রেজিস্টার্ড নং ডি এ-১

বাংলাদেশ গেজেট

অতিরিক্ত সংখ্যা
কর্তৃপক্ষ কর্তৃক প্রকাশিত

বুধবার, সেপ্টেম্বর ১৮, ২০২৪

[বেসরকারি ব্যক্তি এবং কর্পোরেশন কর্তৃক অর্থের বিনিময়ে জারীকৃত বিজ্ঞাপন ও নোটিশসমূহ।]

Civil Aviation Authority of Bangladesh

Gazette

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No. **CAAB 30.31.0000.111.37.006.23** – In exercise of the power conferred by Section 47, read with Section 14 of the Civil Aviation Act, 2017 (Act No. 18 of 2017), hereinafter referred as the "Act", the Chairman of the Civil Aviation Authority of Bangladesh is pleased to issue this Air Navigation Order (ANO) "ANO-10 Vol.1 on Radio Navigation Aids".

2. This ANO shall come into force on the date of its final publication in the Official Gazette.

Air Vice Marshal **M Mafidur Rahman**
BBP, BSP, BUP, ndu, awfc, psc
Chairman
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মূল্য : টাকা ১২০.০০

CHAPTER 1. GENERAL

1.1 Short Title and Commencement

This Air Navigation Order (ANO) may be called the ANO-10 Vol-1 – *"Radio Navigation Aids"*, issued in accordance with the *ICAO Annex 10 Volume I – "ANO-10 vol-1 on Radio Navigation Aids"* (8th Edition up to *the amendment 93*) to the Chicago Convention and referred herein as the "ANO-10 Vol-1" First Edition. This ANO shall be effective immediately upon published in this Official Gazette.

1.2 Applicability

1.2.1 This Air Navigation Order— *"Radio Navigation Aids"* (hereafter referred to as the "ANO-10 Vol. I ") shall be applicable to Aeronautical Communication, Navigation, Surveillance (CNS) Service provider and all aircraft operating agencies.

1.2.2 The provisions in this ANO are based on the Standards and Recommended Practices (SARPs) adopted by the International Civil Aviation Organization (ICAO) and incorporated in the Amendment No.93 to Annex 10 Volume I – "Radio Navigation Aids"

1.2.3 Differences, where they exist, between the provisions in this ANO and those contained in the relevant ICAO Annexes shall be published in section GEN 1.7 of the Bangladesh AIP and also notified to ICAO.

1.2.4 All operators and service providers involved in installation, operation, maintenance, calibration and inspection of CNS facilities for provisioning of air navigation services within airspace of Bangladesh shall comply with all provisions set out in this ANO at all times.

1.3 Definitions

When the following terms are used in this ANO 10 Volume I – "Radio Navigation Aids", they have the following meanings:

Term	Definition
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 tolerances have 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.

Term	Definition
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 mean power 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 monitoring and 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 ANO as the concept of RNP has been overtaken by the concept of PBN. The term RNP in this ANO 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.*

Term	Definition
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 altitude which corresponds to that pressure in the Standard Atmosphere.
Protected 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.
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.

Note.— The terminology used in this ANO to refer to instrument approach operations is based on a previous version of classification of instrument approach and landing operations. It can be mapped to the ANO 6 definitions as follows:

Performance requirements in support of instrument approach operations

ANO 10 system performance		ANO 6 method — Approach operation category
Non-precision approach (NPA)		2D-Type A [(1)]
Approach with vertical guidance (APV)		3D-Type A [(2)]
Precision approach (PA)	Category I, DH equal to or greater than75 m (250 ft)	3D-Type A [(3)]
	Category I, DH equal to or greater than60 m (200 ft) and less than 75 m (250 ft)	3D-Type B — CAT I [(3)]
	Category II	3D-Type B — CAT II
	Category III	3D-Type B — CAT III

(1) Without vertical guidance.

(2) With barometric or SBAS vertical guidance.

(3) With ILS, MLS, GBAS or SBAS vertical guidance

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) N/A

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 of ICAO Annex 10 Vol-I. The title of the Attachment B is Strategy for introduction and application of non-visual aids to approach and landing. It is intended that rationalization of conventional radio navigation aids and evolution toward supporting performance-based navigation will be in accordance withthe strategy shown in Attachment H of ICAO Annex 10 Vol-I. The title of the Attachment C is Strategy for rationalization of conventional radio navigation aids and evolution toward supporting performance-based navigation.

Note 3.— Categories of precision approach and landing operations are classified in ANO 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 satellite service provided by one of its elements (Chapter 3, 3.7.2) onthe basis of at least a six-year advance notice by a service provider.

2.1.4.2 CNS/ATM Division of CAAB shall approve GNSS-based operations ensuring that GNSS data relevant to those operations are recorded.

Note 1.— These recorded data can support accident and incident investigations. They may also support periodic analysis to verify the GNSS performance parameters detailed in the relevant Standards in this ANO.

Note 2.— Guidance material on the recording of GNSS parameters and on GNSS performance assessment is contained in 11 and 12 of Attachment D of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

2.1.4.3 Recordings shall be retained for a period of at least 14 days. When the recordings are pertinent to accident and incident investigations, they shall be retained for longer periods until it is evident that they will nolonger 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 When a radio navigation aid is provided to support precision approach and landing, it shall 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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. 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.

Note.— Guidance material on the application of this Standard in the case of PBN-based operations supported by GNSS is contained in the Performance-based Navigation (PBN) Manual *(Doc 9613).*

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 ANO 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

2.5 Human Factors considerations

2.5.1 Human Factors principles shall 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. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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

3.1 Specification for ILS

3.1.1 Definitions

Term	Definition
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 centre 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.
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 30 m (100 ft) or less above the horizontal plane containing the threshold. *Note.— The lower limit is set to 30 m (100 ft) below the minimum Category I decision height (DH).*

Term	Definition
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. *Note.— The lower limit is set to 15 m (50 ft) below the minimum Category II decision height (DH).*
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.*

Term	Definition
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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.*
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.

Term	Definition
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) an appropriate means to enable glide path verification checks.

Note.— The Procedures for Air Navigation Services — Aircraft Operations *(PANS-OPS) (Doc 8168) provide guidance onthe conduct of glide path verification checks.*

3.1.2.1.1 Distance to threshold information to enable glide path verification checks shall be provided by either VHF marker beacons or distance measuring equipment (DME), together with associated monitor systems and remote control and indicator equipment.

3.1.2.1.2 If one or more VHF marker beacons are used to provide distance to threshold information, the equipment shallconform to the specifications in 3.1.7. If DME is used in lieu of marker beacons, the equipment shall conform to the specifications in 3.1.7.6.5.

Note.— Guidance material relative to the use of DME and/or other standard radio navigation aids as an alternative to themarker beacon is contained in Attachment C, 2.11, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.2.1.3 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 Facility Performance 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 Facility Performance 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.— 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 2.3.1).

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 3.1.2.1.3, 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.

3.1.2.6.1 For Facility Performance Category II and III localizers and glide paths, the level of integrity and continuity of service shall be at least Level 3, as defined in 3.1.3.12.4 (localizer) and 3.1.5.8.4 (glide path).

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 is given in 2.8 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.2.7 At those locations where two separate ILS facilities serve opposite ends of a single runway, and operationally harmful interference would be present if both facilities were transmitting, an interlock shall ensure that only the localizer serving the approach direction in use shall radiate.

Note 1.— While a low height overflight of a transmitting localizer may generate interference within airborne ILS receivers, this interference may only be considered as operationally harmful when it occurs in specific conditions, e.g. without visual cues of the runway, or when the autopilot is engaged. Additional guidance material is contained in 2.1.8 and 2.13 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

Note 2.— Interference may also be caused by transmissions from other localizers not serving the opposite end of the same runway (i.e. crossing, parallel or adjacent runways). In such cases, use of interlock to prevent the interference can also be considered.

Note 3.— An interlock can be provided through hardware, software or an equivalent procedural means.

3.1.2.7.1 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 Volume V, Chapter 4.

3.1.2.8 At those locations where an ILS facility and a GBAS facility serve opposite approach directions to the same runway, when the approach direction in use is not the direction served by the ILS, the localizer shall not radiate when GBAS low visibility operations that require GAST D are being conducted, except where it can be demonstrated that the localizer signal supports compliance with the requirements in 3.6.8.2.2.5 and 3.6.8.2.2.6 of Appendix B *of ICAO Annex 10 Vol-I*, defining the desired to undesired signal ratios and the maximum adjacent channel power tolerable by the GBAS VDB receiver. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

Note.— If the localizer is radiating there is a possibility of interference to the GBAS VDB signals in the region where the aircraft overflies the localizer. A means to ensure that the localizer does not radiate can be provided through either hardware or software interlock or a procedural mitigation. Additional guidance material is contained in Attachment C, 2.1.8.1, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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, and Attachment D, 7.2.3.3 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.1.3 VHF localizer and associated monitor

Introduction. The specifications in this section cover ILS localizers providing either positive guidance information over360 degrees of azimuth, or providing such guidance only within a specified portion of the front coverage (see 3.1.3.7.4). WhereILS localizers providing positive guidance information in a limited sector are installed, information from some suitably locatednavigation 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 onthe 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 asector 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 localizerantenna 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 alternativenavigational 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 lessthan 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 and3.1.3.3.2.3, the field strength shall be not less than 40 microvolts per metre (minus 114 dBW/m^2).

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 thelocalizer course sector from a distance of 18.5 km (10 NM) to a height of 30 m (100 ft) above the horizontal plane containing thethreshold shall be not less than 90 microvolts per metre (minus 107 dBW/m^2).

3.1.3.3.2.2 For Facility Performance Category II localizers, the minimum field strength on the ILS glide path and within thelocalizer course sector shall be not less than 100 microvolts per metre (minus 106 dBW/m^2) at a distance of 18.5 km (10 NM) increasing to not less than 200 microvolts per metre (minus 100 dBW/m^2) at a height of 15 m (50 ft) above the horizontal planecontaining 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/m^2) at a distance of 18.5 km (10 NM), increasing to not less than 200 microvolts per metre (minus 100 dBW/m^2) 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/m^2).

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 requiredfor improved integrity.

3.1.3.3.3 Above 7 degrees, the signals shall 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 of Attachment C, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 than10 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.3.3.5 *For Facility Performance Category III localizers, the ratio of the two carrier signal strengths in space within the front course sector shall 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 exceedthe 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 the ILS reference datum	0.005

and, for Facility Performance Category III only:

ILS reference datum to ILS Point "D"	0.005
ILS Point "D" to ILS Point "E"	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 courseline, when correctly adjusted.

Note 2.— Guidance material relevant to the localizer course structure is given in 2.1.3, 2.1.5, 2.1.6 and 2.1.9 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 shallbe 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 bewithin 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 percent;

b) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 1.5 percent for Facility Performance Category IIinstallations;

c) the modulating tones shall be 90 Hz and 150 Hz within plus or minus 1 percent for Facility Performance Category IIIinstallations;

d) the total harmonic content of the 90 Hz tone shall not exceed 10 percent; 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 percent.

3.1.3.5.3.1 For Facility Performance Category I — ILS, the modulating tones shall be 90 Hz and150 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 navigationtones or their harmonics to produce fluctuations in the course line, shall not exceed 0.05 per cent modulation depth of the radiofrequency 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 phasewithin the half course sector.

Note 2.— Guidance material relative to such measurement is given at Figure C-6 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 Facility Performance Categories I and II localizers: 20 degrees; and

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

2) for Facility Performance 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 carriersignal strengths are approximately equal.

3.1.3.5.3.6 The sum of the modulation depths of the radio frequency carrier due to the 90 Hz and150 Hz tones shall 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 frequencycarrier 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.3.5.3.7 When utilizing a localizer for radiotelephone communications, the sum of the modulation depths of the radiofrequency 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 Undesired frequency and phase modulation on ILS localizer radio frequency carriers that can affect the displayed DDM values in localizer receivers shall be minimized to the extent practical.

Note.— Relevant guidance material is given in 2.15 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 displacementsfrom 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 For Facility Performance Category II localizers, the mean course line shall be adjusted and maintained within limits equivalent to plus or minus 4.5 m (15 ft) displacement from runway centre line at the ILS referencedatum.

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 Facility Performance 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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. Guidance material on protecting localizer course alignment is given in 2.1.9 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 Facility Performance 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 achievedat the ILS Point "B". The maximum course sector angle shall not exceed six degrees.

Note.— Runway codes 1 and 2 are defined in ANO 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 For Facility Performance Category II — ILS, displacement sensitivity shall 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

Note 3.— Guidance material on measurement of localizer displacement sensitivity is given in 2.9 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 Facility Performance 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 modulationson 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:

a) the ratio of peak modulation depth due to the radiotelephone communications to that due to the identification signalis approximately 9:1;

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

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 carriersusing a modulation tone of 1 020 Hz within plus or minus 50 Hz. The depth of modulation shall be between the limits of 5 and15 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 asto 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 maybe 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 dot plus or minus 10 per cent. The interval between letters shall not be less than the duration of three dots.

3.1.3.10 Siting

Note.— Guidance material relevant to siting localizer antennas in the runway and taxiway environment is given in 2.1.9 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.3.10.1 For Facility Performance Categories II and III, the localizer antenna system shall be located on the extensionon 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 obstructionclearance 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 to 0.015 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 functions are provided by the use of a 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 toa 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 Facility Performance Categories II and III installations. As necessary, this problem can be dealt with through special monitoring provisions or highlyreliable 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 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 shall include the case when the DDM in the requiredcoverage 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 ina), 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 Facility Performance Category I localizers;

5 seconds for Facility Performance Category II localizers;

2 seconds for Facility Performance Category III localizers.

Note 1.— The total time periods specified are never-to-be-exceeded limits and are intended to protect aircraft in the finalstages 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 toleranceradiation including period(s) of zero radiation and time required to remove the navigation and identification components fromthe carrier, which might occur during action to restore service, for example, in the course of consecutive monitor functioningand 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 seconds has elapsed.

3.1.3.11.3.2 Where practicable, the total period under 3.1.3.11.3.1 shall be reduced so as not to exceed two seconds for Facility Performance Category II localizers and one second for Facility Performance 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.3.12 Integrity and continuity of service levels and requirements

3.1.3.12.1 A localizer shall be assigned a level of integrity and continuity of service as given in 3.1.3.12.2 to 3.1.3.12.5.

Note.— Levels are used to provide the necessary information for the determination of the category of operation and associated minima, which are a function of the Facility Performance Category, the (separate) integrity and continuity of service level, and a number of operational factors (e.g. aircraft and crew qualification, meteorological conditions, and runway features). If a localizer does not meet its required integrity and continuity of service level, some operational use may still be possible, as stated in the Manual of All-Weather Operations *(Doc 9365), Appendix C on ILS facility classification and downgrading. Similarly, if a localizer exceeds the minimum integrity and continuity of service level, more demanding operations may be possible.*

3.1.3.12.2 The localizer level shall be Level 1 if either:

a) the localizer's integrity of service or its continuity of service, or both, are not demonstrated; or

b) the localizer's integrity of service and its continuity of service are both demonstrated, but at least one of them does not meet the requirements of Level 2.

3.1.3.12.2.1 The probability of not radiating false guidance signals shall not be less than $1 - 1.0 \times 10^{-7}$ in any one landing for Level 1 localizers.

3.1.3.12.2.2 The probability of not losing the radiated guidance signal shall exceed $1 - 4 \times 10^{-6}$ inany period of 15 seconds for Level 1 localizers (equivalent to 1 000 hours mean time between outages).

Note.— A localizer that meets both Recommended Practices 3.1.3.12.2.1 and 3.1.3.12.2.2 also meets Standard 3.1.3.12.3 (Level 2 performance) and is therefore to be identified as Level 2.

3.1.3.12.2.3 In the event that the integrity value for a Level 1 localizer is not available or cannot bereadily calculated, a detailed analysis shall be performed to assure proper monitor fail-safe operation.

3.1.3.12.3 The localizer level shall be Level 2 if:

a) the probability of not radiating false guidance signals is not less than $1 - 1.0 \text{ x } 10^{-7}$ in any one landing; and

b) the probability of not losing the radiated guidance is greater than $1 - 4 \times 10^{-6}$ in any period of 15 seconds (equivalent to 1 000 hours mean time between outages).

3.1.3.12.4 The localizer level shall be Level 3 if:

a) the probability of not radiating false guidance signals is not less than $1 - 0.5 \times 10^{-9}$ in any one landing; and

b) the probability of not losing the radiated guidance is greater than $1 - 2 \times 10^{-6}$ in any period of 15 seconds (equivalentto 2 000 hours mean time between outages).

3.1.3.12.5 The localizer level shall be Level 4 if:

a) the probability of not radiating false guidance signals is not less than $1 - 0.5 \times 10^{-9}$ in any one landing; and

b) the probability of not losing the radiated guidance is greater than $1 - 2 \times 10^{-6}$ in any period of 30 seconds (equivalentto 4000 hours mean time between outages).

Note.— Guidance material on ways to achieve integrity and continuity of service is given in Attachment C, 2.8, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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:

$$2N_1 + N_2 + 72 \leq 0$$

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

and

$$2N_1 + N_2 + 3\,(24 - 20\log\frac{\Delta f}{0{,}4}) \leq 0$$

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-orderintermodulation product on the desired ILS localizer frequency.

N_1 and N_2 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.

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

3.1.4.2 The ILS localizer 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 receiver input (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 containedin Attachment C, 2.2.2, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 tonepredominating above the path to at least an angle equal to 1.75 θ.

3.1.5.1.2 The ILS glide path angle shall be 3 degrees. ILS glide path angles in excess of 3 degrees shall 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 θ for Facility Performance Categories I and II — ILS glide paths;

b) 0.04 θ from θ for 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 and figure C-5 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

Note 3.— Guidance material relevant to protecting the ILS glide path course structure is given in 2.1.9 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.5.1.3 The downward extended straight portion of the ILS glide path shall pass through the ILS reference datum at aheight 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 The height of the ILS reference datum for Facility Performance Category I — ILS shallbe 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 thresholdor to adjust the permitted operating minima.

Note 2.— Appropriate guidance material is given in 2.4 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.5.1.6 The height of the ILS reference datum for Facility Performance Category I — ILS used onshort precision approach runway codes 1 and 2 shall 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 frequencycarrier 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 the assigned frequency. With all tolerances applied, the frequency separation between the carriers shall not be less than 4 kHz nor 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 least 18.5km (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/m^2). 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 directlytoward the facility.

Note 2.— Guidance material on significant airborne receiver parameters is given in 2.2 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

Note 3.— Material concerning reduction in coverage outside 8 degrees on each side of the centre line of the ILS glide pathappears in 2.4 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 whichexceed the following:

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

3.1.5.4.2 For Facility Performance Categories II and III — ILS glide paths, bends in the glide path shall not haveamplitudes 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 ILSglide 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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. Guidancematerial relevant to protecting the ILS glide path course structure is given in 2.1.9 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 to 42.5 percent.

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 percent for Facility Performance Category I — ILS;

b) the modulating tones shall be 90 Hz and 150 Hz within 1.5 percent for Facility Performance Category II — ILS;

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

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

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

3.1.5.5.2.1 For Facility Performance Category I — ILS, the modulating tones shall be 90 Hz and150 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, or at other noise frequencies, shall not exceed 1 percent.

3.1.5.5.3 The modulation shall be phase-locked so that within the ILS half glide path sector, the demodulated 90 Hz and150 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 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 90 Hz. Similarly, the 150 Hz tones of the two carriers shall be phaselocked so that the demodulated waveforms pass through zero in the same direction, within:

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

2) for Facility Performance 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 sector where the two carrier signal strengths are approximately equal.

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

Note.— Relevant guidance material is given in 2.15 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 θ and 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 For Facility Performance Category I — ILS glide paths, the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at 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 shall 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 θ above path with a tolerance of plus 0.02 θ and 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 at angular displacements above and below the glide path of 0.12 θ with a tolerance of plus orminus 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 isreached. This value shall be achieved at an angle not less than 0.30 θ above 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 θ or 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.5.6.6 For Facility Performance Category I — ILS glide paths, the angular displacement sensitivity shall be adjustedand maintained within plus or minus 25 percent of the nominal value selected.

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

3.1.5.6.8 For Facility Performance Category III — ILS glide paths, the angular displacement sensitivity shall be adjustedand maintained within plus or minus 15 percent 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 specified in 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 θ to plus 0.10 θ from 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 Facility Performance 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 percent from the nominalvalue;

e) for Facility Performance Categories II and III — ILS glide paths, a change of displacement sensitivity to a value differing by more than 25 percent 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 θ from horizontal.

Note 4.— Guidance material relating to the condition described in g) appears in Attachment C, 2.4.11, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.5.7.2 Monitoring of the ILS glide path characteristics to smaller tolerances shall bearranged 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 Facility Performance Category I — ILS glide paths;

2 seconds for Facility Performance 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 seconds has elapsed.

3.1.5.7.3.2 *Where practicable, the total period specified under 3.1.5.7.3.1 for Facility Performance Categories II and III — ILS glide paths shall 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.5.8 Integrity and continuity of service levels and requirements

3.1.5.8.1 A glide path shall be assigned a level of integrity and continuity of service as given in 3.1.5.8.2 to 3.1.5.8.4.

Note.— Levels are used to provide the necessary information for the determination of the category of operation and associated minima, which are a function of the Facility Performance Category, the (separate) integrity and continuity of service level, and a number of operational factors (e.g. aircraft and crew qualification, meteorological conditions, and runway features). If a glide path does not meet its required integrity and continuity of service level, some operational use may still be possible, as stated in the Manual of All-Weather Operations *(Doc 9365), Appendix C on ILS facility classification and downgrading. Similarly, if a glide path exceeds the minimum integrity and continuity of service level, more demanding operations may be possible.*

3.1.5.8.2 The glide path level shall be Level 1 if either:

a) the glide path's integrity of service or its continuity of service, or both, are not demonstrated; or

b) the glide path's integrity of service and its continuity of service are both demonstrated, but at least one of them does not meet the requirements of Level 2.

3.1.5.8.2.1 The probability of not radiating false guidance signals shall not be less than $1 - 1.0 \times 10^{-7}$ in any one landing for Level 1 glide paths.

3.1.5.8.2.2 The probability of not losing the radiated guidance signal shall exceed $1 - 4 \times 10^{-6}$ inany period of 15 seconds for Level 1 glide paths (equivalent to 1 000 hours mean time between outages).

Note.— A glide path that meets both Recommended Practices 3.1.5.8.2.1 and 3.1.5.8.2.2 also meets Standard 3.1.5.8.3 (Level 2 performance) and is therefore to be identified as Level 2.

3.1.5.8.2.3 In the event that the integrity value for a Level 1 glide path is not available or cannot bereadily calculated, a detailed analysis shall be performed to assure proper monitor fail-safe operation.

3.1.5.8.3 The glide path level shall be Level 2 if:

a) the probability of not radiating false guidance signals is not less than $1 - 1.0 \times 10^{-7}$ in any one landing; and

b) the probability of not losing the radiated guidance is greater $1 - 4 \times 10^{-6}$ in any period of 15 seconds (equivalent to 1 000 hours mean time between outages).

3.1.5.8.4 The glide path level shall be Level 3 or 4 if:

a) the probability of not radiating false guidance signals is not less than $1 - 0.5 \times 10^{-9}$ in any one landing; and

b) the probability of not losing the radiated guidance is greater than $1 - 2 \times 10^{-6}$ in any period of 15 seconds (equivalent to 2 000 hours mean time between outages).

Note 1.— The requirements for glide path Level 3 and Level 4 are the same. The declaration of the glide path integrity and continuity of service levels shall match the declaration of the localizer (i.e. the glide path is declared as Level 4 if the localizer is meeting Level 4).

Note 2.— Guidance material on ways to achieve integrity and continuity of service is given in 2.8 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 followinglist:

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

Sequence number	*Localizer (MHz)*	*Glide path (MHz)*
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

Note.— Requirements relating to marker beacons apply only when one or more marker beacons are installed.

3.1.7.1 General

a) There shall be two marker beacons in each installation except where, in the opinion of the Competent Authority, a single marker beacon is considered to be sufficient. 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) A marker beacon 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. When the installation comprises only one marker beacon, the requirements applicable to either the middle or the outer marker shall be complied with. If marker beacons are replaced by DME, the requirements of 3.1.7.6.5 shall apply.

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 clearlydistinguishable 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 coverage over the following distances, measured on theILS glide path and localizer course line:

a) *inner marker:* 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/m^2). In addition, the field strength within the coverage area shall rise to at least 3.0 millivolts per metre (minus76 dBW/m^2).

Note 1.— In the design of the ground antenna, it is advisable to ensure that an adequate rate of change of field strength isprovided 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:* 3 000 Hz;

b) *middle marker:* 1 300 Hz;

c) *outer marker:* 400 Hz.

The frequency tolerance of the above frequencies shall be plus or minus 2.5 percent, and the total harmonic content of each ofthe frequencies shall not exceed 15 percent.

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

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:* 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 percent.

3.1.7.6 Siting

3.1.7.6.1 The inner marker 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 If the radiation pattern is vertical, the inner marker shall 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 shall 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.1.7.6.1.2 If the radiation pattern is other than vertical, the equipment shall be located so as toproduce 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 If the radiation pattern is vertical, the middle marker shall be located 1 050 m (3 500ft) 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 (250ft) from the extended centre line of the runway.

Note.— See 2.10 of Attachment C of ICAO Annex 10 Vol-I, regarding the siting of inner and middle marker beacons. The title of the Attachment C is 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.

3.1.7.6.2.2 If the radiation pattern is other than vertical, the equipment shall be located so as toproduce 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 The outer marker shall 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 If the radiation pattern is vertical, the outer marker shall 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 shall 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 ANO 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 transmita 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 percent of normal.

3.1.7.7.2 For each marker beacon, suitable monitoring equipment shall 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 ANO 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 m^2 echoing area or larger, which is within a space bounded by a 20-degree azimuth sector and a 7-degree elevation 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 m^2;

small twin-engined aircraft: from 15 m^2;

medium twin-engined aircraft: from 25 m^2;

four-engined aircraft: from 50 to 100 m^2.

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 ofthe 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 200m (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 thecentre line of the runway. Alternatively, if the equipment is aligned to scan 15 degrees to one side and 5 degrees to the 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 (Figures C-14 to C-17 inclusive) Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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..

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 lineshall be either 0.6 percent of the distance from the PAR antenna plus 10 percent 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 thedeviation 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 the error at the touchdown shall not exceed 6 m (20 ft). The equipment shall be so aligned and adjusted that the displayed error at the touchdown shall be a minimum and shall not exceed 0.2 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 120m (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 The surveillance radar element (SRE)

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 m^2 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 degreesabove 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 at2 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 degreesabove the horizontal plane of the antenna, and by a 20-degree line from the intersection with the 2 400 m (8000 ft) line to theantenna.

3.2.4.2.2 Efforts shall be made in development to increase the coverage on an aircraft of 15 m^2echoing area to at least the volume obtained by amending 3.2.4.2.1 with the following substitutions:

— for *1.5 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 (Figure C-18) Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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..

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 percent of the true distance from the point of observation or 230 m (750 ft), whichever is the greater.

3.2.4.3.2.1 The error in distance indication shall not exceed 3 percent 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 Efforts shall 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 the reference 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 percent.

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 percent.

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 carrier of the existing VORs is reduced to plus or minus 0.002 percent.

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 radiationshall 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 Coverage

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 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 shall be 90 microvolts per metre or minus 107 dBW/m^2.

Note.— Typical equivalent isotropically radiated powers (EIRPs) to achieve specified ranges are contained in 3.1 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.. 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 this FM subcarrier is fixed without respect to azimuth and istermed 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 andup 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 960Hz shall be within the limits of 28 percent and 32 percent.

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 percent. The depth of modulation of the radio frequency carrierdue 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 centon facilities without voice modulation, and within the limits of 20 to 35 percent 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 percent.

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

3.3.5.6

a) For the conventional VOR, the percentage of amplitude modulation of the 9 960 Hz subcarrier shall not exceed5 percent.

b) For the Doppler VOR, the percentage of amplitude modulation of the 9 960 Hz subcarrier shall not exceed 40 percent 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 percent.

3.3.6.3 The audio frequency characteristics of the speech channel shall be within 3 dB relative to the level at 1000 Hz over the range 300 Hz to 3000 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 besent 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 1020 Hz within plus or minus 50 Hz.

3.3.6.5.1 The identification signal shall 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 3.5.3.6.4influence 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 percent except that, where a communication channel is not provided, it shall be permissible to increasethe modulation by the code identification signal to a value not exceeding 20 percent.

3.3.6.6.1 If the VOR provides a simultaneous communication channel ground-to-air, the modulation depth of the code identification signal shall be 5 plus or minus 1 percent in order to provide a satisfactory voicequality.

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 percent 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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, and Attachment E of ICAO Annex 10 Vol-I. The title of the Attachment E is Guidance material on the pre-flight checking of VOR airborne equipment.

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:

$$2N_1 + N_2 + 72 \leq 0$$

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

and

$$2N_1 + N_2 + 3\,(24 - 20 \log \frac{\Delta f}{0,4}) \leq 0$$

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 VOR frequency.

N_1 and N_2 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.

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N_1, 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 levelsin accordance with the following table:

Frequency (MHz)	*Maximum level of unwanted signal atreceiver input (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 3.3.8.1 and 3.3.8.2 is containedin Attachment C, 3.6.5, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.4 Specification for non-directional radio beacon (NDB)

3.4.1 Definitions

Note.— Guidance is given on the meaning and application of rated coverage and effective coverage andon coverage of NDBs in attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 thenature 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 The minimum value of field strength in the rated coverage of an NDB shall be70°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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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, 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 shall 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 coverageover 278 km (150 NM) to the nearest multiple of 92.7 km (50 NM).

3.4.2.3 Where the rated coverage of an NDB is materially different in various operationally significant sectors, its classification shall 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 shall be kept to a minimum and preferablyshall not exceed two.

Note.— The average radius of a given sector of the rated coverage is equal to the radius of the corresponding circle-sectorof 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 above200 W using frequencies of 1 606.5 kHz and above, the tolerance shall be 0.005 per cent.

3.4.4.3 Where two locators are used as supplements to an ILS, the frequency separation betweenthe carriers of the two shall 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 that the 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 Except for those cases where the beacon identification is effected by on/off keying of the carrier, the identification signal shall 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 unmodulated 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 95 per 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, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.4.6.4 The carrier power of an NDB with NON/A2A emissions shall 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 (50NM), 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 thebeacon 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 oftechnique 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 Where locators are used as a supplement to the ILS, they shall 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 shall 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 shall be selected, taking into accountthe relevant obstacle clearance provisions of the PANS-OPS *(Doc 8168).*

3.4.7.2 Where locators are installed at both the middle and outer marker positions, they shall 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 than 50 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 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 shall be capable of detecting such powersupply 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 During the hours of service of an NDB other than a locator, the means of monitoring shall 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.5 Specification for UHF distance measuring equipment (DME)

Note.— In the following section, provision is made for two types of DME facility: DME/N for general application, andDME/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 frequencycan 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 pulseenvelope, 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 desiredcourse 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 pulseenvelope, 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 pulseenvelope, 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 owninterrogations 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 leadingedge 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 distanceof 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. Theaircraft 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 N/A

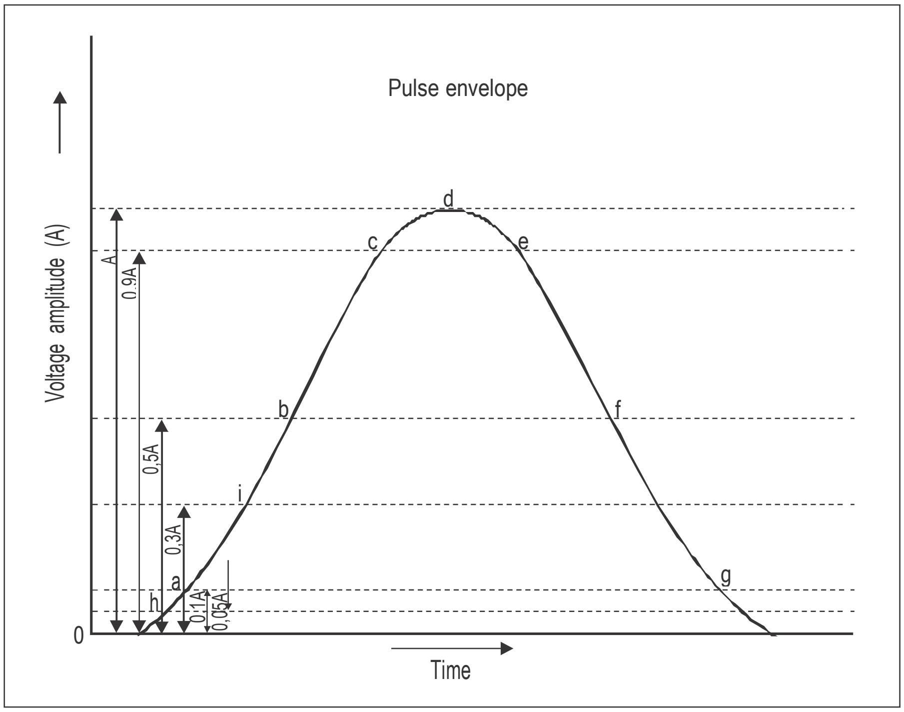

Figure 3-1

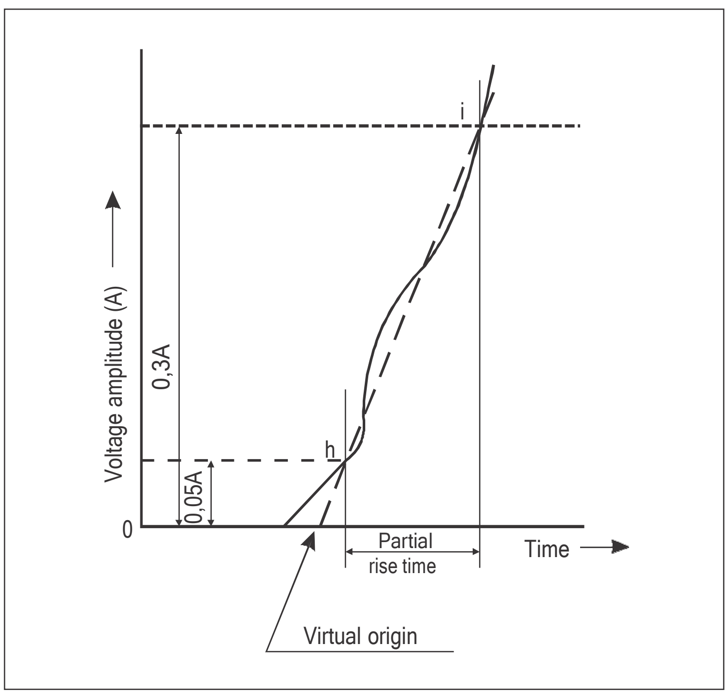

Figure 3-2

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 fixingaccuracy 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.— Guidance on the association of DME with ILS is given in 2.11 of Attachment C of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

3.5.2.6.3 N/A

3.5.2.7 The Standards in 3.5.3, 3.5.4 and 3.5.5 denoted by shall apply only to DEM 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 ILSor of the MLS azimuth angle guidance coverage sectors.

3.5.3.1.2.3 N/A

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 N/A

3.5.3.2 *Radio frequencies and polarization.* The system shall operate with vertical polarization in the frequency band960 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 N/A

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 (seeVolume 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. After 15 000 pairs of pulses have been transmitted without acquiring indication of distance, the PRF shall 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 N/A

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 Where the peak traffic in an area exceeds 100 aircraft, the transponder shall be capable of handling that peak traffic.

Note.— Guidance material on aircraft handling capacity will be found in Attachment C, 7.1.5, of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 withall 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.

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. If it is desired to preserve a constant duty cycle, an equalizing pair of pulses, having the same characteristics as the identification pulse pairs, shall be transmitted 100 microseconds plus or minus10 microseconds after each identity pair.

3.5.3.6.2.3 N/A

3.5.3.6.2.4 N/A

3.5.3.6.2.5 N/A.

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 in the 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 durationbetween 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 directlyin the airborne equipment as an aural output for the pilot, or other frequencies may be generated at the option of the interrogator 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) N/A

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 N/A

3.5.3.8 N/A.

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 DMEchannel (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 centfrom 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 ofthe pulse in the partial rise time shall not vary by more than plus or minus 20 percent. For accuracy standard 2, the slope shall not vary by more than plus or minus 10 percent.

3) DME/P. Pulse rise time shall 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 percent 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 thenominal 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. The tolerance on the DME/N pulse spacing shall be plus or minus 0.10 microsecond.

3.5.4.1.4.4 N/A.

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. The peak EIRP shall not be less than that required to ensure a peak pulse power density of approximately minus 83 dBW/m^2 at 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/m^2 under all operational weather conditions at any point within coverage specifiedin 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 N/A

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

3.5.4.1.5.5 *The reply capability of the transmitter shall be such that the transponder shall 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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.

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 N/A

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 peak power density at the transponder antenna is at least:

a) minus 103 dBW/m^2 for DME/N with coverage range greater than 56 km (30 NM);

b) minus 93 dBW/m^2 for DME/N with coverage range not greater than 56 km (30 NM);

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 efficiencyof at least:

a) 70 per cent for DME/N;

‡3.5.4.2.3.3 *DME/N dynamic range.* The performance of the transponder shall be maintained when the power density ofthe 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/m^2 when installed with ILS or MLS and minus 35 dBW/m^2 when installed for other applications.

3.5.4.2.3.4 N/A

3.5.4.2.3.5 The transponder sensitivity level shall not vary by more than 1 dB for transponder loadings between 0 and 90per 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 N/A

3.5.4.2.4 Load limiting

3.5.4.2.4.1 DME/N. When transponder loading exceeds 90 per cent of the maximum transmission rate, the receiver sensitivity shall 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 shall be at least 50 dB.)

3.5.4.2.4.2 N/A

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 signalsare those specified in 3.5.5.1.3.

3.5.4.2.6.3 N/A

3.5.4.2.6.4 N/A

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 withinthe 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 statedin 3.5.4.1.6.

3.5.4.2.9 CW and echo suppression

CW and echo suppression shall 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

Protection against interference outside the DME frequency band shall be adequate for the sites atwhich 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 N/A

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 edgeof 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.

		Pulse pair spacing (μs)		*Time delay (μs)*	
Channel suffix	*Operating mode*	*Interrogation*	*Reply*	*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	–

		Pulse pair spacing (μs)		*Time delay (μs)*	
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 N/A

3.5.4.4.2.1 N/A

3.5.4.4.3 For the DME/N the transponder time delay shall 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 *N/A*

3.5.4.4.3.3 *N/A*

3.5.4.4.4 DME/N. Transponders shall 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 of ICAO Annex 10 Vol-I. The title of the Attachment C is 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 and 5 of Attachment G of ICAO Annex 10 Vol-I. The title of the Attachment C is Information and material for guidance in the application of the MLS Standards and Recommended Practices. 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. 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 shall 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 theairborne 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 systemerror.

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)) to the overall system error.

3.5.4.5.3 N/A.

3.5.4.5.4 N/A

3.5.4.5.5 N/A

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 N/A

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 The monitor shall 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 3.5.4.4.1by 1 microsecond or more.

3.5.4.7.2.4 The monitor shall 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 more than 120 times per second for either monitoring or automatic frequency control purposes, or both.

3.5.4.7.2.7 N/A

3.5.4.7.3 N/A

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.

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 percent of maximum amplitude and the point of the trailing edge which is 95 percent 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 spectrumcontrol 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 powercontained 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. The tolerance on the pulse spacing shall be plus or minus 0.25 micro-second.

3.5.5.1.4.4 N/A.

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 N/A

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 replyfrequency shall not exceed 20 microwatts (minus 47 dBW).

Note.— Although spurious CW radiation between pulses is limited to levels not exceeding minus 47 dBW, CNS/ATM Division of CAAB shall be responsible where DME interrogators and secondary surveillance radar transponders are employed in the same aircraft, itmay be necessary to provide protection to airborne SSR in the band 1 015 MHz to 1 045 MHz. This protection may be providedby 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 tobe noted that only a few of these frequencies are utilized in the VHF/DME pairing plan.

3.5.5.1.7 The spurious pulse power received and measured under the conditions stated in 3.5.5.1.6 shall 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, CNS/ATM Division of CAAB shall employ airbornesecondary 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 N/A

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 reach the 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 condation corresponding to zero distance indications

3.5.5.2.4 N/A

3.5.5.2.5 N/A

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 N/A

‡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 minimum values given in 3.5.4.1.5 and a maximum of minus 18 dBW/m^2.

3.5.5.3.2.4 N/A.

3.5.5.3.3 Bandwidth

3.5.5.3.3.1 *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 3.5.4.1.3.

3.5.5.3.3.2 N/A.

3.5.5.3.3.3 N/A.

3.5.5.3.4 Interference 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 N/A.

3.5.5.3.5 Decoding

3.5.5.3.5.1 The interrogator shall include a decoding circuit such that the 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 to 42 dB above the receiver sensitivity shall be rejected.

3.5.5.3.5.3 N/A.

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 N/A

3.5.5.4.3 N/A

3.5.5.4.4 N/A

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 orminus 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 Bangladesh 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 of ICAO Annex 10 Vol-I,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. The title of the Attachment C is 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.

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. The radiation pattern of a marker beacon normally shall 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. For each marker beacon, suitable monitoring equipment shall 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 anavigation system is out of tolerance.

Alert limit. For a given parameter measurement, the error tolerance not to be exceeded without issuing an alert.

Antenna port. A point where the received signal power is specified. For an active antenna, the antenna port is a fictitious point between the antenna elements and the antenna pre-amplifier. For a passive antenna, the antenna port is the output of the antenna itself.

Axial ratio. The ratio, expressed in decibels, between the maximum output power and the minimum output power of an antenna to an incident linearly polarized wave as the polarization orientation is varied over all directions perpendicular to the direction of propagation.

BeiDou Navigation Satellite System (BDS). The satellite navigation system operated by China.

BDS Open Service (BDS OS). The specified level of positioning, velocity and timing accuracy that is available to any BDS user on a continuous, worldwide basis.

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, GLONASS, Galileo and BDS.

Galileo. The satellite navigation system operated by the European Union.

Galileo Open Service (Galileo OS). The specified level of positioning, velocity and timing accuracy that is available to any Galileo user on a continuous, worldwide basis.

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).

Ionosphere-free pseudo-range. A pseudo-range in which the first order ionosphere effect on signal propagation has been removed by a linear combination of pseudo-range measurements from signals on two distinct frequencies from the same satellite.

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 3.7.3.1.1;

b) Global Navigation Satellite System (GLONASS) that provides the Channel of Standard Accuracy (CSA) as defined in 3.7.3.1.2;

c) Galileo that provides a single- and dual-frequency Open Service (OS) as defined in 3.7.3.1.3;

d) BeiDou Navigation Satellite System (BDS) that provides the BDS Open Service (BDS OS) as defined in 3.7.3.1.4;

e) aircraft-based augmentation system (ABAS) as defined in 3.7.3.3;

f) satellite-based augmentation system (SBAS) as defined in 3.7.3.4;

g) ground-based augmentation system (GBAS) as defined in 3.7.3.5;

h) ground-based regional augmentation system (GRAS) as defined in 3.7.3.5; and

i) aircraft GNSS receiver as defined in 3.7.3.6.

Note.— In order to provide system integrity monitoring, the use of an augmentation as specified in 3.7.2.2.1 e), f), g) or h)is required to meet the performance requirements of 3.7.2.4.

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 ANO 4, Chapter 2, ANO 11, Chapter 2, ANO 14, Volumes I and II, Chapter 1 and ANO 15, Chapter 1.

Note 2.— If GNSS elements using other than WGS-84 coordinates are employed, appropriate conversion parameters are to be applied. If the difference between a GNSS geodetic reference and WGS-84 is negligible for aviation (e.g. of the order of a few centimetres) and a bounding of the maximum difference is specified, then no conversion parameters need 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 Coordinated Universal Time (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 3.7).

Note 1.— 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.

Note 2.— For GBAS approach service (as defined in Attachment D, 7.1.2.1 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.) intended to support approach and landing operations using Category III minima, performance requirements are defined that apply in addition to the signal-in-space requirements defined in Table 3.7.2.4-1.

3.7.3 GNSS elements specifications

3.7.3.1 Core constellations

3.7.3.1.1 GPS Standard Positioning Service (SPS) (L1, L5)

Note.— Unless otherwise specified, the performance standards in 3.7.3.1.1.1 to 3.7.3.1.1.7 below apply to single-frequency ranging, using the L1 coarse acquisition (C/A) code signal or the L5 signal (I5 code or Q5 code), and to dual-frequency ranging using the combination of L1 and L5 signals. In addition, they only apply to current and consistent ephemeris and clock data within the respective curve fit intervals.

3.7.3.1.1.1 Space and control segment accuracy

Note.— The following accuracy standards apply only for healthy GPS SPS signal-in-space (SIS), during normal operations as described in Attachment D, 4.1.1.9 of ICAO Annex 10 Vol-I, and do not include atmospheric or receiver errors as described in Attachment D, 4.1.1.2 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.. GPS SPS SIS health conditions can be found in the United States Department of Defense, Global Positioning System – Standard Positioning Service – Performance Standard*, 5th Edition, April 2020 (hereinafter referred to as "GPS SPS PS"), 2.3.2.*

3.7.3.1.1.1.1 *Positioning accuracy*. The single-frequency L1 C/A code position errors shall not exceed the following limits:

	Global average 95% of the time	Worst site 95% of the time
Horizontal position error	8 m	15 m
Vertical position error	13 m	33 m

3.7.3.1.1.1.2 *Time transfer accuracy*. The GPS SPS time transfer errors shall not exceed 30 nanoseconds 95 per cent of the time.

3.7.3.1.1.1.3 *Range domain accuracy*. The range domain error shall not exceed the following limits during normal operations over all ages of data:

a) range error of any satellite — 30 m with reliability specified in 3.7.3.1.1.3;

b) 95th percentile range rate error of any satellite — 0.006 m per second (global average);

c) 95th percentile range acceleration error of any satellite — 0.002 m per second-squared (global average);

d) 95th percentile range error for any satellite7.0 m (global average); and

e) 95th percentile range error across all satellites occupying defined slots in the constellation — 2.0 m (global average).

3.7.3.1.1.2 *Availability*. The availability for single-frequency L1 C/A code users shall be as follows:

≥99 per cent horizontal service availability, average location (15 m 95 per cent threshold)

≥99 per cent vertical service availability, average location (33 m 95 per cent threshold)

≥90 per cent horizontal service availability, worst-case location (15 m 95 per cent threshold)

≥90 per cent vertical service availability, worst-case location (33 m 95 per cent threshold)

3.7.3.1.1.3 *Reliability*. The GPS SPS reliability relative to the 30 m user range error (URE) statistic in 3.7.3.1.1.1.3 a) shall be within the following limits:

a) reliability — at least 99.94 per cent (global average); and

b) reliability — at least 99.79 per cent (worst single point average).

3.7.3.1.1.4 Probability of major service failure.

Note.— The different alert indications are described in the GPS SPS PS, 2.3.4.

3.7.3.1.1.4.1 *Satellite major service failure onset rate (R_{sat}).* The probability that the instantaneous user range error (URE) of any satellite will exceed 4.42 times the relevant integrity assured user range accuracy (IAURA) value broadcast by that satellite without an alert received at the user receiver antenna within 10 seconds shall not exceed 1×10^{-5} per hour.

3.7.3.1.1.4.2 *Probability of a satellite major service failure condition (P_{sat}).* The probability at any given instant that the instantaneous URE of any satellite will exceed 4.42 times the relevant IAURA value broadcast by that satellite without an alertreceived at the user receiver antenna within 10 seconds shall not exceed 1×10^{-5}.

3.7.3.1.1.4.3 *Probability of a common-cause major service failure condition (P_{const}).* The probability at any given instant that the instantaneous URE of two or more satellites will exceed 4.42 times the relevant IAURA broadcast by each satellite dueto a common fault without an alert received at the user receiver antenna within 10 seconds shall not exceed 1×10^{-8}.

3.7.3.1.1.5 *Continuity.* The probability of losing L1 C/A SIS availability from a slot of the 24-slot constellation due to unscheduled interruption shall not exceed 2×10^{-4} per hour.

3.7.3.1.1.6 *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 , major service failure, continuity and coverage is given in Attachment D, 4.1.1 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices. Additional information is given in the GPS SPS PS.

3.7.3.1.1.7 *Constellation availability*. The probability that 21 or more of the 24 slots will be occupied by either a satellite broadcasting a trackable and healthy L1 C/A signal in the baseline slot configuration or by a pair of satellites each broadcasting a trackable and healthy L1 C/A signal in the expanded slot configurations, shall be at least 0.98. The probability that 20 or more of the 24 slots will be occupied by either a satellite broadcasting a trackable and healthy L1 C/A signal in the baseline slot configuration or by a pair of satellites each broadcasting a trackable and healthy L1 C/A signal in the expanded slot configurations, shall be at least 0.99999.

Note.— There is currently no corresponding standard for the L5 signal or for the combined L1 C/A and L5 signals since older satellites in the constellation do not have the capability to broadcast an L5 signal.

3.7.3.1.1.8 Radio frequency (RF) characteristics

Note.— Detailed RF characteristics are specified in NAVSTAR GPS Space Segment/Navigation User Segment Interfaces, IS No. IS-GPS-200, Rev K (hereinafter referred to as "IS-GPS-200K") for L1 and NAVSTAR GPS Space Segment/User Segment L5 Interfaces, IS No. IS-GPS-705, Rev F (hereinafter referred to as "IS-GPS-705F"); selected characteristics are specified in Appendix B of ICAO Annex 10 Vol-I, 3.1.1.1.1 for L1 and Appendix B of ICAO Annex 10 Vol-I, 3.1.1.1.4 for L5. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.1.8.1 *L1 carrier frequency*. Each GPS satellite shall broadcast an SPS ranging signal at the carrier frequency of 1 575.42 MHz (GPS L1) using code division multiple access (CDMA).

3.7.3.1.1.8.2 *L5 carrier frequency*. Some GPS satellites shall, in addition, broadcast an SPS ranging signal at the carrier frequency of 1 176.45 MHz (GPS L5) using CDMA.

3.7.3.1.1.8.3 *Signal spectrum*. The L1 and L5 signal power shall be contained within ±12 MHz bands centred on the respective carrier frequencies: 1 563.42 –1 587.42 MHz for L1 and 1 164.45 – 1 188.45 for L5.

3.7.3.1.1.8.4 *Polarization*. The transmitted L1 and L5 RF signals shall be right-hand circularly polarized.

3.7.3.1.1.8.5 *Signal structure*. The L1 C/A signal shall consist of one carrier component. The L5 signal shall consist of two carrier components: an in-phase component (I5) and a quadrature component lagging the in-phase component by 90 degrees (Q5).

3.7.3.1.1.8.6 *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 antenna port of a 3 dBi linearly-polarized antenna is within the following ranges for all antenna orientations orthogonal to the direction of propagation: –158.5 dBW to –153 dBW for L1 C/A and –157.9 dBW to –150 dBW for each of the I5 and Q5 channels on L5.

3.7.3.1.1.8.7 *Modulation*. Each SPS L1 and L5 signal shall be bipolar phase shift key (BPSK) modulated with a pseudorandom noise (PRN) code. The C/A code on L1 shall have a rate of 1.023 megachips per second. The codes on I5 and Q5 shall have a rate of 10.23 megachips per second.

3.7.3.1.1.8.7.1 The C/A, I5, and Q5 code sequences shall be repeated each millisecond.

3.7.3.1.1.8.7.2 The transmitted code sequence on L1 shall be the Modulo-2 addition of a 50-bit-per-second legacy navigation (LNAV) message and the C/A code.

3.7.3.1.1.8.7.3 The transmitted code sequence on I5 shall be the Modulo-2 addition of a 50-bit-per-second civil navigation (CNAV) message (rate 1/2 convolution encoded into a 100 symbol per second stream), a 10-bit Neuman-Hofman overlay code clocked at 1 kbps, and the I5 code. The transmitted code sequence on Q5 shall be the Modulo-2 addition of a 20-bit Neuman-Hofman overlay code clocked at 1 kbps and the Q5 code.

Note.— The Q5 signal is not modulated with navigation data.

3.7.3.1.1.8.7.4 *Signal coherence*. All transmitted signals for any satellite shall be coherently derived from the same on- board frequency standard. On the L5 channel, the chip transitions of the two modulating signals, I5 and Q5, shall be such that the average time difference between them does not exceed 10 nanoseconds.

3.7.3.1.1.9 *GPS time*. GPS time shall be referenced to UTC (as maintained by the U.S. Naval Observatory).

3.7.3.1.1.10 *Coordinate system*. The GPS coordinate system shall be WGS-84.

3.7.3.1.1.11 *Navigation information*. The navigation data transmitted by the satellites on L1 and L5 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 of ICAO Annex 10 Vol-I, 3.1.1.1.2 and 3.1.1.1.3 for L1, and 3.1.1.1.5 and 3.1.1.1.6 for L5. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.2 GLONASS Channel of Standard Accuracy (CSA) (L1/L3)

Note.— The GLONASS signals for CSA are broadcast in two frequency bands identified as L1 and L3. In the L1 band, two types of signals are broadcast: L1OF with frequency division multiple access (FDMA) and L1OC with code division multiple access (CDMA). In the L3 band, only CDMA signals (L3OC) are broadcast. Except where otherwise specified, the term GLONASS refers to all satellites in the constellation transmitting either FDMA or CDMA signals.

3.7.3.1.2.1 Space and control segment accuracy

Note.— The single-frequency accuracy Standards do not include atmospheric or receiver errors; ionosphere errors are included for dual-frequency combinations, as described in Attachment D, 4.1.2.2 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.1.2.1.1 *Positioning accuracy*. The GLONASS CSA position errors shall not exceed the following limits:

Signals	L1OF	L1OC	L3OC	L1OF -L3OC	L1OC -L3OC
Global average 95% of the time:					
Horizontal position error Vertical position error	5 m 9 m	5 m 9 m	5 m 9 m	5 m 9 m	5 m 9 m
Worst site 95% of the time:					
Horizontal position error Vertical position error	12 m 25 m	12 m 25 m	12 m 25 m	12 m 25 m	12 m 25 m

3.7.3.1.2.1.2 *Time transfer accuracy*. The GLONASS CSA time transfer errors shall not exceed the following 95 per centof the time:

Signals	L1OF	L1OC	L3OC	L1OF - L3OC	L1OC - L3OC
	40 ns	40 ns	40 ns	40 ns	40 ns

3.7.3.1.2.1.3 *Range domain accuracy*. The range domain error shall not exceed the following limits:

Signals	L1OF	L1OC	L3OC	L1OF - L3OC	L1OC - L3OC
Range error of any satellite with reliability specified in 3.7.3.1.2.3	18 m	18 m	18 m	18 m	18 m
95th percentile range error of any satellite	11.7 m	11.7 m	11.7 m	11.7 m	11.7 m
95th percentile range error overall satellites	7.8 m	7.8 m	7.8 m	7.8 m	7.8 m
95th percentile range rate errorof any satellite	0.014 m/s	0.014 m/s	0.014 m/s	0.014 m/s	0.014 m/s
95th percentile range acceleration error of any satellite	0.005 m/s^2	0.005 m/s^2	0.005 m/s^2	0.005 m/s^2	0.005 m/s^2

3.7.3.1.2.2 *Availability*. The GLONASS CSA availability shall be as follows:

Signals	L1OF	L1OC	L3OC	L1OF - L3OC	L1OC - L3OC
Average location:					
Horizontal service availability	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99% (12 m 95% threshold)	99%, (12 m 95% threshold)
Vertical service availability	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99% (25 m 95% threshold)	99%, (25 m 95% threshold)

Worst-case location:					
Horizontal service availability	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90% (12 m 95% threshold)	90%, (12 m 95% threshold)
Vertical service availability	90%, (25 m 95% threshold	90%, (25 m 95% threshold	90%, (25 m 95% threshold	90% (25 m 95% threshold	90%, (25 m 95% threshold

3.7.3.1.2.3 *Reliability*. The GLONASS CSA reliability shall be within the following limits:

Signals	L1OF	L1OC	L3OC	L1OF – L3OC	L1OC – L3OC
Global average	99.37%	99.37%	99.37%	99.37%	99.37%
Worst single point average	99.14%	99.14%	99.14%	99.14%	99.14%

3.7.3.1.2.4 *Probability of major service failure.* The probability that the user range error (URE) of any satellite will exceed the following tolerance without an alert received at the user receiver antenna within 10 seconds shall not exceed the following probability:

Signals	L1OF	L1OC	L3OC	L1OF – L3OC	L1OC – L3OC
Single satellite failure (P_{sat})	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)

3.7.3.1.2.5 *Probability of constellation fault.* The probability that the user range error (URE) of more than one satellite will exceed the following tolerance simultaneously without an alert received at the user receiver antenna within 10 seconds shall not exceed the following probability:

Signals	L1OF	L1OC	L3OC	L1OF – L3OC	L1OC – L3OC
Constellation fault (P_{const})	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)	1×10^{-4}, (70 m threshold)

3.7.3.1.2.6 *Continuity*. The probability of losing GLONASS CSA healthy signal availability from a slot of the nominal 24-slot constellation due to unscheduled interruption shall not exceed the following limit:

Signals	L1OF	L1OC	L3OC	L1OF – L3OC	L1OC – L3OC
Signal continuity	2×10^{-3}	2×10^{-3}	2×10^{-3}	2×10^{-3}	2×10^{-3}

3.7.3.1.2.7 *Coverage*. The GLONASS CSA shall cover the surface of the earth up to an altitude of 2 000 km.

Note.— Guidance material on GLONASS accuracy, availability, reliability and coverage is given in Attachment D, 4.1.2 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.1.2.8 L1OF RF characteristics

Note.— Detailed RF characteristics are specified in Appendix B, 3.1.2.1.1, of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.2.8.1 *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 ofthe 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.

3.7.3.1.2.8.2 *Signal spectrum.* GLONASS CSA signal power shall be contained within a ±5.75 MHz band centred on each GLONASS carrier frequency.

3.7.3.1.2.8.3 *Polarization*. The transmitted RF signal shall be right-hand circularly polarized.

3.7.3.1.2.8.4 *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 antenna port 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 thesignal 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 antenna port of a 3 dBi linearly polarized antenna is not less then –167 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.2.8.5 Modulation

3.7.3.1.2.8.5.1 Each GLONASS satellite shall transmit at its 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.

3.7.3.1.2.8.5.2 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.

3.7.3.1.2.9 L3OC RF characteristics

Note.— Detailed RF characteristics are specified in Appendix B, 3.1.2.1.5 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.2.9.1 *Carrier frequency.* GLONASS L3OC navigation signals shall be broadcast at the carrier frequency of 1 202.025 MHz using code division multiple access (CDMA).

3.7.3.1.2.9.2 *Signal spectrum.* GLONASS CSA L3OC signal power shall be contained within the 1 190.35 – 1 212.23 MHz band.

3.7.3.1.2.9.3 *Polarization*. The transmitted L3OC signal shall be right-hand circularly polarized.

3.7.3.1.2.9.4 *Signal power level*. GLONASS L3OC navigation signals shall be broadcast 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 antenna port of a 3 dBi linearly polarized antenna is within the range of – 158.5 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

Note.— 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).

3.7.3.1.2.9.5 Modulation

Note.— Additional information concerning the modulation is given in the GLONASS CDMA ICD Open Service Navigation Signal in L3 frequency band (Edition 1.0), dated 2016 (hereinafter referred to as "GLONASS CDMA ICD L3 band").

3.7.3.1.2.9.5.1 GLONASS L3OC navigation signals shall contain two components using the same BPSK(10)-modulated binary train: an in-phase data component and a quadrature-phase pilot component identified as L3OCd and L3OCp, respectively. The pilot component leads the data component by $\pi/2$ radians.

3.7.3.1.2.9.5.2 The L3OCd signal component shall be generated by the Modulo-2 addition of the following three binary signals:

a) ranging code with length N=10230, period T=1 ms, clock rate 10.23 MHz;

b) 100 bits/s navigation message encoded using a convolutional encoder with constraint length 7 and code rate 1/2 toyield 200 symbols per second; and

c) overlay code "00010" with period T=5 ms.

3.7.3.1.2.9.5.3 The L3OCp signal component shall be generated by the Modulo-2 addition of the following two binary signals:

a) ranging code with length N=10230, period T=1 ms, clock rate 10.23 MHz; and

b) overlay code "0000110101" with period T=10 ms.

3.7.3.1.2.10 L1OC RF characteristics

Note.— Detailed RF characteristics are specified in Appendix B, 3.1.2.1.5 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.2.10.1 *Carrier frequency.* GLONASS L1OC navigation signals shall be broadcast at the carrier frequency of 1600.995 MHz using code division multiple access (CDMA).

3.7.3.1.2.10.2 *Signal spectrum.* GLONASS CSA L1OC signal power shall be contained within the 1 592.9 – 1 610 MHz band.

3.7.3.1.2.10.3 *Polarization*. The transmitted L1OC signal shall be right-hand circularly polarized.

3.7.3.1.2.10.4 *Signal power level*. GLONASS L1OC navigation signals shall be broadcast 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 antenna port of a 3 dBi linearly polarized antenna is within the range of –158.5 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

Note.— 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).

3.7.3.1.2.10.5 Modulation

Note.— Additional information concerning the modulation is given in the GLONASS CDMA ICD Open Service Navigation Signal in L1 frequency band (Edition 1.0), dated 2016 (hereinafter referred to as "GLONASS CDMA ICD L1 band").

3.7.3.1.2.10.5.1 GLONASS L1OC navigation signals shall contain two components: a data component and a pilot component identified as L1OCd and L1OCp, respectively. Both components shall be at one phase quadrature using time- division multiplexing. L1OCd shall be modulated using binary phase-shift keying BPSK(1), while L1OCp shall be modulatedby binary offset carrier BOC(1,1) modulation.

3.7.3.1.2.10.5.2 The L1OCd signal component shall be generated by the Modulo-2 addition of the following three binarysignals:

a) ranging code with length N=1023, period T=2 ms, clock rate 0.5115 MHz;

b) 125 bits/s navigation message encoded using a convolutional encoder with constraint length 7 and code rate 1/2 toyield 250 symbols per second; and

c) overlay code “01” with period T=4 ms.

3.7.3.1.2.10.5.3 The L1OCp signal component shall be generated by the Modulo-2 addition of the following two binarysignals:

a) ranging code with length N=4092, period T=8 ms, clock rate 0.5115 MHz; and

b) meander sequence “0101” with clock rate 2.046 MHz.

3.7.3.1.2.11 *GLONASS time.* GLONASS time shall be referenced to UTC(SU) (as maintained by the National Time Service of Russia).

3.7.3.1.2.12 *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, 3.1.2.5.2 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.2.13 *Navigation information.* The navigation data transmitted by the satellite shall include the necessaryinformation to determine:

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) time transfer to UTC;

f) constellation status;

g) ionospheric delay effects (L1OC, L3OC only); and

h) satellite orientation in umbra (L1OC, L3OC only).

Note.— Structure and contents of data are specified in Appendix B, 3.1.2.1.2 and 3.1.2.1.3, respectively of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.3 Galileo Open Service (Galileo OS) (E1, E5)

Note 1.— The Galileo signals for Galileo OS are broadcast in two frequency bands identified as E1 and E5. In the E5 band, two types of signals are broadcast with code division multiple access (CDMA): E5a and E5b. For aviation purposes, the Galileo single-frequency OS is based on either E1 or E5a signals; and the Galileo dual-frequency OS is based on a combination of E1 and E5a signals.

Note 2.— The E5b signal component is described in this ANO since it is a subset of the overall Galileo signal modulated on the E5 frequency carrier. However, there is currently no intention that the E5b signal be used by aviation receivers.

Note 3.— The following performance standards only apply if "healthy" signals-in-space are used (see Appendix B, 3.1.3.1.3.4 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).).

Note 4.— The following performance standards do not include atmospheric or receiver errors such as ionosphere, troposphere, interference, receiver noise or multipath.

Note 5.— Guidance material on Galileo OS accuracy, availability, continuity, probability of satellite/constellation failure and coverage, is given in Attachment D, 4.1.3 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.1.3.1 Positioning accuracy. The Galileo position errors shall not exceed the following limits*:*

Signals	E1	E5a	E1-E5a
Global average 95% of the time:			
Horizontal position error over a measurement period of 30 days	5 m	5 m	5 m
Vertical position error over a measurement period of 30 days	8 m	8 m	8 m
Worst site 95% of the time:			
Horizontal position error over a measurement period of 30 days	10 m	10 m	10 m
Vertical position error over a measurement period of 30 days	16 m	16 m	16 m

3.7.3.1.3.2 Time determination accuracy. The Galileo UTC time determination error shall not exceed 30 nanoseconds, 95 per cent of the time.

3.7.3.1.3.3 Range domain accuracy. The Galileo range domain error shall not exceed the following limits:

Signals	E1	E5a	E1-E5a
99.9th percentile range error of any satellite (worst-case location)	20 m	20 m	20 m
99.9th percentile range error of any satellite (global average)	10 m	10 m	10 m
95th percentile range error of any satellite (global average)	7 m	7 m	7 m
95th percentile range error over all satellites (global average)	2 m	2 m	2 m
95th percentile range rate error of any satellite (global average)	5 mm/s	5 mm/s	5 mm/s

Note 1.— The ranging accuracy considers only healthy Galileo OS SIS above a minimum elevation angle of 5 degrees.

Note 2.— Single-frequency (E1 or E5a) ranging accuracy includes broadcast group delay (BGD) errors. BGD definition is specified in Attachment D, 4.1.3.3.2 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.1.3.4 Availability. The Galileo OS availability shall be as follows:

Signals	E1	E5a	E1-E5a
Average location:			
Horizontal service availability over ameasurement period of 30 days	99% (10 m 95% threshold)	99% (10 m 95% threshold)	99% (10 m 95% threshold)
Vertical service availability over a measurement period of 30 days	99% (16 m 95% threshold)	99% (16 m 95% threshold)	99% (16 m 95% threshold)
Worst-case location:			
Horizontal service availability over ameasurement period of 30 days	90% (10 m 95% threshold)	90% (10 m 95% threshold)	90% (10 m 95% threshold)
Vertical service availability over a measurement period of 30 days	90% (16 m 95% threshold)	90% (16 m 95% threshold)	90% (16 m 95% threshold)

3.7.3.1.3.5 Probability of satellite failure (Psat). The probability that one satellite of Galileo operational core constellationprovides an instantaneous SIS range error higher than *k* times the Galileo user range accuracy (Galileo URA) and no notification is given to the user, shall not exceed 3×10^{-5}.

Note 1.— A change in the SIS health status is notified through the flags contained in the navigation message. The mapping between Galileo SIS status and flags contained in the navigation data message is specified in Appendix B, 3.1.3.1.3.4 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).. In the future, these flags may be complemented with an additional flag specific for aircraft-based augmentation system (ABAS) users.

Note 2.— Galileo URA corresponds either to σURA,DF for dual-frequency users or to σURA,SF for single-frequency users.

Note 3.— P_{sat} *definition is further specified in Attachment D, 4.1.3.6.1 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.*

3.7.3.1.3.6 Probability of constellation failure (P_{const}). The probability that, due to a common cause, any subset of two or more satellites within Galileo operational constellation provides an instantaneous SIS range error higher than *k* times the Galileo URA and no notification is given to the user, shall not exceed 2×10^{-4}.

Note 1.— A change in the SIS health status is notified through the flags contained in the navigation message. The mapping between Galileo SIS status and flags contained in the navigation data message is specified in Appendix B, 3.1.3.1.3.4 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).. In the future, these flags may be complemented with an additional flag specific for ABAS users.

Note 2.— Galileo URA corresponds either to σURA,DF for dual-frequency users or to σURA,SF for single-frequency users.Note 3.— P_{const} *definition is further specified in Attachment D, 4.1.3.6.2 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.*

Note 3.—Psat definition is further specified in Attachment D, 4.1.3.6.1

3.7.3.1.3.7 Galileo URA for dual-frequency (σURA,DF). Galileo *σURA,DF* shall not exceed 6 m.

Note 1.— σURA,DF applies to a dual-frequency E1-E5a signal combination.

Note 2.— σURA,DF is defined in Attachment D, 4.1.3.6.3

3.7.3.1.3.8 Galileo URA for single-frequency (σURA,SF). Galileo *σURA,SF* shall not exceed 7.5 m.

Note 1.— σURA,SF applies to a single-frequency user, either E1 or E5a. Note 2.— σURA,SF is defined in Attachment D, 4.1.3.6.4 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.1.3.9 *Continuity*. The probability of losing Galileo OS SIS availability from a slot of the nominal 24-slot constellation due to unscheduled interruption, shall not exceed the following limit:

Signals	E1	E5a	E1-E5a
Continuity	4×10^{-4} per hour	4×10^{-4} per hour	4×10^{-4} per hour

3.7.3.1.3.10 Coverage. The Galileo OS shall cover the surface of the earth up to an altitude of 30.48 km.

3.7.3.1.3.11 Radio frequency (RF) characteristics. All Galileo satellites shall broadcast Galileo OS signals E1, E5a and E5b.

Note 1.— E5a and E5b signals are multiplexed together through an AltBOC scheme and transmitted at the E5 carrier frequency centred at 1191.795 MHz. AltBOC modulation allows E5a signal components and E5b signal components to be recovered separately by using a QPSK receiver centred on the individual E5a and E5b frequencies.

Note 2.— AltBOC modulation is specified in Appendix B, 3.1.3.1.1.3.13 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)..

Note 3.— Detailed Galileo signals RF characteristics are specified in Appendix B, 3.1.3.1.1 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)..

3.7.3.1.3.11.1 E1 radio frequency (RF) characteristics

3.7.3.1.3.11.1.1 *E1 carrier frequency.* Each Galileo satellite shall broadcast E1 signal at the carrier frequency of 1575.420 MHz using CDMA.

3.7.3.1.3.11.1.2 *E1 signal spectrum*. The Galileo signal power on E1 shall be contained within a 24.552 MHz band centred on the E1 frequency.

3.7.3.1.3.11.1.3 *E1 signal polarization*. The transmitted E1 RF signal shall be right-hand circularly polarized.

3.7.3.1.3.11.1.4 *E1 minimum signal power level.* Each Galileo satellite shall broadcast an E1 navigation signal 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 antenna port of a 3 dBi linearly-polarized antenna shall not be less than –157.9 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.3.11.1.5 *E1 maximum signal power level.* Each Galileo satellite shall broadcast an E1 navigation signal such that the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna shall not exceed –151.45 dBW.

3.7.3.1.3.11.1.6 *E1 signal modulation.* The E1 signal shall be a composite binary offset carrier (CBOC) generated by multiplexing a wideband binary offset carrier (BOC) signal BOC(6,1) with a narrowband signal BOC(1,1) in such a way that 1/11 of the power is allocated, in average, to the high frequency component.

Note. — CBOC modulation is specified in Appendix B, 3.1.3.1.1.2.7 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)..

3.7.3.1.3.11.2 *E5a radio frequency (RF) characteristics*

Note.— Additional information concerning the overall E5 signal modulation is given in the European GNSS (Galileo) Open Service Signal-In-Space Interface Control Document (Issue 2.0), dated January 2021 (hereinafter referred to as "Galileo OS SIS ICD").

3.7.3.1.3.11.2.1 *E5a carrier frequency.* Each Galileo satellite shall broadcast E5a signal at the carrier frequency of1 176.45 MHz using CDMA.

3.7.3.1.3.11.2.2 *E5a signal spectrum.* The Galileo signal power on E5a shall be contained within a 20.460 MHz band centred on the E5a frequency.

3.7.3.1.3.11.2.3 *E5a signal polarization.* The transmitted E5a RF signal shall be right-hand circularly polarized.

3.7.3.1.3.11.2.4 *E5a minimum signal power level*. Each Galileo satellite shall broadcast an E5a navigation signal 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 antenna port of a 3 dBi linearly-polarized antenna shallnot be less than –155.90 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.3.11.2.5 *E5a maximum signal power level.* Each Galileo satellite shall broadcast an E5a navigation signal such that the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna shall not exceed –149.45 dBW.

3.7.3.1.3.11.2.6 *E5a signal modulation.* The E5a signal shall be generated from Modulo-2 addition of the E5a navigationdata stream with the 10.23 megachips per second E5a data channel ranging code (E5a-I), and the 10.23 megachips per second E5a pilot channel ranging code (E5a-Q).

3.7.3.1.3.11.3 E5b radio frequency (RF) characteristics

Note.— Additional information concerning the overall E5 signal modulation is given in Galileo OS SIS ICD.

3.7.3.1.3.11.3.1 E5b carrier frequency. Each Galileo satellite shall broadcast E5b signal at the carrier frequency of 1207.14 MHz using CDMA.

3.7.3.1.3.11.3.2 E5b signal spectrum. The Galileo signal power on E5b shall be contained within a 20.460 MHz band centred on the E5b frequency.

3.7.3.1.3.11.3.3 E5b signal polarization. The transmitted E5b RF signal shall be right-hand circularly polarized.

3.7.3.1.3.11.3.4 E5b minimum signal power level. Each Galileo satellite shall broadcast an E5b navigation signal 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 antenna port of a 3 dBi linearly-polarized antenna shall not be less than –155.90 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.3.11.3.5 E5b maximum signal power level. Each Galileo satellite shall broadcast an E5b navigation signal such that the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna shall not exceed –149.45 dBW.

3.7.3.1.3.11.3.6 E5b signal modulation. The E5b signal shall be generated from Modulo-2 addition of the E5b navigationdata stream with the 10.23 megachips per second E5b data channel ranging code (E5b-I), and the 10.23 megachips per second E5b pilot channel ranging code (E5b-Q).

3.7.3.1.3.12 Galileo system time. Galileo system time (GST) shall be referenced to UTC BIPM (UTC as coordinated by the International Bureau of Weights and Measures).

Note.— Further details on GST are specified in Appendix B, 3.1.3.4.1 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.3.13 Coordinate system. The Galileo coordinate system shall be Galileo Terrestrial Reference Frame (GTRF).

Note.— GTRF details are specified in Appendix B, 3.1.3.5.2 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.3.14 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) ionospheric delay effects;

f) time transfer to UTC; and

g) constellation status.

Note.— Structure and contents of data are specified in Appendix B, 3.1.3.1.2 and 3.1.3.1.3, respectively of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.4 BDS Open Service (BDS OS) (B1I, B1C, B2a)

Note 1.— The BDS OS signals are broadcast in three frequency bands identified as B1I, B1C and B2a. The single-frequency BDS OS is based on any one of the B1I, B1C or B2a signals. The dual-frequency BDS OS is based on a combination of the B1C and B2a signals.

Note 2.— BDS OS signals B1I, B1C and B2a are broadcast by all BDS-3 (BDS third-phase) medium earth orbit (MEO) and inclined geosynchronous orbit (IGSO) satellites.

Note 3.— All requirements specified in this section are based on the BDS-3 constellation configuration of 24 MEO and 3IGSO satellites.

3.7.3.1.4.1 Space and control segment accuracy

Note.— The following accuracy standards do not include atmospheric or receiver errors as described in Attachment D,4.1.4.2 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices. They only apply under the condition that the aircraft receiver uses healthy satellites.

3.7.3.1.4.1.1 Positioning accuracy. The BDS position errors shall not exceed the following limits:

Signals	B1I	B1C	B2a	B1C-B2a
Global average 95% threshold:				
Horizontal position over ameasurement period of 7 days	9 m	9 m	9 m	9 m
Vertical position error over a measurement period of 7 days	15 m	15 m	15 m	15 m
Worst site 95% threshold:				
Horizontal position error over a measurement period of 7 days	15 m	15 m	15 m	15 m
Vertical position error over a measurement period of 7 days	22 m	22 m	22 m	22 m

3.7.3.1.4.1.2 Time transfer accuracy. The BDS OS time transfer error shall not exceed 50 nanoseconds, 95 per cent ofthe time.

3.7.3.1.4.1.3 Range domain accuracy. The BDS range domain error shall not exceed the following limits:

Signals	B1I	B1C	B2a	B1C- B2a
Range error of any satellite with reliability specified in 3.7.3.1.4.3	15 m	15 m	15 m	15 m
95th percentile error of any satellite over a measurement period of 7 days (global average)	4.6 m	4.6 m	4.6 m	4.6 m
95th percentile range rate error of any satellite (global average)	0.02 m per second	0.02 m per second	0.02 m per second	0.02 m per second
95th percentile range acceleration error of any satellite (global average)	0.008 m per second squared	0.008 m per second squared	0.008 m per second squared	0.008 m per second squared

3.7.3.1.4.2 AVailability. The BDS OS availability shall be as follows:

Signals	B1I	B1C	B2a	B1C- B2a
Average location:				
Horizontal service availability over a measurement period of 7 days	≥ 99% (15 m 95% threshold)	≥ 90% (15 m 95% threshold)	≥ 99% (15 m 95% threshold)	≥ 99% (15 m 95% threshold)
Vertical service availability over a measurement period of 7 days	≥ 99% (22 m 95% threshold)	≥ 90% (22 m 95% threshold)	≥ 99% (22 m 95% threshold)	≥ 99% (22 m 95% threshold)
Worst-case location:				
Horizontal service availability over a measurement period of 7 days	≥ 90% (15 m 95% threshold)	≥ 90% (15 m 95% threshold)	≥ 90% (15 m 95% threshold)	≥ 90% (15 m 95% threshold)
Vertical service availability over a measurement period of 7 days	≥ 90% (22 m 95% threshold)	≥ 90% (22 m 95% threshold)	≥ 90% (22 m 95% threshold)	≥ 90% (22 m 95% threshold)

Note.—Availability applies under the condition that the aircraft receiver uses healthy satellites.

3.7.3.1.4.3 *Reliability.* The BDS OS reliability relative to the 15 m range error requirement in 3.7.3.1.4.2 shall be withinthe following limits:

a) reliability — at least 99.94 per cent (global average); and

b) reliability — at least 99.79 per cent (worst single point average).

Note. — Reliability applies under the condition that the satellite is broadcasting a healthy indication.

3.7.3.1.4.4 *Probability of major service failure*

Note.— The standards apply under the condition that the satellite is broadcasting a healthy indication.

3.7.3.1.4.4.1 *Probability of a satellite major service failure condition (P_{sat}).* The probability that the BDS OS SIS user range error of any satellite will exceed the not-to-exceed (NTE) tolerance without an alert received at the user receiver antennawithin 300 seconds, shall not exceed 1×10^{-5}.

3.7.3.1.4.4.2 *Probability of a common-cause major service failure condition (P_{const}).*The probability that the BDS OS SIS user range error of two or more satellites will exceed the NTE tolerance due to a common fault without an alert received at theuser receiver antenna within 300 seconds, shall not exceed 6×10^{-5}.

Note 1.— For B1I signals, the NTE tolerance is defined to be 4.42 times the upper bound of the URA range correspondingto the URA index (URAI) value being broadcast in D1 navigation messages, as described in Appendix B, 3.1.4.1.3.1.2 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

Note 2.— For B1C and B2a signals, the NTE tolerance is defined to be 4.42 times the signal-in-space accuracy (SISA) value calculated as described in Appendix B, 3.1.4.2.5 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

Note 3.— The mapping between BDS B1I SIS status and BDS B1I flags contained in the navigation data message is specified in Appendix B, 3.1.4.1.3.1.3 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS). The mapping between BDS B1C and B2a SIS status and BDS B1C and B2a flags contained in the navigation data message is specified in Appendix B, 3.1.4.1.3.2.7.2 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.4.5 *Continuity.* The probability of losing BDS OS SIS availability from a slot of the nominal 27-slot constellation due to unscheduled interruption, shall not exceed the following limits:

Signals	B1I	B1C	B2a
MEO	2×10^{-3} per hour	2×10^{-3} per hour	2×10^{-3} per hour
IGSO	5×10^{-3} per hour	2×10^{-3} per hour	2×10^{-3} per hour

Note.— Continuity applies under the condition that the satellite is broadcasting a healthy indication.

3.7.3.1.4.6 *Coverage.* BDS OS shall cover the surface of the earth up to an altitude of 1 000 km.

3.7.3.1.4.7 *Radio frequency (RF) characteristics*

Note.— Detailed BDS OS signals RF characteristics are specified in Appendix B, 3.1.4.1.1 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.4.8 *B1I radio frequency (RF) characteristics*

3.7.3.1.4.8.1 *B1I carrier frequency.* Each BDS-3 MEO or IGSO satellite shall broadcast a BDS B1I OS signal at the carrier frequency of 1 561.098 MHz using code division multiple access (CDMA).

3.7.3.1.4.8.2 *B1I signal spectrum.* The BDS OS B1I signal power shall be contained within a ±2.046 MHz band (1 559.052 – 1 563.144 MHz) centred on the 1 561.098 MHz frequency.

3.7.3.1.4.8.3 *B1I signal polarization.* The transmitted B1I RF signal shall be right-hand circularly polarized.

3.7.3.1.4.8.4 *B1I signal power levels*

3.7.3.1.4.8.4.1 Each BDS-3 MEO satellite shall broadcast a B1I navigation signal 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 antenna port of a 3 dBi linearly-polarized antenna is within the range of –163 dBW to –154.8 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.8.4.2 Each BDS-3 IGSO satellite shall broadcast a B1I navigation signal 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 antenna port of a 3 dBi linearly-polarized antenna is within the range of –163 dBW to –156.5 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.8.5 *B1I signal modulation*. The BDS OS B1I signal shall be binary phase shift key (BPSK) modulated.

3.7.3.1.4.9 B1C radio frequency (RF) characteristics

3.7.3.1.4.9.1 B1C carrier frequency. Each BDS-3 MEO or IGSO satellite shall broadcast a BDS OS B1C signal at the carrier frequency of 1 575.42 MHz using CDMA.

3.7.3.1.4.9.2 B1C signal spectrum. The BDS OS signal power on B1C shall be contained within a 32.736 MHz band centred on the B1C frequency.

3.7.3.1.4.9.3 B1C signal polarization. The transmitted B1C RF signal shall be right-hand circularly polarized.

3.7.3.1.4.9.4 *B1C signal power levels*

3.7.3.1.4.9.4.1 Each BDS-3 MEO satellite shall broadcast a B1C navigation signal 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 antenna port of a 3 dBi linearly-polarized antenna is within the range of –159 dBW to –152.5 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.9.4.2 Each BDS-3 IGSO satellite shall broadcast a B1C navigation signal 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 antenna port of a 3 dBi linearly-polarized antenna is within the range of –161 dBW to –153.5 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.9.5 *B1C signal modulation.* The B1C signal shall comprise two components, known as B1C data component and B1C pilot component. The B1C data component shall be sine-phased binary offset carrier (BOC) modulated with the Modulo-2 addition of the ranging code and the navigation data. The B1C pilot component shall be quadrature multiplexed BOC (QMBOC) modulated with the ranging code. Ranging codes on B1C data component and B1C pilot component shall have the same chipping rate of 1.023 megachips per second.

Note.— Additional information concerning B1C modulation is given in the BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal B1C (Version 1.0), dated December 2017 (hereinafter referred to as "BDS OS B1C ICD"), 4.2.

3.7.3.1.4.10 B2a radio frequency (RF) characteristics

3.7.3.1.4.10.1 B2a carrier frequency. Each BDS-3 MEO and IGSO satellite shall broadcast a BDS OS B2a signal at the carrier frequency of 1 176.45 MHz using CDMA.

3.7.3.1.4.10.2 B2a signal spectrum. The BDS OS signal power on B2a shall be contained within a 20.46 MHz band centred on the B2a frequency.

3.7.3.1.4.10.3 B2a signal polarization. The transmitted B2a RF signal shall be right-hand circularly polarized.

3.7.3.1.4.10.4 *B2a signal power levels*

3.7.3.1.4.10.4.1 Each BDS-3 MEO satellite shall broadcast a B2a navigation signal 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, thelevel of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –156 dBW to -148.5 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.10.4.2 Each BDS-3 IGSO satellite shall broadcast a B2a navigation signal 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, thelevel of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –158 dBW to -150.5 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.10.5 *B2a signal modulation.* The B2a signal shall comprise two components, known as B2a data component and B2a pilot component. The B2a data component shall be BPSK modulated with the Modulo-2 addition of the ranging codeand the navigation data. The B2a pilot component shall be BPSK modulated with the ranging code. Ranging codes on B2a data component and B2a pilot component shall have the same chipping rate of 10.23 megachips per second.

Note.— Additional information concerning B2a modulation is given in the BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal B2a (Version 1.0), dated December 2017 (hereinafter referred to as "BDS OS B2a ICD"), 4.2.

3.7.3.1.4.11 BDS time. BDS time (BDT) shall be referenced to UTC as maintained by the National Time Service Center(NTSC), Chinese Academy of Sciences.

Note.— BDT details are specified in Appendix B, 3.1.4.4 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.4.12 *Coordinate system.* The BDS coordinate system shall be BeiDou Coordinate System (BDCS).

Note.— BDCS details are specified in Appendix B, 3.1.4.5 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.1.4.13 *Navigation information.* The navigation data transmitted by the satellites shall include the necessaryinformation to determine:

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) ionospheric delay effects;

f) time transfer to UTC; and

g) constellation status.

3.7.3.2 Reserved.

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 for the intended operation.

Note.— For GNSS receivers supporting the ABAS function, the requirements to be resistant to interference, as specifiedin 3.7.4, apply.

3.7.3.4 Satellite-based augmentation system (SBAS)

Note.— All SBAS have to fulfil the requirements introduced in this section and in Appendix B, 3.5 of ICAO Annex 10 Vol-I, except when a specificcondition is mentioned in the requirement such as the provision of optional functions. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

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, throughout the corresponding service area (see 3.7.3.4.4).

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.

3.7.3.4.1.1 SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for signal-in-space integrity as stated in 3.7.2.4, throughout the SBAS coverage area.

Note.— For L1 SBAS, message Types 27 or 28 can be used to comply with the integrity requirements in the coverage area. Additional guidance on the rationale and interpretation of this requirement is provided in Attachment D, 3.3 and 6.2.3 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.4.2 *Functions.* SBAS shall perform one or more of the following functions:

a) L1 SBAS ranging: provide an additional L1 ranging signal with an accuracy indicator from an SBAS satellite (3.7.3.4.3 and 3.5.7.2 of Appendix B *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)*);

b) L1 SBAS GNSS satellite status: determine and transmit the GNSS satellite health status (Appendix B, 3.5.7.3 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)*);

c) L1 SBAS basic differential correction: provide GNSS satellite ephemeris and clock corrections (fast and long-term) to be applied to the L1 pseudo-range measurements from satellites (Appendix B, 3.5.7.4 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)*);

d) L1 SBAS precise differential correction: determine and transmit the L1 ionospheric corrections and associated integrity data (Appendix B, 3.5.7.5 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)*);

e) dual-frequency, multi-constellation (DFMC) SBAS ranging: provide additional ionosphere-free ranging capability using L1 and L5 signals from SBAS satellites (Appendix B, 3.5.14.2 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)*); and

f) DFMC SBAS ionosphere-free differential correction: determine and transmit GNSS satellite health status, satellite ephemeris and clock corrections to be applied to the ionosphere-free pseudo-range measurements from satellites (Appendix B, 3.5.14.3 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS)*) and associated integrity data.

Note 1.— For single-frequency users, if functions b) and c) are provided, SBAS in combination with core satellite constellation(s) can support departure, en-route, terminal and non-precision approach operations, and if function d) is provided in addition to b) and c), then SBAS can also support precision approach operations including Category I. 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.

Note 2.— For dual-frequency users, if function f) is provided, SBAS in combination with core satellite constellation(s) can support departure, en-route, terminal, non-precision approach operations and precision approach operations including Category I.

Note 3.— In order to provide function e), SBAS needs to broadcast an L1 signal that meets the requirements for ionosphere- free ranging using L1 and L5 pseudo-range measurements.

Note 4.— The ionospheric corrections are only broadcast on L1. Dual-frequency users will use an ionosphere-free pseudo-range measurement and not require ionospheric corrections. Ionosphere-free pseudo-range combination for DFMC SBAS is further defined in Appendix B, 3.5.15.1 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.4.3 *Ranging.* When SBAS is providing a ranging service, the following Standards shall apply:

3.7.3.4.3.1 Excluding atmospheric effects, the range error for the ranging signal from SBAS satellites shall not exceed 25 m (82 ft) (95 per cent).

3.7.3.4.3.2 The probability that the SBAS L1 range error exceeds 150 m (490 ft) in any hour shall not exceed 10^{-5}.

3.7.3.4.3.3 The probability of unscheduled outages of the ranging function from an SBAS satellite in any hour shall not exceed 10^{-3}.

3.7.3.4.3.4 The range rate error shall not exceed 2 m (6.6 ft) per second.

3.7.3.4.3.5 The range acceleration error shall not exceed 0.019 m (0.06 ft) per second-squared.

3.7.3.4.4 *Service area*. An SBAS service area for any approved type of operation shall be a declared area within theSBAS coverage area where SBAS meets the corresponding requirements of 3.7.2.4.

Note 1.— An SBAS system can have different service areas corresponding to different types of operation (e.g. APV-I, Category I, etc.).

Note 2.— The coverage area is that area within which the SBAS broadcast can be received (i.e. the union of SBAS satellitefootprints).

Note 3.— SBAS coverage and service areas are discussed in Attachment D, 6.2 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.4.5 RF characteristics for the SBAS L1 signal

Note.— Detailed RF characteristics are specified, for L1 in 3.5.2 of Appendix B of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.4.5.1 *L1 carrier frequency*. The L1 carrier frequency shall be 1 575.42 MHz.

3.7.3.4.5.2 *L1 signal spectrum*. At least 95 per cent of the L1 broadcast power shall be contained within a ±12 MHz bandcentred on the L1 frequency. The bandwidth of the L1 signal transmitted by an SBAS satellite shall be at least 2.2 MHz.

Note.— The SBAS L1 RF link needs to provide a higher transmission bandwidth to support the SBAS ranging accuracy figure in Appendix B of ICAO Annex 10 Vol-I, 3.5.15.4.1, for DFMC SBAS ranging service. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS). A higher transmission bandwidth will improve the performance of the L1 SBAS ranging service. See Attachment D, 6.4.6 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.4.5.3 L1 satellite signal power level

3.7.3.4.5.3.1 Each SBAS satellite placed in orbit before 1 January 2014 shall broadcast navigation signals on L1 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 antenna port 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.

3.7.3.4.5.3.2 Each SBAS satellite broadcasting an SBAS L1 signal placed in orbit after 31 December 2013 shall complywith the following requirements:

a) The satellite shall broadcast navigation signals on L1 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at or above the minimum elevation angle for which a trackable geostationary orbit (GEO) satellite signal needs to be provided, the level of the received RF signal at the antenna portof the antenna specified in Appendix B *of ICAO Annex 10 Vol-I*, Table B-172, is at least –164.0 dBW. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

b) The minimum elevation angle used to determine GEO coverage shall not be less than 5 degrees for a user near the ground.

c) The level of a received SBAS RF signal on L1 at the antenna port of a 0 dBic antenna located near the ground shall not exceed –152.5 dBW.

d) The ellipticity of the broadcast L1 signal shall be no worse than 2 dB for the angular range of ±9.1° from boresight.

3.7.3.4.5.4 *Polarization*. The broadcast signal on L1 shall be right-hand circularly polarized.

3.7.3.4.5.5 *Modulation.* The transmitted sequence on L1 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 carrierat a rate of 1.023 megachips per second.

3.7.3.4.6 RF characteristics for the SBAS L5 signal

Note.— Detailed RF characteristics are specified in 3.5.9 for L5 in Appendix B of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.4.6.1 *L5 carrier frequency.* The L5 carrier frequency shall be 1 176.45 MHz.

3.7.3.4.6.2 *L5 signal spectrum.* At least 95 per cent of the L5 broadcast power shall be contained within a bandwidth centred on the L5 frequency and between 20 MHz and 24 MHz.

3.7.3.4.6.3 *L5 signal power level.* Each SBAS satellite broadcasting an SBAS L5 signal shall comply with the followingadditional requirements:

a) The satellite shall broadcast navigation signals on L5 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at or above the minimum elevation angle for which a trackable signal needs to be provided, the level of the received RF signal at the output of a 3 dBi linearly polarized antenna shallbe at least –158 dBW for all antenna orientations orthogonal to the direction of propagation.

b) The minimum elevation angle used to determine SBAS satellite coverage shall not be less than 5 degrees for a user near the ground.

c) The level of a received SBAS RF signal on L5 at the output of a 0 dBic right-hand circularly polarized antenna locatednear the ground shall not exceed –150.5 dBW.

d) The ellipticity of the broadcast L5 signal shall be no worse than 2 dB for the angular range of ±9.1° from boresight.

Note.— The received signal levels, from a) and c), are measured within a ±10 MHz frequency band centred on the L5 frequency.

3.7.3.4.6.4 *Polarization.* The broadcast signal on L5 shall be right-hand circularly polarized.

3.7.3.4.6.5 *Modulation*. The transmitted sequence on L5 in-phase shall be the result of the 250-bits of the navigation message with forward error correction (FEC) applied for 500 symbols per second that is then bi-binary encoded and finally combined with the 10 230 bit pseudo-random noise code using Modulo-2 addition. The resulting sequence shall then be BPSK-modulated onto the carrier at a rate of 10.23 megachips per second.

Note.— Detailed L5 modulation characteristics for L5 are specified in Appendix B, 3.5.9 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.4.7 Timing

3.7.3.4.7.1 *SBAS network time (SNT) for L1 SBAS.* The difference between SNT of the SBAS corrections on L1 and GPStime shall not exceed 50 nanoseconds.

3.7.3.4.7.2 *SBAS network time (SNT) for DFMC SBAS.* The difference between SNT of the SBAS corrections broadcast on L5 and the reference time of the core constellation designated as reference constellation (see the time reference identifier parameter in Appendix B, 3.5.11.4 broadcast by DFMC SBAS, *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).*) shall not exceed 1 microsecond.

3.7.3.4.8 *L1 SBAS navigation information.* The navigation data transmitted by an SBAS satellite on L1 shall include the necessary information to support L1 SBAS services 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 (optional); and

h) service level status.

Note.— Structure and contents of data are specified in 3.5.3 and 3.5.4, respectively of Appendix B of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.4.9 *DFMC SBAS navigation information.* The navigation data transmitted by an SBAS satellite on L5 shall include the necessary information to support DFMC SBAS services to determine:

a) SBAS satellite time of transmission;

b) SBAS satellite position;

c) corrected satellite time for all monitored satellites;

d) corrected satellite position for all monitored satellites;

e) user position integrity; and

f) time transfer to UTC (optional).

Note.— Structure and contents of data are specified in 3.5.10 and 3.5.11 of Appendix B of ICAO Annex 10 Vol-1 respectively. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.5 Ground-based augmentation system (GBAS) and ground-based regional augmentation system (GRAS)

Note.— Except where specifically annotated, GBAS Standards and Recommended Practices apply to GBAS and GRAS.

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 within the service volume for the service used to support the operation as defined in 3.7.3.5.3.

Note.— GBAS is intended to support all types of approach, landing, guided take-off, 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 all categories of precision approach, approach with vertical guidance, and a GBAS positioning service.

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 Service volume

3.7.3.5.3.1 *General requirement for approach services.* The minimum GBAS approach service volume 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 thefinal 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) to an upper bound of 3 000 m (10 000 ft) height above threshold (HAT) 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. The lower bound is half the lowest decision height supported or 3.7 m (12 ft), whichever is larger.

Note 1.— LTP/FTP and GPIP are defined in Appendix B, 3.6.4.5.1 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

Note.2 — Guidance material concerning the approach service volume is provided in Attachment D, 7.3 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.5.3.2 *Approach services supporting autoland and guided take-off*. The minimum additional GBAS service volume to support approach operations that include automatic landing and roll-out, including during guided take-off, shall be as follows,except where operational requirements permit:

a) Horizontally, within a sector spanning the width of the runway beginning at the stop end of the runway and extendingparallel with the runway centre line towards the LTP to join the minimum service volume as described in 3.7.3.5.3.1.

b) Vertically, between two horizontal surfaces one at 3.7 m (12 ft) and the other at 30 m (100 ft) above the runway centre line to join the minimum service volume as described in 3.7.3.5.3.1.

Note.— Guidance material concerning the approach service volume is provided in Attachment D, 7.3 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.5.3.3 *GBAS positioning service.* The service volume for the GBAS positioning service shall be 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 volume is provided in Attachment D, 7.3 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.5.4 Data broadcast characteristics

Note.— RF characteristics are specified in Appendix B, 3.6.2 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

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 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

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 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.; 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 1.— 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 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

Note 2.— The minimum and maximum field strengths are consistent with a minimum distance of 80 m (263 ft) from the transmitter antenna for a range of 43 km (23 NM).

Note 3.— When supporting approach services at airports with challenging VDB transmitter siting constraints, it is acceptable to adjust the service volume when operational requirements permit (as stated in the service volume definition in 3.7.3.5.3.1 and 3.7.3.5.3.2). Such adjustments of the service volume may be operationally acceptable when they have no impacton the GBAS service outside a radius of 80 m (263 ft) from the VDB antenna, assuming a nominal effective isotropically radiated power of 47dBm (Attachment D, Table D-6 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices).

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 isotropically radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) and a maximum field strength of 0.879 volts per metre (–27 dBW/m^2) within the GBAS service volume as specified in 3.7.3.5.3.1. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. Within the additional GBAS service volume, as specified in 3.7.3.5.3.2, the effective isotropically radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) below 36 ft and down to 12 ft above the runway surface and 650 microvolts per metre (–89.5 dBW/m^2) at 36 ft or more above the runway surface.

Note.— Guidance material concerning the approach service volume is provided in Attachment D, 7.3 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

3.7.3.5.4.4.2 GBAS/E

3.7.3.5.4.4.2.1 *An elliptically polarized signal shall be broadcast whenever practical*.

3.7.3.5.4.4.2.2 When an elliptically polarized signal is broadcast, the horizontally polarized component shall meet the requirements in 3.7.3.5.4.4.1.2, and the effective isotropically radiated power (EIRP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre (–103 dBW/m^2) and a maximum field strength of 0.555 volts per metre (–31 dBW/m^2) within the GBAS service volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst.

3.7.3.5.4.5 *Power transmitted in adjacent channel*s. 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 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 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 of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).

3.7.3.6 Aircraft GNSS receiver

3.7.3.6.1 The aircraft GNSS receiver shall process the signals of those GNSS elements that it intends to use as specified in Appendix B, 3.1.1 (for GPS), Appendix B, 3.1.2 (for GLONASS), Appendix B, 3.1.3 (for Galileo), Appendix B, 3.1.4 (for BDS), Appendix B 3.3 (for combined core satellite constellations), Appendix B, 3.4 (for ABAS), Appendix B, 3.5 (for SBAS) and Appendix B, 3.6 (for GBAS and GRAS) *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).*

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 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).*

Note.— GNSS elements operating within the frequency bands 1 164 – 1 215 MHz and 1 559 – 1 610 MHz are classified by the ITU as operating in the radionavigation-satellite service (RNSS). Those frequency bands also include global allocations to the ~~and~~ aeronautical radionavigation service (ARNS). Both aeronautical uses of those services are considered "safety services" and are afforded special spectrum protection status in the ITU radio regulations. 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 1 164 – 1 215 MHz and 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 ANO 4, ANO 11, ANO 14 and ANO 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 of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.

Table 3.7.2.4-1 Signal-in-space performance requirements

Typical operation	Accuracy horizontal95% (Notes 1 and 3)	Accuracyvertical 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)		$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
		N/A				
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)(Note 8)	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) (Note 8)	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 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).* And guidance material is given in Attachment D, 3.2 *of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices.*

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 *of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices*. These alert limits are:

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continentallow 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 *of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices*). 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 *of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices*).

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 *of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices*).

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 *of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices*).

7. GNSS performance requirements intended to support Category II and III precision approach operations necessitate lower level requirements in the technical appendix (Appendix B, 3.6 *of ICAO Annex 10 Vol-I. The title of the Appendix B is Technical specifications for the global navigation satellite system (GNSS).*) to be applied in addition to these signal-in-space requirements (see Attachment D, 7.5.1 *of ICAO Annex 10 Vol-I. The title of the Attachment D is Information and material for guidance in the application of the GNSS Standards and Recommended Practices*).

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 ANO and in the presence also of an unwanted signal from a direction90 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 N/A

* Review required for the tables under 3.11

CHAPTER 4. REPEAL AND SAVINGS

4.1 As soon as may be after the commencement of this ANO, the First Edition of ANO (COM) A.1 issued on 15th February 2009 shall stand repealed.

4.2 Despite such repeal under sub-section (4.1),

(a) any act done, measures taken, any order, ANO,□circular, or notice issued, certificate, licence or permit given or any agreement entered into or document signed under the said ANO shall be deemed to have done, taken, entered, issued,□□given, made or signed under this ANO;

(b) any proceeding, going on or pending, shall, in so far as possible, be disposed of under this ANO; and

(c) any suit and other legal proceedings instituted before any court shall, if pending, be disposed of in such way as if the said ANO had not been repeale

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