CIVIL AVIATION REQUIREMENTS
SECTION 9 – AIR SPACE AND AIR
** TRAFFIC MANAGEMENT**
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Subject : **Aeronautical Telecommunications – Radio Navigation Aids**

INTRODUCTION

In pursuant to Article 28 of the Convention on International Civil Aviation each contracting State undertakes to provide in its territory, air navigation facilities to facilitate air navigation and also adopt and put into operation the appropriate standard systems for communication procedures, codes, markings, signals etc., in accordance with standards which may be recommended or established from time to time, pursuant to the Convention. International Civil Aviation Organization adopts and amends from time to time, as may be necessary, international standards and recommended practices and procedures for Aeronautical Telecommunications – Radio Navigation Aids in Annex 10 Volume I.

This CAR is issued under the provisions of Rule 29C and Rule 133A of the Aircraft Rules, 1937 for the requirements to be followed in respect of Aeronautical Telecommunications – Radio Navigation Aids.

This CAR is issued in supersession of CAR Section 4 Series 'D' Part II dated 12th July 2006.

1. DEFINITIONS

Note 1.0 All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radio communication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).
Note 2.0 Intentionally left blank

Note 3.0— *The terminology used in this CAR to refer to instrument approach operations is based on a previous version of the Annex 6 classification of instrument approach and landing operations. It can be mapped to the Annex 6 definitions as follows:*

Performance requirements in support of instrument approach operations	
Annex 10 system performance	Annex 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 than 75 m (250 ft)	3D-Type A [3]
Category I, DH equal to or greater than 60 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.	

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

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

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.

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

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

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

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

Note: A time of 1/10 second during which the 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 as previously defined as "a statement of the navigation performance, necessary for operation within a defined airspace", has been removed from this Annex as the concept of RNP has been overtaken by the concept of PBN. The term RNP in this Annex is now solely used in 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 the PBN Manual (Doc 9613).

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.

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

Global navigation satellite system (GNSS)

1.1 A standard aid to navigation shall be the global navigation satellite system (GNSS) conforming to the Standards contained in Chapter 2, 2.

Note 1.— It is intended that any change in, or addition to, Standards in Chapter 2, 2 that will require the replacement of GNSS equipment can become applicable on the basis of a six-year advance notice.

Note 2.— GNSS is expected to support all phases of flight and aerodrome surface operations, however, present SARPs provide for en-route, terminal and approach and landing operations down to Category I precision approach.

1.2 It shall be permissible to terminate a GNSS satellite service provided by one of its elements (Chapter 2, 2.2) on the basis of at least a six-year advance notice by a service provider.

1.3 **Recording and retention of GNSS data**

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

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

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

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

2. **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)
> b) the VHF Omni-directional radio range (VOR)
> c) the global navigation satellite system (GNSS) confirming to the Standards contained in Chapter 3.3.7
> d) the non-directional beacon (NDB)
> e) the distance measuring equipment (DME)
> f) the en-route VHF marker beacon

Note1: Since radio navigation is essential for the final stages of approach and landing, the installation of non-visual aids does not obviate the need for visual aids to approach and landing in conditions of low visibility.

2.1.2. Differences in radio navigation aids in any respect of provisions in para 3 of this CAR shall be published in an Aeronautical Information Publication (AIP).

2.1.3. Wherever there is installed a radio navigation aid that is not an ILS but which may be used in whole or in part with aircraft equipment designed for use with the ILS, full details of parts that may be so used shall be published in an Aeronautical Information Publication (AIP).

Note: This provision is to establish requirement for promulgation of relevant information rather than to authorize such installation

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) on the basis of at least a six-year advance notice by a service provider.

2.1.4.2 The service provider shall *ensure that GNSS data relevant to the provision of GNSS services for GNSS operations are recorded.*

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

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

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

2.1.5 Intentionally left blank.

2.1.5.1 Intentionally left blank.

2.1.5.2 The SRE may be installed and operated without the PAR for:

a) the assistance of air traffic control in handling aircraft intending to use a radio navigation aid, or for;

b) Surveillance radar approaches and departures.

2.1.6 When a radio navigation aid is provided to support precision approach and landing it should be supplemented by a source of guidance information which,

when used in conjunction with appropriate procedures, will provide effective guidance to the desired reference path.

Note:VOR, NDB, DME, GNSS and aircraft navigation systems have been established for purposes mentioned above.

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 are subject of periodic ground and flight tests.

Note: NDB shall not be subjected to periodic flight tests.

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

2.3.1   Aerodrome control towers and units providing approach control service shall be provided without delay with information on the operational status of radio navigation aids essential for approach, landing and take-off at the aerodrome(s) with which they are concerned.

2.4   Power supply for radio navigation aids and communication systems

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

2.5   Human Factors considerations

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

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

3.   Specifications For Radio Navigation Aids

3.1.   Specification for ILS

3.1.1.   Definitions

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

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

Course line: The locus of the 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 larger signal minus the percentage modulation depth of the smaller signal , divided by 100.

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

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

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 15m (50 ft) or less above the horizontal plane containing the threshold.

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

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

Half course sector: The sector. In a horizontal place containing the course line and limited by the loci of points nearest to the course line at which the DGM is 0.0775.

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

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

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

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

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

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

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

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

ILS Point "B": A point on the ILS glide path measured along the extended runway centre line in the approach direction a distance of 1 050m (3500ft) 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 30m (100ft) above the horizontal plane containing the threshold.

ILS Point "D": A point 4m (12ft) above the runway centre line and 900m (3000ft) from the threshold in the direction of localizer.

ILS Point "E": A point 4m (12ft) above the runway centre line and 600m (2000ft) from the stop end of the runway in the direction of the threshold.

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 (See figure 1).

Two Frequency glide path system: An ILS glide path in which coverage is achieved by the use of two independent radiation field patterns spaced on separate carrier frequencies within the particular glide path channel.

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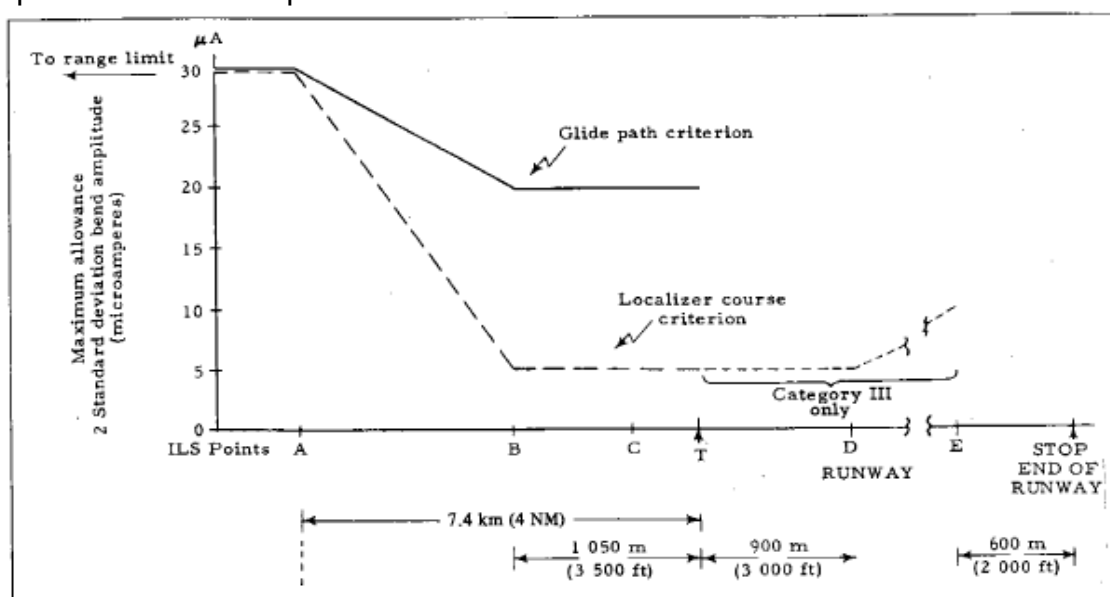

Figure 1

3.1.2. Basic requirements

3.1.2.1   The ILS shall comprise the following basic components:

a) VHF localizer equipment, associated monitor system, remote control and indicator equipment;
b) UHF glide path equipment, associated monitor system, remote control and indicator equipment;
c) VHF marker beacons, or a distance measuring equipment (DME) in accordance with para 3.5, together with associated monitor system and remote control and status indicator equipment.

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

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

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

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

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

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

3.1.2.3   The localizer and glide path components specified in 3.2.1. a) And b) above which form part of a facility Performance Category I – ILS shall comply at least with the provisions in para 3.1.3 and 3.1.5 below 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) above 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 – ILD, as supplemented or amended by the provisions in para 3.1.3 and 3.1.5 below in which application to facility Performance Category II – ILS is prescribed.

3.1.2.5 The localizer and glide path components and ancillary equipment specified in 3.1.2.1.1 above, which form part of a Facility Performance Category III – ILS, shall otherwise comply with the provisions applicable to these components in Facility Performance Categories I and II – ILS, except as supplemented by the Standards specified is of a high value, consistent with category of operational performance.

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

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

3.1.2.7.1.1 At those locations where two separate ILS facilities serve opposite ends of a single runway and where a facility performance Category I – ILS is to be used for auto coupled approaches and landing in visual conditions, an interlock shall ensure that only the localizer serving the approach direction in use radiates providing the other localizer is not required for simultaneous operational use.

3.1.2.7.2 At locations where ILS facilities serving opposite ends of the same runway or different runways at the same airport use the same paired frequencies, an interlock shall ensure that only on 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.

3.1.3 VHF localizer and associated monitor

The provisions of 3.1.3 cover ILS localizers providing wither positive guidance information over 360 degrees of azimuth, or providing such guidance only with a specified portion of the front coverage (see para 3.1.3.7.4 below). Where ILS localizers providing positive guidance information in a limited sector are installed, information from some suitably located navigation aid, together with appropriate procedures, will generally be required to ensure that any misleading guidance information outside the sector is not operationally significant.

3.1.3.1 General

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

3.1.3.1.2 When an observer faces the localizer from the approach end of a runway, the depth of modulation of the radio frequency carrier due to the 150 Hz tone shall predominate on his right hand and that due to the 90 Hz tone shall predominate o his 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 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, the all tolerances applied, the frequency separation between the carriers shall not be less than 5 KHz nor more than 14 KHz.

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

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

3.1.3.2.3 For Facility Performance Category III localizers, the signals emanating from the transmitter shall contain no components which result in a apparent course line fluctuation of more than 0.005 DDM peak to peak in the frequency band 01.01 Hz to 10 Hz.

3.1.3.3 Coverage

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

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

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

c) 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 operation requirements permit, the limits may be reduced down to 33.3 km (18NM) within the plus or minus 10 degree sector and 18.5 km (10NM) within the remainder of the coverage when alternative navigational means provide satisfactory coverage within the intermediate approach area. The localizer signals shall be receivable at the distances specified at and above a height of 600 m (2000ft) above the elevation the threshold, or 300m (1000ft) 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 1350m (4500 ft) above the elevation of the threshold at 35 degrees from the front course line. Such signals shall be receivable, to the distances specified, up to a surface extending outward from the localizer antenna and inclined at 7 degrees above the horizontal.

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

3.1.3.3.2 In all parts of the coverage volume specified in 3.1.3.3.1 above, other than as specified in 3.1.3.3.2.1, 3.1.3.3.2.2 and 3.1.3.3.2.3 below, the field strength shall be not less than 50 micro volts per meter (minus 114dbW/m^2). This field strength is required to permit satisfactory operational usage of ILS localizer facilities.

3.1.3.3.2.1 For Facility Performance Category I localizers, the minimum field strength on the ILS glide path and within the localizer course sector from a distance of 18.5 km (10 NM) to a height of 60m (200ft) above the horizontal place containing the threshold shall be not less than 90 micro volts per meter (minus 107 db W/ 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 the localizer course sector shall be not less than 100 microvolt per meter (minus 106 dB W/m^2) at a distance of 18.5 km (10NM) increasing to not less than 200 µ volts per meter (minus 100 dB W/m^2) at height of 15m (50 ft) above the horizontal plane containing the threshold. This field strength is necessary to provide the signal to noise ration required for improve integrity.

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 μ volts per meter (minus 106 dB W/m^2) at a distance of 18.5km (10 NM), increasing to not less than 200 μ volts per meter (minus 100 dB W/m^2) at 6 m (20ft) above the horizontal plane containing the threshold. From this point to a further point 4 m (12 ft) above the runway centre line, and 300m (1000ft) from the threshold in the direction of the localizer, and thereafter at height of 4m (12ft) along the length of the runway in the direction of the localizer, the field strength shall be not less than 100 μ volts per meter (minus 106 dB W/m^2). This field strength is necessary to provide the signal to noise ratio required for improved integrity.
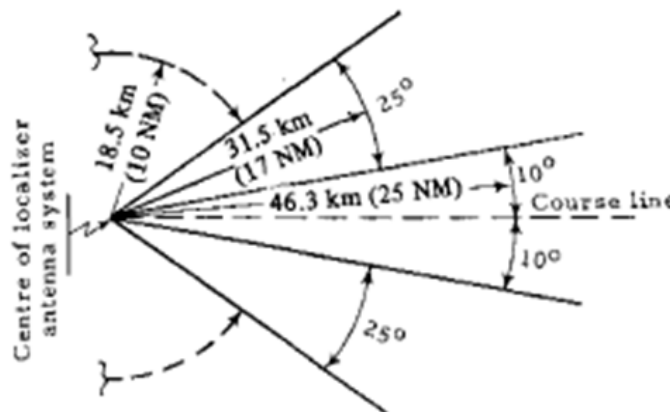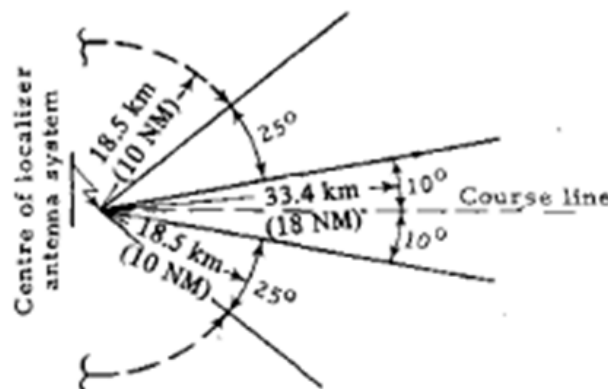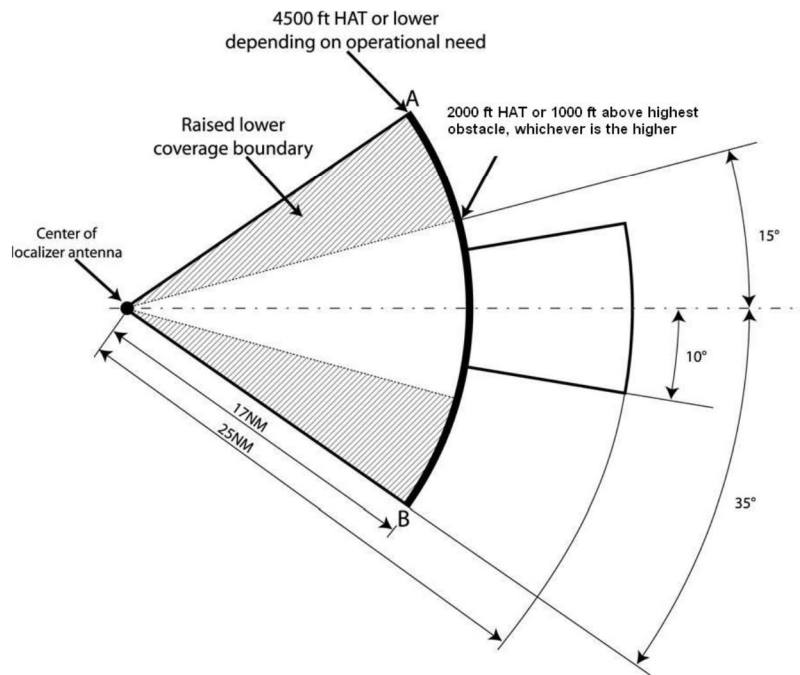

Figure 2 Localizer Coverage with respect to azimuth

Figure 2A Reduced Localizer Coverage with respect to azimuth

Figure 3.

View from approach side of arc AB:
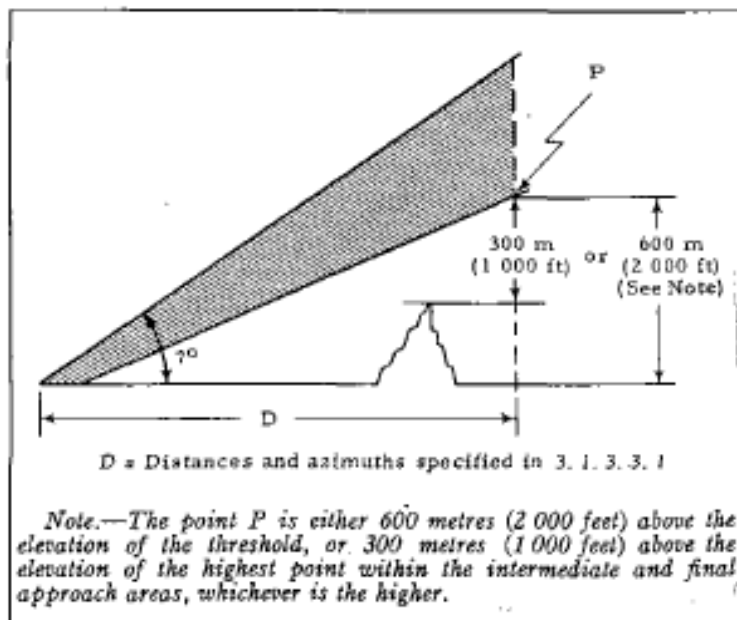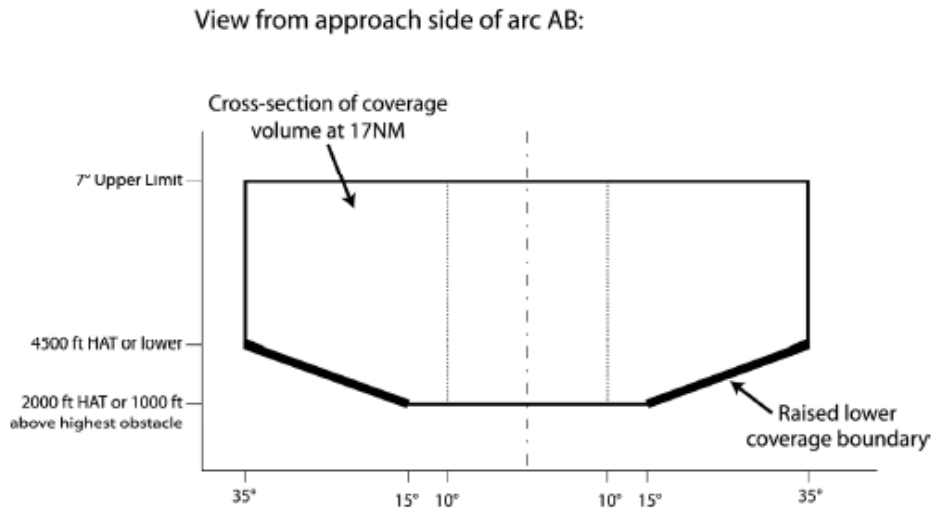
Figure 3A Reduced Localizer Coverage with respect to elevation

Note: Because of the siting problems and terrain limitations, some localizers may not meet the standard coverage area described above. In such cases approach plate design will assure aircraft remain within areas of adequate signal coverage and such information will be duly annotated on the approach plate.

3.1.3.3.3 Above 7 degrees, the signals should be reduced to as low as practicable.

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 above shall not be less than 10 dB.

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 should not be less than 16 dB.

3.1.3.4 Course structure

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

Zone	Amplitude (DDM) (95% Probability)
Outer limit of coverage to ILS point "A"	0.031
ILS point "A" to ILS Point "B"	0.031 at ILS Point "A" decreasing at a linear rate to 0.015 at ILS point "B"
ILS Point "B" to ILS Point "C"	015

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

Zone	Amplitude (DDM) (95% Probability)
Outer limit of coverage to ILS point "A"	0.031
ILS point "A" to ILS Point "B"	0.031 at ILS Point "A" decreasing at a linear rate to 0.005 at ILS point "B"
ILS point "B" to ILS reference datum	0.005

and, for Category

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"

(L) = Theodolite corrected sample of course/path bends (microamperes)

(M) = Mean value of course/path bends (microamperes)

T = Region to be evaluated ($\pm$ 20 seconds wide)

$\pm 2\sigma_N$ = Max. bend amplitude specification at point (K) (microamperes)

$t_1, t_2, t_3, \ldots$ = Time intervals that noise exceeds allowable $2\sigma_N$ value. For the facility to be acceptable in this region:

$$100 \frac{[T - (t_1 + t_2 + t_3 \ldots)]}{T} \geq 95\%$$
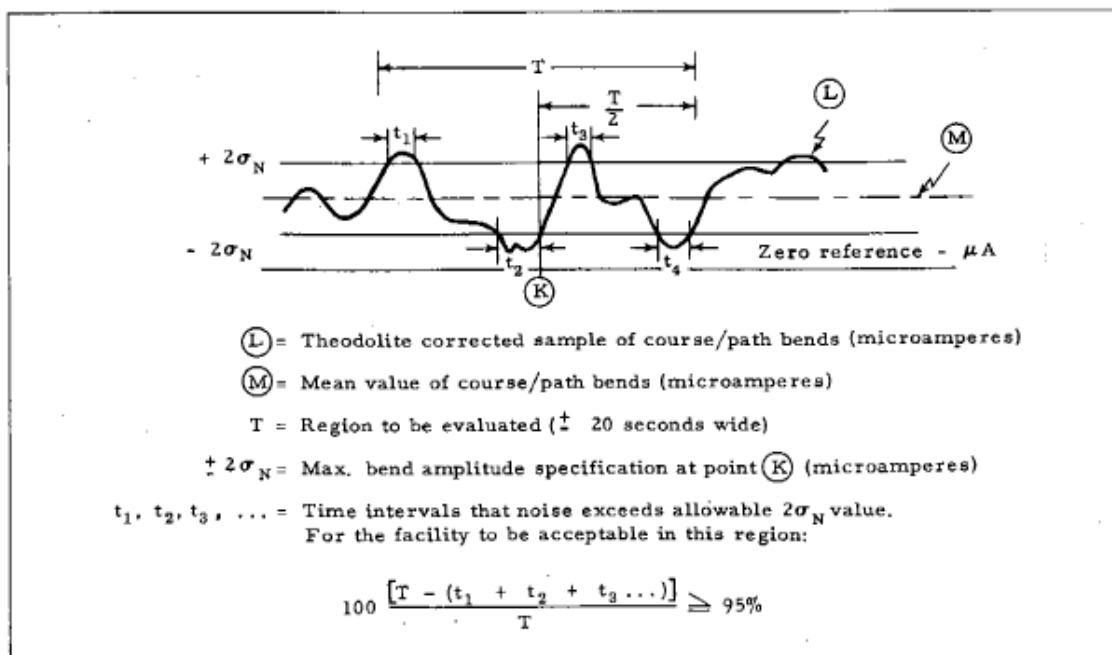
Figure 4

3.1.3.5   Carrier modulation

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

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

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

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

 b) the modulating tones shall be 90 Hz and 150Hz within plus or minus 1.5 per cent for facility performance category II installations;

 c) the modulating tones shall be 90 Hz and 150Hz within plus or minus 1 per cent for facility performance category III installations;

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

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

3.1.3.5.3.1. For facility performance category I – ILS, the modulating tones should be 90 Hz and 150 Hz within plus or minus 1.5 per cent where practicable.

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

3.1.3.5.3.3. The modulation tones shall be phase-locked so that within the half course sector, the demodulation 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.

3.1.3.5.3.4. With two-frequency localizer systems, 3.1.3.5.3.3 above shall apply to each carrier. In addition, the 90 Hz modulating tone of one carrier shall be phase locked to the 90 Hz modulating tone of the other carrier so that the demodulated wave forms pass through zero in the same direction within:
a) for categories I and II localizers: 20 degrees; and
c) for category III localizers: 10 degrees,

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

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

2) for categories 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 above 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 above.

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

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

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

Note 1: If the sum of the modulation depths is greater than 60 percent for Facility Performance Category 1 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.

The accompanying graphs illustrate a method that can be used to measure the relative phase relationship between the 90 Hz and 150 Hz tones. The upper portion of each graph shows the individual waveforms and their relationship at the limit of phase differences allowed by Chapter 3, 3.1.3.5.3.3 and 3.1.5.5.3. The lower portion shows the combined waveforms as would be seen on an oscilloscope. By taking the ratio of P_1 and P_2, which gives a value equal to or less than unity, it is possible to determine if the phasing is within tolerance. For Categories I and II ILS the ratio should be greater than 0.903 and for Category III the ratio should be greater than 0.951.

Figure 5 ILS Wave forms illustrating relative audio phasing of the 90 Hz & 150 Hz tones.
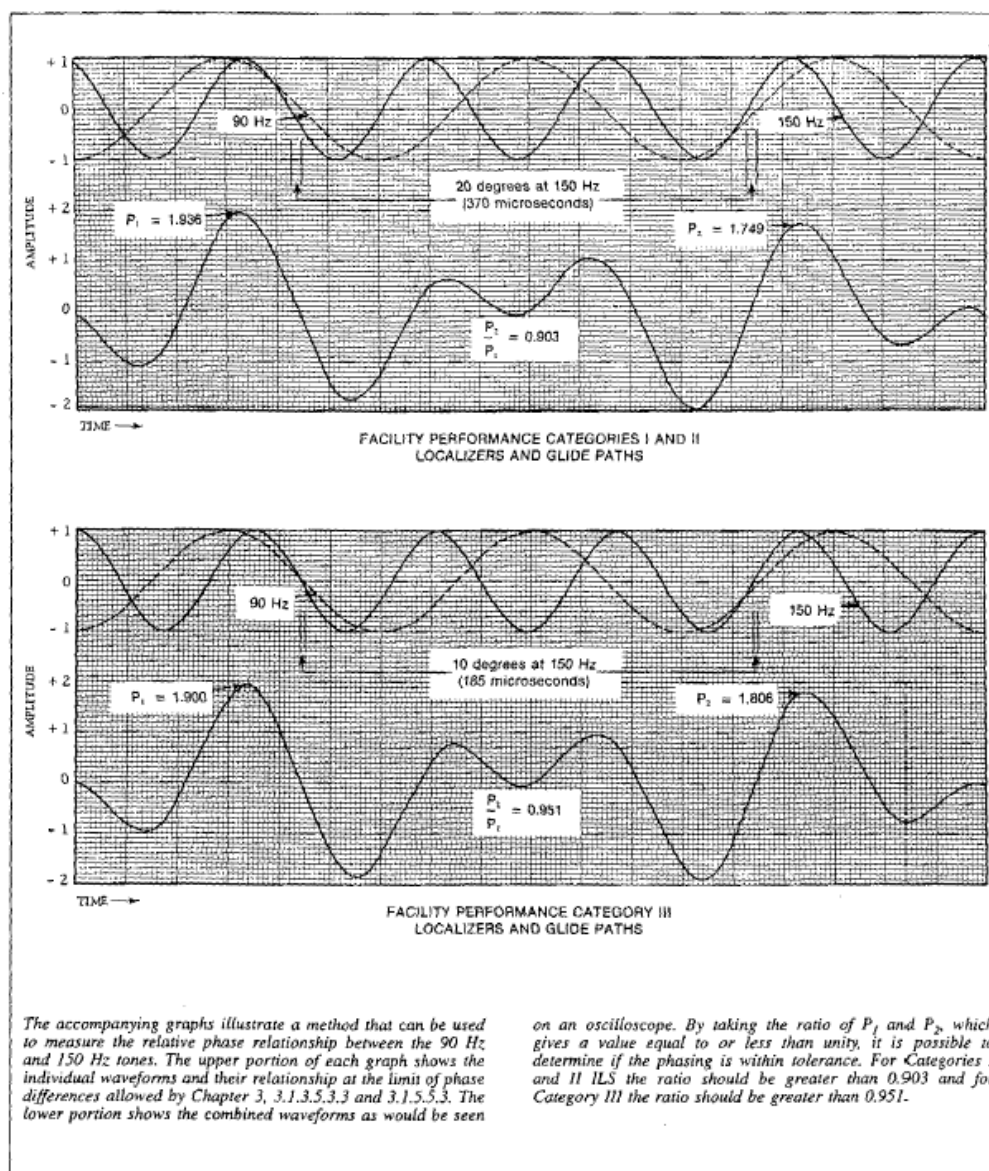
3.1.3.5.3.7. When utilizing a localizer for radiotelephone communications, the sum of the modulation depths of the radio frequency carrier due to the 90 Hz and 150 Hz tones shall not exceed 65 percent with 10 degrees of the course line and shall not exceed 78 percent at any other point around the localizer.

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 should be minimized to the extent practical.

3.1.3.6   Course alignment accuracy

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

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

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

    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 should be adjusted and maintained within limits equivalent to plus or minus 4.5m (15ft) displacement from runway centre line at the ILS reference datum.

3.1.3.7 Displacement sensitivity

3.1.3.7.1 The normal displacement sensitivity within the half course sector shall be the equivalent of 0.00145 DDM/m 0.00044 DDM/ft) at the ILS reference datum except that for Category I localizers, where the specified nominal displacement sensitivity cannot be met, the displacement sensitivity shall be adjusted as near as possible to the value. For facility Performance Category I localizers on runway codes 1 and 2, the nominal displacement sensitivity shall be achieved at the ILS point "B". The maximum course sector angle shall not exceed 6 degrees.

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 should be adjusted and maintained with the limits of plus or minus 10 percent where practicable.

Note:The figures given in 3.1.3.7.1, 3.1.3.7.2 & 3.1.3.7.3 above are based up on a nominal sector width of 210m (700 feet) at the appropriate time i.e. ILS point "B" on runway codes 1&2 and the ILS reference datum on other runways.
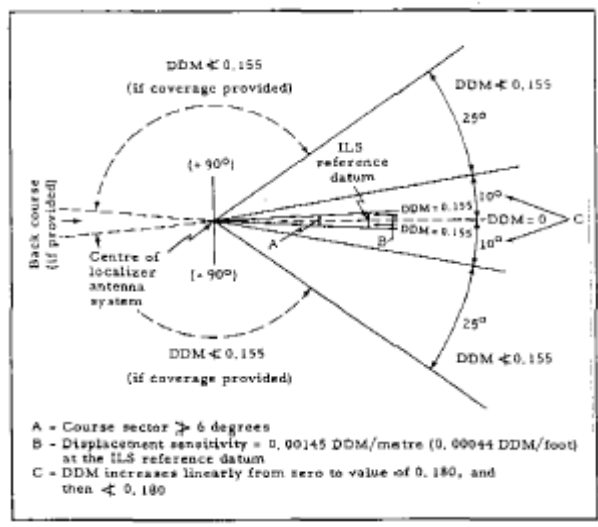
Figure 6 Difference in depth of modulation and displacement sensitivity

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 that 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 neighborhood of the course line.

Note 2: The above DDM in the 10-35 degree sector is to be considered a minimum requirement of 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 a operationally desirable distances provided that limits on modulation percentage given in 3.1.3.5.3.6 are met.

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

3.1.3.8 Voice

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

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

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

3.1.3.8.3.1 The channel shall be on the same radio frequency carrier or carriers as used for the localizer function and the rad8iation shall be horizontally polarized. Where to carriers are modulated with speech, the relative phases of the modulations on the two carriers shall be such as to avoid the occurrence of nulls within the coverage of the localizer.

3.1.3.8.3.2 The peak modulation depth of the carrier of carriers due to the radiotelephone communications shall not exceed 50 per cent bust shall be adjusted so that:

a) the ratio of peak modulation depth due to the radiotelephone communications to that due to identification signal is approximately 9:1;
b) the sum of modulation components due to use of the radiotelephone channel, navigational signals and identification signals shall not exceed 95 per cent.

3.1.3.8.3.3 The audio frequency characteristics of the radiotelephone channel shall be flat to with 3 dB relative to the level at 1000 Hz over the range 300 Hz to 3000 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 of carriers as used for the localizer function. The transmission of the identification signal shall not interfere in any way with the basic localizer function.

3.1.3.9.2 The identification signal shall be produced by Class A2A modulation of the radio frequency carrier or carriers using a modulation tone of 1020 Hz within plus or minus 50 Hz. The depth of modulation shall be between the limits of 5 and 15 per cent except that, where a radiotelephone communication channel is provided, the depth of modulation shall be adjusted so that the ratio of peak modulation depth due to radiotelephone communications to that due to the identification signal modulation is approximately 9:1 (see 3.1.3.8.3.2 above). The emissions carrying the identification signal shall be horizontally polarized. Where two carriers are modulated with identification signals, the relative phase of the modulations shall be such as to avoid the occurrence of nulls within the coverage of the localizer.

3.1.3.9.3 The identification signal shall employ the International Morse Code and consist of two or three letters. It may be preceded by the International Morse Code signal of the letter "I", followed by a short pause where it is necessary to distinguish the ILS facilities 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 transmission of the localizer is not available for operational use, as, for example, after removal of navigational 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 percent. The interval between letters shall not be less than the duration of three dots.

3.1.3.10 Siting

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

3.1.3.10.2 For Facility Performance Category I, the localizer antenna system shall be located and adjusted as in 3.1.3.10.1, unless site constraints dictate that the antenna be offset from the centre line of the runway.

3.1.3.10.2.1 The offset localizer system shall be located and adjusted in accordance with the offset ILS provisions of the 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 below, if any of the conditions stated in 3.1.3.11.2 below persists:

a) radiation to cease

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

3.1.3.11.2 The condition requiring monitor action shall be the following;

a) for Category I localizers, a shift of the mean course line from the runway center line equivalent to more than 10.5m (35ft), or the linear equivalent to 0.015 DDM, whichever is less, at the ILS reference datum;

b) for Facility Performance Category II localizer, a shift of 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 localizer, a shift of the mean course line from the runway center line equivalent to more than 6m (20ft) at the ILS reference datum ;

d) in the case of localizer 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 to a level that is less than 50 percent of the normal level (whichever comes 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 above.

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

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

Note: In selecting the power reduction figure to be employed in monitoring referred to in 3.1.3.11.2 e) above, particular attention is directed to vertical and horizontal lobe structure (vertical lobbing due to different antenna heights) of the combined radiation systems when two carriers are employed. Large changes in the power ratio between carriers may results 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 above.

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 should include the case when the DDM in the required coverage beyond plus or minus 10 degrees from the front course line, except in the back course sector, decreases below 0.155.

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

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

10 seconds for Category I localizers;
5 seconds for Category II localizers;
2 seconds for Category III localizers.

Note 1: *The total time periods specified are never-to-be-exceeded limits and are intended to protect aircraft in the final stages of approach against prolonged or repeated periods of localizer guidance outside the monitor limits. For this reason, they include not only the initial period of outside tolerance operation but also the total of any or all periods of outside tolerance radiation including periods(s) of zero radiation, and time required to remove the navigation and identification component from the carrier, which might occur during action to restore service, for example, in the course of consecutive monitor functioning and consequent change-over(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 should be reduced so as not to exceed two seconds for Category II localizers and one second for Category III localizers.

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

3.1.3.12 Integrity and continuity of service requirements.

3.1.3.12.1 The probability of not radiating false guidance signals shall not be less than 10.5×10^{-9} in any one landing for Facility Performance Categories II and III localizers.

3.1.3.12.2 The probability of not radiating false guidance signals should not be less than $1 - 1.0 \times 10^{-7}$ in any one landing for Facility Performance Category I localizers.

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

a) $1 - 2 \times 10^{-6}$ in any period of 15 seconds for Facility Performance Category II localizers or localizers intended to be used for the full range for Category III A operations (equivalent to 2000 hours mean time between outages) ; and

b) $1 - 2 \times 10^{-6}$ in any period of 30 seconds for Facility Performance Category III localizers intended to be used for the full range of Category III operations (equivalent to 4000 hours mean time between outages).

3.1.3.12.4 The probability of not losing the radiated guidance signal should exceed $1 - 4 \times 10$ in any period of 15 seconds for Facility Performance Category I localizers (equivalent to 1000 hours mean time between outages).

3.1.4 Interference immunity performance for ILS localizer receiving system.

3.1.4.1 The ILS localizer receiving system shall provide adequate immunity to interference from two-signal, third-order inter-modulation 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

$$2N_1+N_2+3(24-20\log \Delta f/0.4) \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz,

where the frequencies of the two VHF FM sound broadcasting signals procedure, within the receiver, a two-signal, third-order inter-modulation product on the desired ILS localizer frequency.

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

F=108.1-f1, where f1 is the frequency of N1, the VHF FM sound broadcasting signal closer to 108.1 MHz

3.1.4.2 The ILS localizer receiving system shall not 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

3.1.4.3 Intentionally left blank.

3.1.5   UHF glide path equipment and associated monitor.

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

3.1.5.1   General

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

150 Hz tone predominating below the path and the 90 Hz tone predominating above the path to at least an angle equal to 1.75 θ.

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

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

   a) 0.075 θ from 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.

3.1.5.1.3 The downward extended straight portion of the ILS glide path shall pass through the ILS reference datum at a height ensuring safe guidance over obstructions and also safe and efficient use of the RWY 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 (50ft). A tolerance of plus 3 m (10ft) is permitted.

3.1.5.1.5 The height of the ILS reference datum for facility performance category I - ILS should be 15 m (50 Feet). A tolerance of plus 3m (10) feet is permitted.

3.1.5.1.6 The height of the ILS reference datum for facility performance category I - ILS used on short precision approach RWY codes 1 and 2 should be 12m (40ft). A tolerance of plus 6m (20ft) is permitted.

3.1.5.2 Radio Frequency

3.1.5.2.1 The glide path equipment shall operate in the bank 328.6 MHz to 335.4 MHz. Where a   single radio frequency carrier is used, the frequency tolerance shall not exceed 0.005 percent. Where two carrier glide path systems are used, the frequency tolerance shall not exceed 0.002 percent 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 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

18.5 km (10nm) 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 above, the minimum field strength within this coverage sector shall be 400 μ volts per metre (minus 95 dbW/meter square). For facility performance category I glide paths, this field strength shall be provided down to a height of 30m (100ft) 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 (50ft) above the horizontal plane containing the threshold.
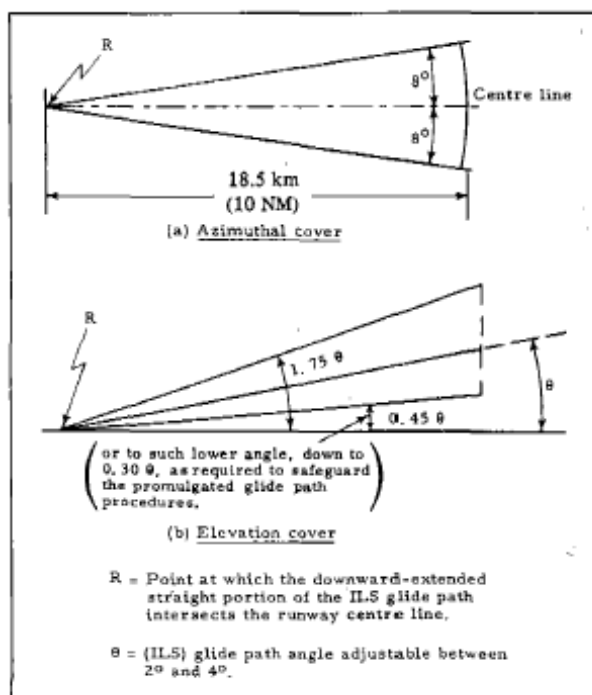
Figure 7

Note: Because of the siting problems and terrain limitations, some glide paths may not meet the standard coverage area described above. The information regarding such glide paths shall be published in AIP for each specific system.

3.1.5.4 ILS Glide Path Structure

3.1.5.4.1 For facility performance category I—ILS glide paths, bends in the glide path shall not have amplitudes which exceed the following:

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

3.1.5.4.2 For facility performance categories II and III, ILS glide paths, bends in the glide path shall not have amplitudes which exceed the following.

Zone	Amplitude (DDM) (95% probability)
Outer limit of coverage 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

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 percent along the ILS glide path. The depth of modulation shall not deviate outside the limits of 37.5 percent 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 should be 90 Hz and 150 Hz within plus or minus 1.5 percent 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 and 150 Hz wave forms pass through zero in the same direction within.

a) For facility performance categories I and II ILS glide paths 20 degrees.

b) For facility performance category III ILS glide path: 10 degrees

of phase relative to the 150 Hz components, every half cycle of the combined 90 Hz and 150 Hz wave form. (refer fig C-6 above)

3.1.5.5.3.1 With two frequency glide path systems, 3.1.5.5.3 above 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 cat I and II ILS glide paths 20 degrees.

b) For cat III ILS glide paths 10 degrees.

of phase relative to 90 Hz. Similarly, 150 Hz tones of the two carriers shall be phased locked so that the demodulated waveforms pass through zero in the same direction, within;

1) for Category I and II - ILS glide paths: 20 degrees;
2) for Category III ILS Glide paths : 10 degrees off 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 above 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 3.1.5.5.3.1 above.

3.1.5.6 Displacement sensitivity:

3.1.5.6.1 For facility performance CAT 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.

3.1.5.6.2 For facility performance CAT I ILS glide paths, the nominal angular displacement sensitivity should correspond to a DDM of 0.0875 at angular displacement below the glide path of 0.12 θ with a tolerance of plus or minus 0. 02 θ.   The upper and lower sectors should be as symmetrical as practicable within the limits specified in 3.1.5.6.1 above.

3.1.5.6.3 For facility performance CAT 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) 0.012 θ above path with a tolerance of plus 0.02 θ and minus 0.05 θ.

3.1.5.6.4 For facility performance CAT 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 0.12 θ with a tolerance of plus or minus 0.02 θ.

3.1.5.6.5 The DDM below the ILS glide path shall increase smoothly for decreasing angle until a value of 0.22 DDM is reached. This value shall be achieved at an angle not less than 0.30 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.

3.1.5.6.6 For facility performance CAT I ILS glide paths, the angular displacement sensitivity shall be adjusted and maintained within plus or minus 25 percent of the nominal value selected.

3.1.5.6.7 For facility performance CAT II ILS glide paths, the angular displacement sensitivity shall be adjusted and maintained within plus or minus 20 percent of the nominal value selected.

3.1.5.6.8 For facility performance CAT III ILS glide paths, the angular displacement sensitivity shall be adjusted and 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 deg to plus 0.10 deg from deg.

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 percent 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 percent of normal, except that a greater reduction to between 80 percent and 50 percent 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.

d) For facility performance CAT 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 deg or

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

e) For facility performance CAT 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 deg from horizontal.

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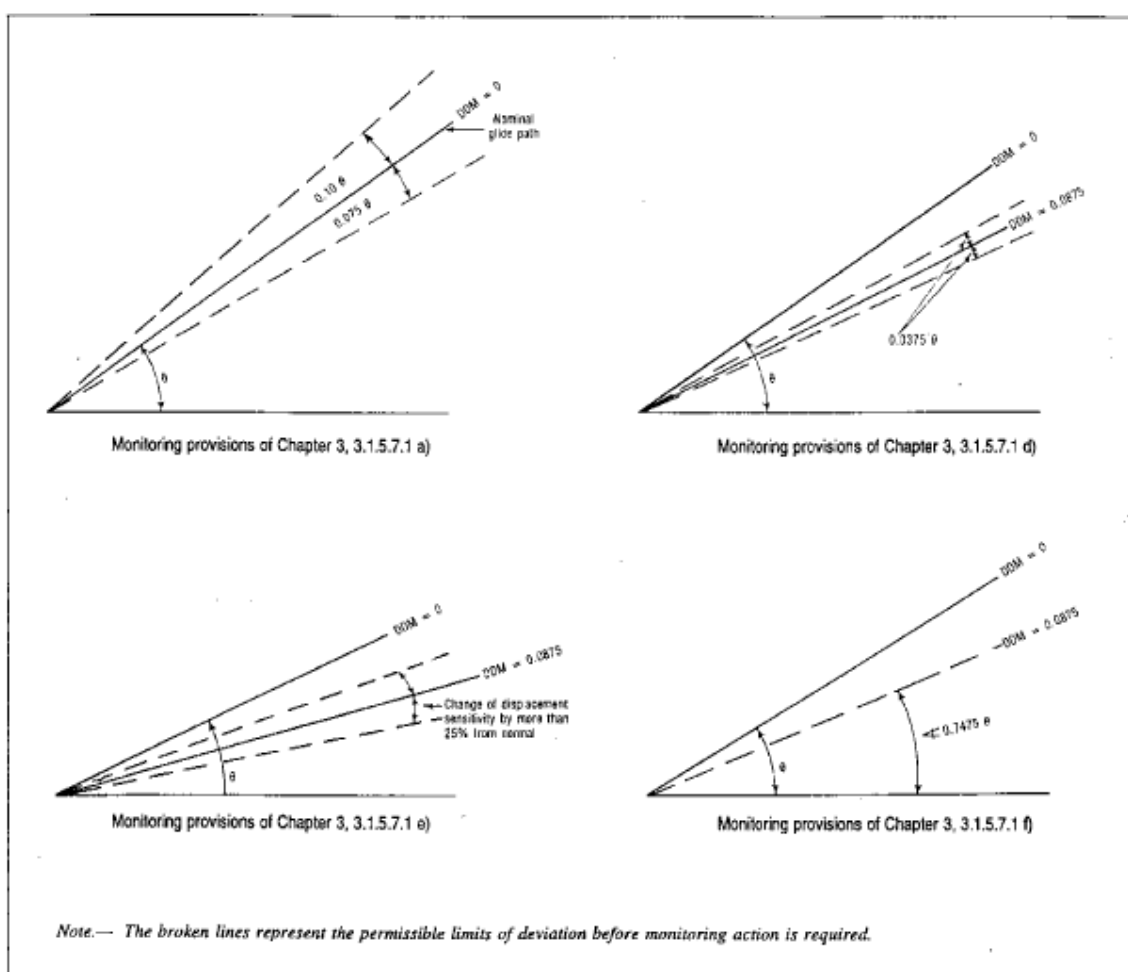

Figure 8

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.

Note 2: Sub paragraphs 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 sec to protect against sector deviations below 0.7475 θ from horizontal.

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

3.1.5.7.3 The total period of radiation, including periods 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 CAT I ILS glide paths
    2 seconds for CAT 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 changeover 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 above for categories II and III ILS glide paths should not exceed 1 second.

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

3.1.5.8 Integrity and continuity of service requirements

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

3.1.5.8.2 The probability of not radiating false guidance signals shall not be less than 1- 1.0 x 10^{-7} in any one landing for Facility Performance Category II glide paths.

3.1.5.8.3 The probability of not losing the radiated guidance signal shall be greater than 1- 2 x 10^{-6} in any period of 15 seconds for Facility Performance Categories II and II glide paths (equivalent to 2000 hours mean time between outages).

3.1.5.8.4 The probability of not losing the radiated guidance signal should exceed 1- 4 x 10^{-6} in any period of 15 seconds for Facility Performance Category I glide paths (equivalent 10 00 hours mean time between outages).

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 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)	
108.1	334.7	
108.15		334.55
108.3	334.1	
108.35		333.95
108.5	329.9	
108.55		329.75
108.7	330.5	
108.75		330.35
108.9	329.3	
108.95		329.15
109.1	331.4	
109.15		331.25
109.3	332.0	
109.35		331.85
109.5	332.6	
109.55		332.45
109.7	333.2	
109.75		333.05
109.9	333.8	
109.95		333.65
110.1	334.4	
110.15		334.25
110.3	335.0	
110.35		334.85
110.5	329.6	

110.55		329.45
110.7	330.2	
110.75		330.05
110.9	330.8	
110.95		330.65
111.1	331.7	
111.15		331.55
111.3	332.3	
111.35		332.15
111.5	332.9	
111.55		332.75
111.7	333.5	
111.75		333.35
111.9	331.1	
111.95		333.95

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

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

3.1.6.2 Where existing ILS localizers meeting national requirements are operating on frequencies ending even tenths of megahertz, they shall be re-assigned 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 re-assignment 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 0odd tenths plus one twentieth of megahertz except where, by regional agreement, general use may be made of any of the channels listed in 3.1.6.1 (see CAR Section 4 Series 'D' Part VI Para 4.4.2).

3.1.7 VHF Marker beacons

3.1.7.1 General

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

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

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

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

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

3.1.7.2 Radio frequency

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

3.1.7.3 Coverage

3.1.7.3.1 The marker beacon system shall be adjusted to provide coverage over the following distances, measured on the ILS glide path and localizer course line:

a) **Inner marker:** (where installed): 150 m plus of minus 50 m (500 ft plus or minus 160ft)

b) **Middle marker:** 300 m plus or minus 100m (1000ft plus of minus 325 ft)

c) **Outer marker:** 600m plus or minus 200m (2000ft plus or minus 650ft).

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 dB W/m^2). In addition, the field strength within the coverage area shall rise to at least 3.0 millivolts per metre (76 dB W/m^2).

Note 1: Satisfactory operation of 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 dB W/m^2).

3.1.7.4 Modulation

3.1.7.4.1 The modulation frequencies shall be as follows:

   a) **Inner marker:** (when installed): 3000Hz

   b) **Middle marker:** 1300 Hz:

   c) **Outer marker:** 400 Hz

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

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

3.1.7.5 Identification

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

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

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

   c) **Outer marker:** 2 dashes per second continuously.

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

3.1.7.6 Siting

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

3.1.7.6.1.1 If the radiation pattern is vertical, the inner marker, when installed, should be located between 75 m (250ft) and 450 m (1500 ft) from the threshold and at not more than 30 m (100ft) from the extended centre line of the runway.

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

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

3.1.7.6.2.1 If the radiation pattern is vertical, the middle marker should be located 1050m (3500ft) plus or minus 150 m (500ft), from the landing threshold at the approach end of the runway and at not more than 75 m (250 ft) from the extended centre line of the runway.

3.1.7.6.2.2 If the radiation pattern is other than vertical, the equipment should be located so as to produce a field with 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 should be located 7.2 km (3.9NM) 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 should be not more than 75 m (250 ft) from the extended centre line of the runway. If the radiation pattern is other than vertical, the equipment should be located so as to produce a field within the course sector and ILS glide path sector that is substantially similar to that produced by an antenna radiating a vertical pattern.

3.1.7.6.5 The positions of marker beacons, or where applicable, the equivalent distance(s) indicated by the DME when used as an alternative to part or all of the market beacon component of the ILS, shall be published in accordance with the provisions of CAR Section 4 Series 'X' Part II.

3.1.7.6.5.1 When so used, the DME shall provide distance information operationally equivalent to that furnished by Marker Beacons.

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

3.1.7.6.5.3 The DME in 3.1.7.6.6 above shall conform to the specification in 3.5 below.

3.1.7.7 Monitoring

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

a) Failure of the modulation or keying;

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

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

3.2   Specification For Precision Approach Radar System

3.2.1   Intentionally left blank

3.2.2   Intentionally left blank

3.2.3   Intentionally left blank

3.2.4   The Surveillance Radar element (SRE)

3.2.4.1 A Surveillance Radar used as 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 50 m square echoing area and larger, which are in light of sight of the antenna within a volume described as follows:

The rotation through 360 degrees about the antenna of vertical plane surface bounded by a line at an angle of 1.5 degrees above the horizontal plane of the antenna, extending from the antenna to 37 Km (20 NM); by a vertical line at 37 Km (20 NM) from the intersection with the 1.5 line up to 2004 m (8000 ft) above the level of antenna; by a horizontal line at 2004 m (8000 ft) from 37 Km (20 NM) back towards the antenna to the intersection with a line from the antenna at 20 ° above the horizontal plane of the antenna, and by a 20 ° line from the intersection with the 2004 m (8000 ft) line to the antenna.

3.2.4.2.2 Efforts should be made in development to increase the coverage on an aircraft of 50 m square echoing area to at least the volume obtained by amending 3.2.4.2.1 above with the following substitution.

-- for 1.5 °, read 0.5 °
-- for 37 Km (20 NM), read 46.3 Km (20 NM)
-- for 2400 m (8000 ft), read 3000 m (10000 ft)
-- for 20 °, read 30 °

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 position of two aircraft which are at 4 ° of azimuth of one another.

3.2.4.3.2 Distance Accuracy: The error in distance indication shall not exceed 5 percent of true distance or 150 m, whichever is the greater. It shall be possible to resolve the position of two aircraft that are separated by a distance of 1 percent of the true distance from the point of observation or 230 m whichever is greater.

3.2.4.3.2.1 The error in distance indication should not exceed 3 percent of the true distance of 150 m, 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 ever 4 seconds.

3.2.4.5 Efforts should be made to reduce, as far as possible, the disturbance caused by ground echoes.

3.3   Specification for VHF Omni Directional 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 (bearing), 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. The channel separation shall be in increments of 50 KHZ. The frequency tolerance of the radio frequency carrier where 50 KHz channel spacing is in

use shall be plus or minus 0.002 per cent. 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 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 installations in India 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 radiation shall be as small   as possible.

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 elevations angles between 0 to 40 degrees, measured from the center 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 satisfactorily operation of a typical aircraft installation at the minimum service level at the maximum specified service radius should be 90 micro volt per meter or minus 107 db W/m square.

3.3.5 Modulation of navigational signals:

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

   a)   a sub carrier of 9960 Hz of constant amplitude, frequency modulated at 30 Hz r)

   1) For the conventional VOR, the 30 Hz component of this FM sub carrier is fixed without respect to azimuth and is termed the "reference phase" and shall have a deviation ratio of 16 plus or minus 1 (i.e. 15 to 17);

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

b) A 30 Hz amplitude modulation component:

1) For the conventional VOR, this component results from a rotating field pattern, the phase of which varies with azimuth, and is termed the "variable phase".

2) For the Doppler VOR, this component, of constant phase with relation to azimuth and constant amplitude, is radiated omni directionally 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 sub carrier of 9960 Hz shall be within the limits of 28 percent and 32 percent.

3.3.5.3 The depth of modulation of the radio frequency carrier due to the 30 Hz, as observed at any angle of elevation up to 5 degrees, shall be within 25 to 35 percent. The depth of modulation of the radio frequency carrier due to the 9960 Hz signal, as observed at any angle of elevation up to 5 degrees, shall be within the limits of 20 to 55 per cent on facilities without voice modulation and within the limits of 20 to 35 per cent on facilities with voice modulation.

Note.— When modulation is measured during flight testing under strong dynamic multipath conditions, variations in the received modulation percentages are to be expected. Short-term variations beyond these values may be acceptable. Doc 8071 contains additional information on 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 sub carrier modulation mid-frequency shall be 9960 Hz within plus or minus 1 percent.

3.3.5.6   a) For the conventional VOR, the percentage of amplitude modulation of the 9960 Hz sub carrier shall not exceed 5 percent.

b) For the Doppler VOR, the percentage of amplitude modulation of the 9960 Hz subcarrier shall not exceed 40 percent when measured at a point at least 300 m (1000ft) from the VOR.

3.3.5.7 Where 50 KHz VOR channel spacing is implemented, the sideband level of the harmonics of the 9960 Hz component in the radiated signal shall not exceed the following levels referred to the level of the 9960 Hz sideband:

Subcarrier	Level
9960Hz	0 dB reference
2nd Harmonics	- 30 dB
3rd Harmonics	-50 dB
4th Harmonics & 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 3dB relative to the level 1000Hz over the range 300Hz to 3000Hz.

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

3.3.6.5 The identification signal shall employ the International Morse code and consist of two or three letters. It shall be sent at a speed corresponding to approximately 7 words per minutes. The signal shall be repeated at least once every 30 seconds and the Modulation tone shall be 1020Hz within plus or minus 50Hz.

3.3.6.5.1 The identification signal should be transmitted at least three   times each 30 seconds, spaced equally within that time period. One of these identification signals may take the form of voice 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 increase the modulation by the code identification signal to a value not exceeding to 20 percent.

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

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

3.3.6.8 The VOR receiving function shall permit positive identification of the wanted signal under signal conditions encountered within the specified coverage

limits, and with the modulation parameters specified at 2.6.5, 2.6.7 and 2.6.9 above

3.3.7 M**onitoring**

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 to a control point and either remove the identification and navigational components from the carrier or cause radiation to cease if any one or a combination of the following deviations from established arises:

   a) A change in excess of 1 degree at the monitor 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 sub carrier, or 30 Hz amplitude modulation signals or both.

Note: Where it is not possible to provide status indication to a control point, the same shall be published in AIP.

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

   a) By removing the identification and navigations components from the carrier; or

   b) Cause radiation to cease.

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 signals, third order inter-modulation 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

$$2N_1 + N_2 + 3 (24 - 20 \log \Delta f / 0.4) \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz,

where the frequencies of the two VHF FM sound broadcasting signals produced, within the receiver, at two signal, third order inter-modulation 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 below.

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

3.3.8.2 The VOR receiving system shall not 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
88 – 102	+ 15 dBm
104	+ 10 dBm
106	+ 5 dBm
107.9	- 10 dBm

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

3.4 Specification for non-directional Radio beacon (NDB)

3.4.1 Definitions:

Average Radius of rated coverage: The radius of a circle having the same areas as the rated coverage.

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

Locator: An LF/MF NDB used 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 should be 70 micro volts per meter.

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

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

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

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

3.4.2.3 Where the rated coverage of an NDB is materially different in various operationally significant factors, its classifications should be expressed in terms of the average radius of rated coverage and the angular limits of each sector as follows.

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

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

3.4.3 Limitations in radiated power

The power radiated from an NDB shall not exceed by more than 2dB 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 1750 kHz.

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

3.4.4.3 Where two locators are used as supplements to an ILS, the frequency separation between the carriers of the two should be not less than 15KHZ to ensure correct operation of the radio compass and preferably not more than 25KHZ 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.

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 the on/off keying of the carrier.   In this latter case, the identification shall be at approximately I-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 should be transmitted at least three times each 30 seconds, spaced equally within that time period.

3.4.5.3 For NDBs with an average radius of rate 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 from identification shall be 1020 Hz plus or minus 50 Hz or 400 Hz plus or minus 25 Hz.

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 conjunctions 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 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 (50NM), may be identified by on/off keying of the un modulated carrier (NON/AIA) 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/AIA 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: The foregoing requirement necessitates as high a percentage modulation as practicable, together with maintenance of an adequate radiated carrier power during identification.

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

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

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

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

3.4.7 Siting of Locators

3.4.7.1 Where locators are used as a supplement to the ILS, they should be located at the sites of the outer and middle marker beacons. Where only one locator is used as a supplement to the ILS, preference should be given to location at the site of the outer marker beacon.   Where locators are employed as an aid to final approach in the absence of an ILS, equivalent location to those applying when an ILS is installed should be selected, taking into account the relevant obstacle clearance provisions of the ICAO Doc 8168 – Procedures for Air Navigation Services (Aircraft Operations)

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

3.4.8 Monitoring:

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

   a) a decrease in radiated carrier power of more 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 should be capable of detecting such power supply modulation on the carrier in excess of 5 per cent.

3.4.8.3 During the hours of service of a locator, the means of monitoring shall provide for a 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) above.

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

3.5 Specification for UHF distance measuring equipment (DME)

Note 1: In the following section, provision is made for two type of DME facility: DME/N for general application and DME/P as outlined in 3.11.3 below.

3.5.1 Definition

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 below)

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. (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 enroute of TMA navigation, where the "N" stands for narrow spectrum characteristics (to be distinguished from "W").

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 (E.I.R.P.): The product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Virtual Origin: The point at which the straight line through the 30 per cent and 5 per cent amplitude points on the pulse leading edge intersects the 0 per cent amplitude axis (see Figure 3-2)
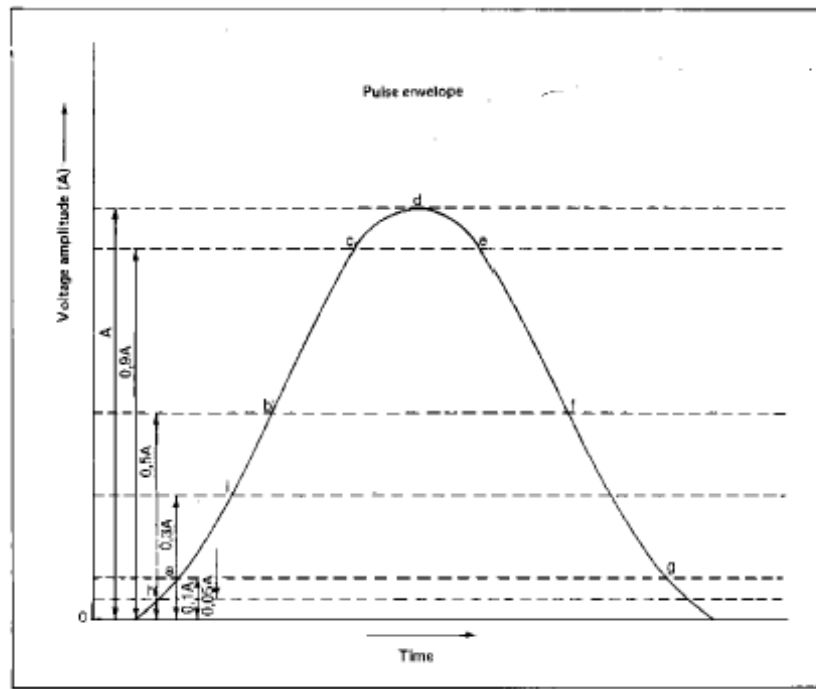
Figure 3 - 1
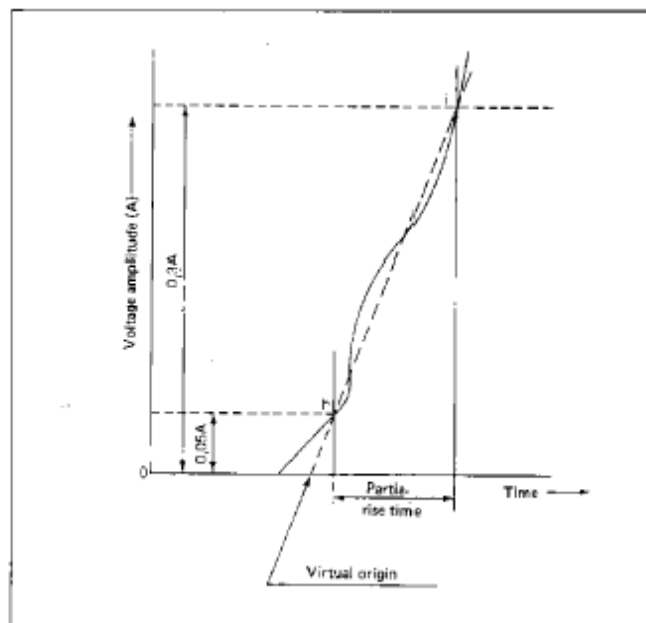
Figure 3 - 2

3.5.2   General

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

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

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

3.5.2.4 Intentionally left blank

3.5.2.5 When a DME associated with either an ILS or VOR for the purpose of constituting a single facility, they shall be considered to be associated in a manner complying with para 2.2.2 only when :

   a) they shall be operated on a standard frequency pairing in accordance with 3.5.3.3.5 below;

   b) they shall be Collocated within the limits prescribed for associated facilities in 3.5.2.6 below;

   c) they shall comply with the identification provisions of 3.5.3.6.4 below.

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 following:

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

   b) for purposes other than those indicated in a) the separation of the VOR and DME antennas does not exceed 600m (2000ft).

3.5.2.6.2 Association of DME with ILS

3.5.2.6.2.1 When DME is used as an alternative to ILS marker beacons, the DME should be located on the airport so that the zero range indication will be a point near the Runway.

3.5.2.6.2.2 In order to reduce the triangulation error, the DME should be sited to ensure a small angle (less than 20 degrees) between the approach path and the direction to the DME at points where the distant information is required.

3.5.2.6.2.3 The use of DME as an alternative to the Middle Marker beacon assumes a DME system accuracy of 0.37 km (0.2NM) or better and resolution of the air bore indication such as to allow this accuracy to be attained.

3.5.2.6.2.4 When DME is used as an alternative for the outer marker, frequency pairing is preferred to simplify pilot operation and to enable aircraft with two ILS receivers to use both receivers on the ILS channels.

3.5.2.6.2.5 When the DME is frequency paired with the localizer, the DME transponder identification should be obtained by the "associated" signal from the frequency paired localizer

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

3.5.3 System characteristics

3.5.3.1 Performance

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

3.5.3.1.2 Coverage:

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

3.5.3.1.2.2 When associated with an ILS DME/N coverage shall be at least that of the ILS coverage sector.

3.5.3.1.3 Accuracy

3.5.3.1.3.1 System accuracy: The accuracy standards specified in 3.5.3.1.3.4, 3.5.4.5 and 3.5.5.4 shall be met on at 95 percent probability basis.

3.5.3.2 Radio frequencies and polarization: The system shall operate with vertical polarization in the frequency band 960 MHz to 1215 MHz. The interrogation and reply frequencies shall be assigned with 1 MHz spacing between channels.

3.5.3.3 Channeling

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 Intentionally left blank

3.5.3.3.3 DME operating channels shall be chosen from Table A 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 the DME operating channel shall be paired with the VHF channel as given in table A.

3.5.3.4 Interrogation pulse repetition frequency

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 percent of the time is occupied for tracing.

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 airs of pulses per second.

3.5.3.4.3 DME/N: After 15000 pairs of pulses have been transmitted without acquiring indication of distance, the PRF should not exceeds 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.

3.5.3.5 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 of 100 aircraft, whichever is the lesser.

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

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 below:

   a) An "independent" identification consisting of coded (international Morse Code) identity pulses which can be used with all transponders.

   b) An "associated" signal which can be used for transponders specifically associated with a VHF navigation 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 1350 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 below. 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, should be transmitted 100 microseconds plus or minus 10 microseconds after each identity pair.

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

Note: The tone identification signal is transmitted at a repetition rate of 1350 pps. This frequency may be used directly in the airborne equipment as an aural output for the pilot, or other frequencies may be generated at the option of the interrogator designer (see 3.5.3.6.2 above)

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

   a) when associated with a VHF facility, the identification shall be transmitted in the form of dots and dashes (international Morse code) as in 3.5.3.6.3 above 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 facility identification, where these are provided, transmitted during the remaining periods:

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.

3.5.3.6.5.2 Wherever a transponder is specifically associated with a VHF navigational 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.

3.5.4   Detailed technical characteristics of transponder and associated monitor

3.5.4.1 Transmitter

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

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

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

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

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

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

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

e) For DME/N the spectrum of the pulse modulated signal shall be such that during the pulse the E.I.R.P contained in a 05 MHz band centered 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 E.I.R.P contained in a 05 MHz band centered on frequencies 2 MHz above and 2 MHz below the nominal channel frequency in each case shall not exceed 2mW.The E.I.R.P contained within any 0.5 MHz band shall decrease monotonically as the band center frequency moves away from the nominal channel frequency.

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

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 should be plus or minus 01.10 microsecond.

3.5.4.1.4.4 Intentionally left blank

3.5.4.1.4.5 The pulse spacing 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 E.I.R.P power should not be less than that required to ensure a peak pulse power density of minus 89 Dbw/m^2 under all I operational weather conditions at any point within coverage specified in 3.5.3.1.2 above.

3.5.4.1.5.2 DME / N. The peak equivalent isotropically radiated power shall not be less than that required to ensure peak pulse power density of minus 89 dBW / m^2 under all operational weather condition at any point with in coverage specified in 3.5.3.1.2 above.

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

3.5.4.1.5.3 Intentionally left blank

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 should be such that the transponder should be capable of continuous operation at a transmission rate of 2700 plus or minus 90 pulse pairs per second (if 100 aircraft are to be served).

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 seconds except during identity. The minimum transmission rate shall be as close as practicable to 700 pulse pairs per seconds.

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.

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

3.5.4.1.6.2 Intentionally left blank

3.5.4.1.6.3Out of band spurious radiation: At all frequencies from 10 to 1800 MHz but excluding the band of frequencies from 960 to 1215 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 center frequency shall be the interrogation frequency appropriate to the assigned DME operating channel (see 3.5.3.3.3 above)

3.5.4.2.2 Frequency stability: The centre frequency of the receiver shall not vary more than plus or minus 0.002 percent 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 minus103 dBW/m^2 for DME/N.

3.5.4.2.3.2 The minimum power densities specified in 3.5.4.2.3.1 above shall cause the transponder to reply with an efficiency of at least 70 percent for DME/N.

3.5.4.2.3.3DME/N dynamic range: The performance of the transponder shall be maintained when the power density of the interrogation signal at the transponder antenna has any value between the minimum specified in 3.5.4.2.3.1 above up to a maximum of minus 22 dBW/m^2 when installed with ILS and minus 35 dBW/m^2 when installed for other applications.

3.5.4.2.3.4 Intentionally left blank

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

3.5.4.2.3.6DME/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.

3.5.4.2.4 Load limiting:

3.5.4.2.4.1DME/N: When transponder loading exceeds 90 percent of the maximum transmission rate, the receiver sensitivity should be automatically reduced in order to limit the transponder replies, so as to ensure that the maximum permissible transmission rate is not exceeded. (The available range of sensitivity reduction should be at least 50 Db.

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

3.5.4.2.6 Band width

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 then 3dB when the total receiver drift is added to an incoming interrogation frequency drift of plus or minus 100 kHz.

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

3.5.4.2.6.3 Intentionally left blank

3.5.4.2.6.4 Intentionally left blank

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 shall not trigger the transponder. Signals arriving at the intermediate frequency shall be suppressed at least 80dB. All other spurious response or signals within the 9mmhz to 1215 MHz band and image frequencies shall be suppressed at least 75 dB.

3.5.4.2.7 Recovery time. Within 8 micro second of the reception of a signal between 0db and 60db above minimum sensitivity level, the minimum sensitivity level of the transponder to a desired signal shall be within 3db of the value obtained in the absence of signals. This requirement shall be met with echo suppression circuits, if any rendered in operative. 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 3.5.1.3 below.

3.5.4.2.8 Spurious Radiations: Radiation from any part of the receiver or allied circuits shall meet the requirements stated in 3.5.4.1.6 above

3.5.4.2.9 CW and echo suppression: CW and echo suppression should be adequate for the sites at which the transponder will be used.

Note: In this connection, echoes mean undesired signals caused by multi path transmission (reflection, etc).

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

3.5.4.3 Decoding

3.5.4.3.1 The transponder shall include a decoding circuit such that the transponder can be triggered only by pairs of received pulses having pulse duration and pulse spacing appropriate to interrogator signals as described in 3.5.5.1.3 and3.5.5.1.4 below.

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 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**.**

3.5.4.4 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 half voltage point on the reply transmission. This delay shall be consistent with the following table, when it is desired that aircraft interrogations are to indicate distance from transponder site.

Channel Suffix	Operating mode	Pulse pair spacing (micro µs)		Time delay (micro µs)	
		Interr.	Reply	1st pulse timing	2nd Pulse timing
X	DME/N	12	12	50	50
Y	DME/N	36	30	56	50

3.5.4.4.2 Intentionally left blank

3.5.4.4.3 For the DME/N the transponder time delay should be capable of being set to an appropriate value between the nominal value of the time delay minus 15 micro-seconds and the nominal value of the time delay, to permit aircraft interrogations 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

3.5.4.4.3.1DME/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.

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

Note: 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.

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 (500ft) to the over-all system error.

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

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

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

Note.— This error contribution limit includes errors from all causes except the airborne equipment, and assumes that the airborne equipment measures tie 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 micro-second (75m (250ft) to the over-all system error.

3.5.4.6 Efficiency

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

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.

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 below 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.

Note : Where it is not possible to provide status indication to a control point, the same shall be published in AIP.

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

   a) the transponder delay differs from the assigned value by 1 microseconds(75m(500ft)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 microseconds(75m(250ft) or more;

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

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

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

b) a fall of 6dB 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 above 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 above which are monitored can persist for a certain period before the monitor takes the 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.

3.5.4.7.3 DME/P monitoring action

3.5.4.7.3.1 Intentionally left blank
3.5.4.7.3.2 Intentionally left blank
3.5.4.7.3.3 Intentionally left blank
3.5.4.7.3.4 Intentionally left blank

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

3.5.5 Technical characteristics of interrogator

Note: The following sub paragraph specifies 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 above)

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** for DME/N shall not exceed 3 micro seconds.

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

c) **Pulse decay time** shall normally 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 trailing edge which id 95 percent of the maximum amplitude, fall below a value which is 95 percent of the maximum voltage amplitude of the pulse.

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

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

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

3.5.5.1.4.3 DME/N The tolerance on the pulse spacing should be plus or minus 0.25 microseconds.

3.5.5.1.4.4 Intentionally left blank

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 above.

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

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

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

3.5.5.1.7 The spurious pulse power received and measured under the condition stated in 3.5.5.1.6 above should be 80 dB below the required peak pulse power received.

Note: Reference 3.5.5.1.6 and 3.5.5.1.7 above—although limitation of spurious CW radiation between pulses to levels not exceeding 80 dB below the peak pulse power received is recommended, States are cautioned that where users employ airborne secondary surveillance radar transponder 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.

3.5.5.2 Time delay

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

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 condition corresponding to zero distance indication.

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 above).

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 below for the signal power density specified in 3.5.4.1.5.2 above.

3.5.5.3.2.2 Intentionally left blank

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 above and a maximum of minus18 dBW/m^2.

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.

3.5.5.3.4 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.

3.5.5.3.5 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 spacing 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 micro seconds, or more, from the nominal value and with any signal level up to 42 dB above the receiver sensitivity shall be rejected.

3.5.5.4 Accuracy

3.5.5.4.1 DME/N The interrogator shall not contribute more than plus or minus 315m (plus or minus 0.17NM) or 0.25 per cent of indicated range, whichever is greater to overall system error.

3.6   Intentionally left blank

3.7   **Requirements for the Global Navigation Satellite System (GNSS)**

3.7.1   Definitions

Aircraft-based augmentation system (ABAS). An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft.

Alert. An indication provided to other aircraft systems or annunciation to the pilot to identify that an operating parameter of a navigation system is out of tolerance.

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

Channel of standard accuracy (CSA). The specified level of positioning, velocity and timing accuracy that is available to any GLONASS user on a continuous, worldwide basis.

Core satellite constellation(s). The core satellite constellations are GPS and GLONASS.

GAGAN: GPS Aided GEO Augmented Navigation, An Indian SBAS

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.

Integrity. A measure of the trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts).

Pseudo-range. The difference between the time of transmission by a satellite and reception by a GNSS receiver multiplied by the speed of light in a vacuum, including bias due to the difference between a GNSS receiver and satellite time reference.

Satellite-based augmentation system (SBAS). A wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter.

Standard positioning service (SPS). The specified level of positioning, velocity and timing accuracy that is available to any global positioning system (GPS) user on a continuous, worldwide basis.

Time-to-alert. The maximum allowable time elapsed from the onset of the navigation system being out of tolerance until the equipment enunciates the alert.

3.7.2 General

3.7.2.1 *Functions*

3.7.2.1.1 The GNSS shall provide position and time data to the aircraft.

Note— these data are derived from pseudo-range measurements between an aircraft equipped with a GNSS receiver and various signal sources on satellites or on the ground.

3.7.2.2 *GNSS elements*

3.7.2.2.1 The GNSS navigation service shall be provided using various combinations of the following elements installed on the ground, on satellites and/or on board the aircraft:

a) Global Positioning System (GPS) that provides the Standard Positioning Service (SPS) as defined in 3.7.3.1;

b) Global Navigation Satellite System (GLONASS) that provides the Channel of Standard Accuracy (CSA) navigation signal as defined in 3.7.3.2

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

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

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

f) Intentionally Left Blank

g) Aircraft GNSS receiver as defined in 3.7.3.6

3.7.2.3 *Space and time reference*

3.7.2.3.1 *Space reference*. The position information provided by the GNSS to the user shall be expressed in terms of the World Geodetic System — 1984 (WGS-84) geodetic reference datum.

Note 1.— *SARPs for WGS-84 are contained in Annex 4, Chapter 2, Annex 11, Chapter 2, Annex 14, Volumes I and II,Chapter 2 and Annex 15, Chapter 3.*

Note 2.— *If GNSS elements using other than WGS-84 coordinates are employed, appropriate conversion parameters are to be applied.*

3.7.2.3.2 *Time reference*. The time data provided by the GNSS to the user shall be expressed in a time scale that takes the Universal Time Coordinated (UTC) as reference.

3.7.2.4 *Signal-in-space performance*

3.7.2.4.1 The combination of GNSS elements and a fault-free GNSS user receiver shall meet the signal-in-space requirements defined in Table 3.7.2.4-1

Note: The concept of a fault-free user receiver is applied only as a means of defining the performance of combinations of different GNSS elements. The fault-free receiver is assumed to be a receiver with nominal accuracy and time-to-alert performance. Such a receiver is assumed to have no failures that affect the integrity, availability and continuity performance.

Table 3.7.2.4-1 Signal-in-space performance requirements

Typical Operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$ /h	5 min	$1 - 1 \times 10^{-4}$ /h to $1 - 1 \times 10^{-8}$ /h	0.99 to 0.99999
En-route Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$ /h	15 s	$1 - 1 \times 10^{-4}$ /h to $1 - 1 \times 10^{-8}$ /h	0.99 to 0.99999
Initial approach. Intermediate approach. Non-precision approach (NPA). Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$ /h	10 s	$1 - 1 \times 10^{-4}$ /h to $1 - 1 \times 10^{-8}$ /h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ /h in any approach	10 s	$1 - 8 \times 10^{-6}$ /h Per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ /h in any approach	6 s	$1 - 8 \times 10^{-6}$ /h 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)	$1 - 2 \times 10^{-7}$ /h in any approach	6 s	$1 - 8 \times 10^{-6}$ /h Per 15 s	0.99 to 0.99999

NOTES-

1.The 95th-percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment D. 3.2.

2.The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. For Category I precision approach, a vertical alert limit (VAL) greater than 10 m for a specific system design may only be used if a system-specific safety analysis has been completed. Further guidance on the alert limits is provided in Attachment D. 3.3.6 to 3.3.10. These alert limits are:

Typical operation	Horizontal alert limit	Vertical alert limit
En-route (oceanic/continental low density)	7.4 km (4 NM)	N/A

En-route (continental)	3.7 km (2 NM)	N/A
En-route, Terminal	1.85 km (1 NM)	N/A
NPA	556 m (0.3 NM)	N/A
APV-I	40 m (130 ft)	50 m (164 ft)
APV-II	40 m (130 ft)	20.0 m (66 ft)
Category I precision approach	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33 ft)

3. The accuracy and time-to-alert requirements include the nominal performance of a fault-free receiver.

4. Ranges of values are given for the continuity requirement for en-route, terminal, initial approach, NPA and departure operations, as this requirement is dependent upon several factors including the intended operation, traffic density, complexity of airspace and availability of alternative navigation aids. The lower value given is the minimum requirement for areas with low traffic density and airspace complexity. The higher value given is appropriate for areas with high traffic density and airspace complexity (see Attachment D. 3.4.2). Continuity requirements for APV and Category I operations apply to the average risk (over time) of loss of service, normalized to a 15-second exposure time (see Attachment D. 3.4.3).

5. A range of values is given for the availability requirements as these requirements are dependent upon the operational need which is based upon several factors including the frequency of operations, weather environments, the size and duration of the outages, availability of alternate navigation aids, radar coverage, traffic density and reversionary operational procedures. The lower values given are the minimum availabilities for which a system is considered to be practical but are not adequate to replace non-GNSS navigation aids. For en-route navigation, the higher values given are adequate for GNSS to be the only navigation aid provided in an area. For approach and departure, the higher values given are based upon the availability requirements at airports with a large amount of traffic assuming that operations to or from multiple runways are affected but reversionary operational procedures ensure the safety of the operation (see Attachment D, 3.5).

6. A range of values is specified for Category I precision approach. The 4.0 m (13 feet) requirement is based upon ILS specifications and represents a conservative derivation from these specifications (see Attachment D, 3.2.7).

7. GNSS performance requirements for Category II and III precision approach operations are under review and will be included at a later date.

8. *The terms APV-I and APV-II refer to two levels of GNSS approach and landing operations with vertical guidance (APV) and these terms are not necessarily intended to be used operationally.*

3.7.3 GNSS elements specifications

3.7.3.1 *GPS Standard Positioning Service (SPS) (L1)*

3.7.3.1.1 *Space and control segment accuracy*

Note— The following accuracy standards do not include atmospheric or receiver errors as described in Attachment D, 4.1.2.They apply under the conditions specified in Appendix B,3.1.3.1.1

3.7.3.1.1.1*Positioning accuracy.* The GPS SPS position errors shall not exceed the following limits:

	Global average 95% of the time	Worst site 95% of the time
Horizontal position error (56ft)	9m (30ft)	17m
Vertical position error (121ft)	15m (49ft)	37m

3.7.3.1.1.2*Time transfer accuracy.* The GPS SPS time transfer errors shall not exceed 40 nanoseconds 95 per cent of the time.

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

a) Range error of any satellite —30m(100 ft)with reliability specified in 3.7.3.1.3

b) 95th percentile range rate error of any satellite —0.006m (0.02ft) per second;(global average);

c) 95th percentile range acceleration error of any satellite —0.002m (0.006ft) per second-squared(global average); and

d) 95th percentile range error for any satellites over all time differences between time of data generation and time of use of data 7.8m (26 ft) (global average).

3.7.3.1.2 *Availability.* The GPS SPS availability shall be as follows:

≥99 per cent horizontal service availability, average location (17 m 95 per cent threshold)

≥99 per cent vertical service availability, average location (37 m 95 per cent threshold)

≥90 per cent horizontal service availability, worst-case location (17 m 95 per cent threshold)

≥90 per cent vertical service availability, worst-case location (37 m 95 per cent threshold)

3.7.3.1.3 *Reliability*. The GPS SPS reliability 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).

3.7.3.1.4 Probability of major service failure. The probability that the user range error (URE) of any satellite will exceed 4.42 times the upper bound on the user range accuracy (URA) broadcast by that satellite without an alert received at the user receiver antenna within 10 seconds shall not exceed 1×10^{-5} per hour.

Note.— The different alert indications are described in the United States Department of Defense, *Global Positioning System - Standard Positioning Service - Performance Standard,* 4th Edition, September 2008, Section 2.3.4.

3.7.3.1.5 Continuity. The probability of losing GPS SPS signal-in-space (SIS) availability from a slot of the nominal 24-slot constellation due to unscheduled interruption shall not exceed 2×10^{-4} per hour

3.7.3.1.6 Coverage. The GPS SPS shall cover the surface of the earth up to an altitude of 3000 kilometres.

Note.— Guidance material on GPS accuracy, availability, reliability and coverage is given in Attachment D, 4.1

3.7.3.1.7 Intentionally left blank.

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

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

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

a) satellite time of transmission;
b) satellite position;
c) satellite health;
d) satellite clock correction;
e) propagation delay effects;
f) time transfer to UTC; and

g) constellation status.

Note.— *Structure and contents of data are specified in Appendix B, 3.1.1.2 and 3.1.1.3, respectively.*

3.7.3.2 GLONASS Channel of Standard Accuracy (CSA) (L1)

Note.— *In this section, the term GLONASS refers to all satellites in the constellation. Standards relating only to GLONASS-M satellites are qualified accordingly.*

3.7.3.2.1 Space and control segment accuracy

Note.— *The following accuracy Standards do not include atmospheric or receiver errors as described in Attachment D, 4.2.2*

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

	Global average 95% of the time	Worst site 95% of the time
Horizontal position error	5 m (17 ft.)	12 m (40 ft.)
Vertical position error	9 m (29 ft.)	25 m (97 ft.)

3.7.3.2.1.2 Time transfer accuracy. The GLONASS CSA time transfer errors shall not exceed 700 nanoseconds 95 per cent of the time.

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

  a) range error of any satellite — 18 m (59.7 ft);
  b) range rate error of any satellite — 0.02 m (0.07 ft) per second;
  c) range acceleration error of any satellite — 0.007 m (0.023 ft) per second squared;
  d) root-mean-square range error over all satellites — 6 m (19.9 ft).

3.7.3.2.2 Availability. The GLONASS CSA availability shall be as follows:

  a) ≥99 per cent horizontal service availability, average location (12 m, 95 percent threshold);
  b) ≥99 per cent vertical service availability, average location (25 m, 95 percent threshold);
  c) ≥90 per cent horizontal service availability, worst-case location (12 m, 95 per cent threshold);
  d) ≥90 per cent vertical service availability, worst-case location (25 m, 95 per cent threshold).

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

a) frequency of a major service failure — not more than three per year for the constellation (global average); and

b) reliability — at least 99.7 per cent (global average).

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

Note.— Guidance material on GLONASS accuracy, availability, reliability and coverage is given in Attachment D, 4.2.

3.7.3.2.5 *RF characteristics*

Note.— Detailed RF characteristics are specified in Appendix B, 3.2.1.1.

3.7.3.2.5.1*Carrier frequency.* Each GLONASS satellite shall broadcast CSA navigation signal at its own carrier frequency in the L1 (1.6 GHz) frequency band using frequency division multiple access (FDMA).

Note 1.— GLONASS satellites may have the same carrier frequency but in this case they are located in antipodal slots of the same orbital plane.

Note 2.— GLONASS-M satellites will broadcast an additional ranging code at carrier frequencies in the L2 (1.2 GHz) frequency band using FDMA.

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

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

3.7.3.2.5.4*Signal power level.* Each GLONASS satellite shall broadcast CSA navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the output of a 3 dBi linearly polarized antenna is within the range of – 161 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

Note 1.— The power limit of 155.2 dBW is based on the predetermined characteristics of a user antenna, atmospheric losses of 0.5 dB and an error of an angular position of a satellite that does not exceed one degree (in the direction causing the signal level to increase).

Note 2.— GLONASS-M satellites will also broadcast a ranging code on L2 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the output of a 3 dBi linearly polarized antenna is not less then –167 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.2.5.5 Modulation

3.7.3.2.5.5.1 Each GLONASS satellite shall transmit at its carrier frequency the navigation RF signal using a BPSKmodulated binary train. The phase shift keying of the carrier shall be performed at π-radians with the maximum error ±0.2 radian. The pseudo-random code sequence shall be repeated each millisecond.

3.7.3.2.5.5.2 The modulating navigation signal shall be generated by the Modulo-2 addition of the following three binary signals:
a) ranging code transmitted at 511 kbits/s;
b) navigation message transmitted at 50 bits/s; and
c) 100 Hz auxiliary meander sequence.

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

3.7.3.2.7 *Coordinate system.* The GLONASS coordinate system shall be PZ-90.

Note.— *Conversion from the PZ-90 coordinate system used by GLONASS to the WGS-84 coordinates is defined in Appendix B, 3.2.5.2.*

3.7.3.2.8 *Navigation information.* The navigation data transmitted by the satellite shall include the necessary information to determine:
a) satellite time of transmission;
b) satellite position;
c) satellite health;
d) satellite clock correction;
e) time transfer to UTC; and
f) constellation status.

Note.— *Structure and contents of data are specified in Appendix B, 3.2.1.2 and 3.2.1.3, respectively.*

3.7.3.3 *Aircraft-based augmentation system (ABAS)*

3.7.3.3.1 *Performance.* The ABAS function combined with one or more of the other GNSS elements and both a fault-free GNSS receiver and fault-free aircraft system used for the ABAS function shall meet the requirements for accuracy, integrity, continuity and availability as stated in 3.7.2.4.

3.7.3.4 *Satellite-based augmentation system (SBAS)- GAGAN*

3.7.3.4.1 *Performance.* GAGAN combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for system accuracy, integrity, continuity and availability for the intended operation as stated in 3.7.2.4.

Note.— *GAGAN complements the core satellite constellation(s) by increasing accuracy, integrity, continuity and availability of navigation provided within a service area, typically including multiple aerodromes.*

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

a) Intentionally left Blank

b) GNSS satellite status: determine and transmit the GNSS satellite health status (Appendix B, 3.5.7.3);

c) Basic differential correction: provide GNSS satellite ephemeris and clock corrections (fast and long-term) to be applied to the pseudo-range measurements from satellites (Appendix B, 3.5.7.4); and

d) Precise differential correction: determine and transmit the Ionospheric corrections (Appendix B, 3.5.7.5).

3.7.3.4.2.1 Intentionally left blank

3.7.3.4.3 *Service area.* The GAGAN service area shall be a defined area where GAGAN meets the requirements of 3.7.2.4 and supports the corresponding approved operations.

Note 1.— *The coverage area is that area within which the SBAS broadcast can be received (e.g. the geostationary satellite footprints).*

Note 2.— *SBAS coverage and service areas are discussed in Attachment D, 6.2.*

3.7.3.4.4 *RF characteristics*

Note.— *Detailed RF characteristics are specified in Appendix B, 3.5.2.*

3.7.3.4.4.1 *Carrier frequency.* The carrier frequency shall be 1 575.42 MHz.

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

3.7.3.4.4.3 *Signal power level*

3.7.3.4.4.3.1 Each GAGAN satellite shall broadcast navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the output of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.4.4.3.2 Each SBAS satellite placed in orbit after 31 December 2013 shall broadcast navigation signals 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 GEO signal needs to be provided, the level of the received RF signal at the output of the antenna specified in Appendix B, Table B-87, is at least −164.0 dBW.

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

3.7.3.4.4.3.2.2 The level of a received GAGAN RF signal at the output of a 0 dBic antenna located near the ground shall not exceed −152.5 dBW.

3.7.3.4.4.4 *Polarization.* The broadcast signal shall be right-hand circularly polarized.

3.7.3.4.4.5 *Modulation.* The transmitted sequence shall be the Modulo-2 addition of the navigation message at a rate of 500 symbols per second and the 1 023 bit pseudo-random noise code. It shall then be BPSK-modulated onto the carrier at a rate of 1.023 mega-chips per second.

3.7.3.4.5 *GAGAN network time (GNT).* The difference between GNT and GPS time shall not exceed 50 nanoseconds.

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

a) GAGAN satellite time of transmission;
b) GAGAN satellite position;
c) Corrected satellite time for all satellites;
d) Corrected satellite position for all satellites;
e) Ionospheric propagation delay effects;
f) User position integrity;
g) Time transfer to UTC; and
h) Service level status.

Note.— *Structure and contents of data are specified in Appendix B, 3.5.3 and 3.5.4, respectively.*

3.7.3.5 *Ground-based augmentation system (GBAS)*

Note: Except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.

3.7.3.5.1 *Performance.* GBAS combined with one or more of the other GNSS elements and a fault-free GNSS receiver shall meet the requirements for system accuracy, continuity, availability and integrity for the intended operation as stated in 3.7.2.4.

Note— GBAS is intended to support all types of approach, landing, departure and surface operations and may support en-route and terminal operations. The following SARPs are developed to support Category I precision approach, approach with vertical guidance, and a GBAS positioning service. In order to achieve interoperability and enable efficient spectrum utilization, it is intended that the data broadcast is the same for all operations.

3.7.3.5.2 *Functions.* GBAS shall perform the following functions:

> a) provide locally relevant pseudo-range corrections;
> b) provide GBAS-related data;
> c) provide final approach segment data when supporting precision approach;
> d) provide predicted ranging source availability data; and
> e) provide integrity monitoring for GNSS ranging sources.

3.7.3.5.3 *Coverage*

3.7.3.5.3.1 *Category I precision approach and approach with vertical guidance.* The GBAS coverage to support each Category I precision approach or approach with vertical guidance shall be as follows, except where topographical features dictate and operational requirements permit:

> a) laterally, beginning at 140 m (450 ft) each side of the landing threshold point/fictitious threshold point (LTP/FTP) and projecting out ±35 degrees either side of the final approach path to 28 km (15 NM) and ±10 degrees either side of the final approach path to 37 km (20 NM); and

> b) vertically, within the lateral region, up to the greater of 7 degrees or 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the glide path interception point (GPIP) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure. This coverage applies between 30 m (100 ft) and 3 000 m (10 000 ft) height above threshold (HAT).

Note.— LTP/FTP and GPIP are defined in Appendix B, 3.6.4.5.1.

3.7.3.5.3.1.1 Recommendation.— *For Category I precision approach, the data broadcast as specified in 3.7.3.5.4 should extend down to 3.7 m (12 ft) above the runway surface.*

3.7.3.5.3.1.2 Recommendation.— *The data broadcast should be omni-directional when required to support the intended applications.*

Note.— Guidance material concerning coverage for Category I precision approach and APV is provided in Attachment D, 7.3.

3.7.3.5.3.2 *GBAS positioning service.* The GBAS positioning service area shall be that area where the data broadcast can be received and the positioning service meets the requirements of 3.7.2.4 and supports the corresponding approved operations.

Note — Guidance material concerning the positioning service coverage is provided in Attachment D, 7.3.

3.7.3.5.4 *Data broadcast characteristics*

Note — RF characteristics are specified in Appendix B, 3.6.2.

3.7.3.5.4.1 *Carrier frequency.* The data broadcast radio frequencies used shall be selected from the radio frequencies in the band 108 to 117.975 MHz. The lowest assignable frequency shall be 108.025 MHz and the highest assignable frequency shall be 117.950 MHz. The separation between assignable frequencies (channel spacing) shall be 25 kHz.

Note 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;

3.7.3.5.4.3 *Modulation.* GBAS data shall be transmitted as 3-bit symbols, modulating the data broadcast carrier by D8PSK, at a rate of 10 500 symbols per second.

3.7.3.5.4.4 *Data broadcast RF field strength and polarization*

Note.— GBAS can provide a VHF data broadcast with either horizontal (GBAS/H) or elliptical (GBAS/E) polarization that employs both horizontal polarization (HPOL) and vertical polarization (VPOL) components. Aircraft using a VPOL component will not be able to conduct operations with GBAS/H equipment. Relevant guidance material is provided in Attachment D, 7.1.

3.7.3.5.4.4.1 *GBAS/H*

3.7.3.5.4.4.1.1 A horizontally polarized signal shall be broadcast.

3.7.3.5.4.4.1.2 The effective radiated power (ERP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m2) and a maximum field strength of 0.350 volts per metre (–35 dBW/m2) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and any VPOL components shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL users throughout the coverage volume.

3.7.3.5.4.4.2 *GBAS/E*

3.7.3.5.4.4.2.1 Recommendation.—_An elliptically polarized signal should be broadcast whenever practical._

3.7.3.5.4.4.2.2 When an elliptically polarized signal is broadcast, the horizontally polarized component shall meet the requirements in 3.7.3.5.4.4.1.2, and the effective radiated power (ERP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre (–103 dBW/m2) and a maximum field strength of 0.221 volts per metre (–39 dBW/m2) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and VPOL components, shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL and VPOL users throughout the coverage volume.

**Note.—** The minimum and maximum field strengths in 3.7.3.5.4.4.1.2 and 3.7.3.5.4.4.2.2 are consistent with a minimum receiver sensitivity of –87 dBm and minimum distance of 200 m (660 ft) from the transmitter antenna for a coverage range of 43 km (23 NM).

3.7.3.5.4.5 Power transmitted in adjacent channels. The amount of power during transmission under all operating conditions when measured over a 25 kHz bandwidth centered on the ith adjacent channel shall not exceed the values shown in Table 3.7.3.5-1.

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.

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. Total power in any VDB harmonic or discrete signal shall not be greater than –53 dBm.

Table 3.7.3.5-2. GBAS broadcast unwanted emissions   .

Frequency	Relative unwanted	Maximum unwanted

	emission level (Note 2)	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.

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3.7.3.5.5 *Navigation information.* The navigation data transmitted by GBAS shall include the following information:

a) pseudo-range corrections, reference time and integrity data;
b) GBAS-related data;
c) final approach segment data when supporting precision approach; and
d) predicted ranging source availability data.

Note.— Structure and contents of data are specified in Appendix B, 3.6.3.

3.7.3.6 *Aircraft GNSS receiver*

3.7.3.6.1 The aircraft GNSS receiver shall process the signals of those GNSS elements that it intends to use as specified in ,   Appendix B, 3.1 (for GPS), Appendix B, 3.2 (for GLONASS), Appendix B, 3.3 (for combined GPS and GLONASS), Appendix B, 3.5 (for GAGAN) and Appendix B, 3.6 (for GBAS).

3.7.4   Resistance to interference

3.7.4.1 GNSS shall comply with performance requirements defined in 3.7.2.4 and Appendix B, 3.7 in the presence of the interference environment defined in Appendix B, 3.7.

Note.— GPS and GLONASS operating in the frequency band 1559 – 1610 MHz are classified by the ITU as providing a radio navigation satellite service (RNSS) and aeronautical radio navigation service (ARNS) and are afforded special spectrum protection status for RNSS. In order to achieve the performance objectives for precision approach guidance to be supported by the GNSS and its augmentations, RNSS/ARNS is intended to remain the only global allocation in the 1 559 –1 610 MHz band and emissions from systems in this and adjacent frequency bands are intended to be tightly controlled by national and/or international regulation.

3.7.5   Database

Note.— SARPs applicable to aeronautical data are provided in relevant CARS for Aeronautical charts, Air Traffic Management, Aerodrome and Ground Aids and Aeronautical Information Service.

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.

3.8   Intentionally left blank

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 and in the presence also of an unwanted signal from a direction 90 degrees from the wanted signal and:

a) on the same frequency and 15 dB weaker; or
b) plus or minus 2 kHz away and 4 dB weaker; or
c) plus or minus 6 kHz or more away and 55 dB stronger.

Note.— The above bearing error is exclusive of aircraft magnetic compass error.

(M. Sathiyavathy)
Director General of Civil Aviation

Table A. DME/VOR and DME/ILS channeling and pairing

Channel pairing		DMR Parameters			
		Interrogation		Reply	
DME Channel Number	VHF Frequency MHz	Frequency MHz	Pulse code DME/N Micro Sec	Frequency MHz	Pulse codes Micro Sec
*1X	-	1025	12	962	12
**1Y	-	1025	36	1088	30
*2X	-	1026	12	963	12
**2Y	-	1026	36	1089	30
*3X	-	1027	12	964	12
**3Y	-	1027	36	1090	30
*4X	-	1028	12	965	12
**4Y	-	1028	36	1091	30
*5X	-	1029	12	966	12
**5Y	-	1029	36	1092	30
*6X	-	1030	12	967	12
**6Y	-	1030	36	1093	30
*7X	-	1031	12	968	12
**7Y	-	1031	36	1094	30
*8X	-	1032	12	969	12
**8Y	-	1032	36	1095	30
*9X	-	1033	12	970	12
**9Y	-	1033	36	1096	30
*10X	-	1034	12	971	12
**10Y	-	1034	36	1097	30
*11X	-	1035	12	972	12
**11Y	-	1035	36	1098	30
*12X	-	1036	12	973	12
**12Y	-	1036	36	1099	30
*13X	-	1037	12	974	12
**13Y	-	1037	36	1100	30
*14X	-	1038	12	975	12
**14Y	-	1038	36	1101	30
*15X	-	1039	12	976	12
**15Y	-	1039	36	1102	30
*16X	-	1040	12	977	12
**16Y	-	1040	36	1103	30
17X	108.00	1041	12	978	12
17Y	108.05	1041	36	1104	30
18X	108.10	1042	12	979	12
18Y	108.15	1042	36	1105	30
19X	108.20	1043	12	980	12
19Y	108.25	1043	36	1106	30

Channel pairing		DMR Parameters			
		Interrogation		Reply	
DME Channel Number	VHF Frequency MHz	Frequency MHz	Pulse code DME/N Micro Sec	Frequency MHz	Pulse codes Micro Sec
20X	108.30	1044	12	981	12
20Y	108.35	1044	36	1107	30
21X	108.40	1045	12	982	12
21Y	108.45	1045	36	1108	30
22X	108.50	1046	12	983	12
22Y	108.55	1046	36	1109	30
23X	108.60	1047	12	984	12
23Y	108.65	1047	36	1110	30
24X	108.70	1048	12	985	12
24Y	108.75	1048	36	1111	30
25X	108.80	1049	12	986	12
25Y	108.85	1049	36	1112	30
26X	108.90	1050	12	987	12
26Y	108.95	1050	36	1113	30
27X	109.00	1051	12	988	12
27Y	109.05	1051	36	1114	30
28X	109.10	1052	12	989	12
28Y	109.15	1052	36	1115	30
29X	109.20	1053	12	990	12
29Y	109.25	1053	36	1116	30
30X	109.30	1054	12	991	12
30Y	109.35	1054	36	1117	30
31X	109.40	1055	12	992	12
31Y	109.45	1055	36	1118	30
32X	109.50	1056	12	993	12
32Y	109.55	1056	36	1119	30
33X	109.60	1057	12	994	12
33Y	109.65	1057	36	1120	30
34X	109.70	1058	12	995	12
34Y	109.75	1058	36	1121	30
35X	109.80	1059	12	996	12
35Y	109.85	1059	36	1122	30
36X	109.90	1060	12	997	12
36Y	109.95	1060	36	1123	30
37X	110.00	1061	12	998	12
37Y	110.05	1061	36	1124	30
38X	110.10	1062	12	999	12
38Y	110.15	1062	36	1125	30

Channel pairing		DMR Parameters			
		Interrogation		Reply	
DME Channel Number	VHF Frequency MHz	Frequency MHz	Pulse code DME/N Micro Sec	Frequency MHz	Pulse codes Micro Sec
39X	110.20	1063	12	1000	12
39Y	110.25	1063	36	1126	30
40X	110.30	1064	12	1001	12
40Y	110.35	1064	36	1127	30
41X	110.40	1065	12	1002	12
41Y	110.45	1065	36	1128	30
42X	110.50	1066	12	1003	12
42Y	110.55	1066	36	1129	30
43X	110.60	1067	12	1004	12
43Y	110.65	1067	36	1130	30
44X	110.70	1068	12	1005	12
44Y	110.75	1068	36	1131	30
45X	110.80	1069	12	1006	12
45Y	110.85	1069	36	1132	30
46X	110.90	1070	12	1007	12
46Y	110.95	1070	36	1133	30
47X	111.00	1071	12	1008	12
47Y	1110.5	1071	36	1134	30
48X	111.10	1072	12	1009	12
48Y	111.15	1072	36	1135	30
49X	111.20	1073	12	1010	12
49Y	111.25	1073	36	1136	30
50X	111.30	1074	12	1011	12
50Y	111.35	1074	36	1137	30
51X	111.40	1075	12	1012	12
51Y	111.45	1075	36	1138	30
52X	111.50	1076	12	1013	12
52Y	111.55	1076	36	1139	30
53X	111.60	1077	12	1014	12
53Y	111.65	1077	36	1140	30
54X	111.70	1078	12	1015	12
54Y	111.75	1078	36	1141	30
55X	111.80	1079	12	1016	12
55Y	111.85	1079	36	1142	30
56X	111.90	1080	12	1017	12
56Y	111.95	1080	36	1143	30
57X	112.00	1081	12	1018	12
57Y	112.05	1081	36	1144	30

Channel pairing		DMR Parameters			
		Interrogation		Reply	
DME Channel Number	VHF Frequency MHz	Frequency MHz	Pulse code DME/N Micro Sec	Frequency MHz	Pulse codes Micro Sec
58X	112.10	1082	12	1019	12
58Y	112.15	1082	36	1145	30
59X	112.20	1083	12	1020	12
59Y	112.25	1083	36	1146	30
**60X	-	1084	12	1021	12
**60Y	-	1084	36	1147	30
**61X	-	1085	12	1022	12
**61Y	-	1085	36	1148	30
**62X	-	1086	12	1023	12
**62Y	-	1086	36	1149	30
**63X	-	1087	12	1024	12
**63Y	-	1087	36	1150	30
**64X	-	1088	12	1151	12
**64Y	-	1088	36	1025	30
**65X	-	1089	12	1152	12
**65Y	-	1089	36	1026	30
**66X	-	1090	12	1153	12
**66Y	-	1090	36	1027	30
**67X	-	1091	12	1154	12
**67Y	-	1091	36	1028	30
**68X	-	1092	12	1155	12
**68Y	-	1092	36	1029	30
**69X	-	1093	12	1156	12
**69Y	-	1093	36	1030	30
70X	112.30	1094	12	1157	12
**70Y	112.35	1094	36	1031	30
71X	112.40	1095	12	1158	12
**71Y	112.45	1095	36	1032	30
72X	112.50	1096	12	1159	12
**72Y	112.55	1096	36	1033	30
73X	112.60	1097	12	1160	12
**73Y	112.65	1097	36	1034	30
74X	112.70	1098	12	1161	12
**74Y	112.75	1098	36	1035	30
75X	112.80	1099	12	1162	12
**75Y	112.85	1099	36	1036	30
76X	112.90	1100	12	1163	12
**76Y	112.95	1100	36	1037	30

Channel pairing		DMR Parameters			
		Interrogation		Reply	
DME Channel Number	VHF Frequency MHz	Frequency MHz	Pulse code DME/N Micro Sec	Frequency MHz	Pulse codes Micro Sec
77X	113.00	1101	12	1164	12
**77Y	113.05	1101	36	1038	30
78X	113.10	1102	12	1165	12
**78Y	113.15	1102	36	1039	30
79X	113.20	1103	12	1166	12
**79Y	113.25	1103	36	1040	30
80X	113.30	1104	12	1167	12
80Y	113.35	1104	36	1041	30
81X	113.40	1105	12	1168	12
81Y	113.45	1105	36	1042	30
82X	113.50	1106	12	1169	12
82Y	113.55	1106	36	1043	30
83X	113.60	1107	12	1170	12
83Y	113.65	1107	36	1044	30
84X	113.70	1108	12	1171	12
84Y	113.75	1108	36	1045	30
85X	113.80	1109	12	1172	12
85Y	113.85	1109	36	1046	30
86X	113.90	1110	12	1173	12
86Y	113.95	1110	36	1047	30
87X	114.00	1111	12	1174	12
87Y	114.05	1111	36	1048	30
88X	114.10	1112	12	1175	12
88Y	114.15	1112	36	1049	30
89X	114.20	1113	12	1176	12
89Y	114.25	1113	36	1050	30
90X	114.30	1114	12	1177	12
90Y	114.35	1114	36	1051	30
91X	114.40	1115	12	1178	12
91Y	114.45	1115	36	1052	30
92X	114.50	1116	12	1179	12
92Y	114.55	1116	36	1053	30
93X	114.60	1117	12	1180	12
93Y	114.65	1117	36	1054	30
94X	114.70	1118	12	1181	12
94Y	114.75	1118	36	1055	30
95X	114.80	1119	12	1182	12
95Y	114.85	1119	36	1056	30

| Channel pairing | | DMR Parameters | | | |
| | | Interrogation | | Reply | |
DME Channel Number	VHF Frequency MHz	Frequency MHz	Pulse code DME/N Micro Sec	Frequency MHz	Pulse codes Micro Sec
96X	114.90	1120	12	1183	12
96Y	114.95	1120	36	1057	30
97X	115.00	1121	12	1184	12
97Y	115.05	1121	36	1058	30
98X	115.10	1122	12	1185	12
98Y	115.15	1122	36	1059	30
99X	115.20	1123	12	1186	12
99Y	115.25	1123	36	1060	30
100X	115.30	1124	12	1187	12
100Y	115.35	1124	36	1061	30
101X	115.40	1125	12	1188	12
101Y	115.45	1125	36	1062	30
102X	115.50	1126	12	1189	12
102Y	115.55	1126	36	1063	30
103X	115.60	1127	12	1190	12
103Y	115.65	1127	36	1064	30
104X	115.70	1128	12	1191	12
104Y	115.75	1128	36	1065	30
105X	115.80	1129	12	1192	12
105Y	115.85	1129	36	1066	30
106X	115.90	1130	12	1193	12
106Y	115.95	1130	36	1067	30
107X	116.00	1131	12	1194	12
107Y	116.05	1131	36	1068	30
108X	116.10	1132	12	1195	12
108Y	116.15	1132	36	1069	30
109X	116.20	1133	12	1196	12
109Y	116.25	1133	36	1070	30
110X	116.30	1134	12	1197	12
110Y	116.35	1134	36	1071	30
111X	116.40	1135	12	1198	12
111Y	116.45	1135	36	1072	30
112X	116.50	1136	12	1199	12
112Y	116.55	1136	36	1073	30
113X	116.60	1137	12	1200	12
113Y	116.65	1137	36	1074	30
114X	116.70	1138	12	1201	12
114Y	116.75	1138	36	1075	30

Channel pairing		DMR Parameters			
		Interrogation		Reply	
DME Channel Number	VHF Frequency MHz	Frequency MHz	Pulse code DME/N Micro Sec	Frequency MHz	Pulse codes Micro Sec
115X	116.80	1139	12	1202	12
115Y	116.85	1139	36	1076	30
116X	116.90	1140	12	1203	12
116Y	116.95	1140	36	1077	30
117X	117.00	1141	12	1204	12
117Y	117.05	1141	36	1078	30
118X	117.10	1142	12	1205	12
118Y	117.15	1142	36	1079	30
119X	117.20	1143	12	1206	12
119Y	117.25	1143	36	1080	30
120X	117.30	1144	12	1207	12
120Y	117.35	1144	36	1081	30
121X	117.40	1145	12	1208	12
121Y	117.45	1145	36	1082	30
122X	117.50	1146	12	1209	12
122Y	117.55	1146	36	1083	30
123X	117.60	1147	12	1210	12
123Y	117.65	1147	36	1084	30
124X	118.70	1148	12	1211	12
**124Y	117.75	1148	36	1085	30
125X	117.80	1149	12	1212	12
**125Y	117.85	1149	36	1086	30
126X	117.90	1150	12	1213	12
**126Y	117.95	1150	36	1087	30

*These channels are reserved exclusively for national allotments.
**These channels may be used for national allotment on a secondary basis.

Appendix – A - Intentionally left blank

APPENDIX B.   TECHNICAL SPECIFICATIONS FOR THE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

1.   DEFINITIONS

GBAS/E. A ground-based augmentation system transmitting an elliptically-polarized VHF data broadcast.

GBAS/H. A ground-based augmentation system transmitting a horizontally-polarized VHF data broadcast.

Receiver. A subsystem that receives GNSS signals and includes one or more sensors.

Reserved (bits/words/fields). Bits/words/fields that are not allocated, but which are reserved for a particular GNSS application.

Spare (bits/words/fields). Bits/words/fields that are not allocated or reserved, and which are available for future allocation.

Note.— All spare bits are set to zero.

2.   GENERAL

Note.— The following technical specifications supplement the provisions of Chapter 3, 3.7.

3.   GNSS ELEMENTS

3.1   Global Positioning System (GPS) Standard Positioning Service (SPS) (L1)

3.1.1   NON-AIRCRAFT ELEMENTS

3.1.1.1 *RADIO FREQUENCY (RF) CHARACTERISTICS*

3.1.1.1.1 *Carrier phase noise.* The carrier phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian (1 sigma).

3.1.1.1.2 *Spurious emissions.* In-band spurious emissions shall be at least 40 dB below the unmodulated L1 carrier over the allocated channel bandwidth.

3.1.1.1.3 *Correlation loss.* The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 1 dB.

Note.— The loss in signal power is the difference between the broadcast power in a 2.046 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with 1-chip correlator spacing and a 2.046 MHz bandwidth.

3.1.1.1.4 *Coarse/acquisition (C/A) code generation and timing.* Each C/A code pattern $G_i(t)$ shall be formed by the Modulo-2 sum of two 1 023-bit linear patterns, G1 and $G2_i$. The $G2_i$ sequence shall be formed by effectively delaying the G2 sequence by an integer number of chips to produce one of 36 unique $G_i(t)$ patterns defined in Table B-1. The G1 and G2 sequences shall be generated by 10-stage shift registers having the following polynomials as referred to in the shift register input:

   a)   G1: $X^{10} + X^3 + 1$; and

   b)   G2: $X^{10} + X^9 + X^8 + X^6 + X^3 + X^2 + 1$.

The initialization vector for the G1 and G2 sequences shall be "1111111111". The code phase assignments shall be as shown in Table B-1. The G1 and G2 registers shall be clocked at a 1.023 MHz rate. Timing relationships related to the C/A code shall be as shown in Figure B-1.[*]

3.1.1.2   *Data structure.* The navigation message shall be formatted as shown in Figure B-2. Each page, as shown in Figure B-6, shall utilize a basic format of a 1 500-bit-long frame with up to 5 subframes, each of 300 bits in length. All words shall be transmitted most significant bit (MSB) first.

3.1.1.2.1 *Subframe structure.* Each subframe and/or page of a subframe shall start with a telemetry (TLM) word followed by a handover word (HOW). The HOW shall be followed by 8 data words. Each word in each frame shall contain 6 parity bits. The TLM word and HOW formats shall be as shown in Figures B-3 and B-4, respectively.

3.1.1.2.2   *End/start of week.* At the end/start of week:

   a)   the cyclic paging of subframes 1 through 5 shall restart with subframe 1 regardless of which subframe was last transmitted prior to the end/start of week; and

   b)   the cycling of 25 pages of subframes 4 and 5 shall restart with page 1 of each of the subframes, regardless of which page was transmitted prior to the end/start of week. All upload and page cutovers shall occur on frame boundaries (i.e. Modulo 30 seconds relative to the end/start of week).

   Note.— New data in subframes 4 and 5 may start to be transmitted with any of the 25 pages of these subframes.

3.1.1.2.3 *Data parity*. Words 1 through 10 of subframes 1 through 5 shall each contain 6 parity bits as their least significant bits (LSBs). In addition, two non-information bearing bits shall be provided as bits 23 and 24 of words 2 and 10 for parity computation purposes.

3.1.1.2.4 *Telemetry (TLM) word*. Each TLM word shall be 30 bits long, occur every 6 seconds in the data frame and be the first word in each subframe. The TLM format shall be as shown in Figure B-3. Each TLM word shall begin with a preamble, followed by 16 reserved bits and 6 parity bits.

3.1.1.2.5 *Handover word (HOW)*. The HOW shall be 30 bits long and shall be the second word in each subframe/page, immediately following the TLM word. A HOW shall occur every 6 seconds in the data frame. The HOW format and content shall be as shown in Figure B-4. The full time-of-week (TOW) count shall consist of the 19 LSBs of the 29-bit Z-count (3.1.1.2.6). The HOW shall begin with the 17 MSBs of the TOW count. These 17 bits shall correspond to the TOW count at the 1.5-second epoch that occurs at the start (leading edge) of the next following subframe.

3.1.1.2.5.1 *Bit 18*. On satellites designed by configuration code 001, bit 18 shall be an "alert" flag. When this flag is raised (bit 18 is a "1"), it shall indicate to the user that the satellite user range accuracy (URA) may be worse than indicated in subframe 1 and that use of the satellite is at the user's risk.

*All figures are located at the end of the appendix.

Table B-1. Code phase assignments

Satellite ID number	GPS PRN signal	G2 delay (chips)	First 10 chips octal*
1	1	5	1440
2	2	6	1620
3	3	7	1710
4	4	8	1744
5	5	17	1133
6	6	18	1455
7	7	139	1131
8	8	140	1454
9	9	141	1626
10	10	251	1504
11	11	252	1642
12	12	254	1750
13	13	255	1764
14	14	256	1772
15	15	257	1775
16	16	258	1776
17	17	469	1156
18	18	470	1467
19	19	471	1633
20	20	472	1715
21	21	473	1746
22	22	474	1763
23	23	509	1063
24	24	512	1706
25	25	513	1743
26	26	514	1761
27	27	515	1770
28	28	516	1774

29	29	859	1127
30	30	860	1453
31	31	861	1625
32	32	862	1712
***	33	863	1745
***	34**	950	1713
***	35	947	1134
***	36	948	1456
***	37**	950	1713

* In the octal notation for the first 10 chips of the C/A code as shown in this column, the first digit represents a "1" for the first chip and the last three digits are the conventional octal representation of the remaining 9 chips (e.g. the first 10 chips of the C/A code for pseudo-random noise (PRN) signal assembly 1 are: 1100100000).

** C/A codes 34 and 37 are common.

*** PRN signal assemblies 33 through 37 are reserved for other uses (e.g. ground transmitters).

3.1.1.2.5.2   *Bit 19*. Bit 19 shall be reserved.

3.1.1.2.5.3   *Bits 20, 21 and 22*. Bits 20, 21 and 22 of the HOW shall provide the identification (ID) of the subframe in which that particular HOW is the second word. The ID code shall be as defined below:

ID	Code
1	001
2	010
3	011
4	100
5	101

3.1.1.2.6 *Satellite Z-count*. Each satellite shall internally derive a 1.5-second epoch that shall contain a convenient unit for precisely counting and communicating time. Time stated in this manner shall be referred to as a Z-count. The Z-count shall be provided to the user as a 29-bit binary number consisting of two parts as follows.

3.1.1.2.6.1   *Time-of-week (TOW) count*. The binary number represented by the 19 LSBs of the Z-count shall be referred to as the TOW count and is defined as being equal to the number of 1.5-second epochs that have occurred since the transition from the previous week. The count shall be short-cycled such that the range of the TOW count is from 0 to 403 199 1.5-second epochs (equaling one week) and shall be reset to zero at the end of each week. The TOW count's zero state shall be the 1.5-second epoch that is coincident with the start of the present week. A truncated version of the TOW count, consisting of its 17 MSBs, shall be contained in the HOW of the L1 downlink data stream. The relationship between the

actual TOW count and its truncated HOW version shall be as indicated in Figure B-5.

   Note.— The above-mentioned epoch occurs at (approximately) midnight Saturday night/Sunday morning, where midnight is defined as 0000 hours on the UTC scale which is nominally referenced to the Greenwich Meridian.

3.1.1.2.6.2   *Week count.* The 10 MSBs of the Z-count shall be a binary representation of the sequential number assigned to the present GPS week (Modulo 1024). The range of this count shall be from 0 to 1 023. Its zero state shall be that week which starts with the 1.5-second epoch occurring at (approximately) the UTC zero time point (3.1.4). At the expiration of GPS week number 1 023, the GPS week number shall roll over to zero. The previous 1 024 weeks in conversions from GPS time to a calendar date shall be accounted for by the user.

3.1.1.3   *DATA CONTENT*

3.1.1.3.1 *Subframe 1 — satellite clock and health data.* The content of words 3 through 10 of subframe 1 shall contain the clock parameters and other data as indicated in Table B-2. The parameters in a data set shall be valid during the interval of time in which they are transmitted and shall remain valid for an additional period of time after transmission of the next data set has started.

3.1.1.3.1.1   *Week number.* The 10 MSBs of word 3 shall contain the 10 MSBs of the 29-bit Z-count and shall represent the number of the current GPS week at the start of the data set transmission interval with all zeros indicating week "zero." The GPS week number shall increment at each end/start of week epoch.

3.1.1.3.1.2   *User range accuracy (URA).* Bits 13 through 16 of word 3 shall provide the predicted satellite URA as shown in Table B-3.

Note 1.— The URA does not include error estimates due to inaccuracies of the single-frequency ionospheric delay model. Note

2.— The URA is a statistical indicator of the contribution of the apparent clock and ephemeris prediction accuracies to the ranging accuracies obtainable with a specific satellite based on historical data.

Table B-2.   Subframe 1 parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
Week number	10	1		weeks

Satellite accuracy	4			
Satellite health	6	1		discretes
T_{GD}	8*	2^{-31}		seconds
IODC	10			
t_{oc}	16	2^4	604 784	seconds
a_{f2}	8*	2^{-55}		seconds/second^2
A_{f1}	16*	2^{-43}		seconds/second
a_{f0}	22*	2^{-31}		Seconds

* Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.
** See Figure B-6 for complete bit allocation.
***   Unless otherwise indicated in this column, effective range is the maximum range.

Table B-3.   User range accuracy

URA	Accuracy
0	2 m
1	2.8 m
2	4 m
3	5.7 m
4	8 m
5	11.3 m
6	16 m
7	32 m
8	64 m
9	128 m
10	256 m
11	512 m
12	1 024 m
13	2 048 m
14	4 096 m
15	Do not use

3.1.1.3.1.3   *Health.* The transmitting satellite 6-bit health indication shall be provided by bits 17 through 22 of word 3. The MSB shall indicate a summary of the health of the navigation data, where:

a) 0 = all navigation data are valid; and

b) 1 = some of the navigation data are not valid.

The 5 LSBs shall indicate the health of the signal components in accordance with 3.1.1.3.3.4. The health indication shall be provided relative to the capabilities of each satellite as designated by the configuration code in 3.1.1.3.3.5. Any satellite that does not have a certain capability shall be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a receiver standpoint and does not require that capability. Additional health data shall be given in subframes 4 and 5.

   Note.— The data given in subframe 1 may differ from that shown in subframes 4 and/or 5 of other satellites since the latter may be updated at a different time.

3.1.1.3.1.4   *Issue of data, clock (IODC).* Bits 23 and 24 of word 3 in subframe 1 shall be the 2 MSBs of the 10-bit IODC term. Bits 1 through 8 of word 8 in subframe 1 shall contain the 8 LSBs of the IODC. The IODC shall indicate the issue number of data set. The transmitted IODC shall be different from any value transmitted by the satellite during the preceding 7 days.

   Note.— The relationship between the IODC and the Issue of Data, Ephemeris (IODE) terms is defined in 3.1.1.3.2.2.

3.1.1.3.1.5   *Estimated group delay differential.* Bits 17 through 24 of word 7 shall contain the correction term, T_{GD}, to account for the effect of satellite group delay differential.

   Note.— T_{GD} does not include any C/A to P(Y) code relative group delay error.

3.1.1.3.1.6   *Satellite clock correction parameters.* Bits 9 through 24 of word 8, bits 1 through 24 of word 9, and bits 1 through 22 of word 10 shall contain the parameters needed by the users for apparent satellite clock correction (t_{oc}, a_{f2}, a_{f1} and a_{f0}).

3.1.1.3.1.7   *Reserved data fields*. Reserved data fields shall be as indicated in Table B-4. All reserved data fields shall support valid parity within their respective words.

3.1.1.3.2 *Subframes 2 and 3 — satellite ephemeris data.* Subframes 2 and 3 shall contain the ephemeris representation of the transmitting satellite.

3.1.1.3.2.1   *Ephemeris parameters.* The ephemeris parameters shall be as indicated in Table B-5. For each parameter in subframe 2 and 3, the number of bits, the scale factor of the LSB, the range, and the units shall be as specified in Table B-6.

3.1.1.3.2.2   *Issue of data, ephemeris (IODE).* The IODE shall be an 8-bit number equal to the 8 LSBs of the 10-bit IODC of the same data set. The IODE shall be provided in both subframes 2 and 3 for the purpose of comparison with the 8 LSBs of the IODC term in subframe 1. Whenever these three terms do not match, as a result of a data set cutover, new data shall be collected. The transmitted IODE shall be different from any value transmitted by the satellite during the preceding six hours (Note 1). Any change in the subframe 2 and 3 data shall be accomplished in concert with a change in both IODE

words. Change to new data sets shall occur only on hour boundaries except for the first data set of a new upload. Additionally, the t_{oe} value, for at least the first data set transmitted by a satellite after an upload, shall be different from that transmitted prior to the change (Note 2).

Table B-4.   Subframe 1 reserved data fields

Word	Bit
3	11 – 12
4	1 – 24
5	1 – 24
6	1 – 24
7	1 – 16

Table B-5.   Ephemeris data

M_0	Mean anomaly at reference time
Δn	Mean motion difference from computed value
e	Eccentricity
$\sqrt{A}$	Square root of the semi-major axis
$OMEGA_0$	Longitude of ascending node of orbit plane at weekly epoch
i_0	Inclination angle at reference time
ω	Argument of perigee
OMEGADOT	Rate of right ascension
iDOT	Rate of inclination angle
C_{uc}	Amplitude of the cosine harmonic correction term to the argument of latitude
C_{us}	Amplitude of the sine harmonic correction term to the argument of latitude
C_{rc}	Amplitude of the cosine harmonic correction term to the orbit radius
C_{rs}	Amplitude of the sine harmonic correction term to the orbit radius
C_{ic}	Amplitude of the cosine harmonic correction term to the angle of inclination
C_{is}	Amplitude of the sine harmonic correction term to the angle of inclination
t_{oe}	Reference time, ephemeris
IODE	Issue of data, ephemeris

Table B-6.   Ephemeris parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
IODE	8			
C_{rs}	16*	2^{-5}		metres
Δn	16*	2^{-43}		semi-circles/second
M_0	32*	2^{-31}		semi-circles
C_{uc}	16*	2^{-29}		radians
e	32	2^{-33}	0.03	dimensionless
C_{us}	16*	2^{-29}		radians
$\sqrt{A}$	32	2^{-19}		$\text{metres}^{1/2}$
T_{oe}	16	2^{4}	604 784	second
C_{ic}	16*	2^{-29}		radians
$OMEGA_0$	32*	2^{-31}		semi-circles
C_{is}	16*	2^{-29}		radians
i_0	32*	2^{-31}		semi-circles
C_{rc}	16*	2^{-5}		Metres
ω	32*	2^{-31}		semi-circles
OMEGADOT	24*	2^{-43}		semi-circles/second
iDOT	14*	2^{-43}		semi-circles/second

*   Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

**   See Figure B-6 for complete bit allocation in subframe.

***   Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.

Note 1.— The IODE/IODC terms provide the receiver with a means for detecting any changes in the ephemeris/clock representation parameters.

Note 2.— The first data set may change (3.1.1.2.2) at any time during the hour and therefore may be transmitted by the satellite for less than 1 hour.

3.1.1.3.2.3   *Reserved data fields.* Within word 10, subframe 2, bits 17 through 22 shall be reserved. Reserved data fields shall support the valid parity within their respective words.

3.1.1.3.3 *Subframes 4 and 5 — support data.* Both subframes 4 and 5 shall be subcommutated 25 times each. With the possible exception of "reserved" pages and explicit repeats, each page shall contain different data in words 3 through 10. The pages of subframe 4 shall use 6 different formats, and the pages of subframe 5 shall use two different formats as indicated in Figure B-6.

Pages of subframe 4 shall be as follows:

a) Pages 2, 3, 4, 5, 7, 8, 9 and 10: almanac data for satellites 25 through 32 respectively. If the 6-bit health status word of page 25 is set to 6 "ones" (3.1.1.3.3.4) then the satellite ID of the page shall not have a value in the range of 25 through 32;

Note.— These pages may be designed for other functions. The format and content for each page is defined by the satellite ID of that page.

b)   Page 17: special messages;

c)   Page 18: ionospheric and UTC data;

d)   Page 25: satellite configurations for 32 satellites; and

e)   Pages 1, 6, 11, 12, 13, 14, 15, 16, 19, 20, 21, 22, 23 and 24: reserved.

Pages of subframe 5 shall be as follows:

a)Pages 1 through 24: almanac data for satellite 1 through 24; and

b)   Page 25: satellite health data for satellite 1 through 24, the almanac reference time and the almanac reference week number.

3.1.1.3.3.1   *Data ID.* The two MSBs of word 3 in each page shall contain the data ID that defines the applicable GPS navigation data structure. The data ID shall be as indicated in Table B-7 in accordance with the following:

a)   for those pages which are assigned to contain the almanac data of one specific satellite, the data ID shall define the data structure utilized by that satellite whose almanac data are contained in that page;

b) for all other pages, the data ID shall denote the data structure of the transmitting satellite;

and c) data ID "1" (denoted by binary state 00) shall not be used.

3.1.1.3.3.2   *Satellite ID.* The satellite ID shall be provided by bits 3 through 8 of word 3 in each page. The satellite IDs shall be utilized two ways:

a) for those pages which contain the almanac data of a given satellite, the satellite ID shall be the same number that is assigned the PRN code phase of that satellite in accordance with Table B-1; and

b) for all other pages the satellite ID assigned in accordance with Table B-7 shall serve as the "page ID". IDs 1 through 32 shall be assigned to those pages which contain the almanac data of specific satellites (pages 1 through 24 of subframe 5 and pages 2 through 5, and 7 through 10 of subframe 4). The "0" ID (binary all zeros) shall be assigned to indicate a dummy satellite, while IDs 51 through 63 shall be utilized for pages containing other than almanac data for a specific satellite (Notes 1 and 2).

Note 1.— Specific IDs are reserved for each page of subframes 4 and 5; however, the satellite ID of pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 may change for each page to reflect the alternate contents for that page.

Note 2.— The remaining IDs (33 through 50) are unassigned.

Table B-7.   Data IDs and satellite IDs in subframes 4 and 5

	Subframe 4		Subframe 5	
Page	Data ID	Satellite ID*	Data ID	Satellite ID*
1	***	57	**	1
2****	**	25	**	2
3****	**	26	**	3
4****	**	27	**	4
5****	**	28	**	5

6	***	57	**	6
7****	**	29	**	7
8****	**	30	**	8
9****	**	31	**	9
10****	**	32	**	10
11	***	57	**	11
12	***	62	**	12
13	***	52	**	13
14	***	53	**	14
15	***	54	**	15
16	***	57	**	16
17	***	55	**	17
18	***	56	**	18
19	***	58*****	**	19
20	***	59*****	**	20
21	***	57	**	21
22	***	60*****	**	22
23	***	61*****	**	23
24	***	62	**	24
25	***	63	***	51

*   "0" indicates "dummy" satellite. When using "0" to indicate a dummy satellite, the data ID of the transmitting satellite is used.

**   Data ID of that satellite whose satellite ID appears in that page.

***   Data ID of transmitting satellite.

****   Pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 may contain almanac data for satellites 25 through 32, respectively, or data for other functions as identified by a different satellite ID from the value shown.

***** Satellite ID may vary.

3.1.1.3.3.3   *Almanac.* Pages 1 through 24 of subframe 5, as well as pages 2 through 5 and 7 through 10 of subframe 4 shall contain the almanac data and a satellite health status word (3.1.1.3.3.4) for up to 32 satellites. The almanac data shall be a reduced-precision subset of the clock and ephemeris parameters. The data shall occupy all bits of words 3 through 10 of each page except the 8 MSBs of word 3 (data ID and satellite ID), bits 17 through 24 of word 5 (satellite health), and the 50 bits devoted to parity. The number of bits, the scale factor (LSB), the range and the units of the almanac parameters shall be as indicated in Table B-8. The almanac message for any dummy satellite shall contain alternating "ones" and "zeros" with a valid parity.

3.1.1.3.3.3.1   *Almanac reference time.* The almanac reference time, t_{oa}, shall be a multiple of 2^{12} seconds occurring approximately 70 hours after the first valid transmission time for this almanac data set. The almanac shall be updated often enough to ensure that GPS time, t, will differ from t_{oa} by less than 3.5 days during the transmission period. The almanac parameters shall be updated at least once every 6 days during normal operations.

3.1.1.3.3.3.2 *Almanac time parameters*. The almanac time parameters shall consist of an 11-bit constant term (a_{f0}) and an 11-bit first order term (a_{f1}).

3.1.1.3.3.3.3 *Almanac reference week*. Bits 17 through 24 of word 3 in page 25 of subframe 5 shall indicate the number of the week (WN_a) to which the almanac reference time (t_{oa}) is referenced. The WN_a term shall consist of the 8 LSBs of the full week number. Bits 9 through 16 of word 3 in page 25 of subframe 5 shall contain the value of t_{oa} that is referenced to this WN_a.

3.1.1.3.3.4 *Health summary*. Subframes 4 and 5 shall contain two types of satellite health data:

a) each of the 32 pages that contain the clock/ephemeris related almanac data shall provide an 8-bit satellite health status word regarding the satellite whose almanac data they carry; and

b) the 25th pages of subframes 4 and 5 jointly shall contain 6-bit health data for up to 32 satellites.

3.1.1.3.3.4.1 The 8-bit health status words shall occupy bits 17 through 24 of word 5 in those 32 pages that contain the almanac data for individual satellites. The 6-bit health status words shall occupy the 24 MSBs of words 4 through 9 in page 25 of subframe 5, and bits 19 through 24 of word 8, the 24 MSBs of word 9, and the 18 MSBs of word 10 in page 25 of subframe 4.

Table B-8.   Almanac parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units

e	16	2^{-21}		dimensionless
t_{oa}	8	2^{12}	602 112	seconds
δ_i****	16*	2^{-19}		semi-circles
OMEGADOT	16*	2^{-38}		semi-circles/second
$\sqrt{A}$	24*	2^{-11}		metres$^{1/2}$
$OMEGA_0$	24*	2^{-23}		semi-circles
ω	24*	2^{-23}		semi-circles
M_0	24*	2^{-23}		semi-circles
a_{f0}	11*	2^{-20}		seconds
a_{f1}	11*	2^{-38}		seconds/second

*   Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

**   See Figure B-6 for complete bit allocation in subframe.

***   Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.

****   Relative to $i_0 = 0.30$ semi-circles.

3.1.1.3.3.4.2   The 3 MSBs of the 8-bit health status words shall indicate health of the navigation data in accordance with the code given in Table B-9. The 6-bit words shall provide a 1-bit summary of the navigation data's health status in the MSB position in accordance with 3.1.1.3.1.3. The 5 LSBs of both the 8-bit and the 6-bit health status words shall provide the health status of the satellite's signal components in accordance with the code given in Table B-10.

Table B-9.   Navigation data health indication

137	138	139	Indication
Bit position in page			
0	0	0	ALL DATA OK
0	0	1	PARITY FAILURE — some or all parity bad
0	1	0	TLM/HOW FORMAT PROBLEM — any departure from standard format (e.g. preamble misplaced and/or incorrect), except for incorrect Z-count, as reported in HOW
0	1	1	Z-COUNT in HOW BAD — any problem with Z-count value not reflecting actual code phase
1	0	0	SUBFRAMES 1, 2, 3 — one or more elements in words 3 through 10 of one or more subframes are bad
1	0	1	SUBFRAMES 4, 5 — one or more elements in words 3 through 10 of one or more subframes are bad
1	1	0	ALL UPLOADED DATA BAD — one or more elements in words 3 through 10 of any one (or more) subframes are bad
1	1	1	ALL DATA BAD — TLM word and/or HOW and one or more elements in any one (or more) subframes are bad

Table B-10.   Codes for health of satellite signal components

MSB				LSB	Indication
0	0	0	0	0	ALL SIGNALS OK
1	1	1	0	0	SATELLITE IS TEMPORARILY OUT — do not use this satellite during current pass ___
1	1	1	0	1	SATELLITE WILL BE TEMPORARILY OUT — use with caution ___
1	1	1	1	0	SPARE
1	1	1	1	1	MORE THAN ONE COMBINATION WOULD BE REQUIRED TO DESCRIBE ANOMALIES, EXCEPT THOSE MARKED BY ___
All other combinations					SATELLITE EXPERIENCING CODE MODULATION AND/OR

SIGNAL POWER LEVEL TRANSMISSION PROBLEMS. The user may experience intermittent tracking problems if satellite is acquired.

3.1.1.3.3.4.3   A special meaning shall be assigned, to the 6 "ones" combination of the 6-bit health status words in the 25th pages of subframes 4 and 5; it shall indicate that "the satellite which has that ID is not available and there may be no data regarding that satellite in the page of subframe 4 or 5 that is assigned to normally contain the almanac data of that satellite".

   Note.— This special meaning applies to the 25th pages of subframes 4 and 5 only. There may be data regarding another satellite in the almanac page referred to above as defined in 3.1.1.3.3.3.

3.1.1.3.3.4.4   The health indication shall be provided relative to the capabilities of each satellite as designated by the configuration code in 3.1.1.3.3.5. Accordingly, any satellite that does not have a certain capability shall be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a receiver standpoint and does not require that capability. The predicted health data shall be updated at the time of upload.

   Note 1.— The transmitted health data may not correspond to the actual health of the transmitting satellite or other satellites in the constellation.

   Note 2.— The data given in subframes 1, 4 and 5 of the other satellites may differ from that shown in subframes 4 and/or 5 since the latter may be updated at a different time.

3.1.1.3.3.5   *Satellite configuration summary.* Page 25 of subframe 4 shall contain a 4-bit-long term for each of up to 32 satellites to indicate the configuration code of each satellite. These 4-bit terms shall occupy bits 9 through 24 of words 3, the 24 MSBs of words 4 through 7, and the 16 MSBs of word 8, all in page 25 of subframe 4. The MSB of each 4-bit term shall indicate whether anti-spoofing is activated (MSB = 1) or not activated (MSB = 0). The 3 LSBs shall indicate the configuration of each satellite using the following code:

Code	Satellite configuration
001	Block II/IIA/IIR satellite
010	Block IIR-M satellite
011	Block IIF satellite

3.1.1.3.3.6   *UTC parameters.* Page 18 of subframe 4 shall include:

   a) the parameters needed to relate GPS time to UTC time; and
   b) notice to the user regarding the scheduled future or past (relative to navigation message upload) value of the delta time due to leap seconds (t_{LSF}), together with the week number (WN_{LSF}) and the day number (DN) at the end of which the leap second becomes effective. "Day one" shall be the first day relative to the end/start of week and the WN_{LSF} value consists of the 8 LSBs of the full week number. The absolute value

of the difference between the untruncated WN and WN_{LSF} values shall not exceed 127.

Note.— The user is expected to account for the truncated nature of this parameter as well as truncation of WN, WN_t and WN_{LSF} due to rollover of the full week number (3.1.1.2.6.2).

3.1.1.3.3.6.1   The 24 MSBs of words 6 through 9, and the 8 MSBs of word 10 in page 18 of subframe 4 shall contain the parameters related to correlating UTC time with GPS time. The bit length, scale factors, ranges, and units of these parameters shall be as specified in Table B-11.

3.1.1.3.3.7   *Ionospheric parameters.* The ionospheric parameters that allow the GPS SPS user to utilize the ionospheric model for computation of the ionospheric delay shall be contained in page 18 of subframe 4 as specified in Table B-12.

3.1.1.3.3.8   *Special message.* Page 17 of subframe 4 shall be reserved for special messages.

Table B-11.   UTC parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
A_0	32*	2^{-30}		seconds
A_1	24*	2^{-50}		seconds/second
Δt_{LS}	8*	1		seconds
t_{ot}	8	2^{12}	602 112	seconds
WN_t	8	1		weeks
WN_{LSF}	8	1		weeks
DN	8****	1	7	days
Δt_{LSF}	8*	1		seconds

*   Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.
**   See Figure B-6 for complete bit allocation in subframe.
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.
****   Right justified.

Table B-12.   Ionospheric parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
α_0	8*	2^{-30}		seconds
α_1	8*	2^{-27}		seconds/semi-circle
α_2	8*	2^{-24}		seconds/semi-circle^2

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α_3	8*	2^{-24}	seconds/semi-circle^3
β_0	8*	2^{11}	Seconds
β_1	8*	2^{14}	seconds/semi-circle
β_2	8*	2^{16}	seconds/semi-circle^2
β_3	8*	2^{16}	seconds/semi-circle^3

* Parameters so indicated are two's complement, with the sign bit (+ or –) occupying the MSB.

** See Figure B-6 for complete bit allocation in subframe.

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with the indicated bit allocation and scale factor.

3.1.1.3.3.9   *Reserved data fields.* All bits of words 3 through 10, except the 58 bits used for data ID, satellite (page) ID, parity (six LSBs of each word) and parity computation (bits 23 and 24 of word 10) of pages 1, 6, 11, 12, 13, 14, 15, 16, 19, 20, 21, 22, 23 and 24 of subframe 4, and those almanac pages assigned satellite ID of zero shall be designated as reserved. Other reserved bits in subframes 4 and 5 shall be as shown in Table B-13. Reserved bit positions of each word shall contain a pattern of alternating ones and zeros with a valid word parity.

3.1.2   DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters that are not transmitted, but are used by either or both non-aircraft and aircraft elements, and that define terms applied to determine the navigation solution and its integrity.

Table B-13.   Reserved bits in subframes 4 and 5

Subframe	Pages	Words	Reserved bit position in word
4	17	10	17 – 22
4	18	10	9 – 22
4	25	8	17 – 18
4	25	10	19 – 22
5	25	10	4 – 22

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Table B-14.   Parity encoding algorithms

$D_1 \quad = \quad d_1 \oplus D^*_{30}$

$D_2 \quad = \quad d_2 \oplus D^*_{30}$

$D_3 \quad = \quad d_3 \oplus D^*_{30}$

•   •

•   •

•   •

•   •

$D_{24} \quad = \quad d_{24} \oplus D^*_{30}$

$D_{25} \quad = \quad D^*_{29} \oplus d_1 \oplus d_2 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_{10} \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{17} \oplus d_{18} \oplus d_{20} \oplus d_{23}$

$D_{26} \quad = \quad D^*_{30} \oplus d_2 \oplus d_3 \oplus d_4 \oplus d_6 \oplus d_7 \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{18} \oplus d_{19} \oplus d_{21} \oplus d_{24}$

$D_{27} \quad = \quad D^*_{29} \oplus d_1 \oplus d_3 \oplus d_4 \oplus d_5 \oplus d_7 \oplus d_8 \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{19} \oplus d_{20} \oplus d_{22}$

$D_{28} \quad = \quad D^*_{30} \oplus d_2 \oplus d_4 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{20} \oplus d_{21} \oplus d_{23}$

$D_{29} \quad = \quad D^*_{30} \oplus d_1 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_7 \oplus d_9 \oplus d_{10} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{18} \oplus d_{21} \oplus d_{22} \oplus d_{24}$

$D_{30} \quad = \quad D^*_{29} \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{10} \oplus d_{11} \oplus d_{13} \oplus d_{15} \oplus d_{19} \oplus d_{22} \oplus d_{23} \oplus d_{24}$

where:

$D_1, D_2, D_3, ... D_{29}, D_{30}$ are the bits transmitted by the satellite;

$D_{25}, ... D_{30}$ are the computed parity bits;

$d_1, d_2, ... d_{24}$ are the source data bits;

$\oplus$ is the Modulo-2 or "Exclusive-Or" operation; and

* is used to identify the last two bits of the previous word of the subframe.

3.1.2.1   *Parity algorithm*. GPS parity algorithms are defined as indicated in Table B-14.

3.1.2.2   *Satellite clock correction parameters*. GPS system time t is defined as:

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$$t = t_{sv} - (\Delta t_{sv})_{L1}$$

where

t	=	GPS system time (corrected for beginning and end-of-week crossovers);
t_{sv}	=	satellite time at transmission of the message;
$(\Delta t_{sv})_{L1}$	=	the satellite PRN code phase offset;
$(\Delta t_{sv})_{L1}$	=	$a_{f0} + a_{f1}(t - t_{oc}) + a_{f2}(t - t_{oc})^2 + \Delta t_r - T_{GD}$

where

a_{f0}, a_{f1} and a_{f2} and t_{oc}, are contained in subframe 1; and
Δt_r = the relativistic correction term (seconds)
Δt_r = $Fe \sqrt{A} \sin E_k$

where

e and A are contained in subframes 2 and 3;
E_k is defined in Table B-15; and

$$F = \frac{-2 (\mu)^{\frac{1}{2}}}{c^2} = -4.442807633(10)^{-10} \text{ s/m}^{\frac{1}{2}}$$

where

μ = WGS-84 universal gravitational parameter (3.986005×10^{14} m^3/s^2)
c = the speed of light in a vacuum (2.99792458×10^8 m/s)

Note.— The value of t is intended to account for the beginning or end-of-week crossovers. That is, if the quantity t-t_{oc} is greater than 302 400 seconds, subtract 604 800 seconds from t. If the quantity t-t_{oc} is less than –302 400 seconds, add 604 800 seconds to t.

3.1.2.3   *Satellite position.* The current satellite position (X_k, Y_k, Z_k) is defined as shown in Table B-15.

3.1.2.4   *Ionospheric correction.* The ionospheric correction (T_{iono}) is defined as:

$$T_{iono}=\begin{cases} F\times\left[5,0\times10^{-9}+AMP\left(1-\frac{x^2}{2}+\frac{x^4}{24}\right)\right], |x|<1,57 \\ F\times\left(5,0\times10^{-9}\right)+ \qquad\qquad\qquad |x|\geq1,57 \end{cases} \text{(seconds)}$$

where

$$AMP=\begin{cases} \sum_{n=0}^{3}\alpha_n\phi_m^n, & AMP\geq0 \\ si\ AMP<0, & AMP=0 \end{cases}\text{(seconds)}$$

$$x=\frac{2\pi(t-50\ 400)}{PER},\text{(radians)}$$

$$PER=\begin{cases} \sum_{n=0}^{3}\beta_n\phi_m^n, & PER\geq72\ 000 \\ si\ PER<72\ 000, & PER=72\ 000 \end{cases}\text{(seconds)}$$

$$F = 1.0 + 16.0[0.53 - E]^3$$

α_n and β_n are the satellite transmitted data words with $n = 0, 1, 2$ and 3

$\phi_m \quad = \phi_i + 0.064 \cos (\lambda_i - 1.617)$ (semi-circles)

$\lambda_i \quad = \lambda_u + \frac{\psi\ sen\ A}{\cos\phi_i}$ (semi-circles)

$\bar{\phi}_i \quad = \phi_u + \psi \cos A$ (semi-circles)

$$\phi_I=\begin{cases} \phi_i=\bar{\phi}_i\ si\ |\bar{\phi}_i|\leq0.416 \\ \phi_i=+0.416\ si\ \bar{\phi}_i>0.416, \\ \phi_i=-0.416\ si\ \bar{\phi}_i<-0.416 \end{cases}\text{(semi-circles)}$$

$\psi = \frac{0.0137}{E+0.11} - 0.022$ (semi-circles)

$t \quad = \quad 4.32\times10^4\ \lambda_i + $ GPS time (seconds) where $0\leq t<86\ 400$, therefore: if $t\geq86\ 400$ seconds, subtract 86 400 seconds; and if $t<0$ seconds, add 86 400 seconds

$E \quad = \quad$ satellite elevation angle

3.1.2.4.1   The terms used in computation of ionospheric delay are as follows:

a) Satellite transmitted terms

    α_n =   the coefficients of a cubic equation representing the amplitude of the vertical delay (4 coefficients = 8 bits each)

    β_n =   the coefficients of a cubic equation representing the period of the model (4 coefficients = 8 bits each)

b) Receiver generated terms

    E   =   elevation angle between the user and satellite (semi-circles)

    A   =   azimuth angle between the user and satellite, measured clockwise positive from the true North (semi-circles)

    ϕ_u =   user geodetic latitude (semi-circles) WGS-84

    λ_u =   user geodetic longitude (semi-circles) WGS-84

    GPS time   =   receiver computed system time

c) Computed terms

    x   =   phase (radians)

    F   =   obliquity factor (dimensionless)

    t   =   local time (seconds)

    ϕ_m =   geomagnetic latitude of the earth projection of the ionospheric intersection point (mean ionospheric height assumed 350 km) (semi-circles)

    λ_i =   geomagnetic longitude of the earth projection of the ionospheric intersection point (semi-circles)

    ϕ_i =   geomagnetic latitude of the earth projection of the ionospheric intersection point (semi-circles)

    ψ =   earth's central angle between user position and earth projection of ionospheric intersection point (semi-circles)

Table B-15.   Elements of coordinate systems

$$A = \left(\sqrt{A}\right)^2 \qquad \text{Semi-major axis}$$

$$n_0 = \sqrt{\frac{\mu}{A^3}} \qquad \text{Computed mean motion}$$

$$t_k = t - t_{oe} \qquad \text{Time from ephemeris reference epoch}^*$$

$$n = n_0 + \Delta n \qquad \text{Corrected mean motion}$$

$$M_k = M_0 + nt_k \qquad \text{Mean anomaly}$$

$$M_k = E_k - e \sin E_k \qquad \text{Kepler's equation for eccentric anomaly (may be solved by iteration)}$$

$$v_k = \tan^{-1}\left\{\frac{\text{sen } v_k}{\cos v_k}\right\} = \tan^{-1}\left\{\frac{\sqrt{1-e^2}\,\text{sen } E_k/(1-e\cos E_k)}{(\cos E_k - e)/(1 - e \cos E_k)}\right\} \qquad \text{True anomaly}$$

$$E_k = \cos^{-1}\left\{\frac{e + \cos v_k}{1 + e \cos v_k}\right\} \qquad \text{Eccentric anomaly}$$

$$\phi_k = v_k + \omega \qquad \text{Argument of latitude}$$

Second Harmonic Perturbations

$$\delta u_k = C_{us} \sin 2\phi_k + C_{uc} \cos 2\phi_k \qquad \text{Argument of latitude correction}$$

$$\delta r_k = C_{rc} \sin 2\phi_k + C_{rs} \sin 2\phi_k \qquad \text{Radius correction}$$

$$\delta i_k = C_{ic} \cos 2\phi_k + C_{is} \sin 2\phi_k \qquad \text{Inclination correction}$$

$$u_k = \phi_k + \delta u_k \qquad \text{Corrected argument of latitude}$$

$$r_k = A(1 - e \cos E_k) + \delta r_k \qquad \text{Corrected radius}$$

$$i_k = i_0 + \delta i_k + (\text{iDOT})t_k \qquad \text{Corrected inclination}$$

$$\left.\begin{array}{l} x'_k = r_k \cos u_k \\ y'_k = r_k \text{sen } u_k \end{array}\right\} \qquad \text{Positions in orbital plane}$$

$$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)t_k - \dot{\Omega}_e t_{oe} \qquad \text{Corrected longitude of ascending node}$$

$$\left.\begin{array}{l} x_k = x'_k \cos \Omega_k - y'_k \cos i_k \text{ sen } \Omega_k \\ y_k = x'_k \text{ sen } \Omega_k - y'_k \cos i_k \cos \Omega_k \\ z_k = y'_k \text{ sen } i_k \end{array}\right\} \qquad \text{Earth-centred, earth-fixed coordinates}$$

* t is GPS system time at time of transmission, i.e. GPS time corrected for transit time (range/speed of light). Furthermore, t_k is the actual total time difference between the time t and the epoch time t_{oe}, and must account for beginning or end-of-week crossovers. That is, if t_k is greater than 302 400 seconds, subtract 604 800 seconds from t_k. If t_k is less than −302 400 seconds, add 604 800 seconds to t_k.

3.1.3   *AIRCRAFT ELEMENTS*

3.1.3.1   *GNSS (GPS) RECEIVER*

3.1.3.1.1 *Satellite exclusion*. The receiver shall exclude any marginal or unhealthy satellite.

Note.— *Conditions indicating that a satellite is "healthy", "marginal" or "unhealthy" can be found in U.S. Department of Defense,* "Global Positioning System - Standard Positioning Service - Performance Standard", *4th Edition, September 2008, Section 2.3.2.*

3.1.3.1.2 *Satellite tracking*. The receiver shall provide the capability to continuously track a minimum of four satellites and generate a position solution based upon those measurements.

3.1.3.1.3 *Doppler shift*. The receiver shall be able to compensate for dynamic Doppler shift effects on nominal SPS signal carrier phase and C/A code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.1.3.1.4 *Resistance to interference*. The receiver shall meet the requirements for resistance to interference as specified in Chapter 3, 3.7.

3.1.3.1.5 *Application of clock and ephemeris data*. The receiver shall ensure that it is using the correct ephemeris and clock data before providing any position solution. The receiver shall monitor the IODC and IODE values, and to update ephemeris and clock databased upon a detected change in one or both of these values. The SPS receiver shall use clock and ephemeris data with corresponding IODC and IODE values for a given satellite.

3.1.4   TIME

GPS time shall be referenced to a UTC (as maintained by the U.S. Naval Observatory) zero time-point defined as midnight on the night of 5 January 1980/morning of 6 January 1980. The largest unit used in stating GPS time shall be 1 week, defined as 604 800 seconds. The GPS time scale shall be maintained to be within 1 microsecond of UTC (Modulo 1 second) after correction for the integer number of leap seconds difference. The navigation data shall contain the requisite data for relating GPS time to UTC.

3.2   Global navigation satellite system (GLONASS) channel of standard accuracy (CSA) (L1)

Note.— *In this section the term GLONASS refers to all satellites in the constellation. Standards relating only to GLONASS-M satellites are qualified accordingly.*

3.2.1   NON-AIRCRAFT ELEMENTS

3.2.1.1 *RF CHARACTERISTICS*

3.2.1.1.1 *Carrier frequencies.* The nominal values of L1 carrier frequencies shall be as defined by the following expressions:

$$f_{k1} = f_{01} + k\Delta f_1$$

where k $\quad = -7, \ldots, 0, 1, \ldots, 6$ are carrier numbers (frequency channels) of the signals transmitted by GLONASS satellites in the L1 sub-band;

$$f_{01} \quad = 1\,602 \text{ MHz; and}$$

$$\Delta f_1 \quad = 0.5625 \text{ MHz.}$$

Carrier frequencies shall be coherently derived from a common on-board time/frequency standard. The nominal value of frequency, as observed on the ground, shall be equal to 5.0 MHz. The carrier frequency of a GLONASS satellite shall be within $\pm 2 \times 10^{-11}$ relative to its nominal value f_k.

Note 1.— The nominal values of carrier frequencies for carrier numbers k are given in Table B-16.

Note 2.— For GLONASS-M satellites, the L2 channel of standard accuracy (CSA) navigation signals will occupy the 1 242.9375 – 1 251.6875 MHz ±0.511 MHz bandwidth as defined by the following expressions:

$$f_{k2} = f_{02} + k\Delta f_2,$$

$$f_{02} = 1\,246 \text{ MHz; } \Delta f_2 = 0.4375 \text{ MHz.}$$

For any given value of k the ratio of carrier frequencies of L1 and L2 sub-bands will be equal to:

$$\frac{f_{k2}}{f_{k1}} = \frac{7}{9}$$

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Table B-16.   L1 carrier frequencies

Carrier number	HA_n (see 3.2.1.3.4)	Nominal value of frequency in L1 sub-band (MHz)
06	6	1 605.3750
05	5	1 604.8125
4	4	1 604.2500
3	3	1 603.6875
2	2	1 603.1250
1	1	1 602.5625
0	0	1 602.0000
−1	31	1 601.4375
−2	30	1 600.8750
−3	29	1 600.3125
−4	28	1 599.7500
−5	27	1 599.1875
−6	26	1 598.6250
−7	25	1 598.0625

3.2.1.1.2   *Carrier phase noise*. The phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth provides the accuracy of carrier phase tracking not worse than 0.1 radian (1 sigma).

3.2.1.1.3 *GLONASS pseudo-random code generation*. The pseudo-random ranging code shall be a 511-bit sequence that is sampled at the output of the seventh stage of a 9-stage shift register. The initialisation vector to generate this sequence shall be "111111111". The generating polynomial that corresponds to the 9-stage shift register shall be:

$$G(x) = 1 + x^5 + x^9.$$

3.2.1.1.4 *Spurious emissions*. The power of the transmitted RF signal beyond the GLONASS allocated bandwidth shall not be more than –40 dB relative to the power of the unmodulated carrier.

Note 1.— GLONASS satellites launched during 1998 to 2005 and beyond use filters limiting out-of-band emissions to the harmful interference limit contained in Recommendation ITU-R RA.769 for the 1 660 – 1 670 MHz band.

Note 2.— GLONASS satellites launched beyond 2005 use filters limiting out-of-band emissions to the harmful interference limit contained in Recommendation ITU-R RA.769 for the 1 610.6 – 1 613.8 MHz and 1 660 – 1 670 MHz bands.

3.2.1.1.5   *Correlation loss*. The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 0.8 dB.

Note.— The loss in signal power is the difference between the broadcast power in a 1.022 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with 1-chip correlator spacing and a 1.022 MHz bandwidth.

3.2.1.2   *DATA STRUCTURE*

3.2.1.2.1 *General*. The navigation message shall be transmitted as a pattern of digital data which are coded by Hamming code and transformed into relative code. Structurally, the data pattern shall be generated as continuously repeating superframes. The superframe shall consist of the frames and the frames shall consist of the strings. The boundaries of strings, frames and superframes of navigation messages from different GLONASS satellites shall be synchronized within 2 milliseconds.

3.2.1.2.2 *Superframe structure*. The superframe shall have a 2.5-minute duration and shall consist of 5 frames. Within each superframe a total content of non-immediate information (almanac for 24 GLONASS satellites) shall be transmitted.
Note.— Superframe structure with indication of frame numbers in the superframe and string numbers in the frames is shown in Figure B-7.

3.2.1.2.3 *Frame structure*. Each frame shall have a 30-second duration and shall consist of 15 strings. Within each frame the total content of immediate information (ephemeris and time parameters) for given satellite and a part of non- immediate information (almanac) shall be transmitted. The frames 1 through 4 shall contain the part of almanac for 20 satellites (5 satellites per frame) and frame 5 shall contain the remainder of almanac for 4 satellites. The almanac for one satellite shall occupy two strings.

Note.— Frame structures are shown in Figures B-8 and B-9.

3.2.1.2.4 *String structure*. Each string shall have a 2-second duration and shall contain binary chips of data and time mark. During the last 0.3 second within this 2-second interval (at the end of each string) the time mark shall be transmitted. The time mark (shortened pseudo-random sequence) shall consist of 30 chips with a time duration for each chip of 10 milliseconds and having the following sequence:

1 1 1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 1 0.

During the first 1.7 seconds within this 2-second interval (in the beginning of each string) 85 bits of data (each data bit of a 20 milliseconds duration) shall be transmitted in bi-binary format. The numbers of bits in the string shall be increased from right to left. Along with information bits (bit positions 9 through 84) the check bits of Hamming code (KX) (bit positions 1 through 8) shall be transmitted. The Hamming code shall have a code length of 4. The data of one string shall be separated from the data of adjacent strings by time mark (MB). The words of the data shall be registered by MSB ahead. In each string bit position, 85 shall be an idle chip ("0") and be transmitted first.

3.2.1.2.4.1   *Strings 1 through 4.* The information contained in strings 1 through 4 of each frame shall correspond to the satellite from which it is transmitted. This information shall not be changed within the superframe.

3.2.1.2.4.2   *Strings 5 through 15*. Strings 5 through 15 of each frame shall contain GLONASS almanac for 4 or 5 satellites. The information contained in the fifth string shall be repeated in each frame of the superframe.

   Note.— *String structure is given in Figure B-10.*

3.2.1.3   DATA CONTENT

3.2.1.3.1   *Ephemeris and time parameters.* The ephemeris and time parameters shall be as follows:

m =   the string number within the frame;

t_k =   the time referenced to the beginning of the frame within the current day. It is calculated according to the satellite time scale. The integer number of hours elapsed since the beginning of the current day is registered in the 5 MSBs. The integer number of minutes elapsed since the beginning of the current hour is registered in the next 6 bits. The number of 30-second intervals elapsed since the beginning of the current minute is registered in the one LSB. The beginning of the day according to the satellite time scale coincides with the beginning of the recurrent superframe;

t_b =   the time interval within the current day according to UTC(SU) + 03 hours 00 min. The immediate data transmitted within the frame are referred to the middle of t_b. Duration of the time interval and therefore the maximum value of t_b depends on the value of the flag P1;

$\gamma_n(t_b)$ =   the relative deviation of predicted carrier frequency value of n-satellite from the nominal value at the instant t_b, i.e.

$$\gamma_n(t_b) = \frac{f_n(t_b) - f_{Hn}}{f_{Hn}},$$

where

$f_n(t_b)$	=	the forecast frequency of n-satellite clocks at an instant t_b;
f_{Hn}	=	the nominal value of frequency of n-satellite clocks;
$\tau_n(t_b)$	=	the correction to the n-satellite time t_n relative to GLONASS time t_c at an instant t_b, i.e. $\tau_n(t_b) = t_c(t_b) - t_n(t_b)$;
$x_n(t_b), y_n(t_b), z_n(t_b)$	=	the coordinates of n-satellite in PZ-90 coordinate system at an instant t_b;
$\dot{x}_n(t_b), \dot{y}_n(t_b), \dot{z}_n(t_b)$	=	the velocity vector components of n-satellite in PZ-90 coordinate system at an instant t_b;
$\ddot{x}_n(t_b), \ddot{y}_n(t_b), \ddot{z}_n(t_b)$	=	the acceleration components of n-satellite in PZ-90 coordinate system at an instant t_b, which are caused by effect of sun and moon;

E_n = an indication of the "age" of the immediate information, i.e. a time interval elapsed since the instant of its calculation (uploading) until the instant t_b for n-satellite;

B_n = the health flag. Values greater than 3 indicate the fact of malfunction of given satellite;

P1 = a flag indicating the time interval between the current and previous value of the t_b parameters in minutes as shown:

P1	Time interval between adjacent values of t_b in minutes
0	0
1	30
10	45
11	60

P2 = a flag indicating whether the value of t_b is odd or even. A value of "1" indicates a 30-minute interval of service information transmit (t_b = 1, 3, 5 …), a value of "0" indicates a 60-minute interval of service information transmit (t_b = 2, 6, 10 …);

P3 = a flag indicating the number of satellites for which an almanac is transmitted within a given frame. "1" corresponds to 5 satellites and "0" corresponds to 4 satellites; and

$\Delta\tau_n$ = the time difference between the navigation RF signal transmitted in L2 sub-band and navigation RF signal transmitted in L1 sub-band by given satellite:

$$\Delta\tau_n = t_{f2} - t_{f1}$$

where t_{f1}, t_{f2} are the equipment delays in L1 and L2 sub-bands respectively, expressed in units of time.

3.2.1.3.2   *Ephemeris and time parameters*. The ephemeris and time parameters shall be as indicated in Table B-17. For the words for which numeric values may be positive or negative, the MSB shall be the sign bit. The chip "0" shall correspond to the "+" sign and the chip "1" shall correspond to the "−" sign.

3.2.1.3.3   *Arrangement of the ephemeris and time parameters*. Arrangements of the ephemeris and time parameters within a frame shall be as indicated in Table B-18.

3.2.1.3.4   *Almanac parameters*. The almanac parameters shall be as follows:

A	=	an index showing relation of this parameter with the almanac;
M^A_n	=	an index of the modification of n^A-satellite: "00" indicates GLONASS satellite, and "01" indicates GLONASS-M satellite;
τ_c	=	the GLONASS time scale correction to UTC(SU) time. The correction τ_c is given at the instant of day N^A;
N^A	=	the calendar day number within the 4-year period beginning since the leap year. The correction τ_c and other almanac data (almanac of orbits and almanac of phases) relate to this day number;
n^A	=	the slot number occupied by n-satellite;
H^A_n	=	the channel number of a carrier frequency of n^A-satellite (Table B-16);
λ^A_n	=	the longitude of the first (within the N^A-day) ascending node of n^A-satellite orbit in PZ-90 coordinate system;
$t^A_{\lambda n}$	=	the time of the first ascending node passage of n^A-satellite within N^A-day;

Table B-17.   Ephemeris and time parameters

Parameter	Number of bits	Scale factor (LSB)	Effective range	Units
m	4	1		dimensionless
	5	1	0 to 23	hours
t_k	6	1	0 to 59	minutes
	1	30	0 or 30	seconds
t_b	7	15	15...1 425	minutes
$\gamma_n(t_b)$	11	2^{-40}	$\pm 2^{-30}$	dimensionless
$\tau_n(t_b)$	22	2^{-30}	$\pm 2^{-9}$	seconds
$x_n(t_b), y_n(t_b), z_n(t_b)$	27	2^{-11}	$\pm 2.7 \times 10^4$	km
$\dot{x}_n(t_b), \dot{y}_n(t_b), \dot{z}_n(t_b)$	24	2^{-20}	± 4.3	km/second
$\ddot{x}_n(t_b), \ddot{y}_n(t_b), \ddot{z}_n(t_b)$	5	2^{-30}	$\pm 6.2 \times 10^{-9}$	km/second^2
E_n	5	1	0 to 31	days
B_n	3	1	0 to 7	dimensionless
P1	2		as detailed in 3.2.1.3.1	

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Table B-18. Arrangements of the ephemeris and time parameters within the frame

Parameter	Number of bits	Scale factor	String number	Effective range	Units	Bit number within the frame
m	4		1...15			81 – 84
t_k	12		1			65 – 76
t_b	7		2			70 – 76
$\gamma_n(t_b)$	5	2^{-30}	3	$\pm 13.97 \times 10^{-9}$	seconds	69 – 79
$\tau_n(t_b)$	22		4			59 – 80
$x_n(t_b)$	27		1			9 – 35
$y_n(t_b)$	27		2			9 – 35
$z_n(t_b)$	27		3			9 – 35
$\dot{x}_n(t_b)$	24		1			41 – 64
$\dot{y}_n(t_b)$	24		2			41 – 64
$\dot{z}_n(t_b)$	24		3			41 – 64
$\ddot{x}_n(t_b)$	5		1			36 – 40
$\ddot{y}_n(t_b)$	5		2			36 – 40
$\ddot{z}_n(t_b)$	5		3			36 – 40
E_n	5		4			49 – 53
B_n	3		2			78 – 80
P1	2		1			77 – 78
P2	1		2			77
P3	1		3			80
$\Delta\tau_n$	5		4			54 – 58

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Δi^A_n = the correction to the mean value of inclination of n^A-satellite at instant of $t_\lambda{}^A_n$ (mean value of inclination is equal to 63 degrees);

ΔT^A_n = the correction to the mean value of Draconian period of the n^A-satellite at the instant of $t_\lambda{}^A_n$ (mean value of Draconian period T is equal to 43 200 seconds);

$\Delta \dot{T}^A_n$ = the rate of change of Draconian period of n^A-satellite;

ε^A_n = the eccentricity of n^A-satellite at instant of $t_\lambda{}^A_n$;

ω^A_n = the argument of perigee of n^A-satellite at the instant of $t_\lambda{}^A_n$;

τ^A_n = the coarse value of n^A-satellite time correction to GLONASS time at instant of $t_\lambda{}^A_n$;

C^A_n = a generalized "unhealthy flag" of n^A-satellite at instant of almanac upload almanac of orbits and phases.
When $C_n = 0$, this indicates that n-satellite is non-operational. When $C_n = 1$, this indicates that n-satellite is operational.

3.2.1.3.5 *Partition and coding of almanac parameters*. The GLONASS almanac, transmitted within the superframe, shall be partitioned over the superframe, as indicated in Table B-19. The numeric values of almanac parameters shall be positive or negative. The MSB shall be the sign bit, the chip "0" shall correspond to the "+" sign, and the chip "1" shall correspond to the "–" sign. The almanac parameters shall be coded as indicated in Table B-20.

3.2.1.3.6 *Arrangement of the almanac parameters*. Arrangement of the almanac words within the frame shall be as indicated in Table B-21.

3.2.1.4 *CONTENT AND STRUCTURE OF ADDITIONAL DATA TRANSMITTED BY GLONASS-M SATELLITES*

3.2.1.4.1 *Letter designation of additional data*. In addition to the GLONASS data, GLONASS-M satellites shall transmit the following additional data as indicated in Table B-17-A:

n — an index of the satellite transmitting the given navigation signal: it corresponds to a slot number within GLONASS constellation;

l_n — health flag for n-th satellite: "0" indicates the n-th satellite is healthy, "1" indicates the malfunction of the n-th satellite;

B1 — coefficient to determine $\Delta UT1$: it is equal to the difference between UT1 and UTC at the beginning of the day (N^A), expressed in seconds;

B2 — coefficient to determine $\Delta UT1$: it is equal to the daily change of the difference $\Delta UT1$ (expressed in seconds for a mean sun day).
These coefficients shall be used to transform between UTC(SU) and UT1:

$$\Delta UT1 = UTC(SU) - UT1,$$

where

UT1 — Universal Time referenced to the Mean Greenwich Meridian (taking account of Pole motion),

UTC(SU) — Coordinated Universal Time of the Russian Federation State Standard,

$$\Delta UT1 = B1 + B2 \times (N_T - N^A),$$

KP — notification of a forthcoming leap second correction of UTC (± 1 s) as shown:

KP	UTC second correction data
00	No UTC correction at the end of the current quarter
01	UTC correction by plus 1 s at the end of the current quarter
11	UTC correction by minus 1 s at the end of the current quarter

Note.— GLONASS system timescale correction is usually performed once a year at midnight 00 hours 00 minutes 00 seconds in accordance with the early notification of the International Time Bureau (BIH/BIPM) at the end of a quarter:

from 31 December to 1 January — first quarter,
from 31 March to 1 April — second quarter,
from 30 June to 1 July — third quarter,
from 30 September to 1 October — fourth quarter.

N_T — current date, calendar number of the day within the four-year interval starting from 1 January in a leap year;

Note.— An example of N_T transformation into the common form of current data information (dd/mm/yy) is presented in Attachment D, 4.2.7.1.

N_4 — four-year interval number starting from 1996;

F_T — a parameter that provides the predicted satellite user range accuracy at time t_b. Coding is as indicated in Table B-17-B;

M — type of satellite transmitting the navigation signal. 00 refers to a GLONASS satellite; 01 refers to a GLONASS-M satellite;

P4 — flag to show that updated ephemeris parameters are present. "1" indicates that an updated ephemeris or frequency/time parameters have been uploaded by the control segment;

Note.— Updated ephemeris or frequency/time information is transmitted in the next interval after the end of the current interval t_b.

P   —   technological parameter of control segment indicating the satellite operation mode in respect of time parameters:

      00 — τ_c parameter relayed from control segment, τ_{GPS} parameter relayed from control segment;

      01 — τ_c parameter relayed from control segment, τ_{GPS} parameter calculated on-board the GLONASS-M satellite;

      10 — τ_c parameter calculated on-board the GLONASS-M satellite; τ_{GPS} parameter relayed from control segment;

      11 — τ_c parameter calculated on-board the GLONASS-M satellite; τ_{GPS} parameter calculated on-board the GLONASS-M satellite;

τ_{GPS} — correction to GPS time relative to GLONASS time:

$$T_{GPS} - T_{GL} = \Delta T + \tau_{GPS},$$

where

    ΔT is the integer part, and τ_{GPS} is the fractional part of the difference between the system timescales expressed in seconds.

    Note.— The integer part ΔT is determined from the GPS navigation message by the user receiver.

M^A_n — type of satellite n^A: coding "00" indicates a GLONASS satellite, coding "01" indicates a GLONASS-M satellite.

3.2.1.4.2   *Additional data parameters.* Additional data parameters are defined in Tables B-17-A to B-18-A.

3.2.1.4.3   *Location of additional data words within GLONASS-M navigation message.* The required location of additional data words within the GLONASS-M navigation message is defined in Table B-18-A.

Table B-17-A.   Additional data parameters

Parameter	No. of bits	Scale factor (LSB)	Effective range	Units
n	5	1	0 to 31	Dimensionless
l_n	1	1	0; 1	Dimensionless
B1	11	2^{-10}	±0.9	seconds
B2	10	2^{-16}	$(-4.5 \text{ to } 3.5) \times 10^{-3}$	s/mean sun day
KP	2	1	0 to 3	Dimensionless
N_T	11	1	0 to 1 461	days
N_4	5	1	1 to 31	four-year interval
F_T	4		See table B-17-B	

M	2	1	0 to 3	Dimensionless
P4	1	1	0; 1	Dimensionless
P	2	1	00,01,10,11	Dimensionless
τ_{GPS}	22	2^{-30}	$\pm 1.9 \times 10^{-3}$	seconds
M^A_n	2	1	0 to 3	Dimensionless

Table B-17-B. F_T word coding

FT value	Pseudorange accuracy, 1 sigma (m)
0	1
1	2
2	2.5
3	4
4	5
5	7
6	10
7	12
8	14
9	16
10	32
11	64
12	128
13	256
14	512
15	Not used

Table B-18-A. Location of additional data words within the GLONASS-M navigation message.

Word	Number of bits	String number within the superframe	Bit number within the string
n	5	4, 19, 34, 49, 64	11 – 15
l_n	1	5, 7, 9, 11, 13, 15, 20,	9
		22, 24, 26, 28, 30, 35,	
		37, 39, 41, 43, 45, 50,	
		52, 54, 56, 58, 60,	
		65, 67, 69, 71, 73, 75	
		3, 18, 33, 48, 63	65
B1	11	74 (within the superframe)	70 – 80
B2	10	74 (within the superframe)	60 – 69
KP	2	74 (within the superframe)	58 – 59

N_T	11	4, 19, 34, 49, 64	16 – 26
N_4	5	5, 20, 35, 50, 65	32 – 36
F_T	4	4, 19, 34, 49, 64	30 – 33
M	2	4, 19, 34, 49, 64	9 – 10
P4	1	4, 19, 34, 49, 64	34
P	2	3, 18, 33, 48, 63	66 – 67
ιGPS	22	5, 20, 35, 50, 65	10 – 31
M^A_n	2	6, 8, 10, 12, 14	78 – 79

Table B-19.   Almanac partition within the superframe

Frame number within the superframe	Satellite numbers, for which almanac is transmitted within given frame
1	1 to 5
2	6 to 10
3	11 to 15
4	16 to 20
5	21 to 24

Table B-20.   Almanac parameters coding

Parameter	Number of bits	Scale factor (LSB)	Effective range	Units
M^A_n	2	1	0 to 3	dimensionless
τ_c	28	2^{-27}	± 1	seconds
N^A	11	1	1 to 1 461	days
n^A	5	1	1 to 24	dimensionless
H^A_n	5	1	0 to 31	dimensionless
λ^A_n	**21**	**2^{-20}**	**± 1**	**semi-circles**
$t_\lambda A_n$	21	2^{-5}	0 to 44 100	seconds
Δi^A_n	18	2^{-20}	± 0.067	semi-circles
ΔT^A_n	22	2^{-9}	$\pm 3.6 \times 10^3$	seconds/revolution
$\Delta \dot{T}^A_n$	7	2^{-14}	$\pm 2^{-8}$	seconds/revolution^2
ε^A_n	15	2^{-20}	0 to 0.03	dimensionless
ω^A_n	16	2^{-15}	± 1	semi-circles
t^A	10	2^{-18}	$\pm 1.9 \times 10^{-3}$	seconds
C^A_n	1	1	0 to 1	dimensionless

Table B-21.   Arrangement of almanac parameters within the frame

Parameter	Number of bits	String number within the frame	Bit number within the string
M^A_n	2	6, 8, 10, 12, 14	78 – 79
τ_c	28	5	42 – 69
N^A	11	5	70 – 80
n^A	5	6, 8, 10, 12, 14	73 – 77
H^A_n	5	7, 9, 11, 13, 15	10 – 14
λ^A_n	21	6, 8, 10, 12, 14	42 – 62
$t\lambda^A_n$	21	7, 9, 11, 13, 15	44 – 64
Δi^A_n	18	6, 8, 10, 12, 14	24 – 41
ΔT^A_n	22	7, 9, 11, 13, 15	22 – 43
$\Delta \dot{T}^A_n$	7	7, 9, 11, 13, 15	15 – 21
ε^A_n	15	6, 8, 10, 12, 14	9 – 23
ω^A_n	16	7, 9, 11, 13, 15	65 – 80
$t_\tau{}^A_n$	10	6, 8, 10, 12, 14	63 – 72
C^A_n	1	6, 8, 10, 12, 14	80

Note.— String numbers of the first four frames within superframe are given. There are no almanac parameters in 14th and 15th strings of 5th frame.

3.2.2   DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters that are not transmitted, but are used by either or both non-aircraft and aircraft elements, and that define terms applied to determine the navigation solution and its integrity.

Table B-22.   Parity checking algorithm

$b85, b84, \ldots, b10, b9$ are the data bits (position 9 to 85 in the string);

$\beta1, \beta2, \ldots, \beta8$ are the check bits of the Hamming code (positions 1 to 8 in the string);

$c_1, c_2, \ldots, c_7, c_\Sigma$ are the checksums generated using the following:

$c_1 = \beta \oplus [\Sigma_i \, b_i]_{mod\,2}$
$i \quad = \quad$ 9, 10, 12, 13, 15, 17, 19, 20, 22, 24, 26, 28, 30, 32, 34, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84.

$c_2 = \beta_2 \oplus [\Sigma_j \, b_j]_{mod\,2}$
$j \quad = \quad$ 9, 11, 12, 14, 15, 18, 19, 21, 22, 25, 26, 29, 30, 33, 34, 36, 37, 40, 41, 44, 45, 48, 49, 52, 53, 56, 57, 60, 61, 64, 65, 67, 68, 71, 72, 75, 76, 79, 80, 83, 84.

$c_3 = \beta_3 \oplus [\Sigma_k \, b_k]_{mod\,2}$
$k \quad = \quad$ 10, 11, 12, 16, 17, 18, 19, 23, 24, 25, 26, 31, 32, 33, 34, 38, 39, 40, 41, 46, 47, 48, 49, 54, 55, 56, 57, 62, 63, 64, 65, 69, 70, 71, 72, 77, 78, 79, 80, 85.

$c_4 = \beta_4 \oplus [\Sigma_l \, b_l]_{mod\,2}$
$l \quad = \quad$ 13, 14, 15, 16, 17, 18, 19, 27, 28, 29, 30, 31, 32, 33, 34, 42, 43, 44, 45, 46, 47, 48, 49, 58, 59, 60, 61, 62, 63, 64, 65, 73, 74, 75, 76, 77, 78, 79, 80.

$c_5 = \beta_5 \oplus [\Sigma_m \, b_m]_{mod\,2}$
$m \quad = \quad$ 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 81, 82, 83, 84, 85.

$c_6 = \beta_6 \oplus [\Sigma_n \, b_n]_{mod\,2}$
$n \quad = \quad$ 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65.

$c_7 = \beta_7 \oplus [\Sigma_p \, b_p]_{mod\,2}$
$p \quad = \quad$ 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85.

$c_\Sigma = [\Sigma \, \beta_q]_{mod\,2} \oplus [\Sigma \, b_r]_{mod\,2}$
$q \quad = \quad$ 1, 2, 3, 4, 5, 6, 7, 8
$r \quad = \quad$ 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85.

3.2.2.1 *Parity checking algorithm for data verification.* The algorithm shown in Table B-22 and as detailed below is used to detect and correct an error of 1 bit within the string and to detect an error of 2 or more bits within a string.

3.2.2.1.1   Each string includes the 85 data bits where the 77 MSBs are data chips (b_{85}, b_{84}, …, b_{10}, b_9), and the 8 LSBs are the check bits of Hamming code length of 4 (β_8, β_7, …, β_2, β_1).

3.2.2.1.2   To correct 1-bit errors within the string the following checksums are generated: (c_1, c_2, …, c_7), and to detect 2-bit errors (or more-even-number-of-bits errors) a checksum c_Σ is generated, as shown in Table B-22. The following is used for correcting single errors and detecting multiple errors:

a) A string is considered correct if all checksums (c_1, ..., c_7, and c_Σ) are equal to "0", or if only one of the checksums (c_1, ..., c_7) is equal to "1" and c_Σ is equal to "1".

b) If two or more of the checksums (c_1, ..., c_7) are equal to "1" and c_Σ is equal to "1", then character "b_{icor}" is corrected to the opposite character in the following bit position:

$$\text{"}i_{cor}\text{"} = c_7\,c_6\,c_5\,c_4\,c_3\,c_2\,c_1 + 8 - K, \text{ provided that "}i_{cor}\text{"} \leq 85,$$

where "$c_7\,c_6\,c_5\,c_4\,c_3\,c_2\,c_1$" is a binary number generated from the checksums (c_1, ..., c_7) with c_1 being the LSB and c_7 being the MSB. K is the ordinal number of the most significant checksum not equal to "0".

If $i_{cor} > 85$, then there is an odd number of multiple errors, and the data shall be rejected.

c) If at least one of the checksums (c_1, ..., c_7) is equal to "1" and c_Σ is equal to "0", or if all checksums (c_1, ..., c_7) are equal to "0" but c_Σ is equal to "1", then there are multiple errors and the data shall be rejected.

3.2.2.2   *SATELLITE CLOCK CORRECTION PARAMETERS*

3.2.2.2.1   GLONASS system time is determined as:

$$t_{GLONASS} = t_k + \tau_n(t_b) - \gamma_n(t_b)\,(t_k - t_b)$$

where t_k, $\tau_n(t_b)$, $\gamma_n(t_b)$ are parameters described in 3.2.1.3.1.

3.2.2.2.2   GLONASS time is related to National Time Service of Russia (UTC(SU)) time as indicated below:

$$t_{UTC(SU)} = t_{GLONASS} + \tau_c - 03 \text{ hours } 00 \text{ minutes}$$

where

τ_c is a parameter described in 3.2.1.3.4 and

03 hours 00 minutes is continuous time shift caused by difference between Moscow time and Greenwich time.

3.2.2.3   *SATELLITE POSITION*

3.2.2.3.1   The current satellite position is defined using ephemeris parameters from GLONASS navigation, as indicated and in Table B-17.

3.2.2.3.2   Recalculation of ephemeris from instant t_b to instant t_i within the interval ($|\tau_i| = |t_i - t_b| \leq 15$ minutes) is performed using a technique of numeric integration of differential equations describing the motion of the satellites. In the right-hand parts of these equations the accelerations are determined using the gravitational constant μ and the second zonal harmonic of the geopotential J^2_0 which defines polar flattening of the earth, and accelerations due to luni-solar perturbation are taken into account. The equations are integrated in the PZ-90 (3.2.5) coordinate system by applying the Runge-Kutta technique of fourth order, as indicated below:

$$\frac{dx}{dt} = Vx$$

$$\frac{dy}{dt} = Vy$$

$$\frac{dz}{dt} = Vz$$

$$\frac{dV_x}{dt} = -\frac{\mu}{r^3}x - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}x\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 x + 2\omega V_y + \bar{x}$$

$$\frac{dV_y}{dt} = -\frac{\mu}{r^3}y - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}y\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 y + 2\omega V_x + \bar{y}$$

$$\frac{dV_z}{dt} = -\frac{\mu}{r^3}z - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}z\left(1 - \frac{5z^2}{r^2}\right) + \bar{z}$$

where

r = $\sqrt{x^2+y^2+z^2}$;
μ = earth's universal gravitational constant ($398\ 600.44 \times 10^9\ \mathrm{m^3/s^2}$);
a_e = major semi-axis ($6\ 378\ 136$ m);
J_0^2 = second zonal harmonic of the geopotential ($1\ 082\ 625.7 \times 10^{-9}$); and
ω = earth's rotation rate (7.292115×10^{-5} radians/s).

Coordinates $x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$, and velocity vector components $\dot{x}_n(t_b) = V_x$, $\dot{y}_n(t_b) = V_y$, $\dot{z}_n(t_b) = V_z$ are initial conditions for the integration. Accelerations due to luni-solar perturbation $\bar{x}_n(t_b)$, $\bar{y}_n(t_b)$, $\bar{z}_n(t_b)$ are constant on the integration interval ± 15 minutes.

3.2.3   AIRCRAFT ELEMENTS

3.2.3.1   *GNSS (GLONASS) RECEIVER*

3.2.3.1.1   *Satellite exclusion*. The receiver shall exclude any satellite designated unhealthy in the GLONASS navigation message.

3.2.3.1.2   *Satellite tracking.* The receiver shall provide the capability to continuously track a minimum of four satellites and generate a position solution based upon those measurements.

3.2.3.1.3   *Doppler shift.* The receiver shall be able to compensate for dynamic Doppler shift effects on nominal GLONASS signal carrier phase and standard code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.2.3.1.4   *Resistance to interference*. The receiver shall meet the requirements for resistance to interference as specified in 3.7.

3.2.3.1.4.1   *Intrasystem interference.* When receiving a navigation signal with frequency channel k = n, the interference created by a navigation signal with frequency channel number k = n – 1 or k = n + 1 shall not be more than –48 dBc with

respect to the minimum specified satellite power at the surface of the earth provided that the satellites transmitting these signals are simultaneously located in user's visibility zone.

Note.— The intrasystem interference is the intercorrelation properties of the ranging pseudo-random signal with regard to frequency division multiple access.

3.2.3.1.5   *Application of clock and ephemeris data.* The receiver shall ensure that it is using the correct ephemeris and clock data before providing any position solution.

3.2.3.1.6   *Leap second correction.* Upon GLONASS time leap second correction (see 3.2.1.3.1, t_b) the GLONASS receiver shall be capable of:

a)   generating a smooth and valid series of pseudo-range measurements; and

b)   resynchronizing the data string time mark without loss of signal tracking.

3.2.3.1.6.1   After GLONASS time leap second correction the GLONASS receiver shall utilize the UTC time as follows:

a)   utilize the old (prior to the correction) UTC time together with the old ephemeris (transmitted before 00 hours 00 minutes 00 seconds UTC); and

b)   utilize the updated UTC time together with the new ephemeris (transmitted after 00 hours 00 minutes 00 seconds UTC).

3.2.4   TIME

3.2.4.1   For the GLONASS-M satellites, the navigation message shall contain the data necessary to relate UTC(SU) time to UT1. GLONASS time shall be maintained to be within 1 millisecond of UTC(SU) time after correction for the integer number of hours due to GLONASS control segment specific features:

$$| \, t_{GLONASS} - (UTC + 03 \text{ hours } 00 \text{ minutes}) \, | < 1 \text{ ms}$$

The navigation data shall contain the requisite data to relate GLONASS time to UTC time (as maintained by the National Time Service of Russia, UTC (SU)) within 1 microsecond.

Note 1.— The timescales of GLONASS satellites are periodically compared with central synchronizer time. Corrections to the timescales of GLONASS satellites relative to GLONASS time and UTC(SU) time are computed at the GLONASS ground-based control complex and uploaded to the satellites twice per day.

Note 2.— There is no integer-second difference between GLONASS time and UTC time. The GLONASS timescale is periodically corrected to integer number of seconds simultaneously with UTC corrections which are performed according to

the Bureau International de l'Heure notification (leap second correction). These corrections are performed at 00 hours 00 minutes 00 seconds UTC time at midnight at the end of a quarter of the year. Upon the GLONASS leap second correction the time mark within navigation message changes its position (in a continuous timescale) to become synchronized with 2-second epochs of corrected UTC timescale. GLONASS users are notified in advance on these planned corrections. For the GLONASS-M satellites, notification of these corrections is provided to users via the navigation message parameter KP.

3.2.4.2   Accuracy of mutual satellite timescales synchronization shall be 20 nanoseconds (1 sigma) for GLONASS satellites and 8 nanoseconds (1 sigma) for GLONASS-M satellites.

3.2.4.3   The correction to GPS time relative to GLONASS time (or difference between these timescales) broadcast by the GLONASS-M satellites, τ_{GPS}, shall not exceed 30 nanoseconds (1 sigma).

Note.— The accuracy of τ_{GPS} (30 ns) is determined with reference to the GPS SPS coarse acquisition signal and may be refined upon completion of trials of the GLONASS system using GLONASS-M satellites.

3.2.5   COORDINATE SYSTEM

3.2.5.1   *PZ-90 (Parameters of common terrestrial ellipsoid and gravitational field of the earth 1990).* The GLONASS broadcast ephemeris shall describe a position of transmitting antenna phase centre of a given satellite in the PZ-90 earth-centred earth-fixed reference frame.

3.2.5.2   *Conversion between PZ-90 and WGS-84.* The following conversion parameters shall be used to obtain position coordinates in WGS-84 from position coordinates in PZ-90 (Version 2):

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS-84} = \begin{bmatrix} -0.36 \\ +0.08 \\ +0.18 \end{bmatrix} + \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{PZ-90}$$

Note.— X, Y and Z are expressed in metres.

3.2.5.2.1   The conversion error shall not exceed 0.1 metres (1 sigma) along each coordinate axis.

3.3   Combined use of GPS and GLONASS

3.3.1   AIRCRAFT ELEMENTS

3.3.1.1   *Combined GNSS receiver.* The combined GNSS receiver shall process signals from GPS and GLONASS in accordance with the requirements specified in 3.1.3.1, GPS (GNSS) receiver, and 3.2.3.1, GLONASS (GNSS) receiver.

3.3.1.1.1   *Resistance to interference.* The combined GNSS receiver shall meet the individual requirements for GPS and GLONASS as specified in 3.7.

3.3.1.2   *Antenna(e)*. GPS and GLONASS signals shall be received through one or more antennae.

Note.— Performance characteristics of GNSS receiver antennae are defined in 3.8.

3.3.1.3   *Conversion between coordinate systems*. Position information provided by a combined GPS and GLONASS receiver shall be expressed in WGS-84 earth coordinates. The GLONASS satellite position, obtained in PZ-90 coordinate frame, shall be converted to account for the differences between WGS-84 and PZ-90, as defined in 3.2.5.2.

3.3.1.4   *GPS/GLONASS time*. When combining measurements from GLONASS and GPS, the difference between GLONASS time and GPS time shall be taken into account.

3.4   Aircraft-based augmentation system (ABAS)

Note.— Guidance on ABAS is given in Attachment D, section 5.

3.5   Satellite-based augmentation system (SBAS)

3.5.1   GENERAL

Note.— Parameters in this section are defined in WGS-84.

3.5.2   RF CHARACTERISTICS

3.5.2.1   *Carrier frequency stability*. The short-term stability of the carrier frequency (square root of the Allan Variance) at the output of the satellite transmit antenna shall be better than 5×10^{-11} over 1 to 10 seconds.

3.5.2.2   *Carrier phase noise*. The phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian (1 sigma).

3.5.2.3   *Spurious emissions*. Spurious emissions shall be at least 40 dB below the unmodulated carrier power over all frequencies.

3.5.2.4   *Code/carrier frequency coherence*. The short-term (less than 10 seconds) fractional frequency difference between the code phase rate and the carrier frequency shall be less than 5×10^{-11} (standard deviation). Over the long term (less than 100 seconds), the difference between the change in the broadcast code phase, converted to carrier cycles by multiplying the number of code chips by 1 540, and the change in the broadcast carrier phase, in cycles, shall be within one carrier cycle (standard deviation).

Note.— This applies to the output of the satellite transmit antenna and does not include code/carrier divergence due to

ionospheric refraction in the downlink propagation path.

3.5.2.5   *Correlation loss*. The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 1 dB.

Note.— *The loss in signal power is the difference between the broadcast power in a 2.046 MHz bandwidth and the signal power recovered by a noise-free, loss-free receiver with 1-chip correlator spacing and a 2.046 MHz bandwidth.*

3.5.2.6   *Maximum code phase deviation*. The maximum uncorrected code phase of the broadcast signal shall not deviate from the equivalent SBAS network time (SNT) by more than $\pm 2^{-20}$ seconds.

3.5.2.7   *Code/data coherence*. Each 2-millisecond symbol shall be synchronous with every other code epoch.

3.5.2.8   *Message synchronization*. The leading edge of the first symbol that depends on the first bit of the current message shall be broadcast from the SBAS satellite synchronous with a 1-second epoch of SNT.

3.5.2.9   *Convolutional encoding*. A 250-bit-per-second data stream shall be encoded at a rate of 2 symbols per bit using a convolutional code with a constraint length of 7 to yield 500 symbols per second. The convolutional encoder logic arrangement shall be as illustrated in Figure B-11 with the G3 output selected for the first half of each 4-millisecond data bit period.

3.5.2.10   *Pseudo-random noise (PRN) codes*. Each PRN code shall be a 1 023-bit Gold code which is itself the Modulo-2 addition of two 1 023-bit linear patterns, G1 and $G2_i$. The $G2_i$ sequence shall be formed by delaying the G2 sequence by the associated integer number of chips as illustrated in Table B-23. Each of the G1 and G2 sequences shall be defined as the output of stage 10 of a 10-stage shift register, where the input to the shift register is the Modulo-2 addition of the following stages of the shift register:

a)   G1: stages 3 and 10; and
b)   G2: stages 2, 3, 6, 8, 9 and 10.

The initial state for the G1 and G2 shift registers shall be "1111111111".

Table B-23.   SBAS PRN codes

PRN code number	G2 delay (chips)	First 10 SBAS chips (Leftmost bit represents first transmitted chip, binary)
120	145	110111001
121	175	101011110
122	52	1101001000
123	21	1101100101
124	237	1110000
125	235	111000001
126	886	1011
127	657	1000110000
128	634	10100101
129	762	101010111
130	355	1100011110
131	1 012	1010010110
132	176	1010101111
133	603	100110
134	130	1000111001
135	359	101110001
136	595	1000011111
137	68	111111000
138	386	1011010111

3.5.3 DATA STRUCTURE

3.5.3.1   *Format summary.* All messages shall consist of a message type identifier, a preamble, a data field and a cyclic redundancy check as illustrated in Figure B-12.

3.5.3.2   *Preamble.* The preamble shall consist of the sequence of bits "01010011 10011010 11000110", distributed over three successive blocks. The start of every other 24-bit preamble shall be synchronous with a 6-second GPS subframe epoch.

3.5.3.3   *Message type identifier.* The message type identifier shall be a 6-bit value identifying the message type (Types 0 to 63) as defined in Table B-24. The message type identifier shall be transmitted MSB first.

3.5.3.4   *Data field.* The data field shall be 212 bits as defined in 3.5.6. Each data field parameter shall be transmitted MSB first.

3.5.3.5   *Cyclic redundancy check (CRC).* The SBAS message CRC code shall be calculated in accordance with 3.9.

3.5.3.5.1   The length of the CRC code shall be k = 24 bits.

3.5.3.5.2   The CRC generator polynomial shall be:

$$G(x) = x^{24} + x^{23} + x^{18} + x^{17} + x^{14} + x^{11} + x^{10} + x^7 + x^6 + x^5 + x^4 + x^3 + x + 1$$

Table B-24.   Broadcast message types

Message type	Contents
0	"Do Not Use" (SBAS test mode)
1	PRN mask
2 to 5	Fast corrections
6	Integrity information
7	Fast correction degradation factor
8	Spare
9	GEO ranging function parameters
10	Degradation parameters
11	Spare
12	SBAS network time/UTC offset parameters
13 to 16	Spare
17	GEO satellite almanacs
18	Ionospheric grid point masks
19 to 23	Spare
24	Mixed fast/long-term satellite error corrections
25	Long-term satellite error corrections
26	Ionospheric delay corrections
27	SBAS service message
28	Clock-ephemeris covariance matrix
29 to 61	Spare
62	Reserved
63	Null message

3.5.3.5.3　The CRC information field, M(x), shall be:

$$M(x)= \sum_{i=1}^{226} m_i x^{226-i} = m_1 x^{225} + m_2 x^{224} + \cdots + m_{226} x^0$$

3.5.3.5.4　M(x) shall be formed from the 8-bit SBAS message preamble, 6-bit message type identifier, and 212-bit data field. Bits shall be arranged in the order transmitted from the SBAS satellite, such that m_1 corresponds to the first transmitted bit of the preamble, and m_{226} corresponds to bit 212 of the data field.

3.5.3.5.5　The CRC code r-bits shall be ordered such that r_1 is the first bit transmitted and r_{24} is the last bit transmitted.

3.5.4　DATA CONTENT

3.5.4.1　*PRN mask parameters*. PRN mask parameters shall be as follows:

PRN code number: a number that uniquely identifies the satellite PRN code and related assignments as shown in Table B-25.

PRN mask: 210 PRN mask values that correspond to satellite PRN code numbers. The mask shall set up to 51 of the 210 PRN mask values.

Note.— The first transmitted bit of the PRN mask corresponds to PRN code number 1.

Table B-25.　PRN code number assignments

PRN code number	Assignment
1 – 37	GPS
38 – 61	GLONASS slot number plus 37
62 – 119	Spare
120 – 138	SBAS
139 – 210	Spare

PRN mask value: a bit in the PRN mask indicating whether data are provided for the associated satellite PRN code number (1 to 210).

Coding:　0　=　data not provided
　　　　　1　=　data provided

PRN mask number: the sequence number (1 to 51) of the mask values set in the PRN mask.

Note.— The PRN mask number is "1" for the lowest satellite PRN number for which the PRN mask value is "1".

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Issue of data — PRN (IODP): an indicator that associates the correction data with a PRN mask.

Note.— Parameters are broadcast in the following messages:

    a)   *PRN mask (consisting of 210 PRN mask values) in Type 1 message;*

    b)   *PRN mask number in Type 24, 25 and 28 messages;*

    c)   *PRN code number in Type 17 message; and*

    d)   *IODP in Type 1 to 5, 7, 24, 25 and 28 messages.*

3.5.4.2   *Geostationary orbit (GEO) ranging function parameters.* GEO ranging function parameters shall be as follows:

$t_{0,GEO}$: the reference time for the GEO ranging function data, expressed as the time after midnight of the current day.

$[X_G Y_G Z_G]$: the position of the GEO at time $t_{0,GEO}$.

$[\dot{X}_G \dot{Y}_G \dot{Z}_G]$: the velocity of the GEO at time $t_{0,GEO}$.

$[\ddot{X}_G \ddot{Y}_G \ddot{Z}_G]$: the acceleration of the GEO at time $t_{0,GEO}$.

a_{Gf0}: the time offset of the GEO clock with respect to SNT, defined at $t_{0,GEO}$.

a_{Gf1}: the drift rate of the GEO clock with respect to SNT.

User range accuracy (URA): an indicator of the root-mean-square ranging error, excluding atmospheric effects, as described in Table B-26.

Note.— All parameters are broadcast in Type 9 message.

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Table B-26. User range accuracy

URA	Accuracy (rms)
0	2 m
1	2.8 m
2	4 m
3	5.7 m
4	8 m
5	11.3 m
6	16 m
7	32 m
8	64 m
9	128 m
10	256 m
11	512 m
12	1 024 m
13	2 048 m
14	4 096 m
15	"Do Not Use"

3.5.4.3   *GEO almanac parameters.* GEO almanac parameters shall be as follows:

PRN code number: see 3.5.4.1.

Health and status: an indication of the functions provided by the SBAS. The service provider identifiers are shown in Table B-27.

Coding:	Bit 0 (LSB)	Ranging	On (0)	Off (1)
	Bit 1	Precision corrections	On (0)	Off (1)
	Bit 2	Satellite status and basic corrections	On (0)	Off (1)
	Bits 3	Spare		
	Bits 4 to 7	Service provider identifier		

Note.— A service provider ID of 14 is used for GBAS and is not applicable to SBAS.

$[X_{G,A} Y_{G,A} Z_{G,A}]$: the position of the GEO at time $t_{almanac}$.

$[\dot{X}_{G,A} \dot{Y}_{G,A} \dot{Z}_{G,A}]$: the velocity of the GEO at time $t_{almanac}$.

$t_{almanac}$: the reference time for the GEO almanac data, expressed as the time after midnight of the current day.

Note.— All parameters are broadcast in Type 17 message.

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3.5.4.4   *SATELLITE CORRECTION BROADCAST PARAMETERS*

3.5.4.4.1   Long-term correction parameters shall be as follows:

Issue of data (IOD$_i$): an indicator that associates the long-term corrections for the ith satellite with the ephemeris data broadcast by that satellite.

Note 1.— For GPS, the IOD$_i$ matches the IODE and 8 LSBs of the IODC (3.1.1.3.1.4 and 3.1.1.3.2.2).

Note 2.— For GLONASS, the IOD$_i$ indicates a period of time that GLONASS data are to be used with SBAS data. It consists of two fields as shown in Table B-28.

δx_i: for satellite i, the ephemeris correction for the x axis.

δy_i: for satellite i, the ephemeris correction for the y axis.

δz_i: for satellite i, the ephemeris correction for the z axis.

$\delta a_{i,f0}$: for satellite i, the ephemeris time correction.

$\delta \dot{x}_i$: for satellite i, ephemeris velocity correction for x axis.

$\delta \dot{y}_i$: for satellite i, ephemeris velocity correction for y axis.

$\delta \dot{z}_i$: for satellite i, ephemeris velocity correction for z axis.

$\delta a_{i,f1}$: for satellite i, rate of change of the ephemeris time correction.

$t_{i,LT}$: the time of applicability of the parameters δx_i, δy_i, δz_i, $\delta a_{i,f0}$, $\delta \dot{x}_i$, $\delta \dot{y}_i$, $\delta \dot{z}_i$ and $\delta a_{i,f1}$, expressed in seconds after midnight of the current day.

Velocity code: an indicator of the message format broadcast (Table B-48 and Table B-49).

Coding: 0   = $\delta \dot{x}_i$, $\delta \dot{y}_i$, $\delta \dot{z}_i$ and $\delta a_{i,f1}$ are not broadcast.
          1   = $\delta \dot{x}_i$, $\delta \dot{y}_i$, $\delta \dot{z}_i$ and $\delta a_{i,f1}$ are broadcast.

Note.— All parameters are broadcast in Type 24 and 25 messages.

Table B-27.   SBAS service provider identifiers

Identifier	Service provider
0	WAAS
1	EGNOS
2	MSAS
3	GAGAN
4	SDCM
5 to 13	Spare
14, 15	Reserved

Table B-28.   IOD$_i$ for GLONASS satellites

MSB	LSB
Validity interval (5 bits)	Latency time (3 bits)

3.5.4.4.2 Fast correction parameters shall be as follows:

Fast correction (FC$_i$): for satellite *i*, the pseudo-range correction for rapidly varying errors, other than tropospheric or ionospheric errors, to be added to the pseudo-range after application of the long-term correction.

   Note.— The user receiver applies separate tropospheric corrections (3.5.8.4.2 and 3.5.8.4.3).

Fast correction type identifier: an indicator (0, 1, 2, 3) of whether the Type 24 message contains the fast correction and integrity data associated with the PRN mask numbers from Type 2, Type 3, Type 4 or Type 5 messages, respectively.

Issue of data-fast correction (IODF$_j$): an indicator that associates UDREI$_i$s with fast corrections. The index *j* shall denote the message type (j = 2 to 5) to which IODF$_j$ applies (the fast correction type identifier +2).

   Note.— The fast correction type identifier is broadcast in Type 24 messages. The FC$_i$ are broadcast in Type 2 to 5, and Type 24 messages. The IODF$_j$ are broadcast in Type 2 to 6, and Type 24 messages.

   3.5.4.5   *Fast and long-term correction integrity parameters.* Fast and long-term correction integrity parameters shall be as follows:

UDREI$_i$: an indicator that defines the $\sigma^2_{i,UDRE}$ for satellite *i* as described in Table B-29.

Model variance of residual clock and ephemeris errors ($\sigma^2_{i,UDRE}$): the variance of a normal distribution associated with the user differential range errors for satellite *i* after application of fast and long-term corrections, excluding atmospheric effects and used in horizontal protection level/vertical protection level computations (3.5.5.6).

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Note.— All parameters are broadcast in Type 2 to 6, and Type 24 messages.

3.5.4.6   *Ionospheric correction parameters.* Ionospheric correction parameters shall be as follows:

IGP mask: a set of 11 ionospheric grid point (IGP) band masks defined in Table B-30.

IGP band mask: a set of IGP mask values which correspond to all IGP locations in one of the 11 IGP bands defined in Table B-30.

Table B-29.   Evaluation of UDREI$_i$

UDREI$_i$	$\sigma^2_{i,UDRE}$
0	0.0520 m^2
1	0.0924 m^2
2	0.1444 m^2
3	0.2830 m^2
4	0.4678 m^2
5	0.8315 m^2
6	1.2992 m^2
7	1.8709 m^2
8	2.5465 m^2
9	3.3260 m^2
10	5.1968 m^2
11	20.7870 m^2
12	230.9661 m^2
13	2 078.695 m^2
14	"Not Monitored"
15	"Do Not Use"

IGP mask value: a bit indicating whether data are provided within that IGP band for the associated IGP.

Coding: 0   =   data are not provided
          1   =   data are provided

Number of IGP bands: the number of IGP band masks being broadcast.

IGP band identifier: the number identifying the ionospheric band as defined in Table B-30.

IGP block identifier: the identifier of the IGP block. The IGP blocks are defined by dividing into groups of 15 IGPs the sequence of IGPs within an IGP band mask which have IGP mask values of "1". The IGP blocks are numbered in an order of IGP mask value transmission, starting with "0".

Validity interval (V): the time interval for which the GLONASS ephemeris data are applicable (coded with an offset of 30 s) as described in Table B-31.

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Latency time (L): the time interval between the time the last GLONASS ephemeris has been received by the ground segment and the time of transmission of the first bit of the long-term correction message at the GEO(t_{ltc}) as described in Table B-32.

$IODI_k$: an indication of when the kth IGP band mask changes.

IGP vertical delay estimate: an estimate of the delay induced for a signal at 1 575.42 MHz if it traversed the ionosphere vertically at the IGP.

Coding: The bit pattern "111111111" indicates "Do Not Use".

$GIVEI_i$: an indicator that defines the $\sigma^2_{i,GIVE}$ as described in Table B-33.

Model variance of residual ionospheric errors ($\sigma^2_{i,GIVE}$): the variance of a normal distribution associated with the residual ionospheric vertical error at the IGP for an L1 signal.

Note.— All parameters are broadcast in Type 18 and Type 26 messages.

Table B-30.   IGP locations and band numbers

IGP location		Transmission order in IGP band mask
Band 0		
180 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	1 – 28
175 W	55S, 50S, 45S, ..., 45N, 50N, 55N	29 – 51
170 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	52 – 78
165 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
160 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
155 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
150 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
145 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 1		
140 W	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 28
135 W	55S, 50S, 45S, ..., 45N, 50N, 55N	29 – 51
130 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	52 – 78
125 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
120 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
115 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151

110 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
105 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 2		
100 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
95 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
90 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	51 – 78
85 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
80 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
75 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
70 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
65 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 3		
60 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
55 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
50 W	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 78
45 W	55S, 50S, 45S, ..., 45N, 50N, 55N	79 – 101
40 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	102 – 128
35 W	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
30 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
25 W	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 4		
20 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
15 W	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
10 W	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
5 W	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
0	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	101 – 128
5 E	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
10 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
15 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 5		
20 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
25 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50

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	IGP location	Transmission order in IGP band mask
30 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
35 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
40 E	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 128
45 E	55S, 50S, 45S, ..., 45N, 50N, 55N	129 – 151
50 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	152 – 178
55 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 6		
60 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
65 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
70 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
75 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
80 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
85 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
90 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N, 85N	151 – 178
95 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 7		
100 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
105 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
110 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
115 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
120 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127
125 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
130 E	85S, 75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	151 – 178
135 E	55S, 50S, 45S, ..., 45N, 50N, 55N	179 – 201
Band 8		
140 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	1 – 27
145 E	55S, 50S, 45S, ..., 45N, 50N, 55N	28 – 50
150 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	51 – 77
155 E	55S, 50S, 45S, ..., 45N, 50N, 55N	78 – 100
160 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	101 – 127

165 E	55S, 50S, 45S, ..., 45N, 50N, 55N	128 – 150
170 E	75S, 65S, 55S, 50S, 45S, ..., 45N, 50N, 55N, 65N, 75N	151 – 177
175 E	55S, 50S, 45S, ..., 45N, 50N, 55N	178 – 200
Band 9		
60 N	180W, 175W, 170W, …, 165E, 170E, 175E	1 – 72
65 N	180W, 170W, 160W, …, 150E, 160E, 170E	73 – 108
70 N	180W, 170W, 160W, …, 150E, 160E, 170E	109 – 144
IGP location		Transmission order in IGP band mask
75 N	180W, 170W, 160W, …, 150E, 160E, 170E	145 – 180
85 N	180W, 150W, 120W, …, 90E, 120E, 150E	181 – 192
Band 10		
60 S	180W, 175W, 170W, …, 165E, 170E, 175E	1 – 72
65 S	180W, 170W, 160W, …, 150E, 160E, 170E	73 – 108
70 S	180W, 170W, 160W, …, 150E, 160E, 170E	109 – 144
75 S	180W, 170W, 160W, …, 150E, 160E, 170E	145 – 180
85 S	170W, 140W, 110W, …, 100E, 130E, 160E	181 – 192

Table B-31.   Validity interval

Data	Bits used	Range of values	Resolution
Validity interval (V)	5	30 s to 960 s	30 s

Table B-32.   Latency time

Data	Bits used	Range of values	Resolution
Latency time (L)	3	0 s to 120 s	30 s

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Table B-33.   Evaluation of GIVEI$_i$

GIVEI$_i$	$\sigma^2_{i,GIVE}$
0	0.0084 m^2
1	0.0333 m^2
2	0.0749 m^2
3	0.1331 m^2
4	0.2079 m^2
5	0.2994 m^2
6	0.4075 m^2
7	0.5322 m^2
8	0.6735 m^2
9	0.8315 m^2
10	1.1974 m^2
11	1.8709 m^2
12	3.3260 m^2
13	20.787 m^2
14	187.0826 m^2
15	"Not Monitored"

3.5.4.7   *Degradation parameters.* Degradation parameters, whenever used, shall be as follows:

Fast correction degradation factor indicator (ai$_i$): an indicator of the fast correction degradation factor (a$_i$) for the ith satellite as described in Table B-34.
  Note.— The ai$_i$ is also used to define the time-out interval for fast corrections, as described in 3.5.8.1.1.
System latency time (t$_{lat}$): the time interval between the origin of the fast correction degradation and the user differential range estimate indicator (UDREI) reference time.
B$_{rrc}$: a parameter that bounds the noise and round-off errors when computing the range rate correction degradation as in 3.5.5.6.2.2.
C$_{ltc\_lsb}$: the maximum round-off error due to the resolution of the orbit and clock information.
C$_{ltc\_v1}$: the velocity error bound on the maximum range rate difference of missed messages due to clock and orbit rate differences.
I$_{ltc\_v1}$: the update interval for long-term corrections if velocity code = 1 (3.5.4.4.1).
C$_{ltc\_v0}$: a parameter that bounds the difference between two consecutive long-term corrections for satellites with a velocity code = 0.
I$_{ltc\_v0}$: the minimum update interval for long-term messages if velocity code = 0 (3.5.4.4.1).

C$_{GEO\_lsb}$: the maximum round-off error due to the resolution of the orbit and clock information.

C$_{GEO\_v}$: the velocity error bound on the maximum range rate difference of missed messages due to clock and orbit rate differences.

I$_{GEO}$: the update interval for GEO ranging function messages.

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Table B-34.   Fast correction degradation factor

Fast correction degradation factor indicator (ai_i)	Fast correction degradation factor (a_i)
0	0.0 mm/s^2
1	0.05 mm/s^2
2	0.09 mm/s^2
3	0.12 mm/s^2
4	0.15 mm/s^2
5	0.20 mm/s^2
6	0.30 mm/s^2
7	0.45 mm/s^2
8	0.60 mm/s^2
9	0.90 mm/s^2
10	1.50 mm/s^2
11	2.10 mm/s^2
12	2.70 mm/s^2
13	3.30 mm/s^2
14	4.60 mm/s^2
15	5.80 mm/s^2

C_{er}: the bound on the residual error associated with using data beyond the precision approach/approach with vertical guidance time-out.

C_{iono_step}: the bound on the difference between successive ionospheric grid delay values.

I_{iono}: the minimum update interval for ionospheric correction messages.

$C_{iono\ ramp}$: the rate of change of the ionospheric corrections.

RSS_{UDRE}: the root-sum-square flag for fast and long-term correction residuals.

Coding: 0 = correction residuals are linearly summed
            1 = correction residuals are root-sum-squared

RSS_{iono}: the root-sum-square flag for ionospheric residuals.

Coding: 0 = correction residuals are linearly summed
            1 = correction residuals are root-sum-squared

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$C_{covariance}$: the term which is used to compensate for quantization effects when using the Type 28 message.

Note 1.— The parameters a_i and t_{lat} are broadcast in Type 7 message. All other parameters are broadcast in Type 10 message.

Note 2.— If message Type 28 is not broadcast, $C_{covariance}$ is not applicable.

3.5.4.8 *Time parameters.* Time parameters, whenever used, shall be as follows:

UTC standard identifier: an indication of the UTC reference source as defined in Table B-35.

GPS time-of-week count: the number of seconds that have passed since the transition from the previous GPS week (similar to the GPS parameter in 3.1.1.2.6.1 but with a 1-second resolution).

Table B-35. UTC standard identifier

UTC standard identifier	UTC standard
0	UTC as operated by the Communications Research Laboratory, Tokyo, Japan
1	UTC as operated by the U.S. National Institute of Standards and Technology
2	UTC as operated by the U.S. Naval Observatory
3	UTC as operated by the International Bureau of Weights and Measures
4	Reserved for UTC as operated by a European laboratory
5 to 6	Spare
7	UTC not provided

GPS week number (week count): see 3.1.1.2.6.2.

GLONASS indicator: a flag indicating if GLONASS time parameters are provided.

Coding: 0 = GLONASS time parameters are not provided
            1 = GLONASS time parameters are provided

GLONASS time offset ($\delta a_{i,GLONASS}$): A parameter that represents the stable part of the offset between the GLONASS time and the SBAS network time.

Note.— If SBAS does not support GLONASS, $\delta a_{i,GLONASS}$ is not applicable.

UTC parameters: A_{1SNT}, A_{0SNT}, t_{0t}, WN_t, Δt_{LS}, WN_{LSF}, DN and Δt_{LSF} are as described in 3.1.1.3.3.6, with the exception that the SBAS parameters relate SNT to UTC time, rather than GPS time.

Note.— All parameters are broadcast in Type 12 message.

3.5.4.9   *Service region parameters.* Service region parameters shall be as follows:

Issue of data, service (IODS): an indication of a change of the service provided in the region.

Number of service messages: the number of different Type 27 SBAS service messages being broadcast. (Value is coded with an offset of 1.)

Service message number: a sequential number identifying the message within the currently broadcast set of Type 27 messages (from 1 to number of service messages, coded with an offset of 1).

Number of regions: the number of service regions for which coordinates are broadcast in the message.

Priority code: an indication of a message precedence if two messages define overlapping regions. The message with a higher value of priority code takes precedence. If priority codes are equal, the message with the lower δUDRE takes precedence.

δUDRE indicator-inside: an indication of regional UDRE degradation factor (δUDRE) applicable at locations inside any region defined in the message, in accordance with Table B-36.

δUDRE indicator-outside: an indication of regional UDRE degradation factor (δUDRE) applicable at locations outside all regions defined in all current Type 27 messages, in accordance with Table B-36.

Coordinate latitude: the latitude of one corner of a region.

Coordinate longitude: the longitude of one corner of a region.

Region shape: an indication of whether a region is a triangle or quadrangle.

Coding: 0 = triangle
           1 = quadrangle

Note 1.— Coordinate 3 has Coordinate 1 latitude and Coordinate 2 longitude. If region is a quadrangle, Coordinate 4 has Coordinate 2 latitude and Coordinate 1 longitude. Region boundary is formed by joining coordinates in the sequence 1-2-3-1 (triangle) or 1-3-2-4-1 (quadrangle). Boundary segments have either constant latitude, constant longitude, or constant slope in degrees of latitude per degree of longitude. The change in latitude or longitude along any boundary segment between two coordinates is less than ±180 degrees.

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Note 2.— All parameters are broadcast in Type 27 message.

Table B-36.   δUDRE indicator evaluation

δUDRE indicator	δUDRE
0	1
1	1.1
2	1.25
3	1.5
4	2
5	3
6	4
7	5
8	6
9	8
10	10
11	20
12	30
13	40
14	50
15	100

3.5.4.10   *Clock-ephemeris covariance matrix parameters*. Clock-ephemeris covariance matrix parameters shall be as follows:

PRN mask number: see 3.5.4.1.

Scale exponent: A term to compute the scale factor used to code the Cholesky factorization elements.

Cholesky factorization elements ($E_{i,j}$): Elements of an upper triangle matrix which compresses the information in the clock and ephemeris covariance matrix. These elements are used to compute the user differential range estimate (UDRE) degradation factor (δUDRE) as a function of user position.

3.5.5   DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

Note.— This section provides definitions of parameters used by the non-aircraft or aircraft elements that are not transmitted. These parameters, necessary to ensure interoperability of SBAS, are used to determine the navigation solution and its integrity (protection levels).

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3.5.5.1 *GEO POSITION AND CLOCK*

3.5.5.1.1   *GEO position estimate*. The estimated position of a GEO at any time t_k is:

$$\begin{bmatrix} \hat{X}_G \\ \hat{Y}_G \\ \hat{Z}_G \end{bmatrix} = \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} + \begin{bmatrix} \dot{X}_G \\ \dot{Y}_G \\ \dot{Z}_G \end{bmatrix}(t-t_{0,GEO}) + \frac{1}{2}\begin{bmatrix} \ddot{X}_G \\ \ddot{Y}_G \\ \ddot{Z}_G \end{bmatrix}(t-t_{0,GEO})^2$$

3.5.5.1.2   *GEO clock correction*. The clock correction for a SBAS GEO satellite i is applied in accordance with the following equation:

$$t = t_G - \Delta t_G$$

where

t	=	SBAS network time;
t_G	=	GEO code phase time at transmission of message; and
Δt_G	=	GEO code phase offset.

3.5.5.1.2.1   GEO code phase offset (Δt_G) at any time t is:

$$\Delta t_G = a_{Gf0} + a_{Gf1}(t - t_{0,GEO})$$

where $(t - t_{0,GEO})$ is corrected for end-of-day crossover.

3.5.5.2 *LONG-TERM CORRECTIONS*

3.5.5.2.1   *GPS clock correction*. The clock correction for a GPS satellite i is applied in accordance with the following equation:

$$t = t_{SV,i} - [(\Delta t_{SV,i})_{L1} + \delta \Delta t_{SV,i}]$$

where

t	=	SBAS network time;
$t_{SV,i}$	=	the GPS satellite time at transmission of message;
$(\Delta t_{SV,i})_{L1}$	=	the satellite PRN code phase offset as defined in 3.1.2.2; and
$\delta \Delta t_{SV,i}$	=	the code phase offset correction.

3.5.5.2.1.1   The code phase offset correction ($\delta \Delta t_{SV,i}$) for a GPS or SBAS satellite i at any time of day t_k is:

$$\delta \Delta t_{SV,i} = \delta a_{i,f0} + \delta a_{i,f1}(t_k - t_{i,LT})$$

3.5.5.2.2   *GLONASS clock correction*. The clock correction for a GLONASS satellite i is applied in accordance with the

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following equation:

$$t = t_{SV,i} + \tau_n(t_b) - \gamma_n(t_b)(t_{SV,i} - t_b) - \delta\Delta t_{SV,i}$$

where

t	$=$	SBAS network
$t_{SV,i}$	$=$	the GLONASS satellite time at transmission of message
$t_b, \tau_n(t_b), \gamma_n(t_b)$	$=$	the GLONASS time parameters as defined in 3.2.2.2
$\delta\Delta t_{SV,i}$	$=$	the code phase offset correction

The code phase offset correction $\delta\Delta t_{SV,i}$ for a GLONASS satellite i is:

$$\delta\Delta t_{SV,i} = \delta a_{i,f0} + \delta a_{i,f1}(t - t_{i,LT}) + \delta a_{i,GLONASS}$$

where $(t - t_{i,LT})$ is corrected for end-of-day crossover. If the velocity code $= 0$, then $\delta a_{i,f1} = 0$.

3.5.5.2.3   *Satellite position correction*. The SBAS-corrected vector for a core satellite constellation(s) or SBAS satellite i at time t is:

$$\begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}_{corrected} = \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} + \begin{bmatrix} \delta x_i \\ \delta y_i \\ \delta z_i \end{bmatrix} + \begin{bmatrix} \delta \dot{x}_i \\ \delta \dot{y}_i \\ \delta \dot{z}_i \end{bmatrix} (t-t_{i,LT})$$

where

$(t - t_{i,LT})$ is corrected for end-of-day crossover; and
$[x_i\ y_i\ z_i]^T$ = the core satellite constellation(s) or SBAS satellite position vector as defined in 3.1.2.3, 3.2.2.3 and 3.5.5.1.1.

If the velocity code $= 0$, then $[\delta \dot{x}_i\ \delta \dot{y}_i\ \delta \dot{z}_i]^T = [0\ \ 0\ \ 0]^T$.

3.5.5.3   *Pseudo-range corrections*. The corrected pseudo-range at time t for satellite i is:

$$PR_{i,corrected} = PR_i + FC_i + RRC_i (t - t_{i,0f}) + IC_i + TC_i$$

where

PR_i	$=$	the measured pseudo-range after application of the satellite clock correction;
FC_i	$=$	the fast correction;
RRC_i	$=$	the range rate correction;
IC_i	$=$	the ionospheric correction;
TC_i	$=$	the tropospheric correction (negative value representing the troposphere delay); and
$t_{i,0f}$	$=$	the time of applicability of the most recent fast corrections, which is the start of the epoch of the SNT second that is coincident with the transmission at the SBAS satellite of the first symbol of the message block.

3.5.5.4 *Range rate corrections (RRC)*. The range rate correction for satellite *i* is:

$$RRC_i = \frac{FC_{i,current} - FC_{i,previous}}{t_{i,0f} - t_{i,0f\_previous}}$$

where

$FC_{i,current}$ = the most recent fast correction;
$FC_{i,previous}$ = a previous fast correction;
$t_{i,0f}$ = the time of applicability of $FC_{i,current}$; and
$t_{i,0f\_previous}$ = the time of applicability of $FC_{i,previous}$.

3.5.5.5 *BROADCAST IONOSPHERIC CORRECTIONS*

3.5.5.5.1 *Location of ionospheric pierce point (IPP)*. The location of an IPP is defined to be the intersection of the line segment from the receiver to the satellite and an ellipsoid with constant height of 350 km above the WGS-84 ellipsoid. This location is defined in WGS-84 latitude (ϕ_{pp}) and longitude (λ_{pp}).

3.5.5.5.2 *Ionospheric corrections*. The ionospheric correction for satellite *i* is:

$$IC_i = - F_{pp} \, \tau_{vpp}$$

where

F_{pp} = obliquity factor $= \left[1 - \left(\frac{R_e \cos\theta_i}{R_e + h_I} \right)^2 \right]^{-\frac{1}{2}}$;

τ_{vpp} = interpolated vertical ionospheric delay estimate (3.5.5.5.3);
R_e = 6 378.1363 km;
θ_i = elevation angle of satellite *i*; and
h_I = 350 km.

Note.— For GLONASS satellites, the ionospheric correction (IC_i) is to be multiplied by the square of the ratio of the GLONASS to the GPS frequencies ($f_{GLONASS}/f_{GPS}$)[2].

3.5.5.5.3 *Interpolated vertical ionospheric delay estimate.* When four points are used for interpolation, the interpolated vertical ionospheric delay estimate at latitude ϕ_{pp} and longitude λ_{pp} is:

$$\tau_{vpp} = \sum_{k=1}^{4} W_k \, \tau_{vk}$$

where

τ_{vk}: the broadcast grid point vertical delay values at the kth corner of the IGP grid, as shown in Figure B-13.

$W_1 = x_{pp} \, y_{pp};$
$W_2 = (1 - x_{pp}) \, y_{pp};$
$W_3 = (1 - x_{pp}) \, (1 - y_{pp});$ and
$W_4 = x_{pp} \, (1 - y_{pp}).$

3.5.5.5.3.1   For IPPs between N85° and S85°:

$$x_{pp} = \frac{\lambda_{pp} - \lambda_1}{\lambda_2 - \lambda_1}$$

$$y_{pp} = \frac{\phi_{pp} - \phi_1}{\phi_2 - \phi_1}$$

where

λ_1 = longitude of IGPs west of IPP;
λ_2 = longitude of IGPs east of IPP;
ϕ_1 = latitude of IGPs south of IPP; and
ϕ_2 = latitude of IGPs north of IPP.

Note.— If λ_1 and λ_2 cross 180 degrees of longitude, the calculation of x_{pp} must account for the discontinuity in longitude values.

3.5.5.5.3.2   For IPPs north of N85° or south of S85°:

$$y_{pp} = \frac{|\phi_{pp}| - 85°}{10°}$$

$$x_{pp} = \frac{\lambda_{pp} - \lambda_3}{90°} \times (1 - 2 y_{pp}) + y_{pp}$$

where

λ_1 = longitude of the second IGP to the east of the IPP;

λ_2 = longitude of the second IGP to the west of the IPP;

λ_3 = longitude of the closest IGP to the west of the IPP; and

λ_4 = longitude of the closest IGP to the east of the IPP.

When three points are used for interpolation, the interpolated vertical ionospheric delay estimated is:

3.5.5.5.3.3   For points between S75° and N75°:

$$\tau_{vpp} = \sum_{k=1}^{3} W_k \, \tau_{vk}$$

where

$W_1 = y_{pp}$;

$W_2 = 1 - x_{pp} - y_{pp}$; and

$W_3 = x_{pp}$.

3.5.5.5.3.4 x_{pp} and y_{pp} are calculated as for four-point interpolation, except that λ_1 and ϕ_1 are always the longitude and latitude of IGP2, and λ_2 and ϕ_2 are the other longitude and latitude. IGP2 is always the vertex opposite the hypotenuse of the triangle defined by the three points, IGP1 has the same longitude as IGP2, and IGP3 has the same latitude as IGP2 (an example is shown in Figure B-14).

3.5.5.5.3.5   For points north of N75° and south of S75°, three-point interpolation is not supported.

3.5.5.5.4   *Selection of ionospheric grid points (IGPs).* The protocol for the selection of IGPs is:

a)   For an IPP between N60° and S60°:

   1)   if four IGPs that define a 5-degree-by-5-degree cell around the IPP are set to "1" in the IGP mask, they are selected; else,

   2)   if any three IGPs that define a 5-degree-by-5-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

   3)   if any four IGPs that define a 10-degree-by-10-degree cell around the IPP are set to "1" in the IGP mask, they are selected; else,

   4)   if any three IGPs that define a 10-degree-by-10-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

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    5)   an ionospheric correction is not available.

b)   For an IPP between N60° and N75° or between S60° and S75°:

    1)   if four IGPs that define a 5-degree-latitude-by-10-degree longitude cell around the IPP are set to "1" in the IGP mask, they are selected; else,

    2)   if any three IGPs that define a 5-degree-latitude-by-10-degree longitude triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

    3)   if any four IGPs that define a 10-degree-by-10-degree cell around the IPP are set to "1" in the IGP mask, they are selected; else,

    4)   if any three IGPs that define a 10-degree-by-10-degree triangle that circumscribes the IPP are set to "1" in the IGP mask, they are selected; else,

    5)   an ionospheric correction is not available.

c)   For an IPP between N75° and N85° or between S75° and S85°:

    1)   if the two nearest IGPs at 75° and the two nearest IGPs at 85° (separated by 30° longitude if Band 9 or 10 is used, separated by 90° otherwise) are set to "1" in the IGP mask, a 10-degree-by-10-degree cell is created by linearly interpolating between the IGPs at 85° to obtain virtual IGPs at longitudes equal to the longitudes of the IGPs at 75°; else,

    2)   an ionospheric correction is not available.

d)   For an IPP north of N85°:

    1)   if the four IGPs at N85° latitude and longitudes of W180°, W90°, 0° and E90° are set to "1" in the IGP mask, they are selected; else,

    2)   an ionospheric correction is not available.

e)   For an IPP south of S85°:

    1)   if the four IGPs at S85° latitude and longitudes of W140°, W50°, E40° and E130° are set to "1" in the IGP mask, they are selected; else,

    2)   an ionospheric correction is not available.

Note.— This selection is based only on the information provided in the mask, without regard to whether the selected IGPs are monitored, "Not Monitored", or "Do Not Use". If any of the selected IGPs is identified as "Do Not Use", an ionospheric correction is not available. If four IGPs are selected, and one of the four is identified as "Not Monitored", then three-point interpolation is used if the IPP is within the triangular region covered by the three corrections that are provided.

3.5.5.6   *Protection levels.* The horizontal protection level (HPL) and the vertical protection level (VPL) are:

$$HPL_{SBAS} = \begin{cases} K_{H,NPA} \times d_{major} & \text{for en-route through non-precision approach (NPA) modes} \\ K_{H,PA} \times d_{major} & \text{for precision approach (PA) and approach with vertical guidance (APV) modes} \end{cases}$$

$$VPL_{SBAS} = K_{V,PA} \times d_V$$

where

$$d_V^2 = \sum_{i=1}^{N} s_{v,i}^2 \sigma_i^2 = \text{variance of model distribution that overbounds the true error distribution in the vertical axis;}$$

$$d_{mayor} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}} \ ;$$

where

$$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2 \qquad \text{– variance of model distribution that overbounds the true error distribution in the x axis;}$$

$$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2 \qquad \text{– variance of model distribution that overbounds the true error distribution in the y axis;}$$

$$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2 \qquad \text{– covariance of model distribution in the x and y axis;}$$

where

$s_{x,i}$ – the partial derivative of position error in the x-direction with respect to pseudo-range error on the ith satellite;

$s_{y,i}$ – the partial derivative of position error in the y-direction with respect to pseudo-range error on the ith satellite;

$s_{V,i}$ – the partial derivative of position error in the vertical direction with respect to pseudo-range error on the ith satellite; and

$$\sigma_i^2 \ - \ \sigma_{i,flt}^2 + \sigma_{i,UIRE}^2 + \sigma_{i,air}^2 + \sigma_{i,tropo}^2.$$

The variances ($\sigma_{i,flt}^2$ and $\sigma_{i,UIRE}^2$) are defined in 3.5.5.6.2 and 3.5.5.6.3.1. The parameters ($\sigma_{i,air}^2$ and $\sigma_{i,tropo}^2$) are determined by the aircraft element (3.5.8.4.2 and 3.5.8.4.3).

The x and y axes are defined to be in the local horizontal plane, and the v axis represents local vertical.

For a general least-squares position solution, the projection matrix S is:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \cdots & S_{x,N} \\ S_{y,1} & S_{y,2} & \cdots & S_{y,N} \\ S_{v,1} & S_{v,2} & \cdots & S_{v,N} \\ S_{t,1} & S_{t,2} & \cdots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

where

G_i – [–cos El_i cos Az_i –cos El_i sin Az_i –sin El_i 1] – i^{th} row of G;

$$W^{-1} = \begin{bmatrix} w_1 & 0 & \cdots & 0 \\ 0 & w_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & & \cdots & w_i \end{bmatrix};$$

El_i – the elevation angle of the ith ranging source (in degrees);
Az_i – the azimuth of the ith ranging source taken counter-clockwise from the x axis in degrees; and
w_i – the inverse weight associated with satellite $i – \sigma_i^2$.

Note 1.— To improve readability, the subscript i *was omitted from the protection matrix's equation.*

Note 2.— For an unweighted least-squares solution, the weighting matrix is an identity matrix (w_i = 1).

3.5.5.6.1   *Definition of K values.* The K values are:

$$K_{H,NPA} = 6.18;$$

$$K_{H,PA} = 6.0; \text{ and}$$

$$K_{V,PA} = 5.33.$$

3.5.5.6.2   *Definition of fast and long-term correction error model.* If fast corrections and long-term correction/GEO ranging parameters are applied, and degradation parameters are applied:

$$\sigma_{i,flt}^2 = \begin{cases} [(\sigma_{i,UDRE})(\delta_{UDRE}) + \varepsilon_{fc} + \varepsilon_{rrc} + \varepsilon_{ltc} + \varepsilon_{er}]^2, & \text{si } RSS_{UDRE} - 0 \text{ (Message Type 10)} \\ [(\sigma_{i,UDRE})(\delta_{UDRE})]^2 + \varepsilon_{fc}^2 + \varepsilon_{rrc}^2 + \varepsilon_{ltc}^2 + \varepsilon_{er}^2, & \text{si } RSS_{UDRE} - 1 \text{ (Message Type 10)} \end{cases}$$

where

if using message Type 27, δ_{UDRE} is a region-specific term as defined in section 3.5.4.9,
if using message Type 28, δ_{UDRE} is a satellite-specific term as defined in section 3.5.5.6.2.5,
if using neither message, δ_{UDRE} = 1.

If fast corrections and long-term corrections/GEO ranging parameters are applied, but degradation parameters are not applied:

$$\sigma^2_{i,flt} = [(\sigma_{i,UDRE}) (\delta_{UDRE}) + 8m]^2$$

3.5.5.6.2.1 *Fast correction degradation.* The degradation parameter for fast correction data is:

$$\varepsilon_{fc} = \frac{a(t-t_u+t_{lat})^2}{2}$$

where

t   =   the current time;

t_u =   (UDREI$_i$ reference time): if IODF$_j \neq 3$, the start time of the SNT 1-second epoch that is coincident with the start of the transmission of the message block that contains the most recent UDREI$_i$ data (Type 2 to 6, or Type 24 messages) that matches the IODF$_j$ of the fast correction being used. If IODF$_j$ = 3, the start time of the epoch of the SNT 1-second epoch that is coincident with the start of transmission of the message that contains the fast correction for the ith satellite; and

t_{lat} =   (as defined in 3.5.4.7).

Note.— For UDREs broadcast in Type 2 to 5, and Type 24 messages, t_u equals the time of applicability of the fast corrections since they are in the same message. For UDREs broadcast in Type 6 message and if the IODF = 3, t_u also equals the time of applicability of the fast corrections (t_{0f}). For UDREs broadcast in Type 6 message and IODF $\neq$ 3, t_u is defined to be the time of transmission of the first bit of Type 6 message at the GEO.

3.5.5.6.2.2 *Range rate correction degradation*

3.5.5.6.2.2.1 If the RRC = 0, then ε_{rrc} = 0.

3.5.5.6.2.2.2 If the RRC $\neq$ 0 and IODF $\neq$ 3, the degradation parameter for fast correction data is:

$$\varepsilon_{rrc} = \begin{cases} 0, & si \ (IODF_{actual} - IODF_{anterior})MOD3 = 1 \\ \left(\dfrac{aI_{fc}}{4} + \dfrac{B_{rrc}}{\Delta t}\right)(t - t_{0f}), & si \ (IODF_{actual} - IODF_{anterior})MOD3 \neq 1 \end{cases}$$

3.5.5.6.2.2.3 If RRC $\neq$ 0 and IODF = 3, the degradation parameter for range rate data is:

$$\varepsilon_{rrc} = \begin{cases} 0, & si \ \left|\Delta t - \dfrac{I_{fc}}{2}\right| = 0 \\ \left(\dfrac{a\left|\Delta t - \dfrac{I_{fc}}{2}\right|}{2} + \dfrac{B_{rrc}}{\Delta t}\right)(t - t_{0f}), & si \ \left|\Delta t - \dfrac{I_{fc}}{2}\right| \neq 0 \end{cases}$$

where

t	—	the current time;
$IODF_{current}$	=	IODF associated with most recent fast correction;
$IODF_{previous}$	=	IODF associated with previous fast correction;
Δt	=	$t_{1,0f} - t_{1,0f\_previous}$; and
I_{fc}	=	the user time-out interval for fast corrections.

3.5.5.6.2.3   *Long-term correction degradation*

3.5.5.6.2.3.1   *Core satellite constellation(s)*

3.5.5.6.2.3.1.1   For velocity code = 1, the degradation parameter for long-term corrections of satellite *i* is:

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{i,LT} < t < t_{i,LT} + I_{ltc\_v1} \\ C_{ltc\_lsb} + C_{ltc\_v1} \max\left(0, t_{i,LT} - t, t - t_{i,LT} - I_{ltc\_v1}\right), & \text{otherwise} \end{cases}$$

3.5.5.6.2.3.1.2   For velocity code = 0, the degradation parameter for long-term corrections is:

$$\varepsilon_{ltc} = C_{ltc\_v0} \left[\frac{t - t_{ltc}}{I_{lt-v0}}\right]$$

where

t   —   the current time;
t_{ltc} =   the time of transmission of the first bit of the long-term correction message at the GEO; and
[*x*]   =   the greatest integer less than *x*.

3.5.5.6.2.3.2   *GEO satellites.* The degradation parameter for long-term corrections is:

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{0,GEO} < t < t_{0,GEO} + I_{GEO} \\ C_{geo\_lsb} + C_{geo\_v} \max\left(0, t_{0,GEO} - t, t - t_{0,GEO} - I_{geo}\right), & \text{otherwise} \end{cases}$$

where t = the current time.

   Note.— *When long-term corrections are applied to a GEO satellite, the long-term correction degradation is applied and the GEO navigation message degradation is not applied.*

3.5.5.6.2.4   *Degradation for en-route through non-precision approach*

$$\varepsilon_{er} = \begin{cases} 0, & \text{if neither fast nor long-term corrections have timed out for precision approach/approach with vertical guidance} \\ C_{er}, & \text{if fast or long-term corrections have timed out for precision approach/approach with vertical guidance} \end{cases}$$

3.5.5.6.2.5   *UDRE degradation factor calculated with message Type 28 data.* The δUDRE is:

$$\delta_{UDRE} = \sqrt{I^T \cdot C \cdot I} + \varepsilon_c$$

where

$$I \quad = \quad \begin{bmatrix} i_x \\ i_y \\ i_z \\ 1 \end{bmatrix},$$

$$\begin{bmatrix} i_x \\ i_y \\ i_z \end{bmatrix} = \text{the unit vector from the user to the satellite in the WGS-84 ECEF coordinate frame}$$

$$C \quad = \quad R^T \cdot R$$

$$\varepsilon_C \quad = \quad C_{covariance} \cdot SF$$

$$SF \quad = \quad 2^{scale\ exponent-5}$$

$$R \quad = \quad E \cdot SF$$

$$E \quad = \quad \begin{bmatrix} E_{1,1} & E_{1,2} & E_{1,3} & E_{1,4} \\ 0 & E_{2,2} & E_{2,3} & E_{2,4} \\ 0 & 0 & E_{3,3} & E_{3,4} \\ 0 & 0 & 0 & E_{4,4} \end{bmatrix}$$

3.5.5.6.3   *Definition of ionospheric correction error model*

3.5.5.6.3.1   *Broadcast ionospheric corrections.* If SBAS-based ionospheric corrections are applied, σ^2_{UIRE} is:

$$\sigma^2_{UIRE} = F^2_{pp} \times \sigma^2_{UIVE}$$

where

F_{pp} =   (as defined in 3.5.5.5.2);

$$\sigma^2_{UIVE} = \sum_{n=1}^{4} W_n \cdot \sigma^2_{n,ionogrid} \text{ o } \sigma^2_{UIVE} = \sum_{n=1}^{3} W_n \cdot \sigma^2_{n,ionogrid}$$

using the same ionospheric pierce point weights (W_n) and grid points selected for the ionospheric correction (3.5.5.5). For each grid point:

`

$$\sigma^2_{i,ionogrid} = \begin{cases} (\sigma_{GIVE} + \varepsilon_{iono})^2, & \text{si } RSS_{iono} = 0 \text{ (Type 10 message)} \\ \sigma^2_{GIVE} + \varepsilon^2_{iono}, & \text{si } RSS_{iono} = 1 \text{ (Type 10 message)} \end{cases}$$

where

$$\varepsilon_{iono} = C_{iono\_step}\left[\frac{t-t_{iono}}{I_{iono}}\right] + C_{iono\_ramp}(t - t_{iono});$$

t — the current time;

t_{iono} = the time of transmission of the first bit of the ionospheric correction message at the GEO; and

$[x]$ = the greatest integer less than x.

Note.— For GLONASS satellites, both σ_{GIVE} and σ_{IONO} parameters are to be multiplied by the square of the ratio of the GLONASS to the GPS frequencies $(f_{GLONASS}/f_{GPS})^2$.

3.5.5.6.3.2 *Ionospheric corrections.* If SBAS-based ionospheric corrections are not applied, σ^2_{UIRE} is:

$$\sigma^2_{UIRE} = MAX\left\{\left(\frac{T_{iono}}{5}\right)^2, \left(F_{pp}\cdot\tau_{vert}\right)^2\right\}$$

where

T_{iono} = the ionospheric delay estimated by the chosen model (GPS correction or other model);

F_{pp} = (as defined in 3.5.5.5.2);

$$\tau_{vert} = \begin{cases} 9\text{ m}, & 0 \le |\phi_{pp}| \le 20 \\ 4.5\text{ m}, & 20 < |\phi_{pp}| \le 55; y \\ 6\text{ m}, & 55 < |\phi_{pp}| \end{cases}$$

ϕ_{pp} = latitude of the ionospheric pierce point.

3.5.5.6.3.3 *GLONASS clock.* The degradation parameter for GLONASS clock correction is:

$$\varepsilon_{GLONASS\_CLOCK} = C_{GLONASS\_CLOCK} \bullet [t - t_{GLONASS\_CLOCK}]$$

where

t = the current time

$t_{GLONASS\_CLOCK}$ = the time of transmission of the first bit of the timing message (MT12) at the GEO

$[sc]$ = the greatest integer less than sc.

Note 1.— For non-GLONASS satellites $\varepsilon_{GLONASS\_CLOCK} = 0$.

Note 2.— $C_{GLONASS\_CLOCK} = 0.00833$ cm/s.

3.5.6   MESSAGE TABLES

Each SBAS message shall be coded in accordance with the corresponding message format defined in Tables B-37 through B-53. All signed parameters in these tables shall be represented in two's complement, with the sign bit occupying the MSB.

Note.— The range for the signed parameters is smaller than indicated, as the maximum positive value is constrained to

be one value less (the indicated value minus the resolution).

Table B-37.   Type 0 "Do Not Use" message

Data content	Bits used	Range of values	Resolution
Spare	212	—	—

Table B-38.   Type 1 PRN mask message

Data content	Bits used	Range of values	Resolution
For each of 210 PRN code numbers			
Mask value	1	0 or 1	1
IODP	2	0 to 3	1

Note.— All parameters are defined in 3.5.4.1.

Table B-39.   Types 2 to 5 fast correction message

Data content	Bits used	Range of values	Resolution
$IODF_j$	2	0 to 3	1
IODP	2	0 to 3	1
For 13 slots			
Fast correction (FC_i)	12	±256.000 m	0.125 m
For 13 slots			
$UDREI_i$	4	(see Table B-29)	(see Table B-29)

Notes.—
1. The parameters $IODF_j$ and FC_i are defined in 3.5.4.4.2.
2. The parameter IODP is defined in 3.5.4.1.
3. The parameter $UDREI_i$ is defined in 3.5.4.5.

Table B-40.   Type 6 integrity message

Data content	Bits used	Range of values	Resolution
$IODF_2$	2	0 to 3	1
$IODF_3$	2	0 to 3	1
$IODF_4$	2	0 to 3	1
$IODF_5$	2	0 to 3	1
For 51 satellites (ordered by PRN mask number)			
$\quad UDREI_i$	4	(see Table B-29)	(see Table B-29)

Notes.—
1. The parameters $IODF_j$ are defined in 3.5.4.4.2.
2. The parameter $UDREI_i$ is defined in 3.5.4.5.

Table B-41.   Type 7 fast correction degradation factor message

Data content	Bits used	Range of values	Resolution
System latency (t_{lat})	4	0 to 15 s	1 s
IODP	2	0 to 3	1
Spare	2	—	—
For 51 satellites (ordered by PRN mask number)			
$\quad$ Degradation factor indic tor (ai_i)	4	(see Table B-34)	(see Table B-34)

Notes.—
1. The parameters t_{lat} and ai_i are defined in 3.5.4.7.
2. The parameter IODP is defined in 3.5.4.1.

Table B-42.   Type 9 ranging function message

Data content	Bits used	Range of values	Resolution
Reserved	8	—	—
$t_{0,GEO}$	13	0 to 86 384 s	16 s
URA	4	(see Table B-26)	(see Table B-26)
X_G	30	±42 949 673 m	0.08 m
Y_G	30	±42 949 673 m	0.08 m
Z_G	25	±6 710 886.4 m	0.4 m
X_G	17	±40.96 m/s	0.000625 m/s
Y_G	17	±40.96 m/s	0.000625 m/s
Z_G	18	±524.288 m/s	0.004 m/s
X_G	10	±0.0064 m/s^2	0.0000125 m/s^2
Y_G	10	±0.0064 m/s^2	0.0000125 m/s^2
Z_G	10	±0.032 m/s^2	0.0000625 m/s^2
a_{Gf0}	12	±0.9537 × 10^{-6} s	2^{-31} s
a_{Gf1}	8	±1.1642 × 10^{-10} s/s	2^{-40} s/s

Note.— All parameters are defined in 3.5.4.2.

X_G

Table B-43.   Type 10 degradation parameter message

Data content	Bits used	Range of values	Resolution
B_{rrc}	10	0 to 2.046 m	0.002 m
$C_{ltc\ lsb}$	10	0 to 2.046 m	0.002 m
$C_{ltc\ v1}$	10	0 to 0.05115 m/s	0.00005 m/s
$I_{ltc\ v1}$	9	0 to 511 s	1 s
$C_{ltc\ v0}$	10	0 to 2.046 m	0.002 m
$I_{ltc\ v0}$	9	0 to 511 s	1 s
$C_{geo\ lsb}$	10	0 to 0.5115 m	0.0005 m
$C_{geo\ v}$	10	0 to 0.05115 m/s	0.00005 m/s
I_{geo}	9	0 to 511 s	1 s
C_{er}	6	0 to 31.5 m	0.5 m
$C_{iono\ step}$	10	0 to 1.023 m	0.001 m
I_{iono}	9	0 to 511 s	1 s
$C_{iono\ ramp}$	10	0 to 0.005115 m/s	0.000005 m/s

RSS_{UDRE}	1	0 or 1	1
RSS_{iono}	1	0 or 1	1
$C_{covariance}$	7	0 to 12.7	0.1
Spare	81	—	—

Note.— All parameters are defined in 3.5.4.7.

Table B-44.   Type 12 SBAS network time/UTC message

Data content	Bits used	Range of values	Resolution
A_{1SNT}	24	$\pm 7.45 \times 10^{-9}$ s/s	2^{-50} s/s
A_{0SNT}	32	± 1 s	2^{-30} s
t_{0t}	8	0 to 602 112 s	4 096 s
WN_t	8	0 to 255 weeks	1 week
Δt_{LS}	8	± 128 s	1 s
WN_{LSF}	8	0 to 255 weeks	1 week
DN	8	1 to 7 days	1 day
Δt_{LSF}	8	± 128 s	1 s
UTC standard identifier	3	(see Table B-35)	(see Table B-35)
GPS time-of-week (TOW)	20	0 to 604 799 s	1 s
GPS week number (WN)	10	0 to 1 023 weeks	1 week
GLONASS indicator	1	0 or 1	1
$\delta a_{i, GLONASS}$ (Note 2)	24	$\pm 2.0 \cdot 10^{-8}$ s	$2.0 \cdot 10^{-31}$ s
Spare	50	—	—

Notes.—
1.   All parameters are defined in 3.5.4.8.
2.   Applies only if SBAS sends GLONASS timing information in message Type 12 (see 3.5.7.4.4, Timing data).

Table B-45.   Type 17 GEO almanac message

Data content	Bits used	Range of values	Resolution
For each of 3 satellites			
Reserved	2	0	—
PRN code number	8	0 to 210	1
Health and status	8	—	—
$X_{G,A}$	15	±42 598 400 m	2 600 m
$Y_{G,A}$	15	±42 598 400 m	2 600 m
$Z_{G,A}$	9	±6 656 000 m	26 000 m
$\dot{X}_{G,A}$	3	±40 m/s	10 m/s
$\dot{Y}_{G,A}$	3	±40 m/s	10 m/s
$\dot{Z}_{G,A}$	4	±480 m/s	60 m/s
$t_{almanac}$ (applies to all three satellites)	11	0 to 86 336 s	64 s

Note.— All parameters are defined in 3.5.4.3.

Table B-46.   Type 18 IGP mask message

Data content	Bits used	Range of values	Resolution
Number of IGP bands	4	0 to 11	1
IGP band identifier	4	0 to 10	1
Issue of data — ionosphere ($IODI_k$)	2	0 to 3	1
For 201 IGPs			
IGP mask value	1	0 or 1	1
Spare	1	—	—

Note.— All parameters are defined in 3.5.4.6.

Table B-47.   Type 24 mixed fast/long-term satellite error correction message

Data content	Bits used	Range of values	Resolution
For 6 slots			
Fast correction (FC_i)	12	±256.000 m	0.125 m
For 6 slots			
$UDREI_i$	4	(see Table B-31)	(see Table B-31)

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IODP	2	0 to 3	1
Fast correction type identifier	2	0 to 3	1
$IODF_j$	2	0 to 3	1
Spare	4	—	—
Type 25 half-message	106	—	—

Notes.—
1. *The parameters fast correction type identifier, $IODF_j$, and FC_i are defined in 3.5.4.4.2.*
2. *The parameter IODP is defined in 3.5.4.1.*
3. *The parameter $UDREI_i$ is defined in 3.5.4.5.*
4. *The long-term satellite error correction message is divided into two half-messages. The half message for a velocity code = 0 is defined in Table B-48. The half message for a velocity code = 1 is defined in Table B-49.*

**Table B-48. Type 25 long-term satellite error correction half message
(VELOCITY CODE = 0)**

Data content	Bits used	Range of values	Resolution
Velocity Code = 0	1	0	1
For 2 Satellites			
PRN mask number	6	0 to 51	1
Issue of data (IOD_i)	8	0 to 255	1
δx_i	9	±32 m	0.125 m
δy_i	9	±32 m	0.125 m
δz_i	9	±32 m	0.125 m
$\delta a_{i,f0}$	10	$\pm 2^{-22}$ s	2^{-31} s
IODP	2	0 to 3	1
Spare	1	—	—

Notes.—
1. The parameters PRN mask number and IODP are defined in 3.5.4.1.
2. All other parameters are defined in 3.5.4.4.1.

**Table B-49. Type 25 long-term satellite error correction half message
(VELOCITY CODE = 1)**

Data content	Bits used	Range of values	Resolution
For 1 Satellite			
Velocity Code = 1	1	1	1
PRN mask number	6	0 to 51	1
Issue of data (IOD_i)	8	0 to 255	1
δx_i	11	±128 m	0.125 m
δy_i	11	±128 m	0.125 m
δz_i	11	±128 m	0.125 m
$\delta a_{i,f0}$	11	$\pm 2^{-21}$ s	2^{-31} s
$\delta \dot{x}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta \dot{y}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta \dot{z}_i$	8	±0.0625 m/s	2^{-11} m/s
$\delta a_{i,f1}$	8	$\pm 2^{-32}$ s/s	2^{-39} s/s
Time-of-applicability ($t_{i,LT}$)	13	0 to 86 384 s	16 s
IODP	2	0 to 3	1

Notes.—
1. The parameters PRN mask number and IODP are defined in 3.5.4.1.
2. All other parameters are defined in 3.5.4.4.1.

Table B-50.   Type 26 ionospheric delay message

Data content	Bits used	Range of values	Resolution
IGP band identifier	4	0 to 10	1
IGP block identifier	4	0 to 13	1
For each of 15 grid points			
IGP vertical delay estimate	9	0 to 63.875 m	0.125 m
Grid ionospheric vertical error indicator ($GIVEI_i$)	4	(see Table B-33)	(see Table B-33)
$IODI_k$	2	0 to 3	1
Spare	7	—	—

Note.— All parameters are defined in 3.5.4.6.

Table B-51.   Type 27 SBAS service message

Data content	Bits used	Range of values	Resolution
Issue of data, service (IODS)	3	0 to 7	1
Number of service messages	3	1 to 8	1
Service message number	3	1 to 8	1
Number of regions	3	0 to 5	1

Priority code	2	0 to 3	1
δUDRE indicator-inside	4	0 to 15	1
δUDRE indicator-outside	4	0 to 15	1
For each of 5 regions			
Coordinate 1 latitude	8	±90°	1°
Coordinate 1 longitude	9	±180°	1°
Coordinate 2 latitude	8	±90°	1°
Coordinate 2 longitude	9	±180°	1°
Region shape	1	—	—
Spare	15	—	—

Note.— All parameters are defined in 3.5.4.9.

Table B-52. Type 63 null message

Data content	Bits used	Range of values	Resolution
Spare	212	—	—

Table B-53. Type 28 clock-ephemeris covariance matrix

Data content	Bits used	Range of values	Resolution
IODP	2	0 to 3	1
For two satellites			
PRN mask number	6	0 to 51	1
Scale exponent	3	0 to 7	1
$E_{1,1}$	9	0 to 511	1
$E_{2,2}$	9	0 to 511	1
$E_{3,3}$	9	0 to 511	1
$E_{4,4}$	9	0 to 511	1
$E_{1,2}$	10	±512	1
$E_{1,3}$	10	±512	1
$E_{1,4}$	10	±512	1
$E_{2,3}$	10	±512	1
$E_{2,4}$	10	±512	1
$E_{3,4}$	10	±512	1

Notes.—
1. The parameters PRN mask number and IODP are defined in 3.5.4.1.
2. All other parameters are defined in 3.5.4.10.

3.5.7   NON-AIRCRAFT ELEMENTS

Note 1.— Depending on the level of service offered by a particular SBAS, different functions can be implemented as described in Chapter 3, 3.7.3.4.2.

Note 2.— The parameters that are referred to in this section are defined in 3.5.4.

3.5.7.1   *GENERAL*

3.5.7.1.1   *Required data and broadcast intervals*. SBAS shall broadcast the data required for the supported functions as shown in Table B-54. If the SBAS broadcasts data that are not required for a particular function, the requirements for that data supporting other functions shall apply. The maximum interval between broadcasts for all data of each data type provided shall be as defined in Table B-54.

3.5.7.1.2   *SBAS radio frequency monitoring*. The SBAS shall monitor the SBAS satellite parameters shown in Table B-55 and take the indicated action.

Note.— SBAS may broadcast null messages (Type 63 messages) in each time slot for which no other data are broadcast.

3.5.7.1.3   *"Do Not Use"*. SBAS shall broadcast a "Do Not Use" message (Type 0 message) when necessary to inform users not to use the SBAS satellite ranging function and its broadcast data.

3.5.7.1.4   The Doppler shift in the GEO satellite signal seen at any fixed location within the GEO footprint for any GEO shall not exceed ±450 Hz.

Note .— This maximum Doppler shift corresponds approximately to the maximum GEO satellite orbit inclination that can be supported by the coding ranges for Type 9 and Type 17 messages.

3.5.7.1.5 *Geostationary orbit (GEO) ranging function parameters*. Each SBAS satellite shall broadcast geostationary orbit (GEO) ranging function parameters (defined in 3.5.4.2).

Note — It is necessary to broadcast geostationary orbit ranging function parameters even when a ranging function is not provided, so that airborne receivers may implement a positive identification of the broadcasting SBAS satellite. When ranging is not provided, the accuracy of the Type 17 data (and Type 9 data) only needs to support the acquisition of the satellite.

3.5.7.1.5.1   The error in the Doppler shift of a GEO satellite derived from any Type 9 message that has not timed out, with respect to the true GEO Doppler shift seen at any fixed location within the GEO footprint, shall not exceed ±210 Hz.

3.5.7.1.6   *Almanac data*. Each SBAS satellite shall broadcast almanac data (defined in 3.5.4.3) for all SBAS satellites of the same service provider.

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3.5.7.1.6.1   The error in the estimated position of the satellite derived from any Type 17 message broadcast within the previous 15 minutes, with respect to the true satellite position, shall not exceed 3,000 km.

3.5.7.1.6.2   The separation distance between the estimated position of the satellite derived from any Type 17 message broadcast within the previous 15 minutes and the position of the satellite derived from the GEO ranging parameters in any Type 9 message that has not timed out shall not exceed 200 km.

3.5.7.1.6.3   The error in the Doppler shift of a GEO satellite derived from any Type 17 message broadcast within the previous 15 minutes, with respect to the true GEO Doppler shift seen at any fixed location within the GEO footprint, shall not exceed ±210 Hz.

3.5.7.1.6.4   SBAS shall not broadcast almanac data for any SBAS satellite from a different service provider for which the position estimated from the almanac data broadcast within the previous 15 minutes would be within 200 km of the position of any of its own GEOs as derived from the GEO ranging parameters from any Type 9 message that has not timed out.

3.5.7.1.6.5   Where the estimated position of a GEO satellite providing a ranging function, derived from the Type 17 message broadcast within the previous 15 minutes, is within 200 km of the position of another GEO satellite of the same service provider, derived from a Type 9 message for this GEO that has not timed out, the GEO UDRE value shall be set sufficiently large to account for the possibility that a user could misidentify the PRN of the GEO providing the ranging function.

3.5.7.1.6.6   The health and status parameter shall indicate the satellite status and the service provider identifier, as defined in 3.5.4.3.

3.5.7.1.6.7   Unused almanac slots in Type 17 messages shall be coded with a PRN code number of "0".

3.5.7.1.6.8   The service provider shall ensure the correctness of the service provider ID broadcast in any almanac.

3.5.7.2   *Ranging function*. If an SBAS provides a ranging function, it shall comply with the requirements contained in this section in addition to the requirements of 3.5.7.1.

3.5.7.2.1   *Performance requirements*

   Note.— See Chapter 3, 3.7.3.4.2.1.

3.5.7.2.2   *Ranging function data*. SBAS shall broadcast ranging function data such that the SBAS satellite position error projected on the line-of-sight to any user in the satellite footprint is less than 256 metres. Each SBAS satellite shall broadcast a URA representing an estimate of the standard deviation of the ranging errors referenced to SNT.

3.5.7.3   *GNSS satellite status function*. If an SBAS provides a satellite status function, it shall also comply with the requirements contained in this section.

Note — An SBAS may be able to provide integrity on some GPS satellites that are designated either marginal or unhealthy.

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3.5.7.3.1 *Performance of satellite status functions*. Given any valid combination of active data, the probability of a horizontal error exceeding the HPL_{SBAS} (as defined in 3.5.5.6) for longer than 8 consecutive seconds shall be less than 10^{-7} in any hour, assuming a user with zero latency.

Note.— Active data is defined to be data that have not timed out per 3.5.8.1.1. This requirement includes core satellite constellation(s) and SBAS failures.

3.5.7.3.2   *PRN mask and Issue of data — PRN (IODP)*. SBAS shall broadcast a PRN mask and IODP (Type 1 message). The PRN mask values shall indicate whether or not data are being provided for each GNSS satellite. The IODP shall change when there is a change in the PRN mask. The change of IODP in Type 1 messages shall occur before the IODP changes in any other message. The IODP in Type 2 to 5, 7, 24 and 25 messages shall equal the IODP broadcast in the PRN mask message (Type 1 message) used to designate the satellites for which data are provided in that message.

Table B-54.   Data broadcast intervals and supported functions

Data type	Maximum broadcast interval	Ranging	GNSS satellite status	Basic differential correction	Precise differential correction	Associated message types
Clock-Ephemeris covariance matrix	120 s					28
SBAS in test mode	6 s					0
PRN mask	120 s		R	R	R	1
UDREI	6 s		R*	R	R	2 to 6, 24
Fast corrections	$I_{fc}/2$ (see Note 4)		R*	R	R	2 to 5, 24
Long-term corrections	120 s		R*	R	R	24, 25
GEO ranging function data	120 s	R	R	R	R	9
Fast correction degradation	120 s		R*	R	R	7
Degradation parameters	120 s				R	10
Ionospheric grid mask	300 s				R	18
Ionospheric corrections, GIVEI	300 s				R	26
Timing data	300 s	R (see Note 3)	R (see Note 3)	R (see Note 3)	R (see Note 3)	12
Almanac data	300 s	R	R	R	R	17

Service level   300 s   27

Notes.—
1. "R" indicates that the data must be broadcast to support the function.
2. "R" indicates special coding as described in 3.5.7.3.3.*
3. Type 12 messages are only required if data are provided for GLONASS satellites.
4. I_{fc} refers to the PA/APV time-out interval for fast corrections, as defined in Table B-57.

Table B-55.   SBAS radio frequency monitoring

Parameter	Reference	Alarm limit	Required action
Signal power level	Chapter 3, 3.7.3.4.4.3	minimum = –161 dBW maximum = –153 dBW (Note 2)	Minimum: cease ranging function (Note 1). Maximum: cease broadcast.
Modulation	Chapter 3, 3.7.3.4.4.5	monitor for waveform distortion	Cease ranging function (Note 1).
SNT-to-GPS time	Chapter 3, 3.7.3.4.5	N/A (Note 3)	Cease ranging function unless URA reflects error.
Carrier frequency stability	coherence	3.5.2.1	N/A (Note 3)
Code/frequency	Maximum code phase deviation	3.5.2.4	N/A (Note 3)

3.5.2.6

N/A
(Notes 2 and 3)

Cease ranging function unless σ^2_{UDRE} and URA reflect error.

Cease ranging function unless σ^2_{UDRE} and URA reflect error.

Cease ranging function unless σ^2_{UDRE} and URA reflect error.

| Convolutional encoding | 3.5.2.9 | all transmit messages are erroneous | Cease broadcast. |

Notes.—

1. *Ceasing the ranging function is accomplished by broadcasting a URA and σ^2_{UDRE} of "Do Not Use" for that SBAS satellite.*
2. *These parameters can be monitored by their impact on the received signal quality (C/N_0 impact), since that is the impact on the user.*
3. *Alarm limits are not specified because the induced error is acceptable, provided it is represented in the σ^2_{UDRE} and URA parameters. If the error cannot be represented, the ranging function must cease.*

3.5.7.3.2.1   **Recommendation.—** *When the PRN mask is changed, SBAS should repeat the Type 1 message several times before referencing it in other messages to ensure that users receive the new mask.*

3.5.7.3.3   *Integrity data*. If SBAS does not provide the basic differential correction function, it shall transmit fast corrections, long-term corrections and fast correction degradation parameters coded to zero for all visible satellites indicated in the PRN mask.

3.5.7.3.3.1   If SBAS does not provide the basic differential correction function, SBAS shall indicate that the satellite is unhealthy ("Do Not Use") if the pseudo-range error exceeds 150 metres.

3.5.7.3.3.2   If SBAS does not provide the basic differential correction function, SBAS shall indicate that the satellite is "Not Monitored" if the pseudo-range error cannot be determined.

3.5.7.3.3.3   If SBAS does not provide the basic differential correction function, SBAS shall transmit a UDREI$_i$ of 13 if the satellite is not "Do Not Use" or "Not Monitored".

3.5.7.3.3.4   The IODF$_j$ parameter in Type 2 to 5, 6 or 24 messages shall be equal to 3.

3.5.7.4 *Basic differential correction function*. If an SBAS provides a basic differential correction function, it shall comply with the requirements contained in this section in addition to the GNSS satellite status function requirements defined in 3.5.7.3.

3.5.7.4.1 *Performance of basic differential correction function*. Given any valid combination of active data, the probability of a horizontal error exceeding the HPL$_{SBAS}$ (as defined in 3.5.5.6) for longer than 8 consecutive seconds shall be less than 10^{-7} in any hour, assuming a user with zero latency.

   Note.— *Active data is defined to be data that has not timed out per 3.5.8.1.1. This requirement includes core satellite constellation(s) and SBAS failures.*

3.5.7.4.2 *Long-term corrections*. Except for SBAS satellites from the same service provider, SBAS shall determine and broadcast long-term corrections for each visible GNSS satellite (see Note) indicated in the PRN mask (PRN mask value equal to "1"). The long-term corrections shall be such that the core satellite constellation(s) satellite position error projected on the line-of-sight to any user in the satellite footprint after application of these long-term corrections is less than 256 metres. For each GLONASS satellite, SBAS shall translate satellite coordinates into WGS-84 as defined in 3.5.5.2 prior to determining the long-term corrections. For each GPS satellite, the broadcast IOD shall match both the GPS IODE and 8 LSBs of IODC associated with the clock and ephemeris data used to compute the corrections (3.1.1.3.1.4 and 3.1.1.3.2.2). Upon transmission of a new ephemeris by a GPS satellite, SBAS shall continue to use the old ephemeris to determine the fast and long-term error corrections for at least 2 minutes and not more than 4 minutes. For each GLONASS satellite, SBAS shall compute and broadcast an IOD that consists of a latency and a validity interval as defined in 3.5.4.4.1.

   Note.— *The criteria for satellite visibility include the locations of reference stations and the achieved mask angle at those locations.*

3.5.7.4.2.1   **Recommendation.—** *To ensure accurate range rate corrections, SBAS should minimize discontinuities in the satellite ephemerides after application of long-term corrections.*

3.5.7.4.3   *Fast corrections*. SBAS shall determine fast corrections for each visible GNSS satellite indicated in the PRN mask (PRN mask value equal to "1"). Unless the IODF = 3, each time any fast correction data in Type j (j = 2, 3, 4 or 5) message changes, the IODF$_j$ shall sequence "0, 1, 2, 0, ...".

   Note.— *If there is an alarm condition, the IODF$_j$ may equal 3 (see 3.5.7.4.5).*

3.5.7.4.4   *Timing data*. If data are provided for GLONASS, SBAS shall broadcast the timing message (Type 12 message) including GLONASS time offset as defined in Table B-44.

3.5.7.4.5   *Integrity data*. For each satellite for which corrections are provided, SBAS shall broadcast integrity data (UDREI$_i$ and, optionally, Type 27 or 28 message data to calculate δUDRE) such that the integrity requirement in 3.5.7.4.1 is met. If the fast corrections or long-term corrections exceed their coding range, SBAS shall indicate that the satellite is unhealthy ("Do Not Use"). If $\sigma^2_{i,UDRE}$ cannot be determined, SBAS shall indicate that the satellite is "Not Monitored".

If Type 6 message is used to broadcast $\sigma^2_{i,UDRE}$, then:

a)   the IODF$_j$ shall match the IODF$_j$ for the fast corrections received in Type j message to which the $\sigma^2_{i,UDRE}$ apply; or

b)   the IODF$_j$ shall equal 3 if the $\sigma^2_{i,UDRE}$ apply to all valid fast corrections received in Type j message which have not timed out.

3.5.7.4.6   *Degradation data*. SBAS shall broadcast degradation parameters (Type 7 message) to indicate the applicable time out interval for fast corrections and ensure that the integrity requirement in 3.5.7.4.1 is met.

3.5.7.5   *Precise differential correction function*. If SBAS provides a precise differential correction function, it shall comply with the requirements contained in this section in addition to the basic differential correction function requirements in 3.5.7.4.

3.5.7.5.1 *Performance of precise differential correction function*. Given any valid combination of active data, the probability of an out-of-tolerance condition for longer than the relevant time-to-alert shall be less than 2×10^{-7} during any approach, assuming a user with zero latency. The time-to-alert shall be 5.2 seconds for an SBAS that supports precision approach or APV-II operations, and 8 seconds for an SBAS that supports APV-I operations. An out-of-tolerance condition shall be defined as a horizontal error exceeding the HPL$_{SBAS}$ or a vertical error exceeding the VPL$_{SBAS}$ (as defined in 3.5.5.6). When an out-of-tolerance condition is detected, the resulting alert message (broadcast in a Type 2 to 5 and 6, 24, 26 or 27 messages) shall be repeated three times after the initial notification of the alert condition for a total of four times in 4 seconds.

Note 1.— Active data is defined to be data that has not timed out per 3.5.8.1.1. This requirement includes core satellite constellation(s) and SBAS failures.

Note 2.— Subsequent messages can be transmitted at the normal update rate.

3.5.7.5.2   *Ionospheric grid point (IGP) mask*. SBAS shall broadcast an IGP mask and IODI$_k$ (up to 11 Type 18 messages, corresponding to the 11 IGP bands). The IGP mask values shall indicate whether or not data are being provided for each IGP. If IGP Band 9 is used, then the IGP mask values for IGPs north of 55°N in Bands 0 through 8 shall be set to "0". If IGP Band 10 is used, then the IGP mask values for IGPs south of 55°S in Bands 0 through 8 shall be set to "0". The IODI$_k$ shall change when there is a change of IGP mask values in the kth band. The new IGP mask shall be broadcast in a Type 18 message before it is referenced in a related Type 26 message. The IODI$_k$ in Type 26 message shall equal the IODI$_k$ broadcast in the IGP mask message (Type 18 message) used to designate the IGPs for which data are provided in that message.

3.5.7.5.2.1   **Recommendation.—** *When the IGP mask is changed, SBAS should repeat the Type 18 message several times before referencing it in a Type 26 message to ensure that users receive the new mask. The same $IODI_k$ should be used for all bands.*

3.5.7.5.3   *Ionospheric corrections.* SBAS shall broadcast ionospheric corrections for the IGPs designated in the IGP mask (IGP mask values equal to "1").

3.5.7.5.4   *Ionospheric integrity data.* For each IGP for which corrections are provided, SBAS shall broadcast GIVEI data such that the integrity requirement in 3.5.7.5.1 is met. If the ionospheric correction or $\sigma^2_{i,GIVE}$ exceed their coding range, SBAS shall indicate the status "Do Not Use" (designated in the correction data, 3.5.4.6) for the IGP. If $\sigma^2_{i,GIVE}$ cannot be determined, SBAS shall indicate that the IGP is "Not Monitored" (designated in the GIVEI coding).

3.5.7.5.5   *Degradation data.* SBAS shall broadcast degradation parameters (Type 10 message) such that the integrity requirement in 3.5.7.5.1 is met.

3.5.7.6   *OPTIONAL FUNCTIONS*

3.5.7.6.1 *Timing data.* If UTC time parameters are broadcast, they shall be as defined in 3.5.4.8 (Type 12 message).

3.5.7.6.2   *Service indication.* If service indication data are broadcast, they shall be as defined in 3.5.4.9 (Type 27 message) and Type 28 messages shall not be broadcast. The IODS in all Type 27 messages shall increment when there is a change in any Type 27 message data.

3.5.7.6.3 *Clock-ephemeris covariance matrix.* If clock-ephemeris covariance matrix data are broadcast, they shall be broadcast for all monitored satellites as defined in 3.5.4.10 (Type 28 message) and Type 27 messages shall not be broadcast.

3.5.7.7   *MONITORING*

3.5.7.7.1   *SBAS radio frequency monitoring.* The SBAS shall monitor the SBAS satellite parameters shown in Table B-55 and take the indicated action.

   Note.— In addition to the radio frequency monitoring requirements in this section, it will be necessary to make special provisions to monitor pseudo-range acceleration specified in Chapter 3, 3.7.3.4.2.1.5, and carrier phase noise specified in 3.5.2.2 and correlation loss in 3.5.2.5, unless analysis and testing shows that these parameters cannot exceed the stated limits.

3.5.7.7.2   *Data monitoring.* SBAS shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers with the tracking performance defined in Attachment D, 8.11.

3.5.7.7.2.1   The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo- range corrections.

3.5.7.7.2.2 The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the Early-Late discriminator function as defined in Attachment D, 8.11.

3.5.7.7.2.3   The monitor action shall be to set UDRE to "Do Not Use" for the satellite.

3.5.7.7.2.4   SBAS shall monitor all active data that can be used by any user within the service area.

3.5.7.7.2.5   SBAS shall raise an alarm within 5.2 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for precision approach or APV II (3.5.7.5.1).

3.5.7.7.2.6   SBAS shall raise an alarm within 8 seconds if any combination of active data and GNSS signals-in-space results in an out-of-tolerance condition for en-route through APV I (3.5.7.4.1).

   Note.— The monitoring applies to all failure conditions, including failures in core satellite constellation(s) or SBAS satellites. This monitoring assumes that the aircraft element complies with the requirements of RTCA/DO-229C, except as superseded by 3.5.8 and Attachment D, 8.11.

3.5.7.8   *Robustness to core satellite constellation(s) failures*. Upon occurrence of a core satellite constellation(s) satellite anomaly, SBAS shall continue to operate normally using the available healthy satellite signals that can be tracked.

3.5.8   AIRCRAFT ELEMENTS

   Note 1.— The parameters that are referred to in this section are defined in 3.5.4.

   Note 2.— Some of the requirements of this section may not apply to equipment that integrates additional navigation sensors, such as equipment that integrates SBAS with inertial navigation sensors.

3.5.8.1 *SBAS-capable GNSS receiver*. Except as specifically noted, the SBAS-capable GNSS receiver shall process the signals of the SBAS and meet the requirements specified in 3.1.3.1 (GPS receiver) and/or 3.2.3.1 (GLONASS receiver). Pseudo-range measurements for each satellite shall be smoothed using carrier measurements and a smoothing filter which deviates less than 0.1 metre within 200 seconds after initialization, relative to the steady-state response of the filter defined in 3.6.5.1 in the presence of drift between the code phase and integrated carrier phase of up to 0.01 metre per second.

3.5.8.1.1 GEO satellite acquisition. The receiver shall be able to acquire and track GEO satellites for which a stationary receiver at the user receiver location would experience a Doppler shift as large as ±450 Hz

3.5.8.1.2 *Conditions for use of data*. The receiver shall use data from an SBAS message only if the CRC of this message has been verified. Reception of a Type 0 message from an SBAS satellite shall result in deselection of that satellite and all data from that satellite shall be discarded for at least 1 minute. For GPS satellites, the receiver shall apply long-term corrections only if the IOD matches both the IODE and 8 least significant bits of the IODC. For GLONASS satellites, the receiver shall apply long-term corrections only if the time of reception (t_r) of the GLONASS ephemeris is inside the

following IOD validity interval, as defined in 3.5.4.4.1:

$$t_{LT} - L - V < t_r < t_{LT} - L$$

Note 1.— For SBAS satellites, there is no mechanism that links GEO ranging function data (Type 9 message) and long-term corrections.

Note 2.— This requirement does not imply that the receiver has to stop tracking the SBAS satellite.

3.5.8.1.2.1 *SBAS satellite identification.* Upon acquisition or re-acquisition of an SBAS satellite, the receiver shall not use SBAS satellite data unless the calculated separation between the satellite position derived from its GEO ranging function parameters and the satellite position derived from the almanac message most recently received from the same service provider within the last 15 minutes is less than 200 km.

Note. — This check ensures that a receiver will not mistake one SBAS satellite for another due to cross-correlation during acquisition or re-acquisition.

3.5.8.1.2.2 The receiver shall use integrity or correction data only if the IODP associated with that data matches the IODP associated with the PRN mask.

3.5.8.1.2.3 The receiver shall use SBAS-provided ionospheric data (IGP vertical delay estimate and $GIVEI_i$) only if the $IODI_k$ associated with that data in a Type 26 message matches the $IODI_k$ associated with the relevant IGP band mask transmitted in a Type 18 message.

3.5.8.1.2.4 The receiver shall use the most recently received integrity data for which the $IODF_j$ equals 3 or the $IODF_j$ matches the $IODF_j$ associated with the fast correction data being applied (if corrections are provided).

3.5.8.1.2.5 The receiver shall apply any regional degradation to the $\sigma^2_{i,UDRE}$ as defined by a Type 27 service message. If a Type 27 message with a new IODS indicates a higher δ_{UDRE} for the user location, the higher δ_{UDRE} shall be applied immediately. A lower δ_{UDRE} in a new Type 27 message shall not be applied until the complete set of messages with the new IODS has been received.

3.5.8.1.2.6 The receiver shall apply satellite-specific degradation to the $\sigma_{i,UDRE}^2$ as defined by a Type 28 clock-ephemeris covariance matrix message. The δ_{UDRE} derived from a Type 28 message shall be applied immediately.

3.5.8.1.2.7 In the event of a loss of four successive SBAS messages, the receiver shall no longer support SBAS-based precision approach or APV operations.

3.5.8.1.2.8 The receiver shall not use a broadcast data parameter after it has timed out as defined in Table B-56.

Table B-56.   Data time-out intervals

Data	Associated message types	En-route, terminal, NPA time-out	Precision approach, APV time-out
Clock-ephemeris covariance matrix	28	360	240
SBAS in test mode	0	N/A	N/A
PRN mask	1	600 s	600 s
UDREI	2 to 6, 24	18 s	12 s
Fast corrections	2 to 5, 24	(see Table B-57)	(see Table B-57)
Long-term corrections	24, 25	360 s	240 s
GEO ranging function data	9	360 s	240 s
Fast correction degradation	7	360 s	240 s
Degradation parameters	10	360 s	240 s
Ionospheric grid mask	18	1 200 s	1 200 s
Ionospheric corrections, GIVEI	26	600 s	600 s
Timing data	12	86 400 s	86 400 s
GLONASS time offset	12	600 s	600 s
Almanac data	17	None	None
Service level	27	86 400 s	86 400 s

Note.— The time-out intervals are defined from the end of the reception of a message.

Table B-57. Fast correction time-out interval evaluation

Fast correction degradation factor indicator (ai$_i$)	NPA time-out interval for fast corrections (If$_c$)	PA/APV time-out interval for fast corrections (If$_c$)
0	180 s	120 s
1	180 s	120 s
2	153 s	102 s
3	135 s	90 s
4	135 s	90 s
5	117 s	78 s
6	99 s	66 s
7	81 s	54 s
8	63 s	42 s
9	45 s	30 s
10	45 s	30 s
11	27 s	18 s
12	27 s	18 s
13	27 s	18 s
14	18 s	12 s
15	18 s	12 s

3.5.8.1.2.9 The receiver shall not use a fast correction if Δt for the associated RRC exceeds the time-out interval for fast corrections, or if the age of the RRC exceeds 8Δt.

3.5.8.1.2.10 The calculation of the RRC shall be reinitialized if a "Do Not Use" or "Not Monitored" indication is received for that satellite.

3.5.8.1.2.11 For SBAS-based precision approach or APV operations, the receiver shall only use satellites with elevation angles at or above 5 degrees.

3.5.8.1.2.12 The receiver shall no longer support SBAS-based precision approach or APV operation using a particular satellite if the UDREI$_i$ received is greater than or equal to 12.

3.5.8.2 *RANGING FUNCTION*

3.5.8.2.1 *Precision approach and APV operations*. The root-mean-square (1 sigma) of the total airborne error contribution to the error in a corrected pseudo-range for an SBAS satellite at the minimum received signal power level (Chapter 3, 3.7.3.4.4.3) under the worst interference environment as defined in 3.7 shall be less than or equal to 1.8 metres, excluding multipath effects, tropospheric and ionospheric residual errors.

Note.— *The aircraft element will bound the errors caused by multipath and troposphere (3.5.8.4.1). For the purpose of predicting service, the multipath error is assumed to be less than 0.6 metres (1 sigma).*

3.5.8.2.2 *Departure, en-route, terminal, and non-precision approach operations*. The root-mean-square (1 sigma) of the total airborne contribution to the error in a corrected pseudo-range for an SBAS satellite at the minimum received signal power level (Chapter 3, 3.7.3.4.4.3) under the worst interference environment as defined in 3.7 shall be less than or equal to 5 metres, excluding multipath, tropospheric and ionospheric errors.

3.5.8.2.3 *SBAS satellite position*

3.5.8.2.3.1 *Position computation*. The receiver shall decode Type 9 message and determine the code phase offset and position (X_G, Y_G, Z_G) of the SBAS satellite.

3.5.8.2.3.2 *SBAS satellite identification*. The receiver shall discriminate between SBAS satellites.

Note.— *This requirement applies to false acquisition of a satellite due to cross-correlation.*

3.5.8.2.4 *Almanac data*

3.5.8.2.4.1 **Recommendation.—** *The almanac data provided by the SBAS should be used for acquisition.*

Note.— Health and status information provided in the GEO almanac data *does not override or invalidate data provided in other SBAS messages. The use of bits 0to 2 by airborne equipment is optional; there are no requirements covering their usage.*

3.5.8.3 GNSS satellite status function. The receiver shall exclude satellites from the position solution if they are identified as "Do Not Use" by SBAS. If SBAS-provided integrity is used, the receiver shall not be required to exclude GPS satellites based on the GPS-provided ephemeris health flag as required in 3.1.3.1.1 or to exclude GLONASS satellites based on GLONASS-provided ephemeris health flag as required in 3.2.3.1.1.

Note 1.— *In the case of a satellite designated marginal or unhealthy by the core satellite constellation(s) health flag, SBAS may be able to broadcast ephemeris and clock corrections that will allow the user to continue using the satellite.*

Note 2.— *If satellites identified as "Not Monitored" by SBAS are used in the position solution, integrity is not provided by SBAS. ABAS or GBAS may be used to provide integrity, if available.*

3.5.8.4   *BASIC AND PRECISE DIFFERENTIAL FUNCTIONS*

3.5.8.4.1 *Core satellite constellation(s) ranging accuracy.* The root-mean-square (1 sigma) of the total airborne contribution to the error in a corrected pseudo-range for a GPS satellite at the minimum received signal power level (Chapter 3, 3.7.3.1.5.4) under the worst interference environment as defined in 3.7 shall be less than or equal to 0.4 metres, excluding multipath effects, tropospheric and ionospheric residual errors. The RMS of the total airborne contribution to the error in a corrected pseudo-range for a GLONASS satellite at the minimum received signal power level (Chapter 3, 3.2.5.4) under the worst interference environment as defined in 3.7 shall be less than or equal to 0.8 metres, excluding multipath effects, tropospheric and ionospheric residual errors.

3.5.8.4.2 *Precision approach and APV operations*

3.5.8.4.2.1   The receiver shall compute and apply long-term corrections, fast corrections, range rate corrections and the broadcast ionospheric corrections. For GLONASS satellites, the ionospheric corrections received from the SBAS shall be multiplied by the square of the ratio of GLONASS to GPS frequencies $(f_{GLONASS}/f_{GPS})^2$.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment D, 6.7.3.

3.5.8.4.2.2   The receiver shall use a weighted-least-squares position solution.

3.5.8.4.2.3   The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a 1 sigma deviation less than 0.07 metres.

Note.— A model was developed that meets this requirement. Guidance is provided in Attachment D, 6.7.3.
.

3.5.8.4.2.4   The receiver shall compute and apply horizontal and vertical protection levels defined in 3.5.5.6. In this computation, σ_{tropo} shall be:

$$\frac{1}{\sqrt{0,002+sen^2(\theta_i)}} \times 0,12 \text{ m}$$

where θ_i is the elevation angle of the ith satellite.

In addition, σ_{air} shall satisfy the condition that a normal distribution with zero mean and a standard deviation equal to σ_{air} bounds the error distribution for residual aircraft pseudo-range errors as follows:

$$\int_{y}^{\infty} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where

$f_n(x)$ =   probability density function of the residual aircraft pseudo-range error and

$$Q(x) \quad = \quad \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}} dt$$

Note.— The standard allowance for airborne multipath defined in 3.6.5.5.1 may be used to bound the multipath errors.

3.5.8.4.2.5   The parameters that define the approach path for a single precision approach or APV shall be contained in the FAS data block.

Note 1.— The FAS path is a line in space defined by the landing threshold point/fictitious threshold point (LTP/FTP), flight path alignment point (FPAP), threshold crossing height (TCH) and glide path angle (GPA). The local level plane for the approach is a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). Local vertical for the approach is normal to the WGS-84 ellipsoid at the LTP/FTP. The glide path intercept point (GPIP) is where the final approach path intercepts the local level plane.

Note 2.— For SBAS, FAS data blocks are stored in airborne databases. The format of the data for validation of a cyclic redundancy check is shown in Attachment D, 6.6. It differs from the GBAS FAS data block in 3.6.4.5.

3.5.8.4.2.5.1 FAS data block parameters shall be as follows (see Table B-57A):

Operation type: straight-in approach procedure or other operation types.

Coding: 0   = straight-in approach procedure
1 to 15 = spare

SBAS service provider ID: indicates the service provider associated with this FAS data block.

Coding: See Table B-27.

14 = FAS data block is to be used with GBAS only.

15 = FAS data block can be used with any SBAS service provider.

Airport ID: the three- or four-letter designator used to designate an airport.

Coding: Each character is coded using the lower 6 bits of its IA-5 representation. For each character, b_1 is transmitted first, and 2 zero bits are appended after b_6, so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character airport ID, the rightmost (first transmitted) character shall be IA-5 "space".

Runway number: the runway orientation, point in space final approach course, or SBAS circling only procedure course rounded to the nearest 10 degrees and truncated to two characters.

Coding: 01 to 36 = runway number

Note.— For heliport operations, the runway number value is the integer nearest to one tenth of the final approach course, except when that integer is zero, in which case the runway number is 36.

Runway letter: the one-letter designator used, as necessary, to differentiate between parallel runways.

Coding: 0 = no letter
          1   = R (right)
          2   = C (centre)
          3   = L (left)

Approach performance designator: this field is not used by SBAS.

Table B-57A. Final approach segment (FAS) data block

Data content	Bits used	Range of values	Resolution
Operation type	4	0 to 15	1
SBAS provider ID	4	0 to 15	1
Airport ID	32	—	
Runway number	6	01 to 36	1
Runway letter	2	—	—
Approach performance designator	3	0 to 7	1
Route indicator	5	—	—
Reference path data selector	8	0 to 48	1
Reference path identifier	32		
LTP/FTP latitude	32	±90.0°	0.0005 arcsec
LTP/FTP longitude	32	±180.0°	0.0005 arcsec
LTP/FTP height	16	-512.0 to 6 041.5 m	0.1 m
ΔFPAP latitude	24	±1.0°	0.0005 arcsec
ΔFPAP longitude	24	±1.0°	0.0005 arcsec
Approach TCH (Note 1)	15	0 to 1 638.35 m or 0 to 3 276.7 ft	0.05 m or 0.1 ft
Approach TCH units selector	1	—	—
GPA	16	0 to 90.0°	0.01°
Course width	8	80 to 143.75 m	0.25 m
ΔLength offset	8	0 to 2 032 m	8 m
Horizontal alert limit (HAL)	8	0 to 51.0 m	0.2 m
Vertical alert limit (VAL) (Note 2)	8	0 to 51.0 m	0.2 m
Final approach segment CRC	32		

Note 1.— Information can be provided in either feet or metres as indicated by the approach TCH unit selector.

Note 2.— A VAL of 0 indicates that the vertical deviations cannot be used (i.e., a lateral only approach). This does not preclude providing advisory vertical guidance on such approaches, refer to FAA AC 20-138().

Route indicator: a "blank" or the one-letter identifier used to differentiate between multiple procedures to the same runway end.

Note.— Procedures are considered to be different even if they only differ by the missed approach segment.

Coding: The letter is coded using bits b1 through b5 of its IA-5 representation. Bit b1 is transmitted first. Only upper case letters, excluding "I" and "O", or IA-5 "space" (blank) are used. Blank indicates that there is only one procedure to the runway end. For multiple procedures to the same runway end the route indicator is coded using a letter starting from Z and moving backward in the alphabet for additional procedures.

Reference path data selector (RPDS): this field is not used by SBAS.

Reference path identifier (RPI): four characters used to uniquely designate the reference path. The four characters consist of three alphanumeric characters plus a blank or four alphanumeric characters.

Note.— The best industry practice matches the 2nd and 3rd character encoding to the encoded runway number. The last character is a letter starting from A or a "blank."

Coding: Each character is coded using bits b1 through b6 of its IA-5 representation. For each character, b1 is transmitted first, and 2 zero bits are appended after b6 so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character reference path identifier, the rightmost (first transmitted) character shall be IA-5 "space".

Note.— The LTP/FTP is a point over which the FAS path passes at a height above the LTP/FTP height specified by the TCH.

LTP/FTP latitude: the latitude of the LTP/FTP point in arc seconds

      Coding: positive value denotes north latitude.
            negative value denotes south latitude.

LTP/FTP longitude: the longitude of the LTP/FTP point in arc seconds.

      Coding: positive value denotes east longitude.
            negative value denotes west longitude.

LTP/FTP height: the height of the LTP/FTP above the WGS-84 ellipsoid.

Coding: This field is coded as an unsigned fixed-point number with an offset of -512 metres. A value of zero in this field places the LTP/FTP 512 metres below the earth ellipsoid.

Note.— The FPAP is a point at the same height as the LTP/FTP that is used to define the alignment of the approach. The origin of angular deviations in the lateral direction is defined to be 305 metres (1 000 ft) beyond the FPAP along the lateral FAS path. For an approach aligned with the runway, the FPAP is at or beyond the stop end of the runway.

ΔFPAP latitude: the difference of latitude of the runway FPAP from the LTP/FTP in arc seconds

> *Coding:* Positive value denotes the FPAP latitude north of LTP/FTP latitude
> Negative value denotes the FPAP latitude south of the LTP/FTP latitude

ΔFPAP longitude: the difference of longitude of the runway FPAP from the LTP/FTP in arc seconds

> *Coding:* Positive value indicates the FPAP longitude east of LTP/FTP longitude.
> Negative value indicates the FPAP longitude west of LTP/FTP longitude.

Approach TCH: the height of the FAS path above the LTP/FTP defined in either feet or metres as indicated by the TCH units selector.

Approach TCH units selector: the units used to describe the TCH.
> Coding: 0 = feet
> 1 = metres

Glide path angle (GPA): the angle of the FAS path with respect to the horizontal plane tangent to the WGS-84 ellipsoid at the LTP/FTP.

Course width: the lateral displacement from the path defined by the FAS at the LTP/FTP at which full-scale deflection of a course deviation indicator is attained.

Coding: This field is coded as an unsigned fixed-point number with an offset of 80 metres. A value of zero in this field indicates a course width of 80 metres at the LTP/FTP.

ΔLength offset: the distance from the stop end of the runway to the FPAP. Coding: 1111 1111 = not provided

HAL: Horizontal alert limit to be used during the approach in meters. *VAL:* Vertical alert limit to be used during the approach in meters.

Final approach segment CRC: the 32-bit CRC appended to the end of each FAS data block in order to ensure approach data integrity. The 32-bit final approach segment CRC shall be calculated in accordance with 3.9. The length of the CRC code shall be k = 32 bits.

The CRC generator polynomial shall be:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^8 + x^7 + x^5 + x^3 + x + 1$$

The CRC information field, M(x), shall be:

$$M(x) = \sum_{i=1}^{288} m_i x^{288-i} = m_1 x^{287} + m_2 x^{286} + \cdots + m_{288} x^0$$

M(x) shall be formed from all bits of the associated FAS data block, excluding the CRC. Bits shall be arranged in the order transmitted, such that m_1 corresponds to the LSB of the operation type field, and m_{288} corresponds to the MSB of the Vertical Alert Limit (VAL) field. The CRC shall be ordered such that r_1 is the LSB and r_{32} is the MSB.

   3.5.8.4.2.5.2 For precision approach and APV operations, the service provider ID broadcast Type 17 message shall be identical to the service provider ID in the FAS data block, except if ID equals 15 in the FAS data block.

   If the service provider ID in the FAS data block equals 15, then any service provider can be used. If the service provider ID in the FAS data block equals 14, then SBAS precise differential corrections cannot be used for the approach.

3.5.8.4.2.5.3 SBAS FAS data points accuracy. The survey error of all the FAS data points, relative to WGS-84, shall be less than 0.25 metres vertical and 1 metre horizontal.

   3.5.8.4.3   *Departure, en-route, terminal, and non-precision approach operations*

   3.5.8.4.3.1   The receiver shall compute and apply long-term corrections, fast corrections and range rate corrections.

   3.5.8.4.3.2   The receiver shall compute and apply ionospheric corrections.

   Note.— Two methods of computing ionospheric corrections are provided in 3.1.2.4 and 3.5.5.5.2.

   3.5.8.4.3.3   The receiver shall apply a tropospheric model such that residual pseudo-range errors have a mean value (μ) less than 0.15 metres and a standard deviation less than 0.07 metres.

   3.5.8.4.3.4   The receiver shall compute and apply horizontal and vertical protection levels as defined in 3.5.5.6. In this computation, s_{tropo} shall be:

$$\frac{1}{\sqrt{0,002+\mathrm{sen}^2(\theta_i)}}\times 0,12\text{ m}$$

where θ_i is the elevation angle of the ith satellite.

In addition, σ_{air} shall satisfy the condition that a normal distribution with zero mean and standard deviation equal to σ_{air} bounds the error distribution for residual aircraft pseudo-range errors as follows:

$$\int_y^\infty f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int_{-\infty}^{-y} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

In addition, σ_{air} shall satisfy the condition that a normal distribution with zero mean and standard deviation equal to σ_{air} bounds the error distribution for residual aircraft pseudo-range errors as follows:

$$\int_{y}^{\infty} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0 \text{ and}$$

$$\int^{-y} f_n(x)dx \leq Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \geq 0$$

where

$f_n(x)$ = probability density function of the residual aircraft pseudo-range error and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{t^2}{2}} dt$$

Note.— The standard allowance for airborne multipath defined in 3.6.5.5.1 may be used to bound the multipath errors.

3.5.8.4.4   **Recommendation.—** *For departure, en-route, terminal, and non-precision approach operations, the receiver should use the broadcast ionospheric corrections, when available, and a tropospheric model with performance equal to that specified in 3.5.8.4.3.*

3.5.9   INTERFACE BETWEEN SBAS

Note.— Guidance material on the interface between different SBAS service providers is given in Attachment D, 6.3.

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

Note.— In this section, except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.

3.6.1   GENERAL

The GBAS shall consist of a ground subsystem and an aircraft subsystem. The GBAS ground subsystem shall provide data and corrections for the GNSS ranging signals over a digital VHF data broadcast to the aircraft subsystem. The GRAS ground subsystem shall consist of one or more GBAS ground subsystems.

Note.— Guidance material is provided in Attachment D, 7.1.

3.6.2   RF CHARACTERISTICS

3.6.2.1   *Carrier frequency stability*. The carrier frequency of the data broadcast shall be maintained within ±0.0002 per cent of the assigned frequency.

3.6.2.2   *Bit-to-phase-change encoding*. GBAS messages shall be assembled into symbols, each consisting of 3 consecutive message bits. The end of the message shall be padded by 1 or 2 fill bits if necessary to form the last 3-bit symbol of the message. Symbols shall be converted to D8PSK carrier phase shifts ($\Delta\phi_k$) in accordance with Table B-58.

Note.— The carrier phase for the kth symbol (ϕ_k) is given by: $\phi_k = \phi_{k-1} + \Delta\phi_k$. The D8PSK signal may be produced as shown in Figure B-19 by combining two quadrature RF signals which are independently suppressed-carrier amplitude-modulated by base band filtered impulses. A positive increase in $\Delta\phi_k$ represents a counterclockwise rotation in the complex I-Q plane of Figure B-19.

3.6.2.3   *Modulation wave form and pulse shaping filters*. The output of differential phase encoder shall be filtered by a pulse shaping filter whose output, s(t), is described as follows:

$$s(t) = \sum_{k=-\infty}^{k=\infty} e^{j\phi_k} h(t - kT)$$

where

h	=	the impulse response of the raised cosine filter;
ϕ_k	=	(as defined in 3.6.2.2);
t	=	time; and
T	=	the duration of each symbol = 1/10 500 second.

This pulse shaping filter shall have a nominal complex frequency response of a raised-cosine filter with α = 0.6. The time response, h(t), and frequency response, H(f), of the base band filters shall be as follows:

$$h(t) = \frac{\operatorname{sen}\left(\frac{\pi t}{T}\right)\cos\left(\frac{\pi \alpha t}{T}\right)}{\frac{\pi t}{T}\left[1 - \left(\frac{2\alpha t}{T}\right)^2\right]}$$

$$H(f) = \begin{cases} 1 & \text{for} & 0 \le f < \dfrac{1-\alpha}{2T} \\[3mm] \dfrac{1 - \operatorname{sen}\left(\dfrac{\pi}{2\alpha}(2fT - 1)\right)}{2} & \text{for} \ \dfrac{1-\alpha}{2T} \le f \le \dfrac{1+\alpha}{2T} \\[3mm] 0 & \text{for} & f > \dfrac{1+\alpha}{2T} \end{cases}$$

The output s(t) of the pulse shaping filter shall modulate the carrier.

3.6.2.4 *Error vector magnitude*. The error vector magnitude of the transmitted signal shall be less than 6.5 per cent root-mean-square (1 sigma).

3.6.2.5 *RF data rate*. The symbol rate shall be 10 500 symbols per second ±0.005 per cent, resulting in a nominal bit rate of 31 500 bits per second.

Message bits			Symbol phase shift
I_{3k-2}	I_{3k-1}	I_{3k}	$\Delta\phi_k$
0	0	0	$0\pi/4$
0	0	1	$1\pi/4$
0	1	1	$2\pi/4$
0	1	0	$3\pi/4$
1	1	0	$4\pi/4$
1	1	1	$5\pi/4$
1	0	1	$6\pi/4$
1	0	0	$7\pi/4$

Note.— I_j is the jth bit of the burst to be transmitted, where I_1 is the first bit of the training sequence.

3.6.2.6 *Emissions in unassigned time slots*. Under all operating conditions, the maximum power over a 25 kHz channel bandwidth, centred on the assigned frequency, when measured over any unassigned time slot, shall not exceed –105 dBc referenced to the authorized transmitter power.

Note.— If the authorized transmitter power is higher than 150 W, the –105 dBc may not protect reception of emissions in a slot assigned to another desired transmitter for receivers within 200 metres from the undesired transmitting antenna.

3.6.3   DATA STRUCTURE

3.6.3.1 *TRANSMITTER TIMING*

3.6.3.1.1 *Data broadcast timing structure*. The time division multiple access (TDMA) timing structure shall be based on frames and time slots. Each frame shall be 500 milliseconds in duration. There shall be 2 such frames contained in each 1-second UTC epoch. The first of these frames shall start at the beginning of the UTC epoch and the second frame shall start 0.5 seconds after the beginning of the UTC epoch. The frame shall be time division multiplexed such that it shall consist of 8 individual time slots (A to H) of 62.5-millisecond duration.

3.6.3.1.2   *Bursts*. Each assigned time slot shall contain at most 1 burst. To initiate the use of a time slot, the GBAS shall broadcast a burst in that time slot in each of 5 consecutive frames. For each time slot in use, the ground subsystem shall broadcast a burst in at least 1 frame of every 5 consecutive frames.

Note 1.— Bursts contain one or more messages and may be of variable length up to the maximum allowed within the slot as required by 3.6.3.2.

Note 2.— During time slot initiation, the airborne receiver may not receive the first 4 bursts.

3.6.3.1.3   *Timing budget for bursts*

3.6.3.1.3.1   Each burst shall be contained in a 62.5-millisecond time slot.

3.6.3.1.3.2   The beginning of the burst shall occur 95.2 microseconds after the beginning of the time slot with a tolerance of ±95.2 microseconds.

3.6.3.1.3.3   For GBAS/E equipment, the start of the synchronization and ambiguity resolution portion of the burst, transmitted with horizontal polarization (HPOL), shall occur within 10 microseconds of the start of the burst transmitted with vertical polarization (VPOL).

Note.— Table B-59 illustrates the burst timing.

3.6.3.1.4   *Ramp-up and transmitter power stabilization*. The transmitter shall ramp up to 90 per cent of the steady-state power level within 190.5 microseconds after the beginning of the burst (2 symbols). The transmitter shall stabilize at the steady-state power within 476.2 microseconds after the beginning of the burst (5 symbols).

Note.— The transmitter power stabilization period may be used by the aircraft receiver to settle its automatic gain control.

3.6.3.1.5   *Ramp-down*. After the final information symbol is transmitted in an assigned time slot, the transmitter output power level shall decrease to at least 30 dB below the steady-state power within 285.7 microseconds (3 symbols).

3.6.3.2   *Burst organization and coding*. Each burst shall consist of the data elements shown in Table B-60. Encoding of the messages shall follow the sequence: application data formatting, training sequence forward error correction (FEC) generation, application FEC generation and bit scrambling.

3.6.3.2.1   *Synchronization and ambiguity resolution*. The synchronization and ambiguity resolution field shall consist of the 48-bit sequence shown below, with the rightmost bit transmitted first:

<div align="center">010 001 111 101 111 110 001 100 011 101 100 000 011 110 010 000</div>

Table B-59.   Burst timing

Event	Nominal event duration	Nominal percentage of steady-state power
Ramp-up	190.5 µs	0% to 90%
Transmitter power stabilization	285.7 µs	90% to 100%
Synchronization and ambiguity resolution	1 523.8 µs	100%
Transmission of scrambled data	58 761.9 µs	100%
Ramp-down	285.7 µs (Note 1)	100% to 0%

Notes.—

1.   *Event duration indicated for transmission of scrambled data is for maximum application data length of 1 776 bits, 2 fill bits and nominal symbol duration.*

2.   *These timing requirements provide a propagation guard time of 1 259 microseconds, allowing for a one-way propagation range of approximately 370 km (200 NM).*

3.   *Where bursts from a GBAS broadcast antenna can be received at a range more than 370 km (200 NM) greater than the range from another broadcast antenna using the next adjacent slot, a longer guard time is required to avoid loss of both bursts. To provide a longer guard time, it is necessary to limit the application data length of the first burst to 1 744 bits. This allows a difference in propagation ranges of up to 692 km (372 NM) without conflict.*

Table B-60.   Burst data content

Element	Data content	Number of bits
Beginning of burst	all zeros	15
Power stabilization		
Synchronization and ambiguity resolution	3.6.3.2.1	48
Scrambled data:	3.6.3.3	
station slot identifier (SSID)	3.6.3.3.1	3
transmission length	3.6.3.3.2	17
training sequence FEC	3.6.3.3.3	5
application data	3.6.3.3.4	up to 1 776
application FEC	3.6.3.3.5	48

| fill bits (Note) | 3.6.2.2 | 0 to 2 |

Note.— Data scrambling of the fill bits is optional (3.6.3.3.6).

3.6.3.3   SCRAMBLED DATA CONTENT

3.6.3.3.1   *Station slot identifier (SSID).* The SSID shall be a numeric value corresponding to the letter designation A to H of the first time slot assigned to the GBAS ground subsystem, where slot A is represented by 0, B by 1, C by 2, … and H by 7. The identifier is transmitted LSB first.

3.6.3.3.2   *Transmission length.* The transmission length shall indicate the total number of bits in both application data and application FEC. The transmission length is transmitted LSB first.

3.6.3.3.3   *Training sequence FEC.* The training sequence FEC shall be computed over the SSID and transmission length fields, using a (25, 20) block code, in accordance with the following equation:

$$[P_1, ..., P_5] = [SSID_1, …, SSID_3, TL_1, …, TL_{17}] \; H^T$$

where

P_n =   the nth bit of the training sequence FEC (P_1 shall be transmitted first);
$SSID_n$ =   the nth bit of the station slot identifier ($SSID_1$ = LSB);
TL_n =   the nth bit in the transmission length (TL_1 = LSB); and
H^T =   the transpose of the parity matrix, defined below:

$$H^T = \begin{vmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \end{vmatrix}^T$$

Note.— This code is capable of correcting all single bit errors and detecting 75 of 300 possible double bit errors.

3.6.3.3.4   *Application data.* The application data shall consist of one or more message blocks, as defined in 3.6.3.4. The message blocks shall be mapped directly into the application data with no additional overhead of intervening layers.

3.6.3.3.5   *Application FEC.* The application FEC shall be calculated using the application data by means of a systematic, fixed-length, Reed-Solomon (R-S) (255, 249) code.

3.6.3.3.5.1   The field-defining primitive, p(x), of the R-S code shall be:

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

3.6.3.3.5.2   The generator polynomial of the R-S code, g(x), shall be:

$$g(x) = \prod_{i=120}^{125} (x - \alpha^i) = x^6 + \alpha^{176}x^5 + \alpha^{196}x^4 + \alpha^{244}x^3 + \alpha^{176}x^2 + \alpha^{156}x + \alpha^{225}$$

where α is a root of p(x) used for construction of the Galois Field of size 2^8, GF(256), and α^i is the ith primitive element in GF(256).

3.6.3.3.5.3   In generating the application FEC, the data to be encoded, m(x), shall be grouped into 8-bit R-S symbols. All data fields in the message blocks that define the application data shall be ordered such as specified in Tables B-61 and B-62, and in the message tables in 3.6.6. However, since the R-S code is a block code, application data blocks shorter than 249 bytes (1 992 bits) shall be extended to 249 bytes by virtual fill bits set to zero and appended to the application data. These virtual fill bits shall not be transferred to the bit scrambler. The data to be encoded, m(x), shall be defined by:

$$m(x) = a_{248}x^{248} + a_{247}x^{247} + ... + a_{248\text{-length}+1} x^{248\text{-length}+1} + a_{248\text{-length}} x^{248\text{-length}} + ... + a_1 x + a_0$$

where

length represents the number of 8-bit bytes in the application data block;

a_{248} represents the message block identifier, with the rightmost bit defined as the LSB and the first bit of the application data sent to the bit scrambler;

$a_{248\text{-length}+1}$ represents the last byte of the message block CRC, with the leftmost bit defined as the MSB and the last bit of the application data sent to the bit scrambler; and

$a_{248\text{-length}}$, ..., a_1, a_0 are the virtual fill bits (if any).

3.6.3.3.5.4   The 6 R-S check symbols (b_i) shall be defined as the coefficients of the remainder resulting from dividing the message polynomial $x^6 m(x)$ by the generator polynomial g(x):

$$b(x) = \sum_{i=0}^{5} b_i x^i + b_5 x^5 + b_4 x^4 + b_3 x^3 + b_2 x^2 + b_1 x^1 + b_0 = [x^6 m(x)] \bmod g(x)$$

3.6.3.3.5.5   The 8-bit R-S check symbols shall be appended to the application data. Each 8-bit R-S check symbol shall

be transmitted MSB first from b_0 to b_5, i.e. the first application FEC bit transferred to the bit scrambler shall be the MSB of b_0 and the last application FEC bit transferred to the bit scrambler shall be the LSB of b_5.

Note 1.— This R-S code is capable of correcting up to 3 symbol errors.

Note 2.— The order of the transmitted 8-bit R-S check symbols of the appended application FEC differs from the VHF data link (VDL) Mode 2. Moreover, for VDL Mode 2 each R-S check symbol is transmitted LSB first.

Note 3.— Example results of application FEC encoding are given in Attachment D, 7.15.

Table B-61.   Format of a GBAS message block

Message block	Bits
Message block header	48
Message	up to 1 696
CRC	32

Table B-62.   Format of message block header

Data field	Bits
Message block identifier	8
GBAS ID	24
Message type identifier	8
Message length	8

3.6.3.3.6   *Bit scrambling*

3.6.3.3.6.1   The output of a pseudo-noise scrambler with a 15-stage generator register shall be exclusive OR'ed with the burst data starting with the SSID and ending with the application FEC. Bit scrambling of the fill bits is optional and the set value of the fill bits is optional.

Note.— The fill bits are not used by the aircraft receiver and their values have no impact on the system.

3.6.3.3.6.2   The polynomial for the register taps of the scrambler shall be $1 + x + x^{15}$. The register content shall be rotated at the rate of one shift per bit. The initial status of the register, prior to the first SSID bit of each burst, shall be "1101 0010 1011 001", with the leftmost bit in the first stage of the register. The first output bit of the scrambler shall be sampled prior to the first register shift.

Note.— A diagram of the bit scrambler is given in Attachment D, 7.4.

3.6.3.4   *Message block format.* The message blocks shall consist of a message block header, a message and a 32-bit CRC. Table B-61 shows the construction of the message block. All signed parameters shall be two's complement numbers and all unsigned parameters shall be unsigned fixed point numbers. The scaling of the data shall be as shown in the message tables in 3.6.6. All data fields in the message block shall be transmitted in the order specified in the message tables, with the LSB of each field transmitted first.

Note.— All binary representations reading left to right are MSB to LSB.

3.6.3.4.1   *Message block header.* The message block header shall consist of a message block identifier, a GBAS identifier (ID), a message type identifier and a message length, as shown in Table B-62.

Message block identifier: the 8-bit identifier for the operating mode of the GBAS message block.

Coding: 1010 1010 =   normal GBAS message
          1111 1111 =   test GBAS message
          All other values are reserved.

GBAS ID: the four-character GBAS identification to differentiate between GBAS ground subsystems.

Coding: Each character is coded using bits b_1 through b_6 of its International Alphabet No. 5 (IA-5) representation. For each character, bit b_1 is transmitted first and six bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character GBAS ID, the rightmost (first transmitted) character shall be IA-5 "space".

Note.— The GBAS ID is normally identical to the location indicator at the nearest airport. Assignment of GBAS IDs will be coordinated as appropriate to avoid conflicts.

Message type identifier: the numeric label identifying the content of the message (Table B-63).

Message length: the length of the message in 8-bit bytes including the 6-byte message block header, the message and the 4-byte message CRC code.

3.6.3.4.2   *Cyclic redundancy check (CRC).* The GBAS message CRC shall be calculated in accordance with 3.9.

3.6.3.4.2.1   The length of the CRC code shall be k = 32 bits.

3.6.3.4.2.2   The CRC generator polynomial shall be:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^8 + x^7 + x^5 + x^3 + x + 1$$

3.6.3.4.2.3   The CRC information field, M(x), shall be:

$$M(x)= \sum_{i=1}^{n} m_i x^{n-i} + m_1 x^{n-1} + m_2 x^{n-2} + \ldots + m_n x^0$$

3.6.3.4.2.4   M(x) shall be formed from the 48-bit GBAS message block header and all bits of the variable-length message, excluding the CRC. Bits shall be arranged in the order transmitted, such that m_1 corresponds to the first transmitted bit of the message block header, and m_n corresponds to the last transmitted bit of the (n-48) message bits.

3.6.3.4.2.5   The CRC shall be ordered such that r_1 is the first bit transmitted and r_{32} is the last bit transmitted.

3.6.4   DATA CONTENT

3.6.4.1   *Message types*. The message types that can be transmitted by GBAS shall be as in Table B-63.

3.6.4.2   *TYPE 1 MESSAGE — PSEUDO-RANGE CORRECTIONS*

3.6.4.2.1   The Type 1 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70). The message shall contain three sections:

a)   message information (time of validity, additional message flag, number of measurements and the measurement type);

b)   low-frequency information (ephemeris decorrelation parameter, satellite ephemeris CRC and satellite availability information); and

c)   satellite data measurement blocks.

Note.— Transmission of the low-frequency data for SBAS ranging sources is optional.

3.6.4.2.2   Each Type 1 message shall include ephemeris decorrelation parameter, ephemeris CRC and source availability duration parameters for one satellite ranging source. The ephemeris decorrelation parameter, ephemeris CRC and source availability duration shall apply to the first ranging source in the message.

3.6.4.2.3   Pseudo-range correction parameters shall be as follows:

Modified Z-count: the indication of the time of applicability for all the parameters in the message.

Coding: the modified Z-count resets on the hour (xx:00), 20 minutes past the hour (xx:20) and 40 minutes past the hour (xx:40) referenced to GPS time.

Additional message flag: an identification of whether the set of measurement blocks in a single frame for a particular measurement type is contained in a single Type 1 message or a linked pair of messages.

Coding: 0 = All measurement blocks for a particular measurement type are contained in one Type 1 message.
1 = This is the first transmitted message of a linked pair of Type 1 messages that together contain the set of all measurement blocks for a particular measurement type.
2 = Spare
3 = This is the second transmitted message of a linked pair of Type 1 messages that together contain the set of all measurement blocks for a particular measurement type.

Note.— When a linked pair of Type 1 messages is used for a particular measurement type, the number of measurements and low-frequency data are computed separately for each of the two individual messages.

Number of measurements: the number of measurement blocks in the message.

Measurement type: the type of ranging signal from which the corrections have been computed.

Table B-63.   GBAS VHF data broadcast messages

Message type identifier	Message name
0	Spare
1	Pseudo-range corrections
2	GBAS-related data
3	Null message
4	Final approach segment (FAS) data
5	Predicted ranging source availability
6	Reserved
7	Reserved for national applications
8	Reserved for test applications
9 to 100	Spare
101	GRAS pseudo-range corrections
102 to 255	Spare

Note.— See 3.6.6 for message formats.

Coding: 0   = C/A or CSA code L1
       1   = reserved
       2   = reserved
       3   = reserved
       4 to 7   = spare

Ephemeris decorrelation parameter (P): a parameter that characterizes the impact of residual ephemeris errors due to decorrelation for the first measurement block in the message.

For a SBAS geostationary satellite, the ephemeris decorrelation parameter, if transmitted, shall be coded as all zeros.

For GBAS ground subsystems that do not broadcast the additional data block 1 in the Type 2 message, the ephemeris decorrelation parameter shall be coded as all zeros.

Ephemeris CRC: the CRC computed with the ephemeris data used to determine corrections for the first measurement block in the message. The ephemeris CRC for core satellite constellation(s) ranging sources shall be calculated in accordance with 3.9. The length of the CRC code shall be k = 16 bits. The CRC generator polynomial shall be:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The CRC information field, M(x), for a given satellite shall be:

$$M(x) = \sum_{i=1}^{n} m_i x^{n-1} + m_1 x^{n-1} + m_2 x^{n-2} + \ldots + m_n x^0$$

For a GPS satellite, M(x) shall be of length n = 576 bits. M(x) for a GPS satellite shall be calculated using the first 24 bits from each of words 3 to S10 of subframes 1, 2 and 3 of the data transmission from that satellite, ANDed with the GPS satellite ephemeris mask of Table B-64. M(x) shall be arranged in the order that bytes are transmitted by the GPS satellite, but with each byte ordered LSB first, such that m_1 corresponds to bit 68 of subframe 1, and m_{576} corresponds to bit 287 of subframe 3.

     Note.— M(x) for a GPS satellite does not include word 1 (TLM) or word 2 (HOW), which start each subframe, or the 6 parity bits at the end of each word.

For a GLONASS satellite, M(x) shall be of length n = 340 bits. M(x) for a GLONASS satellite shall be calculated using strings 1, 2, 3 and 4 of the data transmission from that satellite, ANDed with the GLONASS satellite ephemeris mask of Table B-65. Bits shall be arranged in transmission order such that m_1 corresponds to bit 85 of string 1, and m_{340} corresponds to bit 1 of string 4.

For a SBAS geostationary satellite, the ephemeris CRC, if transmitted shall be coded as all zeros.

The CRC shall be transmitted in the order r_9, r_{10}, r_{11}...., r_{16}, r_1, r_2, r_3...r_8, where r_i is the ith coefficient of the remainder R(x) as

defined in 3.9.

Source availability duration: the predicted duration for which corrections for the ranging source are expected to remain available, relative to the modified Z-count for the first measurement block.

Coding: 1111 1110 = The duration is greater than or equal to 2 540 seconds.
         1111 1111 = Prediction of source availability duration is not provided by this ground subsystem.

3.6.4.2.4   The measurement block parameters shall be as follows:

Ranging source ID: the identity of the ranging source to which subsequent measurement block data are applicable.

Table B-64.   GPS satellite ephemeris mask

Subframe 1:	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Word 3	0000 0000	0000 0000	0000 0011	Word 4	0000 0000	0000 0000	0000 0000
Word 5	0000 0000	0000 0000	0000 0000	Word 6	0000 0000	0000 0000	0000 0000
Word 7	0000 0000	0000 0000	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	1111 1100
Subframe 2:	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Word 3	1111 1111	1111 1111	1111 1111	Word 4	1111 1111	1111 1111	1111 1111
Word 5	1111 1111	1111 1111	1111 1111	Word 6	1111 1111	1111 1111	1111 1111
Word 7	1111 1111	1111 1111	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	0000 0000
Subframe 3:	Byte 1	Byte 2	Byte 3		Byte 1	Byte 2	Byte 3
Word 3	1111 1111	1111 1111	1111 1111	Word 4	1111 1111	1111 1111	1111 1111
Word 5	1111 1111	1111 1111	1111 1111	Word 6	1111 1111	1111 1111	1111 1111
Word 7	1111 1111	1111 1111	1111 1111	Word 8	1111 1111	1111 1111	1111 1111
Word 9	1111 1111	1111 1111	1111 1111	Word 10	1111 1111	1111 1111	1111 1100

Table B-65.   GLONASS satellite ephemeris mask

String 1:
0 0000 0000 0000 0000 0000 1111 1111 1111 1111 1111 1111 1111
1111 1111 1111 1111 1111 1111 1111 0000 0000
String 2:
0 0000 0000 0000 0000 0000 1111 1111 1111 1111 1111 1111 1111
1111 1111 1111 1111 1111 1111 1111 0000 0000
String 3:
0 0000 0111 1111 1111 0000 1111 1111 1111 1111 1111 1111 1111
1111 1111 1111 1111 1111 1111 1111 0000 0000
String 4:
0 0000 1111 1111 1111 1111 1111 1100 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000 0000

Coding: 1 to 36   = GPS satellite IDs (PRN)
            37   = reserved
            38 to 61   = GLONASS satellite IDs (slot number plus 37)
            62 to 119   = spare
            120 to 138 = SBAS satellite IDs (PRN)
            139 to 255 = spare

Issue of data (IOD): The issue of data associated with the ephemeris data used to determine pseudo-range and range rate corrections.

Coding: for GPS, IOD   = GPS IODE parameter (3.1.1.3.2.2)
            for GLONASS, IOD = GLONASS "t_b" parameter (see 3.2.1.3.1)
            for SBAS, IOD   = 1111 1111

   Note.— For GLONASS insert 0 in the MSB of the IOD.

Pseudo-range correction (PRC): the correction to the ranging source pseudo-range.

Range rate correction (RRC): the rate of change of the pseudo-range correction.

σ_{pr_gnd}: the standard deviation of a normal distribution associated with the signal-in-space contribution of the pseudo-range error at the GBAS reference point (3.6.5.5.1, 3.6.5.5.2 and 3.6.7.2.2.4).

Coding: 1111 1111 = Ranging source correction invalid.

B_1 through B_4: are the integrity parameters associated with the pseudo-range corrections provided in the same measurement block. For the ith ranging source these parameters correspond to $B_{i,1}$ through $B_{i,4}$ (3.6.5.5.1.2, 3.6.5.5.2.2 and 3.6.7.2.2.4). The indices "1-4" correspond to the same physical reference receiver for every frame transmitted from a given ground subsystem during continuous operation.

Coding: 1000 0000 = Reference receiver was not used to compute the pseudo-range correction.

Note.— Some airborne receivers may expect a static correspondence of the reference receivers to the indices for short service interruptions. However, the B-value indices may be reassigned after the ground subsystem has been out of service for an extended period of time, such as for maintenance.

3.6.4.3   *Type 2 message — GBAS-related data.* Type 2 message shall identify the location of the GBAS reference point at which the corrections provided by the GBAS apply and shall give other GBAS-related data (Table B-71). GBAS-related data parameters shall be as follows:

Note.— Additional data blocks may be included in the Type 2 message. Additional data block 1 and additional data block 2 are defined. In the future, other additional data blocks may be defined. Data blocks 2 through 255 are variable length and may be appended to the message after additional data block 1 in any order.

GBAS reference receivers: the number of GNSS reference receivers installed in this GBAS ground subsystem.

Coding: 0 = GBAS installed with 2 reference receivers
         1 = GBAS installed with 3 reference receivers
         2 = GBAS installed with 4 reference receivers
         3 = The number of GNSS reference receivers installed in this GBAS ground subsystem is not applicable

Ground accuracy designator letter: the letter designator indicating the minimum signal-in-space accuracy performance provided by GBAS (3.6.7.1.1).

Coding: 0 = accuracy designation A
         1 = accuracy designation B
         2 = accuracy designation C
         3 = spare

GBAS continuity/integrity designator (GCID): numeric designator indicating the operational status of the GBAS.

Coding: 0 = spare
         1 = GCID 1

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2 = GCID 2
3 = GCID 3
4 = GCID 4
5 = spare
6 = spare
7 = unhealthy

Note 1.— The values of GCID 2, 3 and 4 are specified in order to ensure compatibility of equipment with future GBAS.

Note 2.— The value of GCID 7 indicates that a precision approach or APV cannot be initiated.

Local magnetic variation: the published magnetic variation at the GBAS reference point.

Coding: Positive value denotes east variation (clockwise from true north), Negative value denotes west variation (counter-clockwise from true north)
100 0000 0000 = Precision approach procedures supported by this GBAS are published based on true bearing.

Note.— Local magnetic variation is chosen to be consistent with procedure design and is updated during magnetic epoch years.

$\sigma_{vert\_iono\_gradient}$: the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation (3.6.5.4).

Refractivity index (N_r): the nominal tropospheric refractivity index used to calibrate the tropospheric correction associated with the GBAS ground subsystem (3.6.5.3).

Coding: This field is coded as two's complement number with an offset of +400. A value of zero in this field indicates a refractivity index of 400.

Scale height (h_o): a scale factor used to calibrate the tropospheric correction and residual tropospheric uncertainty associated with the GBAS ground subsystem (3.6.5.3).

Refractivity uncertainty (σ_n): the standard deviation of a normal distribution associated with the residual tropospheric uncertainty (3.6.5.3).

Latitude: the latitude of the GBAS reference point defined in arc seconds.

Coding: Positive value denotes north latitude.
Negative value denotes south latitude.

Longitude: the longitude of the GBAS reference point defined in arc seconds.

Coding: Positive value denotes east longitude.
           Negative value denotes west longitude.

Reference point height: the height of the GBAS reference point above the WGS-84 ellipsoid.

  3.6.4.3.1   *Additional data block 1 parameters*. Additional data block 1 parameters shall be as follows:

REFERENCE STATION DATA SELECTOR (RSDS): the numerical identifier that is used to select the GBAS ground subsystem.

  Note.— The RSDS is different from every other RSDS and every reference path data selector (RPDS) broadcast on the same frequency by every GBAS ground subsystem within the broadcast region.

Coding: 1111 1111 = GBAS positioning service is not provided

MAXIMUM USE DISTANCE (D_{max}): the maximum distance (slant range) from the GBAS reference point for which the integrity is assured.

  Note.— This parameter does not indicate a distance within which VHF data broadcast field strength requirements are met.

Coding: 0 = No distance limitation

GPS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e\_POS,GPS}$): the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources or that do not provide the GBAS positioning service, this parameter shall be coded as all zeros.

GPS EPHEMERIS MISSED DETECTION PARAMETER, Category I Precision Approach and APV ($K_{md\_e,GPS}$): the multiplier for computation of the ephemeris error position bound for Category I precision approach and APV derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite.

For GBAS ground subsystems that do not broadcast corrections for GPS ranging sources, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, GBAS Positioning Service ($K_{md\_e,\_POS,GLONASS}$): the multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources or that do not provide positioning service, this parameter shall be coded as all zeros.

GLONASS EPHEMERIS MISSED DETECTION PARAMETER, Category I Precision Approach and APV ($K_{md\_e\_,GLONASS}$): the multiplier for computation of the ephemeris error position bound for Category I precision approach and APV derived from the probability of missed detection given that there is an ephemeris error in a GLONASS satellite.

For GBAS ground subsystems that do not broadcast corrections for GLONASS ranging sources, this parameter shall be coded as all zeros.

3.6.4.3.2   *Additional data blocks*. For additional data blocks other than additional data block 1, the parameters for each data block shall be as follows:

ADDITIONAL DATA BLOCK LENGTH: the number of bytes in the additional data block, including the additional data block length and additional data block number fields.

ADDITIONAL DATA BLOCK NUMBER: the numerical identifier of the type of additional data block.

Coding: 0 to 1   =   reserved
          2   =   additional data block 2, GRAS broadcast stations
          3   =   reserved for future services supporting Category II/III operations
          4   =   additional data block 4, VDB authentication parameters
          5 to 255 =   spare

ADDITIONAL DATA PARAMETERS: the set of data defined in accordance with the additional data block number.

3.6.4.3.2.1   *GRAS broadcast stations*

Parameters for additional data block 2 shall include data for one or more broadcast stations as follows (Table B-65A):

CHANNEL NUMBER: the channel number, as defined in 3.6.5.7, associated with a GBAS broadcast station.
    Note.— The channel number in this field refers to a frequency and an RSDS.
Δ*LATITUDE*: the difference of latitude of a GBAS broadcast station, measured from the latitude provided in the latitude parameter of Type 2 message.

Coding: Positive value denotes that the GBAS broadcast station is north of the GBAS reference point.
          Negative value denotes that the GBAS broadcast station is south of the GBAS reference point.

Δ*LONGITUDE*: the difference of longitude of a GBAS broadcast station, measured from the longitude provided in the longitude parameter of Type 2 message.

Coding: Positive value denotes that the GBAS broadcast station is east of the GBAS reference point.
           Negative value denotes that the GBAS broadcast station is west of the GBAS reference point.

Note.— Guidance material concerning additional data block 2 is provided in Attachment D, 7.17.

Table B-65A.   GRAS broadcast station data

Data content	Bits used	Range of values	Resolution
Channel number	16	20001 to 39999	1
ΔLatitude	8	±25.4°	0.2°
ΔLongitude	8	±25.4°	0.2°

3.6.4.3.2.2   *VDB authentication parameters*

Additional data block 4 includes information needed to support VDB authentication protocols (Table B-65B).

Slot group definition: This 8-bit field indicates which of the 8 slots (A-H) are assigned for use by the ground station. The field is transmitted LSB first. The LSB corresponds to slot A, the next bit to slot B, and so on. A "1" in the bit position indicates the slot is assigned to the ground station. A "0" indicates the slot is not assigned to the ground station.

Table B-65B.   VDB authentication parameters

Data content	Bits used	Range of values	Resolution
Slot group definition	8	—	—

3.6.4.4   *TYPE 3 MESSAGE — NULL MESSAGE*

    3.6.4.4.1   The Type 3 message is a variable length "null message" which is intended to be used by ground subsystems that support the authentication protocols (see section 3.6.7.4).

3.6.4.4.2   The parameters for the Type 3 message shall be as follows:

Filler: a sequence of bits alternating between "1" and "0" with a length in bytes that is 10 less than the value in the message length field in the message header.

3.6.4.5   *Type 4 message — Final approach segment (FAS).* Type 4 message shall contain one or more sets of FAS data, each defining a single precision approach (Table B-72). Each Type 4 message data set shall include the following:

Data set length: the number of bytes in the data set. The data set includes the data set length field and the associated FAS data block, FAS vertical alert limit (FASVAL)/approach status and FAS lateral alert limit (FASLAL)/approach status fields.

FAS data block: the set of parameters to identify a single precision approach or APV and define its associated approach path.

Coding: See 3.6.4.5.1 and Table B-66.

   Note.— Guidance material for FAS path definition is contained in Attachment D, 7.11.

FASVAL/approach status: the value of the parameter FASVAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use vertical deviations.

   Note.— The range and resolution of values for FASVAL depend upon the approach performance designator in the associated FAS data block.

FASLAL/approach status: the value of the parameter FASLAL as used in 3.6.5.6.

Coding: 1111 1111 = Do not use approach.

3.6.4.5.1   *FAS data block.* The FAS data block shall contain the parameters that define a single precision approach or APV. The FAS path is a line in space defined by the landing threshold point/fictitious threshold point (LTP/FTP), flight path alignment point (FPAP), threshold crossing height (TCH) and glide path angle (GPA). The local level plane for the approach is a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). Local vertical for the approach is normal to the WGS-84 ellipsoid at the LTP/FTP. The glide path intercept point (GPIP) is where the final approach path intercepts the local level plane. FAS data block parameters shall be as follows:

Operation type: straight-in approach procedure or other operation types.

Coding: 0   = straight-in approach procedure
             1 to 15 = spare

SBAS service provider ID: indicates the service provider associated with this FAS data block.

Coding: See Table B-27.
        14 = FAS data block is to be used with GBAS only.
        15 = FAS data block can be used with any SBAS service provider.

Note.— This parameter is not used for approaches conducted using GBAS or GRAS pseudo-range corrections.

Table B-66.   Final approach segment (FAS) data block

Data content	Bits used	Range of values	Resolution
Operation type	4	0 to 15	1
SBAS provider ID	4	0 to 15	1
Airport ID	32	—	—
Runway number	6	1 to 36	1
Runway letter	2	—	—
Approach performance designator	3	0 to 7	1
Route indicator	5	—	—
Reference path data selector	8	0 to 48	1
Reference path identifier	32	—	—
LTP/FTP latitude	32	±90.0°	0.0005 arcsec
LTP/FTP longitude	32	±180.0°	0.0005 arcsec
LTP/FTP height	16	−512.0 to 6 041.5 m	0.1 m
ΔFPAP latitude	24	±1.0°	0.0005 arcsec
ΔFPAP longitude	24	±1.0°	0.0005 arcsec
Approach TCH (Note)	15	0 to 1 638.35 m or	0.05 m or
		0 to 3 276.7 ft	0.1 ft
Approach TCH units selector	1	—	—
GPA	16	0 to 90.0°	0.01°
Course width	8	80 to 143.75 m	0.25 m
ΔLength offset	8	0 to 2 032 m	8 m
Final approach segment CRC	32	—	—

Note.— Information can be provided in either feet or metres as indicated by the approach TCH unit selector.

Airport ID: the three- or four-letter designator used to designate an airport.

Coding: Each character is coded using the lower 6 bits of its IA-5 representation. For each character, b_i is transmitted first,

and 2 zero bits are appended after b_6, so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character airport ID, the rightmost (first transmitted) character shall be IA-5 "space".

Runway number: the approach runway number.

Coding: 1 to 36   = runway number

   Note.— *For heliport and point-in-space operations, the runway number value is the integer nearest to one tenth of the final approach course, except when that integer is zero, in which case the runway number is 36.*

Runway letter: the one-letter designator used, as necessary, to differentiate between parallel runways.

Coding: 0 = no letter
          1 = R (right)
          2 = C (centre)
          3 = L (left)

Approach performance designator: the general information about the approach design.

Coding: 0   = APV
          1   = Category I
          2   = reserved for Category II
          3   = reserved for Category III
          4 to 7   = spare

   Note.— *Some airborne equipment designed for Category I performance is insensitive to the value of the APD. It is intended that airborne equipment designed for Category I performance accepts APD values of at least 1-4 as valid to accommodate future extensions to higher performance types using the same FAS data block.*

Route indicator: the one-letter identifier used to differentiate between multiple approaches to the same runway end.

Coding: The letter is coded using bits b_1 through b_5 of its IA-5 representation. Bit b_1 is transmitted first. Only upper case letters, excluding "I" and "O", or IA-5 "space" are used.

Reference path data selector (RPDS): the numeric identifier that is used to select the FAS data block (desired approach).

   Note.— *The RPDS for a given FAS data block is different from every other RPDS and every reference station data selector (RSDS) broadcast on the same frequency by every GBAS within the broadcast region.*

Reference path identifier (RPI): the three or four alphanumeric characters used to uniquely designate the reference path.

Coding: Each character is coded using bits b_1 through b_6 of its IA-5 representation. For each character, b_1 is transmitted first, and 2 zero bits are appended after b_6 so that 8 bits are transmitted for each character. Only upper case letters, numeric digits and IA-5 "space" are used. The rightmost character is transmitted first. For a three-character reference path identifier, the rightmost (first transmitted) character shall be IA-5 "space".

   Note.— The LTP/FTP is a point over which the FAS path passes at a relative height specified by the TCH. LTP is normally located at the intersection of the runway centreline and the threshold.

LTP/FTP latitude: the latitude of the LTP/FTP point in arc seconds.

  Coding: Positive value denotes north latitude.
             Negative value denotes south latitude.

LTP/FTP longitude: the longitude of the LTP/FTP point in arc seconds.

  Coding: Positive value denotes east longitude.
             Negative value denotes west longitude.

LTP/FTP height: the height of the LTP/FTP above the WGS-84 ellipsoid.

Coding: This field is coded as an unsigned fixed-point number with an offset of –512 metres. A value of zero in this field places the LTP/FTP 512 metres below the earth ellipsoid.

   Note.— The FPAP is a point at the same height as the LTP/FTP that is used to define the alignment of the approach. The origin of angular deviations in the lateral direction is defined to be 305 metres (1 000 ft) beyond the FPAP along the lateral FAS path. For an approach aligned with the runway, the FPAP is at or beyond the stop end of the runway.

ΔFPAP latitude: the difference of latitude of the runway FPAP from the LTP/FTP in arc seconds.

  Coding: Positive value denotes the FPAP latitude north of LTP/FTP latitude.
             Negative value denotes the FPAP latitude south of the LTP/FTP latitude.

ΔFPAP longitude: the difference of longitude of the runway FPAP from the LTP/FTP in arc seconds.

  Coding: Positive value indicates the FPAP longitude east of LTP/FTP longitude.
             Negative value indicates the FPAP longitude west of LTP/FTP longitude.

Approach TCH: the height of the FAS path above the LTP/FTP defined in either feet or metres as indicated by the TCH units

selector.

Approach TCH units selector: the units used to describe the TCH.

Coding: 0 = feet
             1 = metres

Glide path angle (GPA): the angle of the FAS path with respect to the horizontal plane tangent to the WGS-84 ellipsoid at the LTP/FTP.

Course width: the lateral displacement from the path defined by the FAS at the LTP/FTP at which full-scale deflection of a course deviation indicator is attained.

Coding: This field is coded as an unsigned fixed-point number with an offset of 80 metres. A value of zero in this field indicates a course width of 80 metres at the LTP/FTP.

ΔLength offset: the distance from the stop end of the runway to the FPAP.

Coding: 1111 1111 = not provided

Final approach segment CRC: the 32-bit CRC appended to the end of each FAS data block in order to ensure approach data integrity. The 32-bit final approach segment CRC shall be calculated in accordance with 3.9. The length of the CRC code shall be k = 32 bits.

The CRC generator polynomial shall be:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^8 + x^7 + x^5 + x^3 + x + 1$$

The CRC information field, M(x), shall be:

$$M(x) = \sum_{i=1}^{272} m_i x^{272-i} = m_1 x^{271} + m_2 x^{270} + \cdots + m_{272} x^0$$

M(x) shall be formed from all bits of the associated FAS data block, excluding the CRC. Bits shall be arranged in the order transmitted, such that m_1 corresponds to the LSB of the operation type field, and m_{272} corresponds to the MSB of the Δlength offset field. The CRC shall be ordered such that r_1 is the LSB and r_{32} is the MSB.

3.6.4.6   *Type 5 message — predicted ranging source availability.* When used, the Type 5 message shall contain rising and setting information for the currently visible or soon to be visible ranging sources. Predicted ranging source availability parameters shall be as follows:

Modified Z-count: indicates the time of applicability of the parameters in this message.

Coding: Same as modified Z-count field in Type 1 message (3.6.4.2).

Number of impacted sources: the number of sources for which duration information applicable to all approaches is provided.
Coding: 0   = Only specified obstructed approaches have limitations.
          1 to 31   = The number of ranging sources impacted.

Ranging source ID: as for Type 1 message (3.6.4.2).

Source availability sense: indicates whether the ranging source will become available or cease to be available.

Coding: 0 = Differential corrections will soon cease to be provided for the associated ranging source.
          1 = Differential corrections will soon start to be provided for the associated ranging source.

Source availability duration: the predicted minimum ranging source availability duration relative to the modified Z-count.

Coding: 111 1111 = The duration is greater than or equal to 1 270 seconds.

Number of obstructed approaches: the number of approaches for which the corrections will be reduced due to approach unique constellation masking.

Reference path data selector: an indication of the FAS data block to which the source availability data applies (3.6.4.5.1).

Number of impacted sources for this approach: the number of sources for which duration information applicable only to this approach is provided.

3.6.4.7   *TYPE 6 MESSAGE*

   Note.— Type 6 message is reserved for future use to provide the information required for Category II/III precision approaches.

3.6.4.8   *TYPE 7 MESSAGE*

   Note.— Type 7 message is reserved for national applications.

3.6.4.9   *TYPE 8 MESSAGE*

   Note.— Type 8 message is reserved for local and regional test applications.

3.6.4.10   *TYPE 101 MESSAGE — GRAS PSEUDO-RANGE CORRECTIONS*

3.6.4.10.1   The Type 101 message shall provide the differential correction data for individual GNSS ranging sources (Table B-70A). The message shall contain three sections:

a) message information (time of validity, additional message flag, number of measurements and the measurement type);

b) low-frequency information (ephemeris decorrelation parameter, satellite ephemeris CRC and satellite availability information); and

c) satellite data measurement blocks.

3.6.4.10.2   Each Type 101 message shall include ephemeris decorrelation parameter, ephemeris CRC and source availability duration parameters for one satellite ranging source. The ephemeris decorrelation parameter, ephemeris CRC and source availability duration shall apply to the first ranging source in the message.

3.6.4.10.3   Pseudo-range correction parameters shall be as follows:

Modified Z-count: as defined in 3.6.4.2.3.

Additional message flag: as defined in 3.6.4.2.3 except applicable to Type 101 messages.

Number of measurements: as defined in 3.6.4.2.3.

Measurement type: as defined in 3.6.4.2.3.

Ephemeris decorrelation parameter (P): as defined in 3.6.4.2.3.

Ephemeris CRC: as defined in 3.6.4.2.3.

Source availability duration: as defined in 3.6.4.2.3.

Number of B parameters: an indication of whether the B parameters are included in the measurement block for each ranging source.

Coding: 0 = B parameters are not included
             1 = 4 B parameters per measurement block

3.6.4.10.4   The measurement block parameters shall be as follows:

Ranging source ID: as defined in 3.6.4.2.4.

Issue of data (IOD): as defined in 3.6.4.2.4.

Pseudo-range correction (PRC): as defined in 3.6.4.2.4.

Range rate correction (RRC): as defined in 3.6.4.2.4.

σ_{pr_gnd}: as defined in 3.6.4.2.4, with the exception of the range of values and resolution.

B1 through B4: as defined in 3.6.4.2.4.

   Note.— *Inclusion of the B parameters in the measurement block is optional for Type 101 messages.*

3.6.5   DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

   Note.— *This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters that are not transmitted, but are used by either or both non-aircraft and aircraft elements, and that define terms applied to determine the navigation solution and its integrity.*

   3.6.5.1   *Measured and carrier smoothed pseudo-range.* The broadcast correction is applicable to carrier smoothed code pseudo-range measurements that have not had the satellite broadcast troposphere and ionosphere corrections applied to them. The carrier smoothing is defined by the following filter:

$$P_{CSC_n} = \alpha P + (1 - \alpha)\left(P_{CSC_{n-1}} + \frac{\lambda}{2\pi}(\phi_n - \phi_{n-1}) \right)$$

where

P_{CSC_n}	=	the smoothed pseudo-range;
$P_{CSC_{n-1}}$	=	the previous smoothed pseudo-range;
P	=	the raw pseudo-range measurement where the raw pseudo-range measurements are obtained from a carrier driven code loop, first order or higher and with a one-sided noise bandwidth greater than or equal to 0.125 Hz;
λ	=	the L1 wavelength;
ϕ_n	=	the carrier phase;
ϕ_{n-1}	=	the previous carrier phase; and
α	=	the filter weighting function equal to the sample interval divided by the time constant of 100 seconds, except as specified in 3.6.8.3.5.1 for airborne equipment.

3.6.5.2 *Corrected pseudo-range.* The corrected pseudo-range for a given satellite at time *t* is:

$$PR_{corrected} = P_{CSC} + PRC + RRC \times (t - tz\text{-count}) + TC + c \times (\Delta t_{sv})_{L1}$$

where

P_{CSC} =   the smoothed pseudo-range (defined in 3.6.5.1); PRC
      =   the pseudo-range correction (defined in 3.6.4.2);
RRC =   the pseudo-range correction rate (defined in 3.6.4.2);
t =   the current time;
$tz\text{-count}$ =   the time of applicability derived from the modified Z-count (defined in 3.6.4.2);
TC =   the tropospheric correction (defined in 3.6.5.3); and
c and $(\Delta t_{sv})_{L1}$ are as defined in 3.1.2.2 for GPS satellites.

3.6.5.3 *TROPOSPHERIC DELAY*

3.6.5.3.1   The tropospheric correction for a given satellite is:

$$TC = N_r h_0 \frac{10^{-6}}{\sqrt{0.002 + sen^2(El_i)}} (1 - e^{-\Delta h/h_0})$$

where

N_r =   refractivity index from the Type 2 message (3.6.4.3);
Δh =   height of the aircraft above the GBAS reference point;
El_i =   elevation angle of the ith satellite; and
h_0 =   troposphere scale height from the Type 2 message.

3.6.5.3.2   The residual tropospheric uncertainty is:

$$\sigma_{tropo} = \sigma_n h_0 \frac{10^{-6}}{\sqrt{0.002 + sen^2(El_i)}} (1 - e^{-\Delta h/h_0})$$

where σ_n = the refractivity uncertainty from the Type 2 message (3.6.4.3).

3.6.5.4 *Residual ionospheric uncertainty.* The residual ionospheric uncertainty for a given satellite is:

$$\sigma_{iono} = F_{pp} \times \sigma_{vert\_iono\_gradient} \times (x_{air} + 2 \times \tau \times v_{air})$$

where

F_{pp} =   the vertical-to-slant obliquity factor for a given satellite (3.5.5.5.2);

$\sigma_{\text{vert\_iono\_gradient}}$ = (as defined in 3.6.4.3);

x_{air} = the distance (slant range) in metres between current aircraft location and the GBAS reference point indicated in the Type 2 message;

τ = 100 seconds (time constant used in 3.6.5.1); and

v_{air} = the aircraft horizontal approach velocity (metres per second).

3.6.5.5 *PROTECTION LEVELS*

3.6.5.5.1 *Category I precision approach and APV.* The signal-in-space vertical and lateral protection levels (VPL and LPL) are upper confidence bounds on the error in the position relative to the GBAS reference point defined as:

$$VPL = MAX\{VPL_{HO}, VPL_{H1}\}$$

$$LPL = MAX\{LPL_{HO}, LPL_{H1}\}$$

3.6.5.5.1.1 *Normal measurement conditions*

3.6.5.5.1.1.1 The vertical protection level (VPL_{H0}) and lateral protection level (LPL_{H0}), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$VPL_{H0} = K_{ffmd} \sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$LPL_{H0} = K_{ffmd} \sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where

K_{ffmd} = the multiplier derived from the probability of fault-free missed detection;

s_vert_i = $s_{v,i} + s_{x,i} \times \tan(\text{GPA})$;

s_lat_i = $s_{y,i}$;

$s_{x,i}$ = the partial derivative of position error in the x-direction with respect to pseudo-range error on the ith satellite;

$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the ith satellite;

$s_{v,i}$ = the partial derivative of position error in the vertical direction with respect to pseudo-range error on the ith satellite;

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GPA   =   the glidepath angle for the final approach path (3.6.4.5.1);
N   =   the number of ranging sources used in the position solution; and
i   =   the ranging source index for ranging sources used in the position solution.

Note.— The coordinate reference frame is defined such that x is along track positive forward, y is crosstrack positive left in the local level tangent plane and v is the positive up and orthogonal to x and y.

3.6.5.5.1.1.2   For a general-least-squares position solution, the projection matrix S is defined as:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \cdots & S_{x,N} \\ S_{y,1} & S_{y,2} & \cdots & S_{y,N} \\ S_{v,1} & S_{v,2} & \cdots & S_{v,N} \\ S_{t,1} & S_{t,2} & \cdots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

where

G_i = $[-\cos El_i \cos Az_i \ -\cos El_i \sin Az_i \ -\sin El_i \ 1]$ = i^{th} row of G; and

$$W = \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_N^2 \end{bmatrix}^{-1}$$

where $\sigma_i^2 = \sigma^2_{pr\_gnd,i} + \sigma^2_{tropo,i} + \sigma^2_{pr\_air,i} + \sigma^2_{iono,i}$;

where

$\sigma_{pr\_gnd,i}$ = σ_{pr_gnd} for the ith ranging source (3.6.4.2);
$\sigma_{tropo,i}$ =   the residual tropospheric uncertainty for the ith ranging source (3.6.5.3);
$\sigma_{iono,i}$ =   the residual ionospheric delay (due to spatial decorrelation) uncertainty for the ith ranging source (3.6.5.4); and

$\sigma_{pr\_air,i}$ = $\sqrt{\sigma^2_{receiver}(El_i) + \sigma^2_{multipath}(El_i)}$, the standard deviation of the aircraft contribution to the corrected pseudo-range error for the ith ranging source. The total aircraft contribution includes the receiver contribution (3.6.8.2.1) and a standard allowance for airframe multipath;

where

$\sigma_{multipath}(El_i)$ = $0.13 + 0.53e^{-El_i/10 \ deg}$, the standard model for the contribution of airframe multipath (in metres);
El_i =   the elevation angle for the ith ranging source (in degrees); and
Az_i =   the azimuth for the ith ranging source taken counterclockwise for the x axis (in degrees).

Note.— To improve readability, the subscript i *was omitted from the projection matrix's equation.*

3.6.5.5.1.2 *Faulted measurement conditions.* When the Type 101 message is broadcast without B parameter blocks, the values for VPL_{H1} and LPL_{H1} are defined as zero. Otherwise, the vertical protection level (VPL_{H1}) and lateral protection level (LPL_{H1}), assuming that a latent fault exists in one, and only one reference receiver, are:

$$VPL_{H1} = \max [VPL_j]$$

$$LPL_{H1} = \max [LPL_j]$$

where VPL_j and LPL_j for j = 1 to 4 are

VPL_j = $|B\_vert_j| + K_{md}\ \sigma_{vert,H1}$ and
LPL_j = $|B\_lat_j| + K_{md}\ \sigma_{lat,H1}$

and

$$B\_vert_j\ =\ \sum_{i=1}^{N}(s\_vert_i \times B_{i,j});$$

$$B\_lat_j\ =\ \sum_{i=1}^{N}(s\_lat_i \times B_{i,j});$$

$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the jth reference receiver measurement for the ith ranging source;

K_{md} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted;

$$\sigma^2_{vert,H1}\ =\ \sum_{i=1}^{N}(s\_vert_i^2 \times \sigma\_H1_i^2);$$

$$\sigma^2_{lat,H1}\ =\ \sum_{i=1}^{N}(s\_lat_i^2 \times \sigma\_H1_i^2);$$

$$\sigma\_H1_i^2\ =\ \left(\frac{M_i}{U_i}\right)\sigma^2_{pr\_gnd,i} + \sigma^2_{pr\_air,i} + \sigma^2_{tropo,i} + \sigma^2_{iono,i};$$

M_i = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source (indicated by the B values); and

U_i = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source, excluding the jth reference receiver.

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.1.3   *Definition of K multipliers for Category I precision approach and APV.* The multipliers are given in Table B-67.

Table B-67.   K-multipliers for Category I precision approach and APV

Multiplier	M_i			
	1 [(Note)]	2	3	4
K_{ffmd}	6.86	5.762	5.81	5.847
K_{md}	Not used	2.935	2.898	2.878

Note.— For APV I approaches supported by Type 101 messages broadcast without the B parameter block.

3.6.5.5.2   *GBAS positioning service.* The signal-in-space horizontal protection level is an upper confidence bound on the horizontal error in the position relative to the GBAS reference point defined as:

$$HPL = MAX\{HPL_{H0}, HPL_{H1}\}$$

3.6.5.5.2.1   *Normal measurements conditions.* The horizontal protection level (HPL_{H0}), assuming that normal measurement conditions (i.e. no faults) exist in all reference receivers and on all ranging sources, is calculated as:

$$HPL_{H0} = K_{ffmd, POS} d_{major}$$

where:

$$d_{mayor} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}}$$

$$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2$$

$$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2$$

$$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2$$

$s_{x,i}$ =   the partial derivative of position error in the x-direction with respect to pseudo-range error on the ith satellite

$s_{y,i}$ =   the partial derivative of position error in the y-direction with respect to pseudo-range error on the ith satellite

$K_{ffmd,POS}$ =   the multiplier derived from the probability of fault-free missed detection

N   =   the number of ranging sources used in the position solution

i   =   the ranging source index for ranging sources used in the position solution
σ_i =   the pseudo-range error term as defined in 3.6.5.5.1.1

Note.— For the GBAS positioning service, the x and y axes define an arbitrary orthogonal basis in the horizontal plane.

3.6.5.5.2.2   *Faulted measurement conditions.* When the Type 101 message is broadcast without B parameter blocks, the value for HPL_{H1} is defined as zero. Otherwise, the horizontal protection level (HPL_{H1}), assuming that a latent fault exists in one and only one reference receiver, is:

$$HPL_{H1} = max\ [HPL_j]$$

where HPL_j for j = 1 to 4 is:

$$HPL_j = |B\_horz_j| + K_{md\_POS}d_{major,H1}$$

and

$$B\_horz_j = \sqrt{\left(\sum_{i=1}^{N} S_{x,i}B_{i,j}\right)^2 + \left(\sum_{i=1}^{N} S_{y,i}B_{i,j}\right)^2}$$

$B_{i,j}$ = the broadcast differences between the broadcast pseudo-range corrections and the corrections obtained excluding the jth reference receiver measurement for the ith ranging source.

K_{md_POS} = the multiplier derived from the probability of missed detection given that the ground subsystem is faulted.

$$d_{mayor,H1} = \sqrt{\frac{d\_H1_x^2 + d\_H1_y^2}{2} + \sqrt{\left(\frac{d\_H1_x^2 - d\_H1_y^2}{2}\right)^2 + d\_H1_{xy}^2}}$$

$$d\_H1_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \, \sigma\_H1_i^2$$

$$d\_H1_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \, \sigma\_H1_i^2$$

$$d\_H1_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \, \sigma\_H1_i^2$$

Note.— For the GBAS positioning service, the x and y axes define an arbitrary orthogonal basis in the horizontal plane.

$$\sigma\_H1_i^2 = \left(\frac{M_i}{U_i}\right) \sigma_{pr\_gnd,i}^2 + \sigma_{pr\_air,i}^2 + \sigma_{tropo,i}^2 + \sigma_{iono,i}^2$$

M_i = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source (indicated by the B values).

U_i = the number of reference receivers used to compute the pseudo-range corrections for the ith ranging source, excluding the jth reference receiver.

Note.— A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the aircraft subsystem.

3.6.5.5.2.3   *Definition of K multipliers for GBAS positioning service.* The multiplier K_{ffmd_POS} is equal to 10.0 and the multiplier K_{md_POS}, is equal to 5.3.

3.6.5.6   *ALERT LIMITS*

Note.— Guidance concerning the calculation of alert limits, including approaches associated with channel numbers 40 000 to 99 999, is provided in Attachment D, 7.13.

3.6.5.6.1   *Category I precision approach alert limits.* The alert limits are defined in Tables B-68 and B-69. For aircraft positions at which the lateral deviation exceeds twice the deviation at which full-scale lateral deflection of a course deviation indicator is achieved, or vertical deviation exceeds twice the deviation at which full-scale fly-down deflection of a course deviation indicator is achieved, both the lateral and vertical alert limits are set to the maximum values given in the tables.

Table B-68.   Category I lateral alert limit

Horizontal distance of aircraft position from the LTP/FTP as translated along the final approach path (metres)	Lateral alert limit (metres)
291 < D ≤ 873	FASLAL
873 < D ≤ 7 500	0.0044D (m) + FASLAL – 3.85
D > 7 500	FASLAL + 29.15

Table B-69.   Category I vertical alert limit

Height above LTP/FTP of aircraft position translated onto the final approach path (feet)	Vertical alert limit (meters)
100 < H ≤ 200	FASVAL
200 < H ≤ 1 340	0.02925H (ft) + FASVAL − 5.85
H > 1 340	FASVAL + 33.35

3.6.5.6.2   *APV alert limits*. The alert limits are equal to the FASLAL and FASVAL for approaches with channel numbers in the range of 20 001 to 39 999. For approaches with channel numbers in the range 40 000 to 99 999, the alert limits are stored in the on-board database.

3.6.5.7   *Channel number*. Each GBAS approach transmitted from the ground subsystem is associated with a channel number in the range of 20 001 to 39 999. If provided, the GBAS positioning service is associated with a separate channel number in the range of 20 001 to 39 999. The channel number is given by:

$$\text{Channel number} = 20\,000 + 40(F - 108.0) + 411(S)$$

where

F = the data broadcast frequency (MHz)
S = RPDS or RSDS

and

RPDS = the reference path data selector for the FAS data block (as defined in 3.6.4.5.1)
RSDS = the reference station data selector for the GBAS ground subsystem (as defined in 3.6.4.3.1)

For channel numbers transmitted in the additional data block 2 of Type 2 message (as defined in 3.6.4.3.2.1), only RSDS are used.

Note 1.— When the FAS is not broadcast for an APV, the GBAS approach is associated with a channel number in the range 40 000 to 99 999.

Note 2.— Guidance material concerning channel number selection is provided in Attachment D, 7.7.

3.6.5.8   *EPHEMERIS ERROR POSITION BOUND*

Note.— Ephemeris error position bounds are computed only for core satellite constellation ranging sources used in the position solution (j index) and not for other types of ranging sources (SBAS satellites or pseudolites) that are not subject to

undetected ephemeris failures. However, the calculations of these position bounds use information from all ranging sources used in the position solution (i index).

    3.6.5.8.1 *Category I precision approach and APV.* The vertical and lateral ephemeris error position bounds are defined as:

$$VEB = \underset{j}{MAX}\{VEB_j\}$$

$$LEB = \underset{j}{MAX}\{LEB_j\}$$

The vertical and lateral ephemeris error position bounds for the jth core satellite constellation ranging source used in the position solution are given by:

$$VEB_j = \left|s\_vert_j\right| x_{air}P_j + K_{md\_e,j}\sqrt{\sum_{i=1}^{N} s\_vert_i^2 \times \sigma_i^2}$$

$$LEB_j = \left|s\_lat_j\right| x_{air}P_j + K_{md\_e,j}\sqrt{\sum_{i=1}^{N} s\_lat_i^2 \times \sigma_i^2}$$

where:

$s\_vert_{i\ or\ j}$ is defined in 3.6.5.5.1.1
$s\_lat_{i\ or\ j}$ is defined in 3.6.5.5.1.1
x_{air} is defined in 3.6.5.4
N is the number of ranging sources used in the position solution
σ_i is defined in 3.6.5.5.1.1
P_j is the broadcast ephemeris decorrelation parameter for the jth ranging source
$K_{md\_e,j}$ is the broadcast ephemeris missed detection multiplier for Category I precision approach and APV associated with the satellite constellation for the jth ranging source ($K_{md\_e,GPS}$ or $K_{md\_e,GLONASS}$)

    3.6.5.8.2 *GBAS positioning service.* The horizontal ephemeris error position bound is defined as:

$$HEB = \underset{j}{MAX}\{HEB_j\}$$

The horizontal ephemeris error position bound for the jth core satellite constellation ranging source used in the position solution is given by:

$$HEB_j = |s_{horz,j}| x_{air} P_j + K_{md\_e\_POS} d_{mayor}$$

where:

$$S_{horz,j}{}^2 = S_{xj}{}^2 + S_{yj}{}^2$$

$s_{x,j}$	is as defined in 3.6.5.5.2.1
$s_{y,j}$	is as defined in 3.6.5.5.2.1
x_{air}	is defined in 3.6.5.4
P_j	is the broadcast ephemeris decorrelation parameter for the jth ranging source
$K_{md\_e\_POS}$	is the broadcast ephemeris missed detection multiplier for the GBAS positioning service associated with the satellite constellation for the jth ranging source ($K_{md\_e\_POS,GPS}$ or $K_{md\_e\_POS,GLONASS}$)
d_{major}	is as defined in 3.6.5.5.2.1

3.6.6   MESSAGE TABLES

Each GBAS message shall be coded in accordance with the corresponding message format defined in Tables B-70 through B-73.

   Note.— Message type structure is defined in 3.6.4.1.

Table B-70.   Type 1 pseudo-range corrections message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Additional message flag	2	0 to 3	1
Number of measurements (N)	5	0 to 18	1
Measurement type	3	0 to 7	1
Ephemeris decorrelation parameter (P)	8	0 to 1.275×10^{-3} m/m	5×10^{-6} m/m
Ephemeris CRC	16	—	—
Source availability duration	8	0 to 2 540 s	10 s
For N measurement blocks			
Ranging source ID	8	1 to 255	1
Issue of data (IOD)	8	0 to 255	1
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s
$\sigma_{pr\ gnd}$	8	0 to 5.08 m	0.02 m
B_1	8	±6.35 m	0.05 m
B_2	8	±6.35 m	0.05 m
B_3	8	±6.35 m	0.05 m

B_4	8	±6.35 m	0.05 m

Table B-70A.   Type 101 GRAS pseudo-range corrections message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Additional message flag	2	0 to 3	1
Number of measurements (N)	5	0 to 18	1
Measurement type	3	0 to 7	1
Ephemeris decorrelation parameter (P)	8	0 to 1.275×10^{-3} m/m	5×10^{-6} m/m
Ephemeris CRC	16	—	—
Source availability duration	8	0 to 2540 s	10 s
Number of B parameters	1	0 or 4	—
Spare	7	—	—
For N measurement blocks			
Ranging source ID	8	1 to 255	1
Issue of data (IOD)	8	0 to 255	1
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m
B parameter block (if provided)			
B_1	8	±25.4 m	0.2 m
B_2	8	±25.4 m	0.2 m
B_3	8	±25.4 m	0.2 m
B_4	8	±25.4 m	0.2 m

Table B-71A.   Type 2 GBAS-related data message

Data content	Bits used	Range of values	Resolution
GBAS reference receivers	2	2 to 4	—
Ground accuracy designator letter	2	—	—
Spare	1	—	—
GBAS continuity/integrity designator	3	0 to 7	1
Local magnetic variation	11	±180°	0.25°
Spare	5	—	—
$\sigma_{\text{vert iono gradient}}$	8	0 to 25.5 × 10^{-6} m/m	0.1 × 10^{-6} m/m
Refractivity index	8	16 to 781	3
Scale height	8	0 to 25 500 m	100 m
Refractivity uncertainty	8	0 to 255	1
Latitude	32	±90.0°	0.0005 arcsec
Longitude	32	±180.0°	0.0005 arcsec
GBAS reference point height	24	±83 886.07 m	0.01 m
Additional data block 1 (if provided)			
Reference station data selector	8	0 to 48	1
Maximum use distance (D_{max})	8	2 to 510 km	2 km
$K_{md\ e\ \text{POS,GPS}}$	8	0 to 12.75	0.05
$K_{md\ e,\text{GPS}}$	8	0 to 12.75	0.05
$K_{md\ e\ \text{POS,GLONASS}}$	8	0 to 12.75	0.05
$K_{md\ e,\text{GLONASS}}$	8	0 to 12.75	0.05
Additional data block 2 (if provided)			
Additional data block length	8	2 to 255	1
Additional data block number	8	2 to 255	1
Additional data parameters	Variable	—	—

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Table B-71B.   Type 3 null message

Data content	Bits used	Range of values	Resolution
Filler	Variable (Note)	N/A	N/A

Note.— The number of bytes in the filler field is 10 less than the message length field in the message header as defined in section 3.6.3.4.

Table B-72.   Type 4 FAS data message

Data content	Bits used	Range of values	Resolution
For N data sets			
Data set length	8	2 to 212	1 byte
FAS data block	304	—	—
FAS vertical alert limit/approach status	8		
(1) when associated approach performance designator indicates APV-I (APD coded as 0)		0 to 50.8 m	0.2 m
(2) when associated approach performance designator does not indicate APV-I (APD not coded as 0)		0 to 25.4 m	0.1 m
FAS lateral alert limit/approach status	8	0 to 50.8 m	0.2 m

Table B-73.   Type 5 predicted ranging source availability message

Data content	Bits used	Range of values	Resolution
Modified Z-count	14	0 to 1 199.9 s	0.1 s
Spare	2	—	—
Number of impacted sources (N)	8	0 to 31	1
For N impacted sources			
Ranging source ID	8	1 to 255	1
Source availability sense	1	—	—
Source availability duration	7	0 to 1 270 s	10 s
Number of obstructed approaches (A)	8	0 to 255	1
For A obstructed approaches			
Reference path data selector	8	0 to 48	—
Number of impacted sources for this approach (N_A)	8	1 to 31	1

For N_A impacted ranging sources for this
Approach

Ranging source ID	8	1 to 255	1
Source availability sense	1	—	—
Source availability duration	7	0 to 1 270 s	10 s

3.6.7   NON-AIRCRAFT ELEMENTS

3.6.7.1   *PERFORMANCE*

3.6.7.1.1   *Accuracy*

3.6.7.1.1.1   The root-mean-square (RMS) (1 sigma) of the ground subsystem contribution to the corrected pseudo-range accuracy for GPS and GLONASS satellites shall be:

$$\text{RMS}_{pr\_gnd} \leq \sqrt{\frac{(a_0 + a_1 e^{-\theta_n/\theta_0})^2}{M} + (a_2)^2}$$

where

M	$=$	the number of GNSS reference receivers, as indicated in the Type 2 message parameter (3.6.4.3), or, when this parameter is coded to indicate "not applicable", the value of M is defined as 1;
n	$=$	n^{th} ranging source;
θ_n	$=$	elevation angle for the nth ranging source; and
a_0, a_1, a_2, and θ_0	$=$	parameters defined in Tables B-74 and B-75 for each of the defined ground accuracy designators (GADs).

Note 1.— The GBAS ground subsystem accuracy requirement is determined by the GAD letter and the number of installed reference receivers.

Note 2.— The ground subsystem contribution to the corrected pseudo-range error specified by the curves defined in Tables B-74 and B-75 and the contribution to the SBAS satellites do not include aircraft noise and aircraft multipath.

Table B-74.   GBAS — GPS accuracy requirement parameters

Ground accuracy designator letter	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)	a_2 (metres)
A	≥ 5	0.5	1.65	14.3	0.08
B	≥ 5	0.16	1.07	15.5	0.08
C	> 35	0.15	0.84	15.5	0.04
	5 to 35	0.24	0	—	0.04

Table B-75.   GBAS — GLONASS accuracy requirement parameters

Ground accuracy designator letter	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)	a_2 (metres)
A	≥ 5	1.58	5.18	14.3	0.078
B	≥ 5	0.3	2.12	15.5	0.078
C	> 35	0.3	1.68	15.5	0.042
	5 to 35	0.48	0	—	0.042

3.6.7.1.1.2   The RMS of the ground subsystem contribution to the corrected pseudo-range accuracy for SBAS satellites shall be:

$$RMS_{pr\_gnd} \leq \frac{1.8}{\sqrt{M}} \text{(metres)}$$

where M is as defined in 3.6.7.1.1.1.

Note.— GAD classifications for SBAS ranging sources are under development.

3.6.7.1.2   *Integrity*

3.6.7.1.2.1   *GBAS ground subsystem integrity risk*

3.6.7.1.2.1.1   *Category I precision approach and APV.* For a GBAS ground subsystem that provides the Category I precision approach or APV, the integrity risk shall be less than 1.5×10^{-7} per approach.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.1) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.2.6 and the integrity risk associated with the monitoring in 3.6.7.3.

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft, results in an out-of-tolerance lateral or vertical relative position error without annunciation for a period longer than the maximum time-to-alert. An out-of-tolerance lateral or vertical relative position error is defined as an error that exceeds the Category I precision approach or APV protection level and, if additional data block 1 is broadcast, the ephemeris error position bound.

3.6.7.1.2.1.1.1   The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast.

Note.— The time-to-alert above is the time between the onset of the out-of-tolerance lateral or vertical relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition.

3.6.7.1.2.1.1.2   The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 5.5 seconds when Type 101 messages are broadcast.

3.6.7.1.2.1.1.3   For Category I precision approach, the value FASLAL for each FAS block, as defined in the FAS lateral alert limit field of the Type 4 message shall be no greater than 40 metres, and the value FASVAL for each FAS block, as defined in the FAS vertical alert limit field of the Type 4 message, shall be no greater than 10 metres.

3.6.7.1.2.1.1.4   For APV, the value FASLAL and FASVAL shall be no greater than the lateral and vertical alert limits given in Annex 10, Volume I, 3.7.2.4.

3.6.7.1.2.1.2   *GBAS positioning service.* For GBAS ground subsystem that provides the GBAS positioning service, integrity risk shall be less than 9.9×10^{-8} per hour.

Note 1.— The integrity risk assigned to the GBAS ground subsystem is a subset of the GBAS signal-in-space integrity risk, where the protection level integrity risk (3.6.7.1.2.2.2) has been excluded and the effects of all other GBAS, SBAS and core satellite constellations failures are included. The GBAS ground subsystem integrity risk includes the integrity risk of satellite signal monitoring required in 3.6.7.2.6 and the integrity risk associated with the monitoring in 3.6.7.3.

Note 2.— GBAS signal-in-space integrity risk is defined as the probability that the ground subsystem provides information which when processed by a fault-free receiver, using any GBAS data that could be used by the aircraft, results in an out-of-tolerance horizontal relative position error without annunciation for a period longer than the maximum time-to-alert. An out-of-tolerance horizontal relative position error is defined as an error that exceeds both the horizontal protection level and the horizontal ephemeris error position bound.

3.6.7.1.2.1.2.1   The GBAS ground subsystem maximum time-to-alert shall be less than or equal to 3 seconds when Type 1 messages are broadcast and less than or equal to 5.5 seconds when Type 101 messages are broadcast.

Note.— The time-to-alert above is the time between the onset of the out-of-tolerance horizontal relative position error and the transmission of the last bit of the message that contains the integrity data that reflects the condition.

3.6.7.1.2.2   *Protection level integrity risk*

3.6.7.1.2.2.1   For a GBAS ground subsystem that provides the Category I precision approach or APV, the protection level integrity risk shall be less than 5×10^{-8} per approach.

Note.— The Category I precision approach and APV protection level integrity risk is the integrity risk due to undetected errors in position relative to the GBAS reference point greater than the associated protection levels under the two following conditions:

a)   *normal measurement conditions defined in 3.6.5.5.1.1; and*

b)   *faulted measurement conditions defined in 3.6.5.5.1.2.*

3.6.7.1.2.2.2   For a GBAS ground subsystem that provides the positioning service, protection level integrity risk shall be less than 10^{-9} per hour.

Note.— The GBAS positioning service protection level integrity risk is the integrity risk due to undetected errors in the horizontal position relative to the GBAS reference point greater than the GBAS positioning service protection level under the two following conditions:

a)   *normal measurement conditions defined in 3.6.5.5.2.1; and*

b)   *faulted measurement conditions defined in 3.6.5.5.2.2.*

3.6.7.1.3   *Continuity of service*

3.6.7.1.3.1   *Continuity of service for Category I precision approach and APV.* The GBAS ground subsystem continuity of service shall be greater than or equal to $1 - 8.0 \times 10^{-6}$ per 15 seconds.

Note.— The GBAS ground subsystem continuity of service is the average probability per 15-second period that the VHF data broadcast transmits data in tolerance, VHF data broadcast field strength is within the specified range and the protection levels are lower than the alert limits, including configuration changes that occur due to the space segment. This continuity of service requirement is the entire allocation of the signal-in-space continuity requirement from Chapter 3, Table 3.7.2.4-1, and therefore all continuity risks included in that requirement must be accounted for by the ground subsystem provider.

3.6.7.1.3.2   *Continuity of service for positioning service*

Note.— For GBAS ground subsystems that provide the GBAS positioning service, there may be additional continuity requirements depending on the intended operations.

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3.6.7.2   *FUNCTIONAL REQUIREMENTS*

3.6.7.2.1   *General*

3.6.7.2.1.1   *Data broadcast rates*

3.6.7.2.1.1.1   A GBAS ground subsystem that supports Category I precision approach or APV-II shall broadcast Type 1 messages. A GBAS ground subsystem that does not support Category I precision approach or APV-II shall broadcast either Type 1 or Type 101 messages. A GBAS ground subsystem shall not broadcast both Type 1 and Type 101 messages.

Note.— Guidance material concerning usage of the Type 101 message is provided in Attachment D, 7.18.

3.6.7.2.1.1.2   Each GBAS ground subsystem shall broadcast Type 2 messages.

3.6.7.2.1.1.3   Each GBAS ground subsystem shall broadcast FAS blocks in Type 4 messages for all Category I precision approaches supported by that GBAS ground subsystem. If a GBAS ground subsystem supports APV and does not broadcast FAS blocks for the corresponding approaches, it shall broadcast additional data block 1 in the Type 2 message.

Note.— FAS blocks for APV procedures may be held within a database on board the aircraft. Broadcasting additional data block 1 allows the airborne receiver to select the GBAS ground subsystem that supports the approach procedures in the airborne database. FAS blocks may also be broadcast to support operations by aircraft without an airborne database. These procedures use different channel numbers as described in Attachment D, 7.7.

3.6.7.2.1.1.4   When the Type 5 message is used, the ground subsystem shall broadcast the Type 5 message at a rate in accordance with Table B-76.

Note.— When the standard 5 degree mask is not adequate to describe satellite visibility at either the ground subsystem antennas or at an aircraft during a specific approach, the Type 5 message may be used to broadcast additional information to the aircraft.

3.6.7.2.1.1.5   *Data broadcast rates.* For all message types required to be broadcast, messages meeting the field strength requirements of Chapter 3, 3.7.3.5.4.4.1.2 and 3.7.3.5.4.4.2.2 and the minimum rates shown in Table B-76 shall be provided at every point within the coverage. The total message broadcast rates from all antenna systems of the ground subsystem combined shall not exceed the maximum rates shown in Table B-76.

Note.— Guidance material concerning the use of multiple antenna systems is provided in Attachment D, 7.12.4.

Table B-76.   GBAS VHF data broadcast rates

Message type	Minimum broadcast rate	Maximum broadcast rate
1 or 101	For each measurement type: All measurement blocks once per frame (Note)	For each measurement type: All measurement blocks once per frame (Note)
2	Once per 20 consecutive frames	Once per frame
4	All FAS blocks once per 20 consecutive frames	All FAS blocks once per frame
5	All impacted sources once per 20 consecutive frames	All impacted sources once per 5 consecutive frames
Note.— One Type 1 or Type 101 message or two Type 1 or Type 101 messages that are linked using the additional message flag described in 3.6.4.2.		

3.6.7.2.1.2   *Message block identifier*. The MBI shall be set to either normal or test according to the coding given in 3.6.3.4.1.

3.6.7.2.1.3   *VDB authentication*

Note.— This section is reserved for forward compatibility with future authentication functions.

3.6.7.2.2   *Pseudo-range corrections*

3.6.7.2.2.1   *Message latency*. The time between the time indicated by the modified Z-count and the last bit of the broadcast Type 1 or Type 101 message shall not exceed 0.5 seconds.

3.6.7.2.2.2   *Low-frequency data*. Except during an ephemeris change, the first ranging source in the message shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 10 seconds. During an ephemeris change, the first ranging source shall sequence so that the ephemeris decorrelation parameter, ephemeris CRC and source availability duration for each core satellite constellation's ranging source are transmitted at least once every 27 seconds. When new ephemeris data are received from a core satellite constellation's ranging source, the ground subsystem shall use the previous ephemeris data from each satellite until the new ephemeris data have been continuously received for at least 2 minutes but shall make a transition to the new ephemeris data before 3 minutes have passed. When this transition is made to using the new ephemeris data for a given ranging source, the ground subsystem shall broadcast the new ephemeris CRC for all occurrences of that ranging source in the low-frequency information of Type 1 or Type 101 message in the next 3 consecutive frames. For a

given ranging source, the ground subsystem shall continue to transmit data corresponding to the previous ephemeris data until the new CRC ephemeris is transmitted in the low-frequency data of Type 1 or Type 101 message (see Note). If the ephemeris CRC changes and the IOD does not, the ground subsystem shall consider the ranging source invalid.

Note.— The delay before the ephemeris transition allow sufficient time for the aircraft subsystem to collect new ephemeris data.

3.6.7.2.2.2.1   **Recommendation.—** *The ephemeris decorrelation parameter and the ephemeris CRC for each core satellite constellation's ranging source should be broadcast as frequently as possible.*

3.6.7.2.2.3   *Broadcast pseudo-range correction.* Each broadcast pseudo-range correction shall be determined by combining the pseudo-range correction estimates for the relevant ranging source calculated from each of the reference receivers. For each satellite, the measurements used in this combination shall be obtained from the same ephemeris data. The corrections shall be based on smoothed code pseudo-range measurements for each satellite using the carrier measurement from a smoothing filter in accordance with 3.6.5.1.

3.6.7.2.2.4   *Broadcast signal-in-space integrity parameters.* The ground subsystem shall provide σ_{pr_gnd} and B parameters for each pseudo-range correction in Type 1 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied. The ground subsystem shall provide σ_{pr_gnd} and, if necessary, B parameters for each pseudo-range correction in Type 101 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

Note.— Broadcast of the B parameters are optional for Type 101 messages. Guidance material regarding the B parameters in Type 101 messages is contained in Attachment D, 7.5.11.

3.6.7.2.2.5   **Recommendation.—** *Reference receiver measurements should be monitored. Faulted measurements or failed reference receivers should not be used to compute the pseudo-range corrections.*

3.6.7.2.2.6   *Repeated transmission of Type 1 or Type 101 messages.* For a given measurement type and within a given frame, all broadcasts of Type 1 or Type 101 messages or linked pairs from all GBAS broadcast stations that share a common GBAS identification, shall have identical data content.

3.6.7.2.2.7   *Issue of data.* The GBAS ground subsystem shall set the IOD field in each ranging source measurement block to be the IOD value received from the ranging source that corresponds to the ephemeris data used to compute the pseudo-range correction.

3.6.7.2.2.8   *Application of signal error models.* Ionospheric and tropospheric corrections shall not be applied to the pseudo-ranges used to calculate the pseudo-range corrections.

3.6.7.2.2.9   *Linked pair of Type 1 or Type 101 messages.* If a linked pair of Type 1 or Type 101 messages is transmitted

then,

    a)   the two messages shall have the same modified Z-count;

    b)   the minimum number of pseudo-range corrections in each message shall be one;

    c)   the measurement block for a given satellite shall not be broadcast more than once in a linked pair of messages;

    d)   the two messages shall be broadcast in different time slots; and

    e)   the order of the B values in the two messages shall be the same.

3.6.7.2.2.10   *Modified Z-count update.* The modified Z-count for Type 1 or Type 101 messages of a given measurement type shall advance every frame.

3.6.7.2.2.11   *Ephemeris decorrelation parameters*

3.6.7.2.2.11.1   *Category I precision approach and APV.* For ground subsystems that broadcast the additional data block 1 in the Type 2 message, the ground subsystem shall broadcast the ephemeris decorrelation parameter for each core satellite constellation ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.1 is met.

3.6.7.2.2.11.2   *GBAS positioning service.* For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris decorrelation parameter for each core satellite constellation's ranging source such that the ground subsystem integrity risk of 3.6.7.1.2.1.2 is met.

3.6.7.2.3   *GBAS-related data*

3.6.7.2.3.1   *Tropospheric delay parameters.* The ground subsystem shall broadcast a refractivity index, scale height, and refractivity uncertainty in a Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.2   *GCID indication.* If the ground subsystem meets the requirements of 3.6.7.1.2.1.1, 3.6.7.1.2.2.1 and 3.6.7.1.3.1 the GCID shall be set to 1 otherwise it shall be set to 7.

3.6.7.2.3.3   *GBAS reference antenna phase centre position accuracy.* For each GBAS reference receiver, the reference antenna phase centre position error shall be less than 8 cm relative to the GBAS reference point.

3.6.7.2.3.4   **Recommendation.—** *GBAS reference point survey accuracy. The survey error of the GBAS reference point, relative to WGS-84, should be less than 0.25 m vertical and 1 m horizontal.*

Note.— Relevant guidance material is given in Attachment D, 7.16.

3.6.7.2.3.5   *Ionospheric uncertainty estimate parameter.* The ground subsystem shall broadcast an ionospheric delay gradient parameter in the Type 2 message such that the protection level integrity risk requirements defined in 3.6.7.1.2.2 are satisfied.

3.6.7.2.3.6   For ground subsystems that provide the GBAS positioning service, the ground subsystem shall broadcast the ephemeris error position bound parameters using additional data block 1 in the Type 2 message.

3.6.7.2.3.7   **Recommendation.—** *All ground subsystems should broadcast the ephemeris error position bound parameters using additional data block 1 in the Type 2 message.*

3.6.7.2.3.8   For ground subsystems that broadcast additional data block 1 in the Type 2 message, the following requirements shall apply:

3.6.7.2.3.8.1   *Maximum use distance*. The ground subsystem shall provide the distance (D_{max}) from the GBAS reference point that defines a volume within which the ground subsystem integrity risk in 3.6.7.1.2.1 and the protection level integrity risk in 3.6.7.1.2.2 are met.

3.6.7.2.3.8.2   *Ephemeris missed detection parameters*. The ground subsystem shall broadcast the ephemeris missed detection parameters for each core satellite constellation such that the ground subsystem integrity risk of 3.6.7.1.2.1 is met.

3.6.7.2.3.8.3   *GBAS positioning service indication*. If the ground subsystem does not meet the requirements of 3.6.7.1.2.1.2 and 3.6.7.1.2.2.2, the ground subsystem shall indicate using the RSDS parameter that the GBAS positioning service is not provided.

3.6.7.2.3.9   If the VHF data broadcast is transmitted at more than one frequency within the GRAS service area, each GBAS broadcast station within the GRAS ground subsystem shall broadcast additional data blocks 1 and 2.

3.6.7.2.3.9.1   **Recommendation.—** *The VHF data broadcast should include additional data block 2 parameters to identify channel numbers and locations of adjacent and nearby GBAS broadcast stations within the GRAS ground subsystem.*

Note.— This facilitates the transition from one GBAS broadcast station to other GBAS broadcast stations in the GRAS ground subsystem.

3.6.7.2.4   *Final approach segment data*

3.6.7.2.4.1   *FAS data points accuracy*. The relative survey error between the FAS data points and the GBAS reference point shall be less than 0.25 metres vertical and 0.40 metres horizontal.

3.6.7.2.4.2   **Recommendation.—** *The final approach segment CRC should be assigned at the time of procedure design, and kept as an integral part of the FAS data block from that time onward.*

3.6.7.2.4.3   **Recommendation.—** *The GBAS should allow the capability to set the FASVAL and FASLAL for any FAS data block to "1111 1111" to limit the approach to lateral only or to indicate that the approach must not be used, respectively.*

3.6.7.2.5   *Predicted ranging source availability data*

Note.— Ranging source availability data are optional for Category I and APV and may be required for possible future operations.

3.6.7.2.6   *Integrity monitoring for GNSS ranging sources*. The ground subsystem shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing for airborne receivers complying with the tracking constraints in Attachment D, 8.11. The ground subsystem shall use the strongest correlation peak in all receivers used to generate the pseudo-range corrections. The monitor time-to-alert shall comply with 3.6.7.1.2. The monitor action shall be to set σ_{pr_gnd} to the bit pattern "1111 1111" for the satellite or to exclude the satellite from the Type 1 or Type 101 message. The ground subsystem shall also detect conditions that cause more than one zero crossing for airborne receivers that use the Early-Late discriminator function as described in Attachment D, 8.11.

3.6.7.3   *MONITORING*

3.6.7.3.1   *RF monitoring*

3.6.7.3.1.1   *VHF data broadcast monitoring*. The data broadcast transmissions shall be monitored. The transmission of the data shall cease within 0.5 seconds in case of continuous disagreement during any 3-second period between the transmitted application data and the application data derived or stored by the monitoring system prior to transmission.

3.6.7.3.1.2   *TDMA slot monitoring*. The risk that the ground subsystem transmits a signal in an unassigned slot and fails to detect an out-of-slot transmission, which exceeds that allowed in 3.6.2.6, within 1 second, shall be less than 1×10^{-7} in any 30-second period. If out-of-slot transmissions are detected, the ground subsystem shall terminate all data broadcast transmissions within 0.5 seconds.

3.6.7.3.1.3   *VDB transmitter power monitor*. The probability that the horizontally or elliptically polarized signal's transmitted power increases by more than 3 dB from the nominal power for more than 1 second shall be less than 2.0×10^{-7} in any 30-second period.

Note.— The vertical component is only monitored for GBAS/E equipment.

3.6.7.3.2   *Data monitoring*

3.6.7.3.2.1   *Broadcast quality monitor*. The ground subsystem monitoring shall comply with the time-to-alert requirements given in 3.6.7.1.2.1. The monitoring action shall be one of the following:

a)   to broadcast Type 1 or Type 101 messages with no measurement blocks; or

b)   to broadcast Type 1 or Type 101 messages with the $\sigma_{pr\_gnd,i}$ field set to indicate the ranging source is invalid for every ranging source included in the previously transmitted frame; or

c)   to terminate the data broadcast.

Note.— Monitoring actions a) and b) are preferred to c) if the particular failure mode permits such a response, because

actions a) and b) typically have a reduced signal-in-space time-to-alert.

3.6.7.4   *FUNCTIONAL REQUIREMENTS FOR AUTHENTICATION PROTOCOLS*

3.6.7.4.1   *Functional requirements for ground subsystems that support authentication*

3.6.7.4.1.1   The ground system shall broadcast the additional data block 4 with the Type 2 message with the slot group definition field coded to indicate which slots are assigned to the ground station.

3.6.7.4.1.2   The ground subsystem shall broadcast every Type 2 message in the slot that corresponds to the SSID coding for the ground subsystem. Slot A is represented by SSID = 0, B by 1, C by 2, and H by 7.

3.6.7.4.1.3   *Assigned slot occupancy*. The ground subsystem shall transmit messages such that 87 per cent or more of every assigned slot is occupied. If necessary, Type 3 messages will be used to fill unused space in any assigned time slot.

3.6.7.4.1.4   *Reference path identifier coding*. Every reference path identifier included in every final approach segment data block broadcast by the ground station via the Type 4 messages shall have the first letter selected to indicate the SSID of the ground station in accordance with the following coding.

```
Coding:  A  =  SSID of 0
         X  =  SSID of 1
         Z  =  SSID of 2
         J  =  SSID of 3
         C  =  SSID of 4
         V  =  SSID of 5
         P  =  SSID of 6
         T  =  SSID of 7
```

3.6.7.4.2   *Functional requirements for ground subsystems that do not support authentication*

3.6.7.4.2.1   *Reference path indicator coding*. Characters in this set: {A X Z J C V P T} shall not be used as the first character of the reference path identifier included in any FAS block broadcast by the ground station via the Type 4 messages.

3.6.8   AIRCRAFT ELEMENTS

3.6.8.1   *GNSS receiver*. The GBAS-capable GNSS receiver shall process signals of GBAS in accordance with the requirements specified in this section as well as with requirements in 3.1.3.1 and/or 3.2.3.1 and/or 3.5.8.1.

3.6.8.2   *PERFORMANCE REQUIREMENTS*

3.6.8.2.1   *GBAS aircraft receiver accuracy*

3.6.8.2.1.1   The RMS of the total aircraft receiver contribution to the error for GPS and GLONASS shall be:

$$RMS_{pr\_air}\,(\theta_n) \le a_0 + a_1 \times e^{-(\theta_n/\theta_0)}$$

where

n   = the nth ranging source;
θ_n = the elevation angle for the nth ranging source; and
$a_0, a_1,$ and θ_0 = as defined in Table B-77 for GPS and Table B-78 for GLONASS.

3.6.8.2.1.2   The RMS of the total aircraft receiver contribution to the error for SBAS satellites shall be as defined in 3.5.8.2.1 for each of the defined aircraft accuracy designators.

Note.— The aircraft receiver contribution does not include the measurement error induced by airframe multipath.

Table B-77.   Aircraft GPS receiver accuracy requirement

Aircraft accuracy designator	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)
A	≥5	0.15	0.43	6.9
B	≥5	0.11	0.13	4

Table B-78.   Aircraft GLONASS receiver accuracy requirement

Aircraft accuracy designator	θ_n (degrees)	a_0 (metres)	a_1 (metres)	θ_0 (degrees)
A	≥5	0.39	0.9	5.7
B	≥5	0.105	0.25	5.5

Note.— The frequency stability of the GBAS ground subsystem, and the worst-case doppler shift due to the motion of the

aircraft, are reflected in the above requirement. The dynamic range of the automatic frequency control should also consider the frequency-stability error budget of the aircraft VHF data broadcast receiver.

3.6.8.2.2.3   *VHF data broadcast sensitivity, range and message failure rate*. The VHF data broadcast receiver shall achieve a message failure rate less than or equal to one failed message per 1 000 full-length (222 bytes) application data messages, while operating over a range from –87 dBm to –1 dBm, provided that the variation in the average received signal power between successive bursts in a given time slot does not exceed 40 dB. Failed messages include those lost by the VHF data broadcast receiver system or which do not pass the CRC after application of the FEC.

Note.— Aircraft VHF data broadcast receiving antenna can be horizontally or vertically polarized. Due to the difference in the signal strength of horizontally and vertically polarized components of the broadcast signal, the total aircraft implementation loss is limited to 15 dB for horizontally polarized receiving antennas and 11 dB for vertically polarized receiving antennas.

3.6.8.2.2.4   *VHF data broadcast time slot decoding*. The VHF data broadcast receiver shall meet the requirements of 3.6.8.2.2.3 for all Type 1, 2 and 4 messages from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

Note.— Other GBAS transmissions may include: a) messages other than Type 1, 2 and 4 with the same SSID, and b) messages with different SSIDs.

3.6.8.2.2.4.1   *Decoding of Type 101 messages*. A VHF data broadcast receiver capable of receiving Type 101 messages, shall meet the requirements of 3.6.8.2.2.3 for all Type 101 messages from the selected GBAS ground subsystem. These requirements shall be met in the presence of other GBAS transmissions in any and all time slots respecting the levels as indicated in 3.6.8.2.2.5.1 b).

3.6.8.2.2.5   *Co-channel rejection*

3.6.8.2.2.5.1   *VHF data broadcast as the undesired signal source*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VHF data broadcast signal that is either:

a)   assigned to the same time slot(s) and 26 dB below the desired VHF data broadcast signal power or lower; or

b)   assigned different time slot(s) and whose power is up to 15 dBm at the receiver input.

3.6.8.2.2.5.2   *VOR as the undesired signal*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of an undesired co-channel VOR signal that is 26 dB below the desired VHF data broadcast signal power.

3.6.8.2.2.6   *Adjacent channel rejection*

3.6.8.2.2.6.1   *First adjacent 25 kHz channels (±25 kHz)*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 25 kHz on either side of the desired channel that is either:

a)   18 dB above the desired signal power when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b)   equal in power when the undesired signal is VOR.

3.6.8.2.2.6.2   *Second adjacent 25 kHz channels (±50 kHz)*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 50 kHz on either side of the desired channel that is either:

a)   43 dB above the desired signal power when the undesired signal is another VHF data broadcast source assigned to the same time slot(s); or

b)   34 dB above the desired signal power when the undesired signal is VOR.

3.6.8.2.2.6.3   *Third and beyond adjacent 25 kHz channels (±75 kHz or more)*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of a transmitted undesired signal offset by 75 kHz or more on either side of the desired channel that is either:

a)   46 dB above the desired signal power when the undesired signal is another VHF data broadcast signal assigned to the same time slot(s); or

b)   46 dB above the desired signal power when the undesired signal is VOR.

3.6.8.2.2.7   *Rejection of off-channel signals from sources inside the 108.000 – 117.975 MHz band*. With no on-channel VHF data broadcast signal present, the VHF data broadcast receiver shall not output data from an undesired VHF data broadcast signal on any other assignable channel.

3.6.8.2.2.8   *Rejection of signals from sources outside the 108.000 – 117.975 MHz band*

3.6.8.2.2.8.1   *VHF data broadcast interference immunity*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of one or more signals having the frequency and total interference levels specified in Table B-79.

3.6.8.2.2.8.2   *Desensitization*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of VHF FM broadcast signals with signal levels shown in Tables B-80 and B-81.

Table B-79. Maximum levels of undesired signals

Frequency	Maximum level of undesired signals at the receiver input (dBm)
50 kHz up to 88 MHz	−13
88 MHz – 107.900 MHz	(see 3.6.8.2.2.8.2)
108.000 MHz – 117.975 MHz	excluded
118.000 MHz	−44
118.025 MHz	−41
118.050 MHz up to 1 660.5 MHz	−13

Notes.—

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

2.   These interference immunity requirements may not be adequate to ensure compatibility between VHF data broadcast receivers and VHF communication systems, particularly for aircraft that use the vertically polarized component of the VHF data broadcast. Without coordination between COM and NAV frequencies assignments or respect of a guard band at the top end of the 112 – 117.975 MHz band, the maximum levels quoted at the lowest COM VHF channels (118.000, 118.00833, 118.01666, 118.025, 118.03333, 118.04166, 118.05) may be exceeded at the input of the VDB receivers. In that case, some means to attenuate the COM signals at the input of the VDB receivers (e.g. antenna separation) will have to be implemented. The final compatibility will have to be assured when equipment is installed on the aircraft.

**Table B-80.   Desensitization frequency and power requirements
that apply for VDB frequencies from 108.025 to 111.975 MHz**

Frequency	Maximum level of undesired signals at the receiver input (dBm)
88 MHz ≤ f ≤ 102 MHz	15
104 MHz	10
106 MHz	5
107.9 MHz	−10

Notes.—

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

2.   This desensitization requirement is not applied for FM carriers above 107.7 MHz and VDB channels at 108.025 or 108.050 MHz. See Attachment D, 7.2.1.2.2.

**Table B-81.   Desensitization frequency and power requirements
that apply for VDB frequencies from 112.000 to 117.975 MHz**

Frequency	Maximum level of undesired signals at the receiver input (dBm)
88 MHz $\leq$ f $\leq$ 104 MHz	15
106 MHz	10
107 MHz	5
107.9 MHz	0

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

3.6.8.2.2.8.3   *VHF data broadcast FM intermodulation immunity*. The VHF data broadcast receiver shall meet the requirements specified in 3.6.8.2.2.3 in the presence of interference from two-signal, third-order intermodulation products of two VHF FM broadcast signals having levels in accordance with the following:

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

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

$$2N_1 + N_2 + 3\left(24 - 20\log\frac{\Delta f}{0.4}\right) \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDB frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VHF data broadcast receiver input. Neither level shall exceed the desensitization criteria set forth in 3.6.8.2.2.8.2.

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

Note.— The FM intermodulation immunity requirements are not applied to a VHF data broadcast channel operating below 108.1 MHz, hence frequencies below 108.1 MHz are not intended for general assignments. Additional information is provided in Attachment D, 7.2.1.2.

3.6.8.3   *AIRCRAFT FUNCTIONAL REQUIREMENTS*

3.6.8.3.1   *Conditions for use of data*

3.6.8.3.1.1   The receiver shall use data from a GBAS message only if the CRC of that message has been verified.

3.6.8.3.1.2   The receiver shall use message data only if the message block identifier is set to the bit pattern "1010 1010".

3.6.8.3.1.2.1   *GBAS message processing capability.* The GBAS receiver shall at a minimum process GBAS message types in accordance with Table B-82.

Table B-82.   Airborne equipment message type processing

Airborne equipment designed performance	Minimum message types processed
APV-I	MT 1 or 101, MT 2 (including ADB 1 and 2 if provided)
APV-II	MT 1, MT 2 (including ADB 1 and 2 if provided), MT 4
Category I	MT 1, MT 2 (including ADB 1 if provided), MT 4

3.6.8.3.1.2.2   *Airborne processing for forward compatibility*

Note.— Provisions have been made to enable future expansion of the GBAS Standards to support new capabilities. New message types may be defined, new additional data blocks for message Type 2 may be defined and new data blocks defining reference paths for inclusion within message Type 4 may be defined. To facilitate these future expansions, all equipment should be designed to properly ignore all data types that are not recognized.

3.6.8.3.1.2.2.1   *Processing of unknown message types.* The existence of messages unknown to the airborne receiver shall not prevent correct processing of the required messages.

3.6.8.3.1.2.2.2   *Processing of unknown Type 2 extended data blocks.* The existence of message Type 2 additional data blocks unknown to the airborne receiver shall not prevent correct processing of the required messages.

3.6.8.3.1.2.2.3   *Processing of unknown Type 4 data blocks.* The existence of message Type 4 data blocks unknown to the airborne receiver shall not prevent correct processing of the required messages.

Note.— While the current SARPs include only one definition of a data block for inclusion within a Type 4 message, future GBAS Standards may include other reference path definitions.

3.6.8.3.1.3   The receiver shall use only ranging source measurement blocks with matching modified Z-counts.

3.6.8.3.1.4   If D_{max} is broadcast by the ground subsystem, the receiver shall only apply pseudo-range corrections when the distance to the GBAS reference point is less than D_{max}.

3.6.8.3.1.5   The receiver shall only apply pseudo-range corrections from the most recently received set of corrections for a given measurement type. If the number of measurement fields in the most recently received Type 1 or Type 101 message indicates that there are no measurement blocks, then the receiver shall not apply GBAS corrections for that measurement type.

3.6.8.3.1.6   The receiver shall exclude from the differential navigation solution any ranging sources for which σ_{pr_gnd} is set to the bit pattern "1111 1111".

3.6.8.3.1.7   The receiver shall only use a ranging source in the differential navigation solution if the time of applicability indicated by the modified Z-count in the Type 1 or Type 101 message containing the ephemeris decorrelation parameter for that ranging source is less than 120 seconds old.

3.6.8.3.1.8   *Conditions for use of data to support Category I precision approach and APV*

3.6.8.3.1.8.1   During the final stages of a Category I or APV approach, the receiver shall use only measurement blocks from Type 1 or Type 101 messages that were received within the last 3.5 seconds.

3.6.8.3.1.8.2   The receiver shall use message data from a GBAS ground subsystem for Category I precision approach or APV guidance only if the GCID indicates 1, 2, 3 or 4 prior to initiating the final stages of an approach.
3.6.8.3.1.8.3   The receiver shall ignore any changes in GCID during the final stages of an approach.

3.6.8.3.1.8.4   The receiver shall not provide approach vertical guidance based on a particular FAS data block transmitted in a Type 4 message if the FASVAL received prior to initiating the final stages of the approach is set to "1111 1111".

3.6.8.3.1.8.5   The receiver shall not provide approach guidance based on a particular FAS data block transmitted in a Type 4 message if the FASLAL received prior to initiating the final stages of the approach is set to "1111 1111".

3.6.8.3.1.8.6   Changes in the values of FASLAL and FASVAL data transmitted in a Type 4 message during the final stages of an approach shall be ignored by the receiver.

3.6.8.3.1.8.7   The receiver shall use FAS data only if the FAS CRC for that data has been verified.

3.6.8.3.1.8.8   The receiver shall only use messages for which the GBAS ID (in the message block header) matches the GBAS ID in the header of the Type 4 message which contains the selected FAS data or the Type 2 message which contains

the selected RSDS.

3.6.8.3.1.8.9   *Use of FAS data*

3.6.8.3.1.8.9.1   The receiver shall use the Type 4 messages to determine the FAS for precision approach.

3.6.8.3.1.8.9.2   The receiver shall use the Type 4 messages to determine the FAS for APV associated with a channel number between 20 001 and 39 999.

3.6.8.3.1.8.9.3   The receiver shall use the FAS held within the on-board database for APV associated with a channel number between 40 000 and 99 999.

3.6.8.3.1.8.10   When the GBAS ground subsystem does not broadcast the Type 4 message and the selected FAS data are available to the receiver from an airborne database, the receiver shall only use messages from the intended GBAS ground subsystem.

3.6.8.3.1.9   *Conditions for use of data to provide the GBAS positioning service*

3.6.8.3.1.9.1   The receiver shall only use measurement blocks from Type 1 messages that were received within the last 7.5 seconds.

3.6.8.3.1.9.2   The receiver shall only use measurement blocks from Type 101 messages that were received within the last 5 seconds.

3.6.8.3.1.9.3   The receiver shall only use message data if a Type 2 message containing additional data block 1 has been received and the RSDS parameter in this block indicates that the GBAS positioning service is provided.

3.6.8.3.1.9.4   The receiver shall only use messages for which the GBAS ID (in the message block header) matches the GBAS ID in the header of the Type 2 message which contains the selected RSDS.

3.6.8.3.2   *Integrity*

3.6.8.3.2.1   *Bounding of aircraft errors.* For each satellite used in the navigation solution, the receiver shall compute a $\sigma_{receiver}$ such that a normal distribution with zero mean and a standard deviation equal to $\sigma_{receiver}$ bounds the receiver contribution to the corrected pseudo-range error as follows:

$$\int_{y}^{\infty} f(x)\,dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \ge 0 \text{ and}$$

$$\int_{-\infty}^{-y} f(x)\,dx \le Q\left(\frac{y}{\sigma}\right) \text{ for all } \frac{y}{\sigma} \ge 0$$

where

$f(x)$ = probability density function of the residual aircraft pseudo-range error and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}}\,dt.$$

3.6.8.3.2.2   *Use of GBAS integrity parameters*. The aircraft element shall compute and apply the vertical, lateral and horizontal protection levels described in 3.6.5.5 using the GBAS broadcast σ_{pr_gnd}, σ_N, h_0, $\sigma_{vert\_iono\_gradient}$, and B parameters as well as the σ_{pr_air} parameter. If a $B_{i,j}$ parameter is set to the bit pattern "1000 0000" indicating that the measurement is not available, the aircraft element shall assume that $B_{i,j}$ has a value of zero. For Category I precision approach and APV, the aircraft element shall verify that the computed vertical and lateral protection levels are smaller than the corresponding vertical and lateral alert limits defined in 3.6.5.6.

3.6.8.3.3   *Use of satellite ephemeris data*

3.6.8.3.3.1   *IOD check.* The receiver shall only use satellites for which the IOD broadcast by GBAS in the Type 1 or Type 101 message matches the core satellite constellation IOD for the clock and ephemeris data used by the receiver.

3.6.8.3.3.2   *CRC check*. The receiver shall compute the ephemeris CRC for each core satellite constellation's ranging source used in the position solution. The computed CRC shall be validated against the ephemeris CRC broadcast in the Type 1 or Type 101 messages within one second of receiving a new broadcast CRC. The receiver shall immediately cease using any satellite for which the computed and broadcast CRC values fail to match.
    Note.— *During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the broadcast ephemeris CRC for that satellite.*
3.6.8.3.3.3   *Ephemeris error position bounds*

3.6.8.3.3.3.1   *Ephemeris error position bounds for Category I precision approach and APV*. If the ground subsystem provides additional data block 1 in the Type 2 messages, the aircraft element shall compute the ephemeris error position bounds defined in 3.6.5.8.1 for each core satellite constellation's ranging source used in the position solution within 1s of receiving the necessary broadcast parameters. The aircraft element shall exclude from the position solution satellites for which the computed vertical or lateral ephemeris error position bounds (VEB_j or LEB_j) are larger than the corresponding

vertical and lateral alert limits defined in 3.6.5.6.

Note.— During initial acquisition of the VHF data broadcast, the receiver may incorporate a satellite into the position solution before receiving the necessary broadcast parameters for that satellite to compute the ephemeris error position bounds.

3.6.8.3.3.3.2   *Ephemeris error position bound for the GBAS positioning service*. The aircraft element shall compute and apply the horizontal ephemeris error position bound (HEB_j) defined in 3.6.5.8.2 for each core satellite constellation's ranging source used in the position solution.

3.6.8.3.4   *Message loss*

3.6.8.3.4.1   For Category I precision approach, the receiver shall provide an appropriate alert if no Type 1 or Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.2   For APV, the receiver shall provide an appropriate alert if no Type 1 and no Type 101 message was received during the last 3.5 seconds.

3.6.8.3.4.3   For the GBAS positioning service using Type 1 messages, the receiver shall provide an appropriate alert if no Type 1 message was received during the last 7.5 seconds.

3.6.8.3.4.4   For the GBAS positioning service using Type 101 messages, the receiver shall provide an appropriate alert if no Type 101 message was received during the last 5 seconds.

3.6.8.3.5   *Airborne pseudo-range measurements*

3.6.8.3.5.1   *Carrier smoothing for airborne equipment*. Airborne equipment shall utilize the standard 100-second carrier smoothing of code phase measurements defined in 3.6.5.1. During the first 100 seconds after filter start-up, the value of α shall be either:

   a)   a constant equal to the sample interval divided by 100 seconds; or

   b)   a variable quantity defined by the sample interval divided by the time in seconds since filter start-up.

3.7   Resistance to interference

 3.7.1 PERFORMANCE OBJECTIVES

Note 1.— For unaugmented GPS and GLONASS receivers the resistance to interference is measured with respect to the following performance parameters:

	GPS	*GLONASS*
Tracking error (1 sigma)	*0.4 m*	*0.8 m*

Note 2.— This tracking error neither includes contributions due to signal propagation such as multipath, tropospheric and ionospheric effects nor ephemeris and GPS and GLONASS satellite clock errors.

Note 3.— For SBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.5.8.2.1 and 3.5.8.4.1.

Note 4.— For GBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.6.7.1.1 and 3.6.8.2.1.

Note 5.— The signal levels specified in this section are defined at the antenna port.

Note 6.— The performance requirements are to be met in the interference environments defined below for various phases of flight.

3.7.2   CONTINUOUS WAVE (CW) INTERFERENCE

3.7.2.1   *GPS AND SBAS RECEIVERS*

3.7.2.1.1   GPS and SBAS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-83 and shown in Figure B-15 and with a desired signal level of −164.5 dBW at the antenna port.

3.7.2.1.2   GPS and SBAS receivers used for non-precision approach shall meet the performance objectives with interference thresholds 3 dB less than specified in Table B-83. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the interference thresholds shall be 6 dB less than those specified in Table B-83.

Table B-83.   CW interference thresholds for GPS and SBAS receivers

Frequency range fi of the interference signal	Interference thresholds for receivers used for precision approach phase of flight

$f_i \leq 1\,315$ MHz	–4.5 dBW
1 315 MHz < $f_i \leq 1\,525$ MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 525 MHz < $f_i \leq 1\,565.42$ MHz	Linearly decreasing from –42 dBW to –150.5 dBW
1 565.42 MHz < $f_i \leq 1\,585.42$ MHz	–150.5 dBW
1 585.42 MHz < $f_i \leq 1\,610$ MHz	Linearly increasing from –150.5 dBW to –60 dBW
1 610 MHz < $f_i \leq 1\,618$ MHz	Linearly increasing from –60 dBW to –42 dBW*
1 618 MHz < $f_i \leq 2\,000$ MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 610 MHz < $f_i \leq 1\,626.5$ MHz	Linearly increasing from –60 dBW to –22 dBW**
1 626.5 MHz < $f_i \leq 2\,000$ MHz	Linearly increasing from –22 dBW to –8.5 dBW**
$f_i > 2\,000$ MHz	–8.5 dBW

*   *Applies to aircraft installations where there are no on-board satellite communications.*
** *Applies to aircraft installations where there is on-board satellite communications.*

3.7.2.2 *GLONASS RECEIVERS*

3.7.2.2.1 GLONASS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-84 and shown in Figure B-16 and with a desired signal level of –165.5 dBW at the antenna port.

Table B-84.   Interference threshold for GLONASS receivers

Frequency range fi of the interference signal	Interference thresholds for receivers used for precision approach phase of flight
$f_i \leq 1\ 315$ MHz	–4.5 dBW
1 315 MHz < $f_i \leq 1\ 562.15625$ MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 562.15625 MHz < $f_i \leq 1\ 583.65625$ MHz	Linearly decreasing from –42 dBW to –80 dBW
1 583.65625 MHz < $f_i \leq 1\ 592.9525$ MHz	Linearly decreasing from –80 dBW to –149 dBW
1 592.9525 MHz < $f_i \leq 1\ 609.36$ MHz	–149 dBW
1 609.36 MHz < $f_i \leq 1\ 613.65625$ MHz	Linearly increasing from –149 dBW to –80 dBW
1 613.65625 MHz < $f_i \leq 1\ 635.15625$ MHz	Linearly increasing from –80 dBW to –42 dBW*
1 613.65625 MHz < $f_i \leq 1\ 626.15625$ MHz	Linearly increasing from –80 dBW to –22 dBW**
1 635.15625 MHz < $f_i \leq 2\ 000$ MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 626.15625 MHz < $f_i \leq 2\ 000$ MHz	Linearly increasing from –22 dBW to –8.5 dBW**
$f_i > 2\ 000$ MHz	–8.5 dBW

* *Applies to aircraft installations where there are no on-board satellite communications.*
** *Applies to aircraft installations where there is on-board satellite communications.*

3.7.2.2.2 GLONASS receivers used for non-precision approach shall meet the performance objectives with interference thresholds 3 dB less than specified in Table B-84. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GLONASS signals prior to steady-state navigation, the interference thresholds shall be 6 dB less than those specified in Table B-84.

3.7.3 BAND-LIMITED NOISE-LIKE INTERFERENCE

3.7.3.1 *GPS AND SBAS RECEIVERS*

3.7.3.1.1 After steady-state navigation has been established, GPS and SBAS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives with noise- like interfering signals present in the frequency range of 1 575.42 MHz ±Bw$_i$/2 and with power levels at the antenna port equal to the interference thresholds specified in Table B-85 and Figure B-17 and with the desired signal level of –164.5 dBW at the antenna port.

Note.— Bw$_i$ is the equivalent noise bandwidth of the interference signal.

3.7.3.1.2 GPS and SBAS receivers used for non-precision approach shall meet their performance objectives with interference thresholds for band-limited noise-like signals 3 dB less than specified in Table B-85. For terminal area and en-route steady-state navigation operations and for initial acquisition of the GPS and SBAS signals prior to steady-state navigation, the interference thresholds for band-limited noise-like signals shall be 6 dB less than those specified in Table B-85.

3.7.3.2 *GLONASS RECEIVERS*

3.7.3.2.1   After steady-state navigation has been established, GLONASS receivers used for the precision approach phase of flight or used on aircraft with on-board satellite communications shall meet the performance objectives while receiving noise-like interfering signals in the frequency band $f_k \pm Bw_i/2$, with power levels at the antenna port equal to the interference thresholds defined in Table B-86 and with a desired signal level of −165.5 dBW at the antenna port.

Note.— f_k is the centre frequency of a GLONASS channel with f_k = 1 602 MHz + k × 0.6525 MHz and k = −7 to +13 as defined in Table B-16 and Bw_i is the equivalent noise bandwidth of the interference signal.

3.7.3.2.2   GLONASS receivers used for non-precision approach shall meet their performance objectives with interference thresholds for band-limited noise-like signals 3 dB less than specified in Table B-85. For terminal area and en- route steady-state navigation operations, and for initial acquisition of the GLONASS signals prior to steady-state navigation, the interference thresholds for band-limited noise-like signals shall be 6 dB less than those specified in Table B-86.

Note.— For the approach phase of flight it is assumed that the receiver operates in tracking mode and acquires no new satellites.

3.7.3.3   *Pulsed interference*. After steady-state navigation has been established, the receiver shall meet the performance objectives while receiving pulsed interference signals with characteristics according to Table B-87 where the interference threshold is defined at the antenna port.

3.7.3.4   SBAS and GBAS receivers shall not output misleading information in the presence of interference including interference levels above those specified in 3.7.

Note.— Guidance material on this requirement is given in Attachment D, 10.6.

3.8   GNSS aircraft satellite receiver antenna

3.8.1   *Antenna coverage*. The GNSS antenna shall meet the performance requirements for the reception of GNSS satellite signals from 0 to 360 degrees in azimuth and from 0 to 90 degrees in elevation relative to the horizontal plane of an aircraft in level flight.

3.8.2   *Antenna gain*. The minimum antenna gain shall not be less than that shown in Table B-88 for the specified elevation angle above the horizon. The maximum antenna gain shall not exceed +4 dBic for elevation angles above 5 degrees.

3.8.3   *Polarization*. The GNSS antenna polarization shall be right-hand circular (clockwise with respect to the direction of propagation).

3.9   Cyclic redundancy check

Each CRC shall be calculated as the remainder, R(x), of the Modulo-2 division of two binary polynomials as follows:

$$\left\{ \frac{[x^k M(x)]}{G(x)} \right\}_{mod\ 2} = Q(x) + \frac{R(x)}{G(x)}$$

where

k   = the number of bits in the particular CRC;
M(x) = the information field, which consists of the data items to be protected by the particular CRC represented as a polynomial;
G(x) = the generator polynomial specified for the particular CRC; Q(x) = the quotient of the division; and

R(x) = the remainder of the division, contains the CRC:

$$R(x) = \sum_{i=1}^{k} r_i x^{k-i} = r_1 x^{k-1} + r_2 x^{k-2} + ... + r_k x^0$$

Table B-85.   Interference threshold for band-limited noise-like interference to GPS and SBAS receivers used for precision approach

Interference bandwidth	Interference threshold
$0\ Hz < Bw_i \le 700\ Hz$	-150.5 dBW
$700\ Hz < Bw_i \le 10\ kHz$	$-150.5 + 6\log_{10}(BW/700)$ dBW
$10\ kHz < Bw_i \le 100\ kHz$	$-143.5 + 3\log_{10}(BW/10000)$ dBW
$100\ kHz < Bw_i \le 1\ MHz$	-140.5 dBW
$1\ MHz < Bw_i \le 20\ MHz$	Linearly increasing from -140.5 to -127.5 dBW*
$20\ MHz < Bw_i \le 30\ MHz$	Linearly increasing from -127.5 to -121.1 dBW*
$30\ MHz < Bw_i \le 40\ MHz$	Linearly increasing from -121.1 to -119.5 dBW*
$40\ MHz < Bw_i$	-119.5 dBW*

* The interference threshold is not to exceed -140.5 dBW/MHz in the frequency range 1 575.42 ±10 MHz.

Table B-86.   Interference threshold for band-limited noise-like interference to GLONASS receivers used for precision approach

Interference bandwidth	Interference threshold
$0\ Hz < Bw_i \le 1\ kHz$	-149 dBW
$1\ kHz < Bw_i \le 10\ kHz$	Linearly increasing from -149 to -143 dBW
$10\ kHz < Bw_i \le 0.5\ MHz$	-143 dBW
$0.5\ MHz < Bw_i \le 10\ MHz$	Linearly increasing from -143 to -130 dBW
$10\ MHz < Bw_i$	-130 dBW

Table B-87.   Interference thresholds for pulsed interference

	GPS and SBAS	GLONASS
Frequency range	1 575.42 MHz ± 10 MHz	1 592.9525 MHz to 1 609.36 MHz
Interference threshold (Pulse peak power) Pulse width	-20 dBW	-20 dBW
Pulse duty cycle	$\le$125 µs	$\le$250 µs
	$\le$1%	$\le$1%

Table B-88.   Minimum antenna gain — GPS, GLONASS and SBAS

Elevation angle degrees	Minimum gain dBic
0	-7
5	-5.5
10	-4
15 to 90	-2.5

Note.— The –5.5 dBic gain at 5 degrees elevation angle is appropriate for an L1 antenna. A higher gain may be required in the future for GNSS signals in the L5/E5 band.
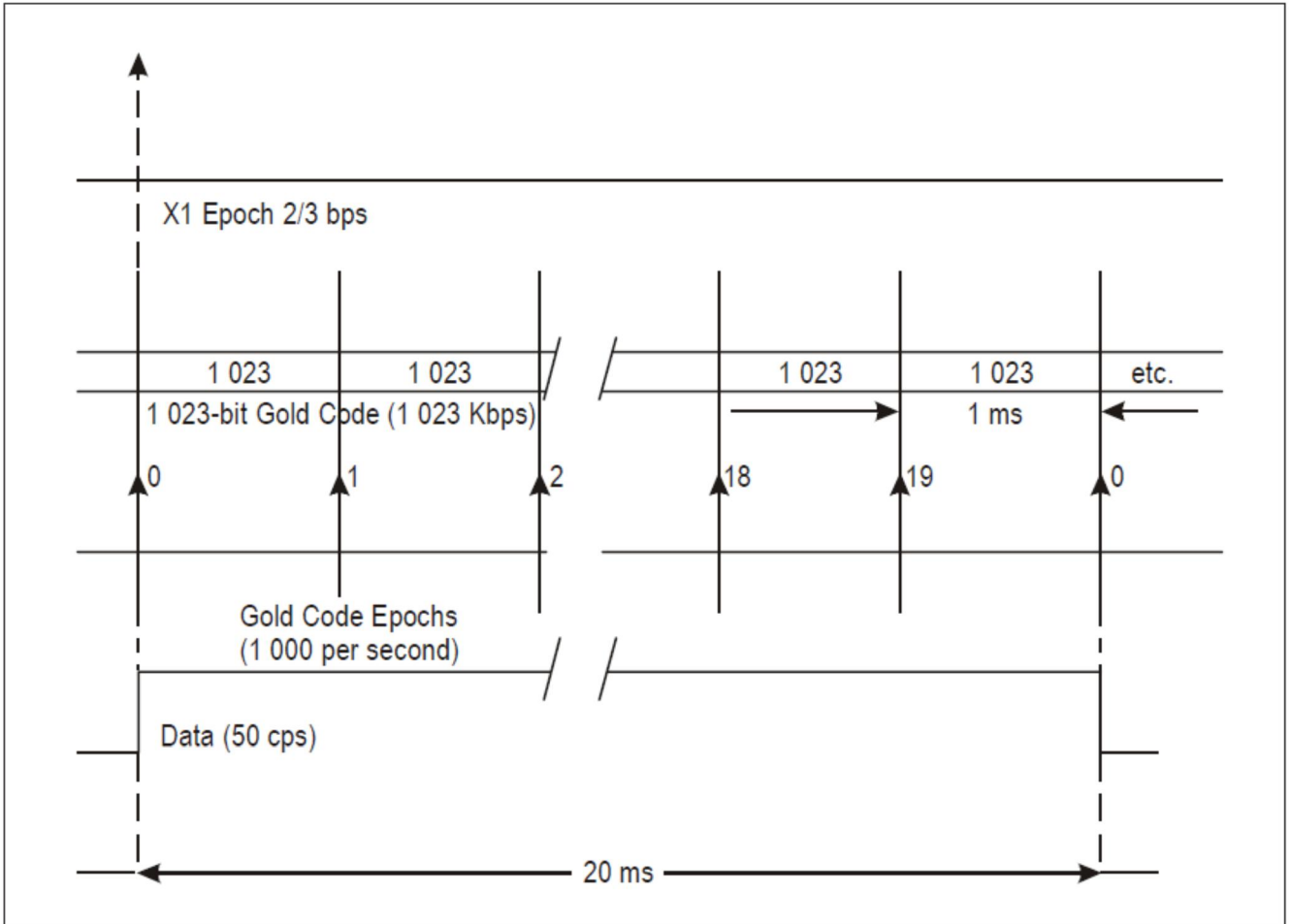
Figure B-1.   C/A code timing relationships

SUBFRAME 1	TLM	HOW	GPS week number, SV accuracy and health
SUBFRAME 2	TLM	HOW	Ephemeris parameters
SUBFRAME 3	TLM	HOW	Ephemeris parameters
SUBFRAME 4 (25 pages)	TLM	HOW	Almanac and health for satellites 25–32, special messages, satellite configuration, flags, ionospheric and UTC
SUBFRAME 5 (25 pages)	TLM	HOW	Almanac and health for satellites 1–24 and almanac reference time and GPS week number

Figure B-2.   Frame structure

Preamble								Reserved																Parity					
1	0	0	0	1	0	1	1	MSB															LSB						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Figure B-3.   TLM word format

TOW count message																		Subframe ID					Parity					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
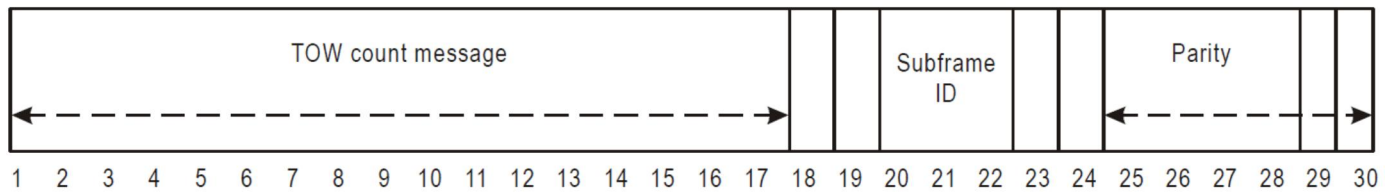
Figure B-4.   HOW format
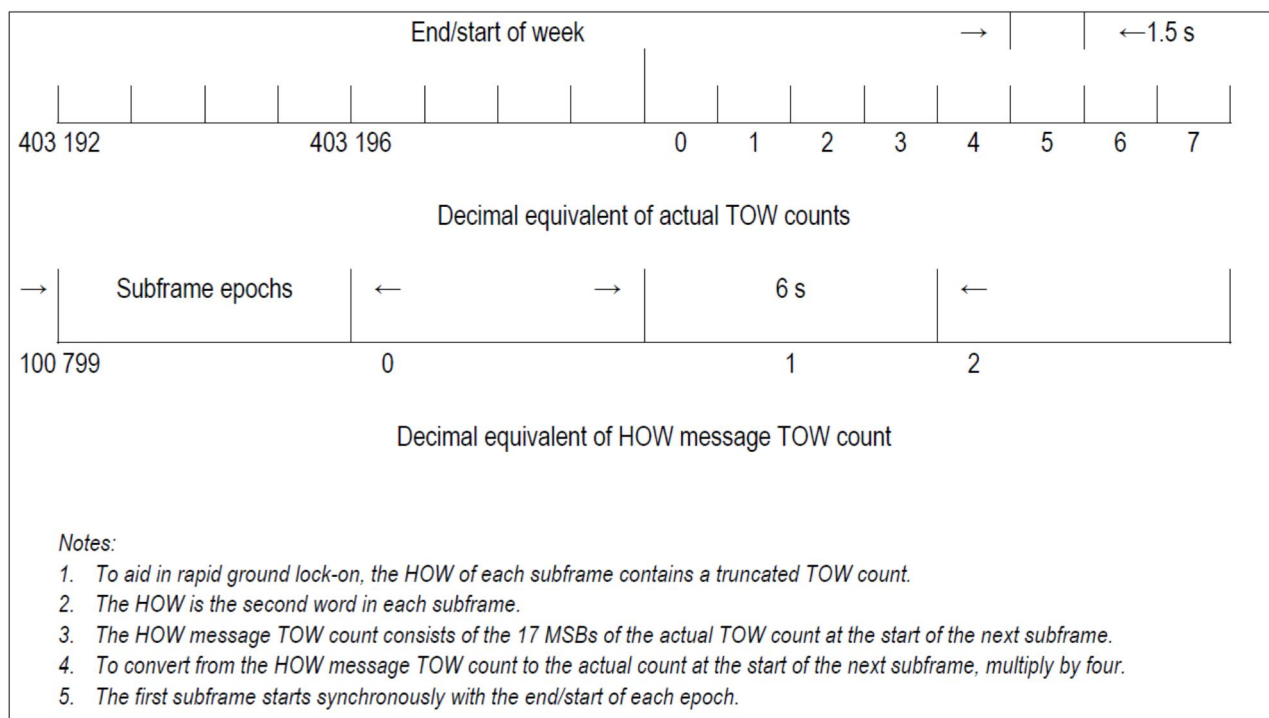
Figure B-5.   Time line relationship of HOW

Figure B-6. **Data format** (1 of 11)
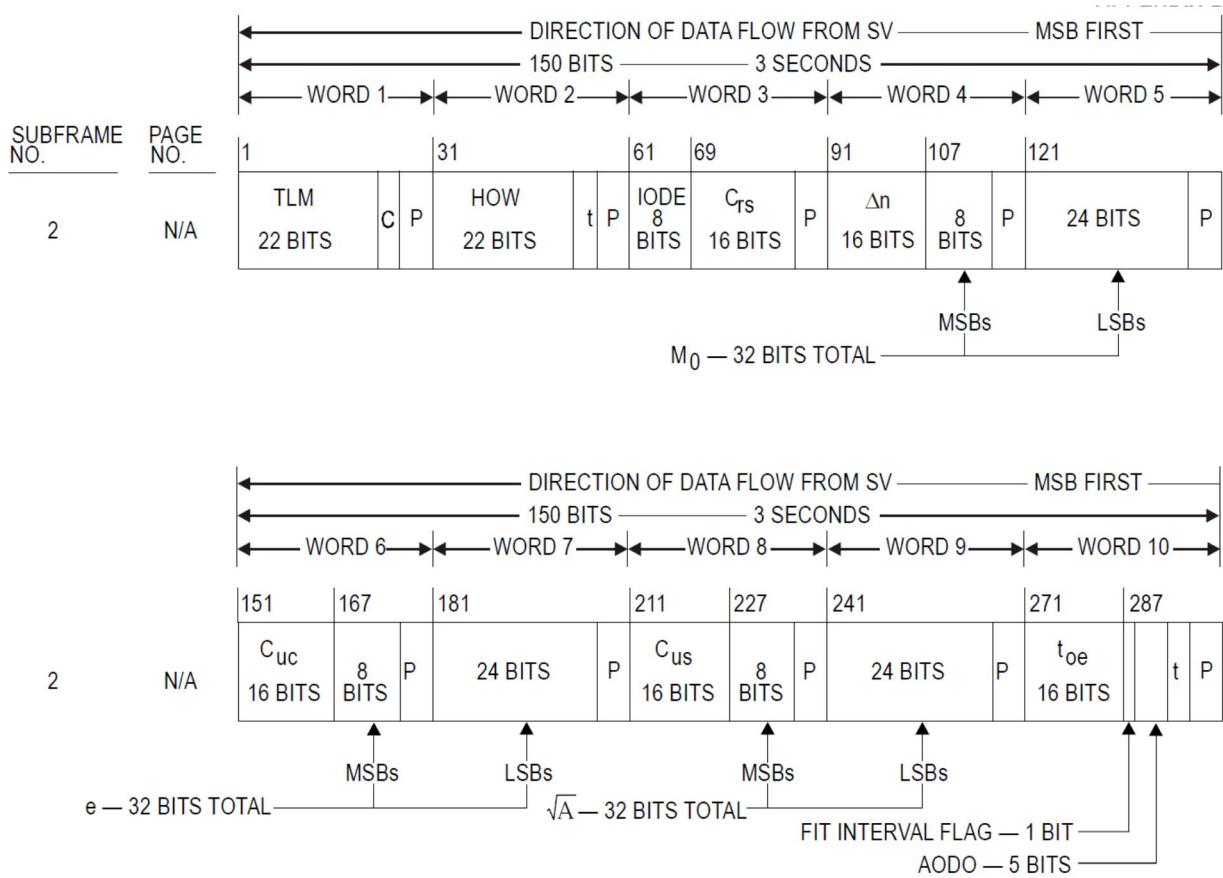
Figure B-6.   Data format (2 of 11)
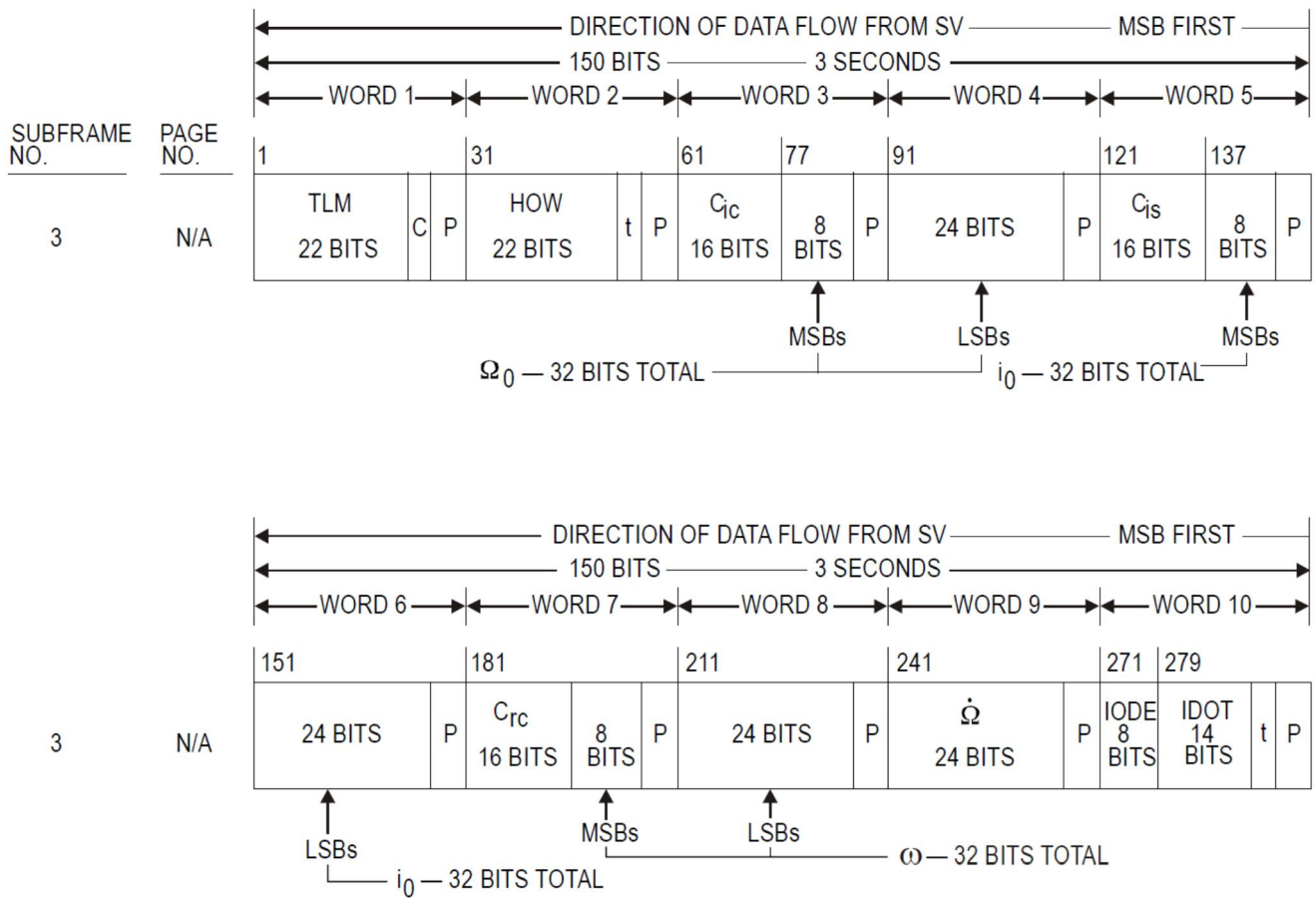
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED
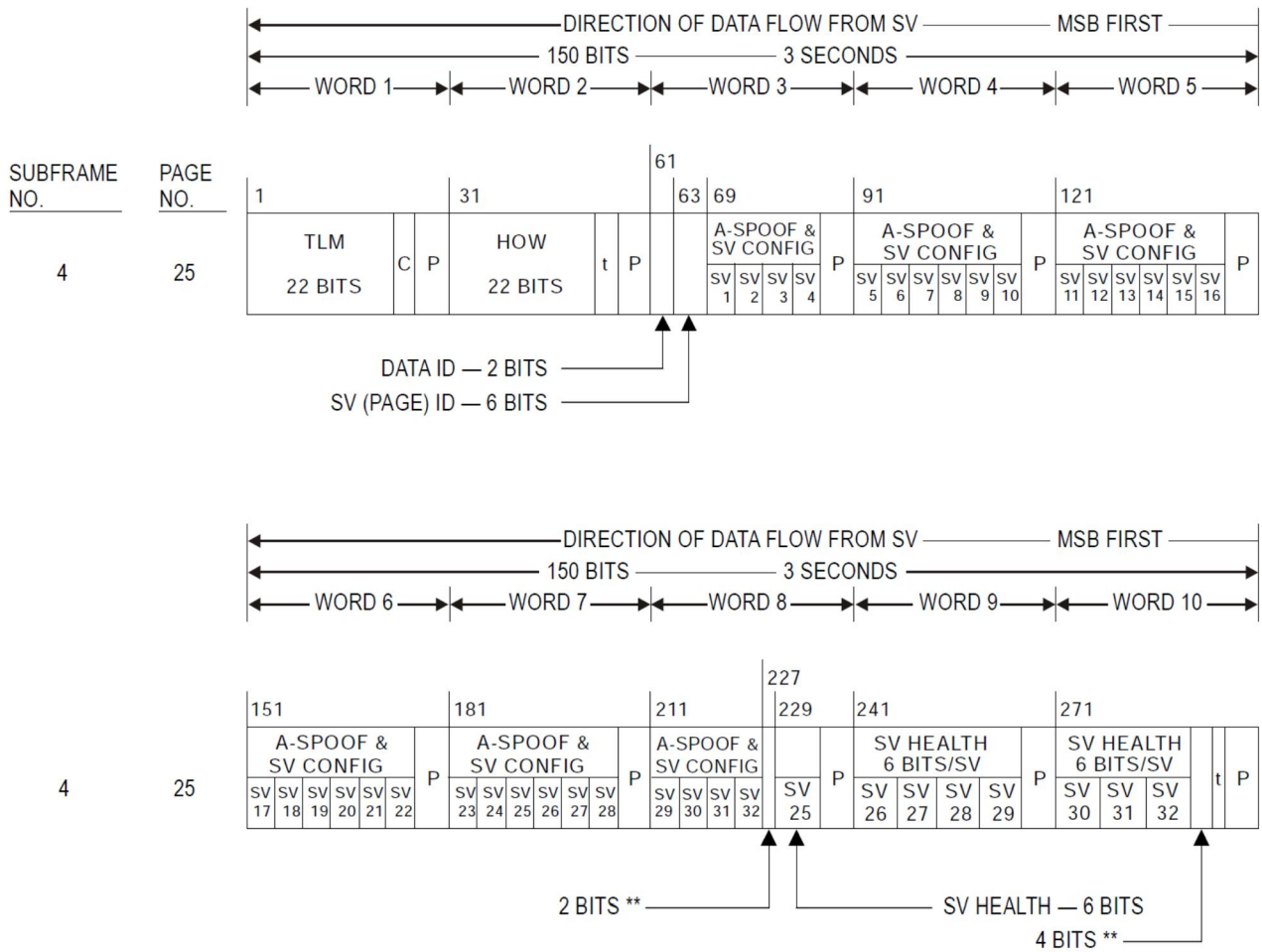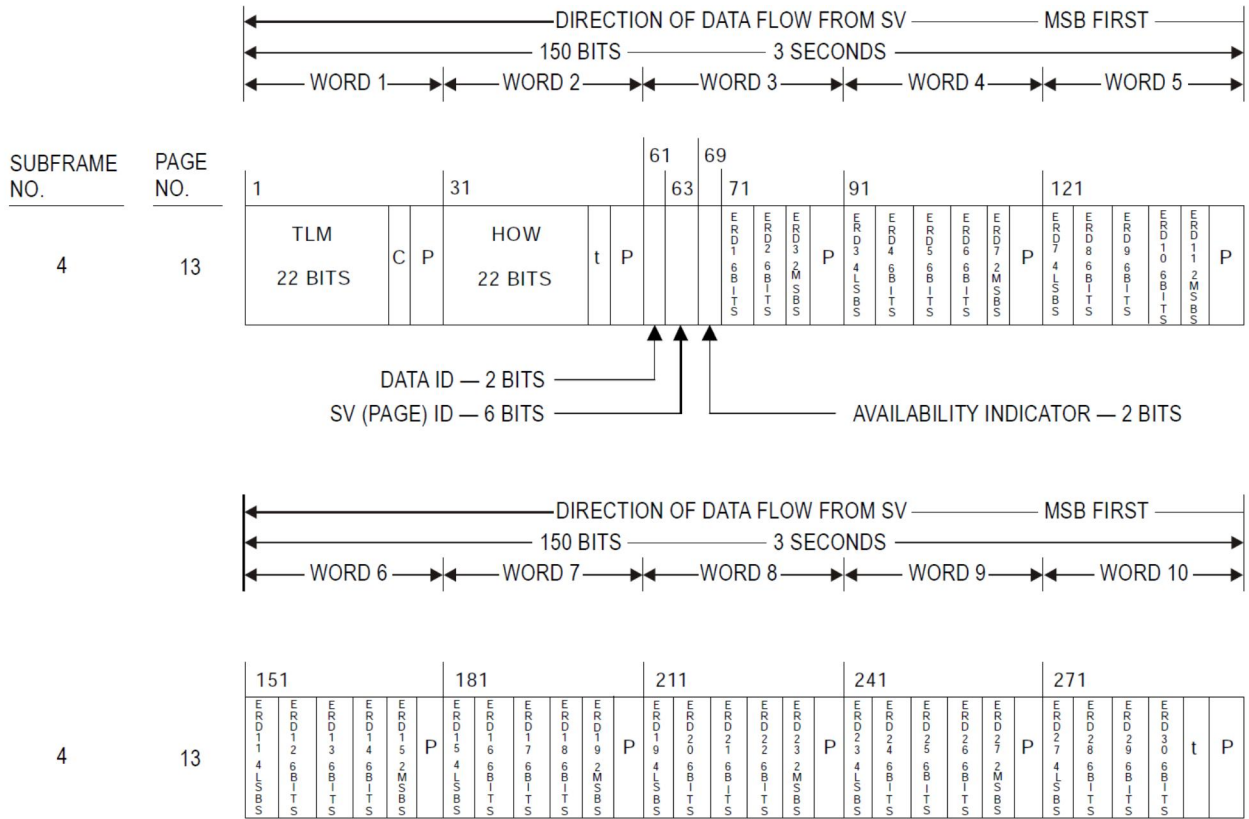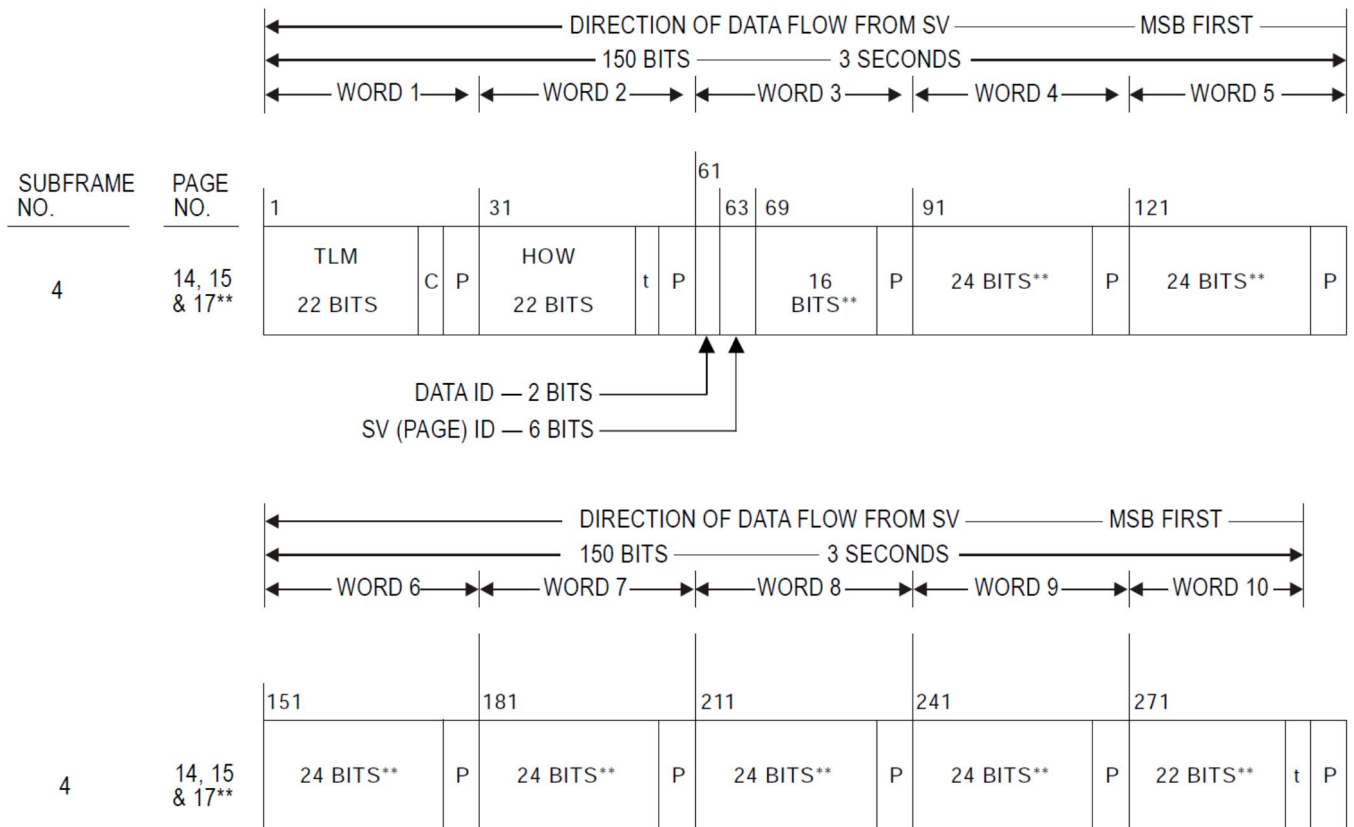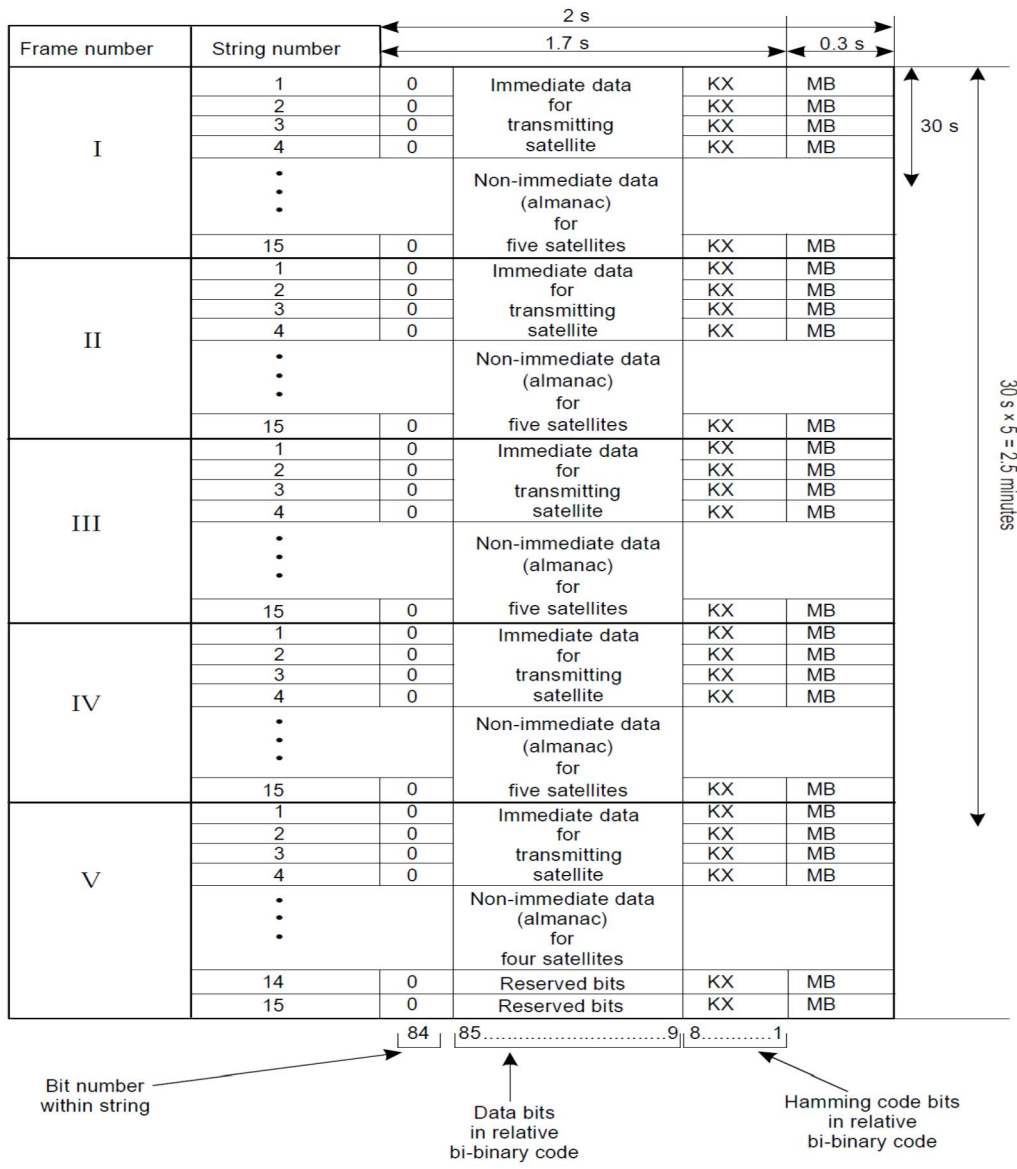
Figure B-6.   Data format (3 of 11)
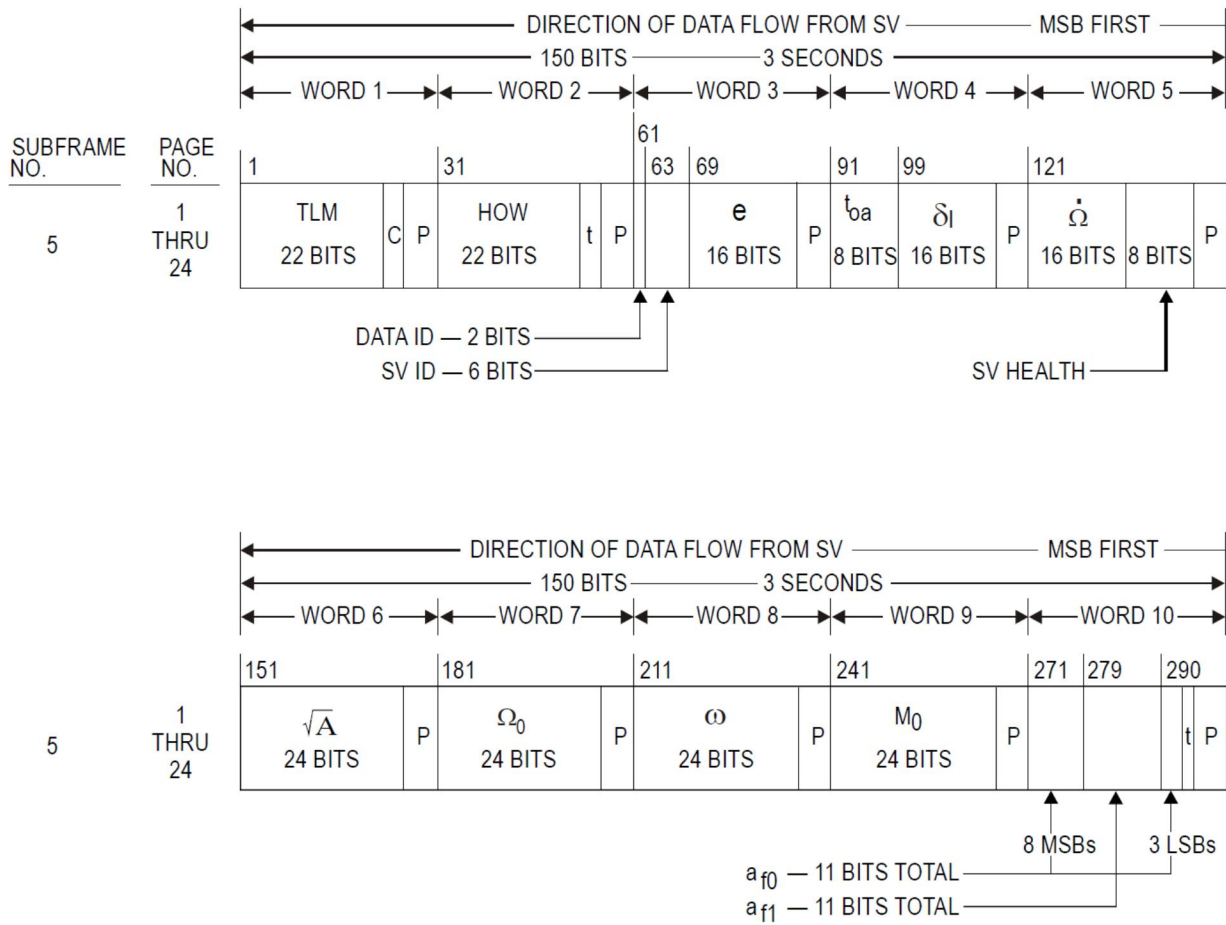
P = 6 PARITY BITS
t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION
C = TLM BITS 23 AND 24 WHICH ARE RESERVED
Note.— Pages 2, 3, 4, 5, 7, 8, 9 and 10 of subframe 4 have the same format as pages 1 through 24 of subframe 5.

Figure B-6.   Data format (4 of 11)

Figure B-6.   Data format (5 of 11)

Figure B-6. Data format (6 of 11)
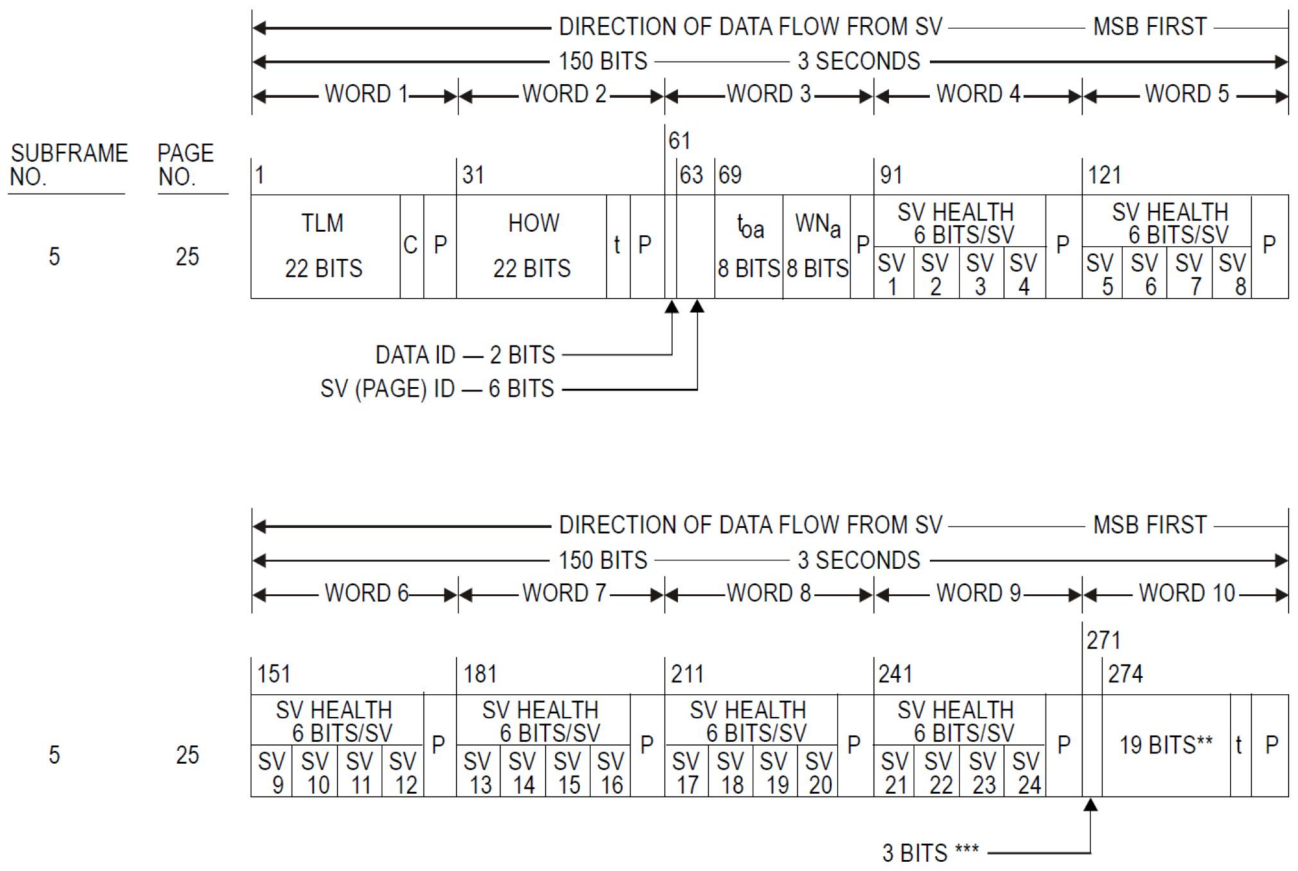
** RESERVED FOR SYSTEM USE

*** RESERVED

P = 6 PARITY BITS

t = 2 NON-INFORMATION BEARING BITS USED FOR PARITY COMPUTATION

C = TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure B-6.   Data format (7 of 11)

Figure B-6.   Data format (8 of 11)

Figure B-6.   Data format (9 of 11)

Figure B-6.   Data format (10 of 11)

Figure B-6.   Data format (11 of 11)

Frame number	String number				
I	1	0	Immediate data	KX	MB
	2	0	for	KX	MB
	3	0	transmitting	KX	MB
	4	0	satellite	KX	MB
	• • •		Non-immediate data (almanac) for		
	15	0	five satellites	KX	MB
II	1	0	Immediate data	KX	MB
	2	0	for	KX	MB
	3	0	transmitting	KX	MB
	4	0	satellite	KX	MB
	• • •		Non-immediate data (almanac) for		
	15	0	five satellites	KX	MB
III	1	0	Immediate data	KX	MB
	2	0	for	KX	MB
	3	0	transmitting	KX	MB
	4	0	satellite	KX	MB
	• • •		Non-immediate data (almanac) for		
	15	0	five satellites	KX	MB
IV	1	0	Immediate data	KX	MB
	2	0	for	KX	MB
	3	0	transmitting	KX	MB
	4	0	satellite	KX	MB
	• • •		Non-immediate data (almanac) for		
	15	0	five satellites	KX	MB
V	1	0	Immediate data	KX	MB
	2	0	for	KX	MB
	3	0	transmitting	KX	MB
	4	0	satellite	KX	MB
	• • •		Non-immediate data (almanac) for four satellites		
	14	0	Reserved bits	KX	MB
	15	0	Reserved bits	KX	MB

2 s

1.7 s   0.3 s

30 s

30 s × 5 = 2.5 minutes

84 | 85 .... 9 | 8 1

Bit number within string

Data bits in relative bi-binary code

Hamming code bits in relative bi-binary code

Figure B-7.   Superframe structure

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Figure B-8. Frame structure (frames 1 to 4)

* Reserved bits within frame

Note.— Data content, definitions and explanations of parameters are given in 3.2.1.3 and 3.2.1.4. Additional data transmitted by GLONASS-M are highlighted in this figure.
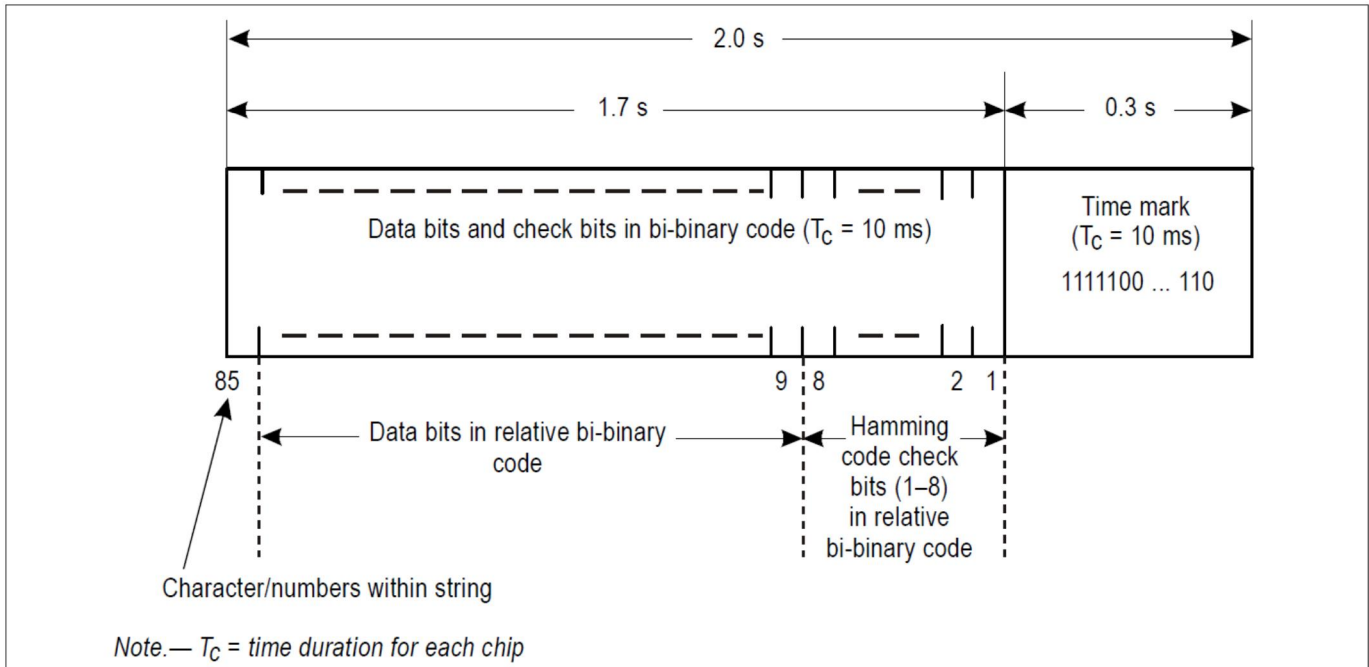
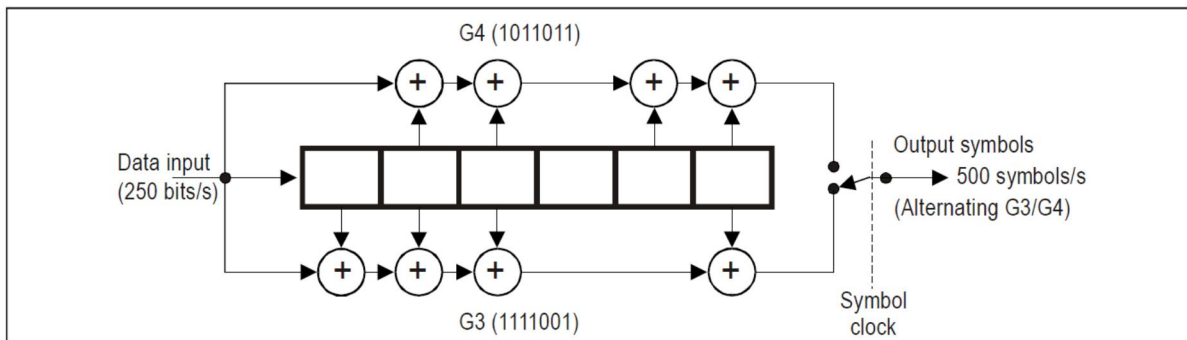**Figure B-9.**   **Frame structure** (frame 5)

Figure B-10.   Data string structure

Figure B-11.   Convolutional encoding

DIRECTION OF DATA FLOW FROM SATELLITE;
MOST SIGNIFICANT BIT (MSB) TRANSMITTED FIRST

250 BITS/SECOND

212-BIT DATA FIELD

24-BIT
CRC

6-BIT MESSAGE TYPE IDENTIFIER (0–63)
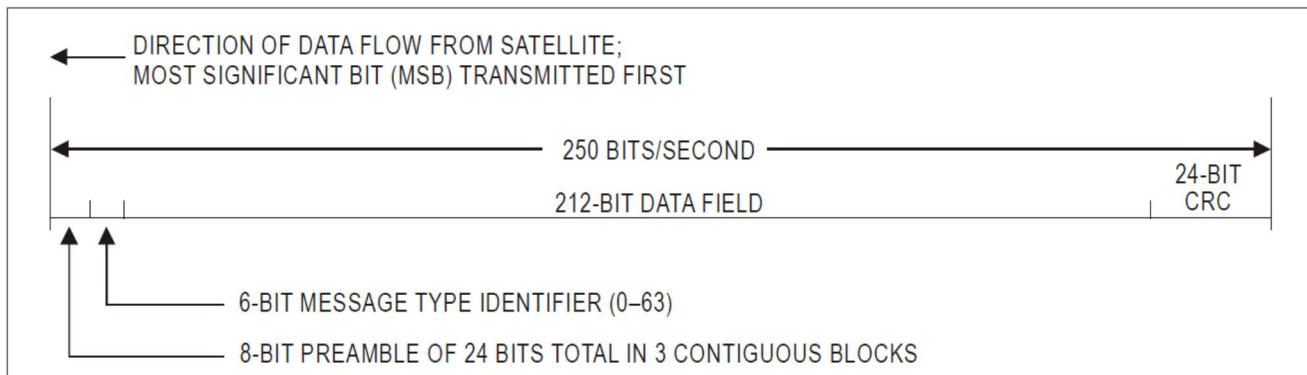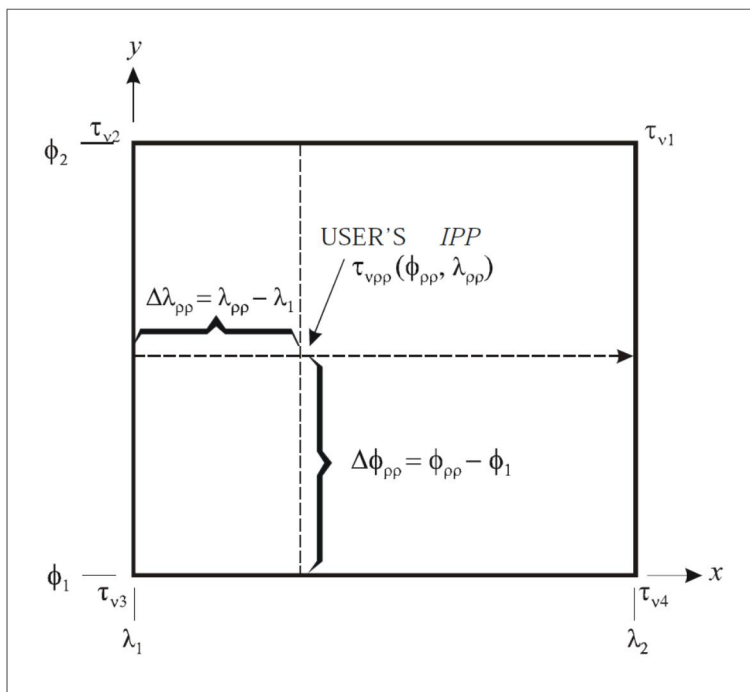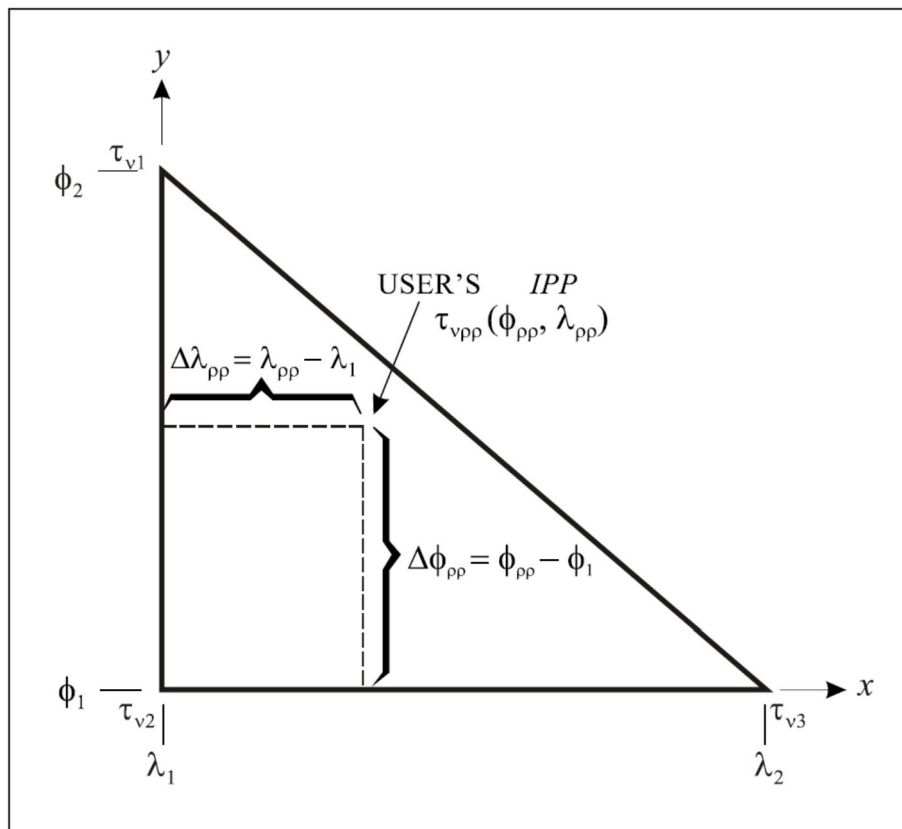
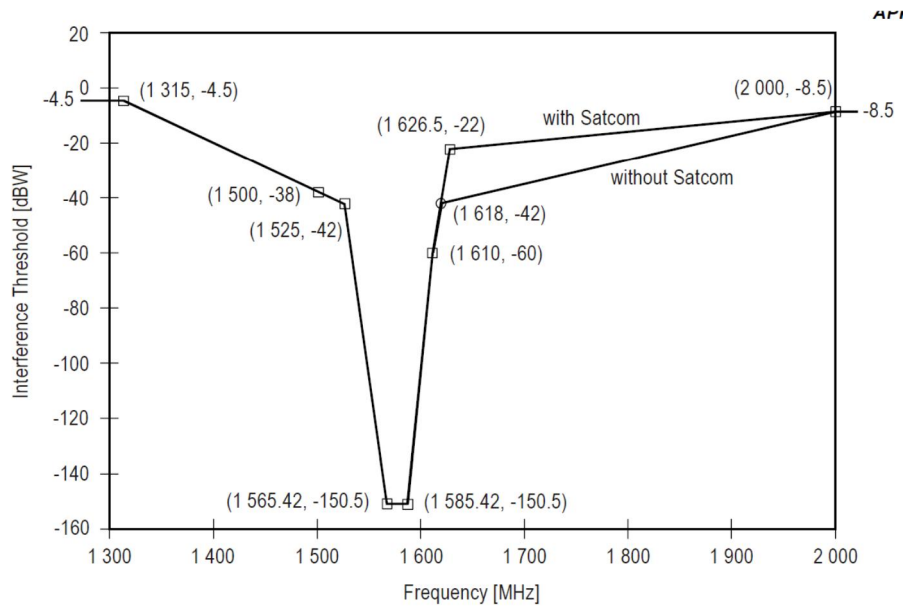8-BIT PREAMBLE OF 24 BITS TOTAL IN 3 CONTIGUOUS BLOCKS

Figure B-12.   Data block format

Figure B-13. **IGP numbering convention** (four IGPs)

Figure B-14. **IGP numbering convention** (three IGPs)

Figure B-15.   **CW interference thresholds for GPS and SBAS receivers used for precision approach**
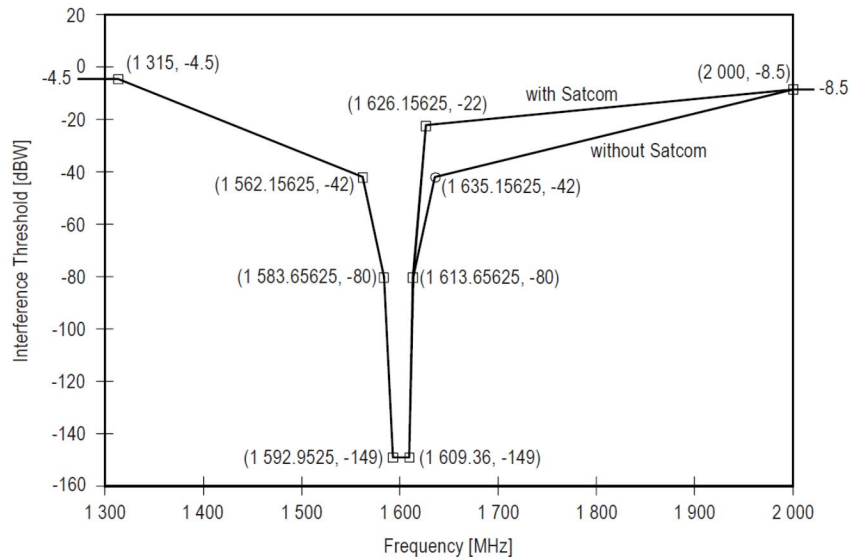
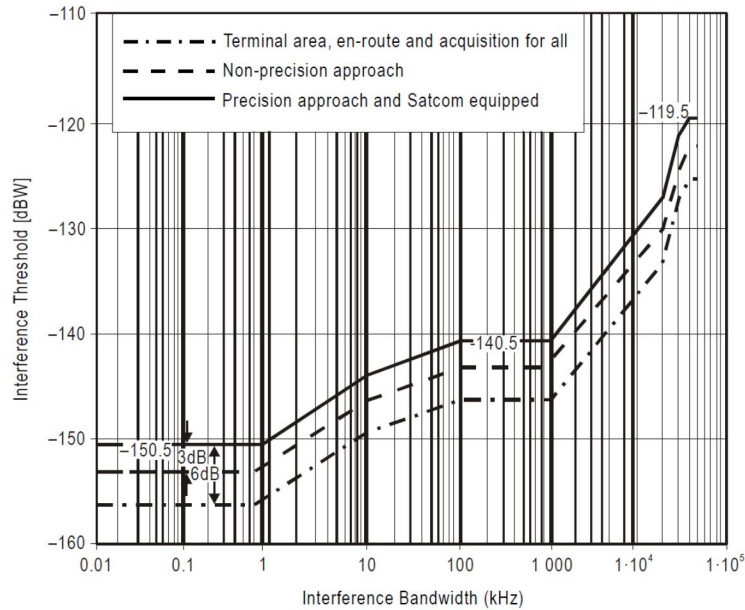**Figure B-16.   CW interference thresholds for GLONASS receivers used for precision approach**

Figure B-17.   Interference thresholds versus bandwidth for GPS and SBAS receivers
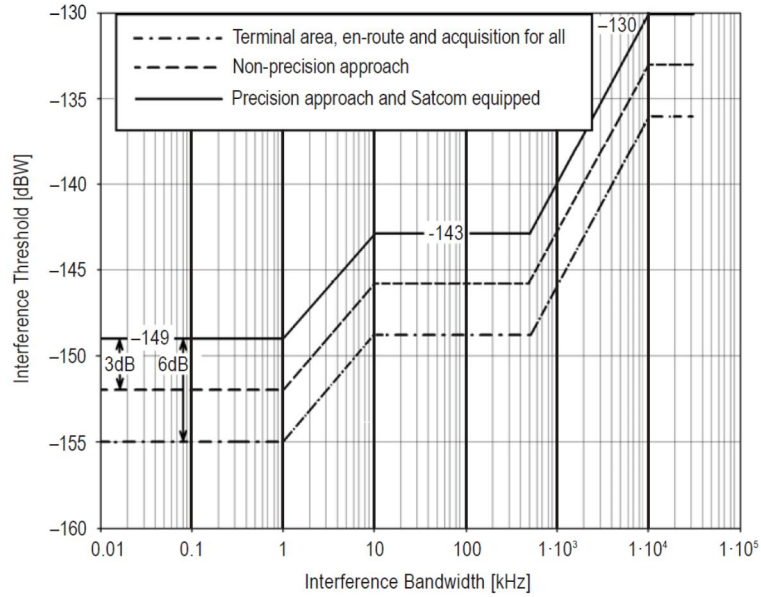
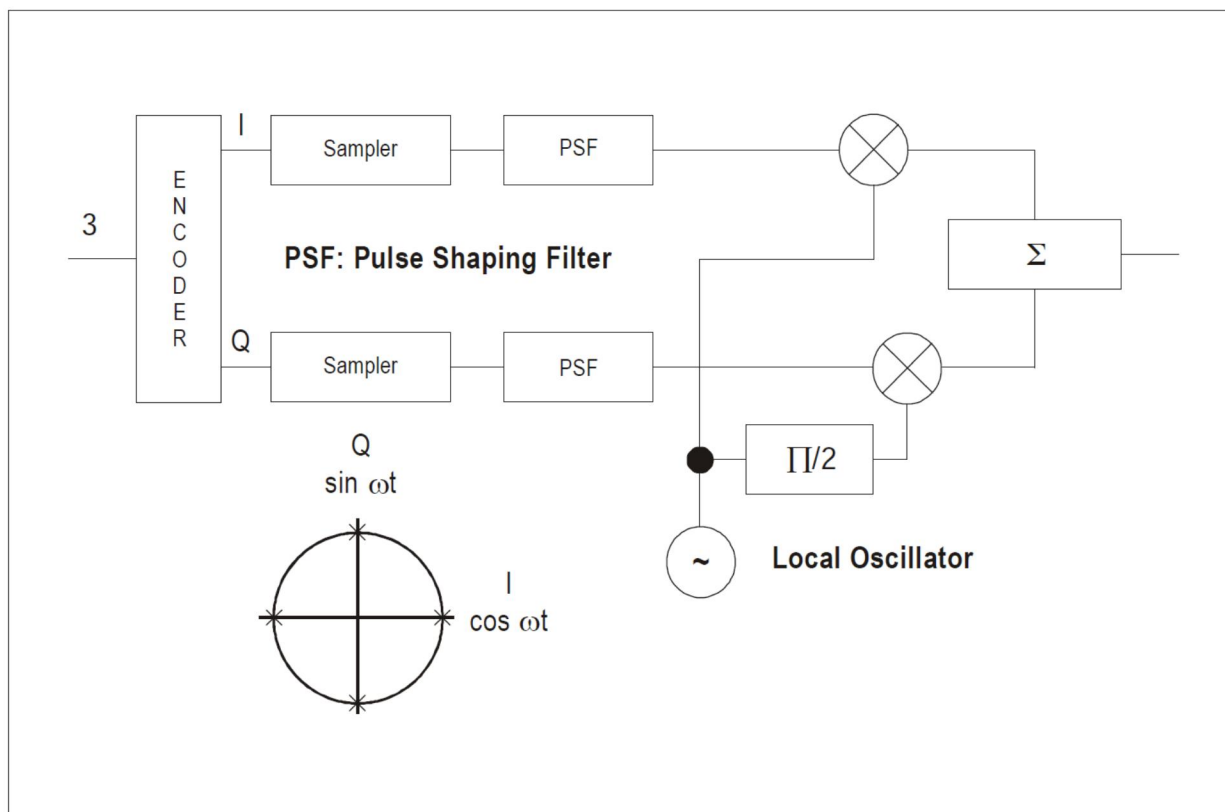**Figure B-18.   Interference thresholds versus bandwidth for GLONASS**

Figure B-19.   Example data modulation

Attachment – A

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Attachment – B

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Attachment – C

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ATTACHMENT D
INFORMATION AND MATERIAL FOR GUIDANCE IN
THE APPLICATION OF THE
GNSS STANDARDS AND RECOMMENDED PRACTICES

1. Definitions

Bi-binary. Bi-binary is known as "Manchester Encoding". It is sometimes referred to as "Differential Manchester Encoding".

Using this system, it is the transition of the edge that determines the bit.

Chip. A single digital bit of the output of a pseudo-random bit sequence.

Gold code. A class of unique codes used by GPS, which exhibit bounded cross-correlation and off-peak auto-correlation values.

Selective availability (SA). A set of techniques for denying the full accuracy and selecting the level of positioning, velocity and time accuracy of GPS available to users of the standard positioning service signal.

Note.— GPS SA was discontinued at midnight on 1 May 2000.

2. General

Standards and Recommended Practices for GNSS contain provisions for the elements identified in Chapter 3, 3.7.2.2. Additional implementation guidance is provided in the *Global Navigation Satellite System (GNSS) Manual* (Doc 9849).

Note.— Except where specifically annotated, GBAS guidance material applies to GRAS.

3. Navigation system performance requirements

3.1. Introduction

3.1.1. Navigation system performance requirements are defined in the *Performance-based Navigation (PBN) Manual* (Doc 9613) for a single aircraft and for the total system which includes the signal-in-space, the airborne equipment and the ability of the aircraft to fly the desired trajectory. These total system requirements were used as a starting point to derive GNSS signal-in-space performance requirements. In the case of GNSS, degraded configurations which may affect multiple aircraft are to be considered. Therefore, certain signal-in-space performance requirements are more stringent to take into account multiple aircraft use of the system.

3.1.2. Two types of approach and landing operations with vertical guidance (APV), APV-I and APV-II, use vertical guidance relative to a glide path, but the facility or navigation system may not satisfy all of the

requirements associated with precision approach. These operations combine the lateral performance equal to that of an ILS Category I localizer with different levels of vertical guidance. Both APV-I and APV-II provide access benefits relative to a non-precision approach, and the service that is provided depends on the operational requirements and the SBAS infrastructure. APV-I and APV-II exceed the requirements (lateral and vertical) for current RNAV approaches using barometric altimetry, and the relevant on- board equipment will therefore be suitable for the conduct of barometric VNAV APV and RNAV non-precision approaches.

3.2. Accuracy

3.2.1. GNSS position error is the difference between the estimated position and the actual position. For an estimated position at a specific location, the probability should be at least 95 per cent that the position error is within the accuracy requirement.

3.2.2. Stationary, ground-based systems such as VOR and ILS have relatively repeatable error characteristics, so that performance can be measured for a short period of time (e.g. during flight inspection) and it is assumed that the system accuracy does not change after the test. However, GNSS errors change over time. The orbiting of satellites and the error characteristics of GNSS result in position errors that can change over a period of hours. In addition, the accuracy itself (the error bound with 95 per cent probability) changes due to different satellite geometries. Since it is not possible to continually measure system accuracy, the implementation of GNSS demands increased reliance on analysis and characterization of errors. Assessment based on measurements within a sliding time window is not suitable for GNSS.

3.2.3. The error for many GNSS architectures changes slowly over time, due to filtering in the augmentation systems and in the user receiver. This results in a small number of independent samples in periods of several minutes. This issue is very important for precision approach applications, because it implies that there is a 5 per cent probability that the position error can exceed the required accuracy for an entire approach. However, due to the changing accuracy described in 3.2.2, this probability is usually much lower.

3.2.4. The 95 per cent accuracy requirement is defined to ensure pilot acceptance, since it represents the errors that will typically be experienced. The GNSS accuracy requirement is to be met for the worst-case geometry under which the system is declared to be available. Statistical or probabilistic credit is not taken for the underlying probability of particular ranging signal geometry.

3.2.5. Therefore, GNSS accuracy is specified as a probability for each and every sample, rather than as a percentage of samples in a particular measurement interval. For a large set of independent samples, at least 95 per cent of the samples should be within the accuracy requirements in Chapter 3, Table 3.7.2.4-1. Data is scaled to the worst-case geometry in order to eliminate the variability in system accuracy that is caused by the geometry of the orbiting satellites.

3.2.6.An example of how this concept can be applied is the use of GPS to support performance required for non- precision approach operations. Assume that the system is intended to support non-precision approaches when the horizontal dilution of precision (HDOP) is less than or equal to 6. To demonstrate this performance, samples should be taken over a long period of time (e.g. 24 hours). The measured position error g for each sample i is denoted g_i. This error is scaled to the worst-case geometry as $6 \times g_i/\text{HDOP}$. Ninety-five per cent of the scaled errors must be less than 220 m for the system to comply with the non-precision accuracy requirement under worst-case geometry conditions. The total number of samples collected must be sufficient for the result to be statistically representative, taking into account the decorrelation time of the errors.

3.2.7. A range of vertical accuracy values is specified for Category I precision approach operations which bounds the different values that may support an equivalent operation to ILS. A number of values have been derived by different groups, using different interpretations of the ILS standards. The lowest value from these derivations was adopted as a conservative value for GNSS; this is the minimum value given for the range. Because this value is conservative, and because GNSS error characteristics are different from ILS, it may be possible to achieve Category I operations using larger values of accuracy within the range. The larger values

would result in increased availability for the operation. The maximum value in the range has been proposed as a suitable value, subject to validation.

3.2.8. The GPS SPS position error (Chapter 3, 3.7.3.1.1.1) accounts for the contribution of the space and control segment to position errors (satellite clock and ephemeris errors) only; it does not include the contributions of ionospheric and tropospheric delay model errors, errors due to multipath effects, and receiver measurement noise errors (Attachment D, 4.1.2). These errors are addressed in the receiver standards. The user positioning error at the output of ABAS-capable equipment is mainly driven by the GNSS receiver used.

3.2.8.1. For Basic GNSS receivers, the receiver qualification standards require demonstration of user positioning accuracy in the presence of interference and a model of selective availability (SA) to be less than 100 m (95 per cent of time) horizontally and 156 m (95 per cent of time) vertically. The receiver standards do not require that a Basic GNSS receiver applies the ionospheric correction described in Appendix B, 3.1.2.4.

Note.— The term "Basic GNSS receiver" designates the GNSS avionics that at least meet the requirements for a GPS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-208 as amended by United States Federal Aviation Administration (FAA) TSO-C129A, or EUROCAE ED-72A (or equivalent).

3.2.8.2. Since the discontinuation of SA, the representative user positioning accuracy of GPS has been conservatively estimated to be as shown in Table D-0. The numbers provided assume that the worst two satellites of a nominal 24 GPS satellite constellation are out of service. In addition, a 7 m (1 σ) ionospheric delay model error, a 0.25 m (1 σ) residual tropospheric delay error, and a 0.80 m (1 σ) receiver noise error are assumed. After discontinuation of SA (Attachment D, 1.), the dominant pseudo-range error for users of the GPS Standard Positioning Service is the ionospheric error that remains after application of the ionospheric corrections. This error is also highly variable and depends on conditions such as user geomagnetic latitude, level of solar activity (i.e. point of the solar cycle that applies), level of ionospheric activity (i.e. whether there is a magnetic storm, or not), elevation angle of the pseudo-range measurement, season of the year, and time of day. The ionospheric delay model error assumption reflected in Table D-0 is generally conservative; however, conditions can be found under which the assumed 7 m (1 σ) error during solar maximum would be inadequate.

Table D-0. GPS user positioning accuracy

	GPS user positioning accuracy 95% of time, global average
Horizontal position error	33 m (108 ft)
Vertical position error	73 m (240 ft)

3.2.9. SBAS and GBAS receivers will be more accurate, and their accuracy will be characterized in real time by the receiver using standard error models, as described in Chapter 3, 3.5, for SBAS and Chapter 3, 3.6, for GBAS.

Note 1.— The term "SBAS receiver" designates the GNSS avionics that at least meet the requirements for an SBAS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-229C, as amended by United States FAA TSO-C145A/TSO-C146A (or equivalent).

Note 2.— The term "GBAS receiver" designates the GNSS avionics that at least meet the requirements for a GBAS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-253A, as amended by United States FAA TSO-C161 and TSO-C162 (or equivalent).

3.3.   Integrity

3.3.1. Integrity is a measure of the trust that can be placed in the correctness of the information supplied by the total system. Integrity includes the ability of a system to provide timely and valid warnings to the user (alerts) when the system must not be used for the intended operation (or phase of flight).

3.3.2. To ensure that the position error is acceptable, an alert limit is defined that represents the largest position error allowable for a safe operation. The position error cannot exceed this alert limit without annunciation. This is analogous to ILS in that the system can degrade so that the error is larger than the 95th percentile but within the monitor limit.

3.3.3. The integrity requirement of the navigation system for a single aircraft to support en-route, terminal, initial approach, non-precision approach and departure is assumed to be $1 - 1 \times 10^{-5}$ per hour.

3.3.4. For satellite-based navigation systems, the signal-in-space in the en-route environment simultaneously serves a large number of aircraft over a large area, and the impact of a system integrity failure on the air traffic management system will be greater than with traditional navigation aids. The performance requirements in Chapter 3, Table 3.7.2.4-1, are therefore more demanding.

3.3.5. For APV and precision approach operations, integrity requirements for GNSS signal-in-space requirements of Chapter 3, Table 3.7.2.4-1, were selected to be consistent with ILS requirements.

3.3.6. Alert limits for typical operations are provided in Note 2 to Table 3.7.2.4-1. A range of alert limits is specified for precision approach operations, reflecting potential differences in system design that may affect the operation. In ILS, monitor thresholds for key signal parameters are standardized, and the monitors themselves have very low measurement noise on the parameter that is being monitored. With differential GNSS, some system monitors have comparably large measurement noise uncertainty whose impact must be considered on the intended operation. In all cases, the effect of the alert limit is to restrict the satellite-user geometry to one where the monitor performance (typically in the pseudorange domain) is acceptable when translated into the position domain.

3.3.7. The smallest precision approach vertical alert limit (VAL) value (10 m (33 ft)) was derived based on the monitor performance of ILS as it could affect the glide slope at a nominal decision altitude of 60 m (200 ft) above the runway threshold. By applying this alert limit, the GNSS error, under faulted conditions, can be directly compared to an ILS error under faulted conditions, such that the GNSS errors are less than or equal to the ILS errors. For those faulted conditions with comparably large measurement noise in GNSS, this results in monitor thresholds are more stringent than ILS.

3.3.8. The largest precision approach VAL value (35 m (115 ft)) was derived to ensure obstacle clearance equivalent to ILS for those error conditions which can be modelled as a bias during the final approach, taking into account that the aircraft decision altitude is independently derived from barometric pressure. An assessment has been conducted of the worst-case effect of a latent bias error equal to the alert limit of 35 m (115 ft), concluding that adequate obstacle clearance protection is provided on the approach and missed approach (considering the decision altitude would be reached early or late, using an independent barometric altimeter). It is important to recognize that this assessment only addressed obstacle clearance and is limited to those error conditions which can be modelled as bias errors. Analysis has shown 35 m (115 ft) bias high and low conditions can be tolerated up to the approach speed category (Categories A through D) glide path angle limits in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS, Doc 8168) without impinging on the ILS obstacle clearance surfaces.

3.3.9. Since the analysis of a 35 m (115 ft) VAL is limited in scope, a system-level safety analysis should be completed before using any value greater than 10 m (33 ft) for a specific system design. The safety analysis should consider obstacle clearance criteria and risk of collision due to navigation error, and the risk of unsafe landing due to navigation error, given the system design characteristics and operational environment (such as the type of aircraft conducting the approach and the supporting airport infrastructure). With respect to the collision risk, it is sufficient to confirm that the assumptions identified in 3.3.8 are valid for the use of a 35 m (115 ft) VAL. With respect to an unsafe landing, the principal mitigation for a navigation error is pilot intervention during the visual segment. Limited operational trials, in conjunction with operational expertise,

have indicated that navigation errors of less than 15 m (50 ft) consistently result in acceptable touchdown performance. For errors larger than 15 m (50 ft), there can be a significant increase in the flight crew workload and potentially a significant reduction in the safety margin, particularly for errors that shift the point where the aircraft reaches the decision altitude closer to the runway threshold where the flight crew may attempt to land with an unusually high rate of descent. The hazard severity of this event is major (see the *Safety Management Manual (SMM)* (Doc 9859)). One acceptable means to manage the risks in the visual segment is for the system to comply with the following criteria:

a) the fault-free accuracy is equivalent to ILS. This includes system 95 per cent vertical navigation system error (NSE) less than 4 m (13 ft), and a fault-free system vertical NSE exceeding 10 m (33 ft) with a probability less than 10^{-7} for each location where the operation is to be approved. This assessment is performed over all environmental and operational conditions under which the service is declared available;

b) under system failure conditions, the system design is such that the probability of an error greater than 15 m (50 ft) is lower than 10^{-5}, so that the likelihood of occurrence is remote. The fault conditions to be taken into account are those affecting either the core constellations or the GNSS augmentation under consideration. This probability is to be understood as the combination of the occurrence probability of a given failure with the probability of detection for applicable monitor(s). Typically, the probability of a single fault is large enough that a monitor is required to satisfy this condition.

3.3.10. For GBAS, a technical provision has been made to broadcast the alert limit to aircraft. GBAS standards require the alert limit of 10 m (33 ft). For SBAS, technical provisions have been made to specify the alert limit through an updatable database (see Attachment C).

3.3.11. The approach integrity requirements apply in any one landing and require a fail-safe design. If the specific risk on a given approach is known to exceed this requirement, the operation should not be conducted. One of the objectives of the design process is to identify specific risks that could cause misleading information and to mitigate those risks through redundancy or monitoring to achieve a fail-safe design. For example, the ground system may need redundant correction processors and to be capable of shutting down automatically if that redundancy is not available due to a processor fault.

3.3.12. A unique aspect of GNSS is the time-varying performance caused by changes in the core satellite geometry. A means to account for this variation is included in the SBAS and GBAS protocols through the protection level equations, which provide a means to inhibit use of the system if the specific integrity risk is too high.

3.3.13. GNSS performance can also vary across the service volume as a result of the geometry of visible core constellation satellites. Spatial variations in system performance can further be accentuated when the ground system operates in a degraded mode following the failure of system components such as monitoring stations or communication links. The risk due to spatial variations in system performance should be reflected in the protection level equations, i.e. the broadcast corrections.

3.3.14. GNSS augmentations are also subject to several atmospheric effects, particularly due to the ionosphere. Spatial and temporal variations in the ionosphere can cause local or regional ionospheric delay errors that cannot be corrected within the SBAS or GBAS architectures due to the definition of the message protocols. Such events are rare and their likelihood varies by region, but they are not expected to be negligible. The resulting errors can be of sufficient magnitude to cause misleading information and should be mitigated in the system design through accounting for their effects in the broadcast parameters (e.g. σ_{iono_vert} in GBAS), and monitoring for excessive conditions where the broadcast parameters are not adequate. The likelihood of encountering such events should be considered when developing any system monitor.

3.3.15. Another environmental effect that should be accounted for in the ground system design is the errors due to multipath at the ground reference receivers, which depend on the physical environment of monitoring station antennas as well as on satellite elevations and times in track.

3.4.   **Continuity of service**

3.4.1. Continuity of service of a system is the capability of the system to perform its function without unscheduled interruptions during the intended operation.

3.4.2. *En-route*

3.4.2.1. For en-route operations, continuity of service relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity throughout the intended operation, assuming that it was available at the start of the operation. The occurrence of navigation system alerts, either due to rare fault-free performance or to failures, constitute continuity failures. Since the durations of these operations are variable, the continuity requirement is specified as a probability on a per-hour basis.

3.4.2.2. The navigation system continuity requirement for a single aircraft is $1 - 1 \times 10^{-4}$ per hour. However, for satellite- based systems, the signal-in-space may serve a large number of aircraft over a large area. The continuity requirements in Chapter 3, Table 3.7.2.4-1, represent reliability requirements for the GNSS signal-in-space, i.e. they derive mean time between outage (MTBO) requirements for the GNSS elements.

3.4.2.3. A range of values is given in Chapter 3, Table 3.7.2.4-1, for the signal-in-space continuity requirement for en-route operations. The lower value is the minimum continuity for which a system is considered to be practical. It is appropriate for areas with low traffic density and airspace complexity. In such areas, the impact of a navigation system failure is limited to a small number of aircraft, and there is, therefore, no need to increase the continuity requirement significantly beyond the single aircraft requirement ($1 - 1 \times 10^{-4}$ per hour). The highest value given (i.e. $1 - 1 \times 10^{-8}$ per hour) is suitable for areas with high traffic density and airspace complexity, where a failure will affect a large number of aircraft. This value is appropriate for navigation systems where there is a high degree of reliance on the system for navigation and possibly for dependent surveillance. The value is sufficiently high for the scenario based on a low probability of a system failure during the life of the system. Intermediate values of continuity (e.g. $1 - 1 \times 10^{-6}$ per hour) are considered to be appropriate for areas of high traffic density and complexity where there is a high degree of reliance on the navigation system but in which mitigation for navigation system failures is possible. Such mitigation may be through the use of alternative navigation means or the use of ATC surveillance and intervention to maintain separation standards. The values of continuity performance are determined by airspace needs to support navigation where GNSS has either replaced the existing navigation aid infrastructure or where no infrastructure previously existed.

3.4.3. *Approach and Landing*

3.4.3.1. For approach and landing operations, continuity of service relates to the capability of the navigation system to provide a navigation output with the specified accuracy and integrity during the approach and landing, given that it was available at the start of the operation. In particular, this means that loss of continuity events that can be predicted and for which NOTAMs have been issued do not have to be taken into account when establishing compliance of a given system design against the SARPs continuity requirement. The occurrence of navigation system alerts, either due to rare fault-free performance or to failures, constitutes a loss of continuity event. In this case, the continuity requirement is stated as a probability for a short exposure time.

3.4.3.2. The continuity requirements for approach and landing operations represent only the allocation of the requirement between the aircraft receiver and the non-aircraft elements of the system. In this case, no increase in the requirement is considered necessary to deal with multiple aircraft use of the system. The continuity value is normally related only to the risk associated with a missed approach and each aircraft can be considered to be independent. However, in some cases, it may be necessary to increase the continuity values since a system failure has to be correlated between both runways (e.g. the use of a common system for approaches to closely-spaced parallel runways).

3.4.3.3. For GNSS-based APV and Category I approaches, missed approach is considered a normal operation, since it occurs whenever the aircraft descends to the decision altitude for the approach and the pilot is unable to continue with visual reference. The continuity requirement for these operations applies

to the average risk (over time) of loss of service, normalized to a 15-second exposure time. Therefore, the specific risk of loss of continuity for a given approach could exceed the average requirement without necessarily affecting the safety of the service provided or the approach. A safety assessment performed for one system led to the conclusion that, in the circumstances specified in the assessment, continuing to provide the service was safer than withholding it.

3.4.3.4. For those areas where the system design does not meet the average continuity risk specified in the SARPs, it is still possible to publish procedures. However, specific operational mitigations should be put in place to cope with the reduced continuity expected. For example, flight planning may not be authorized based solely on a GNSS navigation means with such a high average continuity risk.

3.5. Availability

3.5.1. The availability of GNSS is characterized by the portion of time the system is to be used for navigation during which reliable navigation information is presented to the crew, autopilot, or other system managing the flight of the aircraft.

3.5.2. When establishing the availability requirements for GNSS, the desired level of service to be supported should be considered. If the satellite navigation service is intended to replace an existing en-route navigation aid infrastructure, the availability of the GNSS should be commensurate with the availability provided by the existing infrastructure. An assessment of the operational impact of a degradation in service should be conducted.

3.5.3. Where GNSS availability is low, it is still possible to use the satellite navigation service by restricting the navigation operating times to those periods when it is predicted to be available. This is possible in the case of GNSS since unavailability due to insufficient satellite geometry is repeatable. Under such restrictions, there remains only a continuity risk associated with the failure of necessary system components between the time the prediction is made and the time the operation is conducted.

3.5.4. *En-route*

3.5.4.1. Specific availability requirements for an area or operation should be based upon:

a) traffic density and complexity;

b) alternate navigation aids;

c) primary/secondary surveillance coverage;

d) air traffic

and pilot

procedures;

and

e) duration of

outages.

3.5.4.2. For this reason, the GNSS SARPs specify a range of values for availability requirements. The requirements support GNSS sole-means operations in airspace with various levels of traffic and complexity. The lower end of the range is only sufficient for providing sole means of navigation in a low traffic density and complexity airspace.

3.5.4.3. While augmentations can reduce the dependency of the GNSS on a particular core element, they do not provide usable service without the core elements. The requirement for the availability of a particular augmentation in an area should account for potential degradation in the GNSS core elements (i.e. the minimum constellation of

core elements (number and diversity of satellites) that is expected). Operational procedures should be developed in case such a degraded configuration occurs.

3.5.5. *Approach*

3.5.5.1. Specific requirements for an area should be based upon:

    a) traffic density and complexity;

    b) procedures for filing and conducting an approach to an alternate airport;

    c) navigation system to be used for an alternate airport;

    d) air traffic and pilot procedures;

    e) duration of outages; and

    f) geographic extent of outages.

3.5.5.2. When developing operating procedures for GNSS approach systems, the duration of an outage and its impact on the alternate airport should be considered. Although GNSS outages can occur which affect many approaches, the approach service can be restored without any maintenance because of the orbiting of the satellites.

3.5.6. *Determining GNSS availability*

The availability of GNSS is complicated by the movement of satellites relative to a coverage area under consideration and the potentially long time needed to restore a satellite in the event of a failure. Accurately measuring the availability would require many years to allow for a measurement period longer than the MTBF and repair times. The availability of GNSS should be determined through design, analysis and modelling, rather than measurement. The availability model should account for the ionospheric, tropospheric and receiver error models used by the receiver to verify integrity (e.g. HPL, LPL and VPL calculations). The availability specified in Chapter 3, 3.7.2.4, applies to the design availability.

Note.— Additional guidance material pertaining to reliability and availability of radio communications and navigation aids is contained in Attachment F.

4. GNSS core elements

4.1. GPS

Note.— Additional information concerning GPS can be found in the Global Positioning System Standard Positioning
Service — Performance Standard, *september 2008, and Interface Specification (IS)-GPS-200E.*

    4.1.1. The performance standard is based upon the assumption that a representative standard positioning service (SPS)
      receiver is used. A representative receiver has the following characteristics:
        a) designed in accordance with IS-GPS-200E;
        b) uses a 5-degree masking angle;
        c) accomplishes satellite position and geometric range computations in the most current realization of the World GeodeticSystem 1984 (WGS-84) Earth-Centred, Earth-Fixed (ECEF) coordinate system;
        d) generates a position and time solution from data broadcast by all satellites in view;

e) compensates for dynamic Doppler shift effects on nominal SPS ranging signal carrier phase and C/A code measurements; f)excludes marginal and unhealthy satellites from the position solution;

g) uses up-to-date and internally consistent ephemeris and clock data for all satellites it is using in its position solution; and

h) loses track in the event that a GPS satellite stops transmitting trackable signal.

The time transfer accuracy applies to the data in the broadcast navigation message, which relates GPS SPS time to UTC as maintained by the United States Naval Observatory. A 12-channel receiver will meet performance requirements specified in Chapter 3, 3.7.3.1.1.1 and 3.7.3.1.2. A receiver that is able to track four satellites only (Appendix B, 3.1.3.1.2) will not get the full accuracy and availability performance.

Note.— Conditions indicating that a satellite is "healthy ", "marginal " or "unhealthy " can be found in U.S. Department of Defense, "Global Positioning System - Standard Positioning Service - Performance Standard", *4th Edition, September 2008, Section 2.3.2.*

4.1.2.   Position domain *accuracy*. The position domain accuracy is measured with a representative receiver and a measurement interval of 24 hours for any point within the coverage area. The positioning and timing accuracy are for the signal-in-space (SIS) only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath.

4.1.3. *Range domain accuracy.* The range domain accuracy standard applies to normal operations, which implies that updated navigation data is uplinked to the satellites on regular basis Range domain accuracy is conditioned by the satellite indicating a healthy status and transmitting C/A code and does not account for satellite failures outside of the normal operating characteristics. Range domain accuracy limits can be exceeded during satellite failures or anomalies while uploading data to the satellite. The range rate error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The range acceleration error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area.. Under nominal conditions, all satellites are maintained to the same standards, so it is appropriate for availability modelling purposes to assume that all satellites have a 4-metre RMS SIS user range meter (URE). The standards are restricted to range domain errors allocated to space and control segments.

4.1.4. *Availability.* The availability standard applies to normal operations, which implies that updated navigation data is uplinked to the satellites on regular basis Availability is the percentage of time over any 24-hour interval that the predicted 95 per cent positioning error (due to space and control segment errors) is less than its threshold, for any point within the coverage area. It is based on a 17-metre horizontal 95 per cent threshold; a 37-metre vertical 95 per cent threshold; using a representative receiver; and operating within the coverage area over any 24-hour interval. The service availability assumes a constellation that meets the criteria in 4.1.4.2..

4.1.4.1. *Relationship to augmentation availability.* The availability of ABAS, GBAS and SBAS does not directly relate to the GPS availability defined in Chapter 3, 3.7.3.1.2. States and operators must evaluate the availability of the augmented system by comparing the augmented performance to the requirements. Availability analysis is based on an assumed satellite constellation and the probability of having a given number of satellites.

4.1.4.2. Satellite/constellation availability Twenty-four operational satellites will be maintained on orbit with 0.95 probability (averaged over any day), where a satellite is defined to be operational if it is capable of, but is not necessarily transmitting, a usable ranging signal. At least 21 satellites in the nominal 24 slot positions must be set healthy and must be transmitting a navigation signal with 0.98 probability (normalized annually). At least 20 satellites in the nominal 24 slot positions must be set healthy and must be transmitting a navigation signal with 0.99999 probability (normalized annually)..

4.1.5. *Reliability*. Reliability is the percentage of time over a specified time interval that the instantaneous SPS SIS URE is maintained within the range error limit, at any given point within the coverage area, for

all healthy GPS satellites. The reliability standard is based on a measurement interval of one year and the average of daily values within the coverage area. The worst single point average reliability assumes that the total service failure time of 18 hours will be over that particular point (3 failures each lasting 6 hours).

4.1.6. *Major service failure.* A major service failure is defined to be a condition over a time interval during which a healthy GPS satellite's ranging signal error (excluding atmospheric and receiver errors) exceeds the range error limit of 4.42 times the upper bound on the user range accuracy (URA) broadcast by a satellite for longer than the allowable time to alert (10 seconds). The probability of 1×10^{-5} in Chapter 3, 3.7.3.1.4 corresponds to a maximum of 3 major service failures for the entire constellation per year assuming a maximum constellation of 32 satellites.

4.1.7. **Continuity.** Continuity for a healthy GPS satellite is the probability that the SPS SIS will continue to be healthy without unscheduled interruption over a specified time interval. Scheduled interruptions which are announced at least 48 hours in advance do not contribute to a loss of continuity.

4.1.8. *Coverage*. The SPS supports the terrestrial coverage area, which is from the surface of the earth up to an altitude of 3 000 km.

4.2 GLONASS

Note.— *Additional information concerning GLONASS can be found in the* GLONASS Interface Control Document
published by Scientific Coordination Information Center, Russian Federation Ministry of Defence, Moscow.

4.2.1 *Assumptions.* The performance standard is based upon the assumption that a representative channel of standard accuracy (CSA) receiver is used. A representative receiver has the following characteristics: designed in accordance with GLONASS ICD; uses a 5-degree masking angle; accomplishes satellite position and geometric range computations in the most current realization of the PZ-90 and uses PZ-90 – WGS-84 transformation parameters as indicated in Appendix B,
3.2.5.2; generates a position and time solution from data broadcast by all satellites in view; compensates for dynamic Doppler shift effects on nominal CSA ranging signal carrier phase and standard accuracy signal measurements; excludes GLONASS unhealthy satellites from the position solution; uses up-to-date and internally consistent ephemeris and clock data for all satellites it is using in its position solution; and loses track in the event that a GLONASS satellite stops transmitting standard accuracy code. The time transfer accuracy applies to a stationary receiver operating at a surveyed location.

4.2.2 *Accuracy.* Accuracy is measured with a representative receiver and a measurement interval of 24 hours for any point within the coverage area. The positioning and timing accuracy are for the signal-in-space (SIS) only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath. The accuracy is derived based on the worst two of 24 satellites being removed from the constellation and a 6-metre constellation RMS SIS user range error (URE).

4.2.3 *Range domain accuracy*. Range domain accuracy is conditioned by the satellite indicating a healthy status and transmitting standard accuracy code and does not account for satellite failures outside of the normal operating characteristics. Range domain accuracy limits can be exceeded during satellite failures or anomalies while uploading data to the satellite. Exceeding the range error limit constitutes a major service failure as described in 4.2.6. The range rate error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The range acceleration error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The root-mean-square range error accuracy is the average of the RMS URE of all satellites over any 24-hour interval for any point within the coverage area. Under nominal conditions, all satellites are maintained to the same standards, so it is appropriate for availability modelling purposes to assume that all satellites have a 6-metre RMS SIS URE. The standards are restricted to range domain errors allocated to space and control segments.

4.2.4 *Availability*. Availability is the percentage of time over any 24-hour interval that the predicted

95 per cent positioning error (due to space and control segment errors) is less than its threshold, for any point within the coverage area. It is based on a 12-metre (40-foot) horizontal 95 per cent threshold and a 25-metre (80-foot) vertical 95 per cent threshold, using a representative receiver and operating within the coverage area over any 24-hour interval. The service availability assumes the worst combination of two satellites out of service.

4.2.4.1 *Relationship to augmentation availability.* The availability of ABAS, GBAS and SBAS does not directly relate to the GLONASS availability defined in Chapter 3, 3.7.3.2.2. Availability analysis is based on an assumed satellite constellation and the probability of having a given number of satellites. Twenty-four operational satellites are available in orbit with 0.95 probability (averaged over any day), where a satellite is defined to be operational if it is capable of, but is not necessarily transmitting, a usable ranging signal. At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and must be transmitting a navigation signal with 0.98 probability (yearly averaged).

4.2.5 *Reliability.* Reliability is the percentage of time over a specified time interval that the instantaneous CSA SIS URE is maintained within the range error limit, at any given point within the coverage area, for all healthy GLONASS satellites. The reliability standard is based on a measurement interval of one year and the average of daily values within the coverage area. The single point average reliability assumes that the total service failure time of 18 hours will be over that particular point (3 failures each lasting 6 hours).

4.2.6 *Major service failure.* A major service failure is defined as a condition over a time interval during which a healthy GLONASS satellite's ranging signal error (excluding atmospheric and receiver errors) exceeds the range error limit of 18 m (60 ft) (as defined in Chapter 3, 3.7.3.2.1.3 a)) and/or failures in radio frequency characteristics of the CSA ranging signal, navigation message structure or navigation message contents that deteriorate the CSA receiver's ranging signal reception or processing capabilities.

4.2.7 *Coverage.* The GLONASS CSA supports the terrestrial coverage area, which is from the surface of the earth up to an altitude of 2 000 km.

4.2.8 *GLONASS time.* GLONASS time is generated based on GLONASS Central Synchronizer time. Daily instability of the Central Synchronizer hydrogen clock is not worse than 5×10^{-14}. The difference between GLONASS time and UTC(SU) is within 1 millisecond. The navigation message contains the requisite data to relate GLONASS time to UTC(SU) within 0.7 microsecond.

4.2.8.1 *Transformation of GLONASS-M current data information into common form.* A satellite navigation message contains current data information in N_T parameter. It could be transformed into the common form by the following algorithm:

a)   Current year number J in the four-year interval is calculated:

$$\text{If } 1 \leq N_T \leq 366; \quad J = 1;$$
$$\text{If } 367 \leq N_T \leq 731; J = 2;$$
$$\text{If } 732 \leq N_T \leq 1096; \quad J = 3;$$
$$\text{If } 1097 \leq N_T \leq 1461; J = 4.$$

b)   Current year in common form is calculated by the following formula:

$$Y = 1996 + 4 (N_4 - 1) + (J - 1).$$

c) Current day and month (dd/mm) are extracted from the reference table stored in user equipment ROM. The table interrelates N_T parameter and common form dates.

4.2.9   *GLONASS coordinate system.* The GLONASS coordinate system is PZ-90 as described in *Parameters of Earth, 1990 (PZ-90)*, published by the Topographic Service, Russian Federation Ministry of Defence, Moscow.

4.2.9.1 PZ-90 parameters include fundamental geodetic constants, dimensions of the common terrestrial ellipsoid, the characteristics of the gravitational field of the earth, and the elements of the Krasovsky ellipsoid (coordinate system 1942) orientation relative to the common terrestrial ellipsoid.

4.2.9.2 By definition, the coordinate system PZ-90 is a geocentric Cartesian space system whose origin is located at the centre of the earth's body. The Z-axis is directed to the Conventional Terrestrial Pole as recommended by the International Earth Rotation Service. The X-axis is directed to the point of intersection of the earth's equatorial plane and zero meridian established by the Bureau International de l'Heure. The Y-axis completes the right-handed coordinate system.

4.3   Dilution of precision

Dilution of precision (DOP) factors express how ranging accuracy is scaled by a geometry effect to yield position accuracy. The optimal geometry (i.e. the lowest DOP values) for four satellites is achieved when three satellites are equally spaced on the horizon, at minimum elevation angle, and one satellite is directly overhead. The geometry can be said to "dilute" the range domain accuracy by the DOP factor.

4.4   GNSS receiver

4.4.1 The failures caused by the receiver can have two consequences on navigation system performance which are the interruption of the information provided to the user or the output of misleading information. Neither of these events are accounted for in the signal-in-space requirement.

4.4.2 The nominal error of the GNSS aircraft element is determined by receiver noise, interference, and multipath and tropospheric model residual errors. Specific receiver noise requirements for both the SBAS airborne receiver and the GBAS airborne receiver include the effect of any interference below the protection mask specified in Appendix B, 3.7. The required performance has been demonstrated by receivers that apply narrow correlator spacing or code smoothing techniques.

5.   **Aircraft-based augmentation system (ABAS)**

5.1   ABAS augments and/or integrates the information obtained from GNSS elements with information available on board the aircraft in order to ensure operation according to the values specified in Chapter 3, 3.7.2.4.

5.2   ABAS includes processing schemes that provide:

a) integrity monitoring for the position solution using redundant information (e.g. multiple range measurements). The monitoring scheme generally consists of two functions: fault detection and fault exclusion. The goal of fault detection is to detect the presence of a positioning failure. Upon detection, proper fault exclusion determines and excludes the source of the failure (without necessarily identifying the individual source causing the problem), thereby allowing GNSS navigation to continue without interruption. There are two general classes of integrity monitoring: receiver autonomous integrity monitoring (RAIM), which uses GNSS information exclusively, and aircraft autonomous integrity monitoring (AAIM), which uses information from additional on-board sensors (e.g. barometric altimeter, clock and inertial navigation system (INS));

b)   continuity aiding for the position solution using information of alternative sources, such as INS, barometric altimetry and external clocks;

c)   availability aiding for the position solution (analogous to the continuity aiding); and

d)   accuracy aiding through estimation of remaining errors in determined ranges.

5.3   Non-GNSS information can be integrated with GNSS information in two ways:

a)   integrated within the GNSS solution algorithm (an example is the modelling of altimetry data as an additional satellite measurement); and

b)   external to the basic GNSS position calculation (an example is a comparison of the altimetry data for consistency with the vertical GNSS solution with a flag raised whenever the comparison fails).

5.4   Each scheme has specific advantages and disadvantages, and it is not possible to present a description of all potential integration options with specific numerical values of the achieved performance. The same applies to the situation when several GNSS elements are combined (e.g. GPS and GLONASS).

6.   Satellite-based augmentation system (SBAS)

6.1   An SBAS is made up of three distinct elements:

a)   the ground infrastructure;

b)   the SBAS satellites; and

c)   the SBAS airborne receiver.

6.1.1 The ground infrastructure includes the monitoring and processing stations that receive the data from the navigation satellites and compute integrity, corrections and ranging data which form the SBAS signal-in-space. The SBAS satellites relay the data relayed from the ground infrastructure to the SBAS airborne receivers that determine position and time information using core satellite constellation(s) and SBAS satellites. The SBAS airborne receivers acquire the ranging and correction data and apply these data to determine the integrity and improve the accuracy of the derived position.

6.1.2 The SBAS ground network measures the pseudo-range between the ranging source and an SBAS receiver at the known locations and provides separate corrections for ranging source ephemeris errors, clock errors and ionospheric errors. The user applies a tropospheric delay model.

6.1.3 The ranging source ephemeris error and slow moving clock error are the primary bases for the long-term correction. The ranging source clock error is adjusted for the long-term correction and tropospheric error and is the primary basis for the fast correction. The ionospheric errors among many ranging sources are combined into vertical ionospheric errors at predetermined ionospheric grid points. These errors are the primary bases for ionospheric corrections.

6.2   SBAS coverage area and service areas

6.2.1 It is important to distinguish between the coverage area and service areas for an SBAS. A coverage area comprises one or more service areas, each capable of supporting operations based on some or all of the SBAS functions defined in Chapter 3, 3.7.3.4.2. These functions can be related to the operations that are supported as follows:

a) *Ranging*: SBAS provides a ranging source for use with other augmentation(s) (ABAS, GBAS or other SBAS);

b)   *Satellite status and basic differential corrections*: SBAS provides en-route, terminal, and non-precision approach service. Different operations (e.g. performance-based navigation operations) may be supported in different service areas;

c) *Precise differential corrections*: SBAS provides APV and precision approach service (i.e. APV-I, APV-II and precision approach may be supported in different service areas).

6.2.2 Satellite-based augmentation services are provided by the Wide Area Augmentation System (WAAS) (North America), the European Geostationary Navigation Overlay Service (EGNOS) (Europe and Africa) and the Multifunction Transport Satellite (MTSAT) Satellite-based Augmentation System (MSAS) (Japan). The GPS-aided Geo-augmented Navigation (GAGAN) (India) and the System of Differential Correction and Monitoring (SDCM) (Russia) are also under development to provide these services.

6.2.3 An SBAS may provide accurate and reliable service outside the defined service area(s). The ranging, satellite status and basic differential corrections functions are usable throughout the entire coverage area. The performance of these functions may be technically adequate to support en-route, terminal and non-precision approach operations by providing monitoring and integrity data for core satellite constellations and/or SBAS satellites. The only potential for integrity to be compromised is if there is a satellite ephemeris error that cannot be observed by the SBAS ground network while it creates an unacceptable error outside the service area. For alert limits of 0.3 NM specified for non-precision approach and greater, this is very unlikely.

6.2.4 Each State is responsible for defining SBAS service areas and approving SBAS-based operations within its airspace. In some cases, States will field SBAS ground infrastructure linked to an existing SBAS. This would be required to achieve APV or precision approach performance. In other cases, States may simply approve service areas and SBAS-based operations using available SBAS signals. In either case, each State is responsible for ensuring that SBAS meets the requirements of Chapter 3, 3.7.2.4, within its airspace, and that appropriate operational status reporting and NOTAMs are provided for its airspace.

6.2.5 Before approving SBAS-based operations, a State must determine that the proposed operations are adequately supported by one or more SBASs. This determination should focus on the practicality of using SBAS signals, taking into account the relative location of the SBAS ground network. This could involve working with the State(s) or organization(s) responsible for operating the SBASs. For an airspace located relatively far from an SBAS ground network, the number of visible satellites for which that SBAS provides status and basic corrections would be reduced. Since SBAS receivers are able to use data from two SBASs simultaneously, and to use autonomous fault detection and exclusion when necessary, availability may still be sufficient for approval of operations.

6.2.6 Before publishing procedures based on SBAS signals, a State is expected to provide a status monitoring and NOTAM system. To determine the effect of a system element failure on service, a mathematical service volume model is to be used. The State can either obtain the model from the SBAS operator or develop its own model. Using the current and forecast status data of the basic system elements, and the locations where the State has approved operations, the model would identify airspace and airports where service outages are expected, and it could be used to originate NOTAMs. The system element status data (current and forecast) required for the model could be obtained via a bilateral arrangement with the SBAS service provider, or via connection to a real time "broadcast" of the data if the SBAS service provider chooses to provide data in this way.

6.2.7 Participating States or regions will coordinate through ICAO to ensure that SBAS provides seamless global coverage, taking into account that aircraft equipped to use the signal could suffer operational restrictions in the event that a State or region does not approve the use of one or more of the SBAS signals in its airspace. In such an event, the pilot may have to deselect GNSS altogether since the aircraft equipment may not allow deselection of all SBAS or a particular SBAS.

6.2.8 As the SBAS geostationary orbit satellite coverages (footprints) overlap, there will be interface issues among the
SBASs. As a minimum, the SBAS airborne receivers must be able to operate within the coverage of any SBAS. It is possible
for an SBAS provider to monitor and send integrity and correction data for a geostationary orbit satellite that belongs to another SBAS service provider. This improves availability by adding ranging sources. This improvement does not require any interconnection between SBAS systems and should be accomplished by all SBAS service providers.

6.2.9 Other levels of integration can be implemented using a unique connection between the SBAS networks (e.g. separate satellite communication). In this case, SBASs can exchange either raw satellite measurements from one or more reference stations or processed data (corrections or integrity data) from their master stations. This information can be used to improve system robustness and accuracy through data averaging, or integrity through a cross check mechanism. Availability will also be improved within the service areas, and the technical performance will meet the GNSS SARPs throughout the entire coverage (i.e. monitoring of satellites ephemeris would be improved). Finally, SBAS control and status data could be exchanged to improve system maintenance.

6.3   Integrity

6.3.1 The provisions for integrity are complex, as some attributes are determined within the SBAS ground network and transmitted in the signal-in-space, while other attributes are determined within the SBAS equipment on the aircraft. For the satellite status and basic corrections functions, an error uncertainty for the ephemeris and clock corrections is determined by the SBAS ground network. This uncertainty is modelled by the variance of a zero-mean, normal distribution that describes the user differential range error (UDRE) for each ranging source after application of fast and long-term corrections and excluding atmospheric effects and receiver errors.

6.3.2 For the precise differential function, an error uncertainty for the ionospheric correction is determined. This uncertainty is modelled by the variance of a zero-mean, normal distribution that describes the L1 residual user ionospheric range error (UIRE) for each ranging source after application of ionospheric corrections. This variance is determined from an ionospheric model using the broadcast grid ionospheric vertical error (GIVE).

6.3.3 There is a finite probability that an SBAS receiver would not receive an SBAS message. In order to continue navigation in that case, the SBAS broadcasts degradation parameters in the signal-in-space. These parameters are used in a number of mathematical models that characterize the additional residual error from both basic and precise differential corrections induced by using old but active data. These models are used to modify the UDRE variance and the UIRE variance as appropriate.

6.3.4 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. The horizontal protection level (HPL) provides a bound on the horizontal position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. If the computed HPL exceeds the horizontal alert limit (HAL) for a particular operation, SBAS integrity is not adequate to support that operation. The same is true for precision approach and APV operations, if the VPL exceeds the vertical alert limit (VAL).

6.3.5   One of the most challenging tasks for an SBAS provider is to determine UDRE and GIVE variances so that the protection level integrity requirements are met without having an impact on availability. The performance of an individual SBAS depends on the network configuration, geographical extent and density, the type and quality of measurements used and the algorithms used to process the data. General methods for determining the model variance are described in Section 14.

6.3.6 *Residual clock and ephemeris error (σ_{UDRE})*. The residual clock error is well characterized by a zero-mean, normal distribution since there are many receivers that contribute to this error. The residual ephemeris error depends upon the user location. For the precise differential function, the SBAS provider will ensure that the residual error for all users within a defined service area is reflected in the σ_{UDRE}. For the basic differential function, the residual ephemeris error should be evaluated and may be determined to be negligible.

6.3.7 *Vertical ionospheric error (σ_{GIVE})*. The residual ionospheric error is well represented by a zero-mean, normal distribution since there are many receivers that contribute to the ionospheric estimate. Errors come from the measurement noise, the ionospheric model and the spatial decorrelation of the ionosphere. The position error caused by ionospheric error is mitigated by the positive correlation of the ionosphere itself. In addition, the residual ionospheric error distribution has truncated tails, i.e. the ionosphere cannot create a

negative delay, and has a maximum delay.

6.3.8 *Aircraft element errors*. The combined multipath and receiver contribution is bounded as described in Section 14. This error can be divided into multipath and receiver contribution as defined in Appendix B, 3.6.5.5.1, and the standard model for multipath may be used. The receiver contribution can be taken from the accuracy requirement (Appendix B, 3.5.8.2 and 3.5.8.4.1) and extrapolated to typical signal conditions. Specifically, the aircraft can be assumed to have $\sigma^2_{air} = \sigma^2_{receiver} + \sigma^2_{multipath}$, where it is assumed that $\sigma_{receiver}$ is defined by the RMS_{pr_air} specified for GBAS Airborne Accuracy Designator A equipment, and $\sigma_{multipath}$ is defined in Appendix B, 3.6.5.5.1. The aircraft contribution to multipath includes the effects of reflections from the aircraft itself. Multipath errors resulting from reflections from other objects are not included. If experience indicates that these errors are not negligible, they must be accounted for operationally.

6.3.9 *Tropospheric error*. The receiver must use a model to correct for tropospheric effects. The residual error of the model is constrained by the maximum bias and variance defined in Appendix B, 3.5.8.4.2 and 3.5.8.4.3. The effects of this mean must be accounted for by the ground subsystem. The airborne user applies a specified model for the residual tropospheric error (σ_{tropo}).

6.4   RF characteristics

6.4.1 *Minimum GEO signal power level*. The minimum aircraft equipment (e.g. RTCA/DO-229D) is required to operate with a minimum signal strength of –164 dBW at the input of the receiver in the presence of non-RNSS interference (Appendix B, 3.7) and an aggregate RNSS noise density of –173 dBm/Hz. In the presence of interference, receivers may not have reliable tracking performance for an input signal strength below –164 dBW (e.g. with GEO satellites placed in orbit prior to 2014). A GEO that delivers a signal power below –164 dBW at the output of the standard receiving antenna at
5-degree elevation on the ground can be used to ensure signal tracking in a service area contained in a coverage area defined by a minimum elevation angle that is greater than 5 degrees (e.g. 10 degrees). In this case, advantage is taken from the gain characteristic of the standard antenna to perform a trade-off between the GEO signal power and the size of the service area in which a trackable signal needs to be ensured. When planning for the introduction of new operations based on SBAS, States are expected to conduct an assessment of the signal power level as compared to the level interference from RNSS and non- RNSS sources. If the outcome of this analysis indicates that the level of interference is adequate to operate, then operations can be authorized.

6.4.2 *SBAS network time*. SBAS network time is a time reference maintained by SBAS for the purpose of defining corrections. When using corrections, the user's solution for time is relative to the SBAS network time rather than core satellite constellation system time. If corrections are not applied, the position solution will be relative to a composite core satellite constellation/SBAS network time depending on the satellites used and the resulting accuracy will be affected by the difference among them.

6.4.3   *SBAS convolutional encoding*. Information on the convolutional coding and decoding of SBAS messages can be found in RTCA/DO-229C, Appendix A.

6.4.4   *Message timing*. The users' convolutional decoders will introduce a fixed delay that depends on their respective algorithms (usually 5 constraint lengths, or 35 bits), for which they must compensate to determine SBAS network time (SNT) from the received signal.

6.4.5   S*BAS signal characteristics*. Differences between the relative phase and group delay characteristics of SBAS signals, as compared to GPS signals, can create a relative range bias error in the receiver tracking algorithms. The SBAS service provider is expected to account for this error, as it affects receivers with tracking characteristics within the tracking constraints in Attachment D, 8.11. For GEOs for which the on-board RF filter characteristics have been published in RTCA/DO229D, Appendix T, the SBAS service providers are expected to ensure that the UDREs bound the residual errors including the maximum range bias errors specified in RTCA/DO229D. For other GEOs, the SBAS service providers are expected to work with equipment manufacturers in order to determine, through analysis, the maximum range bias errors that can be expected from existing receivers when they process these specific GEOs. This effect can be minimized by ensuring that the GEOs have a wide bandwidth and small group delay across the pass-band.

6.4.6   *SBAS pseudo-random noise (PRN) codes*. RTCA/DO-229D, Appendix A, provides two methods for SBAS PRN code generation.

6.5   SBAS data characteristics

6.5.1   *SBAS messages.* Due to the limited bandwidth, SBAS data is encoded in messages that are designed to minimize the required data throughput. RTCA/DO-229D, Appendix A, provides detailed specifications for SBAS messages.

6.5.2   *Data broadcast intervals.* The maximum broadcast intervals between SBAS messages are specified in Appendix B, Table B-54. These intervals are such that a user entering the SBAS service broadcast area is able to output a corrected position along with SBAS-provided integrity information in a reasonable time. For en-route, terminal and NPA operations, all needed data will be received within 2 minutes, whereas for precision approach operations, it will take a maximum of 5 minutes. The maximum intervals between broadcasts do not warrant a particular level of accuracy performance as defined in Chapter 3, Table 3.7.2.4-1. In order to ensure a given accuracy performance, each service provider will adopt a set of broadcast intervals taking into account different parameters such as the type of constellations (e.g. GPS with SA, GPS without SA) or the ionospheric activity.

6.5.3   *Time-to-alert.* Figure D-2 provides explanatory material for the allocation of the total time-to-alert defined in Chapter 3, Table 3.7.2.4-1. The time-to-alert requirements in Appendix B, 3.5.7.3.1, 3.5.7.4.1 and 3.5.7.5.1 (corresponding to the GNSS satellite status, basic differential correction and precise differential correction functions, respectively) include both the ground and space allocations shown in Figure D-2.

6.5.4   *Tropospheric function.* Because tropospheric refraction is a local phenomenon, users will compute their own tropospheric delay corrections. A tropospheric delay estimate for precision approach is described in RTCA/DO-229C, although other models can be used.

6.5.5   *Multipath considerations.* Multipath is one of the largest contributors to positioning errors for SBAS affecting both ground and airborne elements. For SBAS ground elements, emphasis should be placed on reducing or mitigating the effects of multipath as much as possible so that the signal-in-space uncertainties will be small. Many mitigation techniques have been studied from both theoretical and experimental perspectives. The best approach for implementing SBAS reference stations with minimal multipath errors is to:

a)   ensure that an antenna with multipath reduction features is chosen;

b)   consider the use of ground plane techniques;

c)   ensure that the antenna is placed in a location with low multipath effects; and

d)   use multipath-reducing receiver hardware and processing techniques.

6.5.6   *GLONASS issue of data.* Since the existing GLONASS design does not provide a uniquely defined identifier for sets of ephemeris and clock data, SBAS will use a specific mechanism to avoid any ambiguity in the application of the broadcast corrections. This mechanism is explained in Figure D-3. The definitions of the latency time and validity interval along with the associated coding requirements can be found in Appendix B, section 3.5.4. The user can apply the long-term corrections received only if the set of GLONASS ephemeris and clock data used on board have been received within the validity interval.

6.6   SBAS final approach segment (FAS) data block

6.6.1   The SBAS final approach segment (FAS) data block for a particular approach procedure is as shown in Appendix B, 3.5.8.4.2.5.1 and Table B-57A It is the same as the GBAS FAS data block defined in Appendix B, section 3.6.4.5.1 and Table B-66, with the following exceptions. The SBAS FAS data block also contains the HAL and VAL to be used for the approach procedure as described in 6.3.4. SBAS user equipment interprets certain fields differently from GBAS user equipment

6.6.2   FAS data blocks for SBAS and some GBAS approaches are held within a common on-board database supporting both SBAS and GBAS. Within this database, channel assignments must be unique for each approach and coordinated with civil authorities. States are responsible for providing the FAS data for incorporation into the database.

6.6.3 An example of the coding of FAS data block for SBAS is provided in Table D-1. This example illustrates the coding of the various application parameters, including the cyclic redundancy check (CRC). The engineering values for the message parameters in the table illustrate the message coding process.

Table D-1. Example of an   SBAS FAS data block

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	CODING RULES (Note 5)	PROCEDURE DESIGN VALUES PROVIDED	FAS DB VALUE USED	BINARY DEFINITION	BINARY REPRESENTATION (Note 1)	HEXADECIMAL REPRESENTATION
Operation Type	4	[0..15]	1	0 : Straight-in approach procedure 1..15 : Spare	Straight-In	0	m4..m1	0000	08
SBAS provider ID	4	[0..15]	1	0 : WAAS 1:EGNOS 2:MSAS 3..13 : Spare 14 : GBAS only 15 : Any SBAS provider	EGNOS	1	m8..m5	0001	
Airport ID	32	$a_1a_2a_3a_4$		a_1, a_2, a_3 = [0..9, A..Z] a4 = [<space>, 0..9, A..Z] Dout = ASCII value & 3F	LFBO	LFBO	m40..m33 m32..m25 m24..m17 m16..m9	'L' 00 001100 'F' 00 000110 'B' 00 000010 'O' 00 001111 (Note 2)	F0 40 60 30
|Runway number	6	[01..36]	1	-	14	14	m46..m41	001110	72
Runway letter	2	[0..3]	1	0 : No letter 1 : Right (R) 2 : Centre (C) 3 : Left (L)	R	1	m48 m47	01	
Approach performance designator	3	[0..7]	1	Not used by SBAS	0 (default value)	0	m51..m49	000	0B
Route indicator	5	a		a = [<space>, A..Z] a ≠ I and a ≠ O	Z	Z	m56..m52	11010	
Reference path data |selector	8	[0..48]		Not used by SBAS	0 (default value)	0	m64..m57	00000000	00
Reference path identifier	32	aia2a3a4		a1 = [E, M, W] a2, a3 = [0..9] a4 = [<space>, A, B, D..K, M..Q, S..Z] Dout = ASCII value & 3F	E14A	E14A	m96..m89 m88..m81 m80..m73 m72..m65	'E' 00 000101 '1' 00 110001 '4' 00 110100 'A' 00 000001 (Note 2)	80 2C 8C A0

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	CODING RULES (Note 5)	PROCEDURE DESIGN VALUES PROVIDED	FAS DB VALUE USED	BINARY DEFINITION	BINARY REPRESENTATION (Note 1)	HEXADECIMAL REPRESENTATION
LTP/FTP latitude	32	[-90.0°..90.0°]	0.0005 arcsec	$Dconv1 = Din \rightarrow$ rounding method (Note 3) $Dconv2 = Dconv1 \rightarrow$ decimal (sec) $Dout = Dconv2 \times 2000$ N : Dout S : Two's complement (Dout)	Din = 43°38'38.8103" N	$Dconv_1 =$ 43°38'38.8105" N $Dconv_2 = 157118.8105$ sec Dout = 314237621	m128..m121 m120..m113 m112..m105 m104..m97	00010010 10111010 11100010 10110101	AD 47 5D 48
LTP/FTP longitude	32	[-180.0°..180.0°]	0.0005 arcsec	$Dconv1 = D_{IN} \rightarrow$ rounding method (Note 3) $Dconv2 = Dconv1 \rightarrow$ decimal (sec) $Dout = Dconv2 \times 2000$ E : Dout W : Two's complement (Dout)	Din = 001°20'45.3591" E	$Dconv1 =$ 001°20'45.3590" E $Dconv2 = 4845.359$ sec Dout = 9690718	m160..m153 m152..m145 m144..m137 m136..m129	00000000 10010011 11011110 01011110	7A 7B C9 00
LTP/FTP height	16	[-512..6041.5]	0.1m	$Dconv = round (D_{IN}, resolution)$ $Dout = (D_{IN} + 512) \times 10$	$D_{IN} = 148.74m$	Dconv = 148.7 Dout = 6607	m176..m169 m168..m161	00011001 11001111	F3 98
ΔFPAP latitude	24	[-1.0°..1.0°]	0.0005 arcsec	$Dconv1 = D_{IN} \rightarrow$ rounding method (Note 3) $Dconv2 = Dconv1 \rightarrow$ decimal (sec) $Dout = Dconv2 \times 2000$ + : Dout - : Two's complement (Dout)	$D_{IN} = -0°01'37.8973"$	$Dconv1 = -00°01'37.8975"$ $Dconv2 = -97.8975"$ Dout = Two's complement (195795) Dout = 16581421	m200..m193 m192..m185 m184..m177	11111101 00000011 00101101	B4 C0 BF
ΔFPAP longitude	24	[-1.0°..1.0°]	0.0005 arcsec	$Dconv1 = Din \rightarrow$ rounding method (Note 3) $Dconv2 = Dconv1 \rightarrow$ decimal (sec) $Dout = Dconv2 \times 2000$ + : Dout - : Two's complement (Dout)	$D_{IN} = 0°01'41.9329"$	$Dconv1 = 0°01'41.9330"$ $Dconv2 = 101.9330"$ Dout = 203866	m224..m217 m216..m209 m208..m201	00000011 00011100 01011010	5A 38 C0
Approach TCH	15	[0..1638.35m] [0..3276.7ft]	0.05m 0.1ft	$Dconv = round (Din, resolution)$ m : $Dout = Din \times 20$ ft : $Dout = Din \times 10$	$D_{IN} = 15.00m$	Dconv = 15.00m Dout = 300	m239..m233 m232..m225	0000001 00101100	34 81
Approach TCH units selector	1	[0,1]		0 : feet 1 : meters	m	1	m240	1	
Glide path angle (GPA)	16	[0..90.00°]	0.01°	$Dconv = round (D_{IN}, resolution)$ $Dout = D_{IN} \times 100$	$D_{IN} = 3.00°$	Dconv = 3.00° Dout = 300	m256..m249 m248..m241	00000001 00101100	34 80

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	CODING RULES (Note 5)	PROCEDURE DESIGN VALUES PROVIDED	FAS DB VALUE USED	BINARY DEFINITION	BINARY REPRESENTATION (Note 1)	HEXADECIMAL REPRESENTATION
Course width	8	[80.00m..143.75m]	0.25m	Dconv = round (D_{IN}, resolution) Dout = (Dconv - 80) x 4	D_{IN} = 105.00m	Dconv = 105.00m Dout = 100	m264..m257	01100100	26
ΔLength offset	8	[0..2032m]	8m	Dconv = round (D_{IN}, resolution) Dout = (integer division of Dconv by 8) + 1 Dout = 255 : not provided value	D_{IN} = 284.86m	Dconv = 288m Dout = 36	m272..m265	00100100	24
Horizontal alert limit (HAL)	8	[0..50.8m]	0.2m	Dconv = round (D_{IN}, resolution) Dout = D_{IN} * 5	D_{IN} = 40.0m	Dconv = 40.0m Dout = 200	m280..m273	11001000	13
Vertical alert limit (VAL)	8	[0..50.8m]	0.2m	Dconv = round (D_{IN}, resolution) Dout = Value * 5 Dout = 0 : vertical deviations cannot be used	D_{IN} = 50.0m	Dconv = 50.0m Dout = 250	m288..m281	11111010	5F
Final approach segment CRC	32	[0..2^{32}-1]		Dout = remainder (P(x) / Q(x))			r32..r25 r24..r17 r16..r9 r8..r1	10101110 11000011 01100100 10001111	75 C3 26 F1 (Note 4)

Notes.

1. The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted to the CRC calculator.

2. The two most significant bits of each byte are set to 0 (see bold characters).

3. The rounding methodology is provided in the PANS-OPS (Doc 8168) Volume II.

4. The FAS CRC value is displayed in the order r25..r32, $r_{17}..r_{24}$, $r_9..r_{16}$, $r_1..r_8$ where ri is th i^{th} coefficient of the remainder R(x) as defined in Appendix B, 3.9.

5. $_{IN}$: raw data value, Dconv : converted data value according to coding rules, Dout : coded data value.

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

Note.— In this section, except where specifically annotated, reference to approach with vertical guidance (APV) means APV-I and APV-II.

7.1   System description

7.1.1   GBAS consists of ground and aircraft elements. A GBAS ground subsystem typically includes a single active VDB transmitter and broadcast antenna, referred to as a broadcast station, and multiple reference receivers. A GBAS ground subsystem may include multiple VDB transmitters and antennas that share a single common GBAS identification (GBAS ID) and frequency as well as broadcast identical data. The GBAS ground subsystem can support all the aircraft subsystems within its coverage providing the aircraft with approach data, corrections and integrity information for GNSS satellites in view. All international aircraft supporting APV should maintain approach data within a database on board the aircraft. The Type 4 message must be broadcast when the ground subsystem supports Category I precision approaches. The Type 4 message must also be broadcast when the ground subsystem supports APV approaches if the approach data is not required by the State to be maintained in the on-board database.

Note.— Allocation of performance requirements between the GBAS subsystems and allocation methodology can be found in RTCA/DO-245, Minimum Aviation System Performance Standards for the Global Positioning System/Local Area Augmentation System (GPS/LAAS). Minimum Operational Performance Standards for GRAS airborne equipment are under development by RTCA.

7.1.2   GBAS ground subsystems provide two services: the approach service and the GBAS positioning service. The approach service provides deviation guidance for FASs in Category I precision approach, APV, and NPA within the operational coverage area. The GBAS positioning service provides horizontal position information to support RNAV operations within the service area. The two services are also distinguished by different performance requirements associated with the particular operations supported (see Table 3.7.2.4-1) including different integrity requirements as discussed in 7.5.1.

7.1.3   A primary distinguishing feature for GBAS ground subsystem configurations is whether additional ephemeris error position bound parameters are broadcast. This feature is required for the positioning service, but is optional for approach services. If the additional ephemeris error position bound parameters are not broadcast, the ground subsystem is responsible for assuring the integrity of ranging source ephemeris data without reliance on the aircraft calculating and applying the ephemeris bound as discussed in 7.5.9.

7.1.4   *GBAS*. There are multiple configurations possible of GBAS ground subsystems conforming to the GNSS Standards, such as:

   a)   configuration that supports Category I precision approach only;

   b)   a configuration that supports Category I precision approach and APV, and also broadcasts the additional ephemeris error position bound parameters;

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c)   a configuration that supports Category I precision approach, APV, and the GBAS positioning service, while also broadcasting the ephemeris error position bound parameters referred to in b); and

d)   a configuration that supports APV and the GBAS positioning service, and is used within a GRAS.

7.1.5   *GRAS configurations.* From a user perspective, a GRAS ground subsystem consists of one or more GBAS ground subsystems (as described in 7.1.1 through 7.1.4), each with a unique GBAS identification, providing the positioning service and APV where required. By using multiple GBAS broadcast stations, and by broadcasting the Type 101 message, GRAS is able to support en-route operations via the GBAS positioning service, while also supporting terminal, departure, and APV operations over a larger coverage region than that typically supported by GBAS. In some GRAS applications, the corrections broadcast in the Type 101 message may be computed using data obtained from a network of reference receivers distributed in the coverage region. This permits detection and mitigation of measurement errors and receiver faults.

7.1.6   *VDB transmission path diversity.* All broadcast stations of a GBAS ground subsystem broadcast identical data with the same GBAS identification on a common frequency. The airborne receiver need not and cannot distinguish between messages received from different broadcast stations of the same GBAS ground subsystem. When within coverage of two such broadcast stations, the receiver will receive and process duplicate copies of messages in different time division multiple access (TDMA) time slots.

7.1.7   Interoperability of the GBAS ground and aircraft elements compatible with RTCA/DO-253A is addressed in Appendix B, 3.6.8.1. GBAS receivers compliant with RTCA/DO-253A will not be compatible with GRAS ground subsystems broadcasting Type 101 messages. However, GRAS and GBAS receivers compliant with RTCA GRAS MOPS, will be compatible with GBAS ground subsystems. SARPs-compliant GBAS receivers may not be able to decode the FAS data correctly for APV transmitted from GBAS ground subsystems. These receivers will apply the FASLAL and FASVAL as if conducting a Category I precision approach. Relevant operational restrictions have to apply to ensure the safety of the operation.

7.1.8   The GBAS VDB transmits with either horizontal or elliptical polarization (GBAS/H or GBAS/E). This allows service providers to tailor the broadcast to their operational requirements and user community.

7.1.9   The majority of aircraft will be equipped with a horizontally-polarized VDB receiving antenna, which can be used to receive the VDB from both GBAS/H and GBAS/E equipment. A subset of aircraft will be equipped with a vertically-polarized antenna due to installation limitations or economic considerations. These aircraft are not compatible with GBAS/H equipment and are, therefore, limited to GBAS-based operations supported by GBAS/E.

7.1.10   GBAS service providers must publish the signal polarization (GBAS/H or GBAS/E), for each GBAS facility in the aeronautical information publication (AIP). Aircraft operators that use vertically polarized receiving antenna will have to take this information into account when managing flight operations, including flight planning and contingency procedures.

7.2   RF characteristics

7.2.1   *Frequency coordination*

7.2.1.1   *Performance factors*

7.2.1.1.1   The geographical separation between a candidate GBAS station, a candidate VOR station and existing VOR or GBAS installations must consider the following factors:

a)   the coverage volume, minimum field strength and effective radiated power (ERP) of the candidate GBAS including the GBAS positioning service, if provided. The minimum requirements for coverage and field strength are found in Chapter 3, 3.7.3.5.3 and 3.7.3.5.4.4, respectively. The ERP is determined from these requirements;

b)   the coverage volume, minimum field strength and ERP of the surrounding VOR and GBAS stations including the GBAS positioning service, if provided. Specifications for coverage and field strength for VOR are found in Chapter 3, 3.3, and respective guidance material is provided in Attachment C;

c)   the performance of VDB receivers, including co-channel and adjacent channel rejection, and immunity to desensitization and intermodulation products from FM broadcast signals. These requirements are found in Appendix B, 3.6.8.2.2;

d)   the performance of VOR receivers, including co-channel and adjacent channel rejection of VDB signals. Since existing VOR receivers were not specifically designed to reject VDB transmissions, desired-to-undesired (D/U) signal ratios for co-channel and adjacent channel rejection of the VDB were determined empirically. Table D-2 summarizes the assumed signal ratios based upon empirical performance of numerous VOR receivers designed for 50 kHz channel spacing;

e)   for areas/regions of frequency congestion, a precise determination of separation may be required using the appropriate criteria;

Table D-2.   Assumed [D/U]$_{required}$ signal ratios to protect VOR from GBAS VDB

Frequency offset	[D/U]$_{required}$ ratio to protect VOR receivers (dB)
Co-channel	26
$\mid f_{VOR} - f_{VDB} \mid$ = 25 kHz	0
$\mid f_{VOR} - f_{VDB} \mid$ = 50 kHz	−34
$\mid f_{VOR} - f_{VDB} \mid$ = 75 kHz	−46
$\mid f_{VOR} - f_{VDB} \mid$ = 100 kHz	−65

f)   that between GBAS installations RPDS and RSDS numbers are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. The requirement is found in Appendix B, 3.6.4.3.1;

g)   that between GBAS installations within radio range of a particular GBAS ground subsystem the reference path

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identifier is assigned to be unique. The requirement is found in Appendix B, 3.6.4.5.1; and

h)   the four-character GBAS ID to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Appendix B, 3.6.3.4.1.

7.2.1.1.2   Nominal link budgets for VDB are shown in Table D-3. The first example in Table D-3 assumes a user receiver height of 3 000 m (10 000 ft) MSL and a transmit antenna designed to suppress ground illumination in order to limit the fading losses to a maximum of 10 dB at coverage edge. In the case of GBAS/E equipment, the 10 dB also includes any effects of signal loss due to interference between the horizontal and vertical components. The second example in Table D-3 provides a link budget for longer range positioning service. It is for a user receiver height sufficient to maintain radio line-of- sight with a multi-path limiting transmitting antenna. No margin is given for fading as it is assumed that the receiver is at low elevation angles of radiation and generally free from significant null for the distances shown in the table (greater than 50 NM).

7.2.1.2   *FM immunity*

7.2.1.2.1   Once a candidate frequency is identified for which the GBAS and VOR separation criteria are satisfied, compatibility with FM transmissions must be determined. This is to be accomplished using the methodology applied when determining FM compatibility with VOR. If FM broadcast violates this criterion, an alternative candidate frequency has to be considered.

7.2.1.2.2   The desensitization is not applied for FM carriers above 107.7 MHz and VDB channels at 108.050 MHz because the off-channel component of such high-level emissions from FM stations above 107.7 MHz will interfere with GBAS VDB operations on 108.025 and 108.050 MHz, hence those assignments will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate interference in the VDB receiver.

7.2.1.2.3   The FM intermodulation immunity requirements are not applied to a VDB channel operating below 108.1 MHz, hence assignments below 108.1 MHz will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate intermodulation products in the VDB receiver.

7.2.1.3   *Geographic separation methodologies*

7.2.1.3.1   The methodologies below may be used to determine the required GBAS-to-GBAS and GBAS-to-VOR geographical separation. They rely on preserving the minimum desired-to-undesired signal ratio. $[D/U]_{required}$ is defined as the signal ratio intended to protect the desired signal from co-channel or adjacent channel interference from an undesired transmission. $[D/U]_{required}$ values required for protection of a GBAS receiver from undesired GBAS or VOR signals are defined in Appendix B, 3.6.8.2.2.5 and 3.6.8.2.2.6. $[D/U]_{required}$ values intended for protection of a VOR receiver from GBAS VDB transmissions as shown in Table D-2 are not defined in SARPs and represent the assumed values based on test results.

7.2.1.3.2   Geographic separation is constrained by preserving $[D/U]_{required}$ at the edge of the desired signal coverage where the desired signal power is derived from the minimum field strength requirements in Chapter 3. This desired signal level,

converted to dBm, is denoted $P_{D,min}$. The allowed signal power of the undesired signal ($P_{U,allowed}$) is:

$P_{Uallowed}(dBm) = (P_{D,min} (dBm) - [D/U]_{required} (dB))$

The undesired signal power P_U converted to dBm is:

$$P_U(dBm) = (Tx_U (dBm) - L (dB))$$

where

Tx_U is the effective radiated power of the undesired transmitter; and

L is the transmission loss of the undesired transmitter, including free-space path loss, atmospheric and ground effects.
This loss depends upon the distance between the undesired transmitter and the edge of the desired signal coverage. To ensure

$D/U_{required}$ is satisfied, $P_u \leq D_{Uallowed}$.

The constraint for assigning a channel is therefore:

$L(dB) \geq ([D/U]_{required} (dB) + Tx_U(dBm) - P_{D,min} (dBm))$

7.2.1.3.3   The transmission loss can be obtained from standard propagation models published in ITU-R Recommendation P.528-2 or from free-space attenuation until the radio horizon and then a constant 0.5 dB/NM attenuation factor. These two methodologies result in slightly different geographical separation for co-channel and first adjacent channels, and identical separation as soon as the second adjacent channel is considered. The free-space propagation approximation is applied in this guidance material.

 7.2.1.4   *Example of GBAS/GBAS geographical separation criteria*

7.2.1.4.1   For GBAS VDB co-channel transmissions assigned to the same time slot, the parameters for horizontal polarization are:

D/U   =   26 dB (Appendix B, 3.6.8.2.2.5.1);

$P_{D,min}$ =   −72 dBm (equivalent to 215 microvolts per metre, Chapter 3, 3.7.3.5.4.4); and

Tx_U =   47 dBm (example link budget, Table D-3);

so

$L \geq (47 + 26 - (-72)) = 145$ dB.

7.2.1.4.2   The geographic separation for co-channel, co-slot GBAS VDB assignments is obtained by determining the distance at which the transmission loss equals 145 dB for receiver altitude of 3 000 m (10 000 ft) above that of the GBAS VDB transmitter antenna. This distance is 318 km (172 NM) using the free-space attenuation approximation and assuming a negligible transmitter antenna height. The minimum required geographical separation can then be determined by adding this distance to the nominal distance between the edge of coverage and the GBAS transmitter 43 km (23 NM). This results in a co-channel, co-slot reuse distance of 361 km (195 NM).

7.2.1.5   *Guidelines on GBAS/GBAS geographical separation criteria*. Using the methodology described above, typical geographic separation criteria can be defined for GBAS to GBAS and GBAS to VOR. The resulting GBAS/GBAS minimum required geographical separation criteria are summarized in Table D-4.

Note.— Geographical separation criteria between the GBAS transmitters providing the GBAS positioning service are under development. A conservative value corresponding to the radiohorizon may be used as an interim value for separation between co-frequency, adjacent time slot transmitters to ensure time slots do not overlap.

7.2.1.6   *Guidelines on GBAS/VOR geographical separation criteria*. The GBAS/VOR minimum geographical separation criteria are summarized in Table D-5 based upon the same methodology and the nominal VOR coverage volumes in Attachment C.

Table D-3.   Nominal VDB link budget

VDB link elements		
For approach service	Vertical component at coverage edge	Horizontal component at coverage edge
Required receiver sensitivity (dBm)	−87	−87
Maximum aircraft implementation loss (dB)	11	15
Power level after aircraft antenna (dBm)	−76	−72
Operating margin (dB)	3	3
Fade margin (dB)	10	10
Free space path loss (dB) at 43 km (23 NM)	106	106

Nominal effective radiated power (ERP) (dBm)		43			47	
For longer range and low radiation angle associated with positioning service		Vertical component			Horizontal component	
Required receiver sensitivity (dBm)		−87			−87	
Maximum aircraft implementation loss (dB)		11			15	
Power level after aircraft antenna (dBm)		−76			−72	
Operating margin (dB)		3			3	
Fade margin (dB)		0			0	
Nominal ERP (dBm)						
Range (km (NM))	Free space loss (dB)	ERP (dBm)	ERP (W)		ERP (dBm)	ERP (W)
93 (50)	113	39.9	10		43.9	25
185 (100)	119	45.9	39		49.9	98
278 (150)	122	49.4	87		53.4	219
390 (200)	125	51.9	155		55.9	389

Notes.—

1. In this table ERP is referenced to an isotropic antenna model.

2. It is possible, with an appropriately sited multipath limiting VDB transmitting antenna with an ERP sufficient to meet the field strength requirements for approach service and considering local topographical limitations, to also satisfy the field strength requirements such that positioning service can be supported at the ranges in this table.

3. Actual aircraft implementation loss (including antenna gain, mismatch loss, cable loss, etc.) and actual receiver sensitivity may be balanced to achieve the expected link budget. For example, if the aircraft implementation loss for the horizontal component is 19 dB, the receiver sensitivity must exceed the minimum requirement and achieve -91 dBm to satisfy the nominal link budget.

Note 1.— When determining the geographical separation between VOR and GBAS, VOR as the desired signal is generally the constraining case due to the greater protected altitude of the VOR coverage region.

Note 2.— Reduced geographical separation requirements can be Pobtained using standard propagation models defined in ITU-R Recommendation P.528-2.

7.2.2   The geographical separation criteria for GBAS/ILS and GBAS/VHF communications are under development.

7.2.3   *Compatibility with ILS.* Until compatibility criteria are developed for GBAS VDB and ILS, VDB cannot be assigned to channels below 112.025 MHz. If there is an ILS with a high assigned frequency at the same airport as a VDB with a frequency near 112 MHz, it is necessary to consider ILS and VDB compatibility. Considerations for assignment of VDB channels include the frequency separation between the ILS and the VDB, the distance separation between the ILS coverage area and the VDB, the VDB and ILS field strengths, and the VDB and ILS sensitivity. For GBAS equipment with transmitter power
of up to 150 W (GBAS/E, 100 W for horizontal component and 50 W for vertical component) or 100 W (GBAS/H), the 16th channel (and beyond) will be below –106 dBm at a distance of 200 m from the VDB transmitter, including allowing for a +5 dB positive reflection. This –106 dBm figure assumes a –86 dBm localizer signal at the ILS receiver input and a minimum 20 dB signal-to-noise ratio.

7.2.4   *Compatibility with VHF communications.* For GBAS VDB assignments above 116.400 MHz, it is necessary to consider VHF communications and GBAS VDB compatibility. Considerations for assignment of these VDB channels include the frequency separation between the VHF communication and the VDB, the distance separation between the transmitters and coverage areas, the field strengths, the polarization of the VDB signal, and the VDB and VHF sensitivity. Both aircraft and ground VHF communication equipment are to be considered. For GBAS/E equipment with a transmitter maximum power of up to 150 W (100 W for horizontal component and 50 W for vertical component), the 64th channel (and beyond) will be below –120 dBm at a distance of 200 m from the VDB transmitter including allowing for a +5 dB positive reflection. For GBAS/H equipment with a transmitter maximum power of 100 W, the 32nd channel (and beyond) will be below –120 dBm at a distance of 200 m from the VDB transmitter including allowing for a +5 dB positive reflection, and a
10 dB polarization isolation. It must be noted that due to differences in the VDB and VDL transmitter masks, separate analysis must be performed to ensure VDL does not interfere with the VDB.

Table D-4.   Typical GBAS/GBAS frequency assignment criteria

Channel of undesired VDB in the same time slots	Path loss (dB)	Minimum required geographical separation for $Tx_U = 47$ dBm and $P_{D,min} = -72$ dBm in km (NM)
Cochannel	145	361 (195)
1st adjacent channel (±25 kHz)	101	67 (36)
2nd adjacent channel (±50 kHz)	76	44 (24)
3rd adjacent channel (±75 kHz)	73	No restriction
4th adjacent channel (±100 kHz)	73	No restriction

Note.— No geographic transmitter restrictions are expected between co-frequency, adjacent time slots provided the undesired VDB

transmitting antenna is located at least 200 m from areas where the desired signal is at minimum field strength.

Table D-5. Minimum required geographical separation for a VOR coverage (12 000 m (40 000 ft) level)

Channel of undesired GBAS VDB	Path loss (dB)	VOR coverage radius		
		342 km (185 NM)	300 km (162 NM)	167 km (90 NM)
Co-channel	152	892 km (481 NM)	850 km (458 NM)	717 km (386 NM)
$\mid f_{Desired} - f_{Undesired} \mid$ = 25 kHz	126	774 km (418 NM)	732 km (395 NM)	599 km (323 NM)
$\mid f_{Desired} - f_{Undesired} \mid$ = 50 kHz	92	351 km (189 NM)	309 km (166 NM)	176 km (94 NM)
$\mid f_{Desired} - f_{Undesired} \mid$ = 75 kHz	80	344 km (186 NM)	302 km (163 NM)	169 km (91 NM)
$\mid f_{Desired} - f_{Undesired} \mid$ = 100 kHz	61	No restriction	No restriction	No restriction

Note.— Calculations are based on reference frequency of 112 MHz and assume GBAS Tx_U = 47 dBm and VOR $P_{D,min}$ = −79 dBm.

7.2.5   For a GBAS ground subsystem that only transmits a horizontally-polarized signal, the requirement to achieve the power associated with the minimum sensitivity is directly satisfied through the field strength requirement. For a GBAS ground subsystem that transmits an elliptically-polarized component, the ideal phase offset between HPOL and VPOL components is 90 degrees. In order to ensure that an appropriate received power is maintained throughout the GBAS coverage volume during normal aircraft manoeuvres, transmitting equipment should be designed to radiate HPOL and VPOL signal components with an RF phase offset of 90 degrees. This phase offset should be consistent over time and environmental conditions. Deviations from the nominal 90 degrees must be accounted for in the system design and link budget, so that any fading due to polarization loss does not jeopardize the minimum receiver sensitivity. System qualification and flight inspection procedures will take into account an allowable variation in phase offset consistent with maintaining the appropriate signal level throughout the GBAS coverage volume. One method of ensuring both horizontal and vertical field strength is to use a single VDB antenna that transmits an elliptically-polarized signal, and flight inspect the effective field strength of the vertical and horizontal signals in the coverage volume.

7.3   Coverage

7.3.1   The GBAS coverage to support approach services is depicted in Figure D-4. When the additional ephemeris error position bound parameters are broadcast, differential corrections may only be used within the Maximum Use Distance (D_{max}) defined in the Type 2 message. Where practical, it is operationally advantageous to provide valid guidance along the visual segment of an approach.

7.3.2   The coverage required to support the GBAS positioning service is dependent upon the specific operations

intended. The optimal coverage for this service is intended to be omni directional in order to support operations using the GBAS positioning service that are performed outside of the precision approach coverage volume. Each State is responsible for defining a service area for the GBAS positioning service and ensuring that the requirements of Chapter 3, 3.7.2.4 are satisfied. When making this determination, the characteristics of the fault-free GNSS receiver should be considered, including the reversion to ABAS-based integrity in the event of loss of GBAS positioning service.

7.3.3 The limit on the use of the GBAS positioning service information is given by the Maximum Use Distance (D_{max}), which defines the range within which the required integrity is assured and differential corrections can be used for either the positioning service or precision approach.

D_{max} however does not delineate the coverage area where field strength requirements specified in Chapter 3, 3.7.3.5.4.4 are met nor matches this area. Accordingly, operations based on the GBAS positioning service can be predicated only in the coverage area(s) (where the field strength requirements are satisfied) within the D_{max} range.

7.3.4   As the desired coverage area of a GBAS positioning service may be greater than that which can be provided by a single GBAS broadcast station, a network of GBAS broadcast stations can be used to provide the coverage. These stations can broadcast on a single frequency and use different time slots (8 available) in neighbouring stations to avoid interference or they can broadcast on different frequencies. Figure D-4A details how the use of different time slots will allow a single frequency to be used without interference subject to guard time considerations noted under Table B-59. For a network based on different VHF frequencies, guidance material in 7.17 should be considered.

7.4   Data structure

A bit scrambler/descrambler is shown in Figure D-5.

Note.— Additional information on the data structure of the VHF data broadcast is given in RTCA/DO-246B, GNSS Based Precision Approach Local Area Augmentation System (LAAS)—Signal-in-Space Interface Control Document (ICD).

7.5   Integrity

7.5.1   Different levels of integrity are specified for precision approach operations and operations based on the GBAS positioning service. The signal-in-space integrity risk for Category I is 2×10^{-7} per approach. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service have to also meet the signal-in- space integrity risk requirement specified for terminal area operations, which is 1×10^{-7}/hour (Chapter 3, Table 3.7.2.4-1). Therefore additional measures are necessary to support these more stringent requirements for positioning service. The signal- in-space integrity risk is allocated between the ground subsystem integrity risk and the protection level integrity risk. The ground subsystem integrity risk allocation covers failures in the ground subsystem as well as core constellation and SBAS failures such as signal quality failures and ephemeris failures. The protection level integrity risk allocation covers rare fault- free performance risks and the case of failures in one of the reference receiver measurements. In both cases the protection level equations ensure that the effects of the satellite geometry used by the aircraft receiver are taken into account. This is described in more detail in the following paragraphs.

7.5.2   The GBAS ground subsystem defines a corrected pseudo-range error uncertainty for the error relative to the

GBAS reference point (σ_{pr_gnd}) and the errors resulting from vertical (σ_{tropo}) and horizontal (σ_{iono}) spatial decorrelation. These uncertainties are modelled by the variances of zero-mean, normal distributions which describe these errors for each ranging source.

7.5.3 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. General methods for determining that the model variance is adequate to guarantee the protection level integrity risk are described in Section 14. The lateral protection level (LPL) provides a bound on the lateral position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. For Category I precision

approach and APV, if the computed LPL exceeds the lateral alert limit (LAL) or the VPL exceeds the vertical alert limit (VAL), integrity is not adequate to support the operation. For the positioning service the alert limits are not defined in the standards, with only the horizontal protection level and ephemeris error position bounds required to be computed and applied. The alert limits will be determined based on the operation being conducted. The aircraft will apply the computed protection level and ephemeris bounds by verifying they are smaller than the alert limits. Two protection levels are defined, one to address the condition when all reference receivers are fault-free (H_0 – Normal Measurement Conditions), and one to address the condition when one of the reference receivers contains failed measurements (H_1 – Faulted Measurement Conditions).

Additionally an ephemeris error position bound provides a bound on the position error due to failures in ranging source ephemeris. For Category I precision approach and APV, a lateral error bound (LEB) and a vertical error bound (VEB) are defined. For the positioning service a horizontal ephemeris error bound (HEB) is defined.

7.5.4 *Ground system contribution to corrected pseudo-range error (σ_{pr_gnd})*. Error sources that contribute to this error include receiver noise, multipath, and errors in the calibration of the antenna phase centre. Receiver noise has a zero-mean, normally distributed error, while the multipath and antenna phase centre calibration can result in a small mean error.

7.5.5   *Residual tropospheric errors*. Tropospheric parameters are broadcast in Type 2 messages to model the effects of the troposphere, when the aircraft is at a different height than the GBAS reference point. This error can be well-characterized by a zero-mean, normal distribution.

7.5.6   *Residual ionospheric errors*. An ionospheric parameter is broadcast in Type 2 messages to model the effects of the ionosphere between the GBAS reference point and the aircraft. This error can be well-characterized by a zero-mean, normal distribution.

7.5.7   *Aircraft receiver contribution to corrected pseudo-range error*. The receiver contribution is bounded as described in Section 14. The maximum contribution, used for analysis by the GBAS provider, can be taken from the accuracy requirement, where it is assumed that $\sigma_{receiver}$ equals RMS_{pr_air} for GBAS Airborne Accuracy Designator A equipment.

7.5.8   *Airframe multipath error*. The error contribution from airframe multipath is defined in Appendix B, 3.6.5.5.1. Multipath errors resulting from reflections from other objects are not included. If experience indicates that these errors are not negligible, they must be accounted for operationally or through inflation of the parameters broadcast by the ground (e.g. σ_{pr_gnd}).

7.5.9   *Ephemeris error uncertainty*. Pseudo-range errors resulting from ephemeris errors (defined as a discrepancy between the true satellite position and the satellite position determined from the broadcast data) are spatially decorrelated and will therefore be different for receivers in different locations. When users are relatively close to the GBAS reference point, the residual differential error due to ephemeris errors will be small and both the corrections and uncertainty parameters σ_{pr_gnd} sent by the ground subsystem will be valid to correct the raw measurements and compute the protection levels. For users further away from the GBAS reference point, protection against ephemeris failures can be ensured in two different ways:

a)   the ground subsystem does not transmit the additional ephemeris error position bound parameters. In this case, the ground subsystem is responsible for assuring integrity in case of satellite ephemeris failures without reliance on the aircraft calculating and applying the ephemeris bound. This may impose a restriction on the distance between the GBAS reference point and the decision altitude/height depending upon the ground subsystem means of detecting ranging source ephemeris failures. One means of detection is to use satellite integrity information broadcast by SBAS; and

b)   the ground subsystem transmits the additional ephemeris error position bound parameters which enable the airborne receiver to compute an ephemeris error bound. These parameters are: coefficients used in the ephemeris error position bound equations ($K_{md\_e\_()}$, where the subscript () means either "GPS", "GLONASS", "POS, GPS" or "POS, GLONASS"), the maximum use distance for the differential corrections (D_{max}), and the ephemeris decorrelation parameters (P). The ephemeris decorrelation parameter (P) in the Type 1 or Type 101 message characterizes the residual error as a function of distance between the GBAS reference point and the aircraft. The value of P is expressed in m/m. The values of P are determined by the ground subsystem for each satellite. One of the main factors influencing the values of P is the ground subsystem monitor design. The quality of the ground monitor will be characterized by the smallest ephemeris error (or minimum detectable error (MDE)) that it can detect. The relationship between the P parameter and the MDE for a particular satellite can be approximated by $P_i = MDE_i/R_i$ where R_i is the smallest of the predicted ranges from the ground subsystem reference receiver antenna(s) for the period of validity of P_i. Being dependent on satellite geometry, the P parameters values are slowly varying. However, it is not a requirement for the ground subsystem to dynamically vary P. Static P parameters could be sent if they properly ensure integrity. In this latter case, the availability would be slightly degraded. Generally, as MDE becomes smaller, overall GBAS availability improves.

7.5.10   *Ephemeris error/failure monitoring*. There are several types of monitoring approaches for detecting ephemeris errors/failures. They include:

a)   *Long baseline*. This requires the ground subsystem to use receivers separated by large distances to detect ephemeris errors that are not observable by a single receiver. Longer baselines translate to better performance in MDE;

b)   *SBAS*. Since SBAS augmentation provides monitoring of satellite performance, including ephemeris data, integrity information broadcast by SBAS can be used as an indication of ephemeris validity. SBAS uses ground subsystem receivers installed over very long baselines, therefore this provides optimum performance for ephemeris monitoring and thus achieves small MDEs; and

c)   *Ephemeris data monitoring*. This approach involves comparing the broadcast ephemeris over consecutive satellite orbits. There is an assumption that the only threat of failure is due to a failure in ephemeris upload from the constellation ground control network. Failures due to uncommanded satellite manoeuvres must be sufficiently improbable to ensure that this approach

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provides the required integrity.

7.5.10.1   The monitor design (for example, its achieved MDE) is to be based upon the integrity risk requirements and the failure model the monitor is intended to protect against. A bound on the GPS ephemeris failure rate can be determined from the reliability requirements defined in Chapter 3, 3.7.3.1.3, since such an ephemeris error would constitute a major service failure.

7.5.10.2   The GLONASS control segment monitors the ephemeris and time parameters, and in case of any abnormal situation it starts to input the new and correct navigation message. The ephemeris and time parameter failures do not exceed 70 m of range errors. The failure rate of GLONASS satellite including the ephemeris and time parameter failures does not exceed 4×10^{-5} per satellite per hour.

7.5.11   A typical GBAS ground subsystem processes measurements from 2 to 4 reference receivers installed in the immediate vicinity of the reference point. The aircraft receiver is protected against a large error or fault condition in a single reference receiver by computing and applying the B parameters from the Type 1 or Type 101 message to compare data from the various reference receivers. Alternative system architectures with sufficiently high redundancy in reference receiver measurements may employ processing algorithms capable of identifying a large error or fault in one of the receivers. This may apply for a GRAS network with receivers distributed over a wide area and with sufficient density of ionospheric pierce points to separate receiver errors from ionospheric effects. The integrity can then be achieved using only the protection levels for normal measurement conditions (VPL_{H0} and LPL_{H0}), with appropriate values for K_{ffmd} and σ_{pr_gnd}. This can be achieved using the Type 101 message with the B parameters excluded.

7.6   Continuity of service

7.6.1   *Ground continuity and integrity designator*. The ground continuity and integrity designator (GCID) provides a classification of GBAS ground subsystems. The ground subsystem meets the requirements of Category I precision approach or APV when GCID is set to 1. GCID 2, 3 and 4 are intended to support future operations with requirements that are more stringent than Category I operations. The GCID is intended to be an indication of ground subsystem status to be used when an aircraft selects an approach. It is not intended to replace or supplement an instantaneous integrity indication communicated in a Type 1 or Type 101 message. GCID does not provide any indication of the ground subsystem capability to support the GBAS positioning service.

7.6.2   *Ground subsystem continuity of service*. GBAS ground subsystems are required to meet the continuity specified in Appendix B to Chapter 3, 3.6.7.1.3 in order to support Category I precision approach and APV. GBAS ground subsystems that are also intended to support other operations through the use of the GBAS positioning service should support the minimum continuity required for terminal area operations, which is $1-10^{-4}$/hour (Chapter 3, Table 3.7.2.4-1). When the Category I precision approach or APV required continuity ($1-8 \times 10^{-6}$/15 seconds) is converted to a per hour value it does not meet the $1-10^{-4}$/hour minimum continuity requirement. Therefore, additional measures are necessary to meet the continuity required for other operations. One method of showing compliance with this requirement is to assume that airborne implementation uses both GBAS and ABAS to provide redundancy and that ABAS provides sufficient accuracy for the intended operation.

7.7   GBAS channel selection

7.7.1   Channel numbers are used in GBAS to facilitate an interface between aircraft equipment and the signal-in-space that is consistent with interfaces for ILS and MLS. The cockpit integration and crew interface for GBAS may be based on entry of the 5-digit channel number. An interface based on approach selection through a flight management function similar to current practice with ILS is also possible. The GBAS channel number may be stored in an on-board navigation database as part of a named approach. The approach may be selected by name and the channel number can automatically be provided to the equipment that must select the appropriate GBAS approach data from the broadcast data. Similarly, the use of the GBAS positioning service may be based on the selection of a 5-digit channel number. This facilitates conducting operations other than the approaches defined by the FAS data. To facilitate frequency tuning, the GBAS channel numbers for neighbouring GBAS ground subsystems supporting positioning service may be provided in the Type 2 message additional data block 2.

7.7.2   A channel number in the range from 20 001 to 39 999 is assigned when the FAS data are broadcast in the Type 4 message. A channel number in the range from 40 000 to 99 999 is assigned when the FAS data associated with an APV are obtained from the on-board database.

7.8   Reference path data selector and reference station data selector

A mapping scheme provides a unique assignment of a channel number to each GBAS approach. The channel number consists of five numeric characters in the range 20 001 to 39 999. The channel number enables the GBAS airborne subsystem to tune to the correct frequency and select the final approach segment (FAS) data block that defines the desired approach. The correct FAS data block is selected by the reference path data selector (RPDS), which is included as part of the FAS definition data in a Type 4 message. Table D-6 shows examples of the relationship between the channel number, frequency and RPDS. The same mapping scheme applies to selection of the positioning service through the reference station data selector (RSDS). The RSDS is broadcast in the Type 2 message and allows the selection of a unique GBAS ground subsystem that provides the positioning service. For GBAS ground subsystems that do not provide the positioning service and broadcast the additional ephemeris data, the RSDS is coded with a value of 255. All RPDS and RSDS broadcast by a ground subsystem must be unique on the broadcast frequency within radio range of the signal. The RSDS value must not be the same as any of the broadcast RPDS values.

7.9   Assignment of RPDS and RSDS by service provider

RPDS and RSDS assignments are to be controlled to avoid duplicate use of channel numbers within the protection region for the data broadcast frequency. Therefore, the GBAS service provider has to ensure that an RPDS and RSDS are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. Assignments of RPDS and RSDS are to be managed along with assignments of frequency and time slots for the VHF data broadcast.

Table D-6.   Channel assignment examples

Channel number (N)	Frequency in MHz (F)	Reference path data selector (RPDS)

		or Reference station data selector (RSDS)
20 001	108.025	0
20 002	108.05	0
20 003	108.075	0
….	….	….
20 397	117.925	0
20 398	117.95	0
20 412 (Note)	108.025	1
20 413	108.05	1
….	….	….

Note.— Channels between 20 398 and 20 412 are not assignable because the channel algorithm maps them to frequencies outside the range of 108.025 MHz and 117.950 MHz. A similar "gap" in the channel assignments occurs at each RPDS transition.

7.10   GBAS identification

The GBAS identification (ID) is used to uniquely identify a GBAS ground subsystem broadcasting on a given frequency within the coverage region of the GBAS. The aircraft will navigate using data broadcast from one or more GBAS broadcast stations of a single GBAS ground subsystem (as identified by a common GBAS identification).

7.11   Final approach segment (FAS) path

7.11.1   FAS path is a line in space defined by the landing threshold point/fictitious threshold point (LTP/FTP), flight path alignment point (FPAP), threshold crossing height (TCH) and glide path angle (GPA). These parameters are determined from data provided in a FAS data block within a Type 4 message or in the on-board database. The relationship between these parameters and the FAS path is illustrated in Figure D-6.

7.11.1.1   FAS data blocks for SBAS and some GBAS approaches are held within a common onboard database supporting both SBAS and GBAS. States are responsible for providing the FAS data to support APV procedures when the Type 4 message is not broadcast. These data comprise the parameters contained within the FAS block, the RSDS, and associated broadcast frequency. The FAS block for a particular approach procedure is described in Appendix B, 3.6.4.5.1 and Table B-66.

7.11.2   *FAS path definition*

7.11.2.1   *Lateral orientation*. The LTP/FTP is typically at or near the runway threshold. However, to satisfy operational needs

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or physical constraints, the LTP/FTP may not be at the threshold. The FPAP is used in conjunction with the LTP/FTP to define the lateral reference plane for the approach. For a straight-in approach aligned with the runway, the FPAP will be at or beyond the stop end of the runway. The FPAP is not placed before the stop end of the runway.

7.11.2.2   Δ*Length offset*. The Δlength offset defines the distance from the end of the runway to the FPAP. This parameter is provided to enable the aircraft equipment to compute the distance to the end of the runway. If the Δlength offset is not set to appropriately indicate the end of the runway relative to the FPAP, the service provider should ensure the parameter is coded as "not provided".

7.11.2.3   *Vertical orientation*. Local vertical for the approach is defined as normal to the WGS-84 ellipsoid at the LTP/FTP and may differ significantly from the local gravity vector. The local level plane for the approach is defined as a plane perpendicular to the local vertical passing through the LTP/FTP (i.e. tangent to the ellipsoid at the LTP/FTP). The datum crossing point (DCP) is a point at a height defined by TCH above the LTP/FTP. The FAS path is defined as a line with an angle (defined by the GPA) relative to the local level plane passing through the DCP. The GPIP is the point where the final approach path intercepts the local level plane. The GPIP may actually be above or below the runway surface depending on the curvature of the runway.

7.11.3   *"ILS look-alike" deviation computations*. For compatibility with existing aircraft designs, it is desirable for aircraft equipment to output guidance information in the form of deviations relative to a desired flight path defined by the FAS path. The Type 4 message includes parameters that support the computation of deviations that are consistent with typical ILS installations.

7.11.3.1   *Lateral deviation definition*. Figure D-6 illustrates the relationship between the FPAP and the origin of the lateral angular deviations. The course width parameter and FPAP are used to define the origin and sensitivity of the lateral deviations. By adjusting the location of the FPAP and the value of the course width, the course width and sensitivity of a GBAS can be set to the desired values. They may be set to match the course width and sensitivity of an existing ILS or MLS. This may be necessary, for example, for compatibility with existing visual landing aids.

7.11.3.1.1   *Lateral deviation reference*. The lateral deviation reference plane is the plane that includes the LTP/FTP, FPAP and a vector normal to the WGS-84 ellipsoid at the LTP/FTP. The rectilinear lateral deviation is the distance of the computed aircraft position from the lateral deviation reference plane. The angular lateral deviation is a corresponding angular displacement referenced to the GBAS azimuth reference point (GARP). The GARP is defined to be beyond the FPAP along the procedure centre line by a fixed offset value of 305 m (1 000 ft).

7.11.3.1.2   *Lateral displacement sensitivity*. The lateral displacement sensitivity is determined by the aircraft equipment from the course width provided in the FAS data block. The service provider is responsible for setting the course width parameter to a value that results in the appropriate angle for full scale deflection (i.e. 0.155 DDM or 150 µA) taking into account any operational constraints.

7.11.3.2   *Vertical deviations*. Vertical deviations are computed by the aircraft equipment with respect to a GBAS elevation reference point (GERP). The GERP may be at the GPIP or laterally offset from the GPIP by a fixed GERP offset value of 150 m. Use of the offset GERP allows the glide path deviations to produce the same hyperbolic effects that are normal

characteristics of ILS and MLS (below 200 ft). The decision to offset the GERP or not is made by the aircraft equipment in accordance with requirements driven by compatibility with existing aircraft systems. Service providers should be aware that users may compute vertical deviations using a GERP which is placed at either location. Sensitivity of vertical deviations is set automatically in the aircraft equipment as a function of the GPA. The specified relationship between GPA and the full scale deflection (FSD) of the vertical deviation sensitivity is: $FSD = 0.25*GPA$. The value 0.25 is the same as for MLS (Attachment G, 7.4.1.2) and differs slightly from the nominal value of 0.24 recommended for ILS (Chapter 3, section 3.1.5.6.2). However, the value specified is well within the tolerances recommended for ILS (0.2 to 0.28). Therefore the resulting sensitivity is equivalent to the glide path displacement sensitivity provided by a typical ILS.

7.11.4   *Approaches not aligned with the runway*. Some operations may require the definition of a FAS path that is not aligned with the runway centre line as illustrated in Figure D-7. For approaches not aligned with the runway, the LTP/FTP may or may not lie on the extended runway centre line. For this type of approach Δlength offset is not meaningful and should be set to "not provided".

7.11.5   *SBAS service provider*. A common format is used for FAS data blocks to be used by both GBAS and SBAS. The SBAS service provider ID field identifies which SBAS system(s) may be used by an aircraft that is using the FAS data during an approach. The GBAS service provider may inhibit use of the FAS data in conjunction with any SBAS service. For precision approaches based on GBAS this field is not used, and it can be ignored by aircraft GBAS equipment.

7.11.6   *Approach identifier*. The service provider is responsible for assigning the approach identifier for each approach. The approach identification should be unique within a large geographical area. Approach identifications for multiple runways at a given aerodrome should be chosen to reduce the potential for confusion and misidentification. The approach identification should appear on the published charts that describe the approach. The first letter of the approach identifier is used in the authentication protocols for GBAS. Ground stations that support the authentication protocols must encode the first character of the identifier for all approaches supported from the set of letters {A X Z J C V P T} as described in Appendix B, section 3.6.7.4.1.4. This enables airborne equipment (that supports the authentication protocols) to determine which slots are assigned to the ground station and therefore to subsequently ignore reception of data broadcast in slots not assigned to the selected ground station. For ground stations that do not support the authentication protocols, the first character of the approach identifier may be assigned any character except those in the set {A X Z J C V P T}.

7.12   Airport siting considerations

7.12.1   The installation of a GBAS ground subsystem involves special considerations in choosing prospective sites for the reference receiver antennas and the VDB antenna(s). In planning antenna siting, Annex 14 obstacle limitation requirements must be met.

7.12.2   *Locating reference receiver antennas*. The site should be selected in an area free of obstructions, so as to permit the reception of satellite signals at elevation angles as low as possible. In general, anything masking GNSS satellites at elevation angles higher than 5 degrees will degrade system availability.

7.12.2.1   The antennas for the reference receivers should be designed and sited to limit multipath signals that interfere with the desired signal. Mounting antennas close to a ground plane reduces long-delay multipath resulting from reflections below the

antenna. Mounting height should be sufficient to prevent the antenna being covered by snow, or being interfered with by maintenance personnel or ground traffic. The antenna should be sited so that any metal structures, such as air vents, pipes and other antennas are outside the near-field effects of the antenna.

7.12.2.2   Besides the magnitude of the multipath error at each reference receiver antenna location, the degree of correlation must also be considered. Reference receiver antennas should be located in places that provide independent multipath environments.

7.12.2.3   The installation of each antenna should include a mounting that will not flex in winds or under ice loads. Reference receiver antennas should be located in an area where access is controlled. Traffic may contribute to error due to multipath or obstruct view of satellites from the antennas.

7.12.3   *Locating the VDB antenna*. The VDB antenna should be located so that an unobstructed line-of-sight exists from the antenna to any point within the coverage volume for each supported FAS. Consideration should also be given to ensuring the minimum transmitter-to-receiver separation so that the maximum field strength is not exceeded. In order to provide the required coverage for multiple FASs at a given airport, and in order to allow flexibility in VBD antenna siting, the actual coverage volume around the transmitter antenna may need to be considerably larger than that required for a single FAS. The ability to provide this coverage is dependent on the VDB antenna location with respect to the runway and the height of the VDB antenna. Generally speaking, increased antenna height may be needed to provide adequate signal strength to users at low altitudes, but may also result in unacceptable multipath nulls within the desired coverage volume. A suitable antenna height trade-off must be made based on analysis, to ensure the signal strength requirements are met within the entire volume. Consideration should also be given to the effect of terrain features and buildings on the multipath environment.

7.12.4   *Use of multiple transmit antennas to improve VDB coverage.* For some GBAS installations, constraints on antenna location, local terrain or obstacles may result in ground multipath and/or signal blockage that make it difficult to provide the specified field strength at all points within the coverage area. Some GBAS ground facilities may make use of one or more additional antenna systems, sited to provide signal path diversity such that collectively they meet the coverage requirements.

7.12.4.1   Whenever multiple antenna systems are used, the antenna sequence and message scheduling must be arranged to provide broadcasts at all points within the coverage area that adhere to the specified minimum and maximum data broadcast rates and field strengths, without exceeding the receiver's ability to adapt to transmission-to-transmission variations in signal strength in a given slot. To avoid receiver processing issues concerning lost or duplicated messages, all transmissions of the Type 1 or Type 101 message, or linked pair of Type 1 or Type 101 messages for a given measurement type within a single frame need to provide identical data content.

7.12.4.2   One example of the use of multiple antennas is a facility with two antennas installed at the same location but at different heights above the ground plane. The heights of the antennas are chosen so that the pattern from one antenna fills the nulls in the pattern of the other antenna that result from reflections from the ground plane. The GBAS ground subsystem alternates broadcasts between the two antennas, using one or two assigned slots of each frame for each antenna. Type 1 or Type 101 messages are broadcast once per frame, per antenna. This allows for reception of one or two Type 1 or Type 101 messages per frame, depending on whether the user is located within the null of one of the antenna patterns. Type 2 and 4 messages are broadcast from the first antenna in one frame, then from the second antenna in the next frame. This allows for reception of one

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each of the Type 2 and 4 messages per one or two frames, depending on the user location.

7.13   Definition of lateral and vertical alert limits

7.13.1   The lateral and vertical alert limits for Category I precision approach are computed as defined in Appendix B, Tables B-68 and B-69. In these computations the parameters D and H have the meaning shown in Figure D-8.

7.13.2   The vertical alert limit for Category I precision approach is scaled from a height of 60 m (200 ft) above the LTP/FTP. For a procedure designed with a decision height of more than 60 m (200 ft), the VAL at that decision height will be larger than the broadcast FASVAL.

7.13.3   The lateral and vertical alert limits for APV procedures associated with channel numbers 40 001 to 99 999 are computed in the same manner as for APV procedures using SBAS as given in Attachment D, 3.2.8.

7.14   Monitoring and maintenance actions

7.14.1   Specific monitoring requirements or built-in tests may be necessary and should be determined by individual States. Since the VDB signal is critical to the operation of the GBAS broadcast station, any failure of the VDB to successfully transmit a usable signal within the assigned slots and over the entire coverage area is to be corrected as soon as possible. Therefore, it is recommended that the following conditions be used as a guide for implementing a VDB monitor:

   a) *Power.* A significant drop in power is to be detected within 3 seconds.

   b)   *Loss of message type.* The failure to transmit any scheduled message type(s). This could be based on the failure to transmit a unique message type in succession, or a combination of different message types.

   c) *Loss of all message types.* The failure to transmit any message type for a period equal to or greater than 3 seconds will be detected.

7.14.2   Upon detection of a failure, and in the absence of a backup transmitter, termination of the VDB service should be considered if the signal cannot be used reliably within the coverage area to the extent that aircraft operations could be significantly impacted. Appropriate actions in operational procedures are to be considered to mitigate the event of the signal being removed from service. These would include dispatching maintenance specialists to service the GBAS VDB or special ATC procedures. Additionally, maintenance actions should be taken when possible for all built-in test failures to prevent loss of GBAS service.

7.15   Examples of VDB messages

7.15.1   Examples of the coding of VDB messages are provided in Tables D-7 through D-10. The examples illustrate the coding of the various application parameters, including the cyclic redundancy check (CRC) and forward error correction (FEC) parameters, and the results of bit scrambling and D8PSK symbol coding. The engineering values for the message parameters in these tables illustrate the message coding process, but are not necessarily representative of realistic values.

7.15.2   Table D-7 provides an example of a Type 1 VDB message. The additional message flag field is coded to indicate

that this is the first of two Type 1 messages to be broadcast within the same frame. This is done for illustration purposes; a second Type 1 message is not typically required, except to allow broadcast of more ranging source corrections than can be accommodated in a single message.

7.15.3   Table D-7A provides an example of a Type 101 VDB message. The additional message flag field is coded to indicate that this is the first of two Type 101 messages to be broadcast within the same frame. This is done for illustration purposes; a second Type 101 message is not typically required, except to allow broadcast of more ranging source corrections than can be accommodated in a single message.

7.15.4   Table D-8 provides examples of a Type 1 VDB message and a Type 2 VDB message coded within a single burst (i.e. two messages to be broadcast within a single transmission slot). The additional message flag field of the Type 1 message is coded to indicate that it is the second of two Type 1 messages to be broadcast within the same frame. The Type 2 message includes additional data block 1. Table D-8A provides an example of Type 1 and Type 2 messages with additional data blocks 1 and 2.

7.15.4.1   Table D-8B provides an example of Type 2 messages with additional data blocks 1 and 4 coded within a single burst with a Type 3 message that is used to fill the rest of the time slot.

7.15.5   Table D-9 provides an example of a Type 4 message containing two FAS data blocks.

7.15.6   Table D-10 provides an example of a Type 5 message. In this example, source availability durations common to all approaches are provided for two ranging sources. Additionally, source availability durations for two individual approaches are provided: the first approach has two impacted ranging sources and the second approach has one impacted ranging source. The Type 2 message includes additional data block 1.

7.16 GBAS survey accuracy

The standards for the survey accuracy for NAVAIDs are contained in Annex 14 — *Aerodromes*. In addition, the *Manual of the World Geodetic System 1984 (WGS-84)* (Doc 9674) provides guidance on the establishment of a network of survey control stations at each aerodrome and how to use the network to establish WGS-84 coordinates. Until specific requirements are developed for GBAS, the Annex 14 survey accuracy requirements for NAVAIDs located at the aerodrome apply to GBAS. The recommendation contained in Appendix B to Chapter 3, 3.6.7.2.3.4, for the survey accuracy of the GBAS reference point is intended to further reduce the error in the WGS-84 position calculated by an airborne user of the GBAS positioning service to a value smaller than that established by the requirements of Appendix B to Chapter 3, 3.6.7.2.4.1 and
3.6.7.2.4.2, in the GBAS standards and to enhance survey accuracy compared to that specified in Annex 14. The integrity of all aeronautical data used for GBAS is to be consistent with the integrity requirements in Chapter 3, Table 3.7.2.4-1.

7.17   Type 2 message additional data blocks

7.17.1   The Type 2 message contains data related to the GBAS facility such as the GBAS reference point location, the GBAS continuity and integrity designator (GCID) and other pertinent configuration information. A method for adding new data to the Type 2 message has been devised to allow GBAS to evolve to support additional service types. The method is through the definition of new additional data blocks that are appended to the Type 2 message. In the future, more additional data blocks may

be defined. Data blocks 2 through 255 have variable length and may be appended to the message after additional data block 1 in any order.

7.17.2   Type 2 message additional data block 1 contains information related to spatial decorrelation of errors and information needed to support selection of the GBAS positioning service (when provided by a given ground station).

7.17.3   Type 2 message additional data block 2 data may be used in GRAS to enable the GRAS airborne subsystem to switch between GBAS broadcast stations, particularly if the GBAS broadcast stations utilize different frequencies. Additional data block 2 identifies the channel numbers and locations of the GBAS broadcast station currently being received and other adjacent or nearby GBAS broadcast stations.

7.17.4   Type 2 message additional data block 3 is reserved for future use.

7.17.5   Type 2 message additional data block 4 contains information necessary for a ground station that supports the authentication protocols. It includes a single parameter which indicates which slots are assigned to the ground station for VDB transmissions. Airborne equipment that supports the authentication protocols will not use data unless it is transmitted in the slots indicated by the slot group definition field in the MT 2 ADB 4.

Table D-7.   Example of a Type 1 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	E	100
Transmission length (bits)	17	0 to 1 824 bits	1 bit	536	000 0000 1000 0110 00
Training sequence FEC	5	—	—	—	0000 1
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 1 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	61	0011 1101
Message (Type 1 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	1st of pair	01
Number of measurements	5	0 to 18	1	4	0 0100
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 $\times 10^{-3}$ m/m	5×10^{-6} m/m	1×10^{-4}	0001 0100
Ephemeris CRC	16	—	—	—	0000 0000 0000 0000
Source availability duration	8	0 to 2 540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	2	0000 0010
Issue of data (IOD)	8	0 to 255	1	255	1111 1111
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	0.98 m	0011 0001
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B_3	8	±6.35 m	0.05 m	–0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Measurement Block 2					
Ranging source ID	8	1 to 255	1	4	0000 0100
Issue of data (IOD)	8	0 to 255	1	126	0111 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	–1.0 m	1111 1111 1001 1100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	+0.2 m/s	0000 0000 1100 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	0.34 m	0001 0001
B_1	8	±6.35 m	0.05 m	+0.20 m	0000 0100
B_2	8	±6.35 m	0.05 m	+0.30 m	0000 0110
B_3	8	±6.35 m	0.05 m	–0.50 m	1111 0110
B_4	8	±6.35 m	0.05 m	Not used	1000 0000

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DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Measurement Block 3					
Ranging source ID	8	1 to 255	1	12	0000 1100
Issue of data (IOD)	8	0 to 255	1	222	1101 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.11 m	0000 0000 0110 1111
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	1.02 m	0011 0011
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.25 m	0000 0101
B_3	8	±6.35 m	0.05 m	–0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Measurement Block 4					
Ranging source ID	8	1 to 255	1	23	0001 0111
Issue of data (IOD)	8	0 to 255	1	80	0101 0000
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	–2.41 m	1111 1111 0000 1111
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.96 m/s	1111 1100 0100 0000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	0.16 m	0000 1000
B_1	8	±6.35 m	0.05 m	+0.20 m	0000 0100
B_2	8	±6.35 m	0.05 m	+0.30 m	0000 0110
B_3	8	±6.35 m	0.05 m	–0.50 m	1111 0110
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block CRC	32	—	—	—	1100 0010 1111 0011 0000 1011 1100 1010
APPLICATION FEC	48	—	—	—	0110 0011 1110 1001 1110 0000 1110 1101 0010 1001 0111 0101
Input to the bit scrambling (Note 2)	0 46 10 10 55 30 CA 10 80 BC 17 C2 20 28 00 00 FF 40 FF 26 00 1C FF 8C 40 C0 DF 01 20 7E 39 FF 13 00 88 20 60 6F 01 30 7B F6 00 1C FF CC 40 A0 DF 01 E8 0A F0 FF 02 3F 10 20 60 6F 01 53 D0 CF 43 AE 94 B7 07 97 C6				
Output from the bit scrambling (Note 3)	0 60 27 98 1F 2F D2 3B 5F 26 C2 1B 12 F4 46 D0 09 81 B6 25 1C 18 D0 7C 2A 7F B9 55 A8 B0 27 17 3A 60 EB 5F 1B 3B A5 FE 0A E1 43 D7 FA D7 B3 7A 65 D8 4E D7 79 D2 E1 AD 95 E6 6D 67 12 B3 EA 4F 1A 51 B6 1C 81 F2 31				
Fill bits	0 to 2	—	—	0	
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650100 12707716 71645524 74035772 26234621 45311123 22460075 52232477 16617052 04750422 07724363 40733535 05120746 45741125 22545252 73171513 51047466 13171745 10622642 17157064 67345046 36541025 07135576 55745512 222				

Notes.—
1.   *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2.   *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3.   *In this example fill bits are not scrambled.*
4.   *This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5 π/4 radians), relative to the phase of the first symbol.*

Table D-7A.   Example of a Type 101 VDB message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3			E	100
Transmission length (bits)	17	0 to 1824 bits	1 bit	416	00000000110100000
Training sequence FEC	5				11011
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 101 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8,101	1	101	0110 0101
Message length	8	10 to 222 bytes	1 byte	46	0010 1110
Message (Type 101 example)					
Modified Z-count	14	0 to 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	1st of pair	01
Number of measurements	5	0 to 18	1	4	0 0100
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275 $\times 10^{-3}$m/m	5×10^{-6}m/m	0.115×10^{-3}m/m	0001 0111
Ephemeris CRC	16			0	0000 0000 0000 0000
Source availability duration	8	0 to 2540 s	10 s	Not provided	1111 1111
Number of B parameters	1	0 to 1	1	0	0
Spare	7			0	000 0000
Measurement Block 1					
Ranging source ID	8	1 to 255	1	2	0000 0010
Issue of data (IOD)	8	0 to 255	1	255	1111 1111
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+3.56 m	0000 0001 0110 0100
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.011 m/s	1111 1111 1111 0101
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	9.8 m	0011 0001
Measurement Block 2					
Ranging source ID	8	1 to 255	1	4	0000 0100
Issue of data (IOD)	8	0 to 255	1	126	0111 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	-1.0 m	1111 1111 1001 1100
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	+0.002 m/s	0000 0000 0000 0010
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	3.4 m	0001 0001

Measurement Block 3					
Ranging source ID	8	1 to 255	1	12	0000 1100
Issue of data (IOD)	8	0 to 255	1	222	1101 1110
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+4.11 m	0000 0001 1001 1011
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.029 m/s	1111 1111 1110 0011
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	10.2 m	0011 0011

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Measurement Block 4					
Ranging source ID	8	1 to 255	1	23	0001 0111
Issue of data (IOD)	8	0 to 255	1	80	0101 0000
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	-2.41 m	1111 1111 0000 1111
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.096 m/s	1111 1111 1010 0000
$\sigma_{pr\ gnd}$	8	0 to 50.8 m	0.2 m	1.6 m	0000 1000
Message Block CRC	32				1000 1000 1001 1111 0111 1000 0000 0100
APPLICATION FEC	48				1100 1100 1110 0110 1111 0110 1100 1110 1101 0110 0110 0010
Input to the bit scrambling (Note 2)	0 41 60 1B 55 73 A4 A8 A6 74 17 C2 20 E8 00 00 FF 00 40 FF 26 80 AF FF 8C 20 7E 39 FF 40 00 88 30 7B D9 80 C7 FF CC E8 0A F0 FF 05 FF 10 20 1E F9 11 46 6B 73 6F 67 33				
Output from the bit scrambling (Note 3)	0 67 57 93 1F 6C BC 83 79 EE C2 1B 12 34 46 D0 09 C1 09 FC 3A 84 80 0F E6 9F 18 6D 77 8E 1E 60 19 1B BA FF BC AB 68 26 7B E7 BC CE FA 0B D3 C4 43 C8 E0 B6 FA 42 84 A1				
Fill bits	0 to 2			0	
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650105 06345463 57026113 51374661 15123376 12066670 44776307 04225000 02735027 73373152 13230100 04706272 74137202 47724524 12715704 15442724 01101677 44571303 66447212 222				

Notes.—
1.   The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.
2.   This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.
3.   In this example, fill bits are not scrambled.
4.   This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.

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Table D-8.   Example of Type 1 and Type 2 VDB messages in a single burst

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	E	10 0
Transmission length (bits)	17	0 to 1 824 bits	1 bit	544	000 0000 1000 1000 00
Training sequence FEC	5	—	—	—	0000 0
APPLICATION DATA					
Message Block 1 (Type 1 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 1 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	2nd of pair	11
Number of measurements	5	0 to 18	1	1	0 0001
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275×10^{-3} m/m	5×10^{-6} m/m	0 (SBAS)	0000 0000
Ephemeris CRC	16	—	—	0	0000 0000 0000 0000
Source availability duration	8	0 to 2 540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	122	0111 1010
Issue of data (IOD)	8	0 to 255	1	2	0000 0010
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+1.0 m	0000 0000 0110 0100
Range rate correction (RRC)	16	±32.767 m	0.001 m/s	–0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	1.96 m	0110 0010
B_1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B_2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B_3	8	±6.35 m	0.05 m	–0.25 m	1111 1011
B_4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block 1 CRC	32	—	—	—	1011 0101 1101 0000 1011 1100 0101 0010
Message Block 2 (Type 2 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	0000 1000 0101 0011 0000 1100

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Message type identifier	8	1 to 8	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	34	0010 0010
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2	—	—	B	01
Spare	1	—	—	0	0

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
GBAS continuity/integrity designator	3	0 to 7	1	1	001
Local magnetic variation	11	±180°	0.25°	58° E	000 1110 1000
Spare	5	—	—	0	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 × 10^{-6} m/m	0.1 × 10^{-6} m/m	0	0000 0000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	45°40'32'' N	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005 arcsec	93°25'13''W	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	±83 886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference Station Data Selector	8	0 to 48	1	5	0000 0101
Maximum Use Distance (D_{max})	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Message Block 2 CRC	32	—	—	—	0101 1101 0111 0110 0010 0011 0001 1110
Application FEC	48				1110 1000 0100 0101 0011 1011 0011 1011 0100 0001 0101 0010
Input to the bit scrambling (Note 2)	0 41 10 00 55 30 CA 10 80 38 17 C3 80 00 00 00 FF 5E 40 26 00 1C FF 46 40 C0 DF 01 4A 3D 0B AD 55 30 CA 10 40 44 A4 17 00 00 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 78 C4 6E BA 4A 82 DC DC A2 17				
Output from the bit scrambling (Note 3)	0 67 27 88 1F 2F D2 3B 5F A2 C2 1A B2 DC 46 D0 09 9F 09 25 1C 18 D0 B6 2A 7F B9 55 C2 F3 15 45 7C 50 A9 6F 3B 10 00 D9 71 17 DC 4B 2D 1B 7B 83 72 D4 F7 CA 62 C8 D9 12 25 5E 13 2E 13 E0 42 44 37 45 68 29 5A B9 55 65				
Fill bits	0 to 2	—	—	1	0
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650105 67443352 35201160 30501336 62023576 12066670 74007653 30010255 31031274 26172772 76236442 41177201 35131033 33421734 42751235 60342057 66270254 17431214 03421036 70316613 46567433 66547730 34732201 40607506 014444				

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Table D-8A.   Example of Type 1 and Type 2 VDB messages with additional data blocks 1 and 2

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3			E	100
Transmission length (bits)	17	0 to 1824 bits	1 bit	592	00000001001010000
Training sequence FEC	5				10110
APPLICATION DATA					
Message Block 1 (Type 1 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8	1	1	0000 0001
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 1 example)					
Modified Z-count	14	0 to 1199.9 s	0.1 s	100 s	00 0011 1110 1000
Additional message flag	2	0 to 3	1	2nd of pair	11
Number of measurements	5	0 to 18	1	1	0 0001
Measurement type	3	0 to 7	1	C/A L1	000
Ephemeris Decorrelation Parameter (P)	8	0 to 1.275×10^{-3} m/m	5×10^{-6} m/m	0 (SBAS)	0000 0000
Ephemeris CRC	16			0	0000 0000 0000 0000
Source availability duration	8	0 to 2540 s	10 s	Not provided	1111 1111
Measurement Block 1					
Ranging source ID	8	1 to 255	1	122	0111 1010
Issue of data (IOD)	8	0 to 255	1	2	0000 0010
Pseudo-range correction (PRC)	16	±327.67 m	0.01 m	+2.09 m	0000 0000 1101 0001
Range rate correction (RRC)	16	±32.767 m/s	0.001 m/s	-0.2 m/s	1111 1111 0011 1000
σ_{pr_gnd}	8	0 to 5.08 m	0.02 m	1.96 m	0110 0010
B1	8	±6.35 m	0.05 m	+0.10 m	0000 0010
B2	8	±6.35 m	0.05 m	+0.15 m	0000 0011
B3	8	±6.35 m	0.05 m	–0.25 m	1111 1011
B4	8	±6.35 m	0.05 m	Not used	1000 0000
Message Block 1 CRC	32				00110010 10100100 11001011 00110000
Message Block 2 (Type 2 message)					
Message Block Header					
Message block identifier	8			Normal	1010 1010
GBAS ID	24			ERWN	00010101 00100101 11001110
Message type identifier	8	1 to 8	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	40	0010 1000

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Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2			B	01
Spare	1			0	0

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
GBAS continuity/integrity designator	3	0 to 7	1	1	001
Local magnetic variation	11	±180°	0.25°	58° E	000 1110 1000
Spare	5			0	0000 0
		0 to			
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005	45°40′	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005	93°25′	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	±83 886.07	0.01 m	892.5	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference Station Data Selector	8	0 to 48	1	5	0000 0101
Maximum Use Distance (Dmax)	8	2 to 510 km	2 km	50 km	0001 1001
Kmd_e_POS,GPS	8	0 to 12.75	0.05	6	0111 1000
Kmd_e,GPS	8	0 to 12.75	0.05	5	0110 0100
Kmd_e_POS,GLONASS	8	0 to 12.75	0.05	0	0000 0000
Kmd_e,GLONASS	8	0 to 12.75	0.05	0	0000 0000
Additional Data Blocks					
Additional Data Block Length	8	2 to 255	1	6	0000 0110
Additional Data Block Number	8	2 to 255	1	2	0000 0010
Additional Data Block 2					
Channel Number	16	20001 to	1	25001	0110 0001 1010 1001
ΔLatitude	8	±25.4°	0.2°	5.2	0001 1010
ΔLongitude	8	±25.4°	0.2°	−3.4	1110 1111
Message Block 2 CRC	32				11100000 01110010 00011101 00100100
Application FEC	48				1110 0010 0101 1100 0000 1111 1010 1011 0011 0100 0100 0000
Input to the bit scrambling (Note 2)		0 42 90 0D 55 73 A4 A8 80 38 17 C3 80 00 00 00 FF 5E 40 8B 00 1C FF 46 40 C0 DF 01 0C D3 25 4C 55 73 A4 A8 40 14 A4 17 00 00 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 60 40 95 86 58 F7 24 B8 4E 07 02 2C D5 F0 3A 47			
Output from the bit scrambling (Note 3)		0 64 A7 85 1F 6C BC 83 5F A2 C2 1A B2 DC 46 D0 09 9F 09 88 1C 18 D0 B6 2A 7F B9 55 84 1D 3B A4 7C 13 C7 D7 3B 40 00 D9 71 17 DC 4B 2D 1B 7B 83 72 D4 F7 CA 62 C8 D9 12 25 5E 13 2E 13 E0 5A C0 CC 79 7A 5C A2 DD B9 75 B6 95 64 52 78 3F			
Fill bits	0 to 2			1	0
Power ramp-down	9				000 000 000

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D8PSK Symbols (Note 4)	00000035 11204546 31650107 56336574 60137224 74145772 26467132 56422234 30443700 05565722 06506741 73647332 27242654 63345227 31575333 33421734 42751235 60342057 66270254 17431214 03421036 70316613 46567433 62077121 37275607 55315167 17135031 34423411 274444

Notes.—
1.   The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.
2.   This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.
3.   In this example, fill bits are not scrambled.
4.   This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)

Table D-8B.   Example of a Type 2 message containing data blocks 1 and 4

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15	—	—	—	000 0000 0000 0000
Synchronization and ambiguity resolution	48	—	—	—	0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier	3	—	—	E	100
Transmission length	17	0 to 1824 bits	1 bit	1704	0 0000 0110 1010 1000
Training sequence FEC	5	—	—	—	01000
APPLICATION DATA					
Message Block 1 (Type 2 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	000010 000101 001100 001100
Message type identifier	8	1 to 101	1	2	0000 0010
Message length	8	10 to 222 bytes	1 byte	37	0010 0101
Message (Type 2 example)					
GBAS reference receivers	2	2 to 4	1	3	01
Ground accuracy designator letter	2	—	—	B	01
Spare	1	—	—	—	0
GBAS continuity/integrity designator	3	0 to 7	1	2	010
Local magnetic variation	11	±180°	0.25°	E58.0°	000 1110 1000
Spare	5	—	—	—	0000 0
$\sigma_{vert\_iono\_gradient}$	8	0 to 25.5 x 10^{-6} m/m	0.1 x 10^{-6} m/m	4 x 10^{-6}	0010 1000
Refractivity index	8	16 to 781	3	379	1111 1001
Scale height	8	0 to 25 500 m	100 m	100 m	0000 0001
Refractivity uncertainty	8	0 to 255	1	20	0001 0100
Latitude	32	±90.0°	0.0005 arcsec	N45° 40' 32" (+164432")	0001 0011 1001 1010 0001 0001 0000 0000
Longitude	32	±180.0°	0.0005 arcsec	W93° 25' 13" (-336313")	1101 0111 1110 1000 1000 1010 1011 0000
Ellipsoid height	24	±83 886.07 m	0.01 m	892.55 m	0000 0001 0101 1100 1010 0111
Additional Data Block 1					
Reference station data selector	8	0 to 48	1	5	0000 0101
Maximum use distance (D_{max})	8	2 to 510 km	2 km	50 km	0001 1001
$K_{md\_e\_POS,GPS}$	8	0 to 12.75	0.05	6	0111 1000
$K_{md\_e\ C,GPS}$	8	0 to 12.75	0.05	5	0110 0100
$K_{md\_e\_POS,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
$K_{md\_e\ C,GLONASS}$	8	0 to 12.75	0.05	0	0000 0000
Additional Data Block 4					
Additional data block length	8	3	1 byte	3	0000 0011
Additional data block number	8	4	1	4	0000 0100
Slot group definition	8	—	—	E	0011 0000
Message Block 1 CRC	32	—	—	—	1100 0101 1110 0000 0010 0110 1100 1011

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
Message Block 2 (Type 3 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	BELL	000010 000101 001100 001100
Message type identifier	8	1 to 101	1	3	0000 0011
Message length	8	N/A	1 byte	170	1010 1010
Message (Type 3 example)					
Filler	1280	—	—	—	1010 1010 …... 1010 1010
Message Block 2 CRC	32	—	—	—	1001 0000 1110 1100 1101 1001 1011 1010
Application FEC	48	—	—	—	0000 1000 0010 0011 1100 1011 1101 0000 1101 0110 1011 0101
Input to the bit scrambling (Note 2)	0 45 58 02 55 30 CA 10 40 A4 A2 17 00 14 9F 80 28 00 88 59 C8 0D 51 17 EB E5 3A 80 A0 98 1E 26 00 00 C0 20 0C D3 64 07 A3 55 30 CA 10 C0 55 5D 9B 37 09 AD 6B 0B D3 C4 10				
Output from the bit scrambling (Note 3)	0 63 6F 8A 1F 2F D2 3B 9F 3E 77 CE 32 C8 D9 50 DE C1 C1 5A D4 09 7E E7 81 5A 5C D4 28 56 00 CE 29 60 A3 5F 77 87 C0 C9 D2 42 73 01 15 DB A6 8F EF 8C F3 88 DC 78 B6 C7 D0 93 58 5D 46 B5 6F D5 0C AA 77 FE D3 30 A2 27 E1 EC E4 F7 17 2D AD F4 0B 29 82 04 61 96 E4 50 E9 58 FA B8 C0 38 99 C7 BB 6C 3D 09 CA 7B 7E C2 CF 60 8D 18 75 B9 2B C5 FC 94 C8 57 79 52 C5 5F 6A B2 FF DF 33 4D DD 74 B5 28 2A 06 01 91 9B A4 43 E9 63 05 1D 95 B4 54 29 56 05 51 95 5B AA BC 00 36 66 2E EE 0F 0E 72 71 21 25 E5 EB 14 FD A8 CB F8 83 38 62 39 1E 3A 4E 3E 8E 30 71 D9 24 BA 17 C1 AC 9B F7 BC D3 C8 A3 78 1D 39 B5 C4 2B 69 FD 04 CA 68 81 07 9A 64 8F 6B 39 7D 2A 34 D0 6F EA				
Fill bits	0 to 2	—	—	2	00
Power ramp-down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)	00000035 11204546 31650102 46331130 13067746 52605627 35467122 62533573 77100603 75554273 01666461 41203311 42111340 14733657 27302663 77076361 44301001 17175104 35263707 43007132 40135774 07012022 52546153 57425454 25413051 54022547 01622754 12302141 24615265 50476225 56622615 23311312 51275055 11132570 45242065 63665236 04052447 35155017 73303745 61650521 06765616 04756006 16264736 30530735 02426407 53610061 12111501 04147002 72512117 74672621 42254251 12533720 37475054 44460104 57516674 46523401 22503075 25125742 03431633 22607072 37230050 35463673 43300570 12353363 77140357 42715724 03470633 30354042 67720645 27225703 50111005 40736127 14021742 36572477 13042222 2				

Notes.—
1. The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.
2. This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.
3. In this example, fill bits are not scrambled.
4. This field represents the phase, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians), relative to the phase of the first symbol.

Table D-9.   Example of a Type 4 message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				010 0011 1110 1111 1100 0110 0011 1011 0000 0011 1100 1000 0
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	D	01 1
Transmission length (bits)	17	0 to 1 824 bits	1 bit	784	000 0000 1100 0100 00
Training sequence FEC	5	—	—	—	0000 0
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 4 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	CMJ	0000 1100 1101 0010 1010 0000
Message type identifier	8	1 to 8	1	4	0000 0100
Message length	8	10 to 222 bytes	1 byte	92	0101 1100
Message (Type 4 example)					
FAS Data Set 1					
Data set length	8	2 to 212	1 byte	41	0010 1001
FAS Data Block 1					
Operation type	4	0 to 15	1	0	0000
SBAS service provider	4	0 to 15	1	15	1111
Airport ID	32	—	—	LFBO	0000 1100 0000 0110 0000 0010 0000 1111
Runway number	6	1 to 36	1	15	00 1111
Runway letter	2	—	—	R	01
Approach performance designator	3	0 to 7	1	CAT 1	001
Route indicator	5	—	—	C	0001 1
Reference path data selector (RPDS)	8	0 to 48	1	3	0000 0011
Reference path identifier	32	—	—	GTBS	0000 0111 0001 0100 0000 0010 0001 0011
LTP/FTP latitude	32	±90.0°	0.0005 arcsec	43.6441075°N	0001 0010 1011 1010 1110 0010 1000 0110
LTP/FTP longitude	32	±180.0°	0.0005 arcsec	1.345940°E	0000 0000 1001 0011 1101 1110 1001 0000
LTP/FTP height	16	–512.0 to 6 041.5 m	0.1 m	197.3	0001 1011 1011 0101
ΔFPAP latitude	24	±1°	0.0005 arcsec	–0.025145°	1111 1101 0011 1100 1100 1100
ΔFPAP longitude	24	±1°	0.0005 arcsec	0.026175°	0000 0010 1110 0000 0010 1100
Approach threshold crossing height (TCH)	15	0 to 1 638.35 m (0 to 3 276.7 ft)	0.05 m (0.1 ft)	17.05 m	000 0001 0101 0101
Approach TCH units selector	1	0 = ft; 1 = m	—	metres	1
Glide path angle (GPA)	16	0 to 90°	0.01°	3°	0000 0001 0010 1100
Course width	8	80.0 to 143.75 m	0.25 m	105	0110 0100
ΔLength offset	8	0 to 2 032 m	8 m	0	0000 0000
FAS Data Block 1 CRC	32	—	—	—	1010 0010 1010 0101 1010 1000 0100 1101
FASVAL/Approach status	8	0 to 25.4	0.1 m	10	0110 0100
FASLAL/Approach status	8	0 to 50.8	0.2 m	40	1100 1000
FAS Data Set 2					
Data set length	8	2 to 2	1 byte	41	0010 1001

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DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
FAS Data Block 2					
Operation type	4	0 to 15	1	0	0000
SBAS service provider	4	0 to 15	1	01	0001
Airport ID	32	—	—	LFBO	0000 1100 0000 0110 0000 0010 0000 1111
Runway number	6	1 to 36	1	33	10 0001
Runway letter	2	—	—	R	01
Approach performance designator	3	0 to 7	1	CAT 1	001
Route indicator	5	—	—	A	0000 1
Reference path data selector (RPDS)	8	0 to 48	1	21	0001 0101
Reference path identifier	32	—	—	GTN	0000 0111 0001 0100 0000 1110 0010 0000
LTP/FTP latitude	32	±90.0°	0.0005 arcsec	43.6156350°N	0001 0010 1011 0111 1100 0001 1011 1100
LTP/FTP longitude	32	±180.0°	0.0005 arcsec	1.3802350°E	0000 0000 1001 0111 1010 0011 0001 1100
LTP/FTP height	16	–512.0 to 6 041.5 m	0.1 m	200.2 m	0001 1011 1101 0010
ΔFPAP latitude	24	±1°	0.0005 arcsec	0.02172375°	0000 0010 0110 0010 1111 1011
ΔFPAP longitude	24	±1°	0.0005 arcsec	–0.0226050°	1111 1101 1000 0100 0011 1100
Approach threshold crossing height (TCH)	15	0 to 1 638.35 m (0 to 3 276.7 ft)	0.05 m (0.1 ft)	15.25 m	000 0001 0011 0001
Approach TCH units selector	1	0 = ft; 1 = m	—	metres	1
Glide path angle (GPA)	16	0 to 90°	0.01°	3.01°	0000 0001 0010 1101
Course width	8	80.0 to 143.75 m	0.25 m	105	0110 0100
ΔLength offset	8	0 to 2 032 m	8 m	0	0000 0000
FAS data block 2 CRC	32	—	—	—	1010 1111 0100 1101 1010 0000 1101 0111
FASVAL/Approach status	8	0 to 25.4	0.1 m	10	0110 0100
FASLAL /Approach status	8	0 to 50.8	0.2 m	40	1100 1000
Message Block CRC	32	—	—	—	0101 0111 0000 0011 1111 1110 1001 1011
APPLICATION FEC	48	—	—	—	0001 1011 1001 0001 0010 1010 1011 1100 0010 0101 1000 0101
Input to the bit scrambling (Note 2)					1 82 30 00 55 05 4B 30 20 3A 94 0F F0 40 60 30 F2 98 C0 C8 40 28 E0 61 47 5D 48 09 7B C9 00 AD D8 33 3C BF 34 07 40 AA 81 34 80 26 00 B2 15 A5 45 26 13 94 08 F0 40 60 30 86 90 A8 04 70 28 E0 3D 83 ED 48 38 C5 E9 00 4B D8 DF 46 40 3C 21 BF 8C 81 B4 80 26 00 EB 05 B2 F5 26 13 D9 7F C0 EA A1 A4 3D 54 89 D8
Output from the bit scrambling (Note 3)					1 A4 07 88 1F 1A 53 1B FF A0 41 D6 C2 9C 26 E0 04 59 89 CB 5C 2C CF 91 2D E2 2E 5D F3 07 1E 45 F1 53 5F C0 4F 53 E4 64 F0 23 C3 ED 05 A9 E6 7F FF FF B5 49 81 DD A3 F2 B5 40 9D A0 17 90 12 60 64 7C CF E3 BE A0 1E 72 FF 61 6E E4 02 44 D9 1E D2 FD 63 D1 12 C3 5A 00 0E F8 89 FE 4C 12 0C 78 4F 9D 55 08 16 F6
Fill bits	0 to 2	—	—	1	0
Power ramp down	9	—	—	—	000 000 000
D8PSK Symbols (Note 4)					00000035112045463165043223007716621707130525566731767243453777761577634616615705436152145764051334016775214231304443061301150266774341755603276241630527536540015247051420322575333462555437707605652760631444624316310135372225012076040752643510345771407777041566527360012232400740203144336275444 4

Table D-10.   Example of a Type 5 message

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
BURST DATA CONTENT					
Power ramp-up and settling	15				000 0000 0000 0000
Synchronization and ambiguity resolution	48				0100 0111 1101 1111 1000 1100 0111 0110 0000 0111 1001 0000
SCRAMBLED DATA					
Station slot identifier (SSID)	3	—	—	D	01 1
Transmission length (bits)	17	0 to 1 824 bits	1 bit	272	000 0000 0100 0100 00
Training sequence FEC	5	—	—	—	0001 1
APPLICATION DATA MESSAGE BLOCK					
Message Block (Type 5 message)					
Message Block Header					
Message block identifier	8	—	—	Normal	1010 1010
GBAS ID	24	—	—	CMJ	0000 1100 1101 0010 1010 0000
Message type identifier	8	1 to 8	1	5	0000 0101
Message length	8	10 to 222 bytes	1 byte	28	0001 1100
Message (Type 5 example)					
Modified Z-count	14	0 to 1 199.9 s	0.1 s	100 s	00 0011 1110 1000
Spare	2	—	—	—	00
Number of impacted sources (N)	8	0 to 31	1	2	0000 0010
First impacted source					
Ranging source ID	8	1 to 255	1	4	0000 0100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	50 s	0000 101
Second impacted source					
Ranging source ID	8	1 to 255	1	3	0000 0011
Source availability sense	1	—	—	Will start	1
Source availability duration	7	0 to 1 270 s	10 s	200 s	0010 100
Number of obstructed approaches (A)	8	0 to 255	1	2	0000 0010
First obstructed approach					
Reference path data selector (RPDS)	8	0 to 48	1	21	0001 0101
Number of impacted sources for first obstructed approach (N_A)	8	1 to 31	1	2	0000 0010
First impacted ranging source of first obstructed approach					
Ranging source ID	8	1 to 255	1	12	0000 1100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	250 s	0011 001
Second impacted ranging source of first obstructed approach					
Ranging source ID	8	1 to 255	1	14	0000 1110
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	1 000 s	1100 100

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Second obstructed approach					
Reference path data selector (RPDS)	8	0 to 48	1	14	0000 1110
Number of impacted sources for second obstructed approach	8	1 to 31	1	1	0000 0001

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	VALUES	BINARY REPRESENTATION (NOTE 1)
First impacted ranging source of second obstructed approach					
Ranging source ID	8	1 to 255	1	12	0000 1100
Source availability sense	1	—	—	Will cease	0
Source availability duration	7	0 to 1 270 s	10 s	220 s	0010 110
Message Block CRC	32	—	—	—	1101 1011 0010 1111 0001 0010 0000 1001
APPLICATION FEC	48	—	—	—	0011 1110 1011 1010 0001 1110 0101 0110 1100 1011 0101 1011
Input to the bit scrambling (Note 2)	1 82 20 18 55 05 4B 30 A0 38 17 C0 40 20 50 C0 94 40 A8 40 30 4C 70 13 70 80 30 34 90 48 F4 DB DA D3 6A 78 5D 7C				
Output from the bit scrambling	1 A4 17 90 1F 1A 53 1B 7F A2 C2 19 72 FC 16 10 62 81 E1 43 2C 48 5F E3 1A 3F 56 60 18 86 EA 33 F3 B3 09 07 26 28				
Fill bits	0 to 2	—	—	0	
Power ramp-down	9				000 000 000
D8PSK Symbols (Note 3)	00000035112045463165043220566605510676024161244773634632207001032240066013321241662311636437771101731157430232344514664444				

Notes.—
1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted or sent to the bit scrambler. All data fields are sent in the order specified in the table.*
2. *This field is coded in hexadecimal with the first bit to be sent to the bit scrambler as its MSB. The first character represents a single bit.*
3. *Symbols are represented by their differential phase with respect to the first symbol of the message, in units of π/4 (e.g. a value of 5 represents a phase of 5π/4 radians) relative to the first symbol.*

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7.18   Type 101 message

Type 101 message is an alternative to Type 1 message developed to fit the specific needs of GRAS systems. The primary difference in the contents and application of these two message types is two-fold: (a) Type 101 message has a larger available range for σpr_gnd values and (b) ground subsystem time-to-alert is larger for a system broadcasting Type 101 messages. The first condition would typically occur in a system where a broadcast station covers a large area, such that decorrelation errors increase the upper limit of the pseudo-range correction errors. The second condition may be typical for systems where a central master station processes data from multiple receivers dispersed over a large area.

8.   Signal quality monitor (SQM) design

8.1   The objective of the signal quality monitor (SQM) is to detect satellite signal anomalies in order to prevent aircraft receivers from using misleading information (MI). MI is an undetected aircraft pseudo-range differential error greater than the maximum error (MERR) that can be tolerated. These large pseudo-range errors are due to C/A code correlation peak distortion caused by satellite payload failures. If the reference receiver used to create the differential corrections and the aircraft receiver have different measurement mechanizations (i.e. receiver bandwidth and tracking loop correlator spacing), the signal distortion affects them differently. The SQM must protect the aircraft receiver in cases when mechanizations are not similar. SQM performance is further defined by the probability of detecting a satellite failure and the probability of incorrectly annunciating a satellite failure.

8.2   The signal effects that might cause a GBAS or SBAS to output MI can be categorized into three different effects on the correlation function as follows:

   a)   *Dead zones:* If the correlation function loses its peak, the receiver's discriminator function will include a flat spot or dead zone. If the reference receiver and aircraft receiver settle in different portions of this dead zone, MI can result.

   b)   *False peaks:* If the reference receiver and aircraft receiver lock to different peaks, MI could exist.

   c)   *Distortions:* If the correlation peak is misshapen, an aircraft that uses a correlator spacing other than the one used by the reference receivers may experience MI.

8.3   The threat model proposed for use in assessment of SQM has three parts that can create the three correlation peak pathologies listed above.

8.4   Threat Model A consists of the normal C/A code signal except that all the positive chips have a falling edge that leads or lags relative to the correct end-time for that chip. This threat model is associated with a failure in the navigation data unit (NDU), the digital partition of a GPS or GLONASS satellite.

8.4.1   Threat Model A for GPS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in fractions of a

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chip. The range for this parameter is $-0.12 \le \Delta \le 0.12$. Threat Model A for GLONASS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in fractions of a chip. The range for this parameter is $-0.11 \le \Delta \le 0.11$.

8.4.2   Within this range, threat Model A generates the dead zones described above. (Waveforms with lead need not be tested, because their correlation functions are simply advances of the correlation functions for lag; hence, the MI threat is identical.)

8.5   Threat Model B introduces amplitude modulation and models degradations in the analog section of the GPS or GLONASS satellite. More specifically, it consists of the output from a second order system when the nominal C/A code baseband signal is the input. Threat Model B assumes that the degraded satellite subsystem can be described as a linear system dominated by a pair of complex conjugate poles. These poles are located at $\sigma \pm j2\pi f_d$, where σ is the damping factor in 10^6 nepers/second and f_d is the resonant frequency with units of 10^6 cycles/second.

8.5.1   The unit step response of a second order system is given by:

$$e^{(t)} = \begin{cases} 0 & t \le 0 \\ 1 - \exp(-\sigma t)\left[cos\omega_d t + \dfrac{\sigma}{\omega_d} \sin \omega_d t \right] & t \ge 0 \end{cases}$$

where $\omega_d = 2\pi f_d$.

8.5.2   Threat Model B for GPS corresponding to second order anomalies uses the following ranges for the parameters Δ, f_d and σ:

$\Delta = 0$; $4 \le f_d \le 17$; and $0.8 \le \sigma \le 8.8$.

Threat Model B for GLONASS corresponding to second order anomalies uses the following ranges for the parameters defined above:

$\Delta = 0$; $10 \le f_d \le 20$; and $2 \le \sigma \le 8$.

8.5.3   Within these parameter ranges, threat Model B generates distortions of the correlation peak as well as false peaks.

8.6   Threat Model C introduces both lead/lag and amplitude modulation. Specifically, it consists of outputs from a second order system when the C/A code signal at the input suffers from lead or lag. This waveform is a combination of the two effects described above.

8.6.1   Threat Model C for GPS includes parameters Δ, f_d and σ with the following ranges:

$-0.12 \le \Delta \le 0.12$; $7.3 \le f_d \le 13$; and $0.8 \le \sigma \le 8.8$. Threat Model C for GLONASS includes parameters Δ, f_d and σ with the

following ranges:

$-0.11 \le \Delta \le 0.11$; $10 \le f_d \le 20$; and $2 \le \sigma \le 8$.

8.6.2   Within these parameter ranges, threat Model C generates dead zones, distortions of the correlation peak and false peaks.

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8.7   Unlike GPS and GLONASS, the SBAS signal is commissioned and controlled by the service provider. Moreover, the service provider also monitors the quality of the signal from the SBAS. To this end, the threat model will be specified and published by the service provider for each SBAS satellite. The SBAS SQM will be designed to protect all avionics that comply with Table D-12. Publication of the threat model is required for those cases where a service provider chooses to allow the SBAS ranging signal from a neighbouring service provider to be used for precision approach by SBAS or GBAS. In these cases, the service provider will monitor the SBAS ranging signal from the neighbouring satellite.

8.8   In order to analyse the performance of a particular monitor design, the monitor limit must be defined and set to protect individual satellite pseudo-range error relative to the protection level, with an allocation of the ground subsystem integrity risk. The maximum tolerable error (denoted as MERR) for each ranging source i can be defined in GBAS as:

$$\text{MERR} = K_{\text{ffmd}}\, \sigma_{\text{pr\_gnd,i}} \quad \text{and}$$

$$MERR = K_{V.PA}\sqrt{\sigma_{i.UDRE}^2 + min\{\sigma_{i.UIRE}^2\}}$$

for SBAS APV and precision approach where $min\{\sigma_{iUIRE}^2\}$ is the minimum possible value for any user. MERR is evaluated at the output of a fault-free user receiver and varies with satellite elevation angle and ground subsystem performance.

8.9   The SQM is designed to limit the UDRE to values below the MERR in the case of a satellite anomaly. Typically, the SQM measures various correlation peak values and generates spacing and ratio metrics that characterize correlation peak distortion. Figure D-9 illustrates typical points at the top of a fault-free, unfiltered correlation peak.

8.9.1   A correlator pair is used for tracking. All other correlator values are measured with respect to this tracking pair.

8.9.2   Two types of test metrics are formed: early-minus-late metrics (D) that are indicative of tracking errors caused by peak distortion, and amplitude ratio metrics (R) that measure slope and are indicative of peak flatness or close-in, multiple peaks.

8.9.3   It is necessary that the SQM has a precorrelation bandwidth that is sufficiently wide to measure the narrow spacing metrics, so as not to cause significant peak distortion itself and not to mask the anomalies caused by the satellite failure. Typically, the SQM receiver must have a precorrelation bandwidth of at least 16 MHz for GPS and at least 15 MHz for GLONASS.

8.9.4   The test metrics are smoothed using low-pass digital filters. The time constant of these filters are to be shorter than those used jointly (and standardized at 100 seconds) by the reference receivers for deriving differential corrections and by the aircraft receiver for smoothing pseudo-range measurements (using carrier smoothing). The smooth metrics are then compared to thresholds. If any one of the thresholds is exceeded, an alarm is generated for that satellite.

8.9.5   The thresholds used to derive performance are defined as minimum detectable errors (MDEs) and minimum detectable ratios (MDRs). Fault-free false detection probability and missed detection probability are used to derive MDEs and MDRs. The noise in metrics (D) and (R), as denoted $\sigma_{D,test}$ and $\sigma_{R,test}$ below, is dominated by multipath errors. Note that the metric test can also have a mean value (μ_{test}) caused by SQM receiver filter distortion. Threshold tests must also account for the mean values.

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8.9.6　　　The MDE and MDR values used in the SQM performance simulations are calculated based on the following equations:

$$MDE = (K_{ffd} + K_{md})\, \sigma_{D,test} \text{ and}$$
$$MDR = (K_{ffd} + K_{md})\, \sigma_{R,test}$$

where

$K_{ffd} = 5.26$　　　　is a typical fault-free detection multiplier representing a false detection probability of 1.5×10^{-7} per test;

$K_{md} = 3.09$　　　　is a typical missed detection multiplier representing a missed detection probability of 10^{-3} per test;

$\sigma_{D,test}$　　　　is the standard deviation of measured values of difference test metric D; and

$\sigma_{R,test}$　　　　is the standard deviation of measured values of ratio test metric R.

8.9.7　If multiple independent SQM receivers are used to detect the failures, the sigma values can be reduced by the square root of the number of independent monitors.

8.9.8　A failure is declared if

$$| D,test - \mu_{D,test} | \geq MDE \text{ or}$$
$$| R,test - \mu_{R,test} | \geq MDR$$

for any of the tests performed, where $\mu_{X,test}$ is the mean value of the test X that accounts for fault-free SQM receiver filter distortion, as well as correlation peak distortion peculiar to the specific C/A code PRN. (Not all C/A code correlation peaks have the same slope. In a simulation environment, however, this PRN distortion can be ignored, and a perfect correlation peak can be used, except for simulated filter distortion.)

8.10　　　The standard deviations of the test statistics, $\sigma_{D,test}$ and $\sigma_{R,test}$ can be determined via data collection on a multicorrelator receiver in the expected operating environment. The data collection receiver utilizes a single tracking pair of correlators and additional correlation function measurement points which are slaved to this tracking pair, as illustrated in Figure D-9. Data is collected and smoothed for all available measurement points in order to compute the metrics. The standard deviation of these metrics define $\sigma_{D,test}$. It is also possible to compute these one sigma test statistics if a multipath model of the installation environment is available.

8.10.1　　　The resulting $\sigma_{D,test}$ is highly dependent on the multipath environment in which the data are collected. The deviation due to multipath can be an order of magnitude greater than that which would result from noise even at minimum carrier-to-noise level. This aspect illustrates the importance of the antenna design and siting criteria which are the primary factors in determining the level of multipath that will enter the receiver. Reducing multipath will significantly decrease the resulting MDEs and thus improve the SQM capabilities.

8.10.2　Mean values $\mu_{D,test}$ and $\mu_{R,test}$, on the other hand, are determined in a relatively error-free environment, such as through the use of GPS and GLONASS signal simulator as input. These mean values model the nominal SQM receiver's filter distortion of the autocorrelation peak, including the effects of distortion due to adjacent minor autocorrelation peaks. The

mean values can differ for the various PRNs based on these properties.

8.10.3   The presence of nominal signal deformation biases may cause the distribution of the monitor detectors to have non-zero mean. These biases can be observed by averaging measurements taken from a real-world data collection. Note that the nominal biases may depend on elevation and they typically change slowly over time.

8.11   In order for the ground monitor to protect users against the different threat models described above, it is necessary to assume that aircraft receivers have specific characteristics. If no such constraints were assumed, the complexity of the ground monitor would be unnecessarily high. Evolution in the technology may lead to improved detection capability in the aircraft receiver and may alleviate the current constraints.

8.11.1   For double-delta correlators, the aircraft receiver tracks the strongest correlation peak over the full code sequence for every ranging source used in the navigation solution.

8.11.2   For double-delta correlators, the precorrelation filter rolls off by at least 30 dB per octave in the transition band. For GBAS receivers, the resulting attenuation in the stop band is required to be greater than or equal to 50 dB (relative to the peak gain in the pass band).

8.11.3   The following parameters are used to describe the tracking performance specific to each type of satellite:

a)   the instantaneous correlator spacing is defined as the spacing between a particular set of early and late samples of the correlation function;

b)   the average correlator spacing is defined as a one-second average of the instantaneous correlator spacing. The average applies over any one-second time frame;

c)   the discriminator Δ is based upon an average of early-minus-late samples with spacings inside the specified range, or is of the type $\Delta = 2\Delta_{d1} - \Delta_{2d1}$, with both d_1 and $2d_1$ in the specified range. Either a coherent or non-coherent discriminator is used;

d)   the differential group delay applies to the entire aircraft system prior to the correlator, including the antenna. The differential group delay is defined as:

$$\left| \frac{d\phi}{d\omega}(f_c) - \frac{d\phi}{d\omega}(f) \right|$$

where

f_c is the precorrelation band pass filter centre frequency;

f is any frequency within the 3dB bandwidth of the precorrelation filter;

ϕ is the combined phase response of precorrelation band pass filter and antenna; and

ω is equal to $2\pi f$.

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8.11.4   For aircraft receivers using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-11 except as noted below.

8.11.4.1 For GBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-11, except that the region 1 minimum bandwidth will increase to 4 MHz and the average correlator spacing is reduced to an average of 0.21 chips or instantaneous of 0.235 chips.

8.11.5   For aircraft receivers using early-late correlators and tracking GLONASS satellites, the precorrelation bandwidth of the installation, the correlator spacing, and the differential group delay are within the ranges as defined in Table D-12.

8.11.6   For aircraft receivers using double-delta correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Tables D-13A and D-13B.

8.11.7   For aircraft receivers using the early-late or double-delta correlators and tracking SBAS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-14.

9.   Status monitoring and NOTAM

9.1   System status

9.1.1   Degradation of GBAS usually has local effects and affects mainly approach operations. System degradation of GBAS is to be distributed as approach-related information.

9.1.2 Degradation of core satellite constellation(s) or SBAS usually has not only local effects, but additional consequences for a wider area, and may directly affect en-route operations. System degradation of these elements is to be distributed as area-related information. An example is a satellite failure.

9.1.3   Degradation of GRAS may have local effects and/or wide area effects. Therefore, if the degradation has only local effects, GRAS system degradation information is to be distributed in accordance with 9.1.1. If the degradation has wide area effects, GRAS system degradation information is to be distributed in accordance with 9.1.2.

9.1.4   Information is to be distributed to indicate the inability of GNSS to support a defined operation. For example, GPS/SBAS may not support a precision approach operation on a particular approach. This information can be generated automatically or manually based upon models of system performance.

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Table D-11.   GPS tracking constraints for early-late correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	$2 < BW \leq 7$ MHz	$0.045 - 1.1$	$0.04 - 1.2$	≤ 600 ns
2	$7 < BW \leq 16$ MHz	$0.045 - 0.21$	$0.04 - 0.235$	≤ 150 ns
3	$16 < BW \leq 20$ MHz	$0.045 - 0.12$	$0.04 - 0.15$	≤ 150 ns
4	$20 < BW \leq 24$ MHz	$0.08 - 0.12$	$0.07 - 0.13$	≤ 150 ns

Table D-12.   GLONASS tracking constraints for early-late correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing range (chips)	Instantaneous correlator spacing range (chips)	Differential group delay
1	$7 < BW \leq 9$ MHz	$0.05 - 1.0$	$0.045 - 1.1$	≤ 100 ns
2	$9 < BW \leq 15$ MHz	$0.05 - 0.2$	$0.045 - 0.22$	≤ 100 ns
3	$15 < BW \leq 18$ MHz	$0.05 - 0.1$	$0.045 - 0.11$	≤ 100 ns

**Table D-13A.   GPS tracking constraints for GRAS and
SBAS airborne receivers with double-delta correlators**

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (X) (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	$(-50 \times X) + 12 < BW \leq 7$ MHz	0.1 – 0.2	0.09 – 0.22	≤ 600 ns
	$2 < BW \leq 7$ MHz	0.2 – 0.6	0.18 – 0.65	
2	$(-50 \times X) + 12 < BW \leq (40 \times X) + 11.2$ MHz	0.045 – 0.07	0.04 – 0.077	
	$(-50 \times X) + 12 < BW \leq 14$ MHz	0.07 – 0.1	0.062 – 0.11	≤ 150 ns
	$7 < BW \leq 14$ MHz	0.1 – 0.24	0.09 – 0.26	
3	$14 < BW \leq 16$ MHz	0.07 – 0.24	0.06 – 0.26	≤ 150 ns

**Table D-13B. GPS tracking constraints for GBAS airborne receivers
with double-delta correlators**

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing range (X) (chips)	Instantaneous correlator spacing range (chips)	Differential group delay
1	$(-50 \times X) + 12 < BW \leq 7$ MHz	0.1 –0.16	0.09 –0.18	≤ 600 ns
	$4 < BW \leq 7$ MHz	0.16 – 0.6	0.14 – 0.65	
2	$(-50 \times X) + 12 < BW \leq (133.33 \times X) + 2.667$ MHz	0.07 – 0.085	0.063 – 0.094	
	$(-50 \times X) + 12 < BW \leq 14$ MHz	0.085 – 0.1	0.077 – 0.11	≤ 150 ns
	$7 < BW \leq 14$ MHz	0.1 – 0.24	0.09 – 0.26	
3	$14 < BW \leq 16$ MHz	0.1 – 0.24	0.09 – 0.26	≤ 150 ns
	($14 < BW < (133.33 \times X) + 2.667$ MHz	0.085 – 0.1	0.077 – 0.11	

Table D-14.   SBAS ranging function tracking constraints

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Instantaneous correlator spacing (chips)	Differential group delay
1	$2 < BW \leq 7$ MHz	$0.045 - 1.1$	$0.04 - 1.2$	≤ 600 ns
2	$7 < BW \leq 20$ MHz	$0.045 - 1.1$	$0.04 - 1.2$	≤ 150 ns

9.2   Information on type of degradation

The following information is to be distributed:

    a)   non-availability of service;

    b)   downgrade of service, if applicable; and

    c)   time and expected duration of degradation.

9.3   Timing of notification

For scheduled events, notification should be given to the NOTAM authority at least 72 hours prior to the event. For unscheduled events, notification to the NOTAM authority should be given within 15 minutes. Notification should be given for events of 15-minute, or longer, duration.

10.   Interference

10.1   Potential for interference

Satellite radio navigation systems such as GPS and GLONASS feature relatively weak received signal power, meaning that an interference signal could cause loss of service. In order to maintain service, it will be necessary to ensure that the maximum interference levels specified in the SARPs are not exceeded.

10.2   Specification of the interference threshold at the antenna port

The indications of the interference threshold levels are referenced to the antenna port. In this context, the term "antenna port" means the interface between the antenna and the GNSS receiver where the satellite signal power corresponds to the nominal minimum received signal power of -164.5 dBW for GPS and -165.5 dBW for GLONASS. Due to the reduced distance from potential interference sources, GNSS receivers that are used for the approach phase of flight must have a higher interference threshold than receivers that are only used for en-route navigation.

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10.3   In-band interference sources

A potential source of in-band harmful interference is Fixed Service operation in certain States. There is a primary allocation to the fixed service for point-to-point microwave links in certain States in the frequency band used by GPS and GLONASS.

10.4   Out-of-band interference sources

Potential sources of out-of-band interference include harmonics and spurious emissions of aeronautical VHF and UHF transmitters. Out-of-band noise, discrete spurious products and intermodulation products from radio and TV broadcasts can also cause interference problems.

10.5   Aircraft generated sources

10.5.1   The potential for harmful interference to GPS and GLONASS on an aircraft depends on the type of aircraft, its size and the transmitting equipment installed. The GNSS antenna location should take into account the possibility of on-board interference (mainly SATCOM).

10.5.2 GNSS receivers that are used on board aircraft with SATCOM equipment must have a higher interference threshold in the frequency range between 1 610 MHz and 1 626.5 MHz than receivers on board aircraft without SATCOM equipment. Therefore, specifications for the interference threshold discriminate between both cases.

Note.— Limits for radiated SATCOM aircraft earth stations are given in Annex 10, Volume III, Part I, Chapter 4, 4.2.3.5.

10.5.3 The principal mitigation techniques for on-board interference include shielding, filtering, receiver design techniques, and, especially on larger aircraft, physical separation of antennas, transmitters and cabling. Receiver design techniques include the use of adaptive filters and interference cancellation techniques that mitigate against narrow in-band interference. Antenna design techniques include adaptive null steering antennas that reduce the antenna gain in the direction of interference sources without reducing the signal power from satellites.

10.6   Integrity in the presence of interference

The requirement that SBAS and GBAS receivers do not output misleading information in the presence of interference is intended to prevent the output of misleading information under unintentional interference scenarios that could arise. It is not intended to specifically address intentional interference. While it is impossible to completely verify this requirement through testing, an acceptable means of compliance can be found in the appropriate receiver Minimum Operational Performance Standards published by RTCA and EUROCAE.

11.   Recording of GNSS parameters

11.1   In order to be able to conduct post-incident/accident investigations (Chapter 2, 2.1.4.2 and 2.1.4.3), it is necessary to record GNSS information both for the augmentation system and for the appropriate GNSS core system constellation used for the operation. The parameters to be recorded are dependent on the type of operation, augmentation system and core elements used. All parameters available to users within a given service area should be recorded at representative locations in the service area.

11.2   The objective is not to provide independent assurance that the GNSS is functioning correctly, nor is it to provide another level of system monitoring for anomalous performance or input data for a NOTAM process. The recording system need not be independent of the GNSS service and may be delegated to other States or entities. In order to enable future reconstruction of position, velocity and time indications provided by specific GNSS configurations, it is recommended to log data continuously, generally at a 1 Hz rate.

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11.3   For GNSS core systems the following monitored items should be recorded for all satellites in view:

   a)   observed satellite carrier-to-noise density (C/N$_0$);

   b)   observed satellite raw pseudo-range code and carrier phase measurements;

   c)   broadcast satellite navigation messages, for all satellites in view; and

   d)   relevant recording receiver status information.

11.4   For SBAS the following monitored items should be recorded for all geostationary satellites in view in addition to the GNSS core system monitored items listed above:

   a)   observed geostationary satellite carrier-to-noise density (C/N$_0$);

   b)   observed geostationary satellite raw pseudo-range code and carrier phase measurements;

   c)   broadcast SBAS data messages; and

   d)   relevant receiver status information.

11.5   For GBAS the following monitored items should be recorded in addition to the GNSS core system and SBAS monitored items listed above (where appropriate):

   a)   VDB power level;

   b)   VDB status information; and

   c)   broadcast GBAS data messages.

12.   GNSS performance assessment

The data described in Section 11 may also support periodic confirmation of GNSS performance in the service area.

13.   GNSS and database

Note.— Provisions relating to aeronautical data are contained in Annex 11, Chapter 2, and Annex 15, Chapter 3.

13.1   The database is to be current with respect to the effective AIRAC cycle, which generally means that a current database be loaded into the system approximately every 28 days. Operating with out-of-date navigation databases has to be avoided.

13.2   In certain situations, operations using an expired database can be conducted safely by implementing a process and/or using procedures to ensure that the required data is correct. These processes and/or procedures need prior approval by the State.

13.2.1   These procedures should be based on one of the following methods:

   a)   require the crew to check, prior to the operation, critical database information against current published information. (This method increases workload and would not be practical for all applications.); or

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    b)   waive the requirement for a current database and frequent checks by the crew of the database information. This waiver can only be applied to very specific cases where aircraft are operated in a strictly limited geographical area and where that area is controlled by a single regulatory agency or multiple agencies that coordinate this process; or

    c)   use another approved method that ensures an equivalent level of safety.

14.   Modelling of residual errors

14.1   Application of the integrity requirements for SBAS and GBAS requires that a model distribution be used to characterize the error characteristics in the pseudo-range. The HPL/LPL and VPL models (see 7.5.3) are constructed based on models of the individual error components (in the pseudo-range domain) that are independent, zero-mean, normal distributions. The relationship between this model and the true error distribution must be defined.

14.2   One method of ensuring that the protection level risk requirements are met is to define the model variance (σ^2), such that the cumulative error distribution satisfies the conditions:

$$\int_{y}^{\infty} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \; for \; all \; \left(\frac{y}{\sigma}\right) \geq 0 \; and$$

$$\int_{-\infty}^{-y} f(x)dx \leq Q\left(\frac{y}{\sigma}\right) \; for \; all \; \left(\frac{y}{\sigma}\right) \geq 0 \; and$$

where

f(x) =   probability density function of the residual aircraft pseudo-range error; and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-\frac{t^2}{2}} dt$$

14.3   This method can be directly applied when the error components have zero-mean, symmetrical and unimodal probability density functions. This is the case for the receiver contribution to corrected pseudo-range error, since the aircraft element is not subjected to low-frequency residual multipath errors.

14.4   This method can be extended to address non-zero-mean, residual errors by inflating the model variance to compensate for the possible effect of the mean in the position domain.

14.5   Verification of the pseudo-range error models must consider a number of factors including:

    a)   the nature of the error components;

    b)   the sample size required for confidence in the data collection and estimation of each distribution;

    c)   the correlation time of the errors; and

    d)   the sensitivity of each distribution to geographic location and time.

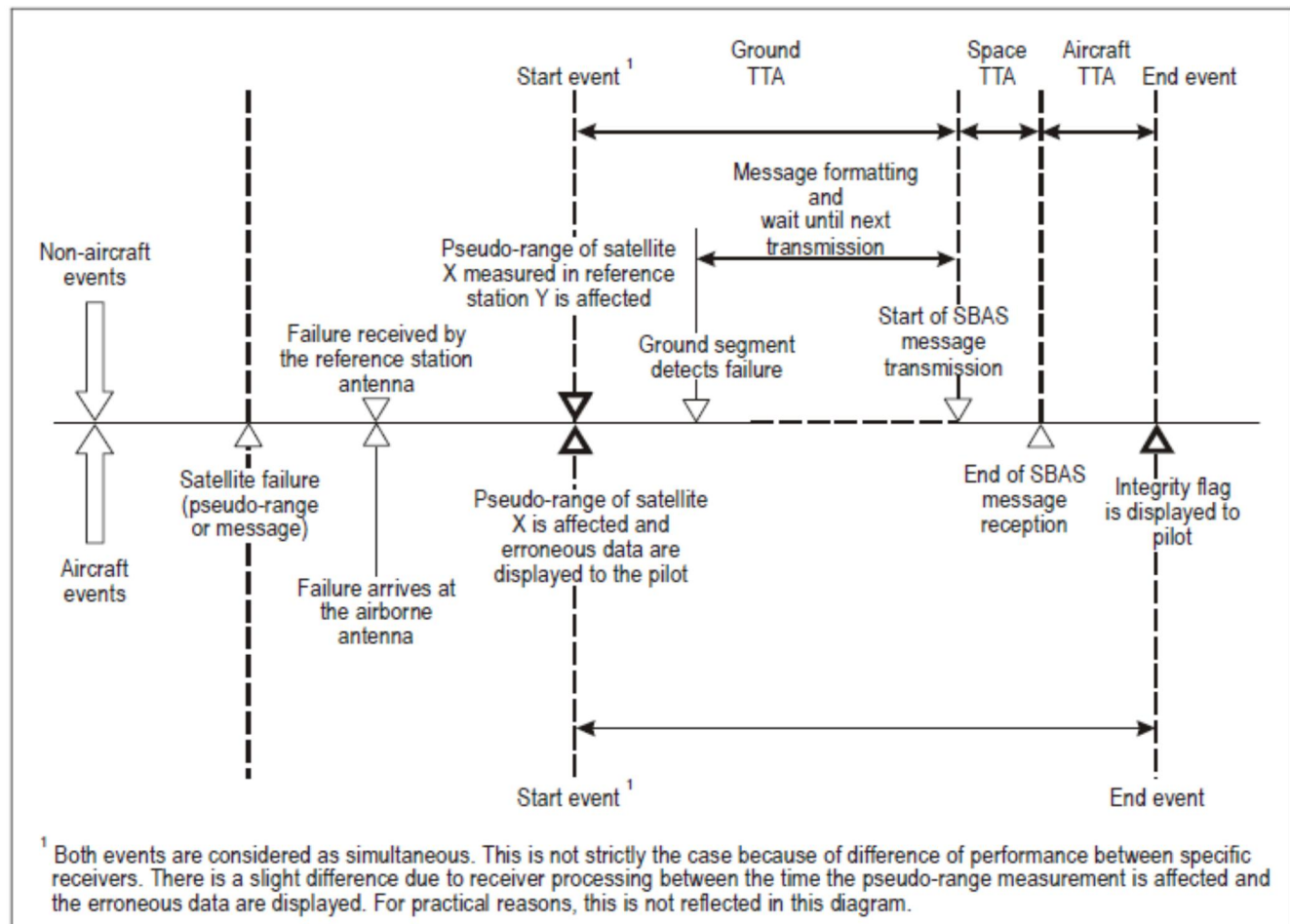Attachment D

Figure D-1. *Reserved*

Figure D-2.   SBAS time-to-alert
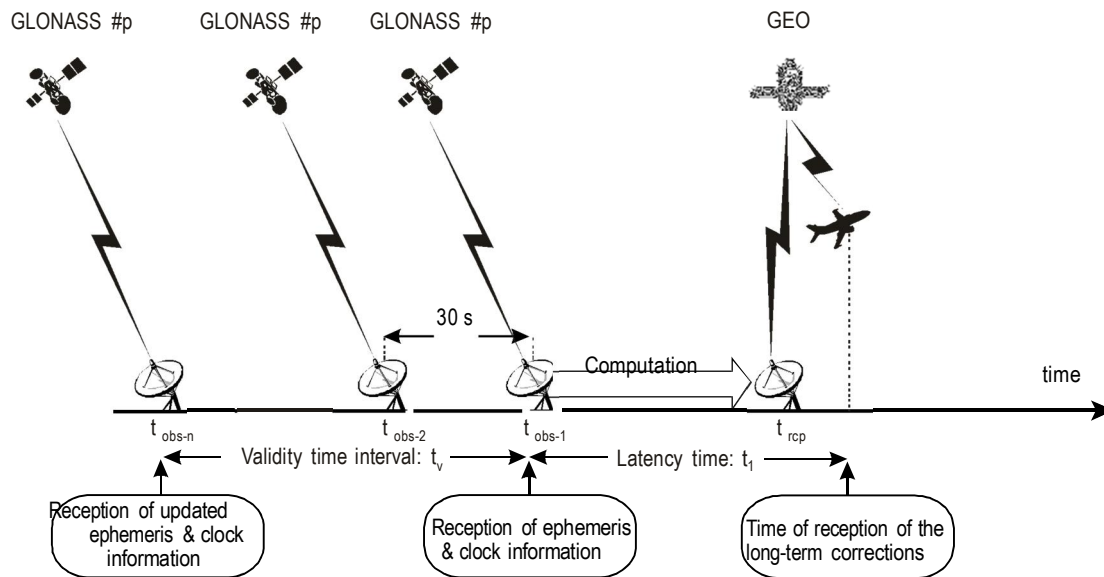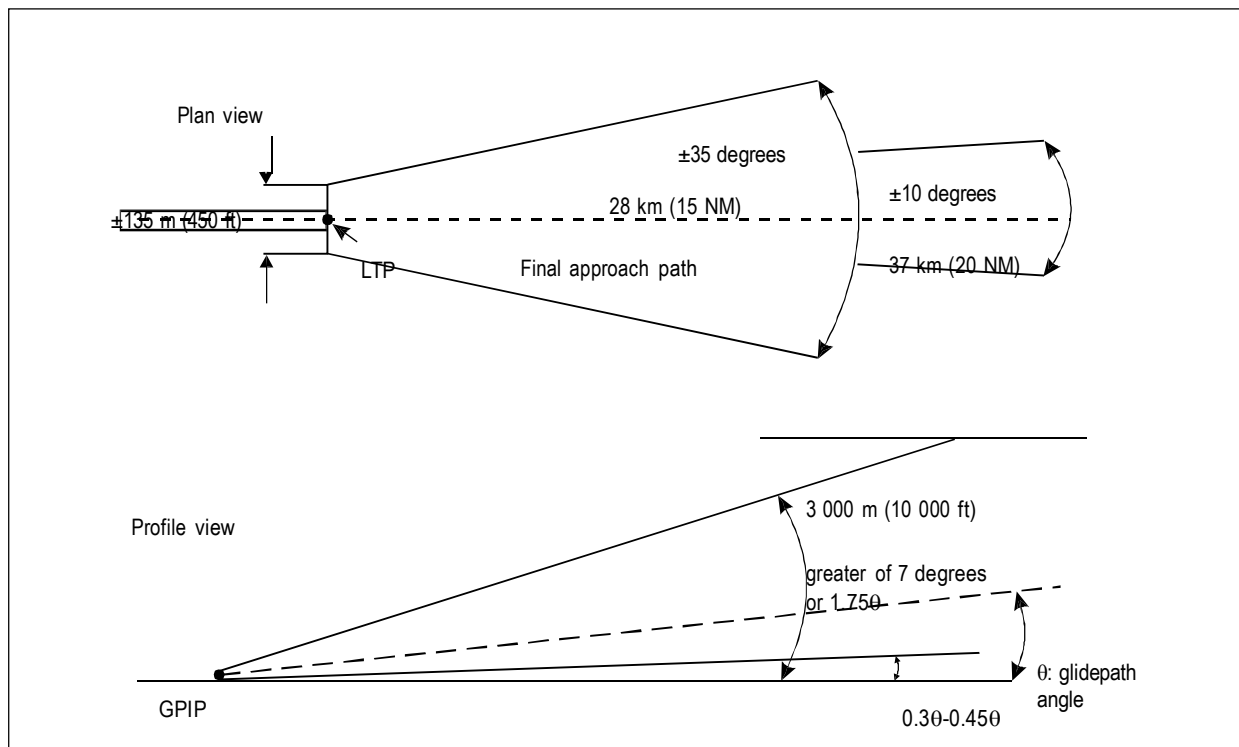
Figure D-3.   GLONASS time

GPIP   — glide path intersection point
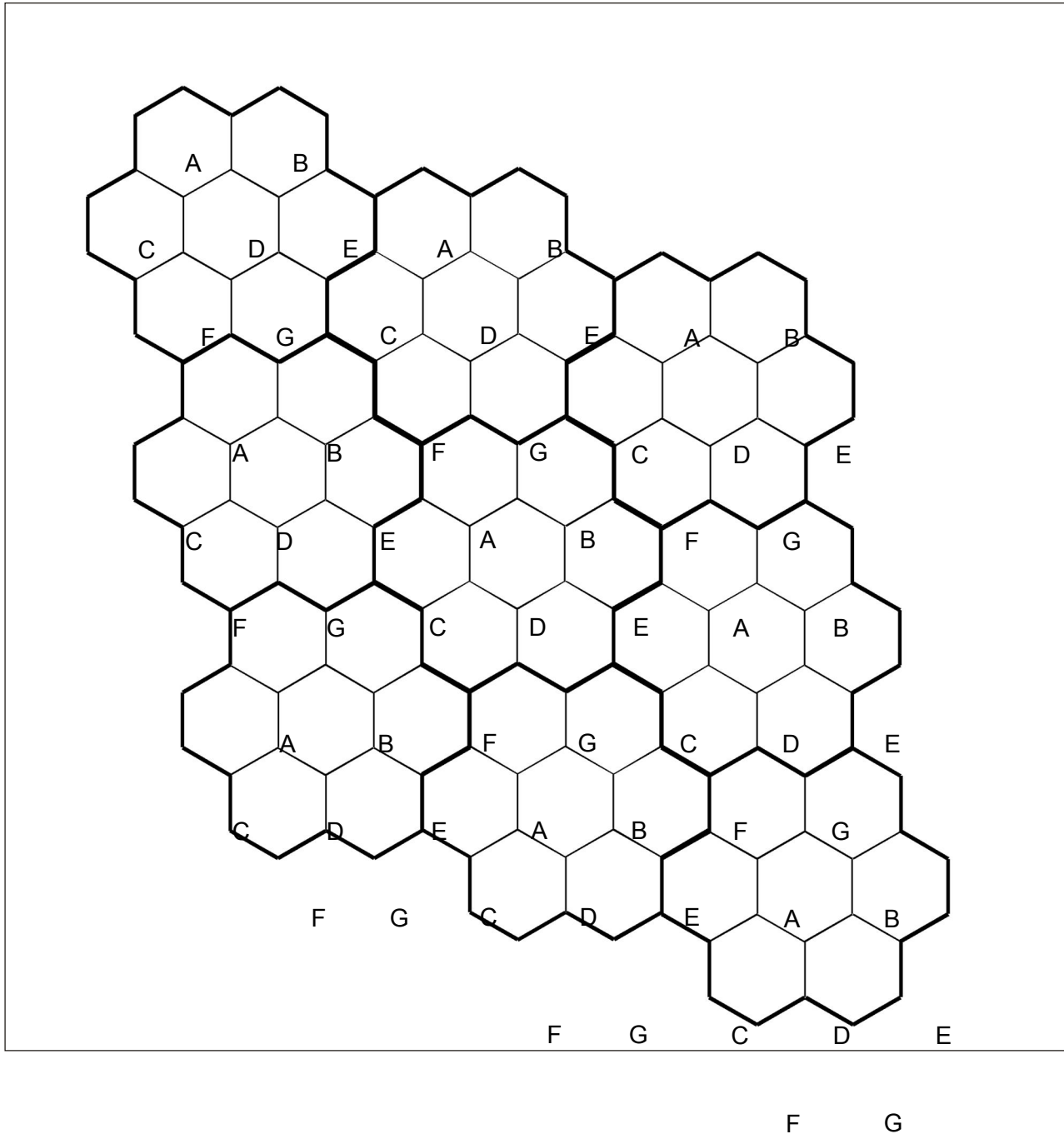LTP   — landing threshold point
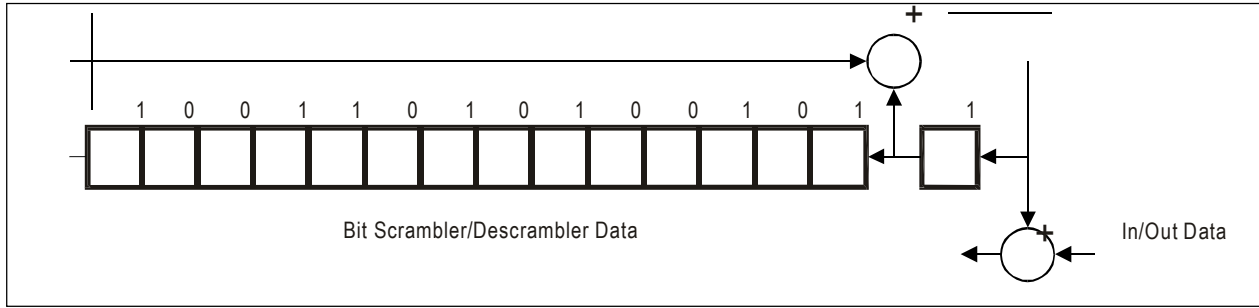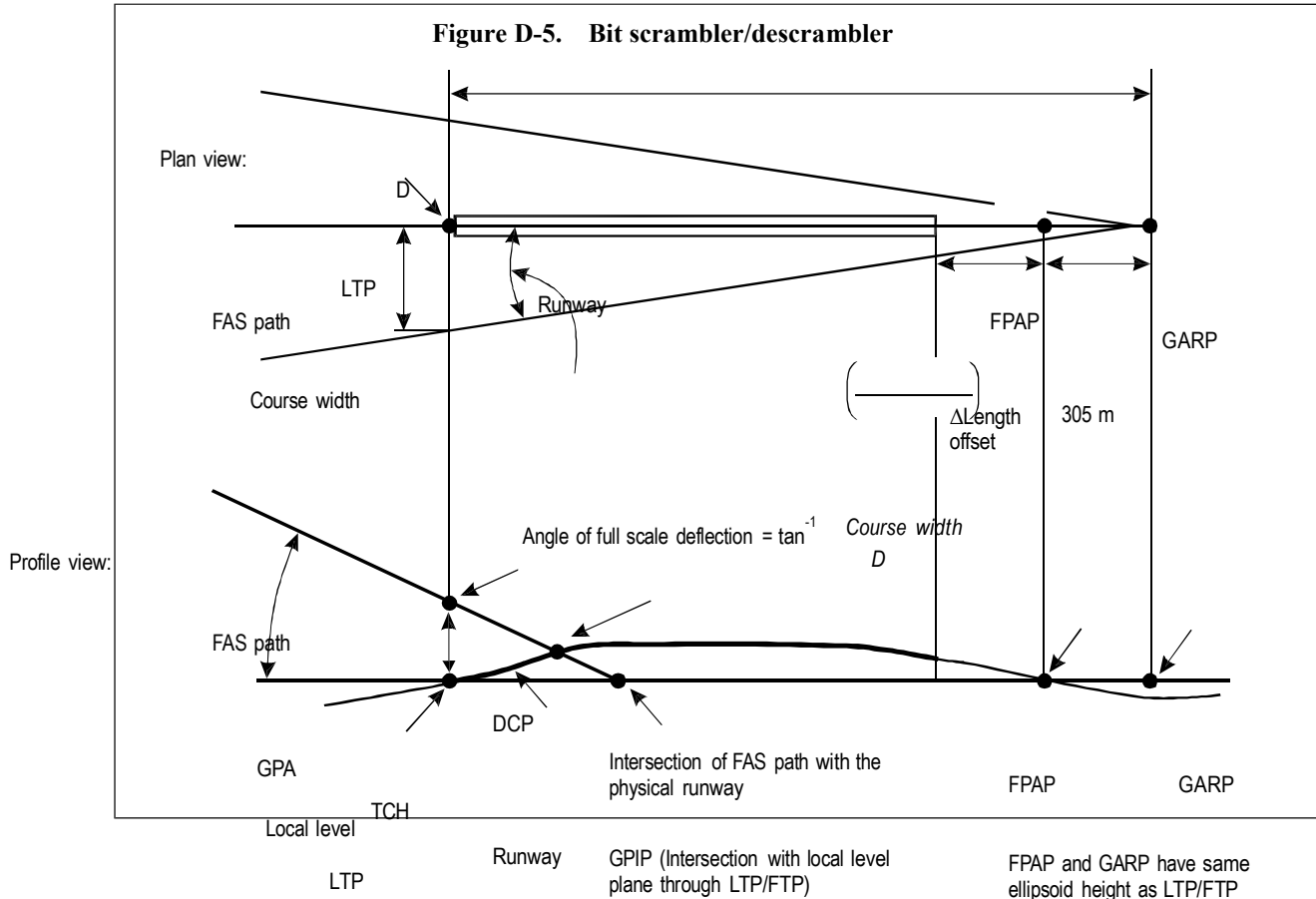
Figure D-4.   Minimum GBAS coverage

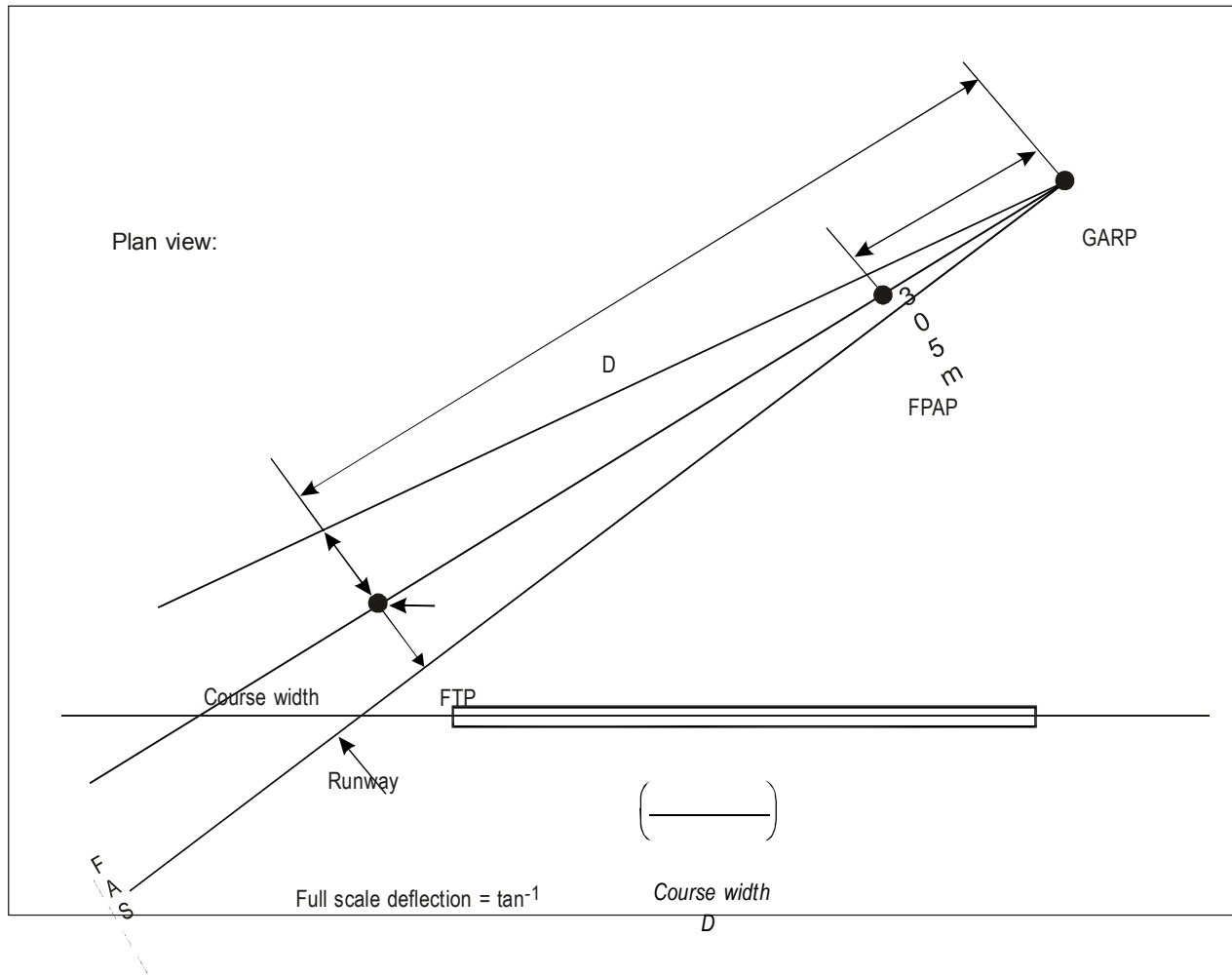**Figure D-4A.   Single frequency GRAS VHF networking using multiple time slots**

Figure D-5.   Bit scrambler/descrambler

DCP   — datum crossing point
FAS   — final approach segment
FPAP — flight path alignment point
FTP   — fictitious threshold point (see Figure D-7)
GARP — GBAS azimuth reference point
GPA   — glide path angle
GPIP — glide path intersection point
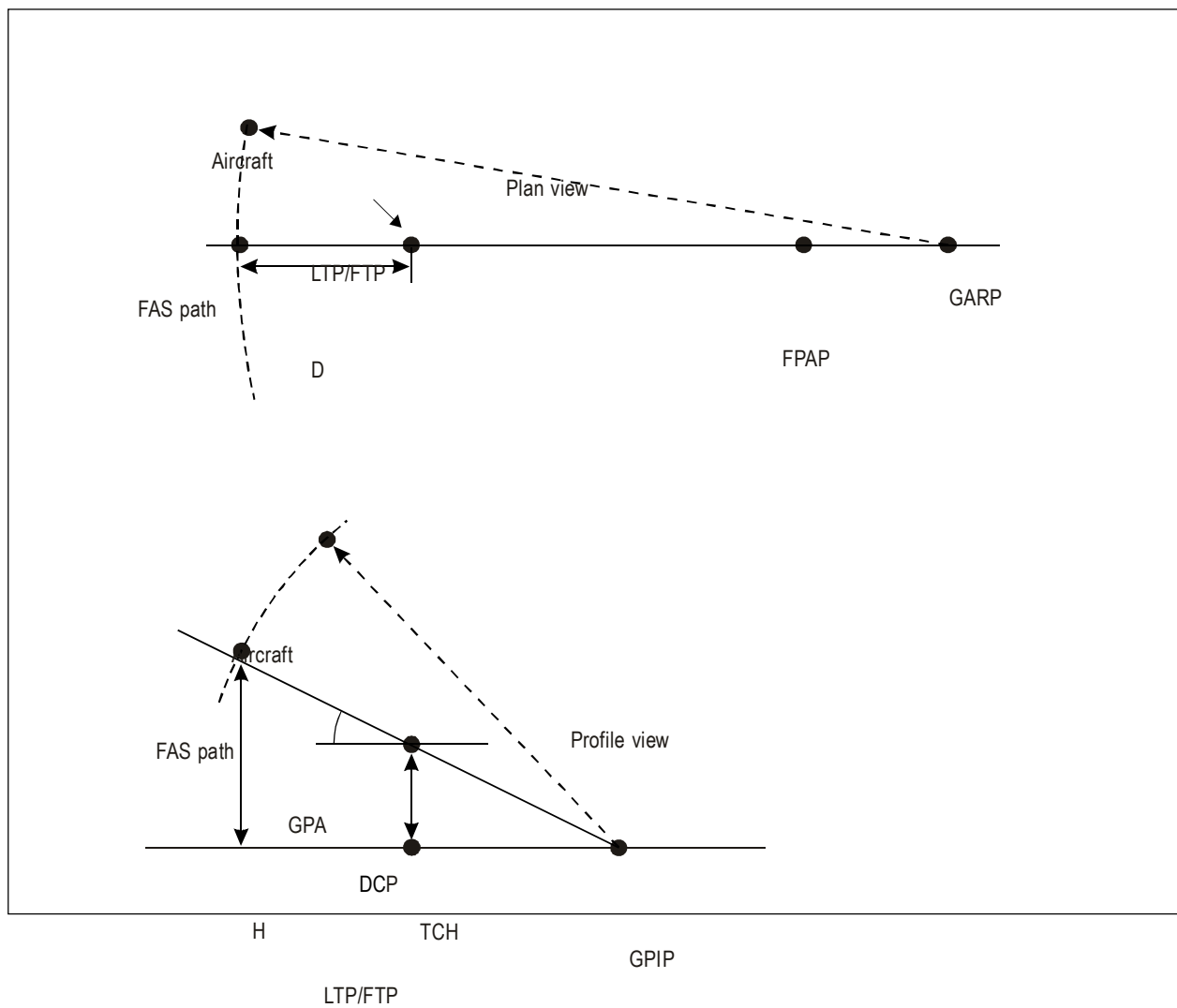LTP   — landing threshold point
TCH   — threshold crossing height

Figure D-6.   FAS path definition

Plan view:

GARP

305 m

FPAP

D

Course width

FTP

Runway

$$\left(\overline{}\right)$$

F
A
S

Full scale deflection = $\tan^{-1} \dfrac{Course\ width}{D}$

FAS — final approach segment
FPAP — flight path alignment point
FTP — fictitious threshold point
GARP — GBAS azimuth reference point

Figure D-7.   FAS path definition for approaches not aligned with the runway

DCP — datum
crossing point
FAS — final
approach segment
FPAP — flight path
alignment point
FTP — fictitious threshold point
(see Figure D-7) GARP — GBAS
azimuth reference point
GPA — glide path angle
GPIP — glide path intersection point
LTP — landing threshold point
TCH — threshold crossing height

Figure D-8.   Definition of D and H parameters in alert limit computations
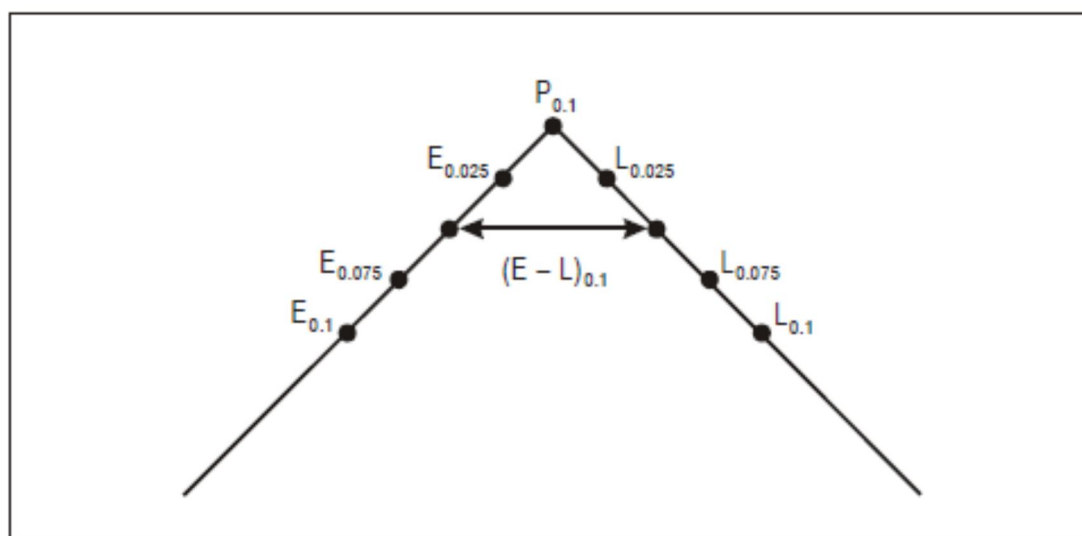
Figure D-9.   "Close-in" correlation peak and measured correlator values