Establishment of the link for message transfers in the opposite direction can be initiated at any time following circuit connection in a similar manner to that described above.

8.6.3.6.2 MESSAGE TRANSFER PROCEDURE

8.6.3.6.2.1 System category B message transfer provides for message associated blocking with longitudinal checking and modulo 8 numbered acknowledgements.

8.6.3.6.2.2 It is permissible for a transmission block to be a complete message or a portion of a message. The sending station shall initiate the transmission with SOTB N followed by:

a) SOH if it is the beginning of a message that contains a heading;

b) STX if it is the beginning of a message that has no heading;

c) SOH if it is an intermediate block that continues a heading;

d) STX if it is an intermediate block that continues a text.

Note.— SOTB N is the two-character transmission control sequence DLE = (characters 1/0, and 3/13) followed by the block number, N, where N is one of the IA-5 characters 0, 1 ... 7 (characters 3/0, 3/1 ... 3/7).

8.6.3.6.2.3 A block which ends at an intermediate point within a message shall be ended with ETB; a block which ends at the end of a message shall be ended with ETX.

8.6.3.6.2.4 It shall be permissible for each station to initiate and continue to send messages to the other concurrently according to the following sequence.

a) It shall be permissible for the sending station (master side) to send blocks, containing messages or parts of messages, continuously to the receiving station (slave side) without waiting for a reply.

b) It shall be permissible for replies, in the form of slave responses, to be transmitted by the receiving station while the sending station is sending subsequent blocks.

Note.— By use of modulo 8 numbering of blocks and replies, it shall be permissible for the sending station to send as many as seven blocks ahead of the received replies before being required to stop transmission until six or less blocks are outstanding.

c) If a negative reply is received, the sending station (master side) shall start retransmission with the block following the last block for which the proper affirmative acknowledgement was received.

8.6.3.6.2.5 Slave responses shall be according to one of the following:

a) if a transmission block is received without error and the station is ready to receive another block, it shall send DLE, a colon, an optional prefix, and the appropriate acknowledgement ACKN (referring to the received block beginning with SOTB N, e.g. ACK0, transmitted as DLE0 is used as the affirmative reply to the block numbered SOTB0, DLE1 for SOTB1, etc.);

b) if a transmission block is not acceptable, the receiving station shall send DLE, a colon, an optional prefix, and NAK.

8.6.3.6.2.6 **Recommendation.** — *Slave responses should be interleaved between message blocks and transmitted at the earliest possible time.*

8.6.3.6.3 *LINK TERMINATION PROCEDURE*

8.6.3.6.3.1 If the link has been established for message transfers in either or both directions, the sending of EOT by a station shall signal the end of message transfers in that direction. To resume message transfers after sending EOT, the link shall be re-established in that direction.

8.6.3.6.3.2 EOT shall only be transmitted by a station after all outstanding slave responses have been received or otherwise accounted for.

8.6.3.6.4 *CIRCUIT DISCONNECTION*

8.6.3.6.4.1 On switched connections, the data links in both directions shall be terminated before the connection is cleared. In addition, the station initiating clearing of the connection shall first announce its intention to do so by transmitting the two-character sequence DLE EOT, followed by any other signals required to clear the connection.

8.6.3.7 DESCRIPTION OF SYSTEM CATEGORY C (CENTRALIZED)

System category C (centralized) is one (like system category A) in which a number of stations are connected by a multipoint link and one station is designated as the control station but (unlike system category A) provides only for centralized (computer-to-terminal) operations where message interchange (with replies) shall be constrained to occur only between the control and a selected tributary station.

8.6.3.7.1 *LINK ESTABLISHMENT PROCEDURE*

8.6.3.7.1.1 To establish the link for transmission the control station shall either:

a) poll one of the tributary stations to assign it master status; or

b) assume master status and select a tributary station to assume slave status and receive a transmission according to either of two prescribed selection procedures:

1) selection with response (see 8.6.3.7.1.5); or

2) fast select (see 8.6.3.7.1.7).

8.6.3.7.1.2 Polling is accomplished by the control station sending a polling supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

8.6.3.7.1.3 A tributary station detecting its assigned polling supervisory sequence shall assume master status and respond in one of two ways:

a) if the station has a message to send, it shall initiate message transfer. The control station assumes slave status;

b) if the station has no message to send, it shall send EOT and master status shall revert to the control station.

8.6.3.7.1.4 If the control station detects an invalid or no response resulting from a poll, it shall terminate by sending EOT prior to resuming polling or selection.

8.6.3.7.1.5 Selection with response is accomplished by the control station assuming master status and sending a selection supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

8.6.3.7.1.6 A tributary station detecting its assigned selection supervisory sequence shall assume slave status and send one of two replies:

a) if the station is ready to receive, it shall send an optional prefix followed by ACK. Upon detecting this reply, the master station shall proceed with message transfer;

b) if the station is not ready to receive, it shall send an optional prefix followed by NAK. Upon detecting NAK, it shall be permissible for the master station to again attempt selecting the same tributary station or initiate termination by sending EOT.

Note.— If the control station receives an invalid or no reply, it is permitted to attempt again to select the same tributary or after N retries (N ≥ 0) either to exit to a recovery procedure or to initiate termination by sending EOT.

8.6.3.7.1.7 Fast select is accomplished by the control station assuming master status and sending a selection supervisory sequence, and without ending this transmission with ENQ or waiting for the selected tributary to respond, proceeding directly to message transfer.

8.6.3.7.2 *MESSAGE TRANSFER PROCEDURE*

8.6.3.7.2.1 The station with master status shall send a single message to the station with slave status and wait for a reply.

8.6.3.7.2.2 The message transmission shall:

a) begin with:

– SOH if the message has a heading,

– STX if the message has no heading;

and

b) be continuous, ending with ETX, immediately followed by BCC.

8.6.3.7.2.3 The slave station, upon detecting ETX followed by BCC, shall send one of two replies:

a) if the messages were accepted and the slave station is ready to receive another message, it shall send an optional prefix followed by ACK. Upon detecting ACK, the master station shall be permitted either to transmit the next message or initiate termination;

b) if the message was not accepted and the slave station is ready to receive another message, it shall send an optional prefix followed by NAK. Upon detecting NAK, the master station may either transmit another message or initiate termination. Following the NAK reply, the next message transmitted need not be a retransmission of the message that was not accepted.

8.6.3.7.2.4 If the master station receives an invalid or no reply to a message, it shall be permitted to send a delivery verification supervisory sequence consisting of an optional prefix followed by ENQ. Upon receipt of a delivery verification supervisory sequence, the slave station repeats its last reply.

8.6.3.7.2.5 N retries ($N \geq 0$) may be made by the master station in order to get a valid slave reply. If a valid reply is not received after N retries, the master station exits to a recovery procedure.

8.6.3.7.3 *LINK TERMINATION PROCEDURE*

8.6.3.7.3.1 The station with master status shall transmit EOT to indicate that it has no more messages to transmit. EOT shall negate the master/slave status of both stations and return master status to the control station.

8.6.4 Ground-ground bit-oriented data link control procedures

Note.— The provisions of this section pertain to ground-ground data interchange applications using bit-oriented data link control procedures enabling transparent, synchronous transmission that is independent of any encoding; data link control functions are accomplished by interpreting designated bit positions in the transmission envelope of a frame.

8.6.4.1 The following descriptions shall apply to data link applications contained in this section:

a) Bit-oriented data link control procedures enable transparent transmission that is independent of any encoding.

b) A data link is the logical association of two interconnected stations, including the communication control capability of the interconnected stations.

c) A station is a configuration of logical elements, from or to which messages are transmitted on a data link, including those elements which control the message flow on the link via communication control procedures.

d) A combined station sends and receives both commands and responses and is responsible for control of the data link.

e) Data communication control procedures are the means used to control and protect the orderly interchange of information between stations on a data link.

f) A component is defined as a number of bits in a prescribed order within a sequence for the control and supervision of the data link.

g) An octet is a group of 8 consecutive bits.

h) A sequence is one or more components in prescribed order comprising an integral number of octets.

i) A field is a series of a specified number of bits or specified maximum number of bits which performs the functions of data link or communications control or constitutes data to be transferred.

j) A frame is a unit of data to be transferred over the data link, comprising one or more fields in a prescribed order.

k) A common ICAO data interchange network (CIDIN) switching centre is that part of an automatic AFTN switching centre which provides for the entry, relay, and exit centre functions using the bit-oriented link and CIDIN networkprocedures specified in this section and includes the appropriate interface(s) with other parts of the AFTN and with other networks.

8.6.4.2 BIT-ORIENTED DATA LINK CONTROL PROCEDURES FOR POINT-TO-POINT, GROUND-GROUND DATA INTERCHANGE APPLICATIONS EMPLOYING SYNCHRONOUS TRANSMISSION FACILITIES

Note.— The following link level procedures are the same asthe LAPB link level procedures described in ITU CCITT Recommendation X.25, Section 2, Yellow Book (1981 version). Later versions of Recommendation X.25 will be reviewed as they are released to ascertain whether or not they should be adopted.

8.6.4.2.1 *Frame format.* Frames shall contain not less than 32 bits, excluding the opening and closing flags, and shall conform to the following format:

FLAG F	ADDRESS A	CONTROL C	INFORMATION I	FCS	FLAG F

8.6.4.2.1.1 A frame shall consist of an opening flag (F), an address field (A), a control field (C), an optional information field (I), a frame check sequence (FCS), and a closing flag sequence (F), and shall be transmitted in that order.

Note.— In relation to CIDIN, the opening flag, the fields A and C, the FCS and the closing flag form together the Data Link Control Field (DLCF). The field I is denoted as the Link Data Field (LDF).

8.6.4.2.1.1.1 The flag (F) shall be the 8-bit sequence 01111110 which delimits the beginning and ending of each frame. It shall be permissible for the closing flag of a frame to also serve as the opening flag of the next frame.

8.6.4.2.1.1.2 The address (A) field shall consist of one octet, excluding 0 bits added to achieve transparent transmission, which shall contain the link address of the combined station.

8.6.4.2.1.1.3 The control (C) field shall consist of one octet, excluding 0 bits added to achieve transparent transmission, and shall contain the commands, responses, and frame sequence number components for the control of the data link.

8.6.4.2.1.1.4 The information (I) field shall contain digital data which may be presented in any code or sequence but shall not exceed a maximum of 259 octets, excluding 0 bits added to achieve transparent transmission. The I field shall always be a multiple of 8 bits in length.

8.6.4.2.1.1.5 The frame check sequence (FCS) shall consist of two octets, excluding 0 bits added to achieve transparent transmission, and shall contain the error detecting bits.

8.6.4.2.2 A frame check sequence (FCS) shall be included in each frame for the purpose of error checking.

8.6.4.2.2.1 The error checking algorithm shall be a cyclic redundancy check (CRC).

8.6.4.2.2.2 The CRC polynomial (P(x)) shall be

$$x^{16} + x^{12} + x^{5} + 1.$$

8.6.4.2.2.3 The FCS shall be a 16-bit sequence. This FCS shall be the ones' complement of the remainder, R(x), obtained from the modulo 2 division of

$$x^{16}[G(x)] + x^{K}(x^{15} + x^{14} + x^{13} + \ldots + x^{2} + x^{1} + 1)$$

by the CRC polynomial, P(x).

G(x) shall be the contents of the frame existing between, but including neither, the final bit of the opening flag nor the first bit of the FCS, excluding bits inserted for transparent transmission.

K shall be the length of G(x) (number of bits).

8.6.4.2.2.4 The generation and checking of the FCS accumulation shall be as follows:

a) the transmitting station shall initiate the FCS accumulation with the first (least significant) bit of the address (A) field and shall include all bits up to and including the last bit preceding the FCS sequence, but shall exclude all 0 bits (if any) inserted to achieve transparent transmission;

b) upon completion of the accumulation the FCS shall be transmitted, starting with bit b1 (highest order coefficient) and proceeding in sequence to bit b16 (lowest order coefficient) as shown below;

First bit transmitted ↓ (b1)

b16	b15	b14	- - - - - - - - - -	b3	b2	b1
x^0	x^1	x^2		x^{13}	x^{14}	x^{15}

c) the receiving station shall carry out the cyclic redundancy check (CRC) on the content of the frame commencing with the first bit received following the opening flag, and shall include all bits up to and including the last bit preceding the closing flag, but shall exclude all 0 bits (if any) deleted according to the rules for achievement of transparency;

d) upon completion of the FCS accumulation, the receiving station shall examine the remainder. In the absence of transmission error, the remainder shall be 1111000010111000 (x 0 through x 15, respectively).

8.6.4.2.3 *Achievement of transparency*. The frame format contents (A, C, link data field, and FCS) shall be capable of containing any bit configuration.

8.6.4.2.3.1 The following rules shall apply to all frame contents, except flag sequences:

a) the transmitting station shall examine the frame contents before transmission, and shall insert a single 0 bit immediately following each sequence of 5 consecutive 1 bits;

b) the receiving station shall examine the received frame contents for patterns consisting of 5 consecutive 1 bits immediately followed by one (or more) 0 bit(s) and shall remove the 0 bit which directly follows 5 consecutive 1 bits.

8.6.4.2.4 *Special transmission sequences and related link states.* In addition to employing the prescribed repertoire of commands and responses to manage the interchange of data and control information, stations shall use the following conventions to signal the indicated conditions:

a) *Abort* is the procedure by which a station in the process of sending a frame ends the frame in an unusual manner such that the receiving station shall ignore the frame. The conventions for aborting a frame shall be:

1) transmitting at least seven, but less than fifteen, one bits (with no inserted zeros);

2) receiving seven one bits.

b) *Active link state*. A link is in an active state when a station is transmitting a frame, an abort sequence, or inter frame time fill. When the link is in the active state, the right of the transmitting station to continue transmission shall be reserved.

c) *Interframe time fill*. Interframe time fill shall be accomplished bytransmitting continuous flags between frames. There is no provision for time fill within a frame.

d) *Idle link state.* A link is in an idle state when a continuous one condition is detected that persists for 15 bit times, or longer. Idle link time fill shall be a continuous one condition on the link.

e) *Invalid frame.* An invalid frame is one that is not properly bounded by two flags or one which is shorter than 32 bits between flags.

8.6.4.2.5 *MODES*

8.6.4.2.5.1 *Operational mode.* The operational mode shall be the asynchronous balanced mode (ABM).

8.6.4.2.5.1.1 It shall be permissible for a combined station in ABM to transmit without invitation from the associated station.

8.6.4.2.5.1.2 A combined station in ABM shall be permitted to transmit any command or response type frame except DM.

8.6.4.2.5.2 *Non-operational mode*. The non-operational mode shall be the asynchronous disconnected mode (ADM) in which a combined station is logically disconnected from the data link.

8.6.4.2.5.2.1 It shall be permissible for a combined station in ADM to transmit without invitation from the associated station.

8.6.4.2.5.2.2 A combined station in ADM shall transmit only SABM, DISC, UA and DM frames. (See 8.6.4.2.7 for a description of the commands and responses to which these frame types refer.)

8.6.4.2.5.2.3 A combined station in ADM shall transmit a DM when a DISC is received, and shall discard all other received command frames except SABM. If a discarded command frame has the P bit set to "1", the combined station shall transmit a DM with the F bit set to "1".

8.6.4.2.6 *Control field functions and parameters.* Control fields contain a command or a response and sequence numbers where applicable. Three types of control fields shall be used to perform:

a) numbered information transfer (I-frames);

b) numbered supervisory functions (S-frames); and

c) unnumbered control functions (U-frames).

The control field formats shall be as shown in Table 8-5. The functional frame designation associated with each type control field as well as the control field parameters employed in performing these functions shall be described in the following paragraphs.

8.6.4.2.6.1 The I-frame type is used to perform information transfers. Except for some special cases it is the only format which shall be permitted to contain an information field.

8.6.4.2.6.2 The S-frame type is used for supervisory commands and responses that perform link supervisory control functions such as acknowledge information frames, request transmission or retransmission of information frames, and to request a temporary suspension of transmission of I-frames. No information field shall be contained in the S-frame.

8.6.4.2.6.3 The U-frame type is used for unnumbered commands and responses that provide additional link control functions. One of the U-frame responses, the frame reject (FRMR) response, shall contain an information field; all other frames of the U-frame type shall not contain an information field.

8.6.4.2.6.4 The station parameters associated with the three control field types shall be as follows:

a) *Modulus.* Each I-frame shall be sequentially numbered with a send sequence count, N(S),having value 0 through modulus minus one (where modulus is the modulus of the sequence numbers). The modulus shall be 8. The maximum number of sequentially numbered I-frames that a station shall have outstanding (i.e. unacknowledged) at any given time shall never exceed one less than the modulus of the sequence numbers. This restriction on the number of outstanding frames is to prevent any ambiguity in the association of transmission frames with sequence numbers during normal operation and/or error recovery.

b) The send state variable V(S) shall denote the sequence number of the next in-sequence I-frame to be transmitted.

1) The send state variable shall take on the value 0 through modulus minus one (modulus is the modulus of the sequence numbering and the numbers cycle through the entire range).

2) The value of V(S) shall be incremented by one with each successive in-sequence I-frame transmission, but shall not exceed the value of N(R) contained in the last received frame by more than the maximum permissible

number of outstanding I-frames (k). See i) below for the definition of k.

c) Prior to transmission of an in-sequence I-frame, the value of N(S) shall be updated to equal the value of V(S).

d) The receive state variable V(R) shall denote the sequence number of the next in-sequence I-frame to be received.

1) V(R) shall take on the values 0 through modulus minus one.

2) The value of V(R) shall be incremented by one after the receipt ofan error-free, in-sequence I-frame whose send sequence number N(S), equals V(R).

e) All I-frames and S-frames shall contain N(R), the expected sequence number of the next received frame. Prior to transmission of either an I or an S type frame, the value of N(R) shall be updated to equal the current value of the receive state variable. N(R) indicates that the station transmitting the N(R) has correctly received all I-frames numbered up to and including N(R) – 1.

f) Each station shall maintain an independent send state variable, V(S), and receive state variable, V(R), on the I-frames it sends and receives. That is, each combined station shall maintain a V(S) count on the I-frames it transmits and a V(R) count on the I-frames it has correctly received from the remote combined station.

g) The poll (P/F) bit shall be used by a combined station to solicit (poll) a response or sequence of responses from the remote combined station.

h) The final (P/F) bit shall be used by the remote combined station to indicate the response frame transmitted as the result of a soliciting (poll) command.

i) The maximum number (k) of sequentially numbered I-frames that a station may have outstanding (i.e. unacknowledged) at any given time is a station parameter which shall never exceed the modulus.

Note.— k is determined by station buffering limitations and should be the subject of bilateral agreement at the time of circuit establishment.

8.6.4.2.7 *Commands and responses*. It shall be permissible for a combined station to generate either commands or responses. A command shall contain the remote station address while a response shall contain the sending station address.

The mnemonics associated with all of the commands and responses prescribed for each of the three frame types (I, S, and U) and the corresponding encoding of the control field are as shown in Table 8-6.

8.6.4.2.7.1 The I-frame command provides the means for transmitting sequentially numbered frames, each of which shall be permitted to contain an information field.

8.6.4.2.7.2 The S-frame commands and responses shall be used to perform numbered supervisory functions (such as acknowledgement, polling, temporary suspension of information transfer, or error recovery).

8.6.4.2.7.2.1 The receive ready command or response (RR) shall be used by a station to:

a) indicate that it is ready to receive an I-frame;

b) acknowledge previously received I-frames numbered up to and including N(R) – 1;

c) clear a busy condition that was initiated by the transmission of RNR.

Note.— It is permissible for a combined station to use the RR command to solicit a response from the remote combined station with the poll bit set to "1".

8.6.4.2.7.2.2 It shall be permissible to issue a reject command or response (REJ) to request retransmission of frames starting with the I-frame numbered N(R) where:

a) I-frames numbered N(R) – 1 and below are acknowledged;

b) additional I-frames pending initial transmission are to be transmitted following the retransmitted I-frame(s);

c) only one REJ exception condition, from one given station to another station, shall be established at any given time: another REJ shall not be issued until the first REJ exception condition has been cleared;

d) the REJ exception condition is cleared (reset) upon the receipt of an I-frame with an N(S) count equal to the N(R) of the REJ command/response.

8.6.4.2.7.2.3 The receive not ready command or response (RNR) shall be used to indicate a busy condition, i.e. temporary inability to accept additional incoming I-frames, where:

a) frames numbered up to and including N(R) – 1 are acknowledged;

b) frame N(R) and any subsequent I-frames received, if any, are not acknowledged (the acceptance status of these frames shall be indicated in subsequent exchanges);

c) the clearing of a busy condition shall be indicated by the transmission of an RR, REJ, SABM, or UA with or without the P/F bit set to "1".

8.6.4.2.7.2.3.1 **Recommendation.—**

a) A station receiving an RNR frame when in the process of transmitting should stop transmitting I-frames at the earliest possible time.

b) Any REJ command or response which was received prior to the RNR should be actioned before the termination of transmission.

c) It should be permissible for a combined station to use the RNR command with the poll bit set to "1" to obtain a supervisory frame with the final bit set to "1" from the remote combined station.

8.6.4.2.7.2.4 It shall be permissible for the selective reject command or response (SREJ) to be used to request retransmission of the single I-frame numbered N(R) where:

a) frames numbered up to N(R) – 1 are acknowledged; frame N(R) is not accepted; the only I-frames accepted are those received correctly and in sequence following the I-frame requested; the specific I-frame to be retransmitted is indicated by the N(R) in the SREJ command/response;

b) the SREJ exception condition is cleared (reset) upon receipt of an I-frame with an N(S) count equal to the N(R) of the SREJ;

c) after a station transmits a SREJ it is not permitted to transmit SREJ or REJ for an additional sequence error until the first SREJ error condition has been cleared;

d) I-frames that have been permitted to be transmitted following the I-frame indicated by the SREJ are not retransmitted as the result of receiving a SREJ; and

e) it is permissible for additional I-frames pending initial transmission to be transmitted following the retransmission of the specific I-frame requested by the SREJ.

8.6.4.2.7.3 The U-frame commands and responses shall be used to extend the number of link control functions.

Transmitted U-frames do not increment the sequence counts at either the transmitting or receiving station.

a) The U-frame mode-setting commands (SABM, and DISC) shall be used to place the addressed station in the appropriate response mode (ABM or ADM) where:

1) upon acceptance of the command, the station send and receive state variables, V(S) and V(R), are set to zero;

2) the addressed station confirms acceptance at the earliest possible time by transmission of a single unnumbered acknowledgement, UA;

3) previously transmitted frames that are unacknowledged when the command is actioned remain unacknowledged;

4) the DISC command is used to perform a logical disconnect, i.e. to inform the addressed combined station that the transmitting combined station is suspending operation. No information field shall be permitted with the DISC command.

b) The unnumbered acknowledge response (UA) shall be used by a combined station to acknowledge the receipt and acceptance of an unnumbered command. Received unnumbered commands are not actioned until the UA response is transmitted. No information field shall be permitted with the UA response.

c) The frame reject response (FRMR), employing the information field described below, shall be used by a combined station in the operational mode (ABM) to report that one of the following conditions resulted from the receipt of a frame without an FCS error:

1) a command/response that is invalid or not implemented;

2) a frame with an information field that exceeds the size of the buffer available;

3) a frame having an invalid N(R) count.

Note.— An invalid N(R)is a count which points to an I-frame which has previously been transmitted and acknowledged or to an I-frame which has not been transmitted and is not the next sequential I-frame pending transmission.

d) The disconnected mode response (DM) shall be used to report a non-operational status where the station is logically disconnected from the link. No information field shall be permitted with the DM response.

Note.— The DM response shall be sent to request the remote combined station to issue a mode-setting command or, if sent in response to the reception of a mode-setting command, to inform the remote combined station that the transmitting station is still in ADM and cannot action the mode-setting command.

8.6.4.3 EXCEPTION CONDITION REPORTING AND RECOVERY

This section specifies the procedures that shall be employed to effect recovery following the detection or occurrence of an exception condition at the link level. Exception conditions described are those situations that may occur as the result of transmission errors, station malfunction, or operational situations.

8.6.4.3.1 *Busy condition.* A busy condition occurs when a station temporarily cannot receive or continue to receive I-frames due to internal constraints, e.g. due to buffering limitations. The busy condition shall be reported to the remote combined station by the transmission of an RNR frame with the N(R) number of the next I-frame that is expected. It shall be permissible for traffic pending transmission at the busy station to be transmitted prior to or following the RNR.

Note.— The continued existence of a busy condition must be reported by retransmission of RNR at each P/F frame exchange.

8.6.4.3.1.1 Upon receipt of an RNR, a combined station in ABM shall cease transmitting I-frames at the earliest possible time by completing or aborting the frame in process. The combined station receiving an RNR shall perform a time-out operation before resuming asynchronous transmission of I-frames unless the busy condition is reported as cleared by the remote combined station. If the RNR was received as a command with the P bit set to “1”, the receiving station shall respond with an S-frame with the F bit set to “1”.

8.6.4.3.1.2 The busy condition shall be cleared at the station which transmitted the RNR when the internal constraint ceases. Clearance of the busy condition shall be reported to the remote station by transmission of an RR, REJ, SABM, or UA frame (with or without the P/F bit set to “1”).

8.6.4.3.2 *N(S) sequence error*. An N(S) sequence exception shall be established in the receiving station when an I-frame that is received error free (no FCS error) contains an N(S) sequence number that is not equal to the receive variable V(R) at the receiving station. The receiving station shall not acknowledge (shall not increment its receive variable V(R)) the frame causing the sequence error, or any I-frames which may follow, until an I-frame with the correct N(S) number is received. A station that receives one or more I-frames having sequence errors, but which are otherwise error free, shall accept the control information contained in the N(R) field and the P/F bit to perform link control functions, e.g. to receive acknowledgement of previously transmitted I-frames (via the N(R)), to cause the station to respond (P bit set to “1”).

8.6.4.3.2.1 The means specified in 8.6.4.3.2.1.1 and 8.6.4.3.2.1.2 shall be available for initiating the retransmission of lost or errored I-frames following the occurrence of a sequence error.

8.6.4.3.2.1.1 Where the REJ command/response is used to initiate an exception recovery following the detection of a sequence error, only one "sent REJ" exception condition, from one station to another station, shall be established at a time. A "sent REJ" exception shall be cleared when the requested I-frame is received. A station receiving REJ shall initiate sequential(re)transmission of I-frames starting with the I-frame indicated by the N(R) contained in the REJ frame.

FRMR INFORMATION FIELD BITS FOR BASIC (SABM) OPERATION

First bit transmitted

1 8	9	10 12	13	14 16	17	18	19	20	21 24
rejected basic control field	0	*V(S)*	*v*	*V(R)*	*w*	*x*	*y*	*z*	set to zero

where:

rejected basic control field is the control field of the received frame which caused the frame reject;

V(*S*) is the current value of the send state variable at the remote combined station reporting the error condition (bit 10 = low order bit);

V(*R*) is the current value of the receive state variable at the remote combined station reporting the error condition (bit 14 = low order bit);

v set to "1" indicates that the received frame which caused rejection was a response;

w set to "1" indicates that the control field received and returned in bits 1 through 8 are invalid or not implemented;

x set to "1" indicates that the control field received and returned in bits 1 through 8 was considered invalid because the frame contained an information field which is not permitted with this command. Bit *w* must be set to "1" in conjunction with this bit;

y set to "1" indicates that the information field received exceeded the maximum information field length which can be accommodated by the station reporting the error condition. This bit is mutually exclusive with bits *w* and *x* above;

z set to "1" indicates that the control field received and returned in bits 1 through 8 contained an invalid *N(R)* count. This bit is mutually exclusive with bit *w*.

8.6.4.3.2.1.2 In the event a receiving station, due to a transmission error, does not receive (or receives and discards) a single I-frame or the last I-frame(s) in a sequence of I-frames, it shall not detect an out-of-sequence exception and, therefore, shall not transmit REJ. The station which transmitted the unacknowledged I-frame(s) shall, following the completion of a system-specified time-out period, take appropriate recovery action to determine the sequence number at which retransmission must begin.

8.6.4.3.2.1.3 **Recommendation.—** A combined station which has timed out waiting for a response should not retransmit all unacknowledged frames immediately. The station may enquire about status with a supervisory frame.

Note 1.— If a station does retransmit all unacknowledged I-frames after a time-out, it must be prepared to receive a subsequent REJ frame with an N(R)greater than its send variable V(S).

Note 2.— Since contention may occur in the case of two-way alternate communications in ABM or ADM, the time-out interval employed by one combined station must be greater than that employed by the other combined station so as to permit contention to be resolved.

8.6.4.3.3 *FCS error*. Any frame with an FCS error shall not be accepted by the receiving station and will be discarded. No action shall be taken by the receiving station as the result of that frame.

8.6.4.3.4 *Frame reject exception condition.* A frame reject exception condition shall be established upon the receipt of an error-free frame which contains an invalid or unimplemented control field, an invalid N(R),or an information field which

has exceeded the maximum established storage capability. If a framereject exception condition occurs in a combined station,

the station shall either:

a) take recovery action without reporting the condition to the remote combined station; or

b) report the condition to the remote combined station with a FRMR response. The remote station will then be expected to take recovery action; if, after waiting an appropriate time, no recovery action appears to have been taken, the combined station reporting the frame reject exception condition may take recovery action. Recovery action for balanced operation includes the transmission of an implemented mode-setting command. Higher level functions may also be involved in the recovery.

8.6.4.3.5 *Mode-setting contention*. A mode-setting contention situation exists when a combined station issues a modesetting command and, before receiving an appropriate response (UA or DM), receives a mode-setting command from the remote combined station. Contention situations shall be resolved in the following manner:

a) when the send and receive mode-setting commands are the same, each combined station shall send a UA response at the earliest respond opportunity. Each combined station shall either enter the indicated mode immediately or defer entering the indicated mode until receiving a UA response. In the latter case, if the UA response is not received:

1) the mode may be entered when the response timer expires; or

2) the mode-setting command may be reissued;

b) when the mode-setting commands are different, each combined station shall enter ADM and issue a DM response at the earliest respond opportunity. In the case of DISC contention with a different mode-setting command, no further action is required.

8.6.4.3.6 *Time-out functions*. Time-out functions shall be used to detect that a required or expected acknowledging action or response to a previously transmitted frame has not been received. Expiration of the time-out function shall initiate appropriate action, e.g. error recovery or reissuance of the P bit. The duration of the following time-out functions is system dependent and subject to bilateral agreement:

a) combined stations shall provide a time-out function to determine that a response frame with F bit set to "1" to a command frame with the P bit set to "1" has not been received. The time-out function shall automatically cease upon receipt of a valid frame with the F bit set to "1";

b) a combined station which has no P bit outstanding, and which has transmitted one or more frames for which responses are anticipated shall start a time-out function to detect the no-response condition. The time-out function shall cease when an I- or S-frame is received with the N(R) higher than the last received N(R) (actually acknowledging one or more I-frames).

8.6.5 Common ICAO data interchange network (CIDIN)

8.6.5.1 INTRODUCTION

Note 1.— The common ICAO data interchange network (CIDIN) is an element of the aeronautical fixed service (AFS) which uses bit-oriented procedures, store and forward techniques and packet switching techniques based on CCITT Recommendation X.25 to carry messages of specific applications of the AFS such as AFTN and operational meteorological information (OPMET).

Note 2.— The CIDIN provides a reliable common network service for the conveyance of application messages in binary or text form to air traffic service providers and aircraft operating agencies.

8.6.5.1.1 CIDIN entry and exit centres or stations shall be used to connect application entities to the CIDIN.

Note.— The interfacing between CIDIN and application entities is a matter for local implementation.

8.6.5.1.2 CIDIN relay centres shall be used to forward packets between CIDIN entry and exit centres or stations which are not directly connected.

8.6.5.2 GENERAL

8.6.5.2.1 There shall be four protocol levels defined to control the transfer of messages between CIDIN switching centres:

— the data link protocol level

— the X.25 packet protocol level

— the CIDIN packet protocol level

— the CIDIN transport protocol level.

Note 1.— The relationship of the terms used is shown in Figures 8-1 and 8-2.

Note 2.— The details of CIDIN communication procedures and system specifications, as implemented in Europe, are shown in the EUR CIDIN Manual(EUR Doc 005).

8.6.5.2.2 *THE DATA LINK PROTOCOL LEVEL*

8.6.5.2.2.1 X.25 packets to be transferred between two CIDIN switching centres or a CIDIN switching centre and a packet switched data network, shall be formatted into data link frames.

8.6.5.2.2.2 Each data link frame shall consist of a data link control field (DLCF), possibly followed by a link data field, and shall be terminated by a frame check sequence and flag (being the second part of the DLCF). If a link data field is present, the frame shall be denoted as an information frame.

8.6.5.2.2.3 X.25 packets shall be transmitted within the link data field of information frames. Only one packet shall be contained in the link data field.

8.6.5.2.3 *THE X.25PACKET PROTOCOL LEVEL*

8.6.5.2.3.1 Each CIDIN packet to be transferred on CIDIN circuits between CIDIN switching centres shall be formatted into one X.25 packet. When a packet switched data network is used, it shall be permissible to format the CIDIN packet into more than one X.25 packet.

8.6.5.2.3.2 The integrity of each CIDIN packet shall be preserved by the X.25 packet protocol by mapping each CIDIN packet onto one complete X.25packet sequence, as defined in CCITT Recommendation X.25.

8.6.5.2.3.3 Each X.25 packet shall consist of an X.25 packet header, possibly followed by a user data field (UDF).

8.6.5.2.3.4 The X.25 packet protocol is based on the application of virtual circuit procedures. A virtual circuit shall be defined as a logical path between two CIDIN switching centres. If a packet switched data network is used to interconnect two CIDIN switching centres, the procedure shall provide full compatibility with the procedures to be followed for virtual circuits according to CCITT Recommendation X.25.

8.6.5.2.4 *THE CIDINPACKET PROTOCOL LEVEL*

8.6.5.2.4.1 Each transport header and the associated segment shall be preceded by a CIDIN packet header. No further segmentation of the CIDIN message shall be used between transport protocol level and CIDIN packet protocol level. Both headers, therefore, shall be used in combination. Together they shall be referred to as the communications control field (CCF).

Together with the message segment they form CIDIN packets that shall be transmitted from entry centre to exit centre(s), when necessary through one or more relay centres, as an entity.

8.6.5.2.4.2 CIDIN packets of one CIDIN message shall be relayed independently via predetermined routes through the network thus allowing alternative routing on a CIDIN packet basis as necessary.

8.6.5.2.4.3 The CIDIN packet header shall contain information to enable relay centres to handle CIDIN packets in the order of priority, to transmit the CIDIN packets on the proper outgoing circuit(s) and to duplicate or multiplicate CIDIN packets when required for multiple dissemination purposes. The information shall be sufficient to apply address stripping on the exit addresses as well as on the addressee indicators of messages in AFTN format.

8.6.5.2.5 *THE TRANSPORT PROTOCOL LEVEL*

8.6.5.2.5.1 Information exchanged over the CIDIN shall be transmitted as CIDIN messages.

8.6.5.2.5.2 The length of a CIDIN message shall be defined by the CIDIN packet sequence number (CPSN). The maximum permissible length is 215packets which in effect results in no practical limitation.

8.6.5.2.5.3 If the length of a CIDIN message and its transport and packet headers (as defined below) exceeds 256 octets, the message shall be divided into segments and placed in the CIDIN user data field of CIDIN packets. Each segment shall be preceded by a transport header containing information to enable the re-assembly of the CIDIN message at the exit centre(s) from individually received segments and to determine further handling of the received complete CIDIN message.

8.6.5.2.5.4 All segments of one CIDIN message shall be provided with the same message identification information in the transport header. Only the CPSN and final CIDIN packet (FCP) indicator shall be different.

8.6.5.2.5.5 Recovery of messages shall be performed at the transport level.

TABLES FOR CHAPTER 8

Table 8-1. International Telegraph Alphabets No. 2 and No. 3

Number of signal	*Letter case*	*Figure case*	*Impulses 5-unit code*		
			Start	*12345*	*Stop*
				International Code No. 2	
1	A	—	A	ZZAAA	Z
2	B	?	A	ZAAZZ	Z
3	C	:	A	AZZZA	Z
4	D	Note 1	A	ZAAZA	Z
5	E	3	A	ZAAAA	Z
6	F		A	ZAZZA	Z
7	G		A	AZAZZ	Z
8	H		A	AAZAZ	Z
9	I	8	A	AZZAA	Z
10	J	Attention signal	A	ZZAZA	Z
11	K	(	A	ZZZZA	Z
12	L	)	A	AZAAZ	Z
13	M	.	A	AAZZZ	Z
14	N	,	A	AAZZA	Z
15	O	9	A	AAAZZ	Z
16	P	0	A	AZZAZ	Z
17	Q	1	A	ZZZAZ	Z
18	R	4	A	AZAZA	Z
19	S	'	A	ZAZAA	Z
20	T	5	A	AAAAZ	Z
21	U	7	A	ZZZAA	Z
22	V	=	A	AZZZZ	Z
23	W	2	A	ZZAAZ	Z
24	X	/	A	ZAZZZ	Z
25	Y	6	A	ZAZAZ	Z
26	Z	+	A	ZAAAZ	Z
27	carriage return		A	AAAZA	Z
28	line feed		A	AZAAA	Z
29	letters		A	ZZZZZ	Z
30	figures		A	ZZAZZ	Z
31	space		A	AAZAA	Z
32	unperforated tape		A	AAAAA	Z
33	signal repetition				
34	signal α				
35	signal ß				

Sign	*Closed circuit*	*Double current*
A	No current	Negative current
Z	Positive current	Positive current

Note 1.— Used for answer-back facility.

Table 8-2. International Alphabet No. 5 (IA-5)
(international reference version)

				b_7	0	0	0	0	1	1	1	1
				b_6	0	0	1	1	0	0	1	1
				b_5	0	1	0	1	0	1	0	1
b_4	b_3	b_2	b_1		0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	TC_7 (DLE)	SP	0	@	P	`	p
0	0	0	1	1	TC_1 (SOH)	DC_1	!	1	A	Q	a	q
0	0	1	0	2	TC_2 (STX)	DC_2	" ④	2	B	R	b	r
0	0	1	1	3	TC_3 (ETX)	DC_3	#	3	C	S	c	s
0	1	0	0	4	TC_4 (EOT)	DC_4	¤ ②	4	D	T	d	t
0	1	0	1	5	TC_5 (ENQ)	TC_8 (NAK)	%	5	E	U	e	u
0	1	1	0	6	TC_6 (ACK)	TC_9 (SYN)	&	6	F	V	f	v
0	1	1	1	7	BEL	TC_{10} (ETB)	' ④	7	G	W	g	w
1	0	0	0	8	FE_0 (BS)	CAN	(	8	H	X	h	x
1	0	0	1	9	FE_1 (HT)	EM	)	9	I	Y	i	y
1	0	1	0	10	$FE_2$① (LF)	SUB	*	:	J	Z	j	z
1	0	1	1	11	FE_3 (VT)	ESC	+	;	K	[	k	{
1	1	0	0	12	FE_4 (FF)	IS_4 (FS)	④ ,	<	L	\	l	|
1	1	0	1	13	$FE_5$① (CR)	IS_3 (GS)	–	=	M	]	m	}
1	1	1	0	14	SO	IS_2 (RS)	.	>	N	^ ④	n	‾ ③
1	1	1	1	15	SI	IS_1 (US)	/	?	O	_	o	DEL

NOTES

Note 1.—The format effectors are intended for equipment in which horizontal and vertical movements are effected separately. If equipment requires the action of CARRIAGE RETURN to be combined with a vertical movement, the format effector for that vertical movement may be used to effect the combined movement. Use of FE 2 for a combined CR and LF operation is not allowed for international transmission on AFS networks.

Note 2.—The symbol ¤ does not designate the currency of a specific country.

Note 3.—Position 7/14 is used for graphic character ‾ (OVERLINE), the graphical representation of which may vary according to national use to represent (TILDE) or another diacritical sign provided that there is no risk of confusion with another graphic character included in the table.

Note 4.—The graphic characters in position 2/2, 2/7, 2/12 and 5/14 have respectively the significance of QUOTATION MARK, APOSTROPHE, COMMA and UPWARD ARROW HEAD; however, these characters take on the significance of the diacritical signs DIAERESIS, ACUTE ACCENT, CEDILLA and CIRCUMFLEX ACCENT when they are preceded or followed by the BACKSPACE character (0/8).

Note 5.—When graphical representation of the control characters of IA-5 is required, it is permissible to use the symbols specified in International Organization for Standardization (ISO) Standard 2047-1975.

CONTROL CHARACTERS

Abbreviation	*Meaning*	*Position in the code table*
ACK	Acknowledge	0/6
BEL	Bell	0/7
BS	Backspace	0/8
CAN	Cancel	1/8
CR	Carriage return*	0/13
DC	Device control	–
DEL	Delete	7/15
DLE	Data link escape	1/0
EM	End of medium	1/9
ENQ	Enquiry	0/5
EOT	End of transmission	0/4
ESC	Escape	1/11
ETB	End of transmission block	1/7
ETX	End of text	0/3
FE	Format effector	–
FF	Form feed	0/12
FS	File separator	1/12
GS	Group separator	1/13
HT	Horizontal tabulation	0/9
IS	Information separator	–
LF	Line feed*	0/10
NAK	Negative acknowledge	1/5
NUL	Null	0/0
RS	Record separator	1/14
SI	Shift-in	0/15
SO	Shift-out	0/14
SOH	Start of heading	0/1
SP	Space	2/0
STX	Start of text	0/2
SUB	Substitute character	1/10
SYN	Synchronous idle	1/6
TC	Transmission control	–
US	Unit separator	1/15
VT	Vertical tabulation	0/11

GRAPHIC CHARACTERS

<table>
<tr><th>Graphic</th><th>Note</th><th>Name</th><th>Position in the code table</th></tr>
<tr><td>(space)</td><td></td><td>Space (see 7.2)</td><td>2/0</td></tr>
<tr><td>!</td><td></td><td>Exclamation mark</td><td>2/1</td></tr>
<tr><td>"</td><td>4</td><td>Quotation mark, Diaeresis</td><td>2/2</td></tr>
<tr><td>#</td><td></td><td>Number sign</td><td>2/3</td></tr>
<tr><td>¤</td><td>2</td><td>Currency sign</td><td>2/4</td></tr>
<tr><td>%</td><td></td><td>Percent sign</td><td>2/5</td></tr>
<tr><td>&</td><td></td><td>Ampersand</td><td>2/6</td></tr>
<tr><td>'</td><td>4</td><td>Apostrophe, Acute accent</td><td>2/7</td></tr>
<tr><td>(</td><td></td><td>Left parenthesis</td><td>2/8</td></tr>
<tr><td>)</td><td></td><td>Right parenthesis</td><td>2/9</td></tr>
<tr><td>*</td><td></td><td>Asterisk</td><td>2/10</td></tr>
<tr><td>+</td><td></td><td>Plus sign</td><td>2/11</td></tr>
<tr><td>,</td><td>4</td><td>Comma, Cedilla</td><td>2/12</td></tr>
<tr><td>–</td><td></td><td>Hyphen, Minus sign</td><td>2/13</td></tr>
<tr><td>.</td><td></td><td>Full stop (period)</td><td>2/14</td></tr>
<tr><td>/</td><td></td><td>Solidus</td><td>2/15</td></tr>
<tr><td>:</td><td></td><td>Colon</td><td>3/10</td></tr>
<tr><td>;</td><td></td><td>Semi-colon</td><td>3/11</td></tr>
<tr><td><</td><td></td><td>Less-than sign</td><td>3/12</td></tr>
<tr><td>=</td><td></td><td>Equal sign</td><td>3/13</td></tr>
<tr><td>></td><td></td><td>Greater-than sign</td><td>3/14</td></tr>
<tr><td>?</td><td></td><td>Question mark</td><td>3/15</td></tr>
<tr><td>@</td><td></td><td>Commercial 'at'</td><td>4/0</td></tr>
<tr><td>[</td><td></td><td>Left square bracket</td><td>5/11</td></tr>
<tr><td>\</td><td></td><td>Reverse solidus</td><td>5/12</td></tr>
<tr><td>]</td><td></td><td>Right square bracket</td><td>5/13</td></tr>
<tr><td>^</td><td>4</td><td>Upward arrow head,
Circumflex accent</td><td>5/14</td></tr>
<tr><td>__</td><td></td><td>Underline</td><td>5/15</td></tr>
<tr><td>`</td><td></td><td>Grave accent</td><td>6/0</td></tr>
<tr><td>{</td><td></td><td>Left curly bracket</td><td>7/11</td></tr>
<tr><td>|</td><td></td><td>Vertical line</td><td>7/12</td></tr>
<tr><td>}</td><td></td><td>Right curly bracket</td><td>7/13</td></tr>
<tr><td>‾</td><td>3</td><td>Overline, Tilde</td><td>7/14</td></tr>
</table>

* See Note 1.

DIACRITICAL SIGNS

In the character set, some printing symbols may be designed to permit their use for the composition of accented letters when necessary for general interchange of information. A sequence of three characters, comprising a letter, BACKSPACE and one of these symbols, is needed for this composition, and the symbol is then regarded as a diacritical sign. It should be noted that these symbols take on their diacritical significance only when they are preceded or followed by the BACKSPACE character: for example, the symbol corresponding to the code combination 2/7 (') normally has the significance of APOSTROPHE, but becomes the diacritical sign ACUTE ACCENT when it precedes or follows the BACKSPACE character.

NAMES, MEANINGS AND FONTS OF GRAPHIC CHARACTERS

At least one name is assigned to denote each of the graphic characters. These names are intended to reflect their customary meanings and are not intended to define or restrict the meanings of graphic characters. No particular style or font design is specified for the graphic characters.

UNIQUENESS OF CHARACTER ALLOCATION

A character allocated to a position in the table may not be placed elsewhere in the table.

FUNCTIONAL CHARACTERISTICS RELATED TO CONTROL CHARACTERS

Some definitions given below are stated in general terms and more explicit definitions of use may be needed for specific implementation of the code table on recording media or on transmission channels. These more explicit definitions and the use of these characters are the subject of ISO publications.

General designations of control characters

The general designation of control characters involves a specific class name followed by a subscript number.
They are defined as follows:

TC — *Transmission control characters* — Control characters intended to control or facilitate transmission of information over telecommunication networks.
The use of the TC characters on the general telecommunication networks is the subject of ISO publications.
The transmission control characters are:
ACK, DLE, ENQ, EOT, ETB, ETX, NAK, SOH, STX and SYN.

FE — *Format effectors* — Control characters mainly intended for the control of the layout and positioning of information on printing and/or display devices. In the definitions of specific format effectors, any reference to printing devices should be interpreted as including display devices. The definitions of format effectors use the following concept:

a) a page is composed of a number of lines of characters;

b) the characters forming a line occupy a number of positions called character positions;

c) the active position is that character position in which the character about to be processed would appear if it were to be printed. The active position normally advances one character position at a time.

The format effector characters are:
BS, CR, FF, HT, LF and VT.

DC — *Device control characters* — Control characters for the control of a local or remote ancillary device (or devices) connected to a data processing and/or telecommunication system. These control characters are not intended to control telecommunication systems; this should be achieved by the use of TCs.
Certain preferred uses of the individual DCs are given below under *Specific control characters*.

IS — *Information separators* — Control characters that are used to separate and qualify data logically. There are four such characters. They may be used either in hierarchical order or non-hierarchically; in the latter case their specific meanings depend on their applications.
When they are used hierarchically, the ascending order is:
US, RS, GS, FS.
In this case data normally delimited by a particular separator cannot be split by a higher order separator but will be considered as delimited by any higher order separator.

Specific control characters

Individual members of the classes of controls are sometimes referred to by their abbreviated class name and a subscript number (e.g. TC_5) and sometimes by a specific name indicative of their use (e.g. ENQ).

Different but related meanings may be associated with some of the control characters but in an interchange of data this normally requires agreement between the sender and the recipient.

ACK — *Acknowledge* — A transmission control character transmitted by a receiver as an affirmative response to the sender.

BEL — *Bell* — A control character that is used when there is a need to call for attention; it may control alarm or attention devices.

BS — *Backspace* — A format effector which moves the active position one character position backwards on the same line.

CAN — *Cancel* — A character, or the first character of a sequence, indicating that the data preceding it are in error. As a result these data are to be ignored. The specific meaning of this character must be defined for each application and/or between sender and recipient.

CR — *Carriage return* — A format effector which moves the active position to the first character position on the same line.

Device controls

DC_1 — A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to restore a device to the basic mode of operation (*see also* DC_2 and DC_3), or for any other device control function not provided by other DCs.

DC_2 — A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to set a device to a special mode of operation (in which case DC_1 is used to restore the device to the basic mode), or for any other device control function not provided by other DCs.

DC_3 — A device control character which is primarily intended for turning off or stopping an ancillary device. This function may be a secondary level stop, e.g. wait, pause, stand-by or halt (in which case DC_1 is used to restore normal operation). If it is not required for this purpose, it may be used for any other device control function not provided by other DCs.

DC_4 — A device control character which is primarily intended for turning off, stopping or interrupting an ancillary device. If it is not required for this purpose, it may be used for any other device control function not provided by other DCs.

Examples of use of the device controls

1) One switching

	on — DC_2	off — DC_4

2) Two independent switchings

First one	on — DC_2	off — DC_4
Second one	on — DC_1	off — DC_3

3) Two dependent switchings

General	on — DC_2	off — DC_4
Particular	on — DC_1	off — DC_3

4) Input and output switching

Output	on — DC_2	off — DC_4
Input	on — DC_1	off — DC_3

DEL — *Delete* — A character used primarily to erase or obliterate an erroneous or unwanted character in punched tape. DEL characters may also serve to accomplish media-fill or time-fill. They may be inserted into or removed from a stream of data without affecting the information content of that stream, but then the addition or removal of these characters may affect the information layout and/or the control of equipment.

DLE — *Data link escape* — A transmission control character which will change the meaning of a limited number of contiguously following characters. It is used exclusively to provide supplementary data transmission control functions. Only graphic characters and transmission control characters can be used in DLE sequences.

EM — *End of medium* — A control character that may be used to identify the physical end of a medium, or the end of the used portion of a medium, or the end of the wanted portion of data recorded on a medium. The position of this character does not necessarily correspond to the physical end of the medium.

ENQ — *Enquiry* — A transmission control character used as a request for a response from a remote station — the response may include station identification and/or station status. When a "Who are you?" function is required on the general switched transmission network, the first use of ENQ after the connection is established shall have the meaning "Who are you?" (station identification). Subsequent use of ENQ may, or may not, include the function "Who are you?", as determined by agreement.

EOT — *End of transmission* — A transmission control character used to indicate the conclusion of the transmission of one or more texts.

ESC — *Escape* — A control character which is used to provide an additional control function. It alters the meaning of a limited number of contiguously following bit combinations which constitute the escape sequence.

Escape sequences are used to obtain additional control functions which may provide among other things graphic sets outside the standard set. Such control functions must not be used as additional transmission controls.

The use of the character ESC and of the escape sequences in conjunction with code extension techniques is the subject of an ISO Standard.

ETB — *End of transmission block* — A transmission control character used to indicate the end of a transmission block of data where data are divided into such blocks for transmission purposes.

ETX — *End of text* — A transmission control character which terminates a text.

FF — *Form feed* — A format effector which advances the active position to the same character position on a predetermined line of the next form or page.

HT — *Horizontal tabulation* — A format effector which advances the active position to the next predetermined character position on the same line.

Information separators

IS_1 (US) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a UNIT.

IS_2 (RS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a RECORD.

IS_3 (GS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a GROUP.

IS_4 (FS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a FILE.

LF — *Line feed* — A format effector which advances the active position to the same character position of the next line.

NAK — *Negative acknowledge* — A transmission control character transmitted by a receiver as a negative response to the sender.

NUL — *Null* — A control character used to accomplish media-fill or time-fill. NUL characters may be inserted into or removed from a stream of data without affecting the information content of that stream, but then the addition or removal of these characters may affect the information layout and/or the control of equipment.

SI — *Shift-in* — A control character which is used in conjunction with SHIFT-OUT and ESCAPE to extend the graphic character set of the code. It may reinstate the standard meanings of the bit combinations which follow it. The effect of this character when using code extension techniques is described in an ISO Standard.

SO — *Shift-out* — A control character which is used in conjunction with SHIFT-IN and ESCAPE to extend the graphic character set of the code. It may alter the meaning of the bit combinations of columns 2 to 7 which follow it until a SHIFT-IN character is reached. However, the characters SPACE (2/0) and DELETE (7/15) are unaffected by SHIFT-OUT. The effect of this character when using code extension techniques is described in an ISO Standard.

SOH — *Start of heading* — A transmission control character used as the first character of a heading of an information message.

SP — *Space* — A character which advances the active position one character position on the same line. This character is also regarded as a non-printing graphic.

STX — *Start of text* — A transmission control character which precedes a text and which is used to terminate a heading.

SUB — *Substitute character* — A control character used in the place of a character that has been found to be invalid or in error. SUB is intended to be introduced by automatic means.

SYN — *Synchronous idle* — A transmission control character used by a synchronous transmission system in the absence of any other character (idle condition) to provide a signal from which synchronism may be achieved or retained between data terminal equipment.

VT — *Vertical tabulation* — A format effector which advances the active position to the same character position on the next predetermined line.

Table 8-3. Conversion from the International Telegraph Alphabet No. 2 (ITA-2) to the International Alphabet No. 5 (IA-5)

ITA-2 letter case of signal No.		*IA-5 column/row*		*ITA-2 figure case of signal No.*		*IA-5 column/row*	
1	A	4/1	A	1	–	2/13	–
2	B	4/2	B	2	?	3/15	?
3	C	4/3	C	3	:	3/10	:
4	D	4/4	D	4		3/15	?
5	E	4/5	E	5	3	3/3	3
6	F	4/6	F	6		3/15	?
7	G	4/7	G	7		3/15	?
8	H	4/8	H	8		3/15	?
9	I	4/9	I	9	8	3/8	8
10	J	4/10	J	10	Attention Signal *(Note 3)*	0/7	Bel
11	K	4/11	K	11	(	2/8	(
12	L	4/12	L	12	)	2/9	)
13	M	4/13	M	13	.	2/14	.
14	N	4/14	N	14	,	2/12	,
15	O	4/15	O	15	9	3/9	9
16	P	5/0	P	16	0	3/0	0
17	Q	5/1	Q	17	1	3/1	1
18	R	5/2	R	18	4	3/4	4
19	S	5/3	S	19	’	2/7	’
20	T	5/4	T	20	5	3/5	5
21	U	5/5	U	21	7	3/7	7
22	V	5/6	V	22	=	3/13	=
23	W	5/7	W	23	2	3/2	2
24	X	5/8	X	24	/	2/15	/
25	Y	5/9	Y	25	6	3/6	6
26	Z	5/10	Z	26	+	2/11	+
27	CR	0/13	CR	27	CR	0/13	CR
28	LF	0/10	LF	28	LF	0/10	LF
29	LTRS	*		29	LTRS	*	
30	FIGS	*		30	FIGS	*	
31	SP	2/0	SP	31	SP	2/0	SP
32		*		32		*	

** No conversion shall be made for these positions and the signal/character shall be removed from the data.*

Note 1.— The end-of-message signal NNNN (in letter and figure case) shall convert to ETX (0/3).

Note 2.— The start-of-message signal ZCZC (in letter and figure case) shall convert to SOH (0/1).

Note 3.— Figures case of Signal No. 10 shall only be converted upon detection of the AFTN priority alarm which shall convert to five occurrences of BEL (0/7).

Note 4.— When converting from ITA-2, a STX (0/2) character shall be inserted once at the beginning of the next line following detection of CR LF or LF CR at the end of the Origin Line.

Note 5.— The sequence of seven signal 28 (LF) shall convert to one VT (0/11) character.

Table 8-4. Conversion from the International Alphabet No. 5 (IA-5) to the International Telegraph Alphabet No. 2 (ITA-2)

Row \ Col.	0	1	2	3	4	5	6	7
0	*	*	31FL	16F	2F	16L	2F	16L
1	Note 5	*	2F	17F	1L	17L	1L	17L
2	*	*	2F	23F	2L	18L	2L	18L
3	Note 1	*	2F	5F	3L	19L	3L	19L
4	*	*	2F	18F	4L	20L	4L	20L
5	*	*	2F	20F	5L	21L	5L	21L
6	*	*	2F	25F	6L	22L	6L	22L
7	Note 2	*	19F	21F	7L	23L	7L	23L
8	*	*	11F	9F	8L	24L	8L	24L
9	*	*	12F	15F	9L	25L	9L	25L
10	28 FL	*	2F	3F	10L	26L	10L	26L
11	Note 3	*	26F	2F	11L	2F	11L	2F
12	*	*	14F	2F	12L	2F	12L	2F
13	27FL	*	1F	22F	13L	2F	13L	2F
14	*	*	13F	2F	14L	2F	14L	2F
15	*	*	24F	2F	15L	2F	15L	*

** No conversion shall be made for these positions and the signal/character shall be removed from the data.*

Example: To find the ITA-2 signal to which the character 3/6 ofIA-5 is to be converted,look at column 3, row 6. 25F means figure case of signal No. 25 (L = letter case, FL = either case designation).

Note 1. – *The character 0/3 (ETX) shall convert to the ITA-2 sequence signals 14L, 14L, 14L, 14L (NNNN).*

Note 2. – *The signal 0/7 (BEL) shall only be converted when a sequence of 5 occurrences is detected, which shall convert to the ITA-2 sequence signals 30, 10F, 10F, 10F, 10F, 10F, 29.*

Note 3. – *The character sequence CR CR LF VT (0/11) ETX (0/3) shall convert to the ITA-2 sequence signals 29, 27, 27, 28, 28, 28, 28, 28, 28, 28, 28, 14L, 14L, 14L, 14L.*

Note 4. – *To prevent redundant generation of figure and letter characters in ITA-2 when converting from IA-5, no case designation shall be assigned to ITA-2 non-printing functions (signals No. 27, 28, 29, 30, 31).*

Note 5. – *The character 0/1 (SOH) shall convert to the ITA-2 sequence signals 26L, 3L, 26L, 3L (ZCZC).*

Table 8-5. Control field formats

Control field format for	Control field bits							
	1	2	3	4	5	6	7	8
Information transfer (I frame)	0	*N(S)*			*P*	*N(R)*		
Supervisory commands/responses (S frame)	1	0	*S*	*S*	*P/F*	*N(R)*		
Unnumbered commands/responses	1	1	*M*	*M*	*P/F*	*M*	*M*	*M*

where:

N(S) = send sequence count (bit 2 = low order bit)
N(R) = receive sequence count (bit 6 = low order bit)
S = supervisory function bits
M = modifier function bits
P = poll bit (in commands)
F = final bit (in responses)

Table 8-6. Commands and response

Type	*Commands*		*Responses*		*C field encoding* 1	2	3	4	5	6	7	8
Information transfer	I	(information)			0		*N(S)*		*P*		*N(R)*	
Supervisory	RR	(receive ready)	RR	(receive ready)	1	0	0	0	*P/F*		*N(R)*	
	RNR	(receive not ready)	RNR	(receive not ready)	1	0	1	0	*P/F*		*N(R)*	
	REJ	(reject)	REJ	(reject)	1	0	0	1	*P/F*		*N(R)*	
Unnumbered			DM	(disconnected mode)	1	1	1	1	*P/F*	0	0	0
	SABM	(set asynchronous balanced mode)			1	1	1	1	*P*	1	0	0
	DISC	(disconnect)			1	1	0	0	*P*	0	1	0
			UA	(unnumbered acknowledgement)	1	1	0	0	*F*	1	1	0
			FRMR	(frame reject)	1	1	1	0	*F*	0	0	1

FIGURES FOR CHAPTER 8

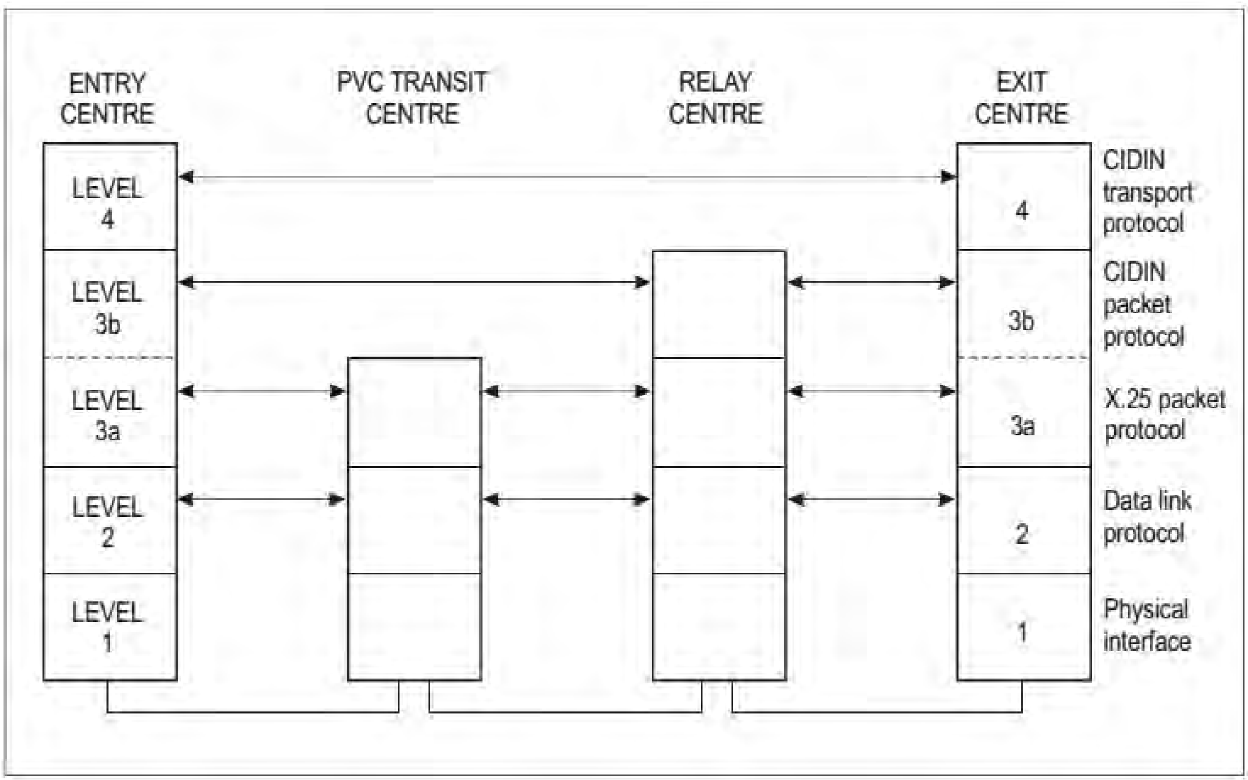


Figure 8-1. CIDIN protocol levels

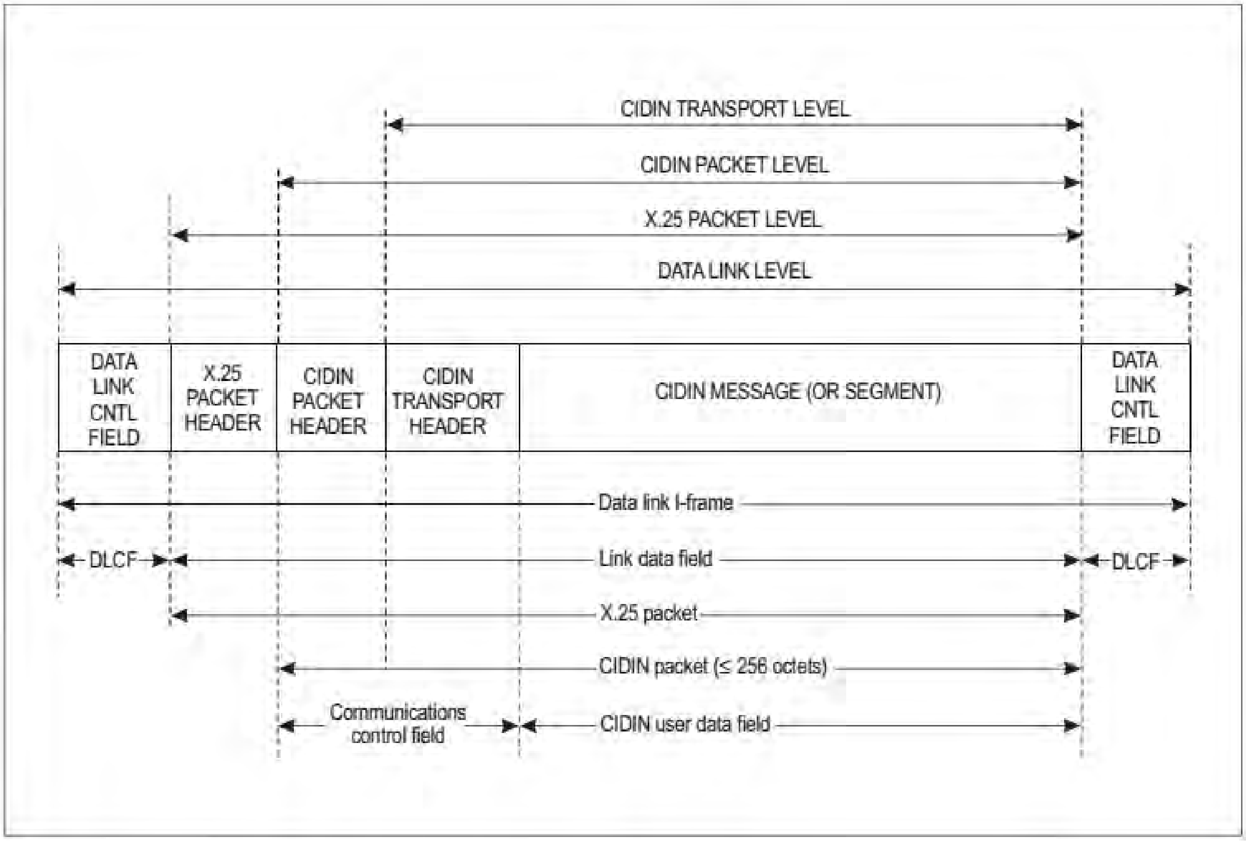


Figure 8-2. CIDIN terminology

CHAPTER 9. AIRCRAFT ADDRESSING SYSTEM

9.1 The aircraft address shall be one of 16 777 214 twenty-four-bit aircraft addresses allocated by ICAO to the State of Registry or common mark registering authority and assigned as prescribed in the Appendix to this chapter.

9.1.1 Non-aircraft transponders that are installed on aerodrome surface vehicles, obstacles or fixed Mode S target detection devices for surveillance and/or radar monitoring purposes shall be assigned 24-bit aircraft addresses.

Note.— Under such specific conditions, the term "aircraft" can be understood as "aircraft (or pseudo-aircraft) or vehicle (A/V)" where a limited set of data is generally sufficient for operational purposes.

9.1.1.1 **Recommendation.—***Mode S transponders used under specific conditions stated in 9.1.1 should not have any negative impact on the performance of existing ATS surveillance systems and ACAS.*

APPENDIX TO CHAPTER 9. A WORLDWIDE SCHEME FOR THE ALLOCATION, ASSIGNMENT AND APPLICATION OF AIRCRAFT ADDRESSES

1. GENERAL

1.1 Global communications, navigation and surveillance systems shall use an individual aircraft address composed of 24 bits. At any one time, no address shall be assigned to more than one aircraft. The assignment of aircraft addresses requires

a comprehensive scheme providing for a balanced and expandable distribution of aircraft addresses applicable worldwide.

2. DESCRIPTION OF THE SCHEME

2.1 Table 9-1 provides for blocks of consecutive addresses available to States for assignment to aircraft. Each block is defined by a fixed pattern of the first 4, 6, 9, 12 or 14 bits of the 24-bit address. Thus, blocks of different sizes (1 048 576, 262 144, 32 768, 4 096 and 1 024 consecutive addresses, respectively) are made available.

3. MANAGEMENT OF THE SCHEME

3.1 The International Civil Aviation Organization (ICAO) shall administer the scheme so that appropriate international distribution of aircraft addresses can be maintained.

4. ALLOCATION OF AIRCRAFT ADDRESSES

4.1 Blocks of aircraft addresses shall be allocated by ICAO to the State of Registry or common mark registering authority. Address allocations to States shall be as shown in Table 9-1.

4.2 A State of Registry or common mark registering authority shall notify ICAO when allocation to that State of an additional block of addresses is required for assignment to aircraft.

4.3 In the future management of the scheme, advantage shall be taken of the blocks of aircraft addresses not yet allocated. These spare blocks shall be distributed on the basis of the relevant ICAO region:

Addresses starting with bit combination 00100: AFI region

Addresses starting with bit combination 00101: SAM region

Addresses starting with bit combination 0101: EUR and NAT regions

Addresses starting with bit combination 01100: MID region

Addresses starting with bit combination 01101: ASIA region

Addresses starting with bit combination 1001: NAM and PAC regions

Addresses starting with bit combination 111011: CAR region

In addition, aircraft addresses starting with bit combinations 1011, 1101 and 1111 have been reserved for future use.

4.4 Any future requirement for additional aircraft addresses shall be accommodated through coordination between ICAO and the States of Registry or common mark registering authority concerned. A request for additional aircraft addresses shall only be made by a registering authority when at least 75 per cent of the number of addresses already allocated to that registering authority have been assigned to aircraft.

4.5 ICAO shall allocate blocks of aircraft addresses to non-Contracting States upon request.

5. ASSIGNMENT OF AIRCRAFT ADDRESSES

5.1 Using its allocated block of addresses, the State of Registry or common mark registering authority shall assign an individual aircraft address to each suitably equipped aircraft entered on a national or international register (Table 9-1).

Note.— For an aircraft delivery, the aircraft operator is expected to inform the airframe manufacturer of an address assignment. The airframe manufacturer or other organization responsible for a delivery flight is expected to ensure installation of a correctly assigned address supplied by the State of Registry or common mark registering authority. Exceptionally, a temporary address may be supplied under the arrangements detailed in paragraph 7.

5.2 Aircraft addresses shall be assigned to aircraft in accordance with the following principles:

a) at any one time, no address shall be assigned to more than one aircraft with the exception of aerodrome surface vehicles on surface movement areas. If such exceptions are applied by the State of Registry, the vehicles which have been allocated the same address shall not operate on aerodromes separated by less than 1 000 km;

b) only one address shall be assigned to an aircraft, irrespective of the composition of equipment on board. In the case when a removable transponder is shared by several light aviation aircraft such as balloons or gliders, it shall be possible to assign a unique address to the removable transponder. The registers 0816, 2016, 2116, 2216and 2516of the removable transponder shall be correctly updated each time the removable transponder is installed in any aircraft;

c) the address shall not be changed except under exceptional circumstances and shall not be changed during flight;

d) when an aircraft changes its State of Registry, the new registering State shall assign the aircraft a new address from its own allocation address block, and the old aircraft address shall be returned to the allocation address block of the State that previously registered the aircraft;

e) the address shall serve only a technical role for addressing and identification of aircraft and shall not be used to convey any specific information; and

f) the addresses composed of 24 ZEROS or 24 ONES shall not be assigned to aircraft.

5.2.1 **Recommendation.—** Any method used to assign aircraft addresses should ensure efficient use of the entire address block that is allocated to that State.

6. APPLICATION OF AIRCRAFT ADDRESSES

6.1 The aircraft addresses shall be used in applications which require the routing of information to or from individual suitably equipped aircraft.

Note 1.— Examples of such applications are the aeronautical telecommunication network (ATN), SSR Mode S and airborne collision avoidance system (ACAS).

Note 2.— This Standard does not preclude assigning the aircraft addresses for special applications associated with the general applications defined therein. Examples of such special *applications are the utilization of the 24-bit address in a pseudo-aeronautical earth station to monitor the aeronautical mobile-satellite service ground earth station and in the fixed Mode S transponders (reporting the on-the-ground status as specified in Annex 10, Volume IV, 3.1.2.6.10.1.2) to monitor the Mode S ground station operation. Address assignments for special applications are to be carried out in conformance with the procedure established by the State to manage the 24-bit address assignments to aircraft.*

6.2 An address consisting of 24 ZEROs shall not be used for any application.

7. ADMINISTRATION OF THE TEMPORARY AIRCRAFT ADDRESS ASSIGNMENTS

7.1 Temporary addresses shall be assigned to aircraft in exceptional circumstances, such as when operators have been unable to obtain an address from their individual States of Registry or Common Mark Registering Authority in a timely manner. ICAO shall assign temporary addresses from the block "ICAO1" shown in Table 9-1.

7.2 When requesting a temporary address, the aircraft operator shall supply to ICAO: aircraft identification, type and make of aircraft, name and address of the operator, and an explanation of the reason for the request.

7.2.1 Upon issuance of the temporary address to the aircraft operators, ICAO shall inform the State of Registry of the issuance of the temporary address, reason and duration.

7.3 The aircraft operator shall:

a) inform the State of Registry of the temporary assignment and reiterate the request for a permanent address; and

b) inform the airframe manufacturer.

7.4 When the permanent aircraft address is obtained from the State of Registry, the operator shall:

a) inform ICAO without delay;

b) relinquish his/her temporary address; and

c) arrange for encoding of the valid unique address within 180 calendar days.

7.5 If a permanent address is not obtained within one year, the aircraft operator shall reapply for a new temporary aircraft address. Under no circumstances shall a temporary aircraft address be used by the aircraft operator for over one year.

Table 9-1. Allocation of aircraft addresses to States

Note.— The left-hand column of the 24-bit address patterns represents the most significant bit (MSB) of the address.

State	*Number of addresses in block* 1 024	4 096	32 768	262 144	1 048 576	*Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)*
Afghanistan		*				0111 00 000 000 -- ----------
Albania	*					0101 00 000 001 00 ----------
Algeria			*			0000 10 100 --- -- ----------
Angola		*				0000 10 010 000 -- ----------
Antigua and Barbuda	*					0000 11 001 010 00 ----------
Argentina				*		1110 00 --- --- -- ----------
Armenia	*					0110 00 000 000 00 ----------
Australia				*		0111 11 --- --- -- ----------
Austria			*			0100 01 000 --- -- ----------
Azerbaijan	*					0110 00 000 000 10 ----------
Bahamas		*				0000 10 101 000 -- ----------
Bahrain		*				1000 10 010 100 -- ----------
Bangladesh		*				0111 00 000 010 -- ----------
Barbados	*					0000 10 101 010 00 ----------
Belarus	*					0101 00 010 000 00 ----------
Belgium			*			0100 01 001 --- -- ----------
Belize	*					0000 10 101 011 00 ----------
Benin	*					0000 10 010 100 00 ----------
Bhutan	*					0110 10 000 000 00 ----------
Bolivia		*				1110 10 010 100 -- ----------
Bosnia and Herzegovina	*					0101 00 010 011 00 ----------
Botswana	*					0000 00 110 000 00 ----------
Brazil				*		1110 01 --- --- -- ----------
Brunei Darussalam	*					1000 10 010 101 00 ----------
Bulgaria			*			0100 01 010 --- -- ----------
Burkina Faso		*				0000 10 011 100 -- ----------
Burundi		*				0000 00 110 010 -- ----------
Cambodia		*				0111 00 001 110 -- ----------
Cameroon		*				0000 00 110 100 -- ----------
Canada				*		1100 00 --- --- -- ----------
Cape Verde	*					0000 10 010 110 00 ----------
Central African Republic		*				0000 01 101 100 -- ----------
Chad		*				0000 10 000 100 -- ----------
Chile		*				1110 10 000 000 -- ----------
China				*		0111 10 --- --- -- ----------
Colombia		*				0000 10 101 100 -- ----------
Comoros	*					0000 00 110 101 00 ----------
Congo		*				0000 00 110 110 -- ----------
Cook Islands	*					1001 00 000 001 00 ----------
Costa Rica		*				0000 10 101 110 -- ----------
Côte d'Ivoire		*				0000 00 111 000 -- ----------
Croatia	*					0101 00 000 001 11 ----------
Cuba		*				0000 10 110 000 -- ----------
Cyprus	*					0100 11 001 000 00 ----------
Czech Republic			*			0100 10 011 --- -- ----------

State	*Number of addresses in block* 1 024	4 096	32 768	262 144	1 048 576	*Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)*
Democratic People's Republic of Korea			*			0111 00 100 --- -- ----------
Democratic Republic of the Congo		*				0000 10 001 100 -- ----------
Denmark			*			0100 01 011 --- -- ----------
Djibouti	*					0000 10 011 000 00 ----------
Dominican Republic		*				0000 11 000 100 -- ----------
Ecuador		*				1110 10 000 100 -- ----------
Egypt			*			0000 00 010 --- -- ----------
El Salvador		*				0000 10 110 010 -- ----------
Equatorial Guinea		*				0000 01 000 010 -- ----------
Eritrea	*					0010 00 000 010 00 ----------
Estonia	*					0101 00 010 001 00 ----------
Ethiopia		*				0000 01 000 000 -- ----------
Fiji		*				1100 10 001 000 -- ----------
Finland			*			0100 01 100 --- -- ----------
France				*		0011 10 --- --- -- ----------
Gabon		*				0000 00 111 110 -- ----------
Gambia		*				0000 10 011 010 -- ----------
Georgia	*					0101 00 010 100 00 ----------
Germany				*		0011 11 --- --- -- ----------
Ghana		*				0000 01 000 100 -- ----------
Greece			*			0100 01 101 --- -- ----------
Grenada	*					0000 11 001 100 00 ----------
Guatemala		*				0000 10 110 100 -- ----------
Guinea		*				0000 01 000 110 -- ----------
Guinea-Bissau	*					0000 01 001 000 00 ----------
Guyana		*				0000 10 110 110 -- ----------
Haiti		*				0000 10 111 000 -- ----------
Honduras		*				0000 10 111 010 -- ----------
Hungary			*			0100 01 110 --- -- ----------
Iceland		*				0100 11 001 100 -- ----------
India				*		1000 00 --- --- -- ----------
Indonesia			*			1000 10 100 --- -- ----------
Iran, Islamic Republic of			*			0111 00 110 --- -- ----------
Iraq			*			0111 00 101 --- -- ----------
Ireland		*				0100 11 001 010 -- ----------
Israel			*			0111 00 111 --- -- ----------
Italy				*		0011 00 --- --- -- ----------
Jamaica		*				0000 10 111 110 -- ----------
Japan				*		1000 01 --- --- -- ----------
Jordan			*			0111 01 000 --- -- ----------
Kazakhstan	*					0110 10 000 011 00 ----------
Kenya		*				0000 01 001 100 -- ----------
Kiribati	*					1100 10 001 110 00 ----------
Kuwait		*				0111 00 000 110 -- ----------
Kyrgyzstan	*					0110 00 000 001 00 ----------
Lao People's Democratic Republic		*				0111 00 001 000 -- ----------
Latvia	*					0101 00 000 010 11 ----------

State	Number of addresses in block					Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)
	1 024	*4 096*	*32 768*	*262 144*	*1 048 576*	
Lebanon			*			0111 01 001 --- -- ----------
Lesotho	*					0000 01 001 010 00 ----------
Liberia		*				0000 01 010 000 -- ----------
Libyan Arab Jamahiriya			*			0000 00 011 --- -- ----------
Lithuania	*					0101 00 000 011 11 ----------
Luxembourg	*					0100 11 010 000 00 ----------
Madagascar		*				0000 01 010 100 -- ----------
Malawi		*				0000 01 011 000 -- ----------
Malaysia			*			0111 01 010 --- -- ----------
Maldives	*					0000 01 011 010 00 ----------
Mali		*				0000 01 011 100 -- ----------
Malta	*					0100 11 010 010 00 ----------
Marshall Islands	*					1001 00 000 000 00 ----------
Mauritania	*					0000 01 011 110 00 ----------
Mauritius	*					0000 01 100 000 00 ----------
Mexico			*			0000 11 010 --- -- ----------
Micronesia, Federated States of	*					0110 10 000 001 00 ----------
Monaco	*					0100 11 010 100 00 ----------
Mongolia	*					0110 10 000 010 00 ----------
Montenegro	*					0101 00 010 110 00 ----------
Morocco			*			0000 00 100 --- -- ----------
Mozambique		*				0000 00 000 110 -- ----------
Myanmar		*				0111 00 000 100 -- ----------
Namibia	*					0010 00 000 001 00 ----------
Nauru	*					1100 10 001 010 00 ----------
Nepal		*				0111 00 001 010 -- ----------
Netherlands, Kingdom of the			*			0100 10 000 --- -- ----------
New Zealand			*			1100 10 000 --- -- ----------
Nicaragua		*				0000 11 000 000 -- ----------
Niger		*				0000 01 100 010 -- ----------
Nigeria		*				0000 01 100 100 -- ----------
Norway			*			0100 01 111 --- -- ----------
Oman	*					0111 00 001 100 00 ----------
Pakistan			*			0111 01 100 --- -- ----------
Palau	*					0110 10 000 100 00 ----------
Panama		*				0000 11 000 010 -- ----------
Papua New Guinea		*				1000 10 011 000 -- ----------
Paraguay		*				1110 10 001 000 -- ----------
Peru		*				1110 10 001 100 -- ----------
Philippines			*			0111 01 011 --- -- ----------
Poland			*			0100 10 001 --- -- ----------
Portugal			*			0100 10 010 --- -- ----------
Qatar	*					0000 01 101 010 00 ----------
Republic of Korea			*			0111 00 011 --- -- ----------
Republic of Moldova	*					0101 00 000 100 11 ----------
Romania			*			0100 10 100 --- -- ----------
Russian Federation					*	0001 -- --- --- -- ----------
Rwanda		*				0000 01 101 110 -- ----------

State	Number of addresses in block					Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)
	1 024	*4 096*	*32 768*	*262 144*	*1 048 576*	
Saint Lucia	*					1100 10 001 100 00 ----------
Saint Vincent and the Grenadines	*					0000 10 111 100 00 ----------
Samoa	*					1001 00 000 010 00 ----------
San Marino	*					0101 00 000 000 00 ----------
Sao Tome and Principe	*					0000 10 011 110 00 ----------
Saudi Arabia			*			0111 00 010 --- -- ----------
Senegal		*				0000 01 110 000 -- ----------
Serbia			*			0100 11 000 --- -- ----------
Seychelles	*					0000 01 110 100 00 ----------
Sierra Leone	*					0000 01 110 110 00 ----------
Singapore			*			0111 01 101 --- -- ----------
Slovakia	*					0101 00 000 101 11 ----------
Slovenia	*					0101 00 000 110 11 ----------
Solomon Islands	*					1000 10 010 111 00 ----------
Somalia		*				0000 01 111 000 -- ----------
South Africa			*			0000 00 001 --- -- ----------
Spain				*		0011 01 --- --- -- ----------
Sri Lanka			*			0111 01 110 --- -- ----------
Sudan		*				0000 01 111 100 -- ----------
Suriname		*				0000 11 001 000 -- ----------
Swaziland	*					0000 01 111 010 00 ----------
Sweden			*			0100 10 101 --- -- ----------
Switzerland			*			0100 10 110 --- -- ----------
Syrian Arab Republic			*			0111 01 111 --- -- ----------
Tajikistan	*					0101 00 010 101 00 ----------
Thailand			*			1000 10 000 --- -- ----------
The former Yugoslav Republic of Macedonia	*					0101 00 010 010 00 ----------
Togo		*				0000 10 001 000 -- ----------
Tonga	*					1100 10 001 101 00 ----------
Trinidad and Tobago		*				0000 11 000 110 -- ----------
Tunisia			*			0000 00 101 --- -- ----------
Turkey			*			0100 10 111 --- -- ----------
Turkmenistan	*					0110 00 000 001 10 ----------
Uganda		*				0000 01 101 000 -- ----------
Ukraine			*			0101 00 001 --- -- ----------
United Arab Emirates		*				1000 10 010 110 -- ----------
United Kingdom				*		0100 00 --- --- -- ----------
United Republic of Tanzania		*				0000 10 000 000 -- ----------
United States					*	1010 -- --- --- -- ----------
Uruguay		*				1110 10 010 000 -- ----------
Uzbekistan	*					0101 00 000 111 11 ----------
Vanuatu	*					1100 10 010 000 00 ----------
Venezuela			*			0000 11 011 --- -- ----------
Viet Nam			*			1000 10 001 --- -- ----------
Yemen		*				1000 10 010 000 -- ----------
Zambia		*				0000 10 001 010 -- ----------
Zimbabwe	*					0000 00 000 100 00 ----------

State	Number of addresses in block					Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)
	1 024	4 096	32 768	262 144	1 048 576	
Other allocations						
ICAO[1]			*			1 1 1 1 0 0 0 0 0 – – – – – – – – – – – – – – –
ICAO[2]	*					1 0 0 0 1 0 0 1 1 0 0 1 0 0 – – – – – – – – – –
ICAO[2]	*					1 1 1 1 0 0 0 0 1 0 0 1 0 0 – – – – – – – – – –

1. ICAO administers this block for assigning temporary aircraft addresses as described in section 7.

2. Block allocated for special use in the interest of flight safety.

CHAPTER 10. POINT-TO-MULTIPOINT COMMUNICATIONS

10.1 SERVICE VIA SATELLITE FOR THE DISSEMINATION OF AERONAUTICAL INFORMATION

10.1.1 Point-to-multipoint telecommunication service via satellite to support the dissemination of aeronautical

information shall be based on full-time, non pre-emptible, protected services as defined in the relevant CCITT

Recommendations.

10.2 SERVICE VIA SATELLITE FOR THE DISSEMINATION OF WAFS PRODUCTS

10.2.1 **Recommendation.—** *System characteristics should include the following:*

a) frequency — C-band, earth-to-satellite, 6 GHz band, satellite-to-earth, 4 GHz band;

b) capacity with effective signalling rate of not less than 9 600 bits/s;

c) bit error rates — better than 1 in 107;

d) forward error correction; and

e) availability 99.95 per cent.

CHAPTER 11. HF DATA LINK

11.1 DEFINITIONS AND SYSTEM CAPABILITIES

Note.— The following Standards and Recommended Practices are specific to the high frequency data link (HFDL) and are in addition to the requirements specified in the ITU Radio Regulations (Appendix 27). The HFDL is a constituent mobile subnetwork of the aeronautical telecommunication network (ATN), operating in the aeronautical mobile (R) high frequency bands. In addition, the HFDL may provide non-ATN functions, such as direct link service (DLS). The HFDL system must enable aircraft to exchange data with ground-based users.

11.1.1 Definitions

Coded chip. A "1" or "0" output of the rate ½ or ¼ convolutional code encoder. Designated operational coverage (DOC) area. The area in which a particular service is provided and in which the service is afforded frequency protection.

Note.— This area may, after proper coordination to ensure frequency protection, extend to areas outside the allotment areas contained in Appendix S27 to the Radio Regulations.

Direct link service (DLS). A data communications service which makes no attempt to automatically correct errors, detected or undetected, at the link layer of the air-ground communications path. (Error control may be effected by end-user systems.)

High frequency network protocol data unit (HFNPDU). User data packet.

Link protocol data unit (LPDU). Data unit which encapsulates a segment of an HFNPDU.

M-ary phase shift keying (M-PSK) modulation. A digital phase modulation that causes the phase of the carrier waveform to take on one of a set of M values.

Media access protocol data unit (MPDU). Data unit which encapsulates one or more LPDUs.

M-PSK symbol. One of the M possible phase shifts of the M-PSK modulated carrier representing a group of log2M coded chips.

Peak envelope power (PEP). The peak power of the modulated signal supplied by the transmitter to the antenna transmission line.

Physical layer protocol data unit (PPDU). Data unit passed to the physical layer for transmission, or decoded by the physical layer after reception.

Quality of service (QOS). The information relating to data transfer characteristics used by various communications protocols to achieve various levels of performance for network users.

Reliable link service (RLS). A data communications service provided by the subnetwork which automatically provides for error control over its link through error detection and requested retransmission of signal units found to be in error.

Squitter protocol data unit (SPDU). Data packet which is broadcast every 32 seconds by an HFDL ground station on each of its operating frequencies, and which contains link management information.

11.2 HF DATA LINK SYSTEM

11.2.1 System architecture

The HFDL system shall consist of one or more ground and aircraft station subsystems, which implement the HFDL protocol (see 11.3). The HFDL system shall also include a ground management subsystem (see 11.4).

11.2.1.1 AIRCRAFT AND GROUND STATION SUBSYSTEMS

The HFDL aircraft station subsystem and the HFDL ground station subsystem shall include the following functions:

a) HF transmission and reception;

b) data modulation and demodulation; and

c) HFDL protocol implementation and frequency selection.

11.2.2 Operational coverage

Frequency assignments for HFDL shall be protected throughout their designated operational coverage (DOC) area.

Note 1.— DOC areas may be different from current MWARAs or RDARAs as defined in Appendix 27 to the ITU Radio Regulations.

Note 2.— Additional coordination with ITU is required in cases where DOC areas are not in conformity with the allotment areas specified in the ITU Radio Regulations.

11.2.3 Requirements for carriage of HFDL equipment

Requirements for mandatory carriage of HFDL equipment shall be made on the basis of regional air navigation agreements that specify the airspace of operation and the implementation timescale.

11.2.3.1 NOTICE

The agreement above shall provide advance notice of at least two years for the mandatory carriage of airborne systems.

11.2.4 Ground station networking

11.2.4.1 **Recommendation**.— *HFDL ground station subsystems should interconnect through a common ground management subsystem.*

Note.— This provides a distributed subnetwork, with a subnetwork point of attachment (SNPA), depending on the method of implementation, which allows for the maintenance of virtual circuit connections as aircraft stations transition between designated operational coverage areas. The distribution may be multi-regional or worldwide.

11.2.5 Ground station synchronization

Synchronization of HFDL ground station subsystems shall be to within ±25 ms of UTC. For any station not operating within ±25 ms of UTC, appropriate notification shall be made to all aircraft and ground station subsystems to allow for continued system operation.

11.2.6 Quality of service

11.2.6.1 RESIDUAL PACKET ERROR RATE

The undetected error rate for a network user packet which contains between 1 and 128 octets of user data shall be equal to or less than 1 in 106.

11.2.6.2 SPEED OF SERVICE

Transit and transfer delays for network user packets (128 octets) with priorities defined in Part I, Chapter 4, Table 4-26 for message priorities 7 through 14, shall not exceed the values of Table 11-1[7].

[7] All tables and figures are located at the end of this chapter.

11.3 HF DATA LINK PROTOCOL

The HFDL protocol shall consist of a physical layer, a link layer, and a subnetwork layer, as specified below.

Note.— The HFDL protocol is a layered protocol and is compatible with the open systems interconnection (OSI) reference model. It permits the HFDL to function as an aeronautical telecommunication network (ATN)-compatible subnetwork. The details of the protocol are described in the Manual on HF Data Link (Doc 9741).

11.3.1 Physical layer RF characteristics

The aircraft and ground stations shall access the physical medium operating in simplex mode.

11.3.1.1 FREQUENCY BANDS

HFDL installations shall be capable of operating at any single sideband (SSB) carrier (reference) frequency available to the aeronautical mobile (R) service in the band 2.8 to 22 MHz, and in compliance with the relevant provisions of the Radio Regulations.

11.3.1.2 CHANNELS

Channel utilization shall be in conformity with the table of carrier (reference) frequencies of Appendix 27 to the ITU Radio Regulations.

11.3.1.3 TUNING

The equipment shall be capable of operating on integral multiples of 1 kHz.

11.3.1.4 SIDEBAND

The sideband used for transmission shall be on the higher side of its carrier (reference) frequency.

11.3.1.5 MODULATION

HFDL shall employ M-ary phase shift keying (M-PSK) to modulate the radio frequency carrier at the assigned frequency. The symbol rate shall be 1 800 symbols per second ±10 parts per million (i.e. 0.018 symbols per second). The value of M and the information data rate shall be as specified in Table 11-2.

11.3.1.5.1 M-PSKCARRIER

The M-PSK carrier expressed mathematically shall be defined as:

$$s(t) = A\Sigma(p(t-kT)\cos[2\pi f_0 t + \varphi(k)]),\ k = 0, 1 \ldots, N-1$$

where:

N = number of M-PSK symbols in transmitted physical layer protocol data unit (PPDU)
s(t) = analog waveform or signal at time t
A = peak amplitude
f0 = SSB carrier (reference) + 1 440 Hz
T = M-PSK symbol period (1/1 800 s)
φ(k) = phase of kth M-PSK symbol
p(t-kT) = pulse shape of kth M-PSK symbol at time t.

Note.— The number of M-PSK symbols sent, N, defines the length (duration = NT seconds) of the PPDU. These parameters are defined in the Manual on HF Data Link (Doc 9741).

11.3.1.5.2 PULSE SHAPE

The pulse shape, p(t), shall determine the spectral distribution of the transmitted signal. The Fourier transform of the pulse shape, P(f), shall be defined by:

$$P(f) = 1, \quad \text{if } 0 < |f| < (1 - b)/2T$$
$$P(f) = \cos\{\pi(2|f|T - 1 + b)/4b\}, \quad \text{if } (1 - b)/2T < |f| < (1 + b)/2T$$
$$P(f) = 0, \quad \text{if } |f| > (1 + b)/2T$$

where the spectral roll-off parameter, b = 0.31, has been chosen so that the –20 dB points of the signal are at SSB carrier (reference) + 290 Hz and SSB carrier (reference) + 2 590 Hz and the peak-to-average power ratio of the waveform is less than 5 dB.

11.3.1.6 TRANSMITTER STABILITY

The basic frequency stability of the transmitting function shall be better than:

a) ±20 Hz for HFDL aircraft station subsystems; and

b) ±10 Hz for HFDL ground station subsystems.

11.3.1.7 RECEIVER STABILITY

The basic frequency stability of the receiving function shall be such that, with the transmitting function stability specified in

11.3.1.6, the overall frequency difference between ground and airborne functions achieved in service does not exceed 70 Hz.

11.3.1.8 PROTECTION

A 15 dB desired to undesired (D/U) signal ratio shall apply for the protection of co-channel assignments for HFDL as follows:

a) data versus data;

b) data versus voice; and

c) voice versus data.

11.3.1.9 CLASS OF EMISSION

The class of emission shall be 2K80J2DEN.

11.3.1.10 ASSIGNED FREQUENCY

The HFDL assigned frequency shall be 1 400 Hz higher than the SSB carrier(reference) frequency.

Note.— By convention, the HFDL assigned frequency is offset from the SSB carrier (reference) frequency by 1 400 Hz. The HFDL M-PSK carrier of the digital modulation is offset from the SSB carrier (reference) frequency by 1 440 Hz. The digital modulation is fully contained within the same overall channel bandwidth as the voice signal and complies with the provisions of Appendix 27 to the ITU Radio Regulations.

11.3.1.11 EMISSION LIMITS

For HFDL aircraft and ground station transmitters, the peak envelope power (Pp) of any emission on any discrete frequency shall be less than the peak envelope power (Pp) of the transmitter in accordance with the following (see Figure 11-1):

a) on any frequency between 1.5 kHz and 4.5 kHz lower than the HFDL assigned frequency, and on any frequency between 1.5 kHz and 4.5 kHz higher than the HFDL assigned frequency: at least 30 dB;

b) on any frequency between 4.5 kHz and 7.5 kHz lower than the HFDL assigned frequency, and on any frequency between 4.5 kHz and 7.5 kHz higher than the HFDL assigned frequency: at least 38 dB; and

c) on any frequency lower than 7.5 kHz below the HFDL assigned frequency and on any frequency higher than 7.5 kHz above the HFDL assigned frequency:

1) HFDL aircraft station transmitters: 43 dB;

2) HFDL ground station transmitters up to and including 50 W:

$[43 + 10 \log_{10} P_p(W)]$ dB; and

3) HFDL ground station transmitters more than 50 W: 60 dB.

11.3.1.12 POWER

11.3.1.12.1 Ground station installations. The peak envelope power (Pp) supplied to the antenna transmission line shall not exceed a maximum value of 6 kW as provided for in Appendix 27 of the Radio Regulations.

11.3.1.12.2 Aircraft station installations. The peak envelope power supplied to the antenna transmission line shall not exceed 400 W, except as provided for in Appendix 27/62 of the Radio Regulations.

11.3.1.13 UNDESIRED SIGNAL REJECTION

For HFDL aircraft and ground station receivers, undesired input signals shall be attenuated in accordance with the following:

a) on any frequency between fc and (fc– 300 Hz), or between (fc+ 2 900 Hz) and (fc+ 3 300 Hz): at least 35 dB below the peak of the desired signal level; and

b) on any frequency below (fc– 300 Hz), or above (fc+ 3 300 Hz): at least 60 dB below the peak of the desired signal level, where fc is the carrier (reference) frequency.

11.3.1.14 RECEIVER RESPONSE TO TRANSIENTS

Recommendation.— *The receiving function should recover from an instantaneous increase in RF power at the antenna terminal of 60 dB within 10 milliseconds. The receiving function should recover from an instantaneous decrease in RF power at the antenna terminal of 60 dB within 25 milliseconds.*

11.3.2 Physical layer functions

11.3.2.1 FUNCTIONS

The functions provided by the physical layer shall include the following:

a) transmitter and receiver control;

b) transmission of data; and

c) reception of data.

11.3.2.2 TRANSMITTER AND RECEIVER CONTROL

The HFDL physical layer shall implement the transmitter/receiver switching and frequency tuning as commanded by the link layer. The physical layer shall perform transmitter keying on demand from the link layer to transmit a packet.

11.3.2.2.1 *TRANSMITTER TO RECEIVER TURNAROUND TIME*

The transmitted power level shall decay at least by 10 dB within 100 milliseconds after completing a transmission. An HFDL station subsystem shall be capable of receiving and demodulating, with nominal performance, an incoming signal within 200 milliseconds of the start of the subsequent receive slot.

11.3.2.2.2 *RECEIVER TO TRANSMITTER TURNAROUND TIME*

An HFDL station subsystem shall provide nominal output power within plus or minus 1 dB to the antenna transmission line within 200 milliseconds of the start of the transmit slot.

11.3.2.3 TRANSMISSION OF DATA

Transmission of data shall be accomplished using a time division multiple access (TDMA) technique. The HFDL data link ground station subsystems shall maintain TDMA frame and slot synchronization for the HFDL system. To ensure that slot synchronization is maintained, each HF data link modulator shall begin outputting a pre-key segment at the beginning of a time slot plus or minus 10 milliseconds.

11.3.2.3.1 *TDMASTRUCTURE*

Each TDMA frame shall be 32 seconds. Each TDMA frame shall be divided into thirteen equal duration slots as follows:

a) the first slot of each TDMA frame shall be reserved for use by the HFDL ground station subsystem to broadcast link management data in SPDU packets; and

b) the remaining slots shall be designated either as uplink slots, downlink slots reserved for specific HFDL aircraft station subsystems, or as downlink random access slots for use by all HFDL aircraft station subsystems on a contention basis. These TDMA slots shall be assigned on a dynamic basis using a combination of reservation, polling and random access assignments.

11.3.2.3.2 *BROADCAST*

The HFDL ground station subsystem shall broadcast a squitter protocol data unit (SPDU) every 32 seconds on each of its operating frequencies.

Note.— Details on the TDMA frame and slot structures, pre-key segment, data structures, including the SPDU, are contained in the Manual on HF Data Link (Doc 9741).

11.3.2.4 RECEPTION OF DATA

11.3.2.4.1 *FREQUENCY SEARCH*

Each HFDL aircraft station shall automatically search the assigned frequencies until it detects an operating frequency.

11.3.2.4.2 *RECEPTION OF PPDUS*

The HF data link receiver shall provide the means to detect, synchronize, demodulate and decode PPDUs modulated according to the waveform defined in 11.3.1.5, subject to the following distortion:

a) the 1 440 Hz audio carrier offset by plus or minus 70 Hz;

b) discrete and/or diffuse multipath distortion with up to 5 ms multipath spread;

c) multipath amplitude fading with up to 2 Hz two-sided RMS Doppler spread and Rayleigh statistics; and

d) additive Gaussian and broadband impulsive noise with varying amplitude and random arrival times.

Note.— Reference CCIR Report 549-2.

11.3.2.4.3 DECODING OF PPDUS

Upon receipt of the preamble segment the receiver shall:

a) detect the beginning of a burst of data;

b) measure and correct the frequency offset between the transmitter and receiver due to Doppler shift and transmitter/receiver frequency offsets;

c) determine the data rate and inter leaver settings to use during data demodulation;

d) achieve M-PSK symbol synchronization; and

e) train the equalizer.

11.3.2.4.4 *SYNCHRONIZATION*

Each HFDL aircraft station subsystem shall synchronize its slot timing to that of its corresponding ground station with respect to the reception time of the last received SPDU.

11.3.2.4.5 *SPECIFIED PACKET ERROR RATE PERFORMANCE*

11.3.2.4.5.1 The number of HFDL media access protocol data units (MPDUs) received with one or more bit errors shall not exceed 5 per cent of the total number of MPDUs received, when using a 1.8 second inter leaver and under the signal-in-space conditions shown in Table 11-3.

11.3.2.4.5.2 Recommendation.— The number of HFDL MPDUs received with one or more bit errors should not exceed 5 per cent of the total number of MPDUs received, when using a 1.8 second interleaver under the conditions shown in Table 11-3a.

11.3.3 Link layer

Note.— Details on link layer functions are contained in the Manual on HF Data Link (Doc 9741).

The link layer shall provide control functions for the physical layer, link management and data service protocols.

11.3.3.1 CONTROL FUNCTIONS

The link layer shall pass commands for frequency tuning, transmitter keying and transmitter/receiver switching to the physical layer.

11.3.3.2 LINK MANAGEMENT

The link layer shall manage TDMA slot assignments, log-on and log-off procedures, ground station and aircraft station TDMA synchronization, and other functions necessary, taking into account message priority, for the establishment and maintenance of communications.

11.3.3.3 DATA SERVICE PROTOCOLS

The link layer shall support a reliable link service (RLS) protocol and a direct link service (DLS) protocol.

11.3.3.3.1 *RLS*

The RLS protocol shall be used to exchange acknowledged user data packets between aircraft and ground peer link layers.

11.3.3.3.2 *DLS*

The DLS protocol shall be used to broadcast unsegmented uplink high frequency network protocol data units (HFNPDUs) and other HFNPDUs not requiring automatic retransmission by the link layer.

11.3.4 Subnetwork layer

Note.— Details on subnetwork layer protocols and services are contained in the Manual on HF Data Link (Doc 9741).

11.3.4.1 *PACKET DATA*

The HFDL subnetwork layer in the HFDL aircraft station subsystem and HFDL ground station subsystem shall provide connection-oriented packet data service by establishing subnetwork connections between subnetwork service users.

11.3.4.2 *CONNECTIVITY NOTIFICATION SERVICE*

The HFDL subnetwork layer in the HFDL aircraft station subsystem shall provide the additional connectivity notification service by sending connectivity notification event messages to the attached ATN router.

11.3.4.2.1 *CONNECTIVITY NOTIFICATION EVENT MESSAGES*

The connectivity notification service shall send connectivity notification event messages to the attached ATN router through the subnetwork access function.

11.3.4.3 HFDLSUBNETWORK LAYER FUNCTIONS

The HFDL subnetwork layer in both the HFDL aircraft station subsystem and HFDL ground station subsystem shall include the following three functions:

a) HFDL subnetwork dependent (HFSND) function;

b) subnetwork access function; and

c) interworking function.

11.3.4.3.1 *HFSND FUNCTION*

The HFSND function shall perform the HFSND protocol between each pair of HFDL aircraft station subsystems and HFDL ground station subsystems by exchanging HFNPDUs. It shall perform the HFSND protocol aircraft function in the HFDL

aircraft station subsystem and the HFSND protocol ground function in the HFDL ground station subsystem.

11.3.4.3.2 *SUBNETWORK ACCESS FUNCTION*

The subnetwork access function shall perform the ISO 8208 protocol between the HFDL aircraft station subsystem or HFDL ground station subsystem and the attached routers by exchanging ISO 8208 packets. It shall perform the ISO 8208 DCE function in the HFDL aircraft station subsystem and the HFDL ground station subsystem.

11.3.4.3.3 *INTERWORKING FUNCTION*

The interworking function shall provide the necessary harmonization functions between the HFSND, the subnetwork access and the connectivity notification functions.

11.4 GROUND MANAGEMENT SUBSYSTEM

Note.— Details on the ground management subsystem functions and interfaces are contained in the Manual on HF Data Link (Doc 9741).

11.4.1 Management functions

The ground management subsystem shall perform the functions necessary to establish and maintain communications channels between the HFDL ground and aircraft station subsystems.

11.4.2 Management/control information exchange

The ground management subsystem shall interface with the ground station subsystem in order to exchange control information required for frequency management, system table management, log status management, channel management, and quality of service (QOS) data collection.

TABLES FOR CHAPTER 11

Table 11-1. Transfer delays

	Direction	*Priority*	*Delay*
Transit delay	To-aircraft	7 through 14	45 s
	From-aircraft	7 through 14	60 s
Transfer delay (95 percentile)	To-aircraft	11 through 14 7 through 10	90 s 120 s
	From-aircraft	11 through 14 7 through 10	150 s 250 s

Table 11-2. Value of M and information data rate

M	*Information data rate (bits per second)*
2	300 or 600
4	1 200
8	1 800

Note.— When M equals the value 2, the data rate may be 300 or 600 bits per second as determined by the channel coding rate. The value of M may change from one data transmission to another depending on the data rate selected.
The channel coding rate is described in the Manual on HF Data Link (Doc 9741).

Table 11-3. HF signal-in-space conditions

Data rate (bits per second)	*Number of channel paths*	*Multipath spread (milliseconds)*	*Fading bandwidth (Hz) per CCIR Report 5492*	*Frequency offset (Hz)*	*Signal to noise ratio (dB) in a 3 kHz bandwidth*	*MPDU size (octets)*
1 200	1 fixed	–	–	40	4	256
1 800	2 fading	2	1	40	16	400
1 200	2 fading	2	1	40	11.5	256
600	2 fading	2	1	40	8	128
300	2 fading	2	1	40	5	64

Table 11-3a. HF signal-in-space conditions

Data rate (bits per second)	*Number of channel paths*	*Multipath spread (milliseconds)*	*Fading bandwidth (Hz) per CCIR Report 5492*	*Frequency offset (Hz)*	*Signal to noise ratio (dB) in a 3 kHz bandwidth*	*MPDU size (octets)*
1 200	2 fading	4	1	40	13	256
1 200	2 fading	2	2	40	11.5	256

FIGURE FOR CHAPTER 11

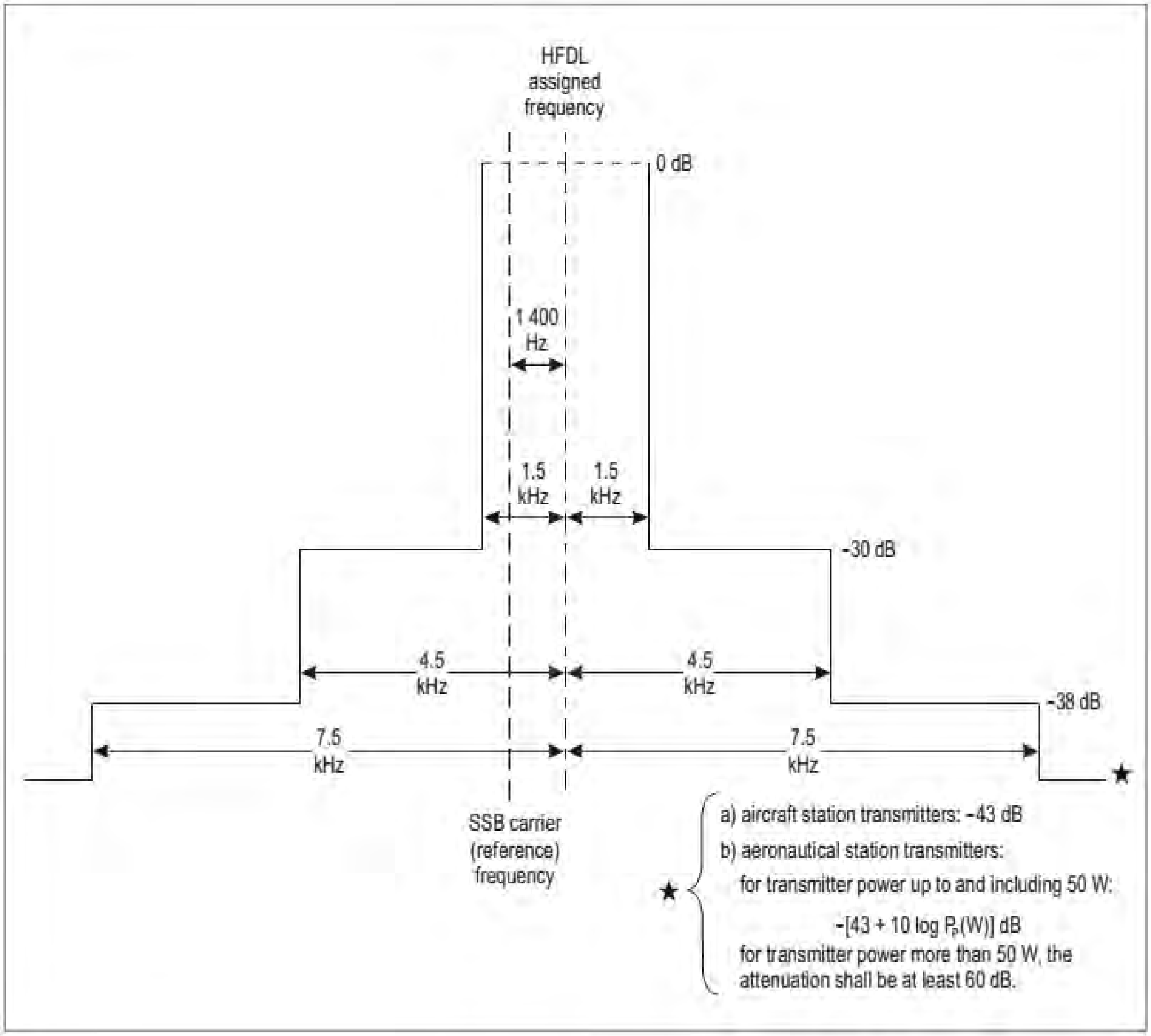


Figure 11-1. Required spectrum limits (in terms of peak power) for HFDL aircraft and ground station transmitters

CHAPTER 12. UNIVERSAL ACCESS TRANSCEIVER (UAT)
12.1 DEFINITIONS AND OVERALL SYSTEM CHARACTERISTICS

12.1.1 Definitions

High performance receiver. A UAT receiver with enhanced selectivity to further improve the rejection of adjacent frequency DME interference (see 12.3.2.2 for further details).

Optimum sampling point. The optimum sampling point of a received UAT bit stream is at the nominal centre of each bit period, when the frequency offset is either plus or minus 312.5 kHz.

Power measurement point (PMP). A cable connects the antenna to the UAT equipment. The PMP is the end of that cable that attaches to the antenna. All power measurements are considered as being made at the PMP unless otherwise specified. The cable connecting the UAT equipment to the antenna is assumed to have 3 dB of loss.

Pseudorandom message data block. Several UAT requirements state that performance will be tested using pseudorandom message data blocks. Pseudorandom message data blocks should have statistical properties that are nearly indistinguishable from those of a true random selection of bits. For instance, each bit should have (nearly) equal probability of being a ONE or a ZERO, independent of its neighbouring bits. There should be a large number of such pseudorandom message data blocks for each message type (Basic ADS-B, Long ADS-B or Ground Uplink) to provide sufficient independent data for statistical performance measurements. See Section 2.3 of Part I of the Manual on the Universal Access Transceiver (UAT)(Doc 9861) for an example of how to provide suitable pseudorandom message data blocks.

Service volume. A part of the facility coverage where the facility provides a particular service in accordance with relevant SARPs and within which the facility is afforded frequency protection.

Standard UAT receiver. A general purpose UAT receiver satisfying the minimum rejection requirements of interference from adjacent frequency distance measuring equipment (DME) (see 12.3.2.2 for further details).

Successful message reception (SMR). The function within the UAT receiver for declaring a received message as valid for passing to an application that uses received UAT messages. See Section 4 of Part I of the Manual on the Universal Access

Transceiver (UAT)(Doc 9861) for a detailed description of the procedure to be usedby the UAT receiver for declaring successful message reception.

UAT ADS-B message. A message broadcasted once per second by each aircraft to convey state vector and other information.

UAT ADS-B messages can be in one of two forms depending on the amount of information to be transmitted in a given second: the Basic UAT ADS-B Message or the Long UAT ADS-B Message(see 12.4.4.1 for definition of each). UAT ground stations can support traffic information service-broadcast (TIS-B) through transmission of individual ADS-B messages in the ADS-B segment of the UAT frame.

UAT ground uplink message. A message broadcasted by ground stations, within the ground segment of the UAT frame, to convey flight information such as text and graphical weather data, advisories, and other aeronautical information, to aircraft that are in the service volume of the ground station (see 12.4.4.2 for further details).

Universal access transceiver (UAT). A broadcast data link operating on 978 MHz, with a modulation rate of 1.041667 Mbps.

12.1.2 UAT overall system characteristics of aircraft and ground stations

Note.— Details on technical requirements related to the implementation of UAT SARPs are contained in Part I of the Manual on the Universal Access Transceiver (UAT) (Doc 9861). Part II of the Manual on the Universal Access Transceiver (UAT) (Doc 9861) (in preparation) will provide additional guidance material.

12.1.2.1 *TRANSMISSION FREQUENCY*

The transmission frequency shall be 978 MHz.

12.1.2.2 *FREQUENCY STABILITY*

The radio frequency of the UAT equipment shall not vary more than ±0.002 per cent (20 ppm) from the assigned frequency.

12.1.2.3 *TRANSMIT POWER*

12.1.2.3.1 *TRANSMIT POWER LEVELS*

UAT equipment shall operate at one of the power levels shown in Table 12-1[8].

[8] All tables and figures are located at the end of the chapter

12.1.2.3.2 *MAXIMUM POWER*

The maximum equivalent isotropically radiated power (EIRP) for a UAT aircraft or ground station shall not exceed +58 dBm.

Note.— For example, the maximum EIRP listed above could result from the maximum allowable aircraft transmitter power shown in Table 12-1 with a maximum antenna gain of 4 dBi.

12.1.2.3.3 *TRANSMIT MASK*

The spectrum of a UAT ADS-B message transmission modulated with pseudorandom message data blocks (MDB) shall fall within the limits specified in Table 12-2 when measured in a 100 kHz bandwidth.

*Note.— Figure 12-1*is a graphical representation of Table 12-2.*

12.1.2.4 SPURIOUS EMISSIONS

Spurious emissions shall be kept at the lowest value which the state of the technique and the nature of the service permit.

Note.— Appendix 3 of the ITU Radio Regulations requires that transmitting stations shall conform to the maximum permitted power levels for spurious emissions or for unwanted emissions in the spurious domain.

12.1.2.5 POLARIZATION

The design polarization of emissions shall be vertical.

12.1.2.6 TIME/AMPLITUDE PROFILE OF UATMESSAGE TRANSMISSION

The time/amplitude profile of a UAT message transmission shall meet the following requirements, in which the reference time is defined as the beginning of the first bit of the synchronization sequence (see 12.4.4.1.1, 12.4.4.2.1) appearing at the output port of the equipment.

Notes.—

1. All power requirements for subparagraphs "a" through "f" below apply to the PMP. For installations that support transmitter diversity, the RF power output on the non-selected antenna port should be at least 20 dB below the level on the selected port.

2. All power requirements for subparagraphs "a" and "f" assume a 300 kHz measurement bandwidth. All power requirements for subparagraphs "b", "c", "d" and "e" assume a 2 MHz measurement bandwidth.

3. The beginning of a bit is 1/2 bit period prior to the optimum sample point.

4. These requirements are depicted graphically in Figure 12-2.

a) Prior to 8 bit periods before the reference time, the RF output power at the PMP shall not exceed –80 dBm.

Note.— This unwanted radiated power restriction is necessary to ensure that the UAT transmitting subsystem does not prevent closely located UAT receiving equipment on the same aircraft from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment at the PMP exceeds 20 dB.

b) Between 8 and 6 bit periods prior to the reference time, the RF output power at the PMP shall remain at least 20 dB below the minimum power requirement for the UAT equipment class.

Note.— Guidance on definition of UAT equipment classes will be provided in Part II of the Manual on the Universal Access Transceiver (UAT)(Doc 9861) (in preparation).

c) During the Active state, defined as beginning at the reference time and continuing for the duration of the message, the RF output power at the PMP shall be greater than or equal to the minimum power requirement for the UAT equipment class.

d) The RF output power at the PMP shall not exceed the maximum power for the UAT equipment class at any time during the Active state.

e) Within 6 bit periods after the end of the Active state, the RF output power at the PMP shall be at a level at least 20 dB below the minimum power requirement for the UAT equipment class.

f) Within 8 bit periods after the end of the Active state, the RF output power at the PMP shall fall to a level not to exceed –80 dBm.

Note.— This unwanted radiated power restriction is necessary to ensure that the transmitting subsystem does not prevent closely located UAT receiving equipment on the same aircraft from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment at the PMP exceeds 20 dB.

12.1.3 Mandatory carriage requirements

Requirements for mandatory carriage of UAT equipment shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment, including the appropriate lead time.

Note.— No changes will be required to aircraft systems or ground systems operating solely in regions not using UAT.

12.2 SYSTEM CHARACTERISTICSOF THE GROUND INSTALLATION

12.2.1 Ground station transmitting function

12.2.1.1 GROUND STATION TRANSMITTER POWER

12.2.1.1.1 **Recommendation**.— *The effective radiated power should be such as to provide a field strength of at least 280 microvolts per metre (minus 97 dBW/m2) within the service volume of the facility on the basis of free-space propagation.*

Note.— This is determined on the basis of delivering a –91 dBm (corresponds to 200 microvolts per metre) signal level at the PMP (assuming an omnidirectional antenna). The 280 µV/m recommendation corresponds to the delivery of a -88 dBm signal level at the PMP of the receiving equipment. The 3 dB difference between –88 dBm and –91 dBm provides margin for excess path loss over free-space propagation.

12.2.2 Ground station receiving function

Note.— An example ground station receiver is discussed in Section 2.5 of Part II of the Manual on the Universal Access Transceiver (UAT) (Doc 9861), with UAT air-to-ground performance estimates consistent with use of that receiver provided in Appendix B of that manual.

12.3 SYSTEM CHARACTERISTICSOF THE AIRCRAFTINSTALLATION

12.3.1 Aircraft transmitting function

12.3.1.1 AIRCRAFT TRANSMITTER POWER

The effective radiated power shall be such as to provide a field strength of at least 225 microvolts per metre (minus 99 dBW/m2) on the basis of free-space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated. Transmitter power shall not exceed 54 dBm at the PMP.

Note 1.— The above field strength is determined on the basis of delivering a –93 dBm (corresponds to 160 microvolts per metre) signal level at the PMP (assuming an omnidirectional antenna). The 3 dB difference between 225 μV/m and 160 μV/m provides margin for excess path loss over free-space propagation when receiving a long UAT ADS-B message. A 4 dB margin is provided when receiving a basic UAT ADS-B message.

Note 2.— Various aircraft operations may have different air-air range requirements depending on the intended ADS-B function of the UAT equipment. Therefore different installations may operate at different power levels (see 12.1.2.3.1).

12.3.2 Receiving function

12.3.2.1 RECEIVER SENSITIVITY

12.3.2.1.1 *LONG UAT ADS-BMESSAGE AS DESIRED SIGNAL*

A desired signal level of –93 dBm applied at the PMP shall produce a rate of successful message reception (SMR) of 90 per cent or better under the following conditions:

a) When the desired signal is of nominal modulation (i.e. FM deviation is 625 kHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±1 200 knots;

b) When the desired signal is of maximum modulation distortion allowed in 12.4.3, at the nominal transmission frequency ±1 parts per million (ppm), and subject to relative Doppler shift at ±1 200 knots.

Note.— The receiver criteria for successful message reception of UAT ADS-B messages are provided in Section 4 of Part I of the Manual on the Universal Access Transceiver (UAT)(Doc 9861).

12.3.2.1.2 *BASIC UAT ADS-BMESSAGE AS DESIRED SIGNAL*

A desired signal level of –94 dBm applied at the PMP shall produce a rate of SMR of 90 per cent or better under the following conditions:

a) When the desired signal is of nominal modulation (i.e. FM deviation is 625 kHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±1 200 knots;

b) When the desired signal is of maximum modulation distortion allowed in 12.4.3, at the nominal transmission frequency ±1 ppm, and subject to relative Doppler shift at ±1 200 knots.

Note.— The receiver criteria for successful message reception of UAT ADS-B messages are provided in Section 4 of Part I of the Manual on the Universal Access Transceiver (UAT)(Doc 9861).

12.3.2.1.3 *UATGROUND UPLINK MESSAGE AS DESIRED SIGNAL*

A desired signal level of –91 dBm applied at the PMP shall produce a rate of an SMR of 90 per cent or better under the following conditions:

a) When the desired signal is of nominal modulation (i.e. FM deviation is 625 kHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±850 knots;

b) When the desired signal is of maximum modulation distortion allowed in 12.4.3, at the nominal transmission frequency ±1 ppm, and subject to relative Doppler shift at ±850 knots.

Notes.—

1. *The receiver criteria for successful message reception of UAT ground uplink messages are provided in Section 4 of Part I of the Manual on the Universal Access Transceiver (UAT) (Doc 9861) (in preparation).*

2. *This requirement ensures the bit rate accuracy supporting demodulation in the UAT equipment is adequate to properly receive the longer UAT ground uplink message.*

12.3.2.2 RECEIVER SELECTIVITY

Notes.—

1. *The undesired signal used is an unmodulated carrier applied at the frequency offset.*

2. *This requirement establishes the receiver's rejection of the off-channel energy.*

3. *It is assumed that ratios in between the specified offsets will fall near the interpolated value.*

4. *The desired signal used is a UAT ADS-B long message at -90 dBm at the PMP, to be received with a 90 per cent successful message reception rate.*

5. The tolerable co-channel continuous wave interference power level for aircraft UAT receivers is assumed to be -101 dBm or less at the PMP.

6. See Section 2.4.2 of Part II of the Manual on the Universal Access Transceiver (UAT) (Doc 9861) for a discussion of when a high-performance receiver is desirable.

a) Standard UAT receivers shall meet the selectivity characteristics given in Table 12-3.

b) High-performance receivers shall meet the more stringent selectivity characteristics given in Table 12-4.

Note.— See Section 2.4.2 of Part II of the Manual on the Universal Access Transceiver (UAT)(Doc 9861) for guidance material on the implementation of high-performance receivers.

12.3.2.3 RECEIVER DESIRED SIGNAL DYNAMIC RANGE

The receiver shall achieve a successful message reception rate for long ADS-B messages of 99 per cent or better when the desired signal level is between –90 dBm and –10 dBm at the PMP in the absence of any interfering signals.

Note.— The value of –10 dBm represents 120-foot separation from an aircraft transmitter transmitting at maximum allowed power.

12.3.2.4 RECEIVER TOLERANCE TO PULSED INTERFERENCE

Note.— All power level requirements in this section are referenced to the PMP.

a) For Standard and High-Performance receivers the following requirements shall apply:

1) The receiver shall be capable of achieving 99 per cent SMR of long UAT ADS-B messages when the desired signal level is between –90 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at either 12 or 30 microseconds pulse spacing at a level of –36 dBm for any 1 MHz DME channel frequency between 980 MHz and 1 213 MHz inclusive.

2) Following a 21 microsecond pulse at a level of ZERO (0) dBm and at a frequency of 1 090 MHz, the receiver shall return to within 3 dB of the specified sensitivity level (see 12.3.2.1) within 12 microseconds.

b) For the standard UAT receiver the following additional requirements shall apply:

1) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a

nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –56 dBm and a frequency of 979 MHz.

2) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –70 dBm and a frequency of 978 MHz.

c) For the high-performance receiver the following additional requirements shall apply:

1) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –43 dBm and a frequency of 979 MHz.

2) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –79 dBm and a frequency of 978 MHz.

12.4 PHYSICAL LAYER CHARACTERISTICS

12.4.1 Modulation rate

The modulation rate shall be 1.041 667 Mbps with a tolerance for aircraft transmitters of ±20 ppm and a tolerance for ground transmitters of ±2 ppm.

Note.— The tolerance on the modulation rate is consistent with the requirement on modulation distortion (see 12.4.3).

12.4.2 Modulation type

a) Data shall be modulated onto the carrier using binary continuous phase frequency shift keying. The modulation index, h, shall be no less than 0.6;

b) A binary ONE (1) shall be indicated by a shift up in frequency from the nominal carrier frequency and a binary ZERO (0) by a shift down from the nominal carrier frequency.

Notes. –

1. *Filtering of the transmitted signal (at base band and/or after frequency modulation) will be required to meet the spectral containment requirement of 12.1.2.3.3. This filtering may cause the deviation to exceed these values at points other than the optimum sampling points.*

2. Because of the filtering of the transmitted signal, the received frequency offset varies continuously between the nominal values of ±312.5 kHz (and beyond), and the optimal sampling point may not be easily identified. This point can be defined in terms of the so-called "eye diagram" of the received signal. The ideal eye diagram is a superposition of samples of the (undistorted) post detection waveform shifted by multiples of the bit period (0.96 microseconds). The optimum sampling point is the point during the bit period at which the opening of the eye diagram (i.e. the minimum separation between positive and negative frequency offsets at very high signal-to-noise ratios) is maximized. An example "eye diagram" can be seen in Figure 12-3. The timing of the points where the lines converge defines the "optimum sampling point". Figure 12-4 shows an eye pattern that has been partially closed by modulation distortion.

12.4.3 Modulation distortion

a) For aircraft transmitters, the minimum vertical opening of the eye diagram of the transmitted signal (measured at the optimum sampling points) shall be no less than 560 kHz when measured over an entire long UAT ADS-B message containing pseudorandom message data blocks.

b) For ground transmitters, the minimum vertical opening of the eye diagram of the transmitted signal (measured at the optimum sampling points) shall be no less than 560 kHz when measured over an entire UAT ground uplink message containing pseudorandom message data blocks.

c) For aircraft transmitters, the minimum horizontal opening of the eye diagram of the transmitted signal (measured at 978 MHz) shall be no less than 0.624 microseconds (0.65 symbol periods) when measured over an entire long UAT ADS-B message containing pseudorandom message data blocks.

d) For ground transmitters, the minimum horizontal opening of the eye diagram of the transmitted signal (measured at

978 MHz) shall be no less than 0.624 microseconds (0.65 symbol periods) when measured over an entire UAT ground uplink message containing pseudorandom message data blocks.

Notes. –

1. *Section 12.4.4 defines the UAT ADS-B message types.*

2. *The ideal eye diagram is a superposition of samples of the (undistorted) post detection waveform shifted by multiples of the bit period (0.96 microseconds).*

12.4.4 Broadcast message characteristics

The UAT system shall support two different message types: the UAT ADS-B message and the UAT ground uplink message.

12.4.4.1 UAT ADS-BMESSAGE

The Active portion (see 12.1.2.6) of a UAT ADS-B message shall contain the following elements, in the following order:

— Bit synchronization

— Message data block

— FEC parity.

12.4.4.1.1 *BIT SYNCHRONIZATION*

The first element of the Active portion of the UAT ADS-B message shall be a 36-bit synchronization sequence. For the UAT ADS-B messages the sequence shall be:

111010101100110111011010010011100010

with the left-most bit transmitted first.

12.4.4.1.2 *THE MESSAGE DATA BLOCK*

The second element of the Active portion of the UAT ADS-B message shall be the message data block. There shall be two lengths of UAT ADS-B message data blocks supported. The basic UAT ADS-B message shall have a 144-bit message data block and the long UAT ADS-B message shall have a 272-bit message data block.

Note.— The format, encoding and transmission order of the message data block element is provided in Section 2.1 of Part I of the Manual on the Universal Access Transceiver (UAT)(Doc 9861).

12.4.4.1.3 FEC *PARITY*

The third and final element of the Active portion of the UAT ADS-B message shall be the FEC parity.

12.4.4.1.3.1 *Code type*

The FEC parity generation shall be based on a systematic Reed-Solomon (RS) 256-ary code with 8-bit code word symbols. FEC parity generation shall be per the following code:

a) Basic UAT ADS-B message: Parity shall be a RS (30, 18) code.

Note.— This results in 12 bytes (code symbols) of parity capable of correcting up to 6 symbol errors per block.

b) Long UAT ADS-B message: Parity shall be a RS (48, 34) code.

Note.— This results in 14 bytes (code symbols) of parity capable of correcting up to 7 symbol errors per block.

For either message length the primitive polynomial of the code shall be as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

The generator polynomial shall be as follows:

$$\prod_{i=120}^{P} (x - \alpha^i)$$

where:

P = 131 for RS (30, 18) code,

P = 133 for RS (48, 34) code, and

α is a primitive element of a Galois field of size 256 (i.e. GF(256)).

12.4.4.1.3.2 *Transmission order of FEC parity*

FEC parity bytes shall be ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte shall be most significant to least significant. FEC parity bytes shall follow the message data block.

12.4.4.2 UATGROUND UPLINK MESSAGE

The Active portion of a UAT ground uplink message shall contain the following elements, in the following order:

— Bit synchronization
— Interleaved message data block and FEC parity.

12.4.4.2.1 *BIT SYNCHRONIZATION*

The first element of the Active portion of the UAT ground uplink message shall bea 36-bit synchronization sequence. For the UAT ground uplink message the sequence shall be:

000101010011001000100101101100011101

with the left-most bit transmitted first.

12.4.4.2.2 *INTERLEAVED MESSAGE DATA BLOCK AND FECPARITY*

12.4.4.2.2.1 *Message data block (before interleaving and after de-interleaving)*

The UAT ground uplink message shall have 3 456 bits of message data block. These bits are divided into 6 groups of 576 bits. FEC is applied to each group as described in 12.4.4.2.2.2.

Note.— Further details on the format, encoding and transmission order of the UAT ground uplink message data block are provided in Section 2.2 of Part I of the Manual on the Universal Access Transceiver (UAT)(Doc 9861).

12.4.4.2.2.2 *FEC parity (before interleaving and after de-interleaving)*

12.4.4.2.2.2.1 *Code type*

The FEC parity generation shall be based on a systematic RS 256-ary code with 8-bit code word symbols. FEC parity generation for each of the six blocks shall be a RS (92,72) code.

Notes.—

1. Section 12.4.4.2.2.3 provides details on the interleaving procedure.

2. This results in 20 bytes (symbols) of parity capable of correcting up to 10 symbol errors per block. The additional use of interleaving for the UAT ground uplink message allows additional robustness against burst errors.

The primitive polynomial of the code is as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

The generator polynomial is as follows:

$$\prod_{i=120}^{P}(x - \alpha^i)$$

where:

P = 139, and

α is a primitive element of a Galois field of size 256 (i.e. GF(256)).

12.4.4.2.2.2.2 *Transmission order of FEC parity*

FEC parity bytes are ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte shall be most significant to least significant. FEC parity bytes shall follow the message data block.

12.4.4.2.2.3 *Interleaving procedure*

UAT ground uplink messages shall be interleaved and transmitted by the ground station, as listed below:

a) **Interleaving procedure**: The interleaved message data block and FEC parity consists of 6 interleaved Reed Solomon blocks. The interleaver is represented by a 6×92 matrix, where each entry is a RS 8-bit symbol. Each row comprises a single RS (92,72) block as shown in Table 12-5. In this table, block numbers prior to interleaving are represented as "A" through "F". The information is ordered for transmission column by column, starting at the upper left corner of the matrix.

b) **Transmission order**: The bytes are then transmitted in the following order:

1,73,145,217,289,361,2,74,146,218,290,362,3,. . .,C/20,D/20,E/20,F/20.

Note.– On reception these bytes need to be de-interleaved so that the RS blocks can be reassembled prior to error correction decoding.

12.5 GUIDANCE MATERIAL

Notes. –

1. The Manual on the Universal Access Transceiver (UAT)(Doc 9861), Part I, provides detailed technical specifications on UAT, including ADS-B message data blocks and formats, procedures for operation of UAT transmitting subsystems, and avionics interface requirements with other aircraft systems.

2. The Manual on the Universal Access Transceiver (UAT)(Doc 9861), Part II, provides information on UAT system operation, description of a range of example avionics equipment classes and their applications, guidance on UAT aircraft and ground station installation aspects, and detailed information on UAT system performance simulation.

TABLES FOR CHAPTER 12

Table 12-1. Transmitter power levels

Transmitter type	*Minimum power at PMP*	*Maximum power at PMP*	*Intended minimum air-to-air ranges*
Aircraft (Low)	7 watts (+38.5 dBm)	18 watts (+42.5 dBm)	20 NM
Aircraft (Medium)	16 watts (+42 dBm)	40 watts (+46 dBm)	40 NM
Aircraft (High)	100 watts (+50 dBm)	250 watts (+54 dBm)	120 NM
Ground Station	Specified by the service provider to meet local requirements within the constraint of 12.1.2.3.2.		

Notes. –

1. The three levels listed for the avionics are available to support applications with varying range requirements. See the discussion of UAT aircraft Equipage Classes in Section 2.4.2 of Part II of the Manual on the Universal Access Transceiver (UAT) (Doc 9861) (in preparation).

2. The intended minimum air-to-air ranges are for high-density air traffic environments. Larger air-to-air ranges will be achieved in low-density air traffic environments.

Table 12-2. UAT transmit spectrum

Frequency offset from centre	*Required attenuation from maximum power level (dB as measured at the PMP)*
All frequencies in the range 0 – 0.5 MHz	0
All frequencies in the range 0.5 – 1.0 MHz	Based on linear* interpolation between these points
1.0 MHz	18
All frequencies in the range 1.0 – 2.25 MHz	Based on linear* interpolation between these points
2.25 MHz	50
All frequencies in the range 2.25 – 3.25 MHz	Based on linear* interpolation between these points
3.25 MHz	60

** based on attenuation in dB and a linear frequency scale*

Table 12-3. Standard UAT receiver rejection ratios

Frequency offset from centre	*Minimum rejection ratio (Undesired/desired level in dB)*
–1.0 MHz	10
+1.0 MHz	15
(±) 2.0 MHz	50
(±) 10.0 MHz	60

Note.— It is assumed that ratios in between the specified offsets will fall near the interpolated value.

Table 12-4. High-performance receiver rejection ratios

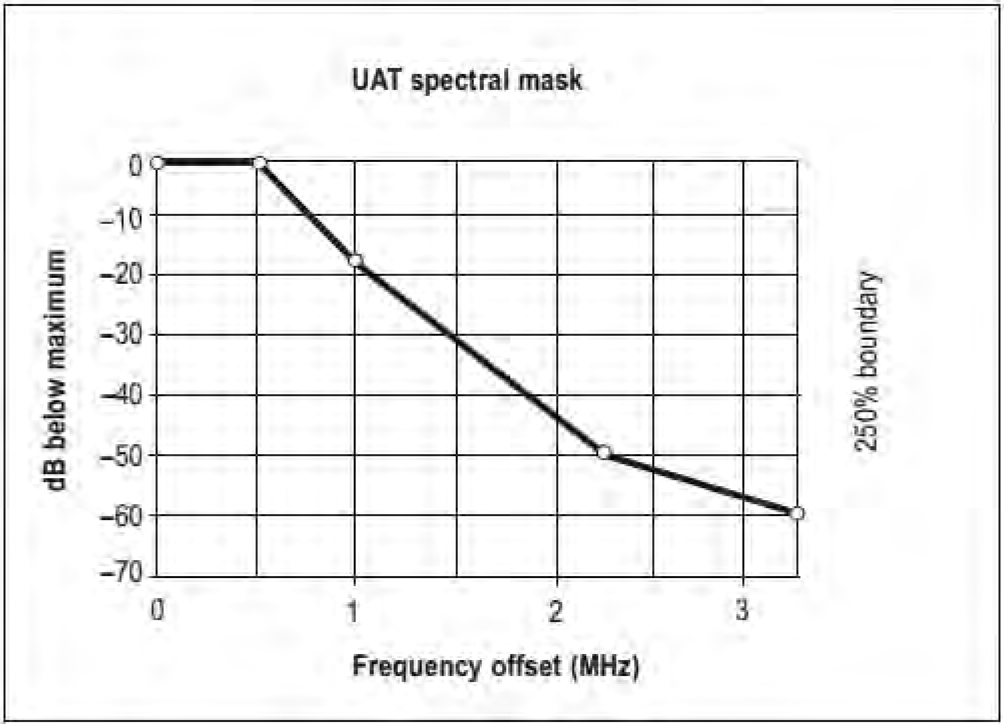
Frequency offset from centre	*Minimum rejection ratio (Undesired/desired level in dB)*
–1.0 MHz	30
+1.0 MHz	40
(±) 2.0 MHz	50
(±) 10.0 MHz	60

Table 12-5. Ground uplink interleaver matrix

RS Block	*MDB Byte #*						*FEC Parity (Block/Byte #)*			
A	1	2	3	…	71	72	A/1	…	A/19	A/20
B	73	74	75	…	143	144	B/1	…	B/19	B/20
C	145	146	147	…	215	216	C/1	…	C/19	C/20
D	217	218	219	…	287	288	D/1	…	D/19	D/20
E	289	290	291	…	359	360	E/1	…	E/19	E/20
F	361	362	363	…	431	432	F/1	…	F/19	F/20

Note.— In Table 12-5, message data block Byte #1 through #72 are the 72 bytes (8 bits each) of message data block information carried in the first RS (92,72) block. FEC parity A/1 through A/20 are the 20 bytes of FEC parity associated with that block (A).

FIGURES FOR CHAPTER 12



Notes. –

1. *99 per cent of the power of the UAT spectrum is contained in 1.3 MHz (±0.65 MHz). This is roughly equivalent to the 20 dB bandwidth.*

2. *Spurious emissions requirements begin at ±250 per cent of the 1.3 MHz value, therefore the transmit mask requirement extends to ±3.25 MHz.*

Figure 12-1. UAT transmit spectrum

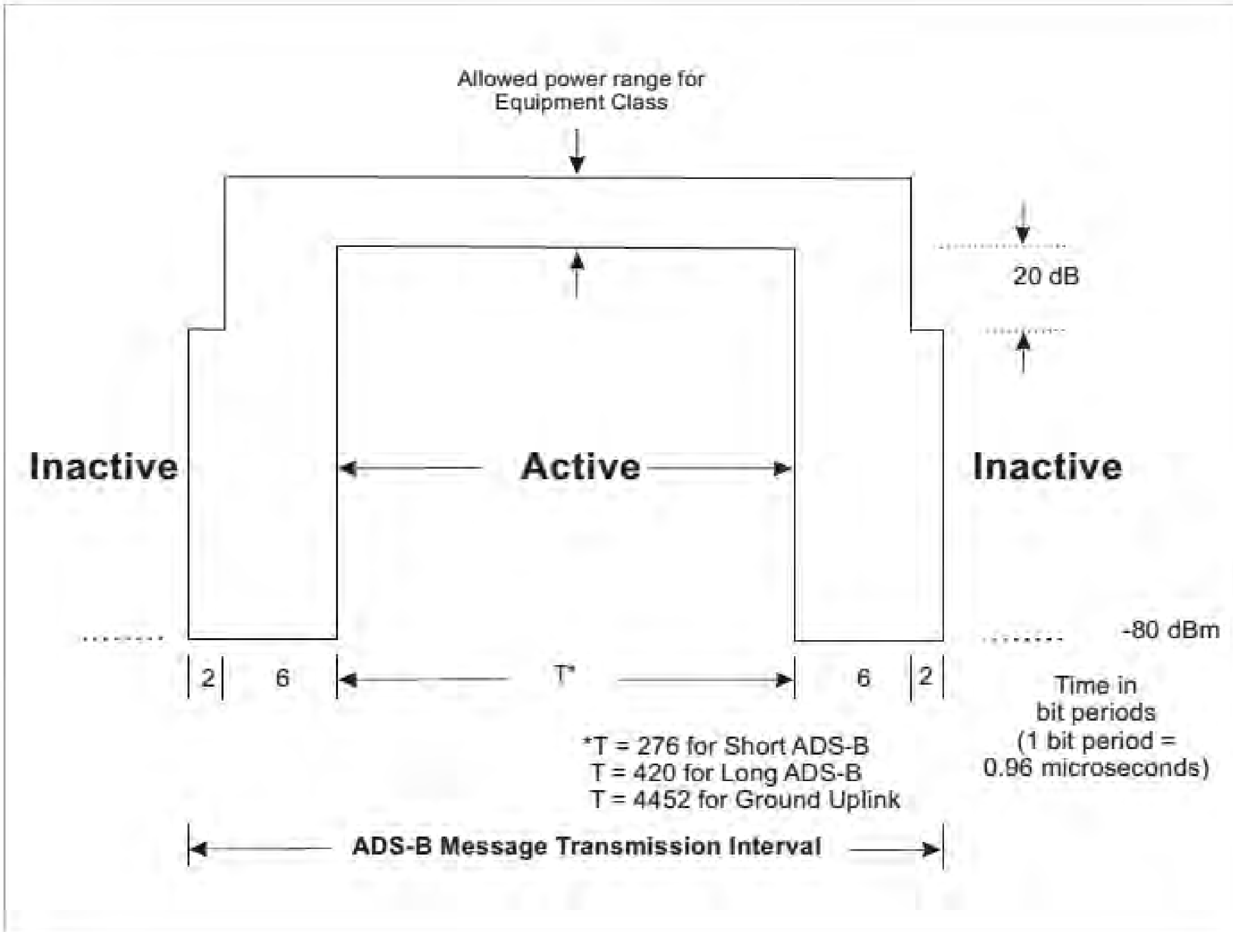


Figure 12-2. Time/amplitude profile of UAT message transmission

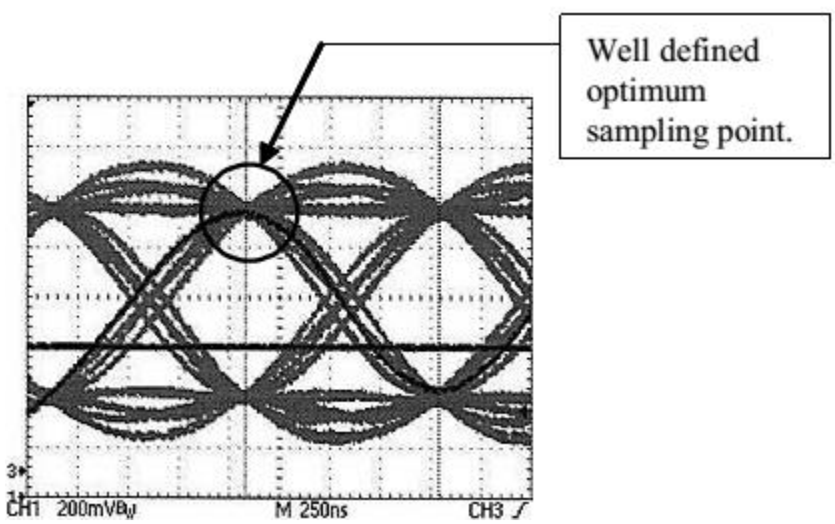


Figure 12-3. Ideal eye diagram

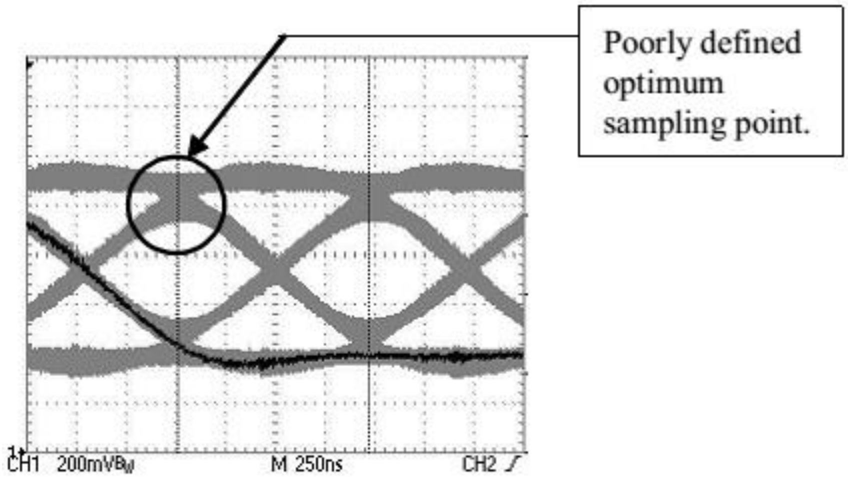


Figure 12-4. Distorted eye diagram

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

PART II — VOICE COMMUNICATION SYSTEMS

CHAPTER 1. DEFINITIONS

Note.— Material on secondary power supply and guidance material concerning reliability and availability for communication systems is contained in Annex 10, Volume I, 2.9 and Volume I, Attachment F, respectively.

CHAPTER 2. AERONAUTICAL MOBILE SERVICE

2.1 AIR-GROUND VHF COMMUNICATION SYSTEM CHARACTERISTICS

Note.— In the following text the channel spacing for 8.33 kHz channel assignments is defined as 25 kHz divided by 3 which is 8.3333 ... kHz.

2.1.1 The characteristics of the air-ground VHF communication system used in the International Aeronautical Mobile Service shall be in conformity with the following specifications:

2.1.1.1 Radiotelephone emissions shall be double sideband (DSB) amplitude modulated (AM) carriers. The designation of emission is A3E, as specified in the ITU Radio Regulations.

2.1.1.2 Spurious emissions shall be kept at the lowest value which the state of technique and the nature of the service permit.

Note.— Appendix S3 to the ITU Radio Regulations specifies the levels of spurious emissions to which transmitters must conform.

2.1.1.3 The radio frequencies used shall be selected from the radio frequencies in the band 117.975 – 137 MHz. The separation between assignable frequencies (channel spacing) and frequency tolerances applicable to elements of the system shall be as specified in Volume V.

Note.— The band 117.975 – 132 MHz was allocated to the Aeronautical Mobile (R) Service in the ITU Radio Regulations (1947). By subsequent revisions at ITU World Administrative Radio Conferences the bands 132 – 136 MHz and 136 – 137 MHz were added under conditions which differ for ITU Regions, or for specified countries or combinations of countries (see RRs S5.203, S5.203A and S5.203B for additional allocations in the band 136 – 137 MHz, and S5.201 for the band 132–136 MHz).

2.1.1.4 The design polarization of emissions shall be vertical.

2.2 SYSTEM CHARACTERISTICSOF THE GROUND INSTALLATION

2.2.1 Transmitting function

2.2.1.1 *Frequency stability*. The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.002 per cent from the assigned frequency. Where 8.33 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.0001 per cent from the assigned frequency.

Note.— The above frequency stability requirements will not be sufficient for offset carrier systems using 25 kHz channel spacing or higher.

2.2.1.1.1 Offset carrier systems in 8.33 kHz, 25 kHz, 50 kHz and 100 kHz channel spaced environments. The stability of individual carriers of an offset carrier system shall be such as to prevent first-order heterodyne frequencies of less than 4 kHz and, additionally, the maximum frequency excursion of the outer carrier frequencies from the assigned carrier frequency shall not exceed 8 kHz. Offset carrier systems for 8.33 kHz channel spacing shall be limited to two-carrier systems using a carrier offset of plus and minus 2.5 kHz.

Note.— Examples of the required stability of the individual carriers of offset carrier systems may be found at the Attachment to Part II.

2.2.1.2 POWER

Recommendation.— *On a high percentage of occasions, the effective radiated power should be such as to provide a field strength of a least 75 microvolts per metre (minus 109 dBW/m2) within the defined operational coverage of the facility, on the basis of free-space propagation.*

2.2.1.3 *Modulation.* A peak modulation factor of at least 0.85 shall be achievable.

2.2.1.4 **Recommendation.—** *Means should be provided to maintain the average modulation factor at the highest practicable value without over modulation.*

2.2.2 Receiving function

2.2.2.1 *Frequency stability*. Where 8.33 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.0001 per cent from the assigned frequency.

2.2.2.2 *Sensitivity.* After due allowance has been made for feeder loss and antenna polar diagram variation, the sensitivity of the receiving function shall be such as to provide on a high percentage of occasions an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 20 microvolts per metre (minus 120 dBW/m2) or more.

2.2.2.3 *Effective acceptance bandwidth*. When tuned to a channel having a width of 25 kHz, 50 kHz or 100 kHz, the receiving system shall provide an adequate and intelligible audio output when the signal specified at 2.2.2.2 has a carrier frequency within plus or minus 0.005 per cent of the assigned frequency. When tuned to a channel having a width of

8.33 kHz, the receiving system shall provide an adequate and intelligible audio output when the signal specified at 2.2.2.2 has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency. Further information on the effective acceptance bandwidth is contained in the Attachment to Part II.

Note.— The effective acceptance bandwidth includes Doppler shift.

2.2.2.4 *Adjacent channel rejection.* The receiving system shall ensure an effective rejection of 60 dB or more at the next assignable channel.

Note.— The next assignable frequency will normally be plus or minus 50 kHz. Where this channel spacing will not suffice, the next assignable frequency will be plus or minus 25 kHz, or plus or minus 8.33 kHz, implemented in accordance with the provisions of Volume V. It is recognized that in certain areas of the world receivers designed for 25 kHz, 50 kHz or 100 kHz channel spacing may continue to be used.

2.3 SYSTEM CHARACTERISTICS OF THE AIRBORNE INSTALLATION

2.3.1 Transmitting function

2.3.1.1 *Frequency stability*. The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced, the radio frequency of operation shall not vary more than plus or minus 0.003 per cent from the assigned frequency. Where 8.33 kHz channel spacing is introduced, the radio frequency of operation shall not vary more than plus or minus 0.0005 per cent from the assigned frequency.

2.3.1.2 *Power*. On a high percentage of occasions, the effective radiated power shall be such as to provide a field strength of at least 20 microvolts per metre (minus 120 dBW/m2) on the basis of free space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated.

2.3.1.3 *Adjacent channel power.* The amount of power from a 8.33 kHz airborne transmitter under all operating conditions when measured over a 7 kHz channel bandwidth centred on the first 8.33 kHz adjacent channel shall not exceed -45 dB below the transmitter carrier power. The above adjacent channel power shall take into account the typical voice spectrum.

Note.— The voice spectrum is assumed to be a constant level between 300 and 800 Hz and attenuated by 10 dB per octave above 800 Hz.

2.3.1.4 *Modulation*. A peak modulation factor of at least 0.85 shall be achievable.

2.3.1.5 **Recommendation.**— *Means should be provided to maintain the average modulation factor at the highest practicable value without over modulation.*

2.3.2 Receiving function

2.3.2.1 *Frequency stability*. Where 8.33 kHz channel spacing is introduced in accordance with Volume V, the radio frequency of operation shall not vary more than plus or minus 0.0005 per cent from the assigned frequency.

2.3.2.2 SENSITIVITY

2.3.2.2.1 **Recommendation.—** *After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function should be such as to provide on a high percentage of occasions an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 75 microvolts per metre (minus 109 dBW/m2).*

Note.— For planning extended range VHF facilities, an airborne receiving function sensitivity of 30 microvolts per metre may be assumed.

2.3.2.3 Effective acceptance bandwidth for 100 kHz, 50 kHz and 25 kHz channel spacing receiving installations. When tuned to a channel designated in Volume V as having a width of 25 kHz, 50 kHz or 100 kHz, the receiving function shall ensure an effective acceptance bandwidth as follows:

a) in areas where offset carrier systems are employed, the receiving function shall provide an adequate audio output when the signal specified at 2.3.2.2 has a carrier frequency within 8 kHz of the assigned frequency;

b) in areas where offset carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified at 2.3.2.2 has a carrier frequency of plus or minus 0.005 per cent of the assigned frequency.

2.3.2.4 Effective acceptance bandwidth for 8.33 kHz channel spacing receiving installations. When tuned to a channel designated in Volume V, as having a width of 8.33 kHz, the receiving function shall ensure an effective acceptance bandwidth as follows:

a) in areas where offset carrier systems are employed, the receiving function shall provide an adequate audio output when the signal specified in 2.3.2.2 has a carrier frequency of plus or minus 2.5 kHz of the assigned frequency; and

b) in areas where offset carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified in 2.3.2.2 has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency. Further information on the effective acceptance bandwidth is contained in Part II, Attachment A.

Note 1.— The effective acceptance bandwidth includes Doppler shift.

Note 2.— When using offset carrier systems (ref. 2.3.2.3 and2.3.2.4), receiver performance may become degraded when receiving two or more similar strength offset carrier signals. Caution is therefore advised with the implementation of offset carrier systems.

2.3.2.5 *Adjacent channel rejection*. The receiving function shall ensure an effective adjacent channel rejection as follows:

a) 8.33 kHz channels:60 dB or more at plus or minus 8.33 kHz with respect to the assigned frequency, and 40 dB or more at plus or minus 6.5 kHz;

Note.— The receiver local oscillator phase noise should be sufficiently low to avoid any degradation of the receiver capability to reject off carrier signals. A phase noise level better than minus 99 dBc/Hz 8.33 kHz away from the carrier is necessary to comply with 45 dB adjacent channel rejection under all operating conditions.

b) 25 kHz channel spacing environment:50 dB or more at plus or minus 25 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 17 kHz;

c) 50 kHz channel spacing environment:50 dB or more at plus or minus 50 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 35 kHz;

d) 100 kHz channel spacing environment:50 dB or more at plus or minus 100 kHz with respect to the assigned frequency.

2.3.2.6 **Recommendation**.— *Whenever practicable, the receiving system should ensure an effective adjacent channel rejection characteristic of 60 dB or more at plus or minus 25 kHz, 50 kHz and 100 kHz from the assigned frequency for receiving systems intended to operate in channel spacing environments of 25 kHz, 50 kHz and 100 kHz, respectively.*

Note.— Frequency planning is normally based on an assumption of 60 dB effective adjacent channel rejection at plus or minus 25 kHz, 50 kHz or 100 kHz from the assigned frequency as appropriate to the channel spacing environment.

2.3.2.7 **Recommendation.—** *In the case of receivers complying with 2.3.2.3 or 2.3.2.4 used in areas where offset carrier systems are in force, the characteristics of the receiver should be such that:*

a) the audio frequency response precludes harmful levels of audio heterodynes resulting from the reception of two or more offset carrier frequencies;

b) the receiver muting circuits, if provided, operate satisfactorily in the presence of audio heterodynes resulting from the reception of two or more offset carrier frequencies.

2.3.2.8 VDL — INTERFERENCE IMMUNITY PERFORMANCE

2.3.2.8.1 For equipment intended to be used in independent operations of services applying DSB-AM and VDL

technology on board the same aircraft, the receiving function shall provide an adequate and intelligible audio output with a

desired signal field strength of not more than 150 microvolts per metre (minus 102 dBW/m2) and with an undesired VDL signal field strength of at least 50 dB above the desired field strength on any assignable channel 100 kHz or more away from the assigned channel of the desired signal.

Note.— This level of VDL interference immunity performance provides a receiver performance consistent with the influence of the VDL RF spectrum mask as specified in Volume III, Part I, 6.3.4 with an effective transmitter/receiver isolation of 68 dB. Better transmitter and receiver performance could result in less isolation required.

2.3.2.8.2 After 1 January 2002, the receiving function of all new installations intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft shall meet the provisions of 2.3.2.8.1.

2.3.2.8.3 After 1 January 2005, the receiving function of all installations intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft shall meet the provisions of 2.3.2.8.1, subject to the conditions of 2.3.2.8.4.

2.3.2.8.4 Requirements for mandatory compliance of the provisions of 2.3.2.8.3 shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales.

2.3.2.8.4.1 The agreement indicated in 2.3.2.8.4 shall provide at least two years' notice of mandatory compliance of airborne systems.

2.3.3 Interference immunity performance

2.3.3.1 After 1 January 1998, the VHF communications receiving system shall provide satisfactory performance in the presence of two signal, third-order intermodulation products caused by VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

2.3.3.2 After 1 January 1998, the VHF communications receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

Note.— Guidance material on immunity criteria to be used for the performance quoted in 2.3.3.1 and 2.3.3.2 is contained in the Attachment to Part II, 1.3.

2.3.3.3 After 1 January 1995, all new installations of airborne VHF communications receiving systems shall meet the

provisions of 2.3.3.1 and 2.3.3.2.

2.3.3.4 Recommendation.— Airborne VHF communications receiving systems meeting the immunity performance

Standards of 2.3.3.1 and 2.3.3.2 should be placed into operation at the earliest possible date.

2.4 SINGLE SIDEBAND (SSB) HF COMMUNICATION SYSTEM CHARACTERISTICS FOR USE IN THE AERONAUTICAL MOBILE SERVICE

2.4.1 The characteristics of the air-ground HF SSB system, where used in the Aeronautical Mobile Service, shall be in conformity with the following specifications.

2.4.1.1 FREQUENCY RANGE

2.4.1.1.1 HF SSB installations shall be capable of operation at any SSB carrier (reference) frequency available to the Aeronautical Mobile (R) Service in the band 2.8 MHz to 22 MHz and necessary to meet the approved assignment plan for the region(s) in which the system is intended to operate, and in compliance with the relevant provisions of the Radio Regulations.

Note 1.— See Introduction to Volume V, Chapter 3, and Figures 2-1 and 2-2[9].

Note 2.— The ITU World Administrative Radio Conference, Aeronautical Mobile (R) Service, Geneva, 1978, established a new Allotment Plan (Appendix 27, Aer to the Radio Regulations) based on single sideband replacing the earlier double sideband Allotment Plan. The World Radiocommunication Conference 1995 redesignated it as Appendix S.27. Minor editorial changes were made at the World Radiocommunication Conference 1997.

2.4.1.1.2 The equipment shall be capable of operating onintegral multiples of 1 kHz.

2.4.1.2 SIDEBAND SELECTION

2.4.1.2.1 The sideband transmitted shall be that on the higher frequency side of its carrier (reference) frequency.

2.4.1.3 CARRIER (REFERENCE) FREQUENCY

2.4.1.3.1 Channel utilization shall be in conformity with the table of carrier(reference) frequencies at 27/16 and the Allotment Plan at 27/186 to 27/207 inclusive (or frequencies established on the basis of 27/21, as may be appropriate) of Appendix S27.

Note.— It is intended that only the carrier (reference)frequency be promulgated in Regional Plans and Aeronautical Publications.

2.4.1.4 CLASSES OF EMISSION AND CARRIER SUPPRESSION

2.4.1.4.1 The system shall utilize the suppressed carrier class of emission J3E (also J7B and J9B as applicable). When SELCAL is employed as specified in Chapter 3 of Part II, the installation shall utilize class H2B emission.

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[9] All figures are located at the end of this chapter.

2.4.1.4.2 By 1 February 1982 aeronautical stations and aircraft stations shall have introduced the appropriate class(es) of emission prescribed in 2.4.1.4.1. Effective this date the use of class A3E emission shall be discontinued except as provided in 2.4.1.4.4.

2.4.1.4.3 Until 1 February 1982 aeronautical stations and aircraft stations equipped for single sideband operations shall also be equipped to transmit class H3E emission where required to be compatible with reception by double sideband equipment. Effective this date the use of class H3E emission shall be discontinued except as provided in 2.4.1.4.4.

2.4.1.4.4 **Recommendation**.— *For stations directly involved in coordinated search and rescue operations using the frequencies 3 023 kHz and 5 680 kHz, the class of emission J3E should be used; however, since maritime mobile and land mobile services may be involved, A3E andH3E classes of emission may be used.*

2.4.1.4.5 After 1 April 1981 no new DSB equipment shall be installed.

2.4.1.4.6 Aircraft station transmitters shall be capable of at least 26 dB carrier suppression with respect to peak envelope power (Pp) for classes of emission J3E, J7B or J9B.

2.4.1.4.7 Aeronautical station transmitters shall be capable of 40 dB carrier suppression with respect to peak envelope power (Pp) for classes of emission J3E, J7B or J9B.

2.4.1.5 AUDIO FREQUENCY BANDWIDTH

2.4.1.5.1 For radiotelephone emissions the audio frequencies shall be limited to between 300 and 2 700 Hz and the occupied bandwidth of other authorized emissions shall not exceed the upper limit of J3E emissions. In specifying these limits, however, no restriction in their extension shall be implied in so far as emissions other than J3E are concerned, provided that the limits of unwanted emissions are met (see 2.4.1.7).

Note.— For aircraft and aeronautical station transmitter types first installed before 1 February 1983 the audio frequencies will be limited to 3 000 Hz.

2.4.1.5.2 For other authorized classes of emission the modulation frequencies shall be such that the required spectrum limits of 2.4.1.7 will be met.

2.4.1.6 FREQUENCY TOLERANCE

2.4.1.6.1 The basic frequency stability of the transmitting function for classes of emission J3E, J7B or J9B shall be such that the difference between the actual carrier of the transmission and the carrier (reference) frequency shall not exceed:

— 20 Hz for airborne installations;
— 10 Hz for ground installations.

2.4.1.6.2 The basic frequency stability of the receiving function shall be such that, with the transmitting function

stabilities specified in 2.4.1.6.1,the overall frequency difference between ground and airborne functions achieved in service and including Doppler shift, does not exceed 45 Hz. However, a greater frequency difference shall be permitted in the case of supersonic aircraft.

2.4.1.7 SPECTRUM LIMITS

2.4.1.7.1 For aircraft station transmitter types and for aeronautical station transmitters first installed before 1 February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B the mean power of any emission on any discrete frequency shall be less than the mean power (Pm) of the transmitter in accordance with the following:

— on any frequency removed by 2 kHz or more up to 6 kHz from the assigned frequency: at least 25 dB;
— on any frequency removed by 6 kHz or more up to 10 kHz from the assigned frequency: at least 35 dB;
— on any frequency removed from the assigned frequency by 10 kHz or more:

a) aircraft station transmitters: 40 dB;

b) aeronautical station transmitters:

$$[43 + 10 \log_{10} P_m \, (W)] \, dB$$

2.4.1.7.2 For aircraft station transmitters first installed after 1 February 1983 and for aeronautical station transmitters in use as of 1 February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B, the peak envelope power (Pp) of any emission on any discrete frequency shall be less than the peak envelope power (Pp) of the transmitter in accordance with the following:

— on any frequency removed by 1.5 kHz or more up to 4.5 kHz from the assigned frequency: at least 30 dB;
— on any frequency removed by 4.5 kHz or more up to 7.5 kHz from the assigned frequency: at least 38 dB;
— on any frequency removed from the assigned frequency by 7.5 kHz or more:

a) aircraft station transmitters: 43 dB;

b) aeronautical station transmitters: for transmitter power up to and including 50 W:

$$[43 + 10 \log_{10} P_p (W)]\ dB$$

For transmitter power more than 50 W: 60 dB.

Note.— See Figures 2-1 and 2-2.

2.4.1.8 POWER

2.4.1.8.1 *Aeronautical station installations.* Except as permitted by the relevant provisions of Appendix S27 to the ITU Radio Regulations, the peak envelope power (Pp) supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emissions shall not exceed a maximum value of 6 kW.

2.4.1.8.2 *Aircraft station installations*. The peak envelope power supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emission shall not exceed 400 W except as provided for in Appendix S27 of the ITU Radio Regulations as follows:

S27/68 It is recognized that the power employed by aircraft transmitters may, in practice, exceed the limits specified in No. 27/60. However, the use of such increased power (which normally should not exceed 600 W Pp) shall not cause harmful interference to stations using frequencies in accordance with the technical principles on which the Allotment Plan is based.

S27/60 Unless otherwise specified in Part II of this Appendix, the peak envelope powers supplied to the antenna transmission line shall not exceed the maximum values indicated in the table below; the corresponding peak effective radiated powers being assumed to be equal to two-thirds of these values:

Class of emission	*Stations*	*Max. peak envelope power (P_p)*
H2B, J3E, J7B, J9B, A3E*, H3E* (100% modulation)	Aeronautical stations Aircraft stations	6 kW 400 W
Other emission such as A1A, F1B	Aeronautical stations Aircraft stations	1.5 kW 100 W

* A3E and H3E to be used only on 3 023 kHz and 5 680 kHz.

2.4.1.9 *Method of operation*. Single channel simplex shall be employed.

FIGURES FOR CHAPTER 2

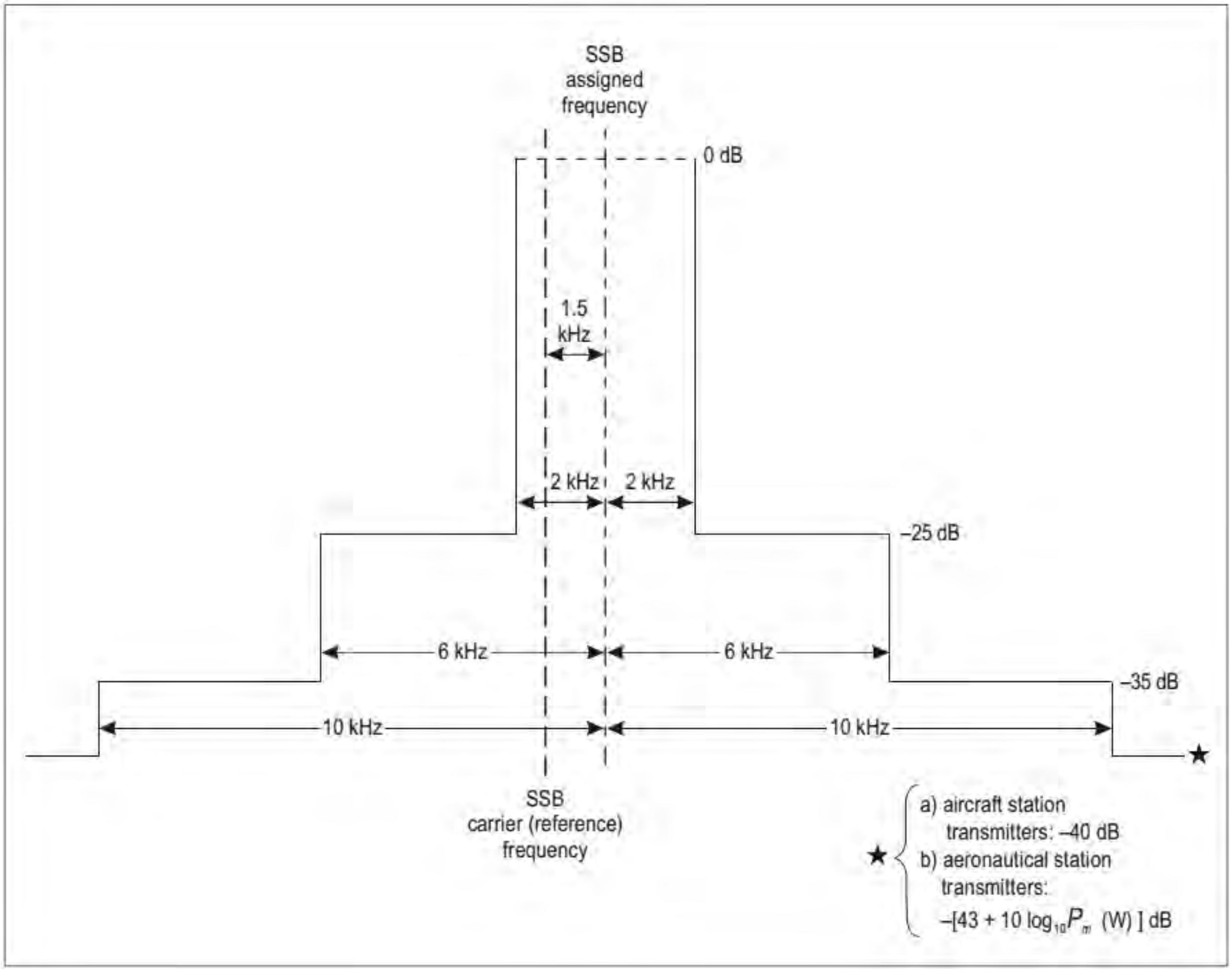

Figure 2-1. Required spectrum limits (in terms of mean power) for aircraft station transmitter types and for aeronautical station transmitters first installed before 1 February 1983

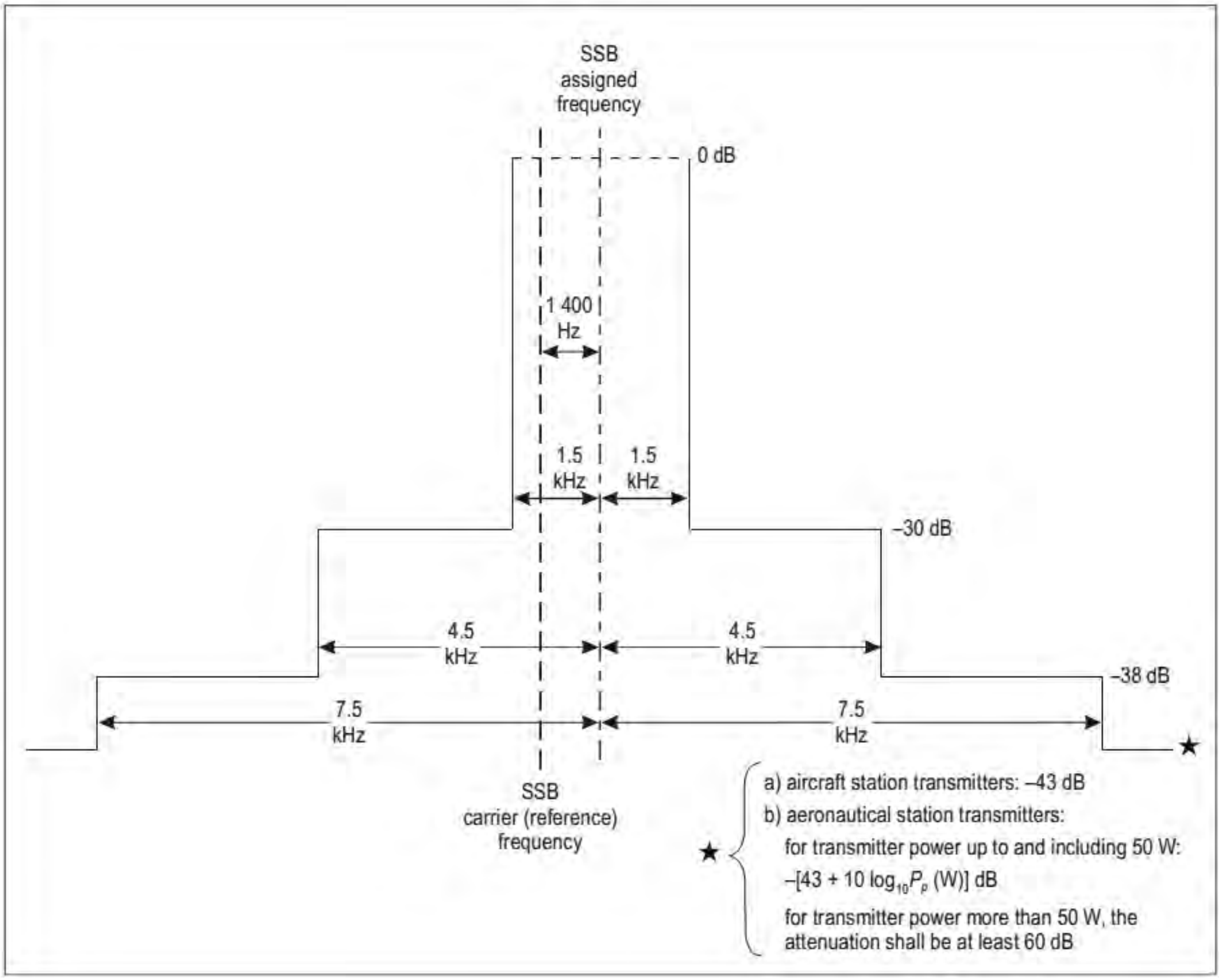

Figure 2-2. Required spectrum limits (in terms of peak power) for aircraft station transmitters first installed after 1 February 1983 and aeronautical station transmitters in use after 1 February 1983

CHAPTER 3. SELCAL SYSTEM

3.1 **Recommendation**.— *Where a SELCAL system is installed, the following system characteristics should be applied:*

a) *Transmitted code*. Each transmitted code should be made up of two consecutive tone pulses, with each pulse containing two simultaneously transmitted tones. The pulses should be of 1.0 plus or minus 0.25 seconds duration, separated by an interval of 0.2 plus or minus 0.1 second.

b) *Stability.* The frequency of transmitted tones should be held to plus or minus 0.15 per cent tolerance to ensure proper operation of the airborne decoder.

c) *Distortion.* The overall audio distortion present on the transmitted RF signal should not exceed15 per cent.

d) *Per cent modulation*. The RF signal transmitted by the ground radio station should contain, within 3 dB, equal amounts of the two modulating tones. The combination of tones should result in a modulation envelope having a nominal modulation percentage as high as possible and in no case less than 60 per cent.

e) *Transmitted tones.* Tone codes should be made up of various combinations of the tones listed in the following table and designated by colour and letter as indicated:

Designation	Frequency (Hz)
Red A	312.6
Red B	346.7
Red C	384.6
Red D	426.6
Red E	473.2
Red F	524.8
Red G	582.1
Red H	645.7
Red J	716.1
Red K	794.3
Red L	881.0
Red M	977.2
Red P	1 083.9
Red Q	1 202.3
Red R	1 333.5

Red S	1 479.1

Note 1.— It should be noted that the tones are spaced by Log–1 0.045 to avoid the possibility of harmonic combinations.

Note 2.— In accordance with the application principles developed by the Sixth Session of the Communications Division, the only codes at present used internationally are selected from the red group.

Note 3.— Guidance material on the use of SELCAL systems is contained in the Attachment to Part II.

Note 4.— The tones Red P, Red Q, Red R, and Red S are applicable after 1 September 1985, in accordance with 3.2.

3.2 As from 1 September 1985, aeronautical stations which are required to communicate with SELCAL-equipped aircraft shall have SELCAL encoders in accordance with the red group in the table of tone frequencies of 3.1. After 1 September 1985, SELCAL codes using the tones Red P, Red Q, Red R, and Red S may be assigned.

CHAPTER 4. AERONAUTICAL SPEECH CIRCUITS

4.1 TECHNICAL PROVISIONS RELATING TO INTERNATIONAL AERONAUTICAL SPEECH CIRCUIT SWITCHING AND SIGNALLING FOR GROUND-GROUND APPLICATIONS

Note.— Guidance material on the implementation of aeronautical speech circuit switching and signalling for groundground applications is contained in theManual on Air Traffic Services (ATS) Ground-Ground Voice Switching and Signalling(Doc 9804). The material includes explanation of terms, performance parameters, guidance on basic call types and additional functions, references to appropriate ISO/IEC international standards and ITU-T recommendations, guidance on the use of signalling systems, details of the recommended numbering scheme and guidance on migration to future schemes.

4.1.1 The use of circuit switching and signalling to provide speech circuits to interconnect ATS units not interconnected by dedicated circuits shall be by agreement between the Administrations concerned.

4.1.2 The application of aeronautical speech circuit switching and signalling shall be made on the basis of regional air navigation agreements.

4.1.3 **Recommendation.—** *The ATC communication requirements defined in Annex 11, Section 6.2 should be met by implementation of one or more of the following basic three call types:*

a) instantaneous access;

b) direct access; and

c) indirect access.

4.1.4 **Recommendation**.— *In addition to the ability to make basic telephone calls, the following functions should be provided in order to meet the requirements set out in Annex 11:*

a) means of indicating the calling/called party identity;

b) means of initiating urgent/priority calls; and

c) conference capabilities.

4.1.5 **Recommendation**.— *The characteristics of the circuits used in aeronautical speech circuit switching and signalling should conform to appropriate ISO/IEC international standards and ITU-T recommendations.*

4.1.6 **Recommendation.** – *Digital signalling systems should be used wherever their use can be justified in terms of any of the following:*

a) improved quality of service;

b) improved user facilities; or

c) reduced costs where quality of service is maintained.

4.1.7 **Recommendation.** – *The characteristics of supervisory tones to be used (such as ringing, busy, number unobtainable) should conform to appropriate ITU-T recommendations.*

4.1.8 **Recommendation**. – *To take advantage of the benefits of interconnecting regional and national aeronautical speech networks, the international aeronautical telephone network numbering scheme should be used.*

CHAPTER 5. EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

5.1 **GENERAL**

5.1.1 Until 1 January 2005, emergency locator transmitters shall operate either on both 406 MHz and 121.5 MHz or on 121.5 MHz.

Note.— From 1 January 2000, ELTs operating on 121.5 MHz will be required to meet the improved technical characteristics contained in 5.2.1.8.

5.1.2 All installations of emergency locator transmitters operating on 406 MHz shall meet the provisions of 5.3.

5.1.3 All installations of emergency locator transmitters operating on 121.5 MHz shall meet the provisions of 5.2.

5.1.4 From 1 January 2005, emergency locator transmitters shall operate on 406 MHz and 121.5 MHz simultaneously.

5.1.5 All emergency locator transmitters installed on or after 1 January 2002 shall operate simultaneously on 406 MHz and 121.5 MHz.

5.1.6 The technical characteristics for the 406 MHz component of an integrated ELT shall be in accordance with 5.3.

5.1.7 The technical characteristics for the 121.5 MHz component of an integrated ELT shall be in accordance with 5.2.

5.1.8 States shall make arrangements for a 406 MHz ELT register. Register information regarding the ELT shall be immediately available to search and rescue authorities.

States shall ensure that the register is updated whenever necessary.

5.1.9 ELT register information shall include the following:

a) transmitter identification (expressed in the form of an alphanumerical code of 15 hexadecimal characters);

b) transmitter manufacturer, model and, when available, manufacturer’s serial number;

c) COSPAS-SARSAT[10] type approval number;

d) name, address (postal and e-mail) and emergency telephone number of the owner and operator;

e) name, address (postal and e-mail) and telephone number of other emergency contacts (two, if possible) to whom the owner or the operator is known;

f) aircraft manufacturer and type; and

g) colour of the aircraft.

Note 1.— Various coding protocols are available to States. Depending on the protocol adopted, States may, at their discretion, include one of the following as supplementary identification information to be registered:

a) aircraft operating agency designator and operator's serial number; or

b) 24-bit aircraft address; or

c) aircraft nationality and registration marks.

The aircraft operating agency designator is allocated to the operator by ICAO through the State administration, and the operator's serial number is allocated by the operator from the block 0001 to 4096.

Note 2.— At their discretion, depending on arrangements in place, States may include other relevant information to be registered such as the last date of register, battery expiry date and place of ELT in the aircraft (e.g. "primary ELT" or "liferaft No. 1").

5.2 SPECIFICATION FOR THE 121.5 MHz COMPONENT OF EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

Note 1.— Information on technical characteristics and operational performance of 121.5 MHz ELTs is contained in RTCA Document DO-183 and European Organization for Civil Aviation Equipment (EUROCAE) Document ED.62.

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[10] COSPAS = Space system for search of vessels in distress;
SARSAT = Search and rescue satellite-aided tracking.

Note 2.— Technical characteristics of emergency locator transmitters operating on 121.5 MHz are contained in ITU-R Recommendation M.690-1. The ITU designation for an ELT is Emergency Position — Indicating Radio Beacon (EPIRB).

5.2.1 Technical characteristics

5.2.1.1 Emergency locator transmitters (ELT) shall operate on 121.5 MHz. The frequency tolerance shall not exceed plus or minus 0.005 per cent.

5.2.1.2 The emission from an ELT under normal conditions and attitudes of the antenna shall be vertically polarized and essentially omnidirectional in the horizontal plane.

5.2.1.3 Over a period of 48 hours of continuous operation, at an operating temperature of minus 20°C, the peak effective radiated power (PERP) shall at no time be less than 50 mW.

5.2.1.4 The type of emission shall be A3X. Any other type of modulation that meets the requirements of 5.2.1.5, 5.2.1.6 and 5.2.1.7 may be used provided that it will not prejudice precise location of the beacon by homing equipment.

Note.— Some ELTs are equipped with an optional voice capability (A3E) in addition to the A3X emission.

5.2.1.5 The carrier shall be amplitude modulated at a modulation factor of at least 0.85.

5.2.1.6 The modulation applied to the carrier shall have a minimum duty cycle of 33 per cent.

5.2.1.7 The emission shall have a distinctive audio characteristic achieved by amplitude modulating the carrier with an audio frequency sweeping downward over a range of not less than 700 Hz within the range 1 600 Hz to 300 Hz and with a sweep repetition rate of between 2 Hz and 4 Hz.

5.2.1.8 After 1 January 2000, the emission shall include a clearly defined carrier frequency distinct from the modulation sideband components; in particular, at least 30 per cent of the power shall be contained at all times within plus orminus 30 Hz of the carrier frequency on 121.5 MHz.

5.3 SPECIFICATION FOR THE 406 MHz COMPONENT OF EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

5.3.1 Technical characteristics

Note 1.— Transmission characteristics for 406 MHz emergency locator transmitters are contained in ITU-R M.633.

Note 2.— Information on technical characteristics and operational performance of 406 MHz ELTs is contained in RTCA Document DO-204 and European Organization for Civil Aviation Equipment (EUROCAE) Document ED-62.

5.3.1.1 Emergency locator transmitters shall operate on one of the frequency channels assigned for use in the frequency band 406.0 to 406.1 MHz.

Note.— The COSPAS-SARSAT 406 MHz channel assignment plan is contained in COSPAS-SARSAT Document C/S T.012.

5.3.1.2 The period between transmissions shall be 50 seconds plus or minus 5 per cent.

5.3.1.3 Over a period of 24 hours of continuous operation at an operating temperature of –20°C, the transmitter power output shall be within the limits of 5 W plus or minus 2 dB.

5.3.1.4 The 406 MHz ELT shall be capable of transmitting a digital message.

5.3.2 Transmitter identification coding

5.3.2.1 Emergency locator transmitters operating on 406 MHz shall be assigned a unique coding for identification of the transmitter or aircraft on which it is carried.

5.3.2.2 The emergency locator transmitter shall be coded in accordance with either the aviation user protocol or one of the serialized user protocols described in the Appendix to this chapter, and shall be registered with the appropriate authority.

APPENDIX TO CHAPTER 5.
EMERGENCY LOCATOR TRANSMITTER CODING
(see Chapter 5, 5.3.2)

Note.— A detailed description of beacon coding is contained in Specification for COSPAS-SARSAT 406 MHz Distress Beacons (C/S T.001). The following technical specifications are specific to emergency locator transmitters used in aviation.

1. GENERAL

1.1 The emergency locator transmitter (ELT) operating on406 MHz shall have the capacity to transmit a programmed digital message which contains information related to the ELT and/or the aircraft on which it is carried.

1.2 The ELT shall be uniquely coded in accordance with 1.3 and be registered with the appropriate authority.

1.3 The ELT digital message shall contain either the transmitter serial number or one of the following information elements:

a) aircraft operating agency designator and a serial number;

b) 24-bit aircraft address;

c) aircraft nationality and registration marks.

1.4 All ELTs shall be designed for operation with the COSPAS-SARSAT[11]system and be type approved.

Note.— Transmission characteristics of the ELT signal can be confirmed by making use of the COSPAS-SARSAT Type Approval Standard (C/S T.007).

2. ELT CODING

2.1 The ELT digital message shall contain information relating to the message format, coding protocol, country code, identification data and location data, as appropriate.

2.2 For ELTs with no navigation data provided, the short message format C/S T.001 shall be used, making use of bits 1 through 112. For ELTs with navigation data, if provided, the long message format shall be used, making use of bits 1 through 144.

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[11] COSPAS = Space system for search of vessels in distress;
SARSAT = Search and rescue satellite-aided tracking.

2.3 Protected data field

2.3.1 The protected data field consisting of bits 25 through 85 shall be protected by an error correcting code and shall be the portion of the message which shall be unique in every distress ELT.

2.3.2 A message format flag indicated by bit 25 shall be set to "0" to indicate the short message format or set to "1" to indicate the long format for ELTs capable of providing location data.

2.3.3 A protocol flag shall be indicated by bit 26 and shall be set to "1" for user and user location protocols, and "0" for location protocols.

2.3.4 A country code, which indicates the State where additional data are available on the aircraft on which the ELT is carried, shall be contained in bits 27 through 36 which designate a three-digit decimal country code number expressed in binary notation.

Note.— Country codes are based on the International Telecommunication Union (ITU) country codes shown in Table 4 of Part I, Volume I of the ITU List of Call Signs and Numerical Identities.

2.3.5 Bits 37 through 39 (user and user location protocols)or bits 37 through 40 (location protocols) shall designate one of the protocols where values "001" and "011" or "0011", "0100", "0101", and "1000" are used for aviation as shown in the examples contained in this appendix.

2.3.6 The ELT digital message shall contain either the transmitter serial number or an identification of the aircraft or operator as shown below.

2.3.7 In the serial user and serial user location protocol(designated by bit 26=1 and bits 37 through 39 being "011"), the serial identification data shall be encoded in binary notation with the least significant bit on the right. Bits 40 through42 shall indicate type of ELT serial identification data encoded where:

— "000" indicates ELT serial number (binary notation) is encoded in bits 44 through 63;

— "001" indicates aircraft operator (3 letter encoded using modified Baudot code shown in Table 5-1) and a serial number (binary notation) are encoded in bits 44 through 61 and 62 through 73, respectively;

— "011" indicates the 24-bit aircraft address is encoded in bits 44 through 67 and each additional ELT number (binary notation) on the same aircraft is encoded in bits 68 through 73.

Note.— States will ensure that each beacon, coded with the country code of the State, is uniquely coded and registered in a database. Unique coding of serialized coded beacons can be facilitated by including the COSPAS-SARSAT Type Approval Certificate Number which is a unique number assigned by COSPAS-SARSAT for each approved ELT model, as part of the ELT message.

2.3.8 In the aviation user or user location protocol (designated by bit 26=1 and bits 37 through 39 being "001"), the aircraft nationality and registration marking shall be encoded in bits 40 through 81, using the modified Baudot code shown in Table 5-1 to encode seven alphanumeric characters. This data shall be right justified with the modified Baudot "space" ("100100") being used where no character exists.

2.3.9 Bits 84 and 85 (user or user location protocol) or bit 112 (location protocols) shall indicate any homing transmitter that may be integrated in the ELT.

2.3.10 In standard and national location protocols, all identification and location data shall be encoded in binary notation with the least significant bit right justified. The aircraft operator designator (3 letter code) shall be encoded in 15 bits using a modified Baudot code (Table 5-1) using only the 5 right most bits per letter and dropping the left most bit which has a value of 1 for letters.

Table 5-1. Modified Baudot code

Letter	Code MSB LSB	Figure	Code MSB LSB
A	111000	(-)*	011000
B	110011		
C	101110		
D	110010		
E	110000	3	010000
F	110110		
G	101011		
H	100101		
I	101100		
J	111010	8	001100
K	111110		
L	101001		
M	100111		
N	100110		
O	100011	9	000011
P	101101	0	001101
Q	111101	1	011101
R	101010	4	001010
S	110100		
T	100001	5	000001
U	111100	7	011100
V	101111		
W	111001	2	011001
X	110111	/	010111
Y	110101	6	010101
Z	110001		
( )**	100100		

MSB = most significant bit
LSB = least significant bit
* = hyphen
** = space

EXAMPLES OF CODING

ELT serial number

25		27 36	37			40				44 63	64 73	74 83		85
F	1	COUNTRY	0	1	1	T	T	T	C	SERIAL NUMBER DATA (20 BITS)	SEE NOTE 1	SEE NOTE 2	A	A

Aircraft address

25		27 36	37			40				44 67	68 73	74 83		85
F	1	COUNTRY	0	1	1	T	T	T	C	AIRCRAFT ADDRESS (24 BITS)	SEE NOTE 3	SEE NOTE 2	A	A

Aircraft operator designator and serial number

25		27 36	37			40				44 61	62 73	74 83		85
F	1	COUNTRY	0	1	1	T	T	T	C	OPERATOR 3-LETTER DESIGNATOR	SERIAL NUMBER 1-4096	SEE NOTE 2	A	A

Aircraft registration marking

25		27 36	37			40 81		83		85
F	1	COUNTRY	0	0	1	AIRCRAFT REGISTRATION MARKING (UP TO 7 ALPHANUMERIC CHARACTERS) (42 BITS)	0	0	A	A

T = Beacon type TTT: = 000 indicates ELT serial number is encoded;
= 001 indicates operating agency and serial number are encoded;
= 011 indicates 24-bit aircraft address is encoded.

C = Certificate flag bit: 1 = to indicate that COSPAS-SARSAT Type Approval Certificate number is encoded in bits 74 through 83 and
0 = otherwise

F = Format flag: 0 = Short Message
1 = Long Message

A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device
01 = 121.5 MHz 11 = other auxiliary radio-locating device Note 1.— 10 bits, all 0s or National use.

Note 2.— COSPAS-SARSAT Type Approval Certificate number in binary notation with the least significant bit on the right, or National use.

Note 3.— Serial number, in binary notation with the least significant bit on the right, of additional ELTs carried in the same aircraft or default to 0s when only one ELT is carried.

EXAMPLE OF CODING (USER LOCATION PROTOCOL)

25	26	←27 36→	←37 39→	←40 83→	85→	←86 106→	←107	112→		←113			132→	←133 144→
1	1	10	3	44	2	21	1	12			13			12
1	1	CC	T	IDENTIFICATION DATA (AS IN ANY OF USER PROTOCOLS ABOVE)	A	21-BIT BCH ERROR CORRECTING CODE	E	LATITUDE			LONGITUDE			12-BIT BCH ERROR CORRECTING CODE
								1	7	4	1	8	4	
								N / S	DEG 0–90 (1 d)	MIN 0–56 (4m)	E / W	DEG 0–180 (1 d)	MIN 0–56 (4m)	

CC = Country Code;
E = Encoded position data source: 1 = Internal navigation device, 0 = External navigation device

EXAMPLE OF CODING (STANDARD LOCATION PROTOCOL)

25	26	←27 36→	←37 40→	←41					85→	←86 106→	107 112	←113					132→	←133 144→
61 BITS											26 BITS							
1	1	10	4	45						21	6	20						12
1	0	CC	PC	IDENTIFICATION DATA		LATITUDE		LONGITUDE			SD	Δ LATITUDE			Δ LONGITUDE			
				24		1	9	1	10			1	5	4	1	5	4	
			0011	AIRCRAFT 24 BIT ADDRESS		N = 0 S = 1	LAT DEG 0–90 (1/4 d)	E = 0 W = 1	LON DEG 0–180 (1/4 d)	21-BIT BCH CODE		– = 0 + = 1	MINUTES 0–30 (1 m)	SECONDS 0–56 (4 s)	– = 0 + = 1	MINUTES 0–30 (1 m)	SECONDS 0–56 (4 s)	12-BIT BCH CODE
				15	9													
			0101	AIRCRAFT OPER. DESIGNATOR	SERIAL No 1–511													
				10	14													
			0100	C/STA No 1–1023	SERIAL No 1–16383													

CC = Country Code;

PC = Protocol Code 0011 indicates 24-bit aircraft address is encoded;

0101 indicates operating agency and serial number are encoded;

0100 indicates ELT serial number is encoded.

SD = Supplementary Data bits 107 – 110 = 1101;

bit 111 = Encoded Position Data Source (1 = internal; 0 = external)

bit 112: 1 = 121.5 MHz auxiliary radio locating device;

0 = other or no auxiliary radio locating device.

Note 1.— Further details on protocol coding can be found in Specification for COSPAS-SARSAT 406 MHz Distress Beacon (C/S T.001).

Note 2. — All identification and location data are to be encoded in binary notation with the least significant bit on the right except for the aircraft operator designator (3 letter code).

Note 3. — For details on BCH error correcting code see Specification for COSPAS-SARSAT 406 MHz Distress Beacon (C/S T.001).

EXAMPLE OF CODING (NATIONAL LOCATION PROTOCOL)

25	26	←27 36→	←37 40→	|←41						85→	←86 106→	107 112	←113					132→		←133 144→
61 BITS PDF-1											BCH-1	26 BITS PDF-2								BCH-2
1	1	10	4	45							21	6	7			7			6	12
1	0	CC	1000	18 bits ID	27 bits LATITUDE LONGITUDE							SD	Δ LATITUDE			Δ LONGITUDE				
				18	1	7	5	1	8	5			1	2	4	1	2	4	NU	
				NATIONAL ID NUMBER	N = 0 S = 1	DEGREES 0–90 (1 d)	MINUTES 0–58 (2 m)	E = 0 W = 1	DEGREES 0–180 (1 d)	MINUTES 0–58 (2 m)	21-BIT BCH CODE		– = 0 + = 1	MINUTES 0–3 (1 m)	SECONDS 0–56 (4 s)	– = 0 + = 1	MINUTES 0–3 (1 m)	SECONDS 0–56 (4 s)		12-BIT BCH CODE

CC = Country Code;

ID = Identification Data = 8-bit identification data consisting of a serial number assigned by the appropriate national authority

SD = Supplementary Data = bits 107 – 109 = 110;

bit 110 = Additional Data Flag describing the use of bits 113 to 132:

1 = Delta position;0 = National assignment;

bit 111 = Encoded Position Data Source: 1 = internal, 0 = external;

bit 112: 1 = 121.5 MHz auxiliary radio locating device;

0 = other or no device

NU = National use = 6 bits reserved for national use (additional beacon type identification or other uses).

Note 1.— Further details on protocol coding can be found in Specification for COSPAS-SARSAT 406 MHz Distress Beacon (C/S T.001).

Note 2.— All identification and location data are to be encoded in binary notation with the least significant bit on the right.

Note 3.— For details on BCH error correcting code see Specification for COSPAS-SARSAT 406 MHZ Distress Beacon (C/S T.001).

ATTACHMENT TO PART I. GUIDANCE MATERIAL FOR THE VHF DIGITAL LINK (VDL)

1. GUIDANCE MATERIAL FOR THE VHF DIGITAL LINK (VDL)

Note.— The Standards and Recommended Practices (SARPs) referred to are contained in Annex 10, Volume III, Part 1, Chapter 6.

2. SYSTEM DESCRIPTION

2.1 The VDL system provides an air-ground data communications link within the aeronautical telecommunications network (ATN). The VDL will operate in parallel with the other ATN air-ground subnetworks.

2.2 VDL ground stations consist of a VHF radio and a computer capable of handling the VDL protocol throughout the coverage area. The VDL stations offer connectivity via a ground-based telecommunications network (e.g. X.25 based) to ATN intermediate systems which will provide access to ground-based ATN end systems.

2.3 In order to communicate with the VDL ground stations, aircraft are required to be equipped with VDL avionics which will include a VHF radio and a computer capable of handling the VDL protocol. The air-ground communication will utilize 25 kHz channels in the VHF aeronautical mobile (route) service band.

3. VDL PRINCIPLES

3.1 Communications transfer principles

3.1.1 Connectivity between applications running in ATN end systems (ES) using the ATN and its subnetworks, including the VDL, for air-ground communication is provided by the transport layer entities in these end systems. Transport connections between airborne and ground end systems shall be maintained through controlled changes of the precise ATN intermediate systems (IS) and VDL network elements that provide this connectivity.

3.1.2 Transport connections between ATN ES are not linked to a particular subnetwork and ISO 8473 network protocol data units transmitted by an ES can pass via any air-ground ATN compatible subnetwork (such as aeronautical mobile satellite service (AMSS) data link, SSR Mode S data link or VDL) that meets the quality of service (QOS) requirements. A transport connection between an aircraft E Sand a ground ES shall be maintained as long as there is at least one air-ground subnetwork connection between the aircraft IS and a ground IS which has connectivity to the ground ES. In order to maximize subnetwork connectivity, aircraft are expected to maintain air-ground subnetwork connections via any subnetwork (AMSS, Mode S or VDL) with which link layer connectivity can be established.

3.1.3 The VDL subnetwork provides connectivity in the form of switched virtual circuits between ISO 8208 data terminal equipment (DTE) entities of aircraft and ground-based ATN intermediate systems. Due to the fact that VHF signals have only line-of-sight propagation, it is necessary for aircraft in flight to regularly establish link connections with new VDL ground stations in order to maintain VHF coverage. An established VDL virtual circuit between an aircraft DTE and a ground DTE is maintained through a controlled change to a ground station through which the ground DTE can be accessed.

3.1.4 VDL virtual circuits may be cleared when the aircraft or ground IS identifies a policy situation where the virtual circuit to the ground DTE is no longer necessary but this shall only happen if another VDL virtual circuit remains established. A policy situation is a situation where considerations other than coverage influence the decision to establish a connection. This could be, for example, a situation where an aircraft is within the designated operational coverage area of ground stations operated by different operators and a decision must be made with which operator to establish a connection. The case where an aircraft crosses a border between two States needs special attention. An aircraft has to establish a virtual circuit to the DTE in the IS of the State entered before clearing the virtual circuit with the DTE in the IS of the State left.

3.1.5 The scenarios for subnetwork connection maintenance are shown in Figure ATT I-1[12]. If the ground stations on each side of a State border do not offer ISO 8208 connectivity to the DTEs of the IS in both States, aircraft crossing the border will have to set up a link connection to a ground station in the State entered before being able to establish a virtual circuit to the IS of that State. Only after establishment of the new link connection and virtual circuit, the aircraft will clear the virtual circuit with the DTE of the IS of the country left over the link which gave access to that IS. If the VDL aeronautical stations on both sides of the State border offer connectivity to the IS in both States, the changeover of the virtual circuits has to take place over the same link connection.

3.2 VDL quality of service for ATN routing

[12] The figure is located at the end of this attachment

3.2.1 The use of the VDL system for air-ground communications will depend on the routing decisions of aircraft and ground-based ATN IS. These ISs will decide on the path to be used for air-ground communications based on quality of service values requested by transmitting ESs.

3.2.2 The IS at each end of the air-ground connections must interpret the requested QOS value and decide which of the available connections can best be met. It is important that the level of QOS which a VDL connection is perceived as providing is set at a level which corresponds to its true performance.

3.2.3 In cases where the VDL is the only data link with which an aircraft has been equipped, all communications must be routed via a VDL connection and the value set for QOS to be provided by the connection must not block the communication.

3.2.4 In other cases where aircraft are equipped with other air-ground data links (such as AMSS and SSR Mode S) there may be simultaneous parallel connections over multiple subnetworks. In these cases, the values for QOS provided by each subnetwork must be set so as to ensure that the VDL connection will be used where appropriate.

3.2.5 It is necessary that coordination take place between aircraft operators, ground station operators and ground system operators to ensure that the right balance is achieved between different subnetworks.

4. VDL GROUND STATION NETWORK CONCEPT

4.1 Access

4.1.1 A VDL ground station will provide access for aircraft to the ground ATN IS using the VDL protocol over a VHF channel.

4.2 Institutional issues concerning VDL ground station network operators

4.2.1 An ATS provider wishing to use VDL for air traffic service (ATS) communications needs to ensure that the VDL service is available. The ATS provider can either operate the VDL ground station network itself or arrange for the operation of the VDL stations (or VDL network) by a telecommunications service provider. It seems likely that individual States will make different arrangements for the provision of VDL service to aircraft. Operation and implementation of VDL need to be coordinated at a regional level in order to ensure acceptable service on international routes.

4.2.2 The use of a VDL ground station network by entities external to the ATS provider will be subject to service agreements between the ATS provider and the telecommunications service provider. These agreements set out the obligations of the two parties and need, in particular, to be specific on the quality of service provided as well as the characteristics of the user interface.

4.2.3 It seems likely that some VDL ground station network operators will levy user charges. These are expected to be levied either on the aircraft operators and/or on the ATS providers. It is necessary to ensure that the use of VDL is feasible for those aircraft operators intended to use VDL for ATS/AOC communications.

4.3 VDL ground station equipment

4.3.1 A VDL ground station will consist of a VHF radio and a computer which may be separate or integrated with the radio. The VDL functionality of the VHF radio equipment will be similar to that installed in aircraft.

4.3.2 The provision of network status monitoring is an important element in the maintenance of the highest availability possible.

4.4 Ground station siting

4.4.1 The line of sight limitations of VHF propagation is an important factor in the siting of ground stations. It is necessary to ensure that the ground stations are installed in a manner which provides coverage throughout the designated operational coverage area (DOC).

4.4.2 The coverage requirements for VDL depend on the applications that are intended to operate over the VDL. These applications may function, for example, when an aircraft is at en-route altitude, in a terminal area or on the ground at an airport.

4.4.3 En-route coverage can be provided using a small number of ground stations with a large DOC (for example, the range of a VHF signal from a station at sea level and an aircraft at 37 000 ft is approximately 200 NM). Hence, it is in fact desirable that the smallest number of ground stations possible be used to provide en-route coverage in order to minimize the possibility of simultaneous uplink transmissions from ground stations which may cause message collisions on the VHF channel. The factors limiting en-route coverage will be availability of landmass and the availability of a communications link from a ground station to other ground systems.

4.4.4 Terminal area coverage requires, in general, the installation of ground stations at all airports where VDL operation is required in order to ensure coverage throughout the terminal area.

4.4.5 Aerodrome surface communication coverage must be provided by a ground station at the airport but, due to the physical structure of the airport, it may not be possible to guarantee coverage in all areas with a single station.

4.5 Ground station frequency engineering

4.5.1 The choice of the VHF channel on which a ground station will operate depends on the coverage that the ground station will be required to provide. Coverage on a particular channel is provided by a collection of ground stations operating on that channel and the communications on that channel will occupy the channel for all the ground stations in a coverage area.

4.5.2 As with VHF voice communications, VDL communications cannot be limited to propagating only within States, and frequency coordination between States will be required in the allocation of VDL frequencies. The nature of the protocol does, however, allow for frequency re-use by several ground stations within the same coverage area and hence the rules for the assignment of frequencies are not the same as for voice communications.

4.5.3 The carrier sense multiple access (CSMA) media access control protocol (MAC) layer used in VDL cannot exclude message collisions if some stations using a frequency channel cannot receive the transmissions of other stations, a situation known as a hidden transmitter situation. Hidden transmitters lead to simultaneous transmissions which can cause the intended receiver of one or both transmissions to be unable to decode the received signal.

4.5.4 A frequency will be assigned to providing en-route coverage and all the en-route stations will be set to operate on this frequency. In order to minimize the probability of simultaneous transmissions on the channel by hidden transmitters in a CSMA environment, this channel may not be used for terminal area or aerodrome surface communications except in areas of very low channel loading.

4.5.5 The VDL SARPs call for the provision of a common signalling channel (CSC) on which access to VDL service will be guaranteed in all areas where VDL Mode 2 service is available. This is especially important at airports and on the edge of VDL en-route coverage zones where aircraft are likely to establish initial VDL connectivity. Since the characteristics of Mode 1 and Mode 2 radio frequency transmissions are not compatible, the CSC cannot be used for Mode 1 communications. There is no requirement for a CSC for VDL Mode 1.

4.6 Ground station connection to intermediate systems

4.6.1 In order to provide access to the ground systems which are connected to the aeronautical telecommunications network, a VDL ground station needs to be connected to one or more ATN IS. The purpose of a VDL ground station is to interconnect aircraft with the ground-based ATN via which communications with terrestrial ATN ES can take place.

4.6.2 The ground-based ATN IS can be co-hosted in the VDL ground station computer in which case the VDL subnetwork virtual circuit will end in that computer. This architecture will have an impact on the exchanges required when an aircraft establishes a VDL link with a new ground station. The exact exchange will depend on whether the ground stations contain separate IS or elements of the same distributed intermediate system.

4.6.3 If the IS is not contained in the VDL ground station, it will be connected to the ground station by one of the following means:

a) wide area network (WAN);

b) local area network (LAN); and

c) dedicated communications line.

4.6.4 In all cases, in order to be in accordance with the Manual of the Aeronautical Telecommunication Network (ATN) (Doc 9578) for providing an open systems interconnection (OSI) compatible connection-oriented subnetwork service between the aircraft IS and the ground-based IS, the VDL ground station computer will be required to extend the VDL virtual circuit across the terrestrial network or link.

4.6.5 In order to provide simultaneous virtual circuits to several terrestrial ISs, the VDL ground station computer needs to contain a VDL subnetwork entity capable of converting addresses in VDL subnetwork call requests into addresses in the ground-based network.

5. VDL AIRBORNE OPERATING CONCEPT

5.1 Avionics

5.1.1 VDL avionics. In order to operate in a VDL network, aircraft need to be equipped with an avionics system providing the VDL subnetwork user (ISO 8208 DTE) function. The system providing this function will also provide the subnetwork user functions for the other air-ground ATN-compatible subnetworks and the aircraft ATN intermediate system function and, hence, its development is necessary in order to provide ATN communications to multiple end-systems or over multiple air-ground subnetworks.

5.2 VDL avionics certification

5.2.1 The VHF digital radio may also provide for double-side band amplitude modulation (DSB-AM) voice capability for emergency back-up to VHF radios used for voice communications. It would be necessary in this case to demonstrate that the VDL functionality of the VDR does not interfere with the DSB-AM voice functionality.

5.2.2 The VDL function in the VHF digital radio provides an air-ground data link service to the VDL subnetwork user entity of the aircraft ATN intermediate system. If the provision of a VHF subnetwork service to an ATN intermediate system were considered an essential service for a particular installation, the VDL functionality of the VDR would need to be certified as an essential function. The use of VDL for ATS communications is not, however, intended to require two aircraft radios to operate simultaneously in VDL mode.

5.3 Registration of aircraft with VDL network operators

5.3.1 For normal communications service, it is to be expected that aircraft operators will be required to register their aircraft with the network operators. In emergency or back-up situations, it must be possible for any VDL-equipped aircraft to establish connectivity over any VDL ground station network.

5.3.2 Registration of aircraft VDL stations with VDL network operators is desirable for network management since, for example, a network operator may identify a temporary fault in the VDL communications from an aircraft and would wish to contact the operator of the aircraft in order to have the fault resolved. Registration of aircraft is also useful in planning the required ground station network capacity. Registration with a VDL ground station network operator does not necessarily imply that the aircraft operator will be charged for use of the VDL ground station network.

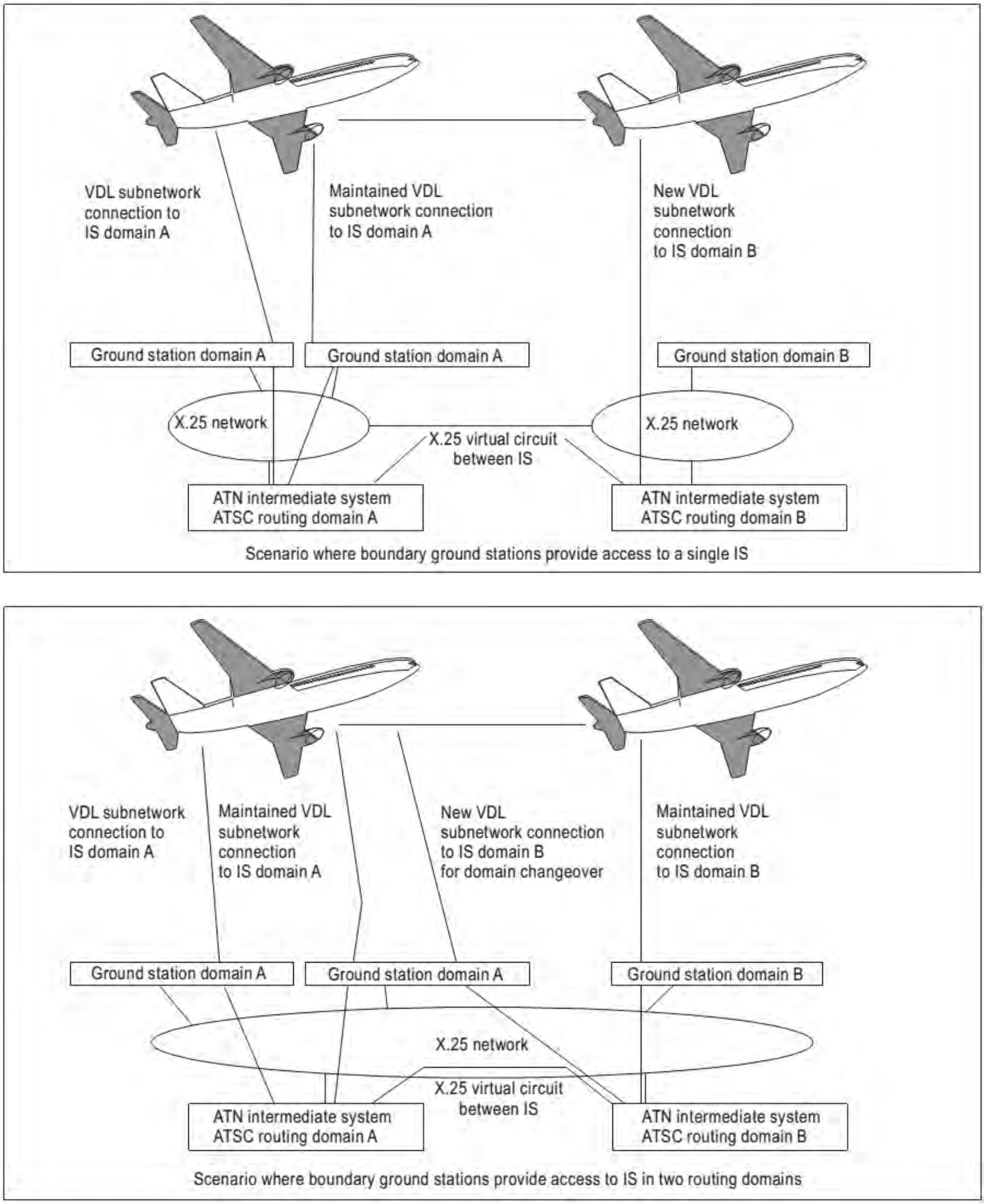


Figure ATT I-1.

ATTACHMENT TO PART II. GUIDANCE MATERIAL FOR COMMUNICATION SYSTEMS

1. VHF COMMUNICATIONS

1.1 Audio characteristics of VHF communication equipment

1.1.1 The aeronautical radiotelephony services represent a special case of the application of radiotelephony, in that the requirement is for the transmission of messages in such a way that fidelity of wave form is of secondary importance, emphasis being upon fidelity of basic intelligence. This means that it is not necessary to transmit those parts of the wave form which are solely concerned with individuality, accent and emphasis.

1.1.2 The effective acceptance bandwidth for 8.33 kHz equipment is required to be at least plus and minus 3 462 Hz. This value considers the general case, i.e. air-to-ground transmissions and consists of 2 500 Hz audio bandwidth, 685 Hz for an aircraft transmitter instability of 5 ppm,137 Hz for a ground receiver instability of1 ppm and 140 Hz due to Doppler shift(2.2.2.4 and 2.3.2.6 of Part II refer).

1.2 Offset carrier system in 25 kHz,50 kHz and 100 kHz spaced channels The following are examples of offset carrier systems which meet the requirements of Part II, 2.2.1.1.1.

a) **2-carrier system**. Carriers should be spaced at plus and minus 5 kHz. This requires a frequency stability of plus or minus 2 kHz (15.3 parts per million at 130 MHz).

b) **3-carrier system.** Carriers should be spaced at zero and plus and minus 7.3 kHz. This requires a frequency stability of plus or minus 0.65 kHz (5 parts per million at 130 MHz).

The following are examples or 4- and 5-carrier systems which meet the requirements of Part II, 2.2.1.1.1.

c) **4-carrier system.** Carriers should be spaced at plus and minus 2.5 kHz and plus and minus 7.5 kHz. This requires a frequency stability of plus or minus 0.5 kHz (3.8 parts per million at 130 MHz).

d) **5-carrier system**. Carriers should be spaced at zero, plus and minus 4 kHz and plus and minus 8 kHz. A frequency stability in the order of plus or minus 40 Hz (0.3 parts per million at 130 MHz) is an achievable and practicable interpretation of the requirement in this case.

Note 1.— The carrier frequency spacings referred to above are with respect to the assigned channel frequency.

Note 2.— In aircraft receivers which employ a measurement of the received carrier-to-noise ratio to operate the mute, the audio heterodynes caused by the reception of two or more off-set carriers can be interpreted as noise and cause the audio output to be muted even when an adequate wanted signal is present. In order that the airborne receiving system can conform with the sensitivity recommendations contained in Part II, 2.3.2.2,the design of the receivers may need to ensure that their sensitivity is maintained at a high level when receiving off-set carrier transmissions. The use of a carrier level override is an unsatisfactory solution to this requirement, but where it is employed, setting the override level as low as possible can ameliorate the problem.

1.3 Immunity performance of COM receiving systems in the presence of VHF FM broadcast interference

1.3.1 With reference to the Note of 2.3.3.2 of Part II, the immunity performance defined there must be measured against an agreed measure of derogation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the checking of receiving station equipment on bench test can be performed to a repeatable set of conditions, and results, and to facilitate their subsequent approval. An adequate measure of immunity performance may be obtained by the use of wanted signal of minus 87 dBm into the receiving equipment and the signal modulated with a 1 kHz tone at 30 per cent modulation depth. The signal-to-noise ratio should not fall below 6 dB when the interfering signals specified at Part II, 2.3.3.1 and 2.3.3.2 are applied. The broadcast signals should be selected from frequencies in the range between 87.5 and 107.9 MHz and should be modulated with a representative broadcast type signal.

Note 1.— The signal level of minus 87 dBm assumes a combined antenna and feeder gain of 0 dB.

Note 2.— The reduction in the signal-to-noise ratio quoted above is for the purpose of standardization when checking that receiving station equipment on bench measurements meet the required immunity. In the planning of frequencies and in the assessment of protection from FM broadcast interference, a value not less than this, and in many cases higher, depending on the operational circumstances in individual cases, should be chosen as the basis of the interference assessment.

2. SELCAL SYSTEM

2.1 This material is intended to provide information and guidance relating to the operation of the SELCAL system. It is associated with the Recommended Practices contained in Part II, Chapter 3.

a) *Function*. The purpose of the SELCAL system is to permit the selective calling of individual aircraft over radiotelephone channels linking the ground station with the aircraft, and is intended to operate on en-route frequencies with existing HF and VHF ground-to-air communications transmitters and receivers with a minimum of electrical and mechanical modification. The normal functioning of the ground-to-air communications link should be unaffected, except at such time as the selective calling function is being formed.

b) *Principles of operation*. Selective calling is accomplished by the coder of the ground transmitter sending a single group of coded tone pulses to the aircraft receiver and decoder. The airborne receiver and decoder equipment is capable of receiving and interpreting, by means of an indicator, the correct code and rejecting all other codes in the presence of random noise and interference. The ground portion of the coding device (ground selective calling unit) supplies coded information to the ground-to-air transmitter. The airborne selective calling unit is the special airborne equipment which operates with existing communications receivers on the aircraft to permit decoding of the ground-to-air signals for display on the signal indicator. The type of signal indicator can be chosen to suit operational requirements of the user and may consist of a lamp, a bell, a chime or any combination of such indicating devices.

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue or the Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services (PANS) are approved by the Council for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.

INTERNATIONAL STANDARDS AND

RECOMMENDED PRACTICES

CHAPTER 1. DEFINITIONS

Note 1.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radiocommunication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies(Doc 9718).

Note 2.— The Mode S extended squitter system is subject to patent rights from the Massachusetts Institute of Technology (MIT) Lincoln Laboratory. On 22 August 1996, MIT Lincoln Laboratory issued a notice in the Commerce Business Daily (CBD), a United States Government publication, of its intent not to assert its rights as patent owner against any and all persons in the commercial or non-commercial practice of the patent, in order to promote the widest possible use of the Mode S extended squitter technology. Further, by letter to ICAO dated 27 August 1998, MIT Lincoln Laboratory confirmed that the CBD notice has been provided to satisfy ICAO requirements for a statement of patent rights for techniques that are included in SARPs, and that the patent holders offer this technique free of charge for any use. Airborne collision avoidance system (ACAS).An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.

Note.— SSR transponders referred to above are those operating in Mode C or Mode S.

Aircraft address. A unique combination of twenty-four bits available for assignment to an aircraft for the purpose of airground communications, navigation and surveillance.

Note.— SSR Mode S transponders transmit extended squitters to support the broadcast of aircraft-derived position for surveillance purposes. The broadcast of this type of information is a form of automatic dependent surveillance (ADS) known as ADS-broadcast (ADS-B).

Automatic dependent surveillance-broadcast (ADS-B) OUT. A function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B IN capable receivers.

Automatic dependent surveillance-broadcast (ADS-B) IN. A function that receives surveillance data from ADS-B OUT data sources.

Collision avoidance logic. The sub-system or part of ACAS that analyses data relating to an intruder and own aircraft, decides whether or not advisories are appropriate and, if so, generates the advisories. It includes the following functions: range and altitude tracking, threat detection and RA generation. It excludes surveillance.

Human Factors principles. Principles which apply to design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

Secondary surveillance radar (SSR). A surveillance radar system which uses transmitters/receivers (interrogators) and transponders.

Note.— The requirements for interrogators and transponders are specified in Chapter 3.

Surveillance radar. Radar equipment used to determine the position of an aircraft in range and azimuth.

Traffic information service – broadcast (TIS-B) IN. A surveillance function that receives and processes surveillance data from TIS-B OUT data sources.

Traffic information service – broadcast (TIS-B) OUT. A function on the ground that periodically broadcasts the surveillance information made available by ground sensors in a format suitable for TIS-B IN capable receivers.

Note.— This technique can be achieved through different data links. The requirements for Mode S extended squitters are specified in Annex 10, Volume IV, Chapter 5. The requirements for VHF digital link (VDL) Mode 4 and universal access transceiver (UAT) are specified in Annex 10, Volume III, Part I.

CHAPTER 2. GENERAL

2.1 SECONDARY SURVEILLANCE RADAR (SSR)

2.1.1 When SSR is installed and maintained in operation as an aid to air traffic services, it shall conform with the provisions of 3.1 unless otherwise specified in this 2.1.

Note.— As referred to in this Annex, Mode A/C transponders are those which conform to the characteristics prescribed in 3.1.1. Mode S transponders are those which conform to the characteristics prescribed in 3.1.2. The functional capabilities of Mode A/C transponders are an integral part of those of Mode S transponders.

2.1.2 Interrogation modes (ground-to-air)

2.1.2.1 Interrogation for air traffic services shall be performed on the modes described in 3.1.1.4.3 or 3.1.2. The uses of each mode shall be as follows:

1) *Mode A*— to elicit transponder replies for identity and surveillance.

2) *Mode C*— to elicit transponder replies for automatic pressure-altitude transmission and surveillance.

3) Intermode —

a) *Mode A/C/S all-call:* to elicit replies for surveillance of Mode A/C transponders and for the acquisition of Mode S transponders.

b) *Mode A/C-only all-call*: to elicit replies for surveillance of Mode A/C transponders. Mode S transponders do not reply.

4) Mode S —

a) *Mode S-only all-call*: to elicit replies for acquisition of Mode S transponders.

b) *Broadcast:* to transmit information to all Mode S transponders. No replies are elicited.

c) *Selective:* for surveillance of, and communication with, individual Mode S transponders. For each interrogation, a reply is elicited only from the transponder uniquely addressed by the interrogation.

Note 1.— Mode A/C transponders are suppressed by Mode S interrogations and do not reply.

Note 2.— There are 25 possible interrogation (uplink) formats and 25 possible Mode S reply (downlink) formats. For format assignment see 3.1.2.3.2, Figures 3-7 and 3-8.

2.1.2.1.1 **Recommendation**.— *Administrations should coordinate with appropriate national and international authorities those implementation aspects of the SSR system which will permit its optimum use.*

Note.— In order to permit the efficient operation of ground equipment designed to eliminate interference from unwanted aircraft transponder replies to adjacent interrogators (defruiting equipment), States may need to develop coordinated plans for the assignment of pulse recurrence frequencies (PRF) to SSR interrogators.

2.1.2.1.2 The assignment of interrogator identifier (II) codes, where necessary in areas of overlapping coverage, across international boundaries of flight information regions, shall be the subject of regional air navigation agreements.

2.1.2.1.3 The assignment of surveillance identifier (SI) codes, where necessary in areas of overlapping coverage, shall be the subject of regional air navigation agreements.

Note.— The SI lockout facility cannot be used unless all Mode S transponders within coverage range are equipped for this purpose.

2.1.2.2 Mode A and Mode C interrogations shall be provided.

Note.— This requirement may be satisfied by intermode interrogations which elicit Mode A and Mode C replies from Mode A/C transponders.

2.1.2.3 **Recommendation**.— *In areas where improved aircraft identification is necessary to enhance the effectiveness of the ATC system, SSR ground facilities having Mode S features should include aircraft identification capability.*

Note.— Aircraft identification reporting through the Mode S data link provides unambiguous identification of aircraft suitably equipped.

2.1.2.4 SIDE-LOBE SUPPRESSION CONTROL INTERROGATION

2.1.2.4.1 Side-lobe suppression shall be provided in accordance with the provisions of 3.1.1.4 and 3.1.1.5 on all Mode A, Mode C and intermode interrogations.

2.1.2.4.2 Side-lobe suppression shall be provided in accordance with the provisions of 3.1.2.1.5.2.1 on all Mode S-only all-call interrogations.

2.1.3 Transponder reply modes (air-to-ground)

2.1.3.1 Transponders shall respond to Mode A interrogations in accordance with the provisions of 3.1.1.7.12.1 and to Mode C interrogations in accordance with the provisions of 3.1.1.7.12.2.

Note.— If pressure-altitude information is not available, transponders reply to Mode C interrogations with framing pulses only.

2.1.3.1.1 The pressure-altitude reports contained in Mode S replies shall be derived as specified in 3.1.1.7.12.2.

Note.— 3.1.1.7.12.2 is intended to relate to Mode C replies and specifies, inter alia, that Mode C pressure-altitude reports be referenced to a standard pressure setting of 1 013.25 hectopascals. The intention of 2.1.3.1.1 is to ensure that all transponders, not just Mode C transponders, report uncorrected pressure-altitude.

2.1.3.2 Where the need for Mode C automatic pressure-altitude transmission capability within a specified airspace has been determined, transponders, when used within the airspace concerned, shall respond to Mode C interrogations with pressure-altitude encoding in the information pulses.

2.1.3.2.1 From1 January 1999, all transponders, regardless of the airspace in which they will be used, shall respond to Mode C interrogations with pressure-altitude information.

Note.— Operation of the airborne collision avoidance system (ACAS) depends upon intruder aircraft reporting pressure altitude in Mode C replies.

2.1.3.2.2 For aircraft equipped with 7.62 m (25 ft) or better pressure-altitude sources, the pressure-altitude information provided by Mode S transponders in response to selective interrogations (i.e. in the AC field, 3.1.2.6.5.4) shall be reported in 7.62 m (25 ft) increments.

Note.— Performance of the ACAS is significantly enhanced when an intruder aircraft is reporting pressure-altitude in 7.62 m (25 ft) increments.

2.1.3.2.3 All Mode A/C transponders shall report pressure-altitude encoded in the information pulses in Mode C replies.

2.1.3.2.4 All Mode S transponders shall report pressure-altitude encoded in the information pulses in Mode C replies and in the AC field of Mode S replies.

2.1.3.2.5 When a Mode S transponder is not receiving more pressure-altitude information from a source with a quantization of 7.62 m (25 ft) or better increments, the reported value of the altitude shall be the value obtained by expressing the measured value of the uncorrected pressure-altitude of the aircraft in 30.48 m (100 ft) increments and the Q bit (see 3.1.2.6.5.4 b)) shall be set to 0.

Note.— This requirement relates to the installation and use of the Mode S transponder. The purpose is to ensure that altitude data obtained from a 30.48 m (100 ft) increment source are not reported using the formats intended for 7.62 m (25 ft) data.

2.1.3.3 Transponders used within airspace where the need for Mode S airborne capability has been determined shall also respond to intermode and Mode S interrogations in accordance with the applicable provisions of 3.1.2.

2.1.3.3.1 Requirements for mandatory carriage of SSR Mode S transponders shall be on the basis of regional air navigation agreements which shall specify the airspace and the airborne implementation timescales.

2.1.3.3.2 **Recommendation.—** *The agreements indicated in 2.1.3.3.1 should provide at least five years' notice.*

2.1.4 Mode A reply codes (information pulses)

2.1.4.1 All transponders shall be capable of generating 4 096 reply codes conforming to the characteristics given in 3.1.1.6.2.

2.1.4.1.**1 Recommendation**.– *ATS authorities should establish the procedures for the allotment of SSR codes in conformity with Regional Air Navigation agreements, taking into account other users of the system.*

Note.– Principles for the allocation of SSR codes are given in Doc 4444, Chapter 8.

2.1.4.2 The following Mode A codes shall be reserved for special purposes:

2.1.4.2.1 Code 7700 to provide recognition of an aircraft in an emergency.

2.1.4.2.2 Code 7600 to provide recognition of an aircraft with radiocommunication failure.

2.1.4.2.3 Code 7500 to provide recognition of an aircraft which is being subjected to unlawful interference.

2.1.4.3 Appropriate provisions shall be made in ground decoding equipment to ensure immediate recognition of Mode A codes 7500, 7600 and 7700.

2.1.4.4 **Recommendation**.– *Mode A code 0000 should be reserved for allocation subject to regional agreement, as a general purpose code.*

2.1.4.5 Mode A code 2000 shall be reserved to provide recognition of an aircraft which has not received any instructions from air traffic control units to operate the transponder.

2.1.5 Mode S airborne equipment capability

2.1.5.1 All Mode S transponders shall conform to one of the following five levels:

Note.– The transponder used for a Mode S site monitor may differ from the requirements defined for a normal Mode S transponder. For example, it may be necessary to reply to all-call interrogations when on the ground. For more details see the Aeronautical Surveillance Manual(Doc 9924) Appendix D.

2.1.5.1.1 Level 1 — Level 1 transponders shall have the capabilities prescribed for:

a) Mode A identity and Mode C pressure-altitude reporting (3.1.1);

b) intermode and Mode S all-call transactions (3.1.2.5);

c) addressed surveillance altitude and identity transaction (3.1.2.6.1, 3.1.2.6.3, 3.1.2.6.5 and 3.1.2.6.7);

d) lockout protocols (3.1.2.6.9);

e) basic data protocols except data link capability reporting (3.1.2.6.10); and

f) air-air service and squitter transactions (3.1.2.8).

Note.— Level 1 permits SSR surveillance based on pressure-altitude reporting and the Mode A identity code. In an SSR Mode S environment, technical performance relative to a Mode A/C transponder is improved due to Mode S selective aircraft interrogation.

2.1.5.1.2 Level 2 — Level 2 transponders shall have the capabilities of 2.1.5.1.1 and also those prescribed for:

a) standard length communications (Comm-A and Comm-B) (3.1.2.6.2, 3.1.2.6.4, 3.1.2.6.6, 3.1.2.6.8 and 3.1.2.6.11);

b) data link capability reporting (3.1.2.6.10.2.2);

c) aircraft identification reporting (3.1.2.9); and

d) data parity with overlay control (3.1.2.6.11.2.5) for equipment certified on or after 1 January 2020.

Note.— Level 2 permits aircraft identification reporting and other standard length data link communications from ground to air and air to ground. The aircraft identification reporting capability requires an interface and appropriate input device.

2.1.5.1.3 Level 3 — Level 3 transponders shall have the capabilities of 2.1.5.1.2 and also those prescribed for ground-to-air extended length message (ELM) communications (3.1.2.7.1 to 3.1.2.7.5).

Note.— Level 3 permits extended length data link communications from ground to air and thus may provide retrieval from ground-based data banks and receipt of other air traffic services which are not available with Level 2 transponders.

2.1.5.1.4 Level 4 — Level 4 transponders shall have the capabilities of 2.1.5.1.3 and also those prescribed for air-to-ground extended length message (ELM) communications (3.1.2.7.7 and 3.1.2.7.8).

Note.— Level 4 permits extended length data link communications from air to ground and thus may provide access from the ground to airborne data sources and the transmission of other data required by air traffic services which are not available with Level 2 transponders.

2.1.5.1.5 Level 5 — Level 5 transponders shall have the capabilities of 2.1.5.1.4 and also those prescribed for enhanced Comm-B and extended length message (ELM) communications (3.1.2.6.11.3.4, 3.1.2.7.6 and 3.1.2.7.9).

Note.— Level 5 permits Comm-B and extended length data link communications with multiple interrogators without requiring the use of multisite reservations. This level of transponder has a higher minimum data link capacity than the other transponder levels.

2.1.5.1.6 Extended squitter —Extended squitter transponders shall have the capabilities of 2.1.5.1.2, 2.1.5.1.3, 2.1.5.1.4 or 2.1.5.1.5, the capabilities prescribed for extended squitter operation (3.1.2.8.6) and the capabilities prescribed for ACAS cross-link operation (3.1.2.8.3 and 3.1.2.8.4). Transponders with these capabilities shall be designated with a suffix "e".

Note.— For example, a level 4 transponder with extended squitter capability would be designated "level 4e".

2.1.5.1.7 SI capability —Transponders with the ability to process SI codes shall have the capabilities of 2.1.5.1.1, 2.1.5.1.2, 2.1.5.1.3, 2.1.5.1.4 or 2.1.5.1.5 and also those prescribed for SI code operation (3.1.2.3.2.1.4, 3.1.2.5.2.1, 3.1.2.6.1.3, 3.1.2.6.1.4.1, 3.1.2.6.9.1.1 and 3.1.2.6.9.2). Transponders with this capability shall be designated with a suffix "s".

Note.— For example, a level 4 transponder with extended squitter capability and SI capability would be designated "level 4es".

2.1.5.1.7.1 SI code capability shall be provided in accordance with the provisions of 2.1.5.1.7 for all Mode S transponders installed on or after 1 January 2003 and by all Mode S transponders by 1 January 2005.

Note.— Mandates from certain States may require applicability in advance of these dates.

2.1.5.1.8 *Extended squitter non-transponder devices.* Devices that are capable of broadcasting extended squitters that are not part of a Mode S transponder shall conform to all of the 1 090 MHz RF signals in space requirements specified for a Mode S transponder, except for transmit power levels for the identified equipment class as specified in 5.1.1.

2.1.5.2 All Mode S transponders used by international civil air traffic shall conform, at least, to the requirements of Level 2 prescribed in 2.1.5.1.2.

Note 1.— Level 1 may be admitted for use within an individual State or within the terms of a regional air navigation agreement. The Mode S Level 1 transponder comprises the minimum set of features for compatible operation of Mode S transponders with SSR Mode S interrogators. It is defined to prevent a proliferation of transponder types below Level 2 which would be incompatible with SSR Mode S interrogators.

Note 2.— The intent of the requirement for a Level 2 capability is to ensure the widespread use of an ICAO standard transponder capability to allow worldwide planning of Mode S ground facilities and services. The requirement also discourages an initial installation with Level 1 transponders that would be rendered obsolete by later requirements in certain airspace for mandatory carriage of transponders having Level 2 capabilities.

2.1.5.3 Mode S transponders installed on aircraft with gross mass in excess of 5 700 kg or a maximum cruising true airspeed capability in excess of 463 km/h (250 kt) shall operate with antenna diversity as prescribed in 3.1.2.10.4 if:

a) the aircraft individual certificate of airworthiness is first issued on or after 1 January 1990; or

b) Mode S transponder carriage is required on the basis of regional air navigation agreement in accordance with 2.1.3.3.1 and 2.1.3.3.2.

Note.— Aircraft with maximum cruising true airspeed exceeding 324 km/h (175 kt) are required to operate with a peak power of not less than 21.0 dBW as specified in 3.1.2.10.2 c).

2.1.5.4 CAPABILITY REPORTING IN MODE SSQUITTERS

2.1.5.4.1 Capability reporting in Mode S acquisition squitters (unsolicited downlink transmissions) shall be provided in accordance with the provisions of 3.1.2.8.5.1 for all Mode S transponders installed on or after 1 January 1995.

2.1.5.4.2 **Recommendation**.— *Transponders equipped for extended squitter operation should have a means to disable acquisition squitters when extended squitters are being emitted.*

Note.— This will facilitate the suppression of acquisition squitters if all ACAS units have been converted to receive the extended squitter.

2.1.5.5 EXTENDED LENGTH MESSAGE (ELM)TRANSMIT POWER

In order to facilitate the conversion of existing Mode S transponders to include full Mode S capability, transponders originally manufactured before 1 January 1999 shall be permitted to transmit a burst of 16 ELM segments at a minimum power level of 20 dBW.

Note.— This represents a 1 dB relaxation from the power requirement specified in 3.1.2.10.2.

2.1.6 SSR Mode S address (aircraft address)

The SSR Mode S address shall be one of 16 777 214 twenty-four-bit aircraft addresses allocated by ICAO to the State of Registry or common mark registering authority and assigned as prescribed in 3.1.2.4.1.2.3.1.1 and the Appendix to Chapter 9, Part I, Volume III, Annex 10.

2.2 HUMAN FACTORS CONSIDERATIONS

Recommendation. — *Human Factors principles should be observed in the design and certification of surveillance radar, transponder and collision avoidance systems.*

Note. — Guidance material on Human Factors principles can be found in Doc 9683, Human Factors Training Manual and Circular 249 (Human Factors Digest No. 11 — Human Factors in CNS/ATM Systems).

2.2.1 Operation of controls

2.2.1.1 Transponder controls which are not intended to be operated in flight shall not be directly accessible to the flight crew.

2.2.1.2 **Recommendation.—** *The operation of transponder controls, intended for use during flight, should be evaluated to ensure they are logical and tolerant to human error. In particular, where transponder functions are integrated with other system controls, the manufacturer should ensure that unintentional transponder mode switching (i.e. an operational state to 'STANDBY' or 'OFF') is minimized.*

Note. — This may take the form of a confirmation of mode switching, required by the flight crew. Typically 'Line Select' Keys, 'Touch Screen' or 'Cursor Controlled/Tracker-ball' methods used to change transponder modes should be carefully designed to minimize flight crew error.

2.2.1.3 **Recommendation.—** *The flight crew should have access at all times to the information of the operational state of the transponder.*

Note. — Information on the monitoring of the operational state of the transponder is provided in RTCA DO-181 E, Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/ Mode Select (ATCRBS/Mode S) Airborne Equipment, and in EUROCAE ED-73E, Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders.

CHAPTER 3. SURVEILLANCE SYSTEMS

3.1 SECONDARY SURVEILLANCE RADAR (SSR) SYSTEM CHARACTERISTICS

Note 1.— Section 3.1.1 prescribes the technical characteristics of SSR systems having only Mode A and Mode C capabilities. Section 3.1.2 prescribes the characteristics of systems with Mode S capabilities. Chapter 5 prescribes additional requirements on Mode S extended squitters.

Note 2.— Systems using Mode S capabilities are generally used for air traffic control surveillance systems. In addition, certain ATC applications may use Mode S emitters, e.g. for vehicle surface surveillance or for fixed target detection on surveillance systems. Under such specific conditions, the term "aircraft" can be understood as "aircraft or vehicle (A/V)".

While those applications may use a limited set of data, any deviation from standard physical characteristics must be considered very carefully by the appropriate authorities. They must take into account not only their own surveillance (SSR) environment but also possible effects on other systems like ACAS.

Note 3.— Non-Standard-International alternative units are used as permitted by Annex 5, Chapter 3, 3.2.2.

3.1.1 Systems having only Mode A and Mode C capabilities

Note 1.— In this section, SSR modes are designated by letters A and C. Suffixed letters, e.g. A2, C4, are used to designate the individual pulses used in the air-to-ground pulse trains. This common use of letters is not to be construed as implying any particular association of modes and codes.

Note 2.— Provisions for the recording and retention of radar data are contained in Annex 11, Chapter 6.

3.1.1.1 INTERROGATION AND CONTROL (INTERROGATION SIDE-LOBE SUPPRESSION) RADIO FREQUENCIES (GROUND-TO-AIR)

3.1.1.1.1 The carrier frequency of the interrogation and control transmissions shall be 1 030 MHz.

3.1.1.1.2 The frequency tolerance shall be plus or minus 0.2 MHz.

3.1.1.1.3 The carrier frequencies of the control transmission and of each of the interrogation pulse transmissions shall not differ from each other by more than 0.2 MHz.

3.1.1.2 REPLY CARRIER FREQUENCY (AIR-TO-GROUND)

3.1.1.2.1 The carrier frequency of the reply transmission shall be 1 090 MHz.

3.1.1.2.2 The frequency tolerance shall be plus or minus 3 MHz.

3.1.1.3 POLARIZATION

Polarization of the interrogation, control and reply transmissions shall be predominantly vertical.

3.1.1.4 INTERROGATION MODES (SIGNALS-IN-SPACE)

3.1.1.4.1 The interrogation shall consist of two transmitted pulses designated P_1 and P_3. A control pulse P2shall be transmitted following the first interrogation pulse P1.

3.1.1.4.2 Interrogation Modes A and C shall be as defined in 3.1.1.4.3.

3.1.1.4.3 The interval between P_1 and P_3. shall determine the mode of interrogation and shall be as follows:

Mode A 8 ±0.2 microseconds
Mode C 21 ±0.2 microseconds

3.1.1.4.4 The interval between P_1 and P_2 shall be 2.0 plus or minus 0.15 microseconds.

3.1.1.4.5 The duration of pulses P_1 , P_2 and P_3 shall be 0.8 plus or minus 0.1 microsecond.

3.1.1.4.6 The rise time of pulses P_1 , P_2 and P_3 shall be between 0.05 and 0.1 microsecond.

Note 1.— The definitions are contained in Figure 3-1 "Definitions of secondary surveillance radar waveform shapes, intervals and the reference point for sensitivity and power".

Note 2.— The intent of the lower limit of rise time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise time.

3.1.1.4.7 The decay time of pulses P_1, P_2 and P_3 shall be between 0.05 and 0.2 microsecond.

Note.— The intent of the lower limit of decay time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated decay time.

3.1.1.5 INTERROGATOR AND CONTROL TRANSMISSION CHARACTERISTICS (INTERROGATION SIDE-LOBE SUPPRESSION —SIGNALS-IN-SPACE)

3.1.1.5.1 The radiated amplitude of P_2 at the antenna of the transponder shall be:

a) equal to or greater than the radiated amplitude of P_1 from the side-lobe transmissions of the antenna radiating P_1; and

b) at a level lower than 9 dB below the radiated amplitude of P_1, within the desired arc of interrogation.

3.1.1.5.2 Within the desired beam width of the directional interrogation (main lobe), the radiated amplitude of P_3 shall be within 1 dB of the radiated amplitude of P_1.

3.1.1.6 REPLY TRANSMISSION CHARACTERISTICS (SIGNALS-IN-SPACE)

3.1.1.6.1 *Framing pulses*. The reply function shall employ a signal comprising two framing pulses spaced 20.3 microseconds as the most elementary code.

3.1.1.6.2 *Information pulses*. Information pulses shall be spaced in increments of 1.45 microseconds from the first framing pulse. The designation and position of these information pulses shall be as follows:

Pulses	Position (microseconds)
C_1	1.45
A_1	2.90
C_2	4.35
A_2	5.80
C_4	7.25
A_4	8.70
X_1	0.15
B_1	11.60
D_1	13.05
B_2	14.50
D_2	15.95
B_4	17.40
D_4	18.85

Note.— The Standard relating to the use of these pulses is given in 2.1.4.1. However, the position of the "X" pulse is not used in replies to Mode A or Mode C interrogations and is specified only as a technical standard to safeguard possible future expansion of the system. It has nevertheless been decided that such expansion should be achieved using Mode S. The presence of a pulse in the X pulse position is used in some States to invalidate replies.

3.1.1.6.3 *Special position identification pulse (SPI)*. In addition to the information pulses provided, a special position identification pulse shall be transmitted but only as a result of manual (pilot) selection. When transmitted, it shall be spaced at an interval of 4.35 microseconds following the last framing pulse of Mode A replies only.

3.1.1.6.4 *Reply pulse shape*. All reply pulses shall have a pulse duration of 0.45 plus or minus 0.1 microsecond, a pulse rise time between 0.05 and 0.1 microsecond and a pulse decay time between 0.05 and 0.2 microsecond. The pulse amplitude variation of one pulse with respect to any other pulse in a reply train shall not exceed 1 dB.

Note.— The intent of the lower limit of rise and decay times (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is not greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise and decay times.

3.1.1.6.5 *Reply pulse position tolerances.* The pulse spacing tolerance for each pulse (including the last framing pulse) with respect to the first framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse interval tolerance of the special position identification pulse with respect to the last framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse spacing tolerance of any pulse in the reply group with respect to any other pulse (except the first framing pulse) shall not exceed plus or minus 0.15 microsecond.

3.1.1.6.6 *Code nomenclature.* The code designation shall consist of digits between 0 and 7 inclusive, and shall consist of the sum of the subscripts of the pulse numbers given in 3.1.1.6.2 above, employed as follows:

Digit	Pulse Group
First (most significant)	A
Second	B
Third	C
Fourth	D

3.1.1.7 TECHNICAL CHARACTERISTICS OF TRANSPONDERS WITH MODE AAND MODE CCAPABILITIES ONLY

3.1.1.7.1 *Reply*. The transponder shall reply (not less than 90 per cent triggering) when all of the following conditions have been met:

a) the received amplitude of P3is in excess of a level 1 dB below the received amplitude of P1but no greater than 3 dB above the received amplitude of P_1;

b) either no pulse is received in the interval 1.3 microseconds to 2.7 microseconds after P_1, or P_1 exceeds by more than 9 dB any pulse received in this interval;

c) the received amplitude of a proper interrogation is more than 10 dB above the received amplitude of random pulses where the latter are not recognized by the transponder as P_1, P_2 or P_3.

3.1.1.7.2 The transponder shall not reply under the following conditions:

a) to interrogations when the interval between pulses P_1 and P_3 differs from those specified in 3.1.1.4.3 by more than plus or minus 1.0 microsecond;

b) upon receipt of any single pulse which has no amplitude variations approximating a normal interrogation condition.

3.1.1.7.3 *Dead time*. After recognition of a proper interrogation, the transponder shall not reply to any other interrogation, at least for the duration of the reply pulse train. This dead time shall end no later than 125 microseconds after the transmission of the last reply pulse of the group.

3.1.1.7.4 SUPPRESSION

Note.— This characteristic is used to prevent replies to interrogations received via the side lobes of the interrogator antenna, and to prevent Mode A/C transponders from replying to Mode S interrogations.

3.1.1.7.4.1 The transponder shall be suppressed when the received amplitude of P_2 is equal to, or in excess of, the received amplitude of P_1 and spaced 2.0 plus or minus 0.15 microseconds. The detection of P_3 is not required as a prerequisite for initiation of suppression action.

3.1.1.7.4.2 The transponder suppression shall be for a period of 35 plus or minus 10 microseconds.

3.1.1.7.4.2.1 The suppression shall be capable of being reinitiated for the full duration within 2 microseconds after the end of any suppression period.

3.1.1.7.4.3 Suppression in presence of S_1 pulse

Note.— The S1pulse is used in a technique employed by ACAS known as "whisper-shout" to facilitate ACAS surveillance of Mode A/C aircraft in higher traffic densities. The whisper-shout technique is explained in the Airborne Collision Avoidance System (ACAS) Manual(Doc 9863).

When an S_1 pulse is detected 2.0 plus or minus 0.15 microseconds before the P_1 of a Mode A or Mode C interrogation:

a) with $S_1$and P_1 above MTL, the transponder shall be suppressed as specified in 3.1.1.7.4.1;

b) with P_1 at MTL and S_1 at MTL, the transponder shall be suppressed and shall reply to no more than 10 per cent of Mode A/C interrogations;

c) with P_1 at MTL and S1at MTL –3 dB, the transponder shall reply to Mode A/C interrogations at least 70 per cent of the time; and

d) with P_1 at MTL andS1at MTL –6 dB, the transponder shall reply to Mode A/C interrogations at least 90 per cent of the time.

Note 1.— The suppression action is because of the detection of $S_1$and P_1 and does not require detection of a P_2 or P_3 pulse.

Note 2.— S1has a lower amplitude than P_1. Certain ACAS use this mechanism to improve target detection (4.3.7.1).

Note 3.— These requirements also apply to a Mode A/C only capable transponder when an S_1 precedes an intermode interrogation (2.1.2.1).

3.1.1.7.5 RECEIVER SENSITIVITY AND DYNAMIC RANGE

3.1.1.7.5.1 The minimum triggering level of the transponder shall be such that replies are generated to at least 90 per cent of the interrogation signals when:

a) the two pulses P1and P3constituting an interrogation are of equal amplitude and P2is not detected; and

b) the amplitude of these signals is nominally 71 dB below 1 mW, with limits between 69 dB and 77 dB below 1 mW.

3.1.1.7.5.2 The reply and suppression characteristics shall apply over a received amplitude of P1between minimum triggering level and 50 dB above that level.

3.1.1.7.5.3 The variation of the minimum triggering level between modes shall not exceed 1 dB for nominal pulse spacings and pulse widths.

3.1.1.7.6 *Pulse duration discrimination.* Signals of received amplitude between minimum triggering level and 6 dB above this level, and of a duration less than 0.3 microsecond, shall not cause the transponder to initiate reply or suppression action. With the exception of single pulses with amplitude variations approximating an interrogation, any single pulse of a duration more than 1.5 microseconds shall not cause the transponder to initiate reply or suppression action over the signal amplitude range of minimum triggering level (MTL) to 50 dB above that level.

3.1.1.7.7 *Echo suppression and recovery.* The transponder shall contain an echo suppression facility designed to permit normal operation in the presence of echoes of signals-in-space. The provision of this facility shall be compatible with the requirements for suppression of side lobes given in 3.1.1.7.4.1.

3.1.1.7.7.1 *Desensitization*. Upon receipt of any pulse more than 0.7 microsecond in duration, the receiver shall be desensitized by an amount that is within at least 9 dB of the amplitude of the desensitizing pulse but shall at no time exceed the amplitude of the desensitizing pulse, with the exception of possible overshoot during the first microsecond following the desensitizing pulse.

Note.— Single pulses of duration less than 0.7 microsecond are not required to cause the specified desensitization nor to cause desensitization of duration greater than permitted by 3.1.1.7.7.1 and 3.1.1.7.7.2.

3.1.1.7.7.2 *Recovery.* Following desensitization, the receiver shall recover sensitivity (within 3 dB of minimum triggering level) within 15 microseconds after reception of a desensitizing pulse having a signal strength up to 50 dB above minimum triggering level. Recovery shall be at an average rate not exceeding 4.0 dB per microsecond.

3.1.1.7.8 *Random triggering rate*. In the absence of valid interrogation signals, Mode A/C transponders shall not generate more than 30 unwanted Mode A or Mode C replies per second as integrated over an interval equivalent to at least 300 random triggers, or 30 seconds, whichever is less. This random triggering rate shall not be exceeded when all possible interfering equipments installed in the same aircraft are operating at maximum interference levels.

3.1.1.7.8.1 *Random triggering rate in the presence of low-level in-band continuous wave (CW) interference.* The total random trigger rate on all Mode A and/or Mode C replies shall not be greater than 10 reply pulse groups or suppressions per second, averaged over a period of 30 seconds, when operated in the presence of non-coherent CW interference at a frequency of 1 030 ±0.2 MHz and a signal level of –60 dBm or less.

3.1.1.7.9 REPLY RATE

3.1.1.7.9.1 All transponders shall be capable of continuously generating at least 500 replies per second for a 15-pulse coded reply. Transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, and in aircraft with a maximum cruising true airspeed not exceeding 175 kt (324 km/h) shall be capable of generating at least 1 000 15-pulse coded replies per second for a duration of 100 milliseconds. Transponder installations operated above 4 500 m (15 000 ft) or in aircraft with a maximum cruising true airspeed in excess of 175 kt (324 km/h), shall be capable of generating at least 1 200 15-pulse coded replies per second for a duration of 100 milliseconds.

Note 1.— A 15-pulse reply includes 2 framing pulses, 12 information pulses, and the SPI pulse.

Note 2.— The reply rate requirement of 500 replies per second establishes the minimum continuous reply rate capability of the transponder. As per the altitude and speed criteria above, the 100 or 120 replies in a 100-millisecond interval defines the peak capability of the transponder. The transponder must be capable of replying to this short-term burst rate, even though the transponder may not be capable of sustaining this rate. If the transponder is subjected to interrogation rates beyond its reply rate capability, the reply rate limit control of 3.1.1.7.9.2 acts to gracefully desensitize the transponder in a manner that favours closer interrogators. Desensitization eliminates weaker interrogation signals.

3.1.1.7.9.2 *Reply rate limit control.* To protect the system from the effects of transponder over-interrogation by preventing response to weaker signals when a predetermined reply rate has been reached, a sensitivity reduction type reply limit control shall be incorporated in the equipment. The range of this control shall permit adjustment, as a minimum, to any value between 500 and 2 000 replies per second, or to the maximum reply rate capability if less than 2 000 replies per second, without regard to the number of pulses in each reply. Sensitivity reduction in excess of 3 dB shall not take effect until 90 per cent of the selected value is exceeded. Sensitivity reduction shall be at least 30 dB for rates in excess of 150 per cent of the selected value.

3.1.1.7.10 *Reply delay and jitter.* The time delay between the arrival, at the transponder receiver, of the leading edge of P3and the transmission of the leading edge of the first pulse of the reply shall be 3 plus or minus 0.5 microseconds. The total jitter of the reply pulse code group, with respect to P3, shall not exceed 0.1 microsecond for receiver input levels between3 dB and 50 dB above minimum triggering level. Delay variations between modes on which the transponder is capable of replying shall not exceed 0.2 microsecond.

3.1.1.7.11 TRANSPONDER POWER OUTPUT AND DUTY CYCLE

3.1.1.7.11.1 The peak pulse power available at the antenna end of the transmission line of the transponder shall be at least 21 dB and not more than 27 dB above 1 W, except that for transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, a peak pulse power available at the antenna end of the transmission line of the transponder of at least 18.5 dB and not more than 27 dB above 1 W shall be permitted.

Note.— An extended squitter non-transponder device on an aerodrome surface vehicle may operate with a lower minimum power output as specified in 5.1.1.2.

3.1.1.7.11.2 **Recommendation**.— *The peak pulse power specified in 3.1.1.7.11.1 should be maintained over a range of replies from code 0000 at a rate of 400 replies per second to a maximum pulse content at a rate of 1 200 replies per second or a maximum value below 1 200 replies per second of which the transponder is capable.*

3.1.1.7.12 REPLY CODES

3.1.1.7.12.1 *Identification*. The reply to a Mode A interrogation shall consist of the two framing pulses specified in 3.1.1.6.1 together with the information pulses (Mode A code) specified in 3.1.1.6.2.

Note.— The Mode A code designation is a sequence of four digits in accordance with 3.1.1.6.6.

3.1.1.7.12.1.1 The Mode A code shall be manually selected from the 4 096 codes available.

3.1.1.7.12.2 *Pressure-altitude transmission*. The reply to Mode C interrogation shall consist of the two framing pulses specified in 3.1.1.6.1 above. When digitized pressure-altitude information is available, the information pulses specified in 3.1.1.6.2 shall also be transmitted.

3.1.1.7.12.2.1 Transponders shall be provided with means to remove the information pulses but to retain the framing pulses when the provision of 3.1.1.7.12.2.4 below is not complied with in reply to Mode C interrogation.

3.1.1.7.12.2.2 The information pulses shall be automatically selected by an analog-to-digital converter connected to a pressure-altitude data source in the aircraft referenced to the standard pressure setting of 1 013.25 hectopascals.

Note.— The pressure setting of 1 013.25 hectopascals is equal to 29.92 inches of mercury.

3.1.1.7.12.2.3 Pressure-altitude shall be reported in 100-ft increments by selection of pulses as shown in the Appendix to this chapter.

3.1.1.7.12.2.4 The digitizer code selected shall correspond to within plus or minus 38.1 m (125 ft), on a 95 per cent probability basis, with the pressure-altitude information (referenced to the standard pressure setting of 1 013.25 hectopascals), used on board the aircraft to adhere to the assigned flight profile.

3.1.1.7.13 *Transmission of the special position identification (SPI) pulse*. When required, this pulse shall be transmitted with Mode A replies, as specified in 3.1.1.6.3, for a period of between 15 and 30 seconds.

3.1.1.7.14 *ANTENNA*

3.1.1.7.14.1 The transponder antenna system, when installed on an aircraft, shall have a radiation pattern which is essentially omnidirectional in the horizontal plane.

3.1.1.7.14.2 **Recommendation**.— *The vertical radiation pattern should be nominally equivalent to that of a quarter wave monopole on a ground plane.*

3.1.1.8 TECHNICAL CHARACTERISTICS OF GROUND INTERROGATORS WITH MODE AAND MODE CCAPABILITIES ONLY

3.1.1.8.1 *Interrogation repetition frequency.* The maximum interrogation repetition frequency shall be 450 interrogations per second.

3.1.1.8.1.1 **Recommendation.**— *To minimize unnecessary transponder triggering and the resulting high density of mutual interference, all interrogators should use the lowest practicable interrogator repetition frequency that is consistent with the display characteristics, interrogator antenna beam width and antenna rotation speed employed.*

3.1.1.8.2 *RADIATED POWER*

Recommendation.– *In order to minimize system interference the effective radiated power of interrogators should be reduced to the lowest value consistent with the operationally required range of each individual interrogator site.*

3.1.1.8.3 **Recommendation**.— *When Mode C information is to be used from aircraft flying below transition levels, the altimeter pressure reference datum should be taken into account.*

Note.— Use of Mode C below transition levels is in accordance with the philosophy that Mode C can usefully be employed in all environments.

3.1.1.9 INTERROGATOR RADIATED FIELD PATTERN

Recommendation.— *The beam width of the directional interrogator antenna radiating P3should not be wider than is operationally required. The side- and back-lobe radiation of the directional antenna should be at least 24 dB below the peak of the main-lobe radiation*.

3.1.1.10 INTERROGATOR MONITOR

3.1.1.10.1 The range and azimuth accuracy of the ground interrogator shall be monitored at sufficiently frequent intervals to ensure system integrity.

Note.— Interrogators that are associated with and operated in conjunction with primary radar may use the primary radar as the monitoring device; alternatively, an electronic range and azimuth accuracy monitor would be required.

3.1.1.10.2 **Recommendation.—** *In addition to range and azimuth monitoring, provision should be made to monitor continuously the other critical parameters of the ground interrogator for any degradation of performance exceeding the allowable system tolerances and to provide an indication of any such occurrence.*

3.1.1.11 SPURIOUS EMISSIONS AND SPURIOUS RESPONSES

3.1.1.11.1 *SPURIOUS RADIATION*

Recommendation.— CW radiation should not exceed 76 dB below 1 W for the interrogator and 70 dB below 1 W for the transponder.

3.1.1.11.2 *SPURIOUS RESPONSES*

Recommendation.— The response of both airborne and ground equipment to signals not within the receiver pass band should be at least 60 dB below normal sensitivity.

3.1.2 Systems having Mode S capabilities

3.1.2.1 *Interrogation signals-in-space characteristics*. The paragraphs herein describe the signals-in-space as they can be expected to appear at the antenna of the transponder.

Note.— Because signals can be corrupted in propagation, certain interrogation pulse duration, pulse spacing and pulse amplitude tolerances are more stringent for interrogators as described in 3.1.2.11.4.

3.1.2.1.1 *Interrogation carrier frequency*. The carrier frequency of all interrogations (uplink transmissions) from ground facilities with Mode S capabilities shall be 1 030 plus or minus 0.01 MHz, except during the phase reversal, while maintaining the spectrum requirements of 3.1.2.1.2.

Note.— During the phase reversal the frequency of the signal may shift by several MHz before returning to the specified value.

3.1.2.1.2 *Interrogation spectrum*. The spectrum of a Mode S interrogation about the carrier frequency shall not exceed the limits specified in Figure 3-2.

Note.— The Mode S interrogation spectrum is data dependent. The broadest spectrum is generated by an interrogation that contains all binary ONEs.

3.1.2.1.3 *Polarization.* Polarization of the interrogation and control transmissions shall be nominally vertical.

3.1.2.1.4 *Modulation.* For Mode S interrogations, the carrier frequency shall be pulse modulated. In addition, the data pulse, P6, shall have internal phase modulation.

3.1.2.1.4.1 *Pulse modulation*. Intermode and Mode S interrogations shall consist of a sequence of pulses as specified in

3.1.2.1.5 and Tables 3-1, 3-2, 3-3, and 3-4.

Note.— The 0.8 microsecond pulses used in intermode and Mode S interrogations are identical in shape to those used in Modes A and C as defined in 3.1.1.4.

3.1.2.1.4.2 *Phase modulation.* The short (16.25-microsecond) and long (30.25-microsecond) P6pulses of 3.1.2.1.4.1 shall have internal binary differential phase modulation consisting of 180-degree phase reversals of the carrier at a 4 megabit per second rate.

3.1.2.1.4.2.1 *Phase reversal duration.* The duration of the phase reversal shall be less than 0.08 microsecond and the phase shall advance (or retard) monotonically throughout the transition region. There shall beno amplitude modulation applied during the phase transition.

Note 1.— The minimum duration of the phase reversal is not specified. Nonetheless, the spectrum requirements of 3.1.2.1.2 must be met.

Note 2.— The phase reversal can be generated using different methods. This includes hard keying with strong amplitude drop and rapid phase reversal or other techniques with little orno amplitude drop, but with frequency shift during the phase reversal and slow phase reversal (80ns). A demodulator cannot make any assumption on the type of modulation technology used and therefore cannot rely on the specificities of the signal during the phase reversal to detect a phase reversal.

3.1.2.1.4.2.2 *Phase relationship.* The tolerance on the 0 and 180-degree phase relationship between successive chips and on the sync phase reversal(3.1.2.1.5.2.2) within the P6pulse shall be plus or minus 5 degrees.

Note.— In Mode S a "chip" is the 0.25 microsecond carrier interval between possible data phase reversals.

3.1.2.1.5 *Pulse and phase reversal sequences.* Specific sequences of the pulses or phase reversals described in 3.1.2.1.4 shall constitute interrogations.

3.1.2.1.5.1 Intermode interrogation

3.1.2.1.5.1.1 *Mode A/C/S all-call interrogation.* This interrogation shall consist of three pulses: P1, P3, and the long P4as shown in Figure 3-3. One or two control pulses (P2alone, or P1and P2) shall be transmitted using a separate antenna pattern to suppress responses from aircraft in the side lobes of the interrogator antenna.

Note.— The Mode A/C/S all-call interrogation elicits a Mode A or Mode C reply (depending on the P1-P3pulse spacing) from a Mode A/C transponder because it does not recognize theP4pulse. A Mode S transponder recognizes the long P4pulse and responds with a Mode S reply. This interrogation was originally planned for use by isolated or clustered interrogators. Lockout for this interrogation was based on the use of II equals 0. The development of the Mode S subnetwork now dictates the use of a non-zero II code for communication purposes. For this reason, II equals 0 has been reserved for use in support of a form of Mode S acquisition that uses stochastic/lockout override (3.1.2.5.2.1.4 and 3.1.2.5.2.1.5). The Mode A/C/S all call cannot be used with full Mode S operation since II equals 0 can only be locked out for short time periods (3.1.2.5.2.1.5.2.1). This interrogation cannot be used with stochastic/lockout override, since probability of reply cannot be specified.

3.1.2.1.5.1.1.1 Mode A/C/S all-call interrogations shall not be used on or after 1 January 2020.

Note 1.— The use of Mode A/C/S all-call interrogations does not allow the use of stochastic lockout override and therefore might not ensure a good probability of acquisition in areas of high density of flights or when other interrogators lockout transponder on II=0 for supplementary acquisition.

Note 2.— The replies to Mode A/C/S all-call interrogations will no longer be supported by equipment certified on or after 1 January 2020 in order to reduce the RF pollution generated by the replies triggered by the false detection of Mode A/C/S all-call interrogations within other types of interrogation.

3.1.2.1.5.1.2 *Mode A/C-only all-call interrogation*. This interrogation shall be identical to that of the Mode A/C/S all call interrogation except that the short P4pulse shall be used.

Note.— The Mode A/C-only all-call interrogation elicits a Mode A or Mode C reply from a Mode A/C transponder. A Mode S transponder recognizes the short P4pulse and does not reply to this interrogation.

3.1.2.1.5.1.3 *Pulse intervals.* The pulse intervals between P1, P2and P3shall be as defined in 3.1.1.4.3 and 3.1.1.4.4.

The pulse interval between P3 and P4 shall be 2 plus or minus 0.05 microsecond.

3.1.2.1.5.1.4 *Pulse amplitudes.* Relative amplitudes between pulses P1, P2and P3shall be in accordance with 3.1.1.5.

The amplitude of P4shall be within 1 dB of the amplitude of P3.

3.1.2.1.5.2 *Mode S interrogation*. The Mode S interrogation shall consist of three pulses: P1, P2and P6as shown in Figure 3-4.

Note.— P6is preceded by a P1– P2pair which suppresses replies from Mode A/C transponders to avoid synchronous garble due to random triggering by the Mode S interrogation. The sync phase reversal within P6is the timing mark for demodulation of a series of time intervals (chips) of 0.25 microsecond duration. This series of chips starts 0.5 microsecond after the sync phase reversal and ends 0.5 microsecond before the trailing edge of P6. A phase reversal may or may not precede each chip to encode its binary information value.

3.1.2.1.5.2.1 *Mode S side-lobe suppression*. The P5pulse shall be used with the Mode S-only all-call interrogation (UF = 11, see 3.1.2.5.2) to prevent replies from aircraft in the side and back lobes of the antenna (3.1.2.1.5.2.5). When used, P5 shall be transmitted using a separate antenna pattern.

Note 1.— The action of P5is automatic. Its presence, if of sufficient amplitude at the receiving location, masks the sync phase reversal of P6.

Note 2.— The P5pulse may be used with other Mode S interrogations.

3.1.2.1.5.2.2 *Sync phase reversal.* The first phase reversal in the P6pulse shall be the sync phase reversal. It shall be the timing reference for subsequent transponder operations related to the interrogation.

3.1.2.1.5.2.3 *Data phase reversals*. Each data phase reversal shall occur only at a time interval (N times 0.25) plus or minus 0.02 microsecond (N equal to, or greater than 2) after the sync phase reversal. The 16.25-microsecond P6 pulse shall contain at most 56 data phase reversals. The 30.25-microsecond P6pulse shall contain at most 112 data phase reversals. The last chip, that is the 0.25-microsecond time interval following the last data phase reversal position, shall be followed by a 0.5-microsecond guard interval.

Note.— The 0.5-microsecond guard interval following the last chip prevents the trailing edge of P6from interfering with the demodulation process.

3.1.2.1.5.2.4 *Intervals*. The pulse interval between P1and P2shall be 2 plus or minus 0.05 microsecond. The interval between the leading edge of P2and the sync phase reversal of P6shall be 2.75 plus or minus 0.05 microsecond. The leading edge of P6shall occur 1.25 plus or minus 0.05 microsecond before the sync phase reversal. P5, if transmitted, shall be centred over the sync phase reversal; the leading edge of P5shall occur 0.4 plus or minus 0.05 microsecond before the sync phase reversal.

3.1.2.1.5.2.5 *Pulse amplitudes.* The amplitude of P2and the amplitude of the first microsecond of P6 shall be greater than the amplitude of P1minus 0.25 dB. Exclusive of the amplitude transients associated with phase reversals, the amplitude variation of P6shall be less than 1 dB and the amplitude variation between successive chips in P6shall be less than 0.25 dB.

The radiated amplitude of P5at the antenna of the transponder shall be:

a) equal to or greater than the radiated amplitude of P6from the side-lobe transmissions of the antenna radiating P6; and

b) at a level lower than 9 dB below the radiated amplitude of P6within the desired arc of interrogation.

3.1.2.2 REPLY SIGNALS-IN-SPACE CHARACTERISTICS

3.1.2.2.1 *Reply carrier frequency.* The carrier frequency of all replies (downlink transmissions) from transponders with Mode S capabilities shall be 1 090 plus or minus 1 MHz.

3.1.2.2.2 *Reply spectrum*. The spectrum of a Mode S reply about the carrier frequency shall not exceed the limits specified in Figure 3-5.

3.1.2.2.3 *Polarization.* Polarization of the reply transmissions shall be nominally vertical.

3.1.2.2.4 *Modulation.* The Mode S reply shall consist of a preamble and a data block. The preamble shall be a 4-pulse sequence and the data block shall be binary pulse-position modulated at a 1 megabit per second data rate.

3.1.2.2.4.1 *Pulse shapes.* Pulse shapes shall be as defined in Table 3-2. All values are in microseconds.

3.1.2.2.5 *Mode S reply.* The Mode S reply shall be as shown in Figure 3-6. The data block in Mode S replies shall consist of either 56 or 112 information bits.

3.1.2.2.5.1 *Pulse intervals.* All reply pulses shall start at a defined multiple of 0.5 microsecond from the first transmitted pulse. The tolerance in all cases shall be plus or minus 0.05 microsecond.

3.1.2.2.5.1.1 *Reply preamble.* The preamble shall consist of four pulses, each with a duration of 0.5 microsecond. The pulse intervals from the first transmitted pulse to the second, third and fourth transmitted pulses shall be 1, 3.5 and 4.5 microseconds, respectively.

3.1.2.2.5.1.2 *Reply data pulses*. The reply data block shall begin 8 microseconds after the leading edge of the first transmitted pulse. Either 56 or 112 one-microsecond bit intervals shall be assigned to each transmission. A 0.5-microsecond pulse shall be transmitted either in the first or in the second half of each interval. When a pulse transmitted in the second half of one interval is followed by another pulse transmitted in the first half of the next interval, the two pulses merge and a one microsecond pulse shall be transmitted.

3.1.2.2.5.2 *Pulse amplitudes.* The pulse amplitude variation between one pulse and any other pulse in a Mode S reply shall not exceed 2 dB.

3.1.2.3 MODE SDATA STRUCTURE

3.1.2.3.1 DATA ENCODING

3.1.2.3.1.1 *Interrogation data*. The interrogation data block shall consist of the sequence of 56 or 112 data chips positioned after the data phase reversals within P6(3.1.2.1.5.2.3). A 180-degree carrier phase reversal preceding a chip shall characterize that chip as a binary ONE. The absence of a preceding phase reversal shall denote a binary ZERO.

3.1.2.3.1.2 *Reply data.* The reply data block shall consist of 56 or 112 data bits formed by binary pulse position modulation encoding of the reply data as described in 3.1.2.2.5.1.2. A pulse transmitted in the first half of the interval shall represent a binary ONE whereas a pulse transmitted in the second half shall represent a binary ZERO.

3.1.2.3.1.3 *Bit numbering.* The bits shall be numbered in the order of their transmission, beginning with bit 1. Unless otherwise stated, numerical values encoded by groups (fields) of bits shall be encoded using positive binary notation and the first bit transmitted shall be the most significant bit (MSB). Information shall be coded in fields which consist of at least one bit.

Note.— In the description of Mode S formats the decimal equivalent of the binary code formed by the bit sequence within a field is used as the designator of the field function or command.

3.1.2.3.2 FORMATS OF MODE SINTERROGATIONS AND REPLIES

Note.— A summary of all Mode S interrogation and reply formats is presented in Figures 3-7 and 3-8. A summary of all fields appearing in uplink and downlink formats is given in Table 3-3 and a summary of all subfields is given in Table 3-4.

3.1.2.3.2.1 *Essential fields.* Every Mode S transmission shall contain two essential fields. One is a descriptor which shall uniquely define the format of the transmission. This shall appear at the beginning of the transmission for all formats.

The descriptors are designated by the UF (uplink format) or DF (downlink format) fields. The second essential field shall be a 24-bit field appearing at the end of each transmission and shall contain parity information. In all uplink and in currently defined downlink formats parity information shall be overlaid either on the aircraft address (3.1.2.4.1.2.3.1) or on the interrogator identifier according to 3.1.2.3.3.2. The designators are AP (address/parity) or PI (parity/interrogator identifier).

Note.— The remaining coding space is used to transmit the mission fields. For specific functions, a specific set of mission fields is prescribed. Mode S mission fields have two-letter designators. Subfields may appear within mission fields. Mode S subfields are labelled with three-letter designators.

3.1.2.3.2.1.1 *UF: Uplink format.* This uplink format field (5 bits long except in format 24 where it is 2 bits long) shall serve as the uplink format descriptor in all Mode S interrogations and shall be coded according to Figure 3-7.

3.1.2.3.2.1.2 *DF: Downlink format.* This downlink format field (5 bits long except in format 24 where it is 2 bits long) shall serve as the downlink format descriptor in all Mode S replies and shall be coded according to Figure 3-8.

3.1.2.3.2.1.3 *AP: Address/parity.* This 24-bit (33-56 or 89-112) field shall appear in all uplink and currently defined downlink formats except the Mode S-only all-call reply, DF = 11. The field shall contain parity overlaid on the aircraft address according to3.1.2.3.3.2.

3.1.2.3.2.1.4 *PI: Parity/interrogator identifier.* This 24-bit (33-56) or (89-112) downlink field shall have parity overlaid on the interrogator's identity code according to 3.1.2.3.3.2 and shall appear in the Mode S all-call reply, DF = 11 and in the extended squitter, DF = 17 or DF = 18. If the reply is made in response to a Mode A/C/S all-call, a Mode S-only all call with CL field (3.1.2.5.2.1.3) and IC field (3.1.2.5.2.1.2) equal to 0, or is an acquisition or an extended squitter (3.1.2.8.5, 3.1.2.8.6 or 3.1.2.8.7), the II and the SI codes shall be 0.

3.1.2.3.2.1.5 *DP: Data parity.* This 24-bit (89-112) downlink field shall contain the parity overlaid on a "Modified AA" field which is established by performing a modulo-2 summation (e.g. Exclusive-Or function) of the discrete address most significant 8 bits and BDS1, BDS2, where BDS1 (3.1.2.6.11.2.2) and BDS2 (3.1.2.6.11.2.3) are provided by the "RR" (3.1.2.6.1.2) and "RRS" (3.1.2.6.1.4.1) as specified in 3.1.2.6.11.2.2 and 3.1.2.6.11.2.3.

Example:

Discrete address	=	AA AA AA Hex	=	1010	1010	1010	1010	1010	1010
BDS1, BDS2	=	5F 00 00 Hex	=	0101	1111	0000	0000	0000	0000
Discrete address	⊕	BDS1, BDS2 Hex	=	1111	0101	1010	1010	1010	1010
"Modified AA"	=	F5 AA AA Hex	=	1111	0101	1010	1010	1010	1010

where "⊕" prescribes modulo-2 addition

The resulting "Modified AA" field then represents the 24-bit sequence (a1, a2…a24) that shall be used to generate the DP field in accordance with paragraph 3.1.2.3.3.2.

The DP field shall be used in DF=20 and DF=21 replies if the transponder is capable of supporting the DP field and if the overlay control (OVC - 3.1.2.6.1.4.1.i)) bit is set to one (1) in the interrogation requesting downlink of GICB registers.

3.1.2.3.2.2 *Unassigned coding space.* Unassigned coding space shall contain all ZEROs as transmitted by interrogators and transponders.

Note.— Certain coding space indicated as unassigned in this section is reserved for other applications such as ACAS, data link, etc.

3.1.2.3.2.3 Zero and unassigned codes. A zero code assignment in all defined fields shall indicate that no action is required by the field. In addition, codes not assigned within the fields shall indicate that no action is required.

Note.— The provisions of 3.1.2.3.2.2 and 3.1.2.3.2.3 ensure that future assignments of previously unassigned coding space will not result in ambiguity. That is, Mode S equipment in which the new coding has not been implemented will clearly indicate that no information is being transmitted in newly assigned coding space.

3.1.2.3.2.4 Formats reserved for military use. States shall ensure that uplink formats are only used for selectively addressed interrogations and that transmissions of uplink or downlink formats do not exceed the RF power, interrogation rate, reply rate and squitter rate requirements of Annex 10.

3.1.2.3.2.4.1 **Recommendation.—** *Through investigation and validation, States should ensure that military applications do not unduly affect the existing 1 030/1 090 MHz civil aviation operations environment.*

3.1.2.3.3 ERROR PROTECTION

3.1.2.3.3.1 *Technique*. Parity check coding shall be used within Mode S interrogations and replies to provide protection against the occurrence of errors.

3.1.2.3.3.1.1 *Parity check sequence*. A sequence of 24 parity check bits shall be generated by the rule described in 3.1.2.3.3.1.2 and shall be incorporated into the field formed by the last 24 bits of all Mode S transmissions. The 24 parity check bits shall be combined with either the address coding or the interrogator identifier coding as described in 3.1.2.3.3.2. The resulting combination then forms either the AP (address/parity, 3.1.2.3.2.1.3) field or the PI (parity/interrogator identifier, 3.1.2.3.2.1.4) field.

3.1.2.3.3.1.2 *Parity check sequence generation*. The sequence of 24 parity bits (p1, p2,..., p24) shall be generated from the sequence of information bits (m1, m2,..., mk) where k is 32 or 88 for short or long transmissions respectively. This shall be done by means of a code generated by the polynomial:

$$G(x) = 1 + x^3 + x^{10} + x^{12} + x^{13} + x^{14} + x^{15} + x^{16}$$

$$+ x^{17} + x^{18} + x^{19} + x^{20} + x^{21} + x^{22} + x^{23} + x^{24}$$

When by the application of binary polynomial algebra, $x^{24}\,[M(x)]$ is divided by G(x)where the information sequence M(x) is:

$$m_k + m_{k-1}x + m_{k-2}x^2 + \ldots + m_1x^{k-1}$$

the result is a quotient and a remainder R(x)of degree less than 24. The bit sequence formed by this remainder represents the parity check sequence. Parity bit pi, for any i from 1 to 24, is the coefficient of x^{24-i} in R(x).

Note.— The effect of multiplying M(x) by x^{24} *is to append 24 ZERO bits to the end of the sequence.*

3.1.2.3.3.2 *AP and PI field generation.* Different address parity sequences shall be used for the uplink and downlink.

Note.— The uplink sequence is appropriate for a transponder decoder implementation. The downlink sequence facilitates the use of error correction in downlink decoding.

The code used in uplink AP field generation shall be formed as specified below from either the aircraft address (3.1.2.4.1.2.3.1.1), the all-call address (3.1.2.4.1.2.3.1.2) or the broadcast address (3.1.2.4.1.2.3.1.3).

The code used in downlink AP field generation shall be formed directly from the sequence of 24 Mode S address bits (a1, a2,..., a24), where ai is the i-th bit transmitted in the aircraft address (AA)field of an all-call reply (3.1.2.5.2.2.2).

The code used in downlink PI field generation shall be formed by a sequence of 24 bits (a1, a2,..., a24), where the first 17 bits are ZEROs, the next three bits are a replica of the code label (CL) field (3.1.2.5.2.1.3) and the last four bits are a replica of the interrogator code (IC)field (3.1.2.5.2.1.2).

Note.— The PI code is not used in uplink transmissions.

A modified sequence (b1, b2,..., b24) shall be used for uplink AP field generation. Bit bi is the coefficient of x48-I in the polynomial G(x)A(x), where:

$$A(x) = a_1x^{23} + a_2x^{22} + \ldots + a_{24}$$

and G(x)is as defined in 3.1.2.3.3.1.2.

In the aircraft address ai shall be the i-th bit transmitted in the AA field of an all-call reply. In the all-call and broadcast addresses aishall equal 1 for all values of i.

3.1.2.3.3.2.1 *Uplink transmission order.* The sequence of bits transmitted in the uplink AP field is:

$$t_{k+1}, t_{k+2} \ldots t_{k+24}$$

where the bits are numbered in order of transmission, starting with k+ 1.

In uplink transmissions:

$$t_{k+i} = b_i \oplus p_i$$

where "$\oplus$" prescribes modulo-2 addition: *i* equals 1 is the first bit transmitted in the AP field.

3.1.2.3.3.2.2 *Downlink transmission order.* The sequence of bits transmitted in the downlink AP and PI field is:

$$t_{k+1}, t_{k+2} \dots t_{k+24}$$

where the bits are numbered in order of transmission, starting with k+ 1. In downlink transmissions:

$$t_{k+i} = a_i \oplus p_i$$

where "$\oplus$" prescribes modulo-2 addition: *i* equals 1 is the first bit transmitted in the AP or PI field.

3.1.2.4 GENERAL INTERROGATION-REPLY PROTOCOL

3.1.2.4.1 *Transponder transaction cycle.* A transponder transaction cycle shall begin when the SSR Mode S transponder has recognized an interrogation. The transponder shall then evaluate the interrogation and determine whether it shall be accepted. If accepted, it shall then process the received interrogation and generate a reply, if appropriate. The transaction cycle shall end when:

a) any one of the necessary conditions for acceptance has not been met, or

b) an interrogation has been accepted and the transponder has either:

1) completed the processing of the accepted interrogation if no reply is required, or

2) completed the transmission of a reply.

A new transponder transaction cycle shall not begin until the previous cycle has ended.

3.1.2.4.1.1 *Interrogation recognition.* SSR Mode S transponders shall be capable of recognizing the following distinct types of interrogations:

a) Modes A and C;

b) intermode; and

c) Mode S.

Note.— The recognition process is dependent upon the signal input level and the specified dynamic range (3.1.2.10.1).

3.1.2.4.1.1.1 *Mode A and Mode C interrogation recognition.* A Mode A or Mode C interrogation shall be recognized when a P1– P3pulse pair meeting the requirements of 3.1.1.4 has been received, and the leading edge of a P4pulse with an amplitude that is greater than a level 6 dB below the amplitude of P3is not received within the interval from 1.7 to 2.3 microseconds following the leading edge of P3.

If a P1– P2suppression pair and a Mode A or Mode C interrogation are recognized simultaneously, the transponder shall be suppressed. An interrogation shall not be recognized as Mode A or Mode C if the transponder is in suppression (3.1.2.4.2). If a Mode A and a Mode C interrogation are recognized simultaneously the transponder shall complete the transaction cycle as if only a Mode C interrogation had been recognized.

3.1.2.4.1.1.2 *Intermode interrogation recognition.* An intermode interrogation shall be recognized when a P1– P3 – P4pulse triplet meeting the requirements of 3.1.2.1.5.1 is received. An interrogation shall not be recognized as an intermode interrogation if:

a) the received amplitude of the pulse in the P4position is smaller than 6 dB below the amplitude of P3; or

b) the pulse interval between P3and P4is larger than 2.3 microseconds or shorter than 1.7 microseconds; or

c) the received amplitude of P1and P3is between MTL and –45 dBm and the pulse duration of P1or P3is less than 0.3 microsecond; or

d) the transponder is in suppression (3.1.2.4.2).

If a P1– P2suppression pair and a Mode A or Mode C intermode interrogation are recognized simultaneously the transponder shall be suppressed.

3.1.2.4.1.1.3 *Mode S interrogation recognition.* A Mode S interrogation shall be recognized when a P6pulse is received with a sync phase reversal within the interval from 1.20 to 1.30 microseconds following the leading edge of P6. A Mode S interrogation shall not be recognized if a sync phase reversal is not received within the interval from 1.05 to 1.45 microseconds following the leading edge of P6.

3.1.2.4.1.2 *Interrogation acceptance*. Recognition according to 3.1.2.4.1 shall be a prerequisite for acceptance of any interrogation.

3.1.2.4.1.2.1 *Mode A and Mode C interrogation acceptance*. Mode A and Mode C interrogations shall be accepted when recognized (3.1.2.4.1.1.1).

3.1.2.4.1.2.2 Intermode interrogation acceptance 3.1.2.4.1.2.2.1 Mode A/C/S all-call interrogation acceptance. A Mode A/C/S all-call interrogation shall be accepted if the trailing edge of P4is received within 3.45 to 3.75 microseconds following the leading edge of P3and no lockout condition (3.1.2.6.9) prevents acceptance. A Mode A/C/S all-call shall not be accepted if the trailing edge of P4is received earlier than 3.3 or later than 4.2 microseconds following the leading edge of P3, or if a lockout condition (3.1.2.6.9) prevents acceptance.

3.1.2.4.1.2.2.2 *Mode A/C-only all-call interrogation acceptance.* A Mode A/C-only all-call interrogation shall not be accepted by a Mode S transponder.

Note.— The technical condition for non-acceptance of a Mode A/C-only all-call is given in the preceding paragraph by the requirement for rejecting an intermode interrogation with a P4pulse having a trailing edge following the leading edge of P3by less than 3.3 microseconds.

3.1.2.4.1.2.3 *Mode S interrogation acceptance.* A Mode S interrogation shall only be accepted if:

a) the transponder is capable of processing the uplink format (UF) of the interrogation (3.1.2.3.2.1.1);

b) the address of the interrogation matches one of the addresses as defined in 3.1.2.4.1.2.3.1 implying that parity is established, as defined in 3.1.2.3.3;

c) in the case of an all-call interrogation, no all-call lockout condition applies, as defined in 3.1.2.6.9; and

d) the transponder is capable of processing the uplinked data of a long air-air surveillance (ACAS) interrogation (UF-16) and presenting it at an output interface as prescribed in3.1.2.10.5.2.2.1.

Note.— A Mode S interrogation may be accepted if the conditions specified in 3.1.2.4.1.2.3 a) and b) are met and the transponder is not capable of both processing the uplinked data of a Comm-A interrogation (UF=20 and 21) and presenting it at an output interface as prescribed in 3.1.2.10.5.2.2.1.

3.1.2.4.1.2.3.1 *Addresses.* Mode S interrogations shall contain either:

a) aircraft address; or

b) the all-call address; or

c) the broadcast address.

3.1.2.4.1.2.3.1.1 *Aircraft address.* If the aircraft's address is identical to the address extracted from a received interrogation according to the procedure of 3.1.2.3.3.2 and 3.1.2.3.3.2.1, the extracted address shall be considered correct for purposes of Mode S interrogation acceptance.

3.1.2.4.1.2.3.1.2 *All-call address*. A Mode S-only all-call interrogation (uplink format UF = 11) shall contain an address, designated the all-call address, consisting of twenty-four consecutive ONEs. If the all-call address is extracted from a received interrogation with format UF =

11according to the procedure of3.1.2.3.3.2 and 3.1.2.3.3.2.1, the address shall be considered correct for Mode S-only all-call interrogation acceptance.

3.1.2.4.1.2.3.1.3 *Broadcast address.* To broadcast a message to all Mode S transponders within the interrogator beam, a Mode S interrogation uplink format 20 or 21 shall be used and an address of twenty-four consecutive ONEs shall be substituted for the aircraft address. If the UF code is 20 or 21 and this broadcast address is extracted from a received interrogation according to the procedure of 3.1.2.3.3.2 and 3.1.2.3.3.2.1, the address shall be considered correct for Mode S broadcast interrogation acceptance.

Note.— Transponders associated with airborne collision avoidance systems also accept a broadcast with UF = 16.

3.1.2.4.1.3 *Transponder replies.* Mode S transponders shall transmit the following reply types:

a) Mode A and Mode C replies; and

b) Mode S replies.

3.1.2.4.1.3.1 *Mode A and Mode C replies*. A Mode A (Mode C) reply shall be transmitted as specified in 3.1.1.6 when a Mode A (Mode C) interrogation has been accepted.

3.1.2.4.1.3.2 *Mode S replies.* Replies to other than Mode A and Mode C interrogations shall be Mode S replies.

3.1.2.4.1.3.2.1 *Replies to intermode interrogations.* A Mode S reply with downlink format 11 shall be transmitted in accordance with the provisions of 3.1.2.5.2.2 when a Mode A/C/S all-call interrogation has been accepted. Equipment certified on or after 1 January 2020 shall not reply to Intermode Mode A/C/S all-call interrogations.

Note.— Since Mode S transponders do not accept Mode A/C-only all-call interrogations, no reply is generated.

3.1.2.4.1.3.2.2 *Replies to Mode S interrogations.* The information content of a Mode S reply shall reflect the conditions existing in the transponder after completion of all processing of the interrogation eliciting that reply. The correspondence between uplink and downlink formats shall be as summarized in Table 3-5.

Note.— Four categories of Mode S replies may be transmitted in response to Mode S interrogations:

a) Mode S all-call replies (DF = 11);

b) surveillance and standard-length communications replies (DF = 4, 5, 20 and 21);

c) extended length communications replies (DF = 24); and

d) air-air surveillance replies (DF = 0 and 16).

3.1.2.4.1.3.2.2.1 *Replies to SSR Mode S-only all-call interrogations.* The downlink format of the reply to a Mode Sonly all-call interrogation (if required) shall be DF = 11. The reply content and rules for determining the requirement to reply shall be as defined in 3.1.2.5.

Note.— A Mode S reply may or may not be transmitted when a Mode S interrogation with UF = 11 has been accepted.

3.1.2.4.1.3.2.2.2 *Replies to surveillance and standard length communications interrogations*. A Mode S reply shall be transmitted when a Mode S interrogation with UF = 4, 5, 20 or 21 and an aircraft address has been accepted. The contents of these interrogations and replies shall be as defined in 3.1.2.6.

Note.— If a Mode S interrogation with UF = 20 or 21 and a broadcast address is accepted, no reply is transmitted (3.1.2.4.1.2.3.1.3).

3.1.2.4.1.3.2.2.3 *Replies to extended length communications interrogations.* A series of Mode S replies ranging in number from 0 to 16 shall be transmitted when a Mode S interrogation with UF = 24 has been accepted. The downlink format of the reply (if any) shall be DF = 24. Protocols defining the number and content of the replies shall be as defined in 3.1.2.7.

3.1.2.4.1.3.2.2.4 *Replies to air-air surveillance interrogations.* A Mode S reply shall be transmitted when a Mode S interrogation with UF = 0 and an aircraft address has been accepted. The contents of these interrogations and replies shall be as defined in 3.1.2.8.

3.1.2.4.2 *SUPPRESSION*

3.1.2.4.2.1 *Effects of suppression.* A transponder in suppression (3.1.1.7.4) shall not recognize Mode A, Mode C or intermode interrogations if either the P1pulse alone or both the P1and P3pulses of the interrogation are received during the suppression interval. Suppression shall not affect the recognition of, acceptance of, or replies to Mode S interrogations.

3.1.2.4.2.2 *Suppression pairs.* The two-pulse Mode A/C suppression pair defined in 3.1.1.7.4.1 shall initiate suppression in a Mode S transponder regardless of the position of the pulse pair in a group of pulses, provided the transponder is not already suppressed or in a transaction cycle.

Note.— The P3– P4pair of the Mode A/C-only all-call interrogation both prevents a reply and initiates suppression.

Likewise, the P1– P2preamble of a Mode S interrogation initiates suppression independently of the waveform that follows it.

3.1.2.4.2.3 Suppression in presence of S1pulse shall be as defined in 3.1.1.7.4.3.

3.1.2.5 INTERMODE AND MODE SALL-CALL TRANSACTIONS

3.1.2.5.1 INTERMODE TRANSACTIONS

Note.— Intermode transactions permit the surveillance of Mode A/C-only aircraft and the acquisition of Mode S aircraft.

The Mode A/C/S all-call interrogation allows Mode A/C-only and Mode S transponders to be interrogated by the same transmissions. The Mode A/C-only all-call interrogation makes it possible to elicit replies only from Mode A/C transponders.

In multisite scenarios, the interrogator must transmit its identifier code in the Mode S only all-call interrogation. Thus, a pair of Mode S-only and Mode A/C-only all-call interrogations are used. The intermode interrogations are defined in 3.1.2.1.5.1 and the corresponding interrogation-reply protocols are defined in 3.1.2.4.

3.1.2.5.2 MODE S-ONLY ALL-CALL TRANSACTIONS

Note.— These transactions allow the ground to acquire Mode S aircraft by use of an interrogation addressed to all Mode S-equipped aircraft. The reply is via downlink format 11 which returns the aircraft address. The interrogation-reply protocols are defined in 3.1.2.4.

Mode S-only all-call interrogation, uplink format 11

1	6	10	14	17	33
UF	PR	IC	CL		AP
5	9	13	16	32	56

The format of this interrogation shall consist of these fields:

Field	Reference
UF uplink format	3.1.2.3.2.1.1
PR probability of reply	3.1.2.5.2.1.1
IC interrogator code	3.1.2.5.2.1.2
CL code label	3.1.2.5.2.1.3
spare — 16 bits	
AP address/parity	3.1.2.3.2.1.3

3.1.2.5.2.1.1 *PR: Probability of reply.* This 4-bit (6-9) uplink field shall contain commands to the transponder specifying the probability of reply to that interrogation (3.1.2.5.4). Codes are as follows:

0	signifies reply with probability of 1
1	signifies reply with probability of 1/2
2	signifies reply with probability of 1/4
3	signifies reply with probability of 1/8
4	signifies reply with probability of 1/16

5, 6, 7	not assigned
8	signifies disregard lockout, reply with probability of 1
9	signifies disregard lockout, reply with probability of 1/2
10	signifies disregard lockout, reply with probability of 1/4
11	signifies disregard lockout, reply with probability of 1/8
12	signifies disregard lockout, reply with probability of 1/16
13, 14, 15	not assigned.

3.1.2.5.2.1.2 *IC: Interrogator code*. This 4-bit (10-13) uplink field shall contain either the 4-bit interrogator identifier code (3.1.2.5.2.1.2.3) or the lower 4 bits of the 6-bit surveillance identifier code (3.1.2.5.2.1.2.4) depending on the value of the CL field (3.1.2.5.2.1.3).

3.1.2.5.2.1.2.1 **Recommendation.**—*It is recommended that whenever possible an interrogator should operate using a single interrogator code.*

3.1.2.5.2.1.2.2 *The use of multiple interrogator codes by one interrogator*. An interrogator shall not interleave Mode Sonly all-call interrogations using different interrogator codes.

Note.— An explanation of RF interference issues, sector size and impact on data link transactions is presented in the Aeronautical Surveillance Manual (Doc 9924).

3.1.2.5.2.1.2.3 *II: Interrogator identifier. This* 4-bit value shall define an interrogator identifier (II) code. These II codes shall be assigned to interrogators in the range from 0 to 15. The II code value of 0 shall only be used for supplementary acquisition in conjunction with acquisition based on lockout override (3.1.2.5.2.1.4 and 3.1.2.5.2.1.5). When two II codes are assigned to one interrogator only, one II code shall be used for full data link purposes.

Note.— Limited data link activity including single segment Comm-A, uplink and downlink broadcast protocols and GICB extraction may be performed by both II codes.

3.1.2.5.2.1.2.4 *SI: Surveillance identifier*. This 6-bit value shall define a surveillance identifier (SI) code. These SI codes shall be assigned to interrogators in the range from 1 to 63. The SI code value of 0 shall not be used. The SI codes shall be used with the multisite lockout protocols (3.1.2.6.9.1). The SI codes shall not be used with the multisite communications protocols (3.1.2.6.11.3.2, 3.1.2.7.4 or 3.1.2.7.7).

3.1.2.5.2.1.3 *CL: Code label*. This 3-bit (14-16) uplink field shall define the contents of the IC field.

Coding (in binary)

000 signifies that the IC field contains the II code
001 signifies that the IC field contains SI codes 1 to 15
010 signifies that the IC field contains SI codes 16 to 31
011 signifies that the IC field contains SI codes 32 to 47
100 signifies that the IC field contains SI codes 48 to 63

The other values of the CL field shall not be used.

3.1.2.5.2.1.3.1 *Surveillance identifier (SI) code capability report*. Transponders which process the SI codes (3.1.2.5.2.1.2.4) shall report this capability by setting bit 35 to 1 in the surveillance identifier capability (SIC) subfield of the MB field of the data link capability report (3.1.2.6.10.2.2).

3.1.2.5.2.1.4 Operation based on lockout override

Note 1.— The Mode S-only all-call lockout override provides the basis for acquisition of Mode S aircraft for interrogators that have not been assigned a unique IC (II or SI code) for full Mode S operation (protected acquisition by ensuring that no other interrogator on the same IC can lock out the target in the same coverage area).

Note 2.— Lockout override is possible using any interrogator code.

3.1.2.5.2.1.4.1 *Maximum Mode S-only all-call interrogation rate.* The maximum rate of Mode S-only all-call interrogations made by an interrogator using acquisition based onlockout override shall depend on the reply probability as follows:

a) for a reply probability equal to 1.0:

the smaller of 3 interrogations per 3 dB beam dwell or 30 interrogations per second;

b) for a reply probability equal to 0.5:

the smaller of 5 interrogations per 3 dB beam dwell or 60 interrogations per second; and

c) for a reply probability equal to 0.25 or less:

the smaller of 10 interrogations per 3 dB beam dwell or 125 interrogations per second.

Note.— These limits have been defined in order to minimize the RF pollution generated by such a method while keeping a minimum of replies to allow acquisition of aircraft within a beam dwell.

3.1.2.5.2.1.4.2 **Recommendation**.—*Passive acquisition without using all-call interrogations should be used in the place of lockout override.*

Note.— The Aeronautical Surveillance Manual(Doc 9924) provides guidance on different passive acquisition methods.

3.1.2.5.2.1.4.3 Field content for a selectively addressed interrogation used by an interrogator without an assigned interrogator code. An interrogator that has not been assigned with a unique discrete interrogator code and is authorized to transmit shall use the II code 0 to perform the selective interrogations. In this case, selectively addressed interrogations used in connection with acquisition using lockout override shall have interrogation field contents restricted as follows:

UF = 4, 5, 20 or 21
PC = 0
RR $\neq$ 16 if RRS = 0
DI = 7
IIS = 0
LOS = 0 except as specified in 3.1.2.5.2.1.5
TMS = 0

Note.— These restrictions permit surveillance and GICB transactions, but prevent the interrogation from making any changes to transponder multisite lockout or communications protocol states.

3.1.2.5.2.1.5 Supplementary acquisition using II equals 0

Note 1.— The acquisition technique defined in 3.1.2.5.2.1.4 provides rapid acquisition for most aircraft. Due to the probabilistic nature of the process, it may take many interrogations to acquire the last aircraft of a large set of aircraft in the same beam dwell and near the same range (termed a local garble zone). Acquisition performance is greatly improved for the acquisition of these aircraft through the use of limited selective lockout using II equals 0.

Note 2.— Supplementary acquisition consists of locking out acquired aircraft to II=0 followed by acquisition by means of the Mode S-only all-call interrogation with II=0. Only the aircraft not yet acquired and not yet locked-out will reply resulting in an easier acquisition.

3.1.2.5.2.1.5.1 *Lockout within a beam dwell*

3.1.2.5.2.1.5.1.1 **Recommendation**.— *When II equals 0 lockout is used to supplement acquisition, all aircraft within the beam dwell of the aircraft being acquired should be commanded to lock out to II equals 0, not just those in the garble zone.*

Note.— Lockout of all aircraft in the beam dwell will reduce the amount of all-call fruit replies generated to the II equals 0 all-call interrogations.

3.1.2.5.2.1.5.2 *Duration of lockout*

3.1.2.5.2.1.5.2.1 Interrogators performing supplementary acquisition using II equals0 shall perform acquisition by transmitting a lockout command for no more than two consecutive scans to each of the aircraft already acquired in the beam dwell containing the garble zone and shall not repeat it before 48 seconds have elapsed.

Note.— Minimizing the lockout time reduces the probability of conflict with the acquisition activities of a neighbouring interrogator that is also using II equals 0 for supplementary acquisition.

3.1.2.5.2.1.5.2.2 **Recommendation.—** *Mode S only all-call interrogations withII=0 for the purpose of supplementary acquisition should take place within a garble zone over no more than two consecutive scans or a maximum of 18 seconds.*

3.1.2.5.2.2 All-call reply, downlink format 11

1 — 5	6 — 8	9 — 32	33 — 56
DF	CA	AA	PI

The reply to the Mode S-only all-call or the Mode A/C/S all-call interrogation shall be the Mode S all-call reply, downlink format 11. The format of this reply shall consist of these fields:

Field	Reference
DF downlink format	3.1.2.3.2.1.2
CA capability	3.1.2.5.2.2.1
AA address announced	3.1.2.5.2.2.2
PI parity/interrogator identifier	3.1.2.3.2.1.4

3.1.2.5.2.2.1 CA: Capability. This 3-bit (6-8) downlink field shall convey information on the transponder level, the additional information below, and shall be used in formats DF = 11 and DF = 17.

Coding

0 signifies Level 1 transponder (surveillance only), and no ability to set CA code 7 and either airborne or on the ground
1 reserved
2 reserved
3 reserved
4 signifies Level 2 or above transponder and ability to set CA code 7 and on the ground
5 signifies Level 2 or above transponder and ability to set CA code 7 and airborne
6 signifies Level 2 or above transponder and ability to set CA code 7 and either airborne or on the ground
7 signifies the DR field is not equal to 0 or the FS field equals 2, 3, 4 or 5, and either airborne or on the ground

When the conditions for CA code 7 are not satisfied, aircraft with Level 2 or above transponders:

a) that do not have automatic means to set the on-the-ground condition shall use CA code 6; and

b) with automatic on-the-ground determination shall use CA code 4 when on the ground and 5 when airborne.

Data link capability reports (3.1.2.6.10.2.2) shall be available from aircraft installations that set CA code 4, 5, 6 or 7.

Note.— CA codes 1 to 3 are reserved to maintain backward compatibility.

3.1.2.5.2.2.2 *AA: Address announced.* This 24-bit (9-32) downlink field shall contain the aircraft address which provides unambiguous identification of the aircraft.

3.1.2.5.3 *Lockout protocol*. The all-call lockout protocol defined in 3.1.2.6.9 shall be used by the interrogator with respect to an aircraft once the address of that specific aircraft has been acquired by an interrogator provided that:

— the interrogator is using an IC code different from zero; and

— the aircraft is located in an area where the interrogator is authorized to use lockout.

Note 1.— Following acquisition, a transponder is interrogated by discretely addressed interrogations as prescribed in

3.1.2.6, 3.1.2.7 and 3.1.2.8 and the all-call lockout protocol is used to inhibit replies to further all-call interrogations.

Note 2.— Regional IC allocation bodies may define rules limiting the use of selective interrogation and lockout protocol (e.g. no lockout in defined limited area, use of intermittent lockout in defined areas, and no lockout of aircraft not yet equipped with SI code capability).

3.1.2.5.4 Stochastic all-call protocol. The transponder shall execute a random process upon acceptance of a Mode Sonly all-call with a PR code equal to 1 to 4 or 9 to 12. A decision to reply shall be made in accordance with the probability specified in the interrogation. A transponder shall not reply if a PR code equal to5, 6, 7, 13, 14 or 15 is received (3.1.2.5.2.1.1).

Note.— The random occurrence of replies makes it possible for the interrogator to acquire closely spaced aircraft, replies from which would otherwise synchronously garble each other.

3.1.2.6 ADDRESSED SURVEILLANCE AND STANDARD LENGTH COMMUNICATION TRANSACTIONS

Note 1.— The interrogations described in this section are addressed to specific aircraft. There are two basic interrogation and reply types, short and long. The short interrogations and replies are UF 4 and 5 and DF 4 and 5, while the long interrogations and replies are UF 20 and 21 and DF 20 and 21.

Note 2.— The communications protocols are given in 3.1.2.6.11. These protocols describe the control of the data exchange.

3.1.2.6.1 SURVEILLANCE,ALTITUDE REQUEST,UPLINK FORMAT 4

1	6	9	14	17	33
UF	PC	RR	DI	SD	AP
5	8	13	16	32	56

The format of this interrogation shall consist of these fields:

Field	Reference
UF uplink format	3.1.2.3.2.1.1
PC protocol	3.1.2.6.1.1
RR reply request	3.1.2.6.1.2
DI designator identification	3.1.2.6.1.3
SD special designator	3.1.2.6.1.4
AP address/parity	3.1.2.3.2.1.3

3.1.2.6.1.1 *PC: Protocol.* This 3-bit, (6-8) uplink field shall contain operating commands to the transponder. The PC field values 2 through 7 shall be ignored and the values 0 and 1 shall be processed for surveillance or Comm-A interrogations containing DI = 3 (3.1.2.6.1.4.1).

Coding

0 signifies no action
1 1 signifies non-selective all-call lockout (3.1.2.6.9.2)
2 not assigned
3 not assigned
4 signifies close out Comm-B (3.1.2.6.11.3.2.3)
5 signifies close out uplink ELM (3.1.2.7.4.2.8)
6 signifies close out downlink ELM (3.1.2.7.7.3)
7 not assigned.

3.1.2.6.1.2 *RR: Reply request.* This 5-bit, (9-13) uplink field shall command the length and content of a requested reply.

The last four bits of the 5-bit RR code, transformed into their decimal equivalent, shall designate the BDS1 code (3.1.2.6.11.2or 3.1.2.6.11.3) of the requested Comm-B message if the most significant bit (MSB) of the RR code is 1 (RR is equal to or greater than 16).

Coding

RR = 0-15 shall be used to request a reply with surveillance format (DF = 4 or 5);
RR = 16-31 shall be used to request a reply with Comm-B format (DF = 20 or 21);
RR = 16 shall be used to request transmission of an air-initiated Comm-B according to 3.1.2.6.11.3;
RR = 17 shall be used to request a data link capability report according to 3.1.2.6.10.2.2;
RR = 18 shall be used to request aircraft identification according to 3.1.2.9;
19-31 are not assigned in section 3.1.

Note.— Codes 19-31 are reserved for applications such as data link communications, airborne collision avoidance systems (ACAS), etc.

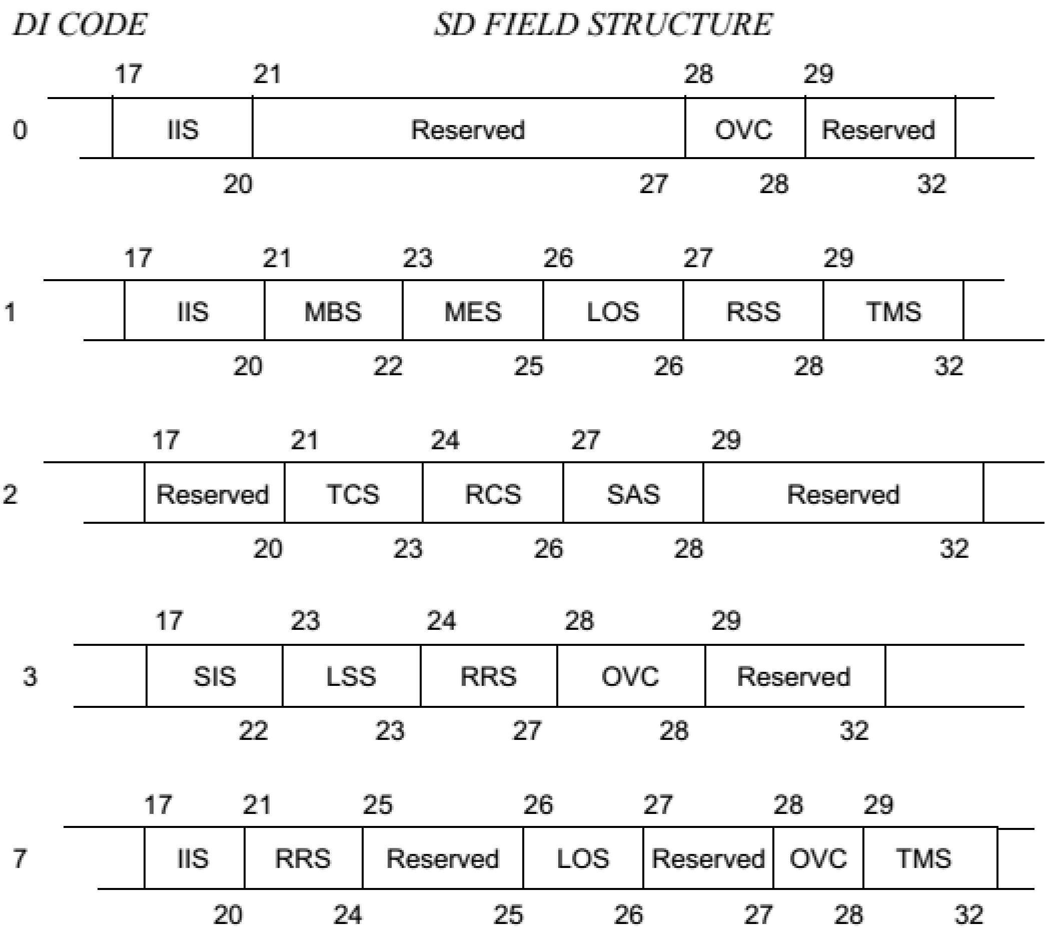
3.1.2.6.1.3 *DI: Designator identification.* This 3-bit (14-16) uplink field shall identify the structure of the SD field (3.1.2.6.1.4).

Coding

0 signifies SD not assigned except for IIS, bits 21-27 and 29-32 are not assigned, and bit 28 contains the "OVC" (overlay control - 3.1.2.6.1.4.1 i))
1 signifies SD contains multisite and communications control information
2 signifies SD contains control data for extended squitter
3 signifies SD contains SI multisite lockout, broadcast and GICB control information, and bit 28 contains the "OVC" (overlay control - 3.1.2.6.1.4.1 i))
4-6 signifies SD not assigned
7 signifies SD contains extended data readout request, multisite and communications control information, and bit 28 contains the "OVC" (overlay control - 3.1.2.6.1.4.1 i))

3.1.2.6.1.4 *SD: Special designator*. This 16-bit (17-32) uplink field shall contain control codes which depend on the coding in the DI field.

Note.— The special designator (SD) field is provided to accomplish the transfer of multisite, lockout and communications control information from the ground station to the transponder.



3.1.2.6.1.4.1 *Subfields in SD*. The SD field shall contain information as follows:

a) If DI = 0, 1 or 7:

IIS, the 4-bit (17-20) interrogator identifier subfield shall contain an assigned identifier code of the interrogator (3.1.2.5.2.1.2.3).

b) If DI = 0:

bits 21-32 are not assigned.

c) If DI = 1:

MBS, the 2-bit (21, 22) multisite Comm-B subfield shall have the following codes:

0 signifies no Comm-B action
1 signifies air-initiated Comm-B reservation request (3.1.2.6.11.3.1)
2 signifies Comm-B closeout (3.1.2.6.11.3.2.3)
3 not assigned.

MES, the 3-bit (23-25) multisite ELM subfield shall contain reservation and closeout commands for ELM as follows:

1 signifies no ELM action
2 signifies uplink ELM reservation request (3.1.2.7.4.1)
3 signifies uplink ELM closeout (3.1.2.7.4.2.8)
4 signifies downlink ELM reservation request (3.1.2.7.7.1.1)
5 signifies downlink ELM closeout (3.1.2.7.7.3)
6 signifies uplink ELM reservation request and downlink ELM closeout
7 signifies uplink ELM closeout and downlink ELM reservation request
8 signifies uplink ELM and downlink ELM closeouts.

RSS, the 2-bit (27, 28) reservation status subfield shall request the transponder to report its reservation status in the UM field. The following codes have been assigned:

0 signifies no request
1 signifies report Comm-B reservation status in UM
2 signifies report uplink ELM reservation status in UM
3 signifies report downlink ELM reservation status in UM.

d) If DI = 1 or 7:

LOS, the 1-bit (26) lockout subfield, if set to 1, shall signify a multisite lockout command from the interrogator indicated in IIS. LOS set to 0, shall be used to signify that no change in lockout state is commanded.

TMS, the 4-bit (29-32) tactical message subfield shall contain communications control information used by the data link avionics.

e) If DI = 7:

RRS, the 4-bit (21-24) reply request subfield in SD shall give the BDS2 code of a requested Comm-B reply.

Bits 25, 27 and 28 are not assigned.

f) If DI = 2:

TCS, the 3-bit (21-23) type control subfield in SD shall control the extended squitter airborne and surface format types reported by the transponder and its response to Mode A/C, Mode A/C/S all-call and Mode S-only all-call interrogations. The following codes have been assigned:

0 signifies no surface format types or reply inhibit command
1 signifies surface format types for the next 15 seconds (see 3.1.2.6.1.4.2)
2 signifies surface format types for the next 60 seconds (see 3.1.2.6.1.4.3)

3 signifies cancel surface format types and reply inhibit commands
4-7 reserved.

The transponder shall be able to accept a new command even though a prior command has not as yet timed out.

RCS, the 3-bit (24-26) rate control subfield in SD shall control the squitter rate of the transponder when it is reporting the extended squitter surface type formats. This subfield shall have no effect on the transponder squitter rate when it is reporting the extended squitter airborne type formats. The following codes have been assigned:

0 signifies no surface extended squitter rate command
1 signifies report high surface extended squitter rate for 60 seconds
2 signifies report low surface extended squitter rate for 60 seconds
3-7 reserved.

Note 1.— The definition of high and low extended squitter rates is given in 3.1.2.8.6.4 and applies to the surface position, aircraft identification and category, and the operational status messages.

Note 2.— As stated in 3.1.2.8.5.2 d), acquisition squitters are transmitted when surface type format extended squitters are not being transmitted.

SAS, the 2-bit (27-28) surface antenna subfield in SD shall control the selection of the transponder diversity antenna that is used for (1) the extended squitter when the transponder is reporting the surface type formats, and (2) the acquisition squitter when the transponder is reporting the on-the-ground status. This subfield shall have no effect on the transponder diversity antenna selection when it is reporting the airborne status. The following codes have been assigned:

0 signifies no antenna command
1 signifies alternate top and bottom antennas for 120 seconds
2 signifies use bottom antenna for 120 seconds
3 signifies return to the default.

Note.— The top antenna is the default condition (3.1.2.8.6.5).

g) If DI = 3:

SIS, the 6-bit (17-22) surveillance identifier subfield in SD shall contain an assigned surveillance identifier code of the interrogator (3.1.2.5.2.1.2.4).

LSS, the 1-bit (23) lockout surveillance subfield, if set to 1, shall signify a multisite lockout command from the interrogator indicated in SIS. If set to 0, LSS shall signify that no change in lockout state is commanded.

RRS, the 4-bit (24-27) reply request subfield in SD shall contain the BDS2 code of a requested GICB register.

Bits 28 to 32 are not assigned.

h) If DI=4, 5 or 6 then the SD field has no meaning and shall not impact other transaction cycle protocols. These DI codes remain reserved until future assignment of the SD field.

i) If DI = 0, 3 or 7: In addition to the requirements provided above, the "SD" shall contain the following:

"OVC": The 1-bit (bit 28) "overlay control" subfield in "SD" is used by the interrogator to command that the data parity ("DP" 3.1.2.3.2.1.5) be overlaid upon the resulting reply to the interrogation in accordance with paragraph 3.1.2.6.11.2.5.

3.1.2.6.1.4.2 *TCS subfield equal to one (1) in the SD field for extended squitters*. When the TCS subfield in the SD field is set equal to one (1), it shall signify the following:

a) broadcast of the extended squitter surface formats, including the surface position message (3.1.2.8.6.4.3), the identification and category message (3.1.2.8.6.4.4), the aircraft operational status message (3.1.2.8.6.4.6) and the aircraft status message (3.1.2.8.6.4.6) for the next 15 seconds at the appropriate rates on the top antenna for aircraft systems having the antenna diversity capability, except if otherwise specified by SAS (3.1.2.6.1.4.1 f));

b) inhibit replies to Mode A/C, Mode A/C/S all-call and Mode S-only all-call interrogations for the next 15 seconds;

c) broadcast of acquisition squitters as per 3.1.2.8.5 using antenna as specified in 3.1.2.8.5.3 a);

d) does not impact the air/ground state reported via the CA, FS and VS fields;

e) discontinue broadcast of the extended squitter airborne message formats; and

f) broadcast of the extended squitter surface formats at the rates according to the TRS subfield unless commanded to transmit at the rates set by the RCS subfield.

3.1.2.6.1.4.3 *TCS subfield equal to two (2) in the SD field for extended squitters.* When the TCS subfield in the SD field is set equal to two (2), it shall signify the following:

a) broadcast of the extended squitter surface formats, including the surface position message (3.1.2.8.6.4.3), the identification and category message (3.1.2.8.6.4.4), the aircraft operational status message (3.1.2.8.6.4.6) and the aircraft status message (3.1.2.8.6.4.6) for the next 60 seconds at the appropriate rates on the top antenna for aircraft systems having the antenna diversity capability, except if otherwise specified by SAS (3.1.2.6.1.4.1 f));

b) inhibit replies to Mode A/C, Mode A/C/S all-call and Mode S-only all-call interrogations for the next 60 seconds;

c) broadcast of acquisition squitters as per 3.1.2.8.5 using antenna as specified in 3.1.2.8.5.3 a);

d) does not impact the air/ground state reported via the CA, FS and VS fields;

e) discontinue broadcast of the extended squitter airborne message formats; and

f) broadcast of the extended squitter surface formats at the rates according tothe TRS subfield unless commanded to transmit at the rates set by the RCS subfield.

3.1.2.6.1.5 *PC and SD field processing.* When DI = 1, PC field processing shall be completed before processing the SD field.

3.1.2.6.2 *COMM-AALTITUDE REQUEST,UPLINK FORMAT 20*

1	6	9	14	17	33	89
UF	PC	RR	DI	SD	MA	AP
5	8	13	16	32	88	112

The format of this interrogation shall consist of these fields:

Field	*Reference*
UF uplink format	3.1.2.3.2.1.1
PC protocol	3.1.2.6.1.1
RR reply request	3.1.2.6.1.2
DI designator identification	3.1.2.6.1.3
SD special designator	3.1.2.6.1.4
MA message, Comm-A	3.1.2.6.2.1
AP address/parity	3.1.2.3.2.1.3

3.1.2.6.2.1 *MA: Message, Comm-A.* This 56-bit (33-88) field shall contain a data link message to the aircraft.

3.1.2.6.3 *SURVEILLANCE IDENTITY REQUEST,UPLINK FORMAT 5*

1	6	9	14	17	33
UF	PC	RR	DI	SD	AP
5	8	13	16	32	56

The format of this interrogation shall consist of these fields:

Field	*Reference*
UF uplink format	3.1.2.3.2.1.1
PC protocol	3.1.2.6.1.1
RR reply request	3.1.2.6.1.2
DI designator identification	3.1.2.6.1.3
SD special designator	3.1.2.6.1.4
AP address/parity	3.1.2.3.2.1.3

3.1.2.6.4 *COMM-AIDENTITY REQUEST,UPLINK FORMAT 21*

1	6	9	14	17	33	89
UF	PC	RR	DI	SD	MA	AP
5	8	13	16	32	88	112

The format of this interrogation shall consist of these fields:

Field	*Reference*
UF uplink format	3.1.2.3.2.1.1
PC protocol	3.1.2.6.1.1
RR reply request	3.1.2.6.1.2
DI designator identification	3.1.2.6.1.3
SD special designator	3.1.2.6.1.4
MA message, Comm-A	3.1.2.6.2.1
AP address/parity	3.1.2.3.2.1.3

3.1.2.6.5 *SURVEILLANCE ALTITUDE REPLY,DOWNLINK FORMAT 4*

1	6	9	14	20	33
DF	FS	DR	UM	AC	AP
5	8	13	19	32	56

This reply shall be generated in response to an interrogation UF 4 or 20 with an RR field value less than 16. The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
FS flight status	3.1.2.6.5.1
DR downlink request	3.1.2.6.5.2
UM utility message	3.1.2.6.5.3

AC altitude code 3.1.2.6.5.4
AP address/parity 3.1.2.3.2.1.3

3.1.2.6.5.1 *FS: Flight status.* This 3-bit (6-8) downlink field shall contain the following information:

Coding

0 signifies no alert and no SPI, aircraft is airborne
1 signifies no alert and no SPI, aircraft is on the ground
2 signifies alert, no SPI, aircraft is airborne
3 signifies alert, no SPI, aircraft is on the ground
4 signifies alert and SPI, aircraft is airborne or on the ground
5 signifies no alert and SPI, aircraft is airborne or on the ground
6 reserved
7 not assigned

Note.— The conditions which cause an alert are given in 3.1.2.6.10.1.1.

3.1.2.6.5.2 *DR: Downlink request.* This 5-bit (9-13) downlink field shall contain requests to downlink information.

Coding

0 signifies no downlink request
1 signifies request to send Comm-B message
2 reserved for ACAS
3 reserved for ACAS
4 signifies Comm-B broadcast message 1 available
5 signifies Comm-B broadcast message 2 available
6 reserved for ACAS
7 reserved for ACAS
8-15 not assigned
16-31 see downlink ELM protocol (3.1.2.7.7.1)

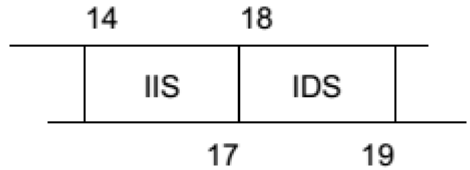
Codes 1-15 shall take precedence over codes 16-31.

Note.— Giving precedence to codes 1-15 permits the announcement of a Comm-B message to interrupt the announcement of a downlink ELM. This gives priority to the announcement of the shorter message.

3.1.2.6.5.3 *UM: Utility message.* This 6-bit (14-19) downlink field shall contain transponder communications status information as specified in 3.1.2.6.1.4.1 and 3.1.2.6.5.3.1.

3.1.2.6.5.3.1 *Subfields in UM for multisite protocols*

UM FIELD STRUCTURE



The following subfields shall be inserted by the transponder into the UM field of the reply if a surveillance or Comm-A interrogation (UF equals 4, 5, 20, 21) contains DI = 1 and RSS other than 0:

IIS: The 4-bit (14-17) interrogator identifier subfield reports the identifier ofthe interrogator that is reserved for multisite communications.

IDS: The 2-bit (18, 19) identifier designator subfield reports the type of reservation made by the interrogator identified in IIS.

Assigned coding is:

0 signifies no information
1 signifies IIS contains Comm-B II code
2 signifies IIS contains Comm-C II code
3 signifies IIS contains Comm-D II code.

3.1.2.6.5.3.2 *Multisite reservation status*. The interrogator identifier of the ground station currently reserved for multisite Comm-B delivery (3.1.2.6.11.3.1) shall be transmitted in the IIS subfield together with code 1 in the IDS subfield ifthe UM content is not specified by the interrogation (when DI = 0 or 7, or when DI = 1 and RSS = 0).

The interrogator identifier of the ground station currently reserved for downlink ELM delivery (3.1.2.7.6.1), if any, shall be transmitted in the IIS subfield together with code 3 in the IDS subfield if the UM content is not specified by the interrogation and there is no current Comm-B reservation.

3.1.2.6.5.4 *AC: Altitude code.* This 13-bit (20-32) field shall contain altitude coded as follows:

a) Bit 26 is designated as the M bit, and shall be 0 if the altitude is reported in feet. M equals 1 shall be reserved to indicate that the altitude reporting is in metric units.

b) If M equals 0, then bit 28 is designated as the Q bit. Q equals 0 shall be used to indicate that the altitude is reported in 100-foot increments. Q equals 1 shall be used to indicate that the altitude is reported in 25-foot increments.

c) If the M bit (bit 26) and the Q bit (bit 28) equal 0, the altitude shall be coded according to the pattern for Mode C replies of 3.1.1.7.12.2.3. Starting with bit 20 the sequence shall be C1, A1, C2, A2, C4, A4, ZERO, B1, ZERO, B2, D2, B4, D4.

d) If the M bit equals 0 and the Q bit equals 1, the 11-bit field represented by bits 20 to 25, 27 and 29 to 32 shall represent a binary coded field with a least significant bit (LSB) of 25 ft. The binary value of the positive decimal integer "N" shall be encoded to report pressure-altitude in the range [(25 N – 1 000) plus or minus 12.5 ft]. The coding of 3.1.2.6.5.4 c) shall be used to report pressure-altitude above 50 187.5 ft.

Note 1.— This coding method is only able to provide values between minus 1 000 ft and plus 50 175 ft.

Note 2.— The most significant bit (MSB) of this field is bit 20 as required by 3.1.2.3.1.3.

e) If the M bit equals 1, the 12-bit field represented by bits 20 to 25 and 27 to 31 shall be reserved for encoding altitude in metric units.

f) 0 shall be transmitted in each of the 13bits of the AC field if altitude information is not available or if the altitude has been determined invalid.

3.1.2.6.6 *COMM-BALTITUDE REPLY,DOWNLINK FORMAT 20*

1	6	9	14	20	33	89
DF	FS	DR	UM	AC	MB	AP
5	8	13	19	32	88	112

This reply shall be generated in response to an interrogation UF4 or 20 with an RR field value greater than 15. The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
FS flight status	3.1.2.6.5.1
DR downlink request	3.1.2.6.5.2
UM utility message	3.1.2.6.5.3
AC altitude code	3.1.2.6.5.4
MB message, Comm-B	3.1.2.6.6.1
AP address/parity	3.1.2.3.2.1.3

3.1.2.6.6.1 *MB: Message, Comm-B*. This 56-bit (33-88) downlink field shall be used to transmit data link messages to the ground.

3.1.2.6.7 *SURVEILLANCE IDENTITY REPLY,DOWNLINK FORMAT 5*

1–5	6–8	9–13	14–19	20–32	33–56
DF	FS	DR	UM	ID	AP

This reply shall be generated in response to an interrogation UF 5 or 21 with an RR field value less than 16. The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
FS flight status	3.1.2.6.5.1
DR downlink request	3.1.2.6.5.2
UM utility message	3.1.2.6.5.3
ID identity	3.1.2.6.7.1
AP address/parity	3.1.2.3.2.1.3

3.1.2.6.7.1 *ID: Identity (Mode A code)*. This 13-bit (20-32) field shall contain aircraft identity code, in accordance with the pattern for Mode A replies in 3.1.1.6. Starting with bit 20, the sequence shall be C1, A1, C2, A2, C4, A4, ZERO, B1, D1, B2, D2, B4, D4.

3.1.2.6.8 *COMM-BIDENTITY REPLY,DOWNLINK FORMAT 21*

1–5	6–8	9–13	14–19	20–32	33–88	89–112
DF	FS	DR	UM	ID	MB	AP

This reply shall be generated in response to an interrogation UF5 or 21 with an RR field value greater than 15. The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
FS flight status	3.1.2.6.5.1
DR downlink request	3.1.2.6.5.2
UM utility message	3.1.2.6.5.3
ID identity	3.1.2.6.7.1
MB message, Comm-B	3.1.2.6.6.1
AP address/parity	3.1.2.3.2.1.3

3.1.2.6.9 *LOCKOUT PROTOCOLS*

Note.— Non-selective all-call lockout and multisite lockout are not mutually exclusive. Interrogators using multisite lockout protocols for interrogator networking coordination may use non-selective lockout commands in the same interrogation. For example, the non-selective lockout may be used to prevent Mode S transponder replies with DF=11 to wrongly detected Mode A/C/S all-call interrogations from Mode A/C-only all-call interrogations. This is because of the misinterpretation of the narrow P4pulse as a wide P4pulse.

3.1.2.6.9.1 *Multisite all-call lockout*

Note.— The multisite lockout protocol prevents transponder acquisition from being denied one ground station by lockout commands from an adjacent ground station that has overlapping coverage.

3.1.2.6.9.1.1 The multisite lockout command shall be transmitted in the SD field (3.1.2.6.1.4.1). A lockout command for an II code shall be transmitted in an SD with DI = 1 or DI = 7. An II lockout command shall be indicated by LOS code equals 1 and the presence of a non-zero interrogator identifier in the IIS subfield of SD. A lockout command for an SI code shall be transmitted in an SD with DI = 3. SI lockout shall be indicated by LSS equals 1 and the presence of a non-zero interrogator identifier in the SIS subfield of SD. After a transponder has accepted an interrogation containing a multisite lockout command, that transponder shall commence to lock out (i.e. not accept) any Mode S-only all-call interrogation which includes the identifier of the interrogator that commanded the lockout. The lockout shall persist for an interval TL(3.1.2.10.3.9) after the last acceptance of an interrogation containing the multisite lockout command. Multisite lockout shall not prevent acceptance of a Mode S-only all-call interrogation containing PR codes 8 to 12. If a lockout command (LOS = 1) is received together with IIS = 0, it shall be interpreted as a non-selective all-call lockout (3.1.2.6.9.2).

Note 1.— Fifteen interrogators can send independent multisite II lockout commands. In addition, 63 interrogators can send independent SI lockout commands. Each of these lockout commands must be timed separately.

Note 2.— Multisite lockout (which only uses non-zero II codes) does not affect the response of the transponder to Mode S-only all-call interrogations containing II equals 0 or to Mode A/C/S all-call interrogations.

3.1.2.6.9.2 *Non-selective all-call lockout*

Note 1.— In cases where the multisite lockout protocol for II codes is not required (e.g. there is no overlapping coverage or there is ground station coordination via ground-to-ground communications) the non-selective lockout protocol may be used. On acceptance of an interrogation containing code 1 in the PC field, a transponder shall commence to lockout (i.e. not accept)two types of all-call interrogations:

a) the Mode S-only all-call (UF = 11), with II equals 0; and

b) the Mode A/C/S all-call of 3.1.2.1.5.1.1.

This lockout condition shall persist for an interval TD(3.1.2.10.3.9) after the last receipt of the command. Non-selective lockout shall not prevent acceptance of a Mode S-only all-call interrogation containing PR codes 8 to 12.

Note 2.— Non-selective lockout does not affect the response of the transponder to Mode S-only all-call interrogations containing II not equal to 0.

3.1.2.6.10 *BASIC DATA PROTOCOLS*

3.1.2.6.10.1 *Flight status protocol*. Flight status shall be reported in the FS field (3.1.2.6.5.1).

3.1.2.6.10.1.1 *Alert.* An alert condition shall be reported in the FS field if the Mode A identity code transmitted in Mode A replies and in downlink formats DF equals 5 and DF equals 21 are changed by the pilot.

3.1.2.6.10.1.1.1 *Permanent alert condition*. The alert condition shall be maintained if the Mode A identity code is changed to 7500, 7600 or 7700.

3.1.2.6.10.1.1.2 *Temporary alert condition.* The alert condition shall be temporary and shall cancel itself after TC seconds if the Mode A identity code is changed to a value other than those listed in 3.1.2.6.10.1.1.1. The TC shall be retriggered and continued for TC seconds after any change has been accepted by the transponder function.

Note 1.— This retriggering is performed to ensure that the ground interrogator obtains the desired Mode A identity code before the alert condition is cleared.

Note 2.— The value of TC is given in 3.1.2.10.3.9.

3.1.2.6.10.1.1.3 *Termination of the permanent alert condition*. The permanent alert condition shall be terminated and replaced by a temporary alert condition when the Mode A identity code is set to a value other than 7500, 7600 or 7700.

3.1.2.6.10.1.2 *Ground report. The* on-the-ground status of the aircraft shall be reported in the CA field (3.1.2.5.2.2.1), the FS field (3.1.2.6.5.1), and the VS field (3.1.2.8.2.1). If an automatic indication of the on-the-ground condition (e.g., from a weight on wheels or strut switch) is available at the transponder data interface, it shall be used as the basis for the reporting of on-the-ground status except as specified in 3.1.2.6.10.3.1. If such indication is not available at the transponder data interface (3.1.2.10.5.1.3), the FS and VS codes shall indicate that the aircraft is airborne and the CA field shall indicate that the aircraft is either airborne or on the ground (CA = 6).

3.1.2.6.10.1.3 *Special position identification (SPI).* An equivalent of the SPI pulse shall be transmitted by Mode S transponders in the FS field and the surveillance status subfield (SSS) when manually activated. This pulse shall be transmitted for TIseconds after initiation (3.1.1.6.3, 3.1.1.7.13 and 3.1.2.8.6.3.1.1).

Note.— The value of TI is given in 3.1.2.10.3.9.

3.1.2.6.10.2 *Capability reporting protocol.* The data structure and content of the data link capability report registers shall be implemented in such a way that interoperability is ensured.

Note 1.— Aircraft capability is reported in special fields as defined in the following paragraphs.

Note 2.— The data format of the registers for reporting capability is specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.6.10.2.1 *Capability report.* The 3-bit CA field, contained in the all-call reply, DF equals 11, shall report the basic capability of the Mode S transponder as described in 3.1.2.5.2.2.1.

3.1.2.6.10.2.2 *Data link capability report.* The data link capability report shall provide the interrogator with a description of the data link capability of the Mode S installation.

Note.— The data link capability report is contained in register 1016 with a possible extension in registers 1116to 1616 when any continuation will be required.

3.1.2.6.10.2.2.1 *Extraction and subfields in MB for data link capability report*

3.1.2.6.10.2.2.1.1 E*xtraction of the data link capability report contained in register 1016.* The report shall be obtained by a ground-initiated Comm-B reply in response to an interrogation containing RR equals 17 and DI is not equal to 7 or DI equals 7 and RRS equals 0 (3.1.2.6.11.2).

3.1.2.6.10.2.2.1.2 *Sources of data link capability.* Data link capability reports shall contain the capabilities provided by the transponder, the ADLP and the ACAS unit. If external inputs are lost, the transponder shall zero the corresponding bits in the data link report.

3.1.2.6.10.2.2.1.3 The data link capability report shall contain information on the following capabilities as specified in Table 3-6.

3.1.2.6.10.2.2.1.4 The Mode S subnetwork version number shall contain information to ensure interoperability with older airborne equipment.

3.1.2.6.10.2.2.1.4.1 The Mode S subnetwork version number shall indicate that all implemented subnetwork functions are in compliance with the requirements of the indicated version number. The Mode S subnetwork version number shall be set to a non-zero value if at least one DTE or Mode S specific service is installed.

Note.— The version number does not indicate that all possible functions of that version are implemented.

3.1.2.6.10.2.2.2 *Updating of the data link capability report.* The transponder shall, at intervals not exceeding four seconds, compare the current data link capability status (bits 41-88 in the data link capability report) with that last reported and shall, if a difference is noted, initiate a revised data link capability report by Comm-B broadcast (3.1.2.6.11.4) for BDS1 = 1 (33-36) and BDS 2 =

0 (37-40). The transponder shall initiate, generate and announce the revised capability report even if the aircraft data link capability is degraded or lost. The transponder shall ensure that the BDS code is set for the data link capability report in all cases, including a loss of the interface.

Note.— The setting of the BDS code by the transponder ensures that a broadcast change of capability report will contain the BDS code for all cases of data link failure (e.g. the loss of the transponder data link interface).

3.1.2.6.10.2.2.3 *Zeroing of bits in the data link capability report*

If capability information to the transponder fails to provide anupdate at a rate of at least once every 4 seconds, the transponder shall insert ZERO in bits 41 to 56 of the data link capability report (transponder register 1016).

Note.— Bits 1 to 8 contain the BDS1 and BDS2 codes. Bits 16 and 37 to 40 contain ACAS capability information. Bit 33 indicates the availability of aircraft identification data and is set by the transponder when the data comes from a separate interface and not from the ADLP. Bit 35 is the SI code indication. All of these bits are inserted by the transponder.

3.1.2.6.10.2.3 *Common usage GICB capability report*. Common usage GICB services which are being actively updated shall be indicated in transponder register 1716.

3.1.2.6.10.2.4 Mode S specific services GICB capability reports. GICB services that are installed shall be reported in registers 1816 to 1C16.

3.1.2.6.10.2.5Mode S specific services MSP capability reports. MSP services that are installed shall be reported in registers 1D16 to 1F16.

3.1.2.6.10.3 *Validation of on-the-ground status declared by an automatic means*

Note.— For aircraft with an automatic means of determining vertical status, the CA field reports whether the aircraft is airborne or on the ground. ACAS II acquires aircraft using the short or extended squitter, both of which contain the CA field. If an aircraft reports on-the-ground status, that aircraft will not be interrogated by ACAS II in order to reduce unnecessary interrogation activity. If the aircraft is equipped to report extended squitter messages, the function that formats these messages may have information available to validate that an aircraft reporting "on-the-ground" is actually airborne.

3.1.2.6.10.3.1 Aircraft with an automatic means for determining the on-the-ground state on which transponders have access to at least one of the parameters, ground speed, radio altitude or airspeed, shall perform the following validation check:

If the automatically determined air/ground status is not available or is "airborne", no validation shall be performed. If the automatically determined air/ground status is available and "on-the-ground" condition is being reported, the air/ground status shall be overridden and changed to "airborne" if:

Ground Speed > 100 knots OR Airspeed > 100 knots OR Radio Altitude > 50 feet

3.1.2.6.11 *STANDARD LENGTH COMMUNICATIONS PROTOCOLS*

Note 1.— The two types of standard length communications protocols are Comm-A and Comm-B; messages using these protocols are transferred under the control of the interrogator. Comm-A messages are sent directly to the transponder and are completed within one transaction. A Comm-B message is used to transfer information from air to ground and can be initiated either by the interrogator or the transponder. In the case of ground-initiated Comm-B transfers, the interrogator requests data to be read out from the transponder, which delivers the message in the same transaction. In the case of air initiated Comm-B transfers, the transponder announces the intention to transmit a message; in a subsequent transaction an interrogator will extract the message.

Note 2.— In a non-selective air-initiated Comm-B protocol all transactions necessary can be controlled by any interrogator.

Note 3.— In some areas of overlapping interrogator coverage there may be no means for coordinating interrogator activities via ground communications. Air-initiated Comm-B communications protocols require more than one transaction for completion. Provision is made to ensure that a Comm-B message is closed out only by the interrogator that actually transferred the message. This can be accomplished through the use of the multisite Comm-B communications protocols or through the use of the enhanced Comm-B communications protocols.

Note 4.— The multisite and the non-selective communications protocols cannot be used simultaneously in a region of overlapping interrogator coverage unless the interrogators coordinate their communications activities via ground communications.

Note 5.— The multisite communications protocol is independent of the multisite lockout protocol. That is, the multisite communications protocol may be used with the non-selective lockout protocol and vice versa. The choice of lockout and communications protocols to be used depends upon the network management technique being used.

Note 6.— The broadcast Comm-B protocol can be used to make a message available to all active interrogators.

3.1.2.6.11.1 *Comm-A.* The interrogator shall deliver a Comm-A message in the MA field of an interrogation UF = 20 or 21.

3.1.2.6.11.1.1 *Comm-A technical acknowledgement.* Acceptance of a Comm-A interrogation shall be automatically technically acknowledged by the transponder, by the transmission of the requested reply (3.1.2.10.5.2.2.1).

Note.— The receipt of a reply from the transponder according to the rules of 3.1.2.4.1.2.3 d) and 3.1.2.4.1.3.2.2.2 is the acknowledgement to the interrogator that the interrogation has been accepted by the transponder. If either uplink or downlink fail, this reply will be missing and the interrogator will normally send the message again. In the case of downlink failure, the transponder may receive the message more than once.

3.1.2.6.11.1.2 *Comm-A broadcast.* If a Comm-A broadcast interrogation is accepted (3.1.2.4.1.2.3.1.3) information transfer shall be handled according to 3.1.2.10.5.2.1.1 but other transponder functions shall not be affected and a reply shallnot be transmitted.

Note 1.— There is no technical acknowledgement to a Comm-A broadcast message.

Note 2.— Since the transponder does not process the control fields of a Comm-A broadcast interrogation, the 27 bits following the UF field are also available for user data.

3.1.2.6.11.2 *Ground-initiated Comm-B*

3.1.2.6.11.2.1 Comm-B data selector, BDS.The 8-bit BDS code shall determine the register whose contents shall be transferred in the MB field of the Comm-B reply. It shall be expressed in two groups of 4 bits each, BDS1 (most significant 4 bits) and BDS2 (least significant 4 bits).

Note.— The transponder register allocation is specified in Annex 10, Volume III, Part I, Chapter 5, Table 5-24.

3.1.2.6.11.2.2 *BDS1 code.* The BDS1 code shall be as defined in the RR field of a surveillance or Comm-A interrogation.

3.1.2.6.11.2.3 *BDS2 code.* The BDS2 code shall be as defined in the RRS subfield of the SD field (3.1.2.6.1.4.1) when DI = 7 or DI = 3. If no BDS2 code is specified (i.e. DI is not equal to either 7 or 3) it shall signify that BDS2 = 0.

3.1.2.6.11.2.4 *Protocol.* On receipt of such a request, the MB field of the reply shall contain the contents of the requested ground-initiated Comm-B register.

3.1.2.6.11.2.4.1 If the requested register is not servicedby the aircraft installation, the transponder shall reply and the MB field of the reply shall contain all ZEROs.

3.1.2.6.11.2.5 Overlay control. If the "DI" code of the Comm-B requesting interrogation is 0, 3 or 7, the "SD" contains the overlay control (OVC) field in accordance with paragraph 3.1.2.6.1.4.1 i).

a) If the "OVC" is equal to "1," then the reply to the interrogation shall contain the "DP" (data parity) field in accordance with paragraph 3.1.2.3.2.1.5; and

b) If the "OVC" is equal to "0," then the reply to the interrogation shall contain the "AP" field in accordance with paragraph 3.1.2.3.2.1.3.

3.1.2.6.11.3 *Air-initiated Comm-B*

3.1.2.6.11.3.1 *General protocol*. The transponder shall announce the presence of an air-initiated Comm-B message with the insertion of code 1 in the DR field. To extract an air-initiated Comm-B message, the interrogator shall transmit a request for a Comm-B message reply in a subsequent interrogation with RR equal to 16 and, if DI equals 7, RRS must be equal to 0 (3.1.2.6.11.3.2.1 and 3.1.2.6.11.3.3.1). Receipt of this request code shall cause the transponder to transmit the air initiated Comm-B message. If a command to transmit an air-initiated Comm-B message is received while no message is waiting to be transmitted, the reply shall contain all ZEROs in the MB field.

The reply that delivers the message shall continue to contain code 1 in the DR field. After a Comm-B closeout has been accomplished, the message shall be cancelled and the DR code belonging to this message immediately removed. If another air-initiated Comm-B message is waiting to be transmitted, the transponder shall set the DR code to 1, so that the reply contains the announcement of this next message.

Note.— The announcement and cancellation protocol ensures that an air-initiated message will not be lost due to uplink or downlink failures that occur during the delivery process.

3.1.2.6.11.3.2 *Additional protocol for multisite air-initiated Comm-B*

Note.— The announcement of an air-initiated Comm-B message waiting to be delivered may be accompanied by a multisite reservation status report in the UM field (3.1.2.6.5.3.2).

Recommendation.— *An interrogator should not attempt to extract a message if it has determined that it is not the reserved site.*

3.1.2.6.11.3.2.1 *Message transfer.* An interrogator shall request a Comm-B reservation and extract an air-initiated Comm-B message by transmitting a surveillance or Comm-A interrogation UF equals 4, 5, 20 or 21 containing:

RR = 16
DI = 1
IIS = assigned interrogator identifier
MBS = 1 (Comm-B reservation request)

Note.— A Comm-B multisite reservation request is normally accompanied by a Comm-B reservation status request (RSS = 1). This causes the interrogator identifier of the reserved site to be inserted in the UM field of the reply.

3.1.2.6.11.3.2.1.1 Protocol procedure in response to this interrogation shall depend upon the state of the B-timer which indicates if a Comm-B reservation is active. This timer shall run for TR seconds.

Note 1.— The value of TRis given in 3.1.2.10.3.9.

a) If the B-timer is not running, the transponder shall grant a reservation to the requesting interrogator by:

1) storing the IIS of the interrogation as the Comm-B II; and

2) starting the B-timer.

A multisite Comm-B reservation shall not be granted by the transponder unless an air-initiated Comm-B message is waiting to be transmitted and the requesting interrogation contains RR equals 16, DI equals 1, MBS equals 1 and IIS is not 0.

b) If the B-timer is running and the IIS of the interrogation equals the Comm-B II, the transponder shall restart the B timer.

c) If the B-timer is running and the IIS of the interrogation does not equal the Comm-B II, then there shall be no change to the Comm-B II or the B-timer.

Note 2.— In case c) the reservation request has been denied.

3.1.2.6.11.3.2.1.2In each case the transponder shall reply with the Comm-B message in the MB field.

3.1.2.6.11.3.2.1.3 An interrogator shall determine if it isthe reserved site for this message through coding in the UM field. If it is the reserved site it shall attempt to close out the message in a subsequent interrogation. If it is not the reserved site it shall not attempt to close out the message.

3.1.2.6.11.3.2.2 *Multisite-directed Comm-B transmissions.* To direct an air-initiated Comm-B message to a specific interrogator, the multisite Comm-B protocol shall be used. When the B-timer is not running, the interrogator identifier of the desired destination shall be stored as the Comm-B II. Simultaneously the B-timer shall be started and the DR code shall be set to 1. For a multisite-directed Comm-B message, the B-timer shall not automatically time out but shall continue to run until:

a) the message is read and closed out by the reserved site; or

b) the message is cancelled (3.1.2.10.5.4) by the data link avionics.

Note.— The protocols of 3.1.2.6.5.3 and 3.1.2.6.11.3.2.1 will then result in delivery of the message to the reserved site. The data link avionics may cancel the message if delivery to the reserved site cannot be accomplished.

3.1.2.6.11.3.2.3 *Multisite Comm-B closeout*. The interrogator shall close out a multisite air-initiated Comm-B by transmitting either a surveillance or a Comm-A interrogation containing:

either DI = 1
IIS = assigned interrogator identifier
MBS = 2 (Comm-B closeout)
or DI = 0, 1 or 7
IIS = assigned interrogator identifier
PC = 4 (Comm-B closeout)

The transponder shall compare the IIS of the interrogation to the Comm-B II and if the interrogator identifiers do not match, the message shall not be cleared and the status of the Comm-B II, B-timer, and DR code shall not be changed. If the interrogator identifiers match, the transponder shall set the Comm-B II to 0, reset the B-timer, clear the DR code for this message and clear the message itself. The transponder shall not close out a multisite air-initiated Comm-B message unless it has been read out at least once by the reserved site.

3.1.2.6.11.3.2.4 *Automatic expiration of Comm-B reservation.* If the B-timer period expires before a multisite closeout has been accomplished, the Comm-B II shall be set to 0 and the B-timer reset. The Comm-B message and the DR field shall not be cleared by the transponder.

Note.— This makes it possible for another site to read and clear this message.

3.1.2.6.11.3.3 Additional protocol for non-selective air-initiated Comm-B

Note.— In cases where the multisite protocols are not required (i.e. no overlapping coverage or sensor coordination via ground-to-ground communication), the non-selective air-initiated Comm-B protocol may be used.

3.1.2.6.11.3.3.1 *Message transfer*. The interrogator shall extract the message by transmitting either RR equals 16 and DI is not equal to 7, or RR equals 16, DI equals 7 and RRS equals 0 in a surveillance or Comm-A interrogation.

3.1.2.6.11.3.3.2 *Comm-B closeout.* The interrogator shall close out a non-selective air-initiated Comm-B message by transmitting PC equals 4 (Comm-B closeout).On receipt of this command, the transponder shall perform closeout, unless the B-timer is running. If the B-timer is running, indicating thata multisite reservation is in effect, closeout shall be accomplished as per 3.1.2.6.11.3.2.3. The transponder shall not close out a non-selective air-initiated Comm-B message unless it has been read out at least once by an interrogation using non-selective protocols.

3.1.2.6.11.3.4 Enhanced air-initiated Comm-B protocol

Note.— The enhanced air-initiated Comm-B protocol provides a higher data link capacity by permitting parallel delivery of air-initiated Comm-B messages by up to sixteen interrogators, one for each II code. Operation without the need for multisite Comm-B reservations is possible in regions of overlapping coverage for interrogators equipped for the enhanced air-initiated Comm-B protocol. The protocol is fully *conformant to the standard multisite protocol and thus is compatible with interrogators that are not equipped for the enhanced protocol.*

3.1.2.6.11.3.4.1 The transponder shall be capable of storing each of the sixteen II codes: (1) an air-initiated or multisite-directed Comm-B message and (2) the contents of GICB registers 2 through 4.

Note.— GICB registers 2 through 4 are used for the Comm-B linking protocol defined in the Mode S subnetwork SARPs (Annex 10, Volume III, Part I, Chapter 5).

3.1.2.6.11.3.4.2 *Enhanced multisite air-initiated Comm-B protocol*

3.1.2.6.11.3.4.2.1 *Initiation.* An air-initiated Comm-B message input into the transponder shall be stored in the registers assigned to II = 0.

3.1.2.6.11.3.4.2.2 *Announcement and extraction.* A waiting air-initiated Comm-B message shall be announced in the DR field of the replies to all interrogators for which a multisite directed Comm-B message is not waiting. The UM field of the announcement reply shall indicate that the message is not reserved for any II code, i.e. the IIS subfield shall be set to 0. When a command to read this message is received from a given interrogator, the reply containing the message shall contain an IIS subfield content indicating that the message is reserved for the II code contained in the interrogation from that interrogator. After readout and until closeout, the message shall continue to be assigned to that II code. Once a message is assigned to a specific II code, announcement of this message shall be no longer made in the replies to interrogators with other II codes. If the message is not closed out by the assigned interrogator for the period of the B-timer, the message shall revert back to multisite air-initiated status and the process shall repeat. Only one multisite air-initiated Comm-B message shall be in process at a time.

3.1.2.6.11.3.4.2.3 *Closeout.* A closeout for a multisite air-initiated message shall only be accepted from the interrogator that is currently assigned to transfer the message.

3.1.2.6.11.3.4.2.4 *Announcement of the next message waiting.* The DR field shall indicate a message waiting in the reply to an interrogation containing a Comm-B closeout if an unassigned air-initiated message is waiting and has not been assigned to a II code, or if a multisite-directed message is waiting for that II code (3.1.2.6.11.3.4.3).

3.1.2.6.11.3.4.3 *Enhanced multisite directed Comm-B protocol*

3.1.2.6.11.3.4.3.1 *Initiation.* When a multisite directed message is input into the transponder, it shall be placed in the Comm-B registers assigned to the II code specified for the message. If the registers for this II code are already occupied, (i.e. a multisite directed message is already in process to this II code) the new message shall be queued until the current transaction with that II code is closed out.

3.1.2.6.11.3.4.3.2 *Announcement.* Announcement of a Comm-B message waiting transfer shall be made using the DR field as specified in 3.1.2.6.5.2 with the destination interrogator II code contained in the IIS subfield as specified in

3.1.2.6.5.3.2. The DR field and IIS subfield contents shall be set specifically for the interrogator that is to receive the reply. A waiting multisite directed message shall only be announced in the replies to the intended interrogator. It shall not be announced in the replies to other interrogators.

Note 1.— If a multisite-directed message is waiting for II = 2, the surveillance replies to that interrogator will contain DR = 1 and IIS = 2. If this is the only message in process, replies to all other interrogators will indicate that no message is waiting.

Note 2.— In addition to permitting parallel operation, this form of announcement enables a greater degree of announcement of downlink ELMs. The announcements for the downlink ELM and the Comm-B share the DR field. Only one announcement can take place at a time due to coding limitations. In case both a Comm-B and a downlink ELM are waiting, announcement preference is given to the Comm-B. In the example above, if an air-directed Comm-B was waiting for II = 2 and a multisite-directed downlink ELM was waiting for II = 6, both interrogators would see their respective announcements on the first scan since there would be no Comm-B announcement to II = 6 to block the announcement of the waiting downlink ELM.

3.1.2.6.11.3.4.3.3 *Closeout.* Closeout shall be accomplished as specified in 3.1.2.6.11.3.2.3.

3.1.2.6.11.3.4.3.4 Announcement of the next message waiting.The DR field shall indicate a message waiting in the reply to an interrogation containing a Comm-B closeout if another multisite directed message is waiting for that II code, or if an air-initiated message is waiting and has not been assigned to a II code. (See 3.1.2.6.11.3.4.2.4.)

3.1.2.6.11.3.4.4 *Enhanced non-selective Comm-B protocol.* The availability of a non-selective Comm-B message shall be announced to all interrogators. Otherwise, the protocol shall be as specified in 3.1.2.6.11.3.3.

3.1.2.6.11.4 *Comm-B broadcast*

Note 1.— A Comm-B message may be broadcast to all active interrogators within range. Messages are alternately numbered 1 and 2 and are self-cancelling after 18 seconds. Interrogators have no means to cancel Comm-B broadcast messages.

Note 2.— Use of the Comm-B broadcast is restricted to transmission of information which does not require a subsequent ground-initiated uplink response.

Note 3.— The timer used for the Comm-B broadcast cycle is the same as that used for the Comm-B multisite protocol.

Note 4.— Data formats for Comm-B broadcast are specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.6.11.4.1 *Initiation.* A Comm-B broadcast cycle shall not be initiated when an air-initiated Comm-B is waiting to be transmitted. A Comm-B broadcast cycle shall begin with:

a) the insertion of DR code 4 or 5, (3.1.2.6.5.2) into replies with DF 4, 5, 20 or 21; and

b) the starting of the B-timer.

3.1.2.6.11.4.2 *Extraction*. To extract the broadcast message, an interrogator shall transmit RR equals 16 and DI not equal to 7 or RR equals 16 and DI equals 7 with RRS equals 0 in a subsequent interrogation.

3.1.2.6.11.4.3 *Expiration.* When the B-timer period expires, the transponder shall clear the DR code for this message, discard the present broadcast message and change the broadcast message number (from 1 to 2 or 2 to 1) in preparation for a subsequent Comm-B broadcast.

3.1.2.6.11.4.4 *Interruption. In* order to prevent a Comm-B broadcast cycle from delaying the delivery of an air-initiated Comm-B message, provision shall be made for an air-initiated Comm-B to interrupt a Comm-B broadcast cycle. If a broadcast cycle is interrupted, the B-timer shall be reset, the interrupted broadcast message shall be retained and the messagenumber shall not be changed. Delivery of the interrupted broadcast message shall recommence when no air-initiated CommB transaction is in effect. The message shall then be broadcast for the full duration of the B-timer.

3.1.2.6.11.4.5 *Enhanced broadcast Comm-B protocol*. A broadcast Comm-B message shall be announced to all interrogators using II codes. The message shall remain active for the period of the B-timer for each II code. The provision forinterruption of a broadcast by non-broadcast Comm-B as specified in 3.1.2.6.11.4.4 shall apply separately to each II code. When the B-timer period has been achieved for all II codes, the broadcast message shall be automatically cleared as specified in 3.1.2.6.11.4.3. A new broadcast message shall not beinitiated until the current broadcast has been cleared.

Note.— Due to the fact that broadcast message interruption occurs independently for each II code, it is possible that the broadcast message timeout will occur at different times for different II codes.

3.1.2.7 *EXTENDED LENGTH COMMUNICATION TRANSACTIONS*

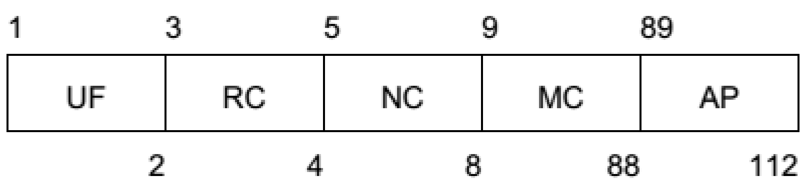
Note 1.— Long messages, either on the uplink or the downlink, can be transferred by the extended length message (ELM) protocols through the use of Comm-C (UF = 24) and Comm-D (DF = 24) formats respectively. The ELM uplink protocol provides for the transmission on the uplink of up to sixteen 80-bit message segments before requiring a reply from the transponder. They also allow a corresponding procedure on the downlink.

Note 2.— In some areas of overlapping interrogator coverage there may be no means for coordinating interrogator activities via ground communications. However, the ELM communication protocols require more than one transaction for completion; coordination is thus necessary to ensure that segments from different messages are not interleaved and that transactions are not inadvertently closed out by the wrong interrogator. This can be accomplished through the use of the multisite communications protocols or through the use of the enhanced ELM protocols.

Note 3.— Downlink extended length messages are transmitted only after authorization by the interrogator. The segments to be transmitted are contained in Comm-D replies. As with air-initiated Comm-B messages, downlink ELMs are either announced to all interrogators or directed to a specific interrogator. In the former case an individual interrogator can use the multisite protocol to reserve for itself the ability to close out the downlink ELM transaction. A transponder can be instructed to identify the interrogator that has reserved the transponder for an ELM transaction. Only that interrogator can close out the ELM transaction and reservation.

Note 4.— The multisite protocol and the non-selective protocol cannot be used simultaneously in a region of overlapping interrogator coverage unless the interrogators coordinate their communications activities via ground communications.

3.1.2.7.1 *COMM-C,UPLINK FORMAT 24*



The format of this interrogation shall consist of these fields:

Field	*Reference*
UF uplink format	3.1.2.3.2.1.1
RC reply control	3.1.2.7.1.1
NC number of C-segment	3.1.2.7.1.2
MC message, Comm-C	3.1.2.7.1.3
AP address/parity	3.1.2.3.2.1.3

3.1.2.7.1.1 *RC: Reply control*. This 2-bit (3-4) uplink field shall designate segment significance and reply decision.

Coding

RC = 0 signifies uplink ELM initial segment in MC
= 1 signifies uplink ELM intermediate segment in MC
= 2 signifies uplink ELM final segment in MC

= 3 signifies a request for downlink ELM delivery (3.1.2.7.7.2)

3.1.2.7.1.2 *NC: Number of C-segment*. This 4-bit (5-8) uplink field shall designate the number of the message segment contained in MC (3.1.2.7.4.2.1). NC shall be coded as a binary number.

3.1.2.7.1.3 *MC: Message, Comm-C*. This 80-bit (9-88) uplink field shall contain:

a) one of the segments of a sequence used to transmit an uplink ELM to the transponder containing the 4-bit (9-12) IIS subfield; or

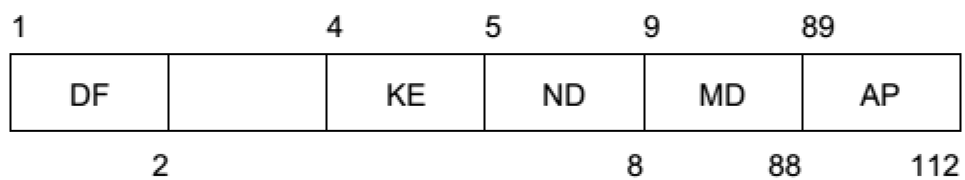
b) control codes for a downlink ELM, the 16-bit (9-24) SRS subfield (3.1.2.7.7.2.1) and the 4-bit (25-28) IIS subfield.

Note.— Message content and codes are not included in this chapter except for 3.1.2.7.7.2.1.

3.1.2.7.2 INTERROGATION-REPLY PROTOCOL FOR UF24

Note.— Interrogation-reply coordination for the above format follows the protocol outlined in Table 3-5 (3.1.2.4.1.3.2.2)

3.1.2.7.3 *COMM-D,DOWNLINK FORMAT 24*



The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2 spare — 1 bit
KE control, ELM	3.1.2.7.3.1
ND number of D-segment	3.1.2.7.3.2
MD message, Comm-D	3.1.2.7.3.3
AP address/parity	3.1.2.3.2.1.3

3.1.2.7.3.1 *KE: Control, ELM.* This 1-bit (4) downlink field shall define the content of the ND and MD fields.

Coding

KE = 0 signifies downlink ELM transmission
1 signifies uplink ELM acknowledgement

3.1.2.7.3.2 *ND: Number of D-segment*. This 4-bit (5-8) downlink field shall designate the number of the message segment contained in MD (3.1.2.7.7.2). ND shall be coded as a binary number.

3.1.2.7.3.3 *MD: Message, Comm-D.* This 80-bit (9-88) downlink field shall contain:

a) one of the segments of a sequence used to transmit a downlink ELM to the interrogator; or

b) control codes for an uplink ELM.

3.1.2.7.4 *MULTISITE UPLINK ELMPROTOCOL*

3.1.2.7.4.1 *Multisite uplink ELM reservation*. An interrogator shall request a reservation for an uplink ELM by transmitting a surveillance or Comm-A interrogation containing:

DI = 1
IIS = assigned interrogator identifier
MES = 1 or 5 (uplink ELM reservation request)

Note.— A multisite uplink ELM reservation request is normally accompanied by an uplink ELM reservation status request (RSS = 2). This causes the interrogator identifier of the reserved site to be inserted in the UM field of the reply.

3.1.2.7.4.1.1 Protocol procedure in response to this interrogation shall depend upon the state of the C-timer which indicates if an uplink ELM reservation is active. This timer shall run for TR seconds.

Note 1.— The value of TR is given in 3.1.2.10.3.9.

a) If the C-timer is not running, the transponder shall grant a reservation to the requesting interrogator by:

1) storing the IIS of the interrogation as the Comm-C II and,

2) starting the C-timer.

b) If the C-timer is running and the IIS of the interrogation equals the Comm-C II, the transponder shall restart the C timer.

c) If the C-timer is running and the IIS of the interrogation does not equal the Comm-C II, there shall be no change to the Comm-C II or the C-timer.

Note 2.— In case c) the reservation request has been denied.

3.1.2.7.4.1.2 An interrogator shall not start ELM activity unless, during the same scan, having requested an uplink ELM status report, it has received its own interrogator identifier as the reserved interrogator for uplink ELM in the UM field.

Note.— If ELM activity is not started during the same scan as the reservation, a new reservation request may be made during the next scan.

3.1.2.7.4.1.3 If uplink ELM delivery is not completed on the current scan, the interrogator shall ensure that it still has a reservation before delivering additional segments on a subsequent scan.

3.1.2.7.4.2 *Multisite uplink ELM delivery.* The minimum length of an uplink ELM shall be 2 segments, the maximum length shall be 16 segments.

3.1.2.7.4.2.1 *Initial segment transfer.* The interrogator shall begin the ELM uplink delivery for an n-segment message (NC values from 0 to n-1) by a Comm-C transmission containing RC equals 0. The message segment transmitted in the MC field shall be the last segment of the message and shall carry NC equals n-1.

On receipt of an initializing segment (RC = 0) the transponder shall establish a "setup" defined as:

a) clearing the number and content of previous segment storage registers and the associated TAS field;

b) assigning storage space for the number of segments announced in NC ofthis interrogation; and

c) storing the MC field of the segment received.

The transponder shall not reply to this interrogation.

Receipt of another initializing segment shall result in a new setup within the transponder.

3.1.2.7.4.2.2 *Transmission acknowledgement*. The transponder shall use the TAS subfield to report the segments received so far in an uplink ELM sequence. The information contained in the TAS subfield shall be continually updated by the transponder as segments are received.

Note.— Segments lost in uplink transmission are noted by their absence in the TAS report and are retransmitted by the interrogator which will then send further final segments to assess the extent of message completion.

3.1.2.7.4.2.2.1 *TAS, transmission acknowledgement subfield in MD.* This 16-bit (17-32) downlink subfield in MD reports the segment numbers received so far in an uplink ELM sequence. Starting with bit 17, which denotes segment number 0, each of the following bits shall be set to ONE if the corresponding segment of the sequence has been received. TAS shall appear in MD if KE equals 1 in the same reply.

3.1.2.7.4.2.3 *Intermediate segment transfer.* The interrogator shall transfer intermediate segments by transmitting Comm-C interrogations with RC equals 1. The transponder shall store the segments and update TAS only if the setup of

3.1.2.7.4.2.1 is in effect and if the received NC is smaller than the value stored at receipt of the initial segment. No reply shall be generated on receipt of an intermediate segment.

Note.— Intermediate segments may be transmitted in any order.

3.1.2.7.4.2.4 *Final segment transfer.* The interrogator shall transfer a final segment by transmitting a Comm-C interrogation with RC equals 2. The transponder shall store the content of the MC field and update TAS if the setup of

3.1.2.7.4.2.1 is in effect and if the received NC is smaller than the value of the initial segment NC. The transponder shall reply under all circumstances as per 3.1.2.7.4.2.5.

Note 1.— This final segment transfer interrogation can contain any message segment.

Note 2.— RC equals 2 is transmitted any time that the interrogator wants to receive the TAS subfield in the reply. Therefore, more than one "final" segment may be transferred during the delivery of an uplink ELM.

3.1.2.7.4.2.5 *Acknowledgement reply*. On receipt of a final segment, the transponder shall transmit a Comm-D reply (DF = 24), with KE equals 1 and with the TAS subfield in the MD field. This reply shall be transmitted at 128 microseconds plus or minus 0.25 microsecond following the sync phase reversal of the interrogation delivering the final segment.

3.1.2.7.4.2.6 *Completed message.* The transponder shall deem the message complete if all segments announced by NC in the initializing segment have been received. If the message is complete, the message content shall be delivered to the outside via the ELM interface of 3.1.2.10.5.2.1.3 and cleared. No later-arriving segments shall be stored. The TAS content shall remain unchanged until either a new setup is called for (3.1.2.7.4.2.1) or until closeout (3.1.2.7.4.2.8).

3.1.2.7.4.2.7 *C-timer restart*. The C-timer shall be restarted each time that a received segment is stored and the CommC II is not 0.

Note.— The requirement for the Comm-C II to be non-zero prevents the C-timer from being restarted during a nonselective uplink ELM transaction.

3.1.2.7.4.2.8 *Multisite uplink ELM closeout.* The interrogator shall close out a multisite uplink ELM by transmitting either a surveillance or a Comm-A interrogation containing:

either DI = 1
IIS = assigned interrogator identifier

MES = 2, 6 or 7 (uplink ELM closeout)

or DI = 0, 1 or 7

IIS = assigned interrogator identifier

PC = 5 (uplink ELM closeout)

The transponder shall compare the IIS of the interrogation to the Comm-C II and if the interrogator identifiers do not match, the state of the ELM uplink process shall not be changed. If the interrogator identifiers match, the transponder shall set the Comm-C II to 0, reset the C-timer, clear the stored TAS and discard any stored segments of an incomplete message.

3.1.2.7.4.2.9 *Automatic multisite uplink ELM closeout*. If the C-timer period expires before a multisite closeout has been accomplished the closeout actions described in 3.1.2.7.4.2.8 shall be initiated automatically by the transponder.

3.1.2.7.5 NON-SELECTIVE UPLINK ELM

Note.— In cases where the multisite protocols are not required (for example, no overlapping coverage or sensor coordination via ground-to-ground communication), the non-selective uplink ELM protocol may be used. Non-selective uplink ELM delivery shall take place as for multisite uplink ELMs described in 3.1.2.7.4.2. The interrogator shall close out an uplink ELM by transmitting PC equals 5 (uplink ELM closeout) in a surveillance or Comm-A interrogation. On receipt of this command, the transponder shall perform closeout, unless the C-timer is running. If the C-timer is running, indicating that a multisite reservation is in effect, the closeout shall be accomplished as per 3.1.2.7.4.2.8. An uncompleted message, present when the closeout is accepted, shall be cancelled.

3.1.2.7.6 *ENHANCED UPLINK ELMPROTOCOL*

Note.— The enhanced uplink ELM protocol provides a higher data link capacity by permitting parallel delivery of uplink ELM messages by up to sixteen interrogators, one for each II code. Operation without the need for multisite uplink ELM reservations is possible in regions of overlapping coverage for interrogators equipped for the enhanced uplink ELM protocol. The protocol is fully conformant to the standard multisite protocol and thus is compatible with interrogators that are not equipped for the enhanced protocol.

3.1.2.7.6.1 *General*

3.1.2.7.6.1.1 The interrogator shall determine from the data link capability report whether the transponder supports the enhanced protocols. If the enhanced protocols are not supported by both the interrogator and the transponder, the multisite reservation protocols specified in 3.1.2.7.4.1 shall be used.

Note.— If the enhanced protocols are supported, uplink ELMs delivered using the multisite protocol may be delivered without a prior reservation.

3.1.2.7.7 *MULTISITE DOWNLINK ELMPROTOCOL*

3.1.2.7.7.1 *Initialization.* The transponder shall announce the presence of a downlink ELM of n segments by making the binary code corresponding to the decimal value 15 + navailable for insertion in the DR field of a surveillance or Comm-B reply, DF equals 4, 5, 20, 21. This announcement shall remain active until the ELM is closed out (3.1.2.7.7.3, 3.1.2.7.8.1).

3.1.2.7.7.1.1 *Multisite downlink ELM reservation*. An interrogator shall request a reservation for extraction of a downlink ELM by transmitting a surveillance or Comm-A interrogation containing:

DI = 1
IIS = assigned interrogator identifier
MES = 3 or 6 (downlink ELM reservation request)

Note.— A multisite downlink ELM reservation request is normally accompanied by a downlink ELM reservation status request (RSS = 3). This causes the interrogator identifier of the reserved interrogator to be inserted in the UM field of the reply.

3.1.2.7.7.1.1.1 Protocol procedure in response to this interrogation shall depend upon the state of the D-timer which indicates if a downlink ELM reservation is active. This timer shall run for TR seconds.

Note 1.— The value of TR is given in 3.1.2.10.3.9.

a) if the D-timer is not running, the transponder shall grant a reservation to the requesting interrogator by:

1) storing the IIS of the interrogation as the Comm-D II; and

2) starting the D-timer.

A multisite downlink ELM reservation shall not be granted by the transponder unless a downlink ELM is waiting to be transmitted.

b) if the D-timer is running and the IIS of the interrogation equals the Comm-D II, the transponder shall restart the D-timer; and

c) if the D-timer is running and the IIS of the interrogation does not equal the Comm-D II, there shall be no change to the Comm-D II or D-timer.

Note 2.— In case c) the reservation request has been denied.

3.1.2.7.7.1.1.2 An interrogator shall determine if it is the reserved site through coding in the UM field and, if so, it isauthorized to request delivery of the downlink ELM. Otherwise, ELM activity shall not be started during this scan.

Note.— If the interrogator is not the reserved site, a new reservation request may be made during the next scan.

3.1.2.7.7.1.1.3 If downlink ELM activity is not completed on the current scan, the interrogator shall ensure that it still has a reservation before requesting additional segments on a subsequent scan.

3.1.2.7.7.1.2 *Multisite-directed downlink ELM transmissions.* To direct a downlink ELM message to a specific interrogator, the multisite downlink ELM protocol shall be used. When the D-timer is not running, the interrogator identifier of the desired destination shall be stored as the Comm-D II. Simultaneously, the D-timer shall be started and the DR code (3.1.2.7.7.1) shall be set. For a multisite-directed downlink ELM, the D-timer shall not automatically time out but shall continue to run until:

3.1.2.7.6.1.2 **Recommendation**.— *If the transponder and the interrogator are equipped for the enhanced protocol, the interrogator should use the enhanced uplink protocol.*

3.1.2.7.6.1.3 The transponder shall be capable of storing a sixteen segment message for each of the sixteen II codes.

3.1.2.7.6.2 *Reservation processing.* The transponder shall support reservation processing for each II code as specified in 3.1.2.7.4.1

Note 1.— Reservation processing is required for interrogators that do not support the enhanced protocol.

Note 2.— Since the transponder can process simultaneous uplink ELMs for all sixteen II codes, a reservation will always be granted.

3.1.2.7.6.3 *Enhanced uplink ELM delivery and closeout*. The transponder shall process received segments separately by II code. For each value of II code, uplink ELM delivery and closeout shall be performed as specified in3.1.2.7.4.2 except that the MD field used to transmit the technical acknowledgment shall also contain the 4-bit (33-36) IIS subfield.

Note.— The interrogator may use the II code contained in the technical acknowledgement in order to verify that it has received the correct technical acknowledgement.

a) the message is read and closed out by the reserved site; or

b) the message is cancelled (3.1.2.10.5.4) by the data link avionics.

Note.— The protocols of 3.1.2.7.7.1 will then result in the delivery of the message to the reserved site. The data link avionics may cancel the message if delivery to the reserved site cannot be accomplished.

3.1.2.7.7.2 *Delivery of downlink ELMs*. The interrogator shall extract a downlink ELM by transmitting a Comm-C interrogation with RC equals 3. This interrogation shall carry the SRS subfield which specifies the segments to be transmitted.On receipt of this request, the transponder shall transfer the requested segments by means of Comm-D replies with KE equals 0 and ND corresponding to the number of the segment in MD. The first segment shall be transmitted 128 microseconds plus or minus 0.25 microsecond following the sync phase reversal of the interrogation requesting delivery and subsequent segments shall be transmitted at a rate of one every 136 microseconds plus or minus 1 microsecond. If a request is received to transmit downlink ELM segments and no message is waiting, each reply segment shall contain all ZEROs in the MD field.

Note 1.— The requested segments may be transmitted in any order.

Note 2.— Segments lost in downlink transmissions will be requested again by the interrogator on a subsequent interrogation carrying the SRS subfield. This process isrepeated until all segments have been transferred.

3.1.2.7.7.2.1 *SRS, segment request subfield in MC*. This 16-bit (9-24) uplink subfield in MC shall request the transponder to transfer downlink ELM segments. Starting with bit 9, which denotes segment number 0, each of the following bits shall be set to ONE if the transmission of the corresponding segment is requested. SRS shall appear in MC if RC equals 3 in the same interrogation.

3.1.2.7.7.2.2 *D-timer restart.* The D-timer shall be restarted each time that a request for Comm-D segments is received if the Comm-D II is non-zero.

Note.— The requirement for the Comm-DII to be non-zero prevents the D-timer from being restarted during a nonselective downlink ELM transaction.

3.1.2.7.7.3 *Multisite downlink ELM closeout*. The interrogator shall close out a multisite downlink ELM by transmitting either a surveillance or a Comm-A interrogation containing:

either DI = 1
    IIS = assigned interrogator identifier
    MES = 4, 5 or 7 (downlink ELM closeout)
or   DI = 0, 1 or 7
    IIS = assigned interrogator identifier
    PC = 6 (downlink ELM closeout).

The transponder shall compare the IIS of the interrogation to the Comm-D II and if the interrogator identifiers do not match, the state of the downlink process shall not be changed.

If the interrogator identifiers match, and if a request for transmission has been complied with at least once, the transponder shall set the Comm-D II to 0, reset the D-timer, clear the DR code for this message and clear the message itself.

If another downlink ELM is waiting to be transmitted, the transponder shall set the DR code (if no Comm-B message is waiting to be delivered) so that the reply contains the announcement of the next message.

3.1.2.7.7.4 *Automatic expiration of downlink ELM reservation.* If the D-timer period expires before a multisite closeout has been accomplished, the Comm-D II shall be set to 0, and the D-timer reset. The message and DR code shall not be cleared.

Note.— This makes it possible for another site to read and clear this message.

3.1.2.7.8 *NON-SELECTIVE DOWNLINK ELM*

Note.— In cases where the multisite protocols are not required (i.e. no overlapping coverage or sensor coordination via ground-to-ground communication), the non-selective downlink ELM protocol may be used.

Non-selective downlink ELM delivery shall take place as described in 3.1.2.7.7.2.

3.1.2.7.8.1 *Non-selective downlink ELM closeout.* The interrogator shall close out a non-selective downlink ELM by transmitting PC equals 6 (downlink ELM closeout) in a surveillance or Comm-A interrogation. On receipt of this command, and if a request for transmission has been complied with at least once, the transponder shall perform closeout unless the D-timer is running. If the D-timer is running, indicating that a multisite reservation is in effect, the closeout shall be accomplished as per 3.1.2.7.7.3.

3.1.2.7.9 *ENHANCED DOWNLINK ELMPROTOCOL*

Note.— The enhanced downlink ELM protocol provides a higher data link capacity by permitting parallel delivery of downlink ELM messages by up to sixteen interrogators, one for each II code. Operation without the need for multisite downlink ELM reservations is possible in regions of overlapping coverage for interrogators equipped for the enhanced downlink ELM protocol. The protocol is fully conformant to the standard multisite protocol and thus is compatible with interrogators that are not equipped for the enhanced protocol.

3.1.2.7.9.1 *General*

3.1.2.7.9.1.1 The interrogator shall determine from the data link capability report whether the transponder supports the enhanced protocols. If the enhanced protocols are not supported by both the interrogator and the transponder, the multisite reservation protocols specified in 3.1.2.6.11 shall be used for multisite and multisite-directed downlink ELMs.

Note.— If the enhanced protocols are supported, downlink ELMs delivered using the multisite-directed protocol can be delivered without a prior reservation.

3.1.2.7.9.1.2 **Recommendation.—** *If the transponder and the interrogator are equipped for the enhanced protocol, the interrogator should use the enhanced downlink protocol.*

3.1.2.7.9.2 *Enhanced multisite downlink ELM protocol*

3.1.2.7.9.2.1 The transponder shall be capable of storing a sixteen segment message for each of the sixteen II codes.

3.1.2.7.9.2.2 *Initialization.* A multisite message input into the transponder shall be stored in the registers assigned to II = 0.

3.1.2.7.9.2.3 *Announcement and extraction.* A waiting multisite downlink ELM message shall be announced in the DR field of the replies to all interrogators for which a multisite directed downlink ELM message is not waiting. The UM field of the announcement reply shall indicate that the message is not reserved for any II code, i.e. the IIS subfield shall be set to 0.

When a command to reserve this message is received from a given interrogator, the message shall be reserved for the II code contained in the interrogation from that interrogator. After readout and until closeout, the message shall continue to be assigned to that II code. Once a message is assigned to a specific II code, announcement of this message shall no longer be made in the replies to interrogators with other II codes. If the message is not closed out by the associated interrogator for the period of the D-timer, the message shall revert back to multisite status and the process shall repeat. Only one multisite downlink ELM message shall be in process at a time.

3.1.2.7.9.2.4 *Closeout*. A closeout for a multisite message shall only be accepted from the interrogator that was assigned most recently to transfer the message.

3.1.2.7.9.2.5 *Announcement of the next message waiting*. The DR field shall indicate a message waiting in the reply to an interrogation containing a downlink ELM closeout if an unassigned multisite downlink ELM is waiting, or if a multisite directed message is waiting for that II code (3.1.2.7.9.2).

3.1.2.7.9.3 Enhanced multisite directed downlink ELM protocol

3.1.2.7.9.3.1 *Initialization*. When a multisite directed message is input into the transponder, it shall be placed in the downlink ELM registers assigned to the II code specified for the message. If the registers for this II code are already in use (i.e. a multisite directed downlink ELM message is already in process for this II code), the new message shall be queued until the current transaction with that II code is closed out.

3.1.2.7.9.3.2 *Announcement*. Announcement of a downlink ELM message waiting transfer shall be made using the DR field as specified in 3.1.2.7.7.1 with the destination interrogator II code contained in the IIS subfield as specified in

3.1.2.6.5.3.2. The DR field and IIS subfield contents shall be set specifically for the interrogator that is to receive the reply. A waiting multisite directed message shall only be announced in the replies to the intended interrogator. It shall not be announced in replies to other interrogators.

3.1.2.7.9.3.3 *Delivery*. An interrogator shall determine if it is the reserved site through coding in the UM field. The delivery shall only be requested if it is the reserved site and shall be as specified in 3.1.2.7.7.2. The transponder shall transmit the message contained in the buffer associated with the II code specified in the IIS subfield of the segment request interrogation.

3.1.2.7.9.3.4 *Closeout*. Closeout shall be accomplished as specified in 3.1.2.7.7.3 except that a message closeout shall only be accepted from the interrogator with a II code equal to the one that transferred the message.

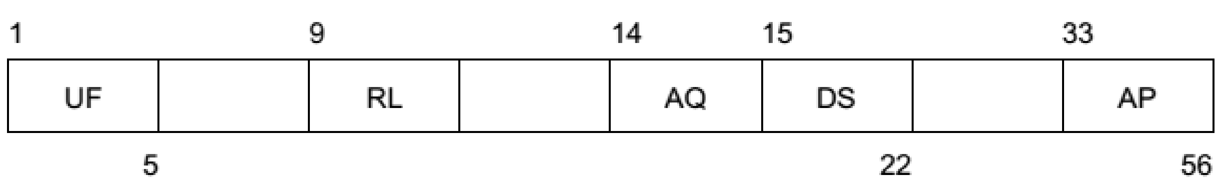
3.1.2.7.9.3.5 *Announcement of the next message waiting*. The DR field shall indicate a message waiting in the reply to an interrogation containing a downlink ELM closeout if another multisite directed message is waiting for that II code, or if a downlink message is waiting that has not been assigned a II code (3.1.2.7.9.2).

3.1.2.7.9.4 *Enhanced non-selective downlink ELM protocol*. The availability of a non-selective downlink ELM message shall be announced to all interrogators. Otherwise, the protocol shall be as specified in 3.1.2.7.7.

3.1.2.8 AIR-AIR SERVICE AND SQUITTER TRANSACTIONS

Note.— Airborne collision avoidance system (ACAS) equipment uses the formats UF or DF equals 0 or 16 for air-air surveillance.

3.1.2.8.1 *SHORT AIR-AIR SURVEILLANCE,UPLINK FORMAT 0*



The format of this interrogation shall consist of these fields:

Field *Reference*

UF uplink format 3.1.2.3.2.1.1 spare — 3 bits
RL reply length 3.1.2.8.1.2 spare — 4 bits

AQ acquisition 3.1.2.8.1.1
DS data selector 3.1.2.8.1.3 spare — 10 bits
AP address/parity 3.1.2.3.2.1.3

3.1.2.8.1.1 *AQ: Acquisition.* This 1-bit (14) uplink field shall contain a code which controls the content of the RI field.

3.1.2.8.1.2 *RL: Reply length.* This 1-bit (9) uplink field shall command the format to be used for the reply.

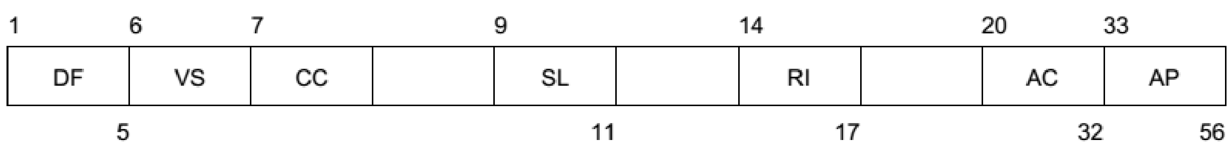
Coding

0 signifies a reply with DF = 0
1 signifies a reply with DF = 16

Note.— A transponder that does not support DF = 16 (i.e. transponder which does not support the ACAS cross-link capability and is not associated with airborne collision avoidance equipment) would not reply to a UF=0 interrogation with RL=1.

3.1.2.8.1.3 *DS: Data selector.* This 8-bit (15-22) uplink field shall contain the BDS code (3.1.2.6.11.2.1) of the GICB register whose contents shall be returned to the corresponding reply with DF = 16.

3.1.2.8.2 *SHORT AIR-AIR SURVEILLANCE,DOWNLINK FORMAT 0*



This reply shall be sent in response to an interrogation with UF equals 0 and RL equals 0. The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
VS vertical status	3.1.2.8.2.1
C cross-link capability	3.1.2.8.2.3
spare — 1 bit	
SL sensitivity level, ACAS	4.3.8.4.2.5
spare — 2 bits	
RI reply information	3.1.2.8.2.2
spare — 2 bits	
AC altitude code	3.1.2.6.5.4

AP address/parity 3.1.2.3.2.1.3

3.1.2.8.2.1 *VS: Vertical status:* This 1-bit (6) downlink field shall indicate the status of the aircraft (3.1.2.6.10.1.2).

Coding

0 signifies that the aircraft is airborne
1 signifies that the aircraft is on the ground

3.1.2.8.2.2 *RI: Reply information, air-air.* This 4-bit (14-17) downlink field shall report the aircraft's maximum cruising true airspeed capability and type of reply to interrogating aircraft. The coding shall be as follows:

0 signifies a reply to an air-air interrogation UF = 0 with AQ = 0, no operating ACAS
1-7 reserved for ACAS
8-15 signifies a reply to an air-air interrogation UF = 0 with AQ = 1 and that the maximum airspeed is as follows:
8 no maximum airspeed data available
9 maximum airspeed is .LE. 140 km/h (75 kt)
10 maximum airspeed is .GT. 140 and .LE. 280 km/h (75 and 150 kt)
11 maximum airspeed is .GT. 280 and .LE. 560 km/h (150 and 300 kt)
12 maximum airspeed is .GT. 560 and .LE. 1 110 km/h (300 and 600 kt)
13 maximum airspeed is .GT. 1 110 and .LE. 2 220 km/h (600 and 1 200 kt)
14 maximum airspeed is more than 2 220 km/h (1 200 kt)
15 not assigned.

Note.— ".LE." means "less than or equal to" and ".GT." means "greater than".

3.1.2.8.2.3 *CC: Cross-link capability*. This 1-bit (7) downlink field shall indicate the ability of the transponder to support the cross-link capability, i.e. decode the contents of the DS field in an interrogation with UF equals 0 and respond with the contents of the specified GICB register in the corresponding reply with DF equals 16.

Coding

0 signifies that the transponder cannot support the cross-link capability
1 signifies that the transponder supports the cross-link capability.

3.1.2.8.3 *LONG AIR-AIR SURVEILLANCE,DOWNLINK FORMAT 16*

1	6		9		14		20	33	89
DF	VS		SL		RI		AC	MV	AP
5			11		17		32	88	112

This reply shall be sent in response to an interrogation with UF equals 0 and RL equals 1. The format of this reply shall consist of these fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
VS vertical status	3.1.2.8.2.1
spare — 2 bits	
SL sensitivity level, ACAS	4.3.8.4.2.5
spare — 2 bits	
RI reply information	3.1.2.8.2.2
spare — 2 bits	
AC altitude code	3.1.2.6.5.4
MV message, ACAS	3.1.2.8.3.1
AP address/parity	3.1.2.3.2.1.3

3.1.2.8.3.1 *MV: Message, ACAS.* This 56-bit (33-88) downlink field shall contain GICB information as requested in the DS field of the UF 0 interrogation that elicited the reply.

Note.— The MV field is also used by ACAS for air-air coordination (4.3.8.4.2.4).

3.1.2.8.4 *AIR-AIR TRANSACTION PROTOCOL*

Note.— Interrogation-reply coordination for the air-air formats follows the protocol outlined in Table 3-5 (3.1.2.4.1.3.2.2).

The most significant bit (bit 14) of the RI field of an air-air reply shall replicate the value of the AQ field (bit 14) received in an interrogation with UF equals 0.

If AQ equals 0 in the interrogation, the RI field of the reply shall contain the value 0.

If AQ equals 1 in the interrogation, the RI field of the reply shall contain the maximum cruising true airspeed capability of the aircraft as defined in 3.1.2.8.2.2.

In response to a UF = 0 with RL = 1 and DS ≠0, the transponder shall reply with a DF = 16 reply in which the MV field shall contain the contents of the GICB register designated by the DS value. If the requested register is not serviced by the aircraft installation, the transponder shall reply and the MV field of the reply shall contain all ZEROs.

3.1.2.8.5 *ACQUISITION SQUITTER*

Note.— SSR Mode S transponders transmit acquisition squitters (unsolicited downlink transmissions) to permit passive acquisition by interrogators with broad antenna beams, where active acquisition may be hindered by all-call synchronous garble. Examples of such interrogators are an airborne collision avoidance system and an airport surface surveillance system.

3.1.2.8.5.1 *Acquisition squitter format.* The format used for acquisition squitter transmissions shall be the all-call reply, (DF = 11) with II = 0.

3.1.2.8.5.2 *Acquisition squitter rate.* Acquisition squitter transmissions shall be emitted at random intervals that are uniformly distributed over the range from 0.8 to 1.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous acquisition squitter, with the following exceptions:

a) the scheduled acquisition squitter shall be delayed if the transponder is in a transaction cycle (3.1.2.4.1);

b) the acquisition squitter shall be delayed if an extended squitter is in process;

c) the scheduled acquisition squitter shall be delayed if a mutual suppression interface is active (see Note 1 below); or

d) acquisition squitters shall only be transmitted on the surface if the transponder is not reporting the surface position type of Mode S extended squitter.

An acquisition squitter shall not be interrupted by link transactions or mutual suppression activity after the squitter transmission has begun.

Note 1.— A mutual suppression system may be used to connect onboard equipment operating in the same frequency band in order to prevent mutual interference. Acquisition squitter action resumes as soon as practical after a mutual suppression interval.

Note 2.— The surface report type may be selected automatically by the aircraft or by commands from a squitter ground station (3.1.2.8.6.7).

3.1.2.8.5.3 *Acquisition squitter antenna selection.* Transponders operating with antenna diversity (3.1.2.10.4) shall transmit acquisition squitters as follows:

a) when airborne (3.1.2.8.6.7), the transponder shall transmit acquisition squitters alternately from the two antennas; and

b) when on the surface (3.1.2.8.6.7), the transponder shall transmit acquisition squitters under control of SAS (3.1.2.6.1.4.1 f)). In the absence of any SAS commands, use of the top antenna only shall be the default.

Note.— Acquisition squitters are not emitted on the surface if the transponder is reporting the surface type of extended squitter (3.1.2.8.6.4.3).

3.1.2.8.6 *EXTENDED SQUITTER,DOWNLINK FORMAT 17*

1	6	9	33	89
DF	CA	AA	ME	PI
5	8	32	88	112

Note.— SSR Mode S transponders transmit extended squitters to support the broadcast of aircraft-derived position for surveillance purposes. The broadcast of this type of information is a form of automatic dependent surveillance (ADS) known as ADS-broadcast (ADS-B).

3.1.2.8.6.1 *Extended squitter format.* The format used for the extended squitter shall be a 112-bit downlink format (DF = 17) containing the following fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
CA capability	3.1.2.5.2.2.1
AA address, announced	3.1.2.5.2.2.2
ME message, extended squitter	3.1.2.8.6.2
PI parity/interrogator identifier	3.1.2.3.2.1.4

The PI field shall be encoded with II equal to 0.

3.1.2.8.6.2 *ME: Message, extended squitter.* This 56-bit (33-88) downlink field in DF = 17 shall be used to transmit broadcast messages. Extended squitter shall be supported by registers 05, 06, 07, 08, 09, 0A {HEX} and 61-6F {HEX} and shall conform to either version 0, version 1 orversion 2 message formats as described below:

a) Version 0 ES message formats and related requirements report surveillance quality by navigation uncertainty category (NUC), which can be an indication of either the accuracy or integrity of the navigation data used by ADS-B. However, there is no indication as to which of these, integrity or accuracy, the NUC value is providing an indication of.

b) Version 1 ES message formats and related requirements report surveillance accuracy and integrity separately as navigation accuracy category (NAC), navigation integrity category (NIC) and surveillance integrity level (SIL). Version 1 ES formats also include provisions for enhanced reporting of status information; and

c) Version 2 ES message formats and related requirements contain the provisions of version 1 but further enhance integrity and parameter reporting. Version 2 ES formats separately report position source integrity from the integrity of the ADS-B transmitting equipment. Version 2 ES formats also separate vertical accuracy reporting from horizontal position accuracy, remove vertical integrity from position integrity, and provide for the reporting of the SSR Mode A code, GNSS antenna offset and additional horizontal position integrity values. Version 2 ES formats also modify the target state report to include selected altitude, selected heading, and barometric pressure setting.

Note 1.— The formats and update rates of each register are specified in the Technical Provisions for Mode S Services and Extended Squitter(Doc 9871). The formats and update rates for individual squitters are defined by the version number of the extended squitter.

Note 2.— The formats for the three different versions are interoperable. An extended squitter receiver can recognize and decode signals of its own version, as well as lower versions' message formats. The receiver, however, can decode higher version signals according to its own capability.

Note 3.— Guidance material on transponder register formats and data sources is included in the Technical Provisions for Mode S Services and Extended Squitter(Doc 9871).

3.1.2.8.6.3 *Extended squitter types*

3.1.2.8.6.3.1 *Airborne position squitter.* The airborne position extended squitter type shall use format DF = 17 with the contents of GICB register 05 {HEX} inserted in the ME field.

Note.— A GICB request (3.1.2.6.11.2) containing RR equals16 and DI equals 3 or 7 and RRS equals 5 will cause the resulting reply to contain the airborne position message in its MB field.

3.1.2.8.6.3.1.1 SSS, surveillance status subfield in ME. The transponder shall report the surveillance status of the transponder in this 2-bit (38, 39) subfield of ME when ME contains an airborne position message.

Coding

0 signifies no status information
1 signifies transponder reporting permanent alert condition (3.1.2.6.10.1.1.1)
2 signifies transponder reporting a temporary alert condition (3.1.2.6.10.1.1.2)
3 signifies transponder reporting SPI condition (3.1.2.6.10.1.3)

Codes 1 and 2 shall take precedence over code 3.

3.1.2.8.6.3.1.2 *ACS, altitude code subfield in ME.* Under control of ATS (3.1.2.8.6.3.1.3), the transponder shall report either navigation-derived altitude, or the barometric altitude code in this 12-bit (41-52) subfield of ME when ME contains an airborne position message. When barometric altitude is reported, the contents of the ACS shall be as specified for the 13-bit AC field (3.1.2.6.5.4) except that the M-bit (bit 26) shall be omitted.

3.1.2.8.6.3.1.3 *Control of ACS reporting.* Transponder reporting of altitude data in ACS shall depend on the altitude type subfield (ATS) as specified in 3.1.2.8.6.8.2. Transponder insertion of barometric altitude data in the ACS subfield shall take place when the ATS subfield has the value of ZERO. Transponder insertion of barometric altitude data in ACS shall be inhibited when ATS has the value 1.

3.1.2.8.6.3.2 *Surface position squitter.* The surface position extended squitter type shall use format DF = 17 with the contents of GICB register 06 {HEX} inserted in the ME field.

Note.— A GICB request (3.1.2.6.11.2) containing RR equals16 and DI equals 3 or 7 and RRS equals 6 will cause the resulting reply to contain the surface position message in its MB field..

3.1.2.8.6.3.3 *Aircraft identification squitter.* The aircraft identification extended squitter type shall use format DF = 17 with the contents of GICB register 08 {HEX} inserted in the ME field.

Note.— A GICB request (3.1.2.6.11.2) containing RR equals16 and DI equals 3 or 7 and RRS equals 8 will cause the resulting reply to contain the aircraft identification message in its MB field.

3.1.2.8.6.3.4 *Airborne velocity squitter.* The airborne velocity extended squitter type shall use format DF = 17 with the contents of GICB register 09 {HEX} inserted in the ME field.

Note.— A GICB request (3.1.2.6.11.2) containing RR equals16 and DI equals 3 or 7 and RRS equals 9 will cause the resulting reply to contain the airborne velocity message in its MB field.

3.1.2.8.6.3.5 *Periodic status and event-driven squitters*

3.1.2.8.6.3.5.1 *Periodic status squitter*. The periodic status extended squitter types shall use format DF = 17 to convey aircraft status and other surveillance data. The aircraft operational status extended squitter type shall use the contents of GICB register 65 {HEX} inserted in the ME field. The target state and status extended squitter type shall use the contents of GICB register 62 {HEX} inserted in the ME field.

Note 1.— A GICB request (3.1.2.6.11.2)containing RR equals 22 and DI equals 3 or 7 and RRS equals 5 will cause the resulting reply to contain the aircraft operational status message in its MB field.

Note 2.— A GICB request (3.1.2.6.11.2)containing RR equals 22 and DI equals 3 or 7 and RRS equals 2 will cause the resulting reply to contain the target state and status information in its MB field.

3.1.2.8.6.3.5.2 *Event-driven squitter.* The event-driven extended squitter type shall use format DF = 17 with the contents of GICB register 0A {HEX} inserted in the ME field.

Note.— A GICB request (3.1.2.6.11.2) containing RR equals 16 and DI equals 3 or 7 and RRS equals 10 will cause the resulting reply to contain the event-driven message in its MB field.

3.1.2.8.6.4 *Extended squitter rate*

3.1.2.8.6.4.1 *Initialization.* At power up initialization, the transponder shall commence operation in a mode in which it broadcasts only acquisition squitters (3.1.2.8.5). The transponder shall initiate the broadcast of extended squitters for airborne position, surface position, airborne velocity and aircraft identification when data are inserted into transponder registers 05, 06, 09 and 08 {HEX}, respectively. This determination shall be made individually for each squitter type. When extended squitters are broadcast, transmission rates shall be as indicated in the following paragraphs. Acquisition squitters shall be reported in addition to extended squitters unless the acquisition squitter is inhibited (2.1.5.4). Acquisition squitters shall always be reported if both position and velocity extended squitters are not reported.

Note 1.— This suppresses the transmission of extended squitters from aircraft that are unable to report position, velocity or identity. If input to the register for the position squitter type stops for 60 seconds, broadcast will be discontinued until data insertion is resumed. Broadcast of airborne position squitters is not discontinued if barometric altitude data is available. Terminating broadcast of other squitter types is described in Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

Note 2.— After timeout (3.1.2.8.6.6), the position squitter type may contain an ME field of all zeroes.

3.1.2.8.6.4.2 *Airborne position squitter rate*. Airborne position squitter transmissions shall be emitted when the aircraft is airborne (3.1.2.8.6.7) at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds using a time quantization of no greater than 15 milliseconds relative to the previous airborne position squitter, with the exceptions as specified in 3.1.2.8.6.4.7.

3.1.2.8.6.4.3 Surface position squitter rate. Surface position squitter transmissions shall be emitted when the aircraft is on the surface (3.1.2.8.6.7) using one of two rates depending upon whether the high or low squitter rate has been selected (3.1.2.8.6.9). When the high squitter rate has been selected, surface position squitters shall be emitted at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds using a time quantization of no greater than 15 milliseconds relative to the previous surface position squitter (termed the high rate). When the low squitter rate has been selected, surface position squitters shall be emitted at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous surface position squitter (termed the low rate).

Exceptions to these transmission rates are specified in 3.1.2.8.6.4.7.

3.1.2.8.6.4.4 *Aircraft identification squitter rate*. Aircraft identification squitter transmissions shall be emitted at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous identification squitter when the aircraft is reporting the airborne position squitter type, or when the aircraft is reporting the surface position squitter type and the high surface squitter rate has been selected.

When the surface position squitter type is being reported at the low surface rate, the aircraft identification squitter shall be emitted at random intervals that are uniformly distributed over the range of 9.8 to 10.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous identification squitter. Exceptions to these transmission rates are specified in 3.1.2.8.6.4.7.

3.1.2.8.6.4.5 *Airborne velocity squitter rate*. Airborne velocity squitter transmissions shall be emitted when the aircraft is airborne (3.1.2.8.6.7) at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds using a time quantization of no greater than 15 milliseconds relative to the previous airborne velocity squitter, with the exceptions as specified in 3.1.2.8.6.4.7.

3.1.2.8.6.4.6 *Periodic status and event-driven squitter rates*

3.1.2.8.6.4.6.1 *Periodic status squitter rates.* The periodic status squitter types supported by a Mode S extended squitter transmitting system class, as specified in 5.1.1.2, shall be periodically emitted at defined intervals depending on the on-the-ground status and whether their content has changed.

Note.— The aircraft operational status extended squitter type and the target state and status extended squitter type rates are specified in the Technical Provisions for Mode S Services and Extended Squitter(Doc 9871).

3.1.2.8.6.4.6.2 *Event-driven squitter rate.* The event-driven squitter shall be transmitted once, each time that GICB register 0A {HEX} is loaded, while observing the delay conditions specified in 3.1.2.8.6.4.7. The maximum transmission rate for the event-driven squitter shall be limited by the transponder to twice per second. If a message is inserted in the event driven register and cannot be transmitted due to rate limiting, it shall be held and transmitted when the rate limiting condition has cleared. If a new message is received before transmission is permitted, it shall overwrite the earlier message.

3.1.2.8.6.4.7 *Delayed transmission.* Extended squitter transmission shall be delayed in the following circumstances:

a) if the transponder is in a transaction cycle (3.1.2.4.1);

b) if an acquisition or another type of extended squitter is in process; or

c) if a mutual suppression interface is active.

The delayed squitter shall be transmitted as soon as the transponder becomes available.

3.1.2.8.6.5 *Extended squitter antenna selection*. Transponders operating with antenna diversity (3.1.2.10.4) shall transmit extended squitters as follows:

a) when airborne (3.1.2.8.6.7), the transponder shall transmit each type of extended squitter alternately from the two antennas; and

b) when on the surface (3.1.2.8.6.7), the transponder shall transmit extended squitters under control of SAS (3.1.2.6.1.4.1 f)).

In the absence of any SAS commands, use of the top antenna only shall be the default condition.

3.1.2.8.6.6 Register time-out and termination. The transponder shall clear and terminate broadcast of information in extended squitter registers as required to prevent the reporting of outdated information.

Note.— Timeout and termination of extended squitter broadcast is specified in the Technical Provisions for Mode S Services and Extended Squitter(Doc 9871).

3.1.2.8.6.7 Airborne/surface state determination. Aircraft with an automatic means of determining on-the-ground conditions shall use this input to select whether to report the airborne or surface message types. Aircraft without such means shall report the airborne type messages, except as specified in Table 3-7. Use of this table shall only be applicable to aircraft that are equipped to provide data for radio altitude AND, as a minimum, airspeed OR ground speed. Otherwise, aircraft in the specified categories that are only equipped to provide data for airspeed and ground speed shall broadcast the surface format if:

airspeed < 50 knots AND ground speed < 50 knots

Aircraft with or without such automatic on-the-ground determination shall use position message types as commanded by control codes in TCS (3.1.2.6.1.4.1 f)). After time-out of the TCS commands, control of airborne/surface determination shall revert to the means described above.

Note 1. — Use of this technique may result in the surface position format being transmitted when the air-ground status in the CA fields indicates "airborne or on the ground".

Note 2.— Extended squitter ground stations determine aircraft airborne or on-the-ground status by monitoring aircraft position, altitude and ground speed. Aircraft determined to be on the ground that are not reporting the surface position message types will be commanded to report the surface formats via TCS (3.1.2.6.1.4.1 f)). The normal return to the airborne position message types is via a ground command to report airborne message types. To guard against loss of communications after take-off, commands to report the surface position message types automatically time-out.

3.1.2.8.6.8 *Squitter status reporting.* A GICB request (3.1.2.6.11.2) containing RR equals 16 and DI equals 3 or 7 and RRS equals 7 shall cause the resulting reply to contain the squitter status report in its MB field.

3.1.2.8.6.8.1 *TRS, transmission rate subfield in MB*. The transponder shall report the capability of the aircraft to automatically determine its surface squitter rate and its current squitter rate in this 2-bit (33, 34) subfield of MB.

Coding

0 signifies no capability to automatically determine surface squitter rate
1 signifies that the high surface squitter rate has been selected
2 signifies that the low surface squitter rate has been selected
3 unassigned

Note 1.— High and low squitter rate is determined on board the aircraft.

Note 2.— The low rate is used when the aircraft is stationary and the high rate is used when the aircraft is moving. For details of how "moving" is determined, see the data format of register 0716in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.8.6.8.2 ATS, altitude type subfield in MB. The transponder shall report the type of altitude being provided in the airborne position extended squitter in this 1-bit (35) subfield of MB when the reply contains the contents of transponder register 07 {HEX}.

Coding

0 signifies that barometric altitude shall be reported in the ACS (3.1.2.8.6.3.1.2) of transponder register 05 {HEX}.
1 signifies that navigation-derived altitude shall be reported in the ACS (3.1.2.8.6.3.1.2) of transponder register 05 {HEX}.

Note.— Details of the contents of transponder registers 05 {HEX} and 07 {HEX} are shown in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.8.6.9 *Surface squitter rate control.* Surface squitter rate shall be determined as follows:

a) once per second the contents of the TRS shall be read. Ift he value of TRS is 0 or 1, the transponder shall transmit surface squitters at the high rate. If the value of TRS is 2, the transponder shall transmit surface squitters at the low rate;

b) the squitter rate determined via TRS shall be subject to being overridden by commands received via RCS (3.1.2.6.1.4.1 f)). RCS code 1 shall cause the transponder to squitter at the high rate for 60 seconds. RCS code 2 shall cause the transponder to squitter at the low rate for 60 seconds. These commands shall be able to be refreshed for a new 60 second period before time-out of the prior period; and

c) after time-out and in the absence of RCS codes 1 and 2, control shall return to TRS.

3.1.2.8.6.10 *Latitude/longitude coding using compact position reporting (CPR).* Mode S extended squitter shall use compact position reporting (CPR) to encode latitude and longitude efficiently into messages.

Note.— The method used to encode/decode CPR is specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.8.6.11 *Data insertion*. When the transponder determines that it is time to emit an airborne position squitter, it shall insert the current value of the barometric altitude (unless inhibited by the ATS subfield, 3.1.2.8.6.8.2) and surveillance status into the appropriate fields of register 05 {HEX}. The contents of this register shall then be inserted into the ME field of DF = 17 and transmitted.

Note.— Insertion in this manner ensures that (1) the squitter contains the latest altitude and surveillance status, and (2) ground read-out of register 05 {HEX} will yield exactly the same information as the AC field of a Mode S surveillance reply.

3.1.2.8.7 *EXTENDED SQUITTER/SUPPLEMENTARY,DOWNLINK FORMAT 18*

10010	CF:3			PI:24

Note 1.— This format supports the broadcast of extended squitter ADS-B messages by non-transponder devices, i.e. they are not incorporated into a Mode S transponder. A separate format is used to clearly identify this non-transponder case to prevent ACAS II or extended squitter ground stations from attempting to interrogate these devices.

Note 2.— This format is also used for ground broadcast of ADS-B related services such as traffic information broadcast (TIS-B).

Note 3.— The format of the DF = 18 transmission is defined by the value of the CF field.

3.1.2.8.7.1 *ES supplementary format*. The format used for ES supplementary shall be a 112-bit downlink format (DF = 18) containing the following fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
CF control field	3.1.2.8.7.2
PI parity/interrogator identifier	3.1.2.3.2.1.4

The PI field shall be encoded with II equal to zero.

3.1.2.8.7.2 *Control field.* This 3-bit (6-8) downlink field in DF = 18 shall be used to define the format of the 112-bit transmission as follows.

Code 0 = ADS-B ES/NT devices that report the ICAO 24-bit address in the AA field (3.1.2.8.7)

Code 1 = Reserved for ADS-B for ES/NT devices that use other addressing techniques in the AA field (3.1.2.8.7.3)

Code 2 = Fine format TIS-B message

Code 3 = Coarse format TIS-B message

Code 4 = Reserved for TIS-B management messages

Code 5 = TIS-B messages that relay ADS-B messages that use other addressing techniques in the AA field

Code 6 = ADS-B rebroadcast using the same type codes and message formats as defined for DF = 17 ADS-B messages

Code 7 = Reserved

Note 1.— Administrations may wish to make address assignments for ES/NT devices in addition to the 24-bit addresses allocated by ICAO (Annex 10, Volume III, Part I, Chapter 9) in order to increase the available number of 24-bit addresses.

Note 2.— These non-ICAO 24-bit addresses are not intended for international use.

3.1.2.8.7.3 *ADS-B for extended squitter/non-transponder (ES/NT) devices*

10010	CF=0	AA:24	ME:56	PI:24

3.1.2.8.7.3.1 *ES/NT format.* The format used for ES/NT shall be a 112-bit downlink format (DF = 18) containing the following fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
CF control field = 0	3.1.2.8.7.2
AA address, announced	3.1.2.5.2.2.2
ME message, extended squitter	3.1.2.8.6.2
PI parity/interrogator identifier	3.1.2.3.2.1.4

The PI field shall be encoded with II equal to zero.

3.1.2.8.7.3.2 *ES/NT squitter types*

3.1.2.8.7.3.2.1 *Airborne position squitter.* The airborne position type ES/NT shall use format DF = 18 with the format for register 05 {HEX} as defined in 3.1.2.8.6.2 inserted in the ME field.

3.1.2.8.7.3.2.2 *Surface position squitter*. The surface position type ES/NT shall use format DF = 18 with the format for register 06 {HEX} as defined in 3.1.2.8.6.2 inserted in the ME field.

3.1.2.8.7.3.2.3 *Aircraft identification squitter.* The aircraft identification type ES/NT shall use format DF = 18 with the format for register 08 {HEX} as defined in 3.1.2.8.6.2 inserted in the ME field.

3.1.2.8.7.3.2.4 *Airborne velocity squitter*. The airborne velocity type ES/NT shall use format DF = 18 with the format for register 09 {HEX} as defined in 3.1.2.8.6.2 inserted in the ME field.

3.1.2.8.7.3.2.5 Periodic status and event-driven squitters

3.1.2.8.7.3.2.5.1 *Periodic status squitters*. The periodic status extended squitter types shall use format DF = 18 to convey aircraft status and other surveillance data. The aircraft operational status extended squitter type shall use the format of

GICB register 65 {HEX} as defined in 3.1.2.8.6.4.6.1 inserted in the ME field. The target state and status extended squitter type shall use the format of GICB register 62 {HEX} as defined in 3.1.2.8.6.4.6.1 inserted in the ME field.

3.1.2.8.7.3.2.5.2 *Event-driven squitter.* The event-driven type ES/NT shall use format DF = 18 with the format for register 0A {HEX} as defined in 3.1.2.8.6.2 inserted in the ME field.

3.1.2.8.7.3.3 *ES/NT squitter rate*

3.1.2.8.7.3.3.1 *Initialization.* At power up initialization, the non-transponder device shall commence operation in a mode in which it does not broadcast any squitters. The non-transponder device shall initiate the broadcast of ES/NT squitters for airborne position, surface position, airborne velocity and aircraft identification when data are available for inclusion in the ME field of these squitter types. This determination shall bemade individually for each squitter type. When ES/NT squitters are broadcast, transmission rates shall be as indicated in 3.1.2.8.6.4.2 to 3.1.2.8.6.4.6.

Note 1.— This suppresses the transmission of extended squitters from aircraft that are unable to report position, velocity or identity. If input to the register for the position squitter type stops for 60 seconds, broadcast will cease until data insertion resumes, except for an ES/NT device operating on the surface (as specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871)). Broadcast of airborne position squitters is not discontinued if barometric altitude data is available. Terminating broadcast of other squitter types is described in Doc 9871.

Note 2.— After timeout (3.1.2.8.7.6) this squitter type may contain an ME field of all zeros.

3.1.2.8.7.3.3.2 *Delayed transmission.* ES/NT squitter transmission shall be delayed if the non-transponder device is busy broadcasting one of the other squitter types.

3.1.2.8.7.3.3.2.1 The delayed squitter shall be transmitted as soon as the non-transponder device becomes available.

3.1.2.8.7.3.3.3 *ES/NT antenna selection.* Non-transponder devices operating with antenna diversity (3.1.2.10.4) shall transmit ES/NT squitters as follows:

a) when airborne (3.1.2.8.6.7), the non-transponder device shall transmit each type of ES/NT squitter alternately from the two antennas; and

b) when on the surface (3.1.2.8.6.7), the non-transponder device shall transmit ES/NT squitters using the top antenna.

3.1.2.8.7.3.3.4 *Register timeout and termination.* The non-transponder device shall clear message fields and terminate broadcast of extended squitter messages as required to prevent the reporting of outdated information.

Note.— The timeout and termination of an extended squitter broadcast is specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.8.7.3.3.5 *Airborne/surface state determination.* Aircraft with an automatic means of determining the on-theground state shall use this input to select whether to report the airborne or surface message types except as specified in

3.1.2.6.10.3.1. Aircraft without such means shall report the airborne type message.

3.1.2.8.7.3.3.6 *Surface squitter rate control.* Aircraft motion shall be determined once per second. The surface squitter rate shall be set according to the results of this determination.

Note.— The algorithm to determine aircraft motion is specified in the definition of register 0716in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.8.7.4 *Use of ES by other surveillance systems.*

3.1.2.8.7.4.1 *Surface system control*

Recommendation.— *When a surface surveillance system uses DF=18 as part of a surveillance function, it should not use the formats that have been allocated for the purpose of surveillance of aircraft, vehicles and/or obstacles.*

Note 1.— The formats allocated for the purpose of surveillance of aircraft, vehicles and/or obstacles are specified in the Technical Provisions for Mode S Services and Extended Squitter(Doc 9871).

Note 2.— The transmission of any message format used for conveying position, velocity, identification, state information, etc., may result in the initiation and maintenance of false tracks in other 1090ES receivers. The use of these messages for this purpose may be prohibited in the future.

3.1.2.8.7.4.2 *Surface system status*

Recommendation.— *The surface system status message type (Type Code=24) should be the only message used to provide the status or synchronization of surface surveillance systems.*

Note.— The surface system status message is specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871). This message will be used only by the surface surveillance system that generated it and will be ignored by other surface systems.

3.1.2.8.8 *EXTENDED SQUITTER MILITARY APPLICATION,DOWNLINK FORMAT 19*

10011	AF:3	

Note.— This format supports the broadcast of extended squitter ADS-B messages in support of military applications.
A separate format is used to distinguish these extended squitters from the standard ADS-B message set broadcast using DF = 17 or 18.

3.1.2.8.8.1 *Military format.* The format used for DF = 19 shall be a 112-bit downlink format containing the following fields:

Field	*Reference*
DF downlink format	3.1.2.3.2.1.2
AF control field	3.1.2.8.8.2

3.1.2.8.8.2 *Application field.* This 3-bit (6-8) downlink field in DF = 19 shall be used to define the format of the 112-bit transmission.

Code 0 to 7 = Reserved

3.1.2.8.9 *EXTENDED SQUITTER MAXIMUM TRANSMISSION RATE*

3.1.2.8.9.1 The maximum total number of full power extended squitters (DF = 17, 18 and 19) emitted by any extended squitter installation shall not exceed the following:

a) 6.2 messages per second averaged over 60 seconds for nominal aircraft operations with no emergency and no ACAS RA activity, while not exceeding 11 messages being transmitted in any 1-second interval; or

b) 7.4 messages per second averaged over 60 seconds under an emergency and/or ACAS RA condition, while not exceeding 11 messages being transmitted in any 1-second interval.

3.1.2.8.9.2 For installations capable of emitting DF = 19 squitters and in accordance with 3.1.2.8.8, transmission rates for lower power DF = 19 squitters shall be limited to a peak of forty DF = 19 squitters per second, and thirty DF = 19 squitters per second averaged over 10 seconds, provided that the maximum total squitter power-rate product for the sum of full power DF = 17 squitters, full power DF= 18 squitters, full power DF = 19 squitters, and lower power DF = 19 squitters, is maintained at or below a level equivalent to the power sum of 6.2 full power squitters per second averaged over 10 seconds.

3.1.2.8.9.3 States shall ensure that the use of low power and higher rate DF = 19 operation (as per 3.1.2.8.9.2) is compliant with the following requirements:

a) it is limited to formation or element lead aircraft engaged in formation flight, directing the messages toward wing and other lead aircraft through a directional antenna with a beamwidth of no more than 90 degrees; and

b) the type of information contained in the DF = 19 message is limited to the same type of information in the DF = 17 message, that is, information for the sole purpose of safety-of-flight.

Note.— This low-power, higher squitter rate capability is intended for limited use by State aircraft in coordination with appropriate regulatory bodies.

3.1.2.8.9.4 All UF = 19 airborne interrogations shall be included in the interference control provisions of 4.3.2.2.2.2.

3.1.2.9 AIRCRAFT IDENTIFICATION PROTOCOL

3.1.2.9.1 *Aircraft identification reporting*. A ground-initiated Comm-B request (3.1.2.6.11.2) containing RR equals 18 and either DI does not equal 7 or DI equals 7 and RRS equals 0 shall cause the resulting reply to contain the aircraft identification in its MB field.

3.1.2.9.1.1 *AIS, aircraft identification subfield in MB.* The transponder shall report the aircraft identification in the 48-bit (41-88) AIS subfield of MB. The aircraft identification transmitted shall be that employed in the flight plan. When no flight plan is available, the registration marking of the aircraft shall be inserted in this subfield.

Note.— When the registration marking of the aircraft is used, it is classified as "fixed direct data" (3.1.2.10.5.1.1).

When another type of aircraft identification is used, it is classified as "variable direct data" (3.1.2.10.5.1.3).

3.1.2.9.1.2 *Coding of the AIS subfield.* The AIS subfield shall be coded as follows:

33	41	47	53	59	65	71	77	83
BDS	Char. 1	Char. 2	Char. 3	Char. 4	Char. 5	Char. 6	Char. 7	Char. 8
40	46	52	58	64	70	76	82	88

Note.— Aircraft identification coding provides up to eight characters.

The BDS code for the aircraft identification message shall be BDS1 equals 2 (33-36) and BDS2 equals 0 (37-40).

Each character shall be coded as a 6-bit subset of the International Alphabet Number 5 (IA-5) as illustrated in Table 3-8. The character code shall be transmitted with the high order unit (b6) first and the reported aircraft identification shall be transmitted with its left-most character first. Characters shall be coded consecutively without intervening SPACE code. Any unused character spaces at the end of the subfield shall contain a SPACE character code.

3.1.2.9.1.3 *Aircraft identification capability report. Transponders* which respond to a ground-initiated request for aircraft identification shall report this capability in the data link capability report (3.1.2.6.10.2.2.2) by setting bit 33 of the MB subfield to 1.

3.1.2.9.1.4 Change of aircraft identification. If the aircraft identification reported in the AIS subfield is changed in flight, the transponder shall report the new identification to the ground by use of the Comm-B broadcast message protocol of

3.1.2.6.11.4 for BDS1 = 2 (33 - 36) and BDS2 = 0 (37 - 40). The transponder shall initiate, generate and announce the revised aircraft identification even if the interface providing flight identification is lost. The transponder shall ensure that the BDS code is set for the aircraft identification report in all cases, including a loss of the interface. In this latter case, bits 41 - 88 shall contain all ZEROs.

Note.— The setting of the BDS code by the transponder ensures that a broadcast change of aircraft identification will contain the BDS code for all cases of flight identification failure (e.g. the loss of the interface providing flight identification).

3.1.2.10 ESSENTIAL SYSTEM CHARACTERISTICS OF THE SSR MODE STRANSPONDER

3.1.2.10.1 *Transponder sensitivity and dynamic range*. Transponder sensitivity shall be defined in terms of a given interrogation signal input level and a given percentage of corresponding replies. Only correct replies containing the required bit pattern for the interrogation received shall be counted. Given an interrogation that requires a reply according to 3.1.2.4,the minimum triggering level, MTL, shall be defined as the minimum input power level for 90 per cent reply-to-interrogation ratio. The MTL shall be –74 dBm ±3 dB for Mode S interrogations (interrogations using P6), and as defined in 3.1.1.7.5.1 b) for Mode A and C, and inter-mode interrogations. The reply-to-interrogation ratio of a Mode S transponder shall be:

a) at least 99 per cent for signal input levels between 3 dB above MTL and –21 dBm; and

b) no more than 10 per cent at signal input levels below –81 dBm.

Note.— Transponder sensitivity and output power are described inthis section in terms of signal level at the terminals of the antenna. This gives the designer freedom to arrange the installation, optimizing *cable length and receiver-transmitter design, and does not exclude receiver and/or transmitter components from becoming an integral part of the antenna subassembly.*

3.1.2.10.1.1 *Reply ratio in the presence of interference*

Note.— The following paragraphs present measures of the performance of the Mode S transponder in the presence of interfering Mode A/C interrogation pulses and low-level in-band CW interference.

3.1.2.10.1.1.1 *Reply ratio in the presence of an interfering pulse.* Given a Mode S interrogation which requires a reply (3.1.2.4), the reply ratio of a transponder shall be at least 95 per cent in the presence of an interfering Mode A/C interrogation pulse if the level of the interfering pulse is 6 dB or more below the signal level for Mode S input signal levels between -68 dBm and –21 dBm and the interfering pulse overlaps the P6pulse of the Mode S interrogation anywhere after the sync phase reversal.

Under the same conditions, the reply ratio shall be at least 50 per cent if the interference pulse level is 3 dB or more below the signal level.

3.1.2.10.1.1.2 *Reply ratio in the presence of pulse pair interference.* Given an interrogation which requires a reply (3.1.2.4), the reply ratio of a transponder shall be at least 90 per cent in the presence of an interfering P1– P2pulse pair if the level of the interfering pulse pair is 9 dB or more below signal level for input signal levels between –68 dBm and –21 dBm and the P1pulse of the interfering pair occurs no earlier than the P1pulse of the Mode S signal.

3.1.2.10.1.1.3 *Reply ratio in the presence of low level asynchronous interference.* For all received signals between – 65 dBm and –21 dBm and given a Mode S interrogation that requires a reply according to 3.1.2.4 and if no lockout condition is in effect, the transponder shall reply correctly with at least 95 per cent reply ratio in the presence of asynchronous interference. Asynchronous interference shall be taken to be a single Mode A/C interrogation pulse occurring at all repetition rates up to 10 000 Hz at a level 12 dB or more below the level of the Mode S signal.

Note.— Such pulses may combine with the P1and P2pulses of the Mode S interrogation to form a valid Mode A/C-only all-call interrogation. The Mode S transponder does not respond to Mode A/C-only all-call interrogations. A preceding pulse may also combine with the P2of the Mode S interrogation to form a valid Mode A or Mode C interrogation. However, the P1 – P2pair of the Mode S preamble takes precedence (3.1.2.4.1.1.1). The Mode S decoding process is independent of the Mode A/Mode C decoding process and the Mode S interrogation is accepted.

3.1.2.10.1.1.4 *Reply ratio in the presence of low-level in-band CW interference.* In the presence of non-coherent CW interference at a frequency of 1 030 ±0.2 MHz at signal levels of 20 dB or more below the desired Mode A/C or Mode S interrogation signal level, the transponder shall reply correctly to at least 90 per cent of the interrogations.

3.1.2.10.1.1.5 *Spurious response*

3.1.2.10.1.1.5.1 **Recommendation.** – *The response to signals not within the receiver pass band should be at least 60 dB below normal sensitivity.*

3.1.2.10.1.1.5.2 For equipment certified after 1 January 2011, the spurious Mode A/C reply ratio generated by low level Mode S interrogations shall be no more than:

a) an average of 1 per cent in the input interrogation signal range between –81 dBm and the Mode S MTL; and

b) a maximum of 3 per cent at any given level in the input interrogation signal range between –81 dBm and the Mode S MTL.

Note.— Failure to detect a low level Mode S interrogation can also result in the transponder decoding a three-pulse Mode A/C/S all-call interrogation. This would result in the transponder responding with a Mode S all-call (DF = 11) reply.

The above requirement will also control these DF = 11 replies since it places a limit on the probability of failing to correctly detect the Mode S interrogation.

3.1.2.10.2 *Transponder peak pulse power.* The peak power of each pulse of a reply shall:

a) not be less than 18.5dBW for aircraft not capable of operating at altitudes exceeding 4 570 m (15 000 ft);

b) not be less than 21.0 dBW for aircraft capable of operating above 4 570 m (15 000 ft);

c) not be less than 21.0 dBW for aircraft with maximum cruising speed exceeding 324 km/h (175 kt); and

d) not exceed 27.0 dBW.

3.1.2.10.2.1 *Inactive state transponder output power.* When the transponder is in the inactive state the peak pulse power at 1 090 MHz plus or minus 3 MHz shall not exceed –50dBm. The inactive state is defined to include the entire period between transmissions less 10-microsecond transition periods preceding the first pulse and following the last pulse of the transmission.

Note.— Inactive state transponder power is constrained in this way to ensure that an aircraft, when located as near as 185 m (0.1 NM) to a Mode A/C or Mode S interrogator, does not cause interference to that installation. In certain applications of Mode S, airborne collision avoidance for example, where a 1 090 MHz transmitter and receiver are in the same aircraft, it may be necessary to further constrain the inactive state transponder power.

3.1.2.10.2.2 *Spurious emission radiation*

Recommendation.— *CW radiation should not exceed 70 dB below 1 watt.*

3.1.2.10.3 *SPECIAL CHARACTERISTICS*

3.1.2.10.3.1 *Mode S side-lobe suppression*

Note.— Side-lobe suppression for Mode S formats occurs when a P5pulse overlays the location of the sync phase reversal of P6, causing the transponder to fail to recognize the interrogation (3.1.2.4.1.1.3).

Given a Mode S interrogation that requires a reply, the transponder shall:

a) at all signal levels between MTL +3 dB and –21 dBm, have a reply ratio of less than 10 per cent if the received amplitude of P5exceeds the received amplitude of P6by 3 dB or more;
b) at all signal levels between MTL +3 dB and –21 dBm, have a reply ratio of at least 99 per cent if the received amplitude of P6exceeds the received amplitude of P5by 12 dB or more.

3.1.2.10.3.2 *Mode S dead time*. Dead time shall be defined as the time interval beginning at the end of a reply transmission and ending when the transponder has regained sensitivity to within 3 dB of MTL. Mode S transponders shall not have more than 125 microseconds' dead time.

3.1.2.10.3.3 *Mode S receiver desensitization.* The transponder's receiver shall be desensitized according to 3.1.1.7.7.1 on receipt of any pulse of more than 0.7 microseconds duration.

3.1.2.10.3.3.1 *Recovery from desensitization.* Recovery from desensitization shall begin at the trailing edge of each pulse of a received signal and shall occur at the rate prescribed in 3.1.1.7.7.2, provided that no reply or data transfer is made in response to the received signal.

3.1.2.10.3.4 *Recovery after Mode S interrogations that do not elicit replies*

3.1.2.10.3.4.1 *Recovery after a single Mode S interrogation*

3.1.2.10.3.4.1.1 The transponder shall recover sensitivity to within 3 dB of MTL no later than 128 microseconds after receipt of the sync phase reversal following a Mode S interrogation that is not accepted (3.1.2.4.1.2) or that is accepted but requires no reply.

3.1.2.10.3.4.1.2 **Recommendation**.— *The transponder should recover sensitivity to within 3 dB of MTL no later than 45 microseconds after receipt of the sync phase reversal following a Mode S interrogation that is not accepted (3.1.2.4.1.2) or that is accepted but requires no reply.*

3.1.2.10.3.4.1.3 All Mode S transponders installed on or after 1 January 1999 shall recover sensitivity to within 3 dB of MTL no later than 45 microseconds after receipt of the sync phase reversal following a Mode S interrogation that is not accepted (3.1.2.4.1.2) or that is accepted but requires no reply.

3.1.2.10.3.4.2 *Recovery after a Mode S Comm-C interrogation.* A Mode S transponder with Comm-C capability shall recover sensitivity to within 3 dB of MTL no later than 45 microseconds after receipt of the sync phase reversal following acceptance of a Comm-C interrogation for which no reply is required.

3.1.2.10.3.5 *Unwanted Mode S replies.* Mode S transponders shall not generate unwanted Mode S replies more often than once in 10 seconds. Installation in the aircraft shall be made in such a manner that this standard shall be achieved when all possible interfering equipments installed in the same aircraft are operating at maximum interference levels.

3.1.2.10.3.5.1 Unwanted Mode S replies in the presence of low-level in-band CW interference. In the presence of noncoherent CW interference at a frequency of 1 030 ±0.2 MHz and at signal levels of -60 dBm or less, and in the absence of valid interrogation signals, Mode S transponders shall not generate unwanted Mode S replies more often than once per 10 seconds.

3.1.2.10.3.6 *Reply rate limiting*

Note.— Reply rate limiting is prescribed separately for Modes A and C and for Mode S.

3.1.2.10.3.6.1 *Mode S reply rate limiting*. Reply rate limiting is not required for the Mode S formats of a transponder.

If such limiting is incorporated for circuit protection, it shall permit the minimum reply rates required in 3.1.2.10.3.7.2 and3.1.2.10.3.7.3.

3.1.2.10.3.6.2 *Modes A and C reply rate limiting. Reply* rate limiting for Modes A and C shall be effected according to 3.1.1.7.9.1. The prescribed sensitivity reduction (3.1.1.7.9.2) shall not affect the Mode S performance of the transponder.

3.1.2.10.3.7 *Minimum reply rate capability, Modes A, C and S*

3.1.2.10.3.7.1 All reply rates specified in 3.1.2.10.3.7shall be in addition to any squitter transmissions that the transponder is required to make.

3.1.2.10.3.7.2 *Minimum reply rate capability, Modes A and C.* The minimum reply rate capability for Modes A and C shall be in accordance with 3.1.1.7.9.

3.1.2.10.3.7.3 *Minimum reply rate capability, Mode S*. A transponder capable of transmitting only short Mode S replies shall be able to generate replies at the following rates:

50 Mode S replies in any 1-second interval
18 Mode S replies in a 100-millisecond interval
8 Mode S replies in a 25-millisecond interval
4 Mode S replies in a 1.6-millisecond interval

In addition to any downlink ELM transmissions, a level 2, 3 or 4 transponder shall be able to generate as long replies at least:

16 of 50 Mode S replies in any 1-second interval
6 of 18 Mode S replies in a 100-millisecond interval
4 of 8 Mode S replies in a 25-millisecond interval
2 of 4 Mode S replies in a 1.6-millisecond interval

In addition to downlink ELM transmissions, a level 5 transponder shall be able to generate as long replies at least:

24 of 50 Mode S replies in any 1-second interval
9 of 18 Mode S replies in a 100-millisecond interval
6 of 8 Mode S replies in a 25-millisecond interval
2 of 4 Mode S replies in a 1.6-millisecond interval

In addition, a transponder within an ACAS installation shall be able to generate as ACAS coordination replies at least 3 of 50 Mode S replies in any 1-second interval.

3.1.2.10.3.7.4 Minimum Mode S ELM peak reply rate

Note 1.— When a downlink ELM is initialized (3.1.2.7.7.1), the Mode S transponder announces the length (in segments) of the waiting message. The transponder must be able to transmit this number of segments, plus an additional margin to make up for missed replies, during the beam dwell of the ground interrogator.

At least once every second a Mode S transponder equipped for ELM downlink operation shall be capable of transmitting in a 25-millisecond interval, at least 25 per cent more segments than have been announced in the initialization (3.1.2.7.7.1). The minimum length downlink ELM capability for level 4 and 5 transponders shall be as specified in 3.1.2.10.5.2.2.2.

Note 2.— A transponder capable of processing the maximum length downlink ELM (16 segments) is therefore required to be able to transmit 20 long replies under the above conditions. Level 4 transponders may be built which process less than the maximum message length. These transponders cannot initialize a message length that exceeds their transmitter capability.
For example, a transponder that can transmit at most 10 long replies under the above conditions can never announce a message of more than 8 segments.

3.1.2.10.3.8 *Reply delay and jitter*

Note.— After an interrogation has been accepted and if a reply is required, this reply transmission begins after a fixed delay needed to carry out the protocols. Different values for this delay are assigned for Modes A and C, for Mode S and for Modes A/C/S all-call replies.

3.1.2.10.3.8.1 *Reply delay and jitter for Modes A and C.* The reply delay and jitter for Modes A and C transactions shall be as prescribed in 3.1.1.7.10.

3.1.2.10.3.8.2 *Reply delay and jitter for Mode S.* For all input signal levels between MTL and –21 dBm, the leading edge of the first preamble pulse of the reply (3.1.2.2.5.1.1) shall occur 128 plus or minus 0.25 microsecond after the sync phase reversal (3.1.2.1.5.2.2) of the received P6. The jitter of the reply delay shall not exceed 0.08 microsecond, peak (99.9 percentile).

3.1.2.10.3.8.3 *Reply delay and jitter for Modes A/C/S all call.* For all input signal levels between MTL +3 dB and –21 dBm the leading edge of the first preamble pulse of the reply (3.1.2.2.5.1.1) shall occur 128 plus or minus 0.5 microseconds after the leading edge of the P4pulse of the interrogation (3.1.2.1.5.1.1). Jitter shall not exceed 0.1 microsecond, peak (99.9 percentile).

Note.— A peak jitter of 0.1 microsecond is consistent with the jitter prescribed in 3.1.1.7.10.

3.1.2.10.3.9 *Timers.* Duration and features of timers shall be as shown in Table 3-9. All timers shall be capable of being restarted. On receipt of any start command, they shall run for their specified times. This shall occur regardless of whether they are in the running or the non-running state at the time that the start command is received. A command to reset a timer shall cause the timer to stop running and to return to its initial state in preparation for a subsequent start command.

3.1.2.10.3.10 *Inhibition of replies.* Replies to Mode A/C/S all-call and Mode S-only all-call interrogations shall always be inhibited when the aircraft declares the on-the-ground state. It shall not be possible to inhibit replies to discretely addressed Mode S interrogations regardless of whether the aircraft is airborne or on the ground.

3.1.2.10.3.10.1 **Recommendation**.— *Aircraft should provide means to determine the on-the-ground state automatically and provide that information to the transponder.*

3.1.2.10.3.10.2 **Recommendation**.— *Mode A/C replies should be inhibited when the aircraft is on the ground to prevent interference when in close proximity to an interrogator or other aircraft.*

Note.— Mode S discretely addressed interrogations do not give rise to such interference and may be required for data link communications with aircraft on the airport surface. Acquisition squitter transmissions may be used for passive surveillance of aircraft on the airport surface.

3.1.2.10.4 *Transponder antenna system and diversity operation.* Mode S transponders equipped for diversity operation shall have two RF ports for operation with two antennas, one antenna on the top and the other on the bottom of the aircraft's fuselage. The received signal from one of the antennas shall be selected for acceptance and the reply shall be transmitted from the selected antenna only.

3.1.2.10.4.1 *Radiation pattern.* The radiation pattern of Mode S antennas when installed on an aircraft shall be nominally equivalent to that of a quarter-wave monopole on a ground plane.

Note.— Transponder antennas designed to increase gain at the expense of vertical beamwidth are undesirable because of their poor performance during turns.

3.1.2.10.4.2 *Antenna location.* The top and bottom antennas shall be mounted as near as possible to the centre line of the fuselage. Antennas shall be located so as to minimize obstruction to their fields in the horizontal plane.

3.1.2.10.4.2.1 **Recommendation.—** The horizontal distance between the top and bottom antennas should not be greater than 7.6 m (25 ft).

Note.— This recommendation is intended to support the operation of any diversity transponder (including cables) with any diversity antenna installation and still satisfy the requirement of 3.1.2.10.4.5.

3.1.2.10.4.3 *Antenna selection.* Mode S transponders equipped for diversity operation shall have the capability to evaluate a pulse sequence simultaneously received on both antenna channels to determine individually for each channel if the P1pulse and the P2pulse of a Mode S interrogation preamble meet the requirements for a Mode S interrogation as defined in

3.1.2.1 and if the P1pulse and the P3pulse of a Mode A, Mode C or intermode interrogation meet the requirements for Mode A and Mode C interrogations as defined in 3.1.1.

Note.— Transponders equipped for diversity operation may optionally have the capability to evaluate additional characteristics of the received pulses of the interrogations in making a diversity channel selection. The transponder may as an option evaluate a complete Mode S interrogation simultaneously received on both channels to determine individually for each channel if the interrogation meets the requirements for Mode S interrogation acceptance as defined in 3.1.2.4.1.2.3.

3.1.2.10.4.3.1 If the two channels simultaneously receive at least a P1– P2pulse pair that meets the requirements for a Mode S interrogation, or a P1– P3pulse pair that meets the requirements for a Mode A or Mode C interrogation, or if the two channels simultaneously accept a complete interrogation, the antenna at which the signal strength is greater shall be selected for the reception of the remainder (if any) of the interrogation and for the transmission of the reply.

3.1.2.10.4.3.2 If only one channel receives a pulse pair that meets the requirements for an interrogation, or if only one channel accepts an interrogation, the antenna associated with that channel shall be selected regardless of received signal strength.

3.1.2.10.4.3.3 *Selection threshold*. If antenna selection is based on signal level, it shall be carried out at all signal levels between MTL and –21 dBm.

Note.— Either antenna may be selected if the difference in signal level is less than 3 dB.

3.1.2.10.4.3.4 *Received signal delay tolerance.* If an interrogation is received at one antenna 0.125 microsecond or less in advance of reception at the other antenna, the interrogations shall be considered to be simultaneous interrogations, and the above antenna selection criteria applied. If an accepted interrogation is received at either antenna 0.375 microsecond or more in advance of reception at the other antenna, the antenna selected for the reply shall be that which received the earlier interrogation. If the relative time of receipt is between 0.125 and 0.375 microsecond, the transponder shall select the antenna for reply either on the basis of the simultaneous interrogation criteria or on the basis of the earlier time of arrival.

3.1.2.10.4.4 *Diversity transmission channel isolation*. The peak RF power transmitted from the selected antenna shall exceed the power transmitted from the non-selected antenna by at least 20 dB.

3.1.2.10.4.5 *Reply delay of diversity transponders.* The total two-way transmission difference in mean reply delay between the two antenna channels (including the differential delay caused by transponder-to-antenna cables and the horizontal distance along the aircraft centre line between the two antennas) shall not exceed 0.13 microsecond for interrogations of equal amplitude. This requirement shall hold for interrogation signal strengths between MTL +3 dB and –21 dBm. The jitter requirements on each individual channel shall remain as specified for non-diversity transponders.

Note.— This requirement limits apparent jitter caused by antenna switching and by cable delay differences.

3.1.2.10.5 *DATA PROCESSING AND INTERFACES*

3.1.2.10.5.1 *Direct data.* Direct data shall be those which are required for the surveillance protocol of the Mode S system.

3.1.2.10.5.1.1 *Fixed direct data*. Fixed direct data are data from the aircraft which do not change in flight and shall be:

a) the aircraft address (3.1.2.4.1.2.3.1.1 and 3.1.2.5.2.2.2);

b) the maximum airspeed (3.1.2.8.2.2); and

c) the registration marking if used for flight identification (3.1.2.9.1.1).

3.1.2.10.5.1.2 *Interfaces for fixed direct data*

Recommendation.— *Interfaces from the transponder to the aircraft should be designed such that the values of the fixed direct data become a function of the aircraft installation rather than of the transponder configuration.*

Note.— The intent of this recommendation is to encourage an interface technique which permits transponder exchange without manipulation of the transponder itself for setting the fixed direct data.

3.1.2.10.5.1.3 *Variable direct data.* Variable direct data are data from the aircraft which can change in flight and shall be:

a) the Mode C altitude code (3.1.2.6.5.4);

b) the Mode A identity code (3.1.2.6.7.1);

c) the on-the-ground condition (3.1.2.5.2.2.1, 3.1.2.6.5.1 and 3.1.2.8.2.1);

d) the aircraft identification if different from the registration marking (3.1.2.9.1.1); and

e) the SPI condition (3.1.2.6.10.1.3).

3.1.2.10.5.1.4 *Interfaces for variable direct data.*

3.1.2.10.5.1.4.1 A means shall be provided, while on the ground or during flight, for the SPI condition to be inserted by the pilot, without the entry or modification of other flight data.

3.1.2.10.5.1.4.2 A means shall be provided, while on the ground or during flight, for the Mode A identity code to be displayed to the pilot and modified without the entry or modification of other flight data.

3.1.2.10.5.1.4.3 For transponders of Level 2 and above, a means shall be provided, while on the ground or during flight, for the aircraft identification to be displayed to the pilot, and, when containing variable data (3.1.2.10.5.1.3 d)), to be modified without the entry or modification of other flight data.

Note.— Implementation of the pilot action for entry of data will be as simple and efficient as possible in order to minimize the time required and reduce the possibility of errors in the data entry.

3.1.2.10.5.1.4.4 Interfaces shall be included to accept the pressure-altitude and on-the-ground coding.

Note.— A specific interface design for the variable direct data is not prescribed.

3.1.2.10.5.2 *Indirect data*

Note.— Indirect data are those which pass through the transponder in either direction but which do not affect the surveillance function.

If origins and/or destinations of indirect data are not within the transponder's enclosure, interfaces shall be used for the necessary connections.

3.1.2.10.5.2.1 *The function of interfaces*

Note.— Indirect data interfaces for standard transactions serve interrogations which require a reply and the broadcast function. Indirect data interfaces for ELM serve that system and require buffering and protocol circuitry within the transponder. Interface ports can be separate for each direction and for each service or can be combined in any manner.

3.1.2.10.5.2.1.1 *Uplink standard length transaction interface.* The uplink standard length transaction interface shall transfer all bits of accepted interrogations, (with the possible exception of the AP field), except for UF = 0, 11 or 16.

Note.— AP can also be transferred to aid in integrity implementation.

3.1.2.10.5.2.1.2 *Downlink standard length transaction interface*. A transponder which transmits information originating in a peripheral device shall be able to receive bits or bit patterns for insertion at appropriate locations within the transmission. These locations shall not include those into which bit patterns generated internally by the transponder are inserted, nor the AP field of the reply. A transponder which transmits information using the Comm-B format shall have immediate access to requested data in the sense that the transponder shall respond to an interrogation with data requested by that interrogation.

Note.— This requirement may be met in two ways:

a) the transponder may have provisions for internal data and protocol buffering;

b) the transponder may employ a "real time" interface which operates such that uplink data leave the transponder before the corresponding reply is generated and downlink data enter the transponder in time to be incorporated in the reply.

3.1.2.10.5.2.1.3 *Extended length message interface*

Note.— The ELM interface extracts from, and enters into, the transponder the data exchanged between air and ground by means of the ELM protocol (3.1.2.7).

3.1.2.10.5.2.2 *Indirect data transaction rates*

3.1.2.10.5.2.2.1 *Standard length transactions.* A transponder equipped for information transfer to and from external devices shall be capable of processing the data of at least as many replies as prescribed for minimum reply rates in 3.1.2.10.3.7.2 and uplink data from interrogations being delivered at a rate of at least:

50 long interrogations in any 1-second interval
18 long interrogations in a 100-millisecond interval
8 long interrogations in a 25-millisecond interval
4 long interrogations in a 1.6-millisecond interval.

Note 1.— A transponder capable of reply rates higher than the minimum of 3.1.2.10.3.7.2 need not accept long interrogations after reaching the uplink data processing limits above.

Note 2.— The Mode S reply is the sole means of acknowledging receipt of the data content of a Mode S interrogation.

Thus, if the transponder is capable of replying to an interrogation, the Mode S installation must be capable of accepting the data contained in that interrogation regardless of the timing between it and other accepted interrogations. Overlapping Mode S beams from several interrogators could lead to the requirement for considerable data processing and buffering. The minimum described here reduces data processing to a realistic level and the non-acceptance provision provides for notification to the interrogator that data will temporarily not be accepted.

3.1.2.10.5.2.2.2 *Extended length transactions.* Level 3 (2.1.5.1.3) and level 4 (2.1.5.1.4) transponders shall be able to transfer data from at least four complete sixteen segment uplink ELMs (3.1.2.7.4) in any four second interval. A level 5 transponder (2.1.5.1.5) shall be able to transfer the data from at least four complete sixteen segment uplink ELMs in any one second interval and shall be capable of accepting at least two complete sixteen segment uplink ELMs with the same II code in a 250 millisecond interval. A level 4 transponder shall be able to transmit at least one four-segment downlink ELM (3.1.2.7.7 and 3.1.2.10.3.7.3) in any one second interval. A level 5 transponder shall be able to transmit at least one sixteen segment downlink ELM in any one second interval.

3.1.2.10.5.2.2.2.1 **Recommendation.—** *Level 3 and level 4 transponders should be able to accept at least two complete sixteen segment uplink ELMs in a 250 millisecond interval.*

3.1.2.10.5.2.3 Data formats for standard length transactions and required downlink aircraft parameters (DAPs)

3.1.2.10.5.2.3.1 All level 2 and above transponders shall support the following registers:

— the capability reports (3.1.2.6.10.2);

— the aircraft identification protocol register 20 {HEX} (3.1.2.9); and

— for ACAS-equipped aircraft, the active resolution advisory register 30{HEX} (4.3.8.4.2.2).

3.1.2.10.5.2.3.2 Where required, DAPs shall be supported by the registers listed in Table 3-10. The formats and minimum update rates of transponder registers shall be implemented consistently to ensure interoperability.

3.1.2.10.5.2.3.3 The downlink standard length transaction interface shall deliver downlink aircraft parameters (DAPs) to the transponder which makes them available to the ground. Each DAP shall be packed into the Comm-B format ('MB' field) and can be extracted using either the ground-initiated Comm-B (GICB) protocol, or using MSP downlink channel 3 via the data flash application.

Note.— The formats and update rates of each register and the data flash application are specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

3.1.2.10.5.3 *Integrity of data content transfer.* A transponder which employs data interfaces shall include sufficient protection to ensure error rates of less than one error in 10^3messages and less than one undetected error in 10^7 112-bit transmissions in both directions between the antenna and each interface port.

3.1.2.10.5.4 *Message cancellation*. The downlink standard length transaction interface and the extended length message interface shall include the capability to cancel a message sent to the transponder for delivery to the ground, but whose delivery cycle has not been completed (i.e. a closeout has not been accomplished by a ground interrogator).

Note.— One example of the need for this capability is to cancel a message if delivery is attempted when the aircraft is not within coverage of a Mode S ground station. The message must then be cancelled to prevent it from being read and interpreted as a current message when the aircraft re-enters Mode S airspace.

3.1.2.10.5.5 *Air-directed messages*. The transfer of this type of message requires all of the actions indicated in 3.1.2.10.5.4 plus the transfer to the transponder of the interrogator identifier of the site that is to receive the message.

3.1.2.11 ESSENTIAL SYSTEM CHARACTERISTICS OF THE GROUND INTERROGATOR

Note.— To ensure that Mode S interrogator action is not detrimental to Mode A/C interrogators, performance limits exist for Mode S interrogators.

3.1.2.11.1 *Interrogation repetition rates.* Mode S interrogators shall use the lowest practicable interrogation repetition rates for all interrogation modes.

Note.— Accurate azimuth data at low interrogation rates can be obtained with monopulse techniques.

3.1.2.11.1.1 *All-call interrogation repetition rate*

3.1.2.11.1.1.1 The interrogation repetition rate for the Mode A/C/S all-call, used for acquisition, shall be less than 250 per second. This rate shall also apply to the paired Mode S-only and Mode A/C-only all-call interrogations used for acquisition in the multisite mode.

3.1.2.11.1.1.2 *Maximum number of Mode S all-call replies triggered by an interrogator.* For aircraft that are not locked out, a Mode S interrogator shall not trigger, on average, more than 6 all-call replies per period of 200 ms and no more than 26 all-call replies counted over a period of 18 seconds.

3.1.2.11.1.2 *Interrogation repetition rate to a single aircraft*

3.1.2.11.1.2.1 *Interrogations requiring a reply*. Mode S interrogations requiring a reply shall not be transmitted to a single aircraft at intervals shorter than 400 microseconds.

3.1.2.11.1.2.2 *Uplink ELM interrogations.* The minimum time between the beginning of successive Comm-C interrogations shall be 50 microseconds.

3.1.2.11.1.3 *Transmission rate for selective interrogations*

3.1.2.11.1.3.1 For all Mode S interrogators, the transmission rate for selective interrogations shall be:

a) less than 2 400 per second averaged over a 40-millisecond interval; and

b) less than 480 into any 3-degree sector averaged over a 1-second interval.

3.1.2.11.1.3.2 Additionally, for a Mode S interrogator that has overlapping coverage with the sidelobes of any other Mode S interrogator, the transmission rate for selective interrogations shall be:

a) less than 1 200 per second averaged over a 4-second interval; and

b) less than 1 800 per second averaged over a 1-second interval.

Note.— Typical minimum distance to ensure sidelobe separation between interrogators is 35 km.

3.1.2.11.2 *INTERROGATOR-EFFECTIVE RADIATED POWER*

Recommendation.— The effective radiated power of all interrogation pulses should be minimized as described in 3.1.1.8.2.

3.1.2.11.3 *Inactive-state interrogator output power.* When the interrogator transmitter is not transmitting an interrogation, its output shall not exceed –5 dBm effective radiated power at any frequency between 960 MHz and 1 215 MHz.

Note.— This constraint ensures that aircraft flying near the interrogator (as close as 1.85 km (1 NM)) will not receive interference that would prevent them from being tracked by another interrogator. In certain instances even smaller interrogator-to-aircraft distances are of significance, for example if Mode S surveillance on the airport surface is used. In such cases a further restraint on inactive state interrogator output power may be necessary.

3.1.2.11.3.1 *Spurious emission radiation*

Recommendation.— CW radiation should not exceed 76 dB below 1 watt.

3.1.2.11.4 *Tolerances on transmitted signals.* In order that the signal-in-space be received by the transponder as described in 3.1.2.1, the tolerances on the transmitted signal shall be as summarized in Table 3-11.

3.1.2.11.5 *SPURIOUS RESPONSE*

Recommendation.— The response to signals not within the passband should be at least 60 dB below normal sensitivity.

3.1.2.11.6 *Lockout coordination.* A Mode S interrogator shall not be operated using all-call lockout until coordination has been achieved with all other operating Mode S interrogators having any overlapping coverage volume in order to ensure that no interrogator can be denied the acquisition of Mode S-equipped aircraft.

Note.— This coordination may be via ground network or by the allocation of interrogator identifier (II) codes and will involve regional agreements where coverage overlaps international boundaries.

3.1.2.11.7 *MOBILE INTERROGATORS*

Recommendation.— Mobile interrogators should acquire, whenever possible, Mode S aircraft through the reception of squitters.

Note.— Passive squitter acquisition reduces channel loading and can be accomplished without the need for coordination.

TABLES FOR CHAPTER 3

Table 3-1. Pulse shapes — Mode S and intermode interrogations

Pulse	*Duration*	*Duration tolerance*	*(Rise time)* *Min.*	*(Rise time)* *Max.*	*(Decay time)* *Min.*	*(Decay time)* *Max.*
P_1, P_2, P_3, P_5	0.8	±0.1	0.05	0.1	0.05	0.2
P_4 (short)	0.8	±0.1	0.05	0.1	0.05	0.2
P_4 (long)	1.6	±0.1	0.05	0.1	0.05	0.2
P_6 (short)	16.25	±0.25	0.05	0.1	0.05	0.2
P_6 (long)	30.25	±0.25	0.05	0.1	0.05	0.2
S_1	0.8	±0.1	0.05	0.1	0.05	0.2

Table 3-2. Pulse shapes — Mode S replies

Field		*Format*		
Designator	*Function*	*UF*	*DF*	*Reference*
AA	Address announced		11, 17, 18	3.1.2.5.2.2.2
AC	Altitude code		4, 20	3.1.2.6.5.4
AF	Application field		19	3.1.2.8.8.2
AP	Address/parity	All	0, 4, 5, 16, 20, 21, 24	3.1.2.3.2.1.3
AQ	Acquisition	0		3.1.2.8.1.1
CA	Capability		11, 17	3.1.2.5.2.2.1
CC	Cross-link capability		0	3.1.2.8.2.3
CF	Control field		18	3.1.2.8.7.2
CL	Code label	11		3.1.2.5.2.1.3
DF	Downlink format		All	3.1.2.3.2.1.2

Field		*Format*		*Reference*
Designator	*Function*	*UF*	*DF*	
DI	Designator identification	4, 5, 20, 21		3.1.2.6.1.3
DP	Data parity		20, 21	3.1.2.3.2.1.5
DR	Downlink request		4, 5, 20, 21	3.1.2.6.5.2
DS	Data selector	0		3.1.2.8.1.3
FS	Flight status		4, 5, 20, 21	3.1.2.6.5.1
IC	Interrogator code	11		3.1.2.5.2.1.2
ID	Identity		5, 21	3.1.2.6.7.1
KE	Control, ELM		24	3.1.2.7.3.1
MA	Message, Comm-A	20, 21		3.1.2.6.2.1
MB	Message, Comm-B		20, 21	3.1.2.6.6.1
MC	Message, Comm-C	24		3.1.2.7.1.3
MD	Message, Comm-D		24	3.1.2.7.3.3
ME	Message, extended squitter		17, 18	3.1.2.8.6.2
MU	Message, ACAS	16		4.3.8.4.2.3
MV	Message, ACAS		16	3.1.2.8.3.1, 4.3.8.4.2.4
NC	Number of C-segment	24		3.1.2.7.1.2
ND	Number of D-segment		24	3.1.2.7.3.2
PC	Protocol	4, 5, 20, 21		3.1.2.6.1.1
PI	Parity/interrogator identifier		11, 17, 18	3.1.2.3.2.1.4
PR	Probability of reply	11		3.1.2.5.2.1.1
RC	Reply control	24		3.1.2.7.1.1
RI	Reply information		0	3.1.2.8.2.2
RL	Reply length	0		3.1.2.8.1.2
RR	Reply request	4, 5, 20, 21		3.1.2.6.1.2
SD	Special designator	4, 5, 20, 21		3.1.2.6.1.4
SL	Sensitivity Level (ACAS)		0, 16	4.3.8.4.2.5
UF	Uplink format	All		3.1.2.3.2.1.1
UM	Utility message		4, 5, 20, 21	3.1.2.6.5.3
VS	Vertical status		0	3.1.2.8.2.1

Table 3-4. Subfield definitions

Subfield			
Designator	*Function*	*Field*	*Reference*
ACS	Altitude code subfield	ME	3.1.2.8.6.3.1.2
AIS	Aircraft identification subfield	MB	3.1.2.9.1.1
ATS	Altitude type subfield	MB	3.1.2.8.6.8.2
BDS 1	Comm-B data selector subfield 1	MB	3.1.2.6.11.2.1
BDS 2	Comm-B data selector subfield 2	MB	3.1.2.6.11.2.1
IDS	Identifier designator subfield	UM	3.1.2.6.5.3.1
IIS	Interrogator identifier subfield	SD	3.1.2.6.1.4.1 a)
		UM	3.1.2.6.5.3.1
LOS	Lockout subfield	SD	3.1.2.6.1.4.1 d)
LSS	Lockout surveillance subfield	SD	3.1.2.6.1.4.1 g)
MBS	Multisite Comm-B subfield	SD	3.1.2.6.1.4.1 c)
MES	Multisite ELM subfield	SD	3.1.2.6.1.4.1 c)
OVC	Overlay control	SD	3.1.2.6.1.4.1 i)
RCS	Rate control subfield	SD	3.1.2.6.1.4.1 f)
RRS	Reply request subfield	SD	3.1.2.6.1.4.1 e) and g)
RSS	Reservation status subfield	SD	3.1.2.6.1.4.1 c)
SAS	Surface antenna subfield	SD	3.1.2.6.1.4.1 f)
SCS	Squitter capability subfield	MB	3.1.2.6.10.2.2.1
SIC	Surveillance identifier capability	MB	3.1.2.6.10.2.2.1
SIS	Surveillance identifier subfield	SD	3.1.2.6.1.4.1 g)
SRS	Segment request subfield	MC	3.1.2.7.7.2.1
SSS	Surveillance status subfield	ME	3.1.2.8.6.3.1.1
TAS	Transmission acknowledgement subfield	MD	3.1.2.7.4.2.6
TCS	Type control subfield	SD	3.1.2.6.1.4.1 f)
TMS	Tactical message subfield	SD	3.1.2.6.1.4.1 d)
TRS	Transmission rate subfield	MB	3.1.2.8.6.8.1

Table 3-5. Interrogation — reply protocol summary

Interrogation UF	*Special conditions*	*Reply DF*
0	RL (3.1.2.8.1.2) equals 0	0
	RL (3.1.2.8.1.2) equals 1	16
4	RR (3.1.2.6.1.2) less than 16	4
	RR (3.1.2.6.1.2) equal to or greater than 16	20
5	RR (3.1.2.6.1.2) less than 16	5
	RR (3.1.2.6.1.2) equal to or greater than 16	21
11	Transponder locked out to interrogator code, IC (3.1.2.5.2.1.2)	No reply
	Stochastic reply test fails (3.1.2.5.4)	No reply
	Otherwise	11
20	RR (3.1.2.6.1.2) less than 16	4
	RR (3.1.2.6.1.2) equal to or greater than 16	20
	AP contains broadcast address (3.1.2.4.1.2.3.1.3)	No reply
21	RR (3.1.2.6.1.2) less than 16	5
	RR (3.1.2.6.1.2) equal to or greater than 16	21
	AP contains broadcast address (3.1.2.4.1.2.3.1.3)	No reply
24	RC (3.1.2.7.1.1) equals 0 or 1	No reply
	RC (3.1.2.7.1.1) equals 2 or 3	24

Table 3-6. Table for register 10_{16}

Subfields of register 10_{16}	*MB bits*	*Comm-B bits*
Continuation flag	9	41
Overlay command capability	15	47
ACAS capability	16 and 37-40	48 and 69-72
Mode S subnetwork version number	17-23	49-55
Transponder enhanced protocol indicator	24	56
Specific services capability	25	57
Uplink ELM capability	26-28	58-60
Downlink ELM capability	29-32	61-64
Aircraft identification capability	33	65
Squitter capability subfield (SCS)	34	66
Surveillance identifier code capability (SIC)	35	67
Common usage GICB capability report	36	68
Status of DTE sub-addresses 0 to 15	41-56	73-88

Table 3-7. Surface format broadcast without an automatic means of on-the-ground determination

	ADS-B Emitter Category set "A"					
Coding	*Meaning*	*Ground Speed*		*Airspeed*		*Radio Altitude*
0	No ADS-B emitter category information	Always report airborne position message (3.1.2.8.6.3.1)				
1	Light (<15 500 lbs or 7 031 kg)	Always report airborne position message (3.1.2.8.6.3.1)				
2	Small (15 500 to 75 000 lbs or 7 031 to 34 019 kg)	< 100 knots	and	<100 knots	and	<50 feet
3	Large (75 000 lbs to 300 000 lbs or 34 019 to 136 078 kg)	<100 knots	and	<100 knots	and	<50 feet
4	High-vortex aircraft	<100 knots	and	<100 knots	and	<50 feet
5	Heavy (> 300 000 lbs or 136 078 kg)	<100 knots	and	<100 knots	and	<50 feet
6	High performance (>5g acceleration and >400 knots)	<100 knots	and	<100 knots	and	<50 feet
7	Rotorcraft	Always report airborne position message (3.1.2.8.6.3.1)				
	ADS-B Emitter Category Set "B"					
Coding	*Meaning*	*Ground Speed*		*Airspeed*		*Radio Altitude*
0	No ADS-B emitter category information	Always report airborne position message (3.1.2.8.6.3.1)				
1	Glider/sailplane	Always report airborne position message (3.1.2.8.6.3.1)				
2	Lighter-than-air	Always report airborne position message (3.1.2.8.6.3.1)				
3	Parachutist/skydiver	Always report airborne position message (3.1.2.8.6.3.1)				
4	Ultra-light/hang-glider/paraglider	Always report airborne position message (3.1.2.8.6.3.1)				
5	Reserved	Reserved				
6	Unmanned aerial vehicle	Always report airborne position message (3.1.2.8.6.3.1)				
7	Space/trans-atmospheric vehicle	<100 knots	and	<100 knots	and	<50 feet
	ADS-B Emitter Category Set "C"					
Coding	*Meaning*					
0	No ADS-B emitter category information	Always report airborne position message (3.1.2.8.6.3.1)				
1	Surface vehicle – emergency vehicle	Always report surface position message (3.1.2.8.6.3.2)				
2	Surface vehicle - service vehicle	Always report surface position message (3.1.2.8.6.3.2)				
3	Fixed ground or tethered obstruction	Always report airborne position message (3.1.2.8.6.3.1)				
4 – 7	Reserved	Reserved				
	ADS-B Emitter Category Set "D"					
Coding	*Meaning*					
0	No ADS-B emitter category information	Always report airborne position message (3.1.2.8.6.3.1)				
1 – 7	Reserved	Reserved				

Table 3-8. Character coding for transmission of aircraft identification by data link

(subset of IA-5 — see 3.1.2.9.1.2)

				b_6	0	0	1	1
				b_5	0	1	0	1
b_4	b_3	b_2	b_1					
0	0	0	0			P	SP	0
0	0	0	1		A	Q		1
0	0	1	0		B	R		2
0	0	1	1		C	S		3
0	1	0	0		D	T		4
0	1	0	1		E	U		5
0	1	1	0		F	V		6
0	1	1	1		G	W		7
1	0	0	0		H	X		8
1	0	0	1		I	Y		9
1	0	1	0		J	Z		
1	0	1	1		K			
1	1	0	0		L			
1	1	0	1		M			
1	1	1	0		N			
1	1	1	1		O			

Table 3-9. Timer characteristics

Timer *Name*	*Number*	*Reference*	*Symbol*	*Duration* *s*	*Tolerance* *s*	*Resettable*
Non-selective lock-out	1	3.1.2.6.9.2	T_D	18	±1	no
Temporary alert	1	3.1.2.6.10.1.1.2	T_C	18	±1	no
SPI	1	3.1.2.6.10.1.3	T_I	18	±1	no
Reservations B, C, D	3*	3.1.2.6.11.3.1	T_R	18	±1	yes
Multisite lockout	78	3.1.2.6.9.1	T_L	18	±1	no

* As required

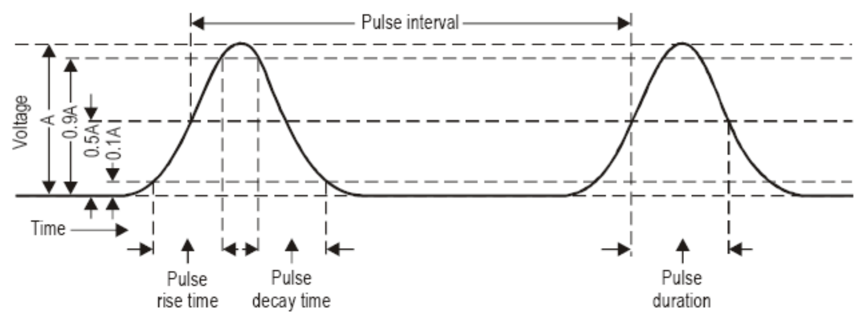
Table 3-10. DAPs registers

Register	*Name*	*Data content*	*Bits*
40 {HEX}	Selected vertical intention	MCP/FCU selected altitude	1-13
		FMS selected altitude	14-26
		Barometric pressure setting minus 800 mb	27-39
		MCP/FCU mode bits	48-51
		Target altitude source bits	54-56
50 {HEX}	Track and turn report	Roll angle	1-11
		True track angle	12-23
		Ground speed	24-34
		Track angle rate	35-45
		True airspeed	46-56
60 {HEX}	Heading and speed report	Magnetic heading	1-12
		Indicated airspeed	13-23
		Mach	24-34
		Barometric altitude rate	35-45
		Inertial vertical velocity	46-56

Table 3-11. Transmitted signal tolerances

Reference	*Function*	*Tolerance*
3.1.2.1.4.1	Pulse duration P_1, P_2, P_3, P_4, P_5 Pulse duration P_6	±0.09 microsecond ±0.20 microsecond
3.1.1.4	Pulse duration $P_1 - P_3$ Pulse duration $P_1 - P_2$	±0.18 microsecond ±0.10 microsecond
3.1.2.1.5.1.3	Pulse duration $P_3 - P_4$	±0.04 microsecond
3.1.2.1.5.2.4	Pulse duration $P_1 - P_2$ Pulse duration P_2 — sync phase reversal Pulse duration P_6 — sync phase reversal Pulse duration P_5 — sync phase reversal	±0.04 microsecond ±0.04 microsecond ±0.04 microsecond ±0.05 microsecond
3.1.1.5	Pulse amplitude P_3	P_1 ±0.5 dB
3.1.2.1.5.1.4	Pulse amplitude P_4	P_3 ±0.5 dB
3.1.2.1.5.2.5	Pulse amplitude P_6	Equal to or greater than $P_2 - 0.25$ dB
3.1.2.1.4.1	Pulse rise times	0.05 microsecond minimum, 0.1 microsecond maximum
3.1.2.1.4.1	Pulse decay times	0.05 microsecond minimum, 0.2 microsecond maximum

FIGURES FOR CHAPTER 3



Definitions

Phase reversal. A 180-degree change in the phase of the radio frequency carrier.
Phase reversal duration. The time between the 10-degree and 170-degree points of a phase reversal.
Pulse amplitude A. The peak voltage amplitude of the pulse envelope.
Pulse decay time. The time between 0.9A and 0.1A on the trailing edge of the pulse envelope.
Pulse duration. The time interval between 0.5A points on leading and trailing edges of the pulse envelope.
Pulse interval. The time interval between the 0.5A point on the leading edge of the first pulse and the 0.5A point on the leading edge of the second pulse.
Pulse rise time. The time between 0.1A and 0.9A on the leading edge of the pulse envelope.
Time intervals. The intervals are referenced to:

a) the 0.5A point on the leading edge of a pulse;
b) the 0.5A point on the trailing edge of a pulse; or
c) the 90-degree point of a phase reversal.

Transponder sensitivity and power reference point. The antenna end of the transmission line of the transponder.

Figure 3-1. Definitions of secondary surveillance radar waveform shapes, intervals and the reference point for sensitivity and power

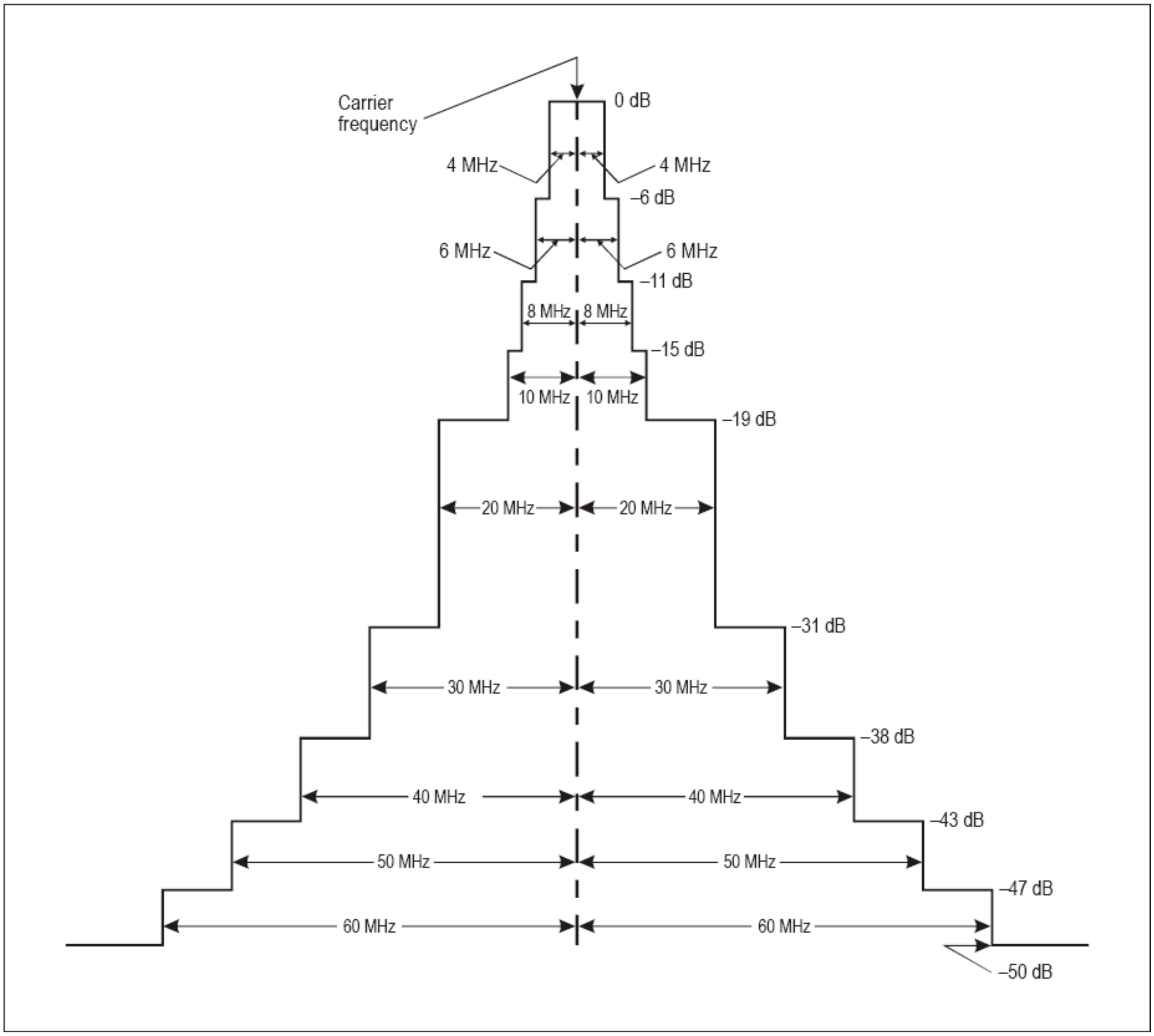


Figure 3-2. Required spectrum limits for interrogator transmitter

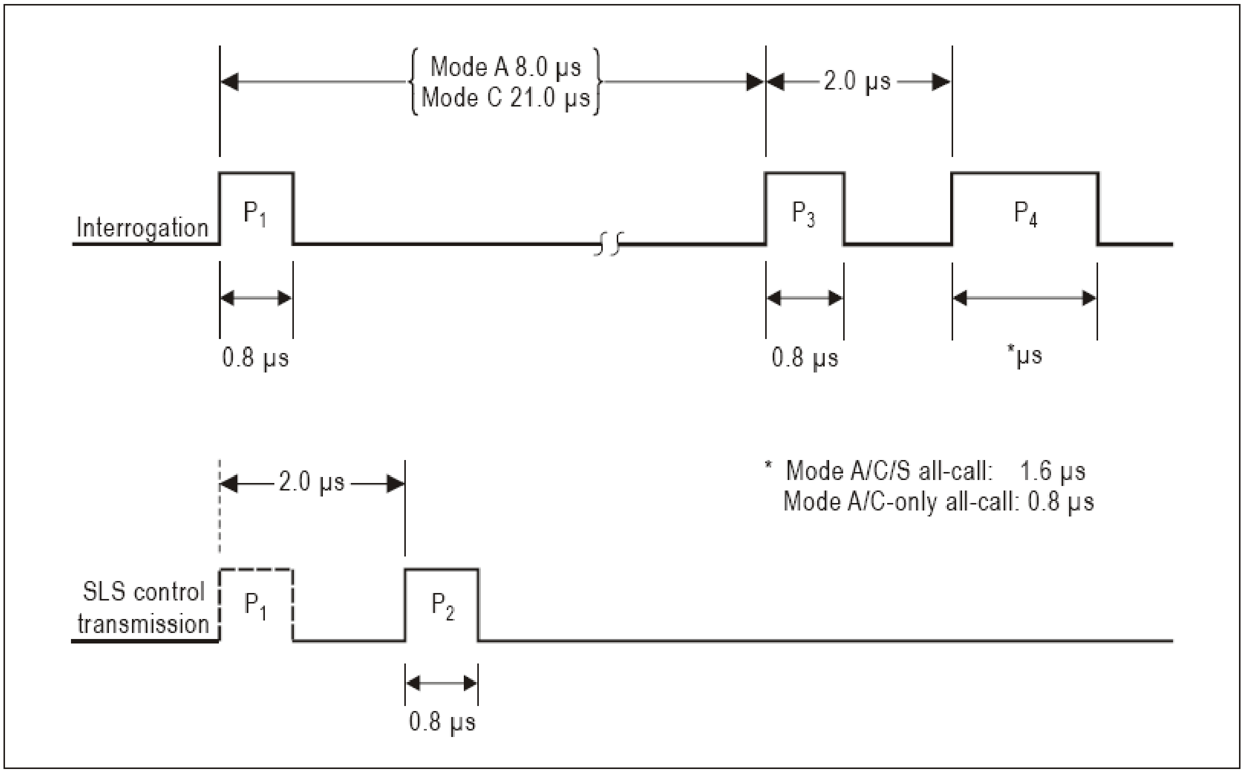


Figure 3-3. Intermode interrogation pulse sequence

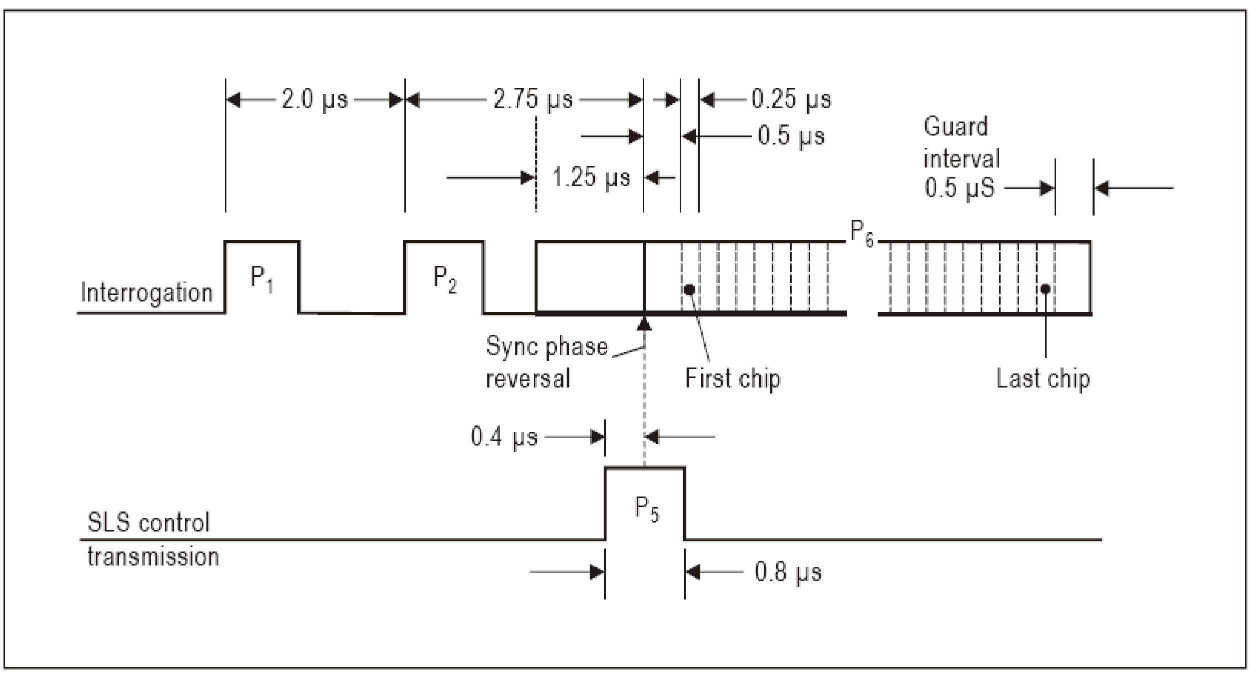


Figure 3-4. Mode S interrogation pulse sequence

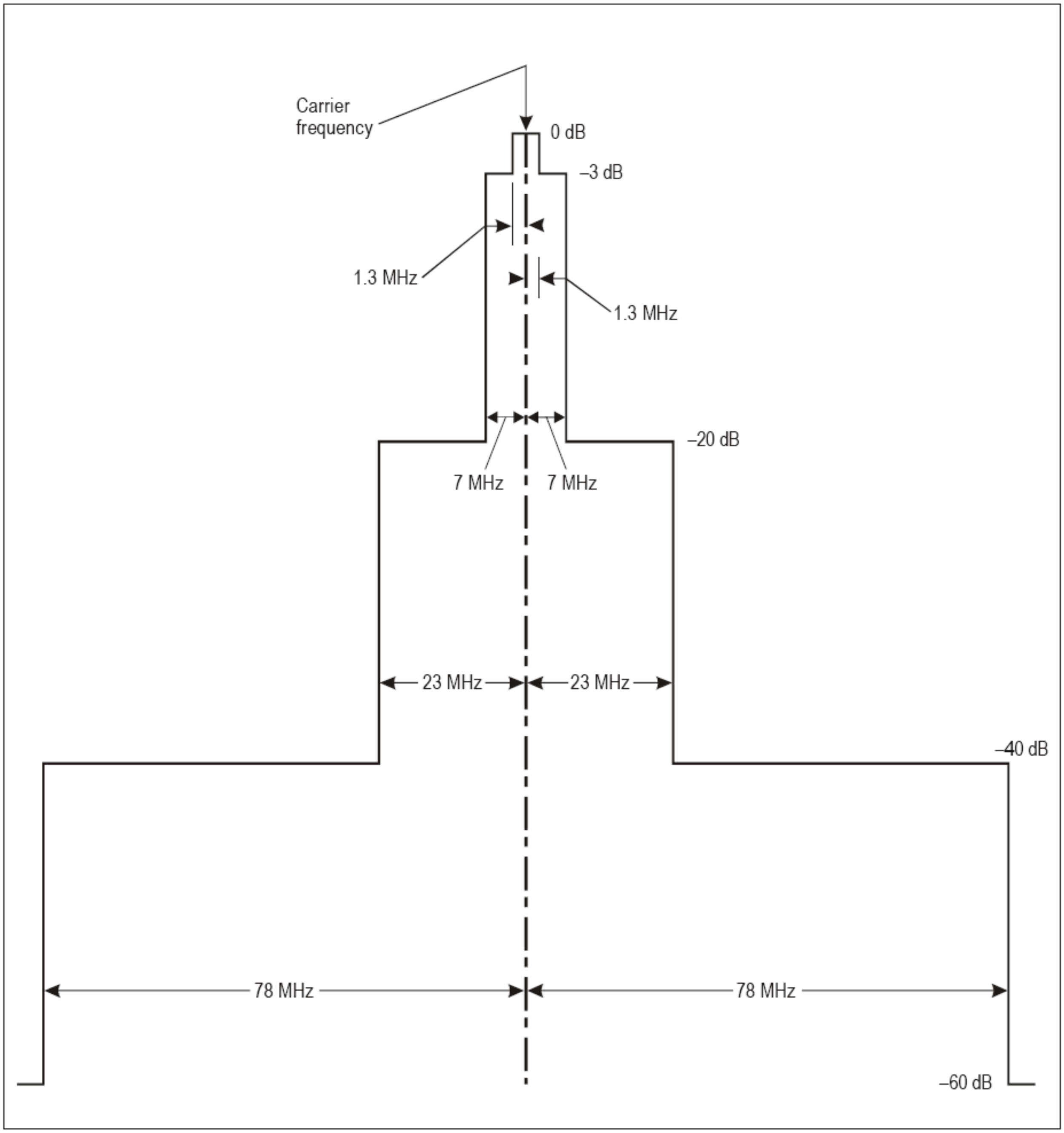


Figure 3-5. Required spectrum limits for transponder transmitter

Note.— This figure shows the spectrum centred on the carrier frequency and will therefore shift in its entirety plus orminus 1 MHz along with the carrier frequency.

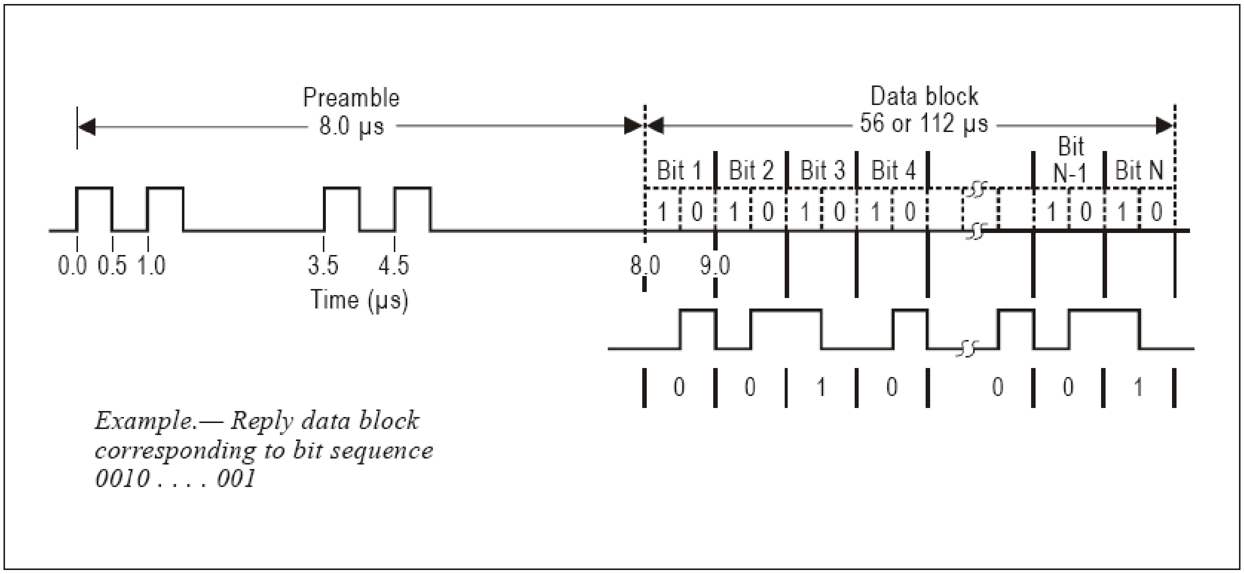


Figure 3-6. Mode S reply

Format No.	UF								
0	00000	3	RL:1	4	AQ:1	DS:8	10	AP:24	.... Short air-air surveillance (ACAS)
1	00001	27 or 83						AP:24	... Reserved
2	00010	27 or 83						AP:24	... Reserved
3	00011	27 or 83						AP:24	... Reserved
4	00100	PC:3	RR:5	DI:3	SD:16			AP:24	.... Surveillance, altitude request
5	00101	PC:3	RR:5	DI:3	SD:16			AP:24	.... Surveillance, identify request
6	00110	27 or 83						AP:24	... Reserved
7	00111	27 or 83						AP:24	... Reserved
8	01000	27 or 83						AP:24	... Reserved
9	01001	27 or 83						AP:24	... Reserved
10	01010	27 or 83						AP:24	... Reserved
11	01011	PR:4	IC:4	CL:3	16			AP:24	.... Mode S only all-call
12	01100	27 or 83						AP:24	... Reserved
13	01101	27 or 83						AP:24	... Reserved
14	01110	27 or 83						AP:24	... Reserved
15	01111	27 or 83						AP:24	... Reserved
16	10000	3	RL:1	4	AQ:1	18	MU:56	AP:24	.... Long air-air surveillance (ACAS)
17	10001	27 or 83						AP:24	... Reserved
18	10010	27 or 83						AP:24	... Reserved
19	10011	27 or 83						AP:24	... Reserved for military use
20	10100	PC:3	RR:5	DI:3	SD:16	MA:56		AP:24	.... Comm-A, altitude request
21	10101	PC:3	RR:5	DI:3	SD:16	MA:56		AP:24	.... Comm-A, identify request
22	10110	27 or 83						AP:24	... Reserved for military use
23	10111	27 or 83						AP:24	... Reserved
24	11	RC:2	NC:4	MC:80				AP:24	.... Comm-C (ELM)

NOTES:

1. [XX:M] denotes a field designated "XX" which is assigned M bits.

2. 

denotes unassigned coding space with N available bits. These shall be coded as ZEROs for transmission.

3. For uplink formats (UF) 0 to 23 the format number corresponds to the binary code in the first five bits of the interrogation. Format number 24 is defined as the format beginning with "11" in the first two bit positions while the following three bits vary with the interrogation content.

4. All formats are shown for completeness, although a number of them are unused. Those formats for which no application is presently defined remain undefined in length. Depending on future assignment they may be short (56 bits) or long (112 bits) formats. Specific formats associated with Mode S capability levels are described in later paragraphs.

5. The PC, RR, DI and SD fields do not apply to a Comm-A broadcast interrogation.

Figure 3-7. Summary of Mode S interrogation or uplink formats

Format No.	DF										
0	00000	VS:1	CC:1	1	SL:3	2	RI:4	2	AC:13	AP:24	.... Short air-air surveillance (ACAS)
1	00001	27 or 83								P:24	... Reserved
2	00010	27 or 83								P:24	... Reserved
3	00011	27 or 83								P:24	... Reserved
4	00100	FS:3	DR:5	UM:6	AC:13					AP:24	.... Surveillance, altitude reply
5	00101	FS:3	DR:5	UM:6	ID:13					AP:24	.... Surveillance, identify reply
6	00110	27 or 83								P:24	... Reserved
7	00111	27 or 83								P:24	... Reserved
8	01000	27 or 83								P:24	... Reserved
9	01001	27 or 83								P:24	... Reserved
10	01010	27 or 83								P:24	... Reserved
11	01011	CA:3	AA:24							PI:24	.... All-call reply
12	01100	27 or 83								P:24	... Reserved
13	01101	27 or 83								P:24	... Reserved
14	01110	27 or 83								P:24	... Reserved
15	01111	27 or 83								P:24	... Reserved
16	10000	VS:1	2	SL:3	2	RI:4	2	AC:13	MV:56	AP:24	.... Long air-air surveillance (ACAS)
17	10001	CA:3	AA:24	ME:56						PI:24	... Extended squitter
18	10010	CF:3	AA:24	ME:56						PI:24	... Extended squitter/non transponder
19	10011	AF:3	104								... Military extended squitter
20	10100	FS:3	DR:5	UM:6	AC:13	MB:56				AP:24 / DP:24	.... Comm-B, altitude reply .... (see *Note 5*)
21	10101	FS:3	DR:5	UM:6	ID:13	MB:56				AP:24 / DP:24	.... Comm-B, identify reply .... (see *Note 5*)
22	10110	27 or 83								P:24	... Reserved for military use
23	10111	27 or 83								P:24	... Reserved
24	11	1	KE:1	ND:4	MD:80					AP:24	.... Comm-D (ELM)

NOTES:

1. XX:M denotes a field designated "XX" which is assigned M bits.

P:24 denotes a 24-bit field reserved for parity information.

2. N denotes unassigned coding space with N available bits. These shall be coded as ZEROs for transmission.

3. For downlink formats (DF) 0 to 23 the format number corresponds to the binary code in the first five bits of the reply. Format number 24 is defined as the format beginning with "11" in the first two bit positions while the following three bits may vary with the reply content.

4. All formats are shown for completeness, although a number of them are unused. Those formats for which no application is presently defined remain undefined in length. Depending on future assignment they may be short (56 bits) or long (112 bits) formats. Specific formats associated with Mode S capability levels are described in later paragraphs.

5. The Data parity (DP) (3.1.2.3.2.1.5) is used if it has been commanded by the OVC (3.1.2.6.1.4.1.i) in accordance with paragraph 3.1.2.6.11.2.5.

Figure 3-8. Summary of Mode S reply or downlink formats

APPENDIX TO CHAPTER 3

SSR AUTOMATIC PRESSURE-ALTITUDE TRANSMISSION CODE (PULSE POSITION ASSIGNMENT)

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
-1 000	to	-950	0	0	0	0	0	0	0	0	0	1	0
-950	to	-850	0	0	0	0	0	0	0	0	1	1	0
-850	to	-750	0	0	0	0	0	0	0	0	1	0	0
-750	to	-650	0	0	0	0	0	0	0	1	1	0	0
-650	to	-550	0	0	0	0	0	0	0	1	1	1	0
-550	to	-450	0	0	0	0	0	0	0	1	0	1	0
-450	to	-350	0	0	0	0	0	0	0	1	0	1	1
-350	to	-250	0	0	0	0	0	0	0	1	0	0	1
-250	to	-150	0	0	0	0	0	0	1	1	0	0	1
-150	to	-50	0	0	0	0	0	0	1	1	0	1	1
-50	to	50	0	0	0	0	0	0	1	1	0	1	0
50	to	150	0	0	0	0	0	0	1	1	1	1	0
150	to	250	0	0	0	0	0	0	1	1	1	0	0
250	to	350	0	0	0	0	0	0	1	0	1	0	0
350	to	450	0	0	0	0	0	0	1	0	1	1	0
450	to	550	0	0	0	0	0	0	1	0	0	1	0
550	to	650	0	0	0	0	0	0	1	0	0	1	1
650	to	750	0	0	0	0	0	0	1	0	0	0	1
750	to	850	0	0	0	0	0	1	1	0	0	0	1
850	to	950	0	0	0	0	0	1	1	0	0	1	1
950	to	1 050	0	0	0	0	0	1	1	0	0	1	0
1 050	to	1 150	0	0	0	0	0	1	1	0	1	1	0
1 150	to	1 250	0	0	0	0	0	1	1	0	1	0	0
1 250	to	1 350	0	0	0	0	0	1	1	1	1	0	0
1 350	to	1 450	0	0	0	0	0	1	1	1	1	1	0
1 450	to	1 550	0	0	0	0	0	1	1	1	0	1	0
1 550	to	1 650	0	0	0	0	0	1	1	1	0	1	1
1 650	to	1 750	0	0	0	0	0	1	1	1	0	0	1
1 750	to	1 850	0	0	0	0	0	1	0	1	0	0	1
1 850	to	1 950	0	0	0	0	0	1	0	1	0	1	1
1 950	to	2 050	0	0	0	0	0	1	0	1	0	1	0
2 050	to	2 150	0	0	0	0	0	1	0	1	1	1	0
2 150	to	2 250	0	0	0	0	0	1	0	1	1	0	0
2 250	to	2 350	0	0	0	0	0	1	0	0	1	0	0
2 350	to	2 450	0	0	0	0	0	1	0	0	1	1	0
2 450	to	2 550	0	0	0	0	0	1	0	0	0	1	0
2 550	to	2 650	0	0	0	0	0	1	0	0	0	1	1
2 650	to	2 750	0	0	0	0	0	1	0	0	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
2 750	to	2 850	0	0	0	0	1	1	0	0	0	0	1
2 850	to	2 950	0	0	0	0	1	1	0	0	0	1	1
2 950	to	3 050	0	0	0	0	1	1	0	0	0	1	0
3 050	to	3 150	0	0	0	0	1	1	0	0	1	1	0
3 150	to	3 250	0	0	0	0	1	1	0	0	1	0	0
3 250	to	3 350	0	0	0	0	1	1	0	1	1	0	0
3 350	to	3 450	0	0	0	0	1	1	0	1	1	1	0
3 450	to	3 550	0	0	0	0	1	1	0	1	0	1	0
3 550	to	3 650	0	0	0	0	1	1	0	1	0	1	1
3 650	to	3 750	0	0	0	0	1	1	0	1	0	0	1
3 750	to	3 850	0	0	0	0	1	1	1	1	0	0	1
3 850	to	3 950	0	0	0	0	1	1	1	1	0	1	1
3 950	to	4 050	0	0	0	0	1	1	1	1	0	1	0
4 050	to	4 150	0	0	0	0	1	1	1	1	1	1	0
4 150	to	4 250	0	0	0	0	1	1	1	1	1	0	0
4 250	to	4 350	0	0	0	0	1	1	1	0	1	0	0
4 350	to	4 450	0	0	0	0	1	1	1	0	1	1	0
4 450	to	4 550	0	0	0	0	1	1	1	0	0	1	0
4 550	to	4 650	0	0	0	0	1	1	1	0	0	1	1
4 650	to	4 750	0	0	0	0	1	1	1	0	0	0	1
4 750	to	4 850	0	0	0	0	1	0	1	0	0	0	1
4 850	to	4 950	0	0	0	0	1	0	1	0	0	1	1
4 950	to	5 050	0	0	0	0	1	0	1	0	0	1	0
5 050	to	5 150	0	0	0	0	1	0	1	0	1	1	0
5 150	to	5 250	0	0	0	0	1	0	1	0	1	0	0
5 250	to	5 350	0	0	0	0	1	0	1	1	1	0	0
5 350	to	5 450	0	0	0	0	1	0	1	1	1	1	0
5 450	to	5 550	0	0	0	0	1	0	1	1	0	1	0
5 550	to	5 650	0	0	0	0	1	0	1	1	0	1	1
5 650	to	5 750	0	0	0	0	1	0	1	1	0	0	1
5 750	to	5 850	0	0	0	0	1	0	0	1	0	0	1
5 850	to	5 950	0	0	0	0	1	0	0	1	0	1	1
5 950	to	6 050	0	0	0	0	1	0	0	1	0	1	0
6 050	to	6 150	0	0	0	0	1	0	0	1	1	1	0
6 150	to	6 250	0	0	0	0	1	0	0	1	1	0	0
6 250	to	6 350	0	0	0	0	1	0	0	0	1	0	0
6 350	to	6 450	0	0	0	0	1	0	0	0	1	1	0
6 450	to	6 550	0	0	0	0	1	0	0	0	0	1	0
6 550	to	6 650	0	0	0	0	1	0	0	0	0	1	1
6 650	to	6 750	0	0	0	0	1	0	0	0	0	0	1
6 750	to	6 850	0	0	0	1	1	0	0	0	0	0	1
6 850	to	6 950	0	0	0	1	1	0	0	0	0	1	1
6 950	to	7 050	0	0	0	1	1	0	0	0	0	1	0
7 050	to	7 150	0	0	0	1	1	0	0	0	1	1	0
7 150	to	7 250	0	0	0	1	1	0	0	0	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
7 250	to	7 350	0	0	0	1	1	0	0	1	1	0	0
7 350	to	7 450	0	0	0	1	1	0	0	1	1	1	0
7 450	to	7 550	0	0	0	1	1	0	0	1	0	1	0
7 550	to	7 650	0	0	0	1	1	0	0	1	0	1	1
7 650	to	7 750	0	0	0	1	1	0	0	1	0	0	1
7 750	to	7 850	0	0	0	1	1	0	1	1	0	0	1
7 850	to	7 950	0	0	0	1	1	0	1	1	0	1	1
7 950	to	8 050	0	0	0	1	1	0	1	1	0	1	0
8 050	to	8 150	0	0	0	1	1	0	1	1	1	1	0
8 150	to	8 250	0	0	0	1	1	0	1	1	1	0	0
8 250	to	8 350	0	0	0	1	1	0	1	0	1	0	0
8 350	to	8 450	0	0	0	1	1	0	1	0	1	1	0
8 450	to	8 550	0	0	0	1	1	0	1	0	0	1	0
8 550	to	8 650	0	0	0	1	1	0	1	0	0	1	1
8 650	to	8 750	0	0	0	1	1	0	1	0	0	0	1
8 750	to	8 850	0	0	0	1	1	1	1	0	0	0	1
8 850	to	8 950	0	0	0	1	1	1	1	0	0	1	1
8 950	to	9 050	0	0	0	1	1	1	1	0	0	1	0
9 050	to	9 150	0	0	0	1	1	1	1	0	1	1	0
9 150	to	9 250	0	0	0	1	1	1	1	0	1	0	0
9 250	to	9 350	0	0	0	1	1	1	1	1	1	0	0
9 350	to	9 450	0	0	0	1	1	1	1	1	1	1	0
9 450	to	9 550	0	0	0	1	1	1	1	1	0	1	0
9 550	to	9 650	0	0	0	1	1	1	1	1	0	1	1
9 650	to	9 750	0	0	0	1	1	1	1	1	0	0	1
9 750	to	9 850	0	0	0	1	1	1	0	1	0	0	1
9 850	to	9 950	0	0	0	1	1	1	0	1	0	1	1
9 950	to	10 050	0	0	0	1	1	1	0	1	0	1	0
10 050	to	10 150	0	0	0	1	1	1	0	1	1	1	0
10 150	to	10 250	0	0	0	1	1	1	0	1	1	0	0
10 250	to	10 350	0	0	0	1	1	1	0	0	1	0	0
10 350	to	10 450	0	0	0	1	1	1	0	0	1	1	0
10 450	to	10 550	0	0	0	1	1	1	0	0	0	1	0
10 550	to	10 650	0	0	0	1	1	1	0	0	0	1	1
10 650	to	10 750	0	0	0	1	1	1	0	0	0	0	1
10 750	to	10 850	0	0	0	1	0	1	0	0	0	0	1
10 850	to	10 950	0	0	0	1	0	1	0	0	0	1	1
10 950	to	11 050	0	0	0	1	0	1	0	0	0	1	0
11 050	to	11 150	0	0	0	1	0	1	0	0	1	1	0
11 150	to	11 250	0	0	0	1	0	1	0	0	1	0	0
11 250	to	11 350	0	0	0	1	0	1	0	1	1	0	0
11 350	to	11 450	0	0	0	1	0	1	0	1	1	1	0
11 450	to	11 550	0	0	0	1	0	1	0	1	0	1	0
11 550	to	11 650	0	0	0	1	0	1	0	1	0	1	1
11 650	to	11 750	0	0	0	1	0	1	0	1	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
11 750	to	11 850	0	0	0	1	0	1	1	1	0	0	1
11 850	to	11 950	0	0	0	1	0	1	1	1	0	1	1
11 950	to	12 050	0	0	0	1	0	1	1	1	0	1	0
12 050	to	12 150	0	0	0	1	0	1	1	1	1	1	0
12 150	to	12 250	0	0	0	1	0	1	1	1	1	0	0
12 250	to	12 350	0	0	0	1	0	1	1	0	1	0	0
12 350	to	12 450	0	0	0	1	0	1	1	0	1	1	0
12 450	to	12 550	0	0	0	1	0	1	1	0	0	1	0
12 550	to	12 650	0	0	0	1	0	1	1	0	0	1	1
12 650	to	12 750	0	0	0	1	0	1	1	0	0	0	1
12 750	to	12 850	0	0	0	1	0	0	1	0	0	0	1
12 850	to	12 950	0	0	0	1	0	0	1	0	0	1	1
12 950	to	13 050	0	0	0	1	0	0	1	0	0	1	0
13 050	to	13 150	0	0	0	1	0	0	1	0	1	1	0
13 150	to	13 250	0	0	0	1	0	0	1	0	1	0	0
13 250	to	13 350	0	0	0	1	0	0	1	1	1	0	0
13 350	to	13 450	0	0	0	1	0	0	1	1	1	1	0
13 450	to	13 550	0	0	0	1	0	0	1	1	0	1	0
13 550	to	13 650	0	0	0	1	0	0	1	1	0	1	1
13 650	to	13 750	0	0	0	1	0	0	1	1	0	0	1
13 750	to	13 850	0	0	0	1	0	0	0	1	0	0	1
13 850	to	13 950	0	0	0	1	0	0	0	1	0	1	1
13 950	to	14 050	0	0	0	1	0	0	0	1	0	1	0
14 050	to	14 150	0	0	0	1	0	0	0	1	1	1	0
14 150	to	14 250	0	0	0	1	0	0	0	1	1	0	0
14 250	to	14 350	0	0	0	1	0	0	0	0	1	0	0
14 350	to	14 450	0	0	0	1	0	0	0	0	1	1	0
14 450	to	14 550	0	0	0	1	0	0	0	0	0	1	0
14 550	to	14 650	0	0	0	1	0	0	0	0	0	1	1
14 650	to	14 750	0	0	0	1	0	0	0	0	0	0	1
14 750	to	14 850	0	0	1	1	0	0	0	0	0	0	1
14 850	to	14 950	0	0	1	1	0	0	0	0	0	1	1
14 950	to	15 050	0	0	1	1	0	0	0	0	0	1	0
15 050	to	15 150	0	0	1	1	0	0	0	0	1	1	0
15 150	to	15 250	0	0	1	1	0	0	0	0	1	0	0
15 250	to	15 350	0	0	1	1	0	0	0	1	1	0	0
15 350	to	15 450	0	0	1	1	0	0	0	1	1	1	0
15 450	to	15 550	0	0	1	1	0	0	0	1	0	1	0
15 550	to	15 650	0	0	1	1	0	0	0	1	0	1	1
15 650	to	15 750	0	0	1	1	0	0	0	1	0	0	1
15 750	to	15 850	0	0	1	1	0	0	1	1	0	0	1
15 850	to	15 950	0	0	1	1	0	0	1	1	0	1	1
15 950	to	16 050	0	0	1	1	0	0	1	1	0	1	0
16 050	to	16 150	0	0	1	1	0	0	1	1	1	1	0
16 150	to	16 250	0	0	1	1	0	0	1	1	1	0	0

RANGE			PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments (*Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
16 250	to	16 350	0	0	1	1	0	0	1	0	1	0	0
16 350	to	16 450	0	0	1	1	0	0	1	0	1	1	0
16 450	to	16 550	0	0	1	1	0	0	1	0	0	1	0
16 550	to	16 650	0	0	1	1	0	0	1	0	0	1	1
16 650	to	16 750	0	0	1	1	0	0	1	0	0	0	1
16 750	to	16 850	0	0	1	1	0	1	1	0	0	0	1
16 850	to	16 950	0	0	1	1	0	1	1	0	0	1	1
16 950	to	17 050	0	0	1	1	0	1	1	0	0	1	0
17 050	to	17 150	0	0	1	1	0	1	1	0	1	1	0
17 150	to	17 250	0	0	1	1	0	1	1	0	1	0	0
17 250	to	17 350	0	0	1	1	0	1	1	1	1	0	0
17 350	to	17 450	0	0	1	1	0	1	1	1	1	1	0
17 450	to	17 550	0	0	1	1	0	1	1	1	0	1	0
17 550	to	17 650	0	0	1	1	0	1	1	1	0	1	1
17 650	to	17 750	0	0	1	1	0	1	1	1	0	0	1
17 750	to	17 850	0	0	1	1	0	1	0	1	0	0	1
17 850	to	17 950	0	0	1	1	0	1	0	1	0	1	1
17 950	to	18 050	0	0	1	1	0	1	0	1	0	1	0
18 050	to	18 150	0	0	1	1	0	1	0	1	1	1	0
18 150	to	18 250	0	0	1	1	0	1	0	1	1	0	0
18 250	to	18 350	0	0	1	1	0	1	0	0	1	0	0
18 350	to	18 450	0	0	1	1	0	1	0	0	1	1	0
18 450	to	18 550	0	0	1	1	0	1	0	0	0	1	0
18 550	to	18 650	0	0	1	1	0	1	0	0	0	1	1
18 650	to	18 750	0	0	1	1	0	1	0	0	0	0	1
18 750	to	18 850	0	0	1	1	1	1	0	0	0	0	1
18 850	to	18 950	0	0	1	1	1	1	0	0	0	1	1
18 950	to	19 050	0	0	1	1	1	1	0	0	0	1	0
19 050	to	19 150	0	0	1	1	1	1	0	0	1	1	0
19 150	to	19 250	0	0	1	1	1	1	0	0	1	0	0
19 250	to	19 350	0	0	1	1	1	1	0	1	1	0	0
19 350	to	19 450	0	0	1	1	1	1	0	1	1	1	0
19 450	to	19 550	0	0	1	1	1	1	0	1	0	1	0
19 550	to	19 650	0	0	1	1	1	1	0	1	0	1	1
19 650	to	19 750	0	0	1	1	1	1	0	1	0	0	1
19 750	to	19 850	0	0	1	1	1	1	1	1	0	0	1
19 850	to	19 950	0	0	1	1	1	1	1	1	0	1	1
19 950	to	20 050	0	0	1	1	1	1	1	1	0	1	0
20 050	to	20 150	0	0	1	1	1	1	1	1	1	1	0
20 150	to	20 250	0	0	1	1	1	1	1	1	1	0	0
20 250	to	20 350	0	0	1	1	1	1	1	0	1	0	0
20 350	to	20 450	0	0	1	1	1	1	1	0	1	1	0
20 450	to	20 550	0	0	1	1	1	1	1	0	0	1	0
20 550	to	20 650	0	0	1	1	1	1	1	0	0	1	1
20 650	to	20 750	0	0	1	1	1	1	1	0	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
20 750	to	20 850	0	0	1	1	1	0	1	0	0	0	1
20 850	to	20 950	0	0	1	1	1	0	1	0	0	1	1
20 950	to	21 050	0	0	1	1	1	0	1	0	0	1	0
21 050	to	21 150	0	0	1	1	1	0	1	0	1	1	0
21 150	to	21 250	0	0	1	1	1	0	1	0	1	0	0
21 250	to	21 350	0	0	1	1	1	0	1	1	1	0	0
21 350	to	21 450	0	0	1	1	1	0	1	1	1	1	0
21 450	to	21 550	0	0	1	1	1	0	1	1	0	1	0
21 550	to	21 650	0	0	1	1	1	0	1	1	0	1	1
21 650	to	21 750	0	0	1	1	1	0	1	1	0	0	1
21 750	to	21 850	0	0	1	1	1	0	0	1	0	0	1
21 850	to	21 950	0	0	1	1	1	0	0	1	0	1	1
21 950	to	22 050	0	0	1	1	1	0	0	1	0	1	0
22 050	to	22 150	0	0	1	1	1	0	0	1	1	1	0
22 150	to	22 250	0	0	1	1	1	0	0	1	1	0	0
22 250	to	22 350	0	0	1	1	1	0	0	0	1	0	0
22 350	to	22 450	0	0	1	1	1	0	0	0	1	1	0
22 450	to	22 550	0	0	1	1	1	0	0	0	0	1	0
22 550	to	22 650	0	0	1	1	1	0	0	0	0	1	1
22 650	to	22 750	0	0	1	1	1	0	0	0	0	0	1
22 750	to	22 850	0	0	1	0	1	0	0	0	0	0	1
22 850	to	22 950	0	0	1	0	1	0	0	0	0	1	1
22 950	to	23 050	0	0	1	0	1	0	0	0	0	1	0
23 050	to	23 150	0	0	1	0	1	0	0	0	1	1	0
23 150	to	23 250	0	0	1	0	1	0	0	0	1	0	0
23 250	to	23 350	0	0	1	0	1	0	0	1	1	0	0
23 350	to	23 450	0	0	1	0	1	0	0	1	1	1	0
23 450	to	23 550	0	0	1	0	1	0	0	1	0	1	0
23 550	to	23 650	0	0	1	0	1	0	0	1	0	1	1
23 650	to	23 750	0	0	1	0	1	0	0	1	0	0	1
23 750	to	23 850	0	0	1	0	1	0	1	1	0	0	1
23 850	to	23 950	0	0	1	0	1	0	1	1	0	1	1
23 950	to	24 050	0	0	1	0	1	0	1	1	0	1	0
24 050	to	24 150	0	0	1	0	1	0	1	1	1	1	0
24 150	to	24 250	0	0	1	0	1	0	1	1	1	0	0
24 250	to	24 350	0	0	1	0	1	0	1	0	1	0	0
24 350	to	24 450	0	0	1	0	1	0	1	0	1	1	0
24 450	to	24 550	0	0	1	0	1	0	1	0	0	1	0
24 550	to	24 650	0	0	1	0	1	0	1	0	0	1	1
24 650	to	24 750	0	0	1	0	1	0	1	0	0	0	1
24 750	to	24 850	0	0	1	0	1	1	1	0	0	0	1
24 850	to	24 950	0	0	1	0	1	1	1	0	0	1	1
24 950	to	25 050	0	0	1	0	1	1	1	0	0	1	0
25 050	to	25 150	0	0	1	0	1	1	1	0	1	1	0
25 150	to	25 250	0	0	1	0	1	1	1	0	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
25 250	to	25 350	0	0	1	0	1	1	1	1	1	0	0
25 350	to	25 450	0	0	1	0	1	1	1	1	1	1	0
25 450	to	25 550	0	0	1	0	1	1	1	1	0	1	0
25 550	to	25 650	0	0	1	0	1	1	1	1	0	1	1
25 650	to	25 750	0	0	1	0	1	1	1	1	0	0	1
25 750	to	25 850	0	0	1	0	1	1	0	1	0	0	1
25 850	to	25 950	0	0	1	0	1	1	0	1	0	1	1
25 950	to	26 050	0	0	1	0	1	1	0	1	0	1	0
26 050	to	26 150	0	0	1	0	1	1	0	1	1	1	0
26 150	to	26 250	0	0	1	0	1	1	0	1	1	0	0
26 250	to	26 350	0	0	1	0	1	1	0	0	1	0	0
26 350	to	26 450	0	0	1	0	1	1	0	0	1	1	0
26 450	to	26 550	0	0	1	0	1	1	0	0	0	1	0
26 550	to	26 650	0	0	1	0	1	1	0	0	0	1	1
26 650	to	26 750	0	0	1	0	1	1	0	0	0	0	1
26 750	to	26 850	0	0	1	0	0	1	0	0	0	0	1
26 850	to	26 950	0	0	1	0	0	1	0	0	0	1	1
26 950	to	27 050	0	0	1	0	0	1	0	0	0	1	0
27 050	to	27 150	0	0	1	0	0	1	0	0	1	1	0
27 150	to	27 250	0	0	1	0	0	1	0	0	1	0	0
27 250	to	27 350	0	0	1	0	0	1	0	1	1	0	0
27 350	to	27 450	0	0	1	0	0	1	0	1	1	1	0
27 450	to	27 550	0	0	1	0	0	1	0	1	0	1	0
27 550	to	27 650	0	0	1	0	0	1	0	1	0	1	1
27 650	to	27 750	0	0	1	0	0	1	0	1	0	0	1
27 750	to	27 850	0	0	1	0	0	1	1	1	0	0	1
27 850	to	27 950	0	0	1	0	0	1	1	1	0	1	1
27 950	to	28 050	0	0	1	0	0	1	1	1	0	1	0
28 050	to	28 150	0	0	1	0	0	1	1	1	1	1	0
28 150	to	28 250	0	0	1	0	0	1	1	1	1	0	0
28 250	to	28 350	0	0	1	0	0	1	1	0	1	0	0
28 350	to	28 450	0	0	1	0	0	1	1	0	1	1	0
28 450	to	28 550	0	0	1	0	0	1	1	0	0	1	0
28 550	to	28 650	0	0	1	0	0	1	1	0	0	1	1
28 650	to	28 750	0	0	1	0	0	1	1	0	0	0	1
28 750	to	28 850	0	0	1	0	0	0	1	0	0	0	1
28 850	to	28 950	0	0	1	0	0	0	1	0	0	1	1
28 950	to	29 050	0	0	1	0	0	0	1	0	0	1	0
29 050	to	29 150	0	0	1	0	0	0	1	0	1	1	0
29 150	to	29 250	0	0	1	0	0	0	1	0	1	0	0
29 250	to	29 350	0	0	1	0	0	0	1	1	1	0	0
29 350	to	29 450	0	0	1	0	0	0	1	1	1	1	0
29 450	to	29 550	0	0	1	0	0	0	1	1	0	1	0
29 550	to	29 650	0	0	1	0	0	0	1	1	0	1	1
29 650	to	29 750	0	0	1	0	0	0	1	1	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
29 750	to	29 850	0	0	1	0	0	0	0	1	0	0	1
29 850	to	29 950	0	0	1	0	0	0	0	1	0	1	1
29 950	to	30 050	0	0	1	0	0	0	0	1	0	1	0
30 050	to	30 150	0	0	1	0	0	0	0	1	1	1	0
30 150	to	30 250	0	0	1	0	0	0	0	1	1	0	0
30 250	to	30 350	0	0	1	0	0	0	0	0	1	0	0
30 350	to	30 450	0	0	1	0	0	0	0	0	1	1	0
30 450	to	30 550	0	0	1	0	0	0	0	0	0	1	0
30 550	to	30 650	0	0	1	0	0	0	0	0	0	1	1
30 650	to	30 750	0	0	1	0	0	0	0	0	0	0	1
30 750	to	30 850	0	1	1	0	0	0	0	0	0	0	1
30 850	to	30 950	0	1	1	0	0	0	0	0	0	1	1
30 950	to	31 050	0	1	1	0	0	0	0	0	0	1	0
31 050	to	31 150	0	1	1	0	0	0	0	0	1	1	0
31 150	to	31 250	0	1	1	0	0	0	0	0	1	0	0
31 250	to	31 350	0	1	1	0	0	0	0	1	1	0	0
31 350	to	31 450	0	1	1	0	0	0	0	1	1	1	0
31 450	to	31 550	0	1	1	0	0	0	0	1	0	1	0
31 550	to	31 650	0	1	1	0	0	0	0	1	0	1	1
31 650	to	31 750	0	1	1	0	0	0	0	1	0	0	1
31 750	to	31 850	0	1	1	0	0	0	1	1	0	0	1
31 850	to	31 950	0	1	1	0	0	0	1	1	0	1	1
31 950	to	32 050	0	1	1	0	0	0	1	1	0	1	0
32 050	to	32 150	0	1	1	0	0	0	1	1	1	1	0
32 150	to	32 250	0	1	1	0	0	0	1	1	1	0	0
32 250	to	32 350	0	1	1	0	0	0	1	0	1	0	0
32 350	to	32 450	0	1	1	0	0	0	1	0	1	1	0
32 450	to	32 550	0	1	1	0	0	0	1	0	0	1	0
32 550	to	32 650	0	1	1	0	0	0	1	0	0	1	1
32 650	to	32 750	0	1	1	0	0	0	1	0	0	0	1
32 750	to	32 850	0	1	1	0	0	1	1	0	0	0	1
32 850	to	32 950	0	1	1	0	0	1	1	0	0	1	1
32 950	to	33 050	0	1	1	0	0	1	1	0	0	1	0
33 050	to	33 150	0	1	1	0	0	1	1	0	1	1	0
33 150	to	33 250	0	1	1	0	0	1	1	0	1	0	0
33 250	to	33 350	0	1	1	0	0	1	1	1	1	0	0
33 350	to	33 450	0	1	1	0	0	1	1	1	1	1	0
33 450	to	33 550	0	1	1	0	0	1	1	1	0	1	0
33 550	to	33 650	0	1	1	0	0	1	1	1	0	1	1
33 650	to	33 750	0	1	1	0	0	1	1	1	0	0	1
33 750	to	33 850	0	1	1	0	0	1	0	1	0	0	1
33 850	to	33 950	0	1	1	0	0	1	0	1	0	1	1
33 950	to	34 050	0	1	1	0	0	1	0	1	0	1	0
34 050	to	34 150	0	1	1	0	0	1	0	1	1	1	0
34 150	to	34 250	0	1	1	0	0	1	0	1	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
34 250	to	34 350	0	1	1	0	0	1	0	0	1	0	0
34 350	to	34 450	0	1	1	0	0	1	0	0	1	1	0
34 450	to	34 550	0	1	1	0	0	1	0	0	0	1	0
34 550	to	34 650	0	1	1	0	0	1	0	0	0	1	1
34 650	to	34 750	0	1	1	0	0	1	0	0	0	0	1
34 750	to	34 850	0	1	1	0	1	1	0	0	0	0	1
34 850	to	34 950	0	1	1	0	1	1	0	0	0	1	1
34 950	to	35 050	0	1	1	0	1	1	0	0	0	1	0
35 050	to	35 150	0	1	1	0	1	1	0	0	1	1	0
35 150	to	35 250	0	1	1	0	1	1	0	0	1	0	0
35 250	to	35 350	0	1	1	0	1	1	0	1	1	0	0
35 350	to	35 450	0	1	1	0	1	1	0	1	1	1	0
35 450	to	35 550	0	1	1	0	1	1	0	1	0	1	0
35 550	to	35 650	0	1	1	0	1	1	0	1	0	1	1
35 650	to	35 750	0	1	1	0	1	1	0	1	0	0	1
35 750	to	35 850	0	1	1	0	1	1	1	1	0	0	1
35 850	to	35 950	0	1	1	0	1	1	1	1	0	1	1
35 950	to	36 050	0	1	1	0	1	1	1	1	0	1	0
36 050	to	36 150	0	1	1	0	1	1	1	1	1	1	0
36 150	to	36 250	0	1	1	0	1	1	1	1	1	0	0
36 250	to	36 350	0	1	1	0	1	1	1	0	1	0	0
36 350	to	36 450	0	1	1	0	1	1	1	0	1	1	0
36 450	to	36 550	0	1	1	0	1	1	1	0	0	1	0
36 550	to	36 650	0	1	1	0	1	1	1	0	0	1	1
36 650	to	36 750	0	1	1	0	1	1	1	0	0	0	1
36 750	to	36 850	0	1	1	0	1	0	1	0	0	0	1
36 850	to	36 950	0	1	1	0	1	0	1	0	0	1	1
36 950	to	37 050	0	1	1	0	1	0	1	0	0	1	0
37 050	to	37 150	0	1	1	0	1	0	1	0	1	1	0
37 150	to	37 250	0	1	1	0	1	0	1	0	1	0	0
37 250	to	37 350	0	1	1	0	1	0	1	1	1	0	0
37 350	to	37 450	0	1	1	0	1	0	1	1	1	1	0
37 450	to	37 550	0	1	1	0	1	0	1	1	0	1	0
37 550	to	37 650	0	1	1	0	1	0	1	1	0	1	1
37 650	to	37 750	0	1	1	0	1	0	1	1	0	0	1
37 750	to	37 850	0	1	1	0	1	0	0	1	0	0	1
37 850	to	37 950	0	1	1	0	1	0	0	1	0	1	1
37 950	to	38 050	0	1	1	0	1	0	0	1	0	1	0
38 050	to	38 150	0	1	1	0	1	0	0	1	1	1	0
38 150	to	38 250	0	1	1	0	1	0	0	1	1	0	0
38 250	to	38 350	0	1	1	0	1	0	0	0	1	0	0
38 350	to	38 450	0	1	1	0	1	0	0	0	1	1	0
38 450	to	38 550	0	1	1	0	1	0	0	0	0	1	0
38 550	to	38 650	0	1	1	0	1	0	0	0	0	1	1
38 650	to	38 750	0	1	1	0	1	0	0	0	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
38 750	to	38 850	0	1	1	1	1	0	0	0	0	0	1
38 850	to	38 950	0	1	1	1	1	0	0	0	0	1	1
38 950	to	39 050	0	1	1	1	1	0	0	0	0	1	0
39 050	to	39 150	0	1	1	1	1	0	0	0	1	1	0
39 150	to	39 250	0	1	1	1	1	0	0	0	1	0	0
39 250	to	39 350	0	1	1	1	1	0	0	1	1	0	0
39 350	to	39 450	0	1	1	1	1	0	0	1	1	1	0
39 450	to	39 550	0	1	1	1	1	0	0	1	0	1	0
39 550	to	39 650	0	1	1	1	1	0	0	1	0	1	1
39 650	to	39 750	0	1	1	1	1	0	0	1	0	0	1
39 750	to	39 850	0	1	1	1	1	0	1	1	0	0	1
39 850	to	39 950	0	1	1	1	1	0	1	1	0	1	1
39 950	to	40 050	0	1	1	1	1	0	1	1	0	1	0
40 050	to	40 150	0	1	1	1	1	0	1	1	1	1	0
40 150	to	40 250	0	1	1	1	1	0	1	1	1	0	0
40 250	to	40 350	0	1	1	1	1	0	1	0	1	0	0
40 350	to	40 450	0	1	1	1	1	0	1	0	1	1	0
40 450	to	40 550	0	1	1	1	1	0	1	0	0	1	0
40 550	to	40 650	0	1	1	1	1	0	1	0	0	1	1
40 650	to	40 750	0	1	1	1	1	0	1	0	0	0	1
40 750	to	40 850	0	1	1	1	1	1	1	0	0	0	1
40 850	to	40 950	0	1	1	1	1	1	1	0	0	1	1
40 950	to	41 050	0	1	1	1	1	1	1	0	0	1	0
41 050	to	41 150	0	1	1	1	1	1	1	0	1	1	0
41 150	to	41 250	0	1	1	1	1	1	1	0	1	0	0
41 250	to	41 350	0	1	1	1	1	1	1	1	1	0	0
41 350	to	41 450	0	1	1	1	1	1	1	1	1	1	0
41 450	to	41 550	0	1	1	1	1	1	1	1	0	1	0
41 550	to	41 650	0	1	1	1	1	1	1	1	0	1	1
41 650	to	41 750	0	1	1	1	1	1	1	1	0	0	1
41 750	to	41 850	0	1	1	1	1	1	0	1	0	0	1
41 850	to	41 950	0	1	1	1	1	1	0	1	0	1	1
41 950	to	42 050	0	1	1	1	1	1	0	1	0	1	0
42 050	to	42 150	0	1	1	1	1	1	0	1	1	1	0
42 150	to	42 250	0	1	1	1	1	1	0	1	1	0	0
42 250	to	42 350	0	1	1	1	1	1	0	0	1	0	0
42 350	to	42 450	0	1	1	1	1	1	0	0	1	1	0
42 450	to	42 550	0	1	1	1	1	1	0	0	0	1	0
42 550	to	42 650	0	1	1	1	1	1	0	0	0	1	1
42 650	to	42 750	0	1	1	1	1	1	0	0	0	0	1
42 750	to	42 850	0	1	1	1	0	1	0	0	0	0	1
42 850	to	42 950	0	1	1	1	0	1	0	0	0	1	1
42 950	to	43 050	0	1	1	1	0	1	0	0	0	1	0
43 050	to	43 150	0	1	1	1	0	1	0	0	1	1	0
43 150	to	43 250	0	1	1	1	0	1	0	0	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
43 250	to	43 350	0	1	1	1	0	1	0	1	1	0	0
43 350	to	43 450	0	1	1	1	0	1	0	1	1	1	0
43 450	to	43 550	0	1	1	1	0	1	0	1	0	1	0
43 550	to	43 650	0	1	1	1	0	1	0	1	0	1	1
43 650	to	43 750	0	1	1	1	0	1	0	1	0	0	1
43 750	to	43 850	0	1	1	1	0	1	1	1	0	0	1
43 850	to	43 950	0	1	1	1	0	1	1	1	0	1	1
43 950	to	44 050	0	1	1	1	0	1	1	1	0	1	0
44 050	to	44 150	0	1	1	1	0	1	1	1	1	1	0
44 150	to	44 250	0	1	1	1	0	1	1	1	1	0	0
44 250	to	44 350	0	1	1	1	0	1	1	0	1	0	0
44 350	to	44 450	0	1	1	1	0	1	1	0	1	1	0
44 450	to	44 550	0	1	1	1	0	1	1	0	0	1	0
44 550	to	44 650	0	1	1	1	0	1	1	0	0	1	1
44 650	to	44 750	0	1	1	1	0	1	1	0	0	0	1
44 750	to	44 850	0	1	1	1	0	0	1	0	0	0	1
44 850	to	44 950	0	1	1	1	0	0	1	0	0	1	1
44 950	to	45 050	0	1	1	1	0	0	1	0	0	1	0
45 050	to	45 150	0	1	1	1	0	0	1	0	1	1	0
45 150	to	45 250	0	1	1	1	0	0	1	0	1	0	0
45 250	to	45 350	0	1	1	1	0	0	1	1	1	0	0
45 350	to	45 450	0	1	1	1	0	0	1	1	1	1	0
45 450	to	45 550	0	1	1	1	0	0	1	1	0	1	0
45 550	to	45 650	0	1	1	1	0	0	1	1	0	1	1
45 650	to	45 750	0	1	1	1	0	0	1	1	0	0	1
45 750	to	45 850	0	1	1	1	0	0	0	1	0	0	1
45 850	to	45 950	0	1	1	1	0	0	0	1	0	1	1
45 950	to	46 050	0	1	1	1	0	0	0	1	0	1	0
46 050	to	46 150	0	1	1	1	0	0	0	1	1	1	0
46 150	to	46 250	0	1	1	1	0	0	0	1	1	0	0
46 250	to	46 350	0	1	1	1	0	0	0	0	1	0	0
46 350	to	46 450	0	1	1	1	0	0	0	0	1	1	0
46 450	to	46 550	0	1	1	1	0	0	0	0	0	1	0
46 550	to	46 650	0	1	1	1	0	0	0	0	0	1	1
46 650	to	46 750	0	1	1	1	0	0	0	0	0	0	1
46 750	to	46 850	0	1	0	1	0	0	0	0	0	0	1
46 850	to	46 950	0	1	0	1	0	0	0	0	0	1	1
46 950	to	47 050	0	1	0	1	0	0	0	0	0	1	0
47 050	to	47 150	0	1	0	1	0	0	0	0	1	1	0
47 150	to	47 250	0	1	0	1	0	0	0	0	1	0	0
47 250	to	47 350	0	1	0	1	0	0	0	1	1	0	0
47 350	to	47 450	0	1	0	1	0	0	0	1	1	1	0
47 450	to	47 550	0	1	0	1	0	0	0	1	0	1	0
47 550	to	47 650	0	1	0	1	0	0	0	1	0	1	1
47 650	to	47 750	0	1	0	1	0	0	0	1	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
47 750	to	47 850	0	1	0	1	0	0	1	1	0	0	1
47 850	to	47 950	0	1	0	1	0	0	1	1	0	1	1
47 950	to	48 050	0	1	0	1	0	0	1	1	0	1	0
48 050	to	48 150	0	1	0	1	0	0	1	1	1	1	0
48 150	to	48 250	0	1	0	1	0	0	1	1	1	0	0
48 250	to	48 350	0	1	0	1	0	0	1	0	1	0	0
48 350	to	48 450	0	1	0	1	0	0	1	0	1	1	0
48 450	to	48 550	0	1	0	1	0	0	1	0	0	1	0
48 550	to	48 650	0	1	0	1	0	0	1	0	0	1	1
48 650	to	48 750	0	1	0	1	0	0	1	0	0	0	1
48 750	to	48 850	0	1	0	1	0	1	1	0	0	0	1
48 850	to	48 950	0	1	0	1	0	1	1	0	0	1	1
48 950	to	49 050	0	1	0	1	0	1	1	0	0	1	0
49 050	to	49 150	0	1	0	1	0	1	1	0	1	1	0
49 150	to	49 250	0	1	0	1	0	1	1	0	1	0	0
49 250	to	49 350	0	1	0	1	0	1	1	1	1	0	0
49 350	to	49 450	0	1	0	1	0	1	1	1	1	1	0
49 450	to	49 550	0	1	0	1	0	1	1	1	0	1	0
49 550	to	49 650	0	1	0	1	0	1	1	1	0	1	1
49 650	to	49 750	0	1	0	1	0	1	1	1	0	0	1
49 750	to	49 850	0	1	0	1	0	1	0	1	0	0	1
49 850	to	49 950	0	1	0	1	0	1	0	1	0	1	1
49 950	to	50 050	0	1	0	1	0	1	0	1	0	1	0
50 050	to	50 150	0	1	0	1	0	1	0	1	1	1	0
50 150	to	50 250	0	1	0	1	0	1	0	1	1	0	0
50 250	to	50 350	0	1	0	1	0	1	0	0	1	0	0
50 350	to	50 450	0	1	0	1	0	1	0	0	1	1	0
50 450	to	50 550	0	1	0	1	0	1	0	0	0	1	0
50 550	to	50 650	0	1	0	1	0	1	0	0	0	1	1
50 650	to	50 750	0	1	0	1	0	1	0	0	0	0	1
50 750	to	50 850	0	1	0	1	1	1	0	0	0	0	1
50 850	to	50 950	0	1	0	1	1	1	0	0	0	1	1
50 950	to	51 050	0	1	0	1	1	1	0	0	0	1	0
51 050	to	51 150	0	1	0	1	1	1	0	0	1	1	0
51 150	to	51 250	0	1	0	1	1	1	0	0	1	0	0
51 250	to	51 350	0	1	0	1	1	1	0	1	1	0	0
51 350	to	51 450	0	1	0	1	1	1	0	1	1	1	0
51 450	to	51 550	0	1	0	1	1	1	0	1	0	1	0
51 550	to	51 650	0	1	0	1	1	1	0	1	0	1	1
51 650	to	51 750	0	1	0	1	1	1	0	1	0	0	1
51 750	to	51 850	0	1	0	1	1	1	1	1	0	0	1
51 850	to	51 950	0	1	0	1	1	1	1	1	0	1	1
51 950	to	52 050	0	1	0	1	1	1	1	1	0	1	0
52 050	to	52 150	0	1	0	1	1	1	1	1	1	1	0
52 150	to	52 250	0	1	0	1	1	1	1	1	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
52 250	to	52 350	0	1	0	1	1	1	1	0	1	0	0
52 350	to	52 450	0	1	0	1	1	1	1	0	1	1	0
52 450	to	52 550	0	1	0	1	1	1	1	0	0	1	0
52 550	to	52 650	0	1	0	1	1	1	1	0	0	1	1
52 650	to	52 750	0	1	0	1	1	1	1	0	0	0	1
52 750	to	52 850	0	1	0	1	1	0	1	0	0	0	1
52 850	to	52 950	0	1	0	1	1	0	1	0	0	1	1
52 950	to	53 050	0	1	0	1	1	0	1	0	0	1	0
53 050	to	53 150	0	1	0	1	1	0	1	0	1	1	0
53 150	to	53 250	0	1	0	1	1	0	1	0	1	0	0
53 250	to	53 350	0	1	0	1	1	0	1	1	1	0	0
53 350	to	53 450	0	1	0	1	1	0	1	1	1	1	0
53 450	to	53 550	0	1	0	1	1	0	1	1	0	1	0
53 550	to	53 650	0	1	0	1	1	0	1	1	0	1	1
53 650	to	53 750	0	1	0	1	1	0	1	1	0	0	1
53 750	to	53 850	0	1	0	1	1	0	0	1	0	0	1
53 850	to	53 950	0	1	0	1	1	0	0	1	0	1	1
53 950	to	54 050	0	1	0	1	1	0	0	1	0	1	0
54 050	to	54 150	0	1	0	1	1	0	0	1	1	1	0
54 150	to	54 250	0	1	0	1	1	0	0	1	1	0	0
54 250	to	54 350	0	1	0	1	1	0	0	0	1	0	0
54 350	to	54 450	0	1	0	1	1	0	0	0	1	1	0
54 450	to	54 550	0	1	0	1	1	0	0	0	0	1	0
54 550	to	54 650	0	1	0	1	1	0	0	0	0	1	1
54 650	to	54 750	0	1	0	1	1	0	0	0	0	0	1
54 750	to	54 850	0	1	0	0	1	0	0	0	0	0	1
54 850	to	54 950	0	1	0	0	1	0	0	0	0	1	1
54 950	to	55 050	0	1	0	0	1	0	0	0	0	1	0
55 050	to	55 150	0	1	0	0	1	0	0	0	1	1	0
55 150	to	55 250	0	1	0	0	1	0	0	0	1	0	0
55 250	to	55 350	0	1	0	0	1	0	0	1	1	0	0
55 350	to	55 450	0	1	0	0	1	0	0	1	1	1	0
55 450	to	55 550	0	1	0	0	1	0	0	1	0	1	0
55 550	to	55 650	0	1	0	0	1	0	0	1	0	1	1
55 650	to	55 750	0	1	0	0	1	0	0	1	0	0	1
55 750	to	55 850	0	1	0	0	1	0	1	1	0	0	1
55 850	to	55 950	0	1	0	0	1	0	1	1	0	1	1
55 950	to	56 050	0	1	0	0	1	0	1	1	0	1	0
56 050	to	56 150	0	1	0	0	1	0	1	1	1	1	0
56 150	to	56 250	0	1	0	0	1	0	1	1	1	0	0
56 250	to	56 350	0	1	0	0	1	0	1	0	1	0	0
56 350	to	56 450	0	1	0	0	1	0	1	0	1	1	0
56 450	to	56 550	0	1	0	0	1	0	1	0	0	1	0
56 550	to	56 650	0	1	0	0	1	0	1	0	0	1	1
56 650	to	56 750	0	1	0	0	1	0	1	0	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
56 750	to	56 850	0	1	0	0	1	1	1	0	0	0	1
56 850	to	56 950	0	1	0	0	1	1	1	0	0	1	1
56 950	to	57 050	0	1	0	0	1	1	1	0	0	1	0
57 050	to	57 150	0	1	0	0	1	1	1	0	1	1	0
57 150	to	57 250	0	1	0	0	1	1	1	0	1	0	0
57 250	to	57 350	0	1	0	0	1	1	1	1	1	0	0
57 350	to	57 450	0	1	0	0	1	1	1	1	1	1	0
57 450	to	57 550	0	1	0	0	1	1	1	1	0	1	0
57 550	to	57 650	0	1	0	0	1	1	1	1	0	1	1
57 650	to	57 750	0	1	0	0	1	1	1	1	0	0	1
57 750	to	57 850	0	1	0	0	1	1	0	1	0	0	1
57 850	to	57 950	0	1	0	0	1	1	0	1	0	1	1
57 950	to	58 050	0	1	0	0	1	1	0	1	0	1	0
58 050	to	58 150	0	1	0	0	1	1	0	1	1	1	0
58 150	to	58 250	0	1	0	0	1	1	0	1	1	0	0
58 250	to	58 350	0	1	0	0	1	1	0	0	1	0	0
58 350	to	58 450	0	1	0	0	1	1	0	0	1	1	0
58 450	to	58 550	0	1	0	0	1	1	0	0	0	1	0
58 550	to	58 650	0	1	0	0	1	1	0	0	0	1	1
58 650	to	58 750	0	1	0	0	1	1	0	0	0	0	1
58 750	to	58 850	0	1	0	0	0	1	0	0	0	0	1
58 850	to	58 950	0	1	0	0	0	1	0	0	0	1	1
58 950	to	59 050	0	1	0	0	0	1	0	0	0	1	0
59 050	to	59 150	0	1	0	0	0	1	0	0	1	1	0
59 150	to	59 250	0	1	0	0	0	1	0	0	1	0	0
59 250	to	59 350	0	1	0	0	0	1	0	1	1	0	0
59 350	to	59 450	0	1	0	0	0	1	0	1	1	1	0
59 450	to	59 550	0	1	0	0	0	1	0	1	0	1	0
59 550	to	59 650	0	1	0	0	0	1	0	1	0	1	1
59 650	to	59 750	0	1	0	0	0	1	0	1	0	0	1
59 750	to	59 850	0	1	0	0	0	1	1	1	0	0	1
59 850	to	59 950	0	1	0	0	0	1	1	1	0	1	1
59 950	to	60 050	0	1	0	0	0	1	1	1	0	1	0
60 050	to	60 150	0	1	0	0	0	1	1	1	1	1	0
60 150	to	60 250	0	1	0	0	0	1	1	1	1	0	0
60 250	to	60 350	0	1	0	0	0	1	1	0	1	0	0
60 350	to	60 450	0	1	0	0	0	1	1	0	1	1	0
60 450	to	60 550	0	1	0	0	0	1	1	0	0	1	0
60 550	to	60 650	0	1	0	0	0	1	1	0	0	1	1
60 650	to	60 750	0	1	0	0	0	1	1	0	0	0	1
60 750	to	60 850	0	1	0	0	0	0	1	0	0	0	1
60 850	to	60 950	0	1	0	0	0	0	1	0	0	1	1
60 950	to	61 050	0	1	0	0	0	0	1	0	0	1	0
61 050	to	61 150	0	1	0	0	0	0	1	0	1	1	0
61 150	to	61 250	0	1	0	0	0	0	1	0	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
61 250	to	61 350	0	1	0	0	0	0	1	1	1	0	0
61 350	to	61 450	0	1	0	0	0	0	1	1	1	1	0
61 450	to	61 550	0	1	0	0	0	0	1	1	0	1	0
61 550	to	61 650	0	1	0	0	0	0	1	1	0	1	1
61 650	to	61 750	0	1	0	0	0	0	1	1	0	0	1
61 750	to	61 850	0	1	0	0	0	0	0	1	0	0	1
61 850	to	61 950	0	1	0	0	0	0	0	1	0	1	1
61 950	to	62 050	0	1	0	0	0	0	0	1	0	1	0
62 050	to	62 150	0	1	0	0	0	0	0	1	1	1	0
62 150	to	62 250	0	1	0	0	0	0	0	1	1	0	0
62 250	to	62 350	0	1	0	0	0	0	0	0	1	0	0
62 350	to	62 450	0	1	0	0	0	0	0	0	1	1	0
62 450	to	62 550	0	1	0	0	0	0	0	0	0	1	0
62 550	to	62 650	0	1	0	0	0	0	0	0	0	1	1
62 650	to	62 750	0	1	0	0	0	0	0	0	0	0	1
62 750	to	62 850	1	1	0	0	0	0	0	0	0	0	1
62 850	to	62 950	1	1	0	0	0	0	0	0	0	1	1
62 950	to	63 050	1	1	0	0	0	0	0	0	0	1	0
63 050	to	63 150	1	1	0	0	0	0	0	0	1	1	0
63 150	to	63 250	1	1	0	0	0	0	0	0	1	0	0
63 250	to	63 350	1	1	0	0	0	0	0	1	1	0	0
63 350	to	63 450	1	1	0	0	0	0	0	1	1	1	0
63 450	to	63 550	1	1	0	0	0	0	0	1	0	1	0
63 550	to	63 650	1	1	0	0	0	0	0	1	0	1	1
63 650	to	63 750	1	1	0	0	0	0	0	1	0	0	1
63 750	to	63 850	1	1	0	0	0	0	1	1	0	0	1
63 850	to	63 950	1	1	0	0	0	0	1	1	0	1	1
63 950	to	64 050	1	1	0	0	0	0	1	1	0	1	0
64 050	to	64 150	1	1	0	0	0	0	1	1	1	1	0
64 150	to	64 250	1	1	0	0	0	0	1	1	1	0	0
64 250	to	64 350	1	1	0	0	0	0	1	0	1	0	0
64 350	to	64 450	1	1	0	0	0	0	1	0	1	1	0
64 450	to	64 550	1	1	0	0	0	0	1	0	0	1	0
64 550	to	64 650	1	1	0	0	0	0	1	0	0	1	1
64 650	to	64 750	1	1	0	0	0	0	1	0	0	0	1
64 750	to	64 850	1	1	0	0	0	1	1	0	0	0	1
64 850	to	64 950	1	1	0	0	0	1	1	0	0	1	1
64 950	to	65 050	1	1	0	0	0	1	1	0	0	1	0
65 050	to	65 150	1	1	0	0	0	1	1	0	1	1	0
65 150	to	65 250	1	1	0	0	0	1	1	0	1	0	0
65 250	to	65 350	1	1	0	0	0	1	1	1	1	0	0
65 350	to	65 450	1	1	0	0	0	1	1	1	1	1	0
65 450	to	65 550	1	1	0	0	0	1	1	1	0	1	0
65 550	to	65 650	1	1	0	0	0	1	1	1	0	1	1
65 650	to	65 750	1	1	0	0	0	1	1	1	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
65 750	to	65 850	1	1	0	0	0	1	0	1	0	0	1
65 850	to	65 950	1	1	0	0	0	1	0	1	0	1	1
65 950	to	66 050	1	1	0	0	0	1	0	1	0	1	0
66 050	to	66 150	1	1	0	0	0	1	0	1	1	1	0
66 150	to	66 250	1	1	0	0	0	1	0	1	1	0	0
66 250	to	66 350	1	1	0	0	0	1	0	0	1	0	0
66 350	to	66 450	1	1	0	0	0	1	0	0	1	1	0
66 450	to	66 550	1	1	0	0	0	1	0	0	0	1	0
66 550	to	66 650	1	1	0	0	0	1	0	0	0	1	1
66 650	to	66 750	1	1	0	0	0	1	0	0	0	0	1
66 750	to	66 850	1	1	0	0	1	1	0	0	0	0	1
66 850	to	66 950	1	1	0	0	1	1	0	0	0	1	1
66 950	to	67 050	1	1	0	0	1	1	0	0	0	1	0
67 050	to	67 150	1	1	0	0	1	1	0	0	1	1	0
67 150	to	67 250	1	1	0	0	1	1	0	0	1	0	0
67 250	to	67 350	1	1	0	0	1	1	0	1	1	0	0
67 350	to	67 450	1	1	0	0	1	1	0	1	1	1	0
67 450	to	67 550	1	1	0	0	1	1	0	1	0	1	0
67 550	to	67 650	1	1	0	0	1	1	0	1	0	1	1
67 650	to	67 750	1	1	0	0	1	1	0	1	0	0	1
67 750	to	67 850	1	1	0	0	1	1	1	1	0	0	1
67 850	to	67 950	1	1	0	0	1	1	1	1	0	1	1
67 950	to	68 050	1	1	0	0	1	1	1	1	0	1	0
68 050	to	68 150	1	1	0	0	1	1	1	1	1	1	0
68 150	to	68 250	1	1	0	0	1	1	1	1	1	0	0
68 250	to	68 350	1	1	0	0	1	1	1	0	1	0	0
68 350	to	68 450	1	1	0	0	1	1	1	0	1	1	0
68 450	to	68 550	1	1	0	0	1	1	1	0	0	1	0
68 550	to	68 650	1	1	0	0	1	1	1	0	0	1	1
68 650	to	68 750	1	1	0	0	1	1	1	0	0	0	1
68 750	to	68 850	1	1	0	0	1	0	1	0	0	0	1
68 850	to	68 950	1	1	0	0	1	0	1	0	0	1	1
68 950	to	69 050	1	1	0	0	1	0	1	0	0	1	0
69 050	to	69 150	1	1	0	0	1	0	1	0	1	1	0
69 150	to	69 250	1	1	0	0	1	0	1	0	1	0	0
69 250	to	69 350	1	1	0	0	1	0	1	1	1	0	0
69 350	to	69 450	1	1	0	0	1	0	1	1	1	1	0
69 450	to	69 550	1	1	0	0	1	0	1	1	0	1	0
69 550	to	69 650	1	1	0	0	1	0	1	1	0	1	1
69 650	to	69 750	1	1	0	0	1	0	1	1	0	0	1
69 750	to	69 850	1	1	0	0	1	0	0	1	0	0	1
69 850	to	69 950	1	1	0	0	1	0	0	1	0	1	1
69 950	to	70 050	1	1	0	0	1	0	0	1	0	1	0
70 050	to	70 150	1	1	0	0	1	0	0	1	1	1	0
70 150	to	70 250	1	1	0	0	1	0	0	1	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
70 250	to	70 350	1	1	0	0	1	0	0	0	1	0	0
70 350	to	70 450	1	1	0	0	1	0	0	0	1	1	0
70 450	to	70 550	1	1	0	0	1	0	0	0	0	1	0
70 550	to	70 650	1	1	0	0	1	0	0	0	0	1	1
70 650	to	70 750	1	1	0	0	1	0	0	0	0	0	1
70 750	to	70 850	1	1	0	1	1	0	0	0	0	0	1
70 850	to	70 950	1	1	0	1	1	0	0	0	0	1	1
70 950	to	71 050	1	1	0	1	1	0	0	0	0	1	0
71 050	to	71 150	1	1	0	1	1	0	0	0	1	1	0
71 150	to	71 250	1	1	0	1	1	0	0	0	1	0	0
71 250	to	71 350	1	1	0	1	1	0	0	1	1	0	0
71 350	to	71 450	1	1	0	1	1	0	0	1	1	1	0
71 450	to	71 550	1	1	0	1	1	0	0	1	0	1	0
71 550	to	71 650	1	1	0	1	1	0	0	1	0	1	1
71 650	to	71 750	1	1	0	1	1	0	0	1	0	0	1
71 750	to	71 850	1	1	0	1	1	0	1	1	0	0	1
71 850	to	71 950	1	1	0	1	1	0	1	1	0	1	1
71 950	to	72 050	1	1	0	1	1	0	1	1	0	1	0
72 050	to	72 150	1	1	0	1	1	0	1	1	1	1	0
72 150	to	72 250	1	1	0	1	1	0	1	1	1	0	0
72 250	to	72 350	1	1	0	1	1	0	1	0	1	0	0
72 350	to	72 450	1	1	0	1	1	0	1	0	1	1	0
72 450	to	72 550	1	1	0	1	1	0	1	0	0	1	0
72 550	to	72 650	1	1	0	1	1	0	1	0	0	1	1
72 650	to	72 750	1	1	0	1	1	0	1	0	0	0	1
72 750	to	72 850	1	1	0	1	1	1	1	0	0	0	1
72 850	to	72 950	1	1	0	1	1	1	1	0	0	1	1
72 950	to	73 050	1	1	0	1	1	1	1	0	0	1	0
73 050	to	73 150	1	1	0	1	1	1	1	0	1	1	0
73 150	to	73 250	1	1	0	1	1	1	1	0	1	0	0
73 250	to	73 350	1	1	0	1	1	1	1	1	1	0	0
73 350	to	73 450	1	1	0	1	1	1	1	1	1	1	0
73 450	to	73 550	1	1	0	1	1	1	1	1	0	1	0
73 550	to	73 650	1	1	0	1	1	1	1	1	0	1	1
73 650	to	73 750	1	1	0	1	1	1	1	1	0	0	1
73 750	to	73 850	1	1	0	1	1	1	0	1	0	0	1
73 850	to	73 950	1	1	0	1	1	1	0	1	0	1	1
73 950	to	74 050	1	1	0	1	1	1	0	1	0	1	0
74 050	to	74 150	1	1	0	1	1	1	0	1	1	1	0
74 150	to	74 250	1	1	0	1	1	1	0	1	1	0	0
74 250	to	74 350	1	1	0	1	1	1	0	0	1	0	0
74 350	to	74 450	1	1	0	1	1	1	0	0	1	1	0
74 450	to	74 550	1	1	0	1	1	1	0	0	0	1	0
74 550	to	74 650	1	1	0	1	1	1	0	0	0	1	1
74 650	to	74 750	1	1	0	1	1	1	0	0	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
74 750 to 74 850	1	1	0	1	0	1	0	0	0	0	1
74 850 to 74 950	1	1	0	1	0	1	0	0	0	1	1
74 950 to 75 050	1	1	0	1	0	1	0	0	0	1	0
75 050 to 75 150	1	1	0	1	0	1	0	0	1	1	0
75 150 to 75 250	1	1	0	1	0	1	0	0	1	0	0
75 250 to 75 350	1	1	0	1	0	1	0	1	1	0	0
75 350 to 75 450	1	1	0	1	0	1	0	1	1	1	0
75 450 to 75 550	1	1	0	1	0	1	0	1	0	1	0
75 550 to 75 650	1	1	0	1	0	1	0	1	0	1	1
75 650 to 75 750	1	1	0	1	0	1	0	1	0	0	1
75 750 to 75 850	1	1	0	1	0	1	1	1	0	0	1
75 850 to 75 950	1	1	0	1	0	1	1	1	0	1	1
75 950 to 76 050	1	1	0	1	0	1	1	1	0	1	0
76 050 to 76 150	1	1	0	1	0	1	1	1	1	1	0
76 150 to 76 250	1	1	0	1	0	1	1	1	1	0	0
76 250 to 76 350	1	1	0	1	0	1	1	0	1	0	0
76 350 to 76 450	1	1	0	1	0	1	1	0	1	1	0
76 450 to 76 550	1	1	0	1	0	1	1	0	0	1	0
76 550 to 76 650	1	1	0	1	0	1	1	0	0	1	1
76 650 to 76 750	1	1	0	1	0	1	1	0	0	0	1
76 750 to 76 850	1	1	0	1	0	0	1	0	0	0	1
76 850 to 76 950	1	1	0	1	0	0	1	0	0	1	1
76 950 to 77 050	1	1	0	1	0	0	1	0	0	1	0
77 050 to 77 150	1	1	0	1	0	0	1	0	1	1	0
77 150 to 77 250	1	1	0	1	0	0	1	0	1	0	0
77 250 to 77 350	1	1	0	1	0	0	1	1	1	0	0
77 350 to 77 450	1	1	0	1	0	0	1	1	1	1	0
77 450 to 77 550	1	1	0	1	0	0	1	1	0	1	0
77 550 to 77 650	1	1	0	1	0	0	1	1	0	1	1
77 650 to 77 750	1	1	0	1	0	0	1	1	0	0	1
77 750 to 77 850	1	1	0	1	0	0	0	1	0	0	1
77 850 to 77 950	1	1	0	1	0	0	0	1	0	1	1
77 950 to 78 050	1	1	0	1	0	0	0	1	0	1	0
78 050 to 78 150	1	1	0	1	0	0	0	1	1	1	0
78 150 to 78 250	1	1	0	1	0	0	0	1	1	0	0
78 250 to 78 350	1	1	0	1	0	0	0	0	1	0	0
78 350 to 78 450	1	1	0	1	0	0	0	0	1	1	0
78 450 to 78 550	1	1	0	1	0	0	0	0	0	1	0
78 550 to 78 650	1	1	0	1	0	0	0	0	0	1	1
78 650 to 78 750	1	1	0	1	0	0	0	0	0	0	1
78 750 to 78 850	1	1	1	1	0	0	0	0	0	0	1
78 850 to 78 950	1	1	1	1	0	0	0	0	0	1	1
78 950 to 79 050	1	1	1	1	0	0	0	0	0	1	0
79 050 to 79 150	1	1	1	1	0	0	0	0	1	1	0
79 150 to 79 250	1	1	1	1	0	0	0	0	1	0	0

RANGE			PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively*)										
Increments (*Feet*)			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
79 250	to	79 350	1	1	1	1	0	0	0	1	1	0	0
79 350	to	79 450	1	1	1	1	0	0	0	1	1	1	0
79 450	to	79 550	1	1	1	1	0	0	0	1	0	1	0
79 550	to	79 650	1	1	1	1	0	0	0	1	0	1	1
79 650	to	79 750	1	1	1	1	0	0	0	1	0	0	1
79 750	to	79 850	1	1	1	1	0	0	1	1	0	0	1
79 850	to	79 950	1	1	1	1	0	0	1	1	0	1	1
79 950	to	80 050	1	1	1	1	0	0	1	1	0	1	0
80 050	to	80 150	1	1	1	1	0	0	1	1	1	1	0
80 150	to	80 250	1	1	1	1	0	0	1	1	1	0	0
80 250	to	80 350	1	1	1	1	0	0	1	0	1	0	0
80 350	to	80 450	1	1	1	1	0	0	1	0	1	1	0
80 450	to	80 550	1	1	1	1	0	0	1	0	0	1	0
80 550	to	80 650	1	1	1	1	0	0	1	0	0	1	1
80 650	to	80 750	1	1	1	1	0	0	1	0	0	0	1
80 750	to	80 850	1	1	1	1	0	1	1	0	0	0	1
80 850	to	80 950	1	1	1	1	0	1	1	0	0	1	1
80 950	to	81 050	1	1	1	1	0	1	1	0	0	1	0
81 050	to	81 150	1	1	1	1	0	1	1	0	1	1	0
81 150	to	81 250	1	1	1	1	0	1	1	0	1	0	0
81 250	to	81 350	1	1	1	1	0	1	1	1	1	0	0
81 350	to	81 450	1	1	1	1	0	1	1	1	1	1	0
81 450	to	81 550	1	1	1	1	0	1	1	1	0	1	0
81 550	to	81 650	1	1	1	1	0	1	1	1	0	1	1
81 650	to	81 750	1	1	1	1	0	1	1	1	0	0	1
81 750	to	81 850	1	1	1	1	0	1	0	1	0	0	1
81 850	to	81 950	1	1	1	1	0	1	0	1	0	1	1
81 950	to	82 050	1	1	1	1	0	1	0	1	0	1	0
82 050	to	82 150	1	1	1	1	0	1	0	1	1	1	0
82 150	to	82 250	1	1	1	1	0	1	0	1	1	0	0
82 250	to	82 350	1	1	1	1	0	1	0	0	1	0	0
82 350	to	82 450	1	1	1	1	0	1	0	0	1	1	0
82 450	to	82 550	1	1	1	1	0	1	0	0	0	1	0
82 550	to	82 650	1	1	1	1	0	1	0	0	0	1	1
82 650	to	82 750	1	1	1	1	0	1	0	0	0	0	1
82 750	to	82 850	1	1	1	1	1	1	0	0	0	0	1
82 850	to	82 950	1	1	1	1	1	1	0	0	0	1	1
82 950	to	83 050	1	1	1	1	1	1	0	0	0	1	0
83 050	to	83 150	1	1	1	1	1	1	0	0	1	1	0
83 150	to	83 250	1	1	1	1	1	1	0	0	1	0	0
83 250	to	83 350	1	1	1	1	1	1	0	1	1	0	0
83 350	to	83 450	1	1	1	1	1	1	0	1	1	1	0
83 450	to	83 550	1	1	1	1	1	1	0	1	0	1	0
83 550	to	83 650	1	1	1	1	1	1	0	1	0	1	1
83 650	to	83 750	1	1	1	1	1	1	0	1	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
83 750	to	83 850	1	1	1	1	1	1	1	1	0	0	1
83 850	to	83 950	1	1	1	1	1	1	1	1	0	1	1
83 950	to	84 050	1	1	1	1	1	1	1	1	0	1	0
84 050	to	84 150	1	1	1	1	1	1	1	1	1	1	0
84 150	to	84 250	1	1	1	1	1	1	1	1	1	0	0
84 250	to	84 350	1	1	1	1	1	1	1	0	1	0	0
84 350	to	84 450	1	1	1	1	1	1	1	0	1	1	0
84 450	to	84 550	1	1	1	1	1	1	1	0	0	1	0
84 550	to	84 650	1	1	1	1	1	1	1	0	0	1	1
84 650	to	84 750	1	1	1	1	1	1	1	0	0	0	1
84 750	to	84 850	1	1	1	1	1	0	1	0	0	0	1
84 850	to	84 950	1	1	1	1	1	0	1	0	0	1	1
84 950	to	85 050	1	1	1	1	1	0	1	0	0	1	0
85 050	to	85 150	1	1	1	1	1	0	1	0	1	1	0
85 150	to	85 250	1	1	1	1	1	0	1	0	1	0	0
85 250	to	85 350	1	1	1	1	1	0	1	1	1	0	0
85 350	to	85 450	1	1	1	1	1	0	1	1	1	1	0
85 450	to	85 550	1	1	1	1	1	0	1	1	0	1	0
85 550	to	85 650	1	1	1	1	1	0	1	1	0	1	1
85 650	to	85 750	1	1	1	1	1	0	1	1	0	0	1
85 750	to	85 850	1	1	1	1	1	0	0	1	0	0	1
85 850	to	85 950	1	1	1	1	1	0	0	1	0	1	1
85 950	to	86 050	1	1	1	1	1	0	0	1	0	1	0
86 050	to	86 150	1	1	1	1	1	0	0	1	1	1	0
86 150	to	86 250	1	1	1	1	1	0	0	1	1	0	0
86 250	to	86 350	1	1	1	1	1	0	0	0	1	0	0
86 350	to	86 450	1	1	1	1	1	0	0	0	1	1	0
86 450	to	86 550	1	1	1	1	1	0	0	0	0	1	0
86 550	to	86 650	1	1	1	1	1	0	0	0	0	1	1
86 650	to	86 750	1	1	1	1	1	0	0	0	0	0	1
86 750	to	86 850	1	1	1	0	1	0	0	0	0	0	1
86 850	to	86 950	1	1	1	0	1	0	0	0	0	1	1
86 950	to	87 050	1	1	1	0	1	0	0	0	0	1	0
87 050	to	87 150	1	1	1	0	1	0	0	0	1	1	0
87 150	to	87 250	1	1	1	0	1	0	0	0	1	0	0
87 250	to	87 350	1	1	1	0	1	0	0	1	1	0	0
87 350	to	87 450	1	1	1	0	1	0	0	1	1	1	0
87 450	to	87 550	1	1	1	0	1	0	0	1	0	1	0
87 550	to	87 650	1	1	1	0	1	0	0	1	0	1	1
87 650	to	87 750	1	1	1	0	1	0	0	1	0	0	1
87 750	to	87 850	1	1	1	0	1	0	1	1	0	0	1
87 850	to	87 950	1	1	1	0	1	0	1	1	0	1	1
87 950	to	88 050	1	1	1	0	1	0	1	1	0	1	0
88 050	to	88 150	1	1	1	0	1	0	1	1	1	1	0
88 150	to	88 250	1	1	1	0	1	0	1	1	1	0	0

RANGE	PULSE POSITIONS (*0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments (*Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
88 250 to 88 350	1	1	1	0	1	0	1	0	1	0	0
88 350 to 88 450	1	1	1	0	1	0	1	0	1	1	0
88 450 to 88 550	1	1	1	0	1	0	1	0	0	1	0
88 550 to 88 650	1	1	1	0	1	0	1	0	0	1	1
88 650 to 88 750	1	1	1	0	1	0	1	0	0	0	1
88 750 to 88 850	1	1	1	0	1	1	1	0	0	0	1
88 850 to 88 950	1	1	1	0	1	1	1	0	0	1	1
88 950 to 89 050	1	1	1	0	1	1	1	0	0	1	0
89 050 to 89 150	1	1	1	0	1	1	1	0	1	1	0
89 150 to 89 250	1	1	1	0	1	1	1	0	1	0	0
89 250 to 89 350	1	1	1	0	1	1	1	1	1	0	0
89 350 to 89 450	1	1	1	0	1	1	1	1	1	1	0
89 450 to 89 550	1	1	1	0	1	1	1	1	0	1	0
89 550 to 89 650	1	1	1	0	1	1	1	1	0	1	1
89 650 to 89 750	1	1	1	0	1	1	1	1	0	0	1
89 750 to 89 850	1	1	1	0	1	1	0	1	0	0	1
89 850 to 89 950	1	1	1	0	1	1	0	1	0	1	1
89 950 to 90 050	1	1	1	0	1	1	0	1	0	1	0
90 050 to 90 150	1	1	1	0	1	1	0	1	1	1	0
90 150 to 90 250	1	1	1	0	1	1	0	1	1	0	0
90 250 to 90 350	1	1	1	0	1	1	0	0	1	0	0
90 350 to 90 450	1	1	1	0	1	1	0	0	1	1	0
90 450 to 90 550	1	1	1	0	1	1	0	0	0	1	0
90 550 to 90 650	1	1	1	0	1	1	0	0	0	1	1
90 650 to 90 750	1	1	1	0	1	1	0	0	0	0	1
90 750 to 90 850	1	1	1	0	0	1	0	0	0	0	1
90 850 to 90 950	1	1	1	0	0	1	0	0	0	1	1
90 950 to 91 050	1	1	1	0	0	1	0	0	0	1	0
91 050 to 91 150	1	1	1	0	0	1	0	0	1	1	0
91 150 to 91 250	1	1	1	0	0	1	0	0	1	0	0
91 250 to 91 350	1	1	1	0	0	1	0	1	1	0	0
91 350 to 91 450	1	1	1	0	0	1	0	1	1	1	0
91 450 to 91 550	1	1	1	0	0	1	0	1	0	1	0
91 550 to 91 650	1	1	1	0	0	1	0	1	0	1	1
91 650 to 91 750	1	1	1	0	0	1	0	1	0	0	1
91 750 to 91 850	1	1	1	0	0	1	1	1	0	0	1
91 850 to 91 950	1	1	1	0	0	1	1	1	0	1	1
91 950 to 92 050	1	1	1	0	0	1	1	1	0	1	0
92 050 to 92 150	1	1	1	0	0	1	1	1	1	1	0
92 150 to 92 250	1	1	1	0	0	1	1	1	1	0	0
92 250 to 92 350	1	1	1	0	0	1	1	0	1	0	0
92 350 to 92 450	1	1	1	0	0	1	1	0	1	1	0
92 450 to 92 550	1	1	1	0	0	1	1	0	0	1	0
92 550 to 92 650	1	1	1	0	0	1	1	0	0	1	1
92 650 to 92 750	1	1	1	0	0	1	1	0	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
92 750	to	92 850	1	1	1	0	0	0	1	0	0	0	1
92 850	to	92 950	1	1	1	0	0	0	1	0	0	1	1
92 950	to	93 050	1	1	1	0	0	0	1	0	0	1	0
93 050	to	93 150	1	1	1	0	0	0	1	0	1	1	0
93 150	to	93 250	1	1	1	0	0	0	1	0	1	0	0
93 250	to	93 350	1	1	1	0	0	0	1	1	1	0	0
93 350	to	93 450	1	1	1	0	0	0	1	1	1	1	0
93 450	to	93 550	1	1	1	0	0	0	1	1	0	1	0
93 550	to	93 650	1	1	1	0	0	0	1	1	0	1	1
93 650	to	93 750	1	1	1	0	0	0	1	1	0	0	1
93 750	to	93 850	1	1	1	0	0	0	0	1	0	0	1
93 850	to	93 950	1	1	1	0	0	0	0	1	0	1	1
93 950	to	94 050	1	1	1	0	0	0	0	1	0	1	0
94 050	to	94 150	1	1	1	0	0	0	0	1	1	1	0
94 150	to	94 250	1	1	1	0	0	0	0	1	1	0	0
94 250	to	94 350	1	1	1	0	0	0	0	0	1	0	0
94 350	to	94 450	1	1	1	0	0	0	0	0	1	1	0
94 450	to	94 550	1	1	1	0	0	0	0	0	0	1	0
94 550	to	94 650	1	1	1	0	0	0	0	0	0	1	1
94 650	to	94 750	1	1	1	0	0	0	0	0	0	0	1
94 750	to	94 850	1	0	1	0	0	0	0	0	0	0	1
94 850	to	94 950	1	0	1	0	0	0	0	0	0	1	1
94 950	to	95 050	1	0	1	0	0	0	0	0	0	1	0
95 050	to	95 150	1	0	1	0	0	0	0	0	1	1	0
95 150	to	95 250	1	0	1	0	0	0	0	0	1	0	0
95 250	to	95 350	1	0	1	0	0	0	0	1	1	0	0
95 350	to	95 450	1	0	1	0	0	0	0	1	1	1	0
95 450	to	95 550	1	0	1	0	0	0	0	1	0	1	0
95 550	to	95 650	1	0	1	0	0	0	0	1	0	1	1
95 650	to	95 750	1	0	1	0	0	0	0	1	0	0	1
95 750	to	95 850	1	0	1	0	0	0	1	1	0	0	1
95 850	to	95 950	1	0	1	0	0	0	1	1	0	1	1
95 950	to	96 050	1	0	1	0	0	0	1	1	0	1	0
96 050	to	96 150	1	0	1	0	0	0	1	1	1	1	0
96 150	to	96 250	1	0	1	0	0	0	1	1	1	0	0
96 250	to	96 350	1	0	1	0	0	0	1	0	1	0	0
96 350	to	96 450	1	0	1	0	0	0	1	0	1	1	0
96 450	to	96 550	1	0	1	0	0	0	1	0	0	1	0
96 550	to	96 650	1	0	1	0	0	0	1	0	0	1	1
96 650	to	96 750	1	0	1	0	0	0	1	0	0	0	1
96 750	to	96 850	1	0	1	0	0	1	1	0	0	0	1
96 850	to	96 950	1	0	1	0	0	1	1	0	0	1	1
96 950	to	97 050	1	0	1	0	0	1	1	0	0	1	0
97 050	to	97 150	1	0	1	0	0	1	1	0	1	1	0
97 150	to	97 250	1	0	1	0	0	1	1	0	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
97 250	to	97 350	1	0	1	0	0	1	1	1	1	0	0
97 350	to	97 450	1	0	1	0	0	1	1	1	1	1	0
97 450	to	97 550	1	0	1	0	0	1	1	1	0	1	0
97 550	to	97 650	1	0	1	0	0	1	1	1	0	1	1
97 650	to	97 750	1	0	1	0	0	1	1	1	0	0	1
97 750	to	97 850	1	0	1	0	0	1	0	1	0	0	1
97 850	to	97 950	1	0	1	0	0	1	0	1	0	1	1
97 950	to	98 050	1	0	1	0	0	1	0	1	0	1	0
98 050	to	98 150	1	0	1	0	0	1	0	1	1	1	0
98 150	to	98 250	1	0	1	0	0	1	0	1	1	0	0
98 250	to	98 350	1	0	1	0	0	1	0	0	1	0	0
98 350	to	98 450	1	0	1	0	0	1	0	0	1	1	0
98 450	to	98 550	1	0	1	0	0	1	0	0	0	1	0
98 550	to	98 650	1	0	1	0	0	1	0	0	0	1	1
98 650	to	98 750	1	0	1	0	0	1	0	0	0	0	1
98 750	to	98 850	1	0	1	0	1	1	0	0	0	0	1
98 850	to	98 950	1	0	1	0	1	1	0	0	0	1	1
98 950	to	99 050	1	0	1	0	1	1	0	0	0	1	0
99 050	to	99 150	1	0	1	0	1	1	0	0	1	1	0
99 150	to	99 250	1	0	1	0	1	1	0	0	1	0	0
99 250	to	99 350	1	0	1	0	1	1	0	1	1	0	0
99 350	to	99 450	1	0	1	0	1	1	0	1	1	1	0
99 450	to	99 550	1	0	1	0	1	1	0	1	0	1	0
99 550	to	99 650	1	0	1	0	1	1	0	1	0	1	1
99 650	to	99 750	1	0	1	0	1	1	0	1	0	0	1
99 750	to	99 850	1	0	1	0	1	1	1	1	0	0	1
99 850	to	99 950	1	0	1	0	1	1	1	1	0	1	1
99 950	to	100 050	1	0	1	0	1	1	1	1	0	1	0
100 050	to	100 150	1	0	1	0	1	1	1	1	1	1	0
100 150	to	100 250	1	0	1	0	1	1	1	1	1	0	0
100 250	to	100 350	1	0	1	0	1	1	1	0	1	0	0
100 350	to	100 450	1	0	1	0	1	1	1	0	1	1	0
100 450	to	100 550	1	0	1	0	1	1	1	0	0	1	0
100 550	to	100 650	1	0	1	0	1	1	1	0	0	1	1
100 650	to	100 750	1	0	1	0	1	1	1	0	0	0	1
100 750	to	100 850	1	0	1	0	1	0	1	0	0	0	1
100 850	to	100 950	1	0	1	0	1	0	1	0	0	1	1
100 950	to	101 050	1	0	1	0	1	0	1	0	0	1	0
101 050	to	101 150	1	0	1	0	1	0	1	0	1	1	0
101 150	to	101 250	1	0	1	0	1	0	1	0	1	0	0
101 250	to	101 350	1	0	1	0	1	0	1	1	1	0	0
101 350	to	101 450	1	0	1	0	1	0	1	1	1	1	0
101 450	to	101 550	1	0	1	0	1	0	1	1	0	1	0
101 550	to	101 650	1	0	1	0	1	0	1	1	0	1	1
101 650	to	101 750	1	0	1	0	1	0	1	1	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
101 750 to 101 850	1	0	1	0	1	0	0	1	0	0	1
101 850 to 101 950	1	0	1	0	1	0	0	1	0	1	1
101 950 to 102 050	1	0	1	0	1	0	0	1	0	1	0
102 050 to 102 150	1	0	1	0	1	0	0	1	1	1	0
102 150 to 102 250	1	0	1	0	1	0	0	1	1	0	0
102 250 to 102 350	1	0	1	0	1	0	0	0	1	0	0
102 350 to 102 450	1	0	1	0	1	0	0	0	1	1	0
102 450 to 102 550	1	0	1	0	1	0	0	0	0	1	0
102 550 to 102 650	1	0	1	0	1	0	0	0	0	1	1
102 650 to 102 750	1	0	1	0	1	0	0	0	0	0	1
102 750 to 102 850	1	0	1	1	1	0	0	0	0	0	1
102 850 to 102 950	1	0	1	1	1	0	0	0	0	1	1
102 950 to 103 050	1	0	1	1	1	0	0	0	0	1	0
103 050 to 103 150	1	0	1	1	1	0	0	0	1	1	0
103 150 to 103 250	1	0	1	1	1	0	0	0	1	0	0
103 250 to 103 350	1	0	1	1	1	0	0	1	1	0	0
103 350 to 103 450	1	0	1	1	1	0	0	1	1	1	0
103 450 to 103 550	1	0	1	1	1	0	0	1	0	1	0
103 550 to 103 650	1	0	1	1	1	0	0	1	0	1	1
103 650 to 103 750	1	0	1	1	1	0	0	1	0	0	1
103 750 to 103 850	1	0	1	1	1	0	1	1	0	0	1
103 850 to 103 950	1	0	1	1	1	0	1	1	0	1	1
103 950 to 104 050	1	0	1	1	1	0	1	1	0	1	0
104 050 to 104 150	1	0	1	1	1	0	1	1	1	1	0
104 150 to 104 250	1	0	1	1	1	0	1	1	1	0	0
104 250 to 104 350	1	0	1	1	1	0	1	0	1	0	0
104 350 to 104 450	1	0	1	1	1	0	1	0	1	1	0
104 450 to 104 550	1	0	1	1	1	0	1	0	0	1	0
104 550 to 104 650	1	0	1	1	1	0	1	0	0	1	1
104 650 to 104 750	1	0	1	1	1	0	1	0	0	0	1
104 750 to 104 850	1	0	1	1	1	1	1	0	0	0	1
104 850 to 104 950	1	0	1	1	1	1	1	0	0	1	1
104 950 to 105 050	1	0	1	1	1	1	1	0	0	1	0
105 050 to 105 150	1	0	1	1	1	1	1	0	1	1	0
105 150 to 105 250	1	0	1	1	1	1	1	0	1	0	0
105 250 to 105 350	1	0	1	1	1	1	1	1	1	0	0
105 350 to 105 450	1	0	1	1	1	1	1	1	1	1	0
105 450 to 105 550	1	0	1	1	1	1	1	1	0	1	0
105 550 to 105 650	1	0	1	1	1	1	1	1	0	1	1
105 650 to 105 750	1	0	1	1	1	1	1	1	0	0	1
105 750 to 105 850	1	0	1	1	1	1	0	1	0	0	1
105 850 to 105 950	1	0	1	1	1	1	0	1	0	1	1
105 950 to 106 050	1	0	1	1	1	1	0	1	0	1	0
106 050 to 106 150	1	0	1	1	1	1	0	1	1	1	0
106 150 to 106 250	1	0	1	1	1	1	0	1	1	0	0

RANGE			PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)										
Increments (Feet)			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
106 250	to	106 350	1	0	1	1	1	1	0	0	1	0	0
106 350	to	106 450	1	0	1	1	1	1	0	0	1	1	0
106 450	to	106 550	1	0	1	1	1	1	0	0	0	1	0
106 550	to	106 650	1	0	1	1	1	1	0	0	0	1	1
106 650	to	106 750	1	0	1	1	1	1	0	0	0	0	1
106 750	to	106 850	1	0	1	1	0	1	0	0	0	0	1
106 850	to	106 950	1	0	1	1	0	1	0	0	0	1	1
106 950	to	107 050	1	0	1	1	0	1	0	0	0	1	0
107 050	to	107 150	1	0	1	1	0	1	0	0	1	1	0
107 150	to	107 250	1	0	1	1	0	1	0	0	1	0	0
107 250	to	107 350	1	0	1	1	0	1	0	1	1	0	0
107 350	to	107 450	1	0	1	1	0	1	0	1	1	1	0
107 450	to	107 550	1	0	1	1	0	1	0	1	0	1	0
107 550	to	107 650	1	0	1	1	0	1	0	1	0	1	1
107 650	to	107 750	1	0	1	1	0	1	0	1	0	0	1
107 750	to	107 850	1	0	1	1	0	1	1	1	0	0	1
107 850	to	107 950	1	0	1	1	0	1	1	1	0	1	1
107 950	to	108 050	1	0	1	1	0	1	1	1	0	1	0
108 050	to	108 150	1	0	1	1	0	1	1	1	1	1	0
108 150	to	108 250	1	0	1	1	0	1	1	1	1	0	0
108 250	to	108 350	1	0	1	1	0	1	1	0	1	0	0
108 350	to	108 450	1	0	1	1	0	1	1	0	1	1	0
108 450	to	108 550	1	0	1	1	0	1	1	0	0	1	0
108 550	to	108 650	1	0	1	1	0	1	1	0	0	1	1
108 650	to	108 750	1	0	1	1	0	1	1	0	0	0	1
108 750	to	108 850	1	0	1	1	0	0	1	0	0	0	1
108 850	to	108 950	1	0	1	1	0	0	1	0	0	1	1
108 950	to	109 050	1	0	1	1	0	0	1	0	0	1	0
109 050	to	109 150	1	0	1	1	0	0	1	0	1	1	0
109 150	to	109 250	1	0	1	1	0	0	1	0	1	0	0
109 250	to	109 350	1	0	1	1	0	0	1	1	1	0	0
109 350	to	109 450	1	0	1	1	0	0	1	1	1	1	0
109 450	to	109 550	1	0	1	1	0	0	1	1	0	1	0
109 550	to	109 650	1	0	1	1	0	0	1	1	0	1	1
109 650	to	109 750	1	0	1	1	0	0	1	1	0	0	1
109 750	to	109 850	1	0	1	1	0	0	0	1	0	0	1
109 850	to	109 950	1	0	1	1	0	0	0	1	0	1	1
109 950	to	110 050	1	0	1	1	0	0	0	1	0	1	0
110 050	to	110 150	1	0	1	1	0	0	0	1	1	1	0
110 150	to	110 250	1	0	1	1	0	0	0	1	1	0	0
110 250	to	110 350	1	0	1	1	0	0	0	0	1	0	0
110 350	to	110 450	1	0	1	1	0	0	0	0	1	1	0
110 450	to	110 550	1	0	1	1	0	0	0	0	0	1	0
110 550	to	110 650	1	0	1	1	0	0	0	0	0	1	1
110 650	to	110 750	1	0	1	1	0	0	0	0	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
110 750	to	110 850	1	0	0	1	0	0	0	0	0	0	1
110 850	to	110 950	1	0	0	1	0	0	0	0	0	1	1
110 950	to	111 050	1	0	0	1	0	0	0	0	0	1	0
111 050	to	111 150	1	0	0	1	0	0	0	0	1	1	0
111 150	to	111 250	1	0	0	1	0	0	0	0	1	0	0
111 250	to	111 350	1	0	0	1	0	0	0	1	1	0	0
111 350	to	111 450	1	0	0	1	0	0	0	1	1	1	0
111 450	to	111 550	1	0	0	1	0	0	0	1	0	1	0
111 550	to	111 650	1	0	0	1	0	0	0	1	0	1	1
111 650	to	111 750	1	0	0	1	0	0	0	1	0	0	1
111 750	to	111 850	1	0	0	1	0	0	1	1	0	0	1
111 850	to	111 950	1	0	0	1	0	0	1	1	0	1	1
111 950	to	112 050	1	0	0	1	0	0	1	1	0	1	0
112 050	to	112 150	1	0	0	1	0	0	1	1	1	1	0
112 150	to	112 250	1	0	0	1	0	0	1	1	1	0	0
112 250	to	112 350	1	0	0	1	0	0	1	0	1	0	0
112 350	to	112 450	1	0	0	1	0	0	1	0	1	1	0
112 450	to	112 550	1	0	0	1	0	0	1	0	0	1	0
112 550	to	112 650	1	0	0	1	0	0	1	0	0	1	1
112 650	to	112 750	1	0	0	1	0	0	1	0	0	0	1
112 750	to	112 850	1	0	0	1	0	1	1	0	0	0	1
112 850	to	112 950	1	0	0	1	0	1	1	0	0	1	1
112 950	to	113 050	1	0	0	1	0	1	1	0	0	1	0
113 050	to	113 150	1	0	0	1	0	1	1	0	1	1	0
113 150	to	113 250	1	0	0	1	0	1	1	0	1	0	0
113 250	to	113 350	1	0	0	1	0	1	1	1	1	0	0
113 350	to	113 450	1	0	0	1	0	1	1	1	1	1	0
113 450	to	113 550	1	0	0	1	0	1	1	1	0	1	0
113 550	to	113 650	1	0	0	1	0	1	1	1	0	1	1
113 650	to	113 750	1	0	0	1	0	1	1	1	0	0	1
113 750	to	113 850	1	0	0	1	0	1	0	1	0	0	1
113 850	to	113 950	1	0	0	1	0	1	0	1	0	1	1
113 950	to	114 050	1	0	0	1	0	1	0	1	0	1	0
114 050	to	114 150	1	0	0	1	0	1	0	1	1	1	0
114 150	to	114 250	1	0	0	1	0	1	0	1	1	0	0
114 250	to	114 350	1	0	0	1	0	1	0	0	1	0	0
114 350	to	114 450	1	0	0	1	0	1	0	0	1	1	0
114 450	to	114 550	1	0	0	1	0	1	0	0	0	1	0
114 550	to	114 650	1	0	0	1	0	1	0	0	0	1	1
114 650	to	114 750	1	0	0	1	0	1	0	0	0	0	1
114 750	to	114 850	1	0	0	1	1	1	0	0	0	0	1
114 850	to	114 950	1	0	0	1	1	1	0	0	0	1	1
114 950	to	115 050	1	0	0	1	1	1	0	0	0	1	0
115 050	to	115 150	1	0	0	1	1	1	0	0	1	1	0
115 150	to	115 250	1	0	0	1	1	1	0	0	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
115 250	to	115 350	1	0	0	1	1	1	0	1	1	0	0
115 350	to	115 450	1	0	0	1	1	1	0	1	1	1	0
115 450	to	115 550	1	0	0	1	1	1	0	1	0	1	0
115 550	to	115 650	1	0	0	1	1	1	0	1	0	1	1
115 650	to	115 750	1	0	0	1	1	1	0	1	0	0	1
115 750	to	115 850	1	0	0	1	1	1	1	1	0	0	1
115 850	to	115 950	1	0	0	1	1	1	1	1	0	1	1
115 950	to	116 050	1	0	0	1	1	1	1	1	0	1	0
116 050	to	116 150	1	0	0	1	1	1	1	1	1	1	0
116 150	to	116 250	1	0	0	1	1	1	1	1	1	0	0
116 250	to	116 350	1	0	0	1	1	1	1	0	1	0	0
116 350	to	116 450	1	0	0	1	1	1	1	0	1	1	0
116 450	to	116 550	1	0	0	1	1	1	1	0	0	1	0
116 550	to	116 650	1	0	0	1	1	1	1	0	0	1	1
116 650	to	116 750	1	0	0	1	1	1	1	0	0	0	1
116 750	to	116 850	1	0	0	1	1	0	1	0	0	0	1
116 850	to	116 950	1	0	0	1	1	0	1	0	0	1	1
116 950	to	117 050	1	0	0	1	1	0	1	0	0	1	0
117 050	to	117 150	1	0	0	1	1	0	1	0	1	1	0
117 150	to	117 250	1	0	0	1	1	0	1	0	1	0	0
117 250	to	117 350	1	0	0	1	1	0	1	1	1	0	0
117 350	to	117 450	1	0	0	1	1	0	1	1	1	1	0
117 450	to	117 550	1	0	0	1	1	0	1	1	0	1	0
117 550	to	117 650	1	0	0	1	1	0	1	1	0	1	1
117 650	to	117 750	1	0	0	1	1	0	1	1	0	0	1
117 750	to	117 850	1	0	0	1	1	0	0	1	0	0	1
117 850	to	117 950	1	0	0	1	1	0	0	1	0	1	1
117 950	to	118 050	1	0	0	1	1	0	0	1	0	1	0
118 050	to	118 150	1	0	0	1	1	0	0	1	1	1	0
118 150	to	118 250	1	0	0	1	1	0	0	1	1	0	0
118 250	to	118 350	1	0	0	1	1	0	0	0	1	0	0
118 350	to	118 450	1	0	0	1	1	0	0	0	1	1	0
118 450	to	118 550	1	0	0	1	1	0	0	0	0	1	0
118 550	to	118 650	1	0	0	1	1	0	0	0	0	1	1
118 650	to	118 750	1	0	0	1	1	0	0	0	0	0	1
118 750	to	118 850	1	0	0	0	1	0	0	0	0	0	1
118 850	to	118 950	1	0	0	0	1	0	0	0	0	1	1
118 950	to	119 050	1	0	0	0	1	0	0	0	0	1	0
119 050	to	119 150	1	0	0	0	1	0	0	0	1	1	0
119 150	to	119 250	1	0	0	0	1	0	0	0	1	0	0
119 250	to	119 350	1	0	0	0	1	0	0	1	1	0	0
119 350	to	119 450	1	0	0	0	1	0	0	1	1	1	0
119 450	to	119 550	1	0	0	0	1	0	0	1	0	1	0
119 550	to	119 650	1	0	0	0	1	0	0	1	0	1	1
119 650	to	119 750	1	0	0	0	1	0	0	1	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
119 750	to	119 850	1	0	0	0	1	0	1	1	0	0	1
119 850	to	119 950	1	0	0	0	1	0	1	1	0	1	1
119 950	to	120 050	1	0	0	0	1	0	1	1	0	1	0
120 050	to	120 150	1	0	0	0	1	0	1	1	1	1	0
120 150	to	120 250	1	0	0	0	1	0	1	1	1	0	0
120 250	to	120 350	1	0	0	0	1	0	1	0	1	0	0
120 350	to	120 450	1	0	0	0	1	0	1	0	1	1	0
120 450	to	120 550	1	0	0	0	1	0	1	0	0	1	0
120 550	to	120 650	1	0	0	0	1	0	1	0	0	1	1
120 650	to	120 750	1	0	0	0	1	0	1	0	0	0	1
120 750	to	120 850	1	0	0	0	1	1	1	0	0	0	1
120 850	to	120 950	1	0	0	0	1	1	1	0	0	1	1
120 950	to	121 050	1	0	0	0	1	1	1	0	0	1	0
121 050	to	121 150	1	0	0	0	1	1	1	0	1	1	0
121 150	to	121 250	1	0	0	0	1	1	1	0	1	0	0
121 250	to	121 350	1	0	0	0	1	1	1	1	1	0	0
121 350	to	121 450	1	0	0	0	1	1	1	1	1	1	0
121 450	to	121 550	1	0	0	0	1	1	1	1	0	1	0
121 550	to	121 650	1	0	0	0	1	1	1	1	0	1	1
121 650	to	121 750	1	0	0	0	1	1	1	1	0	0	1
121 750	to	121 850	1	0	0	0	1	1	0	1	0	0	1
121 850	to	121 950	1	0	0	0	1	1	0	1	0	1	1
121 950	to	122 050	1	0	0	0	1	1	0	1	0	1	0
122 050	to	122 150	1	0	0	0	1	1	0	1	1	1	0
122 150	to	122 250	1	0	0	0	1	1	0	1	1	0	0
122 250	to	122 350	1	0	0	0	1	1	0	0	1	0	0
122 350	to	122 450	1	0	0	0	1	1	0	0	1	1	0
122 450	to	122 550	1	0	0	0	1	1	0	0	0	1	0
122 550	to	122 650	1	0	0	0	1	1	0	0	0	1	1
122 650	to	122 750	1	0	0	0	1	1	0	0	0	0	1
122 750	to	122 850	1	0	0	0	0	1	0	0	0	0	1
122 850	to	122 950	1	0	0	0	0	1	0	0	0	1	1
122 950	to	123 050	1	0	0	0	0	1	0	0	0	1	0
123 050	to	123 150	1	0	0	0	0	1	0	0	1	1	0
123 150	to	123 250	1	0	0	0	0	1	0	0	1	0	0
123 250	to	123 350	1	0	0	0	0	1	0	1	1	0	0
123 350	to	123 450	1	0	0	0	0	1	0	1	1	1	0
123 450	to	123 550	1	0	0	0	0	1	0	1	0	1	0
123 550	to	123 650	1	0	0	0	0	1	0	1	0	1	1
123 650	to	123 750	1	0	0	0	0	1	0	1	0	0	1
123 750	to	123 850	1	0	0	0	0	1	1	1	0	0	1
123 850	to	123 950	1	0	0	0	0	1	1	1	0	1	1
123 950	to	124 050	1	0	0	0	0	1	1	1	0	1	0
124 050	to	124 150	1	0	0	0	0	1	1	1	1	1	0
124 150	to	124 250	1	0	0	0	0	1	1	1	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
124 250	to	124 350	1	0	0	0	0	1	1	0	1	0	0
124 350	to	124 450	1	0	0	0	0	1	1	0	1	1	0
124 450	to	124 550	1	0	0	0	0	1	1	0	0	1	0
124 550	to	124 650	1	0	0	0	0	1	1	0	0	1	1
124 650	to	124 750	1	0	0	0	0	1	1	0	0	0	1
124 750	to	124 850	1	0	0	0	0	0	1	0	0	0	1
124 850	to	124 950	1	0	0	0	0	0	1	0	0	1	1
124 950	to	125 050	1	0	0	0	0	0	1	0	0	1	0
125 050	to	125 150	1	0	0	0	0	0	1	0	1	1	0
125 150	to	125 250	1	0	0	0	0	0	1	0	1	0	0
125 250	to	125 350	1	0	0	0	0	0	1	1	1	0	0
125 350	to	125 450	1	0	0	0	0	0	1	1	1	1	0
125 450	to	125 550	1	0	0	0	0	0	1	1	0	1	0
125 550	to	125 650	1	0	0	0	0	0	1	1	0	1	1
125 650	to	125 750	1	0	0	0	0	0	1	1	0	0	1
125 750	to	125 850	1	0	0	0	0	0	0	1	0	0	1
125 850	to	125 950	1	0	0	0	0	0	0	1	0	1	1
125 950	to	126 050	1	0	0	0	0	0	0	1	0	1	0
126 050	to	126 150	1	0	0	0	0	0	0	1	1	1	0
126 150	to	126 250	1	0	0	0	0	0	0	1	1	0	0
126 250	to	126 350	1	0	0	0	0	0	0	0	1	0	0
126 350	to	126 450	1	0	0	0	0	0	0	0	1	1	0
126 450	to	126 550	1	0	0	0	0	0	0	0	0	1	0
126 550	to	126 650	1	0	0	0	0	0	0	0	0	1	1
126 650	to	126 750	1	0	0	0	0	0	0	0	0	0	1

CHAPTER 4. AIRBORNE COLLISION AVOIDANCE SYSTEM

Note 1.— Guidance material relating to the airborne collision avoidance system is contained in the Airborne Collision Avoidance System (ACAS) Manual *(Doc 9863).*

Note 2.— Non-SI alternative units are used as permitted by Annex 5, Chapter 3, 3.2.2. In limited cases, to ensure consistency at the level of the logic calculations, units such as ft/s, NM/s and kt/s are used.

Note 3.— The system that is compliant with Chapter 4 in its entirety is the one that incorporates the traffic alert and collision avoidance systems (TCAS) Version 7.1 and therefore meets the RTCA/DO-185B or EUROCAE/ED-143 specification.

Note 4.— Equipment complying with RTCA/DO-185A standards (also known as TCAS Version 7.0) is not compliant with Chapter 4 in its entirety.

4.1 DEFINITIONS RELATING TO AIRBORNE COLLISION AVOIDANCE SYSTEM

ACAS I. An ACAS which provides information as an aid to "see and avoid" action but does not include the capability for generating resolution advisories (RAs).

Note.— ACAS I is not intended for international implementation and standardization by ICAO. Therefore, only ACAS I characteristics required to ensure compatible operation with other ACAS configurations and interference limiting are defined in 4.2.

ACAS II. An ACAS which provides vertical resolution advisories (RAs) in addition to traffic advisories (TAs).

ACAS III. An ACAS which provides vertical and horizontal resolution advisories (RAs) in addition to traffic advisories (TAs).

ACAS broadcast. A long Mode S air-air surveillance interrogation (UF = 16) with the broadcast address.

Active RAC. An RAC is active if it currently constrains the selection of the RA. RACs that have been received within the last six seconds and have not been explicitly cancelled are active.

Altitude crossing RA. A resolution advisory is altitude crossing if own ACAS aircraft is currently at least 30 m (100 ft) below or above the threat aircraft for upward or downward sense advisories, respectively.

Climb RA. A positive RA recommending a climb but not an increased climb.

Closest approach. The occurrence of minimum range between own ACAS aircraft and the intruder. Thus range at closest approach is the smallest range between the two aircraft and time of closest approach is the time at which this occurs.

Coordination. The process by which two ACAS-equipped aircraft select compatible resolution advisories (RAs) by the exchange of resolution advisory complements (RACs).

Coordination interrogation. A Mode S interrogation (uplink transmission) radiated by ACAS II or III and containing a resolution message.

Coordination reply. A Mode S reply (downlink transmission) acknowledging the receipt of a coordination interrogation by the Mode S transponder that is part of an ACAS II or III installation.

Corrective RA. A resolution advisory that advises the pilot to deviate from the current flight path.

Cycle. The term "cycle" used in this chapter refers to one complete pass through the sequence of functions executed by ACAS II or ACAS III, nominally once a second.

Descend RA. A positive RA recommending a descent but not an increased descent.

Established track. A track generated by ACAS air-air surveillance that is treated as the track of an actual aircraft.

Increased rate RA. A resolution advisory with a strength that recommends increasing the altitude rate to a value exceeding that recommended by a previous climb or descend RA.

Intruder. An SSR transponder-equipped aircraft within the surveillance range of ACAS for which ACAS has an established track.

Own aircraft. The aircraft fitted with the ACAS that is the subject of the discourse, which ACAS is to protect against possible collisions, and which may enter a manoeuvre in response to an ACAS indication.

Positive RA. A resolution advisory that advises the pilot either to climb or to descend (applies to ACAS II).

Potential threat. An intruder deserving special attention either because of its close proximity to own aircraft or because successive range and altitude measurements indicate that it could be on a collision or near-collision course with own aircraft. The warning time provided against a potential threat is sufficiently small that a traffic advisory (TA) is justified but not so small that a resolution advisory (RA) would be justified.

Preventive RA. A resolution advisory that advises the pilot to avoid certain deviations from the current flight path but does not require any change in the current flight path.

RA sense. The sense of an ACAS II RA is "upward" if it requires climb or limitation of descent rate and "downward" if it requires descent or limitation of climb rate. It can be both upward and downward simultaneously if it requires limitation of the vertical rate to a specified range.

Note.— The RA sense may be both upward and downward when, having several simultaneous threats, ACAS generates an RA aimed at ensuring adequate separation below some threat(s) and above some other threat(s).

Resolution advisory (RA). An indication given to the flight crew recommending:

a) a manoeuvre intended to provide separation from all threats; or

b) a manoeuvre restriction intended to maintain existing separation.

Resolution advisory complement (RAC). Information provided by one ACAS to another via a Mode S interrogation in order to ensure complementary manoeuvres by restricting the choice of manoeuvres available to the ACAS receiving the RAC.

Resolution advisory complements record (RAC record). A composite of all currently active vertical RACs (VRCs) and horizontal RACs (HRCs) that have been received by ACAS. This information is provided by one ACAS to another ACAS or to a Mode S ground station via a Mode S reply.

Resolution advisory strength. The magnitude of the manoeuvre indicated by the RA. An RA may take on several successive strengths before being cancelled. Once a new RA strength is issued, the previous one automatically becomes void.

Resolution message. The message containing the resolution advisory complement (RAC).

Reversed sense RA. A resolution advisory that has had its sense reversed.

Sensitivity level (S). An integer defining a set of parameters used by the traffic advisory (TA) and collision avoidance algorithms to control the warning time provided by the potential threat and threat detection logic, as well as the values of parameters relevant to the RA selection logic.

Threat. An intruder deserving special attention either because of its close proximity to own aircraft or because successive range and altitude measurements indicate that it could be on a collision or near-collision course with own aircraft. The warning time provided against a threat is sufficiently small that an RA is justified.

Track. A sequence of at least three measurements representing positions that could reasonably have been occupied by an aircraft.

Traffic advisory (TA). An indication given to the flight crew that a certain intruder is a potential threat.

Vertical speed limit (VSL) RA. A resolution advisory advising the pilot to avoid a given range of altitude rates. A VSL RA can be either corrective or preventive.

Warning time. The time interval between potential threat or threat detection and closest approach when neither aircraft accelerates.

4.2 ACAS I GENERAL PROVISIONS AND CHARACTERISTICS

4.2.1 *Functional requirements.* ACAS I shall perform the following functions:

a) surveillance of nearby SSR transponder-equipped aircraft; and

b) provide indications to the flight crew identifying the approximate position of nearby aircraft as an aid to visual acquisition.

Note.— ACAS I is intended to operate using Mode A/C interrogations only. Furthermore, it does not coordinate with other ACAS. Therefore, a Mode S transponder is not required as a part of an ACAS I installation.

4.2.2 *Signal format.* The RF characteristics of all ACAS I signals shall conform to the provisions of Chapter 3, 3.1.1.1 through 3.1.1.6 and 3.1.2.1 through 3.1.2.4.

4.2.3 Interference control

4.2.3.1 *Maximum radiated RF power.* The effective radiated power of an ACAS I transmission at 0 degree elevation relative to the longitudinal axis of the aircraft shall not exceed 24 dBW.

4.2.3.2 *Unwanted radiated power.* When ACAS I is not transmitting an interrogation, the effective radiated power in any direction shall not exceed –70 dBm.

Note.— This requirement is to ensure that, when not transmitting an interrogation, ACAS I does not radiate RF energy that could interfere with, or reduce the sensitivity of, the SSR transponder or radio equipment in other nearby aircraft or ground facilities.

4.2.3.3 *Interference limiting.* Each ACAS I interrogator shall control its interrogation rate or power or both in all SSR modes to minimize interference effects (4.2.3.3.3 and 4.2.3.3.4).

Note.— These limits are a means of ensuring that all interference effects resulting from these interrogations, together with the interrogations from all other ACAS I, ACAS II and ACAS III interrogators in the vicinity are kept to a low level.

4.2.3.3.1 *Determination of own transponder reply rate.* ACAS I shall monitor the rate that own transponder replies to interrogations to ensure that the provisions in 4.2.3.3.3 are met.

4.2.3.3.2 *Determination of the number of ACAS II and ACAS III interrogators.* ACAS I shall count the number of ACAS II and ACAS III interrogators in the vicinity to ensure that the provisions in 4.2.3.3.3 or 4.2.3.3.4 are met. This count shall be obtained by monitoring ACAS broadcasts (UF = 16), (4.3.7.1.2.4) and shall be updated as the number of distinct ACAS aircraft addresses received within the previous 20-s period at a nominal frequency of at least 1 Hz.

4.2.3.3.3 *Mode A/C ACAS I interference limits.* The interrogator power shall not exceed the following limits:

n_a	Upper limit for $\{\sum_{k=1}^{k_t} P_a(\text{k})\}$	
	If $f_r \leq 240$	If $f_r > 240$
0	250	118
1	250	113
2	250	108
3	250	103
4	250	98
5	250	94
6	250	89
7	250	84
8	250	79
9	250	74
10	245	70
11	228	65
12	210	60
13	193	55
14	175	50
15	158	45
16	144	41
17	126	36
18	109	31
19	91	26
20	74	21
21	60	17
≥22	42	12

where:

n_a = number of operating ACAS II and ACAS III equipped aircraft near own (based on ACAS broadcasts received with a transponder receiver threshold of –74 dBm);

{ } = average value of the expression within the brackets over last 8 interrogation cycles;

$P_a(k)$ = peak power radiated from the antenna in all directions of the pulse having the largest amplitude in the group of pulses comprising a single interrogation during the k^{th} Mode A/C interrogation in a 1 s interrogation cycle, W;

k = index number for Mode A/C interrogations, k = 1, 2,..., kt;

k_t = number of Mode A/C interrogations transmitted in a 1 s interrogation cycle;

f_r = Mode A/C reply rate of own transponder.

4.2.3.3.4 *Mode S ACAS I interference limits*. An ACAS I that uses Mode S interrogations shall not cause greater interference effects than an ACAS I using Mode A/C interrogations only.

4.3 GENERAL PROVISIONS RELATING TO ACAS II AND ACAS III

Note 1.— The acronym ACAS is used in this section to indicate either ACAS II or ACAS III.

Note 2.— Carriage requirements for ACAS equipment are addressed in Annex 6.

Note 3.— The term "equipped threat" is used in this section to indicate a threat fitted with ACAS II or ACAS III.

4.3.1 Functional requirements

4.3.1.1 *ACAS functions.* ACAS shall perform the following functions:

a) surveillance;

b) generation of TAs;

c) threat detection;

d) generation of RAs;

e) coordination; and

f) communication with ground stations.

The equipment shall execute functions b) through e) on each cycle of operation.

Note.— Certain features of these functions must be standardized to ensure that ACAS units cooperate satisfactorily with other ACAS units, with Mode S ground stations and with the ATC system. Each of the features that are standardized is discussed below. Certain other features are given herein as recommendations.

4.3.1.1.1 The duration of a cycle shall not exceed 1.2 s.

4.3.2 Surveillance performance requirements

4.3.2.1 *General surveillance requirements.* ACAS shall interrogate SSR Mode A/C and Mode S transponders in other aircraft and detect the transponder replies. ACAS shall measure the range and relative bearing of responding aircraft. Using these measurements and information conveyed by transponder replies, ACAS shall estimate the relative positions of each responding aircraft. ACAS shall include provisions for achieving such position determination in the presence of ground reflections, interference and variations in signal strength.

4.3.2.1.1 *Track establishment probability.* ACAS shall generate an established track, with at least a 0.90 probability that the track is established 30 s before closest approach, on aircraft equipped with transponders when all of the following conditions are satisfied:

a) the elevation angles of these aircraft are within ±10 degrees relative to the ACAS aircraft pitch plane;

b) the magnitudes of these aircraft's rates of change of altitude are less than or equal to 51 m/s (10 000 ft/min);

c) the transponders and antennas of these aircraft meet the Standards of Chapter 3, 3.1.1 and 3.1.2;

d) the closing speeds and directions of these aircraft, the local density of SSR transponder-equipped aircraft and the number of other ACAS interrogators in the vicinity (as determined by monitoring ACAS broadcasts, 4.3.7.1.2.4) satisfy the conditions specified in Table 4-1; and

e) the minimum slant range is equal to or greater than 300 m (1 000 ft).

Table 4-1. ACAS design assumptions

Conditions									*Performance*
Quadrant						*Maximum traffic density*		*Maximum number of other ACAS within 56 km (30 NM)*	*Probability of success*
Forward		*Side*		*Back*					
Maximum closing speed									
m/s	*kt*	*m/s*	*kt*	*m/s*	*kt*	*aircraft/ km²*	*aircraft/ NM²*		
260	500	150	300	93	180	0.087	0.30	30	0.90
620	1 200	390	750	220	430	0.017	0.06	30	0.90

Note.— Table 4-1 shows the design assumption upon which the development of ACAS was based. Operational experience and simulation show that ACAS provides adequate surveillance for collision avoidance even when the maximum number of other ACAS within 56 km (30 NM) is somewhat higher than that shown in Table 4-1. Future ACAS designs will take account of current and expected ACAS densities.

4.3.2.1.1.1 ACAS shall continue to provide surveillance with no abrupt degradation in track establishment probability as any one of the condition bounds defined in 4.3.2.1.1 is exceeded.

4.3.2.1.1.2 ACAS shall not track Mode S aircraft that report that they are on the ground.

Note.— A Mode S aircraft may report that it is on the ground by coding in the capability (CA) field in a DF = 11 or DF = 17 transmission (Chapter 3, 3.1.2.5.2.2.1) or by coding in the vertical status (VS) field in a DF = 0 transmission (Chapter 3, 3.1.2.8.2.1). Alternatively, if the aircraft is under Mode S ground surveillance, ground status may be determined by monitoring the flight status (FS) field in downlink formats DF = 4, 5, 20 or 21 (Chapter 3, 3.1.2.6.5.1).

4.3.2.1.1.3 **Recommendation.—** *ACAS should achieve the required tracking performance when the average SSR Mode A/C asynchronous reply rate from transponders in the vicinity of the ACAS aircraft is 240 replies per second and when the peak interrogation rate received by the individual transponders under surveillance is 500 per second.*

Note.— The peak interrogation rate mentioned above includes interrogations from all sources.

4.3.2.1.2 *False track probability.* The probability that an established Mode A/C track does not correspond in range and altitude, if reported, to an actual aircraft shall be less than 10-2. For an established Mode S track this probability shall be less than 10-6. These limits shall not be exceeded in any traffic environment.

4.3.2.1.3 *RANGE AND BEARING ACCURACY*

4.3.2.1.3.1 Range shall be measured with a resolution of 14.5 m (1/128 NM) or better.

4.3.2.1.3.2 **Recommendation.—** The errors in the relative bearings of the estimated positions of intruders should not exceed 10 degrees rms.

Note.— This accuracy in the relative bearing of intruders is practicable and sufficient as an aid to the visual acquisition of potential threats. In addition, such relative bearing information has been found useful in threat detection, where it can indicate that an intruder is a threat. However, this accuracy is not sufficient as a basis for horizontal RAs, nor is it sufficient for reliable predictions of horizontal miss distance.

4.3.2.2 INTERFERENCE CONTROL

4.3.2.2.1 *Maximum radiated RF power.* The effective radiated power of an ACAS transmission at 0 degree elevation relative to the longitudinal axis of the aircraft shall not exceed 27 dBW.

4.3.2.2.1.1 *Unwanted radiated power.* When ACAS is not transmitting an interrogation, the effective radiated power in any direction shall not exceed –70 dBm.

4.3.2.2.2 *Interference limiting.* Each ACAS interrogator operating below a pressure-altitude of 5 490 m (18 000 ft) shall control its interrogation rate or power or both so as to conform with specific inequalities (4.3.2.2.2.2).

4.3.2.2.2.1 *Determination of the number of other ACAS.* ACAS shall count the number of other ACAS II and III interrogators in the vicinity to ensure that the interference limits are met. This count shall be obtained by monitoring ACAS broadcasts (UF = 16), (4.3.7.1.2.4). Each ACAS shall monitor such broadcast interrogations to determine the number of other ACAS within detection range.

4.3.2.2.2.2 *ACAS interference limiting inequalities.* ACAS shall adjust its interrogation rate and interrogation power such that the following three inequalities remain true, except as provided in 4.3.2.2.2.2.1.

$$\{\sum_{i=1}^{i_t}\left[\frac{p(i)}{250}\right]^{\alpha}\} < minimum\left[\frac{280}{1+n_a}, \frac{11}{\alpha^2}\right] \qquad (1)$$

$$\{\sum_{i=1}^{i_t} m(i)\} < 0.01 \qquad (2)$$

$$\{\frac{1}{B}\sum_{k=1}^{k_t}\frac{P_a(k)}{250}\} < minimum\left[\frac{80}{1+n_a}, 3\right] \qquad (3)$$

The variables in these inequalities shall be defined as follows:

i_t = number of interrogations (Mode A/C and Mode S) transmitted in a 1 s interrogation cycle. This shall include allMode S interrogations used by the ACAS functions, including those in addition to UF = 0 and UF = 16 interrogations, except as provided in 4.3.2.2.2.2.1;

Note.— UF = 19 interrogations are included in it as specified in 3.1.2.8.9.4.

i = index number for Mode A/C and Mode S interrogations, i = 1, 2,..., *it*;

α = the minimum of α_1 calculated as 1/4 [n_b/n_c] subject to the special conditions given below and α_2 calculated as Log10 [n_a/n_b] / Log10 25, where n_b and n_c are defined as the number of operating ACAS II and ACAS III equipped aircraft (airborne or on the ground) within 11.2 km (6 NM) and 5.6 km (3 NM) respectively, of own ACAS (based on ACAS surveillance). ACAS aircraft operating on the ground or at or below a radio altitude of 610 m (2 000 ft) AGL shall include both airborne and on-ground ACAS II and ACAS III aircraft in the value for n_b and n_c. Otherwise, ACAS shall include only airborne ACAS II and ACAS III aircraft in the value for n_b and n_c. The values of α, α_1 and α_2 are further constrained to a minimum of 0.5 and a maximum of 1.0.

In addition;

IF [($n_b \leq 1$) OR ($n_b \leq 4$ AND $n_c \leq 2$ AND $n_a > 25$)] THEN $\alpha_1 = 1.0$,

IF [($n_c > 2$) AND ($n_b > 2\, n_c$) AND ($n_a < 40$)] THEN $\alpha_1 = 0.5$;

p(i) = peak power radiated from the antenna in all directions of the pulse having the largest amplitude in the group of pulses comprising a single interrogation during the i^{th} interrogation in a 1 s interrogation cycle, W;

m(i) = duration of the mutual suppression interval for own transponder associated with the *i*th interrogation in a 1 s interrogation cycle, s;

B = beam sharpening factor (ratio of 3 dB beam width to beamwidth resulting from interrogation side-lobe suppression). For ACAS interrogators that employ transmitter side-lobe suppression (SLS), the appropriate beamwidth shall be the extent in azimuth angle of the Mode A/C replies from one transponder as limited by SLS, averaged over the transponder population;

{ } see 4.2.3.3.3

Pa(k) "

k "

k_t "

n_a "

Note.— RA and ACAS broadcasts (4.3.6.2.1 and 4.3.7.1.2.4) are interrogations.

4.3.2.2.2.2.1 *Transmissions during RAs.* All air-to-air coordination interrogations shall be transmitted at full power and these interrogations shall be excluded from the summations of Mode S interrogations in the left-hand terms of inequalities (1) and (2) in 4.3.2.2.2.2 for the duration of the RA.

4.3.2.2.2.2.2 *Transmissions from ACAS units on the ground.* Whenever the ACAS aircraft indicates that it is on the ground, ACAS interrogations shall be limited by setting the number of other ACAS II and III aircraft (n_a) count in the interference limiting inequalities to a value that is three times the value obtained based on ACAS broadcasts received with a transponder receiver threshold of –74 dBm. Whenever Mode A/C interrogation power is reduced because of interference limiting, the Mode A/C interrogation power in the forward beam shall be reduced first until the forward sequence matches the right and left sequences. The forward, right and left interrogation powers shall then sequentially be reduced until they match the rear interrogation power. Further reduction of Mode A/C power shall be accomplished by sequentially reducing the forward, side and rear interrogation powers.

4.3.2.2.2.2.3 *Transmissions from ACAS units above 5 490 m (18 000 ft) altitude.* Each ACAS interrogator operating above a pressure-altitude of 5 490 m (18 000 ft) shall control its interrogation rate or power or both such that inequalities (1) and (3) in 4.3.2.2.2.2 remain true when *na* and α are equal to 1, except as provided in 4.3.2.2.2.2.1.

4.3.3 Traffic advisories (TAs)

4.3.3.1 *TA function.* ACAS shall provide TAs to alert the flight crew to potential threats. Such TAs shall be accompanied by an indication of the approximate relative position of potential threats to facilitate visual acquisition.

4.3.3.1.1 *Display of potential threats.* If potential threats are shown on a traffic display, they shall be displayed in amber or yellow.

Note 1.— These colours are generally considered suitable for indicating a cautionary condition.

Note 2.—Additional information assisting in the visual acquisition such as vertical trend and relative altitude may be displayed as well.

Note 3.— Traffic situational awareness is improved when tracks can be supplemented by display of heading information (e.g. as extracted from received ADS-B messages).

4.3.3.2 PROXIMATE TRAFFIC DISPLAY

4.3.3.2.1 **Recommendation.—** While any RA and/or TA are displayed, proximate traffic within 11 km (6 NM) range and, if altitude reporting, ±370 m (1 200 ft) altitude should be displayed. This proximate traffic should be distinguished (e.g. by colour or symbol type) from threats and potential threats, which should be more prominently displayed.

4.3.3.2.2 **Recommendation.—** While any RA and/or TA are displayed, visual acquisition of the threats and/or potential threat should not be adversely affected by the display of proximate traffic or other data (e.g. contents of received ADS-B messages) unrelated to collision avoidance.

4.3.3.3 *TAs as RA precursors.* The criteria for TAs shall be such that they are satisfied before those for an RA.

4.3.3.3.1 *TA warning time.* For intruders reporting altitude, the nominal TA warning time shall not be greater than (T+20 s) where T is the nominal warning time for the generation of the resolution advisory.

Note.— Ideally, RAs would always be preceded by a TA but this is not always possible, e.g. the RA criteria might be already satisfied when a track is first established, or a sudden and sharp manoeuvre by the intruder could cause the TA lead time to be less than a cycle.

4.3.4 Threat detection

4.3.4.1 *Declaration of threat.* ACAS shall evaluate appropriate characteristics of each intruder to determine whether or not it is a threat.

4.3.4.1.1 *Intruder characteristics.* As a minimum, the characteristics of an intruder that are used to identify a threat shall include:

a) tracked altitude;

b) tracked rate of change of altitude;

c) tracked slant range;

d) tracked rate of change of slant range; and

e) sensitivity level of intruder's ACAS, *Si*.

For an intruder not equipped with ACAS II or ACAS III, *Si* shall be set to 1.

4.3.4.1.2 *Own aircraft characteristics.* As a minimum, the characteristics of own aircraft that are used to identify a threat shall include:

a) altitude;

b) rate of change of altitude; and

c) sensitivity level of own ACAS (4.3.4.3).

4.3.4.2 *Sensitivity levels.* ACAS shall be capable of operating at any of a number of sensitivity levels. These shall include:

a) S = 1, a "standby" mode in which the interrogation of other aircraft and all advisories are inhibited;

b) S = 2, a "TA only" mode in which RAs are inhibited; and

c) S = 3-7, further levels that enable the issue of RAs that provide the warning times indicated in Table 4-2 as well as TAs.

4.3.4.3 *Selection of own sensitivity level (So).* The selection of own ACAS sensitivity level shall be determined by sensitivity level control (SLC) commands which shall be accepted from a number of sources as follows:

a) SLC command generated automatically by ACAS based on altitude band or other external factors;

b) SLC command from pilot input; and

c) SLC command from Mode S ground stations.

Table 4-2

Sensitivity level	*2*	*3*	*4*	*5*	*6*	*7*
Nominal warning time	no RAs	15s	20s	25s	30s	35s

4.3.4.3.1 *Permitted SLC command codes.* As a minimum, the acceptable SLC command codes shall include:

	Coding
for SLC based on altitude band	2-7
for SLC from pilot input	0,1,2
for SLC from Mode S ground stations	0,2-6

4.3.4.3.2 *Altitude-band SLC command.* Where ACAS selects an SLC command based on altitude, hysteresis shall be applied to the nominal altitude thresholds at which SLC command value changes are required as follows: for a climbing ACAS aircraft the SLC command shall be increased at the appropriate altitude threshold plus the hysteresis value; for a descending ACAS aircraft the SLC command shall be decreased at the appropriate altitude threshold minus the hysteresis value.

4.3.4.3.3 *Pilot SLC command.* For the SLC command set by the pilot the value 0 shall indicate the selection of the “automatic” mode for which the sensitivity level selection shall be based on the other commands.

4.3.4.3.4 *Mode S ground station SLC command.* For SLC commands transmitted via Mode S ground stations (4.3.8.4.2.1.1), the value 0 shall indicate that the station concerned is not issuing an SLC command and that sensitivity level selection shall be based on the other commands, including non-0 commands from other Mode S ground stations. ACAS shall not process an uplinked SLC value of 1.

4.3.4.3.4.1 *ATS selection of SLC command code.* ATS authorities shall ensure that procedures are in place to inform pilots of any ATS selected SLC command code other than 0 (4.3.4.3.1).

4.3.4.3.5 *Selection rule.* Own ACAS sensitivity level shall be set to the smallest non-0 SLC command received from any of the sources listed in 4.3.4.3.

4.3.4.4 *Selection of parameter values for RA generation.* When the sensitivity level of own ACAS is 3 or greater, the parameter values used for RA generation that depend on sensitivity level shall be based on the greater of the sensitivity level of own ACAS, *So*, and the sensitivity level of the intruder’s ACAS, *Si*.

4.3.4.5 *Selection of parameter values for TA generation.* The parameter values used for TA generation that depend on sensitivity level shall be selected on the same basis as those for RAs (4.3.4.4) except when an SLC command with a value of 2 (“TA only” mode) has been received from either the pilot or a Mode S ground station. In this case, the parameter values for TA generation shall retain the values they would have had in the absence of the SLC command from the pilot or Mode S ground station.

4.3.5 Resolution advisories (RAs)

4.3.5.1 *RA generation.* For all threats, ACAS shall generate an RA except where it is not possible to select an RA that can be predicted to provide adequate separation either because of uncertainty in the diagnosis of the intruder’s flight path or because there is a high risk that a manoeuvre by the threat will negate the RA.

4.3.5.1.1 *Display of threats*. If threats are shown on a traffic display, they shall be displayed in red.

Note.— This colour is generally considered suitable for indicating a warning condition.

4.3.5.1.2 *RA cancellation.* Once an RA has been generated against a threat or threats it shall be maintained or modified until tests that are less stringent than those for threat detection indicate on two consecutive cycles that the RA may be cancelled, at which time it shall be cancelled.

4.3.5.2 *RA selection.* ACAS shall generate the RA that is predicted to provide adequate separation from all threats and that has the least effect on the current flight path of the ACAS aircraft consistent with the other provisions in this chapter.

4.3.5.3 *RA effectiveness.* The RA shall not recommend or continue to recommend a manoeuvre or manoeuvre restriction that, considering the range of probable threat trajectories, is more likely to reduce separation than increase it, subject to the provisions in 4.3.5.5.1.1 and 4.3.5.6.

Note.– See also 4.3.5.8.

4.3.5.3.1 New ACAS installations after 1 January 2014 shall monitor own aircraft's vertical rate to verify compliance with the RA sense. If non-compliance is detected, ACAS shall stop assuming compliance, and instead shall assume the observed vertical rate.

Note 1.– This overcomes the retention of an RA sense that would work only if followed. The revised vertical rate assumption is more likely to allow the logic to select the opposite sense when it is consistent with the non-complying aircraft's vertical rate.

Note 2.– Equipment complying with RTCA/DO-185 or DO-185A standards (also known as TCAS Version 6.04A or TCAS Version 7.0) do not comply with this requirement.

Note 3.– Compliance with this requirement can be achieved through the implementation of traffic alert and collision avoidance system (TCAS) Version 7.1 as specified in RTCA/DO-185B or EUROCAE/ED-143.

4.3.5.3.2 **Recommendation.—** *All ACAS should be compliant with the requirement in 4.3.5.3.1.*

4.3.5.3.3 After 1 January 2017, all ACAS units shall comply with the requirements stated in 4.3.5.3.1.

4.3.5.4 *Aircraft capability.* The RA generated by ACAS shall be consistent with the performance capability of the aircraft.

4.3.5.4.1 *Proximity to the ground.* Descend RAs shall not be generated or maintained when own aircraft is below 300 m (1 000 ft) AGL.

4.3.5.4.2 ACAS shall not operate in sensitivity levels 3-7 when own aircraft is below 300 m (1 000 ft) AGL.

4.3.5.5 *Reversals of sense.* ACAS shall not reverse the sense of an RA from one cycle to the next, except as permitted in 4.3.5.5.1 to ensure coordination or when the predicted separation at closest approach for the existing sense is inadequate.

4.3.5.5.1 *Sense reversals against equipped threats.* If an RAC received from an equipped threat is incompatible with the current RA sense, ACAS shall modify the RA sense to conform with the received RAC if own aircraft address is higher in value than that of the threat.

Note.— 4.3.6.1.3 requires that the own ACAS RAC for the threat is also reversed.

4.3.5.5.1.1 ACAS shall not modify an RA sense in a way that makes it incompatible with an RAC received from an equipped threat if own aircraft address is higher in value than that of the threat.

4.3.5.6 *RA strength retention.* Subject to the requirement that a descend RA is not generated at low altitude (4.3.5.4.1), an RA shall not be modified if the time to closest approach is too short to achieve a significant response or if the threat is diverging in range.

4.3.5.7 *Weakening an RA.* An RA shall not be weakened if it is likely that it would subsequently need to be strengthened.

4.3.5.8 *ACAS-equipped threats.* The RA shall be compatible with all the RACs transmitted to threats (4.3.6.1.3). If an RAC is received from a threat before own ACAS generates an RAC for that threat, the RA generated shall be compatible with the RAC received unless such an RA is more likely to reduce separation than increase it and own aircraft address is lower in value than that of the threat.

Note.— In encounters with more than one threat where it is necessary to pass above some threats and below other threats, this standard can be interpreted as referring to the whole duration of the RA. Specifically, it is permissible to retain an RA to climb (descend) towards a threat that is above (below) own aircraft provided there is a calculated intention to provide adequate separation from all threats by subsequently levelling-off.

4.3.5.9 *Encoding of ARA subfield.* On each cycle of an RA, the RA sense, strength and attributes shall be encoded in the active RA (ARA) subfield (4.3.8.4.2.2.1.1). If the ARA subfield has not been refreshed for an interval of 6 s, it shall be set to 0, along with the MTE subfield in the same message (4.3.8.4.2.2.1.3).

4.3.5.10 *System response time.* The system delay from receipt of the relevant SSR reply to presentation of an RA sense and strength to the pilot shall be as short as possible and shall not exceed 1.5 s.

4.3.6 Coordination and communication

4.3.6.1 PROVISIONS FOR COORDINATION WITH ACAS-EQUIPPED THREATS

4.3.6.1.1 *Multi-aircraft coordination.* In a multi-aircraft situation, ACAS shall coordinate with each equipped threat individually.

4.3.6.1.2 *Data protection during coordination.* ACAS shall prevent simultaneous access to stored data by concurrent processes, in particular, during resolution message processing.

4.3.6.1.3 *Coordination interrogation.* Each cycle ACAS shall transmit a coordination interrogation to each equipped threat, unless generation of an RA is delayed because it is not possible to select an RA that can be predicted to provide adequate separation (4.3.5.1). The resolution message transmitted to a threat shall include an RAC selected for that threat. If an RAC has been received from the threat before ACAS selects an RAC for that threat, the selected RAC shall be compatible with the received RAC unless no more than three cycles have elapsed since the RAC was received, the RAC is altitudecrossing, and own aircraft address is lower in value than that of the threat in which case ACAS shall select its RA independently. If an RAC received from an equipped threat is incompatible with the RAC own ACAS has selected for that threat, ACAS shall modify the selected RAC to be compatible with the received RAC if own aircraft address is higher in value than that of the threat.

Note.— The RAC included in the resolution message is in the form of a vertical RAC (VRC) for ACAS II (4.3.8.4.2.3.2.2) and a vertical RAC (VRC) and/or horizontal RAC (HRC) for ACAS III.

4.3.6.1.3.1 *Coordination termination*. Within the cycle during which an intruder ceases to be a reason for maintaining the RA, ACAS shall send a resolution message to that intruder by means of a coordination interrogation. The resolution message shall include the cancellation code for the last RAC sent to that intruder while it was a reason for maintaining the RA.

Note.— During an encounter with a single threat, the threat ceases to be a reason for the RA when the conditions for cancelling the RA are met. During an encounter with multiple threats, a threat ceases to be a reason for the RA when the conditions for cancelling the RA are met in respect of that threat, even though the RA may have to be maintained because of other threats.

4.3.6.1.3.2 ACAS coordination interrogations shall be transmitted until a coordination reply is received from the threat, up to a maximum of not less than six and not more than twelve attempts. The successive interrogations shall be nominally equally spaced over a period of 100 ±5 ms. If the maximum number of attempts is made and no reply is received, ACAS shall continue its regular processing sequence.

4.3.6.1.3.3 ACAS shall provide parity protection (4.3.8.4.2.3.2.6 and 4.3.8.4.2.3.2.7) for all fields in the coordination interrogation that convey RAC information.

Note.— This includes the vertical RAC (VRC), the cancel vertical RAC (CVC), the horizontal RAC (HRC) and the cancel horizontal RAC (CHC).

4.3.6.1.3.4 Whenever own ACAS reverses its sense against an equipped threat, the resolution message that is sent on the current and subsequent cycles to that threat shall contain both the newly selected RAC and the cancellation code for the RAC sent before the reversal.

4.3.6.1.3.5 When a vertical RA is selected, the vertical RAC (VRC) (4.3.8.4.2.3.2.2) that own ACAS includes in a resolution message to the threat shall be as follows:

a) "do not pass above" when the RA is intended to provide separation above the threat;

b) "do not pass below" when the RA is intended to provide separation below the threat.

4.3.6.1.4 *Resolution message processing.* Resolution messages shall be processed in the order in which they are received and with delay limited to that required to prevent possible concurrent access to stored data and delays due to the processing of previously received resolution messages. Resolution messages that are being delayed shall be temporarily queued to prevent possible loss of messages. Processing a resolution message shall include decoding the message and updating the appropriate data structures with the information extracted from the message.

Note.— According to 4.3.6.1.2, resolution message processing must not access any data whose usage is not protected by the coordination lock state.

4.3.6.1.4.1 An RAC or an RAC cancellation received from another ACAS shall be rejected if the encoded sense bits indicate the existence of a parity error or if undefined value(s) are detected in the resolution message. An RAC or an RAC cancellation received without parity errors and without undefined resolution message values shall be considered valid.

4.3.6.1.4.2 *RAC storage.* A valid RAC received from another ACAS shall be stored or shall be used to update the previously stored RAC corresponding to that ACAS. A valid RAC cancellation shall cause the previously stored RAC to be deleted. A stored RAC that has not been updated for an interval of 6 s shall be deleted.

4.3.6.1.4.3 *RAC record update.* A valid RAC or RAC cancellation received from another ACAS shall be used to update the RAC record. If a bit in the RAC record has not been refreshed for an interval of 6 s by any threat, that bit shall be set to 0.

4.3.6.2 PROVISIONS FOR ACAS COMMUNICATION WITH GROUND STATIONS

4.3.6.2.1 *Air-initiated downlink of ACAS RAs.* When an ACAS RA exists, ACAS shall:

a) transfer to its Mode S transponder an RA report for transmission to the ground in a Comm-B reply (4.3.11.4.1); and b) transmit periodic RA broadcasts (4.3.7.3.2).

4.3.6.2.2 *Sensitivity level control (SLC) command.* ACAS shall store SLC commands from Mode S ground stations. An SLC command received from a Mode S ground station shall remain effective until replaced by an SLC command from the same ground station as indicated by the site number contained in the IIS subfield of the interrogation. If an existing stored command from a Mode S ground station is not refreshed within 4 minutes, or if the SLC command received has the value 15 (4.3.8.4.2.1.1), the stored SLC command for that Mode S ground station shall be set to 0.

4.3.6.3 PROVISIONS FOR DATA TRANSFER BETWEEN ACAS AND ITS MODE S TRANSPONDER

4.3.6.3.1 Data transfer from ACAS to its Mode S transponder:

a) ACAS shall transfer RA information to its Mode S transponder for transmission in an RA report (4.3.8.4.2.2.1) and in a coordination reply (4.3.8.4.2.4.2);

b) ACAS shall transfer current sensitivity level to its Mode S transponder for transmission in a sensitivity level report (4.3.8.4.2.5); and

c) ACAS shall transfer capability information to its Mode S transponder for transmission in a data link capability report (4.3.8.4.2.2.2).

4.3.6.3.2 Data transfer from Mode S transponder to its ACAS:

a) ACAS shall receive from its Mode S transponder sensitivity level control commands (4.3.8.4.2.1.1) transmitted by Mode S ground stations;

b) ACAS shall receive from its Mode S transponder ACAS broadcast messages (4.3.8.4.2.3.3) transmitted by other ACAS; and

c) ACAS shall receive from its Mode S transponder resolution messages (4.3.8.4.2.3.2) transmitted by other ACAS for air-air coordination purposes.

4.3.7 ACAS protocols

4.3.7.1 SURVEILLANCE PROTOCOLS

4.3.7.1.1 *SURVEILLANCE OF MODE A/C TRANSPONDERS*

4.3.7.1.1.1 ACAS shall use the Mode C-only all-call interrogation (Chapter 3, 3.1.2.1.5.1.2) for surveillance of aircraft equipped with Mode A/C transponders.

4.3.7.1.1.2 Using a sequence of interrogations with increasing power, surveillance interrogations shall be preceded by an *S*1-pulse (Chapter 3, 3.1.1.7.4.3) to reduce interference and improve Mode A/C target detection.

4.3.7.1.2 *SURVEILLANCE OF MODE S TRANSPONDERS*

4.3.7.1.2.1 *Detection.* ACAS shall monitor 1 090 MHz for Mode S acquisition squitters (DF = 11). ACAS shall detect the presence and determine the address of Mode S-equipped aircraft using their Mode S acquisition squitters (DF = 11) or extended squitters (DF = 17).

Note 1.— It is acceptable to acquire individual aircraft using either acquisition or extended squitters (DF = 11 or DF = 17), and to monitor for both squitters. However, ACAS must monitor for acquisition squitters because, at any time, not all aircraft will transmit the extended squitter.

Note 2.— If, in the future, it becomes permitted for aircraft not to transmit the acquisition squitter, relying instead on continual transmission of the extended squitter, it would become essential for all ACAS units to monitor for both the acquisition and the extended squitters.

4.3.7.1.2.2 *Surveillance interrogations.* On first receipt of a 24-bit aircraft address from an aircraft that is determined to be within the reliable surveillance range of ACAS based on reception reliability and that is within an altitude band 3 050 m (10 000 ft) above and below own aircraft, ACAS shall transmit a short air-air interrogation (UF = 0) for range acquisition. Surveillance interrogations shall be transmitted at least once every five cycles when this altitude condition is satisfied. Surveillance interrogations shall be transmitted each cycle if the range of the detected aircraft is less than 5.6 km (3 NM) or the calculated time to closest approach is less than 60 s, assuming that both the detected and own aircraft proceed from their current positions with unaccelerated motion and that the range at closest approach equals 5.6 km (3 NM). Surveillance interrogations shall be suspended for a period of five cycles if:

a) a reply was successfully received; and

b) own aircraft and intruder aircraft are operating below a pressure-altitude of 5 490 m (18 000 ft); and

c) the range of the detected aircraft is greater than 5.6 km (3 NM) and the calculated time to closest approach exceeds 60 seconds, assuming that both the detected and own aircraft proceed from their current positions with unaccelerated motion and that the range at closest approach equals 5.6 km (3 NM).

4.3.7.1.2.2.1 *Range acquisition interrogations.* ACAS shall use the short air-air surveillance format (UF = 0) for range acquisition. ACAS shall set AQ = 1 (Chapter 3, 3.1.2.8.1.1) and RL = 0 (Chapter 3, 3.1.2.8.1.2) in an acquisition interrogation.

Note 1.— Setting AQ = 1 results in a reply with bit 14 of the RI field equal to 1 and serves as an aid in distinguishing the reply to own interrogation from replies elicited from other ACAS units (4.3.7.1.2.2.2).

Note 2.— In the acquisition interrogation RL is set to 0 to command a short acquisition reply (DF = 0).

4.3.7.1.2.2.2 *Tracking interrogations.* ACAS shall use the short air-air surveillance format (UF = 0) with RL = 0 and AQ = 0 for tracking interrogations.

4.3.7.1.2.3 *Surveillance replies.* These protocols are described in 4.3.11.3.1.

4.3.7.1.2.4 *ACAS broadcast.* An ACAS broadcast shall be made nominally every 8 to 10 s at full power from the top antenna. Installations using directional antennas shall operate such that complete circular coverage is provided nominally every 8 to 10 s.

Note.— A broadcast causes other Mode S transponders to accept the interrogation without replying and to present the interrogation content containing the MU field at the transponder output data interface. The UDS1 = 3, UDS2 = 2 combination identifies the data as an ACAS broadcast containing the 24-bit address of the interrogating ACAS aircraft. This provides each ACAS with a means of determining the number of other ACAS within its detection range for limiting interference. The format of the MU field is described in 4.3.8.4.2.3.

4.3.7.2 AIR-AIR COORDINATION PROTOCOLS

4.3.7.2.1 *Coordination interrogations.* ACAS shall transmit UF = 16 interrogations (Chapter 3, 3.1.2.3.2, Figure 3-7) with AQ = 0 and RL = 1 when another aircraft reporting RI = 3 or 4 is declared a threat (4.3.4). The MU field shall contain the resolution message in the subfields specified in 4.3.8.4.2.3.2.

Note 1.— A UF = 16 interrogation with AQ = 0 and RL = 1 is intended to cause a DF = 16 reply from the other aircraft.

Note 2.— An aircraft reporting RI = 3 or RI = 4 is an aircraft equipped with an operating ACAS which has vertical only or vertical and horizontal resolution capability, respectively.

4.3.7.2.2 *Coordination reply.* These protocols are described in 4.3.11.3.2.

4.3.7.3 PROTOCOLS FOR ACAS COMMUNICATION WITH GROUND STATIONS

4.3.7.3.1 *RA reports to Mode S ground stations.* These protocols are described in 4.3.11.4.1.

4.3.7.3.2 *RA broadcasts.* RA broadcasts shall be transmitted at full power from the bottom antenna at jittered, nominally 8 s intervals for the period that the RA is indicated. The RA broadcast shall include the MU field as specified in 4.3.8.4.2.3.4. The RA broadcast shall describe the most recent RA that existed during the preceding 8 s period. Installations using directional antennas shall operate such that complete circular coverage is provided nominally every 8 s and the same RA sense and strength is broadcast in each direction.

4.3.7.3.3 *Data link capability report.* These protocols are described in 4.3.11.4.2.

4.3.7.3.4 *ACAS sensitivity level control.* ACAS shall act upon an SLC command if and only if TMS (Chapter 3, 3.1.2.6.1.4.1) has the value 0 and DI is either 1 or 7 in the same interrogation.

4.3.8 Signal formats

4.3.8.1 The RF characteristics of all ACAS signals shall conform to the Standards of Chapter 3, 3.1.1.1 through 3.1.1.6, 3.1.2.1 through 3.1.2.3, 3.1.2.5 and 3.1.2.8.

4.3.8.2 RELATIONSHIP BETWEEN ACAS AND MODE S SIGNAL FORMATS

Note.— ACAS uses Mode S transmissions for surveillance and communications. ACAS air-air communication functions permit RA decisions to be coordinated with ACAS-equipped threats. ACAS air-ground communication functions permit the reporting of RAs to ground stations and the uplinking of commands to ACAS-equipped aircraft to control parameters of the collision avoidance algorithms.

4.3.8.3 *Signal format conventions.* The data encoding of all ACAS signals shall conform to the Standards of Chapter 3, 3.1.2.3.

Note.— In air-air transmissions used by ACAS, interrogations transmitted at 1 030 MHz are designated as uplink transmissions and contain uplink format (UF) codes. Replies received at 1 090 MHz are designated as downlink transmissions and contain downlink format (DF) codes.

4.3.8.4 FIELD DESCRIPTION

Note 1.— The air-air surveillance and communication formats which are used by ACAS but not fully described in Chapter 3, 3.1.2 are given in Figure 4-1.

Note 2.— This section defines the Mode S fields (and their subfields) that are processed by ACAS to accomplish ACAS functions. Some of the ACAS fields (those also used for other SSR Mode S functions) are described with unassigned ACAS codes in Chapter 3, 3.1.2.6. Such codes are assigned in 4.3.8.4.1. Fields and subfields used only by ACAS equipment are assigned in 4.3.8.4.2.

Note 3.— The bit numbering convention used in 4.3.8.4 reflects the bit numbering within the entire uplink or downlink format rather than the bits within individual fields or subfields.

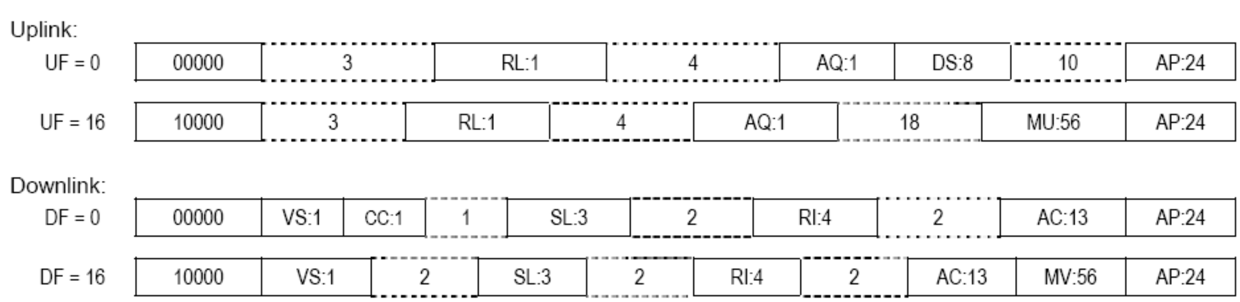


Figure 4-1. Surveillance and communication formats used by ACAS

4.3.8.4.1 *FIELDS AND SUBFIELDS INTRODUCED IN CHAPTER 3, 3.1.2*

Note.— Codes for mission fields and subfields that are designated "reserved for ACAS" in Chapter 3, 3.1.2, are specified in this section.

4.3.8.4.1.1 *DR (downlink request).* The significance of the coding of the downlink request field shall be as follows:

Coding	
0-1	See Chapter 3, 3.1.2.6.5.2
2	ACAS message available
3	Comm-B message available and ACAS message available
4-5	See Chapter 3, 3.1.2.6.5.2
6	Comm-B broadcast message 1 available and ACAS message available
7	Comm-B broadcast message 2 available and ACAS message available
8-31	See Chapter 3, 3.1.2.6.5.2

4.3.8.4.1.2 *RI (air-air reply information).* The significance of the coding in the RI field shall be as follows:

Coding	
0	No operating ACAS
1	Not assigned
2	ACAS with resolution capability inhibited
3	ACAS with vertical-only resolution capability
4	ACAS with vertical and horizontal resolution capability
5-7	Not assigned
8-15	See Chapter 3, 3.1.2.8.2.2

Bit 14 of the reply format containing this field shall replicate the AQ bit of the interrogation. The RI field shall report "no operating ACAS" (RI = 0) if the ACAS unit has failed or is in standby. The RI field shall report "ACAS with resolution capability inhibited" (RI = 2) if sensitivity level is 2 or TA only mode has been selected.

Note.— Codes 0-7 in the RI field indicate that the reply is a tracking reply and also give the ACAS capability of the interrogated aircraft. Codes 8-15 indicate that the reply is an acquisition reply and also give the maximum true airspeed capability of the interrogated aircraft.

4.3.8.4.1.3 *RR (reply request).* The significance of the coding in the reply request field shall be as follows:

Coding	
0-18	See Chapter 3, 3.1.2.6.1.2
19	Transmit a resolution advisory report
20-31	See Chapter 3, 3.1.2.6.1.2

4.3.8.4.2 *ACAS FIELDS AND SUBFIELDS*

Note.— The following paragraphs describe the location and coding of those fields and subfields that are not defined in Chapter 3, 3.1.2 but are used by aircraft equipped with ACAS.

4.3.8.4.2.1 *Subfield in MA*

4.3.8.4.2.1.1 *ADS (A-definition subfield).* This 8-bit (33-40) subfield shall define the remainder of MA.

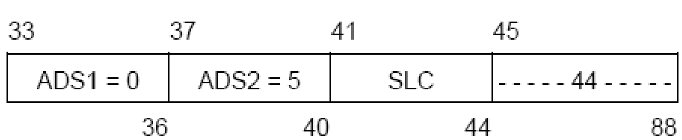
Note.— For convenience of coding, ADS is expressed in two groups of four bits each, ADS1 and ADS2.

4.3.8.4.2.1.2 When ADS1 = 0 and ADS2 = 5, the following subfield shall be contained in MA:

4.3.8.4.2.1.3 *SLC (ACAS sensitivity level control (SLC) command).* This 4-bit (41-44) subfield shall denote a sensitivity level command for own ACAS.

Coding	
0	No command issued
1	Not assigned
2	Set ACAS sensitivity level to 2
3	Set ACAS sensitivity level to 3
4	Set ACAS sensitivity level to 4
5	Set ACAS sensitivity level to 5
6	Set ACAS sensitivity level to 6
7-14	Not assigned
15	Cancel previous SLC command from this ground station

Note.— Structure of MA for a sensitivity level control command:



4.3.8.4.2.2 *Subfields in MB*

4.3.8.4.2.2.1 *Subfields in MB for an RA report.* When BDS1=3 and BDS2=0, the subfields indicated below shall be contained in MB.

Note.— The requirements for communication of information relating to the current or recent RAs is described in 4.3.11.4.1.

4.3.8.4.2.2.1.1 *ARA (active RAs).* This 14-bit (41-54) subfield shall indicate the characteristics of the RA, if any, generated by the ACAS associated with the transponder transmitting the subfield (4.3.6.2.1 a)). The bits in ARA shall have meanings determined by the value of the MTE subfield (4.3.8.4.2.2.1.4) and, for vertical RAs, the value of bit 41 of ARA. The meaning of bit 41 of ARA shall be as follows:

Coding	
0	There is more than one threat and the RA is intended to provide separation below some threat(s) and above some other threat(s) or no RA has been generated (when MTE = 0)
1	Either there is only one threat or the RA is intended to provide separation in the same direction for all threats

When ARA bit 41 = 1 and MTE = 0 or 1, bits 42-47 shall have the following meanings:

Bit	*Coding*	
42	0	RA is preventive
	1	RA is corrective
43	0	Upward sense RA has been generated
	1	Downward sense RA has been generated
44	0	RA is not increased rate
	1	RA is increased rate
45	0	RA is not a sense reversal
	1	RA is a sense reversal
46	0	RA is not altitude crossing
	1	RA is altitude crossing
47	0	RA is vertical speed limit
	1	RA is positive
48-54		Reserved for ACAS III

When ARA bit 41 = 0 and MTE = 1, bits 42-47 shall have the following meanings:

Bit	*Coding*	
42	0	RA does not require a correction in the upward sense
	1	RA requires a correction in the upward sense
43	0	RA does not require a positive climb
	1	RA requires a positive climb
44	0	RA does not require a correction in the downward sense
	1	RA requires a correction in the downward sense
45	0	RA does not require a positive descend
	1	RA requires a positive descend
46	0	RA does not require a crossing
	1	RA requires a crossing
47	0	RA is not a sense reversal

1	RA is a sense reversal
48-54	Reserved for ACAS III

Note.— When ARA bit 41 = 0 and MTE = 0, no vertical RA has been generated.

4.3.8.4.2.2.1.2 *RAC (RACs record).* This 4-bit (55-58) subfield shall indicate all the currently active RACs, if any, received from other ACAS aircraft. The bits in RAC shall have the following meanings:

Bit	*Resolution advisory complement*
55	Do not pass below
56	Do not pass above
57	Do not turn left
58	Do not turn right

A bit set to 1 shall indicate that the associated RAC is active. A bit set to 0 shall indicate that the associated RAC is inactive.

4.3.8.4.2.2.1.3 *RAT (RA terminated indicator).* This 1-bit (59) subfield shall indicate when an RA previously generated by ACAS has ceased being generated.

Coding	
0	ACAS is currently generating the RA indicated in the ARA subfield
1	The RA indicated by the ARA subfield has been terminated (4.3.11.4.1)

Note 1.— After an RA has been terminated by ACAS, it is still required to be reported by the Mode S transponder for 18±1 s (4.3.11.4.1). The RA terminated indicator may be used, for example, to permit timely removal of an RA indication from an air traffic controller's display, or for assessments of RA duration within a particular airspace.

Note 2.— RAs may terminate for a number of reasons: normally, when the conflict has been resolved and the threat is diverging in range; or when the threat's Mode S transponder for some reason ceases to report altitude during the conflict. The RA terminated indicator is used to show that the RA has been removed in each of these cases.

4.3.8.4.2.2.1.4 *MTE (multiple threat encounter).* This 1-bit (60) subfield shall indicate whether two or more simultaneous threats are currently being processed by the ACAS threat resolution logic.

Coding

0 One threat is being processed by the resolution logic (when ARA bit 41 = 1); or no threat is being processed by the resolution logic (when ARA bit 41 = 0)

1 Two or more simultaneous threats are being processed by the resolution logic

4.3.8.4.2.2.1.5 *TTI (threat type indicator subfield).* This 2-bit subfield (61-62) shall define the type of identity data contained in the TID subfield.

Coding	
0	No identity data in TID
1	TID contains a Mode S transponder address
2	TID contains altitude, range and bearing data
3	Not assigned

4.3.8.4.2.2.1.6 *TID (threat identity data subfield).* This 26-bit subfield (63-88) shall contain the Mode S address of the threat or the altitude, range, and bearing if the threat is not Mode S equipped. If two or more threats are simultaneously processed by the ACAS resolution logic, TID shall contain the identity or position data for the most recently declared threat. If TTI = 1, TID shall contain in bits 63-86 the aircraft address of the threat, and bits 87 and 88 shall be set to 0. If TTI = 2, TID shall contain the following three subfields.

4.3.8.4.2.2.1.6.1 *TIDA (threat identity data altitude subfield).* This 13-bit subfield (63-75) shall contain the most recently reported Mode C altitude code of the threat.

Coding

Bit	63	64	65	66	67	68	69	70	71	72	73	74	75
Mode C code bit	C_1	A_1	C_2	A_2	C_4	A_4	0	B_1	D_1	B_2	D_2	B_4	D_4

4.3.8.4.2.2.1.6.2 *TIDR (threat identity data range subfield).* This 7-bit subfield (76-82) shall contain the most recent threat range estimated by ACAS.

Coding (n)

n	*Estimated range (NM)*
0	No range estimate available
1	Less than 0.05
2-126	$(n\text{-}1)/10 \pm 0.05$
127	Greater than 12.55

4.3.8.4.2.2.1.6.3 *TIDB (threat identity data bearing subfield).* This 6-bit subfield (83-88) shall contain the most recent estimated bearing of the threat aircraft, relative to the ACAS aircraft heading.

Coding (n)

n	*Estimated bearing (degrees)*
0	No bearing estimate available
1-60	Between 6(*n*-1) and 6*n*
61-63	*Not assigned*

Note.— Structure of MB for an RA report:

33	37	41	55	59	60	61	63
BDS1 = 3	BDS2 = 0	ARA	RAC	RAT	MTE	TTI = 1	TID
36	40	54	58	59	60	62	88

33	37	41	55	59	60	61	63	76	83
BDS1 = 3	BDS2 = 0	ARA	RAC	RAT	MTE	TTI = 2	TIDA	TIDR	TIDB
36	40	54	58	59	60	62	75	82	88

4.3.8.4.2.2.2 *Subfields in MB for the data link capability report.* When BDS1 = 1 and BDS2 = 0, the following bit patterns shall be provided to the transponder for its data link capability report:

Bit	*Coding*	
48	0	ACAS failed or on standby
	1	ACAS operating
69	0	Hybrid surveillance not operational
	1	Hybrid surveillance fitted and operational
70	0	ACAS generating TAs only
	1	ACAS generating TAs and RAs

Bit 72	Bit 71	ACAS version
0	0	RTCA/DO-185 (pre-ACAS)
0	1	RTCA/DO-185A
1	0	RTCA/DO-185B & EUROCAE ED 143
1	1	Reserved for future versions (see *Note 3*)

Note 1.— A summary of the MB subfields for the data link capability report structure is described in Chapter 3, 3.1.2.6.10.2.2.

Note 2.— The use of hybrid surveillance to limit ACAS active interrogations is described in 4.5.1. The ability only to support decoding of DF = 17 extended squitter messages is not sufficient to set bit 72.

Note 3.— Future versions of ACAS will be identified using part numbers and software version numbers specified in registers E516 and E616.

4.3.8.4.2.3 *MU field.* This 56-bit (33-88) field of long air-air surveillance interrogations (Figure 4-1) shall be used to transmit resolution messages, ACAS broadcasts and RA broadcasts.

4.3.8.4.2.3.1 *UDS (U-definition subfield).* This 8-bit (33-40) subfield shall define the remainder of MU.

Note.— For convenience in coding, UDS is expressed in two groups of four bits each, UDS1 and UDS2.

4.3.8.4.2.3.2 *Subfields in MU for a resolution message.* When UDS1 = 3 and UDS2 = 0 the following subfields shall be contained in MU:

4.3.8.4.2.3.2.1 *MTB (multiple threat bit).* This 1-bit (42) subfield shall indicate the presence or absence of multiple threats.

Coding

0	Interrogating ACAS has one threat
1	Interrogating ACAS has more than one threat

4.3.8.4.2.3.2.2 *VRC (vertical RAC).* This 2-bit (45-46) subfield shall denote a vertical RAC relating to the addressed aircraft.

Coding

0	No vertical RAC sent
1	Do not pass below
2	Do not pass above
3	Not assigned

4.3.8.4.2.3.2.3 *CVC (cancel vertical RAC).* This 2-bit (43-44) subfield shall denote the cancellation of a vertical RAC previously sent to the addressed aircraft. This subfield shall be set to 0 for a new threat.

Coding

0	No cancellation
1	Cancel previously sent “Do not pass below”
2	Cancel previously sent “Do not pass above”
3	Not assigned

4.3.8.4.2.3.2.4 *HRC (horizontal RAC).* This 3-bit (50-52) subfield shall denote a horizontal RAC relating to the addressed aircraft.

Coding	
0	No horizontal RAC or no horizontal resolution capability
1	Other ACAS sense is turn left; do not turn left
2	Other ACAS sense is turn left; do not turn right
3	Not assigned
4	Not assigned
5	Other ACAS sense is turn right; do not turn left
6	Other ACAS sense is turn right; do not turn right
7	Not assigned

4.3.8.4.2.3.2.5 *CHC (cancel horizontal RAC).* This 3-bit (47-49) subfield shall denote the cancellation of a horizontal RAC previously sent to the addressed aircraft. This subfield shall be set to 0 for a new threat.

Coding	
0	No cancellation or no horizontal resolution capability
1	Cancel previously sent "Do not turn left"
2	Cancel previously sent "Do not turn right"
3-7	Not assigned

4.3.8.4.2.3.2.6 *VSB (vertical sense bits subfield).* This 4-bit (61-64) subfield shall be used to protect the data in the CVC and VRC subfields. For each of the 16 possible combinations of bits 43-46 the following VSB code shall be transmitted:

	CVC		VRC		VSB			
Coding	43	44	45	46	61	62	63	64
0	0	0	0	0	0	0	0	0
1	0	0	0	1	1	1	1	0
2	0	0	1	0	0	1	1	1
3	0	0	1	1	1	0	0	1
4	0	1	0	0	1	0	1	1
5	0	1	0	1	0	1	0	1
6	0	1	1	0	1	1	0	0
7	0	1	1	1	0	0	1	0
8	1	0	0	0	1	1	0	1
9	1	0	0	1	0	0	1	1
10	1	0	1	0	1	0	1	0
11	1	0	1	1	0	1	0	0
12	1	1	0	0	0	1	1	0
13	1	1	0	1	1	0	0	0
14	1	1	1	0	0	0	0	1
15	1	1	1	1	1	1	1	1

Note.— The rule used to generate the VSB subfield bit setting is a distance 3 Hamming code augmented with a parity bit, producing the ability to detect up to three errors in the eight transmitted bits.

4.3.8.4.2.3.2.7 *HSB (horizontal sense bits subfield).* This 5-bit (56-60) subfield shall be used to protect the data in the CHC and HRC subfields. For each of the 64 possible combinations of bits 47-52 the following HSB code shall be transmitted:

	CHC				HRC		HSB				
Coding	47	48	49	50	51	52	56	57	58	59	60
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	0	1	0	1	1
2	0	0	0	0	1	0	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0
4	0	0	0	1	0	0	1	1	1	0	0
5	0	0	0	1	0	1	1	0	1	1	1
6	0	0	0	1	1	0	0	1	1	1	1
7	0	0	0	1	1	1	0	0	1	0	0
8	0	0	1	0	0	0	0	1	1	0	1
9	0	0	1	0	0	1	0	0	1	1	0
10	0	0	1	0	1	0	1	1	1	1	0
11	0	0	1	0	1	1	1	0	1	0	1
12	0	0	1	1	0	0	1	0	0	0	1
13	0	0	1	1	0	1	1	1	0	1	0
14	0	0	1	1	1	0	0	0	0	1	0
15	0	0	1	1	1	1	0	1	0	0	1
16	0	1	0	0	0	0	1	0	1	0	1
17	0	1	0	0	0	1	1	1	1	1	0
18	0	1	0	0	1	0	0	0	1	1	0
19	0	1	0	0	1	1	0	1	1	0	1
20	0	1	0	1	0	0	0	1	0	0	1
21	0	1	0	1	0	1	0	0	0	1	0
22	0	1	0	1	1	0	1	1	0	1	0
23	0	1	0	1	1	1	1	0	0	0	1
24	0	1	1	0	0	0	1	1	0	0	0
25	0	1	1	0	0	1	1	0	0	1	1
26	0	1	1	0	1	0	0	1	0	1	1
27	0	1	1	0	1	1	0	0	0	0	0
28	0	1	1	1	0	0	0	0	1	0	0
29	0	1	1	1	0	1	0	1	1	1	1
30	0	1	1	1	1	0	1	0	1	1	1
31	0	1	1	1	1	1	1	1	1	0	0
32	1	0	0	0	0	0	1	1	0	0	1
33	1	0	0	0	0	1	1	0	0	1	0
34	1	0	0	0	1	0	0	1	0	1	0
35	1	0	0	0	1	1	0	0	0	0	1
36	1	0	0	1	0	0	0	0	1	0	1
37	1	0	0	1	0	1	0	1	1	1	0
38	1	0	0	1	1	0	1	0	1	1	0
39	1	0	0	1	1	1	1	1	1	0	1
40	1	0	1	0	0	0	1	0	1	0	0
41	1	0	1	0	0	1	1	1	1	1	1
42	1	0	1	0	1	0	0	0	1	1	1
43	1	0	1	0	1	1	0	1	1	0	0
44	1	0	1	1	0	0	0	1	0	0	0

	CHC				HRC		HSB				
Coding	47	48	49	50	51	52	56	57	58	59	60
45	1	0	1	1	0	1	0	0	0	1	1
46	1	0	1	1	1	0	1	1	0	1	1
47	1	0	1	1	1	1	1	0	0	0	0
48	1	1	0	0	0	0	0	1	1	0	0
49	1	1	0	0	0	1	0	0	1	1	1
50	1	1	0	0	1	0	1	1	1	1	1
51	1	1	0	0	1	1	1	0	1	0	0
52	1	1	0	1	0	0	1	0	0	0	0
53	1	1	0	1	0	1	1	1	0	1	1
54	1	1	0	1	1	0	0	0	0	1	1
55	1	1	0	1	1	1	0	1	0	0	0
56	1	1	1	0	0	0	0	0	0	0	1
57	1	1	1	0	0	1	0	1	0	1	0
58	1	1	1	0	1	0	1	0	0	1	0
59	1	1	1	0	1	1	1	1	0	0	1
60	1	1	1	1	0	0	1	1	1	0	1
61	1	1	1	1	0	1	1	0	1	1	0
62	1	1	1	1	1	0	0	1	1	1	0
63	1	1	1	1	1	1	0	0	1	0	1

Note.— The rule used to generate the HSB subfield bit setting is a distance 3 Hamming code augmented with a parity bit, producing the ability to detect up to three errors in the eleven transmitted bits.

4.3.8.4.2.3.2.8 *MID (Aircraft address).* This 24-bit (65-88) subfield shall contain the 24-bit aircraft address of the interrogating ACAS aircraft.

Note.— Structure of MU for a resolution message:

33–36	37–40	41–64	65–88
UDS1 = 3	UDS2 = 2	------ 24 ------	MID

4.3.8.4.2.3.4 *Subfields in MU for an RA broadcast.* When UDS1 = 3 and UDS2 = 1, the following subfields shall be contained in MU:

4.3.8.4.2.3.4.1 *ARA (active RAs).* This 14-bit (41-54) subfield shall be coded as defined in 4.3.8.4.2.2.1.1.

4.3.8.4.2.3.4.2 *RAC (RACs record).* This 4-bit (55-58) subfield shall be coded as defined in 4.3.8.4.2.2.1.2.

4.3.8.4.2.3.4.3 *RAT (RA terminated indicator).* This 1-bit (59) subfield shall be coded as defined in 4.3.8.4.2.2.1.3.

4.3.8.4.2.3.4.4 *MTE (multiple threat encounter).* This 1-bit (60) subfield shall be coded as defined in 4.3.8.4.2.2.1.4.

4.3.8.4.2.3.4.5 *AID (Mode A identity code).* This 13-bit (63-75) subfield shall denote the Mode A identity code of the reporting aircraft.

Coding

Bit	63	64	65	66	67	68	69	70	71	72	73	74	75
Mode A code bit	A_4	A_2	A_1	B_4	B_2	B_1	0	C_4	C_2	C_1	D_4	D_2	D_1

4.3.8.4.2.3.4.6 *CAC (Mode C altitude code).* This 13-bit (76-88) subfield shall denote the Mode C altitude code of the reporting aircraft.

Coding

Bit	76	77	78	79	80	81	82	83	84	85	86	87	88
Mode C code bit	C_1	A_1	C_2	A_2	C_4	A_4	0	B_1	D_1	B_2	D_2	B_4	D_4

Note.— Structure of MU for an RA broadcast:

33	37	41	55	59	60	61	63	76
UDS1 = 3	UDS2 = 1	ARA	RAC	RAT	MTE	-2-	AID	CAC
36	40	54	58	59	60	62	75	88

4.3.8.4.2.4 *MV field.* This 56-bit (33-88) field of long air-air surveillance replies (Figure 4-1) shall be used to transmit air-air coordination reply messages.

4.3.8.4.2.4.1 *VDS (V-definition subfield).* This 8-bit (33-40) subfield shall define the remainder of MV.

Note.— For convenience in coding, VDS is expressed in two groups of four bits each, VDS1 and VDS2.

4.3.8.4.2.4.2 *Subfields in MV for a coordination reply.* When VDS1 = 3 and VDS2 = 0, the following subfields shall be contained in MV:

4.3.8.4.2.4.2.1 *ARA (active RAs).* This 14-bit (41-54) subfield shall be coded as defined in 4.3.8.4.2.2.1.1.

4.3.8.4.2.4.2.2 *RAC (RACs record).* This 4-bit (55-58) subfield shall be coded as defined in 4.3.8.4.2.2.1.2.

4.3.8.4.2.4.2.3 *RAT (RA terminated indicator).* This 1-bit (59) subfield shall be coded as defined in 4.3.8.4.2.2.1.3.

4.3.8.4.2.4.2.4 *MTE (multiple threat encounter).* This 1-bit (60) subfield shall be coded as defined in 4.3.8.4.2.2.1.4.

Note.— Structure of MV for a coordination reply:

33	37	41	55	59	60	61
VDS1 = 3	VDS2 = 0	ARA	RAC	RAT	MTE	-28-
36	40	54	58	59	60	88

4.3.8.4.2.5 *SL (sensitivity level report).* This 3-bit (9-11) downlink field shall be included in both short and long air-air reply formats (DF = 0 and 16). This field shall denote the sensitivity level at which ACAS is currently operating.

Coding	
0	ACAS inoperative
1	ACAS is operating at sensitivity level 1
2	ACAS is operating at sensitivity level 2
3	ACAS is operating at sensitivity level 3
4	ACAS is operating at sensitivity level 4
5	ACAS is operating at sensitivity level 5
6	ACAS is operating at sensitivity level 6
7	ACAS is operating at sensitivity level 7

4.3.8.4.2.6 *CC: Cross-link capability*. This 1-bit (7) downlink field shall indicate the ability of the transponder to support the cross-link capability, i.e. decode the contents of the DS field in an interrogation with UF equals 0 and respond with the contents of the specified GICB register in the corresponding reply with DF equals 16.

Coding	
0	signifies that the transponder cannot support the cross-link capability.
1	signifies that the transponder supports the cross-link capability.

4.3.9 ACAS equipment characteristics

4.3.9.1 *Interfaces.* As a minimum, the following input data shall be provided to the ACAS:

a) aircraft address code;

b) air-air and ground-air Mode S transmissions received by the Mode S transponder for use by ACAS (4.3.6.3.2);

c) own aircraft's maximum cruising true airspeed capability (Chapter 3, 3.1.2.8.2.2);

d) pressure-altitude; and

e) radio altitude.

Note.— Specific requirements for additional inputs for ACAS II and III are listed in the appropriate sections below.

4.3.9.2 *Aircraft antenna system.* ACAS shall transmit interrogations and receive replies via two antennas, one mounted on the top of the aircraft and the other on the bottom of the aircraft. The top-mounted antenna shall be directional and capable of being used for direction finding.

4.3.9.2.1 *Polarization.* Polarization of ACAS transmissions shall be nominally vertical.

4.3.9.2.2 *Radiation pattern.* The radiation pattern in elevation of each antenna when installed on an aircraft shall be nominally equivalent to that of a quarter-wave monopole on a ground plane.

4.3.9.2.3 *ANTENNA SELECTION*

4.3.9.2.3.1 *Squitter reception*. ACAS shall be capable of receiving squitters via the top and bottom antennas.

4.3.9.2.3.2 *Interrogations.* ACAS interrogations shall not be transmitted simultaneously on both antennas.

4.3.9.3 *Pressure-altitude source*. The altitude data for own aircraft provided to ACAS shall be obtained from the source that provides the basis for own Mode C or Mode S reports and they shall be provided at the finest quantization available.

4.3.9.3.1 **Recommendation.—** *A source providing a resolution finer than 7.62 m (25 ft) should be used.*

4.3.9.3.2 Where a source providing a resolution finer than 7.62 m (25 ft) is not available, and the only altitude data available for own aircraft is Gilham encoded, at least two independent sources shall be used and compared continuously in order to detect encoding errors.

4.3.9.3.3 **Recommendation.—** *Two altitude data sources should be used and compared in order to detect errors before provision to ACAS.*

4.3.9.3.4 The provisions of 4.3.10.3 shall apply when the comparison of the two altitude data sources indicates that one of the sources is in error.

4.3.10 Monitoring

4.3.10.1 *Monitoring function.* ACAS shall continuously perform a monitoring function in order to provide a warning if any of the following conditions at least are satisfied:

a) there is no interrogation power limiting due to interference control (4.3.2.2.2) and the maximum radiated power is reduced to less than that necessary to satisfy the surveillance requirements specified in 4.3.2; or

b) any other failure in the equipment is detected which results in a reduced capability of providing TAs or RAs; or

c) data from external sources indispensable for ACAS operation are not provided, or the data provided are not credible.

4.3.10.2 *Effect on ACAS operation.* The ACAS monitoring function shall not adversely affect other ACAS functions.

4.3.10.3 *Monitoring response.* When the monitoring function detects a failure (4.3.10.1), ACAS shall:

a) indicate to the flight crew that an abnormal condition exists;

b) prevent any further ACAS interrogations; and

c) cause any Mode S transmission containing own aircraft's resolution capability to indicate that ACAS is not operating.

4.3.11 Requirements for a Mode S transponder used in conjunction with ACAS

4.3.11.1 *Transponder capabilities.* In addition to the minimum transponder capabilities defined in Chapter 3, 3.1, the Mode S transponder used in conjunction with ACAS shall have the following capabilities:

a) ability to handle the following formats:

Format No.	Format name
UF = 16	Long air-air surveillance interrogation
DF = 16	Long air-air surveillance reply

b) ability to receive long Mode S interrogations (UF = 16) and generate long Mode S replies (DF = 16) at a continuous rate of 16.6 ms (60 per second);

c) means for delivering the ACAS data content of all accepted interrogations addressed to the ACAS equipment;

d) antenna diversity (as specified in Chapter 3, 3.1.2.10.4);

e) mutual suppression capability; and

f) inactive state transponder output power restriction.

When the Mode S transponder transmitter is in the inactive state, the peak pulse power at 1 090 MHz ±3 MHz at the terminals of the Mode S transponder antenna shall not exceed –70 dBm.

4.3.11.2 DATA TRANSFER BETWEEN ACAS AND ITS MODE S TRANSPONDER

4.3.11.2.1 Data transfer from ACAS to its Mode S transponder:

a) The Mode S transponder shall receive from its ACAS RA information for transmission in an RA report (4.3.8.4.2.2.1) and in a coordination reply (4.3.8.4.2.4.2);

b) the Mode S transponder shall receive from its ACAS current sensitivity level for transmission in a sensitivity level report (4.3.8.4.2.5);

c) the Mode S transponder shall receive from its ACAS capability information for transmission in a data link capability report (4.3.8.4.2.2.2) and for transmission in the RI field of air-air downlink formats DF = 0 and DF = 16 (4.3.8.4.1.2); and

d) the Mode S transponder shall receive from its ACAS an indication that RAs are enabled or inhibited for transmission in the RI field of downlink formats 0 and 16.

4.3.11.2.2 Data transfer from Mode S transponder to its ACAS:

a) The Mode S transponder shall transfer to its ACAS received sensitivity level control commands (4.3.8.4.2.1.1) transmitted by Mode S stations;

b) the Mode S transponder shall transfer to its ACAS received ACAS broadcast messages (4.3.8.4.2.3.3) transmitted by other ACASs;

c) the Mode S transponder shall transfer to its ACAS received resolution messages (4.3.8.4.2.3.2) transmitted by other ACASs for air-air coordination purposes; and

d) the Mode S transponder shall transfer to its ACAS own aircraft's Mode A identity data for transmission in an RA broadcast (4.3.8.4.2.3.4.5).

4.3.11.3 COMMUNICATION OF ACAS

INFORMATION TO OTHER ACAS

4.3.11.3.1 *Surveillance reply.* The ACAS Mode S transponder shall use the short (DF = 0) or long (DF = 16) surveillance formats for replies to ACAS surveillance interrogations. The surveillance reply shall include the VS field as specified in Chapter 3, 3.1.2.8.2, the RI field as specified in Chapter 3, 3.1.2.8.2 and in 4.3.8.4.1.2, and the SL field as specified in 4.3.8.4.2.5.

4.3.11.3.2 *Coordination reply.* The ACAS Mode S transponder shall transmit a coordination reply upon receipt of a coordination interrogation from an equipped threat subject to the conditions of 4.3.11.3.2.1. The coordination reply shall use the long air-air surveillance reply format, DF = 16, with the VS field as specified in Chapter 3, 3.1.2.8.2, the RI field as specified in Chapter 3, 3.1.2.8.2 and in 4.3.8.4.1.2, the SL field as specified in 4.3.8.4.2.5 and the MV field as specified in 4.3.8.4.2.4. Coordination replies shall be transmitted even if the minimum reply rate limits of the transponder (Chapter 3, 3.1.2.10.3.7.2) are exceeded.

4.3.11.3.2.1 The ACAS Mode S transponder shall reply with a coordination reply to a coordination interrogation received from another ACAS if and only if the transponder is able to deliver the ACAS data content of the interrogation to its associated ACAS.

4.3.11.4 COMMUNICATION OF ACAS

INFORMATION TO GROUND STATIONS

4.3.11.4.1 *RA reports to Mode S ground stations.* During the period of an RA and for 18±1 s following the end of the RA, the ACAS Mode S transponder shall indicate that it has an RA report by setting the appropriate DR field code in replies to a Mode S sensor as specified in 4.3.8.4.1.1. The RA report shall include the MB field as specified in 4.3.8.4.2.2.1. The RA report shall describe the most recent RA that existed during the preceding 18±1 s period.

Note 1.— The last sentence of 4.3.11.4.1 means that for 18±1 s following the end of an RA, all MB subfields in the RA report with the exception of bit 59 (RA terminated indicator) will retain the information reported at the time the RA was last active.

Note 2.— Upon receipt of a reply with DR = 2, 3, 6 or 7, a Mode S ground station may request downlink of the RA report by setting RR = 19 and either DI = 7, or DI = 7 and RRS = 0 in a surveillance or Comm-A interrogation to the ACAS aircraft. When this interrogation is received, the transponder replies with a Comm-B reply whose MB field contains the RA report.

4.3.11.4.2 *Data link capability report.* The presence of an ACAS shall be indicated by its Mode S transponder to a ground station in the Mode S data link capability report.

Note.– This indication causes the transponder to set codes in a data link capability report as specified in 4.3.8.4.2.2.2.

4.3.12 Indications to the flight crew

4.3.12.1 CORRECTIVE AND PREVENTIVE RAS

Recommendation.— *Indications to the flight crew should distinguish between preventive and corrective RAs.*

4.3.12.2 ALTITUDE CROSSING RAS

Recommendation.— *If ACAS generates an altitude crossing RA, a specific indication should be given to the flight crew that it is crossing.*

4.4 PERFORMANCE OF THE ACAS II COLLISION AVOIDANCE LOGIC

Note.– Caution is to be observed when considering potential improvements to the reference ACAS II system described in Section 4 of the guidance material in the Attachment since changes may affect more than one aspect of the system performance. It is essential that alternative designs would not degrade the performances of other designs and that such compatibility is demonstrated with a high degree of confidence.

4.4.1 Definitions relating to the performance of the collision avoidance logic

Note.– The notation [t1, t2] is used to indicate the interval between t1 and t2.

Altitude layer. Each encounter is attributed to one of six altitude layers as follows:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
from		2 300 ft	5 000 ft	10 000 ft	20 000 ft	41 000 ft
to	2 300 ft	5 000 ft	10 000 ft	20 000 ft	41 000 ft	

The altitude layer of an encounter is determined by the average altitude of the two aircraft at closest approach.

Note.— For the purposes of defining the performance of the collision avoidance logic, there is no need to specify the physical basis of the altitude measurement or the relationship between altitude and ground level.

Approach angle. The difference in the ground headings of the two aircraft at closest approach, with 180 degrees defined as head on and 0 degrees defined as parallel.

Crossing encounter. An encounter in which the altitude separation of the two aircraft exceeds 100 ft at the beginning and at the end of the encounter window, and the relative vertical position of two aircraft at the end of the encounter window is reversed from that at the beginning of the encounter window.

Encounter. For the purposes of defining the performance of the collision avoidance logic, an encounter consists of two simulated aircraft trajectories. The horizontal coordinates of the aircraft represent the actual position of the aircraft but the vertical coordinate represents an altimeter measurement of altitude.

Encounter class. Encounters are classified according to whether or not the aircraft are transitioning at the beginning and end of the encounter window, and whether or not the encounter is crossing.

Encounter window. The time interval [*tca* – 40 s, *tca* + 10 s].

Horizontal miss distance (hmd). The minimum horizontal separation observed in an encounter.

Level aircraft. An aircraft that is not transitioning.

Original trajectory. The original trajectory of an ACAS-equipped aircraft is that followed by the aircraft in the same encounter when it was not ACAS equipped.

Original rate. The original rate of an ACAS-equipped aircraft at any time is its altitude rate at the same time when it followed the original trajectory.

Required rate. For the standard pilot model, the required rate is that closest to the original rate consistent with the RA.

tca. Nominally, the time of closest approach. For encounters in the standard encounter model (4.4.2.6), a reference time for the construction of the encounter at which various parameters, including the vertical and horizontal separation (*vmd* and *hmd*), are specified.

Note.— Encounters in the standard encounter model (4.4.2.6) are constructed by building the trajectories of the two aircraft outwards starting at tca. *When the process is complete,* tca *may not be the precise time of closest approach and differences of a few seconds are acceptable.*

Transitioning aircraft. An aircraft having an average vertical rate with a magnitude exceeding 400 feet per minute (ft/min), measured over some period of interest.

Turn extent. A heading difference defined as an aircraft's ground heading at the end of a turn minus its ground heading at the beginning of the turn.

Vertical miss distance (vmd). Notionally, the vertical separation at closest approach. For encounters in the standard encounter model (4.4.2.6), by construction the vertical separation at the time *tca*.

4.4.2 Conditions under which the requirements apply

4.4.2.1 The following assumed conditions shall apply to the performance requirements specified in 4.4.3 and 4.4.4:

a) range and bearing measurements and an altitude report are available for the intruder each cycle as long as it is within 14 NM, but not when the range exceeds 14 NM;

b) the errors in the range and bearing measurements conform to standard range and bearing error models (4.4.2.2 and 4.4.2.3);

c) the intruder's altitude reports, which are its Mode C replies, are expressed in 100 ft quanta;

d) an altitude measurement that has not been quantized and is expressed with a precision of 1 ft or better is available for own aircraft;

e) errors in the altitude measurements for both aircraft are constant throughout any particular encounter;

f) the errors in the altitude measurements for both aircraft conform to a standard altimetry error model (4.4.2.4);

g) the pilot responses to RAs conform to a standard pilot model (4.4.2.5);

h) the aircraft operate in an airspace in which close encounters, including those in which ACAS generates an RA, conform to a standard encounter model (4.4.2.6);

i) ACAS-equipped aircraft are not limited in their ability to perform the manoeuvres required by their RAs; and

j) as specified in 4.4.2.7:

1) the intruder involved in each encounter is not equipped (4.4.2.7 a)); or

2) the intruder is ACAS-equipped but follows a trajectory identical to that in the unequipped encounter (4.4.2.7 b)); or

3) the intruder is equipped with an ACAS having a collision avoidance logic identical to that of own ACAS (4.4.2.7 c)).

Note.— The phrase "altitude measurement" refers to a measurement by an altimeter prior to any quantization.

4.4.2.1.1 The performance of the collision avoidance logic shall not degrade abruptly as the statistical distribution of the altitude errors or the statistical distributions of the various parameters that characterize the standard encounter model or the response of pilots to the advisories are varied, when surveillance reports are not available on every cycle or when the quantization of the altitude measurements for the intruder is varied or the altitude measurements for own aircraft are quantized.

4.4.2.2 STANDARD RANGE ERROR MODEL

The errors in the simulated range measurements shall be taken from a Normal distribution with mean 0 ft and standard deviation 50 ft.

4.4.2.3 STANDARD BEARING ERROR MODEL

The errors in the simulated bearing measurements shall be taken from a Normal distribution with mean 0.0 degrees and standard deviation 10.0 degrees.

4.4.2.4 STANDARD ALTIMETRY ERROR MODEL

4.4.2.4.1 The errors in the simulated altitude measurements shall be assumed to be distributed as a Laplacian distribution with zero mean having probability density

$$p(e) = \frac{1}{2\lambda}\exp\left(-\frac{|e|}{\lambda}\right)$$

4.4.2.4.2 The parameter λ required for the definition of the statistical distribution of altimeter error for each aircraft shall have one of two values, λ_1 and λ_2, which depend on the altitude layer of the encounter as follows:

Layer	*1*		*2*		*3*		*4*		*5*		*6*	
	m	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*
λ_1	10	35	11	38	13	43	17	58	22	72	28	94
λ_2	18	60	18	60	21	69	26	87	30	101	30	101

4.4.2.4.3 For an aircraft equipped with ACAS the value of λ shall be λ_1.

4.4.2.4.4 For aircraft not equipped with ACAS, the value of λ shall be selected randomly using the following probabilities:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
prob(λ_1)	0.391	0.320	0.345	0.610	0.610	0.610
prob(λ_2)	0.609	0.680	0.655	0.390	0.390	0.390

4.4.2.5 STANDARD PILOT MODEL

The standard pilot model used in the assessment of the performance of the collision avoidance logic shall be that:

a) any RA is complied with by accelerating to the required rate (if necessary) after an appropriate delay;

b) when the aircraft’s current rate is the same as its original rate and the original rate complies with the RA, the aircraft continues at its original rate, which is not necessarily constant due to the possibility of acceleration in the original trajectory;

c) when the aircraft is complying with the RA, its current rate is the same as the original rate and the original rate changes and consequently becomes inconsistent with the RA, the aircraft continues to comply with the RA;

d) when an initial RA requires a change in altitude rate, the aircraft responds with an acceleration of 0.25 *g* after a delay of 5 s from the display of the RA;

e) when an RA is modified and the original rate complies with the modified RA, the aircraft returns to its original rate (if necessary) with the acceleration specified in g) after the delay specified in h);

f) when an RA is modified and the original rate does not comply with the modified RA, the aircraft responds to comply with the RA with the acceleration specified in g) after the delay specified in h);

g) the acceleration used when an RA is modified is 0.25 *g* unless the modified RA is a reversed sense RA or an increased rate RA in which case the acceleration is 0.35 *g*;

h) the delay used when an RA is modified is 2.5 s unless this results in the acceleration starting earlier than 5 s from the initial RA in which case the acceleration starts 5 s from the initial RA; and

i) when an RA is cancelled, the aircraft returns to its original rate (if necessary) with an acceleration of 0.25 *g* after a delay of 2.5 s.

4.4.2.6 STANDARD ENCOUNTER MODEL

4.4.2.6.1 *ELEMENTS OF THE STANDARD ENCOUNTER MODEL*

4.4.2.6.1.1 In order to calculate the effect of ACAS on the risk of collision (4.4.3) and the compatibility of ACAS with air traffic management (ATM) (4.4.4), sets of encounters shall be created for each of:

a) the two aircraft address orderings;

b) the six altitude layers;

c) nineteen encounter classes; and

d) nine or ten *vmd* bins as specified in 4.4.2.6.2.4.

The results for these sets shall be combined using the relative weightings given in 4.4.2.6.2.

4.4.2.6.1.1.1 Each set of encounters shall contain at least 500 independent, randomly generated encounters.

4.4.2.6.1.1.2 The two aircraft trajectories in each encounter shall be constructed with the following randomly selected characteristics:

a) in the vertical plane:

1) a *vmd* from within the appropriate *vmd* bin;

2) a vertical rate for each aircraft at the beginning of the encounter window, $\dot{z}_1$, and at the end of the encounter window, $\dot{z}_2$;

3) a vertical acceleration; and

4) a start time for the vertical acceleration; and

b) and in the horizontal plane:

1) an *hmd*;

2) an approach angle;

3) a speed for each aircraft at closest approach;

4) a decision for each aircraft whether or not it turns;

5) the turn extent; the bank angle; and the turn end time;

6) a decision for each aircraft whether or not its speed changes; and

7) the magnitude of the speed change.

Note.— It is possible for the selections made for the various characteristics of an encounter to be irreconcilable. When this occurs, the problem can be resolved by discarding either the selection for a particular characteristic or the whole encounter, as most appropriate.

4.4.2.6.1.3 Two models shall be used for the statistical distribution of *hmd* (4.4.2.6.4.1). For calculations of the effect of ACAS on the risk of collision (4.4.3), *hmd* shall be constrained to be less than 500 ft. For calculations of the compatibility of ACAS with ATM (4.4.4), *hmd* shall be selected from a larger range of values (4.4.2.6.4.1.2).

Note.— 4.4.2.6.2 and 4.4.2.6.3 specify vertical characteristics for the aircraft trajectories in the standard encounter model that depend on whether the hmd *is constrained to be small ("for calculating risk ratio") or can take larger values ("for ATM compatibility"). Otherwise, the characteristics of the encounters in the vertical and horizontal planes are independent.*

4.4.2.6.2 *ENCOUNTER CLASSES AND WEIGHTS*

4.4.2.6.2.1 *Aircraft address.* Each aircraft shall be equally likely to have the higher aircraft address.

4.4.2.6.2.2 *Altitude layers.* The relative weights of the altitude layers shall be as follows:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
prob(layer)	0.13	0.25	0.32	0.22	0.07	0.01

4.4.2.6.2.3 *Encounter classes*

4.4.2.6.2.3.1 The encounters shall be classified according to whether the aircraft are level (L) or transitioning (T) at the beginning (before *tca*) and end (after *tca*) of the encounter window and whether or not the encounter is crossing, as follows:

	Aircraft No. 1		*Aircraft No. 2*		
Class	*before* tca	*after* tca	*before* tca	*after* tca	*Crossing*
1	L	L	T	T	yes
2	L	L	L	T	yes
3	L	L	T	L	yes
4	T	T	T	T	yes
5	L	T	T	T	yes
6	T	T	T	L	yes
7	L	T	L	T	yes
8	L	T	T	L	yes
9	T	L	T	L	yes
10	L	L	L	L	no
11	L	L	T	T	no
12	L	L	L	T	no
13	L	L	T	L	no
14	T	T	T	T	no
15	L	T	T	T	no
16	T	T	T	L	no
17	L	T	L	T	no
18	L	T	T	L	no
19	T	L	T	L	no

4.4.2.6.2.3.2 The relative weights of the encounter classes shall depend on layer as follows:

Class	*for calculating risk ratio* Layers 1-3	*for calculating risk ratio* Layers 4-6	*for ATM compatibility* Layers 1-3	*for ATM compatibility* Layers 4-6
1	0.00502	0.00319	0.06789	0.07802
2	0.00030	0.00018	0.00408	0.00440
3	0.00049	0.00009	0.00664	0.00220
4	0.00355	0.0027	0.04798	0.06593
5	0.00059	0.00022	0.00791	0.00549
6	0.00074	0.00018	0.00995	0.00440
7	0.00002	0.00003	0.00026	0.00082
8	0.00006	0.00003	0.00077	0.00082
9	0.00006	0.00003	0.00077	0.00082
10	0.36846	0.10693	0.31801	0.09011
11	0.26939	0.41990	0.23252	0.35386
12	0.06476	0.02217	0.05590	0.01868
13	0.07127	0.22038	0.06151	0.18571
14	0.13219	0.08476	0.11409	0.07143
15	0.02750	0.02869	0.02374	0.02418
16	0.03578	0.06781	0.03088	0.05714
17	0.00296	0.00098	0.00255	0.00082
18	0.00503	0.00522	0.00434	0.00440
19	0.01183	0.03651	0.01021	0.03077

4.4.2.6.2.4 vmd *bins*

4.4.2.6.2.4.1 The *vmd* of each encounter shall be taken from one of ten *vmd* bins for the non-crossing encounter classes, and from one of nine or ten *vmd* bins for the crossing encounter classes. Each *vmd* bin shall have an extent of 100 ft for calculating risk ratio, or an extent of 200 ft for calculating compatibility with ATM. The maximum *vmd* shall be 1 000 ft for calculating risk ratio, and 2 000 ft otherwise.

4.4.2.6.2.4.2 For non-crossing encounter classes, the relative weights of the *vmd* bins shall be as follows:

vmd *bin*	*for calculating risk ratio*	*for ATM compatibility*
1	0.013	0.128
2	0.026	0.135
3	0.035	0.209
4	0.065	0.171
5	0.100	0.160
6	0.161	0.092
7	0.113	0.043
8	0.091	0.025
9	0.104	0.014
10	0.091	0.009

Note.— The weights for the vmd *bins do not sum to 1.0. The weights specified are based on an analysis of encounters captured in ATC ground radar data. The missing proportion reflects the fact that the encounters captured included some with* vmd *exceeding the maximum* vmd *in the model.*

4.4.2.6.2.4.3 For the crossing classes, the relative weights of the *vmd* bins shall be as follows:

vmd *bin*	*for calculating risk ratio*	*for ATM compatibility*
1	0	0.064
2	0.026	0.144
3	0.036	0.224
4	0.066	0.183
5	0.102	0.171
6	0.164	0.098
7	0.115	0.046
8	0.093	0.027
9	0.106	0.015
10	0.093	0.010

Note.— For the crossing classes, vmd *must exceed 100 ft so that the encounter qualifies as a crossing encounter. Thus, for the calculation of risk ratio there is no* vmd *bin 1, and for calculations of the compatibility with ATM* vmd *bin 1 is limited to [100 ft, 200 ft].*

4.4.2.6.3 *CHARACTERISTICS OF THE AIRCRAFT TRAJECTORIES IN THE VERTICAL PLANE*

4.4.2.6.3.1 *vmd.* The *vmd* for each encounter shall be selected randomly from a distribution that is uniform in the interval covered by the appropriate *vmd* bin.

4.4.2.6.3.2 *Vertical rate*

4.4.2.6.3.2.1 For each aircraft in each encounter, either the vertical rate shall be constant ($\dot{z}$) or the vertical trajectory shall be constructed so that the vertical rate at *tca* – 35 s is $\dot{z}_1$ and the vertical rate at *tca* + 5 s is $\dot{z}_2$. Each vertical rate, $\dot{z}$, $\dot{z}_1$or $\dot{z}_2$, shall be determined by first selecting randomly an interval within which it lies and then selecting the precise value from a distribution that is uniform over the interval selected.

4.4.2.6.3.2.2 The intervals within which the vertical rates lie shall depend on whether the aircraft is level, i.e. marked "L" in 4.4.2.6.2.3.1, or transitioning, i.e. marked "T" in 4.4.2.6.2.3.1, and shall be as follows:

L	T
[240 ft/min, 400 ft/min]	[3 200 ft/min, 6 000 ft/min]
[80 ft/min, 240 ft/min]	[400 ft/min, 3 200 ft/min]
[–80 ft/min, 80 ft/min]	[–400 ft/min, 400 ft/min]
[–240 ft/min, –80 ft/min]	[–3 200 ft/min, –400 ft/min]
[–400 ft/min, –240 ft/min]	[–6 000 ft/min, –3 200 ft/min]

4.4.2.6.3.2.3 For aircraft that are level over the entire encounter window, the vertical rate $\dot{z}$ shall be constant. The probabilities for the intervals within which $\dot{z}$ lies shall be as follows:

$\dot{z}$ *(ft/min)*	*prob*($\dot{z}$)
[240 ft/min, 400 ft/min]	0.0382
[80 ft/min, 240 ft/min]	0.0989
[–80 ft/min, 80 ft/min]	0.7040
[–240 ft/min, –80 ft/min]	0.1198
[–400 ft/min, –240 ft/min]	0.0391

4.4.2.6.3.2.4 For aircraft that are not level over the entire encounter window, the intervals for $\dot{z}_1$ and $\dot{z}_2$ shall be determined jointly by random selection using joint probabilities that depend on altitude layer and on whether the aircraft is transitioning at the beginning of the encounter window (Rate-to-Level), at the end of the encounter window (Level-to-Rate) or at both the beginning and the end (Rate-to-Rate). The joint probabilities for the vertical rate intervals shall be as follows:

for aircraft with Rate-to-Level trajectories in layers 1 to 3,

$\dot{z}_2$ *interval*	*joint probability of* $\dot{z}_1$ *and* $\dot{z}_2$ *interval*				
[240 ft/min, 400 ft/min]	0.0019	0.0169	0.0131	0.1554	0.0000
[80 ft/min, 240 ft/min]	0.0000	0.0187	0.0019	0.1086	0.0000
[–80 ft/min, 80 ft/min]	0.0037	0.1684	0.0094	0.1124	0.0075
[–240 ft/min, –80 ft/min]	0.0037	0.1461	0.0094	0.0243	0.0037
[–400 ft/min, –240 ft/min]	0.0000	0.1742	0.0094	0.0094	0.0019

–6 000 ft/min –3 200 ft/min –400 ft/min 400 ft/min 3 200 ft/min 6 000 ft/min $\dot{z}_1$

for aircraft with Rate-to-Level trajectories in layers 4 to 6,

$\dot{z}_2$ *interval*	*joint probability of* $\dot{z}_1$ *and* $\dot{z}_2$ *interval*				
[240 ft/min, 400 ft/min]	0.0105	0.0035	0.0000	0.1010	0.0105
[80 ft/min, 240 ft/min]	0.0035	0.0418	0.0035	0.1776	0.0279
[–80 ft/min, 80 ft/min]	0.0279	0.1219	0.0000	0.2403	0.0139
[–240 ft/min, –80 ft/min]	0.0035	0.0767	0.0000	0.0488	0.0105
[–400 ft/min, –240 ft/min]	0.0105	0.0453	0.0035	0.0174	0.0000

–6 000 ft/min –3 200 ft/min –400 ft/min 400 ft/min 3 200 ft/min 6 000 ft/min $\dot{z}_1$

for aircraft with Level-to-Rate trajectories in layers 1 to 3,

$\dot{z}_2$ *interval*	*joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval*				
[3 200 ft/min, 6000 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[400 ft/min, 3200 ft/min]	0.0074	0.0273	0.0645	0.0720	0.1538
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.2978	0.2084	0.1365	0.0273	0.0050
[–6 000ft/min, –3 200ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000

–400 ft/min –240 ft/min –80 ft/min 80 ft/min 240 ft/min 400 ft/min $\dot{z}_1$

for aircraft with Level-to-Rate trajectories in layers 4 to 6,

$\dot{z}_2$ *interval*	*joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval*				
[3 200 ft/min, 6 000 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0192
[400 ft/min, 3 200 ft/min]	0.0000	0.0000	0.0962	0.0577	0.1154
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.1346	0.2692	0.2308	0.0577	0.0192
[–6 000 ft/min, –3 200 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000

–400 ft/min –240 ft/min –80 ft/min 80 ft/min 240 ft/min 400 ft/min $\dot{z}_1$

for aircraft with Rate-to-Rate trajectories in layers 1 to 3,\

$\dot{z}_2$ *interval*	*joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval*				
[3 200 ft/min, 6 000 ft/ min]	0.0000	0.0000	0.0007	0.0095	0.0018
[400 ft/min, 3 200 ft/min]	0.0000	0.0018	0.0249	0.2882	0.0066
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.0048	0.5970	0.0600	0.0029	0.0011
[–6 000 ft/min, –3 200 ft/min]	0.0000	0.0007	0.0000	0.0000	0.0000

–6 000 ft/min –3 200 ft/min –400 ft/min 400 ft/min 3 200 ft/min 6 000 ft/min $\dot{z}_1$

for aircraft with Rate-to-Rate trajectories in layers 4 to 6,

$\dot{z}_2$ *interval*	*joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval*				
[3 200 ft/min, 6 000 ft/ min]	0.0014	0.0000	0.0028	0.0110	0.0069
[400 ft/min, 3 200 ft/min]	0.0028	0.0028	0.0179	0.4889	0.0523
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.0317	0.3029	0.0262	0.0152	0.0028
[–6 000 ft/min, –3 200 ft/min]	0.0110	0.0220	0.0014	0.0000	0.0000

–6 000 ft/min –3 200 ft/min –400 ft/min 400 ft/min 3 200 ft/min 6 000 ft/min $\dot{z}_1$

4.4.2.6.3.2.5 For a Rate-to-Rate track, if line $|\dot{z}_2 - \dot{z}_1| < 566$ ft/min then the track shall be constructed with a constant rate equal to $\dot{z}_1$.

4.4.2.6.3.3 *Vertical acceleration*

4.4.2.6.3.3.1 Subject to 4.4.2.6.3.2.5, for aircraft that are not level over the entire encounter window, the rate shall be constant and equal to $\dot{z}_1$ over at least the interval [*tca* – 40 s, *tca* – 35 s] at the beginning of the encounter window, and shall be constant and equal to $\dot{z}_2$ over at least the interval [*tca* + 5 s, *tca* + 10 s] at the end of the encounter window. The vertical acceleration shall be constant in the intervening period.

4.4.2.6.3.3.2 The vertical acceleration ($\ddot{z}$) shall be modelled as follows:

$$\ddot{z} = (A\dot{z}_2 - \dot{z}_1) + \varepsilon$$

where the parameter *A* is case-dependent as follows:

	A(s⁻¹)	
Case	*Layers 1-3*	*Layers 4-6*
Rate-to-Level	0.071	0.059
Level-to-Rate	0.089	0.075
Rate-to-Rate	0.083	0.072

and the error ε is selected randomly using the following probability density:

$$p(\varepsilon) = \frac{1}{2\mu}\exp\left(-\frac{|\varepsilon|}{\mu}\right)$$

where μ = 0.3 ft s^{-2}.

Note.— The sign of the acceleration $\ddot{z}$ is determined by $\dot{z}_1$ and $\dot{z}_2$. An error ε that reverses this sign must be rejected and the error reselected.

4.4.2.6.3.4 *Acceleration start time*. The acceleration start time shall be distributed uniformly in the time interval [*tca* – 35 *s, tca* – 5 s] and shall be such that $\dot{z}_2$ is achieved no later than *tca* + 5 s.

4.4.2.6.4 *CHARACTERISTICS OF THE AIRCRAFT TRAJECTORIES IN THE HORIZONTAL PLANE*

4.4.2.6.4.1 *Horizontal miss distance*

4.4.2.6.4.1.1 For calculations of the effect of ACAS on the risk of collision (4.4.3), *hmd* shall be uniformly distributed in the range [0, 500 ft].

4.4.2.6.4.1.2 For calculations concerning the compatibility of ACAS with ATM (4.4.4), *hmd* shall be distributed so that the values of *hmd* have the following cumulative probabilities:

hmd (ft)	cumulative probability Layers 1-3	Layers 4-6	hmd (ft)	cumulative probability Layers 1-3	Layers 4-6
0	0.000	0.000	17 013	0.999	0.868
1 215	0.152	0.125	18 228	1.000	0.897
2 430	0.306	0.195	19 443		0.916
3 646	0.482	0.260	20 659		0.927
4 860	0.631	0.322	21 874		0.939
6 076	0.754	0.398	23 089		0.946
7 921	0.859	0.469	24 304		0.952
8 506	0.919	0.558	25 520		0.965
9 722	0.954	0.624	26 735		0.983
10 937	0.972	0.692	27 950		0.993

hmd (ft)	cumulative probability Layers 1-3	Layers 4-6	hmd (ft)	cumulative probability Layers 1-3	Layers 4-6
12 152	0.982	0.753	29 165		0.996
13 367	0.993	0.801	30 381		0.999
14 582	0.998	0.821	31 596		1.000
15 798	0.999	0.848			

4.4.2.6.4.2 *Approach angle.* The cumulative distribution for the horizontal approach angle shall be as follows:

approach angle (deg.)	cumulative probability Layers 1-3	Layers 4-6	approach angle (deg.)	cumulative probability Layers 1-3	Layers 4-6
0	0.00	0.00	100	0.38	0.28
10	0.14	0.05	110	0.43	0.31
20	0.17	0.06	120	0.49	0.35
30	0.18	0.08	130	0.55	0.43
40	0.19	0.08	140	0.62	0.50
50	0.21	0.10	150	0.71	0.59
60	0.23	0.13	160	0.79	0.66
70	0.25	0.14	170	0.88	0.79
80	0.28	0.19	180	1.00	1.00
90	0.32	0.22			

4.4.2.6.4.3 *Aircraft speed.* The cumulative distribution for each aircraft's horizontal ground speed at closest approach shall be as follows:

ground speed (kt)	cumulative probability Layers 1-3	cumulative probability Layers 4-6	ground speed (kt)	cumulative probability Layers 1-3	cumulative probability Layers 4-6
45	0.000		325	0.977	0.528
50	0.005		350	0.988	0.602
75	0.024	0.000	375	0.997	0.692
100	0.139	0.005	400	0.998	0.813
125	0.314	0.034	425	0.999	0.883
150	0.486	0.064	450	1.000	0.940
175	0.616	0.116	475		0.972
200	0.700	0.171	500		0.987
225	0.758	0.211	525		0.993
250	0.821	0.294	550		0.998
275	0.895	0.361	575		0.999
300	0.949	0.427	600		1.000

4.4.2.6.4.4 *Horizontal manoeuvre probabilities.* For each aircraft in each encounter, the probability of a turn, the probability of a speed change given a turn, and the probability of a speed change given no turn shall be as follows:

Layer	Prob(turn)	Prob(speed change) given a turn	Prob(speed change) given no turn
1	0.31	0.20	0.5
2	0.29	0.20	0.25
3	0.22	0.10	0.15
4, 5, 6	0.16	0.05	0.10

4.4.2.6.4.4.1 Given a speed change, the probability of a speed increase shall be 0.5 and the probability of a speed decrease shall be 0.5.

4.4.2.6.4.5 *Turn extent.* The cumulative distribution for the extent of any turn shall be as follows:

Turn extent (deg.)	cumulative probability Layers 1-3	cumulative probability Layers 4-6
15	0.00	0.00
30	0.43	0.58
60	0.75	0.90
90	0.88	0.97
120	0.95	0.99
150	0.98	1.00
180	0.99	
210	1.00	

4.4.2.6.4.5.1 The direction of the turn shall be random, with the probability of a left turn being 0.5 and the probability of a right turn being 0.5.

4.4.2.6.4.6 *Bank angle.* An aircraft's bank angle during a turn shall not be less than 15 degrees. The probability that it equals 15 degrees shall be 0.79 in layers 1-3 and 0.54 in layers 4-5. The cumulative distribution for larger bank angles shall be as follows:

	cumulative probability	
Bank angle (deg.)	*Layers 1-3*	*Layers 4-6*
15	0.79	0.54
25	0.96	0.82
35	0.99	0.98
50	1.00	1.00

4.4.2.6.4.7 *Turn end time.* The cumulative distribution for each aircraft's turn end time shall be as follows:

Turn end time	*cumulative probability*	
(seconds before tca*)*	*Layers 1-3*	*Layers 4-6*
0	0.42	0.28
5	0.64	0.65
10	0.77	0.76
15	0.86	0.85
20	0.92	0.94
25	0.98	0.99
30	1.00	1.00

4.4.2.6.4.8 *Speed change.* A constant acceleration or deceleration shall be randomly selected for each aircraft performing a speed change in a given encounter, and shall be applied for the duration of the encounter. Accelerations shall be uniformly distributed between 2 kt/s and 6 kt/s. Decelerations shall be uniformly distributed between 1 kt/s and 3 kt/s.

4.4.2.7 ACAS EQUIPAGE OF THE INTRUDER

The performance requirements specified in 4.4.3 and 4.4.4 each apply to three distinct situations in which the following conditions concerning the intruder's ACAS and trajectory shall apply:

a) where the intruder involved in each encounter is not equipped (4.4.2.1 j) 1)), it follows a trajectory identical to that which it follows when own aircraft is not equipped;

b) where the intruder is ACAS-equipped but follows a trajectory identical to that in the unequipped encounter (4.4.2.1 j) 2)):

1) it follows the identical trajectory regardless of whether or not there is an RA;

2) the intruder ACAS generates an RA and transmits an RAC that is received immediately after any RA is first announced to the pilot of own aircraft;

3) the sense of the RAC generated by the intruder ACAS and transmitted to own aircraft is opposite to the sense of the first RAC selected and transmitted to the intruder by own aircraft (4.3.6.1.3);

4) the RAC transmitted by the intruder is received by own aircraft; and

5) the requirements apply both when own aircraft has the lower aircraft address and when the intruder aircraft has the lower aircraft address; and

c) where the intruder is equipped with an ACAS having a collision avoidance logic identical to that of own ACAS (4.4.2.1 j) 3)):

1) the conditions relating to the performance of own aircraft, ACAS and pilot apply equally to the intruder aircraft, ACAS and pilot;

2) RACs transmitted by one aircraft are received by the other; and

3) the requirements apply both when own aircraft has the lower aircraft address and when the intruder aircraft has the lower aircraft address.

4.4.2.8 COMPATIBILITY BETWEEN DIFFERENT COLLISION AVOIDANCE LOGIC DESIGNS

Recommendation.— When considering alternative collision avoidance logic designs, certification authorities should verify that:

a) the performances of the alternative design are acceptable in encounters involving ACAS units that use existing designs; and

b) the performances of the existing designs are not degraded by the use of the alternative design.

Note.— To address the compatibility between different collision avoidance logic designs, the conditions described in 4.4.2.7 b) are the most severe that can be anticipated in this respect.

4.4.3 Reduction in the risk of collision

Under the conditions of 4.4.2, the collision avoidance logic shall be such that the expected number of collisions is reduced to the following proportions of the number expected in the absence of ACAS:

a) when the intruder is not ACAS equipped 0.18;

b) when the intruder is equipped but does not respond 0.32; and

c) when the intruder is equipped and responds 0.04.

4.4.4 Compatibility with air traffic management (ATM)

4.4.4.1 NUISANCE ALERT RATE

4.4.4.1.1 Under the conditions of 4.4.2, the collision avoidance logic shall be such that the proportion of RAs which are a "nuisance" (4.4.4.1.2) shall not exceed: .06 when own aircraft's vertical rate at the time the RA is first issued is less than 400 ft/min; or .08 when own aircraft's vertical rate at the time the RA is first issued exceeds 400 ft/min.

Note.— This requirement is not qualified by the ACAS equipage of the intruder (4.4.2.7) since it has negligible effect on the occurrence and frequency of nuisance RAs.

4.4.4.1.2 An RA shall be considered a "nuisance" for the purposes of 4.4.4.1.1 unless, at some point in the encounter in the absence of ACAS, the horizontal separation and the vertical separation are simultaneously less than the following values:

	horizontal separation	*vertical separation*
above FL100	2.0 NM	750 ft
below FL100	1.2 NM	750 ft

4.4.4.2 COMPATIBLE SENSE SELECTION

Under the conditions of 4.4.2, the collision avoidance logic shall be such that the proportion of encounters in which following the RA results in an altitude separation at closest approach with the opposite sign to that occurring in the absence of ACAS shall not exceed the following values:

a) when the intruder is not ACAS equipped 0.08;

b) when the intruder is equipped but does not respond 0.08; and

c) when the intruder is equipped and responds 0.12.

4.4.4.3 DEVIATIONS CAUSED BY ACAS

4.4.4.3.1 Under the conditions of 4.4.2, the collision avoidance logic shall be such that the number of RAs resulting in "deviations" (4.4.4.3.2) greater than the values indicated shall not exceed the following proportions of the total number of RAs:

	when own aircraft's vertical rate at the time the RA is first issued	
	is less than 400ft/min	*exceeds 400ft/min*
when the intruder is not ACAS equipped,		
for deviations ≥300 ft	0.15	0.23
for deviations ≥600 ft	0.04	0.13
for deviations ≥1 000 ft	0.01	0.07
when the intruder is equipped but does not respond,		
for deviations ≥300 ft	0.23	0.35
for deviations ≥600 ft	0.06	0.16
for deviations ≥1 000 ft	0.02	0.07
when the intruder is equipped and responds,		
for deviations ≥300 ft	0.11	0.23
for deviations ≥600 ft	0.02	0.12
for deviations ≥1 000 ft	0.01	0.06

4.4.4.3.2 For the purposes of 4.4.4.3.1, the "deviation" of the equipped aircraft from the original trajectory shall be measured in the interval from the time at which the RA is first issued until the time at which, following cancellation of the RA, the equipped aircraft has recovered its original altitude rate. The deviation shall be calculated as the largest altitude difference at any time in this interval between the trajectory followed by the equipped aircraft when responding to its RA and its original trajectory.

4.4.5 Relative value of conflicting objectives

Recommendation.— *The collision avoidance logic should be such as to reduce as much as practicable the risk of collision (measured as defined in 4.4.3) and limit as much as practicable the disruption to ATM (measured as defined in 4.4.4).*

4.5 ACAS USE OF EXTENDED SQUITTER

4.5.1 ACAS hybrid surveillance using extended squitter position data

Note.— Hybrid surveillance is the technique used by ACAS to take advantage of passive position information available via extended squitter DF = 17. Using hybrid surveillance, ACAS validates the position provided by extended squitter through direct active range measurement. An initial validation is performed at track initiation. Revalidation is performed once every

60 seconds for targets that do not meet the conditions in altitude or range. Revalidation is performed once per 10 seconds if the intruder becomes a near threat in altitude or range. Finally, regular active surveillance is performed once per second on intruders that become a near threat in both altitude and range. In this manner, passive surveillance (once validated) is used for non-threatening intruders thus lowering the ACAS interrogation rate. Active surveillance is used whenever an intruder becomes a near threat in order to preserve ACAS independence as an independent safety monitor.

4.5.1.1 DEFINITIONS

Active surveillance. The process of tracking an intruder by using the information gained from the replies to own ACAS interrogations.

Hybrid surveillance. The process of using active surveillance to validate and monitor other aircraft being tracked principally using passive surveillance in order to preserve ACAS independence.

Initial acquisition. The process of starting the formation of a new track upon receipt of a squitter from a Mode S aircraft for which there is no track by making an active interrogation.

Passive surveillance. The process of tracking another aircraft without interrogating it, by using the other aircraft's extended squitters. ACAS uses the information obtained to monitor the need for active surveillance, but not for any other purpose.

Validation. The process of verifying the relative position of an intruder using passive information by comparing it to the relative position obtained by active interrogation.

4.5.1.2 An ACAS equipped to receive extended squitter airborne position messages for passive surveillance of nonthreatening intruders shall utilize this passive position information in the following manner.

4.5.1.3 PASSIVE SURVEILLANCE

4.5.1.3.1 *Validation*. To validate the position of an intruder reported by extended squitter, ACAS shall determine the relative range and relative bearing as computed from the position and geographical heading of own aircraft and the intruder's position as reported in the extended squitter. This derived range and relative bearing and the altitude reported in the squitter shall be compared to the range, relative bearing and altitude determined by active ACAS interrogation of the aircraft.

Differences between the derived and measured range and relative bearing and the squitter and reply altitude shall be computed and used in tests to determine whether the extended squitter data is valid. If these tests are satisfied the passive position shall be considered to be validated and the track shall be maintained on passive data unless it is a near threat as described in 4.5.1.4. If any of these validation tests fail, active surveillance shall be used to track the intruder.

Note.— Suitable tests for validating extended squitter data information for the purposes of ACAS hybrid surveillance can be found in RTCA/DO-300.

4.5.1.3.2 *Supplementary active interrogations*. In order to ensure that an intruder's track is updated at least as frequently as required in the absence of extended squitter data (4.3.7.1.2.2), each time a track is updated using squitter information the time at which an active interrogation would next be required shall be calculated. An active interrogation shall be made at that time if a further squitter has not been received before the interrogation is due.

4.5.1.4 *Near threat.* An intruder shall be tracked under active surveillance if it is a near threat, as determined by separate tests on the range and altitude of the aircraft. These tests shall be such that an intruder is considered a near threat before it becomes a potential threat, and thus triggers a traffic advisory as described in 4.3.3. These tests shall be performed once per second. All near threats, potential threats and threats shall be tracked using active surveillance.

Note.— Suitable tests for determining that an intruder is a near threat can be found in RTCA/DO-300.

4.5.1.5 *Revalidation and monitoring.* If an aircraft is being tracked using passive surveillance, periodic active interrogations shall be performed to validate and monitor the extended squitter data as required in 4.5.1.3.1. The default rates of revalidation shall be once per minute for a non-threat and once per 10 seconds for a near threat. The tests required in 4.5.1.3.1 shall be performed for each interrogation, and active surveillance shall be used to track the intruder if these revalidation tests fail.

4.5.1.6 *Full active surveillance.* If the following condition is met for a track being updated via passive surveillance data:

a) $|a| \leq 10\,000$ ft and both;

b) $|a| \leq 3\,000$ ft or $|a - 3\,000 \text{ ft}| \,/\, |\dot{a}| \leq 60$ s; and

c) $r \leq 3$ NM or $(r - 3 \text{ NM}) / |\dot{r}| \leq 60$ s;

where: a = intruder altitude separation in ft

$\dot{a}$ = altitude rate estimate in ft/s

r = intruder slant range in NM

$\dot{r}$ = range rate estimate in NM/s

the aircraft shall be declared an active track and shall be updated on active range measurements once per second for as long as the above condition is met.

4.5.1.6.1 All near threats, potential threats and threats shall be tracked using active surveillance.

4.5.1.6.2 A track under active surveillance shall transition to passive surveillance if it is neither a near, potential threat nor a threat. The tests used to determine it is no longer a near threat shall be similar to those used in 4.5.1.4 but with larger thresholds in order to have hysteresis which prevents the possibility of frequent transitions between active and passive surveillance.

Note.— Suitable tests for determining that an intruder is no longer a near threat can be found in RTCA/DO-300.

4.5.2 ACAS operation with an improved receiver MTL

Note.— Applications of extended squitter that are independent of ACAS might be implemented (for convenience) using the ACAS receiver. The use of an improved receiver minimum triggering level (MTL) will make it possible to receive extended squitters from ranges of up to 60 NM and beyond in support of such applications.

4.5.2.1 An ACAS operating with a receiver having a MTL more sensitive than –74 dBm shall implement the capabilities specified in the following paragraphs.

4.5.2.2 *Dual minimum triggering levels*. The ACAS receiver shall be capable of setting an indication for each squitter reception as to whether the reply would have been detected by an ACAS operating with a conventional MTL (–74 dBm). Squitter receptions received at the conventional MTL shall be passed to the ACAS surveillance function for further processing. Squitter receptions that do not meet this condition shall not be passed to the ACAS surveillance function.

Note 1.— Extended squitters containing position report information will be disseminated for display in connection with an extended squitter application.

Note 2.— Use of the conventional MTL for the ACAS surveillance function preserves the current operation of ACAS surveillance when operating with a receiver with an improved MTL.

4.5.2.3 *Dual or re-triggerable reply processor.* The ACAS Mode S reply processing function shall:

a) use separate reply processors for Mode S reply formats received at or above the conventional MTL and a separate reply processor for Mode S reply formats received below the conventional MTL; or,

b) use a Mode S reply processor that will re-trigger if it detects a Mode S preamble that is 2 to 3 dB stronger than the reply that is currently being processed.

Note.— Care must be taken to ensure that low-level squitters (i.e. those below the conventional MTL) do not interfere with the processing of acquisition squitters for ACAS. This could happen if the low-level squitter is allowed to capture the reply processor. This can be prevented by using a separate reply processor for each function, or by requiring the reply processor to be re-triggered by a higher level squitter.

CHAPTER 5. MODE S EXTENDED SQUITTER

Note 1.— A functional model of Mode S extended squitter systems supporting ADS-B and/or TIS-B is depicted in Figure 5-1.

Note 2.— Airborne systems transmit ADS-B messages (ADS-B OUT) and may also receive ADS-B and TIS-B messages (ADS-B IN and TIS-B IN). Ground systems (i.e. ground stations) transmit TIS-B (as an option) and receive ADS-B messages.

Note 3.— Although not explicitly depicted in the functional model presented in Figure 5-1, extended squitter systems installed on aerodrome surface vehicles or fixed obstacles may transmit ADS-B messages (ADS-B OUT).

5.1 MODE S EXTENDED SQUITTER TRANSMITTING

SYSTEM CHARACTERISTICS

Note.— Many of the requirements associated with the transmission of Mode S extended squitter are included in Chapter 2 and Chapter 3 for Mode S transponder and non-transponder devices using the message formats defined in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871). The provisions presented within the following subsections are focused on requirements applicable to specific classes of airborne and ground transmitting systems that are supporting the applications of ADS-B and TIS-B.*

5.1.1 ADS-B out requirements

5.1.1.1 Aircraft, surface vehicles and fixed obstacles supporting an ADS-B capability shall incorporate the ADS-B message generation function and the ADS-B message exchange function (transmit) as depicted in Figure 5-1.

5.1.1.1.1 ADS-B transmissions from aircraft shall include position, aircraft identification and type, airborne velocity, periodic status and event driven messages including emergency/priority information.

5.1.1.1.2 **Recommendation.—** Extended squitter transmitting equipment should use formats and protocols of the latest version available.

Note 1.— The data formats and protocols for messages transferred via extended squitter are specified in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

Note 2.— Some States and/or regions require extended squitter version 2 to be transmitted by specific dates.

5.1.1.2 *Extended squitter ADS-B transmission requirements.* Mode S extended squitter transmitting equipment shall be classified according to the unit's range capability and the set of parameters that it is capable of transmitting consistent with the following definition of general equipment classes and the specific equipment classes defined in Tables 5-1 and 5-2:

a) Class A extended squitter airborne systems support an interactive capability incorporating both an extended squitter transmission capability (i.e. ADS-B OUT) with a complementary extended squitter reception capability (i.e. ADS-B IN) in support of onboard ADS-B applications;

b) Class B extended squitter systems provide a transmission only (i.e. ADS-B OUT without an extended squitter reception capability) for use on aircraft, surface vehicles, or fixed obstructions; and

c) Class C extended squitter systems have only a reception capability and thus have no transmission requirements.

5.1.1.3 *Class A extended squitter system requirements.* Class A extended squitter airborne systems shall have transmitting and receiving subsystem characteristics of the same class (i.e. A0, A1, A2, or A3) as specified in 5.1.1.1 and 5.2.1.2.

Note.— Class A transmitting and receiving subsystems of the same specific class (e.g. Class A2) are designed to complement each other with their functional and performance capabilities. The minimum air-to-air range that extended squitter transmitting and receiving systems of the same class are designed to support are:

a) A0-to-A0 nominal air-to-air range is 10 NM;

b) A1-to-A1 nominal air-to-air range is 20 NM;

c) A2-to-A2 nominal air-to-air range is 40 NM; and

d) A3-to-A3 nominal air-to-air range is 90 NM.

The above ranges are design objectives and the actual effective air-to-air range of the Class A extended squitter systems may be larger in some cases (e.g. in environments with low levels of 1 090 MHz fruit) and shorter in other cases (e.g. in environments with very high levels of 1 090 MHz fruit).

5.1.1.4 CONTROL OF ADS-B OUT OPERATION

5.1.1.4.1 **Recommendation.—** Protection against reception of corrupted data from the source providing the position should be satisfied by error detection on the data inputs and the appropriate maintenance of the installation.

5.1.1.4.2 If an independent control of the ADS-B OUT function is provided, then the operational state of the ADS-B OUT function shall be indicated to the flight crew, at all times.

Note.— There is no requirement for an independent control for the ADS-B OUT function.

5.1.2 TIS-B out requirements

5.1.2.1 Ground stations supporting a TIS-B capability shall incorporate the TIS-B message generation function and the TIS-B message exchange function (transmit).

5.1.2.2 The extended squitter messages for TIS-B shall be transmitted by an extended squitter ground station when connected to an appropriate source of surveillance data.

Note 1.— Extended squitter messages for TIS-B are specified in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

Note 2.— Ground stations supporting TIS-B use an extended squitter transmission capability. The characteristics of such ground stations, in terms of transmitter power, antenna gain, transmission rates, etc., are to be tailored to the desired TIS-B service volume of the specific ground station assuming airborne users are equipped with (at least) Class A1 receiving systems.

5.1.2.3 **Recommendation.—** The maximum transmission rates and effective radiated power of the transmissions should be controlled to avoid unacceptable levels of RF interference to other 1 090 MHz systems (i.e. SSR and ACAS).

5.2 MODE S EXTENDED SQUITTER RECEIVING SYSTEM CHARACTERISTICS (ADS-B IN AND TIS-B IN)

Note 1.— The paragraphs herein describe the required capabilities for 1 090 MHz receivers used for the reception of Mode S extended squitter transmissions that convey ADS-B and/or TIS-B messages. Airborne receiving systems support ADSB and TIS-B reception while ground receiving systems support only ADS-B reception.

Note 2.— Detailed technical provisions for Mode S extended squitter receivers can be found within RTCA DO-260B/EUROCAE ED-102A, "Minimum Operational Performance Standards for 1 090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS B)."

5.2.1 Mode S extended squitter receiving system functional requirements

5.2.1.1 Mode S extended squitter receiving systems shall perform the message exchange function (receive) and the report assembler function.

Note.— The extended squitter receiving system receives ADS-B Mode S extended squitter messages and outputs ADS-B reports to client applications. Airborne receiving systems also receive TIS-B extended squitter messages and output TIS-B reports to client applications. This functional model (shown in Figure 5-1) depicts both airborne and ground 1 090 MHz ADS-B receiving systems.

5.2.1.2 *Mode S extended squitter receiver classes*. The required functionality and performance characteristics for the Mode S extended squitter receiving system will vary depending on the ADS-B and TIS-B client applications to be supported and the operational use of the system. Airborne Mode S extended squitter receivers shall be consistent with the definition of receiving system classes shown in Table 5-3.

Note.— Different equipment classes of Mode S extended squitter installations are possible. The characteristics of the receiver associated with a given equipment class are intended to be appropriate to support the required level of operational capability. Equipment classes A0 through A3 are applicable to those Mode S extended airborne installations that include a Mode S extended squitter transmission (ADS OUT) and reception (ADS-B IN) capability. Equipment classes B0 through B3 are applicable to Mode S extended installations with only a transmission (ADS-B OUT) capability and includes equipment classes applicable to airborne, surface vehicles and fixed obstructions. Equipment classes C1 through C3 are applicable to Mode S extended squitter ground receiving systems.

5.2.2 Message exchange function

5.2.2.1 The message exchange function shall include the 1 090 MHz receiving antenna and the radio equipment (receiver/demodulator/decoder/data buffer) sub-functions.

5.2.2.2 *Message exchange functional characteristics*. The airborne Mode S extended squitter receiving system shall support the reception and decoding of all extended squitter messages as listed in Table 5-3. The ground ADS-B extended squitter receiving system shall, as a minimum, support the reception and decoding of all of the extended squitter message types that convey information needed to support the generation of the ADS-B reports of the types required by the client ATM ground applications.

5.2.2.3 *Required message reception performance*. The airborne Mode S extended squitter receiver/demodulation/decoder shall employ the reception techniques and have a receiver minimum trigger threshold level (MTL) as listed in Table 5-3 as a function of the airborne receiver class. The reception technique and MTL for extended squitter ground receiver shall be selected to provide the reception performance (i.e. range and update rates) as required by the client ATM ground applications.

5.2.2.4 *Enhanced reception techniques.* Class A1, A2 and A3 airborne receiving systems shall include the following features to provide improved probability of Mode S extended squitter reception in the presence of multiple overlapping Mode A/C fruit and/or in the presence of an overlapping stronger Mode S fruit, as compared to the performance of the standard reception technique required for Class A0 airborne receiving systems:

a) Improved Mode S extended squitter preamble detection.

b) Enhanced error detection and correction.

c) Enhanced bit and confidence declaration techniques applied to the airborne receiver classes as shown below:

1) Class A1 — Performance equivalent to or better than the use of the "Centre Amplitude" technique.

2) Class A2 — Performance equivalent to or better than the use of the "Multiple Amplitude Samples" baseline technique, where at least 8 samples are taken for each Mode S bit position and are used in the decision process.

3) Class A3 — Performance equivalent to or better than the use of the "Multiple Amplitude Samples" baseline technique, where at least 10 samples are taken for each Mode S bit position and are used in the decision process.

Note 1.— The above enhanced reception techniques are as defined in RTCA DO-260B/EUROCAE ED-102A, Appendix I.

Note 2.— The performance provided for each of the above enhanced reception techniques when used in a high fruit environment (i.e. with multiple overlapping Mode A/C fruit) is expected to be at least equivalent to that provided by the use of the techniques described in RTCA DO-260B/EUROCAE ED-102A, Appendix I.

Note 3.— It is considered appropriate for ground extended squitter receiving systems to employ the enhanced reception techniques equivalent to those specified for airborne Class A2 or A3 receiving systems.

5.2.3 Report assembler function

5.2.3.1 The report assembler function shall include the message decoding, report assembly, and output interface subfunctions.

5.2.3.2 When an extended squitter message is received, the message shall be decoded and the applicable ADS-B report(s) of the types defined in 5.2.3.3 shall be generated within 0.5 seconds.

Note 1.— Two configurations of extended squitter airborne receiving systems, which include the reception portion of the ADS-B message exchange function and the ADS-B/TIS-B report assembly function, are allowed:

a) Type I extended squitter receiving systems receive ADS-B and TIS-B messages and produce application-specific subsets of ADS-B and TIS-B reports. Type I extended squitter receiving systems are customized to the particular client applications using ADS-B and TIS-B reports. Type I extended squitter receiving systems may additionally be controlled by an external entity to produce installation-defined subsets of the reports that those systems are capable of producing.

b) Type II extended squitter receiving systems receive ADS-B and TIS-B messages and are capable of producing complete ADS-B and TIS-B reports in accordance with the equipment class. Type II extended squitter receiving systems may be controlled by an external entity to produce installation-defined subsets of the reports that those systems are capable of producing.

Note 2.— Extended squitter ground receiving systems receive ADS-B messages and produce either application-specific subsets or complete ADS-B reports based on the needs of the ground service provider, including the client applications to be supported.

Note 3.– The extended squitter message reception function may be physically partitioned into hardware separate from those that implement the report assembly function.

5.2.3.3 ADS-B REPORT TYPES

Note 1.— The ADS-B report refers to the restructuring of ADS-B message data received from Mode S extended squitter broadcasts into various reports that can be used directly by a set of client applications. Five ADS-B report types are defined by the following subparagraphs for output to client applications. Additional information on the ADS-B report contents and the applicable mapping from extended squitter messages to ADS-B reports can be found in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871) and RTCA DO-260B / EUROCAE ED-102A.*

Note 2.— The use of precision (e.g. GNSS UTC measured time) versus non-precision (e.g. internal receiving system clock) time sources as the basis for the reported time of applicability is described in 5.2.3.5.

5.2.3.3.1 *State vector report.* The state vector report shall contain time of applicability, information about an airborne or vehicle's current kinematic state (e.g. position, velocity), as well as a measure of the integrity of the navigation data, based on information received in airborne or ground position, airborne velocity, identification and category, aircraft operational status and target state and status extended squitter messages. Since separate messages are used for position and velocity, the time of applicability shall be reported individually for the position related report parameters and the velocity related report parameters. Also, the state vector report shall include a time of applicability for the estimated position and/or estimated velocity information (i.e. not based on a message with updated position or velocity information) when such estimated position and/or velocity information is included in the state vector report.

Note.— Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne). The state vector data is the most dynamic of the four ADS-B reports; hence, the applications require frequent updates of the state vector to meet the required accuracy for the operational dynamics of the typical airborne or ground operations of airborne and surface vehicles.

5.2.3.3.2 *Mode status report.* The mode status report shall contain time of applicability and current operational information about the transmitting participant, including airborne/vehicle address, call sign, ADS-B version number, airborne/vehicle length and width information, state vector quality information, and other information based on information received in aircraft operational status, target state and status, aircraft identification and category, airborne velocity and aircraft status extended squitter messages. Each time that a mode status report is generated, the report assembler function shall update the report time of applicability. Parameters for which valid data is not available shall either be indicated as invalid or omitted from the mode status report.

Note 1.— Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).

Note 2.— The age of the information being reported within the various data elements of a mode status report may vary as a result of the information having been received within different extended squitter messages at different times.

5.2.3.3.3 *Air referenced velocity report.* Air referenced velocity reports shall be generated when air referenced velocity information is received in airborne velocity extended squitter messages. The air referenced velocity report shall contain time of applicability, airspeed and heading information. Only certain classes of extended squitter receiving systems, as defined in 5.2.3.5, are required to generate air referenced velocity reports. Each time that an individual mode status report is generated, the report assembly function shall update the report time of applicability.

Note 1.— The air referenced velocity report contains velocity information that is received in airborne velocity messages along with additional information received in airborne identification and category extended squitter messages. Air referenced velocity reports are not generated when ground referenced velocity information is being received in the airborne velocity extended squitter messages.

Note 2.— Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).

5.2.3.3.4 *Resolution advisory (RA) report.* The RA report shall contain time of applicability and the contents of an active ACAS resolution advisory (RA) as received in a Type=28 and Subtype=2 extended squitter message.

Note.— The RA report is only intended to be generated by ground receiving subsystems when supporting a ground ADS-B client application(s) requiring active RA information. An RA report will nominally be generated each time a Type=28, Subtype=2 extended squitter message is received.

5.2.3.3.5 *TARGET STATE REPORT*

Note.— The target state report will be generated when information is received in target state and status messages, along with additional information received in airborne identification and category extended squitter messages. The target state and status message is defined in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871). Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).*

5.2.3.4 TIS-B REPORT TYPES

5.2.3.4.1 As TIS-B messages are received by airborne receiving systems, the information shall be reported to client applications. Each time that an individual TIS-B report is generated, the report assembly function shall update the report time of applicability to the current time.

Note 1.— The TIS-B message formats are defined in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

Note 2.— The TIS-B report refers to the restructuring of TIS-B message data received from ground Mode S extended squitter broadcasts into reports that can be used by a set of client applications. Two ADS-B report types are defined by the following subparagraphs for output to client applications. Additional information on the TIS-B report contents and the applicable mapping from extended squitter messages to ADS-B reports can be found in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

Note 3.— The use of precision (e.g. GNSS UTC measured time) versus non-precision (e.g. internal receiving system clock) time sources as the basis for the reported time of applicability is described in 5.2.3.5.

5.2.3.4.2 *TIS-B target report.* All received information elements, other than position, shall be reported directly, including all reserved fields for the TIS-B fine format messages and the entire message content of any received TIS-B management message. The reporting format is not specified in detail, except that the information content reported shall be the same as the information content received.

5.2.3.4.3 When a TIS-B position message is received, it is compared with tracks to determine whether it can be decoded into target position (i.e. correlated to an existing track). If the message is decoded into target position, a report shall be generated within 0.5 seconds. The report shall contain the received position information with a time of applicability, the most recently received velocity measurement with a time of applicability, the estimated position and velocity applicable to a common time of applicability, airborne/vehicle address, and all other information in the received message. The estimated values shall be based on the received position information and the track history of the target.

5.2.3.4.4 When a TIS-B velocity message is received, if it is correlated to a complete track, a report shall be generated, within 0.5 seconds of the message reception. The report shall contain the received velocity information with a time of applicability, the estimated position and velocity applicable to a common time of applicability, airborne/vehicle address, and all other information in the received message. The estimated values shall be based on the received ground reference velocity information and the track history of the target.

5.2.3.4.5 *TIS-B management report.* The entire message content of any received TIS-B management message shall be reported directly to the client applications. The information content reported shall be the same as the information content received.

5.2.3.4.5.1 The contents of any received TIS-B management message shall be reported bit-for-bit to the client applications.

5.2.3.5 REPORT TIME OF APPLICABILITY

The receiving system shall use a local source of reference time as the basis for reporting the time of applicability, as defined for each specific ADS-B and TIS-B report type (see 5.2.3.3 and 5.2.3.4).

5.2.3.5.1 *Precision time reference.* Receiving systems intended to generate ADS-B and/or TIS-B reports based on the reception of surface position messages, airborne position messages, and/or TIS-B messages shall use GNSS UTC measured time for the purpose of generating the report time applicability for the following cases of received messages:

a) version zero (0) ADS-B messages, as defined in 3.1.2.8.6.2, when the navigation uncertainty category (NUC) is 8 or 9; or

b) version one (1) or version two (2) ADS-B or TIS-B messages, as defined in 3.1.2.8.6.2 and 3.1.2.8.7 respectively, when the navigation integrity category (NIC) is 10 or 11;

UTC measured time data shall have a minimum range of 300 seconds and a resolution of 0.0078125 (1/128) seconds.

5.2.3.5.2 *NON-PRECISION LOCAL TIME REFERENCE*

5.2.3.5.2.1 For receiving systems not intended to generate ADS-B and/or TIS-B reports based on reception of ADS-B or TIS-B messages meeting the NUC or NIC criteria as indicated in 5.2.3.5.1, a non-precision time source shall be allowed.

In such cases, where there is no appropriate precision time source available, the receiving system shall establish an appropriate internal clock or counter having a maximum clock cycle or count time of 20 milliseconds. The established cycle or clock count shall have a minimum range of 300 seconds and a resolution of 0.0078125 (1/128) seconds.

Note.— The use of a non-precision time reference as described above is intended to allow the report time of applicability to accurately reflect the time intervals applicable to reports within a sequence. For example the applicable time interval between state vector reports could be *accurately determined by a client application, even though the absolute time (e.g. UTC measured time) would not be indicated by the report.*

5.2.3.6 REPORTING REQUIREMENTS

5.2.3.6.1 *Reporting requirements for Type I Mode S extended squitter airborne receiving systems.* As a minimum, the report assembler function associated with Type I Mode S extended squitter receiving systems, as defined in 5.2.3, shall support that subset of ADS-B and TIS-B reports and report parameters, that are required by the specific client applications being served by that receiving system.

5.2.3.6.2 *Reporting requirements for Type II Mode S extended squitter airborne receiving systems.* The report assembler function associated with Type II receiving systems, as defined in 5.2.3, shall generate ADS-B and TIS-B reports according to the class of the receiving system as shown in Table 5-4 when the prerequisite ADS-B and/or TIS-B messages are being received.

5.2.3.6.3 *Reporting requirements for Mode S extended squitter ground receiving systems.* As a minimum, the report assembler function associated with Mode S extended squitter ground receiving systems, as defined in 5.2.3, shall support that subset of ADS-B reports and report parameters, that are required by the specific client applications being served by that receiving system.

5.2.4 Interoperability

The Mode S extended squitter receiving system shall provide interoperability between the different versions of extended squitter ADS-B message formats.

Note 1.— All defined ADS-B versions and their corresponding message formats are contained in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871) and are identified by a version number.*

Note 2.— ADS-B message formats are defined with backward compatibility with previous versions. An extended squitter receiver can recognize and decode signals of its own version, as well as the message formats from lower versions. The receiver, however, can decode the portion of messages received from a higher version transponder according to its own capability.

5.2.4.1 INITIAL MESSAGE DECODING

The Mode S extended squitter receiving system shall, upon acquiring a new ADS-B target, initially apply the decoding provisions applicable to version 0 (zero) ADS B messages until or unless an aircraft operational status message is received indicating that a higher version message format is in use.

5.2.4.2 APPLYING VERSION NUMBER

The Mode S extended squitter receiving system shall decode the version number information conveyed in the aircraft operational status message and shall apply the corresponding decoding rules for the reported version, up to the highest version supported by the receiving system, for the decoding of the subsequent extended squitter ADS-B messages from that specific aircraft or vehicle.

5.2.4.3 HANDLING OF RESERVED MESSAGE SUBFIELDS

The Mode S extended squitter receiving system shall ignore the contents of any message subfield defined as reserved.

Note.— This provision supports interoperability between message versions by allowing the definition of additional parameters that will be ignored by earlier receiver versions and correctly decoded by newer receiver versions.

TABLES FOR CHAPTER 5

Table 5-1. ADS-B Class A equipment characteristics

<table>
<tr><th>Equipment class</th><th>Minimum transmit power (at antenna terminal)</th><th>Maximum transmit power (at antenna terminal)</th><th>Airborne or surface</th><th>Minimum extended squitter message capability required (see Note 2)</th></tr>
<tr><td rowspan="2">A0
(Minimum)</td><td rowspan="2">18.5 dBW
(see Note 1)</td><td rowspan="2">27 dBW</td><td>Airborne</td><td>Airborne position
Aircraft identification and category
Airborne velocity
Aircraft operational status
Extended squitter aircraft status</td></tr>
<tr><td>Surface</td><td>Surface position
Aircraft identification and category
Aircraft operational status
Extended squitter aircraft status</td></tr>
<tr><td rowspan="2">A1
(Basic)</td><td rowspan="2">21 dBW</td><td rowspan="2">27 dBW</td><td>Airborne</td><td>Airborne position
Aircraft identification and category
Airborne velocity
Aircraft operational status
Extended squitter aircraft status</td></tr>
<tr><td>Surface</td><td>Surface position
Aircraft identification and category
Aircraft operational status
Extended squitter aircraft status</td></tr>
<tr><td rowspan="2">A2
(Enhanced)</td><td rowspan="2">21 dBW</td><td rowspan="2">27 dBW</td><td>Airborne</td><td>Airborne position
Aircraft identification and category
Airborne velocity
Aircraft operational status
Extended squitter aircraft status
Target state and status</td></tr>
<tr><td>Surface</td><td>Surface position
Aircraft identification and category
Aircraft operational status
Extended squitter aircraft status</td></tr>
<tr><td rowspan="2">A3
(Extended)</td><td rowspan="2">23 dBW</td><td rowspan="2">27 dBW</td><td>Airborne</td><td>Airborne position
Aircraft identification and category
Airborne velocity
Aircraft operational status
Extended squitter aircraft status
Target state and status</td></tr>
<tr><td>Surface</td><td>Surface position
Aircraft identification and category
Aircraft operational status
Extended squitter aircraft status</td></tr>
<tr><td colspan="5">Note 1.— See Chapter 3, 3.1.2.10.2 for restrictions on the use of this category of Mode S transponder.

Note 2.— The extended squitter messages applicable to Class A equipment are defined in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).</td></tr>
</table>

Table 5-2. ADS-B Class B equipment characteristics

Equipment class	*Minimum transmit power (at antenna terminal)*	*Maximum transmit power (at antenna terminal)*	*Airborne or surface*	*Minimum extended squitter message capability required*
B0 (Airborne)	18.5 dBW (see *Note 1*)	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
B1 (Airborne)	21 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
B2 Low (Ground Vehicle)	8.5 dBW	< 18.5 dBW (see *Note 2*)	Surface	Surface position Aircraft identification and category Aircraft operational status
B2 (Ground Vehicle)	18.5 dBW	27 dBW (see *Note 2*)	Surface	Surface position Aircraft identification and category Aircraft operational status
B3 (Fixed Obstacle)	18.5 dBW	27 dBW (see *Note 2*)	Airborne (see *Note 3*)	Airborne position Aircraft identification and category Aircraft operational status

Note 1.— See Chapter 3, 3.1.2.10.2 for restrictions on the use of this category of Mode S transponder.

Note 2.— The appropriate ATS authority is expected to get the maximum power level permitted.

Note 3.— Fixed obstacles use the airborne ADS-B message formats since knowledge of their location is of primary interest to airborne aircraft.

Table 5-3. Reception performance for airborne receiving systems

Receiver class	*Intended air-to-air operational range*	*Receiver minimum trigger threshold level (MTL) (see* Note 1*)*	*Reception Technique (see* Note 2*)*	*Required extended squitter ADS-B message support*	*Required extended squitter TIS-B message support*
A0 (Basic VFR)	10 NM	−72 dBm	Standard	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management
A1 (Basic IFR)	20 NM	−79 dBm	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management
A2 (Enhanced IFR)	40 NM	−79 dBm	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status Target state and status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management
A3 (Extended capability)	90 NM	−84 dBm (and −87 dBm at 15% probability of reception)	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category Extended squitter airborne status Aircraft operational status Target state and status	Fine airborne position Coarse airborne position Fine surface position Aircraft identification and category Airborne velocity Management

Note 1.— Specific MTL is referenced to the signal level at the output terminal of the antenna, assuming a passive antenna. If electronic amplification is integrated into the antenna assembly, then the MTL is referenced at the input to the amplifier. For Class A3 receivers, a second performance level is defined at a received signal level of −87 dBm where 15 per cent of the messages are to be successfully received. MTL values refer to reception under non-interference conditions.

Note 2.— The extended squitter receiver reception techniques are defined in 5.2.2.4. "Standard" reception techniques refer to the baseline techniques, as required for ACAS 1 090 MHz receivers, that are intended to handle single overlapping Mode A/C fruit. "Enhanced" reception techniques refer to techniques intended to provide improved reception performance in the presence of multiple overlapping Mode A/C fruit and improved decoder re-triggering in the presence of overlapping stronger Mode S fruit. The requirements for the enhanced reception techniques that are applicable to the specific airborne receiver classes are defined in 5.2.2.4.

Table 5-4. Mode S extended squitter airborne receiving system reporting requirements

Receiver class	*Minimum ADS-B reporting requirements*	*Minimum TIS-B reporting requirements*
A0 (Basic VFR)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2)	TIS-B state report and TIS-B management report
A1 (Basic IFR)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2) and ADS-B air referenced velocity report (ARV) (per 5.2.3.3.3)	TIS-B state report and TIS-B management report
A2 (Enhanced IFR)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2) and ADS-B ARV report (per 5.2.3.3.3) and ADS-B target state report (per 5.2.3.3.5)	TIS-B state report and TIS-B management report
A3 (Extended capability)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2) and ADS-B ARV report (per 5.2.3.3.3) and ADS-B target state report (per 5.2.3.3.5)	TIS-B state report and TIS-B management report

FIGURE FOR CHAPTER 5

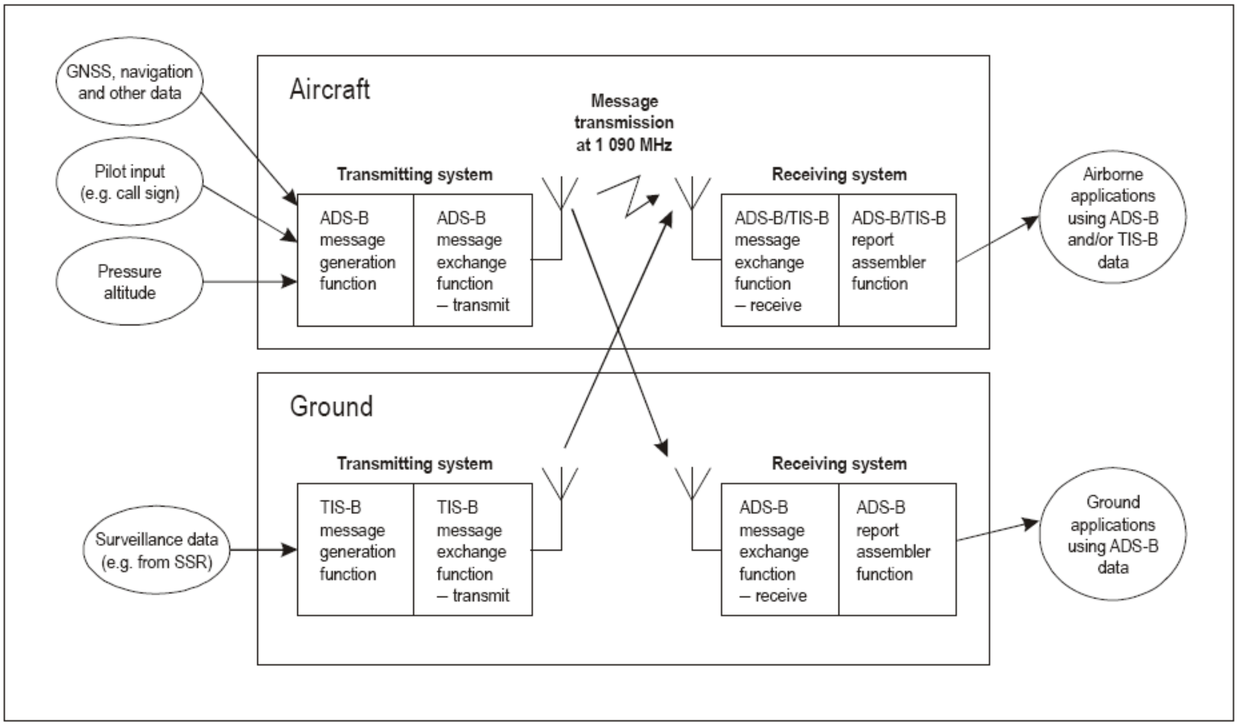


Figure 5-1. ADS-B/TIS-B system functional model

CHAPTER 6. MULTILATERATION SYSTEMS

Note 1.— Multilateration (MLAT) systems use the time difference of arrival (TDOA) of the transmissions of an SSR transponder (or the extended squitter transmissions of a non-transponder device) between several ground receivers to determine the position of the aircraft (or ground vehicle). A multilateration system can be:

a) passive, using transponder replies to other interrogations or spontaneous squitter transmissions;

b) active, in which case the system itself interrogates aircraft in the coverage area; or

c) a combination of a) and b).

Note 2.— Material contained in EUROCAE ED-117 – MOPS for Mode S Multilateration Systems for Use in A-SMGCS and ED-142 – Technical Specifications for Wide Area Multilateration System (WAM) provides a good basis for planning, implementation and satisfactory operation of MLAT systems for most applications.

6.1 DEFINITIONS

Multilateration (MLAT) System. A group of equipment configured to provide position derived from the secondary surveillance radar (SSR) transponder signals (replies or squitters) primarily using time difference of arrival (TDOA) techniques. Additional information, including identification, can be extracted from the received signals.

Time Difference of Arrival (TDOA). The difference in relative time that a transponder signal from the same aircraft (or ground vehicle) is received at different receivers.

6.2 FUNCTIONAL REQUIREMENTS

6.2.1 Radio frequency characteristics, structure and data contents of signals used in 1 090 MHz MLAT systems shall conform to the provisions of Chapter 3.

6.2.2 An MLAT system used for air traffic surveillance shall be capable of determining aircraft position and identity.

Note 1.— Depending on the application, either two- or three-dimensional position of the aircraft may be required.

Note 2.— Aircraft identity may be determined from:

a) Mode A code contained in Mode A or Mode S replies; or *b) Aircraft identification contained in Mode S replies or extended squitter identity and category message.*

Note 3.— Other aircraft information can be obtained by analysing transmissions of opportunity (i.e. squitters or replies to other ground interrogations) or by direct interrogation by the MLAT system.

6.2.3 Where an MLAT system is equipped to decode additional position information contained in transmissions, it shall report such information separately from the aircraft position calculated based on TDOA.

6.3 PROTECTION OF THE RADIO FREQUENCY ENVIRONMENT

Note.— This section only applies to active MLAT systems.

6.3.1 In order to minimize system interferences the effective radiated power of active interrogators shall be reduced to the lowest value consistent with the operationally required range of each individual interrogator site.

Note.— Guidance material on power consideration is contained in the Aeronautical Surveillance Manual *(Doc 9924).*

6.3.2 An active MLAT system shall not use active interrogations to obtain information that can be obtained by passive reception within each required update period.

Note.— Transponder occupancy will be increased by the use of omnidirectional antennas. It is particularly significant for Mode S selective interrogations because of their higher transmission rate. All Mode S transponders will be occupied decoding each selective interrogation not just the addressed transponder.

6.3.3 An active MLAT system consisting of a set of transmitters shall be considered as a single Mode S interrogator.

6.3.4 The set of transmitters used by all active MLAT systems in any part of the airspace shall not cause any transponder to be impacted such that its occupancy, because of the aggregate of all MLAT 1 030 MHz interrogations, is greater than 2 per cent at any time.

Note 1.— This represents a minimum requirement. Some regions may impose stricter requirements.

Note 2.— For an MLAT system using only Mode S interrogations, 2 per cent is equivalent to no more than 400 Mode S interrogations per second received by any aircraft from all systems using MLAT technology.

6.3.5 Active MLAT systems shall not use Mode S All-Call interrogations.

Note.— Mode S aircraft can be acquired by the reception of acquisition squitter or extended squitter even in airspace where there are no active interrogators.

6.4 PERFORMANCE REQUIREMENTS

6.4.1 The performance characteristics of the MLAT system used for air traffic surveillance shall be such that the intended operational service(s) can be satisfactorily supported.

CHAPTER 7. TECHNICAL REQUIREMENTS FOR AIRBORNE SURVEILLANCE APPLICATIONS

Note 1.— Airborne surveillance applications are based on aircraft receiving and using ADS-B message information transmitted by other aircraft/vehicles or ground stations. The capability of an aircraft to receive and use ADS-B/TIS-B message information is referred to as ADS-B/TIS-B IN.

Note 2.— Initial airborne surveillance applications use ADS-B messages on 1 090 MHz extended squitter to provide airborne traffic situational awareness (ATSA) and are expected to include "In-trail procedures" and "Enhanced visual separation on approach".

Note 3.— Detailed description of aforementioned applications can be found in RTCA/DO-289 and DO-312.

7.1 GENERAL REQUIREMENTS

7.1.1 Traffic data functions

Note.— The aircraft transmitting ADS-B messages used by other aircraft for airborne surveillance applications is referred to as the reference aircraft.

7.1.1.1 IDENTIFYING THE REFERENCE AIRCRAFT

7.1.1.1.1 The system shall support a function to identify unambiguously each reference aircraft relevant to the application.

7.1.1.2 TRACKING THE REFERENCE AIRCRAFT

7.1.1.2.1 The system shall support a function to monitor the movements and behaviour of each reference aircraft relevant to the application.

7.1.1.3 TRAJECTORY OF THE REFERENCE AIRCRAFT

7.1.1.3.1 **Recommendation.—** The system should support a computational function to predict the future position of a reference aircraft beyond simple extrapolation.

Note.— It is anticipated that this function will be required for future applications.

7.1.2 Displaying traffic

Note.— Provisions contained in this section apply to cases wherein tracks generated by ACAS and by reception of ADS-B/TIS-B IN messages are shown on a single display.

7.1.2.1 The system shall display only one track for each distinct aircraft on a given display.

Note.— This is to ensure that tracks established by ACAS and ADS-B/TIS-B IN are properly correlated and mutually validated before being displayed.

7.1.2.2 Where a track generated by ADS-B/TIS-B IN and a track generated by ACAS have been determined to belong to the same aircraft, the track generated by ADS-B/TIS-B IN shall be displayed.

Note.— At close distances, it is possible that the track generated by ACAS provides better accuracy than the track generated by ADS-B/TIS-B IN. The requirement above ensures the continuity of the display.

7.1.2.3 The display of the tracks shall comply with the requirements of ACAS traffic display.

Note.— Section 4.3 addresses colour coding and readability of the display.

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES

CHAPTER 1. DEFINITIONS

Note.— All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radio communication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

When the following terms are used in this volume of the Annex, they have the following meanings:

Alternative means of communication. A means of communication provided with equal status, and in addition to the primary means.

Double channel simplex. Simplex using two frequency channels, one in each direction.

Note.— This method was sometimes referred to as cross-band.

Duplex. A method in which telecommunication between two stations can take place in both directions simultaneously.

Frequency channel. A continuous portion of the frequency spectrum appropriate for a transmission utilizing a specified class of emission.

Note.— The classification of emissions and information relevant to the portion of the frequency spectrum appropriate for a given type of transmission (bandwidths) are specified in the Radio Regulations, Article 2 and Appendix 1.

Offset frequency simplex. A variation of single channel simplex wherein telecommunication between two stations is effected by using in each direction frequencies that are intentionally slightly different but contained within a portion of the spectrum allotted for the operation.

Operational control communications. Communications required for the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of a flight.

Note.— Such communications are normally required for the exchange of messages between aircraft and aircraft operating agencies.

Primary means of communication. The means of communication to be adopted normally by aircraft and ground stations as a first choice where alternative means of communication exist.

Simplex. A method in which telecommunication between two stations takes place in one direction at a time.

Note.— In application to the aeronautical mobile service, this method may be subdivided as follows:

a) single channel simplex;

b) double channel simplex;

c) offset frequency simplex.

Single channel simplex. Simplex using the same frequency channel in each direction.

VHF digital link (VDL). A constituent mobile subnetwork of the aeronautical telecommunication network (ATN), operating in the aeronautical mobile VHF frequency band. In addition, the VDL may provide non-ATN functions such as, for instance, digitized voice.

CHAPTER 2. DISTRESS FREQUENCIES

Introduction

The ITU Radio Regulations Article 30 provides general conditions for distress and safety communications for all mobile services. The aeronautical mobile service is also permitted under Article 30, Section III, No. 30.9 to conform to special arrangements between governments where these have been agreed. ICAO Annexes constitute such agreements.

The Standards and Recommended Practices relating to radio frequencies for distress communications take into account certain procedures that have been adopted by ICAO and also certain provisions made by the ITU in its Radio Regulations. Annex 10, Volume II requires that an aircraft in distress when it is airborne should use the frequency in use for normal communications with aeronautical stations at the time. However, it is recognized that, after an aircraft has crashed or ditched, there is a need for designating a particular frequency or frequencies to be used in order that uniformity may be attained on a worldwide basis, and so that a guard may be maintained or set up by as many stations as possible including direction-finding stations, and stations of the maritime mobile service.

The frequency 2 182 kHz also offers possibilities for communication between aircraft and stations of the maritime mobile service. The ITU Radio Regulations specify in Article 30, Section III, No. 30.11 that the frequency 2 182 kHz is the international distress frequency for radiotelephony to be used for emergency communications by ship, aircraft and survival craft stations using frequencies in the authorized bands between 1 605 kHz and 4 000 kHz when requesting assistance from, or communicating with, the maritime service.

With respect to emergency locator transmitters (ELTs) designed to be detected and located by satellite, the Radio Regulations authorize the use of these devices, which are referenced in ITU as satellite emergency position indicating radio beacons (EPIRBs). ITU Radio Regulations Article 31, Section I, No. 31.1 specifies that the band 406 – 406.1 MHz is used exclusively by satellite EPIRBs in the earth-to-space direction.

The frequency 4 125 kHz is also authorized by the ITU to enable communications between stations in the maritime mobile service and aircraft stations in distress. The current ITU Radio Regulations (RR 5.130 and Articles 31 and 32) state that the carrier frequency 4 125 kHz may be used by aircraft stations to communicate with stations of the maritime mobile service for distress and safety purposes. The aeronautical mobile (R) service frequencies 3 023 kHz and 5 680 kHz may be employed for coordinated search and rescue operations with the maritime mobile service under RR 5.115.

With respect to survival craft stations, the Radio Regulations provide for the use of the frequencies 8 364 kHz, 2 182 kHz, 121.500 MHz and 243 MHz, if the survival craft is capable of operating in the bands 4 000 – 27 500 kHz, 1 605 – 2 850 kHz, 117.975 – 137.000 MHz and 235 – 328.6 MHz respectively (RR Articles 31 and 32).

2.1 Frequencies for emergency locator transmitters (ELTs) for search and rescue

2.1.1 All emergency locator transmitters carried in compliance with Standards of Annex 6, Parts I, II and III shall operate on both 406 MHz and 121.500 MHz.

Note 1.— ITU Radio Regulations (5.256) provide for the use of 243 MHz in addition to the above frequencies.

Note 2.— Specifications for ELTs are found in Annex 10, Volume III, Part II, Chapter 5 and the ITU Radio Regulations Article 34, Section I, No. 34.1.

2.2 Search and rescue frequencies

2.2.1 Where there is a requirement for the use of high frequencies for search and rescue scene of action coordination purposes, the frequencies 3 023 kHz and 5 680 kHz shall be employed.

2.2.2 **Recommendation**.— *Where specific frequencies are required for communication between rescue coordination centres and aircraft engaged in search and rescue operations, they should be selected regionally from the appropriate aeronautical mobile frequency bands in light of the nature of the provisions made for the establishment of search and rescue aircraft.*

Note.— Where civil commercial aircraft take part in search and rescue operations, they will normally communicate on the appropriate en-route channels with the flight information centre associated with the rescue coordination centre concerned.

CHAPTER 3. UTILIZATION OF FREQUENCIES BELOW 30 MHz

Introduction

High frequency bands allocated to the
aeronautical mobile (R) service

The frequency bands between 2.8 MHz and 22 MHz allocated to the aeronautical mobile (R) service are given in Article 5 of the ITU Radio Regulations. The utilization of these bands must be in accordance with the relevant provisions of the Radio Regulations and in particular Appendix 27 to the Radio Regulations. In the utilization of these bands, States' attention is drawn to the possibility of harmful radio interference from non-aeronautical sources of radio frequency energy and the need to take appropriate measures to minimize its effects.

3.1 Method of operations

3.1.1 In the aeronautical mobile service, single channel simplex shall be used in radiotelephone communications utilizing radio frequencies below 30 MHz in the bands allocated exclusively to the aeronautical mobile (R) service.

3.1.2 Assignment of single sideband channels

3.1.2.1 Single sideband channels shall be assigned in accordance with Annex 10, Volume III, Part II, Chapter 2, 2.4.

3.1.2.2 For the operational use of the channels concerned, administrations shall take into account the provisions of 27/19 of Appendix 27 of the ITU Radio Regulations.

3.1.2.3 **Recommendation**.— *The use of aeronautical mobile (R) frequencies below 30 MHz for international operations should be coordinated as specified in Appendix 27 of the ITU Radio Regulations as follows:*

27/19 The International Civil Aviation Organization (ICAO) co-ordinates radiocommunications of the aeronautical mobile (R) service with international aeronautical operations and this Organization should be consulted in all appropriate cases in the operational use of the frequencies in the Plan.

3.1.2.4 **Recommendation**.– *Where international operating requirements for HF communications cannot be satisfied by the Frequency Allotment Plan at Part 2 of Appendix 27 to the Radio Regulations, an appropriate frequency may be assigned as specified in Appendix 27 by the application of the following provisions:*

27/20 It is recognized that not all the sharing possibilities have been exhausted in the Allotment Plan contained in this Appendix. Therefore, in order to satisfy particular operational requirements which are not otherwise met by this Allotment Plan, Administrations may assign frequencies from the aeronautical mobile (R) bands in areas other than those to which they are allotted in this Plan. However, the use of the frequencies so assigned must not reduce the protection to the same frequencies in the areas where they are allotted by the Plan below that determined by the application of the procedure defined in Part I, Section II B of this Appendix.

Note.— Part I, Section II B of Appendix 27 relates to Interference Range Contours, and application of the procedure results in a protection ratio of 15 dB.

27/21 When necessary to satisfy the needs of international air operations

Administrations may adapt the allotment procedure for the assignment of aeronautical mobile (R) frequencies, which assignments shall then be the subject of prior agreement between Administrations affected.

27/22 The co-ordination described in No. 27/19 shall be effected where appropriate and desirable for the efficient utilization of the frequencies in question, and especially when the procedures of No. 27/21 are unsatisfactory.

3.1.2.5 The use of classes of emission J7B and J9B shall be subject to the following provisions of Appendix 27:

27/12 For radiotelephone emissions, the audio frequencies will be limited to between 300 and 2 700 Hz and the occupied bandwidth of other authorized emissions will not exceed the upper limit of J3E emissions. In specifying these limits, however, no restriction in their extension is implied in so far as emissions other than J3E are concerned, provided that the limits of unwanted emissions are met (see Nos. 27/73 and 27/74).

27/14 On account of the possibility of interference, a given channel should not be used in the same allotment area for radiotelephony and data transmissions.

27/15 The use of channels derived from the frequencies indicated in 27/18 for the various classes of emissions other than J3E and H2B will be subject to special arrangements by the Administrations concerned and affected in order to avoid harmful interference which may result from the simultaneous use of the same channel for several classes of emission.

3.1.3 Assignment of frequencies for aeronautical operational control communications

3.1.3.1 Worldwide frequencies for aeronautical operational control communications are required to enable aircraft operating agencies to meet the obligations prescribed in Annex 6, Part I. Assignment of these frequencies shall be in accordance with the following provisions of Appendix 27:

27/9 A world-wide allotment area is one in which frequencies are allotted to provide long distance communications between an aeronautical station within that allotment area and aircraft operating anywhere in the world.[1]

27/217 The world-wide frequency allotments appearing in the tables at No. 27/213 and Nos. 27/218 to 27/231, except for carrier (reference) frequencies 3 023 kHz and 5 680 kHz, are reserved for assignment by administrations to stations operating under authority granted by the administration concerned for the purpose of serving one or more aircraft operating agencies. Such assignments are to provide communications between an appropriate aeronautical station and an aircraft station anywhere in the world for exercising control over regularity of flight and for safety of aircraft. Worldwide frequencies are not to be assigned by administrations for MWARA, RDARA and VOLMET purposes. Where the operational area of an aircraft lies wholly within a RDARA or sub-RDARA boundary, frequencies allotted to those RDARAs and sub-RDARAs shall be used.

Note 1.— Tables 27/213 and 27/218 to 27/231 appearing in Appendix 27 to the ITU Radio Regulations refer to, respectively, the Frequency Allotment Plan, listing frequencies by areas, and the Frequency Allotment Plan, listing frequencies in numerical order.

Note 2.— Guidance material on the assignment of worldwide frequencies is contained in Attachment B.

3.2 NDB frequency management

3.2.1 **Recommendation.—** *NDB frequency management should take into account the following:*

[1] The type of communications referred to in27/9 may be regulated by administrations.

a) the interference protection required at the edge of the rated coverage;

b) the application of the figures shown for typical ADF equipment;

c) the geographical spacings and the respective rated coverages;

d) the possibility of interference from spurious radiation generated by non-aeronautical sources (e.g. electric power services, power line communication systems, industrial radiation, etc.).

Note 1.— Guidance material to assist in determining the application of the foregoing is given in Attachment A.

Note 2.— Attention is drawn to the fact that some portions of the bands available for aeronautical beacons are shared with other services.

3.2.2 **Recommendation**.— *To alleviate frequency congestion problems at locations where two separate ILS facilities serve opposite ends of a single runway, the assignment of a common frequency to both of the outer locators should be permitted, and the assignment of a common frequency to both of the inner locators should be permitted, provided that:*

a) the operational circumstances permit;

b) each locator is assigned a different identification signal; and

c) arrangements are made whereby locators using the same frequency cannot radiate simultaneously.

Note.— The Standard in Annex 10, Volume I, 3.4.4.4, specifies the equipment arrangements to be made.

CHAPTER 4. UTILIZATION OF FREQUENCIES ABOVE 30 MHz

Note.— Details pertaining to the allocation of spectrum to aeronautical services, including footnoted allocations and restrictions, are contained in both the International Telecommunication Union (ITU) Radio Regulations and the ICAO Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

4.1 Utilization in the frequency band 117.975 – 137.000 MHz

Introduction

Section 4.1 deals with Standards and Recommended Practices (SARPs) relating to the use of the frequency band 117.975 – 137.000 MHz and includes matters pertaining to the selection of particular frequencies for various aeronautical purposes. These SARPs are introduced by the following preface, which sets out the principles upon which the utilization of this frequency band on a worldwide basis with due regard to economy is being planned.

Preface

The utilization of the frequency band 117.975 – 137.000 MHz on a worldwide basis with due regard to economy and practicability requires a plan that will take into account:

a) the need for an orderly evolution towards improved operation and the required degree of worldwide standardization;

b) the desirability of providing for an economic transition from present utilization to optimum utilization of the frequencies available, taking into account the maximum possible utilization of existing equipment;

c) the need to provide for coordination between international and national utilization so as to ensure mutual protection from interference;

d) the need for providing a global framework for the coordinated developmentof Regional Plans;

e) the need, in certain regions, to have more detailed plans and planning criteria in addition to the provisions in this section;

f) the desirability of incorporating in any group of frequencies to be used those now in use for international air services;

g) the need for keeping the total number of frequencies and their grouping in appropriate relation to the airborne equipment known to be widely used by international air services;

h) a requirement for the provision of a single frequency that may be used for emergency purposes on a worldwide basis and, also, in certain regions, for another frequency that may be used as a common frequency for special purposes;

and

i) the need for providing sufficient flexibility to allow for the differences in application necessitated by regional conditions.

4.1.1 General allotment of frequency band 117.975 – 137.000 MHz

Note.— The plan includes a general Allotment Table that subdivides the complete frequency band 117.975 – 137.000 MHz, the chief subdivisions being the frequency bands allocated to both national and international services, and the frequency bands allocated to national services. Observance of this general subdivision should keep to a minimum the problem of coordinating national and international application.

4.1.1.1 The block allotment of the frequency band 117.975 – 137.000 MHz shall be as shown in Table 4-1.

4.1.2 Frequency separation and limits of assignable frequencies

Note.— In the following text, the channel spacing for 8.33 kHz channel assignments is defined as 25 kHz divided by 3 which is 8.333 ... kHz.

4.1.2.1 In the frequency band 117.975 – 137.000 MHz, the lowest assignable frequency shall be 118.000 MHz and the highest 136.975 MHz.

4.1.2.2 The minimum separation between assignable frequencies in the aeronautical mobile (R) service shall be 8.33 kHz.

Note.— It is recognized that in some regions or areas, 25 kHz channel spacing provides an adequate number of frequencies suitably related to international and national air services and that equipment designed specifically for 25 kHz channel spacing will remain adequate for services operating within such regions or areas. It is further recognized that assignments based on 25 kHz channel spacing as well as 8.33 kHz channel spacing may continue to co-exist within one region or area.

4.1.2.3 Requirements for mandatory carriage of equipment specifically designed for 8.33 kHz channel spacing shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment, including the appropriate lead time.

Note.— No changes will be required to aircraft systems or ground systems operating solely in regions not using 8.33 kHz channel spacing.

4.1.2.4 Requirements for mandatory carriage of equipment specifically designed for VDL Mode 2, VDL Mode 3 and VDL Mode 4 shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment, including the appropriate lead time.

4.1.2.4.1 The agreement indicated in 4.1.2.4 shall provide at least two years' notice of mandatory carriage of airborne systems.

4.1.2.5 In regions where 25 kHz channel spacing (DSB-AM and VHF digital link (VDL)) and 8.33 kHz DSB-AM channel spacing are in operation, the publication of the assigned frequency or channel of operation shall conform to the channel contained in Table 4-1 (bis).

Note.— Table 4-1(bis) provides the frequency channel pairing plan which retains the numerical designator of the 25 kHz DSB-AM environment and allows unique identification of a 25 kHz VDL and 8.33 kHz channel.

Table 4-1. Allotment table

Block allotment frequencies (MHz)	Worldwide utilization	Remarks
a) 118.000 – 121.450 inclusive	International and National Aeronautical Mobile Services	Specific international allotments will be determined in the light of regional agreement. National assignments are covered by the provisions in 4.1.4.8 and 4.1.4.9.
b) 121.500	Emergency frequency	See 4.1.3.1. In order to provide a guard band for the protection of the aeronautical emergency frequency, the nearest assignable frequencies on either side of 121.500 MHz are 121.450 MHz and 121.550 MHz.
c) 121.550 – 121.9917 inclusive	International and National Aerodrome Surface Communications	Reserved for ground movement, pre-flight checking, air traffic services clearances, and associated operations.
d) 122.000 – 123.050 inclusive	National Aeronautical Mobile Services	Reserved for national allotments. National assignments are covered by the provisions of 4.1.4.8 and 4.1.4.9.
e) 123.100	Auxiliary frequency SAR	See 4.1.3.4. In order to provide a guard band for the protection of the aeronautical auxiliary frequency, the nearest assignable frequencies on either side of 123.100 MHz are 123.050 MHz and 123.150 MHz.
f) 123.150 – 123.6917 inclusive	National Aeronautical Mobile Services	Reserved for national allotments, with the exception of 123.450 MHz which is also used as an air-to-air communications channel (see g)). National assignments are covered by the provisions of 4.1.4.8 and 4.1.4.9.
g) 123.450	Air-to-air communications	Designated for use as provided for in 4.1.3.2.
h) 123.700 – 129.6917 inclusive	International and National Aeronautical Mobile Services	Specific international allotments will be determined in light of regional agreement. National assignments are covered by the provisions in 4.1.4.8 and 4.1.4.9.
i) 129.700 – 130.8917 inclusive	National Aeronautical Mobile Services	Reserved for national allotments but may be used in whole or in part, subject to regional agreement, to meet the requirements mentioned in 4.1.6.1.3.
j) 130.900 – 136.875 inclusive	International and National Aeronautical Mobile Services	Specific international allotments will be determined in light of regional agreement. National assignments are covered by the provisions in 4.1.4.8 and 4.1.4.9.
k) 136.900 – 136.975 inclusive	International and National Aeronautical Mobile Services	Reserved for VHF air-ground data link communications.

Table 4-1 (bis). Channelling/frequency pairing

Frequency (MHz)	*Time slot**	*Channel spacing (kHz)*	*Channel*
118.0000		25	118.000
118.0000	A	25	118.001
118.0000	B	25	118.002
118.0000	C	25	118.003
118.0000	D	25	118.004
118.0000		8.33	118.005
118.0083		8.33	118.010
118.0167		8.33	118.015
118.0250	A	25	118.021
118.0250	B	25	118.022
118.0250	C	25	118.023
118.0250	D	25	118.024
118.0250		25	118.025
118.0250		8.33	118.030
118.0333		8.33	118.035
118.0417		8.33	118.040
118.0500		25	118.050
118.0500	A	25	118.051
118.0500	B	25	118.052
118.0500	C	25	118.053
118.0500	D	25	118.054
118.0500		8.33	118.055
118.0583		8.33	118.060
118.0667		8.33	118.065
118.0750	A	25	118.071
118.0750	B	25	118.072
118.0750	C	25	118.073
118.0750	D	25	118.074
118.0750		25	118.075
118.0750		8.33	118.080
118.0833		8.33	118.085
118.0917		8.33	118.090
118.1000		25	118.100
etc.			

* Time slot indication is for VDL Mode 3 channels. (Ref. Annex 10, Volume III, Part I, Chapter 6 for characteristics of VDL Mode 3 operation)

4.1.3 Frequencies used for particular functions

4.1.3.1 *Emergency channel*

4.1.3.1.1 The emergency channel (121.500 MHz) shall be used only for genuine emergency purposes, as broadly outlined in the following:

a) to provide a clear channel between aircraft in distress or emergency and a ground station when the normal channels are being utilized for other aircraft;

b) to provide a VHF communication channel between aircraft and aerodromes, not normally used by international air services, in case of an emergency condition arising;

c) to provide a common VHF communication channel between aircraft, either civil or military, and between such aircraft and surface services, involved in common search and rescue operations, prior to changing when necessary to the appropriate frequency;

d) to provide air-ground communication with aircraft when airborne equipment failure prevents the use of the regular channels;

e) to provide a channel for the operation of emergency locator transmitters (ELTs), and for communication between survival craft and aircraft engaged in search and rescue operations;

f) to provide a common VHF channel for communication between civil aircraft and intercepting aircraft or intercept control units and between civil or intercepting aircraft and air traffic services units in the event of interception of the civil aircraft.

Note 1.— The use of the frequency 121.500 MHz for the purpose outlined in c) is to be avoided if it interferes in any way with the efficient handling of distress traffic.

Note 2.— The ITU Radio Regulations (RR 5.200) permit the use of the aeronautical emergency frequency 121.500 MHz by mobile stations of the maritime mobile service under the conditions laid down in Article 31 of the Radio Regulations for distress and safety purposes with stations of the aeronautical mobile service.

4.1.3.1.2 The frequency 121.500 MHz shall be provided at:

a) all area control centres and flight information centres;

b) aerodrome control towers and approach control offices serving international aerodromes and international alternate aerodromes; and

c) any additional location designated by the appropriate ATS authority, where the provision of that frequency is considered necessary toensure immediate reception of distress calls or to serve the purposes specified in 4.1.3.1.1.

Note.— Where two or more of the above facilities are collocated, provision of 121.500 MHz at one would meet the requirement.

4.1.3.1.3 The frequency 121.500 MHz shall be available to intercept control units where considered necessary for the purpose specified in 4.1.3.1.1 f).

4.1.3.1.4 The emergency channel shall be guarded continuously during the hours of service of the units at which it is installed.

4.1.3.1.5 The emergency channel shall be guarded on a single channel simplex operation basis.

4.1.3.1.6 The emergency channel (121.500 MHz) shall be available only with the characteristics as contained in Annex 10, Volume III, Part II, Chapter 2 (25 kHz).

4.1.3.2 *Air-to-air communications channel*

4.1.3.2.1 An air-to-air VHF communications channel on the frequency of 123.450 MHz shall be designated to enable aircraft engaged in flights over remote and oceanic areas out of range of VHF ground stations to exchange necessary operational information and to facilitate the resolution of operational problems.

Note.— Use of the air-to-air channel can cause interference to and from aircraft using the same frequency for airground communications.

4.1.3.2.2 In remote and oceanic areas out of range of VHF ground stations, the air-to-air VHF communications channel on the frequency 123.450 MHz shall be available only with the characteristics as contained in Annex 10, Volume III, Part II, Chapter 2 (25 kHz).

4.1.3.3 *Common signalling channels for VDL*

4.1.3.3.1 *Common signalling channel VDL Mode 2*. The frequency 136.975 MHz is reserved on a worldwide basis to provide a common signalling channel (CSC) to the VHF digital link Mode 2 (VDL Mode 2). This CSC uses the Mode 2 VDL modulation scheme and carrier sense multiple access (CSMA).

4.1.3.3.2 *Common signalling channels VDL Mode 4*. In areas where VDL Mode 4 is implemented, the frequencies 136.925 MHz and 113.250 MHz shall be provided as common signalling channels (CSCs) to the VHF digital link Mode 4 (VDL Mode 4). These CSCs use the VDL Mode 4 modulation scheme.

4.1.3.4 *Auxiliary frequencies for search and rescue operations*

4.1.3.4.1 Where a requirement is established for the use of a frequency auxiliary to 121.500 MHz, as described in 4.1.3.1.1 c), the frequency 123.100 MHz shall be used.

4.1.3.4.2 The auxiliary search and rescue channel (123.100 MHz) shall be available only with the characteristics as contained in Annex 10, Volume III, Part II, Chapter 2 (25 kHz).

Note.— The ITU Radio Regulations (RR 5.200) permit the use of the aeronautical auxiliary frequency 123.100 MHz by mobile stations of the maritime mobile service under the conditions laid down in Article 31 of the Radio Regulations for distress and safety purposes with stations of the aeronautical mobile service.

4.1.4 Provisions concerning the deployment

of VHF frequencies and the avoidance of harmful interference

Note.— In this section, the protected service volume of each facility is meant in the sense of avoidance of harmful interference.

4.1.4.1 The geographical separation between facilities operating on the same frequency shall, except where there is an operational requirement for the use of common frequencies for groups of facilities, be such that the protected service volume of one facility is separated from the protected service volume of another facility by a distance not less than that required to provide a desired to undesired signal ratio of 20 dB or by a separation distance not less than the sum of the distances to the associated radio horizon of each service volume, whichever is smaller.

4.1.4.2 For areas where frequency assignment congestion is severe or is anticipated to become severe, the geographical separation between facilities operating on the same frequency shall, except where there is an operational requirement for the use of common frequencies for groups of facilities, be such that the protected service volume of one facility is separated from the protected service volume of another facility by a distance not less than that required to provide a desired to undesired signal ratio of 14 dB or by a separation distance not less than the sum of the distances to the associated radio horizon of each service volume, whichever is smaller. This provision shall be implemented on the basis of a regional air navigation agreement.

Note 1.— Guidance material relating to the establishment of the minimum separation distance based on the desired to undesired signal protection ratio of 20 dB or 14 dB and radio line-of-sight is contained in Volume II of the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies(Doc 9718).

Note 2.— The application of the minimum separation distance based on the sum of the radio horizon distance of each facility assumes that it is highly unlikely that two aircraft will be at the closest points between and at the maximum altitude of the protected service volume of each facility.

Note 3.— The distance to the radio horizon from a station in an aircraft is normally given by the formula:

$$D = K \sqrt{h}$$

where D = distance in nautical miles;

h = height of the aircraft station above earth;

K = (corresponding to an effective earth's radius of 4/3 of the actual radius);

= 2.22 when his expressed in metres; and

= 1.23 when his expressed in feet.

Note 4.— In calculating the radio line-of-sight distance between a ground station and an aircraft station, the distance from the radio horizon of the aircraft station computed from Note 3 must be added to the distance from the radio horizon of the ground station. In calculating the latter, the same formula is employed, taking for h the height of the ground station transmitting antenna.

Note 5.— The criteria contained in 4.1.4.1 and 4.1.4.2 are applicable in establishing minimum geographical separation between VHF facilities, with the object of avoiding co-channel air-to-air interference. Guidance material relating to the establishment of separation distances between ground stations and between aircraft and ground stations for co-channel operations is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies(Doc 9718).

4.1.4.3 The geographical separation between facilities operating on adjacent channels shall be such that points at the edge of the protected service volume of each facility are separated by a distance sufficient to ensure operations free from harmful interference.

Note.— Guidance material covering separation distances and related system characteristics is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies(Doc 9718).

4.1.4.4 The protection height shall be a height above a specified datum associated with a particular facility, such that below it harmful interference is improbable.

4.1.4.5 The protection height to be applied to functions or to specific facilities shall be determined regionally, taking into consideration the following factors:

a) the nature of the service to be provided;

b) the air traffic pattern involved;

c) the distribution of communication traffic;

d) the availability of frequency channels in airborne equipment;

e) probable future developments.

4.1.4.6 **Recommendation**.— *Where the protected service volume is less than operationally desirable, separation between facilities operating on the same frequency should not be less than that necessary to ensure that an aircraft at the upper edge of the operational service volume of one facility does not come above the radio horizon with respect to emissions belonging to the service of adjacent facilities.*

Note.— The effect of this recommendation is to establish a geographical separation distance below which harmful interference is probable.

4.1.4.7 The geographical separation between VHF VOLMET stations shall be determined regionally and shall be such that operations free from harmful interference are secured throughout the protected service volume of each VOLMET station.

Note.— Guidance material on the interpretation of 4.1.4.7 is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

4.1.4.8 In the frequency band 117.975 – 137.000 MHz, the frequencies used for National Aeronautical Mobile Services, unless worldwide or regionally allotted to this specific purpose, shall be so deployed that no harmful interference is caused to facilities in the International Aeronautical Mobile Services.

4.1.4.9 **Recommendation**.— *The problem of inter-State interference should be resolved by consultation between the States concerned.*

4.1.4.10 The communication coverage provided by a VHF ground transmitter shall, in order to avoid harmful interference to other stations, be kept to the minimum consistent with the operational requirement for the function.

4.1.5 Method of operation

4.1.5.1 Single channel simplex operation shall be used in the frequency band 117.975 – 137.000 MHz at all stations providing service for aircraft engaged in international air navigation.

4.1.5.2 In addition to the above, the ground-to-air voice channel associated with an ICAO standard radio navigation aid may be used, subject to regional agreement, for broadcast or communication purposes or both.

4.1.6 Plan of assignable VHF radio frequencies for use in the international aeronautical mobile service

Introduction

This plan designates the list of frequencies available for assignment, together with provision for the use by the aeronautical mobile (R) service of all frequencies with a channel spacing of 25 kHz, and of all frequencies with a channel width and spacing of 8.33 kHz.

The plan provides that the total number of frequencies required in any region would be determined regionally.

In many regions particular frequencies have already been allotted for particular functions such as, for instance, aerodrome or approach control. The plan does not make such allotments (except as provided for in 4.1.1.1), such action being taken regionally if considered desirable.

4.1.6.1 The frequencies in the frequency band 117.975 – 137.000 MHz for use in the aeronautical mobile (R) service shall be selected from the lists in 4.1.6.1.1.

Note 1.— The frequencies 136.500 – 136.975 MHz inclusive are not available for assignment to channels of less than 25 kHz width.

Note 2.— Services that continue operation using 25 kHz assignments will be protected in regions implementing 8.33 kHz channel spacing.

4.1.6.1.1 List of assignable frequencies:

List A — assignable frequencies in regions or areas where 25 kHz frequency assignments are deployed:

118.000 – 121.450 MHz in 25 kHz steps
121.550 – 123.050 MHz in 25 kHz steps
123.150 – 136.975 MHz in 25 kHz steps

List B — assignable frequencies in regions or areas where 8.33 kHz frequency assignments are deployed:

118.000 – 121.450 MHz in 8.33 kHz steps
121.550 – 123.050 MHz in 8.33 kHz steps
123.150 – 136.475 MHz in 8.33 kHz steps

4.1.6.1.2 **Recommendation.—** *Frequencies for operational control communications may be required to enable aircraft operating agencies to meet the obligations prescribed in Annex 6, Part I, in which case they should be selected from a dedicated band which is determined regionally.*

Note.— It is recognized that the assignment of such frequencies and the licensing of the operation of the related facilities are matters for national determination. However, in regions where a problem exists with respect to the provision of frequencies for operational control purposes, it may be advantageous if States endeavour to coordinate the requirements of aircraft operating agencies for such channels prior to regional meetings.

4.1.6.2 The frequencies that may be allotted for use in the aeronautical mobile (R) service in a particular region shall be limited to the number determined as being necessary for operational needs in the region.

Note.— The number of frequencies required in a particular region is normally determined by the Council on the recommendations of Regional Air Navigation Meetings.

4.2 Utilization in the frequency band 108 – 117.975 MHz

4.2.1 The block allotment of the frequency band 108 – 117.975 MHz shall be as follows:

– *Band 108 – 111.975 MHz:*

a) ILS in accordance with 4.2.2 and Annex 10, Volume I, 3.1.3;

b) VOR provided that:

1) no harmful adjacent channel interference is caused to ILS;

2) only frequencies ending in either even tenths or even tenths plus a twentieth of a megahertz are used.

c) GNSS ground-based augmentation system (GBAS) in accordance with Annex 10, Volume I, 3.7.3.5, provided that no harmful interference is caused to ILS and VOR.

> *Note.— ILS/GBAS geographical separation criteria and geographical separation criteria for GBAS and VHF communication services operating in the 118 – 137 MHz band are under development. Until these criteria are defined and included in the SARPs, it is intended that frequencies in the band 112.050 – 117.900 MHz will be used for GBAS assignments.*

— Band 111.975 – 117.975 MHz:

a) VOR;

b) GNSS ground-based augmentation system (GBAS) in accordance with Annex 10, Volume I, 3.7.3.5, provided that no harmful interference is caused to VOR.

Note 1.— Guidance material relating to the distance separation required to prevent harmful interference between ILS and VOR when using the band 108 – 111.975 MHz is found in Section 3 of Attachment C to Annex 10, Volume I.

Note 2.— Guidance material relating to the distance separation required to prevent harmful interference between VOR and GBAS when using the band 112.050 – 117.900 MHz is found in Section 7.2.1 of Attachment D to Annex 10, Volume I.

4.2.2 For regional assignment planning, the frequencies for ILS facilities shall be selected in the following order:

a) localizer channels ending in odd tenths of a megahertz and their associated glide path channels;

b) localizer channels ending in odd tenths plus a twentieth of a megahertz and their associated glide path channels.

4.2.2.1 ILS channels identified by localizer frequencies ending in an odd tenth plus one twentieth of a megahertz in the band 108 – 111.975 MHz shall be permitted to be utilized on the basis of regional agreement when they become applicable in accordance with the following:

a) for restricted use commencing 1 January 1973;

b) for general use on or after 1 January 1976.

Note.— See Note to 4.2.3.1.

4.2.3 For regional assignment planning, the frequencies for VOR facilities shall be selected in the following order:

a) frequencies ending in odd tenths of a megahertz in the band 111.975 – 117.975 MHz;

b) frequencies ending in even tenths of a megahertz in the band 111.975 – 117.975 MHz;

c) frequencies ending in even tenths of a megahertz in the band 108 – 111.975 MHz;

d) frequencies ending in 50 kHz in the band 111.975 – 117.975 MHz, except as provided in 4.2.3.1;

e) frequencies ending in even tenths plus a twentieth of a megahertz in the band 108 – 111.975 MHz except as provided in 4.2.3.1.

4.2.3.1 Frequencies for VOR facilities ending in even tenths plus a twentieth of a megahertz in the band 108 – 111.975 MHz and all frequencies ending in 50 kHz in the band 111.975 – 117.975 MHz shall be permitted to be utilized on the basis of a regional agreement when they have become applicable in accordance with the following:

a) in the band 111.975 – 117.975 MHz for restricted use;

b) for general use in the band 111.975 – 117.975 MHz at a date fixed by the Council but at least one year after the approval of the regional agreement concerned;

c) for general use in the band 108 – 111.975 MHz at a date fixed by the Council but giving a period of two years or more after the approval of the regional agreement concerned.

Note.— "Restricted use", where mentioned in 4.2.2.1 a) and 4.2.3.1 a), is intended to refer to the limited use of the frequencies by only suitably equipped aircraft and in such a manner that:

a) the performance of ILS or VOR equipment not capable of operating on these frequencies will be protected from harmful interference;

b) a general requirement for the carriage of ILS or VOR airborne equipment capable of operation on these frequencies will not be imposed; and

c) operational service provided to international operators using 100 kHz airborne equipment is not derogated.

4.2.4 To protect the operation of airborne equipment during the initial stages of deploying VORs utilizing 50 kHz channel spacing in an area where the existing facilities may not fully conform with the Standards in Annex 10, Volume I, Chapter 3, all existing VORs within interference range of a facility utilizing 50 kHz channel spacing shall be modified to comply with the provisions of Annex 10, Volume I, 3.3.5.7.

4.2.5 *Frequency deployment.* The geographical separation between facilities operating on the same and adjacent frequencies shall be determined regionally and shall be based on the following criteria:

a) the required functional service radii of the facilities;

b) the maximum flight altitude of the aircraft using the facilities;

c) the desirability of keeping the minimum IFR altitude as low as the terrain will permit.

Note.— Guidance material on this subject is contained in the Attachments to this Annex.

4.2.6 **Recommendation.—** *To alleviate frequency congestion problems at locations where two separate ILS facilities serve opposite ends of the same runway or different runways at the same airport, the assignment of identical ILS localizer and glide path paired frequencies should be permitted, provided that:*

a) the operational circumstances permit;

b) each localizer is assigned a different identification signal; and

c) arrangements are made whereby the localizer and glide path not in operational use cannot radiate.

Note.— The Standards in Annex 10, Volume I, 3.1.2.7.2 and 3.1.3.9, specify the equipment arrangements to be made.

4.3 Utilization in the frequency band 960 – 1 215 MHz for DME

Note.— Guidance on the frequency planning of channels for DME systems is given in Annex 10, Volume I, Attachment C, Section 7.

4.3.1 DME operating channels bearing the suffix "X" or "Y" in Table A, Chapter 3 of Annex 10, Volume I shall be chosen on a general basis without restriction.

Note.— The channel pairing plan provides for the use of certain Y channels with either VOR or MLS. The guidance material in Annex 10, Volume I, Attachment C, Section 7, includes specific provisions relating to situations where the same, or adjacent channel, is used in the same area for both systems.

4.3.2 DME channels bearing the suffix "W" or "Z" in Table A, Chapter 3 of Annex 10, Volume I, shall be chosen on the basis of regional agreement when they become applicable in accordance with the following:

a) for restricted regional use on or after, whichever is the later:

1) 1 January 1989; or

2) a date prescribed by the Council giving a period of two years or more following approval of the regional agreement concerned;

b) for general use on or after, whichever is the later:

1) 1 January 1995; or

2) a date prescribed by the Council giving a period of two years or more following approval of the regional agreement concerned.

Note.— "Restricted use" is intended to refer to the limited use of the channel by only suitably equipped aircraft and in such a manner that:

a) the performance of existing DME equipment not capable of operating on these multiplexed channels will be protected from harmful interference;

b) a general requirement for the carriage of DME airborne equipment capable of operating on these multiplexed channels will not be imposed; and

c) operational service provided to international operators using existing DME equipment without the multiplexed channel capability is not derogated.

4.3.3 For regional assignment planning, the channels for DME associated with MLS shall be selected from Table 4-2.

Table 4-2

Group	*DME channels*	*Associated paired VHF channels*	*Remarks*	*Assignment procedure*
1	EVEN 18X to 56X	ILS 100 kHz spacings	Would normally be used if a single DME is paired with ILS and is part of MLS	for general use (see 4.3.1)
2	EVEN 18Y to 56Y	ILS 50 kHz spacings		
3	EVEN 80Y to 118Y	VOR 50 kHz spacings Odd tenths of a MHz		
4	ODD 17Y to 55Y	VOR 50 kHz spacings		
5	ODD 81Y to 119Y	VOR 50 kHz spacings Even tenths of a MHz		
6	EVEN 18W to 56W	No associated paired VHF channel		for later use (see 4.3.2)
7	EVEN 18Z to 56Z	No associated paired VHF channel		
8	EVEN 80Z to 118Z	No associated paired VHF channel		
9	ODD 17Z to 55Z	No associated paired VHF channel		
10	ODD 81Z to 119Z	No associated paired VHF channel		

Note.— DME channels in Groups 1 and 2 may be used in association with ILS and/or MLS. DME channels in Groups 3, 4 and 5 may be used in association with VOR or MLS.

4.3.3.1 *Groups 1 to 5.* These DME channels shall be permitted to be used generally. In selecting channels for assignment purposes, the following rules are applicable:

a) when an MLS/DME is intended to operate on a runway in association with an ILS, the DME channel, if possible, shall be selected from Group 1 or 2 and paired with the ILS frequency as indicated in the DME channelling and pairing table in Table A of Annex 10, Volume I, Chapter 3. In cases where the composite frequency protection cannot be satisfied for all three components, the MLS channel may be selected from Group 3, 4 or 5;

b) when an MLS/DME is intended to operate on a runway without the coexistence of an ILS, the DME channel to be used shall preferably be selected from Group 3, 4 or 5.

4.3.3.2 *Groups 6 to 10.*These DME channels shall be permitted to be used on the basis of a regional agreement when they have become applicable in accordance with the conditions specified at 4.3.2.

4.3.4 Recommendation.— Coordination of regional DME channel assignments should be effected through ICAO.

4.4 Utilization in the frequency band 5 030.4 – 5 150.0 MHz

Note 1.— Guidance material on the frequency protection planning of MLS facilities is contained in Attachment G to Annex 10, Volume I.

Note 2.— Guidance on determining coordination distances between MLS facilities and ground stations providing feeder links to non-geostationary mobile satellites is contained in ITU-R Recommendation S.1342.

4.4.1 The MLS channels shall be selected from Table A, Chapter 3 of Annex 10, Volume I.

4.4.2 For regional planning purposes, MLS channels shall be selected in accordance with the conditions specified in 4.3.3 for the associated DME facility.

4.4.3 Channel assignments in addition to those specified in 4.4.1 shall be made within the 5 030.4 – 5 150.0 MHz subband as necessary to satisfy future air navigation requirements.

ATTACHMENT A. CONSIDERATIONS AFFECTING THE DEPLOYMENT OF LF/MF FREQUENCIES AND THE AVOIDANCE OF HARMFUL INTERFERENCE

1. Particularly in areas of high density of NDBs, it is recognized that efficient planning is essential in order to: a) ensure satisfactory operation of ADF equipment, and b) provide the most efficient usage of the limited frequency spectrum available for the NDB service. It is axiomatic that regional meetings will so plan facilities as to ensure that all facilities will receive the best possible protection from harmful interference. Nevertheless, in certain regions, congestion of facilities has been such that regional meetings have had to plan in terms of a minimum protection ratio.

Regional meetings include in their planning consideration of such factors as:

a) the possibility of reducing the number of NDBs required, by coordination of system plans;

b) the possibility of reducing the coverage where a lesser grade of service than that obtainable within the rated coverage is acceptable;

c) the characteristics of ADF equipment in use;

d) the atmospheric noise grades, appropriate to the area concerned;

e) ground conductivity; and

f) interference protection required at the edge of the rated coverage.

Of the foregoing factors, that which is most susceptible to improvement of a technical kind is c).

2. The 1979 World Administrative Radio Conference adopted regulations concerning the assignment of frequencies for aeronautical radio beacons operating in the LF/MF frequency bands. A minimum protection ratio (wanted/ unwanted signal ratio) of 15 dB is to be used as the basis for frequency assignment planning (RR Appendix 12). The following data concerning the attenuation characteristics of ADF equipment were used in the EUR region to aid in the frequency assignment process:

Frequency difference (kHz)	*Attenuation (dB)*
0	0
1	1
2	6
2.4	10
3	20
3.6	30
4.3	40
5	50
6	65
7	80

The above figures (or distance separation criteria derived from them) have also been applied in other regions in determining the minimum protection ratio.

Where a bearing accuracy of ±5 degrees is required at the edge of cover, a minimum protection of 15 dB by day should be used as the basis for LF/MF channel assignment planning.

3. In view of the fact that in many regions there is a need to improve the planning criteria, it is considered that the main source from which improvement can be derived is recognition of higher attenuation figures than those given above. Regional meetings are accordingly advised that, when the congestion is such that the use of the above figures no longer permits efficient planning of the LF/MF frequency spectrum available, the following figures represent, from a technical point of view, the best that can be accepted in determining distance separation criteria:

Frequency difference (kHz)	*Attenuation (dB)*
0	0
1	6
3	35
5	65
6	80

When using these figures, it should be noted that the RF selectivity of modern ADF equipment is, in general, better than these figures and that, while the RF selectivity of older ADF equipment is not better than these figures, consideration ofthe dynamic characteristic of this older equipment shows this to be better. It could therefore be expected that frequency planning based on the new figures would considerably improve the service provided to users of modern equipment, and would not materially reduce the service presently provided to those aircraft using the older equipment. Nevertheless, in their planning, regional meetings would need to consider this question most carefully.

4. It is further noted that, in certain regions, many NDBs are used with voice channels and that this usage is aligned with the Note at the head of Annex 10, Volume I, 3.4.6. It is expected that regional meetings will take this fact into account when establishing criteria for frequency planning.

ATTACHMENT B. GUIDING PRINCIPLES FOR LONG DISTANCE OPERATIONAL CONTROL COMMUNICATIONS

Note.— The numerical sequence of the clauses below does not signify any order of relative importance.

1. Aeronautical Operational Control (AOC) HF Stations should be authorized where no other means for the exercise of long distance operational control are available or where the use of the normal communication services provided for safety and regularity of flights are unsuitable or inadequate.

2. The total number of ground stations on the worldwide radio channels should be kept to a minimum consistent with economic and operational efficiency. Consequently,

a) there should normally be not more than one station per State; and

b) where an agreed affinity of interest exists between adjoining States, a single station may be provided by agreement among them to serve the needs of all the aircraft operating agencies requiring a service into those States.

3. Depending on the national policy of the State or States, aeronautical stations could be operated by States on behalf of one or more aircraft operating agencies provided that the agencies' requirements for flexibility and direct communication to their aircraft can be met, or aeronautical stations could be operated by an aircraft operating agency or a communication agency serving the interests of one or more aircraft operating agencies and operating under licence issued by the State or States concerned.

4. The licences should be issued on a regular renewal basis and, pursuant to RR 4.11 and in accordance with RR 43.4, should prohibit "public correspondence", or point-to-point type traffic, or other communications traffic not meeting the definition of operational control communications.

5. VHF (general purpose or AOC channels) and not HF should be used when an aircraft is within the coverage of an appropriate VHF aeronautical station.

Note.— The specific categories of messages that may be handled on aeronautical mobile (R) service channels are prescribed in Annex 10, Volume II, Chapter 5, 5.1.8. The same chapter defines the standard communications procedures for the service including the requirements for maintaining watch in Annex 10, Volume II, Chapter 5, 5.2.2. In accordance with RR 18.6 of the ITU Radio Regulations, licences should define the purpose of the station for aeronautical *operational control (as defined in Annex 6, Part I) and should specify the general characteristics in accordance with Appendix 27 of the Radio Regulations*.