2025/08/17

2025/67/SUPDT-R/41

All KCASR Stockholders and Users

Subject.: ***Notice of Proposed Amendment's (NPA) No. 2025-04 to Kuwait Civil Aviation Safety Regulations KCASR 10 – AERONAUTICAL TELECOMMUNICATIONS VOLUME - I Rev 3.***

Dear Sir,

Purpose:

The purpose of this NPA is to announce to the KCASR users the intention of the Directorate General of Civil Aviation to amend ***KCASR 10 – AERONAUTICAL TELECOMMUNICATIONS VOLUME - I*** (issue 4) to comply with ICAO standers and recommended practices up to amendment (x).

Action Required:

All users of KCASR are required to refer to DGCA/ASD website (https://kcasr.dgca.gov.kw) for reviewing the NPA and mail or email (safety@dgca.gov.kw) their comments to DGCA by 25/Sep/2025 using the attached NPA Response Sheet Forms No. 1500 or using NPA comments & feedback form on the website. If we do not receive your response by this date, it will be assumed that you do not have any comments on the proposal.

If required, the DGCA/Aviation Safety Department personnel are available to answer your questions on the interpretation and intended implementation of the proposed amendments.

This is for your information and distribution to the concerned parties.

Yours Sincerely,

President of Civil Aviation

Eng. Duaij Khalaf Alotaibi

Acting Director General DGCA

CC: Director General of Civil Aviation.
Dy. Dir. Gen. Kuwait. Intel. Airport Affairs.
Dy. Dir. Gen. for Air Navigation Services Affairs.
Safety Management Coordination Center (SMCC).
Head of Technical Office.
Civil Aviation Security Department.
Aviation Safety Director.

EM 22/c

Notes on the presentation of the Amendment
Notice Of Proposed Amendment
(NPA)

The text of the amendment is arranged to show deleted text in Red Color and with a line through it, new text to be inserted is in Blue color as shown below:

~~**Text to be deleted is in Red and shown with a line through it.**~~	**Text to be deleted**
New text to be inserted is in Blue Color.	**New text to be inserted**
~~**Text to be deleted is in Red and shown with a line through it,**~~ **followed by the replacement text which is in Blue Color.**	**New text to replace existing text**
. . . Indicates that remaining text is unchanged in front or following the reflected amendment.	**Text is unchanged**

Notice Of Safety Regulation Amendment
(NPA, NSRA and Revisions)

| **Side bar indicates that text is changed or added.**

NPA RESPONSE FORM

NPA 2025-04

Please add your comments on the proposal by ticking [✓] the appropriate box below.

Any additional constructive comments, suggested amendments or alternative action will be welcome and may be provided on this response sheet or by separate correspondence.

☐ No comments on the proposal.

☐ Comments on the proposal. (Please provide explanatory comment).

Name:	Organization:
Address/Contact No:	
E-Mail:	
Signature:	Date:

الطيران المدني
Civil Aviation
State of Kuwait - دولة الكويت

Kuwait Civil Aviation Safety Regulations

KCASR 10 – Aeronautical Telecommunications

Volume - I

Table of Contents

Contents

Amendment Record

Amendment No	Date of Issue	Remarks
1	Jun 2018	NPA 2018-12 (Up to ICAO amendment 91) and Part Rename
2	Aug 2020	Based on NPA 2020-11 Updated to ICAO Annex 10 – Vol I (Amendment 92)
3	Sep 2023	Updated to ICAO Annex 10 – Vol I (Amendment 93)
5	Sep 2025	Based on NPA 2025-04 Updated to ICAO Annex 10 – Vol I (Amendment 94)

Localizer (MHz)	Glide path (MHz)	Localizer (MHz)	Glide path (MHz)
108.1	334.7	110.1	334.4
108.15	334.55	110.15	334.25
108.3	334.1	110.3	335.0
108.35	333.95	110.35	334.85
108.5	329.9	110.5	329.6
108.55	329.75	110.55	329.45
108.7	330.5	110.7	330.2
108.75	330.35	110.75	330.05
108.9	329.3	110.9	330.8
108.95	329.15	110.95	330.65
109.1	331.4	111.1	331.7
109.15	331.25	111.15	331.55
109.3	332.0	111.3	332.3
109.35	331.85	111.35	332.15
109.5	332.6	111.5	332.9
109.55	332.45	111.55	332.75
109.7	333.2	111.7	333.5
109.75	333.05	111.75	333.35
109.9	333.8	111.9	331.1
109.95	333.65	111.95	330.95

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

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

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

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

3.1.6 3.1.7 VHF marker beacons

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

3.1.7.1 *General*

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

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

3.3 Specification for VHF omnidirectional radio range (VOR)

3.3.1 General

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

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

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

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

3.3.2 Radio frequency

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

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

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

3.3.3 Polarization and pattern accuracy

3.3.3.1 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 per cent. Polarization and pattern accuracy

3.3.3.1 The emission from the VOR shall be horizontally polarized. The vertically polarized

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

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

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

c) comply with the identification provisions of 3.5.3.6.4.

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

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

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

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

3.5.2.6.2 *Association of DME with ILS*

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

3.5.2.6.3 *Association of DME with MLS*

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

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

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

3.5.3 System characteristics

3.5.3.1 *Performance*

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

3.5.3.1.2 *Coverage*

3.5.3.1.2.1 The DME/N 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 at least 40 degrees.

Note.— *Guidance to support performance-based navigation as described in the Performance-based Navigation (PBN) Manual (Doc 9613) is provided in Attachment C, 7.2.1.3.*

~~3.5.3.1.2.1~~3.5.3.1.2.2 When associated with a VOR, DME/N coverage shall be at least that of the VOR to the extent practicable.

3.5.3.1.2.3 When associated with either an ILS or an MLS, DME/N coverage shall be at least that of the respective ILS localizer coverage sector within plus or minus 10 degrees, as defined in Chapter 3, 3.1.3.3.1or of the MLS azimuth angle guidance coverage sectors.

3.5.3.1.2.2 *Note.— Guidance relating to ILS-associated DME/N is provided in Attachment C, 7.1.6.3.*

3.5.3.1.2.33.5.3.1.2.4 DME/P coverage or DME/N coverage when associated with an MLS shall be at least that provided by the MLS azimuth angle guidance coverage sectors.

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

3.5.3.1.3 *Accuracy*

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

DME/P accuracy

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

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

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

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

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

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

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

3.5.3.3 *Channelling*

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

3.5.3.3.2 *Pulse coding.* DME/P channels shall have two different interrogation pulse codes as shown in the table in One shall be used in the initial approach (IA) mode; the other shall be used in the final approach (FA) mode.

The mode of keying shall be such as to provide a dot-and-dash duration together with spacing intervals corresponding to transmission at a rate equivalent to approximately six to ten words per minute. The carrier shall not be interrupted during identification.

3.6.1.2.5 *Coverage and radiation pattern*

Note.- The coverage and radiation pattern of marker beacons will ordinarily be established by Contracting States on the basis of operational requirements, taking into account recommendations of regional meetings.

The most desirable radiation pattern would be one that:

a) in the case of fan marker beacons, results in lamp operation only when the aircraft is within a rectangular parallelepiped, symmetrical about the vertical line through the marker beacon and with the major and minor axes adjusted in accordance with the flight path served;

b) in the case of a Z marker beacon, results in lamp operation only when the aircraft is within a cylinder, the axis of which is the vertical line through the marker beacons.

In practice, the production of such patterns is impracticable and a compromise radiation pattern is necessary. In Attachment C, antenna systems currently in use and which have proved generally satisfactory are described for guidance. Such designs and any new designs providing a closer approximation to the most desirable radiation pattern outlined above will normally meet operational requirements.

3.6.1.2.6 *Determination of coverage.* The limits of coverage of marker beacons shall be determined on the basis of the field strength specified in 3.1.7.3.2.

3.6.1.2.7 *Radiation pattern.* The radiation pattern of a marker beacon normally shall be such that the polar axis is vertical, and the field strength in the pattern is symmetrical about the polar axis in the plane or planes containing the flight paths for which the marker beacon is intended.

Note.- Difficulty in siting certain marker beacons may make it necessary to accept a polar axis that is not vertical.

3.6.1.3 *Monitoring.* For each marker beacon, suitable monitoring equipment shall be provided which will show at an appropriate location:

a) a decrease in radiated carrier power below 50 per cent of normal;

b) a decrease of modulation depth below 70 per cent;

c) a failure of keying.

3.7 Requirements for the Global Navigation Satellite System (GNSS)

3.7.1 Definitions

Advanced receiver autonomous integrity monitoring (ARAIM). An ABAS function making use of ISD.

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.

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

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

BeiDou Navigation Satellite System (BDS). The satellite navigation system operated by the People's Republic of China.

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

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

Core satellite constellation(s). The core satellite constellations are GPS, ~~and~~ GLONASS, Galileo and BDS.

***Galileo*.** The satellite navigation system operated by the European Union and its Member~~.~~ States.

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

Global navigation satellite system (GNSS). A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation.

Global navigation satellite system (GLONASS). The satellite navigation system operated by the Russian Federation.

Global positioning system (GPS). The satellite navigation system operated by the United States.

Integrity support data (ISD). A set of parameters that characterize the signal-in-space (SIS) integrity performance for each specific core satellite constellation and ARAIM service type.

Integrity support message (ISM). A dedicated core satellite constellation broadcast navigation message that contains ISD parameters which may improve ARAIM performance compared to the default ISD values.

__Note__.— The broadcast ISD may be contained in one or more ISMs.

ISM generator (ISMG). Entity which determines the values of the ISD parameters transmitted in the ISM for ARAIM for a given core satellite constellation.

GNSS position error. The difference between the true position and the position determined by the GNSS receiver.

Ground-based augmentation system (GBAS). An augmentation system in which the user receives augmentation information directly from a ground-based transmitter.

Ground-based regional augmentation system (GRAS). An augmentation system in which the user receives augmentation information directly from one of a group of ground-based transmitters covering a region.

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

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

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

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

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

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

3.7.2 General

3.7.2.1 *Functions*

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

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

3.7.2.2 *GNSS elements*

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

a) Global Positioning System (GPS) that provides the Standard Positioning Service (SPS) as defined in 3.7.3.1.1;

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

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

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

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

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

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

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

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

b) meander sequence "0101" with clock rate 2.046 MHz.

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

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

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

3.7.3.1.2.13 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, 3.1.2.1.2 and 3.1.2.1.3, respectively.*

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

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

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

***Note 3:** The following performance standards only apply if "healthy" signals-in-space are used (see Appendix B, 3.1.3.1.3.4).*

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

Note 5: Guidance material on Galileo OS accuracy, availability, continuity, probability of satellite/constellation failure and coverage, is given in Attachment D, 4.1.3.

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

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

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

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

Signals	E1	E5a	E1-E5a
99.9th percentile range error of any satellite (worst-case location)	20m	20m	20m
99.9th percentile range error of any satellite (global average)	10m	10m	10m
95th percentile range error of any satellite (global average)	7m	7m	7m

95th percentile range error over all satellites (global average)	2m	2m	2m
95th percentile range rate error of any satellite (global average)	5mm/s	5mm/s	5mm/s

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

Note 2: Single-frequency (E1 or E5a) ranging accuracy includes broadcast group delay (BGD) errors. BGD definition is specified in Attachment D, 4.1.3.3.2.

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

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

3.7.3.1.3.5 Galileo integrity support data

Note: Galileo integrity support data is specified for measurements derived from Galileo signals received above a 5-degree elevation angle.

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

Note 1: A change in the SIS health status is notified through the flags contained in the navigation message. The mapping between Galileo SIS status and flags contained in the navigation data message is specified in Appendix B, 3.1.3.1.3.4.

Note 2: Galileo URA corresponds either to σ URA,DF for dual-frequency users or to σ URA,SF for single-frequency users, as specified in 3.7.1.3.5.3 and 3.7.1.3.5.4.

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

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

Note 1: A change in the SIS health status is notified through the flags contained in the navigation message. The mapping between Galileo SIS status and flags contained in the navigation data message is specified in Appendix B, 3.1.3.1.3.4.

Note 2: Galileo URA corresponds either to σ URA,DF for dual-frequency users or to σ URA,SF for single-frequency users, as specified in 3.7.1.3.5.3 and 3.7.1.3.5.4.

Note 3: Pconst definition is further specified in Attachment D, 4.1.3.6.2.

3.7.3.1.3.5.3 Galileo URA for dual-frequency (σ URA,DF). Galileo σ URA,DF shall not exceed 6 m.

Note 1: σ URA,DF applies to a dual-frequency E1-E5a signal combination.

Note 2; σ URA,DF is defined in Attachment D, 4.1.3.6.3.

3.7.3.1.3.5.4 Galileo URA for single-frequency (σ URA,SF). Galileo σ URA,SF shall not exceed 6.5 m for E1 and 7.5 m for E5a.

Note : σ URA,SF is defined in Attachment D, 4.1.3.6.4.

3.7.3.1.3.5.5 Galileo *σBGD.* Galileo *σBGD* shall not exceed 2.5 m for both E1 and E5a.

Note: Galileo σBGD is defined in Attachment D, 4.1.3.6.5.

3.7.3.1.3.5.6 *Galileo fault rates Rsat and Rconst*. Galileo Rsat shall not exceed 2×10-5/h and Galileo Rconst shall not exceed 1×10-4/h.

Note.— Fault rates are defined in Appendix B, 3.4.1.1.2.

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

Signal	**E1**	**E5a**	**E1- E5a**
Continuity	**4 × 10-4 per hour**	**4 × 10-4 per hour**	**4 × 10-4 per hour**

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

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

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

__Note 2:__ AltBOC modulation is specified in Appendix B, 3.1.3.1.1.3.13.

__Note 3:__ Detailed Galileo signals RF characteristics are specified in Appendix B, 3.1.3.1.1.

3.7.3.1.3.8.1 E1 radio frequency (RF) characteristics

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

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

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

3.7.3.1.3.8.1.4 E1 minimum signal power level. Each Galileo satellite shall broadcast an E1 navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna shall not be less than –157.9 dBW for all antenna orientations orthogonal to the direction of propagation.

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

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

__Note:__ CBOC modulation is specified in Appendix B, 3.1.3.1.1.2.7.

3.7.3.1.3.8.2 E5a radio frequency (RF) characteristics

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

3.7.3.1.3.8.2.1 E5a carrier frequency. Each Galileo satellite shall broadcast E5a signal at the carrier frequency of 1 176.45 MHz using CDMA.

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

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

3.7.3.1.3.8.2.4 E5a minimum signal power level. Each Galileo satellite shall broadcast an E5a navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna shall not be less than –155.90 dBW for all antenna orientations orthogonal to the direction of propagation.

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

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

3.7.3.1.3.8.3 E5b radio frequency (RF) characteristics

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

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

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

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

3.7.3.1.3.8.3.4 E5b minimum signal power level. Each Galileo satellite shall broadcast an E5b navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna shall not be less than –155.90 dBW for all antenna orientations orthogonal to the direction of propagation.

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

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

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

Note: *Further details on GST are specified in Appendix B, 3.1.3.4.1.*

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

Note: GTRF details are specified in Appendix B, 3.1.3.5.2.

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

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) ionospheric delay effects;

f) time transfer to UTC; and

g) constellation status.

***Note:** Structure and contents of data are specified in Appendix B, 3.1.3.1.2 and 3.1.3.1.3, respectively.*

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

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

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

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

3.7.3.1.4.1 Space and control segment accuracy

Note. The following accuracy standards do not include atmospheric or receiver errors as described in Attachment D, 4.1.4.2. They only apply under the condition that the aircraft receiver uses healthy satellites.

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

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

3.7.3.1.4.10.4.1 Each BDS-3 MEO satellite shall broadcast a B2a navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –156 dBW to –148.5 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.10.4.2 Each BDS-3 IGSO satellite shall broadcast a B2a navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –158 dBW to –150.5 dBW for all antenna orientations orthogonal to the direction of propagation.

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

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

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

Note.— BDT details are specified in Appendix B, section 3.1.4.4.

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

Note.— BDCS details are specified in Appendix B, section 3.1.4.5.

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

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) ionospheric delay effects;

f) time transfer to UTC; and

g) constellation status.

3.7.3.2 Reserved.

3.7.3.3 *Aircraft-based augmentation system (ABAS)*

3.7.3.3.1 *Performance*. The ABAS function combined with one or more of the core satellite constellations 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.

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

~~3.7.3.3.1~~ 3.7.3.3.2 Advanced receiver autonomous integrity monitoring (ARAIM). If the ABAS functionimplements ARAIM using integrity support data (ISD), the function shall meet the requirements in Appendix B, 3.4.1.

3.7.3.4 Satellite-based augmentation system (SBAS)

Note. *All SBAS have to fulfil the requirements introduced in this section and in Appendix B, 3.5 except when a specific condition is mentioned in the requirement such as the provision of optional functions.*

3.7.3.4.1 *Performance*. SBAS combined with one or more of the other GNSS elements and a fault-free receiver shall meet the requirements for system accuracy, integrity, continuity and availability for the intended operation as stated in 3.7.2.4, throughout the corresponding service area (see 3.7.3.4.4).

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

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

Note *For L1 SBAS, message types 27 or 28 ~~can be~~is used to comply with the integrity requirements in the coverage area. See Appendix B, 3.5.7.4.7. Additional guidance on the rationale and interpretation of this requirement is provided in Attachment D, 3.3 and 6.2.3.*

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

a) L1 SBAS ranging: provide an additional L1 ranging signal with an accuracy indicator from an SBAS satellite (3.7.3.4.3 and Appendix B, 3.5.7.2);

b) L1 SBAS GNSS satellite status: determine and transmit the GNSS satellite health status (Appendix B, 3.5.7.3);

c) L1 SBAS basic differential correction: provide GNSS satellite ephemeris and clock corrections (fast and long-term) to be applied to the L1 pseudo-range measurements from satellites (Appendix B, 3.5.7.4);

d) L1 SBAS precise differential correction: determine and transmit the ionospheric corrections and associated integrity data (Appendix B, 3.5.7.5).

e) dual-frequency, multi-constellation (DFMC) SBAS ranging: provide additional ionosphere-free ranging capability using L1 and L5 signals from SBAS satellites

3.7.3.5.3.1 General requirement for approach services. The minimum GBAS approach or approach with vertical guidance approach service volume shall be as follows, except where topographical features dictate and operational requirements permit:

a) laterally, beginning at 140 m (450 ft) each side of the landing threshold point/fictitious threshold point (LTP/FTP) and projecting out ±35 degrees either side of the final approach path to 28 km (15 NM) and ±10 degrees either side of 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) to an upper bound of 3 000 m (10 000 ft) height above threshold (HAT) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure. The lower bound is half the lowest decision height supported or 3 ,.7 m (12 ft), whichever is larger.

Note 1.- LTP/*FTP and GPIP are defined in Appendix B, 3.6.4.5.1.*

Note 2.- Guidance material concerning the approach service volume is provided in Attachment D, 7.3.

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

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

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

Note.— Guidance material concerning the approach service volume is provided in Attachment D, 7.3.

3.7.3.5.3.3 *GBAS positioning service.* The *service volume for the* GBAS positioning service shall be where the data broadcast can be received and the positioning service meets the requirements of 3.7.2.4 and supports the corresponding approved operations.

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

3.7.3.5.4 *Data broadcast characteristics*

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

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

Note 1.- Guidance material on ILS/ VOR/GBAS frequency assignments and geographical separation criteria is given in ~~Attachment D, 7.2.1.~~ the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation *(Doc 9718, Volume II).*

~~Note 2.- ILS/GBAS geographical separation criteria and geographical separation criteria for GBAS and VHF~~

~~communication services operating in the 118 – 137 MHz band are under development. Until these criteria are defined and included in SARPs, it is intended that frequencies in the band 112.050 – 117.900 MHz will be used.~~

3.7.3.5.4.2 *Access technique*. A time division multiple access (TDMA) technique shall be used with a fixed frame structure. The data broadcast shall be assigned one to eight slots.

Note.- Two slots is the nominal assignment. Some GBAS facilities that use multiple VHF data broadcast (VDB) transmit antennas to improve VDB coverage may require assignment of more than two time slots. Guidance on the use of multiple antennas is given in Attachment D, 7.12.4; some GBAS broadcast stations in a GRAS may use one time slot.

3.7.3.5.4.3 Modulation. GBAS data shall be transmitted as 3-bit symbols, modulating the data broadcast carrier by D8PSK, at a rate of 10500 symbols per second.

3.7.3.5.4.4 *Data broadcast RF field strength and polarization*

Note 1.- GBAS can provide a VHF data broadcast with either horizontal (GBAS/H) or elliptical (GBAS/E) polarization that employs both horizontal polarization (HPOL) and vertical polarization (VPOL) components. Aircraft using a VPOL component will not be able to conduct operations with GBAS/H equipment. Relevant guidance material is provided in Attachment D, 7.1.

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

Note 3.- When supporting approach services at airports with challenging VDB transmitter siting constraints, it is acceptable to adjust the service volume when operational requirements permit (as stated in the service volume definition sections 3.7.3.5.3.1 and 3.7.3.5.3.2). Such adjustments of the service volume may be operationally acceptable when they have no impact on the GBAS service outside a radius of 80 m from the VDB antenna, assuming a nominal effective isotropic radiated power of 47dBm (Attachment D, Table D-3)

3.7.3.5.4.4.1 *GBAS/H*

3.7.3.5.4.4.1.1 A horizontally polarized signal shall be broadcast.

3.7.3.5.4.4.1.2 The effective isotropically radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (-99 dBW/m^2) and a maximum field strength of 0.879 volts per metre (–3527 dBW/m^2) within the GBAS service coverage volume as specified in 3.7.3.5.3.1. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst.

volume. Within the additional GBAS service volume as specified in 3.7.3.5.3.2, the isotropic radiated power (EIRP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre (–99 dBW/m^2) below 36 ft and down to 12 ft above the runway surface and 650 microvolts per metre (–89.5 dBW/m^2) at 36 ft or more above the runway surface.

Note.— Guidance material concerning the approach service volume is provided in Attachment D, 7.3.

3.7.3.5.4.4.2 *GBAS/E*

3.7.3.5.4.4.2.1 An elliptically polarized signal shall be broadcast whenever practical.

3.7.3.5.4.4.2.2 When an elliptically polarized signal is broadcast, the horizontally polarized

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	ONE OR MORE SIGNALS ARE DEFORMED*, HOWEVER THE RELEVANT URA PARAMETERS ARE VALID
1	1	1	1	1	MULTIPLE ANOMALIES PRESENT (other than those anomalies or conditions that would result in either of the two satellite temporary outages as codified above.)
All other combinations					SATELLITE EXPERIENCING CODE MODULATION AND/OR SIGNAL POWER LEVEL TRANSMISSION PROBLEMS. The user may not be able to acquire the satellite or may experience intermittent tracking problems if satellite is acquired.
*Deformed means one or more signals do not meet the requirements in IS-GPS-200K, Section 3.					

3.1.1.1.3.1.4 *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~~6 hours.

Note.— The relationship between the IODC and the Issue of Data, Ephemeris (IODE) terms is defined in 3.1.1.1.3.2.2.

3.1.1.1.3.1.5 *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.

3.1.1.1.3.1.6 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}).

3.1.1.1.3.1.7 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.

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

3.1.1.1.3.2.1 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.

3.1.1.1.3.2.2 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 have a small negative offset relative to the nominal location on an hour boundary (midpoint of the curve fit interval) ~~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

$\oplus d_{22} \oplus d_{24}$

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

where:

$D_1, D_2, D_3, \ldots D_{29}, D_{30}$ are the bits transmitted by the satellite; $D_{25}, \ldots D_{30}$ are the computed parity bits;
$d_1, d_2, \ldots d_{24}$ are the source data bits;
$\oplus$ is the Modulo-2 or "Exclusive-Or" operation; and
* is used to identify the last two bits of the previous word of the subframe.

3.1.1.2.1 GPS Protocols for single-frequency L1 users

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

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

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

where

t = GPS system time (corrected for beginning and end-of-week crossovers);
tsv = effective satellite PNR code phase time at transmission of the message;
$(\Delta t_{sv})_{L1}$ = the satellite PRN code phase offset for the L1 C/A signal;

$(\Delta t_{sv})_{L1}$ = ~~$a_{f0} + a_{f1}(t - t_{oc}) + a_{f2}(t - t_{oc})^2 + \Delta t_r - T_{GD}$~~ $\Delta t_{sv} - T_{GD}$

Where

$\Delta t_{sv} = a_{f0} + a_{f1}(t - t_{oc}) + a_{f2}(t - t_{oc})^2 + \Delta t_r$;

T_{GD} is contained in subframe 1;

af0, af1 and af2 and toc, are contained in subframe 1; and
Δt_r = the relativistic correction term (seconds)
$\Delta t_r = F e \sqrt{A} \sin E_k$

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

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

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.

□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)

3.1.1.2.2 GPS PROTOCOLS FOR SINGLE-FREQUENCY (L5) AND DUAL-FREQUENCY (L1/L5) USERS

3.1.1.2.2.1 Parity algorithm. The CNAV CRC word shall be calculated in the forward direction using a seed of 0. The sequence of 24 bits (p1, p2,..., p24) shall be generated from the sequence of information bits (m1, m2,..., m276) using the following generating polynomial:

$$g(X) = \sum_{i=0}^{24} g_i X^i$$

where gi = 1 for 0, 1, 3, 4, 5, 6, 7, 10, 11, 14, 17, 18, 23, 24, and 0 otherwise.

Note.— See IS-GPS-705F for full details on the CNAV parity algorithm.

3.1.1.2.2.2 Satellite clock correction. GPS system time *t* shall be as follows: ~~Section 3.1.1.2.1.2 shall apply.~~

$$t = t_{sv} - \Delta t_{sv}$$

~~3.1.1.2.2.2~~ where Δt_{sv} is computed using the equations defined in 3.1.1.2.1.2 and parameters from CNAV message Types 10 and 11 (for the relativistic correction term) and 30 through 37.

Note.—*Additional terms apply to the satellite clock correction for single-frequency L5 ~~and dual-frequency L1 and L5~~ users Section 3.1.1.2.2.5 shows the satellite PRN code phase offset for the single frequency L5 I5 and L5 Q5 users, and t = tsv – (Δtsv)L5I5 or t = tsv – (Δtsv)L5Q5 ~~as shown in 3.1.1.2.2.5~~.*

3.1.1.2.2.3 Satellite position. The current satellite position (X_k, Y_k, Z_k) shall be calculated as shown in Table B-L5-5.

Note.— *The ephemeris parameters: toe, □A, Ȧ, □n0, □ṅ0, M0-n, en, □n, □0-n, □Ω̇, i0-n, i0-ṅ, Cis-n, Cic-n, Crs-n, Crc-n, Cus-n, and Cuc-n, are provided in CNAV message Types 10 and 11.*

3.1.1.2.2.4 Integrity assured user range accuracy (IAURA)

3.1.1.2.2.4.1 Composite IAURA. The composite IAURA value shall be the RSS of an elevation-dependent (ED) component and a non-elevation-dependent (NED) component.

$$IAURA = \sqrt{(adjusted\ IAURA_{ED})^2 + IAURA_{NED}^2}$$

3.1.1.2.2.4.2 Elevation-dependent (ED) accuracy estimate. An adjusted ED IAURA value (in

3.1.1.3 AIRCRAFT ELEMENTS

3.1.1.3.1 GPS RECEIVER

3.1.1.3.1.1 Reserved.

3.1.1.3.1.2 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.

3.1.1.3.1.3 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.

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

3.1.1.3.1.5 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~~ For LNAV data, the receiver shall monitor the IODC and IODE values, and ~~to~~ shall update ephemeris and clock databased upon a detected change in one or both of these values. For CNAV data, the receiver shall monitor the t_{oe}, t_{oc} and t_{op} values and shall update ephemeris and clock data based upon a detected change in any of these values. ~~The SPS receiver shall use clock and ephemeris data with corresponding IODC and IODE values for a given satellite~~.

3.1.1.3.1.6Application 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.

3.1.1.4 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.

3.1.2 **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.*

3.1.2.1 NON-AIRCRAFT ELEMENTS

3.1.2.1.1 *L1OF (L1 OPEN SERVICE FDMA) RF CHARACTERISTICS*

Note*. Additional information on the L1OF RF characteristics is given in the GLONASS Navigational radio signal in bands L1, L2 Interface Control Document (Edition 5.1), dated 2008 (hereinafter referred to as "GLONASS FDMA ICD").*

3.4 Aircraft-based augmentation system (ABAS)

Note.— Guidance on ABAS and associated signal processing is given in Attachment D, section 5.

3.4.1 ADVANCED RECEIVER AUTONOMOUS INTEGRITY MONITORING (ARAIM)

ARAIM shall consist of a non-aircraft subsystem and an aircraft subsystem. The non-aircraft subsystem shall provide, for each core satellite constellation supported, fault characteristics of the constellation, fault characteristics of the satellites and ranging error models. The aircraft subsystem shall apply the data provided by the non-aircraft subsystem, complemented as appropriate by fault characteristics and ranging error models of the aircraft subsystem components, to meet the requirements as specified in Chapter 3, 3.7.3.3.1.

***Note 1:** The non-aircraft subsystem performs its function by providing integrity support data (ISD as specified below) either through broadcast navigation data or through default values stored in receiver memory. Broadcast navigation data for ARAIM can be contained either in dedicated navigation data messages (ISM as defined below) or in other navigation data messages from core satellite constellations.*

***Note 2**: For GNSS receivers using ARAIM, ranging error models include ionosphere, troposphere, multipath, antenna bias and receiver noise.*

3.4.1.1 Integrity support data (ISD) data content

3.4.1.1.1 ISD general information. The ISD general information shall be as follows:

Validity time: this field shall specify when ISD can be applied by the GNSS receiver using ARAIM.

Applicable core satellite constellation: this field shall identify to which core satellite constellation the ISD applies.

ARAIM service type: this field shall indicate the performance level supported by the ISD parameters.

ARAIM service type A: the ISD supports horizontal positioning for typical operations of en-route, terminal, initial approach, intermediate approach, non-precisions approach and departure in accordance with Chapter 3, 3.7.3.3.1.

ARAIM service type B: reserved.

***Note 1**: Aircraft manufacturers may integrate ARAIM with other ABAS system elements to support additional applications, subject to approval by the appropriate regulatory authority.*

***Note 2**: There may be multiple active sets of ISD per constellation (i.e. different data sets supporting different service types).*

***Note 3**: ARAIM service type B performance is expected to support typical operations of approach with vertical guidance through Category I precision approach.*

3.4.1.1.2 Constellation-specific ISD parameters. The constellation-specific ISD shall be as follows:

Satellite mask: this field shall indicate to which satellite (within the given core satellite constellation) the ISD parameters apply.

***Note:** The interpretation of the satellite mask by the ISMG and the aircraft receiver is specified in 3.4.1.2.2.2 and 3.4.1.3.3.2, respectively.*

P_{const}: the probability that two or more satellites within a core satellite constellation have faulted signals concurrently due to a common cause.

P_{sat} : the probability that a satellite has a faulted signal, where the faulted signal occurs only on one satellite or has independent causes if occurring on more than one satellite.

R_{const}: the rate at which two or more satellites within a core satellite constellation have faulted signals concurrently due to a common cause.

R_{sat}: the rate at which individual satellites have a faulted signal, where the faulted signal occurs only on one satellite or has independent causes if occurring on more than one satellite.

MFD_{const}: the mean duration of faulted signals of two or more satellites within a core satellite constellation due to a common cause.

MFD_{sat}: the mean duration of individual satellites having a faulted signal.

σ_{URA}: the overbounding integrity range error model parameter to be applied for a given satellite signal.

σ_{URE}: the accuracy and continuity range error model parameter to be applied for a given satellite signal.

b_{nom}: the overbounding bias term for a given satellite signal.

__Note 1:__ A faulted signal and the associated fault event occurs when one or more signals indicated as healthy from a given satellite are in fact faulted as described in 3.4.1.2.2.1 and Attachment D, 5.3.1.3. A faulted signal ends through action by the core satellite constellation, either by removal of the cause of the fault or by indication that the affected satellite or satellites are not healthy.

__Note 2:__ ISD parameters apply to healthy signals.

__Note 3:__ Some core satellite constellation providers may use the term "mean time to notify" (MTTN or MTN) interchangeably with MFD.

__Note 4:__ More detailed explanations of the terms σURA, σURE and bnom, are given in 3.4.1.2.2.1 and Attachment D, 5.3.1.4.

3.4.1.2 ARAIM non-aircraft elements

3.4.1.2.1 ISD broadcast and application requirements

__Note:__ These requirements determine how ISD are broadcast to the user by the core satellite constellations.

3.4.1.2.1.1 Interface specifications for broadcast ISD

The broadcast ISD shall be defined by the applicable core satellite constellation providers in interface specifications.

__Note 1:__ The interface specifications define on which signals and in which messages the ISD parameters are encoded.

__Note 2:__ For GPS, σURA and σURE are specified in IS-GPS-705F (message type 10 and message types 30 through 37) and in IS-GPS-200K (subframe 1).

__Note 3:__ ISM interface specifications for GPS, GLONASS and BDS are under development.

3.4.1.2.1.2 ARAIM augmented satellite signals

The ISD parameters shall apply to core satellite constellation signals as specified below:

– For GPS: GPS L1 C/A signal (3.1.1 and Chapter 3, 3.7.3.1.1.8) and GPS L5 signal (3.1.1 and Chapter 3, 3.7.3.1.1.8).

– For GLONASS: GLONASS L1OF signal (3.1.2 and Chapter 3, 3.7.3.1.2.8), GLONASS L1OC signal (3.1.2 and Chapter 3, 3.7.3.1.2.10) and GLONASS L3OC signal (3.1.2 and Chapter 3, 3.7.3.1.2.9).

– For Galileo: Galileo E1 signal (3.1.3.1.1 and Chapter 3, 3.7.3.1.3.11.1) and Galileo E5a signal (3.1.3.1.1 and Chapter 3, 3.7.3.1.3.11.2).

– For BDS: BDS B1C signal (3.1.4 and Chapter 3, 3.7.3.1.4.7) and BDS B2a signal (3.1.4 and Chapter 3, 3.7.3.1.4.7).

3.4.1.2.1.3 ISD and ISM timing

3.4.1.2.1.3.1 When a core satellite constellation broadcasts ISD, the core satellite constellation shall transmit and disseminate worldwide a complete set of broadcast ISD at a minimum broadcast rate (maximum repeat interval) of 15 minutes.

Note: *A complete set of broadcast ISD includes both the entire set of ISD within ISM(s) for a given service type, for all supported satellites and any associated ISD not contained in ISM (e.g. in other navigation data messages). This does not imply a requirement to broadcast ISD for all satellites of a specific core satellite constellation.*

3.4.1.2.1.3.2 The validity time, as defined in 3.4.1.1.1, shall:

a) indicate the start time of ISD applicability; or

b) indicate a start time and an expiration time.

3.4.1.2.1.3.2.1 When no expiration time is provided, the ISMG shall update the broadcast ISD to maintain compliance with 3.4.1.2.2.1.

Note: *The core satellite constellation interface specifications for broadcast ISD (3.4.1.2.1.1) define the associated protocols for data application, including ISD updating.*

3.4.1.2.1.3.3 For a default ISD as specified in 3.4.1.3.3.3, the validity time shall not expire as long as the data remains present in a receiver.

Note: *Default ISD values are based on core satellite constellation minimum performance commitments. They can only be modified by a change to these performance commitments. Airborne equipment maintenance action would be necessary to update these ISD parameters*

3.4.1.2.2 ISM generator requirements (data content)

Note: *The ISM generator (ISMG) is an entity separate from core satellite constellation provider and performing an air navigation service provider function limited to ARAIM. It is expected that close cooperation will exist between the two entities. Further guidance is contained in the Global Navigation Satellite System (GNSS) Manual (Doc 9849).*

3.4.1.2.2.1 Overbounding

3.4.1.2.2.1.1 The ISMG shall ensure that default and broadcast ISD parameters are provided such that the fault-free ranging signal errors are left- and right-overbounded over an interval limited by a not-to-exceed (NTE) threshold, [-NTE, NTE] by the following:

a) for integrity: a gaussian distribution $N(-b_{nom}, \sigma_{URA})$ for left side overbounding and $N(b_{nom}, \sigma_{URA})$ for right side overbounding;

b) for accuracy and continuity (false alert or failed exclusion): a gaussian distribution $N(0, \sigma_{URE})$.

3.4.1.2.2.1.2 The ISMG shall ensure that P_{sat} and R_{sat} provide an upper bound of the probability and rate that an individual satellite broadcasts signals that cause ranging signal errors outside the interval [-NTE, NTE].

3.4.1.2.2.1.3 The ISMG shall ensure that P_{const} and R_{const} provide an upper bound of the probability and rate that more than one satellite concurrently broadcast signals due to a common cause that cause ranging signal errors outside the interval [-NTE, NTE].

***Note 1**.— Faulted signals are signals with ranging errors outside the interval [-NTE, NTE]. Fault-free signals are signals with ranging errors within the interval [-NTE, NTE]. ARAIM accounts for errors due to faulted signals through P_{const} and R_{const} and for errors due to fault-free signals through σ_{URA} and σ_{URE}. Further guidance is provided in Attachment D, 5.3.1.3 to 5.3.1.5.*

***Note 2**.— Core satellite constellation service providers distinguish between fault-free and faulted ranging signals using a predefined core satellite constellation service provider NTE. By this definition, all signals with errors below the threshold are considered fault-free signals and all signals with errors that are above the threshold are considered faulted signals. Fault-free signals include ranging errors due to system-inherent properties as well as any faults characterized by a limited amplitude and frequency which maintain compliance with the overbounding conditions. The ISMG can use this definition to determine the overbounding parameters. However, the ISMG may consider errors below the core satellite constellation service provider NTE as faulted to improve σ_{URA}, provided that P_{sat}, P_{const}, R_{sat} and R_{const} still meet the requirement in 3.4.1.2.2.1.2 and 3.4.1.2.2.1.3.*

***Note 3**.— For consistency with the Gaussian overbounding of fault-free signals, the NTE value is typically set to k × σURA where k corresponds to the inverse of the normal cumulative distribution function of Psat/2. For example, for GPS and Psat of 10-5, the corresponding NTE is specified as 4.42 × σURA and 4.42 corresponds to the inverse of the normal cumulative distribution function of a probability of 0.5 × 10-5. The division by two is because the fault magnitude can be positive or negative. Alternatively, the NTE can be a fixed value.*

***Note 4**.— The ARAIM airborne algorithm will achieve the intended integrity risk when bnom and σURA bound the fault-free distribution and Psat, Rsat, Pconst and Rconst characterize the faulted distributions for both single and dual frequency signal processing. The ARAIM airborne algorithm does not explicitly use NTE.*

3.4.1.2.2.2 Satellite mask. The ISM generator shall ensure that all satellites set to valid in the ISD satellite mask meet the requirements in section 3.4.1.2.2.1 for the associated ISD content.

3.4.1.2.2.3 R_{const}, P_{const},, and MFD_{const}. If multiple ISM are provided for a given constellation and ARAIM service type, the R_{const}, P_{const} and MFD_{const} for a given validity time shall be the same.

3.4.1.2.2.4 Relationship between ISD values and core satellite constellation provider minimum service commitments. For Service Type A, broadcast ISD values as defined in 3.4.1.1 shall always be set to indicate a performance that is equal to or better than the default values specified in 3.4.1.3.3.3.

3.4.1.2.3 ISD parameter integrity requirements

3.4.1.2.3.1 The ISMG shall generate ISD for ARAIM service type A such that GNSS receivers using ARAIM can perform monitoring to meet a 10-7/hour integrity risk using both single and dual frequency signal processing.

3.4.1.2.3.2 Procedures shall be put in place by the ISMG such that the integrity assurance process mitigates the effects of internal faults, to a level consistent with the supported ARAIM service type.

3.4.1.2.4 ISM transmission / data integrity requirements

3.4.1.2.4.1 The data integrity of the ISM parameters shall be maintained throughout the data chain from origination by the ISMG, handover to and broadcast to the user by the core satellite constellation to a level consistent with the supported ARAIM service type.

Note.— Further guidance on ISD parameter data integrity is provided in Attachment D, 5.3.1.7.

3.4.1.2.4.2 A core satellite constellation using cyclic redundancy checks (CRC) for ISM data integrity shall calculate the CRC in accordance with the requirements in 3.9.

Note.— Detailed user implementation guidance is provided in core satellite constellation interface documentation as specified in 3.4.1.2.1.1.

3.4.1.2.5 Receiver design constraint assumptions for ISD generation

3.4.1.2.5.1 The ISMG shall validate broadcast ISD assuming that the GNSS receiver using ARAIM is compliant with the following constraints when processing L1, L5, E1, E5a, B1C and B2a signals:

a) 3 dB bandwidth between 12 and 24 MHz centred around 1575.42 MHz and around 1176.45 MHz;

b) differential group delay not greater than 150 ns;

c) early minus late discriminator;

d) L1/E1/B1C correlator spacing between 0.08 and 0.12 chips;

e) L5/E5a/B2a correlator spacing between 0.9 chips and 1.1 chips;

f) frequency dependent gain roll-off of at least 24 dB per octave in the transition band until reaching a minimum attenuation to meet the performance objectives in the presence of interfering signals at the interference thresholds specified in 3.7;

g) maintain the minimum attenuation to meet the performance objectives in the presence of interfering signals at the out-of-band interference thresholds specified in 3.7;

h) filter centre frequencies around 1575.42 MHz and 1176.45 MHz within ±10% of the 3 dB bandwidth as specified in a).

Note.— The 0 dB level corresponds to the filter's normalized peak in-band response.

3.4.1.2.5.2 The ISMG shall validate broadcast ISD assuming that the GNSS receiver using ARAIM is compliant with the following constraints when processing L1OC and L3OC signals:

a) 3 dB radio frequency / intermediate frequency bandwidth between 12 and 24 MHz centred around 1600.995 MHz and around 1202.025 MHz;

b) differential group delay not greater than 150 ns;

c) early minus late discriminator;

d) L1OC correlator spacing between 0.08 and 0.12 L1 chips;

e) L3OC correlator spacing between 0.9 chips and 1.1 L5 chips;

f) frequency dependent gain roll-off of at least 24 dB per octave in the transition band until reaching a minimum attenuation to meet the performance objectives in the presence of interfering signals at the interference thresholds specified in 3.7;

g) maintain the minimum attenuation to meet the performance objectives in the presence of interfering signals at the out-of-band interference thresholds specified in 3.7;

h) filter centre frequencies around 1600.995 MHz and 1202.025 MHz within ±10% of the 3 dB bandwidth as specified in a).

Note.— The 0 dB level corresponds to the filter's normalized peak in-band response.

3.4.1.2.5.3 The ISMG shall validate broadcast ISD assuming that the GNSS receiver using ARAIM is compliant with the constraints in Table D-23 when processing L1OF signals.

3.4.1.2.6 ISD provision requirements

3.4.1.2.6.1 ISMG shall provide one of the following sets of ISD parameters:

– R_{sat}, P_{sat}; or

– R_{sat}, MFD_{sat}; or

– P_{sat}, R_{sat}, MFD_{sat}.

Note.— When Psat is not provided, it can be derived from the following relationship: probability of fault = rate of fault × mean fault duration.

3.4.1.2.6.2 ISMG shall provide one of the following sets of ISD parameters:

– R_{const}, P_{const}; or

– R_{const}, MFD_{const}; or

– P_{const}, R_{const}, MFD_{const}.

***Note.—** When Pconst is not provided, it can be derived from the following relationship: probability of fault = rate of fault × mean fault duration.*

3.4.1.2.6.3 ISMG shall provide all ISD as defined in 3.4.1.1 to support the applicable ARAIM service type except as specified in 3.4.1.2.6.1 and 3.4.1.2.6.2.

Note.— ISD are provided either through core satellite constellation navigation data broadcast (as defined in 3.4.1.2.1.1) or as defaults as shown in 3.4.1.3.3.3.

3.4.1.2.6.4 The default and broadcast ISD parameters shall be valid for satellite elevation angles between 5 and 90 degrees, inclusive. When core satellite constellations identify a valid minimum elevation angle smaller than 5 degrees, the default and broadcast ISD parameters shall be valid from the minimum specified elevation angle to 90 degrees, inclusive. The elevation angle validity range shall be documented in the interface specifications as defined in 3.4.1.2.1.1.

3.4.1.3 ARAIM aircraft elements

3.4.1.3.1 General receiver processing requirements:

3.4.1.3.1.1 When a GNSS receiver using ARAIM processes core satellite constellation signals, it shall process the signals following the requirements as specified in 3.1.1.3.1 (GPS receiver) and/or 3.1.2.3.1 (GLONASS receiver) and/or 3.1.3.3.1 (Galileo receiver) and/or 3.1.4.3.1 (BDS receiver).

3.4.1.3.1.2 When a GNSS receiver using ARAIM processes core satellite constellation signals, it shall apply the protocols for data application as specified in 3.1.1.2 (GPS) and/or 3.1.2.2 (GLONASS) and/or 3.1.3.2 (Galileo) and/or 3.1.4.2 (BDS).

Note.*— GNSS receivers using ARAIM only use core satellite constellation signals that indicate a healthy status.*

3.4.1.3.2 Design constraints for GNSS receivers using ARAIM

3.4.1.3.2.1 GNSS receivers using ARAIM shall comply with the design constraints listed in section 3.4.1.2.5.

Note*.— Future development may provide more flexibility on receiver design constraints.*

3.4.1.3.3 Application of ISD in ARAIM processing algorithms

3.4.1.3.3.1 When processing broadcast ISD, GNSS receivers using ARAIM shall process ISD as specified in 3.4.1.2.1.1.

3.4.1.3.3.2 When processing ISM, GNSS receivers using ARAIM shall apply ISD consistent with its service type, validity time and applicable satellite mask.

3.4.1.3.3.3 *Default ISD*. GNSS receivers using ARAIM shall store the following default ISD:

Default ISD parameters				
	GPS	GLONASS	Galileo	BDS
$P_{const, default}$	1×10^{-8}	1×10^{-4}	2×10^{-4}	6×10^{-5}
$P_{sat, default}$	1×10^{-5}	1×10^{-4}	3×10^{-5}	1×10^{-5}
$R_{const, default}$	1×10^{-8}/h	1×10^{-5}/h	1×10^{-4}/h	6×10^{-5}/h
$R_{sat, default}$	1×10^{-5}/h	3.4×10^{-5}/h	2×10^{-5}/h	1×10^{-5}/h
$MFD_{const, default}$	1 hour	10 hours	(Note 4)	1 hour
$MFD_{sat, default}$	1 hour	3 hours	(Note 4)	1 hour
$\sigma_{URA, default, dual frequency}$ [m]	IAURA (Note 3)	9	6	7
$\sigma_{URE, default, dual frequency}$ [m]	Nominal URA (Note 3)	8	4	7
$\sigma_{URA, default, single frequency}$ [m]	IAURA (Note 3)	9	6.5 (E1), 7.5 (E5a)	7
$\sigma_{URE, default, single frequency}$ [m]	Nominal URA (Note 3)	8	4.7 (E1), 6 (E5a)	7
$b_{nom, default}$ [m]	0	0	0	0

***Note 1**.— These values correspond to the core satellite constellation commitments (as shown in Attachment D, 5.3.2). They can only be modified by a change to these performance commitments.*

***Note 2**.— Default ISD values have been validated using the receiver design assumptions listed in 3.4.1.2.5.*

***Note 3**.— When CNAV data is available (GPS dual-frequency and L5-only, single-frequency modes), the IAURA is defined in Appendix B, 3.1.1.2.2.4.1, and the nominal URA is defined in IS-GPS-705F sections 20.3.3.1.1.4 (elevation dependent) and 20.3.3.2.4 (non-elevation dependent). If CNAV data is not available (L1-only, single-frequency mode), the IAURA and nominal URA are defined in Appendix B, 3.1.1.1.3.1.2.*

***Note 4**.— Guidance information is provided in Attachment D, 5.3.2.3.*

3.4.1.3.3.4 Mixing satellites from the same constellation with default and broadcast ISD

3.4.1.3.3.4.1 When GNSS receivers using ARAIM apply default ISD to some satellites and broadcast ISD to other satellites from the same core satellite constellation, the receiver shall use default ISD (3.4.1.3.3.3) for the parameters defined in 3.4.1.2.6.2 for all satellites from the corresponding core satellite constellation.

3.5 Satellite-based augmentation system (SBAS)

3.5.1 GENERAL

Note.— Geodetic parameters in this section are defined in WGS-84.

3.5.1.1 *SBAS system and service description.* SBAS shall consist of a non-aircraft subsystem and an aircraft subsystem. The SBAS non-aircraft subsystem shall provide data and corrections for

$\delta \dot{a}_{i,f1}$: 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-65~~27~~. SBAS service provider identifiers

Identifier	Service provider
0	WAAS
1	EGNOS
2	MSAS
3	GAGAN
4	SDCM
5	BDSBAS
6	KASS
7	ANGA
8	SouthPAN
9 ~~to 13~~	Reserved for SBAS
10	PAK-SBAS
11 to 13	Reserved for SBAS
14, 15	Reserved
16 to 31	Reserved for SBAS provider supporting DFMC SBAS only

Note 1.— A service provider ID of 14 is used for GBAS and is not applicable to SBAS.

Note 2.— Service provider IDs of 16 to 31 cannot be coded in the L1 SBAS message.

Table B-~~28~~66. 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).

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~~67. 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

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
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~~69. Validity interval

Data	Bits used	Range of values	Resolution
Validity interval (V)	5	30 s to 960 s	30 s

Table B-~~32~~70. Latency time

Data	Bits used	Range of values	Resolution
Latency time (L)	3	0 s to 120 s	30 s

Table B-~~33~~71. 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 i[th] 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 3.5.8.1.2.

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 tme.

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.

Table B-~~34~~72. 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

$C_{covariance}$: 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-3573. UTC standard identifier

UTC standard identifier	UTC standard
0	UTC as operated by the National Institute of information and Communications Technology, 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 Observatoire de Paris International Bureau of Weights and Measures
4	Reserved for UTC as operated by a European laboratory
5	UTC as operated by the National Time Service Center, Chinese Academy of Sciences
6	Reserved
7	UTC not provided
8 to 15	Reserved for DFMC SBAS only

Note.— UTC standard identifiers of 8 to 15 cannot be coded in the L1 SBAS message.

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 L1 ($\delta a_{i,GLONASS}$): A parameter broadcast on L1 that represents the stable part of the offset between the L1 GLONASS time and the L1 SBAS network time.

Note.— If L1 SBAS does not support GLONASS, $\delta a_{i,GLONASS}$ is not applicable.

UTC parameters: A_{1SNT}, A_{0SNT}, Δt_{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.

δ*UDRE 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.

δ*UDRE indicator-outside:* an indication of regional UDRE degradation factor (δUDRE) applicable at locations outside all regions defined in all current Type 27 messages, in accordance with Table B-36.

Coordinate latitude: the latitude of one corner of a region.

Coordinate longitude: the longitude of one corner of a region.

Region shape: an indication of whether a region is a triangle or quadrangle.

Coding: 0 = triangle

1 = quadrangle

Note 1.— Coordinate 3 has Coordinate 1 latitude and Coordinate 2 longitude. If region is a quadrangle, Coordinate 4 has Coordinate 2 latitude and Coordinate 1 longitude. Region boundary is formed by joining coordinates in the sequence 1-2-3-1 (triangle) or 1-3-2-4-1 (quadrangle). Boundary segments have either constant latitude, constant longitude, or constant slope in degrees of latitude per degree of longitude. The change in latitude or longitude along any boundary segment between two coordinates is less than ±180 degrees.

Note 2.— All parameters are broadcast in Type 27 message.

Table B-~~36~~74. 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 L1 SBAS DATA APPLICATION

Note.— This section provides definitions of parameters used by the non-aircraft or aircraft elements that are not transmitted. These parameters, necessary to ensure interoperability of SBAS, are used to determine the navigation solution and its integrity (protection levels).

3.5.5.1 *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

$$\begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}_{corrected} = \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} + \begin{bmatrix} \delta x_i \\ \delta y_i \\ \delta z_i \end{bmatrix} + \begin{bmatrix} \delta \dot{x}_i \\ \delta \dot{y}_i \\ \delta \dot{z}_i \end{bmatrix} (t - t_{i,LT})$$

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.

~~3.7.5.3~~ 3.5.5.4 Range rate corrections (RRC). The range rate correction for satellite i is:

$$RRC_i = \begin{cases} \dfrac{FC_{i,current} - FC_{i,previous}}{t_{i,0f} - t_{i,0f\_previous}}, & if\ a_i \neq 0 \\ 0, & if\ a_i = 0 \end{cases}$$

$$RRC_i = \begin{cases} \dfrac{FC_{i,current} - FC_{i,previous}}{t_{i,0f} - t_{i,0f\_previous}}, & if\ a_i \neq 0 \\ 0, & if\ a_i = 0 \end{cases}$$

Where

$FC_{i,current}$ = the most recent fast correction;

$FC_{i,previous}$ = a previous fast correction;

$t_{i,0f}$ = the time of applicability of $FC_{i,current}$;

$t_{i,0f\_previous}$ = the time of applicability of $FC_{i,previous}$; and

a_i = fast correction degradation factor (see Table B-34).

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 $= \left[1 - \left(\frac{R_e\cos\theta_i}{R_e + h_1}\right)^2\right]^{-\frac{1}{2}}$;

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.

F_{pp} = obliquity factor $= \left[1 - \left(\frac{R_e\cos\theta_i}{R_e + h_1}\right)^2\right]^{-\frac{1}{2}}$;

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 (ICi) 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:

$$\tau_{vpp} = \sum_{k=1}^{4} W_k\,\tau_{vk}$$

$$\tau_{vpp} = \sum_{k=1}^{4} W_k\,\tau_{vk}$$

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°:

$$x_{pp} = \frac{\lambda_{pp} - \lambda_1}{\lambda_2 - \lambda_1}$$

$$y_{pp} = \frac{\phi_{pp} - \phi_1}{\phi_2 - \phi_1}$$

$$x_{pp} = \frac{\lambda_{pp} - \lambda_1}{\lambda_2 - \lambda_1}$$

$$y_{pp} = \frac{\phi_{pp} - \phi_1}{\phi_2 - \phi_1}$$

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°:

$$y_{pp} = \frac{|\phi_{pp}| - 85^\circ}{10^\circ}$$

$$x_{pp} = \frac{\lambda_{pp} - \lambda_3}{90^\circ} \times (1 - 2\, y_{pp}) + y_{pp}$$

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

5) an ionospheric correction is not available.

c) For an IPP between N75° and N85° or between S75° and S85°:

1) if the two nearest IGPs at 75° and the two nearest IGPs at 85° (separated by 30° longitude if Band 9 or 10 is used, separated by 90° otherwise) are set to "1" in the IGP mask, a 10-degree-by-10-degree cell is created by linearly interpolating between the IGPs at 85° to obtain virtual IGPs at longitudes equal to the longitudes of the IGPs at 75°; else,

2) an ionospheric correction is not available.

d) For an IPP north of N85°:

1) if the four IGPs at N85° latitude and longitudes of W180°, W90°, 0° and E90° are set to "1" in the IGP mask, they are selected; else,

2) an ionospheric correction is not available.

e) For an IPP south of S85°:

1) if the four IGPs at S85° latitude and longitudes of W140°, W50°, E40° and E130° are set to "1" in the IGP mask, they are selected; else,

2) an ionospheric correction is not available.

Note.— This selection is based only on the information provided in the mask, without regard to whether the selected IGPs are monitored, "Not Monitored", or "Do Not Use". If any of the selected IGPs is identified as "Do Not Use", an ionospheric correction is not available. If four IGPs are selected, and one of the four is identified as "Not Monitored", then three-point interpolation is used if the IPP is within the triangular region covered by the three corrections that are provided.

3.5.5.6 *Protection levels*. The horizontal protection level (HPL) and the vertical protection level (VPL) are:

$$HPL_{SBAS} = \begin{cases} K_{H,NPA} \times d_{major} & \text{for en-route through non-precision approach (NPA) modes} \\ K_{H,PA} \times d_{major} & \text{for precision approach (PA) and approach with vertical guidance (APV) modes} \end{cases}$$

$$VPL_{SBAS} = K_{V,PA} \times d_V$$

where

$d_V^2 = \sum_{i=1}^{N} s_{v,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the vertical axis;

$$d_{major} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}}$$

$$HPL_{SBAS}=\begin{cases} K_{H,NPA}\times d_{major} & \text{for en-route through non-precision approach (NPA) modes} \\ K_{H,PA}\times d_{major} & \text{for precision approach (PA) and approach with vertical guidance (APV) modes} \end{cases}$$

$$VPL_{SBAS} = K_{V,PA} \times d_V$$

where

$d_V^2 = \sum_{i=1}^{N} s_{v,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the vertical axis;

$$d_{major} = \sqrt{\frac{d_x^2+d_y^2}{2} + \sqrt{\left(\frac{d_x^2-d_y^2}{2}\right)^2 + d_{xy}^2}}$$

where

$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the x axis;

$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the y axis;

$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2$ = covariance of model distribution in the x and y axis;

where

where

$d_x^2 = \sum_{i=1}^{N} s_{x,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the x axis;

$d_y^2 = \sum_{i=1}^{N} s_{y,i}^2 \sigma_i^2$ = variance of model distribution that overbounds the true error distribution in the y axis;

$d_{xy} = \sum_{i=1}^{N} s_{x,i} s_{y,i} \sigma_i^2$ = covariance of model distribution in the x and y axis;

where

$s_{x,i}$ = the partial derivative of position error in the x-direction with respect to pseudo-range error on the i^{th} satellite;

$s_{y,i}$ = the partial derivative of position error in the y-direction with respect to pseudo-range error on the i^{th} satellite;

$s_{V,i}$ = the partial derivative of position error in the vertical direction with respect to pseudo-range error on the i^{th} satellite; and

$$\sigma^2_i = \sigma^2_{i,flt} + \sigma^2_{i,UIRE} + \sigma^2_{i,air} + \sigma^2_{i,tropo}.$$

The variances ($\sigma^2_{i,flt}$ and $\sigma^2_{i,UIRE}$) are defined in 3.5.5.6.2 and 3.5.5.6.3.1. The parameters ($\sigma^2_{i,air}$ and $\sigma^2_{i,tropo}$) are determined by the aircraft element (3.5.8.4.2 and 3.5.8.4.3).

the aircraft element (3.5.8.4.2 and 3.5.8.4.3).

The x and y axes are defined to be in the local horizontal plane, and the v axis represents local vertical.

For a general least-squares position solution, the projection matrix S is:

$$S \equiv \begin{bmatrix} S_{x,1} & S_{x,2} & \dots & S_{x,N} \\ S_{y,1} & S_{y,2} & \dots & S_{y,N} \\ S_{v,1} & S_{v,2} & \dots & S_{v,N} \\ S_{t,1} & S_{t,2} & \dots & S_{t,N} \end{bmatrix} = (G^T \times W \times G)^{-1} \times G^T \times W$$

where

G_i = $[-\cos El_i \cos Az_i \; -\cos El_i \sin Az_i \; -\sin El_i \; 1]$ = i^{th} row of G;

$$W^{-1} = \begin{bmatrix} w_1 & 0 & \dots & 0 \\ 0 & w_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & & \dots & w_i \end{bmatrix};$$

El_i = the elevation angle of the i^{th} ranging source (in degrees);

Az_i = the azimuth of the i^{th} ranging source taken counter-clockwise from the x axis in degrees; and

w_i = the inverse weight associated with satellite *i* = σ^2_i.

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 (wi = 1).

3.5.5.6.1 *Definition of K values.* The K values are:

$K_{H,NPA}$ = 6.18;

$K_{H,PA}$ = 6.0; and

$K_{V,PA}$ = 5.33.

3.5.5.6.2 *Definition of fast and long-term correction error model*. If fast corrections and long-term correction/GEO ranging parameters are applied, and degradation parameters are applied:

$$\sigma^2_{i,flt} = \begin{cases} \left[(\sigma_{i,UDRE})(\delta_{UDRE}) + \varepsilon_{fc} + \varepsilon_{rrc} + \varepsilon_{ltc} + \varepsilon_{er}\right]^2, & \text{if } RSS_{UDRE} = 0 \text{ (Message Type 10)} \\ \left[(\sigma_{i,UDRE})(\delta_{UDRE})\right]^2 + \varepsilon^2_{fc} + \varepsilon^2_{rrc} + \varepsilon^2_{ltc} + \varepsilon^2_{er}, & \text{if } RSS_{UDRE} = 1 \text{ (Message Type10)} \end{cases}$$

$$\sigma^2_{i,flt} = \begin{cases} \left[(\sigma_{i,UDRE})(\delta_{UDRE}) + \varepsilon_{fc} + \varepsilon_{rrc} + \varepsilon_{ltc} + \varepsilon_{er}\right]^2, & \text{if } RSS_{UDRE} = 0 \text{ (message Type 10)} \\ \left[(\sigma_{i,UDRE})(\delta_{UDRE})\right]^2 + \varepsilon^2_{fc} + \varepsilon^2_{rrc} + \varepsilon^2_{ltc} + \varepsilon^2_{er}, & \text{if } RSS_{UDRE} = 1 \text{ (message Type10)} \end{cases}$$

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 (see Attachment D, 6.5.7).

***Note.** With the requirement to broadcast either a Type 27 message or a Type 28 message in section 3.5.7.4.7, user equipment no longer needs to set δUDRE =1 and can instead wait for broadcast data.*

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 = (UDREIi 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 i^{th} satellite; and

t_{lat} = (as defined in 3.5.4.7).

Note.- For UDREs broadcast in Type 2 to 5, and Type 24 messages, tu 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 ≠ 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 ≠ 0 and IODF ≠ 3, the degradation parameter for fast correction data is:

$$\varepsilon_{rrc}=\begin{cases}0, & \text{if } (IODF_{current}-IODF_{previous})MOD3=1\\ \left(\frac{aI_{fc}}{4}+\frac{B_{rrc}}{\Delta t}\right)(t-t_{0f}), & \text{if } (IODF_{current}-IODF_{previous})MOD3\neq 1\end{cases}$$

3.5.5.6.2.2.3 If RRC ≠ 0 and IODF = 3, the degradation parameter for range rate data is:

$$\varepsilon_{rrc}=\begin{cases}0, & \text{if } \left|\Delta t-\frac{I_{fc}}{2}\right|=0\\ \left(\frac{a\left|\Delta t-\frac{I_{fc}}{2}\right|}{2}+\frac{B_{rrc}}{\Delta t}\right)(t-t_{0f}), & \text{if } \left|\Delta t-\frac{I_{fc}}{2}\right|\neq 0\end{cases}$$

where

t = the current time;

$IODF_{current}$ = IODF associated with most recent fast correction;

$IODF_{previous}$ = IODF associated with previous fast correction;

Δt = $t_{i,0f} - t_{i,0f\_previous}$; 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:

$$\varepsilon_{ltc}=\begin{cases}0, & \text{if } t_{i,LT}<t<t_{i,LT}+I_{ltc\_v1}\\ C_{ltc\_lsb}+C_{ltc\_v1}\max\left(0,t_{i,LT}-t,t-t_{i,LT}-I_{ltc\_v1}\right), & \text{otherwise}\end{cases}$$

$$\varepsilon_{ltc}=\begin{cases}0, & \text{if } t_{i,LT}<t<t_{i,LT}+I_{ltc\_v1}\\ C_{ltc\_lsb}+C_{ltc\_v1}\max\left(0,t_{i,LT}-t,t-t_{i,LT}-I_{ltc\_v1}\right), & \text{otherwise}\end{cases}$$

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:

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{0,GEO} < t < t_{0,GEO} + I_{GEO} \\ C_{geo\_lsb} + C_{geo\_v} \max\left(0, t_{0,GEO} - t, t - t_{0,GEO} - I_{geo}\right), & \text{otherwise} \end{cases}$$

$$\varepsilon_{ltc} = \begin{cases} 0, & \text{if } t_{0,GEO} < t < t_{0,GEO} + I_{GEO} \\ C_{geo\_lsb} + C_{geo\_v} \max\left(0, t_{0,GEO} - t, t - t_{0,GEO} - I_{geo}\right), & \text{otherwise} \end{cases}$$

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*

$\varepsilon_{er} =$
- O, if neither fast nor long-term corrections have timed out for precision approach/approach with vertical guidance
- Cer,if fast or long-term corrections have timed out for precision approach/approach with vertical guidance

3.5.5.6.2.5 *UDRE degradation factor calculated with message Type 28 data*. The δUDRE is:

$$\delta_{UDRE} = \sqrt{I^T \cdot C \cdot I} + \varepsilon_c$$

where

$$I = \begin{bmatrix} i_x \\ i_y \\ i_z \\ 1 \end{bmatrix},$$

$\begin{bmatrix} i_x \\ i_y \\ i_z \end{bmatrix}$ = the unit vector from the user to the satellite in the WGS-84 ECEF coordinate frame

$C = R^T \cdot R$

$\varepsilon_C = C_{covariance} \cdot SF$

$SF = 2^{\text{scale exponent}-5}$

$R = E \cdot SF$

$$E = \begin{bmatrix} E_{1,1} & E_{1,2} & E_{1,3} & E_{1,4} \\ 0 & E_{2,2} & E_{2,3} & E_{2,4} \\ 0 & 0 & E_{3,3} & E_{3,4} \\ 0 & 0 & 0 & E_{4,4} \end{bmatrix}$$

$$\delta_{UDRE} = \sqrt{I^T \cdot C \cdot I} + \varepsilon_c$$

where

$$I = \begin{bmatrix} i_x \\ i_y \\ i_z \\ 1 \end{bmatrix},$$

$\begin{bmatrix} i_x \\ i_y \\ i_z \end{bmatrix}$ = the unit vector from the user to the satellite in the WGS-84 ECEF coordinate frame

$C = R^T \cdot R$

$\varepsilon_C = C_{covariance} \cdot SF$

$SF = 2^{\text{scale exponent}-5}$

$R = E \cdot SF$

$$E = \begin{bmatrix} E_{1,1} & E_{1,2} & E_{1,3} & E_{1,4} \\ 0 & E_{2,2} & E_{2,3} & E_{2,4} \\ 0 & 0 & E_{3,3} & E_{3,4} \\ 0 & 0 & 0 & E_{4,4} \end{bmatrix}$$

3.5.5.6.3 *Definition of ionospheric correction error model*

3.5.5.6.3.1 *Broadcast ionospheric corrections.* If SBAS-based ionospheric corrections are applied, 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);

$$\sigma^2_{UIVE} = \sum_{n=1}^{4} W_n \cdot \sigma^2_{n,ionogrid} \text{ or } \sigma^2_{UIVE} = \sum_{n=1}^{3} W_n \cdot \sigma^2_{n,ionogrid}$$

using the same ionospheric pierce point weights (W_n) and grid points selected for the ionospheric correction (3.5.5.5).

If degradation parameters are used, for each grid point:

$$\sigma^2_{n,ionogrid} = \begin{cases} (\sigma_{n,GIVE} + \varepsilon_{iono})^2, & \text{if } RSS_{iono} = 0 \text{ (Type 10 message)} \\ \sigma^2_{n,GIVE} + \varepsilon^2_{iono}, & \text{if } RSS_{iono} = 1 \text{ (Type 10 message)} \end{cases}$$

Table B-~~37~~75. Type 0 "Do Not Use" message broadcast on L1

Data content	Bits used	Range of values	Resolution
Reserved	212	—	—

Table B-~~38~~76. 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~~77. 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~~78. Type 6 integrity message

Data content	Bits used	Range of values	Resolution
$IODF_2$	2	0 to 3	1
$IODF_3$	2	0 to 3	1
$IODF_4$	2	0 to 3	1
$IODF_5$	2	0 to 3	1
For 51 satellites (ordered by PRN mask number)			
$UDREI_i$	4	(see Table B-29)	(see Table B-29)

Notes.—
1. The parameters $IODF_j$ are defined in 3.5.4.4.2.
2. The parameter $UDREI_i$ is defined in 3.5.4.5.

Table B-~~41~~79. Type 7 fast correction degradation factor message

Data content	Bits used	Range of values	Resolution
System latency (t_{lat})	4	0 to 15 s	1 s
IODP	2	0 to 3	1
Spare	2	—	—
For 51 satellites (ordered by PRN mask number)			
Degradation factor indicator (ai_i)	4	(see Table B-34)	(see Table B-34)

Notes.—
1. The parameters t_{lat} and ai_i are defined in 3.5.4.7.
2. The parameter IODP is defined in 3.5.4.1.

Table B-42. Type 9 ranging function message

Data content	Bits used	Range of values	Resolution
Reserved	8	—	—
$t_{0,GEO}$	13	0 to 86 384 s	16 s
URA	4	(see Table B-26)	(see Table B-26)
X_G	30	±42 949 673 m	0.08 m
Y_G	30	±42 949 673 m	0.08 m
Z_G	25	±6 710 886.4 m	0.4 m
$\dot{X}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Y}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Z}_G$	18	±524.288 m/s	0.004 m/s
$\ddot{X}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Y}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Z}_G$	10	±0.032 m/s^2	0.0000625 m/s^2
a_{Gf0}	12	±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.

Table B-80. 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-64)	(see Table B-64)
X_G	30	±42 949 673 m	0.08 m
Y_G	30	±42 949 673 m	0.08 m
Z_G	25	±6 710 886.4 m	0.4 m
$\dot{X}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Y}_G$	17	±40.96 m/s	0.000625 m/s
$\dot{Z}_G$	18	±524.288 m/s	0.004 m/s
$\ddot{X}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Y}_G$	10	±0.0064 m/s^2	0.0000125 m/s^2
$\ddot{Z}_G$	10	±0.032 m/s^2	0.0000625 m/s^2
a_{Gf0}	12	±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.

Table B-~~43~~81. 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	—	—

Notes.—
1- All parameters are defined in 3.5.4.7.
2-The valid range for Iltc_vo and Iiono is 1 to 511. The value of 0 is not valid and receivers will use a value of 1 in place of a transmitted value of 0.

Table B-4482. 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	$\pm 2^{-8}$s	2^{-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-83. 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-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~~84. 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-4785. Type 24 mixed fast/long-term satellite error correction message

Data content	Bits used	Range of values	Resolution
For 6 slots			
Fast correction (FC_i)	12	±256.000 m	0.125 m
For 6 slots			
$UDREI_i$	4	(see Table B-31)	(see Table B-31)
IODP	2	0 to 3	1
Fast correction type identifier	2	0 to 3	1
$IODF_j$	2	0 to 3	1
Spare	4	—	—
Type 25 half-message	106	—	—

Notes.—

1. *The parameters fast correction type identifier, $IODF_j$, and FC_i are defined in 3.5.4.4.2.*
2. *The parameter IODP is defined in 3.5.4.1.*
3. *The parameter $UDREI_i$ is defined in 3.5.4.5.*
4. *The long-term satellite error correction message is divided into two half-messages. The half message for a velocity code = 0 is defined in Table B-48. The half message for a velocity code = 1 is defined in Table B-49.*

Table B-4886. 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~~88. 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-5189. 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-5290. Type 63 null message

Data content	Bits used	Range of values	Resolution
Reserved	212	—	—

Table B-5391. 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.

Table B-5492. 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		R (see Note 5)	R (see Note 5)	R (see Note 5)	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	R (see Note 5)	R (see Note 5)	R (see Note 5)	R (see Note 5)	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.

4.5. Either a Type 27 message or Type 28 message is to be broadcast as required in 3.5.7.6.2.

Table B-~~55~~93. SBAS L1 radio frequency monitoring

Parameter	Reference	Alarm limit	Required action
Signal power level	Chapter 3, 3.7.3.4.5.3	minimum specified power Maximum specified Power (Note 2)	Cease ranging function (*Note 1*). Cease broadcast.
Modulation	Chapter 3, 3.7.3.4.5.5	monitor for waveform distortion	Cease L1 ranging function (*Note 1*).
SNT-to-GPS time	Chapter 3, 3.7.3.4.7	N/A (*Note 3*)	Cease L1 ranging function unless σ_{UDRE} reflects error.
Carrier frequency stability	3.5.2.1	N/A (*Note 3*)	Cease L1 ranging function unless σ_{UDRE} reflects error.
Code/frequency coherence	3.5.2.4	N/A (*Note 3*)	Cease L1 ranging function unless σ_{UDRE} reflects error.
Maximum code phase deviation	3.5.2.6	N/A (*Notes 2* and *3*)	Cease L1 ranging function unless σ_{UDRE} reflects 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 When the PRN mask is changed, SBAS shall 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 3.5.8.1.2. 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 3.1.2.5.2 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 To ensure accurate range rate corrections, SBAS shall 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,~~ either a 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.

3.5.7.4.7 SBAS shall broadcast service indication data as specified in 3.5.7.6.2 (Type 27 message) or clock-ephemeris covariance matrix data as specified in 3.5.7.6.3 (Type 28 message) to comply throughout the SBAS coverage area with the signal-in-space integrity requirements stated in Chapter 3, 3.7.2.4.

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 operations, and 8 seconds for an SBAS that supports APV or NPA 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 3.5.8.1.2. 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 k^{th} band. The new IGP mask shall be broadcast in a Type 18 message before it is referenced in a related Type 26 message. The $IODI_k$ 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.

~~3.5.7.4.2.1~~ **3.5.7.5.2.1** When the IGP mask is changed, SBAS should repeat the Type 18 message several times before referencing it in a Type 26 message to ensure that users receive the new mask. The same IODIk should be used for all bands.~~When the IGP mask is changed, SBAS shall 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.

3.5.7.6.2.1 If service indication data are broadcast, the δUDRE indicator-inside parameter in Type 27 message shall be equal to 0.

~~3.5.7.6.2~~ *Note.— This requirement ensures compatibility with equipment developed according to RTCA/DO-229. Further information is available in Attachment D, section 6.5.7.*

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, 3.7.3.4.3.5, and carrier phase noise specified in 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.

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:

$$t_{LT} - L - V \le t_r \le t_{LT} - L$$

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 $\sigma^2_{i,UDRE}$ as defined by a Type 28 clock-ephemeris covariance matrix message. The δ_{UDRE} derived from a Type 28 message with an IODP matching that of the PRN mask shall be applied immediately.

3.5.8.1.2.7 In the event of a loss of four successive SBAS messages during an SBAS-based approach operation with a HAL of 40 m or a VAL of 50 m or less, the receiver shall invalidate all UDREI data from that SBAS satellite.

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.

3.5.8.1.2.9 The receiver shall not use a fast correction if t for the associated RRC exceeds the time-out interval for fast corrections, or if the age of the RRC exceeds 8 t.

~~3.5.8.1.2.9~~ 3.5.8.1.2.10 he calculation of the RRC shall be reinitialized if a "Do Not Use" or "Not Monitored" indication is received for that satellite.

~~3.5.8.1.2.10~~ 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.

~~3.5.8.1.2.11~~ 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.

~~3.5.8.1.2.12 The receiver shall no longer support SBAS based precision approach or APV operation using a particular satellite if the UDREI, received is greater than or equal to 12.~~

Table B-~~56~~94. 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~~95. Fast correction time-out interval evaluation

Fast correction degradation factor indicator (aii)	NPA time-out interval for fast corrections (Ifc)	PA/APV time-out interval for fast corrections (Ifc)
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

satellite or SBAS clock-ephemeris correction information received mapping with the satellite ephemeris;

I_{CORR} is the time interval for application of C_{CORR} (see 3.5.11.4);

C_{CORR} is the step degradation parameter for precision approach applications (see 3.5.11.4);

$(R_{CORR})_{SV}$ is the satellite specific degradation factor computed from R_{CORR} (see 3.5.11.4) and δR_{CORR} as in 3.5.11.2 (for the augmented satellites) or in 3.5.11.5 (for SBAS):

if $t\text{-}t_{CORR} \le I_{CORR}$, then $(R_{CORR})_{SV} = R_{CORR} \times \delta R_{CORR}$

if $t\text{-}t_{CORR} > I_{CORR}$, then $(R_{CORR})_{SV} = R_{CORR}$; and

$\lfloor x \rfloor$ is the greatest integer less than or equal to x.

3.5.12.5 Protection level calculation

For a general least-squares position solution, the projection matrix S shall be defined as:

$$S = \begin{bmatrix} S_{east,1} & S_{east,2} & \cdots & S_{east,P} \\ S_{north,1} & S_{north,2} & \cdots & S_{north,P} \\ S_{U,1} & S_{U,2} & \cdots & S_{U,P} \\ S_{t_{C_1},1} & S_{t_{C_1},2} & \cdots & S_{t_{C_1},P} \\ S_{t_{C_1C_2},1} & S_{t_{C_1C_2},2} & \cdots & S_{t_{C_1C_2},P} \end{bmatrix} = (G^T \cdot W \cdot G)^{-1} \cdot G^T \cdot W$$

where

G is the observation matrix defined in 3.5.12.4; and

W is the weighting matrix defined in 3.5.12.4.

3.5.12.5.1 Horizontal protection level (HPL)

The horizontal protection level (HPL) ~~and the vertical protection level (VPL)~~ shall be computed as follows:

$HPL = K_H d_{major}$

~~$VPL = K_{V,PA} d_U$~~

where

~~K_H~~ K_H = {6.18 for en route through non precision approach operations
{6.0 for APV−I and Category I operations ;

~~$K_{V,PA}=5.33;$~~

d_{major} is the error uncertainty along the semi-major axis of the error ellipse defined as

$$d_{major} \equiv \sqrt{\frac{d_{east}^2 + d_{north}^2}{2} + \sqrt{\left(\frac{d_{east}^2 - d_{north}^2}{2}\right)^2 + d_{EN}^2}} ;$$

$$d_{major} \equiv \sqrt{\frac{d_{east}^2 + d_{north}^2}{2} + \sqrt{\left(\frac{d_{east}^2 - d_{north}^2}{2}\right)^2 + d_{EN}^2}} ;$$

~~d_U is the variance of model distribution that overbounds the true error distribution in the vertical axis defined as~~:

$$d_U^2 = \sum_{i=1}^{P} s_{U,i}^2 \sigma_i^2;$$

where

d^2_{east} is the variance of model distribution that overbounds the true error distribution in the east axis:

$$d_{east}^2 = \sum_{i=1}^{P} s_{east,i}^2 \sigma_i^2;$$

d^2_{north} is the variance of model distribution that overbounds the true error distribution in the north axis:

$$d_{north}^2 = \sum_{i=1}^{P} s_{north,i}^2 \sigma_i^2;$$

d_{EN} is the covariance of model distribution in the east and north axis:

$$d_{EN} = \sum_{i=1}^{P} s_{east,i} s_{north,i} \sigma_i^2;$$

$s_{east,i}$ is the partial derivative of position error in the east direction with respect to the pseudo-range error on the i^th satellite;

$s_{north,i}$ is the partial derivative of position error in the north direction with respect to the pseudo-range error on the i^th satellite;

~~$s_{U,i}$ is the partial derivative of position error in the vertical direction with respect to the pseudo-range error on the i^th satellite; and~~

σ_i is defined in 3.5.12.4.

3.5.12.5.2 Vertical protection level (VPL)

The vertical protection level (VPL) shall be computed as follows:

$$VPL = K_{V,PA} \times \sqrt{d_{nt,U}^2 + d_{tropo,U}^2}$$

Where

$K_{V,PA}$=5.33;

$d_{nt,U}^2$ is the variance of model distribution that overbounds the non-tropospheric true error distribution in the vertical axis defined as:

$\sigma_{nt,i}$ is given by:

$$\sigma_{nt,i}^2 = \sigma_{i,DFC}^2 + \sigma_{i,air\_DF}^2 + \sigma_{i,iono}^2 \text{ (sigma terms defined in 3.5.12.4)}$$

$d_{tropo,U}^2$ is given by:

$$d_{tropo,U}^2 = \left(\sum s_{U,i}\,\sigma_{i,tropo}\right)^2$$

$\sigma_{i,tropo}$ is the square root of the model variance for the troposphere residual error for satellite i, as defined in 3.5.8.4.2.5;

3.5.13 DFMC SBAS MESSAGE TABLES

Each SBAS message shall be coded in accordance with the corresponding message format defined in Tables B-94 through B-106. All signed parameters in these tables shall be represented in two's complement, with the sign bit occupying the MSB.

Note 1.— The value of every parameter contained in a DFMC message is computed as follows, considering that fieldvalue is the decimal value of the binary number, after two's complement transformation if specified in the description column of the table:

- *if the parameter is coded as two's complement: parameter = $field_{value}$*$scale_{factor}$; and*
- *if the parameter is not coded as two's complement: parameter = offset + $field_{value}$*$scale_{factor}$, where the offset being specified in the comment column if different from the effective range minimum.*

Note 2.— Reserved bits in DFMC messages can take any value.

Table B-94. Type 0 "Do Not Use" message broadcast on L5

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
Reserved	Reserved	216	-	-	-	-	

Note 1.— This message is the equivalent of the L1 SBAS Type 0 message but with application for the messages broadcast on DFMC SBAS service only.

Note 2.— When this message is broadcast, it indicates that the signal does not support safety-of-life operation. SBAS may broadcast the data field of any message type in each Type 0 message.

Table B-106. Type 63 null message broadcast on L5

Section	Name	Length	Scale factor	Effective Range		Unit	Comment
				min	max		
Reserved	Reserved	216	-	-	-	-	

Note.— The null message is used as a filler message if no other message is available for broadcast for the one-second time slot.

Table B-119~~107~~. L5 message data time-out intervals

Data	Associated message types	Maximum update interval	En-route, terminal, NPA time-out	Precision approach, APV time-out
"Do Not Use"	0	6 s	N/A	N/A
Satellite mask	31	120 s	600 s	600 s
DFREI or DFRECI	32	6 s	18 s	12 s
	34	6 s	18 s	12 s
	35	6 s	18 s	12 s
	36	6 s	18 s	12 s
	40	6 s	18 s	12 s
Satellite clock-ephemeris	32	0.5x(I_{Valid})32 s per	1.5x(IValid)32	(IValid)32
corrections and covariance matrix		corrected satellite		
SBAS satellite clock, ephemeris	39	0.5x(I_{Valid})39/40 s	1.5x(I_{Valid})39/40	(I_{Valid})39/40
and covariance matrix	40			
Degradation parameters	37	120 s	600 s	600 s

DFREI scale table	37	120 s	600 s	600 s
Time reference identifier	37	120 s	600 s	600 s
SBAS service provider identifier	39	120 s	N/A	600 s
	47	120 s	N/A	600 s
SNT-to-UTC offset	42	240 s	Note 3	Note 3

Note 1.— The time-out intervals are defined from the time of arrival at the receiver's antenna port of the last bit of the message

Note 2.— There is no time-out requirement for other parameters of the Type 47 message than those listed above.

Note 3.— The SNT-to-UTC offset information in the Type 42 message times out as defined in 3.5.11.6 taking into account the parameters WNapp, TOWapp and VP.

Data	Associated message types	Maximum update interval	En-route, terminal, NPA time-out	Precision approach, APV time-out
"Do Not Use"	0	6 s	N/A	N/A
Satellite mask	31	120 s	600 s	600 s
DFREI or DFRECI	32	6 s	18 s	12 s
	34	6 s	18 s	12 s
	35	6 s	18 s	12 s
	36	6 s	18 s	12 s
	40	6 s	18 s	12 s
Satellite clock-ephemeris corrections and covariance matrix	32	$0.5x(I_{Valid})_{32}$ s per corrected satellite	$1.5x(I_{Valid})_{32}$	$(I_{Valid})_{32}$
SBAS satellite clock, ephemeris and covariance matrix	39 40	$0.5x(I_{Valid})_{39/40}$ s	$1.5x(I_{Valid})_{39/40}$	$(I_{Valid})_{39/40}$
Degradation parameters	37	120 s	600 s	600 s
DFREI scale table	37	120 s	600 s	600 s
Time reference identifier	37	120 s	600 s	600 s
SBAS service provider identifier	47	120 s	600 s	600 s
SNT-to-UTC offset	42	240 s	Note 3	Note 3

Note 1.— The time-out intervals are defined from the time of arrival at the receiver's antenna port of the last bit of the message.

Note 2.— There is no time-out requirement for other parameters of the Type 47 message than those listed above.

Note 3.— The SNT-to-UTC offset information in the Type 42 message times out as defined in 3.5.11.6 taking into account the parameters WN_{app}, TOW_{app} and VP.

b) for GLONASS: the receiver shall use a BPSK(1) replica for L1OCd and a BPSK(10) replica for L3OCd signal. The satellite position and satellite clock shall be based on ephemeris in strings 10, 11 and 12 of L1OCd or L3OCd;

c) for Galileo: the receiver shall use a BOC(1,1) replica for E1-C signal and a BPSK(10) replica for E5a-Q signal. The satellite position and satellite clock shall be based on ephemeris in F/NAV message on E5a; and

d) for BDS: the receiver shall use a BOC(1,1) replica for B1C_pilot signal and a BPSK(10) replica for B2a_pilot signal. The satellite position and satellite clock shall be based on ephemeris in B-CNAV2 message on B2a.

Note.— The equivalent specific ionosphere-free computation is described in BDS-SIS-ICD-B2a (V1.0), 7.8.3 taking into account the group delays broadcast in B-CNAV2 message.

3.5.15.1.1.2 The satellite time correction ($\Delta t_{SV,i}$) for satellite i, defined in 3.5.12.4, shall be computed using the following information:

a) for GPS: the satellite clock correction $\Delta t_{SV,i}$ shall be $(\Delta t_{sv})_{L1}$, computed as described in 3.1.1.2.1.2 taking into account the group delay correction broadcast in the LNAV message;

b) for GLONASS: the satellite clock correction $\Delta t_{SV,i}$ shall be computed as described in 3.1.2.2.2;

c) for Galileo: the satellite clock correction $\Delta t_{SV,i}$ shall be computed as described in 3.1.3.2.2;

d) for BDS: the satellite clock correction $\Delta t_{SV,i}$ shall be computed as described in 3.1.4.2.2.1; and

e) for SBAS ranging satellite: the satellite clock correction $\Delta t_{SV,i}$ shall be computed as $\Delta t_{SV,i} = a_{Gf0} + a_{Gf1}\Delta_t$ with a_{Gf0} and a_{Gf1} broadcast in the Type 39 message and Δt defined in 3.5.12.3.1.

3.5.15.1.1.3 *DFMC SBAS aircraft element design constraints.*

3.5.15.1.1.3.1 For processing of L1, L5, E1, E5a, B1C and B2a signals, the aircraft element shall comply with the following constraints:

a) 3 dB bandwidth between 12 and 24 MHz centred around 1 575.42 MHz and around 1 176.45 MHz;

b) differential group delay not greater than 150 ns;

c) early minus late discriminator;

d) L1/E1/B1C correlator spacing between 0.08 and 0.12 L1 chips;

e) L5/E5a/B2a correlator spacing between 0.9 chips and 1.1 L5 chips;

f) frequency roll-off of at least 24 dB per octave until reaching a minimum attenuation to meet the performance objectives in the presence of interfering signals at the interference thresholds specified in 3.7;

g) maintain the minimum attenuation to meet the performance objectives in the presence of interfering signals at the interference thresholds specified in 3.7; and

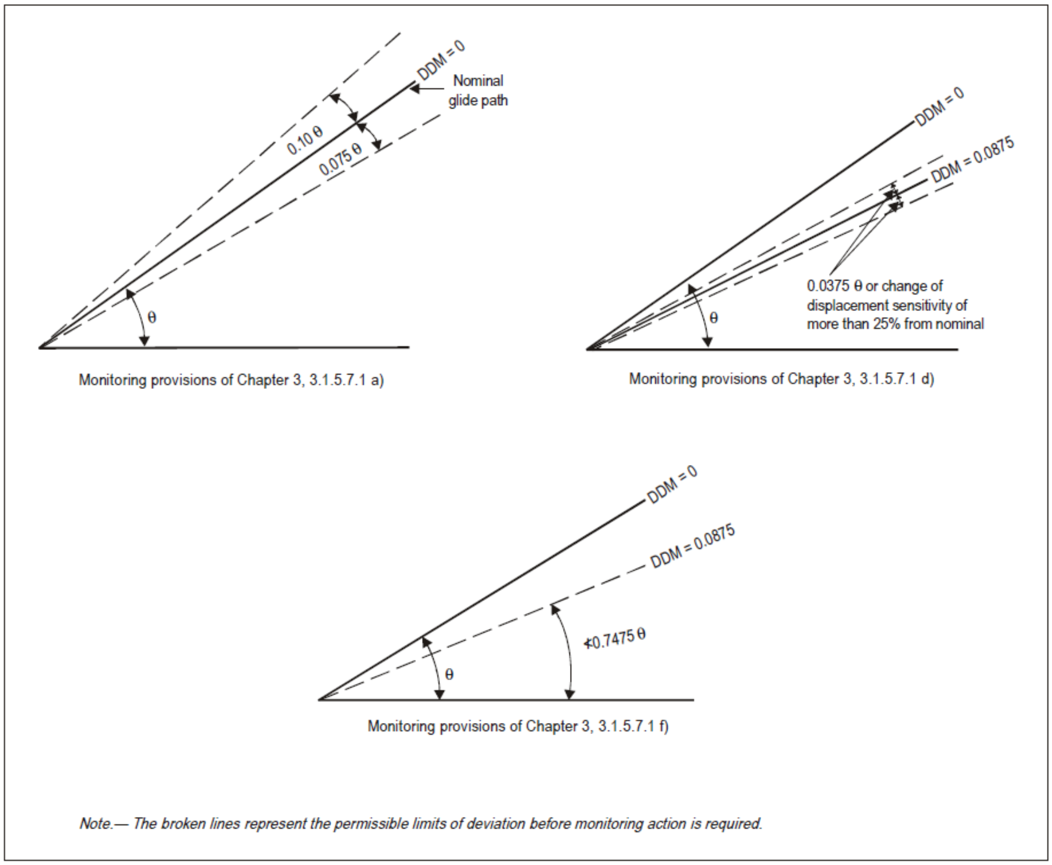

Figure C-12. Glide path monitoring provisions

2.6 Deployment of ILS frequencies

~~2.6~~ *Note.— Guidance material on deployment of ILS frequencies is given in the* Handbook on Radio Frequency Spectrum Requirements for Civil Aviation *(Doc 9718, Volume II), Chapter 3.*

~~2.6.1 In using the figures listed in Table C-1, it must be noted that these are related to ensuring freedom from interference to a point at the protection height and at the limit of service distance of the ILS in the direction of the front beam. If there is an operational requirement for back beam use, the criteria would also be applied to a similar point in the back beam direction. Frequency planning will therefore need to take into account the localizer azimuthal alignment. It is to be noted that the criteria must be applied in respect of each localizer installation, in the sense that while of two localizers, the first may not cause interference to the use of the second, nevertheless the second may cause interference to the use of the first.~~

~~2.6.2 The figures listed in Table C-1 are based on providing an environment within which the airborne receivers can operate correctly.~~

~~2.6.2.1 *ILS localizer receivers*~~

~~2.6.2.1.1 In order to protect receivers designed for 50 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:~~

~~a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;~~

~~b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;~~

~~c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;~~

~~d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.~~

~~2.6.2.1.2 In order to protect receivers designed for 100 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:~~

~~a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;~~

~~b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;~~

~~c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;~~

~~d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.~~

~~2.6.2.2 *ILS glide path receivers*~~

~~2.6.2.2.1 In order to protect receivers designed for 150 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:~~

~~a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;~~

~~b) an undesired glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;~~

~~c) an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.~~

Table C-1. Required distance separations

	Frequency separation	Minimum separation between second facility and the protection point of the first facility km (NM)		
		List A	List B	List C
Localizer	Co-channel 50 kHz 100 kHz 150 kHz 200 kHz	148 (80) — 65 (35) — 11 (6)	148 (80) 37 (20) 9 (5) 0 0	148 (80) 9 (5) 0 0 0
Glide path	Co-channel 150 kHz 300 kHz 450 kHz 600 kHz	93 (50) — 46 (25) — 9 (5)	93 (50) 20 (11) 2 (1) 0 0	93 (50) 2 (1) 0 0 0

List A refers to the use of localizer receivers designed for 200 kHz channel spacing coupled with glide path receivers designed for 600 kHz channel spacing and applicable only in regions where the density of facilities is low.

List B refers to the use of localizer receivers designed for 100 kHz channel spacing coupled with glide path receivers designed for 300 kHz channel spacing.

List C refers to the use of localizer receivers designed for 50 kHz channel spacing coupled with glide path receivers designed for 150 kHz channel spacing.

Note 1.— The above figures are based on the assumption of protection points for the localizer at 46 km (25 NM) distance and 1 900 m (6 250 ft) height and for the ILS glide path at 18.5 km (10 NM) distance and 760 m (2 500 ft) height.

Note 2.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS and VOR facilities in a manner which will preclude the possibility of airborne receiver error due to overloading by high unwanted signal levels when the aircraft is in the initial and final approach phases.

Note 3.— States, in applying the separations shown in the table, have to recognize the necessity to site the ILS glide path facilities in a manner which will preclude the possibility of erroneous glide path indications due to reception of adjacent channel signals when the desired signal ceases to radiate for any reason while the aircraft is in the final approach phase.

2.6.2.2.2 In order to protect receivers designed for 300 kHz spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:

a) a desired signal exceeds an undesired co-channel signal by 20 dB or more;

b) an undesired glide path signal, 150 kHz removed from the desired signal, does not exceed the desired signal (0 dB signal ratio);

c) an undesired glide path signal, 300 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB;

d) an undesired glide path signal, 450 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

2.6.3 The calculations are based on the assumption that the protection afforded to the wanted signal against interference from the unwanted signal is 20 dB. This corresponds to a disturbance of not more than 15 microamperes at the limit of the service distance of ILS.

2.6.4 In so far as the wanted and unwanted carriers may produce a heterodyne note, the protection ratio ensures that the instrumentation is not affected. However, in cases where a voice facility is used, the heterodyne note may interfere with this facility.

2.6.5 In general, when international use of ILS systems is confined to the pairings listed in Chapter 3, 3.1.6.1.1, the criteria are such that, provided they are met for the localizer element, the glide path element is automatically covered. At certain congested locations, where it is necessary to make assignments in both the first ten and the second ten sequence pairings, it may be necessary to select certain pairings out of sequence in order to meet the minimum geographical separation in 2.6.6.

Example: Referring to Chapter 3, 3.1.6.1.1, it will be noted that ILS Sequence Number 2 pairs the localizer frequency of 109.9 MHz with glide path frequency 333.8 MHz. Sequence Numbers 12 and 19, however, although providing wide frequency separation from Sequence Number 2 in the case of the localizers, assign frequencies of 334.1 MHz and 333.5 MHz, respectively, for the glide paths, both being first adjacent channels (300 kHz spacing) to the Sequence Number 2 glide path channel. If selection of ILS channels is confined to either the first ten or the second ten pairings, then the minimum glide path frequency separation will be 600 kHz.

2.6.6 *Table of required distance separations* (see Table C-1)

2.6.7 The application of the figures given in Table C-1 will only be correct within the limitations set by the assumptions which include that facilities are essentially non-directional in character, that they have similar radiated powers, that the field strength is approximately proportional to the angle of elevation for angles up to 10 degrees, and that the aircraft antenna is essentially omnidirectional in character. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves, taking into account the particular directivity factors, radiated power characteristics and the operational requirements as to coverage. Where reduced separation distances are determined by taking into account directivity, etc., flight measurements at the ILS protection point and at all points on the approach path should be made wherever possible to ensure that a protection ratio of at least 20 dB

2.6.8 is achieved in practice.

2.7 Localizers and glide paths achieving coverage with two radio frequency carriers

2.7.1 Localizer and glide path facilities may achieve their coverage requirements by using two facility, and when considering the acceptability of proposed developments in the vicinity of established sites. Doppler VOR is more resistant to multipath interference than conventional VOR and may be used to provide acceptable performance on more challenging multipath sites.

Note.- Guidance on siting of VOR is given in documents EUROCAE ED-52 (including Amendment No. 1), United States Federal Aviation Administration Order 6820.10 and ICAO EUR DOC 015 (First Edition).

3.2.2 The impact of wind farm developments on VOR is an increasing problem in many States due to the growth of interest in alternative energy sources. The impact of wind farms on VOR is difficult to assess for several reasons, including:

a) the cumulative effect of a group of turbines may be unacceptable even though the effect of each of the turbines may be acceptable individually;

b) worst-case errors may be experienced when the turbine blades are stationary (due to either high or low wind speeds). The actual error is a function of the orientation of the turbine and position of the turbine blades when stationary;

c) worst-case errors are likely to be experienced at the limit of coverage and at low elevation angles; and

d) it is unlikely that the worst-case errors can be confirmed by flight inspections due to the factors listed above.

3.2.3 Computer simulations can be used to assess the effect of wind farms on VOR using worst-case assumptions, as outlined above.

3.3 [Reserved]

3.4 Criteria for geographical separation of VOR type facilities

__Note.—__ Guidance material on criteria for geographical separation of VOR type facilities is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapter 4.

~~3.4.1 In using the figures listed in Table C-3, it must be noted that these are derived from the agreed formulae in respect of specific altitudes. In application of the figures, regional meetings would only afford protection to the extent of the operationally required altitude and distance and, by use of the formulae, criteria can be calculated for any distance or altitude.~~

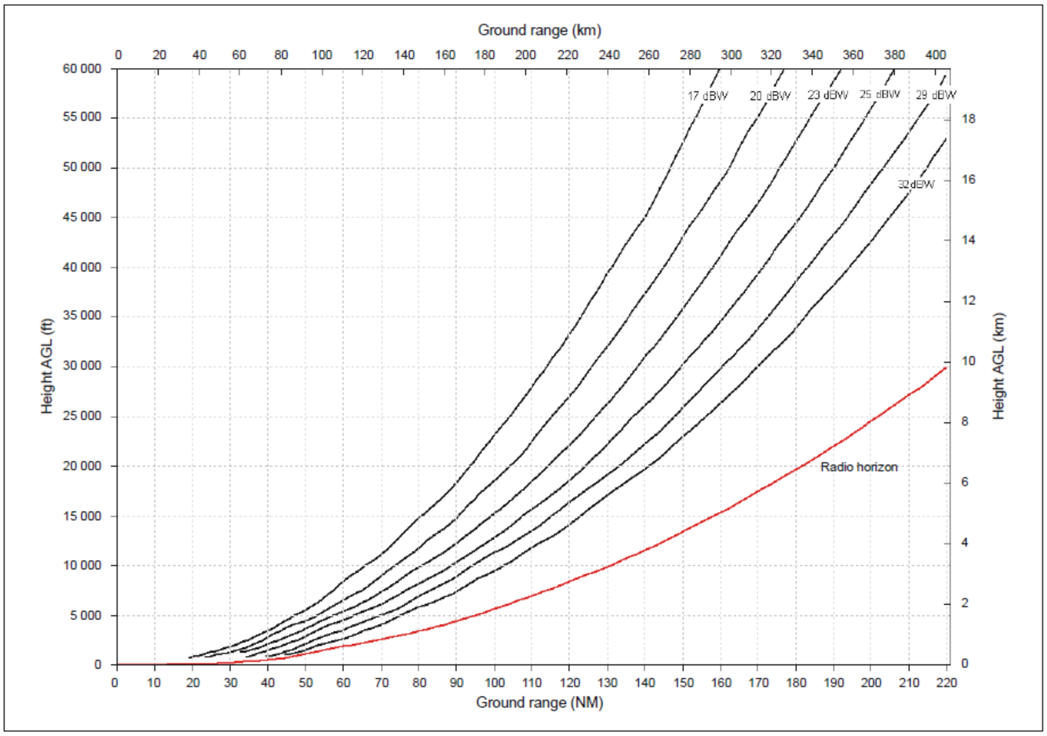

Figure C-13. Necessary EIRP to achieve a field strength of 90 microvolts per metre (–107 dBW/m^2) as a function of height above and distance from the VOR/DVOR

~~*Note 1.— The curves are based on the IF-77 propagation model with a 4/3 Earth radius which has been confirmed by measurements.*~~

~~*Note 2.— The guidance provided assumes that the VOR/DVOR counterpoise height above ground level (AGL) that defines the antenna pattern is at 3 m (10 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.*~~

~~*Note 3.— The transmitted power required to achieve an EIRP value as shown depends upon transmitting antenna gain and cable losses. As an example, an EIRP of 25 dBW can be achieved by a VOR with an output power of 100 W, a cable loss of 1 dB and an antenna gain of 6 dBi.*~~

~~3.4.2 The figures listed are calculated on the assumption that the effective adjacent channel rejection of the airborne receiver is better than 60 dB down at the next assignable channel.~~

~~3.4.3 The calculations are based on the assumption that the protection against interference afforded to the wanted signal from the unwanted signal is 20 dB, corresponding to a bearing error of less than 1 degree due to the unwanted signal.~~

~~3.4.4 It is recognized that, in the case of adjacent channel operation, there is a small region in the vicinity of a VOR facility, in which interference may be caused to an aircraft using another VOR facility. However, the width of this region is so small that the duration of the interference would be negligible and, in any case, it is probable that the aircraft would change its usage from one facility to the other.~~

~~3.4.5 The agreed formulae for calculating the geographical separations are as follows (nautical miles~~

may be substituted for kilometres):

A - *minimum geographical separation (co-channel):*

either $$2\,D_1 + \frac{20-K}{S}\ \text{km}$$

$$\text{where } D_1 > D_2 + \frac{K}{S}$$

or $$2\,D_2 + \frac{20+K}{S}\ \text{km}$$

$$\text{where } D_1 < D_2 + \frac{K}{S}$$

B — *geographical separation (adjacent channel*

collocation case

$$< \frac{40-K}{S}$$

non-collocated case

$$> 2D_1 - \frac{40+K}{S}\ km$$

$$\text{where } D_1 > D_2 + \frac{K}{S}$$

or $$2D_2 - \frac{40-K}{S}\ km$$

$$\text{where } D_1 < D_2 + \frac{K}{S}$$

C - *geographical separation (adjacent channel)*

(receivers designed for 100 kHz channel spacing in a 50 kHz channel spacing environment)

If receivers having an effective adjacent channel rejection of no better than 26 dB are used (e.g. a 100 kHz receiver used in a 50 kHz environment), a figure of 6 should be substituted for the figure of 40 in the above adjacent channel formulae. In this instance, the geographical collocation formula should not be used as the protection afforded may be marginal.

This leads to the following formula:

$$> 2D_1 + \frac{6+K}{S}\ km$$

$$\text{where } D_1 > D_2 + \frac{K}{S}$$

or $$2D_2 - \frac{6-K}{S}\ km$$

$$\text{where } D_1 < D_2 + \frac{K}{S}$$

Table C-3. Values of geographical separation distances for co-channel operation

		VOR facilities of equal effective radiated power		VOR facilities which differ in effective radiated power by 6 dB				VOR facilities which differ in effective radiated power by 12 dB			
		Minimum geo-graphical separation between facilities is $2D_1 + \frac{20}{S}$ $if\, D_1 > D_2$ or $2D_2 + \frac{20}{S}$ $if\, D_2 > D_1$		Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ $if\, D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ $if\, D_1 < D_2 + \frac{K}{S}$				Minimum geographical separation between facilities is $2D_1 + \frac{20-K}{S}$ $if\, D_1 > D_2 + \frac{K}{S}$ or $2D_2 + \frac{20+K}{S}$ $if\, D_1 < D_2 + \frac{K}{S}$			
Altitude m (ft)	S dB/km (NM)	K dB	$\frac{20}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)	K dB	$\frac{K}{S}$ km (NM)	$\frac{20-K}{S}$ km (NM)	$\frac{20+K}{S}$ km (NM)
1	2	3	4	5	6	7	8	9	10	11	12
1 200 (4 000)	0.32 (0.60)	0	61 (33)	6	19 (10)	43 (23)	80 (43)	12	37 (20)	24 (13)	98 (53)
3 000 (10 000)	0.23 (0.43)	0	87 (47)	6	26 (14)	61 (33)	113 (61)	12	52 (28)	35 (19)	137 (74)
4 500 (15 000)	0.18 (0.34)	0	109 (59)	6	33 (18)	76 (41)	143 (77)	12	67 (36)	44 (24)	174 (94)
6 000 (20 000)	0.15 (0.29)	0	128 (69)	6	39 (21)	89 (48)	167 (90)	12	78 (42)	52 (28)	206 (110)
7 500 (25 000)	0.13 (0.25)	0	148 (80)	6	44 (24)	104 (56)	193 (104)	12	89 (48)	59 (32)	237 (128)
9 000 (30 000)	0.12 (0.23)	0	161 (87)	6	48 (26)	113 (61)	209 (113)	12	96 (52)	65 (35)	258 (139)
12 000 (40 000)	0.10 (0.19)	0	195 (105)	6	59 (32)	135 (73)	254 (137)	12	119 (64)	78 (42)	311 (168)
18 000 (60 000)	0.09 (0.17)	0	219 (118)	6	65 (35)	154 (83)	284 (153)	12	130 (70)	87 (47)	348 (188)

Note.— S, K and the sign of K are defined in 3.4.5.

~~In the above formulae:~~

~~*D1*, *D2* = service distances required of the two facilities (km).~~

~~*K* = the ratio (dB) by which the effective radiated power of the facility providing *D1* coverage exceeds that of the facility providing *D2* coverage.~~

~~*Note.— If the facility providing D2 is of higher effective radiated power, then “K” will have a negative value.*~~

~~*S* = slope of the curve showing field strength against distance for constant altitude (dB/km).~~

~~3.4.6 The figures listed in Table C-3 are based on providing an environment within which the airborne receivers can operate correctly.~~

~~3.4.6.1 In order to protect VOR receivers designed for 50 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:~~

~~a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;~~

~~b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;~~

~~c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;~~

~~d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.~~

~~3.4.6.2 In order to protect VOR receivers designed for 100 kHz channel spacing, minimum separations are chosen in order to provide the following minimum signal ratios within the service volume:~~

~~a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;~~

~~b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;~~

~~c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;~~

~~d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.~~

~~3.4.7 Use of the figures given in 3.4.6 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. The assumptions include that the change of field strength with distance (Factor "S") at various altitudes of reception is only valid for angles of elevation at the VOR of up to about 5 degrees, but above the radio line of sight. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves.~~

~~3.4.8 The deployment of 50 kHz channel spacing requires conformity with Chapter 3, 3.3.2.2 and 3.3.5.7 and Annex 10, Volume V, Chapter 4, 4.2.4. Where, due to special circumstances it is essential during the initial conversion period from 100 kHz channel spacing to 50 kHz channel spacing to take account of nearby VOR facilities that do not conform with Chapter 3, 3.3.2.2 and 3.3.5.7 and Annex 10, Volume V, Chapter 4, 4.2.4, greater geographical separation between these and the new facilities utilizing 50 kHz channel spacing will be required to ensure a bearing error of less than one degree due to the unwanted signal. On the assumption that the sideband levels of the 9 960 Hz harmonic of the radiated signal of such facilities do not exceed the following levels:~~

~~9 960 Hz 0 dB reference~~

~~2nd harmonic –20 dB~~

~~3rd harmonic –30 dB~~

~~4th harmonic and above –40 dB~~

~~the separation formulae at 3.4.5 should be applied as follows:~~

~~a) where only receivers designed for 50 kHz channel spacing need to be protected, the value of 40 should be replaced by 20 in the formula at B - non-collocated case;~~

b) where it is necessary to protect receivers designed for 100 kHz channel spacing, the co-channel formula at A - co-channel case, should be applied for the range of altitudes for which protection is required.

3.4.9 When DME/N facilities and VOR facilities are intended to operate in association with each other, as outlined in Chapter 3, 3.5.3.3.4, and have a common service volume, both the co-channel and adjacent channel geographical separation distances required by the DME are satisfied by the separation distances of the VOR as computed in this section, provided the distance between VOR and DME does not exceed 600 m (2 000 ft). A potential interference situation may also occur with the implementation of DME "Y" channels since interference between two DME ground stations spaced 63 MHz apart could occur when transmitting and receiving on the same frequency (e.g. transmissions from channel 17 Y could interfere with reception on channels 80 X and 80 Y). To obviate any ground receiver desensitization due to this interference, a minimum ground separation distance of 18.5 km (10 NM) between facilities is necessary Criteria for geographical separation of VOR/ILS facilities

3.5 Criteria for geographical separation of VOR/ILS facilities

Note.— Guidance material on criteria for geographical separation of VOR/ILS facilities is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation *(Doc 9718, Volume II), Chapter 4.*

3.5.1 In using the figures of 3.5.3.1 and 3.5.3.2, it is to be borne in mind that the following assumptions have been made:

a) that the localizer receiver characteristic is as shown in 2.6.2, and the VOR receiver characteristic as shown in 3.4.2;

b) that the protection ratio for the ILS system and the VOR system is 20 dB as in 2.6.4 and 3.4.3, respectively;

c) that the protection point for ILS is at a service distance of 46.25 km (25 NM) measured along the line of use, and at an altitude of 1 900 m (6 250 ft).

Note.— With the advent of highly directional ILS localizer antenna arrays, the most critical protection point will not be along the extended runway centre line. Directive antennas result in critical protection points at maximum distance, either plus or minus 10 degrees or plus or minus 35 degrees off the runway centre line. Protection of these points should be examined during the frequency assignment process.

3.5.2 Although international VOR and ILS facilities will not appear on the same frequency, it may occur that an international VOR facility may share temporarily the same frequency as, and on a comparable basis with, a national ILS facility. For this reason, guidance is given as to the geographical separation required not only for a VOR and an ILS facility separated by 50 kHz or 100 kHz, but also for co-channel usage.

3.5.3 Because of the differing characteristics of use of the two equipments, the criteria for minimum geographical separation of VOR/ILS to avoid harmful interference are stated separately for each facility where relevant.

3.5.3.1 *Co-channel case*

a) Protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 148 km (80 NM) from the ILS protection point.

b) ~~On the assumption that a VOR having an ERP of 17 dBW (50 W) is to be protected to a service distance of 46.25 km (25 NM) and an altitude of 3000 m (10000 ft), protection of the VOR system requires that the ILS be at least 148 km (80 NM) from the VOR.~~

c) ~~If protection of the VOR is required to, say, 92.5 km (50 NM) and 6000 m (20000 ft), the ILS is to be at least 250 km (135 NM) from the VOR.~~

~~3.5.3.2 *Adjacent channel case.* Protection of the VOR system is effectively obtained without geographical separation of the facilities. However, in the case of:~~

a) ~~a localizer receiver designed for 100 kHz channel spacing and used in an area where navaid assignments are spaced at 100 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 9.3 km (5 NM) from the ILS protection point;~~

b) ~~a localizer receiver designed for 100 kHz channel spacing and used in an area where assignments are spaced at 50 kHz, the protection of the ILS system requires that a VOR having an ERP of 17 dBW (50 W) be at least 79.6 km (43 NM) from the ILS protection point.~~

~~3.5.4 Use of the figures given in 3.5.3 or other figures appropriate to other service distances and altitudes implies recognition of the basic assumptions made in this substitution of an approximate method of calculating separation, and the application of the figures will only be correct within the limitations set by those assumptions. If more precise determination of separation distances is required in areas of frequency congestion, this may be determined for each facility from appropriate propagation curves.~~

~~3.5.5 Protection of the ILS system from VOR interference is necessary where a VOR facility is located near an ILS approach path. In such circumstances, to avoid disturbance of the ILS receiver output due to possible cross modulation effects, suitable frequency separation between the ILS and VOR channel frequencies should be used. The frequency separation will be dependent upon the ratio of the VOR and ILS field densities, and the characteristics of the airborne installation.~~

3.6 Receiving function

3.6.1 *Sensitivity.* After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function should be such as to provide on a high percentage of occasions the accuracy of output specified in 3.6.2, with a signal having a field strength of 90 microvolts per metre or minus 107 dBW/m^2.

3.6.2 *Accuracy.* The error contribution of the airborne installation should not exceed plus or minus 3 degrees with a 95 per cent probability.

Note 1.— The assessment of the error contribution of the receiver will need to take account of:

1) *the tolerance of the modulation components of the ground VOR facility as defined in Chapter 3, 3.3.5;*

2) *variation in signal level and carrier frequency of the ground VOR facility;*

3) *the effects of unwanted VOR and ILS signals.*

Note 2.— The airborne VOR installation is not considered to include any special elements which may be provided for the processing of VOR information in the aircraft and which may introduce errors of their own (e.g. radio magnetic indicator (RMI).).

3.6.3 *Flag alarm operation.* Ideally, the flag alarm should warn a pilot of any unacceptable malfunctioning conditions which might arise within either the ground or airborne equipments. The extent to which such an ideal might be satisfied is specified below.

3.6.3.1 The flag alarm movement is actuated by the sum of two currents which are derived from the 30 Hz and 9 960 Hz elements of the VOR bearing component signal and, therefore, the removal of these elements from the radiated carrier results in the appearance of the flags. Since the VOR ground monitor interrupts the bearing components when any unacceptable condition prevails on the ground, there will be an immediate indication within an aircraft when the system is unusable.

3.6.3.2 The flag alarm movement current is also dependent upon the AGC characteristics of the airborne equipment and any subsequent gain following the receiver's second detector. Thus, if with a correctly adjusted airborne receiver the flag is just out of view when receiving a VOR signal conforming to the modulation characteristics specified in Chapter 3, 3.3.5, the flags will again become visible in the event of a decrease in the receiver's overall gain characteristics.

Note.- Certain types of receivers employ warning indications other than mechanical flags to perform the functions described here.

3.6.4 VOR receiver susceptibility to VOR and localizer signals

~~3.6.4~~ ***Note**.— Guidance material on VOR receiver susceptibility to VOR and localizer signals is given in the* Handbook on Radio Frequency Spectrum Requirements for Civil Aviation *(Doc 9718, Volume II), Chapter 4.*

~~3.6.4.1 The receiver design should provide correct operation in the following environment:~~

~~a) the desired signal exceeds an undesired co-channel signal by 20 dB or more;~~

~~b) an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB (during bench testing of the receiver, in this first adjacent channel case, the undesired signal is varied over the frequency range of the combined ground station (plus or minus 9 kHz) and receiver frequency tolerance);~~

~~c) an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB;~~

~~d) an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.~~

~~*Note 1- It is recognized that not all receivers currently meet requirement b); however, all future equipments are designed to meet this requirement.*~~

~~*Note 2- In some States, a smaller ground station tolerance is used.*~~

3.6.5 Immunity performance of VOR receiving systems to interference from VHF FM broadcast signals.

~~3.6.5~~ ***Note.**— Guidance material on VOR receiving systems to interference from VHF FM broadcast signals is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapter 4.*

~~3.6.5.1 With reference to Chapter 3, 3.3.8, the immunity performance defined therein must be~~

~~measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results and to facilitate their subsequent approval. Additional information can be found in ITU Recommendation ITU-R SM.1140, *Test procedures for measuring aeronautical receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–118 MHz*.~~

~~*Note.— Receiver test procedures are also given in the VOR receiver MOPS (RTCA DO-196, and EUROCAE ED-22B).*~~

~~3.6.5.2 Commonly agreed formulae should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Chapter 3, 3.3.8. The formulae provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R IS.1009-1, *Compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–137 MHz*.~~

3.7 VOR system accuracy

Note.— Guidance material on the determination of VOR system performance values is also contained in Annex 11, Attachment A.

3.7.1 *Purpose.* The following guidance material is intended to assist in the use of VOR systems. It is not intended to represent lateral separation standards or minimum obstacle clearances, although it may of course provide a starting point in their determination. The setting of separation standards or minimum obstacle clearances will necessarily take account of many factors not covered by the following material.

3.7.1.1 There is, however, a need to indicate a system use accuracy figure for the guidance of States planning VOR systems.

3.7.2 *Explanation of terms.* The following terms are used with the meanings indicated:

a) *VOR radial signal error.* The difference between the nominal magnetic bearing to a point of measurement from the VOR ground station and the bearing indicated by the VOR signal at that same point. The VOR radial signal error is made up of certain stable elements, such as course displacement error and most site and terrain effect errors, and certain random variable errors. The VOR radial signal error is associated with the ground station only and excludes other error factors, such as airborne equipment errors and pilotage element.

b) *VOR radial variability error.* That part of the VOR radial signal error which can be expected to vary about the essentially constant remainder. The radial variability error is the sum of the variable errors.

c) *VOR radial displacement error.* That part of the VOR radial signal error which is stable and may be considered as fixed for long periods of time.

indicate zero range at a specified distance from the DME antenna. If this is done, a resulting disadvantage is that such facilities will not be usable to support performance-based navigation as described in 7.2.3. When the indicated DME zero range has a reference other than the DME antenna or the DME provides only sectorial coverage, consideration should be given to publishing this information.

7.1.6.4 In the case of DME/P, in order to meet accuracy and coverage requirements, particularly in the runway region, it is recommended that the DME/P be sited as closely as possible to the MLS azimuth facility, consistent with obstacle clearance criteria. For aircraft equipped with a full MLS capability, the desired zero range indication can then be obtained by utilizing MLS basic data. Note that the DME/P transponder time delay must not be adjusted for this purpose.

7.1.6.5 It is desirable that all users obtain indicated zero range at touchdown irrespective of the airborne equipment fitted. This would necessitate location of the DME/P abeam the runway at the touchdown point. In this case accuracy requirements for DME/P would not be met on the runway. It must be noted that MLS Basic Data Word 3 only permits the coding of DME/P coordinates within certain limits.

7.1.6.6 If an MLS/DME/P and an ILS/DME/N serve the same runway, an aircraft equipped with a minimum MLS capability can have a zero range indication at the MLS approach azimuth site when operating on MLS and a zero range indication at the touchdown point when operating on ILS. As this is considered to be operationally unacceptable, specifically from an ATC point of view, and if ILS/MLS/DME frequency tripling to prevent the relocation of the DME/N is not possible, the implementation of DME/P is to be postponed until the DME/N is withdrawn.

7.1.6.7 The nominal location of the zero range indication provided by a DME/N interrogator needs to be published.

7.1.6.8 In considering DME sites, it is also necessary to take into account technical factors such as runway length, profile, local terrain and transponder antenna height to assure adequate signal levels in the vicinity of the threshold and along the runway, and also to assure the required coverage volume (circular or sector). Care is also to be taken that where distance information is required in the runway region, the selected site is not likely to cause the interrogator to lose track due to excessive rate of change of velocity (i.e. the lateral offset of the DME antenna must be chosen with care).

7.1.7 Geographical separation criteria

~~7.1.7~~ ***Note.***— *Guidance material on DME geographical separation criteria is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapter 5.*

~~7.1.8 In order to allow consideration of actual antenna designs, equipment characteristics, and service volumes, the signal ratios needed to assure interference-free operation of the various facilities operating on DME channels are provided in 7.1.8 and 7.1.9. Given these ratios, the geographical separations of facilities may be readily evaluated by accounting for power losses over the propagation paths.~~

7.1.8 Desired to undesired (D/U) signal ratios at the airborne receiver

~~7.1.8~~ ***Note.***— *Guidance material on desired to undesired (D/U) signal ratios at the airborne DME receiver is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapter 5.*

7.1.8.1 Table C-4 indicates the necessary D/U signal ratios needed to protect the desired transponder reply signal at an airborne receiver from the various co-frequency/adjacent frequency, same code/different code, undesired transponder reply signal combinations that may exist. The prerequisite for any calculation using the provided ratios is that the required minimum power density of the desired DME is met throughout the operationally published coverage volume. For initial assignments, the D/U ratios necessary to protect airborne equipment with 6-microsecond decoder rejection should be used. In making an assignment, each facility must be treated as the desired source with the other acting as the undesired. If both satisfy their unique D/U requirement, then the channel assignment may be made.

7.1.8.2 Accordingly, DME channel assignments depend upon the following:

a) *For co-channel assignments:* This condition occurs when both the desired and undesired signals operate on a channel (W, X, Y or Z) that is co-frequency, same code. The D/U signal ratio should be at least 8 dB throughout the service volume.

b) *For co-frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel. A similar Y channel and a Z channel combination also applies.

c) *For first adjacent frequency, same code assignments:* This condition occurs when both the desired and undesired facilities are of W, X, Y or Z type.

d) *For first adjacent frequency, different code assignments:* This condition occurs when one facility operates on an X channel with the other on a W channel, but with a frequency offset of 1 MHz between transponder reply frequencies. A similar Y channel and a Z channel combination also applies.

Table C-4. Protection ratio D/U (dB)

Type of assignment	A	B
Co-frequency:		
Same pulse code	8	8
Different pulse code	8	–42
First adjacent frequency:		
Same pulse code	$-(P_u - 1)$	–42
Different pulse code	$-(P_u + 7)$	–75
Second adjacent frequency:		
Same pulse code	$-(P_u + 19)$	–75
Different pulse code	$-(P_u + 27)$	–75

Note 1.- The D/U ratios in column A protect those DME/N interrogators operating on X or Y channels. Column A applies to

decoder rejection of 6 microseconds.

Note 2.- The D/U ratios in column B protect those DME/N or DME/P interrogators utilizing discrimination in conformance with 3.5.5.3.4.2 and 3.5.5.3.4.3 of Chapter 3 and providing a decoder rejection conforming to 3.5.5.3.5 of Chapter 3.

Note 3.- Pu is the peak effective radiated power of the undesired signal in dBW.

Note 4.- The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the EIRP of the undesired facility.

Note 5.- In assessing adjacent channel protection, the magnitude of D/U ratio in column A should not exceed the magnitude of the value in column B.

---

e) *For second* adjacent *frequency, same or different code assignments:* The second adjacent frequency combinations generally need not be frequency protected. However, special attention should be given to Note 4 of Table C-4, especially if the undesired facility is a DME/P transponder.

7.1.9 *Special considerations for DME Y and Z channel assignments*

The channel assignment plan for DME is such that the transponder reply frequency for each Y or Z channel is the same as the interrogation frequency of another DME channel. Where the reply frequency of one DME matches the interrogation frequency of a second DME, the two transponders should be separated by a distance greater than the radio horizon distance between them. The radio horizon distance is calculated taking into account the elevations of the two transponder antennas.

7.1.10 *Special considerations for DME/P associated with ILS*

7.1.10.1 For those runways where it is intended to install DME associated with ILS and where early MLS/RNAV operations are planned, installation of DME/P is preferred.

7.1.10.2 When it is intended to use the DME/P ranging information throughout the terminal area, interrogation pulse pairs with the correct spacing and nominal frequency must trigger the transponder if the peak power density at the trans-ponder antenna is at least minus 93 dBW/m^2. This sensitivity level is based on the values contained in Chapter 3, 3.5.4.2.3.1 and it is applied to DME/P IA mode, where at this level DME/P IA mode is intended to comply with DME/N reply efficiency and at least DME/N accuracy.

7.1.11 *Considerations for the universal access transceiver (UAT)*

7.1.11.1 Frequency planning criteria to ensure compatibility between DME and the UAT are contained in Part II of the *Manual on the Universal Access Transceiver (UAT)* (Doc 9861).

7.2 Guidance material concerning DME/N only

7.2.1 Coverage of DME/N

7.2.1.1 Whether a particular installation can provide the required frequency, protected coverage volume can be determined by using Figure C-20. The propagation loss for paths without obstructions uses the IF-77 propagation model.

7.2.1.2 Whenever a DME that provides coverage using either a directional or bi-directional DME antenna, the antenna pattern in azimuth and elevation has to be taken into account to achieve the full benefit of the reduced separation requirements outside the antennas main lobe. The actual radiation patterns of the antennas depend on a number of factors, including height of the antenna phase centre, height of the DME counterpoise above ground level (AGL), terrain surface roughness, terrain form, site elevation above mean sea level (MSL), and conductivity of ground and counterpoise. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the equivalent isotropically radiated power (EIRP). Conversely, practical experience has shown, that under favourable siting conditions, and under the less pessimistic conditions often found in actual service, satisfactory system operation is achieved with a lower EIRP. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, the values in Figure C-20 are recommended.

Note.— Further guidance may be found in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (*Doc 9718, Vol II*).

7.2.1.3 When providing coverage to support performance-based navigation as described in the Performance-based Navigation (PBN) Manual (Doc 9613) and in 7.2.3, the following should be considered:

a) although aircraft approved for PBN based on DME are able to tune to a DME up to a range of 160 NM, automatic DME station tuning by aircraft generally favours more nearby stations. Thus, in airspace volumes served by many DME/N facilities, these facilities may not be used by many aircraft at extended range. Therefore, in such areas served by many DMEs (providing a high level of multi-DME position fixing redundancy), use of extended DME coverage ranges may bring little or no performance benefit, while potentially imposing restrictions on the assignment of frequencies;

b) in airspace volumes served by few DMEs, the coverage for multi-DME position fixing may be improved by the use of extended coverage ranges for individual DMEs. Due to different logic applied in various avionics implementations, the values, coded in navigation database fields could unnecessarily limit the usable coverage range of DMEs for multi-DME position fixing. For example, in ARINC 424 coding the Figure of Merit (FOM), the DME Operational Service Volume (D-OSV) and the coverage field of the NAVAID class can all limit DME usable range in some avionics implementations. To avoid this, coordination with concerned aircraft operators and navigation database providers may be necessary.

7.2.2 *EIRP of DME/N facilities*

7.2.2.1 The power density figure prescribed in Chapter 3, 3.5.4.1.5.2 is based on the following example:

Airborne receiver sensitivity	–120 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+9 dB
Power required at antenna	–111 dBW

Minus 111 dBW at the antenna corresponds to minus 89 dBW/ m^2 at the mid-band frequency.

4.1.2 GLONASS

Note.— Additional information is given in the GLONASS FDMA ICD and in the GLONASS CDMA ICD General Description.

4.1.2.1 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 rang ecomputations in the most current realization of the PZ-90 and uses PZ-90 – WGS-84 transformation parameters as indicated in Appendix B, 3.1.2.5.2; 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.

4.1.2.2 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 of single-frequency solutions are for the signal-in-space (SIS) only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath. Dualfrequency solution accuracy characteristics include ionosphere residual errors. The accuracy is derived based on the worst two of 24 satellites being removed from the constellation and a 6-metre constellation RMS SIS user range error (URE).

4.1.2.3 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 4.1.2.6. 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 range error accuracy over all satellites is the 95 per cent threshold of the URE of all satellites over any 24-hour interval for any point within the coverage area. The range error accuracy for any satellite is calculated over a 30-day interval. Under nominal conditions, all satellites are maintained to the same standards, so it is appropriate for availability modelling purposes to assume that all satellites have a 6-metre RMS SIS URE. The standards are restricted to range domain errors allocated to space and control segments.

4.1.2.4 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.

4.1.2.4.1 Satellite/constellation availability. 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).

4.1.2.5 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 (three failures each lasting six hours).

4.1.2.6 Major service failure. A major service failure is defined as a condition over a time interval during which a single healthy GLONASS satellite's ranging signal error (excluding atmospheric and receiver errors) exceeds the range error limit of 70 m (as defined in Chapter 3, 3.7.3.1.2.4).

4.1.2.7 Constellation fault. Constellation fault is defined as a condition over a time interval during which more than one healthy GLONASS satellite's ranging signal error (excluding atmospheric and receiver errors) exceeds the range error limit of 70 m due to a common cause (as defined in Chapter 3, 3.7.3.1.2.5).

4.1.2.8 Continuity. Continuity for a healthy GLONASS satellite is the probability that the GLONASS 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.

4.1.2.9 Coverage. The GLONASS CSA supports the terrestrial coverage area, which is from the surface of the earth upto an altitude of 2 000 km.

4.1.2.10 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.

4.1.2.11 Transformation of GLONASS-M current data information into common form. A satellite navigation message contains current data information in NT parameter. It could be transformed into the common form by the following algorithm:

a) Current year number J in the four-year interval is calculated:

If 1 ≤ NT ≤ 366; J = 1;

If 367 ≤ NT ≤ 731; J = 2;

If 732 ≤ NT ≤ 1 096; J = 3;

If 1 097 ≤ NT ≤ 1 461; J = 4.

b) Current year in common form is calculated by the following formula:

Y = 1 996 + 4 (N4 – 1) + (J – 1).

c) Current day and month (dd/mm) are extracted from the reference table stored in user equipment ROM. The table interrelates NT parameter and common form dates.

4.1.2.11.1 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.

4.1.2.11.2 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.

4.1.2.11.3 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.

4.1.2.11.4 Geodetic reference systems WGS-84 and PZ-90 are maintained consistent with the International Terrestrial Reference Frame (ITRF). While the current conversion parameters from PZ-90 to WGS 84 are provided in Appendix B, 3.1.2.5.2, the application of previous versions of these parameters is also appropriate as long as performance requirements of Chapter 3, Table 3.7.2.4-1 for intended operation are met.

4.1.3 Galileo

***Note**. Additional information concerning the Galileo Open Service is given in the Galileo OS SIS ICD and Galileo OS SDD.*

4.1.3.1 Assumptions. The Galileo Open Service (OS) performance standard is based upon the assumption that a representative OS receiver is used. A representative receiver has the following characteristics:

a) designed in accordance with Galileo OS SIS ICD;

b) uses a 5-degree masking angle;

c) accomplishes satellite position and geometric range computations in the most current realization of the Galileo Terrestrial Reference Frame (GTRF);

d) generates a position and time solution from data broadcast by all satellites in view;

e) excludes Galileo non-healthy signals from the position solution;

f) uses up-to-date and internally consistent ephemeris and clock data for all satellites it is using in its position solution; and

g) navigation data (ephemeris, satellite clock correction and SISA parameters) is not used beyond the maximum validity time of 4 hours.

4.1.3.2 Position domain accuracy

such as user local contributions depending on the receivers or due to atmospheric effects.

4.1.3.5 Service availability. Service availability is the percentage of time over a 30-day 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 10-metre horizontal 95 per cent threshold; a 16-metre vertical 95 per cent threshold; using a representative receiver; and operating within the coverage area over the 30-day interval. The service availability assumes a constellation that meets the criteria in 4.1.3.5.1.

4.1.3.5.1 SIS per-slot/constellation availability. The probability that an operational slot in the Galileo constellation is occupied by a satellite transmitting healthy SIS is higher than 0.95 (normalized annually). For the Galileo baseline configuration, the probability that at least 21 satellites in the nominal 24-slot positions are set healthy and are transmitting a navigation signal, is higher than 0.97 (normalized annually). The SIS constellation availability can be derived from the SIS per-slot availability by means of a binomial model.

4.1.3.6 Probability of failure

4.1.3.6.1 P_{sat}. P_{sat} is the probability that the instantaneous ranging signal error of a healthy Galileo satellite (excluding atmospheric and receiver errors) exceeds *k* times the Galileo user range accuracy (Galileo URA). Galileo URA in P_{sat} definition corresponds to $\sigma_{URA,DF}$ or to $\sigma_{URA,SF}$ for dual-frequency or single-frequency users, respectively. k is the number of standard deviations from the mean corresponding to a probability of Psat in a normal distribution. The For instance, a *k* factor ~~is~~ of 4.17, corresponds to a~~corresponding to the~~ 3×10-5 Psat value. Psat applies at any given time and at any location in the satellite visibility area to both single-frequency and dual-frequency users.

4.1.3.6.2 P_{const}. P_{const} is the probability that the instantaneous ranging signal errors of two or more healthy Galileo satellites (excluding atmospheric and receiver errors) exceeds k times the Galileo user range accuracy (Galileo URA) due to a common failure. Galileo URA in the P_{const} definition corresponds to $\sigma_{URA,DF}$ or to $\sigma_{URA,SF}$ for dual-frequency or single-frequency users, respectively. Pconst applies at any given time and at any location in the respective visibility areas of the affected satellites to both single-frequency and dual-frequency users.

4.1.3.6.3 $\sigma_{URA,DF}$. Galileo $\sigma_{URA,DF}$ is defined as the standard deviation of a zero-mean normal distribution which overbounds the actual distribution of SIS range errors more probable than Psat. Galileo $\sigma_{URA,DF}$ applies to any user location and to a healthy SIS dual-frequency combination E1/E5a.

4.1.3.6.4 σURA,SF. Galileo $\sigma_{URA,SF}$ is defined as the standard deviation of a zero-mean normal distribution which overbounds the actual distribution of SIS range errors more probable than Psat. Galileo σURA,SF applies to any user location and to a healthy SIS single-frequency user (E1 or E5a). $\sigma_{URA,SF}$ considers the Galileo σ_{BGD} and can be derived from the following expression:

$$\sigma_{URA,SF}^2 = \sigma_{URA,DF}^2 + \gamma_f{}^2 \cdot \sigma_{BGD}^2$$

where

γf represents the frequency inflation factor equal to f_{E1}^2/f_{E5a}^2 for E5a users and to 1 for E1 users.

The same expression applies between Galileo σURE,SF and σURE,DF. The σURE,SF and σURE,DF are defined in Appendix B, section 3.4.1.1.2. This expression can also be used by Galileo receiver to compute the σURA,SF and σURE,SF from broadcast σURA,DF and σURE,DF in Galileo I/NAV word Type 22.

4.1.3.6.5 σ_{BGD}. Galileo σ_{BGD} is defined as the standard deviation of a zero-mean normal distribution, which overbounds the actual distribution of BGD residual errors such that the probability of unbounded errors is negligible with respect to P_{sat}. BGD residual errors are the remaining errors after applying Galileo BGD corrections broadcast in the navigation message.

4.1.3.7 *Continuity*. Continuity for a healthy Galileo satellite is the probability that the Galileo OS SIS will continue to be healthy without unscheduled interruption over the next hour. Scheduled interruptions which are announced at least 48 hours in advance do not contribute to a loss of SIS continuity.

4.1.3.8 Coverage. The Galileo OS supports the terrestrial coverage area, which is from the surface of the earth up to 30.48 km.

4.1.3.9 Galileo system time (GST). The GST is a continuous timescale based on the definition of the second (according to the International System of units, SI) whose origin/reference epoch GST (t0) is defined as 13 seconds before 1999-08-22 00:00:00 UTC. The time synchronization information disseminated in the Galileo SIS (e.g. satellite clock offsets) is referenced to GST. This information allows the Galileo OS users to estimate their local time referenced to the GST realization computed by the Galileo OS receiver. In order to better support timing applications based on UTC, the Galileo OS data message includes additional parameters which enable the Galileo OS users to obtain a realization of the UTC time by applying a correction to the GST.

4.1.3.10 Galileo terrestrial reference frame (GTRF). The GTRF is a highly accurate independent realization of the International Terrestrial Reference System (ITRS) based on the estimated coordinates of each of the Galileo sensor station (GSS) sites. The Galileo system uses the geodetic input information to produce navigation data (e.g. satellite ephemeris) referenced to the GTRF. Accordingly, the user position coordinates derived from Galileo position solutions are referenced to GTRF. Due to the good alignment of GTRF to ITRF both reference frames are understood to be equivalent for aviation. The GTRF is regularly aligned if new ITRF realizations are published. To obtain the position in any reference frame different from ITRF, Galileo OS user equipment needs to apply the appropriate valid transformation parameters between the latest ITRF and the desired reference frame. This transformation is under full control and responsibility of the Galileo OS user. Concerning the interoperability between GPS and Galileo, the GPS terrestrial reference frame WGS-84 and the GTRF are both realizations of the ITRF. Therefore, for most Galileo OS applications, a high level of interoperability is provided between the spatial positions obtained with GPS and those obtained with Galileo,

5. AIRCRAFT-BASED AUGMENTATION SYSTEM (ABAS)

5.1 Introduction

5.1.1 ABAS augments ~~and/or integrates~~ the information obtained from core satellite constellations with additional receiver processing and/or~~GNSS elements~~ with information available from other sensors on board the aircraft in order to ensure operation according to the values specified in Chapter 3, 3.7.2.4.

5.1.2 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 filtering techniques and/or estimation of remaining errors in determined ranges.

5.1.3 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).

5.1.4 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 and/or multiple frequency signals are combined~~ (e.g. GPS and GLONASS)~~.

5.2 Receiver autonomous integrity monitoring (RAIM)

5.2.1 RAIM has been implemented using GPS L1 C/A (“GPS RAIM”) and fixed values for constellation performance.

5.2.2 In contrast with ARAIM (section 5.3), GPS RAIM relies on GPS constellation performance using the the broadcast URA values and a satellite fault probability of Psat = 1 x 10-5 or lower. Furthermore, it assumes that only one satellite fault occurs at a given time and that any bias-like errors are small enough to be overbounded by a zero-mean gaussian distribution.

5.2.3 GPS RAIM can be combined with AAIM and other augmentations including ARAIM.

5.3 Advanced RAIM (ARAIM)

5.3.1 Introduction

5.3.1.1 ARAIM refers to an implementation of GNSS-receiver based ABAS other than GPS RAIM, including single or dual frequency, and single or multiple constellation modes. ARAIM includes the provision of integrity support data (ISD). ISD is either generated by or verified by an entity referred to as the ISM generator (ISMG). There is one ISMG per core constellation. In comparison to GPS RAIM, which can be thought of as using "static ISD", ARAIM enables dynamic ISD where integrity parameters can be adapted to actual core satellite constellation performance and available performance history.

5.3.1.2 ISD will be broadcast in core satellite constellation navigation data messages. Messages containing ISD are called integrity support messages (ISM). Some ISD could also be sent outside of ISM, as part of other navigation data messages (such as IAURA for GPS).

5.3.1.3 The ISD contains parameters that describe a Gaussian overbound of the fault-free ranging signal errors as well as parameters describing the likelihood that the satellite signal is faulted and may not be adequately characterized by the fault-free Gaussian overbounds. The ARAIM algorithm uses the ISD to perform fault monitoring and integrity tests and to calculate the protection level(s) to achieve a target integrity risk performance in accordance with operational requirements. The ARAIM algorithm assumes that the fault events characterized by the ISD are independent. It is not necessary to monitor all possible combinations of satellite and constellation faults, as many of these combinations have very small contributions to the integrity risk. The ARAIM algorithm accounts for the integrity risk of the fault-free position and missed detections of monitored and unmonitored fault modes.

5.3.1.4 The ISD parameters σURA and σURE characterize the fault-free ranging signal errors caused by clock and ephemeris errors and the noise-like error contributions from antenna biases, signal deformations, inter-frequency biases, code-carrier coherence. The bnom term characterizes bias-like errors that can be bounded in magnitude. These are due to antenna biases, signal deformations, inter-frequency biases, nominal code-carrier incoherence, nominal range error variation over the satellite terrestrial footprint (due to antenna anisotropy) or other quasi-static/correlated error sources. The bnom term can also be used to bound asymmetry and non-unimodality in the observed clock and ephemeris error distributions. Flexibility is given to the ISMG when determining a Gaussian overbound described by bnom and σURA as long as the overbounding criteria in Appendix B, 3.4.1.2.2.1 are satisfied. Several overbounding methods are available. bnom, σURA and σURE are not accounting for errors caused by signal propagation through the troposphere and ionosphere.

5.3.1.5 The ISD parameters fault rate (Rsat, Rconst) and fault probability (Psat, Pconst) describe the likelihood that the signal is faulted. If a mean fault duration is provided together with a fault rate, the corresponding fault probability can be derived by the receiver. The fault rate is a conservative estimate of the number of faults per hour. The ISMG can provide ISD values equivalent to the default values. However, if justified based on analysis and observed performance, the ISMG may set the broadcast fault parameters such that fault rate and fault probability are lower than default commitments. The ISMG will need to update the broadcast

ISD if observed behaviour no longer supports the lower parameters. The ISMG may provide margin in the broadcast ISD by artificially inflating the observed faults by one or more to ensure that ISM updating does not become time critical.

5.3.1.6 If a core satellite constellation that does not provide an ISM in its navigation data messages is used in ARAIM, then default ISD values are used in the receiver as specified in Appendix B, 3.4.1.3.3.3. Further details about default ISD are provided in 5.3.2.

5.3.1.7 The ARAIM SARPs allow for some flexibility in the detailed assignment of responsibility for ISD parameter data integrity. For example, an ISMG could assemble or code an ISM, generate an associated CRC and then hand-over the complete message to the core satellite constellation provider for broadcasting. Alternatively, the ISMG could transmit the values to be broadcast to the core satellite constellation provider, who would then assemble or code the ISM, and generate a CRC (or other suitable mechanism) as part of its normal message packaging. Whichever approach is chosen, procedures by the ISMG and the relevant core satellite constellation service provider mitigate the risk of data corruption at any stage of the entire process (Appendix B, 3.4.1.2.4). This is based on a thorough analysis of the overall system architecture. The resulting data quality assurance processes will be consistent with the supported ARAIM service type.

5.3.1.8 ARAIM may be combined with RAIM, AAIM and other augmentations.

5.3.1.9 Additional guidance material on ARAIM is provided in the Global Navigation Satellite System (GNSS) Manual (Doc 9849).

5.3.2 Default ISD and traceability to core satellite constellation definitions

5.3.2.1 Default ISD can be used by GNSS receivers to process satellites for which no ISM is broadcast by the core satellite constellation. Table D-3 provides justification of the values in Appendix B, 3.4.1.3.3.3 by referencing the corresponding sections in the core satellite constellation standards.

Table D-28. Default ISD parameters

Default ISD parameters					
	GPS	GLONASS	Galileo	BDS	Notes
$P_{const,\ default}$	$\leq 1\times10^{-8}$	$\leq 1\times10^{-4}$	$\leq 2\times10^{-4}$	$\leq 6\times10^{-5}$	
SARPs Reference	Chapter 3, 3.7.3.1.1.4.3	Chapter 3, 3.7.3.1.2.5	Chapter 3, 3.7.3.1.3.6	Chapter 3, 3.7.3.1.4.4.2	
$P_{sat,\ default}$	$\leq 1\times10^{-5}$	$\leq 1\times10^{-4}$	$\leq 3\times10^{-5}$	$\leq 1\times10^{-5}$	
SARPs Reference	Chapter 3, 3.7.3.1.1.4.2	Chapter 3, 3.7.3.1.2.4	Chapter 3, 3.7.3.1.3.5	Chapter 3, 3.7.3.1.4.4.1	
$\sigma_{URA,\ default,\ DF}$ [m]	IAURA (Note 2)	9	6	7	If value is not stated in [m], it is a broadcast parameter
SARPs Reference	Appendix B, 3.1.1.1.3.1.2 and 3.1.1.2.2.4	Appendix B, 3.1.2.1.7.3, not exceeding values in Chapter 3, 3.7.3.1.2.4 and 3.7.3.1.2.5	4.1.3.6.3 and 4.1.3.6.4, not exceeding values in Chapter 3, 3.7.3.1.3.7 and 3.7.3.1.3.8	Appendix B, 3.1.4.1.3.1.2 and 3.1.4.2.5	
$\sigma_{URA,\ default,\ SF}$ [m]	IAURA (Note 2)	9	6.5 (E1), 7.5 (E5a) (Note 3)	7	
$\sigma_{URE,\ default,\ DF}$ [m]	Nominal URA (Note 2)	8	4	7	
$\sigma_{URE,\ default,\ SF}$ [m]	Nominal URA (Note 2)	8	4.7 (E1), 6 (E5a) (Note 3)	7	
$b_{nom,\ default}$ [m]	0	0	0	0	
$R_{const,\ default}$ [per hour]	$\leq 1\times10^{-8}$		$\leq 1\times10^{-4}$/h	$\leq 6\times10^{-5}$	
$R_{sat,\ default}$ [per hour]	$\leq 1\times10^{-5}$		$\leq 2\times10^{-5}$/h	$\leq 1\times10^{-5}$	
$MFDconst_{default}$ [hours]	1	10	See 5.3.2.3	1	
$MFDsat_{default}$ [hours]	1	3	See 5.3.2.3	1	

Note 1.— SF refers to single frequency processing and DF to dual frequency.

Note 2.— See Appendix B, 3.4.1.3.3.3, Note 3, for interface control document references.

Note 3.— As indicated in 4.1.3.6.4 for the Galileo σURA,SF, the Galileo single frequency σURA, SF and σURE, SF are linked to the Galileo dual frequency σURA, DF and σURE, DF by the following equation:

$$\sigma_{SF}^2 = \sigma_{DF}^2 + {\gamma_f}^2 \cdot \sigma_{BGD}^2 \text{ with } \gamma_f = \frac{f_{E1}^2}{f_{E5a}^2} \text{ for } E5a,\ \gamma_f = 1 \text{ for } E1 \text{ and } \sigma_{BGD} = 2.5\ m\,.$$

5.3.2.2 Some ISD parameters (Psat, Pconst, Rsat, Rconst) are specified with a "≤" sign. This means that core satellite constellation providers are free to further improve their minimum service commitments (which may or may not be reflected in future amendments to this Annex). However, any such future improvements will likely not be implemented in the default ISD values used by ARAIM receivers already installed in aircraft at that time.

5.3.2.3 The Galileo ARAIM service provision scheme is based on commitments made regarding the fault probabilities (Psat and Pconst) and fault rates (Rsat and Rcont). Those parameters, when complemented by σURA ,σURE and bnom, are sufficient to run the airborne integrity monitoring algorithm under ARAIM augmentation. Galileo MFD is not specified. The users should not assume any MFD values from the Galileo commitments on Psat, Pconst, Rsat and Rconst, since those parameters include margin on top of the actual performance that the user may experience and therefore MFD values derived from them may not be representative of the Galileo system.

6. SATELLITE-BASED AUGMENTATION SYSTEM (SBAS)

6.1 SBAS may provide an L1 SBAS service augmenting GPS and/or GLONASS constellations, a dual-frequency, multi-constellation (DFMC) SBAS service augmenting one or more (up to four) constellations, or both services. The L1 SBAS service uses the L1 message data to support single-frequency service. The DFMC SBAS service uses the L5 message data to support DFMC SBAS service. The SBAS messages and data content of the L1 SBAS and DFMC SBAS services are independent and users can only apply the data from the data channel associated with the specific service. In addition, when the SBAS supports ranging, the SBAS satellite may be used as a single-frequency ranging source on L1 using the L1 data, or a dual-frequency ranging source combining both L1 and L5 pseudo-ranges using the L5 data. 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.

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, L1 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.

6.5.7 δUDRE indicator inside the service area. Equipment built to RTCA/DO-229 standards will apply δUDRE = 1 until receipt of the complete Type 27 service area messages. Since the δUDRE indicator inside the service area is set to 0 as required in Appendix B, 3.5.7.6.2.1, SBAS user equipment operating inside the service area will generate the correct integrity bound in the transient phase, using a δUDRE = 1, before reception of the complete set of Type 27 messages.

6.5.8 Day crossover considerations. The parameters t0,GEO, talmanac and ti,LT are expressed in seconds of day. Equipment standard assumes that those parameters are adjusted by SBAS for day crossover. SBAS needs to set those parameters to mitigate misinterpretation by SBAS equipment.

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, 3.5.8.4.2.6.1 and Table B-57A , with additional description of fields used by DFMC SBAS user equipment in Appendix B, 3.5.15.3.5. The format is the same as the GBAS FAS data block defined in Appendix B, 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 and DFMC SBAS user equipment uses two fields not used by L1 SBAS user equipment. The new fields have been defined such that existing FAS data blocks designed for the L1 SBAS service are compatible for use with DFMC SBAS user equipment. FAS data blocks that have APD codings other than 0 are only for use by and should only be installed on aircraft with DFMC SBAS user equipment.

6.6.2 FAS data blocks for SBAS and some GBAS approaches are held within a common on-board

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.

7.1.11 Availability considerations for GBAS. A single GBAS ground subsystem may provide multiple types of service to multiple users and service for multiple runway ends simultaneously. These different types of service may have different availability and consequently one type of service may be available when another is not. Furthermore, as some elements of GBAS are optional (e.g. augmentation of multiple constellations or use of SBAS ranging sources), the capabilities of different users will vary. For this reason, it is not practical for the service provider to predict if a given user will find a specific service type to be available at any given time. All that can be known by the service provider is the status of the ground subsystem and satellite constellation. An assessment can be made as to whether the ground subsystem is meeting the allocated requirements for some target service type and further, the availability of service can be predicted based on an assumed level of performance and a nominal user. The definition of the nominal user includes which elements of GNSS are used (core satellite systems, SBAS ranges etc.) and within that, which subset of satellites are used in the position solution. For GBAS supporting GAST D this is further complicated by the fact that certain parameters (e.g. geometry screening thresholds) may be adjusted by the airframe designer to ensure adequate landing performance given the characteristics of the specific aircraft type. ANSPs and air space designers should be cognizant of the fact that availability of service for GNSS augmentation systems in general is less predictable than conventional navigation aids. Variations in user capabilities will result in times where service may be available to some users and unavailable to others.

7.2 RF characteristics

7.2.1 *Frequency coordination*

7.2.1.1 *Performance factors*

~~7.2.1.1~~ ***Note.****— Guidance material on VOR and GBAS performance factors that must be considered when determining the geographical separation for the purpose of frequency coordination between a candidate GBAS station, a candidate VOR station and existing VOR or GBAS installations is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapters 4 (VOR) and 6 (GBAS).*

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 service volume, minimum field strength and effective isotropically radiated power (EIRP) of the candidate GBAS including the GBAS positioning service, if provided. The minimum requirements for service volume and field strength are found in Chapter 3, 3.7.3.5.3 and 3.7.3.5.4.4, respectively. The EIRP is determined from these requirements;

b) the coverage and service volume, minimum field strength and EIRP 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
$\vert f_{VOR} - f_{VDB} \vert = 25$ kHz	0
$\vert f_{VOR} - f_{VDB} \vert = 50$ kHz	–34
$\vert f_{VOR} - f_{VDB} \vert = 75$ kHz	–46
$\vert f_{VOR} - f_{VDB} \vert = 100$ kHz	–65

f) that between GBAS installations RPDS and RSDS numbers are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. The requirement is found in Appendix B, 3.6.4.3.1;

g) that between GBAS installations within radio range of a particular GBAS ground subsystem the reference path identifier is assigned to be unique. The requirement is found in Appendix B, 3.6.4.5.1; and

h) the four-character GBAS ID to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Appendix B, 3.6.3.4.1.

i) *Slot assignment.* The relative assignment of slots to a GBAS ground subsystem can impact performance in instances where messages in multiple slots need to be received by the airborne subsystem prior to processing. This will occur when using linked messages and/or for a GAST D ground subsystem where correction data is contained in both the Type 1 and Type 11 messages. In these cases slot assignments for all MT 1 and 11 should be adjacent to avoid unnecessary latency and complexity of design. Non-adjacent assignments may, depending on the design of the ground subsystem, result in a lack of time for the ground subsystem to process fault detections, render some slot combinations unusable and thus result in lower efficiency of spectrum use.

7.2.1.1.2 7.2.1.1.1 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 VDB 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 in Table D-3 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). In practice, installations will experience a fade margin that will be dependent on many parameters including aircraft altitude, distance from transmit antenna, antenna type/design and ground reflectors.

7.2.1.2 FM immunity

7.2.1.2 *Note.— Guidance material on GBAS FM immunity is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapter 6.*

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 *Note.— Guidance material on GBAS geographic separation methodologies is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapter 6.*

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 ≥(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 3000 m (10000 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 the service volume and the VDBtransmitter antenna. For example, using a service volume extending to 43 km (23 NM) from the VDB transmitter antenna 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 VDB transmitters antennas 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 isotropically radiated power (EIRP) (dBm)	43	47
For longer range and low radiation angle associated with		Horizontal component

positioning service		Vertical 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 EIRP (dBm)					
Range (km (NM))	Free space loss (dB)	EIRP (dBm)	EIRP (W)	EIRP (dBm)	EIRP (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. It is possible, with an appropriately sited multipath limiting VDB transmitting antenna with an effective radiated power 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.

2. 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.

3. The long-range performance estimates may generally be optimistic with the assumption of no fade margin, i.e., link budget performance will generally not be as good as these estimates indicate.

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 given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapters 2 and 6under development.

7.2.3 **Compatibility with ILS**. 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 localizer receiver sensitivity. Until compatibility criteria are developed for GBAS VDB and ILS, VDB can generally not be assigned to channels below 112.025 MHz (i.e. a minimum frequency separation of 75 kHz from the highest assignable ILS localizer frequency).

7.2.3.1 Inter-airport compatibility. The minimum geographical separation based on a minimum frequency separation of 75 kHz between ILS localizer and GBAS ground station deployed at different airports is 3 NM between the undesired transmitter antenna location and the edges of the coverage of the desired service that are assumed to be at minimum signal power. Smaller necessary separation distance values may be obtained by taking into account additional information such as the actual desired service field strength and actual undesired service transmit antenna radiation patterns.

Note.— The coverage of the ILS localizer is standardized in Chapter 3, section 3.1.3.3 and the GBAS service *volume is standardized in Chapter 3, section 3.7.3.5.3, respectively.*

7.2.3.2 **Same-airport compatibility**. When applying international frequency assignment planning rules, incompatibility with existing ILS or VOR at or near the same airport may lead to an unsuccessful frequency assignment for a given GBAS VDB. In such a case applying 'same-airport compatibility' assessment may still lead to a compatible GBAS VDB frequency. Guidance on same-airport compatibility assessment is contained in Appendix H of EUROCAE ED114B change 1.~~To analyse the constraints for the deployment of a GBAS ground station at the same airport as ILS, it is necessary to consider ILS and VDB compatibility in detail taking into account information such as the actual desired service field strength and actual undesired service transmit antenna radiation patterns. For GBAS equipment with transmitter power such that the maximum field strength of 0.879 volts per metre (-27 dBW/m^2) for the horizontally polarized signal component is not exceeded in the ILS coverage volume of up to 150 W (GBAS/E, 100 W for horizontal component and 50 W, the 16th channel (and beyond) will be below -100.5106 dBm in a 25 kHz bandwidth at a distance of 80 m from the VDB transmitter antenna, including allowingance for a +5 dB positive reflection increase due to constructive multipath. This -100.5106 dBm in a 25 kHz bandwidth translates to a signal-to-noise ratio of 21.5 dB (above the assumed minimum signal-to-noise ratio of 20 dB) figure assumes for a -7986 dBm localizer signal which corresponds to an ILS localizer field strength of 90 microvolts per metre (minus 107 dBW/m^2)at the ILS receiver input and a minimum 20 dB signal-to-noise.~~

~~*Note.— When deploying GBAS and ILS at the same airport, it is recommended to also analyse the impact of the GBAS VDB transmission on the ILS localizer monitor. Interference may be avoided by installing an appropriate filter.*~~

7.2.3.3 At those locations where an ILS facility and a GBAS facility serve opposite approach directions to the same runway, there is a possibility of interference to the GBAS VDB signals in the region where the aircraft overflies the localizer. The interference can result in exceedance of the message failure rate requirement (Appendix B, 3.6.8.2.2.3) and cause a loss of continuity of GBAS guidance. The condition of unacceptable interference is when the ILS localizer signal does not support compliance with the requirements in Appendix B, 3.6.8.2.2.5 and 3.6.8.2.2.6, defining the desired to undesired signal ratios and the maximum adjacent channel power tolerable by the GBAS VDB receiver. The interference is likely to be higher when the localizer is sited close to the runway threshold. Chapter 3, 3.1.2.8 specifies the conditions under which radiation by localizers not in operational use should not be allowed. Compliance with 3.1.2.8 will ensure there is no interference by the ILS localizer to GBAS during low visibility operations that require GAST D. Generally, this should not be an issue for GAST C operations due to the 3.5 seconds window allowed to receive three Type 1 messages, when the aircraft overflies the localizer. However, there may be conditions during GAST C operations where the VDB signal power does not support the D/U, or the maximum ILS localizer power is incompatible with recovery from short-term excess undesired signal power (Appendix B, 3.6.8.2.2.6.5), and that would require the localizer to be turned off.

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 antenna and coverage areas, the field strengths, the polarization of the VDB~~

~~signal, and the VDB and VHF communication receiver 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 –1120 dBm in a 25 kHz bandwidth at a distance of 80200 m from the VDB transmitter antenna including an allowance allowing for aof +5 dB reflectionincrease due to constructive multipath. For GBAS/H equipment with a transmitter maximum power of 100 W, the 32nd channel (and beyond) will be below –1120 dBm in a 25 kHz bandwidth at a distance of 80200 m from the VDB transmitter including an allowance allowing for aof +5 dB reflection increase due to constructive multipath, and a 10 dB polarization isolation. It must be noted that due to differences in the GBAS VDB and VDL transmitter masks, separate analysis must be performed to ensure VDL does not interfere with the GBAS VDB.~~

Note.— *Guidance material on GBAS compatibility with VHF communications is given in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718, Volume II), Chapters 2 and 6.*

~~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~~

~~Note1.— No geographic transmitter restrictions are expected between co-frequency, adjacent time slots provided the undesired VDB transmitting antenna is located at least 80m from areas where the desired signal is at minimum field strength.~~

~~Note 2.— The PD,min of -72 dBm is the output from an ideal isotropic antenna.~~

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)
| fDesired – fUndesired | = 25 kHz	126	774 km (418 NM)	732 km (395 NM)	599 km (323 NM)
| fDesired – fUndesired | = 50 kHz	92	351 km (189 NM)	309 km (166 NM)	176 km (94 NM)
| fDesired – fUndesired | = 75 kHz	80	344 km (186 NM)	302 km (163 NM)	169 km (91 NM)
| fDesired – fUndesired | = 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 service 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 service 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 service volume.

7.3 Service volume

7.3.1 The minimum GBAS service volumecoverage to support approach services is depicted in Figure D-4. Where practical, it is operationally advantageous to provide valid guidance along the visual segment of an approach. The lateral approach service volume may be different (larger) than the vertical approach service volume. 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. segment of an approach. It is also allowable for D_{max} to extend beyond an approach service volume. Reasons why this may be desirable include providing pilots with situational awareness and GBAS status information prior to intercepting the approach procedure, and improving GBAS course capture at the limits of the service volume. In such cases, the potential for reduced protection level, ephemeris bound, and VDB continuity outside the approach service volume should be considered especially when broadcasting large or unlimited values of D_{max}.

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.

7.5.5.1 Tropospheric parameters. Because tropospheric refraction is a local phenomenon, the tropospheric parameters will be determined by the GBAS provider based on local meteorological data or empirical models. Tropospheric delay is proportional to the refractivity integrated over a height interval from the GBAS ground subsystem to the airborne subsystem. The tropospheric delay consists of the dry and wet (water vapor) air components.

7.5.5.2 Tropospheric scale height. Tropospheric scale height accounts for the dependence of the tropospheric correction and residual tropospheric uncertainty on the height difference between the GBAS ground and airborne subsystems. The height variations of the refractivity of the dry and wet components are different. Because only one scale height can be broadcast in message Type 2, the broadcast scale height should account for the height variation of the total tropospheric refractivity including dry and wet components. One of the acceptable means of modeling the scale height is described below.

7.5.5.2.1 Total scale height. Using $h0$ to estimate TC and $\sigma tropo$ as described in Appendix B, 3.6.5.3.1 and 3.6.5.3.2 is equivalent to approximating the height profile of the tropospheric refractivity by a function decaying exponentially from the refractivity at the ground surface level (hS). The total refractivity (Nr) is the sum of the dry refractivity ($Ndry$) and wet refractivity ($Nwet$). The dry and wet components have different scale heights ($h0,dry$, $h0,wet$). As long as the height difference is much smaller than the scale heights, the total scale height can be described as follows:

$$h_0 = \frac{N_r(h_S)h_{0,dry}h_{0,wet}}{N_{dry}(h_S)h_{0,wet}+N_{wet}(h_S)h_{0,dry}}$$

7.5.5.2.2 Dry and wet scale heights. The height variations of the dry and wet components of the refractivity can be found in literature. According to one of the models (Hopfield, 1971), as long as the height difference is much smaller than the scale heights, the dry and wet scale heights can be described as follows:

$$h_{0,dry} = \frac{h_d - h_S}{\mu}$$
$$h_{0,wet} = \frac{h_w - h_S}{\mu}$$
$$\mu = [g/(R\alpha)] - 1$$

where g is the gravitational acceleration, α the temperature lapse rate by height, and R the gas constant for unit mass of air. hd and hw are respectively the empirically determined equivalent heights where the modelled dry and wet refractivities become zero. For μ=4 corresponding to α=6.7 K/km, Hopfield (1971) obtained the following set of equations to best fit radiosonde measurements:

$$h_{0,dry} = \frac{h_d - h_S}{4}$$
$$h_{0,wet} = \frac{h_w - h_S}{4}$$
$$h_d = 40\ 082 + 148.98 \cdot (T - 273.15)\ \ [m]$$
$$h_w = 13\ 268 - 97.96 \cdot (T - 273.15)\ \ [m].$$

As these expressions were obtained to best fit the observations, estimated TC would be valid even for the standard atmosphere (α=6.5 K/km). For α values other than 6.7 K/km (i.e. μ other than 4), hd and hw must be determined for the specific α value. The tropospheric scale height is different for locations and seasons due to variations of the temperature, temperature lapse rate, dry and wet mixing ratio, and so on. The scale height should be determined to account for the statistics of local meteorological conditions. The error in TC associated with the scale height and the other tropospheric parameters must be bounded by a Gaussian distribution with zero mean and a standard deviation of $\sigma tropo$.

7.5.5.3 Determination of tropospheric parameters. One of the acceptable means to determine the tropospheric parameters is to use a dataset observed at a meteorological station near the GBAS reference point. The dataset should consist of at least the surface pressure, temperature and relative humidity. The meteorological station should be located within the same climatological conditions as the GBAS reference point. It is necessary to correct effects of a difference in altitude on the tropospheric parameters. If certain local and characteristic meteorological phenomena such as the sea breeze are known, they may also need to be considered in selecting the meteorological station. The period of the dataset should at least be over one year to account for the seasonal variation of the meteorological phenomena. Year-to-year and longer-term variations of the tropospheric parameters should be considered. Refractivity index (Nr) is the sum of dry refractivity ($Ndry$) and wet refractivity ($Nwet$) as described in 7.5.5.2.1. $Ndry$ can be obtained from averaged values for surface pressure and temperature during the period. $Nwet$ can be calculated from the surface temperature and partial pressure of the water vapor which can be derived from the surface temperature and relative humidity. The refractivity uncertainty (σn) can be calculated by taking the standard deviation of the Nr to overbound the dataset. This overbounding will account for the year-to-year and longer-term variations. As long as it is determined to overbound the observed dataset, periodic recomputation of the tropospheric parameters is not necessary. The scale height (h0) can be derived from the averaged surface temperature, Nr, $Ndry$ and $Nwet$ according to the equations in 7.5.5.2.1 and 7.5.5.2.2.

7.5.5.4 Other considerations related to the troposphere. The horizontal variation in the tropospheric delay is not considered in the tropospheric correction. However, the tropospheric delay is not necessarily horizontally homogeneous. If a service provider determines that the horizontal gradient is not negligible, the horizontal variation in the tropospheric delay should be accounted for. One of the acceptable means is to include the uncertainty in the tropospheric delay associated with its horizontal variation in $\sigma vert\_iono\_gradient$ because it is a parameter which can account for errors proportional to the distance between the GBAS reference point and the aircraft.

~~7.5.5~~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 during nominal conditions.

7.5.6.1 *Ionospheric anomalies.* Small scale structures in the ionosphere can result in non-differentially corrected errors in the GBAS position. Such phenomena are typically associated with solar storm activity and may be characterized by steep gradients in the ionospheric delay over a relatively short distance (e.g., a few tens of kilometres). The errors that may be induced by these phenomena result when the airborne receiver and ground subsystem are receiving satellite signals that have different propagation delays. Also, since GBAS uses code-carrier smoothing with a relatively long time constant, biases build up in these filters that are a function of the rate of change of ionospheric delay. If the ground subsystem and airborne receivers experience significantly different delays and rates of change of the ionospheric delays, the biases that build up in these filters will not match and will not be cancelled by the differential processing.

7.5.6.1.1 *Ionospheric anomaly mitigation.* Ionospheric anomalies can produce position errors which are significant (i.e. tens of metres) in the context of approach operations. To mitigate these errors, different strategies are used depending on the GBAS approach service type.

7.5.6.1.2 *Ionospheric anomaly mitigation for GAST A, B and C*. For GAST A, B or C, the ground subsystem is responsible for mitigating the potential impact of ionospheric anomalies. This may be handled through various monitoring schemes (e.g. far-field monitors or integration with a wide area ground network supporting SBAS) which detect the presence of ionosphere anomalies and deny service if the resulting user position errors would be unacceptable. One means to deny service is to inflate some combination of the broadcast integrity parameters: σ_{pr_gnd}, $\sigma_{vert\_iono\_gradient}$, the ephemeris decorrelation parameter (P), the ephemeris missed detection parameters $K_{md\_e,GPS}$ and $K_{md\_e\_,GLONASS}$ such that any geometry that could be used by an airborne user will not be subjected to intolerably large errors (given the intended operational use).This inflation scheme could also be used without the complexity of monitoring the ionosphere during operations by assuming ionosphere anomalies are present. In this case, a model of the possible ionosphere conditions that could occur is used to determine the proper values of the broadcast integrity parameters. Since the extremes of ionosphere conditions vary significantly through the world, the model is location dependent. Such an inflation scheme results in a reduction in availability because it inflates the values even when anomalies are not present.