International Civil Aviation Organization
Organisation de l'aviation civile internationale
Organización de Aviación Civil Internacional
Международная организация гражданской авиации
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Ref.: AN 7/62.1.4-21/41

6 July 2021

Subject: Proposals for the amendment of Annex 10, Volume I to: a) support the introduction of dual-frequency, multi-constellation (DFMC) global navigation satellite system (GNSS) by adding provisions for additional frequencies of operation for the global positioning system (GPS), the global navigation satellite system (GLONASS) and the satellite-based augmentation system (SBAS), and by introducing provisions for the new BeiDou Navigation Satellite System (BDS) and Galileo system; and b) support ionospheric gradient mitigation for the ground-based augmentation system (GBAS).

Action required: Comments to reach Montréal by 6 January 2022

Sir/Madam,

1. I have the honour to inform you that the Air Navigation Commission (ANC), at the tenth meeting of its 217th Session held on 22 June 2021, considered proposals developed by the sixth meeting of the Navigation Systems Panel (NSP/6) to amend the Standards and Recommended Practices (SARPs) in Annex 10 — *Aeronautical Telecommunications*, Volume I — *Radio Navigation Aids* to: a) support the introduction of dual-frequency, multi-constellation (DFMC) global navigation satellite system (GNSS) by adding provisions for additional frequencies of operation for the global positioning system (GPS), the global navigation satellite system (GLONASS) and the satellite-based augmentation system (SBAS), and by introducing provisions for the new BeiDou Navigation Satellite System (BDS) and Galileo system; and b) support ionospheric gradient mitigation for the ground-based augmentation system (GBAS). The Commission authorized the transmission of these proposals to Contracting States and appropriate international organizations for comments.

2. Background information on the aforementioned proposals is provided in Attachment A. The proposed amendments to Annex 10, Volume I are contained in Attachment B. The rationales have been provided in text boxes immediately following each proposal.

3. In examining the proposed amendments, you should not feel obliged to comment on editorial aspects as such matters will be addressed by the ANC during its final review of the draft amendment.

4. May I request that any comments you wish to make on the amendment proposals be dispatched to reach me not later than 6 January 2022. To facilitate the processing of replies with substantive comments, I invite you to submit an electronic version in Word format to icaohq@icao.int. The ANC has asked me to specifically indicate that comments received after the due date may not be considered by the Commission and the Council. In this connection, should you anticipate a delay in the receipt of your reply, please let me know in advance of the due date.

5. In addition, the proposed amendment to Annex 10, Volume I is envisaged for applicability on 2 November 2023. Any comments you may have thereon would be appreciated.

6. The subsequent work of the ANC and the Council would be greatly facilitated by specific statements on the acceptability or otherwise of the amendment proposal.

7. Please note that for the review of your comments by the ANC and the Council, replies are normally classified as "agreement with or without comments", "disagreement with or without comments" or "no indication of position". If in your reply the expressions "no objections" or "no comments" are used, they will be taken to mean "agreement without comment" and "no indication of position", respectively. In order to facilitate proper classification of your response, a form has been included in Attachment C which may be completed and returned together with your comments, if any, on the proposals in Attachment B.

Accept, Sir/Madam, the assurances of my highest consideration.

Fang Liu
Secretary General

Enclosures:

A — Background information
B — Proposed amendment to Annex 10 — *Aeronautical Telecommunications*, Volume I — *Radio Navigation Aids*
C — Response form

BACKGROUND INFORMATION

1. GENERAL

1.1 The proposed amendment, as detailed in Attachment B, relates to:

a) support of the introduction of dual-frequency, multi-constellation (DFMC) global navigation satellite system (GNSS) by adding provisions for additional frequencies of operation for the global positioning system (GPS), the global navigation satellite system (GLONASS) and the satellite-based augmentation system (SBAS), and by introducing provisions for the new BeiDou Navigation Satellite System (BDS) and Galileo system; and

b) support of ionospheric gradient mitigation for the ground-based augmentation system (GBAS).

2. DUAL-FREQUENCY, MULTI-CONSTELLATION (DFMC) GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

2.1 Background

2.1.1 GNSS evolution

2.1.1.1 The global GNSS infrastructure is currently undergoing a significant evolution that will enable the introduction of DFMC GNSS in aviation. Multiple GNSS constellations offering dual-frequency signals are being introduced into service by the United States (GPS modernization), the Russian Federation (GLONASS modernization), European Union (Galileo constellation) and China (BeiDou Navigation Satellite System (BDS) constellation). A number of States and regions also plan to deploy DFMC satellite-based augmentation systems (SBASs)[1].

2.1.2 Benefits of DFMC GNSS

2.1.2.1 DFMC GNSS offers an opportunity to further enhance GNSS robustness, navigation performance and operational benefits. The use of dual frequencies will help mitigate vulnerabilities in respect of ionospheric disturbance and radio frequency interference. The availability of multiple constellations will contribute to mitigate ionospheric scintillation and the risk of having insufficient satellites within a single constellation. These technical improvements will enable operational benefits in terms of safety and efficiency, such as improved operational reliability for communications, navigation and surveillance (CNS) applications, increased deployment of 3D instrument approach operations worldwide in line with PBN global goals, introduction of innovative operational concepts and applications and continued rationalization of conventional navigation aids.

[1] The ground-based augmentation system (GBAS) already supports single-frequency, dual-constellation GNSS and it is expected that it will evolve to support DFMC, as reflected in Job Card NSP 005.003 (GNSS Evolution – GBAS).

2.1.3 ICAO standardization

2.1.3.1 The potential benefits to aviation arising from the introduction of DFMC GNSS were identified early on by ICAO. As a result, the NSP was tasked with the development of the related ICAO provisions. The Twelfth and Thirteenth Air Navigation Conferences (Recommendations 6/5 c) and 2.2/2 f), respectively) confirmed the need for the continued development of Standards and Recommended Practices (SARPs) and guidance material.

2.1.3.2 The results of the development, reflecting over a decade of intensive work by ICAO and States, are summarized below. The summary is organized into three sections: common DFMC GNSS provisions, core satellite constellations and DFMC SBAS.

2.2 Common DFMC GNSS provisions (Initial Proposals 1 and 7)

2.2.1 In addition to the system-specific provisions described below, which affect sections of the Annex dedicated to individual GNSS elements (core satellite constellations and SBAS), the proposed amendment also includes a number of provisions affecting sections that cover common aspects of all GNSS elements. They are presented in two separate groupings. The first (Initial Proposal 1) contains definitions and some general provisions (list of GNSS elements, space and time reference), which in the Annex are located before the provisions for individual GNSS elements. The second (Initial Proposal 7) contains provisions for the aircraft-based augmentation system (ABAS), aircraft receivers, resistance to interference, receiver antenna characteristics and signal quality monitor design.

2.3 Core satellite constellations (Initial Proposals 2 - 5)

2.3.1 Scope of core satellite constellation SARPs

2.3.1.1 The proposed draft SARPs for core satellite constellations contain only those signals and services that are intended for aviation use. The level of detail provided in the SARPs is intended to be the minimum required to provide a reference for the development of augmentation systems, which meet the more demanding aviation requirements that cannot be met by core satellite constellations alone, as well as to support receivers that implement combinations of signals from multiple constellations. The structure, style and level of detail of the new SARPs have been harmonized with the already existing GPS and GLONASS SARPs. Within the SARPs, references to original constellation provider documentation (such as constellation performance standards, system definition document, interface control documents and interface specifications) allow access to additional technical detail, as needed.

2.3.2 GPS (Initial Proposal 2)

2.3.2.1 GPS is the satellite navigation system operated by the United States. SARPs for GPS were first included in Annex 10 in 2001. They support the GPS Standard Positioning Service (SPS)[2], which is fully operational today using the C/A-code signal transmitted on the L1 frequency. The SPS is currently being modernized. The modernization includes the addition of a pair of signals (I5-code and Q5-code) transmitted at the L5 frequency[3] along with several other improvements. The proposed amendment to the existing GPS SARPs is intended to reflect the modernized service.

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[2] Annex 10, Volume I, section 3.7.3.1.
[3] 1 176.45 MHz.

2.3.3 GLONASS (Initial Proposal 3)

2.3.3.1 GLONASS is the satellite navigation system operated by the Russian Federation. SARPs for GLONASS were first included in Annex 10 in 2001. They support the GLONASS Channel of Standard Accuracy (CSA)[4] service, which is fully operational today using a frequency division multiple access (FDMA) signal in the L1 frequency band. The CSA is currently being modernized. The modernization includes the addition of code division multiple access (CDMA) signals in the L1 band and in the L3 band[5]. The proposed amendment to the existing GLONASS SARPs is intended to reflect the modernized service.

2.3.4 Galileo (Initial Proposal 4)

2.3.4.1 Galileo is the satellite navigation system operated by the European Union. It is currently not included in Annex 10. The proposed amendment to Annex 10 is intended to introduce the Galileo Open Service (Galileo OS) in Annex 10. The Galileo OS uses signals in two frequency bands to provide positioning, velocity and timing information to Galileo users on a continuous, worldwide basis.

2.3.5 BDS (Initial Proposal 5)

2.3.5.1 BDS is the satellite navigation system operated by the People's Republic of China. It is currently not included in Annex 10. The proposed amendment to Annex 10 is intended to introduce the BDS Open Service (BDS OS) in Annex 10. The BDS OS uses signals in two frequency bands to provide positioning, velocity and timing information to BDS users on a continuous, worldwide basis.

2.3.6 DFMC SBAS (Initial Proposal 6)

2.3.6.1 SBAS is a wide coverage GNSS augmentation system in which the user receives augmentation information from a satellite-based transmitter. SARPs for SBAS were first included in Annex 10 in 2001. Currently, SBAS services are provided by several systems worldwide[6], using signals transmitted on the L1 frequency. The proposed amendment to Annex 10 is intended to introduce an additional signal transmitted on the L5 frequency and to enhance the ability of SBAS to augment multiple constellations. This will enable DFMC SBAS to provide improved availability, continuity and accuracy compared to the existing L1 SBAS.

2.3.6.2 Scope of SBAS DFMC SARPs

2.3.6.2.1 The DFMC SBAS service is independent of the L1 SBAS service, as all the information required for the DFMC SBAS service is transmitted on the L5 frequency. Hence, provision of DFMC SBAS services does not require provision of an L1 SBAS service. However, it is expected that DFMC SBAS providers will provide L1 SBAS service as well, and that all DFMC SBAS avionics will include the capability to operate in L1 SBAS mode. Existing L1 SBAS avionics will continue to function with the existing L1 SBAS service, which is not modified by the proposed amendment.

2.3.6.2.2 The minimum DFMC SBAS capability supports the same operational services as L1 SBAS, namely en route through precision approach operations, using corrections broadcast by an SBAS satellite applied to core satellite constellation satellite pseudo-range. In contrast to L1 SBAS, however, DFMC SBAS mitigates ionosphere delay effects by using the ionosphere-free pseudo-range[7] instead of "raw" pseudo-range measurements, which enables DFMC SBAS users to measure ionosphere delay

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[4] Annex 10, Volume I, section 3.7.3.2.

[5] 1 202.025 MHz.

[6] Annex 10, Volume I, Attachment C, 6.2.2.

[7] The ionosphere-free pseudo-range is 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.

directly. As a result, DFMC SBAS service can be provided even in regions of active ionosphere where availability of an L1 SBAS service would be low. Furthermore, DFMC SBAS enables augmentation of multiple constellations up to a total of 92 satellites, whereas L1 SBAS is limited to the GPS and GLONASS constellations up to a total of 51 satellites.

3. IONOSPHERIC GRADIENT MITIGATION FOR THE GROUND-BASED AUGMENTATION SYSTEM (GBAS)

3.1 Background

3.1.1 GBAS supports approach and landing operations down to Category III minima. The related technical requirements are standardized in Annex 10, Volume I as GBAS Approach Service Types (GAST) A, B, C and D. GAST D was specifically developed to support Category II/III operations but can be used to support Category I operations as well. GAST D SARPs include extensive provisions for mitigation of ionospheric errors affecting GNSS positioning.

3.2 Increase of GBAS GAST D limit on E_{IG} (Initial Proposal 8)

3.2.1 As part of the ionospheric error mitigation provisions, the GBAS SARPs define a parameter called "maximum undetected 30-second smoothed corrected pseudo-range error due to an ionospheric gradient" (E_{IG})[8], with a maximum allowable value of 2.75 m.

3.2.2 By definition, the value of E_{IG} is proportional to the distance between the GBAS ground station and the runway threshold(s) served by that station. Thus, setting a limit on E_{IG} implicitly sets a limit on the maximum distance allowed between the ground station and the threshold(s). Depending on the ionospheric model used by the station, the distance limit can vary; typical values are around 5 km, but values as low as 3 km are also possible. The associated station siting constraints, in conjunction with other siting constraints independent from E_{IG}, can potentially impose significant restrictions on the use of a single GBAS station to support multiple runways, in particular in the case of large airports and/or challenging ionospheric conditions.

3.2.3 To mitigate those restrictions, the NSP conducted a study of the possibility of increasing the E_{IG} limit above 2.75 m. The sensitivity analysis performed as part of the study showed that an increase would have no impact on system integrity, while it could have an impact on service availability depending on the size of the increase, the ionospheric model used by the station, and the aircraft. However, given that the original limit was based on very conservative worst-case assumptions, even with an increase of E_{IG}, the availability in many cases would still meet or exceed the acceptable availability target for GAST D. Thus, while it would it would not be advisable to increase the limit unconditionally, an increase could be beneficial in such cases.

3.2.4 Accordingly, the proposal maintains the original limit as a general provision, but allows deviations for airports in which availability remains acceptable if the limit is increased. A service provider wishing to increase the limit in order to relax GBAS siting restrictions could then do so on the basis of a trade-off analysis between availability and reduction in restrictions. The proposal also contains guidance material on availability estimation to assist the trade-off analysis.

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[8] Annex 10, Volume I, Appendix B, 3.6.5.9.

ATTACHMENT B to State letter AN 7/62.1.4-21/41

PROPOSED AMENDMENT TO ANNEX 10, VOLUME I

NOTES ON THE PRESENTATION OF THE PROPOSED AMENDMENT

The text of the amendment is arranged to show deleted text with a line through it and new text highlighted with grey shading, as shown below:

1.	~~Text to be deleted is shown with a line through it.~~	text to be deleted
2.	New text to be inserted is highlighted with grey shading.	new text to be inserted
3.	~~Text to be deleted is shown with a line through it~~ followed by the replacement text which is highlighted with grey shading.	new text to replace existing text

PROPOSED AMENDMENT TO

**INTERNATIONAL STANDARDS
AND RECOMMENDED PRACTICES**

AERONAUTICAL TELECOMMUNICATIONS

ANNEX 10

TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION

**VOLUME I
RADIO NAVIGATION AIDS**

INITIAL PROPOSAL 1
General provisions for dual-frequency, multi-constellation (DFMC) GNSS – Part 1

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

. . .

3.7 Requirements for the Global Navigation Satellite System (GNSS)

3.7.1 Definitions

. . .

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.

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.

. . .

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.

. . .

3.7.2 General

. . .

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) ~~navigation signal~~ as defined in 3.7.3.1.2;

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

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

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

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

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

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

~~g)~~i) aircraft GNSS receiver as defined in 3.7.3.6.

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

3.7.2.3 *Space and time reference*

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

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

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

. . .

Origin:	*Rationale*:
NSP/6	This proposal addresses Annex provisions that cover common aspects of all GNSS elements and need to be updated to reflect the introduction of DFMC GNSS. It includes amendments to definitions and to some general provisions (list of GNSS elements, space and time reference) which in the Annex are located before the provisions for individual GNSS elements. (Additional common aspects are covered in Initial Proposal 7.)

INITIAL PROPOSAL 2
Global positioning system (GPS)

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

. . .

3.7.3 GNSS elements specifications

3.7.3.1 *Core constellations*

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

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

3.7.3.1.1.1 *Space and control segment accuracy*

Note.— The following accuracy standards apply only for healthy GPS SPS signal-in-space (SIS), during normal operations as described in Attachment D, 4.1.1.9, and do not include atmospheric or receiver errors as described in Attachment D, 4.1.1.2. ~~They apply under the conditions specified in Appendix B, 3.1.3.1.1.~~ GPS SPS SIS health conditions can be found in the United States Department of Defense, Global Positioning System – Standard Positioning Service – Performance Standard, *5th Edition, April 2020 (hereinafter referred to as "GPS SPS PS"), Section 2.3.2.*

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

	Global average 95% of the time	Worst site 95% of the time
Horizontal position error	~~9~~8 m ~~(30 ft)~~	~~17~~15 m ~~(56 ft)~~
Vertical position error	~~15~~13 m ~~(49 ft)~~	~~37~~33 m ~~(121 ft)~~

3.7.3.1.1.1.2 *Time transfer accuracy*. The GPS SPS time transfer errors shall not exceed ~~40~~30 nanoseconds 95 per cent of the time.

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

a) range error of any satellite — 30 m ~~(100 ft)~~ with reliability specified in 3.7.3.1.1.3;

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

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

d) 95th percentile range error for any satellite ~~over all time differences between time of data generation and time of use of data~~ — ~~7.8~~7.0 m ~~(26 ft)~~ (global average)~~.~~; and

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

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

≥99 per cent horizontal service availability, average location (~~17~~15 m 95 per cent threshold)

≥99 per cent vertical service availability, average location (~~37~~33 m 95 per cent threshold)

≥90 per cent horizontal service availability, worst-case location (~~17~~15 m 95 per cent threshold)

≥90 per cent vertical service availability, worst-case location (3~~7~~33 m 95 per cent threshold)

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

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

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

3.7.3.1.1.4 *Probability of major service failure.*

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

3.7.3.1.1.4.1 *Satellite major service failure onset rate (R_{sat}).* The probability that the instantaneous user range error (URE) of any satellite will exceed 4.42 times the ~~upper bound on the user range accuracy~~

~~(URA)~~ relevant integrity assured user range accuracy (IAURA) value broadcast by that satellite without an alert received at the user receiver antenna within 10 seconds shall not exceed $1×10^{-5}$ per hour.

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

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

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

3.7.3.1.1.5 *Continuity.* The probability of losing ~~GPS SPS~~L1 C/A ~~signal-in-space (~~SIS~~)~~ availability from a slot of the ~~nominal~~ 24-slot constellation due to unscheduled interruption shall not exceed $2×10^{-4}$ per hour.

3.7.3.1.1.6 *Coverage.* The GPS SPS shall cover the surface of the earth up to an altitude of 3 000 kilometres.

Note.— Guidance material on GPS accuracy, availability, reliability, major service failure, continuity~~,~~ and coverage is given in Attachment D, 4.1.1. Additional information is given in the GPS SPS PS.

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

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

3.7.3.1.1.~~7~~8 *Radio frequency (RF) characteristics*

Note.— Detailed RF characteristics are specified in NAVSTAR GPS Space Segment/Navigation User Segment Interfaces, IS No. IS-GPS-200, Rev K (hereinafter referred to as "IS-GPS-200K") for L1 and NAVSTAR GPS Space Segment/User Segment L5 Interfaces, IS No. IS-GPS-705, Rev F (hereinafter referred to as "IS-GPS-705F"); selected characteristics are specified in Appendix B, 3.1.1.1.1 for L1 and Appendix B, 3.1.1.1.4 for L5.

3.7.3.1.1.~~7~~8.1 *L1 c~~C~~arrier frequency*. Each GPS satellite shall broadcast an SPS ranging signal at the carrier frequency of 1 575.42 MHz (GPS L1) using code division multiple access (CDMA).

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

~~*Note.— A new civil frequency will be added to the GPS satellites and will be offered by the United States for critical safety-of-life applications. SARPs for this signal may be developed at a later date.*~~

3.7.3.1.1.~~7~~8.~~2~~3 *Signal spectrum*. The ~~GPS SPS~~ L1 and L5 signal power shall be contained within ~~a~~ ±12 MHz bands centred on the respective carrier frequencies: ~~(~~1 563.42 –1 587.42 MHz~~) centred on the~~ for L1 ~~frequency.~~ and 1 164.45 – 1 188.45 for L5.

3.7.3.1.1.~~7~~8.~~3~~4 *Polarization*. The transmitted L1 and L5 RF signals shall be right-hand ~~(clockwise)~~ circularly polarized.

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

3.7.3.1.1.~~7~~8.~~4~~6 *Signal power level*. Each GPS satellite shall broadcast SPS navigation signals with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the following ranges ~~of –158.5 dBW to –153 dBW~~ for all antenna orientations orthogonal to the direction of propagation: –158.5 dBW to –153 dBW for L1 C/A and –157.9 dBW to –150 dBW for each of the I5 and Q5 channels on L5.

3.7.3.1.1.~~7~~8.~~5~~7 *Modulation*. ~~The~~ Each SPS L1 and L5 signal shall be bipolar phase shift key (BPSK) modulated with a pseudo random noise (PRN) ~~1.023 MHz coarse/acquisition~~ code. The C/A code ~~sequence shall be repeated each millisecond. The transmitted code sequence shall be the Modulo-2 addition of a 50 bits per second navigation message and the C/A code.~~ on L1 shall have a rate of 1.023 megachips per second. The codes on I5 and Q5 shall have a rate of 10.23 megachips per second.

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

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

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

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

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

3.7.3.1.1.~~8~~9 *GPS time*. GPS time shall be referenced to UTC (as maintained by the U.S. Naval Observatory).

3.7.3.1.1.~~9~~10 *Coordinate system*. The GPS coordinate system shall be WGS-84.

3.7.3.1.1.~~10~~11 *Navigation information*. The navigation data transmitted by the satellites on L1 and L5 shall include the necessary information to determine:

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) propagation delay effects;

f) time transfer to UTC; and

g) constellation status.

Note.— Structure and contents of data are specified in Appendix B, 3.1.1.1.2 and 3.1.1.1.3, respectively for L1, and 3.1.1.1.5 and 3.1.1.1.6 for L5.

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

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3. GNSS ELEMENTS

3.1 Core constellations

3.1.1 Global Positioning System (GPS) Standard Positioning Service (SPS) (L1 and L5)

3.1.1.1 NON-AIRCRAFT ELEMENTS

3.1.1.1.1 *L1 COARSE ACQUISITION (C/A) SIGNAL RADIO FREQUENCY (RF) CHARACTERISTICS*

3.1.1.1.1.1 *Carrier phase noise*. The carrier phase noise spectral density of the unmodulated L1 carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian (1 sigma).

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

3.1.1.1.1.3 *Correlation loss.* The loss in the recovered signal power due to imperfections in the L1 C/A signal modulation and waveform distortion shall not exceed 1 0.6 dB for all GPS-II satellite generations and 0.3 dB for all GPS-III satellite generations.

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

3.1.1.1.1.4 *L1 ~~Coarse/acquisition (~~C/A~~)~~ code generation and timing.* Each C/A code pattern $G_i(t)$ shall be formed by the Modulo-2 sum of two 1 023-bit linear patterns, G1 and $G2_i$. The $G2_i$ sequence shall be formed by effectively delaying the G2 sequence by an integer number of chips~~ to produce one of 36 unique $G_i(t)$ patterns defined in Table B-1~~. The G1 and G2 sequences shall be generated by 10-stage shift registers having the following polynomials as referred to in the shift register input:

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

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

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

Note. — Additional information on code phase assignments is given in IS-GPS-200K.

3.1.1.1.2 *L1 ~~D~~data structure.* The legacy navigation (LNAV) message shall be formatted as shown in Figure B-2. Each page, as shown in Figure B-6, shall utilize a basic format of a 1 500-bit-long frame with up to 5 subframes, each of 300 bits in length. All words shall be transmitted most significant bit (MSB) first.

Note.— The bit allocations depicted for subframes 4 and 5 in Figure B-6 apply only to satellites broadcasting PRN codes 1 – 32. See IS-GPS-200K for the bit allocations of subframes 4 and 5 for satellites broadcasting PRN codes 33 – 63.

Editorial note.— Renumber paragraphs 3.1.1.2.1 to 3.1.1.2.6.2 as 3.1.1.1.2.1 to 3.1.1.1.2.6.2. *Delete* Table B-1 and *renumber* subsequent tables accordingly.

3.1.1.1.3 *L1 ~~D~~DATA CONTENT*

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

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

3.1.1.1.3.1.2 *User range accuracy (URA).* Bits 13 through 16 of word 3 shall provide a URA index, which prescribes the predicted satellite URA as shown in Table B-3. The integrity assured URA (IAURA) shall be the upper bound URA value corresponding to the URA index, as shown in the last column of Table B-3.

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

Note 2.— The URA is a statistical indicator of the contribution of the apparent clock and ephemeris

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

prediction accuracies to the ranging accuracies obtainable with a specific satellite based on historical data.

Note 3.— The nominal URA value for each URA index is also shown in Table B-3. The nominal URA is suitable for use as a prediction of the RMS signal-in-space pseudo-range errors for accuracy-related purposes.

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Table B-3. User range accuracy

URA index	URA (meters)	Nominal URA ~~Accuracy~~	Corresponding IAURA
0	0.00 < URA ≤ 2.40	2 m	2.40 m
1	2.40 < URA ≤ 3.40	2.8 m	3.40 m
2	3.40 < URA ≤ 4.85	4 m	4.85 m
3	4.85 < URA ≤ 6.85	5.7 m	6.85 m
4	6.85 < URA ≤ 9.65	8 m	9.65 m
5	9.65 < URA ≤ 13.65	11.3 m	13.65 m
6	13.65 < URA ≤ 24.00	16 m	24.00 m
7	24.00 < URA ≤ 48.00	32 m	48.00 m
8	48.00 < URA ≤ 96.00	64 m	96.00 m
9	96.00 < URA ≤ 192.00	128 m	192.00 m
10	192.00 < URA ≤ 384.00	256 m	384.00 m
11	384.00 < URA ≤ 768.00	512 m	768.00 m
12	768.00 < URA ≤ 1 536.00	1 024 m	1 536.00 m
13	1 536.00 < URA ≤ 3 072.00	2 048 m	3 072.00 m
14	3 072.00 < URA ≤ 6 144.00	4 096 m	6 144.00 m
15	6 144.00 < URA (or no accuracy prediction is available - SPS users are advised to use the SV at their own risk)	~~Do not use~~No accuracy prediction is available - SPS users are advised to use the SV at their own risk	N/A

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

a) 0 = all navigation data are valid; and

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

The 5 LSBs shall indicate the health of the signal components in accordance with ~~3.1.1.3.3.4~~ Table B-X. The health indication shall be provided relative to the capabilities of each satellite as designated by the configuration code ~~in 3.1.1.3.3.5~~ provided in page 25 of subframe 4. Any satellite that does not have a certain capability shall be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a receiver standpoint and does not require that capability. Additional health data shall be given in subframes 4 and 5.

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

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

MSB				LSB	Indication
0	0	0	0	0	ALL SIGNALS OK
1	1	1	0	0	SATELLITE IS TEMPORARILY OUT — do not use this satellite during current pass
1	1	1	0	1	SATELLITE WILL BE TEMPORARILY OUT — use with caution
1	1	1	1	0	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.

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 be different from that transmitted prior to the change (*Note 2*).

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Table B-6. Ephemeris parameters

Parameter	Number of bits**	Scale factor (LSB)	Effective range***	Units
IODE	8			
C_{rs}	16*	2^{-5}		metres
Δn	16*	2^{-43}		semi-circles/second
M_0	32*	2^{-31}		semi-circles
C_{uc}	16*	2^{-29}		radians
e	32	2^{-33}	0.03	dimensionless
C_{us}	16*	2^{-29}		radians
$\sqrt{A}$	32	2^{-19}	2 530 to 8 192	metres$^{1/2}$
t_{oe}	16	2^{4}	604 784	seconds
C_{ic}	16*	2^{-29}		radians
$OMEGA_0$	32*	2^{-31}		semi-circles
C_{is}	16*	2^{-29}		radians
i_0	32*	2^{-31}		semi-circles
C_{rc}	16*	2^{-5}		metres
ω	32*	2^{-31}		semi-circles
OMEGADOT	24*	2^{-43}	-6.33×10^{-7} to 0	semi-circles/second
iDOT	14*	2^{-43}		semi-circles/second

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

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

Note 2.— The first data set may change (3.1.1.1.2.2) at any time during the hour and therefore may be transmitted by the satellite for less than 1 hour.

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

3.1.1.1.3.2.3 *Curve fit intervals.* Bit 17 in word 10 of subframe 2 shall be a “fit interval” flag which indicates the curve-fit interval used in determining the ephemeris parameters, as follows:

0 = 4 hours,
1 = greater than 4 hours.

A fit interval flag of zero (0) shall indicate the satellite is undergoing normal operations. A fit interval flag of one (1) shall indicate the satellite is undergoing short- or long-term extended operations.

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

Note.— Subframes 4 and 5 from satellites broadcasting PRN codes 1 – 32 contain almanac and health data for 32 satellites. Subframes 4 and 5 from satellites broadcasting PRN codes 33 – 63 contain almanac and health data for only 31 satellites. See IS-GPS-200K for full details on the content and bit allocations of the data in subframes 4 and 5.

Table B-Y. Subframes 4 and 5 data

Subframe	Page(s)	Data
4	1, 6, 11, 16 and 21	Reserved
	2, 3, 4, 5, 7, 8, 9 and 10*	Almanac data
	12, 19, 20, 22, 23 and 24	Reserved
	13	NMCT**
	14 and 15	Reserved for system use
	17	Special messages**
	18	Ionospheric and UTC data
	25	A-S flags/SV configurations and SV health
5	1 through 24	Almanac data
	25	SV health data

* Page 10 of subframe 4 is only sent from satellites broadcasting PRN codes 1 – 32 (and will contain almanac data for PRN 32); it is not used by satellites broadcasting PRN codes 33 – 63.
**Page not intended for aviation use.

~~Pages of subframe 4 shall be as follows:~~

Editorial note.— Delete remainder of existing 3.1.1.3.3 to 3.1.1.3.3.9 in toto and *insert* new paragraphs from 3.1.1.1.4 to Table B-L5-4 as follows:

3.1.1.1.4 *L5 SIGNAL RADIO FREQUENCY (RF) CHARACTERISTICS*

3.1.1.1.4.1 *Carrier phase noise*. The carrier phase noise spectral density of the unmodulated L5 carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth can track the carrier to an accuracy of 0.1 RMS.

3.1.1.1.4.2 *Spurious emissions.* In-band spurious emissions shall be at least 40 dB below the unmodulated L5 carrier over the allocated channel bandwidth.

3.1.1.1.4.3 *Correlation loss.* The loss in the recovered signal power due to imperfections in the L5 signal modulation and waveform distortion shall not exceed 0.6 dB.

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

3.1.1.1.4.4 *L5 carrier components.* L5 shall have two carrier components modulated by separate bit trains: the I5-code and the Q5-code (see Table B-L5-1).

3.1.1.1.4.4.1 The I5 and Q5 carriers shall be in phase quadrature (within ±100 milliradians) and the Q5 carrier shall be lagging the I5 carrier by 90 degrees.

Table B-L5-1. Composite L5 transmitted signal phase

Nominal composite L5 signal phase*	Code state	
	I5	Q5
0°	0	0
-90°	1	0
+90°	0	1
180°	1	1

* Relative to 0, 0 code state with positive angles leading and negative angles lagging.
** Based on the composite of two L5 carrier components at the same power.

3.1.1.1.4.5 *Code generation.* The I5 and Q5 code patterns $I5_i(t)$ and $Q5_i(t)$ shall each be formed by the Modulo-2 sum of two extended bit patterns clocked at a 10.23 MHz rate, XA(t) and $XBI_i(nI_i, t)$ or XA(t) and $XBQ_i(nQ_i, t)$, where nI_i and nQ_i are the initial states of XBI_i and XBQ_i for satellite i.

3.1.1.1.4.5.1 The XA code shall be a code of length 8 190 with initial condition of all “ones” that is short-cycled 1 chip before its natural ending and restarted to run over a period of 1 millisecond (synchronized with the L1 frequency C/A code) for a total of 10 230 chips.

3.1.1.1.4.5.2 The XBI_i and XBQ_i codes shall be codes of length 8 191 with initial conditions that are specified in IS-GPS-705F, Tables 3-Ia and Ib. The XBI_i and XBQ_i codes shall not be short-cycled and shall be restarted to run over a period of 1 millisecond for a total of 10 230 chips.

3.1.1.1.4.5.3 The generating polynomials for the XA and XBI_i and XBQ_i codes shall be:

a) XA: $X^{13} + X^{12} + X^{10} + X^9 + 1$; and

b) XBI_i and XBQ_i: $X^{13} + X^{12} + X^8 + X^7 + X^6 + X^4 + X^3 + X + 1$.

Note. — Additional details on code phase assignments are specified in the GPS Interface Specification, IS-GPS-705F.

3.1.1.1.4.6 *Navigation data modulation.* The L5 navigation data (CNAV) bit train shall be encoded at a rate of 2 symbols per bit using a convolution code with a constraint length of 7 to yield 100 symbols per second (sps). The 100 sps symbols shall then be modulated (Modulo-2 addition) with the 10-bit Neuman-Hofman code "0000110101" clocked at 1 kHz. The resulting symbol sequence shall be Modulo-2 added with the I5 PRN code and used to modulate the L5 in-phase carrier.

3.1.1.1.4.7 *Signal timing*. The XA code shall be synchronized with the L1 frequency C/A code. The XBI_i and XBQ_i codes shall be synchronized with the XA code.

3.1.1.1.4.8 *Group delay differential*. The absolute value of the mean differential delay between the radiated L1 and L5 signals shall not exceed 30.0 nanoseconds. The total variation about the mean (random plus non-random variations) shall not exceed 3.0 nanoseconds (95 per cent probability).

Note.— Inter-signal corrections (ISCs) are provided in the navigation data, to correct for the bias component of the differential delay.

3.1.1.1.5 *L5 DATA STRUCTURE*

3.1.1.1.5.1 *Forward error correction.* The L5 CNAV bit train shall be rate 1/2 convolution encoded with a forward error correction (FEC) code of constraint length 7.

3.1.1.1.5.2 *Navigation data structure.* The L5 CNAV data shall be provided in a set of six-second 300-bit long messages.

3.1.1.1.5.2.1 Each message shall contain a cyclic redundancy check (CRC) parity block of 24 bits protecting the entire 300-bit message.

3.1.1.1.5.2.2 Each message shall be composed of the following ordered fields: an 8-bit preamble ("10001011"), the 6-bit PRN number of the transmitting satellite, a 6-bit message type ID (range 0 to 63), the 17-bit message time-of-week (TOW) count, a 1-bit alert flag (bit 38), the data field (238 bits), and the 24-bit CRC parity block.

3.1.1.1.5.2.3 The TOW count multiplied by 6 shall provide the satellite time in seconds at the start of the next 6-second message.

3.1.1.1.5.2.4 Bit 38 shall be an "alert flag" where the value "1" indicates that the signal URA components may be worse than indicated in the associated message types and that use of the signal is at the user's risk.

3.1.1.1.6 *L5 (CNAV) DATA CONTENT*

3.1.1.1.6.1 *CNAV message types*. The CNAV data broadcasted on L5 shall contain the message types listed in Table B-L5-2.

Note.—See IS-GPS-705F for details on the content and application of the data contained in each message type.

Table B-L5-2. CNAV message types

Message type	Content
0	Default message (empty)
10	Ephemeris, accuracy, health parameters
11	Ephemeris, accuracy, health parameters
30	SV Clock, accuracy, ionosphere, group delay
31	SV Clock, accuracy, almanac
32	SV Clock, accuracy, earth orientation parameters
33	SV Clock, accuracy, UTC parameters
34	SV Clock, accuracy, differential correction parameters
35	SV Clock, accuracy, GPS/GNSS time offset
36	SV Clock, accuracy, text messages
37	SV Clock, accuracy, midi almanac

3.1.1.1.6.2 Message Type 10 shall contain the elevation-dependent (ED) component of the user range accuracy (URA_{ED}) index corresponding to the maximum elevation-dependent error expected for the current ephemeris curve fit for the worst-case location within the satellite footprint.

Note.— At the best location within the satellite footprint (i.e. nominally directly below the satellite along its nadir vector), the corresponding URA_{ED} is zero (see Table B-L5-3).

3.1.1.1.6.3 Message Types 30 to 37 shall contain the non-elevation-dependent (NED) URA component indices: URA_{NED0} index, URA_{NED1} index, and URA_{NED2} index, respectively, for the transmitting satellite.

The URA_{NED0} value shall be related to the URA_{NED0} index according to Table B-L5-4.

The URA_{NED1} value shall be related to the URA_{NED1} index as:

$$URA_{NED1} = \frac{1}{2^N}$$

where

N = 14 + URA_{NED1} index

The URA_{NED2} value shall be related to the URA_{NED2} index as:

$$URA_{NED2} = \frac{1}{2^N}$$

where

N = 28 + URA_{NED2} index

Note.— URA_{ED}, URA_{NED0}, URA_{NED1} and URA_{NED2} are used to compute the integrity assured URA (IAURA).

Table B-L5-3. Elevation-dependent user range accuracy URA_{ED}

URA_{ED} index	URA_{ED} (m)
15	6 144.00 < URA_{ED} (accuracy prediction not available)
14	3 072.00 < URA_{ED} ≤ 6 144.00
13	1 536.00 < URA_{ED} ≤ 3 072.00
12	768.00 < URA_{ED} ≤ 1 536.00
11	384.00 < URA_{ED} ≤ 768.00
10	192.00 < URA_{ED} ≤ 384.00
9	96.00 < URA_{ED} ≤ 192.00
8	48.00 < URA_{ED} ≤ 96.00
7	24.00 < URA_{ED} ≤ 48.00
6	13.65 < URA_{ED} ≤ 24.00
5	9.65 < URA_{ED} ≤ 13.65
4	6.85 < URA_{ED} ≤ 9.65
3	4.85 < URA_{ED} ≤ 6.85
2	3.40 < URA_{ED} ≤ 4.85
1	2.40 < URA_{ED} ≤ 3.40
0	1.70 < URA_{ED} ≤ 2.40
-1	1.20 < URA_{ED} ≤ 1.70
-2	0.85 < URA_{ED} ≤ 1.20
-3	0.60 < URA_{ED} ≤ 0.85
-4	0.43 < URA_{ED} ≤ 0.60
-5	0.30 < URA_{ED} ≤ 0.43
-6	0.21 < URA_{ED} ≤ 0.30
-7	0.15 < URA_{ED} ≤ 0.21
-8	0.11 <URA_{ED} ≤ 0.15
-9	0.08 < URA_{ED} ≤ 0.11
-10	0.06 < URA_{ED} ≤ 0.08
-11	0.04 < URA_{ED} ≤ 0.06
-12	0.03 < URA_{ED} ≤ 0.04
-13	0.02 < URA_{ED} ≤ 0.03
-14	0.01 < URA_{ED} ≤ 0.02
-15	URA_{ED} ≤ 0.01
-16	Accuracy prediction not available

Table B-L5-4. Non-elevation-dependent user range accuracy URA_{NED0}

URA_{NED0} index	URA_{NED0} (m)
15	6 144.00 < URA_{NED0} (accuracy prediction not available)
14	3 072.00 < URA_{NED0} ≤ 6 144.00
13	1 536.00 < URA_{NED0} ≤ 3 072.00
12	768.00 < URA_{NED0} ≤ 1 536.00
11	384.00 < URA_{NED0} ≤ 768.00
10	192.00 < URA_{NED0} ≤ 384.00
9	96.00 < URA_{NED0} ≤ 192.00
8	48.00 < URA_{NED0} ≤ 96.00
7	24.00 < URA_{NED0} ≤ 48.00
6	13.65 < URA_{NED0} ≤ 24.00
5	9.65 < URA_{NED0} ≤ 13.65
4	6.85 < URA_{NED0} ≤ 9.65
3	4.85 < URA_{NED0} ≤ 6.85
2	3.40 <URA_{NED0} ≤ 4.85
1	2.40 < URA_{NED0} ≤ 3.40
0	1.70 < URA_{NED0} ≤ 2.40
-1	1.20 < URA_{NED0} ≤ 1.70
-2	0.85 < URA_{NED0} ≤ 1.20
-3	0.60 < URA_{NED0} ≤ 0.85
-4	0.43 < URA_{NED0} ≤ 0.60
-5	0.30 < URA_{NED0} ≤ 0.43
-6	0.21 < URA_{NED0} ≤ 0.30
-7	0.15 < URA_{NED0} ≤ 0.21
-8	0.11 < URA_{NED0} ≤ 0.15
-9	0.08 < URA_{NED0} ≤ 0.11
-10	0.06 < URA_{NED0} ≤ 0.08
-11	0.04 < URA_{NED0} ≤ 0.06
-12	0.03 < URA_{NED0} ≤ 0.04
-13	0.02 < URA_{NED0} ≤ 0.03
-14	0.01 < URA_{NED0} ≤ 0.02
-15	URA_{NED0} ≤ 0.01
-16	Accuracy prediction not available

End of new text.

3.1.1.2 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

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

where

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

where

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

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

where

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

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

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

3.1.1.2.1.4 *Ionospheric correction.* The ionospheric correction ($T_{iono,L1}$) is defined as:

$$T_{iono,L1} = \begin{cases} F \times \left[5.0\times10^{-9} + AMP\left(1 - \frac{x^2}{2} + \frac{x^4}{24}\right)\right], & |x| < 1.57 \\ F \times \left(5.0\times10^{-9}\right) + & |x| \geq 1.57 \end{cases} \text{ (seconds)}$$

. . .

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

a) Satellite transmitted terms

α_n	=	the coefficients of a cubic equation representing the amplitude of the vertical delay (4 coefficients = 8 bits each) obtained from page 18 of subframe 4
β_n	=	the coefficients of a cubic equation representing the period of the model (4 coefficients = 8 bits each) obtained from page 18 of subframe 4

. . .

Editorial note.— Insert new sections from 3.1.1.2.2 to Table B-L5-5 as follows:

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 g_i = 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*. Section 3.1.1.2.1.2 shall apply.

Note.—Additional terms apply to the satellite clock correction for single-frequency L5 and dual-frequency L1 and L5 users 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: t_{oe}, ΔA, $\dot{A}$, Δn_0, $\Delta \dot{n}_0$, $M_{0\text{-}n}$, e_n, ω_n, $\Omega_{0\text{-}n}$, $\Delta\dot{\Omega}$, $i_{0\text{-}n}$, $\dot{i}_{0\text{-}n}$, $C_{is\text{-}n}$, $C_{ic\text{-}n}$, $C_{rs\text{-}n}$, $C_{rc\text{-}n}$, $C_{us\text{-}n}$, *and* $C_{uc\text{-}n}$, *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 metres) shall be computed from the upper bound value of the URA_{ED} obtained from message Type 10, Table B-L5-3, and the equation:

$$adjusted\ IAURA_{ED} = URA_{ED}\ (\sin(E+90))$$

where

E is the satellite elevation angle in degrees ($E \geq 0$)

3.1.1.2.2.4.3 *Non-elevation-dependent (NED) accuracy estimate*. The non-elevation-dependent IAURA value (in metres) shall be computed using the upper bound value of URA_{NED0} and the equation:

$$IAURA_{NED} = URA_{NED0} + URA_{NED1}\times(t - t_{op} + 604{,}800\times(WN - WN_{op})$$

when $t - t_{op} + 604{,}800\times(WN - WN_{op}) \leq 93{,}600$ seconds

and

$$IAURA_{NED} = URA_{NED0} + URA_{NED1}\times(t - t_{op} + 604{,}800\times(WN - WN_{op}) \\ + URA_{NED2}\times(t - t_{op} + 604{,}800\bullet(WN - WN_{op}) - 93{,}600)^2$$

when $t - t_{op} + 604{,}800\times(WN - WN_{op}) > 93{,}600$ seconds

where

t = GPS system time
WN, WN_{op}, t_{op}, URA_{NED0}, URA_{NED1}, URA_{NED2} are obtained from message Types 10, 30 to 37, and Table B-L5-4.

3.1.1.2.2.5 *Estimated L5 group delay differential for single-frequency users*.

Note.— Inter-signal biases for L1/L5 dual-frequency users are corrected via the ionosphere-free pseudo-range described in 3.1.1.2.2.7.

3.1.1.2.2.5.1 For the single-frequency L5 I5 user, the satellite clock time, corrected for the L1/L5 inter-signal bias, shall be as follows:

$$(\Delta t_{SV})_{L5I5} = \Delta t_{SV} - T_{GD} + ISC_{L5I5}$$

3.1.1.2.2.5.2 For the single-frequency L5 Q5 user, the satellite clock time, corrected for the L1/L5 inter-signal bias, shall be as follows:

$$(\Delta t_{SV})_{L5Q5} = \Delta t_{SV} - T_{GD} + ISC_{L5Q5}$$

Note.— T_{GD}, ISC_{L5I5} and ISC_{L5Q5} are provided in CNAV message Type 30.

3.1.1.2.2.6 *Ionospheric correction*. For L5, the single-frequency ionospheric correction defined in 3.1.1.2.1.4 shall be multiplied by γ_{15}, ($T_{iono,L5} = \gamma_{15} T_{iono,L1}$), where $\gamma_{15} = (f_{L1}/f_{L5})^2 = (1\ 575.42/1\ 176.45)^2 = (154/115)^2$.

3.1.1.2.2.7 *L1/L5 ionospheric correction for dual-frequency users*.

3.1.1.2.2.7.1 The ionosphere-free pseudo-range for the dual-frequency (L1 C/A and L5 I5) user shall be as follows:

$$PR = \frac{(PR_{L5I5} - \gamma_{15} PR_{L1C/A}) + c(ISC_{L5I5} - \gamma_{15} ISC_{L1C/A})}{1 - \gamma_{15}} - cT_{GD}$$

where

PR	=	pseudo-range corrected for ionospheric effects,
PRi	=	pseudo-range measured on the channel indicated by the subscript,
ISCi	=	inter-signal correction for the channel indicated by the subscript, provided in CNAV message Type 30,
T_{GD}	=	L1 P(Y) and L2 P(Y) inter-signal correction, provided in CNAV message Type 30,
c	=	speed of light, and
γ_{15}	=	$(f_{L1}/f_{L5})^2 = (1\ 575.42/1\ 176.45)^2 = (154/115)^2$.

3.1.1.2.2.7.2 The ionosphere-free pseudo-range for the dual-frequency (L1 C/A and L5 Q5) user shall be as follows:

$$PR = \frac{(PR_{L5Q5} - \gamma_{15} PR_{L1C/A}) + c(ISC_{L5Q5} - \gamma_{15} ISC_{L1C/A})}{1 - \gamma_{15}} - cT_{GD}$$

where

PR, PRi, ISCi, TGD, c and γ_{15} are as defined above.

Table B-L5-5. Elements of coordinate systems for L5 CNAV data

$t_k = t - t_{oe}$	Time from ephemeris reference epoch*
$A_0 = A_{REF} + \Delta A$	Semi-major axis at reference time**
$A_k = A_0 + \dot{A} t_k$	Semi-major axis
$n_0 = \sqrt{\frac{\mu}{A_0^3}}$	Computed mean motion
$\Delta n_A = \Delta n_0 + \frac{1}{2} \Delta \dot{n}_0 t_k$	Mean motion difference from computed value
$n_A = n_0 + \Delta n_A$	Corrected mean motion
$M_k = M_0 + n_A t_k$	Mean anomaly
$M_k = E_k - e_n \sin E_k$	Kepler's equation for eccentric anomaly (may be solved by iteration)
$v_k = \tan^{-1}\left\{\frac{\sin v_k}{\cos v_k}\right\} = \tan^{-1}\left\{\frac{\sqrt{1-e^2}\sin E_k/(1-e\cos E_k)}{(\cos E_k - e)/(1-e\cos E_k)}\right\}$	True anomaly
$E_k = \cos^{-1}\left\{\frac{e + \cos v_k}{1 + e\cos v_k}\right\}$	Eccentric anomaly
$\phi_k = v_k + \omega$	Argument of latitude
	Second Harmonic Perturbations
$\delta u_k = C_{us\text{-}n} \sin 2\phi_k + C_{uc\text{-}n} \cos 2\phi_k$	Argument of latitude correction
$\delta r_k = C_{rc\text{-}n} \sin 2\phi_k + C_{rs\text{-}n} \sin 2\phi_k$	Radius correction
$\delta i_k = C_{is\text{-}n} \sin 2\phi_k + C_{ic\text{-}n} \cos 2\phi_k$	Inclination correction
$u_k = \phi_k + \delta u_k$	Corrected argument of latitude
$r_k = A_k(1 - e_n \cos E_k) + \delta r_k$	Corrected radius
$i_k = i_0 + \dot{i}_{0-n} t_k + \delta i_k$	Corrected inclination
$\left.\begin{array}{l} x'_k = r_k \cos u_k \\ y'_k = r_k \sin u_k \end{array}\right\}$	Positions in orbital plane
$\dot{\Omega} = \dot{\Omega}_{REF} + \Delta\dot{\Omega}$	Rate of right ascension***
$\Omega_k = \Omega_{0-n} + (\dot{\Omega} - \dot{\Omega}_e) t_k - \dot{\Omega}_e t_{oe}$	Corrected longitude of ascending node
$\left.\begin{array}{l} x_k = x'_k \cos \Omega_k - y'_k \cos i_k \sin \Omega_k \\ y_k = x'_k \sin \Omega_k - y'_k \cos i_k \cos \Omega_k \\ z_k = y'_k \sin i_k \end{array}\right\}$	Earth-Centred, Earth-Fixed coordinates

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

** A_{REF} = 26 559 710 metres

*** $\dot{\Omega}_{REF} = -2.6 \times 10^{-9}$ semi-circles/second

End of new text.

3.1.1.3 AIRCRAFT ELEMENTS

3.1.1.3.1 *GNSS (GPS) RECEIVER*

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

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

Editorial note.— Renumber paragraphs 3.1.3.1.2 to 3.1.4 as 3.1.1.3.1.2 to 3.1.1.4.

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ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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4. GNSS CORE ELEMENTS

4.1 Core constellations

4.1.1 GPS

Note.— Additional information concerning GPS can be found in Global Positioning System — Standard Positioning Service — Performance Standard, *September 2008, and the GPS SPS PS, Interface Specification (IS)IS-GPS-200EK, and IS-GPS-705F.*

4.1.1.1 The L1 C/A code performance standards isare based upon the assumption that a representative standard positioning service (SPS) receiver is used. A representative receiver has the following characteristics:

a) designed in accordance with IS-GPS-200EK;

b) tracking the SF L1 C/A code SPS SIS from all satellites in view above uses a 5-degree masking angle;

c) accomplishes satellite position and geometric range computations in the most current realization of the World Geodetic System 1984 (WGS-84) Earth-Centred, Earth-Fixed (ECEF) coordinate system;

d) generates a position and time solution from data broadcast by all satellites in view transmitting PRNs 1-32;

e) compensates for dynamic Doppler shift effects on nominal SPS ranging signal carrier phase and C/A code measurements;

f) excludes marginal and unhealthy satellites from the position solution;

g) uses up-to-date and internally consistent ephemeris and clock data within the respective curve fit intervals for all satellites it is using in its position solution; and

h) loses track in the event that a GPS satellite stops transmitting a trackable signal.

The time transfer accuracy applies to the data in the broadcast navigation message, which relates GPS SPS time to UTC as maintained by the United States Naval Observatory. A 12-channel receiver will meet performance requirements specified in Chapter 3, 3.7.3.1.1.1.1 and 3.7.3.1.1.2. A receiver that is able to track four satellites only (Appendix B, 3.1.1.3.1.2) will not get the full position domain accuracy and availability performance.

Note 1.— No user position domain performance standards are available at this time for L5-only operation because there are no SIS availability or continuity performance standards defined yet for the L5 signals. Availability and continuity performance standards for the L5 signals will be provided in advance of any declaration for an enhanced SPS which includes the L5 service. The performance standards for the L5 signals (range domain accuracy, reliability, major service failure) are at the SIS level and do not require the notion of a user receiver. However, it may be helpful when considering the accuracy and integrity standards for the L5 signals to consider that a user receiver would need to be designed to process the L5 signals in a manner analogous to how it processes the L1 signals; particularly by processing those signals in accordance with IS-GPS-705, continuously monitoring the L5 SIS health, using up-to-date and internally consistent navigation data (CNAV), and using only satellites designated as healthy during normal GPS operations.

Note 2.— Conditions indicating that a satellite is "healthy", "marginal" or "unhealthy" can be found in ~~United States Department of Defense~~, ~~Global Positioning System — Standard Positioning Service — Performance Standard~~*~~, 4th Edition, September 2008~~the GPS SPS PS, Section 2.3.2.*

4.1.1.2 *Position domain accuracy*. The position domain accuracy is measured with a representative receiver and a measurement interval of 24 hours for any point within the coverage area. The positioning and timing accuracy are for the signal-in-space (SIS) only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath. In order to maintain backwards compatibility, the position domain accuracy standard will be met with a representative SPS receiver tracking only PRNs 1 through 32.

4.1.1.3 *Range domain accuracy*. The range domain accuracy standard applies to normal operations, which implies that updated navigation data is uplinked to the satellites on a regular basis. Range domain accuracy is conditioned by the satellite ~~indicating~~ transmitting a healthy status and transmitting C/A code and does not account for satellite failures outside of the normal operating characteristics. Range domain accuracy limits can be exceeded during satellite failures or anomalies while uploading data to the satellite. The range rate error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The range acceleration error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. Under nominal conditions, all satellites are maintained to the same standards, so it is appropriate for availability modelling purposes to assume that all satellites have a ~~4~~3.6-metre RMS SIS user range error (URE). The standards are restricted to range domain errors allocated to space and control segments.

4.1.1.4 *Availability*. The availability standard applies to normal operations, which implies that updated navigation data is uplinked to the satellites on a regular basis. Availability is the percentage of time over any 24-hour interval that the predicted 95 per cent positioning error (due to space and control segment errors) is less than its threshold, for any point within the coverage area. It is based on a ~~17~~15-metre horizontal 95 per cent threshold; a ~~37~~33-metre vertical 95 per cent threshold; using a representative receiver; and operating within the coverage area over any 24-hour interval. The service availability assumes a constellation that meets the criteria in ~~4.1.4.2~~Chapter 3, 3.7.3.1.1.7. As noted for position domain accuracy, in order to maintain backwards compatibility, the availability standard will be met with a representative SPS receiver tracking only PRNs 1 through 32.

~~4.1.4.1 *Relationship to augmentation availability*. The availability of ABAS, GBAS and SBAS does not directly relate to the GPS availability defined in Chapter 3, 3.7.3.1.1.2. States and operators must evaluate the availability of the augmented system by comparing the augmented performance to the requirements. Availability analysis is based on an assumed satellite constellation and the probability of having a given number of satellites.~~

~~4.1.4.2 *Satellite/constellation availability*. Twenty-four operational satellites will be maintained on orbit with 0.95 probability (averaged over any day), where a satellite is defined to be operational if it is capable of, but is not necessarily transmitting, a usable ranging signal. At least 21 satellites in the nominal 24 slot positions must be set healthy and must be transmitting a navigation signal with 0.98 probability (normalized annually). At least 20 satellites in the nominal 24 slot positions must be set healthy and must be transmitting a navigation signal with 0.99999 probability (normalized annually).~~

4.1.1.5 *Reliability*. Reliability is the percentage of time over a specified time interval that the instantaneous SPS SIS URE is maintained within the range error limit, at any given point within the coverage area, for all healthy GPS satellites. The reliability standard is based on a measurement interval of one year and the average of daily values within the coverage area. The worst single point average reliability assumes that the total service failure time of 18 hours will be over that particular point (3 failures each lasting 6 hours).

4.1.1.6 *Major service failure.*

4.1.1.6.1 A major service failure is defined to be a condition over a time interval during which a trackable and healthy GPS satellite's instantaneous ranging signal error (excluding atmospheric and receiver errors) exceeds the range error limit of 4.42 times the ~~upper bound on the~~ integrity assured user range accuracy (IAURA) broadcast by a satellite for longer than the allowable time-to-alert (10 seconds). A major service failure occurs only if no alert is issued within the 10 second time to alert. Events when the instantaneous user range error (URE) exceeds 4.42 times the IAURA for a total duration of less than 10 seconds are not counted as major service failures. Once an alert has been issued, the major service failure event ceases to have any impact on SPS SIS integrity.

4.1.1.6.2 The instantaneous SIS URE will depend upon the combination of SIS components used. The major service failure standards apply for both single-frequency and dual-frequency users using these SIS component combinations in Table D-X.

Table D-X. GPS SPS SIS component combinations

One carrier, single-frequency (SF)	Two carriers, dual-frequency (DF)
C/A-code + LNAV data	(C/A + I5)-codes + CNAV data
I5-code + CNAV data	(C/A + Q5)-codes + CNAV data
Q5-code + CNAV data	(C/A + I5+Q5)-codes + CNAV data
(I5+Q5)-codes + CNAV data	

4.1.1.6.3 For SIS component combinations using LNAV data, the IAURA is equal to the upper bound on the URA value corresponding to the URA index "N" currently broadcast by the satellite in subframe 1. This URA is specific to the broadcasting satellite. For SIS component combinations using CNAV data, the IAURA is the root sum square (RSS) of an elevation-dependent function of the upper bound value of the URA_{ED} component and a non-elevation-dependent function of the upper bound value of the URA_{NED} component currently broadcast by the satellite in MT-10 and MT-3x respectively. This IAURA is also specific to the broadcasting satellite. The IAURA for a marginal SPS SIS is not defined and there is no IAURA for an unhealthy SPS SIS. Since the URAs and IAURAs vary with time, a validity period for each is specified in the GPS interface specifications.

4.1.1.6.4 The onset rate, R_{sat}, is defined as the probability of a major service failure on any particular satellite over any hour, given that the maximum SPS SIS instantaneous URE did not exceed 4.42 times the IAURA at the start of the hour. The mean fault duration is one hour and the worst-case duration is six hours.

4.1.1.6.5 The probabilities of a single satellite major service failure (P_{sat}) for a particular satellite and a common-cause, multi-satellite major service failure (P_{const}) are instantaneous state probabilities equivalent to the fraction of time when the SPS SIS instantaneous URE exceeds 4.42 times the IAURA for more than 10 seconds without an alert issued within those 10 seconds.

4.1.1.6.6 The probability of 1×10^{-5} in Chapter 3, 3.7.3.1.1.4 corresponds to a maximum of 3 major service failures, with one-hour duration, for the entire constellation per year assuming a maximum constellation of 32 satellites.

4.1.1.7 *Continuity*. Continuity for a healthy GPS satellite is the probability that the SPS SIS will continue to be healthy without unscheduled interruption over a specified time interval. Scheduled interruptions which are announced at least 48 hours in advance do not contribute to a loss of continuity.

4.1.1.8 *Coverage*. The SPS supports the terrestrial coverage area, which is from the surface of the earth up to an altitude of 3 000 km.

4.1.1.9 *Normal operations*. In normal operations mode, the satellites are uploaded with fresh navigation (NAV) message data by the control segment on a regular basis. The SPS SIS indicates when the satellite is in the normal operations mode by way of the C/A code signal LNAV data stream fit interval flag being set to "0" (zero) in accordance with IS-GPS-200K. When the fit interval flag is set to "1" (one), the satellite is operating in the extended operations mode. Special SPS SIS accuracy standards apply for the extended operations mode. See IS-GPS-200K for further details on the fit interval flag.

Note 1.— There is no equivalent "normal operations mode" flag (fit interval flag) in the CNAV data stream on the I5-code signal

Note 2.— Additional information concerning normal operations is given in the GPS SPS PS, Sections A.4.3.2 and A.4.3.3.

Origin:	*Rationale*:
NSP/6	This proposal is intended to reflect the ongoing modernization of the GPS satellite navigation system, operated by the United States and already standardized by ICAO (L1 band only). It includes amendments to the existing GPS SARPs to add a pair of signals (I5-code and Q5-code) transmitted in the L5 band, along with several other improvements. The use of two frequency bands (L1 and L5) will help mitigate vulnerabilities in respect of ionospheric disturbance and radio frequency interference.

INITIAL PROPOSAL 3
Global navigation satellite system (GLONASS)

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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3.7.3 GNSS elements specifications

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3.7.3.1 *Core constellations*

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

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

3.7.3.1.2.1 *Space and control segment accuracy*

Note.— The ~~following~~ single-frequency accuracy Standards do not include atmospheric or receiver errors; ionosphere errors are included for dual-frequency combinations, as described in Attachment D, 4.1.2.2.

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

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

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

3.7.3.1.2.1.2 *Time transfer accuracy*. The GLONASS CSA time transfer errors shall not exceed ~~700~~

nanoseconds the following limits 95 per cent of the time:

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

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

a) range error of any satellite — 18 m (59.7 ft);

b) range rate error of any satellite — 0.02 m (0.07 ft) per second;

c) range acceleration error of any satellite — 0.007 m (0.023 ft) per second squared;

d) root-mean-square range error over all satellites — 6 m (19.9 ft).

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

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

a) ⩾99 per cent horizontal service availability, average location (12 m, 95 per cent threshold);

b) ⩾99 per cent vertical service availability, average location (25 m, 95 per cent threshold);

c) ⩾90 per cent horizontal service availability, worst-case location (12 m, 95 per cent threshold);

d) ⩾90 per cent vertical service availability, worst-case location (25 m, 95 per cent threshold).

Signals	L1OF	L1OC	L3OC	L1OF - L3OC	L1OC - L3OC
Average location:					
Horizontal service availability	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)	99%, (12 m 95% threshold)
Vertical service availability	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)	99%, (25 m 95% threshold)
Worst-case location:					
Horizontal service availability	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)	90%, (12 m 95% threshold)
Vertical service availability	90%, (25 m 95% threshold	90%, (25 m 95% threshold	90%, (25 m 95% threshold	90%, (25 m 95% threshold	90%, (25 m 95% threshold

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

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

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

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

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

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

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

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

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

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

3.7.3.1.2~~.4~~.7 *Coverage*. The GLONASS CSA shall cover the surface of the earth up to an altitude of 2 000 km.

Note.— Guidance material on GLONASS accuracy, availability, reliability and coverage is given in Attachment D, 4.1.2.

3.7.3.1.2~~.5~~.8 *L1OF RF characteristics*

Note.— Detailed RF characteristics are specified in Appendix B, 3.1.2.1.1.

Editorial note.— Renumber paragraphs 3.7.3.2.5.1 to 3.7.3.2.5.5.2 as 3.7.3.1.2.8.1 to 3.7.3.1.2.8.5.2.

Editorial note.— Insert new text as follows:

3.7.3.1.2.9 *L3OC RF characteristics*

Note.— Detailed RF characteristics are specified in Appendix B, 3.1.2.1.5.

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

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

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

3.7.3.1.2.9.4 *Signal power level*. GLONASS L3OC navigation signals shall be broadcast with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly polarized antenna is within the range of –158.5 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

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

3.7.3.1.2.9.5 *Modulation*

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

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

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

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

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

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

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

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

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

3.7.3.1.2.10 *L1OC RF characteristics*

Note.— Detailed RF characteristics are specified in Appendix B, 3.1.2.1.5.

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

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

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

3.7.3.1.2.10.4 *Signal power level*. GLONASS L1OC navigation signals shall be broadcast with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly polarized antenna is within the range of –158.5 dBW to –155.2 dBW for all antenna orientations orthogonal to the direction of propagation.

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

3.7.3.1.2.10.5 *Modulation*

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

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

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

End of new text

3.7.3.1.2~~.6~~.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~~.7~~.12 *Coordinate system*. The GLONASS coordinate system shall be PZ-90.

Note.— Conversion from the PZ-90 coordinate system used by GLONASS to the WGS-84 coordinates is defined in Appendix B, 3.1.2.5.2.

3.7.3.1.2~~.8~~.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~~.~~;

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

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

Note.— Structure and contents of data are specified in Appendix B, 3.1.2.1.2 and 3.1.2.1.3, respectively.

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

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3. GNSS ELEMENTS

3.1 Core constellations

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3.1.2 Global navigation satellite system (GLONASS) channel of standard accuracy (CSA) (L1/L3)

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").

Editorial note.— Renumber paragraphs from 3.2.1.1.1 to 3.2.1.1.5 as 3.1.2.1.1.1 to 3.1.2.1.1.5.

3.1.2.1.2 *L1OF (L1 OPEN SERVICE FDMA) DATA STRUCTURE*

Note.— Additional information concerning the data structure is given in the GLONASS FDMA ICD.

Editorial note.— Renumber paragraphs from 3.2.1.2.1 to 3.2.1.2.4.2 as 3.1.2.1.2.1 to 3.1.2.1.2.4.2.

3.1.2.1.3 *L1OF (L1 OPEN SERVICE FDMA) DATA CONTENT*

Note.— Additional information concerning the data content is given in the GLONASS FDMA ICD.

Editorial note.— Renumber paragraphs from 3.2.1.3.1 to 3.2.1.3.6 as 3.1.2.1.3.1 to 3.1.2.1.3.6.

3.1.2.1.4 *CONTENT AND STRUCTURE OF ADDITIONAL DATA TRANSMITTED BY GLONASS-M SATELLITES IN L1OF (L1 OPEN SERVICE FDMA)*

Note.— Additional information concerning the data content and structure is given in the GLONASS FDMA ICD.

Editorial note.— Renumber paragraphs from 3.2.1.4.1 to 3.2.1.4.3 as 3.1.2.1.4.1 to 3.1.2.1.4.3 and *replace* the reference to Attachment D, 4.2.7.1 in 3.2.1.4.1 with a reference to Attachment D, 4.1.2.7.1.

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Editorial note.— Insert new sections 3.1.2.1.5 to 3.1.2.1.7 as follows:

3.1.2.1.5 *L1OC, L3OC RF CHARACTERISTICS*

Note.— Additional information concerning the RF characteristics is given in the GLONASS CDMA ICD General Description of CDMA Signal System, Edition 1.0, dated 2016 (hereinafter referred to as "GLONASS CDMA ICD General Description"); in the GLONASS CDMA ICD L1 band; and in the GLONASS CDMA ICD L3 band.

3.1.2.1.5.1 The L1OC signal shall contain L1OCd data and L1OCp pilot components of equal power levels. These components shall be obtained by chip-by-chip time-division multiplexing of two pseudo random noise sequences. The L1OC signal shall be in phase quadrature with the L1SC signal. L1OC leads L1SC by π/2 radians as shown in Figure B-7A.

Note.— The L1SC signal is a CDMA secured service navigation signal in the L1 frequency band and is not used in aviation.

3.1.2.1.5.2 The L3OC signal shall contain L3OCd data and L3OCp pilot components of equal power levels. These components shall occupy phase quadratures I and Q, respectively. L3OCd leads L3OCp by π/2 radians as shown in Figure B-7A.

3.1.2.1.5.3 *Carrier phase noise*. The phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth shall be able to track the carrier to accuracy no worse than 0.01 radians rms.

3.1.2.1.5.4 *Spurious emissions*. The power of the transmitted RF signal beyond the GLONASS allocated bandwidth shall not be more than –40 dB relative to the power of the unmodulated carrier.

Note 1.— The GLONASS allocated bandwidths are L1 (1 592.9 – 1 610 MHz), L2 (1 237.8 – 1 256.8 MHz) and L3 (1 190.35 – 1 212.23 MHz).

Note 2.— GLONASS satellites use filters limiting out-of-band emissions to the harmful interference limit contained in Recommendation ITU-R RA.769 for the 1 610.6 – 1 613.8 MHz and 1 660 – 1 670 MHz bands.

3.1.2.1.5.5 *Correlation loss*. The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 0.6 dB.

Note.— The loss in signal power is the difference between the broadcast power in the specified bandwidth and the signal power recovered by a noise-free, loss-free receiver with 1-chip correlator spacing and an RF front-end with the same bandwidth.

3.1.2.1.6 *L1OC, L3OC DATA STRUCTURE*

Note.— Additional information concerning the data structure is given in the GLONASS CDMA ICD General Description; in the GLONASS CDMA ICD L1 band; and in the GLONASS CDMA ICD L3 band.

3.1.2.1.6.1 *General*. The GLONASS CDMA navigation message shall be transmitted as a variable sequence of strings. Strings shall comprise service and data fields (separate bits or groups of bits containing specific parameters).

Note.— A pseudoframe is a set of strings of immediate and non-immediate data starting with the three strings of ephemeris and clock data (immediate data). The remaining strings of a pseudoframe contain non-immediate data.

3.1.2.1.6.2 *Service fields.* The structure of a service section shall be the same for each type of signal and include preamble, type of the string, time of the beginning of the string (TS), satellite ID number, signal parameters and cyclic redundancy check (CRC) bits to check the integrity of the string data.

3.1.2.1.6.3 *Data fields*. The structure of data fields shall depend on the string type. Each type of string shall contain a complete individual block of data with the exception of orbit and clock data, which occupies three types of strings and shall be transmitted as a continuous packet.

Note.— The message design may evolve together with future evolutions of GLONASS. This evolution may involve the inclusion of additional new string types, which can either contain new data types or modify the existing string types.

3.1.2.1.6.4 L1OC message characteristics

3.1.2.1.6.4.1 The L1OCd navigation message shall be transmitted at 125 bits/s. The message shall consist of 250-bit strings of 2-second duration as well as of 125- and 375-bit anomalous strings of 1- and 3-second duration, respectively.

3.1.2.1.6.4.2 *L1OCd nominal string structure*. Each L1OCd nominal string shall consist of 50-bit service fields, a 184-bit data field and a 16-bit CRC service field as shown in Figure B-7B. Transmission of a string shall start with bit 1 (the first bit of the preamble and end with bit 250 (last bit of CRC)).

3.1.2.1.6.4.3 *L1OCd service fields* shall be as shown in Table B-19A.

Table B-19A. Parameters of L1OCd service fields

Field	Number of bits	Least significant bit	Value range	Unit	Description
Preamble	12	1	010111110001	-	Constant time stamp
Type	6	1	0 – 63	-	Type of a current string
j	6	1	0 – 63	-	ID number of a satellite that transmits this navigation message. SV ID number “0” is reserved and can only be enabled upon termination of combined use of GLONASS CDMA and FDMA signals.
H^j	1	1	0, 1	-	healthy (“0”) or unhealthy (“1”) navigation signal
l^j	1	1	0, 1	-	validity (“0”) or invalidity (“1”) of the data transmitted in the current string
P1	4	Ground control call. This field is not used by user receivers.			
P2	1	Attribute of SV orientation regime: SV is Sun-pointing (“0”) or performs noon/midnight turn manoeuvre (“1”)			
KP	2	1	00, 01, 10, 11	-	Indication of the expected UTC(SU) correction at the end of current quarter on GMT. UTC(SU) corrections shall result in the corresponding corrections of L1OCd time: 00 – no correction planned; 01 – day length is increased by 1 s; 10 – correction decision is pending; 11 – day length is reduced by 1 s.
A	1	1	0, 1	-	Indication of the expected L1OCd signal time correction at the end of the next string: A = 0 – no correction is planned. A = 1 – correction is planned. The combination of A = 1 and KP = 11 in the current string denotes that the next string will be a Type 1 anomalous string of 1 s duration. The combination of A = 1 and KP = 01 in the current string denotes that the next string will be a Type 2 anomalous string of 3 s duration.
TS	16	1	0 – 43199	2 s	Time stamp digits expressed in 2-second intervals within a current day in L1OCd time.
CRC	16	1	Check bits of the cyclic code		

3.1.2.1.6.4.4 *L1OCd anomalous strings.* Anomalous strings shall be indicated by string Types 1 and 2. Strings of Type 1 shall be used to indicate the leap second corrections of L1OCd signal time when a day's length is reduced by 1 s. Strings of Type 1 shall consist of 50-bit service fields, a 59-bit data field and a 16-bit CRC service field as shown in Figure B-7C. Strings of Type 2 shall be used to indicate the leap second corrections of L1OCd signal time when a day's length is increased by 1 s. Strings of Type 2 shall consist of 50-bit service fields, a 301-bit data field and a 24-bit CRC service field as shown in Figure B-7D.

3.1.2.1.6.4.5 *L1OCd nominal strings CRC*. The CRC (250,234) generator polynomial shall have the following form:

$$g(X) = 1 + X + X^5 + X^6 + X^8 + X^9 + X^{10} + X^{11} + X^{13} + X^{14} + X^{16}.$$

A 234-bit data block shall be delivered to the encoder's input (starting with the 1st bit of the preamble and ending with the 184th bit of the data field). At the encoder's output, a 250-bit encoded block shall be generated by adding 16 check bits.

3.1.2.1.6.4.6 *L1OCd anomalous string Type 1 CRC.* CRC (125,109) shall be used in L1OCd Type 1 strings. It shall be generated similarly to code (250,234) except for the number of bits delivered to the input (109 instead of 234).

3.1.2.1.6.4.7 *L1OCd anomalous strings Type 2 CRC*. CRC (375,351) shall be used in L1OCd Type 2 strings. The CRC (375,351) generator polynomial shall have the following form:

$$g(X) = 1 + X + X^3 + X^4 + X^5 + X^6 + X^7 + X^{10} + X^{11} + X^{14} + X^{17} + X^{18} + X^{23} + X^{24}.$$

A 351-bit data block shall be delivered to the encoder's input (starting with the 1st bit of the preamble and ending with the 301st bit of the data field). At the encoder's output, a 375-bit encoded block shall be generated by adding 24 check bits.

3.1.2.1.6.5 L3OC message characteristics

3.1.2.1.6.5.1 The L3OCd navigation message shall be transmitted at 100 bits/s. The message shall consist of 300-bit strings of 3-second duration as well as of 200- and 400-bit anomalous strings of 2- and 4-second duration, respectively.

3.1.2.1.6.5.2 *L3OCd strings structure*. Each L3OCd nominal string shall consist of 57-bit service fields, a 219-bit long data field and 24-bit long CRC service field, as shown in Figure B-8A. Transmission of a string shall start with bit 1 (the first bit of the preamble) and end with bit 300 (the last bit of CRC).

3.1.2.1.6.5.3 *L3OCd service fields* shall be as shown in Table B-19B.

Table B-19B. Parameters of L3OCd service fields

Field	Number of bits	Least significant bit	Value range	Unit	Description
Preamble	20	1	00000100100101001110	-	Constant time stamp
Type	6	1	0 – 63	-	Type of a current string
TS	15	1	0 – 28799	3 s	Time stamp digits expressed in 3-second intervals within a current day in L3OCd time.
j	6	1	0 – 63	-	ID number of a satellite that transmits this navigation message. SV ID number “0” is reserved, and can only be enabled upon termination of combined use of GLONASS CDMA and FDMA signals.
H^j	1	1	0, 1	-	healthy (“0”) or unhealthy (“1”) navigation signal
I^j	1	1	0, 1	-	validity (“0”) or invalidity (“1”) of the data transmitted in the current string
P1	4	Ground control call. This field is not used by user receivers.			
P2	1	Attribute of SV orientation regime: SV is Sun-pointing (“0”) or performs noon/midnight turn manoeuvre (“1”)			
KP	2	1	00, 01, 10, 11	-	Indication of the expected UTC(SU) correction at the end of current quarter on GMT. UTC(SU) corrections shall result in the corresponding corrections of L3OCd time: 00 – no correction planned; 01 – day length is increased by 1 s; 10 – correction decision is pending; 11 – day length is reduced by 1 s.
A	1	1	0, 1	-	Indication of the expected L3OCd signal time correction at the end of the next string: A = 0 – no correction is planned. A = 1 – correction is planned. The combination of A = 1 and KP = 11 in the current string denotes that the next string will be a Type 1 anomalous string of 1 s duration. The combination of A = 1 and KP = 01 in the current string denotes that the next string will be a Type 2 anomalous string of 3 s duration.
CRC	24	1	Check bits of the cyclic code		

3.1.2.1.6.5.4 *L3OCd anomalous strings.* Anomalous strings shall be indicated by strings Types 1 and 2. Strings of Type 1 shall be used to indicate the leap second corrections of L3OCd signal time when a day's length is reduced by 1 s. Strings of Type 1 shall consist of 57-bit service fields, a 119-bit data field and a 24-bit CRC service field, as shown in Figure B-8B. Strings of Type 2 shall be used to indicate the leap second corrections of L3OCd signal time when a day's length is increased by 1 s. Strings of Type 2 shall consist of 57+20-bit service fields, a 299-bit data field and a 24-bit CRC service field as shown in Figure B-8C.

3.1.2.1.6.5.5 *L3OCd nominal strings CRC*. The CRC (300,276) generator polynomial shall have the following form:

$$g(X) = 1 + X + X^3 + X^4 + X^5 + X^6 + X^7 + X^{10} + X^{11} + X^{14} + X^{17} + X^{18} + X^{23} + X^{24}.$$

A 276-bit data block shall be delivered to the encoder's input (starting with the 1st bit of the preamble and ending with the 219th bit of the data field). At the encoder's output, a 300-bit encoded block shall be generated by adding 24 check bits.

3.1.2.1.6.5.6 *L3OCd anomalous string Type 1 CRC.* CRC (200,176) shall be used in L3OCd Type 1 strings. It shall be generated similarly to code (300,276) except for the number of bits delivered to the input (176 instead of 276).

3.1.2.1.6.5.7 *L3OCd anomalous string Type 2 CRC.* CRC (400,376) shall be used in L3OCd Type 2 strings. It shall be generated similarly to code (300,276) except for the number of bits delivered to the input (376 instead of 276).

3.1.2.1.7 *L1OC, L3OC DATA CONTENT*

Note.— Additional information concerning the data content is given in the GLONASS CDMA ICD General Description; in the GLONASS CDMA ICD L1 band; and in the GLONASS CDMA ICD L3 band.

3.1.2.1.7.1 L1OCd navigation messages shall contain the data in accordance with the list of string types shown in Table B-20A.

Note.— Additional information concerning the data content of the L1OCd service and data fields is given in the GLONASS CDMA ICD L1 band.

Table B-20A. Types of L1OCd strings and their content

String type	Content
10, 11, 12	Immediate data (ephemeris, time, health flags, F_E, F_T)
20	Almanac
25	Earth rotation parameters, ionospheric model parameters, UTC(SU) and international atomic time (TAI) offset model parameters.
16	SV attitude parameters during noon/midnight turn manoeuvre
31, 32	Long-term dynamic model parameters
50	International Satellite System for Search and Rescue (COSPAS–SARSAT) notices of receipt
60	Text messages
0	For technological tasks. Not used by user receivers.
1	Anomalous string used at the moment of leap second correction (-1 s)
2	Anomalous string used at the moment of leap second correction (+1 s)
Note: String Types 10, 11 and 12 compose a data packet; therefore, string Type 11 always follows string Type 10 and string Type 12 always follows string Type 11.	

3.1.2.1.7.2 L3OCd navigation messages shall contain the data in accordance with the list of string types shown in Table B-20B.

Note.— Additional information concerning the data content of the L3OCd service and data fields is given in the GLONASS CDMA ICD L3 band.

Table B-20B. Types of L3OCd strings and their content

String type	Content
10, 11, 12	Immediate data (ephemeris, time, health flags, F_E, F_T)
20	Almanac
25	Earth rotation parameters, ionospheric model parameters, UTC(SU) and international atomic time (TAI) offset model parameters.
16	SV attitude parameters during noon/midnight turn manoeuvre
31, 32	Long-term dynamic model parameters
60	Text messages
0	For technological tasks. Not used by user receivers.
1	Anomalous string used at the moment of leap second correction (-1 s)
2	Anomalous string used at the moment of leap second correction (+1 s)
Note: String Types 10, 11 and 12 compose a data package; therefore, string Type 11 always follows string Type 10 and string Type 12 always follows string Type 11.	

3.1.2.1.7.3 *Accuracy factor fields F_E, F_T.* Fields F_E and F_T shall contain equivalent pseudo-range errors (σ) related to the ephemeris and clock of transmitting satellite. Table B-21C shows values of F_E and F_T and the corresponding errors.

Table B-21C. Ephemeris and time accuracy factors

F_E, F_T	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4
σ, m	0.01	0.02	0.03	0.04	0.06	0.08	0.1	0.15	0.2	0.3	0.4	0.6
F_E, F_T	-3	-2	-1	0	1	2	3	4	5	6	7	8
σ, m	0.7	0.8	0.9	1	2	2.5	4	5	7	10	12	14
F_E, F_T	9	10	11	12	13	14	15					
σ, m	16	32	64	128	256	512	not defined					

3.1.2.1.7.4 The maximum interval of updating immediate data (string Types 10, 11 and 12) shall be 30 minutes. Considering that various types of non-immediate data are updated at various intervals, the maximum update interval for all non-immediate data shall be 48 hours.

Note.— Long-term dynamic model parameters enable the usage of immediate data to propagate the orbit for a 4-hour interval.

End of new text.

3.1.2.2 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

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

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3.1.2.2.1 *Parity checking algorithm for FDMA data verification.* The algorithm shown in Table B-22 and as detailed below shall be used to detect and correct an error of 1 bit within the string and to detect an error of 2 or more bits within a string.

3.1.2.2.1.1 Each string includes the 85 data bits [. . .].

3.1.2.2.1.2 To correct 1-bit errors within the string [. . .].

. . .

3.1.2.2.2 *SATELLITE CLOCK CORRECTION PARAMETERS*

3.1.2.2.2.1 ~~GLONASS system time is determined as~~ GLONASS system time shall be determined using FDMA data as:

$$t_{GLONASS} = t_k + \tau_n(t_b) - \gamma_n(t_b)\,(t_k - t_b)$$

where t_k, $\tau_n(t_b)$, $\gamma_n(t_b)$ are parameters described in 3.1.2.1.3.1.

3.1.2.2.2.2 GLONASS system time shall be determined using CDMA data as:

$$t_{GLONASS} = \mathrm{mod}_{86400}\left[T^{j}_{ST\{signal\}} + \tau^{j}(t_b) - \Delta t_b \cdot \gamma^{j}(t_b) - \Delta t_b^2 \cdot \beta^{j}(t_b)\right]$$

$$\Delta t_b = \frac{T^{j}_{ST\{signal\}} + \tau^{j}(t_b) + \tau_c(t_b) - t_b - \left\langle\left\langle \dfrac{T^{j}_{ST\{signal\}} + \tau^{j}(t_b) + \tau_c(t_b) - t_b}{86400} \right\rangle\right\rangle \cdot 86400}{1 + \gamma^{j}(t_b) - \dot{\tau}_c(t_b)}$$

where

$T^{j}_{ST\{signal\}}$ is the signal time of received signal from satellite *j* and

$\tau^{j}(t_b)$, $\gamma^{j}(t_b)$, $\beta^{j}(t_b)$, $\tau_c(t_b)$, $\dot{\tau}_c(t_b)$ are parameters transmitted in CDMA signals within string of Types 10, 11 and 12 as shown in Table B-20A and Table B-20B.

3.1.2.2.2.~~2~~3 GLONASS system time ~~is related~~ offset to National Time Service of Russia (UTC(SU)) ~~time as indicated~~ shall be determined using FDMA data as:

$$t_{UTC(SU)} = t_{GLONASS} + \tau_c - 03 \text{ hours } 00 \text{ minutes}$$

where

τ_c is a parameter described in 3.1.2.1.3.4 and

03 hours 00 minutes is the continuous time shift caused by the difference between Moscow time and Greenwich time.

3.1.2.2.2.4 GLONASS system time offset to UTC(SU) shall be determined using CDMA data as:

$$t_{UTC(SU)} = \mathrm{mod}_{86400}\left[t_{GLONASS} + \tau_c(t_b) + \Delta t_b \cdot \dot{\tau}_c(t_b) - \ 10800\right]$$

$$\Delta t_b = \frac{t_{GLONASS} + \tau_c(t_b) - t_b - \left\langle\left\langle \frac{t_{GLONASS} + \tau_c(t_b) - t_b}{86400} \right\rangle\right\rangle \cdot 86400}{1 - \dot{\tau}_c(t_b)}$$

where

$\tau_c(t_b)$, $\dot{\tau}_c(t_b)$ are parameters transmitted in CDMA signals within string of Types 10, 11 and 12 as shown in Table B-20A and Table B-20B; and

10 800 seconds is the continuous time shift caused by the difference between Moscow time and Greenwich time.

3.1.2.2.3 *SATELLITE POSITION*

3.1.2.2.3.1 ~~The current satellite position is defined using ephemeris parameters from GLONASS navigation, as indicated in Table B-17.~~ The current satellite centre of mass position shall be defined using ephemeris parameters from GLONASS navigation, as indicated in Table B-17 for GLONASS FDMA signals, in Table B-20A for L1OC and in Table B-20B for L3OC.

3.1.2.2.3.2 Recalculation of ephemeris from instant t_b to instant t_i within the interval ($|\tau_i| = |t_i - t_b| \le$ 15 minutes) is performed using a technique of numeric integration of differential equations describing the motion of the satellites. In the right-hand parts of these equations the accelerations are determined using the gravitational constant μ and the second zonal harmonic of the geopotential J^2_0 which defines polar flattening of the earth, and accelerations due to luni-solar perturbation are taken into account. The equations are integrated in the PZ-90 (3.2.5) coordinate system by applying the Runge-Kutta technique of fourth order, as indicated below:

$$\frac{dx}{dt} = Vx$$

$$\frac{dy}{dt} = Vy$$

$$\frac{dz}{dt} = Vz$$

$$\frac{dV_x}{dt} = -\frac{\mu}{r^3}x - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}x\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 x + 2\omega V_y + \ddot{x}$$

$$\frac{dV_y}{dt} = -\frac{\mu}{r^3}y - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}y\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 y - \cancel{+}\, 2\omega V_x + \ddot{y}$$

$$\frac{dV_z}{dt} = -\frac{\mu}{r^3}z - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}z\left(\cancel{1}3 - \frac{5z^2}{r^2}\right) + \ddot{z}$$

where

$r = \sqrt{x^2+y^2+z^2}$;
μ = earth's universal gravitational constant ($398\ 600.4418 \times 10^9\ m^3/s^2$);
a_e = major semi-axis (6 378 136 m);
J^2_0 = second zonal harmonic of the geopotential ($1\ 082\ 625.75 \times 10^{-9}$); and
ω = earth's rotation rate ($7.2921151467 \times 10^{-5}$ radians/s).

Coordinates $x_n(t_b)$, $y_n(t_b)$, $z_n(t_b)$, and velocity vector components $\dot{x}_n(t_b) = V_x$, $\dot{y}_n(t_b) = V_y$, $\dot{z}_n(t_b) = V_z$ are initial conditions for the integration. Accelerations due to luni-solar perturbation $\ddot{x}_n(t_b)$, $\ddot{y}_n(t_b)$, $\ddot{z}_n(t_b)$ are constant on the integration interval ±15 minutes.

3.1.2.2.3.3 Recalculation of ephemeris from instant t_b to instant t_i within the interval ($|\tau i| = |t_i - t_b| \leqslant$ 4 hours) for CDMA signals shall be performed as in 3.1.2.2.3.2, except that this model includes additional accelerations modelled by a fourth-degree polynomial to accommodate the extended interval as described below:

$$\frac{dx}{dt} = Vx$$

$$\frac{dy}{dt} = Vy$$

$$\frac{dz}{dt} = Vz$$

$$\frac{dV_x}{dt} = -\frac{\mu}{r^3}x - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}x\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 x + 2\omega V_y + \ddot{x} + a_x$$

$$\frac{dV_y}{dt} = -\frac{\mu}{r^3}y - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}y\left(1 - \frac{5z^2}{r^2}\right) + \omega^2 y - 2\omega V_x + \ddot{y} + a_y$$

$$\frac{dV_z}{dt} = -\frac{\mu}{r^3}z - \frac{3}{2}J_0^2\frac{\mu a_e^2}{r^5}z\left(3 - \frac{5z^2}{r^2}\right) + \ddot{z} + a_z$$

$$a_x = \triangle a_{x0} + a_{x1}(t - t_b) + a_{x2}(t - t_b)^2 + a_{x3}(t - t_b)^3 + a_{x4}(t - t_b)^4$$

$$a_y = \triangle a_{y0} + a_{y1}(t - t_b) + a_{y2}(t - t_b)^2 + a_{y3}(t - t_b)^3 + a_{y4}(t - t_b)^4$$

$$a_z = \triangle a_{z0} + a_{z1}(t - t_b) + a_{z2}(t - t_b)^2 + a_{z3}(t - t_b)^3 + a_{z4}(t - t_b)^4$$

Coordinates, velocity vector components at the time t_b, and perturbing accelerations $\ddot{x}, \ddot{y}, \ddot{z}$ shall be transmitted in CDMA signals within string of Types 10, 11 and 12. The long-term dynamic model parameters for the fourth-degree polynomials, accelerations a_x, a_y, and a_z, shall be transmitted in CDMA signals in strings of Types 31 and 32.

3.1.2.2.4 *ALGORITHM FOR DETERMINATION OF SATELLITE ANTENNA PHASE CENTRE POSITION*

3.1.2.2.4.1 For high-precision pseudo-range measurements, an algorithm for computing antenna phase centre position in the PZ-90 coordinate system based on the satellite centre of mass position and data transmitted in CDMA signals within string Type 16 shall be used.

Note.— Additional information concerning a suitable algorithm is given in Appendix R of the GLONASS CDMA ICD General Description.

3.1.2.2.5 *IONOSPHERIC CORRECTION*

3.1.2.2.5.1 The ionospheric correction for a single-frequency receiver shall be defined as:

- for pseudo-ranges, m: $\Delta S_{ion} = 0.40364 \cdot \frac{I_e}{f^2}$;
- for velocities, m/s: $\Delta V_{ion} = 0.40364 \cdot \frac{\dot{I}_e}{f^2}$,

where

f is the signal carrier frequency, in GHz;

I_e is the total electron content (TEC) integrated along the signal propagation path, $1 \times 10^{16}\ m^{-2}$; and
$\dot{I}_e$ is the rate of change of TEC integrated along the signal propagation path, $1 \text{x} 10^{16}\ m^{-2} s^{-1}$.

Note.— Additional information concerning two suitable algorithms for computing TEC integrated along the signal propagation path based on data transmitted within strings of Type 25 is given in Appendix Q of the GLONASS CDMA ICD General Description. The first algorithm is a universal algorithm for terrestrial and space users. It is more complex, accurate, and has wider application. The second algorithm is intended for terrestrial users only. It is easier to implement but it results in larger errors of TEC at less than 30° elevation angles. Residual ionosphere correction errors of the second algorithm do not exceed 4 m (0.95 probability).

3.1.2.3 AIRCRAFT ELEMENTS

3.1.2.3.1 ~~*GNSS (*~~*GLONASS*~~*)*~~ *RECEIVER*

3.1.2.3.1.1 Reserved ~~*Satellite exclusion*. The receiver shall exclude any satellite designated unhealthy in the GLONASS navigation message.~~

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

3.1.2.3.1.3 *Doppler shift.* The receiver shall be able to compensate for dynamic Doppler shift effects on nominal GLONASS signal carrier phase and standard code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.1.2.3.1.4 *Resistance to interference.* The receiver shall meet the requirements for resistance to interference as specified in 3.7.

3.1.2.3.1.4.1 *Intrasystem interference.* When receiving an FDMA navigation signal with frequency channel k = n, the interference created by a navigation signal with frequency channel number k = n – 1 or k = n + 1 shall not be more than –48 dBc with respect to the minimum specified satellite power at the surface of the earth provided that the satellites transmitting these signals are simultaneously located in user's visibility zone.

Note.— The intrasystem interference is the intercorrelation properties of the ranging pseudo-random signal with regard to frequency division multiple access.

3.1.2.3.1.4.2 For CDMA signals, multiple access interference shall be defined by the intercorrelation properties of ranging codes and will depend on the number of elementary symbols *N* in the periods of these codes. Multiple access interference power in relation to the power of the L1OCd signal shall not exceed the level of -30 dB. Multiple access interference power in relation to the power of the L1OCp signal shall not exceed the level of -36 dB. Multiple access interference power in relation to the power of the L3OC signal shall not exceed the level of -40 dB.

3.1.2.3.1.5 *Application of clock and ephemeris data.* The receiver shall ensure that it is using the correct ephemeris and clock data before providing any position solution.

3.1.2.3.1.6 *Leap second correction.* Upon GLONASS time leap second correction (see 3.1.2.1.3.1, t_b) the GLONASS receiver shall be capable of:

a) generating a smooth and valid series of pseudo-range measurements; and

b) resynchronizing the data string time mark without loss of signal tracking.

3.1.2.3.1.6.1 After GLONASS time leap second correction the GLONASS receiver shall utilize the UTC time as follows:

a) utilize the old (prior to the correction) UTC time together with the old ephemeris (transmitted before 00 hours 00 minutes 00 seconds UTC); and

b) utilize the updated UTC time together with the new ephemeris (transmitted after 00 hours 00 minutes 00 seconds UTC).

Note — Additional information concerning the specific aspects of receiver operation during scheduled corrections of GLONASS time and Moscow time in the specified situations is given in Appendix E of the GLONASS CDMA ICD General Description.

Editorial note.— Renumber paragraphs from 3.2.4 to 3.2.4.3 as 3.1.2.4 to 3.1.2.4.3.

3.1.2.4.4 Signal time shall be generated and maintained by an on-board clock based on atomic frequency standard, shall be synchronized with GLONASS time and shall be distributed in radio navigation signals.

Note 1.— Signal time differs from on-board clock time by the group delay value. Thus signal time corrections in string Types 10, 11 and 12 include group delay values.

Note 2.— Additional information concerning signal time is given in the GLONASS CDMA ICD General Description.

3.1.2.4.4.1 Navigation data for any GLONASS CDMA signal shall contain the estimated parameters of the polynomial model for relating signal time broadcast in this signal to GLONASS time as well as for relating a pilot component of this signal to its data component.

3.1.2.4.4.2 When GLONASS time is corrected for ±1 s during scheduled leap second corrections of UTC(SU), simultaneous correction of signal time for all satellites shall be carried out through changing the time stamps of the pulse sequence representing seconds.

Note.— Navigation data provides advance notifications to users of the day and the sign of the correction.

Editorial note.— Renumber paragraphs from 3.2.5 to 3.2.5.2.1 as 3.1,2.5 to 3.1.2.5.2.1 and *replace* the reference to Attachment D, 4.2.9.3 in 3.1.2.5.2.1, *Note 2*, with a reference to Attachment D, 4.1.2.9.3.

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Editorial note.— Insert new Figures B-7A, B-7B, B-7C and B-7D after Figure B-7.

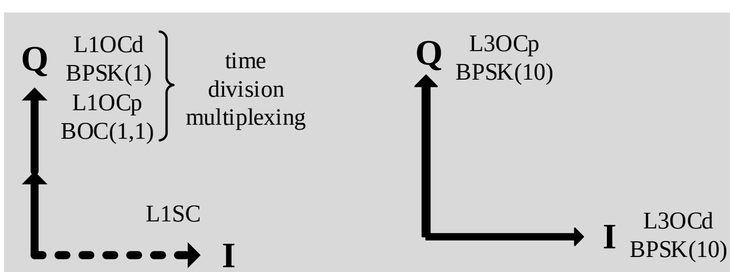

Figure B-7A. L1OC and L3OC signal structure

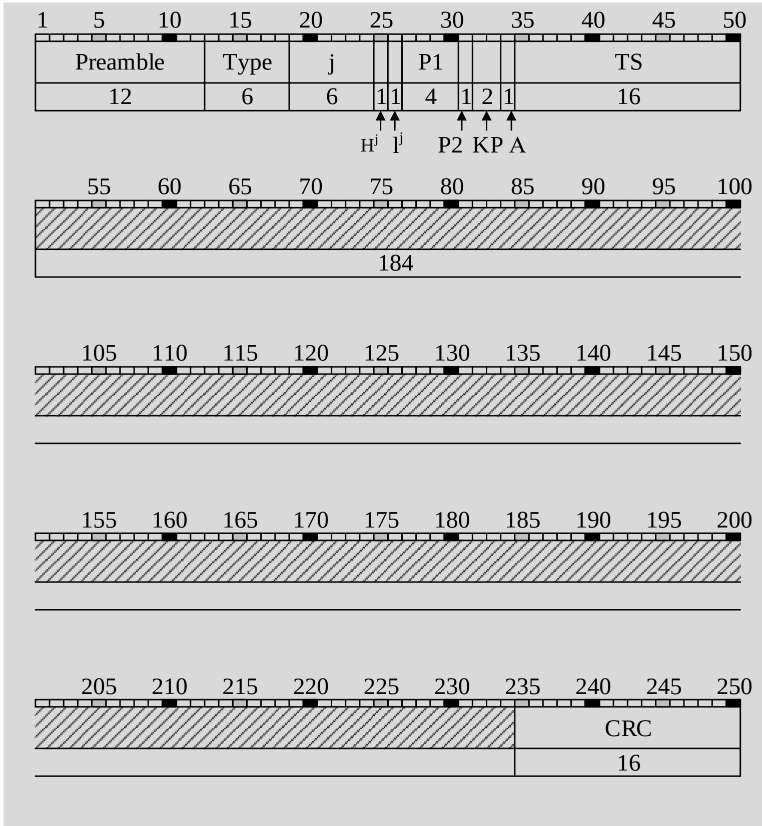

Figure B-7B. General structure of L1OCd data string

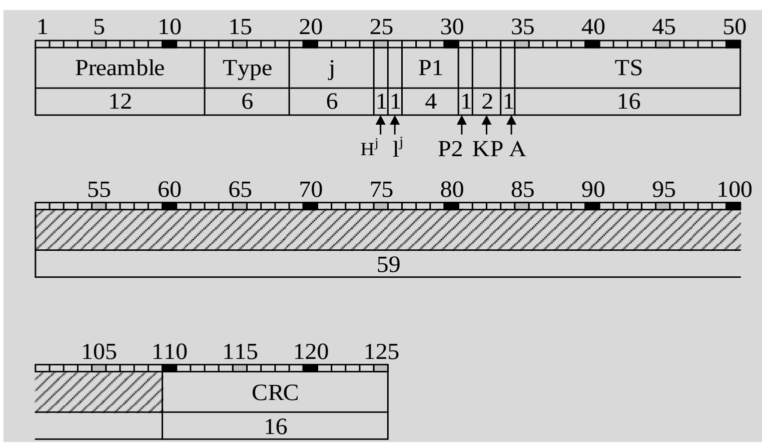

Figure B-7C. Anomalous L1OCd data string Type 1

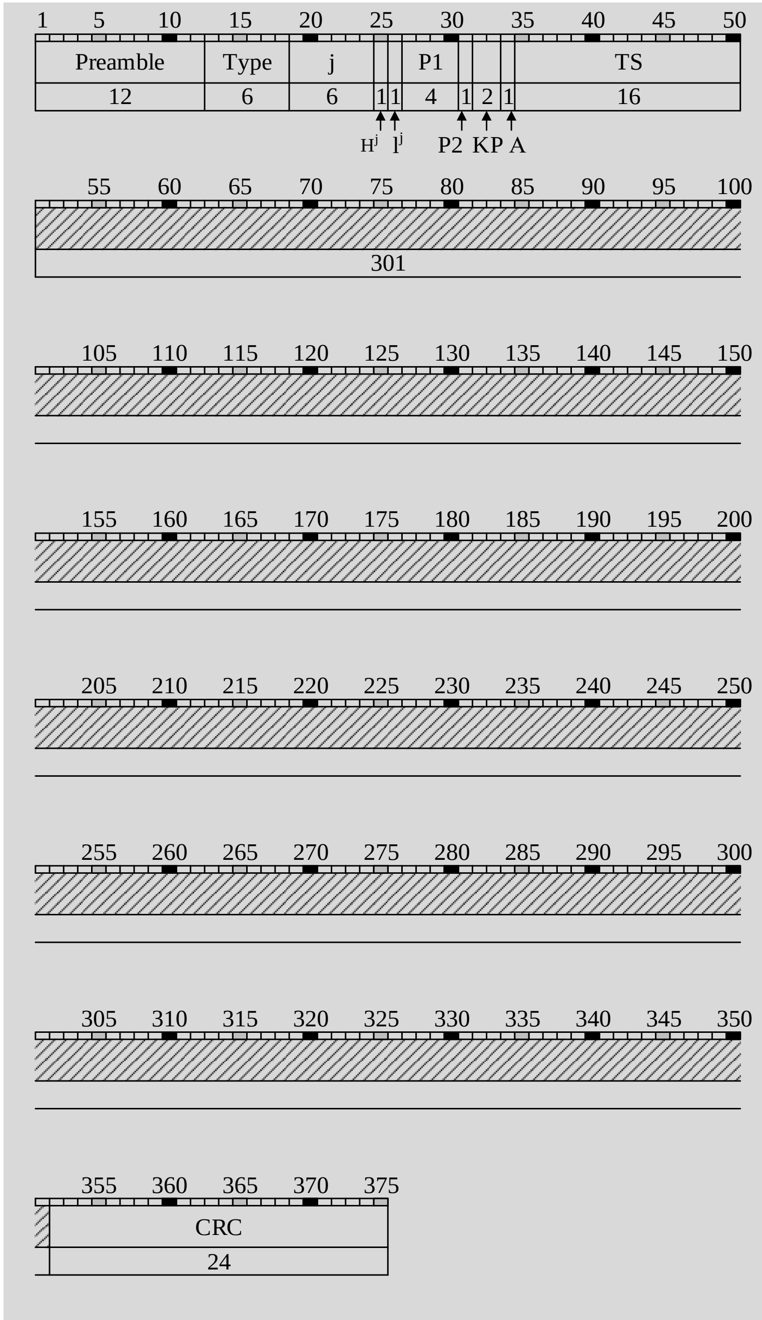

Figure B-7D. Anomalous L1OCd data string Type 2

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Editorial note.— Insert new Figures B-8A, B-8B and B-8C after Figure B-8.

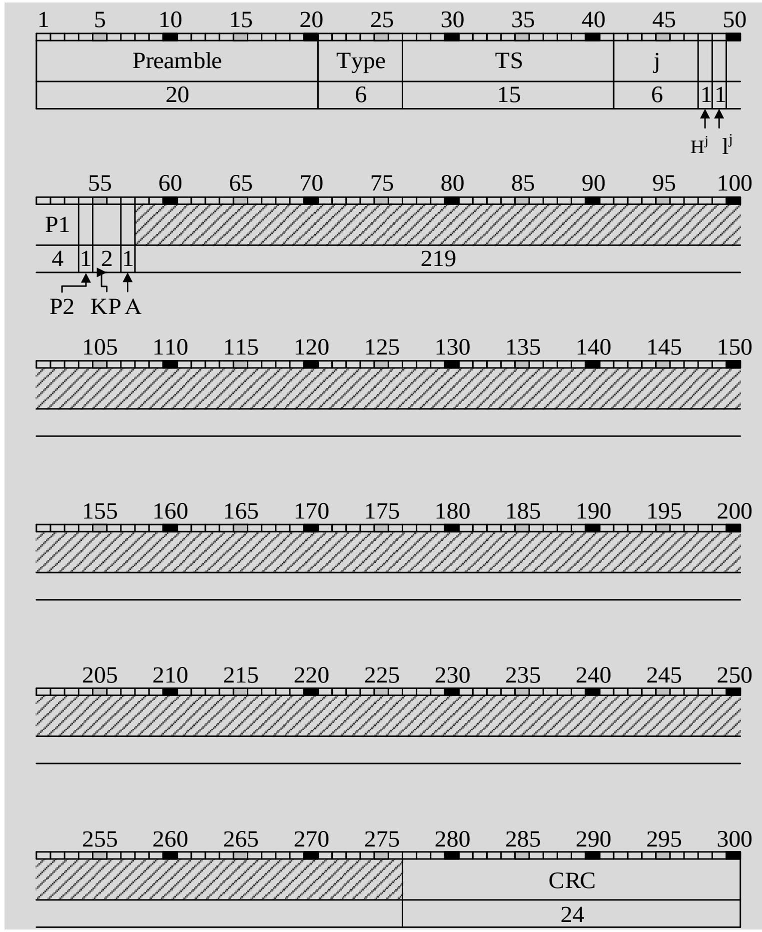

Figure B-8A. General structure of L3OCd data string

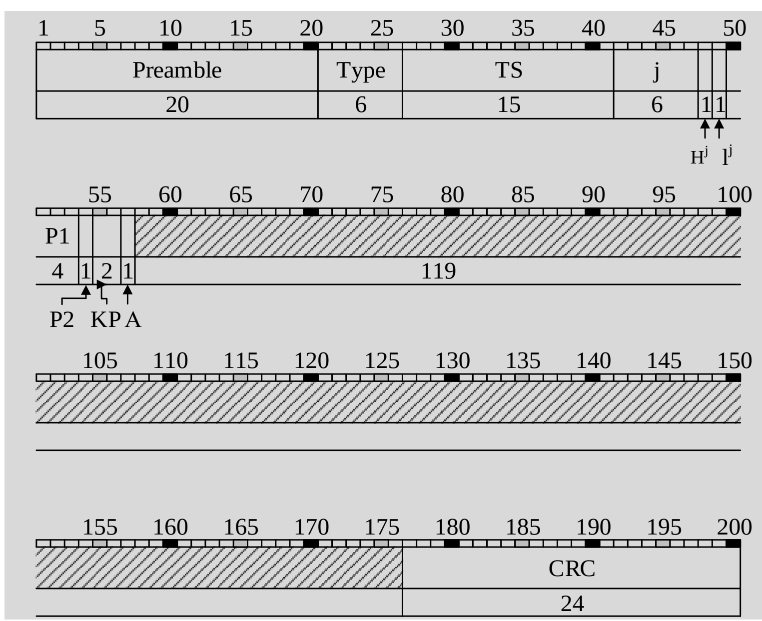

Figure B-8B. Anomalous L3OCd data string Type 1

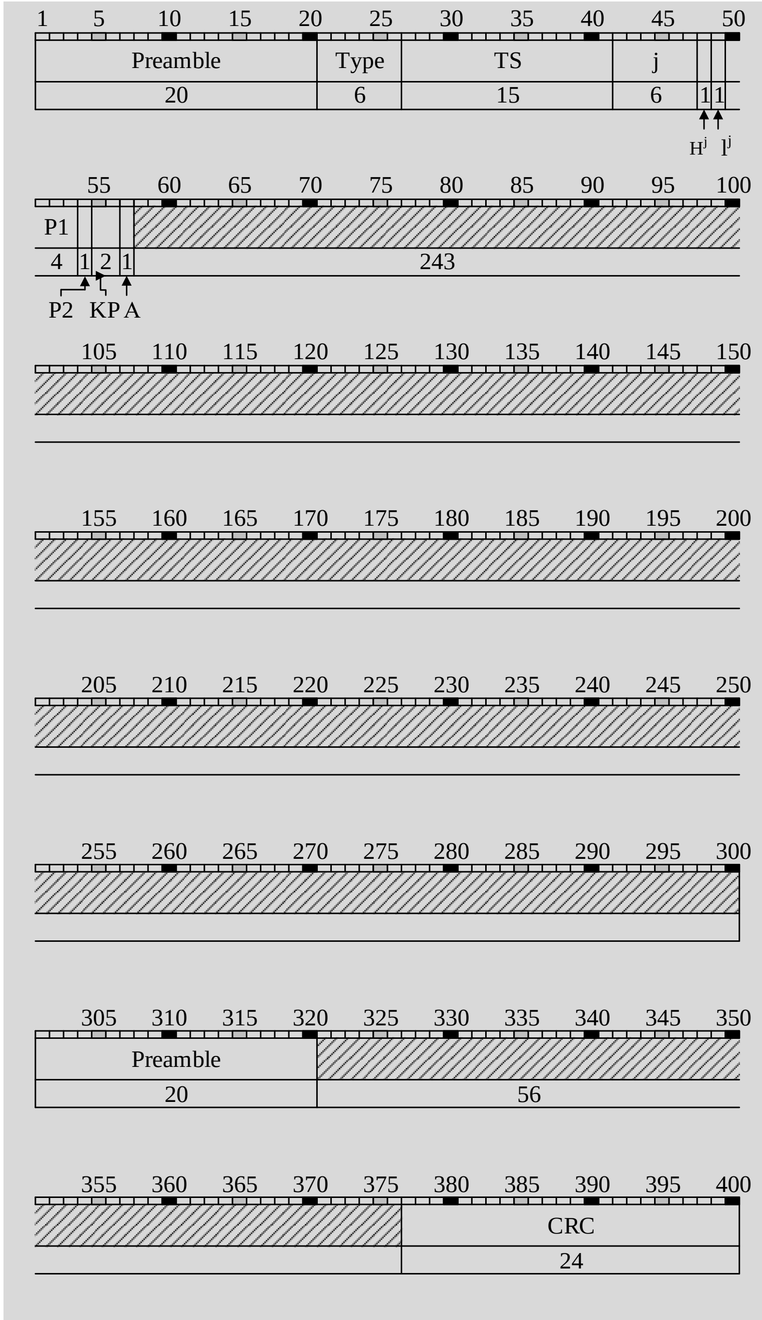

Figure B-8C. Anomalous L3OCd data string Type 2

ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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4. GNSS CORE ELEMENTS

4.1 Core constellations

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4.1.2 GLONASS

Note.— Additional information ~~*concerning GLONASS can be found in the GLONASS Interface Control Document published by Scientific Coordination Information Center, Russian Federation Ministry of Defence, Moscow.*~~*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 range computations in the most current realization of the PZ-90 and uses PZ-90 – WGS-84 transformation parameters as indicated in Appendix B, 3.1.2.5.2; 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. Dual-frequency 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 ~~root-mean-square~~ range error accuracy over all satellites is the ~~average~~ 95 per cent threshold of the ~~RMS~~ 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 ~~*Relationship to augmentation*~~ *Satellite/constellation availability*. ~~The availability of ABAS, GBAS and SBAS does not directly relate to the GLONASS availability defined in Chapter 3, 3.7.3.1.2.2. Availability analysis is based on an assumed satellite constellation and the probability of having a given number of satellites.~~ Twenty-four operational satellites are available in orbit with 0.95 probability (averaged over any day), where a satellite is defined to be operational if it is capable of, but is not necessarily transmitting, a usable ranging signal. At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and must be transmitting a navigation signal with 0.98 probability (yearly averaged).

4.1.2.5 *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 (~~3~~ three failures each lasting ~~6~~ 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 ~~18~~ 70 m ~~(60 ft)~~ (as defined in Chapter 3, 3.7.3.1.2.4~~1.3 a)~~) ~~and/or failures in radio frequency characteristics of the CSA ranging signal~~, ~~navigation message structure or navigation message contents that deteriorate the CSA receiver's ranging signal reception or processing capabilities.~~

4.1.2.7 *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.

Editorial note.— Renumber paragraphs from 4.2.7 to 4.2.9.3 as 4.1.2.9 to 4.1.2.11.3.

Origin:	*Rationale*:
NSP/6	This proposal is intended to reflect the ongoing modernization of the GLONASS satellite navigation system, operated by the Russian Federation and already standardized by ICAO (L1 band only). It includes amendments to the existing GLONASS SARPs to add a code division multiple access (CDMA) signal in the L3 band and a new CDMA signal in the L1 band. The use of two frequency bands (L1 and L3) will help mitigate vulnerabilities in respect of ionospheric disturbance and radio frequency interference.

INITIAL PROPOSAL 4
Galileo

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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3.7.3 GNSS elements specifications

3.7.3.1 *Core constellations*

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Editorial note.— Insert new section 3.7.3.1.3 as follows:

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

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

Note 2.— The E5b signal component is described in this 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	5 m	5 m	5 m
Vertical position error over a measurement period of 30 days	8 m	8 m	8 m
Worst site 95% of the time:			
Horizontal position error over a measurement period of 30 days	10 m	10 m	10 m
Vertical position error over a measurement period of 30 days	16 m	16 m	16 m

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

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

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

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

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

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 *Probability of satellite failure (P_{sat})*. 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. In the future, these flags may be complemented with an additional flag specific for aircraft-based augmentation system (ABAS) users.

Note 2.— Galileo URA corresponds either to $\sigma_{URA,DF}$ for dual-frequency users or to $\sigma_{URA,SF}$ for single-frequency users.

Note 3.— P_{sat} definition is further specified in Attachment D, 4.1.3.6.1.

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

Note 1.— A change in the SIS health status is notified through the flags contained in the navigation message. The mapping between Galileo SIS status and flags contained in the navigation data message is specified in Appendix B, 3.1.3.1.3.4. In the future, these flags may be complemented with an additional flag specific for ABAS users.

Note 2.— Galileo URA corresponds either to $\sigma_{URA,DF}$ for dual-frequency users or to $\sigma_{URA,SF}$ for single-frequency users.

Note 3.— P_{const} definition is further specified in Attachment D, 4.1.3.6.2.

3.7.3.1.3.7 *Galileo URA for dual-frequency ($\sigma_{URA,DF}$)*. Galileo $\sigma_{URA,DF}$ shall not exceed 6 m.

Note 1.— $\sigma_{URA,DF}$ applies to a dual-frequency E1-E5a signal combination.

Note 2.— $\sigma_{URA,DF}$ is defined in Attachment D, 4.1.3.6.3.

3.7.3.1.3.8 *Galileo URA for single-frequency ($\sigma_{URA,SF}$)*. Galileo $\sigma_{URA,SF}$ shall not exceed 7.5 m.

Note 1.— $\sigma_{URA,SF}$ applies to a single-frequency user, either E1 or E5a.

Note 2.— $\sigma_{URA,SF}$ is defined in Attachment D, 4.1.3.6.4.

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

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

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

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

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

Note 2.— AltBOC modulation is specified in Appendix B, 3.1.3.1.1.3.13.

Note 3.— Detailed Galileo signals RF characteristics are specified in Appendix B, 3.1.3.1.1.

3.7.3.1.3.11.1 *E1 radio frequency (RF) characteristics*

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

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

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

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

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

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

Note. — CBOC modulation is specified in Appendix B, 3.1.3.1.1.2.7.

3.7.3.1.3.11.2 *E5a radio frequency (RF) characteristics*

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

3.7.3.1.3.11.2.1 *E5a carrier frequency.* Each Galileo satellite shall broadcast E5a signal at the carrier frequency 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.

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

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

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

3.7.3.1.3.11.2.6 *E5a signal modulation.* The E5a signal shall be generated from Modulo-2 addition of the E5a 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).

3.7.3.1.3.11.3 *E5b radio frequency (RF) characteristics*

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

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

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

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

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

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

3.7.3.1.3.11.3.6 *E5b signal modulation.* The E5b signal shall be generated from Modulo-2 addition of the E5b 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).

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

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

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

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

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

a) satellite time of transmission;

b) satellite position;

c) satellite health;

d) satellite clock correction;

e) ionospheric delay effects;

f) time transfer to UTC; and

g) constellation status.

Note.— Structure and contents of data are specified in Appendix B, 3.1.3.1.2 and 3.1.3.1.2, respectively.

End of new text.

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

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3. GNSS ELEMENTS

3.1 Core constellations

. . .

Editorial note.— Insert new section 3.1.3 as follows:

3.1.3 Galileo Open Service (Galileo OS)

3.1.3.1. NON-AIRCRAFT ELEMENTS

3.1.3.1.1 GALILEO RF CHARACTERISTICS

3.1.3.1.1.1 *E1 and E5 common requirements*

3.1.3.1.1.1.1 *Carrier phase noise.* The carrier phase noise spectral density of the unmodulated carrier on E5 and E1 shall be such that a second-order phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.04 radian root mean square (RMS).

3.1.3.1.1.1.2 *Spurious emissions.* In-band spurious emissions shall be at least 35 dB below the unmodulated E1 and E5 carriers over the allocated channel bandwidth.

3.1.3.1.1.1.3 *Correlation loss.* The loss in the recovered signal power due to imperfections in the signal modulation and waveform distortion shall not exceed 0.6 dB for each signal (E1, E5a and E5b).

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

3.1.3.1.1.1.4 *Code/data coherence*. The edge of each data symbol shall be aligned with the edge of the corresponding ranging code chip. The start of the periodic ranging code shall be aligned with the start of a data symbol. The edge of each secondary code chip shall be aligned with the edge of a primary code chip. The start of a primary code chip shall be aligned with the start of a secondary code chip.

3.1.3.1.1.2 *E1 RF characteristics*

3.1.3.1.1.2.1 *E1 signal components*. The E1 signal shall comprise two signal components: E1-B navigation data component with a navigation data symbol rate of 250 symbols per second and E1-C pilot component.

3.1.3.1.1.2.2 *E1 signal power split.* The E1 signal power shall be equally split between the E1-B and E1-C signal components.

3.1.3.1.1.2.3 *E1-B ranging code (C_{E1-B}).* The E1-B ranging code shall be a 1.023 megachips per second ranging code repeated every 4 milliseconds, derived from a primary ranging code of 4 092 chips.

Note.— Additional information concerning the E1-B ranging codes is given in Galileo OS SIS ICD, Chapter 3 and Annex C.

3.1.3.1.1.2.4 *E1-C ranging code (C_{E1-C}).* The E1-C ranging code shall be a 1.023 megachips per second ranging code repeated every 100 milliseconds, derived from the Modulo-2 addition of a primary ranging code of 4 092 chips and a secondary code of 25 chips.

Note.— Additional information concerning the E1-C ranging codes is given in Galileo OS SIS ICD, Chapter 3 and Annex C.

3.1.3.1.1.2.5 *E1-B data component generation*. The E1-B data component shall be generated from the E1 navigation data stream (D_{E1-B}) and the E1-B ranging code (C_{E1-B}), modulated with two in-phase CBOC subcarriers of 1.023 MHz and 6.138 MHz, respectively, as shown in Figure GAL-1.

Note.— The subcarrier-free component of the E1 navigation data component — that is, before CBOC modulation — is denoted as e_{E1-B}. Additional information concerning e_{E1-B} generation is given in Galileo OS SIS ICD, 2.3.3.

3.1.3.1.1.2.6 *E1-C pilot component generation*. The E1-C pilot component shall be generated from the E1-C ranging code (C_{E1-C}) modulated with two anti-phase CBOC subcarriers of 1.023 MHz and 6.138 MHz, respectively, as shown in Figure GAL-1.

Note.— The subcarrier-free component of the E1 pilot component — that is, before CBOC modulation — is denoted as e_{E1-C}. Additional information concerning e_{E1-C} generation is given in Galileo OS SIS ICD, 2.3.3.

3.1.3.1.1.2.7 *E1 signal modulation*. The E1-B/C composite binary signal shall be generated from the CBOC modulation of the binary signal components, e_{E1-B} and e_{E1-C}, and the subcarriers, as illustrated in Figure GAL-1.

Note.— Additional information concerning E1-B/C generation is given in Galileo OS SIS ICD, 2.3.3.

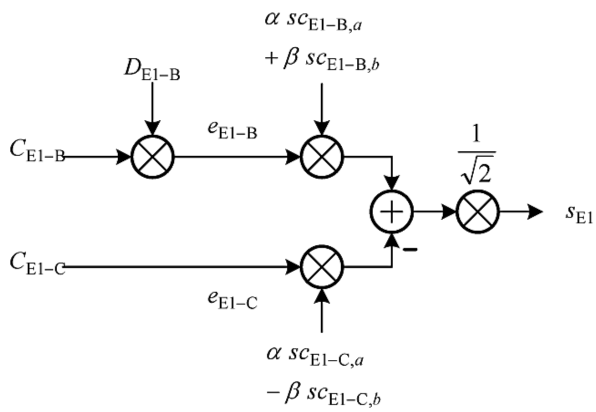

Figure GAL-1. Modulation scheme for the E1 CBOC signal

3.1.3.1.1.3 *E5a and E5b RF characteristics*

3.1.3.1.1.3.1 *E5a signal components*. The E5a signal shall comprise two signal components: E5a-I navigation data component with a navigation data symbol rate of 50 symbols per second and E5a-Q pilot component.

3.1.3.1.1.3.2 *E5a signal power split.* The E5a signal power shall be equally split between the E5a-I and E5a-Q components.

3.1.3.1.1.3.3 *E5a-I ranging code ($C_{E5a\text{-}I}$).* The E5a-I ranging code sequence shall be a 10.230 megachips per second ranging code repeated every 20 milliseconds, derived from the Modulo-2 addition of a primary ranging code of 10 230 chips and a secondary code of 20 chips.

Note.— Additional information concerning E5a-I ranging codes is given in Galileo OS SIS ICD, Chapter 3 and Annex C.

3.1.3.1.1.3.4 *E5a-Q ranging code ($C_{E5a\text{-}Q}$).* The E5a-Q ranging code shall be a 10.230 megachips per second ranging code repeated every 100 milliseconds, derived from the Modulo-2 addition of a primary ranging code of 10 230 chips and a secondary code of 100 chips.

Note.— Additional information concerning E5a-Q ranging codes is given in Galileo OS SIS ICD, Chapter 3 and Annex C.

3.1.3.1.1.3.5 *E5a-I data component generation*. The E5a data component shall be generated from the E5a navigation data stream ($D_{E5a\text{-}I}$) and the E5a-I ranging code ($C_{E5a\text{-}I}$).

Note.— The subcarrier-free component of the E5a navigation data component — that is, before AltBOC modulation — is denoted as $e_{E5a\text{-}I}$.

3.1.3.1.1.3.6 *E5a-Q pilot component generation*. The E5a pilot component shall be generated from the E5a-Q ranging code (C_{E5a-Q}).

Note.— The subcarrier-free component of the E5a pilot component — that is, before AltBOC modulation — is denoted as e_{E5a-Q}.

3.1.3.1.1.3.7 *E5b signal components*. The E5b signal shall comprise two signal components: E5b-I navigation data component with a navigation data symbol rate of 250 symbols per second and E5b-Q pilot component.

3.1.3.1.1.3.8 *E5b signal power split.* The E5b signal power shall be equally split between the E5b-I and E5b-Q components.

3.1.3.1.1.3.9 *E5b-I ranging code* (C_{E5b-I}). The E5b-I ranging code shall be a 10.230 megachips per second ranging code repeated every 4 milliseconds, derived from the Modulo-2 addition of a primary ranging code of 10 230 chips and a secondary code of 4 chips.

Note.— Additional information concerning E5b-I ranging codes is given in Galileo OS SIS ICD, Chapter 3 and Annex C.

3.1.3.1.1.3.10 *E5b-Q Ranging code* (C_{E5b-Q}). The E5b-Q ranging code shall be a 10.230 megachips per second ranging code repeated every 100 milliseconds, derived from the Modulo-2 addition of a primary ranging code of 10 230 chips and a secondary code of 100 chips.

Note.— Additional information concerning E5b-Q ranging codes is given in Galileo OS SIS ICD, Chapter 3 and Annex C.

3.1.3.1.1.3.11 *E5b-I data component generation.* The E5b data component shall be generated from the E5b navigation data stream (D_{E5b-I}) and the ranging code (C_{E5b-I}).

Note.— The subcarrier-free component of the E5b navigation data component — that is, before AltBOC modulation — is denoted as e_{E5b-I}.

3.1.3.1.1.3.12 *E5b-Q pilot component generation.* The E5b pilot component shall be generated from the ranging code (C_{E5b-Q}).

Note.— The subcarrier-free component of the E5b pilot component — that is, before AltBOC modulation — is denoted as e_{E5b-Q}.

3.1.3.1.1.3.13 *E5 signal modulation*. The wideband E5 signal shall be generated with the AltBOC modulation of side-band subcarrier of 15.345 MHz (15 × 1.023 MHz) with the binary signal components e_{E5a-I}, e_{E5a-Q}, e_{E5b-I} and e_{E5b-Q}, as illustrated in Figure GAL-2.

Note 1.— E5a and E5b signals can be processed independently by the user receiver as though they were two separate QPSK signals with a carrier frequency of 1176.45 MHz and 1207.14 MHz, respectively.

Note 2.— Additional information concerning E5 generation is given in Galileo OS SIS ICD, 2.3.1.

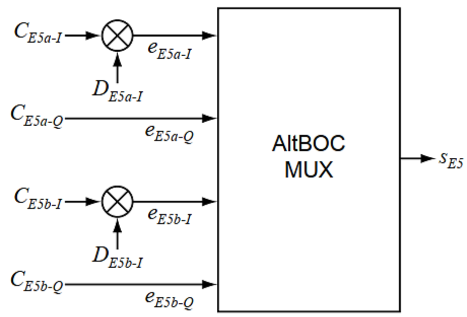

Figure GAL-2. Modulation scheme for the E5 AltBOC signal

3.1.3.1.1.4 *Code assignments to satellites*

3.1.3.1.1.4.1 *Primary ranging code assignment to satellites.* The E5a-I, E5a-Q, E1-B and E1-C primary code number n shall be allocated to the space vehicle IDs (SVID) number n (with n=1 to 36).

3.1.3.1.1.4.2 Secondary ranging code assignment to satellites. The E5a-Q secondary code shall be assigned according to the SVID number n (with n=1 to 36). E5a-I and E1-C secondary codes shall be constant regardless of the SVID.

3.1.3.1.2 *DATA STRUCTURE*

Note.— Additional information concerning the data structure is given in Galileo OS SIS ICD.

3.1.3.1.2.1 *E5a-I message (F/NAV) characteristics*

3.1.3.1.2.1.1 The E5a-I message shall be transmitted as a sequence of frames as indicated in Figure GAL-3. The period of each frame shall be 600 seconds. Each frame shall consist of 12 subframes of period 50 seconds per subframe. Each subframe shall consist of five pages of period 10 seconds per page.

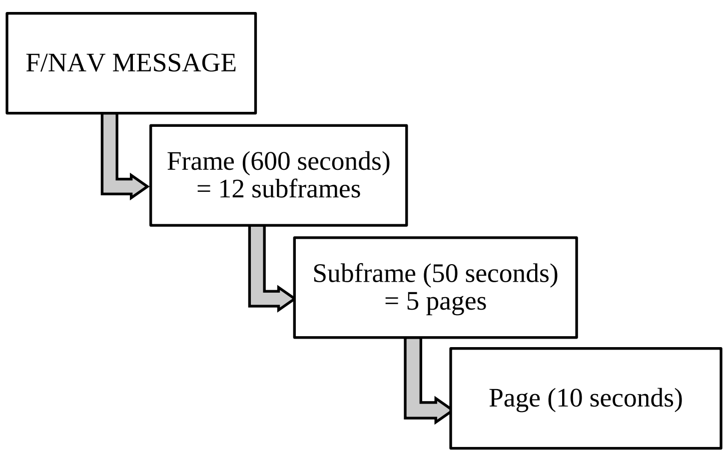

Figure GAL-3. F/NAV message structure

3.1.3.1.2.1.2 *Page structure*. Each page structure shall contain the following elements structured as indicated in Table GAL-1:

- 12 synchronization block symbols
- 488 interleaved message block symbols

Table GAL-1. F/NAV page layout

Sync.	F/NAV symbols	Total (symbols)
12	488	500

F/NAV word (bits)			Tail (bits)	Total (bits)
Page type	Nav. data	CRC		
6	208	24	6	244

3.1.3.1.2.1.3 *Synchronization block.* The first element of each page shall be a 12-symbol synchronization sequence. The synchronization sequence shall be "101101110000" with the MSB transmitted first, and it shall be added to the beginning of the 488 interleaved message block symbols field after the interleaving procedure described in paragraph 3.1.3.1.2.1.6.

3.1.3.1.2.1.4 *F/NAV message word.* The message word shall contain 244 bits consisting of a 6-bit page type, a 208-bit data field, a 24-bit CRC and a 6-bit tail field. The 6-bit tail field shall be "000000".

Note.— Additional information concerning the message words is given in Galileo OS SIS ICD.

3.1.3.1.2.1.5 *F/NAV FEC encoding*. The 25-bit-per-second data stream shall be encoded at a rate of two symbols per bit using a convolution code with a constraint length of seven to yield 50 symbols per second. The convolution encoder logic arrangement shall be as illustrated in Figure GAL-4 with the G1 output selected for the first half of each 40-millisecond data bit period resulting in 488 symbols per page where S_1 is the first symbol and S_{488} is the last symbol.

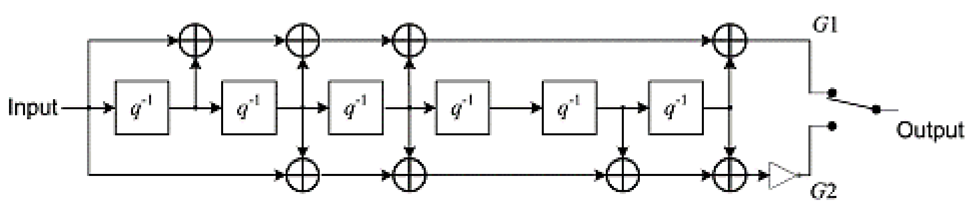

Figure GAL-4. F/NAV convolutional encoding scheme

3.1.3.1.2.1.6 *E5a-I interleaving procedure.* The E5a-I message block symbols shall be interleaved using a 61-column, 8-row matrix, where each entry is one symbol. The message block symbols shall be written into each column and ordered for transmission, row by row, starting at the upper left corner of the matrix as indicated in Table GAL-2.

Table GAL-2. E5a-I interleaver matrix

Columns→ Rows ↓	C_1	C_2	C_3	…	C_{60}	C_{61}
R_1	S_1	S_9	S_{17}	…	S_{473}	S_{481}
R_2	S_2	S_{10}	S_{18}	…	S_{474}	S_{482}
R_3	S_3	S_{11}	S_{19}	…	S_{475}	S_{483}
…	…	…	…	…	…	…
R_7	S_7	S_{15}	S_{23}	…	S_{479}	S_{487}
R_8	S_8	S_{16}	S_{24}	…	S_{480}	S_{488}

3.1.3.1.2.2 *E1-B message (I/NAV) characteristics*

3.1.3.1.2.2.1 The E1-B message shall be transmitted as a sequence of frames as indicated in Figure GAL-5. The period of each frame shall be 720 seconds. Each frame shall consist of 24 subframes of period 30 seconds per subframe. Each subframe consist of 15 nominal pages of period 2 seconds per page. Each page shall consist of two subpages each of period one second.

Note 1.— The two subpages in a page are known as the even page and the odd page.

Note 2.— I/NAV message structure is indicated in Figure GAL-5.

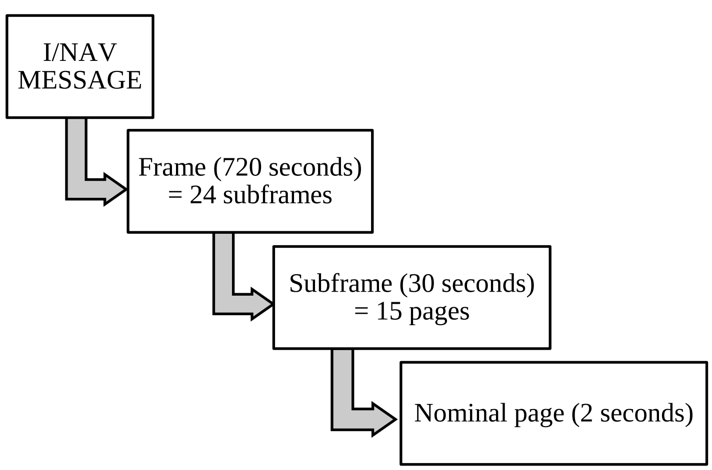

Figure GAL-5. I/NAV message structure

3.1.3.1.2.2.2 *Page type.* There shall be two types of pages, a nominal page and an alert page. The nominal page shall contain the nominal data word.

Note.— The alert page is reserved for future applications.

3.1.3.1.2.2.3 *Nominal page.* A nominal page shall consist of two parts (even and odd) transmitted sequentially over the same frequency and structured as indicated in Table GAL-4. The nominal page shall contain 240 bits so that the first 120 bits shall be in the even nominal subpage, and the second 120 bits shall be in the odd nominal subpage.

3.1.3.1.2.2.4 *Nominal data word*. The nominal E1-B data word shall contain 128 bits consisting of a 6-bit word type and a 122-bit data field.

3.1.3.1.2.2.5 *Subpage structure*. Each subpage structure shall contain the following elements, structured as indicated in Table GAL-3:

a) 10 synchronization block symbols; and

b) 240 interleaved message block symbols.

Table GAL-3. I/NAV subpage layout

Sync.	I/NAV subpage (even or odd) symbols		Total (symbols)
10	240		250
	I/NAV subpage (even or odd) bits	Tail (bits)	Total (bits)
	114	6	120

3.1.3.1.2.2.6 *Synchronization block*. The first element of each subpage shall be a 10-symbol synchronization sequence. The synchronization sequence shall be “0101100000”, with the MSB transmitted first, and shall be added to the beginning of the 240 interleaved message block symbols field after the interleaving procedure described in paragraph 3.1.3.1.2.2.10.

3.1.3.1.2.2.7 *Even subpage*. The even subpage shall contain a bit denoting which part (even or odd) of the subpage is being transmitted, a type bit to indicate that this is a nominal page, the first 112 bits of the nominal data word and a 6-bit tail field, as indicated in Table GAL-4. The tail field shall be “000000”.

3.1.3.1.2.2.8 *Odd subpage.* The odd subpage shall contain a bit denoting which part (even or odd) of the subpage is being transmitted, a type bit to indicate that this is a nominal page, the last 16 bits of the nominal data word, a 40-bit “reserved 1” field, 22 bits for search and rescue (SAR) data, a 2-bit spare field, a 24-bit CRC, an 8-bit “reserved 2” field and a 6-bit tail field, as indicated in Table GAL-4. The tail field shall be “000000”.

Note.— Galileo provides enhanced distress localization and call features for the provision of a SAR service interoperable with the COSPAS-SARSAT system. Galileo SAR service is out of the scope of Annex 10.

Table GAL-4. I/NAV nominal page with bits allocation

E1-B										Total (bits)
Even/odd=1	Page Type=0	Data word (2/2)	Reserved 1	SAR	Spare	CRC	Reserved 2	Tail		Total (bits)
1	1	16	40	22	2	24	8	6		120
Even/odd=0	Page Type=0	Data word (1/2)						Tail		Total (bits)
1	1	112						6		120

Note 1.— Even/odd field (1 bit) indicates the part of the page (0=even/1=odd) that is broadcast.
Note 2.— Page type field (1 bit) equal to 0 indicates the nominal page type.
Note 3.— Data field consists of a nominal data word (described in 3.1.3.1.2.2.4) of 128 bits (comprising 112 bits of data (1/2) and 16 bits of data (2/2)).

3.1.3.1.2.2.9 *I/NAV FEC encoding*. The 125-bit-per-second data in the even and odd subpages shall be encoded at a rate of two symbols per bit using a convolutional code with a constraint length of seven to yield 250 symbols per second. The convolutional encoder logic arrangement shall be as illustrated in Figure GAL-6 with the G1 output selected for the first half of each 8-millisecond data bit period resulting in 240 symbols per page, where S_1 is the first symbol and S_{240} is the last symbol.

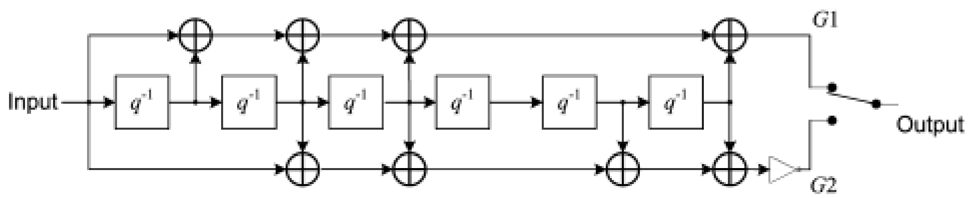

Figure GAL-6. Convolutional encoding scheme

3.1.3.1.2.2.10 *E1-B interleaving procedure*. The E1-B message block symbols shall be interleaved using a 30 column by an eight-row matrix, where each entry is one symbol. The message block symbols shall be written into each column and ordered for transmission row by row starting at the upper left corner of the matrix, as indicated in Table GAL-5.

Table GAL-5. E1-B interleaver matrix

Columns→ Rows ↓	C_1	C_2	C_3	…	C_{29}	C_{30}
R_1	S_1	S_9	S_{17}	…	S_{225}	S_{233}
R_2	S_2	S_{10}	S_{18}	…	S_{226}	S_{234}
R_3	S_3	S_{11}	S_{19}	…	S_{227}	S_{235}
…	…	…	…	…	…	…
R_7	S_7	S_{15}	S_{23}	…	S_{231}	S_{239}
R_8	S_8	S_{16}	S_{24}	…	S_{232}	S_{240}

3.1.3.1.2.2.11 *Transmission sequence of nominal pages on E1*. The pages shall be transmitted on E1-B such that the even subpage of any word shall be transmitted before the odd subpage of the same word.

3.1.3.1.3 *DATA CONTENT*

Note.— Additional information concerning Galileo OS navigation data content and parameters is given in Galileo OS SIS ICD, Chapters 4 and 5.

3.1.3.1.3.1 The contents of F/NAV E5a-I page types shall be according to Table GAL-6.

Note 1.— The odd numbered subframes contain page type 5 and the even numbered subframes contain page type 6. This allows transmission of the almanacs for three satellites within two successive subframes (100 seconds).

Note 2.— The parameter k is a designator for "satellite number 1", k+1 is a designator for "satellite number 2", etc. It is not a navigation data parameter. k is set by the Galileo control system. The complete F/NAV frame layout (12 subframes) can transmit the almanacs for 18 satellites, sequenced as indicated in Galileo OS SIS ICD, 4.2.3.

Note 3.— Additional information concerning the bit allocation of the different F/NAV page types is given in Galileo OS SIS ICD, 4.2.4.

Table GAL-6. F/NAV E5a-I page types content

Page type		Page content
Odd subframe	1	IODnav, SVID, clock correction, SIS accuracy index (SISA), ionospheric correction, broadcast group delay (BGD), signal health status (SHS), Galileo system time (GST) and data validity status (DVS)
	2	IODnav, ephemeris (1/3) and GST
	3	IODnav, ephemeris (2/3) and GST
	4	IODnav, ephemeris (3/3), GST-UTC conversion, GST-GPS conversion and time-of-week (TOW)
	5	IODa, almanac week number, almanac reference time, almanac for satellite k+3(n-1)/2 and almanac for satellite (k+1)+3(n-1)/2 part 1; where n is the number of the subframe
Even subframe	1	IODnav, SVID, clock correction, SISA, ionospheric correction, BGD, SHS, GST and DVS
	2	IODnav, ephemeris (1/3) and GST
	3	IODnav, ephemeris (2/3) and GST
	4	IODnav, ephemeris (3/3), GST-UTC conversion, GST-GPS conversion and TOW
	6	IODa, almanac for satellite (k+1)+3(n-2)/2 part 2 and almanac for satellite (k+2)+3(n-2)/2; where n is the number of the subframe

3.1.3.1.3.2 The contents of I/NAV E1-B word types shall be according to Table GAL-7.

Note 1.— Additional information concerning I/NAV nominal subframe layout is given in Galileo OS SIS ICD, 4.3.3.

Note 2.— The parameter k changes every two subframes (i.e. subframes 1 and 2 have the same k, subframes 3 and 4 have the next, etc.). The complete I/NAV frame layout (24 subframes) can transmit the almanacs for 36 satellites, sequenced as indicated in Galileo OS SIS ICD, 4.3.4.

Note 3.— Additional information concerning the bit allocations of the different I/NAV word types is given in Galileo OS SIS ICD, 4.3.5.

Table GAL-7. I/NAV E1-B word types content

Word type	Word content
0	Spare word
1	IODnav and ephemeris (1/4)
2	IODnav and ephemeris (2/4)
3	IODnav and ephemeris (3/4)
4	IODnav, SVID, ephemeris (4/4) and clock correction
5	Ionospheric correction, BGD, SHS, GST and DVS
6	GST-UTC conversion and TOW
7	IODa, almanac for satellite k (part 1), almanac reference time and almanac reference week number
8	IODa, almanac for satellite k (part 2) and satellite k+1 (part 1)
9	IODa, almanac reference time, almanac reference week number, almanac for satellite k+1 (part 2) and satellite k+2 (part 1)
10	IODa, almanac for satellite k+2 (part 2) and GST-GPS conversion parameters

3.1.3.1.3.3 Ephemeris parameters shall be provided in both I/NAV and F/NAV messages transmitted by each Galileo satellite. A single ephemeris shall be applicable to all signals of a specific satellite.

Note.— The ephemeris is computed with respect to the antenna apparent phase centre common to every frequency.

3.1.3.1.3.4 The Galileo OS SIS status shall take one of the following three values:

- SIS “healthy”: the SIS is expected to meet the minimum performance requirements.
- SIS “unhealthy”: the SIS is out of service or under test.
- SIS “marginal”: the SIS is in neither of the two previous states.

3.1.3.1.3.4.1 The status of the SIS shall be encoded within the navigation message through three SIS status flags: the signal health status (SHS) flag, the data validity status (DVS) flag and the SIS accuracy index (SISA).

Note.— Additional information concerning the position of the Galileo SIS status flags within the navigation message is given in Galileo OS SIS ICD, 5.1.9.3 and 5.1.12.

3.1.3.1.3.4.2 *SISA.* The SISA shall be encoded as shown in Table GAL-8.

Table GAL-8. SISA index

SISA	SIS accuracy value (m)
0 to 49	0 m to 0.49 m with 1 cm resolution
50 to 74	0.50 m to 0.98 m with 2 cm resolution
75 to 99	1.00 m to 1.96 m with 4 cm resolution
100 to 125	2.00 m to 6.00 m with 16 cm resolution
126 to 254	Spare
255	No Accuracy Prediction Available (NAPA)

3.1.3.1.3.4.3 SISA shall be coded as shown in Table GAL-9.

Table GAL-9. SISA parameters

Parameter	Definition	BITS	Scale factor	Units
SISA (E1, E5a)	SIS accuracy index for dual-frequency E1-E5a	8	N/A	Dimensionless
SISA (E1, E5b)	SIS accuracy index for dual-frequency E1-E5b	8	N/A	Dimensionless

3.1.3.1.3.4.4 *Signal health status (SHS).* The SHS index shall be encoded according to the values stated in Table GAL-10.

Table GAL-10. Signal health status index

SHS index	Signal status definition
0	Signal OK
1	Signal out of service
2	Signal will be out of service
3	Signal in test mode

3.1.3.1.3.4.5 *Data validity status (DVS).* The DVS index shall be encoded according to the values in Table GAL-11.

Table GAL-11. Data validity status index

Data validity status index	Signal status definition
0	Navigation data valid (NDV)
1	Working without guarantee (WWG)

3.1.3.1.3.4.6 The mapping between the values of the SIS status flags shall be as presented in Table GAL-12.

Table GAL-12. Galileo OS SIS status vs SIS status flags

SIS status	Dummy message	SIS flags		
		SHS	DVS	SISA
Healthy	NO	Ok	NDV	Not NAPA
Unhealthy	NO	Out of service	Any value	Any value
	NO	In test	Any value	Any value
	YES	N/A	N/A	N/A
Marginal	NO	Ok	WWG	Any value
	NO	Ok	Any value	NAPA
	NO	Will be out of service	Any value	Any value

Note.— Additional information concerning Galileo flags is given in the European GNSS (Galileo) Open Service Definition Document (Issue 1.1), dated May 2019 (hereinafter referred to as "Galileo OS SDD").

3.1.3.1.3.5 *Almanac*. F/NAV and I/NAV messages shall contain the almanac data for a constellation of up to 36 satellites. The almanac data shall be a reduced-precision subset of the clock and ephemeris parameters of the active Galileo satellites in orbit. Also, a predicted satellite health status shall be provided for each of these satellites, giving indications on the satellite's signal components health and navigation data health.

3.1.3.1.3.6 *Dummy messages.* If no valid F/NAV or I/NAV data can be transmitted, then the satellite shall transmit a dummy page with a message ID of 63 in the respective F/NAV or I/NAV signals.

Note.— Additional information concerning the dummy page is given in Galileo OS SIS ICD, 4.2.5 and 4.3.6.

3.1.3.1.3.7 *Issue of data (IOD).* The Galileo satellite shall broadcast the navigation parameters in data sets. Every set of navigation data broadcast by a Galileo satellite shall be identified by an IOD value.

Note.— Two independent IODs are defined for the ephemeris, satellite clock correction parameters and SISA ("IODnav") and the almanacs ("IODa").

3.1.3.1.3.7.1 The IODnav value broadcast by a Galileo satellite in a set of navigation data (ephemeris and clock corrections) shall be unique with respect to any other IODnav broadcast by the same Galileo satellite in the previous 240 minutes.

3.1.3.1.3.8 *Navigation data validity time.* In nominal operations, each navigation message data set shall be superseded before its expiration at four hours by the broadcast of a new navigation message data set.

Note.— The nominal period of ephemeris and clock corrections update ranges from 10 minutes to three hours.

3.1.3.1.3.9 *Galileo time of week (TOW).* The TOW shall cover an entire week from 0 to 604 799 seconds and shall be reset to zero at the end of each week.

Note.— The TOW is defined as the number of seconds that have occurred since the transition from the previous week.

3.1.3.1.3.10 *Galileo week number (WN).* The WN shall consist of 12 bits, which covers 4 096 weeks. The counter shall be reset to zero to cover an additional period Modulo 4 096.

Note.— The WN is an integer counter that gives the sequential week number from the GST start epoch.

3.1.3.2 *DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION*

3.1.3.2.1 *Parity check algorithm.* For the F/NAV and the I/NAV data, a CRC of 24 bits shall be generated from the following generator polynomial *G(X)*:

$$G(X) = (1 + X)P(X)$$

where

$$P(X) = X^{23} + X^{17} + X^{13} + X^{12} + X^{11} + X^{9} + X^{8} + X^{7} + X^{5} + X^{3} + 1$$

Note.— The CRC code is calculated in accordance with section 3.9 of this Appendix.

3.1.3.2.1.1 The F/NAV CRC information field, *M(X)*, shall be computed using the equation:

$$M(X) = \sum_{1}^{214} m_i X^{214-i} = m_1 X^{213} + m_2 X^{212} + \cdots + m_{213} X + m_{214}$$

M(X) shall be formed from the 6-bit E5a-I page type identifier and the 208-bit data field. Bits shall be arranged in the order transmitted from the Galileo satellite, such that m_1 corresponds to the first transmitted bit of the page type identifier, and m_{214} corresponds to bit 208 of the data field.

3.1.3.2.1.2 The I/NAV nominal page CRC information field, *M(X)*, shall be computed using the equation:

$$M(X) = \sum_{1}^{113} m_{e,i+1} X^{194-i} + \sum_{1}^{81} m_{o,i+1} X^{81-i} = m_{e,2} X^{193} + m_{e,3} X^{192} + \cdots + m_{e,113} X^{82} + m_{e,114} X^{81} + m_{o,2} X^{80} + m_{o,3} X^{79} + \ldots + m_{o,81} X + m_{o,82}$$

M(x) shall be formed from the even (e)/odd (0) fields, page type fields, data word fields (1/2 and 2/2), reserved 1 field, SAR (on E1-B only) and spare fields. In nominal mode the CRC shall be computed for the even and odd subpages of the same frequency and shall always be broadcast in the odd subpage.

3.1.3.2.2 *Satellite clock correction parameters.* The predicted offset of the physical satellite signal time of transmission (TOT) relative to the satellite signal TOT in GST shall be computed for the dual-frequency signal combination using the following formula:

$$TOT_c(X) = TOT_m(X) - \Delta t_{SV}(X)$$

where

- $(X)=(f_1,f_2)$ is the dual-frequency combination f_1 and f_2 used for the clock model;
- $TOT_C(X)$ is the corrected satellite TOT in GST for the signal combination X;
- $TOT_m(X)$ is the physical satellite TOT for the signal combination X retrieved through pseudo-range measurements; and
- $\Delta t_{SV}(X)$ is the satellite time correction for the signal combination X computed by means of the time correction data retrieved from the navigation message, as follows:

$$\Delta t_{SV}(X)=a_{f0}(X)+a_{f1}(X)[t-t_{0C}(X)]+a_{f2}(X)[t-t_{0C}(X)]^2+\Delta t_r$$

where

- $a_{f0}(X)$, $a_{f1}(X)$, $a_{f2}(X)$ and $t_{0c}(X)$ are parameters transmitted in F/NAV signals page Type 1 and I/NAV signals word Type 4 as indicated in 3.1.3.1.3;
- $t_{0c}(X)$ is the reference time for the clock correction;
- t is the GST time in seconds; and
- Δt_r, expressed in seconds, is a relativistic correction term, given by $\Delta t_r=F\ e\ A^{1/2}\sin(E)$ where the orbital parameters (e, $A^{1/2}$) are transmitted in F/NAV signals page Type 2 and I/NAV signals word Type 1 as indicated in 3.1.3.1.3, E is the calculated eccentric anomaly and $F = -2\mu^{1/2}/c^2 = -4.442807309 \times 10^{-10}$ s/m$^{1/2}$.

3.1.3.2.2.1 A single-frequency user receiver processing pseudo-ranges from the frequency f_1 shall apply the following correction to the satellite clock correction Δt_{SV} defined in paragraph 3.1.3.2.2:

$$\Delta t_{SV}(f_1) = \Delta t_{SV}(f_1,f_2) - BGD(f_1,f_2)$$

where

$BGD(f_1,f_2)$ is the broadcast group delay transmitted in F/NAV signals page Type 1 and I/NAV signals word Type 5 as indicated in 3.1.3.1.3 and defined as follows:

$$BGD(f_1,f_2) = \frac{TR_1 - TR_2}{1-\left(\frac{f_1}{f_2}\right)^2}$$

where

- f_1 and f_2 denote the carrier frequencies of E1 and E5a, respectively; and
- TR_1 and TR_2 are the group delays of the signals whose carrier frequencies are respectively f_1 and f_2.

3.1.3.2.2.2 A single-frequency user receiver processing pseudo-ranges from the frequency f_2 shall apply the following correction to the satellite clock correction Δt_{SV} defined in paragraph 3.1.3.2.2:

$$\Delta t_{SV}(f_2) = \Delta t_{SV}(f_1,f_2) - \left(\frac{f_1}{f_2}\right)^2 BGD(f_1,f_2)$$

3.1.3.2.3 *GST-UTC conversion algorithm and parameters.* The UTC time t_{UTC} shall be computed through three different cases depending on the epoch of a possible leap second adjustment (scheduled future or recent past) given by the day number (*DN*), the day at the end of which the leap second becomes effective, and the week number (WN_{LSF}) to which *DN* is referenced. "Day one" of *DN* shall be the first day relative to the end/start of week and the WN_{LSF} value shall consist of eight bits, which are a Modulo 256 binary representation of the Galileo week number to which the *DN* is referenced. The following three cases shall apply:

Case A:

Whenever the leap second adjustment time indicated by WN_{LSF} and *DN* is not in the past (relative to the user's present time), and the user's present time does not fall in the time span which starts six hours prior to the effective time, and ends six hours after the effective time, t_{UTC} shall be computed as follows:

$$t_{UTC} = (t_E - \Delta t_{UTC})[\text{Modulo } 86400]$$
$$\text{where } \Delta t_{UTC} = \Delta t_{LS} + A_0 + A_1(t_E - t_{0t} + 604800(WN - WN_{0t}))$$

Case B:

Whenever the user's current time falls within the time span of six hours prior to the leap second adjustment time to six hours after the adjustment time, t_{UTC} shall be computed as follows (Δt_{UTC} as defined in Case A):

$$t_{UTC} = W[\text{Modulo } (86400 + \Delta t_{LSF} - \Delta t_{LS})]$$
$$\text{where } W = (t_E - \Delta t_{UTC} - 43200)[\text{Modulo } 86400] + 43200$$

Case C:

Whenever the leap second adjustment time is in the "past" (relative to the user's current time), and the user's present time does not fall in the time span which starts six hours prior to the leap second adjustment time, and ends six hours after the adjustment time, t_{UTC} shall be computed as follows:

$$t_{UTC} = (t_E - \Delta t_{UTC})[\text{Modulo } 86400]$$
$$\text{where } \Delta t_{UTC} = \Delta t_{LSF} + A_0 + A_1(t_E - t_{0t} + 604800(WN - WN_{0t}))$$

- A_0, A_1, Δt_{LS}, t_{0t}, WN_{0t}, WN_{LSF}, *DN* and Δt_{LSF} are GST to UTC time conversion parameters transmitted in in F/NAV signals page Type 4 and I/NAV signals word Type 6 as indicated in 3.1.3.1.3;

- t_E is the GST as estimated by the user through its GST determination algorithm; and

- *WN* is the week number to which t_E is referenced.

3.1.3.2.4 *Satellite position.* The Earth-Centred, Earth-Fixed (ECEF) coordinates of the satellite antenna phase centre position at GST time *t* shall be computed using the following equations:

$$x = x'\cos(\Omega) - y'\cos(i)\sin(\Omega)$$

$$y = x'\sin(\Omega) + y'\cos(i)\cos(\Omega)$$

$$z = y'\sin(i)$$

where

$\Omega = \Omega_0 + (\dot{\Omega} - \omega_E)t_k - \omega_E t_{0e}$	corrected longitude of ascending node
$x' = r \cos u$	position in orbital plane
$y' = r \sin u$	position in orbital plane
$i = i_0 + \delta i + \frac{di}{dt} t_k$	corrected inclination
$r = A(1-e \cos E) + \delta r$	corrected radius
$u = \Phi + \delta u$	corrected argument of latitude
$A = (A^{1/2})^2$	semi-major axis
$\delta r = C_{rs} \sin 2\Phi + C_{rc} \cos 2\Phi$	radius correction
$\delta u = C_{us} \sin 2\Phi + C_{uc} \cos 2\Phi$	argument of latitude correction
$\delta i = C_{is} \sin 2\Phi + C_{ic} \cos 2\Phi$	inclination correction
$\Phi = v + \omega$	argument of latitude
$v = tan^{-1}\left\{ {\sin v}/{\cos v} \right\}$ $= tan^{-1}\left\{ \frac{\sqrt{1-e^2}\sin E / (1 - e\cos E)}{(\cos E - e) / (1 - e\cos E)} \right\}$	true anomaly
$t_k = t - sdf\ t_{0e}$	t is Galileo system time and t_k is the actual total time difference between the time t and the epoch time t_{0e} (t_{0a} for the almanacs) which accounts for beginning or end of week crossovers
$M = E - e \sin(E)$	Kepler's equation for eccentric anomaly E
$M = M_0 + nt_k$	mean anomaly
$n = n_0 + \Delta n$	corrected mean motion
$n_0 = \sqrt{\mu / A^3}$	computed mean motion (rad/s)
M_0, Δn, e, $A^{1/2}$, Ω_0, i_0, ω, $\dot{\Omega}$, di/dt, C_{uc}, C_{us}, C_{rc}, C_{rs}, C_{ic}, C_{is}, t_{0e}	ephemeris parameters transmitted in in F/NAV signals page Types 2, 3 and 4, as well as I/NAV signals word Types 1, 2, 3 and 4 as indicated in 3.1.3.1.3.
$\pi = 3.1415926535898$	ratio of a circle's circumference to its diameter
$\mu = 3.986004418 \times 10^{14}$ m^3/s^2	geocentric gravitational constant
$\omega_E = 7.2921151467 \times 10^{-5}$ rad/s	mean angular velocity of the earth
c = 299792458 m/s	speed of light in a vacuum

3.1.3.2.5 *Ionospheric correction.*

Note.— Receivers operating in single-frequency mode can use the single-frequency ionospheric correction algorithm described in document EUROCAE ED-259 Minimum Operational Performance Standard for Galileo/Global Positioning System/Satellite-based Augmentation System Airborne Equipment, Appendix J (any version).

3.1.3.3 AIRCRAFT ELEMENTS

3.1.3.3.1 *GALILEO RECEIVER*

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

3.1.3.3.1.2 *Doppler shift.* The receiver shall be able to compensate for dynamic Doppler shift effects on nominal Galileo signal carrier phase and OS code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.1.3.3.1.3 *Resistance to interference.* The receiver shall meet the requirements for resistance to interference as specified in 3.7.

3.1.3.3.1.4 *Application of clock and ephemeris data.* The receiver shall monitor the IODnav value and update ephemeris and clock data based upon a detected change in this parameter. To compute position and clock corrections, receivers shall use for each satellite, IODnav-tagged parameters corresponding to the same IODnav value. These parameters shall be retrieved from the most recent navigation data set received.

Note.— IODnav values are not necessarily incremented in steps of one. An IODnav with higher value does not necessarily mean that it tags more recent data. The only valid comparison between IODnav values is whether they are equal or not. For positioning, users can combine SIS from different satellites with different IODnav values, provided that the navigation parameters derived from each satellite are tagged by a unique IODnav value.

3.1.3.3.1.5 *Navigation data validity duration.* The receiver shall only use the ephemeris and clock corrections from a set of navigation data during a period of time no longer than four hours from the reference time of ephemeris (t_{0e}). The receiver shall not rely on performance commitments in Chapter 3, 3.7.3.1.3, if the age of t_{0e} exceeds four hours.

Note.— See Attachment D, 4.1.3.11 for guidance material on the age of t_{0e}.

3.1.3.4 TIME

3.1.3.4.1 *Galileo system time (GST).* The GST shall be a continuous timescale based on the definition of the second (according to the International System of Units, SI) whose origin/reference epoch (GST (T0)) shall be defined as 13 seconds before 1999-08-22 00:00:00 UTC. The Galileo navigation message shall contain all necessary parameters to convert between GST and UTC.

Note.— See Attachment D, 4.1.3.9 for GST guidance material.

3.1.3.5 COORDINATE SYSTEM

3.1.3.5.1 The Galileo OS broadcast ephemeris shall determine the position of the transmitting antenna phase centre of a given satellite in the Galileo Terrestrial Reference Frame (GTRF) ECEF reference frame.

3.1.3.5.2 The GTRF difference from the latest physical realization of the International Terrestrial Reference Frame (ITRF) shall not exceed 3 cm 95 per cent globally.

Note 1.— WGS-84 and GTRF are both realizations of ITRF. The difference between GTRF and WGS-84 used in GPS, is considered insignificant for aviation.

Note 2.— See Attachment D, 4.1.3.10 for additional information on GTRF.

End of new text.

Editorial note.— Renumber sections 3.1.3 and 3.1.4 as 3.1.4 and 3.1.5, respectively.

ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

. . .

4. GNSS CORE ELEMENTS

4.1 Core constellations

. . .

Editorial note.— Insert new section 4.1.3 as follows:

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*

4.1.3.2.1 *Position domain accuracy for single-frequency Galileo OS.* The horizontal/vertical position domain accuracy is measured with a representative receiver and a measurement interval of 30 days for any point within the coverage area. The position is computed using single-frequency "healthy" SIS. The positioning and timing accuracy are for the SIS only (including BGD errors) and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath.

4.1.3.2.2 *Position domain accuracy for dual-frequency Galileo OS.* The horizontal/vertical position domain accuracy is measured with a representative receiver and a measurement interval of 30 days for any point within the coverage area. The position is computed using dual-frequency "healthy" SIS. The positioning and timing accuracy are for the SIS only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath.

4.1.3.3 *Range domain accuracy.* The Galileo ranging accuracy is defined as a statistical measure of the SIS range error time series. It is only measured for time periods during which the transmitted SIS is healthy. Galileo ranging accuracy is evaluated over all age of data (AOD) values, i.e. the SIS range error time series will consider the navigation message at the age of data when it was observed. It is computed for both single-frequency and dual-frequency users. 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 95th percentile SIS range error accuracy for any satellite is calculated over a 30-day interval. The 99.9th percentile SIS range error accuracy for any satellite is normalized annually.

4.1.3.3.1 *SIS accuracy.* The SIS accuracy is a prediction of the minimum standard deviation (1-sigma) of the unbiased Gaussian distribution which overbounds the predictable distribution of SIS range error for all possible user locations within the satellite coverage area. The SISA parameter, broadcast in Galileo SIS navigation message, provides the user with an indication of the SIS accuracy according to Appendix B, 3.1.3.1.3.4.2. The SISA parameter can assume 255 values. Nevertheless, when it is used as one of the means for determining the SIS status of a Galileo satellite, it must be considered as a binary indicator with its only meaningful values being “no accuracy prediction available” (NAPA) when SISA=255 or “not NAPA” when SISA≠255. SISA values from 126 to 254 are described as spare, and should be considered as “not NAPA”.

4.1.3.3.2 *Galileo BGD.* Galileo BGD is the estimate of the group delay between the different frequencies of a specific Galileo satellite. It is provided as part of the Galileo broadcast navigation data as specified in Appendix B, 3.1.3.1.3.1 and 3.1.3.1.3.2.

4.1.3.4 *Galileo UTC time determination accuracy.* The Galileo UTC time determination accuracy depends on both the instantaneous GST determination error and on the error in the broadcast GST-UTC conversion parameters. This second component is defined as the Galileo SIS UTC time dissemination accuracy.

4.1.3.4.1 *Galileo SIS UTC time dissemination accuracy.* The Galileo SIS UTC time dissemination accuracy is defined as the 95th percentile of the broadcast GST/UTC conversion parameters error. Galileo SIS UTC time dissemination accuracy is the SIS component of the overall user UTC time determination, which is driven by the accuracy of the broadcast GST-UTC parameters. It does not contain effects that are not under the control of the Galileo operator 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 P_{sat} in a normal distribution. The *k* factor is 4.17, corresponding to the 3×10^{-5} P_{sat} value. P_{sat} 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. P_{const} 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 P_{sat}. Galileo $\sigma_{URA,DF}$ applies to any user location and to a healthy SIS dual-frequency combination E1/E5a.

4.1.3.6.4 $\sigma_{URA,SF}$. 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 P_{sat}. Galileo $\sigma_{URA,SF}$ 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

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

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, without further activity by the user equipment.

4.1.3.11 *Age of ephemeris.* The age of ephemeris is the time elapsed between the reference t_{0e} (set at the beginning of each navigation data set) and the time of usage of the ephemeris by a receiver.

Note.— Details on how to compute the age of ephemeris can be found in Galileo OS SDD, Annex C, section 4.4.1.

4.1.3.12 *Age of data (AOD).* The age of data (AOD) is the elapsed time between the generation of a navigation message by the ground segment and its usage at user level. Aging of data (characterized by AOD) impacts the accuracy of the orbit and clock models. The accuracy of their prediction inevitably degrades with higher ages.

End of new text.

Origin:	*Rationale*:
NSP/6	This proposal is intended to reflect the introduction of the Galileo satellite navigation system, operated by the European Union. It is currently not included in Annex 10. The proposed Galileo SARPs include two signals in two frequency bands to provide positioning, velocity and timing information to Galileo users on a continuous, worldwide basis. The availability of this additional constellation using two frequency bands will contribute to mitigate ionospheric scintillation and the risk of having insufficient satellites within a single constellation, as well as vulnerabilities in respect of ionospheric disturbance and radio frequency interference.

INITIAL PROPOSAL 5
BeiDou Navigation Satellite System (BDS)

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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3.7 Requirements for the Global Navigation Satellite System (GNSS)

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3.7.3 GNSS elements specifications

3.7.3.1 *Core constellations*

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Editorial note.— Insert new section 3.7.3.1.4 as follows:

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 period of 7 days	15 m	15 m	15 m	15 m
Worst site 95% threshold:				
Horizontal position error over a measurement period of 7 days	15 m	15 m	15 m	15 m
Vertical position error over a measurement period of 7 days	22 m	22 m	22 m	22 m

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

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

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

3.7.3.1.4.2 *Availability.* The BDS OS availability shall be as follows:

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

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

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

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

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

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

3.7.3.1.4.4 *Probability of major service failure*

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

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

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

Note 1.— For B1I signals, the NTE tolerance is defined to be 4.42 times the upper bound of the URA range corresponding to the URA index (URAI) value being broadcast in D1 navigation messages, as described in Appendix B, section 3.1.4.1.3.1.2.

Note 2.— For B1C and B2a signals, the NTE tolerance is defined to be 4.42 times the signal-in-space accuracy (SISA) value calculated as described in Appendix B, section 3.1.4.2.5.

Note 3.— The mapping between BDS B1I SIS status and BDS B1I flags contained in the navigation data message is specified in Appendix B, 3.1.4.1.3.1.3. The mapping between BDS B1C and B2a SIS status and BDS B1C and B2a flags contained in the navigation data message is specified in Appendix B, 3.1.4.1.3.2.7.2.

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

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

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

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

3.7.3.1.4.7 *Radio frequency (RF) characteristics*

Note.— Detailed BDS OS signals RF characteristics are specified in Appendix B, 3.1.4.1.1.

3.7.3.1.4.8 *B1I radio frequency (RF) characteristics*

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

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

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

3.7.3.1.4.8.4 *B1I signal power levels*

3.7.3.1.4.8.4.1 Each BDS-3 MEO satellite shall broadcast a B1I navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –163 dBW to –154.8 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.8.4.2 Each BDS-3 IGSO satellite shall broadcast a B1I navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –163 dBW to –156.5 dBW for all antenna orientations orthogonal to the direction of propagation.

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

3.7.3.1.4.9 *B1C radio frequency (RF) characteristics*

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

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

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

3.7.3.1.4.9.4 *B1C signal power levels*

3.7.3.1.4.9.4.1 Each BDS-3 MEO satellite shall broadcast a B1C navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –159 dBW to –152.5 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.1.4.9.4.2 Each BDS-3 IGSO satellite shall broadcast a B1C navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly-polarized antenna is within the range of –161 dBW to –153.5 dBW for all antenna orientations orthogonal to the direction of propagation.

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

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

3.7.3.1.4.10 *B2a radio frequency (RF) characteristics*

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

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

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

3.7.3.1.4.10.4 *B2a signal power levels*

3.7.3.1.4.10.4.1 Each BDS-3 MEO satellite shall broadcast a B2a navigation signal with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, 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.

End of new text.

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

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3. GNSS ELEMENTS

3.1 Core constellations

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Editorial note.— Insert new section 3.1.4 as follows:

3.1.4. BeiDou Navigation Satellite System (BDS) Open Service (OS) (B1I, B1C and B2a)

3.1.4.1 NON-AIRCRAFT ELEMENTS

3.1.4.1.1 *BDS RF CHARACTERISTICS*

Note.— This section describes RF characteristics of the BDS B1I, B1C and B2a signals transmitted by BDS-3 MEO and IGSO satellites.

3.1.4.1.1.1 B1I, B1C and B2a common requirements

3.1.4.1.1.1.1 *Carrier phase noise.* The carrier phase noise spectral density of the unmodulated carrier on B1I, B1C and B2a shall be such that a third-order phase locked loop of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian root mean square (RMS).

3.1.4.1.1.1.2 *Spurious emissions.* In-band spurious emissions shall be at least 50 dB below the unmodulated B1I, B1C and B2a carrier over the allocated channel bandwidth.

Note.— The allocated channel bandwidth for the B1I signal is 4.096 MHz. The allocated channel bandwidth for the B1C signal is 32.736 MHz. The allocated channel bandwidth for the B2a signal is 20.46 MHz.

3.1.4.1.1.1.3 *Data/code coherence.* The edge of each data symbol shall be aligned with the edge of the corresponding ranging code chip, and the start time of the first chip of the periodic ranging code shall be aligned with the start time of the data symbol bit. The edges of each secondary code chip shall be aligned with the edges of the primary code chip and the primary code first chip start time shall be aligned with the starting time of the secondary code chip.

3.1.4.1.1.2 *B1I RF characteristics*

3.1.4.1.1.2.1 *B1I correlation loss*. The correlation loss due to payload distortions shall not exceed 0.6 dB on B1I.

3.1.4.1.1.2.2 *B1I ranging code.* The chipping rate of the B1I ranging code shall be 2.046 megachips per second, and the length shall be 2 046 chips. The B1I ranging code (hereinafter referred to as C_{B1I}) shall be a balanced Gold code truncated with the last one chip. The Gold code shall be generated by means of Modulo-2 addition of G1 and G2 sequences, which are respectively derived from two 11-bit linear shift registers. The generator of C_{B1I} shall be as shown in Figure B BDS-1.

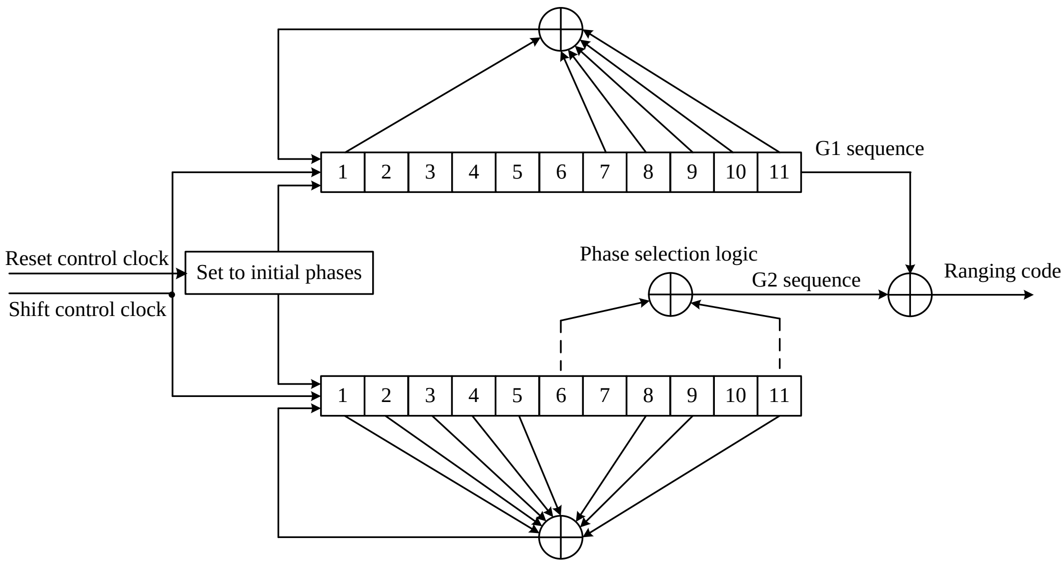

Figure B BDS-1. Generator of C_{B1I}

Note.— Additional information concerning the B1I ranging code is given in the BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal B1I (Version 3.0), dated February 2019 (hereinafter referred to as "BDS OS B1I ICD"), section 4.3.

3.1.4.1.1.3 *B1C RF characteristics*

3.1.4.1.1.3.1 *B1C correlation loss.* The correlation loss due to payload distortions shall not exceed 0.3 dB on B1C.

3.1.4.1.1.3.2 *B1C signal generation*. The B1C signal shall comprise two components, known as B1C data component and B1C pilot component.

3.1.4.1.1.3.3 *B1C signal power split*. The B1C signal power shall be 1:3 split between the B1C data component and the B1C pilot component.

3.1.4.1.1.3.4 *B1C data ranging code (C_{B1C_data}*). The B1C data ranging code sequence shall be a 10 230-chip length primary code repeated every 10 milliseconds.

Note.— Additional information concerning the B1C data primary code is given in BDS OS B1C ICD, section 5.2.1.

3.1.4.1.1.3.5 *B1C pilot ranging code (C_{B1C_pilot}).* The B1C pilot ranging code sequence shall be the Modulo-2 addition of a 10 230-chip length primary code repeated every 10 milliseconds and a 1 800-chip length secondary code repeated every 18 000 milliseconds.

Note. — Additional information concerning the B1C pilot primary code and secondary code is given in BDS OS B1C ICD, sections 5.2.1 and 5.2.2.

3.1.4.1.1.3.6 *B1C data component (S_{B1C_data}) generation.* The B1C data component shall be generated from the navigation message data (D_{B1C_data}) and the ranging code (C_{B1C_data}) modulated with the sine-phased BOC(1,1) subcarrier sc_{B1C_data}.

3.1.4.1.1.3.7 *B1C pilot component (s_{B1C_pilot}) generation.* The B1C pilot component shall be generated from the ranging code (C_{B1C_pilot}) modulated with the QMBOC(6, 1, 4/33) subcarrier sc_{B1C_pilot}. The subcarrier shall be composed of a BOC(1, 1) subcarrier and a BOC(6, 1) subcarrier, which shall be in phase quadrature with each other and have a power ratio of 29:4.

Note. — Additional information concerning B1C modulation is given in BDS OS B1C ICD, section 4.2.

3.1.4.1.1.4 *B2a RF characteristics*

3.1.4.1.1.4.1 *B2a correlation loss*. The correlation loss due to payload distortions shall not exceed 0.6 dB on B2a.

3.1.4.1.1.4.2 *B2a signal generation*. The B2a signal shall comprise two components known as B2a data component and B2a pilot component.

3.1.4.1.1.4.3 *B2a signal power split*. The B2a signal power shall be equally split between the B2a data component and the B2a pilot component.

3.1.4.1.1.4.4 *B2a data ranging code (C_{B2a_data})*. The B2a data ranging code sequence shall be the Modulo-2 addition of a 10 230-chip length primary code repeated every 1 millisecond and a 5-chip length secondary code repeated every 5 milliseconds.

Note.— Additional information concerning B2a_data primary code and secondary code is given in BDS OS B2a ICD, sections 5.2.1 and 5.2.2.

3.1.4.1.1.4.5 *B2a pilot ranging code (C_{B2a_pilot})*. The B2a pilot ranging code sequence shall be the Modulo-2 addition of a 10 230-chip length primary code repeated every 10 millisecond and a 100-chip length secondary code repeated every 100 milliseconds.

Note.— Additional information concerning B2a_pilot primary code and secondary code is given in BDS OS B2a ICD, sections 5.2.1 and 5.2.2.

3.1.4.1.1.4.6 *B2a data component (s_{B2a_data}) generation.* The B2a data component shall be BPSK(10) modulated from the navigation message data (D_{B2a_data}) and the ranging code (C_{B2a_data}).

3.1.4.1.1.4.7 *B2a pilot component (s_{B2a_pilot}) generation.* The B2a pilot component shall be BPSK(10) modulated from the ranging code $C_{B2a\_pilot}(t)$ only.

Note.— Additional information concerning B2a modulation is given in BDS OS B2a ICD, section 4.2.

3.1.4.1.2 DATA STRUCTURE

3.1.4.1.2.1 *B1I D1 message characteristics*

3.1.4.1.2.1.1 *General.* The B1I navigation message broadcast by BDS-3 MEOs and IGSOs B1I signals (“D1 navigation message”) shall be modulated with 1 kbps secondary Neuman-Hofman (NH) code. The D1 navigation message shall be structured into superframes, frames and subframes. The frame structure of the D1 navigation message shall be as shown in Figure B BDS-2.

Note.— Additional information concerning the NH code is given in BDS OS B1I ICD, section 5.2.1.

3.1.4.1.2.1.2 *Superframe*. Every superframe shall contain 36 000 bits. Every superframe shall be composed of 24 frames (24 pages).

3.1.4.1.2.1.3 *Frame*. Every frame shall contain 1 500 bits. Every frame shall be composed of 5 subframes.

3.1.4.1.2.1.4 *Subframe*. Every subframe shall contain 300 bits. Every subframe shall be composed of 10 words. Every word shall contain 30 bits. Every word shall consist of navigation message data and parity bits.

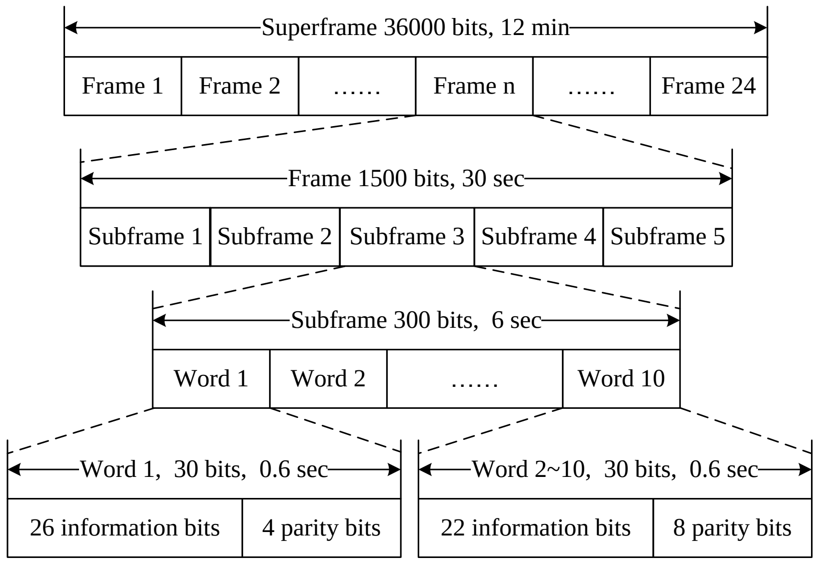

Figure B BDS-2. Frame structure of the D1 navigation message

3.1.4.1.2.1.5 *Data parity.* Word 1 of each subframe shall contain 26 information bits and 4 parity bits in the least significant bits (LSBs), and words 2 through 10 shall contain 22 information bits and 8 parity bits in the LSBs. Bose-Chaudhuri-Hocquenghem (BCH)(15,11,1) encoding shall be used for error control and interleaving.

Note.— Additional information concerning BCH(15,11,1) encoding is given in BDS OS B1I ICD, section 5.1.3.

3.1.4.1.2.1.6 *Preamble.* Bits 1 through 11 of every subframe shall contain a preamble consisting of the sequence of bits "11100010010".

3.1.4.1.2.1.7 *Subframe identification.* Bits 16 through 18 of every subframe shall contain the subframe identification, encoded as follows:

Code	001	010	011	100	101	110	111
Subframe identification	1	2	3	4	5	Reserved	Reserved

3.1.4.1.2.1.8 *Seconds-of-week (SOW).* Bits 19 through 26 and bits 31 through 42 of each subframe of the D1 navigation message shall contain the 20-bit seconds-of-week (SOW), which is defined as the number of seconds that have occurred since the last Sunday, 00:00:00 BDT. The SOW count shall occur at the leading edge of the first preamble bit (MSB) of the subframe.

3.1.4.1.2.1.9 *Reserved bits.* Bits 12 through 15 of every subframe or page of a subframe shall be reserved.

3.1.4.1.2.2 *B1C message characteristics*

3.1.4.1.2.2.1 *General.* The B1C navigation message (B-CNAV1 navigation message) shall be broadcast as a sequence of frames. Each frame shall contain 1 800 symbols with a symbol rate of 100 symbols per second. Each frame shall consist of three subframes with the basic frame structure shown in Figure B BDS-3.

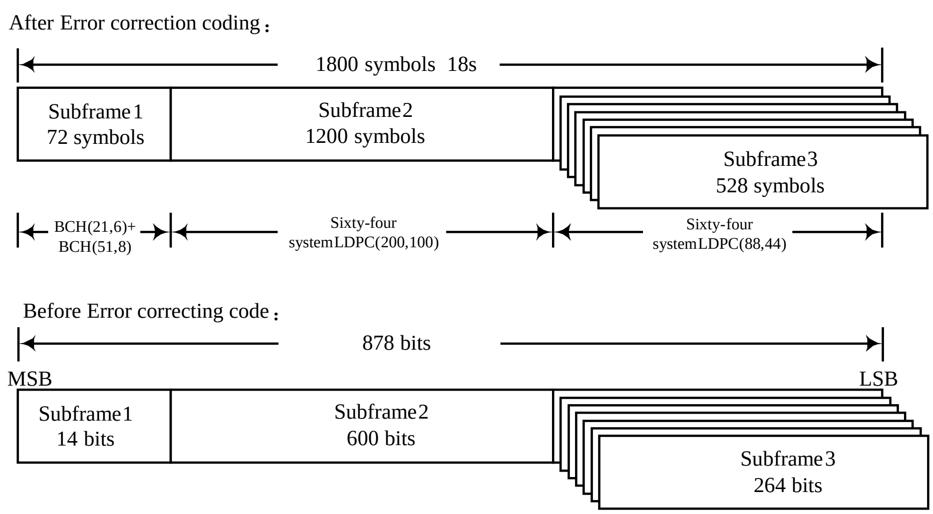

Figure B BDS-3. Basic frame structure of B-CNAV1

3.1.4.1.2.2.2 *Subframe 1*. Subframe 1 shall contain 14 bits before BCH error correction encoding. After BCH (21,6) + BCH (51,8) encoding, its length shall be 72 symbols.

Note.— Additional information concerning BCH(21,6)+BCH(51,8) encoding is given in BDS OS B1C ICD, section 6.2.2.1.

3.1.4.1.2.2.3 *Subframe 2*. Subframe 2 shall contain 600 bits before low-density parity check (LDPC) encoding. The 576 MSBs of subframe 2 shall be included in the CRC calculation, and the 24 LSBs shall be the corresponding CRC bits. After 64-ary LDPC (200, 100) encoding, its length shall be 1 200 symbols.

Note.— Additional information concerning 64-ary LDPC (200, 100) encoding is given in BDS OS B1C ICD, section 6.2.2.2.

3.1.4.1.2.2.4 *Subframe 3*. Subframe 3 shall contain 264 bits before LDPC encoding. The 6 MSBs shall be the page type (PageID), the 24 LSBs shall be CRC bits, and the remaining 234 bits shall be message data. PageID and message data shall be included in the CRC calculation. After 64-ary LDPC (88,44) encoding, its length shall be 528 symbols. The frame structure of subframe 3 shall be as shown in Figure B BDS-4.

Note.— Additional information concerning 64-ary LDPC (88,44) encoding is given in BDS OS B1C ICD, section 6.2.2.3.

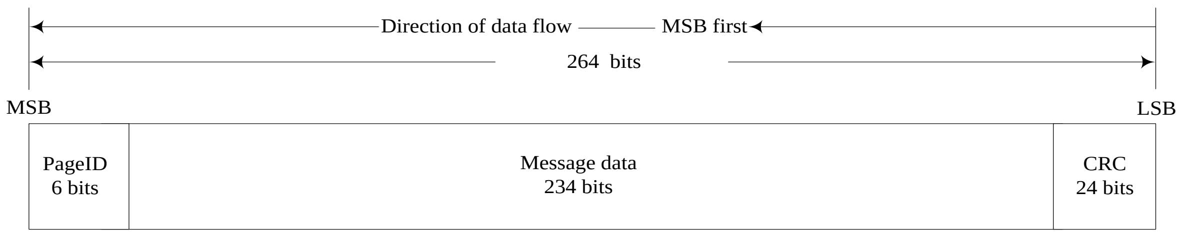

Figure B BDS-4. Frame structure for B-CNAV1 subframe 3

3.1.4.1.2.2.5 *Interleaving.* After encoding, subframe 2 and subframe 3 shall be combined and interleaved using a block interleaver.

Note.— Additional information concerning interleaving is given in BDS OS B1C ICD, section 6.2.2.4.

3.1.4.1.2.3 *B2a message characteristics*

3.1.4.1.2.3.1 *General*. The B2a navigation message ("B-CNAV2 navigation message") shall be broadcast as a sequence of frames. Each frame shall contain 600 symbols with a symbol rate of 200 symbols per second. The B-CNAV2 basic frame structure shall be as shown in Figure B BDS-5.

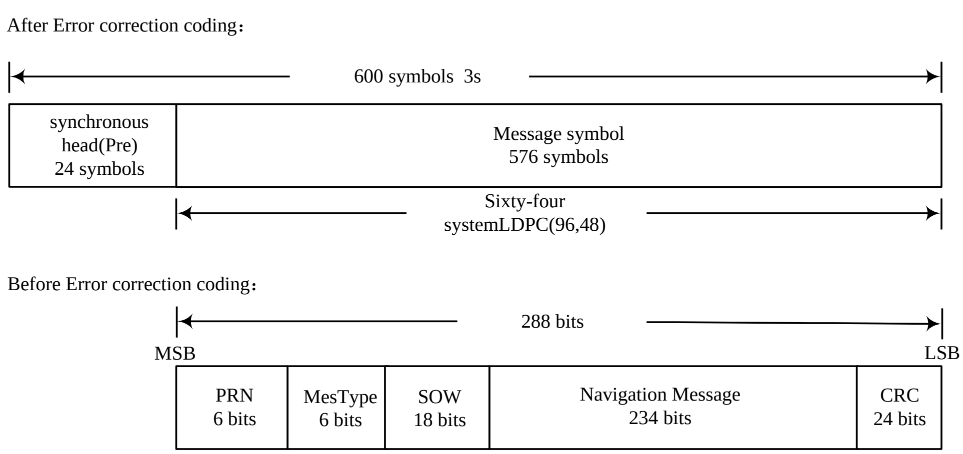

Figure B BDS-5. B-CNAV2 basic frame structure

3.1.4.1.2.3.2 *Frame structure.* Each frame shall consist of a 24-symbol preamble and a 288-bit navigation message before error correction encoding. After encoding by 64-ary LDPC (96,48), its length shall be 1 200 symbols.

Note.— Additional information concerning 64-ary LDPC (96,48) encoding is given in BDS OS B2a ICD, section 6.2.2.

3.1.4.1.2.3.2.1 *Preamble.* Each frame shall contain a preamble consisting of the sequence of bits "111000100100110111101000".

3.1.4.1.2.3.2.2 *Navigation message*. Each frame shall contain 288 bits before LDPC encoding, including the 6-bit PRN code, 6-bit message type, 18-bit SOW, 234-bit message data and 24-bit CRC. PRN, message type, SOW, and message data shall be included in the CRC calculation. After 64-ary LDPC(96, 48) encoding, the frame length shall be 576 symbols.

3.1.4.1.3 *DATA CONTENT*

Note.— A full description of the data content of the words being transmitted is given in BDS OS B1I ICD, BDS OS B1I ICD and BDS OS B2a ICD.

3.1.4.1.3.1 *B1I data content*

3.1.4.1.3.1.1 The B1I D1 navigation data shall contain the information listed in Table B BDS-1.

Note.— Additional information concerning B1I D1 content and application of the data is given in BDS OS B1I ICD, section 5.2.4.

Table B BDS-1. B1I D1 navigation message content

Subframe number	*Page number*	*Data content*
1	*N/A*	Week number (WN), user range accuracy index (URAI), autonomous satellite health flag (SatH1), ionosphere model parameters (α_n, β_n, n=0 - 3), equipment group delay differential (T_{GD1},T_{GD2}), clock correction parameters (t_{oc}, a_0, a_1, a_2), age of data, clock (AODC), age of data, ephemeris (AODE)
2	*N/A*	Ephemeris parameters (1/2) ($\sqrt{A}$, e, Δn, M_0, C_{uc}, C_{us}, C_{rc}, C_{rs})
3	*N/A*	Ephemeris parameters (2/2) (t_{oe}, ω, Ω_0, $\dot{\Omega}$, i_0, IDOT, C_{ic}, C_{is})
4	1 - 24	Pnum, almanac parameters (t_{oa}, $\sqrt{A}$, e, ω, M_0, Ω_0, $\dot{\Omega}$, δ_i, a_0, a_1, AmEpID)
5	1 - 6	
5	7	Pnum, health information for 19 satellites (Hea_i, i=1 - 19)
5	8	Pnum, health information for 11 satellites (Hea_i, i=20 - 30), week number of almanac (WN_a), t_{oa},
5	9	Pnum, time parameters relative to GPS time (A_{0GPS}, A_{1GPS}), time parameters relative to GLONASS time (A_{0GLO}, A_{1GLO}), time parameters relative to Galileo time (A_{0Gal}, A_{1Gal})
5	10	Pnum, time parameters relative to UTC (A_{0UTC}, A_{1UTC}, Δt_{LS}, Δt_{LSF},WN_{LSF}, DN)
5	11 - 23	Pnum, almanac parameters (t_{oa}, $\sqrt{A}$, e, ω, M_0, Ω_0, $\dot{\Omega}$, δ_i, a_0, a_1, AmID)
5	24	Pnum, health information for 14 satellites (Hea_i, i=31 - 43)

3.1.4.1.3.1.2 *User range accuracy index (URAI)*. Bits 49 through 52 of subframe 1 of the D1 message shall contain the URAI. The range of URAI shall be from 0 to 15. The user range accuracy (URA) shall be used to describe the signal-in-space accuracy (SISA) in metres. The relationship between URAI and URA shall be as shown in Table B BDS-2.

Note.— Additional information concerning URAI is given in BDS OS B1I ICD, section 5.2.4.5 and section 5.2.3, Figure 5-8.

Table B BDS-2. Relationship between URAI and URA

Code	URAI	URA range (m, 1σ)
0000	0	0.00 < URA ≤ 2.40
0001	1	2.40 < URA ≤ 3.40
0010	2	3.40 < URA ≤ 4.85
0011	3	4.85 < URA ≤ 6.85
0100	4	6.85 < URA ≤ 9.65
0101	5	9.65 < URA ≤ 13.65
0110	6	13.65 < URA ≤ 24.00
0111	7	24.00 < URA ≤ 48.00
1000	8	48.00 < URA ≤ 96.00
1001	9	96.00 < URA ≤ 192.00
1010	10	192.00 < URA ≤ 384.00
1011	11	384.00 < URA ≤ 768.00
1100	12	768.00 < URA ≤ 1 536.00
1101	13	1 536.00 < URA ≤ 3 072.00
1110	14	3 072.00 < URA ≤ 6 144.00
1111	15	URA > 6 144.00

3.1.4.1.3.1.3 *Autonomous satellite health flag (SatH1)*. Bit 43 of subframe 1 of the D1 message shall provide SatH1. A value of "0" shall indicate that the broadcasting satellite is healthy and a value of "1" shall indicate that the broadcasting satellite is unhealthy.

Note.— Additional information concerning SatH1is given in BDS OS B1I ICD, section 5.2.4.6 and section 5.2.3, Figure 5-8.

3.1.4.1.3.1.4 Satellite clock correction parameter t_{oc} shall be broadcast in the D1 navigation message. The value of t_{oc} shall monotonically increase over the week and shall change if any of the clock parameters change.

Note.— The update of the clock parameters always starts at the beginning of a superframe.

3.1.4.1.3.1.5 Satellite ephemeris parameter t_{oe} shall be broadcast in the D1 navigation message. The value of t_{oe} shall monotonically increase over the week and shall change if any of the ephemeris parameters change. If t_{oe} changes, then t_{oc} shall also change.

Note.— The update of the ephemeris parameters always starts at the beginning of a superframe.

3.1.4.1.3.1.6 *Page number (Pnum*). Both subframe 4 and subframe 5 shall have 24 pages which shall be identified through the page number (Pnum) contained in bits 44 through 50 of the subframes.

3.1.4.1.3.1.7 *Identification of expanded almanacs (AmEpID).* Bits 291 through 292 of pages 1 through 24 of subframe 4 and pages 1 to 6 of subframe 5 shall contain AmEpID. A binary value of "11" of AmEpID shall indicate that pages 11 through 23 of subframe 5 are used to broadcast the almanac parameters for SV ID 31 through 63, and page 24 of subframe 5 is used to broadcast the satellite health information for SV ID 31 through 63. Otherwise, pages 11 through 24 of subframe 5 shall be reserved.

3.1.4.1.3.1.8 *Identification of time-sharing broadcasting (AmID)*. Bits 291 through 292 of pages 11 through 23 of subframe 5 and bits 216 through 217 of page 24 of subframe 5 shall provide AmID. AmID shall be used combining with AmEpID and Pnum to indicate the PRN of the satellite transmitting the almanac parameters in the Pnum page. AmID shall only be used when AmEpID has a binary value of "11". The broadcasting scheme for the almanac parameters of SV ID 31 through 63 shall be as shown in Table B BDS-3.

Table B BDS-3. Broadcasting scheme for the almanac parameters of PRNs 31 through 63

AmEpID	AmID	Pnum	PRN
11	01	11 - 23	31 - 43
	10	11 - 23	44 - 56
	11	11 - 17	57 - 63
		18 - 23	Reserved
	00	11 - 23	Reserved

3.1.4.1.3.2 *B1C and B2a data content*

3.1.4.1.3.2.1 The B-CNAV1 data broadcasted on B1C shall contain the information listed in Table B BDS-4. The B-CNAV2 data broadcasted on B2a shall contain the message types and data content listed in Table B BDS-5.

Note 1.— Additional information concerning B-CNAV1 data content and application of the data is given in BDS OS B1C ICD, section 7.

Note 2.— Additional information concerning B-CNAV2 data content and application of the data is given in BDS OS B2a ICD, section 7.

Table B BDS-4. B1C navigation message information contents

Subframe number	Data content	
1	PRN, SOH	
2	WN, HOW, IODC (issue of data, clock), IODE (issue of data, ephemeris)	
	Data blocks*	Ephemeris I* (t_{oe}, SatType,ΔA, $\dot{A}$, Δn_0, $\Delta \dot{n}_0$, M_0, e, ω)
		Ephemeris II* (Ω_0, i_0, $\dot{\Omega}$, $\dot{i}_0$, C_{is}, C_{ic}, C_{rs}, C_{rc}, C_{us}, C_{uc})
		Clock correction parameters* (t_{oc} , a_0 , a_1 , a_2)
	TGD_{B2ap}, ISC_{B1Cd}, TGD_{B1Cp}, Rev, CRC	
3**	Page Type 1(PageID, health status(HS), data integrity flag (DIF), signal integrity flag (SIF), accuracy integrity flag (AIF), signal-in-space monitored accuracy index (SISMAI)***, SISAIoe, SISAIoc*, ionospheric delay correction model parameters*, BDT-UTC time offset parameters*)	
	Page Type 2 (PageID, HS, DIF, SIF, AIF, SISMAI***, SISAIoc*, WNa, t_{oa} , reduced almanac*)	
	Page Type 3 (PageID, HS, DIF, SIF, AIF, SISMAI***, SISAIoe, earth orientation parameters (EOP), BDT-GNSS time offset (BGTO) parameters)	
	Page Type 4 (PageID, HS, DIF, SIF, AIF, SISMAI***, SISAIoc*, midi almanac*)	

* Data blocks containing a set of parameters.

** At most 63 page types can be defined for subframe 3. Currently, four valid page types have been defined: 1, 2, 3 and 4.

*** SISMA broadcast in B-CNAV1 is reserved for future use.

Table B BDS-5. B2a message types and the data content

	Message type**	Data content
1	10	PRN, MesType, SOW, WN, DIF(B2a), SIF(B2a), AIF(B2a), SISMAI**** , DIF(B1C), SIF(B1C), IODE, ephemeris I*
2	11	PRN, MesType, SOW, HS, DIF(B2a), SIF(B2a), AIF(B2a), SISMAI**** , DIF(B1C), SIF(B1C), ephemeris II*
3	30	PRN, MesType, SOW, HS, DIF(B2a), SIF(B2a), AIF(B2a), SISMAI**** , DIF(B1C), SIF(B1C), clock correction parameters*, IODC, T_{GDB2ap}, ISC_{B2ad}, ionospheric delay correction model parameters* , T_{GDB1Cp}
4	31	PRN, MesType, SOW, HS, DIF(B2a), SIF(B2a), AIF(B2a), SISMAI**** , DIF(B1C), SIF(B1C), clock correction parameters*, IODC, WNa , toa, reduced almanac parameters*
5	32	PRN, MesType, SOW, HS,DIF(B2a), SIF(B2a), AIF(B2a), SISMAI**** , DIF(B1C), SIF(B1C), clock correction parameters*, IODC, EOP
6	33	PRN, MesType, SOW, HS, DIF(B2a), SIF(B2a), AIF(B2a), SISMAI**** , DIF(B1C), SIF(B1C), AIF(B1C), clock correction parameters*, BGTO parameters*, reduced almanac parameters*, IODC, WNa, toa
7	34	PRN, MesType, SOW, HS, DIF(B2a), SIF(B2a), AIF(B2a), SISMAI**** , DIF(B1C), SIF(B1C), SISAIoc* , clock correction parameters*, IODC, BDT-UTC time offset parameter*
8	40	PRN, MesType, SOW, HS, DIF(B2a), SIF(B2a), AIF(B2a),SISMAI**** , DIF(B1C), SIF(B1C), SISAIoe , SISAIoc*, midi almanac parameters*

* Data blocks containing a set of parameters.

** At most 63 message types can be defined for the B-CNAV2 navigation message. Currently, eight valid message types have been defined: 10, 11, 30, 31, 32, 33, 34 and 40.

*** The broadcast order of the B-CNAV2 message types may be dynamically adjusted, however Message Types 10 and 11 are broadcast continuously together.

**** SISMAI broadcast in B-CNAV2 is reserved for future use.

3.1.4.1.3.2.2 *Page type.* Page ID shall be used to identify the page types of subframe 3 in B-CNAV1. It shall be a 6-bit unsigned integer. Its definition shall be as shown in Table B BDS-6.

Table B BDS-6. Page type definition

Page ID (binary)	Page type
000000	Invalid
000001	1
000010	2
000011	3
000100	4
Others	Reserved

3.1.4.1.3.2.3 *Message type (MesType)*. Message type shall be used to identify the message types of the B-CNAV2 frames. It shall be a 6-bit unsigned integer. Its definition shall be as shown in Table B BDS-7.

Table B BDS-7. Message type definition

Message Type (Binary)	Message type
000000	Invalid
001010	10
001011	11
011110	30
011111	31
100000	32
100001	33
100010	34
101000	40
Others	Reserved

3.1.4.1.3.2.4 *Issue of data*

Note 1.— Additional information concerning B1C issue of data is given in BDS OS B1C ICD, section 7.4.1, Table 7-3 and section 7.4.2, Table 7-4.

Note 2.— Additional information concerning B2a issue of data is given in BDS OS B2a ICD, section 7.4.1, Table 7-3 and section 7.4.2, Table 7-4.

3.1.4.1.3.2.4.1 *Issue of data, ephemeris (IODE).* IODE shall indicate the issue number of a set of ephemeris parameters. The IODE value shall be updated when any ephemeris parameter is updated. The IODE values shall indicate the range of the ephemeris data age. The ephemeris data age shall be defined as the offset between the ephemeris parameters reference time (t_{oe}) and the last measured time for generating the ephemeris parameters. The values of IODE shall not be repeated within any 24 hours. The relationship between the IODE values and the ephemeris data age shall be as in Table B BDS-8.

Table B BDS-8. Relationship between the IODE values and the ephemeris data age

IODE value	Ephemeris data age
0 – 59	Less than 12 hours
60 – 119	12 hours – 24 hours
120 – 179	1 day – 7 days
180 – 239	Reserved
240 – 255	More than 7 days

3.1.4.1.3.2.4.2 *Issue of data, clock (IODC).* IODC shall indicate the issue number of a set of clock correction parameters. The IODC value shall be updated when any clock correction parameter is updated. The IODC values shall indicate the range of the clock correction data age. The clock correction data age shall be defined as the offset between the clock correction parameters reference time (t_{oc}) and the last measured time for generating the clock correction parameters. The range of the clock correction data age shall be defined by the 2 MSBs of IODC together with the 8 LSBs of IODC. The values of IODC shall not be repeated within any 24 hours. The relationship between the IODC values and the clock correction data age shall be as in Table B BDS-9.

Table B BDS-9. Relationship between the IODC values and the clock correction data age

2 MSBs of IODC	8 LSBs of IODC	Clock correction data age
00	0 – 59	Less than 12 hours
	60 – 119	12 hours – 24 hours
	120 – 179	1 day – 7 days
	180 – 239	Reserved
	240 – 255	More than 7 days
01	0 – 59	Less than 12 hours
	60 – 119	Less than 12 hours
	120 – 179	Less than 1 day
	180 – 239	Reserved
	240 – 255	No more than 7 days
10	0 – 59	More than 12 hours
	60 – 119	More than 24 hours
	120 – 179	More than 7 days
	180 – 239	Reserved
	240 – 255	More than 7 days
11	Reserved	Reserved

3.1.4.1.3.2.5 *Satellite health status*. Satellite health status (SHS) shall indicate the health status of the transmitting satellite. The definitions of the SHS parameter shall be as shown in Table B BDS-10.

Note 1.— Additional information concerning B1C SHS is given in BDS OS B1C ICD, section 7.14, Table 7-22.

Note 2.— Additional information concerning B2a SHS is given in BDS OS B2a ICD, section 7.14, Table 7-22.

Table B BDS-10. Definitions of the SHS parameter

SHS value	Definition	Description
0	The satellite is healthy	The satellite provides services
1	The satellite is unhealthy or under test	The satellite does not provide services
2	Reserved	Reserved
3	Reserved	Reserved

3.1.4.1.3.2.6 *Satellite integrity status*. The satellite integrity status shall be conveyed by two parameters: data integrity flag (DIF) and signal integrity flag (SIF). Each of them shall occupy 1 bit and their definitions shall be as shown in Table B BDS-11.

Note 1.— Additional information concerning the B1C satellite integrity status flag is given in BDS OS B1C ICD, section 7.15, Table 7-23.

Note 2.— Additional information concerning the B2a satellite integrity status flag is given in BDS OS B2a ICD, section 7.15, Table 7-23.

Table B BDS-11. Definitions of the satellite integrity status flag parameters

Parameter	Value	Definition
DIF	0	The error of message parameters broadcast in this signal does not exceed the predictive accuracy
	1	The error of message parameters broadcast in this signal exceeds the predictive accuracy
SIF	0	This signal is normal
	1	This signal is abnormal

3.1.4.1.3.2.7 *Satellite signal-in-space health status (SISHS)*

3.1.4.1.3.2.7.1 BDS OS signal-in-space health status (SISHS) shall take one of the three states:

a) healthy: the signal meets the minimum service performance specified in this document;

b) unhealthy: the signal is not providing services or is being tested; and

c) marginal: the signal is neither of the two previous states.

3.1.4.1.3.2.7.2 The B1C and B2a SISHS shall be indicated by the combination of four SIS flags: HS, SIF and DIF. The mapping between the values of the three flags and B1C/B2a SISHS shall be as shown in Table B BDS-12.

Table B BDS-12. The mapping between the values of the three flags and B1C/B2a SISHS

B1C/B2a SISHS	HS	SIF	DIF
Healthy	0	0	0
Marginal	0	0	1
	2/3	0	0
Unhealthy	Any value	1	0/1
	1	0/1	0/1

3.1.4.1.3.2.8 *Signal-in-space accuracy (SISA) indices*. The SISA shall describe the predictive accuracy of the orbital parameters and clock correction parameters broadcast in the navigation message. It shall comprise the along-track and cross-track accuracy of the satellite orbit ($SISA_{oe}$) as well as the satellite orbital radius and satellite clock correction accuracy ($SISA_{oc}$).The SISA index parameters listed below shall be used to calculate $SISA_{oe}$ and $SISA_{oc}$ and shall be broadcast in B-CNAV1 Subframe 3 for B1C and B-CNAV2 Message Type 40 for B2a, respectively:

a) $SISAI_{oe}$ which is a signed, two's complement integer in the range of +15 to -16 shall indicate the combined satellite along-track and cross-track orbit accuracy as shown in Table B BDS-12-1;

b) $SISAI_{ocb}$ which is a signed, two's complement integer in the range of +15 to -16 shall indicate the combined satellite orbit radial and satellite clock bias accuracy as shown in Table B BDS-12-2;

c) $SISAI_{oc1}$ with an integer value in the range of 0 to 7 shall indicate the satellite clock drift accuracy;

d) $SISAI_{oc2}$ with an integer value in the range of 0 to 7 shall indicate the satellite clock drift rate accuracy; and

e) t_{op} shall indicate the time of week for data prediction.

Note 1.— Additional information concerning the SISA index parameters is given in BDS OS B1C ICD, section 7.16.

Note 2.— Additional information concerning the SISA index parameters is given in BDS OS B2a ICD, section 7.16.

Table B BDS-12-1. Mapping between $SISA_{oe}$ index and $SISA_{oe}$

$SISA_{oe}$ index	$SISA_{oe}$ (metres)
15	*6 144.00 < $SISA_{oe}$ (or no accuracy prediction is available)*
14	*3 072.00 < $SISA_{oe} \leq$ 6 144.00*
13	*1 536.00 < $SISA_{oe} \leq$ 3 072.00*
12	*768.00 < $SISA_{oe} \leq$ 1 536.00*
11	*384.00 < $SISA_{oe} \leq$ 768.00*
10	*192.00 < $SISA_{oe} \leq$ 384.00*
9	*96.00 < $SISA_{oe} \leq$ 192.00*
8	*48.00 < $SISA_{oe} \leq$ 96.00*
7	*24.00 < $SISA_{oe} \leq$ 48.00*
6	*13.65 < $SISA_{oe} \leq$ 24.00*
5	*9.65 < $SISA_{oe} \leq$ 13.65*
4	*6.85 < $SISA_{oe} \leq$ 9.65*
3	*4.85 < $SISA_{oe} \leq$ 6.85*
2	*3.40 < $SISA_{oe} \leq$ 4.85*
1	*2.40 < $SISA_{oe} \leq$ 3.40*
0	*1.70 < $SISA_{oe} \leq$ 2.40*
-1	*1.20 < $SISA_{oe} \leq$ 1.70*
-2	*0.85 < $SISA_{oe} \leq$ 1.20*
-3	*0.60 < $SISA_{oe} \leq$ 0.85*
-4	*0.43 < $SISA_{oe} \leq$ 0.60*
-5	*0.30 < $SISA_{oe} \leq$ 0.43*
-6	*0.21 < $SISA_{oe} \leq$ 0.30*
-7	*0.15 < $SISA_{oe} \leq$ 0.21*
-8	*0.11 < $SISA_{oe} \leq$ 0.15*
-9	*0.08 < $SISA_{oe} \leq$ 0.11*
-10	*0.06 < $SISA_{oe} \leq$ 0.08*
-11	*0.04 < $SISA_{oe} \leq$ 0.06*
-12	*0.03 < $SISA_{oe} \leq$ 0.04*
-13	*0.02 < $SISA_{oe} \leq$ 0.03*
-14	*0.01 < $SISA_{oe} \leq$ 0.02*
-15	*$SISA_{oe} \leq$ 0.01*
-16	*No accuracy prediction available – used at own risk*

Table B BDS-12-2. Mapping between $SISA_{ocb}$ index and $SISA_{ocb}$

$SISA_{ocb}$ index	$SISA_{ocb}$ (metres)
15	*6 144.00 < $SISA_{ocb}$ (or no accuracy prediction is available)*
14	*3 072.00 < $SISA_{ocb} \leq$ 6 144.00*
13	*1 536.00 < $SISA_{ocb} \leq$ 3 072.00*
12	*768.00 < $SISA_{ocb} \leq$ 1 536.00*
11	*384.00 < $SISA_{ocb} \leq$ 768.00*
10	*192.00 < $SISA_{ocb} \leq$ 384.00*
9	*96.00 < $SISA_{ocb} \leq$ 192.00*
8	*48.00 < $SISA_{ocb} \leq$ 96.00*
7	*24.00 < $SISA_{ocb} \leq$ 48.00*
6	*13.65 < $SISA_{ocb} \leq$ 24.00*
5	*9.65 < $SISA_{ocb} \leq$ 13.65*
4	*6.85 < $SISA_{ocb} \leq$ 9.65*
3	*4.85 < $SISA_{ocb} \leq$ 6.85*
2	*3.40 < $SISA_{ocb} \leq$ 4.85*
1	*2.40 < $SISA_{ocb} \leq$ 3.40*
0	*1.70 < $SISA_{ocb} \leq$ 2.40*
-1	*1.20 < $SISA_{ocb} \leq$ 1.70*
-2	*0.85 < $SISA_{ocb} \leq$ 1.20*
-3	*0.60 < $SISA_{ocb} \leq$ 0.85*
-4	*0.43 < $SISA_{ocb} \leq$ 0.60*
-5	*0.30 < $SISA_{ocb} \leq$ 0.43*
-6	*0.21 < $SISA_{ocb} \leq$ 0.30*
-7	*0.15 < $SISA_{ocb} \leq$ 0.21*
-8	*0.11 < $SISA_{ocb} \leq$ 0.15*
-9	*0.08 < $SISA_{ocb} \leq$ 0.11*
-10	*0.06 < $SISA_{ocb} \leq$ 0.08*
-11	*0.04 < $SISA_{ocb} \leq$ 0.06*
-12	*0.03 < $SISA_{ocb} \leq$ 0.04*
-13	*0.02 < $SISA_{ocb} \leq$ 0.03*
-14	*0.01 < $SISA_{ocb} \leq$ 0.02*
-15	*$SISA_{ocb} \leq$ 0.01*
-16	*No accuracy prediction available – used at own risk*

3.1.4.2 DEFINITIONS OF PROTOCOLS FOR DATA APPLICATION

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

3.1.4.2.1 *Parity algorithms.*

3.1.4.2.1.1 The D1 message uses BCH(15,11,1) encoding as parity algorithms as indicated in section 3.1.4.1.2.1.5.

3.1.4.2.1.2 The B-CNAV1 message and the B-CNAV2 message use a 24-bit CRC. The CRC shall be calculated in accordance with 3.7, with the following generator polynomial:

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

where:

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

3.1.4.2.2 *Satellite clock correction parameters.*

3.1.4.2.2.1 BDS system time t shall be computed as follows:

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

where:

t = BDT in seconds at time of signal transmission;

t_{sv} = the effective satellite ranging code phase time in seconds at time of signal transmission; and

Δt_{sv} = the offset of satellite ranging code phase time in seconds defined as:

$\Delta t_{sv} = a_0 + a_1(t - t_{oc}) + a_2(t - t_{oc})^2 + \Delta t_r$

where:

a_0, a_1 and a_2 and t_{oc} are parameters transmitted in D1 navigation message subframe 1, in B-CNAV1 subframe 2 and B-CNAV2 message Types 30, 31, 32, 33 and 34; and

Δt_r is the relativistic effect correction term defined as:

$$\Delta t_r = F \cdot e \cdot \sqrt{A} \cdot \sin E_k ,$$

where:

e, $\sqrt{A}$, E_k, are parameters that can get from D1 navigation message subframe 2 and subframe 3, from B-CNAV1 subframe 2 and B-CNAV2 message Types 10 and 11;

$F = -2\mu^{1/2}/c^2$;

$\mu = 3.986004418\times10^{14}$ m^3/s^2 is the value of the earth's universal gravitational constant; and

$c = 2.99792458\times10^8$ m/s is the speed of light.

3.1.4.2.2.2 BDS system time related to UTC (NTSC) time. BeiDou system time offset with respect to UTC shall be determined by using B1I data, B1C data or B2a data.

Note.— Additional information concerning time parameters and algorithms relating BeiDou system time to UTC is given in section 5.2.4.18, BDS OS B1I ICD; section 7.12, BDS OS B1C ICD; and section 7.12, BDS OS B2a ICD.

3.1.4.2.3 *Satellite position.*

3.1.4.2.3.1 *B1I satellite position solution.* The current satellite position shall be computed as shown in Table B BDS-13.

Note 1.— The current satellite position is defined using ephemeris parameters. The ephemeris parameters (t_{oe}, $\sqrt{A}$, e, ω, Δn, M_0, Ω_0, $\dot{\Omega}$, i_0, IDOT, C_{uc}, C_{us}, C_{rc}, C_{rs}, C_{ic}, C_{is}) used in the B1I satellite position solution are parameters transmitted by D1 navigation message subframe 2 and subframe 3.

Note 2.— Additional information concerning ephemeris parameters and algorithms is given in BDS OS B1I ICD, section 5.2.4.12.

Table B BDS-13. B1I ephemeris algorithm

Computation steps	Description
$\mu = 3.986004418\times10^{14}$ m^3/s^2	Value of the earth's universal gravitational constant in BDCS
$\dot{\Omega}_e = 7.2921150\times10^{-5}$ rad/s	Value of the earth's rotation rate in BDCS
$\pi = 3.1415926535898$	Ratio of a circle's circumference to its diameter
$A = \left(\sqrt{A}\right)^2$	Computed semi-major axis
$n_0 = \sqrt{\frac{\mu}{A^3}}$	Computed mean motion (radians/s)
$t_k = t - t_{oe}$ *	Computed time from ephemeris reference epoch
$n = n_0 + \Delta n$	Corrected mean motion
$M_k = M_0 + nt_k$	Computed mean anomaly
$M_k = E_k - e\sin E_k$	Kepler's equation for eccentric anomaly (radians)
$\begin{cases} \sin v_k = \frac{\sqrt{1-e^2}\sin E_k}{1-e\cos E_k} \\ \cos v_k = \frac{\cos E_k - e}{1-e\cos E_k} \end{cases}$	Computed true anomaly
$\phi_k = v_k + \omega$	Computed argument of latitude
$\begin{cases} \delta u_k = C_{us}\sin(2\phi_k) + C_{uc}\cos(2\phi_k) \\ \delta r_k = C_{rs}\sin(2\phi_k) + C_{rc}\cos(2\phi_k) \\ \delta i_k = C_{is}\sin(2\phi_k) + C_{ic}\cos(2\phi_k) \end{cases}$	Argument of latitude correction Radius correction Inclination correction
$u_k = \phi_k + \delta u_k$	Corrected argument of latitude parameters
$r_k = A(1 - e\cos E_k) + \delta r_k$	Corrected radius
$i_k = i_0 + IDOT \cdot t_k + \delta i_k$	Corrected inclination
$\begin{cases} x_k = r_k \cos u_k \\ y_k = r_k \sin u_k \end{cases}$	Computed satellite positions in orbital plane
$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)t_k - \dot{\Omega}_e t_{oe}$	Corrected longitude of ascending node in BDCS
$\begin{cases} X_k = x_k\cos\Omega_k - y_k\cos i_k \sin\Omega_k \\ Y_k = x_k\sin\Omega_k + y_k\cos i_k\cos\Omega_k \\ Z_k = y_k \sin i_k \end{cases}$	MEO/IGSO satellite coordinates in BDCS

* In the equations, "t" is the time of signal transmission in BDT. "t_k" is the total time difference between t and ephemeris reference time t_{oe} , after accounting for beginning or end-of-week crossovers by subtracting 604 800 seconds from t_k if t_k is greater than 302 400 or adding 604 800 seconds to t_k if t_k is less than -302 400 seconds.

3.1.4.2.3.2 *B1C and B2a satellite position solution.* The current satellite position shall be computed as shown in Table B BDS-14.

Note 1.— The current satellite position is defined using ephemeris parameters. The ephemeris parameters (t_{oe}, SatType, ΔA, $\dot{A}$, Δn_0, $\Delta\dot{n}_0$, M_0, e, ω, Ω_0, i_0, $\dot{\Omega}$, $\dot{i}_0$, C_{is}, C_{ic}, C_{rs}, C_{rc}, C_{us}, C_{uc}) *used in the B1C and B2a satellite position solution are parameters transmitted by B-CNAV1 navigation message subframe 2 and 3, or by B-CNAV2 navigation message Type 10 and message Type 11.*

Note 2.— Additional information concerning ephemeris parameters and algorithms is given in BDS OS B1C ICD, section 7.7, and in BDS OS B2a ICD, section 7.7.

Table B BDS-14. B1C/B2a ephemeris algorithm

Computation steps	Description
$\mu = 3.986004418 \times 10^{14}\ \mathrm{m^3/s^2}$	Geocentric gravitational constant of BDCS
$\dot{\Omega}_e = 7.2921150 \times 10^{-5}\ \mathrm{rad/s}$	Earth's rotation rate of BDCS
$\pi = 3.1415926535898$	Ratio of a circle's circumference to its diameter
$t_k = t - t_{oe}$ **	Time from ephemeris reference time
$A_0 = A_{ref} + \Delta A$ *	Semi-major axis at reference time
$A_k = A_0 + (\dot{A}) t_k$	Semi-major axis
$n_0 = \sqrt{\frac{\mu}{A_0^3}}$	Computed mean motion (radians/s) at reference time
$\Delta n_A = \Delta n_0 + 1/2\, \Delta\dot{n}_0 t_k$	Mean motion difference from computed value
$n_A = n_0 + \Delta n_A$	Corrected mean motion
$M_k = M_0 + n_A t_k$	Mean anomaly
$M_k = E_k - e \sin E_k$	Kepler's equation for eccentric anomaly (radians)
$\begin{cases} \sin \nu_k = \frac{\sqrt{1-e^2} \sin E_k}{1 - e\cos E_k} \\ \cos \nu_k = \frac{\cos E_k - e}{1 - e\cos E_k} \end{cases}$	True anomaly
$\phi_k = \nu_k + \omega$	Argument of latitude

Computation steps	Description
$\begin{cases}\delta u_k = C_{us}\sin(2\phi_k) + C_{uc}\cos(2\phi_k)\\ \delta r_k = C_{rs}\sin(2\phi_k) + C_{rc}\cos(2\phi_k)\\ \delta i_k = C_{is}\sin(2\phi_k) + C_{ic}\cos(2\phi_k)\end{cases}$	Argument of latitude correction Radius correction Inclination correction
$u_k = \phi_k + \delta u_k$	Corrected argument of latitude
$r_k = A_k(1 - e\cos E_k) + \delta r_k$	Corrected radius
$i_k = i_0 + \dot{i}_0 \cdot t_k + \delta i_k$	Corrected inclination
$\begin{cases}x_k = r_k\cos u_k\\ y_k = r_k\sin u_k\end{cases}$	Position in orbital plane
$\Omega_k = \Omega_0 + (\dot{\Omega} - \dot{\Omega}_e)t_k - \dot{\Omega}_e t_{oe}$	Corrected longitude of ascending node
$\begin{cases}X_k = x_k\cos\Omega_k - y_k\cos i_k\sin\Omega_k\\ Y_k = x_k\sin\Omega_k + y_k\cos i_k\cos\Omega_k\\ Z_k = y_k\sin i_k\end{cases}$	Coordinate of the MEO/IGSO satellite antenna phase centre in BDCS

* Semi-major axis reference value: $A_{ref} = 27906100$m（MEO） $A_{ref} = 42162200$m（IGSO/GEO）.

** In the equation, t is the BDT time of signal transmission, i.e., the BDT time corrected for transit time; t_k is the total time difference between t and the ephemeris reference time t_{oe}, after accounting for beginning or end-of-week crossovers by subtracting 604 800 seconds from t_k if t_k is greater than 302 400 or adding 604 800 seconds to t_k if t_k is less than -302 400 seconds.

3.1.4.2.4 *Ionospheric delay correction.*

3.1.4.2.4.1 *B1I ionospheric delay correction.* The B1I ionospheric delay correction shall be computed as shown in Table B BDS-15.

Table B BDS-15. Single-frequency ionospheric delay computation for B1I

Computation steps	Description
t_E	t_E is the SOW in BDT computed by user.
$\psi = \frac{\pi}{2} - E - \arcsin\left(\frac{R}{R+h} \cdot \cos E\right)$	ψ is the earth's central angle in radians between the user location and the ionospheric pierce point (IPP). R is the mean radius of the earth (6 378 km). E is the satellite elevation from the user's location in radians. H is the height of ionosphere (375 km).
$\phi_M = \arcsin\left(\sin\phi_u \cdot \cos\psi + \cos\phi_u \cdot \sin\psi \cdot \cos A\right)$	ϕ_M is the geographic latitude of the earth projection of the IPP in radians; A is the satellite azimuth from the user location in radians.
$\lambda_M = \lambda_u + \arcsin\left(\frac{\sin\psi \cdot \sin A}{\cos\phi_M}\right)$	λ_M is the geographic longitude of the earth projection of the IPP in radians.
$t = (t_E + \lambda_M \times 43200 / \pi)[\text{mod}ulo\ 86400]$	t is the local time (range 0 – 86 400 s) for the earth projection of the IPP.
$A_2 = \begin{cases} \sum_{n=0}^{3} \alpha_n \left\lvert \phi_M / \pi \right\rvert^n, & A_2 \geq 0 \\ 0, & A_2 < 0 \end{cases}$	A_2 is the amplitude of the Klobuchar cosine curve in the daytime computed from the α_n; α_n: coefficients broadcast in D1 navigation message subframe 3.
$A_4 = \begin{cases} 172800, & A_4 \geq 172800 \\ \sum_{n=0}^{3} \beta_n \left\lvert \phi_M / \pi \right\rvert^n, & 172800 > A_4 \geq 72000 \\ 72000, & A_4 < 72000 \end{cases}$	A4 is the period of the cosine curve in seconds; β_n are the coefficients broadcast in D1 navigation message subframe 3.
$I'_z(t) = \begin{cases} 5 \times 10^{-9} + A_2 \cos[\frac{2\pi(t-50400)}{A_4}], & \lvert t-50400 \rvert < A_4/4 \\ 5 \times 10^{-9}, & \lvert t-50400 \rvert \geq A_4/4 \end{cases}$	$I'_z(t)$ is the vertical ionospheric delay correction.
$I_{B1I}(t) = \frac{1}{\sqrt{1-\left(\frac{R}{R+h} \cdot \cos E\right)^2}} \cdot I'_z(t)$	$I_{B1I(t)}$ is the ionospheric delay along the B1I propagation path.

Note.— Additional information concerning B1I ionospheric delay correction parameters and user algorithms is given in BDS OS B1I ICD, section 5.2.4.7.

3.1.4.2.4.2 *B1C and B2a ionospheric delay correction.*

3.1.4.2.4.2.1 *Single-frequency ionospheric delay correction*. The B1C or B2a ionospheric delay correction shall be computed as shown in Table B BDS-16.

Table B BDS-16. Single-frequency ionospheric delay computation for B1C and B2a

Computation steps	Description
$\psi = \frac{\pi}{2} - E - \arcsin\left(\frac{\mathrm{Re}}{\mathrm{Re}+\mathrm{H}_{\mathrm{ion}}} \cdot \cos E\right)$	ψ indicates the earth's central angle between the user position and the IPP E is the elevation angle between the user and satellite (in radians); $\mathrm{H}_{\mathrm{ion}}$ is the altitude of the ionospheric single-layer shell (400 km) Re is the mean radius of the earth (6 378 km)
$\begin{cases} \varphi_g = \arcsin(\sin\varphi_u \cdot \cos\psi + \cos\varphi_u \cdot \sin\psi \cdot \cos A) \\ \lambda_g = \lambda_u + \arctan\left(\frac{\sin\psi \cdot \sin A \cdot \cos\varphi_u}{\cos\psi - \sin\varphi_u \cdot \sin\varphi_g}\right) \end{cases}$	φ_g is the geographic latitude of the earth projection of the IPP λ_g is the geographic longitude of the earth projection of the IPP φ_u is the user geographic latitude λ_u is the user geographic longitude A is the azimuth angle between the user and the satellite (in radians)
$\begin{cases} \varphi_m = \arcsin\left(\sin\varphi_{\mathrm{M}} \cdot \sin\varphi_g + \cos\varphi_{\mathrm{M}} \cdot \cos\varphi_g \cdot \cos(\lambda_g - \lambda_{\mathrm{M}})\right) \\ \lambda_m = \arctan\left(\frac{\cos\varphi_g \cdot \sin(\lambda_g - \lambda_{\mathrm{M}}) \cdot \cos\varphi_{\mathrm{M}}}{\sin\varphi_{\mathrm{M}} \cdot \sin\varphi_m - \sin\varphi_g}\right) \end{cases}$	φ_m is the geomagnetic latitude of the earth projection of the IPP in the earth-fixed reference frame λ_m is the geomagnetic longitude of the earth projection of the IPP in the earth-fixed reference frame λ_M is the geographic longitude of the north magnetic pole: $\lambda_{\mathrm{M}} = \frac{-72.58°}{180°} \cdot \pi$ rad φ_M is the geographic latitude of the north magnetic pole: $\varphi_{\mathrm{M}} = \frac{80.27°}{180°} \cdot \pi$ rad
$S_{lon} = \pi \cdot \left(1 - 2 \cdot \left(t - \mathrm{int}(t)\right)\right)$	S_{lon} is the mean geographic longitude of the sun (in radians) t is the time (in days) of the calculation epoch expressed by Modified Julian Date (MJD) $\mathrm{int}(\cdot)$ is rounding down

Computation steps	**Description**
$$\begin{cases}\varphi' = \varphi_m \\ \lambda' = \lambda_m - \arctan\left(\dfrac{\sin(S_{lon} - \lambda_{\mathrm{M}})}{\sin\varphi_{\mathrm{M}} \cdot \cos(S_{lon} - \lambda_{\mathrm{M}})}\right)\end{cases}$$	φ' is the geomagnetic latitude of the IPP in the solar-fixed reference frame λ' is the geomagnetic longitude of the IPP in the solar-fixed reference frame
$$\begin{cases}P_{n,n}(\sin\varphi') = (2n-1)!!\left(1-(\sin\varphi')^2\right)^{n/2}, & n=m \\ P_{n,m}(\sin\varphi') = \sin\varphi' \cdot (2m+1) \cdot P_{m,m}(\sin\varphi'), & n=m+1 \\ P_{n,m}(\sin\varphi') = \dfrac{(2n-1)\cdot\sin\varphi'\cdot P_{n-1,m}(\sin\varphi') - (n+m-1)\cdot P_{n-2,m}(\sin\varphi')}{n-m}, & else\end{cases}$$	$P_{n,m}$ is the classic, un-normalized Legendre function $(2n-1)!! = (2n-1)\cdot(2n-3)\cdots 1$ $P_{0,0}(\sin\varphi') = 1$
$$\begin{cases}N_{n,m} = \sqrt{\dfrac{(n-m)!\cdot(2n+1)\cdot(2-\delta_{0,m})}{(n+m)!}} \\ \delta_{0,m} = \begin{cases}1, & m=0 \\ 0, & m>0\end{cases}\end{cases}$$	$N_{n,m}$ is the normalization function
$$\tilde{P}_{n,m} = N_{n,m} \cdot P_{n,m}$$	$\tilde{P}_{n,m}$ is the normalized Legendre function with degree n and order m
$$A_i = \begin{cases}\tilde{P}_{\|n_i\|,\|m_i\|}(\sin\varphi')\cdot\cos(m_i\cdot\lambda') & m_i \ge 0 \\ \tilde{P}_{\|n_i\|,\|m_i\|}(\sin\varphi')\cdot\sin(-m_i\cdot\lambda') & m_i < 0\end{cases}$$	The values of n_i and m_i are shown in Table B BDS-17.
$$\begin{cases}\beta_j = a_{0,j} + \sum_{k=1}^{12}\left(a_{k,j}\cdot\cos(\omega_k\cdot t_p) + b_{k,j}\cdot\sin(\omega_k\cdot t_p)\right) \\ \omega_k = \dfrac{2\pi}{T_k}\end{cases}$$	$a_{k,j}$ and $b_{k,j}$ are the non-broadcast coefficients of the BeiDou global ionosphere delay correction model (BDGIM); T_k is the period for prediction corresponding to the individual non-broadcast coefficients; t_p is the odd hour the day (01:00:00, 03:00:00, 05:00:00..., or 23:00:00 in MJD) which is nearest to the calculation epoch.
$$\begin{cases}A_0 = \sum_{j=1}^{17}\beta_j\cdot B_j, \\ B_j = \begin{cases}\tilde{P}_{\|n_j\|,\|m_j\|}(\sin\varphi')\cdot\cos(m_j\cdot\lambda') & m_j \ge 0 \\ \tilde{P}_{\|n_j\|,\|m_j\|}(\sin\varphi')\cdot\sin(-m_j\cdot\lambda') & m_j < 0\end{cases}\end{cases}$$	A_0 is the predictive ionospheric delay (in TECu)
$$VTEC = A_0 + \sum_{i=1}^{9}\alpha_i A_i$$	*VTEC* is the vertical ionospheric delay (in TECu) of the IPP

Computation steps	Description
$M_{\mathrm{F}} = \dfrac{1}{\sqrt{1-\left(\dfrac{\mathrm{Re}}{\mathrm{Re}+\mathrm{H_{ion}}}\cdot\cos(E)\right)^2}}$	$\boldsymbol{M}_{\mathbf{F}}$ is the ionospheric mapping function of the IPP
$T_{ion} = M_{\mathrm{F}} \cdot \dfrac{40.28\times10^{16}}{f^2}\cdot VTEC$	T_{ion} is the ionospheric delay correction

Table B BDS-17. Values of n_i and m_i

i	1	2	3	4	5	6	7	8	9
n_i/m_i	0/0	1/0	1/1	1/-1	2/0	2/1	2/-1	2/2	2/-2

Note.— Additional information concerning ionospheric delay correction model parameters broadcast on B1C and B2a and the user algorithms are given in BDS OS B1C ICD, section 7.8.2, Table 7-12, and in BDS OS B2a ICD, section 7.8.2, Table 7-12.

3.1.4.2.4.2.2 *Dual-frequency ionospheric delay correction*

For the dual-frequency user applying the B1C and B2a signals, the effect of the ionospheric delay shall be corrected by using the dual-frequency ionosphere-free pseudo-range.

The dual-frequency ionosphere-free pseudo-range from the B1C pilot component and the B2a pilot component ($PR_{\mathrm{B1Cp\text{-}B2ap}}$) shall be computed as follows:

$$PR_{\mathrm{B1Cp\text{-}B2ap}} = \frac{PR_{\mathrm{B2ap}} - k_{12}\cdot PR_{\mathrm{B1Cp}}}{1-k_{12}} - \frac{\mathrm{C}\cdot(\mathrm{T_{GDB2ap}} - k_{12}\cdot \mathrm{T_{GDB1Cp}})}{1-k_{12}}$$

The dual-frequency pseudo-range from the B1C pilot component and the B2a data component ($PR_{\mathrm{B1Cp\text{-}B2ad}}$) shall be computed as follows:

$$PR_{\mathrm{B1Cp\text{-}B2ad}} = \frac{PR_{\mathrm{B2ad}} - k_{12}\cdot PR_{\mathrm{B1Cp}}}{1-k_{12}} - \frac{\mathrm{C}\cdot(\mathrm{T_{GDB2ap}} + \mathrm{ISC_{B2ad}} - k_{12}\cdot \mathrm{T_{GDB1Cp}})}{1-k_{12}}$$

The dual-frequency pseudo-range from the B1C data component and the B2a pilot component ($PR_{\mathrm{B1Cd\text{-}B2ap}}$) shall be computed as follows:

$$PR_{\text{B1Cd-B2ap}} = \frac{PR_{\text{B2ap}} - k_{12} \cdot PR_{\text{B1Cd}}}{1 - k_{12}} - \frac{\text{C} \cdot (\text{T}_{\text{GDB2ap}} - k_{12} \cdot \text{T}_{\text{GDB1Cp}} - k_{12} \cdot \text{ISC}_{\text{B1Cd}})}{1 - k_{12}}$$

The dual-frequency pseudo-range from the B1C data component and the B2a data component (PRB1Cd-B2ad) shall be computed as follows:

$$PR_{\text{B1Cd-B2ad}} = \frac{PR_{\text{B2ad}} - k_{12} \cdot PR_{\text{B1Cd}}}{1 - k_{12}} - \frac{\text{C} \cdot (\text{T}_{\text{GDB2ap}} + \text{ISC}_{\text{B2ad}} - k_{12} \cdot \text{T}_{\text{GDB1Cp}} - k_{12} \cdot \text{ISC}_{\text{B1Cd}})}{1 - k_{12}}$$

where $k_{12} = \left(\frac{1575.42}{1176.45} \right)^2$, is the factor associated with frequency;

PR_{B1Cp} is the measured pseudo-range of the B1C pilot component (corrected by the clock correction but not corrected by T_{GDB1Cp});

PR_{B1Cd} is the measured pseudo-range of the B1C data component (corrected by the clock correction but not corrected by T_{GDB1Cp} and ISC_{B1Cd});

PR_{B2ap} is the measured pseudo-range of the B2a pilot component (corrected by the clock correction but not corrected by T_{GDB2ap});

PR_{B2ad} is the measured pseudo-range of the B2a data component (corrected by the clock correction but not corrected by T_{GDB2ap} and ISC_{B2ad});

T_{GDB1Cp} is the group delay differential of the B1C pilot component;

T_{GDB2ap} is the group delay differential of the B2a pilot component;

ISC_{B1Cd} is the group delay differential between the B1C data component and the B1C pilot component;

ISC_{B2ad} is the group delay differential between the B2a data component and the B2a pilot component;

$c = 2.99792458 \times 10^8$ m/s is the speed of light.

Note 1.— Additional information concerning B1C ionospheric delay model parameters is given in BDS OS B1C ICD, section 7.8.

Note 2.— Additional information concerning B2a ionospheric delay model parameters is given in BDS OS B2a ICD, section 7.8.

3.1.4.2.5 *SISA calculation for B1C and B2a.*

The signal-in-space accuracy (SISA) for integrity use shall be calculated as:

$$SISA = \sqrt{\left(SISA_{oe} \times \sin 14^{o}\right)^{2} + SISA_{oc}^{\;2}}$$

where

$SISA_{oe}$ is the upper bound value corresponding to the $SISA_{oe}$ index "N" as broadcast in B-CNAV1 Subframe 3 for B1C and in B-CNAV2 message Types 34 and 40 for B2a, respectively (defined in 3.1.4.1.3.2.8) as shown in Table B BDS-12-1.

$SISA_{oc}$ shall be calculated with the following equations (in metres):

$$SISA_{oc} = SISA_{ocb} + SISA_{oc1}\left(t - t_{op}\right), \; for \; t - t_{op} \le 93600s$$

$$SISA_{oc} = SISA_{ocb} + SISA_{oc1}\left(t - t_{op}\right) + SISA_{oc2}\left(t - t_{op} - 93600\right)^{2}, \; for \; t - t_{op} > 93600s$$

where

$SISA_{ocb}$ is the upper bound value corresponding to the $SISA_{ocb}$ index "N" as broadcast in B-CNAV1 Subframe 3 for B1C and in B-CNAV2 message Types 34 and 40 for B2a, respectively (defined in 3.1.4.1.3.2.8) as shown in Table B BDS-12-2;

$SISA_{oc1}$ is the satellite clock drift accuracy in metres per second derived from $SISAI_{oc1}$ (defined in 3.1.4.1.3.2.8) as follows:

$$SISA_{oc1} = 2^{-\left(SISAI_{oc1} + 14\right)}$$

$SISA_{oc2}$ is the satellite clock drift rate accuracy in metres per square second derived from $SISAI_{oc2}$ (defined in 3.1.4.1.3.2.8) as follows:

$$SISA_{oc2} = 2^{-\left(SISAI_{oc2} + 28\right)}$$

where

t is the BDS system time in second;

t_{op} is the time of week for data prediction in second broadcast in B-CNAV1 subframe 3 for B1C and in B-CNAV2 message Types 34 and 40 for B2a, respectively.

3.1.4.3 AIRCRAFT ELEMENTS

3.1.4.3.1 *BDS RECEIVER*

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

3.1.4.3.1.2 *Doppler shift*. The receiver shall be able to compensate for dynamic Doppler shift effects on nominal BDS OS signal carrier phase and ranging code measurements. The receiver shall compensate for the Doppler shift that is unique to the anticipated application.

3.1.4.3.1.3 *Resistance to interference*. The receiver shall meet the requirements for resistance to interference as specified in section 3.7.

3.1.4.3.1.4 *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. For B1I, the receiver shall monitor the parameters t_{oc} and t_{oe} to update clock and ephemeris data based upon the detected change in these parameters. For B1C and B2a, the receiver shall monitor the parameters IODC and IODE to update clock and ephemeris data based upon the detected change in these parameters.

3.1.4.4 TIME

The time reference for BDS shall be the BeiDou Navigation Satellite System Time (BDT). BDT shall adopt the International System of Units (SI) seconds, and shall accumulate continuously without leap seconds. The start epoch of BDT shall be 00:00:00 on 1 January 2006 of Coordinated Universal Time (UTC). BDT shall connect with UTC via UTC (NTSC), and the deviation of BDT to UTC shall be maintained within 50 nanoseconds (Modulo 1 second). The leap seconds shall be broadcast in the navigation (NAV) message.

3.1.4.5 COORDINATE SYSTEM

3.1.4.5.1 *BeiDou Coordinate System.* The BDS broadcast ephemeris shall describe the position of the transmitting antenna phase centre of a given satellite in the BeiDou Coordinate System (BDCS).

3.1.4.5.2 The difference between the latest physical realization of ITRF and BDCS shall not exceed 3 cm (95 per cent).

Note 1.— WGS-84 and BDS terrestrial reference frame BDCS are both realizations of ITRF. The difference between BDCS and WGS-84 used in GPS is considered insignificant for aviation.

Note 2.— Additional information on the BDCS is in Attachment D, section 4.1.4.9.

End of new text.

Editorial note.— Renumber section 3.1.4 as 3.1.5

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ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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4. GNSS CORE ELEMENTS

4.1 Core constellations

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Editorial note.— Insert a new section 4.1.4 as follows:

4.1.4 BDS

4.1.4.1 *Assumptions.* The performance standard is based upon the assumption that a representative BDS Open Service (BDS OS) receiver is used. A representative receiver has the following characteristics: it is designed in accordance with BDS ICDs; uses a 5-degree masking angle for MEO satellites and a 12-degree masking angle for IGSO satellites; accomplishes satellite position and geometric range computations in the most current realization of the BDCS (which is equivalent to WGS-84); compensates for dynamic Doppler shift effects on nominal BDS OS ranging signal carrier phase and ranging code measurements; excludes BDS unhealthy or marginal 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 BDS satellite stops transmitting ranging code. The time transfer accuracy applies to a stationary receiver operating at a surveyed location.

4.1.4.2 *Accuracy*. Position domain accuracy is measured with a representative receiver and a measurement interval of 168 hours (seven sidereal days) for any point within the coverage area. The positioning and timing accuracy are for the SIS only and do not include such error sources as: ionosphere, troposphere, interference, receiver noise or multipath. The accuracy is derived based on the worst two of all operational satellites being removed from the constellation and a 4.6-metre 95th percentile user range error of any satellite.

4.1.4.2.1 *Time transfer accuracy.* Time transfer accuracy is the 95 per cent statistical deviation between the BDS OS timing receiver output and Coordinated Universal Time (UTC) maintained by NTSC in China. It can be used to evaluate the timing performance of a navigation satellite system.

4.1.4.3 *Range domain accuracy.* Range domain accuracy is measured with a representative receiver and a measurement interval of 168 hours. Range domain accuracy is conditioned by the satellite indicating a healthy status and transmitting BDS OS ranging code and does not account for satellite failures outside of the normal operating characteristics. Range domain accuracy limits can be exceeded during satellite failures or anomalies while uploading data to the satellite. Exceedance of the range error limit constitutes a major service failure as described in 4.1.4.5. The range rate error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. The range acceleration error limit is the maximum for any satellite measured over any 3-second interval for any point within the coverage area. Under nominal conditions, all satellites are maintained to the same standards, so it is appropriate for availability modelling purposes to assume that all satellites have a 4.6-metre 95th percentile user range error. The standards are restricted to range domain errors allocated to space and control segments.

4.1.4.4 *Availability.* Availability is the percentage of time over any 168-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 15-metre horizontal 95 per cent threshold and a 22-metre vertical 95 per cent threshold; using a representative receiver and operating within the coverage area over any 168-hour interval. The service availability assumes the worst combination of two out-of-service satellites.

4.1.4.4.1 *Satellite/constellation availability.* At least 24 satellites in the 27 nominal plane/slot positions must be set healthy and must be transmitting a navigation signal with a 0.998 probability (yearly averaged). At least 21 satellites in the 27 nominal plane/slot positions must be set healthy and must be transmitting a navigation signal with a 0.99999 probability (yearly averaged).

4.1.4.5 *Major service failure*

4.1.4.5.1 The single satellite major service failure is the condition that the SIS ranging error (excluding atmospheric and receiver errors) of any satellite exceeds the not-to-exceed (NTE) tolerance without an alert to users. For B1I signals, the NTE tolerance is defined to be 4.42 times the upper bound of the URA range corresponding to the URA index (URAI) value being broadcast in D1 navigation messages, as described in Appendix B, section 3.1.4.1.3.1.2. For B1C and B2a signals, the NTE tolerance is defined to be 4.42 times the signal-in-space accuracy (SISA) value calculated as described in Appendix B, section 3.1.4.2.5. The P_{sat} of 1×10^{-5} in Chapter 3, 3.7.3.1.4.4.1 corresponds to a maximum of three major service failures for each BDS OS signal per year assuming a maximum constellation of 30 satellites. The Mean Time to Notify (MTN) is 60 minutes.

4.1.4.5.2 The common-cause major service failure is a condition that the BDS OS SIS user range error of two or more satellites will exceed the NTE tolerance due to a common fault without an alert received at the user receiver antenna. For B1I signals, the NTE tolerance is defined to be 4.42 times the upper bound of the URA range corresponding to the URA index (URAI) value being broadcast in D1 navigation messages, as described in Appendix B, section 3.1.4.1.3.1.2. For B1C and B2a signals, the NTE tolerance is defined to be 4.42 times the SISA value calculated as described in Appendix B, section 3.1.4.2.5. The P_{const} of 6×10^{-5} in Chapter 3, 3.7.3.1.4.4.2 corresponds to a maximum of 0.5 commonly caused major service failures for the entire constellation per year. The MTN is 60 minutes.

4.1.4.6 *Continuity*. Continuity for a healthy BDS satellite is the probability that the BDS OS SIS will continue to be healthy without unscheduled interruption over a specified time interval. Scheduled interruptions, which are announced at least 24 hours in advance, do not contribute to a loss of continuity.

4.1.4.7 *Coverage.* The BDS OS supports the terrestrial coverage area which is from the surface of the earth up to an altitude of 1 000 km.

4.1.4.8 *BDS time*. The time reference for the BDS uses the BeiDou Navigation Satellite System Time (BDT), as described in Appendix B, 3.1.4.4.

4.1.4.9 *BDS coordinate system.* BDS uses the BeiDou Coordinate System (BDCS).

4.1.4.9.1 *BDCS origin, axis and scale.* The origin is located at the earth's centre of mass; the Z-axis is the direction of the IERS (International Earth Rotation and Reference System Service) Reference Pole (IRP); the X-axis is the intersection of IERS Reference Meridian (IRM) and the plane passing through the origin and normal to the Z-axis; the Y-axis, together with the Z-axis and the X-axis, constitute a right-handed orthogonal coordinate system. The length unit is the international system of units (SI) metre.

4.1.4.9.2 *BDCS Ellipsoid.* The geometric centre of the BDCS Ellipsoid coincides with the earth's centre of mass, and the rotation axis of the BDCS Ellipsoid is the Z-axis. The parameters of BDCS Ellipsoid are defined as:

Semi-major axis: $a = 6\,378\,137.0$ m

Geocentric gravitational constant (mass of the earth's atmosphere included):

$\mu = 3.986004418 \times 10^{14}\ m^3/s^2$

Flattening: $f = 1/298.257222101$

Earth rotation rate: $\dot{\Omega}_e = 7.2921150 \times 10^{-5}$ rad/s

End of new text.

Origin:	*Rationale*:
NSP/6	This proposal is intended to reflect the introduction of the BDS satellite navigation system, operated by the People's Republic of China. It is currently not included in Annex 10. The proposed BDS SARPs include two signals in two frequency bands to provide positioning, velocity and timing information to BDS users on a continuous, worldwide basis. The availability of this additional constellation using two frequency bands will contribute to mitigate ionospheric scintillation and the risk of having insufficient satellites within a single constellation, as well as vulnerabilities in respect of ionospheric disturbance and radio frequency interference.

INITIAL PROPOSAL 6
DFMC Satellite-based augmentation system (SBAS)

Editorial note.— Due to the renumbering of the GPS and GLONASS provisions proposed in WP/2 and WP/3, cross-references to those provisions contained in the SBAS provisions will need to be editorially corrected, accordingly.

CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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3.7 Requirements for the Global Navigation Satellite System (GNSS)

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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 3.7.3.4.34).

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, mMessage Types 27 or 28 can be used to comply with the integrity requirements in the coverage area. Additional guidance on the rationale and interpretation of this requirement is provided in Attachment D, 3.3 and 6.2.3.

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

a) L1 SBAS ranging: provide an additional L1 pseudo-range ranging signal with an accuracy indicator from an SBAS satellite (3.7.3.4.2.1 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); and

d) L1 SBAS precise differential correction: determine and transmit the L1 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 (Appendix B, 3.5.14.2); and

f) DFMC SBAS ionosphere-free differential correction: determine and transmit GNSS satellite health status, satellite ephemeris and clock corrections to be applied to the ionosphere-free pseudo-range measurements from satellites (Appendix B, 3.5.14.3) and associated integrity data.

Note 1.— For single-frequency users, if functions b) and c) are provided, SBAS in combination with core satellite constellation(s) can support departure, en-route, terminal and non-precision approach operations, and if function d) is provided in addition to b) and c), then SBAS can also support precision approach operations including Category I. If all the functions are provided, SBAS in combination with core satellite constellation(s) can support departure, en-route, terminal and approach operations including Category I precision approach. The level of performance that can be achieved depends upon the infrastructure incorporated into SBAS and the ionospheric conditions in the geographic area of interest.

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

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

Note 4.— The ionospheric corrections are only broadcast on L1. Dual-frequency users will use an ionosphere-free pseudo-range measurement and not require ionospheric corrections. Ionosphere-free pseudo-range combination for DFMC SBAS is further defined in Appendix B, 3.5.15.1.

3.7.3.4.3~~2.1~~ *Ranging.* When SBAS is providing a ranging service, the following Standards shall apply:

3.7.3.4.3.1~~2.1.1~~ Excluding atmospheric effects, the range error for the ranging signal from SBAS satellites shall not exceed 25 m (82 ft) (95 per cent).

3.7.3.4.3.2~~2.1.2~~ The probability that the SBAS L1 range error exceeds 150 m (490 ft) in any hour shall not exceed 10^{-5}.

3.7.3.4.3.3~~2.1.3~~ The probability of unscheduled outages of the ranging function from an SBAS satellite in any hour shall not exceed 10^{-3}.

3.7.3.4.3.4~~2.1.4~~ The range rate error shall not exceed 2 m (6.6 ft) per second.

3.7.3.4.3.5~~2.1.5~~ The range acceleration error shall not exceed 0.019 m (0.06 ft) per second-squared.

3.7.3.4.4~~3~~ *Service area.* An SBAS service area for any approved type of operation shall be a declared area within the SBAS coverage area where SBAS meets the corresponding requirements of 3.7.2.4.

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

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

Note 3.— SBAS coverage and service areas are discussed in Attachment D, 6.2.

3.7.3.4.5~~-4~~ *RF characteristics for the SBAS L1 signal*

Note.— Detailed RF characteristics are specified in Appendix B, 3.5.2 for L1.

3.7.3.4.5.1~~4.1~~ *L1 carrier frequency.* The L1 carrier frequency shall be 1 575.42 MHz.

~~*Note.— After 2005, when the upper GLONASS frequencies are vacated, another type of SBAS may be introduced using some of these frequencies.*~~

3.7.3.4.5.2~~4.2~~ *L1 signal spectrum.* At least 95 per cent of the L1 broadcast power shall be contained within a ±12 MHz band centred on the L1 frequency. The bandwidth of the L1 signal transmitted by an SBAS satellite shall be at least 2.2 MHz.

Note.— The SBAS L1 RF link needs to provide a higher transmission bandwidth to support the SBAS ranging accuracy figure in Appendix B, 3.5.15.4.1, for DFMC SBAS ranging service. A higher transmission bandwidth will improve the performance of the L1 SBAS ranging service. See Attachment D, 6.4.6.

3.7.3.4.5.3~~4.3~~ *L1 ~~SBAS~~ satellite signal power level*

3.7.3.4.5.3.1~~4.3.1~~ Each SBAS satellite placed in orbit before 1 January 2014 shall broadcast navigation signals on L1 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at an elevation angle of 5 degrees or higher, the level of the received RF signal at the antenna port of a 3 dBi linearly polarized antenna is within the range of –161 dBW to –153 dBW for all antenna orientations orthogonal to the direction of propagation.

3.7.3.4.5.3.2~~4.3.2~~ Each SBAS satellite broadcasting an SBAS L1 signal placed in orbit after 31 December 2013 shall comply with the following requirements:

a) The satellite shall broadcast navigation signals on L1 with sufficient power such that, at all unobstructed locations near the ground from which the satellite is observed at or above the minimum elevation angle for which a trackable geostationary orbit (GEO) satellite signal needs to be provided, the level of the received RF signal at the antenna port of the antenna specified in Appendix B, Table B-88A, is at least –164.0 dBW.

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

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

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

3.7.3.4.5.4~~4.4~~ *Polarization.* The broadcast signal on L1 shall be right-hand circularly polarized.

3.7.3.4.5.5~~4.5~~ *Modulation*. The transmitted sequence on L1 shall be the Modulo-2 addition of the navigation message at a rate of 500 symbols per second and the 1 023 bit pseudo-random noise code. It shall then be BPSK modulated onto the carrier at a rate of 1.023 megachips per second.

3.7.3.4.6 *RF characteristics for the SBAS L5 signal*

Note.— Detailed RF characteristics are specified in Appendix B, 3.5.9 for L5.

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

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

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

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

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

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

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

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

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

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

Note.— Detailed L5 modulation characteristics for L5 are specified in Appendix B, 3.5.9.

3.7.3.4.7 *Timing*

3.7.3.4.~~5~~7.1 *SBAS network time (SNT) for L1 SBAS.* The difference between SNT of the SBAS corrections on L1 and GPS time shall not exceed 50 nanoseconds.

3.7.3.4.7.2 *SBAS network time (SNT) for DFMC SBAS.* The difference between SNT of the SBAS corrections broadcast on L5 and the reference time of the core constellation designated as reference constellation (see the time reference identifier parameter in Appendix B, 3.5.11.4 broadcast by DFMC SBAS) shall not exceed 1 microsecond.

3.7.3.4.8~~6~~ *L1 SBAS navigation information.* The navigation data transmitted by ~~the~~ an SBAS satellite~~s~~ on L1 shall include the necessary information to support L1 SBAS services to determine:

a) SBAS satellite time of transmission;

b) SBAS satellite position;

c) corrected satellite time for all satellites;

d) corrected satellite position for all satellites;

e) ionospheric propagation delay effects;

f) user position integrity;

g) time transfer to UTC (optional); and

h) service level status.

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

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

a) SBAS satellite time of transmission;

b) SBAS satellite position;

c) corrected satellite time for all monitored satellites;

d) corrected satellite position for all monitored satellites;

e) user position integrity; and

f) time transfer to UTC (optional).

Note.— Structure and contents of data are specified in Appendix B, 3.5.10 and 3.5.11, respectively.

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

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3. GNSS ELEMENTS

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3.5 Satellite-based augmentation system (SBAS)

3.5.1 GENERAL

Note.— Geodetic ~~P~~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 the GNSS ranging signals over one or two GNSS frequencies broadcast from a satellite to the aircraft subsystem. The SBAS non-aircraft subsystem shall broadcast on the L1 frequency to support the L1 SBAS service and/or on the L5 frequency to support the DFMC SBAS service.

Note.— The SBAS non-aircraft subsystem may provide a single-frequency ranging signal on the SBAS L1 frequency or a dual-frequency ranging signal as a combination of the signals transmitted on the SBAS L1 and SBAS L5 frequencies.

3.5.1.2 *SBAS pseudo-range definition.*

3.5.1.2.1 *Carrier smoothing.* Carrier smoothing shall be defined by the following filter:

$$P_{CSC,k} = \alpha P_{meas} + (1 - \alpha) P_{proj}$$
$$P_{proj} = \left(P_{CSC,k-1} + \Delta carrier\_range\right)$$

where

$P_{CSC,k}$	=	the carrier smoothed code pseudo-range at time k;
$P_{CSC,k-1}$	=	the previous carrier smoothed code pseudo-range at time k-1;
P_{meas}	=	the measured pseudo-range as defined below;
$\Delta_{carrier\_range}$	=	the change in carrier range as defined below, and
α	=	the filter weighting function equal to the sample interval divided by the smoothing time constant.

$$Pmeas = \begin{cases} single\text{-}frequency: & P_{1,k} \\ ionosphere\text{-}free: & \dfrac{\gamma_{12}\left(P_{1,k}\right) - \left(P_{2,k}\right)}{(\gamma_{12} - 1)} \end{cases}$$

where

$P_{n,k}$	=	the raw pseudo-range of frequency n at time k; and
γ_{12}	=	the square of the ratio of frequency 1 to frequency 2;

$$\Delta carrier\_range = \begin{cases} single\text{-}frequency: & \left(\varphi_{1,k} - \varphi_{1,k-1}\right) \\ ionosphere\text{-}free: & \dfrac{\gamma_{12}\left(\varphi_{1,k} - \varphi_{1,k-1}\right) - \left(\varphi_{2,k} - \varphi_{2,k-1}\right)}{(\gamma_{12} - 1)} \end{cases}$$

where

$\varphi_{n,k}$	=	the accumulated carrier in metres for frequency n at time k; and
$\varphi_{n,k-1}$	=	the accumulated carrier in metres for frequency n at time k-1.

3.5.1.2.2 *Corrected pseudo-range.* The corrected pseudo-range for a given satellite i at time t is:

$$PR_{i,corrected} = P_{CSC,i} + TC_i + b_i$$

where

$P_{CSC,i}$	=	the smoothed pseudo-range (defined in 3.5.1.1);
TC_i	=	the tropospheric correction (defined in 3.5.5.3 for SBAS); and
b_i	=	the clock correction.

3.5.2 SBAS L1 RF CHARACTERISTICS

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3.5.2.6 *Maximum code phase deviation.* The maximum uncorrected code phase of the L1 broadcast signal shall not deviate from the equivalent SBAS network time (SNT) for L1 SBAS by more than $\pm 2^{-20}$ seconds.

3.5.2.7 *Code/data coherence.* Each 2-millisecond symbol shall be synchronous with every other code epoch.

3.5.2.8 *Message synchronization.* The leading edge of the first symbol that depends on the first bit of the current message shall be broadcast from the SBAS satellite synchronous with a 1-second epoch of SNT for L1 SBAS.

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Table B-23. SBAS L1 PRN codes

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3.5.3 DATA STRUCTURE ON SBAS L1 SIGNAL

Note.— Messages broadcast on SBAS L1 signal are independent of those broadcast on SBAS L5 signal. Information broadcast on SBAS L1 signal is used only for the L1 SBAS service using GPS L1 C/A and GLONASS L1OF (FDMA signal).

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3.5.3.2 *Preamble.* For L1, ~~T~~the preamble shall consist of the sequence of bits “01010011 10011010 11000110”, distributed over three successive blocks. The start of every other 24-bit preamble shall be synchronous with a 6-second GPS subframe epoch.

3.5.3.3 *Message type identifier*. The L1 message type identifier shall be a 6-bit value identifying the message type (Types 0 to 63) as defined in Table B-24. The message type identifier shall be transmitted MSB first.

3.5.3.4 *Data field.* The L1 data field shall be 212 bits as defined in 3.5.6. Each data field parameter shall be transmitted MSB first.

3.5.3.5 *Cyclic redundancy check (CRC).* The SBAS message CRC code on L1 shall be calculated in accordance with 3.9.

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Table B-24. L1 ~~B~~broadcast message types

L1 Message type	Contents
0	"Do Not Use" (SBAS test mode) – Content applies to L1 SBAS service only
1	PRN mask
2 to 5	Fast corrections
6	Integrity information
7	Fast correction degradation factor
8	Spare
9	GEO ranging function parameters
10	Degradation parameters
11	Spare
12	SBAS network time/UTC offset parameters
13 to 16	Spare
17	GEO satellite almanacs
18	Ionospheric grid point masks
19 to 23	Spare
24	Mixed fast/long-term satellite error corrections
25	Long-term satellite error corrections
26	Ionospheric delay corrections
27	SBAS service message
28	Clock-ephemeris covariance matrix
29 to 61	Spare
62	Reserved – content applies to L1 SBAS service only
63	Null message – content applies to L1 SBAS service only

Note.— L1 messages (Table B-24) are for use with L1 SBAS service and L5 messages (Table B-90) are for use with DFMC SBAS service. Types 0, 62 and 63 messages are used independently by both L1 SBAS and DFMC SBAS services and their contents only apply to their service.

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3.5.4 L1 SBAS DATA CONTENT

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3.5.4.2 *Geostationary orbit (GEO) ranging function parameters.* GEO ranging function parameters shall be as follows:

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a_{Gf0}: the time offset of the GEO clock with respect to SNT for L1 SBAS, defined at $t_{0,GEO}$.

a_{Gf1}: the drift rate of the GEO clock with respect to SNT for L1 SBAS.

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3.5.4.3 *GEO almanac parameters.* GEO almanac parameters shall be as follows.

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

. . .

Table B-27. SBAS service provider identifiers

Identifier	Service provider
0	WAAS
1	EGNOS
2	MSAS
3	GAGAN
4	SDCM
5	BDSBAS
6	KASS
7	A-SBAS
8	SouthPAN
9 to 13	~~Spare~~Reserved
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. IOD_i for GLONASS satellites

MSB	LSB
Validity interval (5 bits)	Latency time (3 bits)

. . .

Table B-35. UTC standard identifier

UTC standard identifier	UTC standard
0	UTC as operated by the Communications Research Laboratory 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 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	SpareReserved
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.

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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.

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3.5.5 DEFINITIONS OF PROTOCOLS FOR L1 SBAS DATA APPLICATION

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3.5.6 L1 SBAS MESSAGE TABLES

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

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

. . .

Table B-52. Type 63 null message

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

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3.5.7 L1 SBAS NON-AIRCRAFT ELEMENTS

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3.5.7.2 *Ranging function*. If an SBAS provides an L1 SBAS ranging function, it shall comply with the requirements contained in this section in addition to the requirements of 3.5.7.1.

3.5.7.2.1 *Performance requirements*

Note.— See Chapter 3, 3.7.3.4.3~~.2.1~~.

3.5.7.2.2 *Ranging function data*. SBAS shall broadcast ranging function data such that the SBAS satellite position error projected on the line-of-sight to any user in the satellite footprint is less than 256 metres. Each SBAS satellite shall broadcast a URA representing an estimate of the standard deviation of the ranging errors referenced to SNT for L1 SBAS.

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Table B-55. SBAS L1 radio frequency monitoring

Parameter	Reference	Alarm limit	Required action
Signal power level	Chapter 3, 3.7.3.4.~~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.~~4~~5.5	monitor for waveform distortion	Cease L1 ranging function (*Note 1*).
SNT-to-GPS time	Chapter 3, 3.7.3.4.~~5~~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.*

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3.5.7.4.2 *Long-term corrections*. Except for SBAS satellites from the same service provider, SBAS shall determine and broadcast long-term corrections for each visible GNSS satellite (see *Note*) indicated in the PRN mask (PRN mask value equal to "1"). The long-term corrections shall be such that the core satellite constellation(s) satellite position error projected on the line-of-sight to any user in the satellite footprint after application of these long-term corrections is less than 256 metres. For each GLONASS satellite, SBAS shall translate satellite coordinates into WGS-84 as defined in 3.~~5~~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.

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3.5.7.7.1 *SBAS radio frequency monitoring*. The SBAS shall monitor the SBAS satellite parameters shown in Table B-55 and take the indicated action.

Note.— In addition to the radio frequency monitoring requirements in this section, it will be necessary to make special provisions to monitor pseudo-range acceleration specified in Chapter 3, 3.7.3.4.~~2.1~~3.5, and carrier phase noise specified in 3.5.2.2 and correlation loss in 3.5.2.5, unless analysis and testing shows that these parameters cannot exceed the stated limits.

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3.5.8 L1 SBAS AIRCRAFT ELEMENTS

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3.5.8.4.2.6.1 L1 SBAS FAS data block parameters shall be as follows (see Table B-57A):

Note 1.— See 3.5.15.3.5 for the definitions of operation type, SBAS service provider ID and approach performance designator applicable to DFMC SBAS receivers.

Note 2.— "L1 SBAS receivers" refers to receivers that meet the specifications of RTCA/DO-229.

Operation type: straight-in approach procedure or other operation types applicable to L1 SBAS receivers.

Coding:	0	= straight-in approach procedure
	1 to 15	= spare

SBAS service provider ID: shall indicate the service provider associated with this FAS data block.

Coding:	0-13	= See Table B-27.
	14	= FAS data block is to be used with GBAS only.
	15	= FAS data block can be used with any SBAS service provider.

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Approach performance designator: this field ~~is~~ shall not be used by L1 SBAS receivers.

Editorial note.— *Insert* new sections 3.5.9 to 3.5.15 as follows (references to core constellation SARPs to be cross-checked with final version).

3.5.9 SBAS L5 RF CHARACTERISTICS

3.5.9.1 *Carrier frequency stability.* The short-term stability of the L5 carrier frequency (square root of the Allan variance) at the output of the satellite transmit antenna shall be better than 6.7×10^{-11} over 1 to 10 seconds.

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

3.5.9.3 *Spurious emissions*. Spurious emissions shall be at least 40 dB below the unmodulated carrier power over all frequencies.

3.5.9.4 *Code/carrier frequency coherence*

3.5.9.4.1 For L5, the rate of change of code minus carrier shall be less than 0.5 metres/second.

3.5.9.4.2 For DFMC SBAS ranging satellites:

Note.— See 3.5.1.1 and 3.5.1.2 for a description of the smoothing filters to be used for the requirements below.

3.5.9.4.2.1 The root-mean-square (RMS) value over 3 600 seconds of the difference between the L5 code pseudo-range and the L5 code pseudo-range smoothed using a 10-second carrier smoothing of the code based pseudo-range shall be less than 0.200 metres.

3.5.9.4.2.2 The RMS value over 86 400 seconds of the difference between the L5 code pseudo-range and the L5 code pseudo-range smoothed using a 100-second carrier smoothing of the code based pseudo-range shall be less than 0.255 metres.

3.5.9.4.2.3 The RMS value over 3 600 seconds of the difference between the L1 code pseudo-range and the L1 code pseudo-range smoothed using a 10-second carrier smoothing of the code based pseudo-range shall be less than 0.15 metres.

3.5.9.4.2.4 The RMS value over 86 400 seconds of the difference between the L1 code pseudo-range and the L1 code pseudo-range smoothed using a 100-second carrier smoothing of the code based pseudo-range shall be less than 0.19 metres.

3.5.9.4.2.5 *L1 and L5 short-term fractional code/carrier frequency coherence*. For L1 and L5 signals broadcast by an SBAS ranging satellite, the RMS value over 3 600 seconds of the difference between the ionosphere-free pseudo-range and the ionosphere-free pseudo-range smoothed using a 10-second carrier smoothing of the L1/L5 ionosphere-free pseudo-range combination shall be less than 0.29 metres.

3.5.9.4.2.6 *L1 and L5 long-term fractional code/carrier frequency coherence.* For L1 and L5 signals broadcast by an SBAS ranging satellite, the RMS value over 86 400 seconds of the difference between the ionosphere-free pseudo-range and the ionosphere-free pseudo-range smoothed using a 100 seconds carrier smoothing of the L1/L5 ionosphere-free pseudo-range combination shall be less than 0.37 metres.

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

Note.— The correlation loss is defined as the ratio of output powers from a perfect correlator for two cases:

a) the actual received SBAS L5 signal correlated against a perfect unfiltered pseudo-random noise reference; and

b) a perfect unfiltered pseudo-random noise signal normalized to the same total power as the SBAS signal in case a), correlated against a perfect unfiltered pseudo-random noise reference.

3.5.9.6 *Maximum code phase deviation.* The L5 broadcast signal shall not deviate from the equivalent SBAS network time (SNT) for DFMC SBAS by more than $\pm 2^{-10}$ seconds.

3.5.9.7 *Code/data coherence.* Each 2-millisecond symbol shall be synchronous with every other code epoch.

3.5.9.8 *Message synchronization.* The leading edge of the first symbol that depends on the first bit of the current message shall be broadcast from the SBAS satellite synchronous with a 1-second epoch of SNT for DFMC SBAS.

Note.— The SNT time reference is provided by the Type 37 message as described in 3.5.11.5.

3.5.9.9 *Convolutional and bi-binary encoding*

3.5.9.9.1 *Convolution encoding.* A 250-bit-per-second data stream shall be encoded at a rate of 2 symbols per bit using a convolutional code with a constraint length of 7 to yield 500 symbols per second. The convolutional encoder logic arrangement shall be as illustrated in Figure B-11 with the G3 output selected for the first half of each 4-millisecond data bit period.

3.5.9.9.2 *Bi-binary encoding.* In addition to the convolution coding detailed in paragraph 3.5.9.9.1, the convolution encoded 500 symbols per second data channel shall be further bi-binary encoded such that a “0” symbol becomes a “01” pair and a “1” symbol becomes a “10” pair resulting in a data channel operating at a 1 kHz rate.

Note.— See Attachment D, Section 6.4.4.

3.5.9.10 *Pseudo-random noise (PRN) codes for L5.* Each PRN code shall be a 10 230-bit code and be added Modulo-2 with the navigation message data stream generated in paragraph 3.5.9.9.2.

Note.— Additional information on the PRN code is given in IS-GPS-705F.

The initial state for the XA shift register shall be "1111111111111", and the initial state for the XBi register shall be as illustrated in Table B-89.

Table B-89. SBAS L5 PRN codes

PRN code number	Initial XB code state (I channel) (Note 1)	XB code advance (chips) (I channel) (Note 2)
120	1101001100010	2 797
121	1100011001100	934
122	1000011000101	3 023
123	1111011011011	3 632
124	0000001100100	1 330
125	1101110000101	4 909
126	1100001000010	4 867
127	0001101001101	1 183
128	1010100101011	3 990
129	1111011110100	6 217
130	1111111101100	1 224
131	0000010000111	1 733
132	1111110000010	2 319
133	0011100111011	3 928
134	1101100010101	2 380
135	0101011111011	841
136	0001100011011	5 049
137	0001101110111	7 027
138	1110011110000	1 197
139	0111100011111	7 208
140	0011101110000	8 000
141	1111001001000	152
142	0001101110010	6 762
143	0101100111100	3 745
144	0010010111101	4 723
145	1101110110011	5 502
146	0011110011111	4 796
147	1001010101111	123
148	0111111101111	8 142
149	0000100100001	5 091
150	1110001101011	7 875
151	1111010010001	330
152	1011010111101	5 272
153	0001101110000	4 912
154	0000010111100	374
155	0100101111100	2 045
156	1110110111010	6 616
157	1101110101011	6 321
158	1101000110001	7 605

3.5.10 DATA STRUCTURE ON SBAS L5 SIGNAL

Note.— Messages broadcast for use under DFMC SBAS service are independent from those broadcast for use under L1 SBAS service. Information broadcast on SBAS L5 signal is used only for DFMC SBAS service solutions using dual-frequency measurements from core constellations.

3.5.10.1 *Format summary.* All messages shall consist of a preamble, a message type identifier, a data field and a cyclic redundancy check as illustrated in Figure B-21.

3.5.10.2 *Preamble.* For L5, the preamble shall consist of the sequence of bits “0101 1100 0110 1001 0011 1010”, distributed over six successive blocks. The start of every 24-bit preamble shall be synchronous with SNT time of day in seconds Modulo 6 seconds.

3.5.10.3 *Message type identifier.* The L5 message type identifier shall be a 6-bit value identifying the message type as defined in Table B-90. The message type identifier shall be transmitted MSB first.

Table B-90. L5 broadcast message types

L5 message type	Contents
0	“Do Not Use” – content applies to DFMC SBAS service only
1-30	Spare
31	SBAS satellite mask
32	Satellite clock-ephemeris corrections and covariance matrix
33	Spare
34, 35, 36	Integrity information (DFREI and DFRECI)
37	Degradation parameters and DFREI scale table
38	Spare
39	SBAS satellite clock, ephemeris and covariance matrix - 1
40	SBAS satellite clock, ephemeris and covariance matrix - 2
41	Spare
42	SNT-to-UTC offset
43-46	Spare
47	SBAS satellites almanacs
48-61	Spare
62	Reserved – content applies to DFMC SBAS service only
63	Null message – content applies to DFMC SBAS service only

Note.— L1 messages (Table B-24) are for use with L1 SBAS service and L5 messages (Table B-90) are for use with DFMC SBAS service. Types 0, 62 and 63 messages are used independently by both L1 SBAS and DFMC SBAS services and their contents only apply to their service.

3.5.10.4 *Data field.* The L5 data field shall be 216 bits as defined in 3.5.13. Each data field parameter shall be transmitted MSB first.

3.5.10.5 *Cyclic redundancy check* (*CRC).* The SBAS message CRC code on L5 shall be calculated in accordance with 3.9.

3.5.10.5.1 The length of the CRC code shall be k = 24 bits.

3.5.10.5.2 The CRC generator polynomial shall be:

$$G(x) = x^{24} + x^{23} + x^{18} + x^{17} + x^{14} + x^{11} + x^{10} + x^{7} + x^{6} + x^{5} + x^{4} + x^{3} + x + 1$$

3.5.10.5.3 The CRC information field, M(x), shall be:

$$M(x) = \sum_{i=1} m_i x^{226-i} = m_1 x^{225} + m_2 x^{224} + \ldots + m_{226} x^{0}$$

3.5.10.5.4 M(x) shall be formed from the 4-bit SBAS message preamble, 6-bit message type identifier, and 216-bit data field. Bits shall be arranged in the order transmitted from the SBAS satellite, such that m_1 corresponds to the first transmitted bit of the preamble, and m_{226} corresponds to bit 216 of the data field.

3.5.10.5.5 The CRC code r-bits shall be ordered such that r_1 is the first bit transmitted and r_{24} is the last bit transmitted.

3.5.11 DFMC SBAS DATA CONTENT

3.5.11.1 *Satellite mask parameters.* The satellite mask parameters shall be as follows:

SBAS satellite mask: the satellite mask shall be a set of 214 bits such that each bit represents one specific satellite as shown in Table B-91 and the value of that bit shall indicate whether augmentation is, or is not, provided for that satellite. It shall be broadcast in the Type 31 message.

Note.— The satellite mask can set up to 92 satellites from the 214 possible satellites available for augmentation.

Satellite slot number: a unique number representing a specific slot in the SBAS satellite mask (slots numbers range from 1 to 214) assigned to a specific satellite for which augmentation can be provided.

Note 1.— The first transmitted bit of the satellite mask corresponds to GPS PRN code number 1.

Note 2.— This parameter is also broadcast in Type 32 messages to identify the satellite to which the corrections apply.

Table B-91. Satellite slot number assignments

Satellite slot number	Assignment logic
1 – 32	GPS PRN
33 – 37	Reserved (GPS)
38 – 69	GLONASS ID number plus 37
70 – 74	Reserved (GLONASS)
75 – 110	Galileo space vehicle identifier plus 74
111	Reserved (Galileo)
112 – 119	Spare
120 – 158	GEO SBAS PRN
159 – 195	BDS ranging code number plus 158
196 – 207	Reserved
208 – 214	Spare

Note 1.— An SBAS may augment different sets of satellites for the provision of L1 SBAS service and for the provision of DFMC SBAS service.

Note 2.— Reserved means that the slot number has not yet been assigned but is planned for assignment to a specific satellite constellation.

SBAS augmented satellite signals: the DFMC SBAS standards shall allow the augmentation of the ionosphere-free combination of the following signal per core constellation:

a) for GPS: the GPS L1 C/A signal (as described in Chapter 3, 3.7.3.1.1.8 and 3.1.1.1.1) and the GPS L5-Q signal (as described in Chapter 3, 3.7.3.1.8 and 3.1.1.1.4). The LNAV data on GPS L1C/A shall be used in DFMC SBAS position solution;

b) for GLONASS: the GLONASS L1 OC signal (as described in Chapter 3, 3.7.3.1.2.10 and 3.1.2.1.5) and the GLONASS L3 OC signal (as described in Chapter 3, 3.7.3.1.2.9 and 3.1.2.1.5). The data on GLONASS L1 OC shall be used in DFMC SBAS position solution;

c) for Galileo: the Galileo E1-C signal (as described in Chapter 3, 3.7.3.1.3.11 and 3.1.3.1.1.2) and the Galileo E5a-Q signal (as described in Chapter 3, 3.7.3.1.3.11 and 3.1.3.1.1.3). The FNAV data on Galileo E5a-I shall be used in DFMC SBAS position solution;

d) for BDS: the BDS B1C signal (as described in Chapter 3, 3.7.3.1.4.9 and 3.1.4.1.1.3) and the BDS B2a signal (as described in Chapter 3, 3.7.3.1.4.10 and 3.1.4.1.1.4). The B-CNAV2 data on BDS B2a shall be used in DFMC SBAS position solution; and

e) for SBAS: the SBAS L1 signal (as described in 3.5.2) and SBAS L5 signal (as described in 3.5.9). The data broadcast on SBAS L5 shall be used in DFMC SBAS position solution.

Satellite slot value: binary indication per satellite slot to indicate whether correction and integrity data are provided for the satellite.

Coding: 0 = data not provided
1 = data provided

Augmented slot index: a number in the sequence of the satellite slot values set to “1” (1 up to 92) in the SBAS satellite mask.

Note.— The augmented slot index is "1" for the lowest satellite slot number for which the satellite slot value is "1".

Issue of data mask (IODM): an indicator provided in Types 31, 34, 35 and 36 messages that links the integrity data provided in Types 34, 35 and 36 messages with the augmented slot indexes in the Type 31 message with the same IODM.

3.5.11.2 *Satellite clock-ephemeris corrections and covariance matrix parameters.* The clock-ephemeris corrections and covariance matrix function parameters shall be as follows:

Satellite slot number: see 3.5.11.1.

Issue of data navigation (IODN): a 10-bit indicator broadcast in Type 32 messages that associates the clock and ephemeris corrections of a satellite with the ephemeris data broadcast by that satellite. The IODN for a given satellite matches with the following information (IODs) broadcast by the same satellite:

a) for GPS: IODC parameter (3.1.1.1.3.1.4) in the L1 LNAV message;

b) for GLONASS: t_b parameter (3.1.2.1.3.1) in strings Type 10, 31, 32 of L1OC navigation message;

c) for Galileo: IODnav parameter (3.1.3.1.3.7) in the F/NAV message;

d) for BDS: IODC parameter (3.1.4.1.3.2.4.2) in the B-CNAV2 message; and

e) for SBAS: IODG parameter (3.5.11.5) in the Type 39/40 messages.

Orbit and clock parameters corrections: The orbit parameters shall be defined as follows:

$\delta x_{(ECEF)}$: ephemeris correction for the X-axis in WGS84 ECEF coordinates;
$\delta y_{(ECEF)}$: ephemeris correction for the Y-axis in WGS84 ECEF coordinates;
$\delta z_{(ECEF)}$: ephemeris correction for the Z-axis in WGS84 ECEF coordinates;
$\delta B_{(ECEF)}$: clock offset error correction expressed in metres;
$\delta \dot{x}_{(ECEF)}$: ephemeris velocity correction for the X-axis in WGS84 ECEF coordinates;
$\delta \dot{y}_{(ECEF)}$: ephemeris velocity correction for the Y-axis in WGS84 ECEF coordinates;
$\delta \dot{z}_{(ECEF)}$: ephemeris velocity correction for the Z-axis in WGS84 ECEF coordinates;
$\delta \dot{B}_{(ECEF)}$: clock drift error correction expressed in metres per second; and
t_D: time of applicability of the parameters δx, δy, δz, δB, $\delta \dot{x}$, $\delta \dot{y}$, $\delta \dot{z}$ and $\delta \dot{B}$ expressed in seconds of the day (see Attachment D, 6.7.11).

Scale exponent: a term to compute the scale factor used to code the Cholesky factorization elements.

Cholesky factorization elements (Ei,j): elements of an upper triangle matrix which compresses the information in the clock and ephemeris covariance matrix. These elements are used to compute the user location factor (δ_{DFRE}) as a function of user position (see 3.5.12.4.1).

Dual-frequency range error indicator (DFREI): a 4-bit indicator of the dual-frequency range error (DFRE) value, with range from 0 to 15, with value 15 corresponding to "Do Not Use for SBAS".

Note 1.— For other values (from 0 to 14), the table defining the correspondence between the DFREI values and the standard deviation (σ_{DFRE}, in metres) is given in 3.5.11.4.

Note 2.— The broadcast standard deviation values (within the allowed ranges as defined in 3.5.11.4) *are SBAS-dependent.*

δR_{CORR}: the first order degradation parameter multiplier.

Note.— All parameters are broadcast in the Type 32 message.

3.5.11.3 *Integrity message parameters.* The integrity message parameters shall consist of:

Dual-frequency range error change indicator (DFRECI): a 2-bit indicator that denotes the integrity status of a specific satellite identified by its augmented slot index (see 3.5.11.1), as specified in Table B-92.

Table B-92. DFRECI indicator

DFRECI	State
0 (“00”)	Unchanged DFREI
1 (“01”)	Changed DFREI
2 (“10”)	Active DFREI value increased by one
3 (“11”)	Do not use this satellite in SBAS mode
Note.— For a given satellite, the DFRECI indication “00”, and “10” always refers to the last valid DFREI received (active DFREI) for that satellite. An active DFREI could be any broadcast DFREI that has not yet timed out. DFRECI “10” indications are not cumulative.	

Issue of data mask (IODM): see 3.5.11.1.

Dual-frequency range error indicator (DFREI): see 3.5.11.2.

Note.— Parameters are broadcast using one or more the following message types:

a) Type 34 message providing DFRECI for all augmented satellites, DRFEI for up to 7 augmented satellites and IODM; and

b) Types 35 and 36 messages broadcasting IODM and DFREIs for a maximum set of 53 and 39 augmented satellites, respectively.

3.5.11.4 *Degradation parameters and DFREI scale table parameters.* The old but active data (OBAD) parameters and DFREI scale table parameters shall be as follows:

Common OBAD parameters: a set of parameters common to all augmented satellites where

$(I_{VALID})_{32}$ is the Type 32 message validity interval;
$(I_{VALID})_{39/40}$ is the Types 39 and 40 messages validity interval;
C_{ER} is the step degradation parameter for en-route through non-precision approach applications;
$C_{COVARIANCE}$ is the clock-ephemeris covariance degradation parameter; and
Degradation equation selector indicates how the degradation terms combine for the dual-frequency residual error model variance.

Coding: 0 = δ_{DFRE} only multiplies σ_{DFRE}, correction residuals are root-sum squared
1 = δ_{DFRE} multiplies the linear sum of σ_{DFRE} and the degradation parameters

Specific OBAD parameter: a set of parameters linked to a given core constellation used to account for the degradation of corrections that are old but still valid, where:

I_{CORR} is the time interval for application of $C_{CORR;}$
C_{CORR} is the step degradation parameter for precision approach applications; and
R_{CORR} is the first order degradation parameter.

Time reference identifier: a parameter that specifies the GNSS constellation on which the SNT for DFMC SBAS is aligned, where

“0” is GPS;
“1” is GLONASS;
“2” is Galileo;
“3” is BDS;
“4” is reserved; and
“5”, “6” and “7” are spare.

DFREI scale table: provides the mapping between the DFREI parameter (see 3.5.11.2) and σ_{DFRE} as specified in Table B-93.

σ_{DFRE} is the standard deviation of the residual ionosphere-free clock and ephemeris range error following the application of the DFMC SBAS clock and ephemeris corrections (Type 32 message) or of the SBAS satellite clock and ephemeris (Type 39/40 message).

Table B-93. Evaluation of σ_{DFRE} in metres

Field value$_{dec}$	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Field value$_{bin}$	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
$\sigma_{DFRE:}$ DFREI=0	0.125	0.1875	0.25	0.3125	0.375	0.4375	0.5	0.5625	0.625	0.6875	0.75	0.8125	0.875	0.9375	1	1.0625
$\sigma_{DFRE:}$ DFREI=1	0.25	0.375	0.5	0.625	0.75	0.875	1.0	1.125	1.25	1.375	1.5	1.625	1.75	1.875	2.0	2.125
$\sigma_{DFRE:}$ DFREI=2	0.375	0.5	0.625	0.75	0.875	1.0	1.125	1.25	1.375	1.5	1.625	1.75	1.875	2.0	2.125	2.25
$\sigma_{DFRE:}$ DFREI=3	0.5	0.625	0.75	0.875	1.0	1.125	1.25	1.375	1.5	1.625	1.75	1.875	2.0	2.125	2.25	2.375
$\sigma_{DFRE:}$ DFREI=4	0.625	0.75	0.875	1.0	1.125	1.25	1.375	1.5	1.625	1.75	1.875	2.0	2.125	2.25	2.375	2.5
$\sigma_{DFRE:}$ DFREI=5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5
$\sigma_{DFRE:}$ DFREI=6	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75
$\sigma_{DFRE:}$ DFREI=7	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	4	4.25	4.5	4.75	5
$\sigma_{DFRE:}$ DFREI=8	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0	5.25
$\sigma_{DFRE:}$ DFREI=9	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0	5.25	5.5
$\sigma_{DFRE:}$ DFREI=10	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5
$\sigma_{DFRE:}$ DFREI=11	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$\sigma_{DFRE:}$ DFREI=12	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
$\sigma_{DFRE:}$ DFREI=13	4.0	7.0	10.0	13.0	16.0	19.0	22.0	25.0	28.0	31.0	34.0	37.0	40.0	43.0	46.0	49.0
$\sigma_{DFRE:}$ DFREI=14	10.0	16.0	22.0	28.0	34.0	40.0	46.0	52.0	58.0	64.0	70.0	76.0	82.0	88.0	94.0	100.0
$\sigma_{DFRE:}$ DFREI=15	DO NOT USE THIS SATELLITE IN SBAS MODE															

Note.— All parameters are broadcast in the Type 37 message.

3.5.11.5 *SBAS satellite clock, ephemeris and covariance matrix parameters*. The broadcasting SBAS satellite clock, ephemeris and covariance data shall be as follows:

Issue of data GEO (IODG): an issue of data indicator that links Type 39 and 40 messages.

Note.— Each message of a paired Type 39/40 message set contains the same 2-bit IODG.

SBAS service provider ID: identifies the SBAS service provider responsible for the signal broadcast by the SBAS satellite, as defined in Table B-27.

Keplerian parameters: the ephemeris information to determine the ionosphere-free dual-frequency L1/L5 antenna phase centre location is:

C_{uc} is the amplitude of cosine harmonic correction terms to the argument of latitude;
C_{us} is the amplitude of sine harmonic correction terms to the argument of latitude;
I_{dot} is the rate of inclination angle;
a is the semi-major axis;
ω is the argument of perigee;
Ω_0 is longitude of ascending node of orbital plane at t_e;
M_0 is the mean anomaly at t_e;
I is the inclination at t_e; and
e is the eccentricity;

Satellite slot delta: identifies the broadcasting SBAS satellite in Table B-113.

Note.— A satellite slot delta of 0 is used in the Type 47 message to indicate that no almanac data follows.

Table B-113. Satellite slot delta assignments

Satellite slot delta	Assignment logic
0	No SBAS satellite (coding only used in Type 47 messages)
1 – 39	SBAS GEO satellite PRNs 120-158
40 – 63	Spare

SBAS ephemeris time t_e: time of applicability of the ephemeris message in seconds of day;

clock parameters: provided for ionosphere-free position as follows:
a_{Gf0}: clock offset; and
a_{Gf1}: clock rate;

scale exponent: see 3.5.11.2;

covariance matrix: see 3.5.11.2;

dual-frequency range error indicator (DFREI): see 3.5.11.2; and

δR_{CORR}: see 3.5.11.2.

Note.— All parameters are broadcast in combined Type 39 and Type 40 messages.

3.5.11.6 *GNSS time offsets parameters.* The GNSS time parameters shall be as follows:

The common UTC parameters are:

A_{1SNT}: drift coefficient of the SNT scale for DFMC SBAS relative to UTC;
A_{0SNT}: bias coefficient of the SNT scale for DFMC SBAS relative to UTC time scale;
t_{0t}: time data reference time of week;
WN_t: data reference week number;
Δt_{LS}: current or past leap second count;
WN_{LSF}: leap second reference week number;
DN: leap second reference day number;
Δt_{LSF}: current or future leap second count; and
UTC standard identifier (defined in 3.5.4.8).

The validity model parameters of the SNT-to-UTC offset model are:

TOW_{app}: start time in time of week of the validity period of the information broadcast in the common UTC parameter field;

WN_{app}: week number associated to the TOW_{app} defining the validity period of the information broadcast in the common UTC parameter field. WN_{app} set to 0 means that the $WN_{app} = WN_t - 1$. WN_{app} set to 1 means that the $WN_{app} = WN_t$;

VP: identifies the validity period (time-out) duration according to Table B-116 for the common UTC information; and

UTC offset status: SNT-to-UTC offset validity status defined according to Table B-115.

Table B–115. UTC offset status parameter

UTC offset status	State
0	Previously received common UTC information remains valid, no change in validity period.
1	Previously received common UTC information is no longer valid and shall no longer be used.

Table B–116. VP parameter

VP	VP duration	VP	VP duration
0 (“000”)	1 day from broadcast	4 (“100”)	6 hours
1 (“001”)	1 hour	5 (“101”)	9 hours
2 (“010”)	2 hours	6 (“110”)	12 hours
3 (“011”)	4 hours	7 (“111”)	24 hours

The time-out for the SNT-to-UTC offset information (noted TO_{42} below) shall be defined as follows:

a) if VP is set to 0: TO_{42} = Type 42 message received time + 86 400 s;

b) if VP is set to a value different from 0: TO_{42} = start time in seconds (defined by TOW_{app} and WN_{app}) + (VP duration) × 3 600.

Note 1.— All parameters are broadcast in a Type 42 message.

Note 2.— It is not intended that Type 42 messages be used for positioning services with integrity, as no integrity budget is defined in SBAS system for the time offset parameters.

3.5.11.7 *SBAS satellite parameters.* The SBAS satellite parameters shall be as follows:

satellite slot delta: see 3.5.11.5;

SBAS service provider ID: see 3.5.11.5;

broadcast indicator: when set to 1, it identifies the almanac data of the broadcasting satellite. It shall be set to 0 otherwise;

almanac parameters: broadcast using Keplerian parameters, where:

a is the semi-major axis;
e is the eccentricity;
I is the inclination;
ω is the argument of perigee;
Ω_0 is the longitude of ascending node of orbital plane at beginning of week;
$\dot{\Omega}$ is the rate of right ascension of the ascending node;
M_0 is the mean anomaly at t_a; and
t_a is SBAS almanac time (the almanac reference epoch in seconds of day);

week number rollover count ($WNRO_{count}$): the number of week number rollovers already elapsed for the GNSS constellation identified by the time reference identifier at the almanac reference time, t_a, broadcast in the SBAS I Keplerian parameters block of the Type 47 message (see Table B-104). $WNRO_{count}$ value of 15 shall be used to indicate that the parameter is not valid and will be updated. The starting time per constellation with respect to UTC shall be:

a) for GPS: midnight between 5 January 1980 and 6 January 1980 (see 3.1.1.4);

b) for GLONASS: midnight between 31 December 1995 and 1 January 1996 (see 3.1.2.4);

c) for Galileo: 13 seconds before midnight between 21 August 1999 and 22 August 1999 (see 3.1.3.4); and

d) for BDS: midnight between 31 December 2005 and 1 January 2006 (see 3.1.4.4).

Note 1.— All parameters are broadcast in a Type 47 message.

Note 2.— The Type 47 message provides the capacity to transmit the SBAS almanacs parameters of 2 SBAS satellites.

3.5.12 Definitions of protocols for DFMC SBAS data applications

Note.— This section provides the definitions of parameters used by SBAS (non-aircraft and aircraft elements) that are needed to compute the navigation solution and associated integrity (protection levels).

3.5.12.1 General information for DFMC SBAS data protocol

The conventional values to be used for the computation of the earth-fixed coordinates of the SBAS space vehicle antenna phase centre shall be:

$\pi = 3.1415926535898$	(ratio of a circle's circumference to its diameter);
$\mu = 3.986005 \times 10^{14}$ m^3/s^2	(earth's gravitational parameter);
$\dot{\Omega}_e = 7.2921151467 \times 10^{-5}$ rad/s	(earth's rotation rate); and
c = 299 792 458 m/s	(speed of light in a vacuum).

Note.— The values of these parameters are not broadcast by SBAS but use of the correct values is necessary to ensure interoperability between different SBAS implementations.

When computing a time difference $(t - t_0)$ where the reference time t_0 is expressed in the SNT (such as t_D broadcast in Type 32 message, t_e broadcast in Type 40, t_a broadcast in Type 47 message), the time t used in 3.5.12 shall be expressed in the same time frame considering the conversion elements in Table B-117.

Table B-117. Conversion from a core constellation reference time to the SNT

Core constellation reference time		"0"	"1"	"2"	"3"
	GPS	$t^{(SNT=0)} = t^{(GPST)}$	$t^{(SNT=1)} = t^{(GPST)} - \Delta tLS + 10\,800$ s	$t^{(SNT=2)} = t^{(GPST)}$	$t^{(SNT=3)} = t^{(GPST)} - 14$ s
	GLONASS	$t^{(SNT=0)} = t^{(GLONASST)} + \Delta tLS - 10\,800$ s	$t^{(SNT=1)} = t^{(GLONASST)}$	$t^{(SNT=2)} = t^{(GLONASST)} + \Delta tLS - 10\,800$ s	$t^{(SNT=3)} = t^{(GLONASST)} + \Delta tLS - 10\,800$ s
	Galileo	$t^{(SNT=0)} = t^{(GST)}$	$t^{(SNT=1)} = t^{(GST)} - \Delta tLS + 10\,800$ s	$t^{(SNT=2)} = t^{(GST)}$	$t^{(SNT=3)} = t^{(GST)} - 14$ s
	BDS	$t^{(SNT=0)} = t^{(BDT)} + 14$ s	$t^{(SNT=1)} = t^{(BDT)} - \Delta tLS + 10\,800$ s	$t^{(SNT=2)} = t^{(BDT)} + 14$ s	$t^{(SNT=3)} = t^{(BDT)}$

Note 1.— ΔtLS is computed through core constellation information.

Note 2.— Table B-117 describes how to convert a time of day $t^{(GNSST)}$ expressed in one of the GNSS core constellation reference times into time of day $t^{(SNT=i)}$ expressed in the SNT specified by the time reference identifier i.

3.5.12.2 Determination of SBAS satellite position based on its almanac.

The following parameters described in 3.5.11.7 shall be used in the computation of the SBAS satellite position based on its almanac:

t_a: SBAS almanac time (the reference epoch of the almanac (s) as a time of day);
a: semi-major axis (m);
e: eccentricity (dimensionless);
M_0: mean anomaly (rad) at t_a;
ω: argument of perigee (rad);
I: inclination angle (rad);
Ω_0: longitude of ascending node of orbital plane at beginning of week (rad); and
$\dot{\Omega}$: rate of right ascension of the ascending node (rad/s).

The computation of the SBAS satellite position shall be made for the epoch t, expressed in the SNT frame for DFMC SBAS. The "almanac reference epoch" shall be broadcast as a time of day through t_a. The SBAS users shall account for the truncated nature of the t_a parameter.

3.5.12.2.1 Computation of the mean anomaly (M_t)

The mean anomaly (M_t) at the epoch t shall be computed as:

$$M_t = M_0 + n_0 \Delta_t$$

where

$$n_0 = \sqrt{\frac{\mu}{a^3}}$$

$$\Delta_t = t - t_a.$$

Note.— The SBAS user needs to ensure that t and t_a have the same time reference when computing Δt. Since the broadcast parameter t_a is a time of day, conversion is needed to account for day or week changes.

3.5.12.2.2 Computation of the eccentric anomaly (E_t)

The eccentric anomaly (E_t) for epoch t shall be computed solving the equation:

$$M_t = E_t - e\sin(E_t).$$

Note.— This equation may be solved by iteration.

3.5.12.2.3 Computation of the argument of latitude (Φ_t)

The argument of latitude (Φ_t) for epoch t shall be computed as:

$$\phi_t = v_t + \omega$$

where v_t is the true anomaly at epoch t:

$$v_t = 2 \times \operatorname{atan}\left(\sqrt{\frac{1+e}{1-e}}\, tan\left(\frac{E_t}{2}\right)\right)$$

3.5.12.2.4 Computation of the coordinates in the orbital plane (x'_t;y'_t)

The coordinates in the orbital plane (x'_t;y'_t) for epoch t shall be computed as:

$$x'_t = r_t \cos\phi_t$$
$$y'_t = r_t \sin\phi_t$$

where r_t is the orbit radius at epoch t:

$$r_t = a \times [1 - (e \times \cos E_t)]$$

3.5.12.2.5 Computation of the space vehicle fixed earth's coordinates (x_t; y_t; z_t)

The space vehicle fixed earth's coordinates (x_t; y_t; z_t) for epoch t shall be computed as:

$$x_t = (x'_t \cos\Omega_t) - (y'_t \cos I \sin\Omega_t)$$
$$y_t = (x'_t \sin\Omega_t) + (y'_t \cos I \cos\Omega_t)$$
$$z_t = y'_t \sin I$$

where Ω_t is the corrected longitude of the ascending node at epoch t:

$$\Omega_t = \Omega_0 + \left[\left(\dot{\Omega} - \dot{\Omega}_e\right)\Delta_t\right] - \left(\dot{\Omega}_e t_{aTOW}\right)$$

and t_{aTOW} is t_a expressed in seconds as a time of week (or elapsed time since the beginning of the almanac week).

3.5.12.3 Determination of SBAS satellite position based on its ephemeris

The following parameters, described in 3.5.11.5, shall be used in the computation of the SBAS satellite position based on its ephemeris:

t_e: SBAS ephemeris time (the reference epoch of the ephemeris (s) as a time of day);
a: semi-major axis (m);
e: eccentricity (dimensionless);
M_0: mean anomaly (rad) at t_e;
ω: argument of perigee (rad);
I: inclination angle at t_e (rad);
I_{dot}: rate of inclination angle (rad/s);
Ω_0: longitude of the ascending node of orbital plane at t_e (rad);
C_{uc}: amplitude of the cosine harmonic correction to the argument of latitude (rad); and
C_{us}: amplitude of the sine harmonic correction to the argument of latitude (rad).

The computation of the SBAS satellite position shall be made for the epoch t, expressed in the SNT frame for DFMC SBAS. The "ephemeris reference epoch" shall be broadcast as a time of day through t_e. The SBAS users shall account for the truncated nature of the t_e parameter.

3.5.12.3.1 Computation of the mean anomaly (M_t)

The mean anomaly (M_t) at the epoch t shall be computed as:

$$M_t = M_0 + n_0\Delta_t$$

where

$$n_0 = \sqrt{\frac{\mu}{a^3}}$$

$$\Delta_t = t - t_e$$

Note.— The SBAS user needs to ensure that t and t_e have the same time reference when computing Δt. Since the broadcast parameter t_e is a time of day, a conversion is needed to account for day or week changes.

3.5.12.3.2 Computation of the eccentric anomaly (E_t)

The eccentric anomaly (E_t) for epoch t shall be computed solving the equation:

$$M_t = E_t - e\sin(E_t)$$

Note.— This equation may be solved by iteration.

3.5.12.3.3 Computation of the argument of latitude (Φ_t)

The eccentric anomaly (Φ_t) for epoch t shall be computed as:

$$\phi_t = v_t + \omega$$

where v_t is the true anomaly at epoch t:

$$v_t = 2 \times \mathrm{atan}\left(\sqrt{\frac{1+e}{1-e}}\,tan\left(\frac{E_t}{2}\right)\right)$$

3.5.12.3.4 Computation of the corrected argument of latitude (u_t)

The corrected argument of latitude (u_t) for epoch t shall be computed as:

$$u_t = \phi_t + \delta u_t$$

where δu_t is the argument of latitude second harmonic perturbation at epoch t:

$$\delta u_t = [C_{us}\sin(2\phi_t)] + [C_{uc}\cos(2\phi_t)]$$

3.5.12.3.5 Computation of the coordinates in the orbital plane ($\mathbf{x'_t};\mathbf{y'_t}$)

The coordinates in the orbital plane ($x'_t;y'_t$) for epoch t shall be computed as:

$$x'_t = r_t \cos u_t$$
$$y'_t = r_t \sin u_t$$

where r_t is the orbit radius at epoch t:

$$r_t = a[1 - (e\cos E_t)]$$

3.5.12.3.6 Computation of the space vehicle fixed earth's coordinates (x_t; y_t; z_t)

The space vehicle fixed earth's coordinates (**x_t**; y_t; z_t) for epoch t shall be computed as:

$$x_t = (x'_t \cos\Omega_t) - (y'_t \cos i_t \sin\Omega_t)$$
$$y_t = (x'_t \sin\Omega_t) + (y'_t \cos i_t \cos\Omega_t)$$
$$z_t = y'_t \sin i_t$$

where **Ω_t** is the corrected longitude of the ascending node at epoch t:

$$\Omega_t = \Omega_0 - (\dot{\Omega}_e \Delta_t)$$

and i_t is the corrected inclination for epoch t:

$$i_t = I + (I_{dot} \Delta_t)$$

Note 1.— The Sagnac correction (earth's rotation) needs to be taken into account.

Note 2.— The rate of right ascension of the ascending node is assumed to be zero.

3.5.12.4 SBAS DFMC navigation solution

Note.— 3.5.12.4 provides formulas for the SBAS DFMC navigation solution of an SBAS system augmenting two core constellations, Constellation 1 (C1) and Constellation 2 (C2). When the number N of constellations being augmented is different from 2 (N=1, 3 or 4), the size of G and of X will need to vary accordingly. Additional information is available in Attachment D, 6.7.12.

The weighted least square navigation solution takes the following form:

$$\hat{X} = (G^T \cdot W \cdot G)^{-1} \cdot G^T \cdot W \cdot Y$$

where

a) $\hat{X}$ is the weighted least square estimate of the error in the estimated location of the user about which the linearization has been made:

$$X = [x, y, z, ct_{C1}, ct_{C1\text{-}C2}]$$

where

t_{C1} is the clock bias of the receiver in seconds with respect to Constellation 1 reference time; and

$t_{C1\text{-}C2}$is the time difference observed by the receiver in seconds between the reference constellation 2 and the constellation 1, namely $t_{C1\text{-}C2} = t_{C2} - t_{C1}$;

Note.— This is one possible implementation. A second implementation is described in Attachment D, 6.7.12.

b) Y is the P-dimensional vector containing the corrected ionosphere-free pseudo-range measurements $PR_{i,corrected}$, minus the expected ranging values based on the location of the satellites and the estimated location of the user (X), where

P is the number of satellites used in the navigation solution;

$PR_{i,corrected}$ is the corrected ionosphere-free pseudo-range measurement for the satellite i computed as specified in 3.5.1.2 with the parameters as follows:

b_i, defined in 3.5.1.2, is SBAS corrected clock:

$$b_i = c * (\delta\Delta t_{SV,i} + \Delta t_{SV,i});$$

$\delta\Delta t_{SV,i}$ is the time error estimate at time t computed with the parameters described in 3.5.11.2 as follows:

$$c * \delta\Delta t_{SV,i} = \delta B + \delta\dot{B}(t - t_D);$$

$\Delta t_{SV,i}$ is the satellite time correction described in 3.5.15.1.1.2; and

t_D is the reference time of the corrections.

The satellite position error correction vector [δx(t), δy(t), δz(t)] shall be expressed in the WGS-84 ECEF coordinate frame as follows and shall be added to the satellite coordinate vector [x(t), y(t), z(t)]:

$$\begin{bmatrix} \delta x(t) \\ \delta y(t) \\ \delta z(t) \end{bmatrix} = \begin{bmatrix} \delta x \\ \delta y \\ \delta z \end{bmatrix} + \begin{bmatrix} \delta \dot{x} \\ \delta \dot{y} \\ \delta \dot{z} \end{bmatrix} (t - t_D)$$

with δx, δy, δz, $\delta\dot{x}$, $\delta\dot{y}$ and $\delta\dot{z}$ defined in 3.5.11.2.

Note 1.— The SBAS user needs to ensure that t and t_D have the same time reference when computing t-t_D. Since the broadcast parameter t_D is a time of day, a conversion is needed to account for day or week changes.

Note 2.— In case of SBAS ranging, for the SBAS ionosphere-free measurements of the SBAS providing the correction and integrity information, the time error estimate $\delta\Delta t_{SV}$ is zero as there is no correction provided for this satellite.

c) G is the observation matrix:

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

where

El_i is the elevation for satellite i after correction of its position using the parameters described in 3.5.11.2;

Az_i is the azimuth for satellite i after correction of its position using the parameters transmitted described in 3.5.11.2. The positive azimuth is defined clockwise from North; and

n_i is "1" if satellite is part of reference constellation C2 or "0" if it is part of C1.

For SBAS ranging satellite: n_i is "0" if C1 is GPS and n_i is "1" if C2 is GPS.

Note 1.— The DFMC SBAS standards have no provisions for the augmentation of DFMC SBAS ranging signals from other service providers.

Note 2.— If SBAS ranging is provided by the SBAS and if the SBAS is not augmenting GPS, the SBAS range time offset needs to be solved by introducing an additional unknown in the observation matrix as explained in Attachment D, 6.7.12.1.

d) W is the weighting matrix:

$$W = \begin{bmatrix} w_1 & 0 & \dots & 0 \\ 0 & w_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & w_P \end{bmatrix}$$

where

$$w_i = 1/\sigma_i^2 \;;$$

$$\sigma_i^2 = \sigma_{i,DFC}^2 + \sigma_{i,tropo}^2 + \sigma_{i,air\_DF}^2 + \sigma_{i,iono}^2 \;;$$

$\sigma_{i,DFC}^2$ is the model variance for the residual error associated to SBAS corrections for satellite i, as defined in 3.5.12.4.1;

$\sigma_{i,tropo}^2$ is the model variance for the troposphere residual error for satellite i, as defined in 3.5.8.4.2.4 and 3.5.8.4.2.5;

σ_{i,air_DF}^2 is the model variation for the combined measurement noise and multipath residual errors applicable to the ionosphere-free combination of dual-frequency range measurements (see 3.5.15.3.4.2) for satellite i; and

$\sigma_{i,iono}^2$ is the model variance for the ionosphere-free residual error for satellite i, as defined in 3.5.15.3.4.3.

3.5.12.4.1 Computation of the model variance for the residual error associated to SBAS corrections σ_{DFC}^2.

Note.— The following calculations are done for each satellite. For convenience, the index i used in 3.5.12.4 was removed from the equations.

The user location factor (δ_{DFRE}) shall be obtained via the clock-ephemeris covariance matrix C as follows:

$$C = R^T R$$

where

$$R = 2^{(\text{scale exponent} - 5)} \begin{bmatrix} E_{1,1} & E_{1,2} & E_{1,3} & E_{1,4} \\ 0 & E_{2,2} & E_{2,3} & E_{2,4} \\ 0 & 0 & E_{3,3} & E_{3,4} \\ 0 & 0 & 0 & E_{4,4} \end{bmatrix}$$

Then

$$\delta_{DFRE} = \sqrt{I^T C I} + \varepsilon_C$$

where

I is the 4-D line of sight vector from the user to the satellite in the WGS-84 coordinate frame where the first three components are the unit vector from the user to the satellite and the fourth component is 1;

ε_C is derived from $C_{COVARIANCE}$ (defined in 3.5.11.4) as:

$$\varepsilon_C = C_{COVARIANCE} \times 2^{\text{scale exponent} - 5} \text{ ; and}$$

scale exponent is defined in 3.5.11.2 and is transmitted through Type 32 messages for core constellation satellites and Type 40 messages for SBAS satellites.

The model variance for the residual error associated to SBAS corrections (σ^2_{DFC}) at the time t shall be computed using the SBAS corrections parameters described in 3.5.11.2 (for core constellations satellites) and 3.5.11.5 (for SBAS satellite) associated to the OBAD parameters described in 3.5.11.4 based on the broadcast degradation equation selector as follows:

"0": $\sigma^2_{DFC} = \sigma^2_{DFRE} \times \delta^2_{DFRE} + \varepsilon^2_{CORR} + \varepsilon^2_{ER}$
"1": $\sigma^2_{DFC} = (\sigma_{DFRE} + \varepsilon_{CORR} + \varepsilon_{ER})^2 \times \delta^2_{DFRE}$

where

$$\varepsilon_{corr} = \left\lfloor \frac{t - t_{CORR}}{I_{CORR}} \right\rfloor C_{CORR} + (t - t_{CORR}) \frac{(R_{CORR})_{SV}}{1000};$$

σ_{DFRE}	is the standard deviation of the residual ionosphere-free clock and ephemeris range error as defined in 3.5.11.4;
ε_{CORR}	is the degradation parameter for corrections;
ε_{er}	is the degradation parameter for en-route through non-precision approach applications. It shall be equal to 0 if the corrections have not timed out for approach applications (APV-I or Category I). It shall be equal to C_{er} (see 3.5.11.4) if any of the corrections or the DFREI/DFRECI (i.e. information broadcast in a valid Types 32, 34, 35, 36, 39 and 40 messages) have timed out for approach application but are still valid for en-route through non-precision approach applications;
t_{CORR}	is the time of applicability (the start of the epoch of the SNT second that is coincident with the transmission by SBAS of the first bit of the message block) of the latest 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 $t - t_{CORR} \le I_{CORR}$, then $(R_{CORR})_{SV} = R_{CORR} \times \delta R_{CORR}$ if $t - t_{CORR} > I_{CORR}$, 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.

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

$$\mathrm{HPL} = K_H d_{major}$$
$$\mathrm{VPL} = K_{V,PA} d_U$$

where

$$K_H = \begin{cases} 6.18 & \text{for en route through non precision approach operations} \\ 6.0 & \text{for APV} - \text{I and Category I operations} \end{cases};$$

$K_{V,PA} = 5.33$;

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_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_{east}^2 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_{north}^2 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.

3.5.13 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 $field_{value}$ *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-95. Type 31 SBAS satellite mask

Section	Name	Length	Scale factor	Effective range min	Effective range max	Unit	Comment
GPS mask	Satellite slot number 1	1	1	0	1	-	Bit for 1st GPS satellite
	to satellite slot number 32	1	1	0	1	-	to bit for 32nd GPS satellite
	Satellite slot number 33	1	1	0	1	-	GPS reserved, bit 1
	to satellite slot number 37	1	1	0	1	-	to GPS reserved, bit 5
GLONASS mask	Satellite slot number 38	1	1	0	1	-	Bit for 1st GLONASS satellite
	to satellite slot number 69	1	1	0	1	-	to bit for 32nd GLONASS satellite
	Satellite slot number 70	1	1	0	1	-	GLONASS reserved, bit 1
	to satellite slot number 74	1	1	0	1	-	to GLONASS reserved, bit 5
Galileo mask	Satellite slot number 75	1	1	0	1	-	Bit for 1st Galileo satellite
	to satellite slot number 110	1	1	0	1	-	to bit for 36th Galileo satellite
	Satellite slot number 111	1	1	0	1	-	Galileo reserved
Spare	Satellite slot number 112	1	1	0	1	-	
	to satellite slot number 119	1	1	0	1	-	
SBAS mask	Satellite slot number 120	1	1	0	1	-	Bit for 1st GEO SBAS satellite
	to satellite slot number 158	1	1	0	1	-	to bit for 39th GEO SBAS satellite
BDS mask	Satellite slot number 159	1	1	0	1	-	Bit for 1st BDS satellite
	to satellite slot number 195	1	1	0	1	-	to bit for 37th BDS satellite
Reserved	Satellite slot number 196	1	1	0	1	-	reserved, bit 1
	to satellite slot number 207	1	1	0	1	-	to reserved, bit 12
Spare	Satellite slot number 208	1	1	0	1	-	
	to satellite slot number 214	1	1	0	1	-	
IOD	IODM	2	1	0	3	-	

Note.— All parameters are defined in 3.5.11.1.

Table B-96. Type 32 satellite clock-ephemeris corrections and covariance matrix

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
Message header	Satellite slot number	9	1	1	214	-	Offset is 0 and coding range (0 to 511) exceeds the effective range Coding of 1 corresponds to satellite slot number of 1. The effective range is defined in Table B-91
	IODN	10	1	0	1 023	-	
Orbit parameters	$\delta x_{(ECEF)}$	11	0.0625	-64	63.9375	m	Coded as two's complement
	$\delta y_{(ECEF)}$	11	0.0625	-64	63.9375	m	Coded as two's complement
	$\delta z_{(ECEF)}$	11	0.0625	-64	63.9375	m	Coded as two's complement
	$\delta B_{(ECEF)}$	12	0.03125	-64	63.96875	m	Coded as two's complement
	$\delta \dot{x}_{(ECEF)}$	8	2^{-11}	-0.0625	0.06201171875	m/s	Coded as two's complement
	$\delta \dot{y}_{(ECEF)}$	8	2^{-11}	-0.0625	0.06201171875	m/s	Coded as two's complement
	$\delta \dot{z}_{(ECEF)}$	8	2^{-11}	-0.0625	0.06201171875	m/s	Coded as two's complement
	$\delta \dot{B}_{(ECEF)}$	9	2^{-12}	-0.0625	0.062255859375	m/s	Coded as two's complement
	t_D	13	16	0	86 384	s	Coding range (0 to 131 056) exceeds the effective range
Covariance parameters	Scale exponent	3	1	0	7	-	
	$E_{1,1}$	9	1	0	511	-	
	$E_{2,2}$	9	1	0	511	-	
	$E_{3,3}$	9	1	0	511	-	
	$E_{4,4}$	9	1	0	511	-	
	$E_{1,2}$	10	1	-512	511	-	Coded as two's complement
	$E_{1,3}$	10	1	-512	511	-	Coded as two's complement
	$E_{1,4}$	10	1	-512	511	-	Coded as two's complement
	$E_{2,3}$	10	1	-512	511	-	Coded as two's complement
	$E_{2,4}$	10	1	-512	511	-	Coded as two's complement
	$E_{3,4}$	10	1	-512	511	-	Coded as two's complement
Integrity parameters	DFREI	4	1	0	15	-	
δR_{CORR}	R_{CORR} scale factor	3	1/8	1/8	1	-	

Note 1.— This message contains the correction parameters for a single satellite identified by the satellite slot parameter.

Note 2.— All parameters are defined in 3.5.11.2.

Table B-97. Type 34 integrity information message

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
DFRECI	DFRECI 1	2	1	0	3	-	
	to DFRECI 92	2	1	0	3	-	
DFREI	DFREI 1	4	1	0	15	-	
	to DFREI 7	4	1	0	15	-	
Reserved	Reserved	2	-	-	-	-	
IOD	IODM	2	1	0	3	-	

Note 1.— DFREI is defined in 3.5.11.2.

Note 2.— IODM is defined in 3.5.11.1.

Note 3.— DFRECI is defined in 3.5.11.3.

Note 4.— See Attachment D, 6.7.14 for further guidance.

Table B-98. Type 35 integrity information message

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
DFREI	DFREI 1	4	1	0	15	-	
	to DFREI 53	4	1	0	15	-	
Reserved	Reserved	2	-	-	-	-	
IOD	IODM	2	1	0	3	-	

Note 1.— DFREI is defined in 3.5.11.2.

Note 2.— IODM is defined in 3.5.11.1.

Table B-99. Type 36 integrity information message

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
DFREI	DFREI 54	4	1	0	15	-	
	to DFREI 92	4	1	0	15	-	
Spare	Spare	56	-	-	-	-	
Reserved	Reserved	2	-	-	-	-	
IOD	IODM	2	1	0	3	-	

Note 1.— DFREI is defined in 3.5.11.2.

Note 2.— IODM is defined in 3.5.11.1.

Note 3.— See Attachment D, 6.7.14 for further guidance.

Table B-100. Type 37 degradation parameters and DFREI scale table

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
Common OBAD parameters	$(I_{VALID})_{32}$	6	6	30	408	s	
	$(I_{VALID})_{39/40}$	6	6	30	408	s	
	C_{ER}	6	0.5	0	31.5	m	
	$C_{COVARIANCE}$	7	0.1	0	12.7	-	
GPS OBAD parameters	I_{CORR}	5	6	30	216	s	
	C_{CORR}	8	0.01	0	2.55	m	
	R_{CORR}	8	0.2	0	51	mm/s	
GLONASS OBAD parameters	I_{CORR}	5	6	30	216	s	
	C_{CORR}	8	0.01	0	2.55	m	
	R_{CORR}	8	0.2	0	51	mm/s	
Galileo OBAD parameters	I_{CORR}	5	6	30	216	s	
	C_{CORR}	8	0.01	0	2.55	m	
	R_{CORR}	8	0.2	0	51	mm/s	
BDS OBAD parameters	I_{CORR}	5	6	30	216	s	
	C_{CORR}	8	0.01	0	2.55	m	
	R_{CORR}	8	0.2	0	51	mm/s	
SBAS OBAD parameters	I_{CORR}	5	6	30	216	s	
	C_{CORR}	8	0.01	0	2.55	m	
	R_{CORR}	8	0.2	0	51	mm/s	
Reserved OBAD parameters	I_{CORR}	5	6	30	216	s	
	C_{CORR}	8	0.01	0	2.55	m	
	R_{CORR}	8	0.2	0	51	mm/s	
DFREI scale table	σ_{DFRE}: DFREI = 0	4	0.0625	0.125	1.0625	m	
	σ_{DFRE}: DFREI = 1	4	0.125	0.25	2.125	m	
	σ_{DFRE}: DFREI = 2	4	0.125	0.375	2.25	m	
	σ_{DFRE}: DFREI = 3	4	0.125	0.5	2.375	m	
	σ_{DFRE}: DFREI = 4	4	0.125	0.625	2.5	m	
	σ_{DFRE}: DFREI = 5	4	0.25	0.75	4.5	m	
	σ_{DFRE}: DFREI = 6	4	0.25	1	4.75	m	
	σ_{DFRE}: DFREI = 7	4	0.25	1.25	5	m	
	σ_{DFRE}: DFREI = 8	4	0.25	1.5	5.25	m	
	σ_{DFRE}: DFREI = 9	4	0.25	1.75	5.5	m	
	σ_{DFRE}: DFREI = 10	4	0.5	2	9.5	m	
	σ_{DFRE}: DFREI = 11	4	0.5	2.5	10	m	
	σ_{DFRE}: DFREI = 12	4	1	3	18	m	
	σ_{DFRE}: DFREI = 13	4	3	4	49	m	
	σ_{DFRE}: DFREI = 14	4	6	10	100	m	
Time ref. ID	Time reference Identifier	3	1	0	7	-	

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
Common OBAD parameters	Degradation Equation Selector	1	1	0	1	-	
Spare	Spare	1	-	-	-	-	

Note.— All information is defined in 3.5.11.4.

Table B-101. Type 39 SBAS satellite clock, ephemeris and covariance matrix - 1

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
Message header	Satellite slot delta	6	1	1	39	-	Offset is 0 and coding range (0 to 63) exceeds the effective range Coding of 1 corresponds to satellite slot delta of 1 See Table B-113
	IODG	2	1	0	3	-	
	SBAS provider ID	5	1	0	31	-	
Orbit parameters	C_{uc}	19	$\pi \times 2^{-19} \times 10^{-4}$	$-\pi/2 \times 10^{-4}$	$\pi/2 \times 10^{-4} \times (1\text{-}2^{-18})$	rad	Coded as two's complement
	C_{us}	19	$\pi \times 2^{-19} \times 10^{-4}$	$-\pi/2 \times 10^{-4}$	$\pi/2 \times 10^{-4} \times (1\text{-}2^{-18})$	rad	Coded as two's complement
	Idot	22	$7\pi/6 \times 2^{-21} \times 10^{-6}$	$-7\pi/6 \times 10^{-6}$	$7\pi/6 \times 10^{-6} \times (1\text{-}2^{-21})$	rad/s	Coded as two's complement
	ω	34	$\pi \times 2^{-33}$	$-\pi$	$\pi \times (1\text{-}2^{-33})$	rad	Coded as two's complement
	Ω_o	34	$\pi \times 2^{-33}$	$-\pi$	$\pi \times (1\text{-}2^{-33})$	rad	Coded as two's complement
	M_0	34	$\pi \times 2^{-33}$	$-\pi$	$\pi \times (1\text{-}2^{-33})$	rad	Coded as two's complement
Clock parameters	a_{Gf0}	25	0.02	-292 766.06	292 766.06	m	Coded as two's complement Coding range (-335 544.32 to 335 544.30) exceeds the effective range
	a_{Gf1}	16	4×10^{-5}	-1.31072	1.31068	m/s	Coded as two's complement

Note 1.— All information is defined in 3.5.11.5.

Note 2.— 3.5.9.6 limits a_{Gf0} to ±292 766.07 m.

Table B-102. Type 40 SBAS satellite clock, ephemeris and covariance matrix - 2

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
Message header	IODG	2	1	0	3	-	
Orbit parameters	I	33	$\pi \times 2^{-33}$	0	$\pi \times (1-2^{-33})$	rad	
	e	30	2^{-30}	0	$1-2^{-30}$	-	
	a	31	0.02	6 370 000	49 319 672.94	m	
SBAS ephemeris time	t_e	13	16	0	86384	s	Coding range (0 to 131 056) exceeds the effective range
Covariance parameters	Scale exponent	3	1	0	7		
	$E_{1,1}$	9	1	0	511	-	
	$E_{2,2}$	9	1	0	511	-	
	$E_{3,3}$	9	1	0	511	-	
	$E_{4,4}$	9	1	0	511	-	
	$E_{1,2}$	10	1	-512	511	-	Coded as two’s complement
	$E_{1,3}$	10	1	-512	511	-	Coded as two’s complement
	$E_{1,4}$	10	1	-512	511	-	Coded as two’s complement
	$E_{2,3}$	10	1	-512	511	-	Coded as two’s complement
	$E_{2,4}$	10	1	-512	511	-	Coded as two’s complement
	$E_{3,4}$	10	1	-512	511	-	Coded as two’s complement
Integrity parameters	DFREI	4	1	0	15	-	
δR_{CORR}	R_{CORR} scale factor	3	1/8	1/8	1	-	
Spare	Spare	1	1	0	1	-	

Note 1.— DFREI and δR_{CORR} are defined in 3.5.11.2.

Note 2.— All other information is defined in 3.5.11.5.

Table B-103. Type 42 GNSS time offsets

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
Common UTC parameters	A_{1SNT}	24	2^{-50}	$-2^{23}*2^{-50}$	$(2^{23}-1)*2^{-50}$	s/s	Drift coefficient of SBAS time scale relative to UTC time scale (coded as two's complement)
	A_{0SNT}	35	2^{-33}	-2	$2-2^{-33}$	s	Bias coefficient of SBAS time scale relative to UTC time scale (coded as two's complement)
	t_{0t}	8	3 600	0	601 200	s	Time data reference time of week Coding range (0 to 918 000) exceeds the effective range
	WN_t	8	1	0	255	week	Time data reference week number
	Dt_{LS}	8	1	-128	127	s	Current or past leap second count (coded as two's complement)
	WN_{LSF}	8	1	0	255	week	Leap second reference week number
	DN	3	1	1	7	day	Leap second reference day number Offset is 0 and coding range (0 to 7) exceeds the effective range Coding of 1 corresponds to DN of 1
	Dt_{LSF}	8	1	-128	127	s	Current or future leap second count (coded as two's complement)
	UTC standard identifier	4	1	0	15	-	UTC standard identifier
Validity period parameters	UTC offset status	1	1	0	1	-	SNT-to-UTC offset validity status
	TOW_{app}	8	3 600	0	601 200	s	Validity period reference time of week Coding range (0 to 918 000) exceeds the effective range
	WN_{app}	1	1	0	1	-	Validity period reference week number relative to WN_t
	VP	3	1	0	7	-	Validity period duration
Spare	Spare	97	1	-	-	-	

Table B-104. Type 47 SBAS satellite almanacs

Section	Name	Length	Scale factor	Effective range		Unit	Comment
				min	max		
SBAS I header	Satellite slot delta	6	1	1	39	-	Offset is 0 and coding range (0 to 63) exceeds the effective range Coding of 1 corresponds to satellite slot delta of 1 See Table B-113
	SBAS provider ID	5	1	0	31	-	
	Broadcast indicator	1	-	-	-	-	
SBAS I Keplerian parameters	a	16	650	6 370 000	48 967 750	m	
	e	8	2^{-8}	0	0.99609375	-	
	I	13	$\pi \times 2^{-13}$	0	$\pi \times (1-2^{-13})$	rad	
	ω	14	$\pi \times 2^{-13}$	-π	$\pi \times (1-2^{-13})$	rad	Coded as two's complement
	Ω_0	14	$\pi \times 2^{-13}$	-π	$\pi \times (1-2^{-13})$	rad	Coded as two's complement
	$\dot{\Omega}$	8	1×10^{-9}	-1.28×10^{-7}	1.27×10^{-7}	rad/s	Coded as two's complement
	M_0	15	$\pi \times 2^{-14}$	-π	$\pi \times (1-2^{-14})$	rad	Coded as two's complement
	t_a	6	1 800	0	84 600	s	Coding range (0 to 113 400) exceeds the effective range
SBAS II header	Satellite slot delta	6	1	0	39	-	Coding range (0 to 63) exceeds the effective range Coding of 1 corresponds to satellite slot delta of 1 See Table B-113
	SBAS provider ID	5	1	0	31	-	
	Broadcast indicator	1	-	-	-	-	
SBAS II Keplerian parameters	a	16	650	6 370 000	48 967 750	m	
	e	8	2^{-8}	0	0.99609375	-	
	I	13	$\pi \times 2^{-13}$	0	$\pi \times (1-2^{-13})$	rad	
	ω	14	$\pi \times 2^{-13}$	-π	$\pi \times (1-2^{-13})$	rad	Coded as two's complement
	Ω_0	14	$\pi \times 2^{-13}$	-π	$\pi \times (1-2^{-13})$	rad	Coded as two's complement
	$\dot{\Omega}$	8	1×10^{-9}	-1.28×10^{-7}	1.27×10^{-7}	rad/s	Coded as two's complement
	M_0	15	$\pi \times 2^{-14}$	-π	$\pi \times (1-2^{-14})$	rad	Coded as two's complement
	t_a	6	1 800	0	84 600	s	Coding range (0 to 113 400) exceeds the effective range
WN rollover count	$WNRO_{count}$	4	1	0	15	-	15 indicates that the parameter is invalid

Note 1.— SBAS service provider identifiers are defined in 3.5.1.1.

Note 2.— All other parameters are defined in 3.5.11.7.

Table B-105. Reserved

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-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 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.

3.5.14 DFMC SBAS NON-AIRCRAFT ELEMENTS

Note.— The parameters that are referred to in this section are defined in 3.5.11.

3.5.14.1 *General*

3.5.14.1.1 *Required data and broadcast intervals*. SBAS shall broadcast the data required for the supported functions described in Chapter 3, 3.7.3.4.2 as shown in Table B-108.

Note.— SBAS may broadcast null messages (Type 63 messages) in each time slot for which no other data are broadcast.

3.5.14.1.1.1 All data broadcast by SBAS, whether required or not for a particular function, shall meet the update requirements in Table B-108.

Table B-108. L5 data broadcast intervals and supported functions

Data type	Maximum broadcast interval	DFMC SBAS Ranging	Ionosphere-free differential correction	Associated message types
"Do Not Use"	6 s			0
Clock-ephemeris error corrections and covariance matrix data	$0.5x(I_{Valid})_{32}$ s per corrected satellite		R	32
SBAS satellite mask	120 s	R	R	31
Integrity information (DFREI and optionally DFRECI)	6 s	R	R	32, 34, 35, 36 and 40
SBAS satellite clock-ephemeris corrections and covariance matrix data	$0.5x(I_{Valid})_{39/40}$ s	R		39 and 40
OBAD, DFREI scale table and time reference identifier	120 s	R	R	37
SBAS almanac data, broadcast indicator and SBAS service provider ID parameters	120 s	R	R	47
SNT-to-UTC offset	240 s			42

Note 1.— "R" indicates that the data must be broadcast to support the function.

Note 2.— Integrity information includes DFRECI only if the Type 34 message is broadcast, otherwise it is limited to DFREI.

3.5.14.1.2 *SBAS radio frequency monitoring.* The SBAS shall monitor the SBAS satellite parameters shown in Table B-109 and take the indicated action.

Table B-109. SBAS L5 radio frequency monitoring

Parameter	Reference	Alarm limit	Required action (Note 1)
Signal power level	Chapter 3, 3.7.3.4.5.3 and 3.7.3.4.6.3	minimum specified power maximum specified power (Note 2)	Minimum: cease DFMC SBAS ranging function. Maximum: cease broadcast.
Modulation	Chapter 3, 3.7.3.4.5.5 and 3.7.3.4.6.5	Monitor for waveform distortion	Cease DFMC SBAS ranging function.
Carrier frequency stability	3.5.2.1 and 3.5.9.1	N/A (Note 3)	Cease DFMC SBAS ranging function unless σ^2_{DFRE} reflects error.
Code/frequency coherence	3.5.2.4 and 3.5.9.4.2	N/A (Note 3)	Cease DFMC SBAS ranging function unless σ^2_{DFRE} reflects error.
Maximum code phase deviation	3.5.2.6 and 3.5.9.6	N/A (Notes 2 and 3)	Cease DFMC SBAS ranging function unless σ^2_{DFRE} reflects error.
Convolutional and bi-binary encoding	3.5.2.9 and 3.5.9.9	All transmit messages are erroneous	Cease broadcast.

Notes.—

1. *The monitoring parameters which require action to "cease DFMC SBAS ranging function" are required only for SBAS satellites providing DFMC SBAS ranging. Ceasing the ranging function is accomplished by broadcasting a DFREI of "Do Not Use for SBAS" 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_{DFRE} parameter. If the error cannot be represented, the ranging function must cease.*

3.5.14.1.3 *"Do Not Use"*. SBAS shall broadcast a "Do Not Use" message (Type 0 message) when necessary to inform users not to use the SBAS satellite broadcast data on L5 and dual-frequency ranging function.

3.5.14.1.4 *Doppler shift in SBAS satellite*. The Doppler shift in the SBAS satellite signal seen at any fixed location within the footprint for any satellite shall not exceed:

a) ±337 Hz for GEO satellite signal; and

b) ±7 kHz for non-GEO satellite signal.

3.5.14.1.5 *SBAS ephemeris parameters*. When broadcasting ephemeris parameters, each SBAS satellite shall broadcast ephemeris parameters for itself as defined in 3.5.11.5.

3.5.14.1.5.1 The SBAS service provider shall ensure that the SBAS ephemeris time parameter t_e in the Type 40 message is set within -43 200 s and +43 199 s of the broadcast time and adjusted for day crossovers.

Note.— t_e is encoded as a time of day and the applicable day/week complies with the [-43 200 s; +43 199 s] time window.

3.5.14.1.6 *Almanac data*. Each SBAS satellite shall broadcast almanac data as defined in 3.5.11.7 for all SBAS satellites of the same service provider.

Note.— Additional information for certain SBAS orbits is given in Attachment D, 6.7.5.

3.5.14.1.6.1 The error in the estimated position of the satellite derived from any Type 47 message broadcast within the previous 15 minutes, with respect to the true satellite position, shall not exceed 3 000 km.

3.5.14.1.6.2 The error in the predicted Doppler shift computed from the Type 47 message shall not exceed ± 337Hz for a period of seven days after the broadcast of the Type 47 message.

Note.— SBAS receivers can expect this almanac accuracy for seven days from reception of the almanac message. The receiver needs to account for day and week crossovers since the almanac reference time is only in seconds of day.

3.5.14.1.6.3 If only one SBAS satellite almanac is provided in the Type 47 message, the bits from 118 to 225 assigned to the second SBAS satellite almanac shall be coded with “0”.

3.5.14.1.6.4 SBAS shall set the broadcast indicator to “1” for the SBAS satellite broadcasting the Type 47 message, and set the broadcast indicator to “0” for all other SBAS satellites.

3.5.14.1.6.5 SBAS service provider shall ensure the correctness of the SBAS service provider ID using the value allocated to the SBAS service provider as per Table B-27 in any Type 47 message.

3.5.14.1.6.6 SBAS service provider shall ensure that the SBAS almanac time parameter t_a in the Type 47 message is set within -43 200 s and +43 199 s of the broadcast time and adjusted for day crossovers.

Note.— t_a is encoded as a time of day and the applicable day/week complies with the [-43 200 s; +43 199 s] time window.

3.5.14.2 *Ranging function.* If an SBAS provides a DFMC SBAS ranging function, it shall also comply with the requirements contained in this section.

3.5.14.2.1 Performance requirements

Note.— See Chapter 3, 3.7.3.4.3.

3.5.14.2.2 *Ranging function data.* SBAS shall broadcast the ephemeris parameters, covariance matrix and DFREI value only for the broadcasting SBAS satellite through Type 39 and Type 40 messages both linked by their IODG.

3.5.14.2.3 *Active IODG.* SBAS shall have no more than three active IODG. An active IODG corresponds to an IODG parameter broadcast in Types 39 or 40 messages, which have not timed out as per Table B-107.

3.5.14.3 *Ionosphere-free differential correction function.* If an SBAS provides an ionosphere-free differential correction function, it shall also comply with the requirements contained in this section.

3.5.14.3.1 Performance of the ionosphere-free differential correction.

3.5.14.3.1.1 For en-route, terminal and non-precision approach, given any valid combination of active data, the probability of a horizontal error exceeding the HPL (as defined in 3.5.12.5) for longer than eight consecutive seconds shall be less than 10^{-7} in any hour, assuming a user with zero latency.

3.5.14.3.1.2 Given any valid combination of active data, the probability of an out of tolerance condition (e.g. horizontal error exceeding the HPL or vertical error exceeding the VPL, as defined in 3.5.12.5), for longer than 5.2 consecutive seconds time-to-alert shall be less than 2×10^{-7} during any approach, assuming a user with zero latency.

3.5.14.3.1.3 When SBAS detects that the probability of error exceeding the protection level is above the integrity risk requirement for one of the SBAS operations, the resulting alert information (set DFRE to a larger value or to "Do Not Use for SBAS"), broadcast in Types 32, 34, 35, 36 or 40 messages, shall be repeated three times in a row after the initial notification of the alert condition for a total of four times in four seconds.

Note 1.— A Type 0 message can also be sent four times in a row to indicate an alert condition. See attachment D, 6.7.4 for additional guidance.

Note 2.— Active data is defined as data that has not timed out per 3.5.15.1.4.2. This requirement includes core satellite constellation(s) and SBAS failures.

Note 3.— Subsequent messages can be transmitted at the normal update rate.

3.5.14.3.2 *SBAS satellite mask and issue of data mask (IODM).* SBAS shall broadcast an SBAS satellite mask and IODM (Type 31 message). The satellite slot values shall indicate whether or not data are being provided for each GNSS satellite.

3.5.14.3.2.1 SBAS shall change the IODM when there is a change in the SBAS satellite mask by increasing by 1 the IODM Modulo-4 from the latest transmitted value.

3.5.14.3.2.2 The IODM in Type 34, 35 and 36 messages shall equal the IODM broadcast in the satellite mask message (Type 31 message) used to designate the satellites for which data are provided in those messages.

3.5.14.3.2.3 SBAS shall have no more than two active IODMs. An active IODM corresponds to a satellite mask broadcast in a Type 31 message, which has not timed out as per Table B-107.

3.5.14.3.3 *Satellite corrections and covariance matrix data.*

3.5.14.3.3.1 Except for the broadcasting SBAS satellite, SBAS shall broadcast clock and ephemeris corrections and covariance matrix (Type 32 message) for any satellite in the SBAS satellite mask (i.e. with satellite slot value equal to "1") when SBAS sets a DFREI between 0 and 14.

Note.— The Type 39/40 message from the broadcasting satellite does not require further correction and therefore SBAS broadcasting satellite will not send correction data for itself.

3.5.14.3.3.2 SBAS shall broadcast clock and ephemeris correction and covariance matrix data with an issue of data navigation (IODN) matching to the clock and ephemeris data from GNSS satellites being corrected (IODs). The IODN value shall be derived from the IODs of GNSS satellite clock and ephemeris data as described in 3.5.11.2.

3.5.14.3.3.3 In order to enable all SBAS users to acquire the new GNSS data upon transmission of new valid clock and ephemeris data from the GNSS satellites, the SBAS shall continue to broadcast corrections and covariance matrix with respect to the old clock and ephemeris data for a period of time of:

a) 120 to 240 seconds for GPS;

b) 150 to 320 seconds for GLONASS;

c) 150 to 350 seconds for Galileo; and

d) 120 to 300 seconds for BDS.

Note.— "Valid clock and ephemeris data" means that the information broadcast by the GNSS satellites is in line with its signal interface control document (ICD), performance standard and SARPs.

3.5.14.3.3.4 For any non-SBAS satellite, SBAS shall only broadcast a Type 32 message when SBAS has continuously monitored that satellite's ephemeris and clock data for at least 300 seconds.

Note.— IOD is defined in 3.5.11.2 and includes a comparison of the GPS LNAV IODE with the 8 LSB of the GPS LNAV IODC. Ephemeris and clock data is derived from the core constellation navigation message being augmented by DFMC SBAS as mentioned in 3.5.11.1.

3.5.14.3.3.5 SBAS service provider shall ensure that the correction time of applicability parameter t_D in the Type 32 message is set within -43 200 s and +43 199 s of the broadcast time and adjusted for day crossovers

Note.— t_D is encoded as a time of day and the applicable day/week complies with the [-43 200 s; +43 199 s] time window.

3.5.14.3.4 *Integrity data*. For each satellite set in the SBAS satellite mask, SBAS shall broadcast DFREI information using DFREI or DFRECI parameters, covariance matrix, scale exponent and degradation parameters such that the integrity requirement in 3.5.14.3.1 is met. If the corrections exceed their coding range or if $\boldsymbol{\sigma}^2_{\mathbf{DFC}}$ (as described in 3.5.12.4.1) cannot be determined, SBAS shall indicate that the satellite is not appropriate for SBAS position ("Do Not Use for SBAS").

Note.— The SBAS receiver will apply the DFRECI to its current active DFREI which can be any active broadcast DFREI.

3.5.14.3.4.1 SBAS shall provide DFREI information, directly via DFREI parameter or indirectly via DFRECI parameter, allowing the computation of σ_{DFRE} (as defined in 3.5.11.4) for the satellite set in the satellite mask and monitored by SBAS using Types 34, 35 or 36 messages at least every six seconds.

3.5.14.3.4.1.1 When using a Type 34 message, the SBAS shall transmit at most seven DFRECIs set to “1”.

Note 1.— Instead of transmitting updated DFREI values in the Type 34 message, the SBAS can set some DFRECI values to “2” or “3” to change DFREIs on more than seven satellites and still use the Type 34 message. Types 35 or 36 message can also be used instead of Type 34 messages to provide more DFREI value updates.

Note 2.— The DFRECIs are in augmented slot index order derived from the Type 31 message with a matching IODM.

3.5.14.3.4.1.2 When using a Type 34 message with DFRECI set to “1”, the SBAS shall broadcast the new DFREI values in the order corresponding to the order of DFRECI set to “1” across the DFRECI field. The new DFREI value shall apply to the augmented slot index of the corresponding DFRECI value set to “1”.

3.5.14.3.4.2 SBAS shall set to “15” any DFREI value in the associated data field of Types 35 and 36 messages, which corresponds to satellite slot number not set in the mask.

3.5.14.3.4.2.1 When using a Type 34 message, SBAS shall set DFRECI value to “3” for DFRECI slots exceeding the maximum augmented slot index.

3.5.14.3.4.2.2 If in a given Type 34 message, the number N of DFRECI set to “1” is below seven, the last 7-N DFREI values of the Type 34 message shall be set to “15”.

3.5.14.3.4.3 When using a Type 34 message, SBAS shall transmit a DFRECI of “3” (“Do Not Use for SBAS”) instead of transmitting a DFRECI of “2” (“DFREI increased by one”) when the most recent active DFREI was set to “14” and the corresponding DFRE value is no longer adequate to ensure integrity as per 3.5.14.3.1.

3.5.14.3.4.4 SBAS shall send $(I_{VALID})_{32}$ and $(I_{VALID})_{39/40}$ in the Type 37 messages corresponding to the time intervals during which the integrity data of Type 32 and Type 39/40 messages can be used.

Note.— These time intervals are measured from the time of arrival of the last bit of Type 32 or the last bit of the last message in the paired Type 39/40 messages being received at the antenna port of the SBAS receiver.

3.5.14.3.4.5 The integrity requirement in 3.5.14.3.1 shall apply throughout the update of parameters in a Type 37 message.

Note.— It is expected that change in the DFREI scale table will be a rare event in the lifetime of an SBAS.

3.5.14.3.4.5.1 For each DFREI, the σ_{DFRE} value shall always be greater than the σ_{DFRE} value specified for lower DFREI in the scale table in the Type 37 message.

3.5.14.3.5 *Old but active data (OBAD).* SBAS shall broadcast OBAD parameters (Type 37 message) such that the integrity requirement in 3.5.14.3.1 is met.

3.5.14.3.6 *Timing data*

3.5.14.3.6.1 SBAS shall indicate on which reference time the SNT for DFMC SBAS is aligned through the time reference identifier field of the Type 37 message.

3.5.14.3.6.2 If an SBAS provides the $WNRO_{count}$ information with a parameter not permanently set to "15", the SBAS shall monitor the week number rollover by updating the week number rollover count ($WNRO_{count}$) in the Type 47 message for the GNSS constellation identified by the time reference identifier in the Type 37 message.

Note.— The week number rollover count is used to solve the possible ambiguity of the week number value transmitted through the GNSS navigation data. Information on the reference time per constellation to compute the $WNRO_{count}$ *can be found in 3.5.11.7.*

3.5.14.3.6.3 If a Type 42 message is broadcast, SBAS shall provide information to derive the SNT-to-UTC offset in line with the information set in the VP parameter.

Note.— The UTC offset status parameter can be used by the SBAS to time-out previously broadcast information.

3.5.14.3.6.4 If a Type 42 message is broadcast and if a SNT-to-UTC offset cannot be broadcast by SBAS, SBAS shall broadcast all parameters in common parameter field with all bits coded to zero except the UTC standard identifier set to "7".

3.5.14.4 *Monitoring*

3.5.14.4.1 *SBAS radio frequency monitoring.* The SBAS shall monitor the SBAS satellite parameters shown in Table B-109 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 the pseudo-range acceleration specified in Chapter 3, 3.7.3.4.3.5, carrier phase noise specified in 3.5.9.2, and correlation loss in 3.5.9.5, unless analysis and testing shows that these parameters cannot exceed the stated limits.

3.5.14.4.2 *Data monitoring.* The SBAS shall monitor GNSS ranging signals to ensure that active data meets the requirements of 3.5.14.3.1.

3.5.14.4.2.1 The ground subsystem shall lock on main correlation peaks of the tracked signals used for the SBAS augmentation.

3.5.14.4.2.2 The ground subsystem shall ensure that broadcast data bound the residual error for airborne receivers according to DFMC SBAS receiver design constraints defined in 3.5.15.1.1.3 when exposed to GNSS signal distortions defined in Attachment D, 8.

Note.— SBAS receiver locks on the main correlation peak of the tracked signal following the requirement in 3.5.15.1.5.

3.5.14.4.2.3 The monitor action shall be to set DFRE to a larger value or to "Do Not Use for SBAS" for the satellite.

3.5.14.4.2.4 SBAS shall monitor all active data that can be used by any user within the coverage area.

3.5.14.4.2.5 SBAS shall raise an alert within 5.2 seconds if any combination of active data and GNSS signals-in-space results in a horizontal or vertical position error exceeding respectively the HPL or VPL (as per 3.5.14.3.1).

Note.— The monitoring applies to all failure conditions, including failures in core satellite constellation(s) or SBAS satellites. This monitoring assumes that the aircraft element complies with the requirements of 3.5.15.

3.5.14.4.3 *IOD monitoring.* SBAS shall take appropriate action to ensure integrity of the broadcast information when the active IODN as described in 3.5.11.2 can be linked to more than one valid ephemeris.

Note 1.— Active data is defined as data that has not timed out as per Table B-107. This requirement includes core satellite constellation(s) and SBAS failures.

Note 2.— Additional information on the application of SBAS corrections by an SBAS receiver is provided in 3.5.15.1.4.8 and can be used to assess the time during which a mismatch of IODN and core constellation can be considered by SBAS.

3.5.14.5 *Robustness to core constellation(s) failures.* SBAS shall continue to provide SBAS services after removal of one or several satellites, including a complete core constellation.

Note. — SBAS systems are expected to maintain operation in the presence of failures or anomalies on one or several satellites or failure of a complete core constellation. The level of supported service degrades as more satellites are removed. Removal of a failed or unhealthy satellite does not impact the ability to monitor and correct other satellites.

3.5.15 DFMC SBAS AIRCRAFT ELEMENTS

Note 1.— The parameters that are referred to in this section are defined in 3.5.11.

Note 2.— Whereas all SBAS receivers process signals from SBAS GEO satellites, processing non-GEO SBAS signals is optional.

3.5.15.1 DFMC SBAS-capable GNSS receiver.

3.5.15.1.1 *DFMC SBAS-capable GNSS receiver*. Except as specifically noted, the DFMC SBAS-capable GNSS receiver shall process the signals of the SBAS and meet the requirements applicable to the core constellations it tracks 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 receivers), and/or 3.1.4.3.1 (BDS receivers). Pseudo-range measurements for each satellite shall be smoothed using carrier measurements and the filter identified in 3.5.1.1 with the following pseudo-range observables:

$P_{1,k}$ is the L1 C/A or L1OCd or E1-C or B1C_pilot or SBAS L1 raw pseudo-range measurement in metres;

$P_{2,k}$ is the L5-Q or L3OCd or E5a-Q or B2a_pilot or SBAS L5 raw pseudo-range measurement in metres;

$\varphi_{1,k}$ is the accumulated L1 C/A or L1OCd or E1-C or B1C_pilot or SBAS L1 raw carrier phase measurement in metres;

$\varphi_{2,k}$ is the accumulated L5-Q or L3OCd or E5a-Q or B2a_pilot or SBAS L5 raw carrier phase measurement in metres;

$\gamma_{12} = \left(\frac{f_1}{f_2}\right)^2$ is the square frequency ratio, where f_1 is L1 C/A or L1OCd or E1-C or B1C_pilot or SBAS L1 and f_2 is L5-Q or L3OCd or E5a-Q or B2a_pilot or SBAS L5; and

α is the filter weighting function defined as follows: after 100 seconds have elapsed since filter initialization, α shall be equal to the sample interval in seconds divided by the time constant of 100 seconds. In the first 100 seconds since filter initialization, α shall be equal to the sample interval in seconds divided by the time in seconds since filter initialization.

3.5.15.1.1.1 The receiver shall process the augmented signals as follows:

a) for GPS: the receiver shall use a BPSK(1) replica for L1 C/A signal and a BPSK(10) replica for L5-Q signal. The satellite position and satellite clock shall be based on ephemeris in LNAV message on L1. Group delay correction from LNAV message on L1 shall be applied;

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 ($\mathbf{\Delta t}_{SV,i}$) 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 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 Δ_t defined in 3.5.12.3.1.

3.5.15.1.1.3 *DFMC SBAS aircraft element design constraints.* For the processing of L1, L5, E1, E5a, B1C, B2a, L1OC and L3OC signals, the aircraft element shall comply with the following constraints:

a) 3 dB bandwidth between 12 and 24 MHz centred around L1 carrier frequency and around L5 carrier frequency with a minimum of 24 dB per octave gain roll-off;

b) differential group delay not greater than 150 ns;

c) early minus late discriminator;

d) L1/E1/L1OC/B1C correlator spacing between 0.08 and 0.12 L1 chips; and

e) L5/E5a/L3OC/B2a correlator spacing between 0.9 chips and 1.1 L5 chips.

Note.— This requirement constrains the entire aircraft implementation of the DFMC SBAS capability and not only for the DFMC SBAS receiver.

3.5.15.1.2 *GEO SBAS satellite acquisition on L5*. The receiver shall be able to acquire and track GEO satellites for which a stationary receiver at the user receiver location would experience a Doppler shift as large as ±337 Hz.

3.5.15.1.3 *Non-GEO SBAS satellite acquisition on L5*. The non-GEO SBAS capable receiver shall be able to acquire and track non-GEO satellites for which a stationary receiver at the user receiver location would experience a Doppler shift as large as ±7 kHz.

Note.— Information on non-GEO Doppler range is available in Attachment D, 6.7.5.

3.5.15.1.4 Conditions of use of data on L5.

3.5.15.1.4.1 The receiver shall use data from an SBAS message only if the CRC of this message has been verified.

3.5.15.1.4.2 The receiver shall use the information transmitted in DFMC messages only within the time-out period, defined in Table B-107, starting from the reception of the last bit of the message.

3.5.15.1.4.3 Upon reception of a Type 0 message, the receiver shall cease using all data received from this signal that have defined time-out intervals in Table B-107, except for the SBAS service provider identifier which can be used only for the SBAS acquisition process.

3.5.15.1.4.4 The receiver shall only apply integrity data for which Type 34, 35 or 36 messages IODM matches an active Type 31 message IODM.

3.5.15.1.4.5 The reception of new DFREI shall replace the old DFREI.

3.5.15.1.4.6 DFRECI requirements.

3.5.15.1.4.6.1 The receiver shall treat the reception of a DFRECI = 0 or a DFRECI = 2 as though it had received a new copy of the most recent, active DFREI previously received through Type 32, 34, 35, 36 or 40 messages.

3.5.15.1.4.6.2 Upon reception of a DFRECI = 2, the equipment shall use the most recent, active DFREI received through Types 32, 34, 35, 36 or 40 messages and use the σ_{DFRE} corresponding to the active DFREI increased by one.

Note.— The effect of the reception of a DFRECI = 2 ("value increase of 1") is not cumulative.

3.5.15.1.4.6.3 Upon reception of a DFRECI = 3, the receiver shall set the DFREI to "15" ("Do Not Use for SBAS") and exclude the satellite from the SBAS position solution.

3.5.15.1.4.6.4 Upon reception of a DFRECI = 1, the receiver shall update the DFREI value by decoding the corresponding DFREI slot in the order of a Type 34 message DFRECI set to "1" across the DFRECI field.

3.5.15.1.4.7 The receiver shall use the DFREI table through the latest decoded Type 37 message for the computation of σ_{DFRE} based on received DFREI.

3.5.15.1.4.8 Upon reception of the initial valid Type 32 message applicable to a given non-SBAS satellite, the receiver shall invalidate for this satellite any retained clock/ephemeris data set containing at least one parameter received for the last time more than 5 minutes before the reception of the initial valid Type 32 message.

Note.— The "initial valid Type 32 message" is the first Type 32 message received when there is no active Type 32 message from the SBAS L5 signal in use.

3.5.15.1.4.9 The receiver shall apply the ephemeris and clock parameters, the covariance matrix parameters, the OBAD parameters and the integrity parameters as described in 3.5.12.4 and 3.5.12.5.

3.5.15.1.4.10 The receiver shall use the content of Types 39 and 40 messages, only when Types 39 and 40 messages with the same IODG have been received and have not timed out.

3.5.15.1.4.11 The receiver shall correctly account for the day and week rollover change when observed after the last received Type 47 message.

3.5.15.1.4.12 The receiver shall only use SBAS augmented satellite ranges from satellites with elevation angles at or above 5 degrees in the DFMC SBAS position computation.

3.5.15.1.4.13 The receiver shall only use correction, integrity and other data obtained from a single SBAS satellite L5 signal, designated by its PRN code, for all satellites used in the position solution.

Note.— When using additional SBAS satellites for ranging, the receiver uses the clock and ephemeris parameters in the Type 39/40 message from the ranging SBAS satellite(s), and the covariance and integrity parameters (e.g. DFREI, delta_R_{CORR}) in the Type 32 message from the SBAS satellite being used for corrections.

3.5.15.1.4.14 Prior to use, the receiver shall verify that the tracked SBAS PRN code matches the PRN code derived from the satellite slot delta field within the almanac data upon reception of the Type 47 message with the broadcast indicator set to "1" or derived from the satellite slot delta field in an active Type 39 message.

3.5.15.1.4.15 In the event of a loss of four successive SBAS messages, the receiver shall invalidate all DFREIs and DFRECIs previously received from this SBAS PRN.

3.5.15.1.4.16 The receiver shall check that the t_D parameter in Type 32 message, as well as t_e and a_{Gf0} parameters in Type 39/40 message, are within the effective range indicated in the message tables under 3.5.13. If the effective range check fails, the message shall be discarded.

Note.— Message bits or fields marked as "Reserved" or "Spare" may take any value during the operational lifetime of the SBAS service.

3.5.15.1.5 The SBAS receiver shall lock on main correlation peak of each of the tracked signals augmented by the SBAS and used in the SBAS position solution.

3.5.15.2 *SBAS satellite position*

3.5.15.2.1 *Position computation with ephemeris*. When using SBAS ranging, the receiver shall decode Type 39/40 messages and determine the position (X_G, Y_G, Z_G) of the SBAS satellite using the protocol described in 3.5.12.3.

3.5.15.2.2 *Position computation with almanac.* When computing the SBAS satellite position using a Type 47 message, the receiver shall determine the position (X_G, Y_G, Z_G) of the SBAS satellite using the protocol described in 3.5.12.2.

3.5.15.3 *Ionosphere-free differential functions*

3.5.15.3.1 *GNSS satellite status function*. The receiver shall exclude satellites from the SBAS position solution if they are identified as "Do Not Use for SBAS".

Note 1.— In the case of a satellite designated marginal or unhealthy by the core satellite constellation(s) health flags, SBAS may broadcast ephemeris and clock corrections that will allow the user to continue using the satellite as long as performance requirements in 3.5.14.3.1 are met.

Note 2.— If satellites identified as "Do Not Use for SBAS" by SBAS are used in the position solution, integrity is not provided by SBAS.

3.5.15.3.2 *Core satellite constellation(s) ranging accuracy for precision approach.* The RMS (1 sigma) of the total airborne contribution in steady state to the error in a corrected ionosphere-free pseudo-range shall be less than or equal to the value in Table B-114 at minimum and maximum power levels.

Table B-114. Core constellation satellite ionosphere-free receiver ranging accuracy for precision approach

	GPS (See Chapter 3, 3.7.3.1.1.8.6)	GLONASS (See Chapter 3, 3.7.3.1.2.9.4 and 3.7.3.1.2.10.4)	Galileo (See Chapter 3, 3.7.3.1.3.11.1 and 3.7.3.1.3.11.2)	BDS (See Chapter 3, 3.7.3.1.4.9.4.1 and 3.7.3.1.4.10.4.1)
Minimum power level	0.4 m	0.65 m	0.4 m	0.4 m
Maximum power level	0.3 m	0.3 m	0.3 m	0.3 m

3.5.15.3.3 The receiver shall use the protocol described in 3.5.12.4 for the SBAS position solution and for the constellation time difference if more than one constellation is augmented by the SBAS.

3.5.15.3.4 The receiver shall compute the SBAS horizontal and vertical protection levels as defined in 3.5.12.5.

3.5.15.3.4.1 The airborne receiver error variance $\sigma^2_{air,DF}$ for satellite i shall be computed as follows:

$$\sigma^2_{air,DF}[i] = \sigma^2_{noise}[i] + \sigma^2_{MP\&AGDV,DF}[i]$$

where

$\sigma^2_{noise}[i]$ is defined in 3.5.15.3.2;

$\sigma^2_{MP\&AGDV,DF}$, the multipath and antenna group delay variation error model for ionosphere-free dual-frequency 100-second smoothed measurements, described by a normal distribution with zero mean and a standard deviation of:

for GPS, Galileo, GLONASS and BDS: $\sigma_{MP\&AGDV,DF}[i] = 0.34 + 0.4\, exp\left(-El_{deg}\ [i]/14°\right)$ (in metres); and

where $El_{deg}\ [i]$ is the elevation angle of satellite i (in degrees).

Note. — The models are valid when the receiver is in a steady state.

3.5.15.3.4.2 For ionosphere-free dual-frequency measurements, the residual ionospheric uncertainty shall be defined as:

$$\sigma_{i,iono} = \frac{40.0}{261.0+\left(El_{deg}\ [i]\right)^2} + 0.018 \text{ (in metres)}$$

where $El_{deg}\ [i]$ is the elevation angle (in degrees) of satellite i.

3.5.15.3.5 The parameters in the SBAS FAS data block applicable to DFMC SBAS receivers shall be as described in 3.5.8.4.2.6 with the exception of the operation type and the approach performance designator as described below:

Operation type: straight-in approach procedure or other operation types applicable to DFMC SBAS receivers.

Coding:	0	= straight-in approach procedure with SPID from 0 to 13
	1 to 7	= spare
	8	= straight-in approach procedure with SPID from 16 to 31
	9 to 15	= spare

Approach performance designator (APD): shall indicate the SBAS service supporting the requirements in accordance with Table 3.7.2.4-1 for the approach defined by the FAS data block, including the completion of a system-specific safety analysis for Category 1 if the vertical alert limit (VAL) in the FAS data block is greater than 10 m.

Coding:	0	=	DFMC SBAS or L1 SBAS service
	1	=	DFMC SBAS service augmenting one or more constellations (L1 SBAS not supported)
	2	=	DFMC SBAS service augmenting at least two constellations (L1 SBAS not supported)
	3 to 4	=	Spare
	5	=	DFMC SBAS service augmenting one or more constellations (L1 SBAS with reduced continuity/availability)
	6	=	DFMC SBAS service augmenting at least two constellations (L1 SBAS with reduced continuity/availability)
	7	=	Spare

Note 1.— The different APD coding values are intended to communicate potential performance differences available from the SBAS services at the approach location based on the number of GNSS frequencies and the number of augmented constellations used. Only DFMC SBAS airborne receivers use the APD to select the appropriate airborne receiver mode to support the operation. Further information can be found in Attachment D, 6.6.5.

Note 2.— "L1 SBAS not supported" means that, for a Category I approach, the L1 SBAS service in the approach region does not meet the system-specific safety assessment for the published VAL. See also the guidance in Attachment D, 3.3.9 and 6.6.5.

Note 3.— "L1 SBAS service with reduced continuity/availability" means that the L1 SBAS service in the approach region does not meet the availability or continuity requirements for the approach. Additional aircraft element integration may be used to satisfy availability and continuity requirements for the approach. The determination of the SBAS-based position domain NSE availability and continuity, using additional aircraft element system integration, and the assessment of the suitability of that availability and continuity for the approach, is the responsibility of the aircraft element. For a Category 1 approach, the L1 SBAS service does meet the system-specific safety assessment for the published VAL, following the guidance in Attachment D, 3.3.9 and 6.6.5.

3.5.15.3.5.1 For operations defined by a FAS data block, the receiver shall determine the operational SBAS service provider identifier (SPID) applicable to the operation as follows: if the operation type is 0, the operational SPID shall be the value of the FAS data block SPID; if the operation type is 8, the operational SPID shall the sum of 16 and the value of the FAS data block SPID.

3.5.15.3.5.2 For operations defined by a FAS data block and the operational SPID is not 15, the receiver shall select SBAS signals with an active SPID decoded from a received Type 47 message that matches the operational SPID determined from the FAS data block (see 3.5.15.3.5.1).

3.5.15.3.5.3 For operations defined by a FAS data block, the receiver shall use the APD to determine the acceptable combination of SBAS navigation service (i.e. DFMC SBAS and/or L1 SBAS) and the number of constellations required to support the intended operation (see Attachment D, 6.6.5).

3.5.15.3.5.4 For operations defined by a FAS data block with an operational SPID of 15 and an APD of two or six, the receiver shall select SBAS satellites that augment two or more constellations that can be used by the receiver.

Note.— If the operational SPID is 15 and the APD is not two or six, the receiver can select any operational SBAS (not broadcasting MT0).

3.5.15.4 *Ranging function*

3.5.15.4.1 *DFMC SBAS satellite ranging accuracy*. The root-mean-square (1 sigma) of the total airborne contribution in steady state to the error in a corrected ionosphere-free pseudo-range for a dual-frequency SBAS ranging satellite under the worst interference environment as defined in 3.7, excluding multipath effects, tropospheric and ionospheric residual errors, shall be less than or equal to 0.8 metres at the minimum received signal power level or equal to 0.6 metres at the maximum received signal power level (Chapter 3, 3.7.3.4.6.3).

3.5.15.5 *Timing function*

3.5.15.5.1 If a UTC time is derived from an SBAS receiver through a Type 42 message, the receiver shall time-out previously received SNT-to-UTC information if the receiver decodes a UTC offset status set to 1.

3.5.15.5.2 If a UTC time is derived from an SBAS receiver through a Type 42 message, the receiver shall not apply the content of the received Type 42 message if the UTC standard identifier is set to 7.

Note.— The receiver may still use previously received information if not timed-out and if the UTC offset status is set to 0 in the received Type 42 message.

End of new text.

3.5.~~9~~.16 INTERFACE BETWEEN SBAS

Note.— Guidance material on the interface between different SBAS service providers is given in Attachment D, 6.3.

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Figure B-12. L1 ~~D~~data block format

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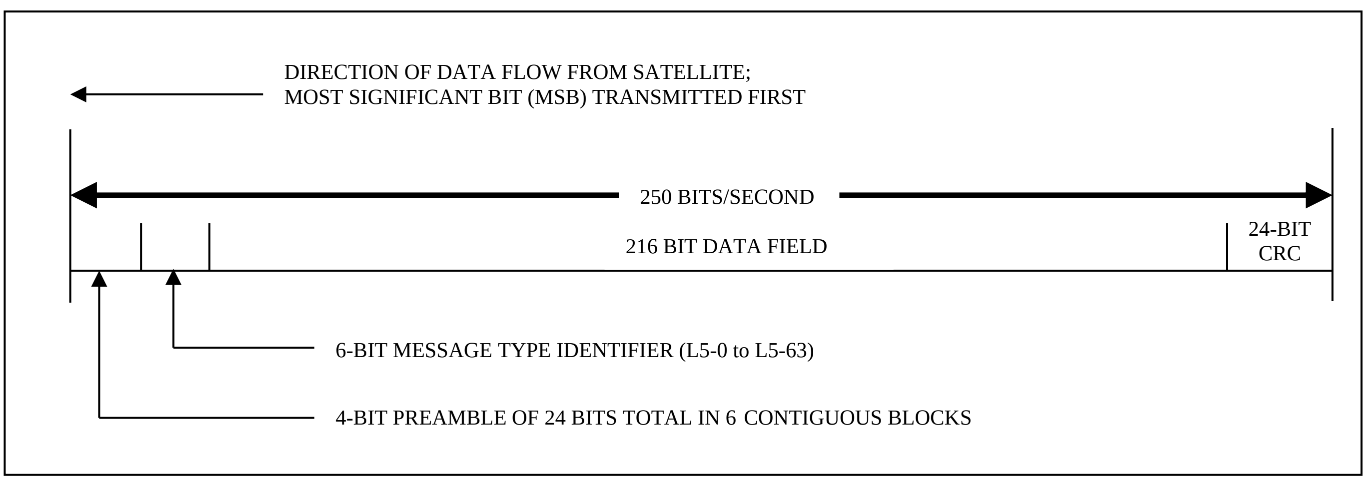

Figure B-21. L5 data block format

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ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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3. NAVIGATION SYSTEM PERFORMANCE REQUIREMENTS

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3.2.9 SBAS and GBAS receivers will be more accurate, and their accuracy will be characterized in real time by the receiver using standard error models, as described in Chapter 3, 3.5, for SBAS and Chapter 3, 3.6, for GBAS.

Note 1.— The term "SBAS receiver" designates the GNSS avionics that at least meet the requirements for an SBAS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-229D with Change 1 (or equivalent) or the specification of the EUROCAE/ED-259 (or equivalent).

Note 2.— The term "GBAS receiver" designates the GNSS avionics that at least meet the requirements for a GBAS receiver as outlined in Annex 10, Volume I and the specifications of RTCA/DO-253A, as amended by United States FAA TSO-C161 and TSO-C162 (or equivalent).

3.3 Integrity

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3.3.14 GNSS single-frequency augmentations are also subject to several atmospheric effects, particularly due to the ionosphere. Spatial and temporal variations in the ionosphere will affect mostly single-frequency navigation because they can cause local or regional ionospheric delay errors that cannot be corrected within the L1 SBAS or GBAS architectures due to the definition of the message protocols and the sparse sampling of augmentation systems. Such events are rare and their likelihood varies by region, but they are not expected to be negligible. The resulting errors can be of sufficient magnitude to cause misleading information and should be mitigated in the system design through accounting for their effects in the broadcast parameters (e.g. σ_{iono_vert} in GBAS), and monitoring for excessive conditions where the broadcast parameters are not adequate. The likelihood of encountering such events should be considered when developing any system monitor. SBAS dual-frequency augmentations use ionosphere-free pseudo-ranges in order to remove the first order ionosphere delay in the position computation. The dual-frequency protection level includes a small error allocation to bound the residual ionosphere errors and greatly reduce the impact of local and temporal variations in ionospheric delays on the navigation solution.

3.3.15 Another environmental effect that should be accounted for in the ground system design is the errors due to multipath at the ground reference receivers, which depend on the physical environment of monitoring station antennas as well as on satellite elevations and times in track.

3.3.16 SBAS needs to assure the integrity of its broadcast corrections as required in Chapter 3, 3.7.2.4, throughout its coverage area. This requirement also applies outside the intended service area, where user receivers could navigate using either an SBAS navigation solution, if available, or L1 fault detection and exclusion (FDE) navigation solution that combines satellites with SBAS corrections and satellites without SBAS corrections. DFMC SBAS corrections are not intended for use in an FDE navigation solution. The L1 SBAS contributions to a single-frequency FDE navigation solution are limited to assuring the integrity of the transmitted corrections. SBAS systems have to comply with all the integrity requirements for all typical operations from En-route to Category I, defined in Chapter 3, Table 3.7.2.4-1, in the coverage area when, for a given operation, the horizontal and vertical protection levels are lower than the corresponding alert limits. This is of particular importance for vertically guided operations using SBAS that are not controlled by FAS data block.

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4.4 GNSS antenna and receiver

4.4.1 The antenna specifications in Appendix B, 3.8.3.1, determine the axial ratio performance of the antennas. The specifications for the single-frequency only antennas do not control the antenna axial ratio except at boresight.

4.4.2 Linear polarization should be assumed for the airborne antenna for SBAS GEO signals received at low-elevation angles. For instance, when receiving an SBAS GEO signal that needs to be provided ~~if the~~ at a minimum elevation angle ~~for which a trackable GEO signal needs to be provided is~~ of 5 degrees, ~~the~~ single-frequency antennas should be presumed to be linearly polarized with −2.5 dBil (−5.5 dBic) gain ~~when receiving this signal~~. This should be taken into account in the SBAS GEO satellite link budget in order to ensure that the minimum received RF signal at the antenna port meets the requirements of Chapter 3, 3.7.3.4.~~4~~ 5.3.2 and 3.7.3.4.6.3.

4.4.3~~2~~ The failures caused by the receiver can have two consequences on navigation system performance which are the interruption of the information provided to the user or the output of misleading information. Neither of these events are accounted for in the signal-in-space requirement.

4.4.4~~3~~ The nominal error of the GNSS aircraft element is determined by receiver noise, interference, and multipath and tropospheric model residual errors. Specific receiver noise requirements for both the SBAS airborne receiver and the GBAS airborne receiver include the effect of any interference below the protection mask specified in Appendix B, 3.7. The required performance has been demonstrated by receivers that apply narrow correlator spacing or code smoothing techniques.

4.4.5 The method for the search of the in-band, near-band and out-of-band maximum non-aeronautical interference tolerable power consists, for each interference bandwidth BWi, in computing the largest value of the Spectral Separation Coefficient (SSC) for all PRNs and for all central frequencies $fc_i = fc_{L1orL5}$ +/- max(BW_{GNSS}/2, BWi/2), where BW_{GNSS} = 20 MHz. For all GNSS signals' modulations (BPSK and MBOC) considered in the SARPs, this process results in an in-band, near-band maximum tolerable power monotonously increasing with BWi. The out-of-band maximum tolerable power is evaluated for BWi = 1 kHz.

4.4.6 Following Note 5 in Table B-87 of Appendix B, Table B-87 does not describe non-aeronautical pulsed interferences in the environment to be considered for the L5 channel in an L1/L5 receiver as their impact is negligible compared to DME/TACAN and JTIDS/MIDS impact considered in the environment.

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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.

6.1.2 The SBAS ground network measures the pseudo-range between the ranging source and an SBAS receiver at the known locations and provides separate corrections for ranging source ephemeris errors, clock errors and, in addition for the L1 SBAS service, ionospheric delays and errors. The user applies a tropospheric delay model.

6.1.3 The ranging source ephemeris error and slow moving clock error are the primary basis for the corrections provided in DFMC SBAS service and provided in ~~bases for~~ the long-term correction in L1 SBAS. The ranging source clock error is adjusted for the long-term correction and tropospheric error and is the primary basis for the fast correction provided in L1 SBAS service. The ionospheric errors among many ranging sources are combined into vertical ionospheric errors at predetermined ionospheric grid points. These errors are the primary ~~bases~~ basis for ionospheric corrections provided in L1 SBAS service. No fast corrections are provided in DFMC SBAS service as a result of the slow clock drift performance of GNSS core constellations. No ionospheric corrections are provided in DFMC SBAS service as DFMC SBAS corrections are provided for ranging derived from the ionosphere-free combination of satellite signals, which removes almost all ionospheric delay from the ranging measurements.

6.2 SBAS coverage area and service areas

6.2.1 It is important to distinguish between the coverage area and service areas for an SBAS. A coverage area typically corresponds to the ~~GEOs~~ union of SBAS satellite footprint areas and comprises one or more service areas. Service areas are declared by SBAS service providers or by the State or group of States managing the SBAS, for the typical operations defined in Table 3.7.2.4-1 (e.g. En-route, APV-I, Category I) where the corresponding accuracy, integrity and continuity requirements are met with a certain availability (e.g. 99 per cent). Some SBAS service providers publish service areas of their systems (e.g. WAAS Performance standard, EGNOS Service Definition Document and AIPs). The service area for En-route may be ~~wider~~ larger than the service area for APV-I. DFMC SBAS can provide service areas that can be larger than service areas provided by L1 SBAS for the same service levels. For the GNSS receiver, the SIS is usable whenever the protection levels are lower than the alert limits for the intended operation (VPL<VAL and HPL<HAL), irrespective of whether or not the GNSS receiver is inside the corresponding service area defined by the SBAS service provider. SBAS systems support operations based on some or all of the SBAS functions defined in Chapter 3, 3.7.3.4.2. These functions can be related to the operations that are supported as follows:

a) *Ranging*: SBAS can provide~~s~~ a single-frequency ranging source on L1. L1 ranging can be used in the SBAS solution or for ~~use with~~ other augmentation(s) (ABAS, GBAS or other SBAS); SBAS can provide a dual-frequency ranging source using L1 and L5 frequencies suitable for a DFMC SBAS position derived from the broadcasting SBAS system.

b) *Satellite status and basic differential corrections*: L1 SBAS provides en-route, terminal, and non-precision approach service. Different operations (e.g. performance-based navigation (PBN) operations) may be supported in different service areas;

c) *Precise differential corrections*: L1 SBAS provides APV and precision approach service (i.e. APV-I~~, APV-II~~ and Category I precision approach may be supported in different service areas)~~.~~;

d) *Ionosphere-free differential correction*: DFMC SBAS provides en-route, terminal, non-precision approach, APV and precision approach service (i.e. APV-I and Category I precision approach). Different operations (e.g. PBN operations) may be supported in different service areas.

6.2.2 Satellite-based augmentation services are provided by the Wide Area Augmentation System (WAAS) (North America), the European Geostationary Navigation Overlay Service (EGNOS) (Europe and Africa), the Michibiki Satellite-based Augmentation Service (MSAS) (Japan) and the GPS-aided Geo-augmented Navigation (GAGAN) (India). The System ~~of~~for Differential Correction and Monitoring (SDCM) (Russia), the BeiDou Satellite-based Augmentation System ~~SBAS~~ (BDSBAS) (China), the Korea Augmentation Satellite System (KASS) (Republic of Korea), the SBAS for Africa and Indian Ocean (A-SBAS) (ASECNA) and the Southern Positioning Augmentation Network (SouthPAN) (Australia and New Zealand) are also under development to provide these services.

6.2.3 An SBAS may provide accurate and reliable service outside the defined service area(s). The ranging, satellite status,~~and~~ basic differential corrections and ionosphere-free differential correction functions are usable throughout the entire coverage area. The performance of these functions may be technically adequate to support en-route, terminal and non-precision approach operations by providing monitoring and integrity data for core satellite constellations and/or SBAS satellites. L1 SBAS mitigates errors which cannot be monitored by its ground network through message Type~~s~~ 27 or message Type 28. DFMC SBAS mitigates errors that cannot be monitored by its ground network through message Type 32.

6.2.4 Each State is responsible for approving SBAS-based operations within its airspace. In some cases, States will field SBAS ground infrastructure linked to an SBAS. In other cases, States may ~~simply~~ approve service areas and SBAS-based operations using available SBAS signals. In either case, each State is responsible for ensuring that SBAS meets the requirements of Chapter 3, 3.7.2.4, within its airspace, and that appropriate operational status reporting and NOTAMs are provided for its airspace.

6.2.5 Before approving SBAS-based operations, a State must determine that the proposed operations are adequately supported by one or more SBASs. This determination should focus on the practicality of using SBAS signals, taking into account the relative location of the SBAS ground network. This could involve working with the State(s) or organization(s) responsible for operating the SBASs. For an airspace located relatively far from an SBAS ground network, the number of visible satellites for which that SBAS provides status and basic corrections would be reduced. Since L1 SBAS receivers are able to use data from two SBASs simultaneously, and to use autonomous fault detection and exclusion when necessary, availability may still be sufficient for approval of operations. Unlike the L1 SBAS service that can only provide ionospheric delay estimate near the SBAS reference network, the ionosphere-free differential corrections will provide a valid solution in airspace located relatively far from the SBAS reference network. In most cases, there will be overlap of DFMC services from neighbouring SBAS systems and users will be able to transition directly from one SBAS system to another. There is no benefit from the combination of ranging sources corrected by two or more SBAS services, but there would be additional error bounding to account for potential differences among SBAS services. Therefore, the use of multiple SBAS is not permitted when using dual-frequency service.

6.2.6 Before publishing procedures based on SBAS signals, a State is expected to provide a status monitoring and NOTAM system. To determine the effect of a system element failure on service, a mathematical service volume model is to be used. The State can either obtain the model from the SBAS operator or develop its own model. Using the current and forecast status data of the basic system elements, and the locations where the State has approved operations, the model would identify airspace and airports where service outages are expected, and it could be used to originate NOTAMs. The system element status data (current and forecast) required for the model could be obtained via a bilateral arrangement with the SBAS service provider, or via connection to a real time “broadcast” of the data if the SBAS service provider chooses to provide data in this way.

6.2.7 Participating States or regions will coordinate through ICAO to ensure that SBAS provides seamless global coverage, taking into account that aircraft equipped to use the signal could suffer operational restrictions in the event that a State or region does not approve the use of one or more of the SBAS signals in its airspace. In such an event, the pilot may have to deselect GNSS altogether since the aircraft equipment may not allow deselection of all SBAS or a particular SBAS.

6.2.8 As the SBAS ~~geostationary orbit~~ satellite coverages (footprints) overlap, it ~~there~~ will be necessary for SBAS equipment to handle selection and transition mechanisms ~~interface issues~~ among the SBASs. As a minimum, the SBAS airborne receivers must be able to operate within the coverage of any SBAS. It is possible for an L1-only SBAS provider to monitor and send integrity and correction data for a geostationary orbit satellite that belongs to another SBAS service provider. For L1 SBAS, augmenting ranging SBAS satellites can improve ~~This improves~~ availability by adding ranging sources for user receivers that can track additional SBAS satellites. This improvement does not require any interconnection between SBAS systems and should be accomplished by all SBAS service providers. For DFMC SBAS, the ranging signal from the SBAS PRN in use may be used. Ranging signal from other SBAS satellite(s) from the same provider may be used with Type 32 message augmentation. Ranging signal from other SBAS providers cannot be used.

6.2.9 Other levels of integration can be implemented using a unique connection between the SBAS networks (e.g. separate satellite communication). In this case, SBASs can exchange either raw satellite measurements from one or more reference stations or processed data (corrections or integrity data) from their master stations. This information can be used to improve system robustness and accuracy through data averaging, or integrity through a cross check mechanism. Availability will also be improved within the service areas, and the technical performance will meet the GNSS SARPs throughout the entire coverage (i.e. monitoring of satellites ephemeris would be improved). Finally, SBAS control and status data could be exchanged to improve system maintenance.

6.3 Integrity

6.3.1 The provisions for integrity are complex, as some attributes are determined within the SBAS ground network and transmitted in the signal-in-space, while other attributes are determined within the SBAS equipment on the aircraft. For the satellite status ~~and~~, basic corrections functions and ionosphere-free differential corrections functions, an error uncertainty for the ephemeris and clock corrections is determined by the SBAS ground network. This uncertainty is modelled by the variance of a zero-mean, normal distribution that describes the user differential range error (UDRE) or dual-frequency range error (DFRE) for each ranging source after application of fast (L1 SBAS) and long-term (L1 and DFMC SBAS) corrections and excluding atmospheric effects and receiver errors.

6.3.2 For the precise differential function, an error uncertainty for the ionospheric correction is determined. This uncertainty is modelled by the variance of a zero-mean, normal distribution that describes the L1 residual user ionospheric range error (UIRE) for each ranging source after application of ionospheric corrections. This variance is determined from an ionospheric model using the broadcast grid ionospheric vertical error (GIVE).

6.3.3 There is a finite probability that an SBAS receiver would not receive an SBAS message. In order to continue navigation in that case, the SBAS broadcasts degradation parameters in the signal-in-space. These parameters are used in a number of mathematical models that characterize the additional residual error from ~~both~~ basic ~~and~~, precise and ionosphere-free differential corrections induced by using old but active data. These models are used to modify the UDRE/DFRE variance and the UIRE variance as appropriate.

6.3.4 The individual error uncertainties described above are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudo-range error models to the position domain. The horizontal protection level (HPL) provides a bound on the horizontal position error with a probability derived from the integrity requirement. Similarly, the vertical protection level (VPL) provides a bound on the vertical position. If the computed HPL exceeds the horizontal alert limit (HAL) for a particular operation, SBAS integrity is not adequate to support that operation. The same is true for precision approach and APV operations, if the VPL exceeds the vertical alert limit (VAL).

6.3.5 One of the most challenging tasks for an SBAS provider is to determine UDRE ~~and~~ /GIVE or DFRE variances so that the protection level integrity requirements are met without having an impact on availability. The performance of an individual SBAS depends on the network configuration, geographical extent and density, the type and quality of measurements used and the algorithms used to process the data. General methods for determining the model variance are described in section 14.

6.3.6 *Residual clock and ephemeris error* (σ_{UDRE}). The residual clock error is well characterized by a zero-mean, normal distribution since there are many receivers that contribute to this error. The residual ephemeris error depends upon the user location. For the precise differential function, the SBAS provider will ensure that the residual error for all users within a defined service area is reflected in the σ_{UDRE}. For the basic differential function, the residual ephemeris error should be evaluated and may be determined to be negligible.

6.3.7 *Ionosphere-free residual clock and ephemeris error (σ_{DFRE})*. The residual clock error is well characterized by a zero-mean, normal distribution since there are many receivers that contribute to this error. The residual ephemeris error depends upon the user location. For the ionosphere-free differential correction function, the SBAS provider will ensure that the residual error for all users within a coverage area is reflected in the σ_{DFRE}. The residual error needs to account for the increased noise in the ionosphere-free dual-frequency combination.

6.3.~~7~~8 *Vertical ionospheric error (σ_{GIVE})*. The residual ionospheric error is well represented by a zero-mean, normal distribution since there are many receivers that contribute to the ionospheric estimate. Errors come from the measurement noise, the ionospheric model and the spatial decorrelation of the ionosphere. The position error caused by ionospheric error is mitigated by the positive correlation of the ionosphere itself. In addition, the residual ionospheric error distribution has truncated tails, i.e. the ionosphere cannot create a negative delay, and has a maximum delay.

6.3.~~8~~9 *Aircraft element errors*. The combined multipath and receiver contribution is bounded as described in section 14. This error can be divided into multipath and receiver contribution as defined in Appendix B, 3.6.5.5.1, and the standard model for multipath described in Appendix B, 3.6.5.5.1.1.2 may be used. The receiver contribution can be taken from the accuracy requirement (Appendix B, 3.5.8.2~~ and~~, 3.5.8.4.1 and 3.5.15.3.2) and extrapolated to typical signal conditions. Specifically, the aircraft can be assumed to have $\sigma^2_{air} = \sigma^2_{receiver} + \sigma^2_{multipath}$, where it is assumed that $\sigma_{receiver}$ is defined by the RMS_{pr_air} specified for GBAS Airborne Accuracy Designator A equipment, and $\sigma_{multipath}$ is defined in Appendix B, 3.6.5.5.1 for L1 SBAS equipment and 3.5.15.3.4.1 for DFMC SBAS equipment. The aircraft contribution to multipath includes the effects of reflections from the aircraft itself. Multipath errors resulting from reflections from other objects are not included. If experience indicates that these errors are not negligible, they must be accounted for operationally. The standard multipath model in Appendix B, 3.5.15.3.4.1 accounts for multipath error in the ionosphere-free combination.

6.3.~~9~~ 10 *Tropospheric error*. The receiver must use a model to correct for tropospheric effects. The residual error of the model is constrained by the maximum bias and variance defined in Appendix B, 3.5.8.4.2, ~~and~~ 3.5.8.4.3 and 3.5.15.3.4. The effects of this mean must be accounted for by the ground subsystem. The airborne user applies a specified model for the residual tropospheric error (σ_{tropo}).

6.4 RF characteristics

6.4.1 *Minimum SBAS L1 GEO signal power level*. The minimum aircraft equipment (e.g. RTCA/DO-229D with Change 1) is required to operate with a minimum signal strength of –164 dBW at the antenna port in the presence of non-RNSS interference (Appendix B, 3.7) and an aggregate RNSS noise density of –17~~3~~2.8 dBm/Hz. In the presence of interference, receivers may not have reliable tracking performance for a signal strength at the antenna port below –164 dBW (e.g. with GEO satellites placed in orbit prior to 2014). A GEO that delivers a signal power below –164 dBW at the receiving antenna port at 5-degree elevation on the ground can be used to ensure signal tracking in a service area contained in a coverage area defined by a minimum elevation angle that is greater than 5 degrees (e.g. 10 degrees). In this case, advantage is taken from the gain characteristic of the minimum standard (e.g. RTCA/DO-301) antenna to perform a trade-off between the GEO signal power and the size of the service area in which a trackable signal needs to be ensured. When planning for the introduction of new operations based on SBAS, States are expected to conduct an assessment of the signal power level as compared to the level interference from RNSS and non-RNSS sources. If the outcome of this analysis indicates that the level of interference is adequate to operate, then operations can be authorized.

6.4.2 *Minimum SBAS L5 signal power level*. The minimum aircraft equipment is required to operate with a minimum signal strength of –158 dBW at the antenna port in the presence of non-RNSS interference (Appendix B, 3.7) and an aggregate RNSS noise density of –171.4 dBm/Hz. An SBAS satellite that delivers a signal power below –158 dBW at the receiving antenna port at 5-degree elevation on the ground can be used to ensure signal tracking in a service area contained in a coverage area defined by a minimum elevation angle that is greater than 5 degrees (e.g. 10 degrees). In this case, advantage is taken from the gain characteristic of the standard antenna to perform a trade-off between the SBAS satellite power and the size of the service area in which a trackable signal needs to be ensured. When planning for the introduction of new operations based on SBAS, States are expected to conduct an assessment of the signal power level as compared to the level of interference from RNSS and non-RNSS sources. If the outcome of this analysis indicates that the level of interference is adequate to operate, then operations can be authorized.

6.4.~~2~~3 *SBAS network time*. SBAS network time is a time reference maintained by SBAS for the purpose of defining corrections. When using corrections, the user's solution for time is relative to the SBAS network time rather than core satellite constellation system time. In L1 SBAS only, i~~I~~f corrections are not applied, the position solution will be relative to a composite core satellite constellation/SBAS network time depending on the satellites used and the resulting accuracy will be affected by the difference among them. Mix of uncorrected and SBAS corrected measurement is not allowed in DFMC SBAS. L1 SBAS and DFMC SBAS services are independent. The SBAS network time used for L1 SBAS and that used for DFMC SBAS may be different. In DFMC SBAS, a time reference identifier parameter is broadcast in Type 37 message to inform DFMC user about the core constellation time reference used to steer the SBAS network time in DFMC SBAS (see Chapter 3, 3.7.3.4.7.2 which specifies the maximum time difference between SNT and core constellation reference time). It refers to the time reference of a GNSS constellation, which will be assumed to be the constellation of reference when computing SBAS user position and estimating time offset for other constellation augmented by the SBAS system.

6.4.~~3~~4 *SBAS convolutional and bi-binary encoding*. Information on the convolutional coding and decoding of L1 SBAS messages can be found in RTCA/DO-229D with Change 1, Appendix A. Information on the convolutional coding and decoding of DFMC SBAS messages can be found in EUROCAE/ED-259, Appendix A. The SBAS L5 signals use bi-binary (Manchester) encoding (see section 1). SBAS L5 signals without bi-binary encoding are suitable for testing and validation purposes only. Figure D-19 shows the convention of the bi-binary encoding, where a "0" is expressed by a low-to-high transition ("0" during the first half of the bit period and "1" during the second half) and where a "1" is expressed by a high-to-low transition ("1" during the first half of the bit period and "0" during the second half).

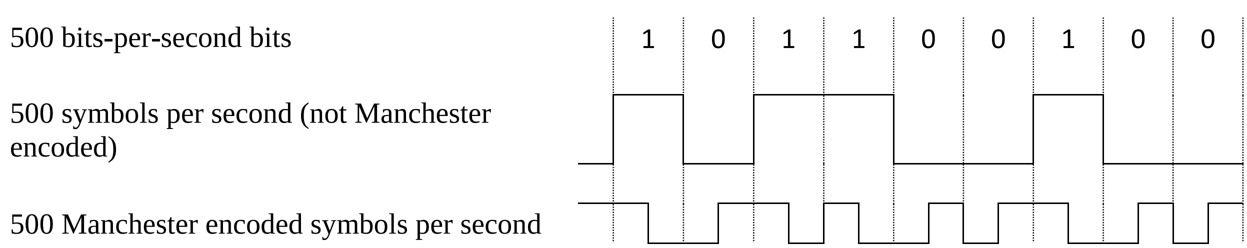

Figure D-19. Bi-binary (Manchester) encoding scheme

6.4.~~4~~5 *Message timing*. The users' convolutional decoders will introduce a fixed delay that depends on their respective algorithms (usually 5 constraint lengths, or 35 bits), for which they must compensate to determine SBAS network time (SNT) from the received signal.

6.4.~~5~~6 *SBAS signal characteristics*. Differences between the relative phase and group delay characteristics of SBAS signals, as compared to GPS signals, can create a relative range bias error in the receiver tracking algorithms. The SBAS service provider is expected to account for this error, as it affects receivers with tracking characteristics within the tracking constraints in Attachment D, 8.11 and Appendix B, 3.5.15.1.1.3. For GEOs supporting L1 SBAS ranging for which the on-board RF filter characteristics have been published in RTCA/DO-229D with Change 1, Appendix T, the SBAS service providers are expected to ensure that the UDREs bound the residual errors including the maximum range bias errors specified in RTCA/DO-229D with Change 1. For other SBAS ~~GEOs~~ satellites supporting L1 SBAS ranging or DFMC SBAS ranging, the SBAS service providers are expected to work with equipment manufacturers in order to determine, through analysis, the maximum range bias errors that can be expected from existing receivers when they process these specific satellites ~~GEOs~~. This effect can be minimized by ensuring that the satellites ~~GEOs~~ have a wide transmission bandwidth and small group delay across the pass-band. Additionally, the DFMC SBAS tracking error in Appendix B, 3.5.15.4.1 is developed with the presumption that the SBAS L1 signal supporting DFMC SBAS ranging is a wideband signal. SBAS service providers are expected to ensure that the DFREs bound the residual errors including tracking bias errors for the DFMC SBAS ranging signals.

6.4.~~6~~7 *SBAS pseudo-random noise (PRN) codes*. RTCA/DO-229D with Change 1, Appendix A, provides two methods for SBAS L1 PRN code generation. EUROCAE/ED-259, Appendix A, provides a method for SBAS L5 PRN code generation.

6.4.8 *SBAS L5 carrier phase noise*. A practical way to comply with the SBAS L5 code carrier noise requirement would be to comply with the following table specification:

Table D-15. L5 carrier phase noise

Frequency offset from L5 carrier (Hz)	**Phase noise relative to the carrier (dBc/Hz)**
0	0
1	-19.5
5	-47.5
10	-52.5
10^2	-66.5
10^3	-74.5
10^4	-85.5
10^5	-90.5
$3x10^5$	-90.5
Greater than 10^6	-92.5

6.4.9 *Cross-correlation loss.* Cross-correlation loss is defined as the ratio of the following two correlation outputs: (1) the actual received signal correlated against a perfect unfiltered reference signal; and (2) a perfect unfiltered signal normalized to the same total power as the signal in case (1), correlated against a perfect unfiltered reference signal. The correlation loss can be calculated as indicated in the equation below:

$$-20\,Log_{10}\left[\frac{C_{XY}}{\sqrt{C_{XX}}\sqrt{C_{YY}}}\right] < 1\,dB$$

where "C_{XX}" is the value resulting from correlation of the unfiltered reference signal with itself, "C_{YY}" is the value resulting from correlation of the actual received signal with itself, and "C_{XY}" is the value resulting from correlation of the actual received signal with the unfiltered reference signal when these two signals are optimally aligned for maximal cross correlation. The bracketed term above is the correlation coefficient between the actual received signal and the unfiltered reference signal.

6.5 ~~SBAS d~~Data characteristics on SBAS L1 signal

6.5.1 *SBAS messages*. Due to the limited bandwidth, SBAS L1 signal data is encoded in messages that are designed to minimize the required data throughput. RTCA/DO-229D with Change 1, Appendix A, provides detailed specifications for SBAS messages.

6.5.2 *Data broadcast intervals*. The maximum broadcast intervals between L1 SBAS messages are specified in Appendix B, Table B-54. These intervals are such that a user entering the L1 SBAS service broadcast area is able to output a corrected position along with SBAS-provided integrity information in a reasonable time. For en-route, terminal and NPA operations, all needed data will be received within 2 minutes, whereas for precision approach operations, it will take a maximum of 5 minutes. The maximum intervals between broadcasts do not warrant a particular level of accuracy performance as defined in Chapter 3, Table 3.7.2.4-1. In order to ensure a given accuracy performance, each service provider will adopt a set of broadcast intervals taking into account different parameters such as the type of constellations (e.g. GPS with SA, GPS without SA) or the ionospheric activity.

6.5.3 *Time-to-alert*. Figure D-2 provides explanatory material for the allocation of the total time-to-alert defined in Chapter 3, Table 3.7.2.4-1. The time-to-alert requirements in Appendix B, 3.5.7.3.1, 3.5.7.4.1 and 3.5.7.5.1 (corresponding to the GNSS satellite status, basic differential correction and precise differential correction functions, respectively) include both the ground and space allocations shown in Figure D-2.

6.5.4 *Tropospheric function*. Because tropospheric refraction is a local phenomenon, users will compute their own tropospheric delay corrections. A tropospheric delay estimate for precision approach is described in RTCA/DO-229D with Change 1, although other models can be used.

6.5.5 *Multipath considerations*. Multipath is one of the largest contributors to positioning errors for L1 SBAS affecting both ground and airborne elements. For SBAS ground elements, emphasis should be placed on reducing or mitigating the effects of multipath as much as possible so that the signal-in-space uncertainties will be small. Many mitigation techniques have been studied from both theoretical and experimental perspectives. The best approach for implementing SBAS reference stations with minimal multipath errors is to:

a) ensure that an antenna with multipath reduction features is chosen;

b) consider the use of ground plane techniques;

c) ensure that the antenna is placed in a location with low multipath effects; and

d) use multipath-reducing receiver hardware and processing techniques.

6.5.6 *GLONASS issue of data*. Since the existing GLONASS design does not provide a uniquely defined identifier for sets of ephemeris and clock data, 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.

6.6 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~~. It~~ is the same as the GBAS FAS data block defined in Appendix B, ~~section~~ 3.6.4.5.1 and Table B-66, with the following exceptions. The SBAS FAS data block also contains the HAL and VAL to be used for the approach procedure as described in 6.3.4. SBAS user equipment interprets certain fields differently from GBAS user equipment 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 database supporting both SBAS and GBAS. Within this database, channel assignments must be unique for each approach and coordinated with civil authorities. States are responsible for providing the FAS data for incorporation into the database.

6.6.3 An example of the coding of FAS data block for SBAS is provided in Table D-1. This example illustrates the coding of the various application parameters, including the cyclic redundancy check (CRC). The engineering values for the message parameters in the table illustrate the message coding process.

6.6.4 DFMC SBAS user equipment uses the operation type field from the FAS data block to determine the required SBAS service provider identifier (SPID) for the approach. The DFMC SBAS service broadcasts a 5-bit SPID while the FAS data block only supports a 4-bit SPID. To differentiate the additional 16 SPID values, the DFMC SBAS user equipment looks for the operation type field. User equipment that receives an operation type of 0 or does not read the operation type field will interpret the SPID as published with values between 0 and 15. User equipment that receives an operation type of 8 will add 16 to the value of the SPID from the FAS data block, resulting in a range from 16 to 31. This expanded range can only be broadcast on the DFMC SBAS service and is intended for use by SBAS systems that only provide a DFMC SBAS service.

Table D-1. Example of an SBAS FAS data block

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	CODING RULES (*Note 5*)	PROCEDURE DESIGN VALUES PROVIDED	FAS DB VALUE USED	BINARY DEFINITION	BINARY REPRESENTATION (*Note 1*)	HEXADECIMAL REPRESENTATION
Operation Type	4	[0..15]	1	0: Straight-in approach procedure 1-7: Spare 8: Straight-in approach with SBAS service provider ID extension 9-15: Spare (Note 1)	Straight-In	0	$m_4..m_1$	0000	08
SBAS service provider ID	4	[0..15]	1	For operation type = 0 0 – 13: See Table B-27 14 : GBAS only 15 : Any SBAS provider For operation type = 8 0 – 15: SBAS service provider ID 16 to 31 (See Table B-27)	EGNOS	1	$m_8..m_5$	0001	
Airport ID	32	$\alpha_1\alpha_2\alpha_3\alpha_4$	-	α_1, α_2, α_3 = [0..9, A..Z] α4 = [<space>, 0..9, A..Z] D_{OUT} = ASCII value & 3F	LFBO	LFBO	$m_{40}..m_{33}$ $m_{32}..m_{25}$ $m_{24}..m_{17}$ $m_{16}..m_9$	'L' **00** 001100 'F' **00** 000110 'B' **00** 000010 'O' **00** 001111 (*Note 2*)	F0 40 60 30
Runway number	6	[01..36]	1	-	14	14	$m_{46}..m_{41}$	001110	72
Runway letter	2	[0..3]	1	0 : No letter 1 : Right I 2 : Centre (C) 3 : Left (L)	R	1	m_{48} m_{47}	01	
Approach performance designator	3	[0..7]	1	~~Not used by SBAS~~ See Appendix B, 3.5.15.3.5	0 (~~default value~~ L1 SBAS or DFMC SBAS)	0	$m_{51}..m_{49}$	000	0B
Route indicator	5	α	-	α = [<space>, A..Z] α ≠ I and α ≠ O	Z	Z	$m_{56}..m_{52}$	11010	
Reference path data selector	8	[0..48]	-	Not used by SBAS	0 (default value)	0	$m_{64}..m_{57}$	00000000	00
Reference path identifier	32	$\alpha_1\alpha_2\alpha_3\alpha_4$	-	α_1 = [E, M, W] α_2, α_3 = [0..9] α_4 = [<space>, A, B, D..K, M..Q, S..Z] D_{OUT} = ASCII value & 3F	E14A	E14A	$m_{96}..m_{89}$ $m_{88}..m_{81}$ $m_{80}..m_{73}$ $m_{72}..m_{65}$	'E' **00** 000101 '1' **00** 110001 '4' **00** 110100 'A' **00** 000001 (*Note 2*)	80 2C 8C A0
LTP/FTP latitude	32	[-90.0°.. 90.0°]	0.0005 arcsec	D_{CONV1} = D_{IN} -> rounding method (*Note 3*) D_{CONV2} = D_{CONV1} -> decimal (sec) D_{OUT} = D_{CONV2} x 2 000 N : D_{OUT} S : Two's complement (D_{OUT})	D_{IN} = 43°38'38.8103" N	D_{CONV1} = 43°38'38.8105" N D_{CONV2} = 157118.8105 sec D_{OUT} = 314 237 621	$m_{128}..m_{121}$ $m_{120}..m_{113}$ $m_{112}..m_{105}$ $m_{104}..m_{97}$	00010010 10111010 11100010 10110101	AD 47 5D 48
LTP/FTP longitude	32	[-180.0°.. 180.0°]	0.0005 arcsec	D_{CONV1} = D_{IN} -> rounding method (*Note 3*) D_{CONV2} = D_{CONV1} -> decimal (sec) D_{OUT} = D_{CONV2} x 2 000 E : D_{OUT} W : Two's complement (D_{OUT})	D_{IN} = 001°20'45.3591" E	D_{CONV1} = 001°20'45.3590" E D_{CONV2} = 4845.359 sec D_{OUT} = 9 690 718	$m_{160}..m_{153}$ $m_{152}..m_{145}$ $m_{144}..m_{137}$ $m_{136}..m_{129}$	00000000 10010011 11011110 01011110	7A 7B C9 00
LTP/FTP height	16	[-512.. 6041.5]	0.1m	D_{CONV} = round (D_{IN}, resolution) D_{OUT} = (D_{IN} + 512) x 10	D_{IN} = 148.74m	D_{CONV} = 148.7 D_{OUT} = 6 607	$m_{176}..m_{169}$ $m_{168}..m_{161}$	00011001 11001111	F3 98

DATA CONTENT DESCRIPTION	BITS USED	RANGE OF VALUES	RESOLUTION	CODING RULES (*Note 5*)	PROCEDURE DESIGN VALUES PROVIDED	FAS DB VALUE USED	BINARY DEFINITION	BINARY REPRESENTATION (*Note 1*)	HEXADECIMAL REPRESENTATION
ΔFPAP latitude	24	[-1.0°..1.0°]	0.0005 arcsec	D_{CONV1} = D_{IN} -> rounding method (*Note 3*) D_{CONV2} = D_{CONV1} -> decimal (sec) D_{OUT} = D_{CONV2} x 2 000 + : D_{OUT} - : Two's complement (D_{OUT})	D_{IN} = -0°01'37.8973"	D_{CONV1} = -00°01'37.8975" D_{CONV2} = -97.8975" D_{OUT} = Two's complement (195795) D_{OUT} = 16 581 421	$m_{200}..m_{193}$ $m_{192}..m_{185}$ $m_{184}..m_{177}$	11111101 00000011 00101101	B4 C0 BF
ΔFPAP longitude	24	[-1.0°..1.0°]	0.0005 arcsec	D_{CONV1} = D_{IN} -> rounding method (*Note 3*) D_{CONV2} = D_{CONV1} -> decimal (sec) D_{OUT} = D_{CONV2} x 2 000 + : D_{OUT} - : Two's complement (D_{OUT})	D_{IN} = 0°01'41.9329"	D_{CONV1} = 0°01'41.9330" D_{CONV2} = 101.9330" D_{OUT} = 203 866	$m_{224}..m_{217}$ $m_{216}..m_{209}$ $m_{208}..m_{201}$	00000011 00011100 01011010	5A 38 C0
Approach TCH	15	[0..1638.35m] [0..3276.7ft]	0.05m 0.1ft	D_{CONV} = round (D_{IN}, resolution) m : D_{OUT} = D_{IN} x 20 ft : D_{OUT} = D_{IN} x 10	D_{IN} = 15.00m	D_{CONV} = 15.00m D_{OUT} = 300	$m_{239}..m_{233}$ $m_{232}..m_{225}$	0000001 00101100	34 81
Approach TCH units selector	1	[0,1]	-	0 : feet 1 : metres	m	1	m_{240}	1	
Glide path angle (GPA)	16	[0..90.00°]	0.01°	D_{CONV} = round (D_{IN}, resolution) D_{OUT} = D_{IN} x 100	D_{IN} = 3.00°	D_{CONV} = 3.00° D_{OUT} = 300	$m_{256}..m_{249}$ $m_{248}..m_{241}$	00000001 00101100	34 80
Course width	8	[80.00m.. 143.75m]	0.25m	D_{CONV} = round (D_{IN}, resolution) D_{OUT} = (D_{CONV} - 80) x 4	D_{IN} = 105.00m	D_{CONV} = 105.00m D_{OUT} = 100	$m_{264}..m_{257}$	01100100	26
ΔLength offset	8	[0..2032m]	8m	D_{CONV} = round (D_{IN}, resolution) D_{OUT} = (integer division of D_{CONV} by 8) + 1 D_{OUT} = 255 : not provided value	D_{IN} = 284.86m	D_{CONV} = 288m D_{OUT} = 36	$m_{272}..m_{265}$	00100100	24
Horizontal alert limit (HAL)	8	[0..50.8m]	0.2m	D_{CONV} = round (D_{IN}, resolution) D_{OUT} = D_{IN} * 5	D_{IN} = 40.0m	D_{CONV} = 40.0m D_{OUT} = 200	$m_{280}..m_{273}$	11001000	13
Vertical alert limit (VAL)	8	[0..50.8m]	0.2m	D_{CONV} = round (D_{IN}, resolution) D_{OUT} = Value * 5 D_{OUT} = 0 : vertical deviations cannot be used	D_{IN} = 50.0m	D_{CONV} = 50.0m D_{OUT} = 250	$m_{288}..m_{281}$	11111010	5F
Final approach segment CRC	32	[0..2^{32}-1]		D_{OUT} = remainder (P(x) / Q(x))	-	-	$r_{32}..r_{25}$ $r_{24}..r_{17}$ $r_{16}..r_{9}$ $r_{8}..r_{1}$	10101110 11000011 01100100 10001111	75 C3 26 F1 (*Note 4*)

Notes.
1. *The rightmost bit is the LSB of the binary parameter value and is the first bit transmitted to the CRC calculator.*
2. *The two most significant bits of each byte are set to 0 (see bold characters).*
3. *The rounding methodology is provided in the PANS-OPS (Doc 8168) Volume II.*
4. *The FAS CRC value is displayed in the order $r_{25}..r_{32}$, $r_{17}..r_{24}$, $r_{9}..r_{16}$, $r_{1}..r_{8}$ where r_i is th i^{th} coefficient of the remainder R(x) as defined in Appendix B, 3.9 .*
5. *D_{IN} : raw data value, D_{CONV} : converted data value according to coding rules, D_{OUT} : coded data value.*

Editorial note — Insert new text as follows:

6.6.5 DFMC SBAS user equipment uses the approach performance designator (APD) field to identify which of the SBAS services provide adequate performance to support the procedure identified in the FAS data block. The service modes are the L1 SBAS service, the DFMC SBAS when one or more augmented constellations are usable, and the DFMC SBAS service when two or more augmented constellations are usable. Constellations are usable when the SBAS provides augmentation and the user equipment can use the augmentation. For procedures using APV performance level, the user equipment can check the computed protection level(s) against the associated alert limit(s) to determine suitability of the navigation. For procedures using the Category 1 performance level, the integrity referred to in Chapter 3, Table 3.7.2.4.-1, Note 2 requires a system-specific safety analysis when the VAL is set to be greater than 10 m. This includes a performance assessment that the SBAS service provider makes, which the ANSP can use to support the decision on the APD coding for published procedures. Since the DFMC SBAS service will have a significantly larger service volume than the L1 SBAS service, ANSPs will be able to publish approach procedures based on DFMC SBAS services that an associated L1 SBAS service cannot fully support. In some circumstances, the L1 SBAS service might not meet the availability or continuity for the approach but would otherwise meet the performance requirements and could be used, if available. ANSPs can then publish the procedure with APD codings of 5 or 6 based on the L1 SBAS service performance provided by the SBAS service provider. In some circumstances, when the L1 SBAS service does not meet the criteria in 3.3.9 or when the ANSP determines that the L1 SBAS service is not suitable for use, ANSPs can then publish procedures with APD codings of 1 or 2. The table below provides an indication of when the different APD codings are appropriate. ANSPs code DFMC SBAS procedure with an APD of 1 or 2 when there is no L1 SBAS service deemed to be available in support of flying the published approach.

0	• Any procedure based on the APV performance level when the L1 SBAS service meets availability and continuity. • Any procedure using the Category 1 performance level when the L1 SBAS service meets availability, continuity, and the system-specific safety assessment.
1	• Any procedure based on the APV performance level when the ANSP wants to control the operation to DFMC mode only with at least one constellation. • Any procedure based on the Category 1 performance level when the system specific safety assessment is met with the DFMC SBAS service with at least one constellation, but would not be met with an L1 SBAS service.
2	• Any procedure based on the APV performance level when the ANSP wants to control the operation to DFMC mode only and two or more constellations are required to meet the availability and continuity requirements with the DFMC SBAS service. • Any procedure based on the Category 1 performance level when the system specific safety assessment is met with the DFMC SBAS service but would not be met with an L1 SBAS service, and two or more constellations are required to meet the availability and continuity requirements with the DFMC SBAS service.
5	• Any procedure based on the APV performance level when the L1 SBAS service is not expected to meet availability or continuity while DFMC SBAS service meets availability and continuity with at least one constellation. • Any procedure based on the Category 1 performance level when both the DFMC and L1 SBAS services satisfy the system specific safety assessment, although the L1 SBAS service is not expected to meet availability and/or continuity.
6	• Any procedure based on the APV performance level when availability and continuity are met only using a DFMC SBAS service augmenting more than one constellation. Neither single constellation DFMC SBAS, nor a L1 SBAS service are expected to meet availability and continuity. • Any procedure based on the Category 1 performance level when availability and continuity are met only using a DFMC SBAS service augmenting more than one constellation. Neither single constellation DFMC SBAS, nor a L1 SBAS service are expected to meet availability and/or continuity, but all services meet the system specific safety assessment.

6.6.6 User equipment not designed to process DFMC SBAS (e.g. compliant with RTCA/DO-229 standards) is not required to use the APD field (see Chapter 3, Appendix B, 3.5.8.4.2.6.1) whereas DFMC SBAS equipment uses this field. SBAS procedures developed for L1 SBAS service use an APD coded as 0. The 0 coding is therefore retained for procedures supported by both L1 SBAS and DFMC SBAS. SBAS user equipment not designed to process DFMC SBAS (e.g. compliant with RTCA/DO-229 standards) should only be used in combination with FAS data blocks with APD set to 0.

6.7 DFMC SBAS considerations

6.7.1 *Data broadcast intervals*. The maximum broadcast intervals between DFMC SBAS messages are specified in Appendix B, Table B-107. These intervals are such that a user entering the DMFC SBAS coverage area is able to output a corrected position along with SBAS-provided integrity information in a reasonable time. For en-route, terminal, NPA and precision approach operations, all needed data will be received within 3 minutes considering a maximum of 92 satellites set in the DFMC SBAS mask. The maximum intervals between broadcasts do not warrant a particular level of accuracy performance as defined in Chapter 3, Table 3.7.2.4-1. In order to ensure a given accuracy performance, each service provider will adopt a set of broadcast intervals taking into account different parameters such as the number of constellations augmented and the number of SBAS satellites used by the service provider.

6.7.2 *DFMC SBAS mask*

6.7.2.1 *SBAS mask parameters*. Appendix B, Table B-91, provides the mapping between the DFMC SBAS satellite mask and GNSS satellites. It was decided to define specific satellites per constellation that could be augmented in DFMC SBAS. It concerns the GPS PRN numbers 1 to 32 and 120 to 158 (SBAS PRN), GLONASS ID number 1 to 37, Galileo SVID 1 to 36 and BDS ranging code number 1 to 37. If any constellation broadcasts a signal from a satellite identified with a parameter exceeding the ranges specified, this satellite is not eligible for DFMC SBAS augmentation. DFMC SBAS mask broadcast in Type 31 message is independent from the L1 SBAS mask broadcast in Type 1 message even if both services are delivered by an SBAS provider.

6.7.2.2 *SBAS mask transition.* The Standard does not specify the means to conduct a mask transition, therefore SBAS providers might choose different mask transition strategies. The user requires a valid mask to decode the integrity messages sent every six seconds in the Type 34, 35 or 36 messages. The user needs to receive a valid integrity message at least every 12 seconds in order to continue vertical operations, since the integrity parameters time out after 12 seconds. The satellite mask message (Type 31) is valid for 360 seconds. Therefore, one method for mask transitions would be to start the transition with the broadcast of a new Type 31 message while continuing to reference the old Type 31 in the integrity messages. After the second (or third) transmission of the new Type 31, the SBAS would transition the integrity messages to use the new satellite mask message. Users should be able to receive the new satellite mask with two or three transmissions and, in the meantime, would continue to operate normally. Other satellite mask transition options could be used such as: broadcast two integrity messages per cycle, one using the old satellite mask and one using the new satellite mask. SBAS providers need to assess the impact on continuity of service associated with the selected mechanism for SBAS mask transition when the user misses some messages.

6.7.3 *DFMC SBAS almanac and ephemeris generation.* The DFMC SBAS ephemeris and almanac messages were designed to provide a set of Keplerian parameters. This design enables using SBAS satellites whose orbits are not geostationary ones. The DFMC SBAS ephemeris and almanac messages enable the broadcast of satellites in MEO, HEO, IGSO and GEO orbital position. For some special case orbits, like low-inclination (geostationary) orbits or circular, zero eccentricity orbits, some of the Keplerian parameters are not well defined and therefore are not unique. Valid sets of Keplerian parameters exist and the user will be able to properly determine the satellite position provided the SBAS creates a valid set of parameters. SBAS providers can set the problematic parameters to constant values and the resulting ephemeris or almanac fit will converge to a good solution. The SBAS calculation removed the rate of right ascension of ascending node (RAAN) since the validity time of the ephemeris is short. Proper selection of the harmonic correction to argument of latitude can correct the error introduced by the removal of rate of RAAN for the geostationary satellite case. For the case of inclined orbits, the error is still not negligible and the compensation needs to include IDOT in combination with C_{us} and C_{uc}. These correction parameters were chosen in general as they allow for (roughly) along-track (C_{us}, C_{uc}) and cross-track (IDOT) corrections. Since the elimination of rate of RAAN is addressed by other parameters, a long parameter fitting interval may degrade accuracy of SBAS satellite position.

6.7.4 *Integrity considerations*

6.7.4.1 *General.* While the SBAS corrections remove the observable error, there remains some uncertainty on the residual error. The SBAS ground segment selects DFREs to broadcast to provide protection level bounding of the user's residual position errors after the application of SBAS corrections. The SBAS ground segment should account for the growth of the uncertainty in the nominal error that occurs when the user applies any received augmentation data that remains valid (has not timed out). The SBAS ground segment can choose and broadcast the associated degradation parameters to help maintain this bounding. This ensures that alerts will not be necessary under normal conditions over the validity period of the corrections and the DFREs. As the uncertainty increases, the SBAS can increase the DFREs to maintain adequate bounding. Provided that the degradation parameters add sufficient bounding to meet the integrity requirements of Appendix B, 3.5.14.3, an increase in the current DFREs to cover nominal behaviour will not require an alert to protect users still applying older active values. As specified in Appendix B, 3.5.14.4.2, the SBAS system is required to monitor for satellite ranging faults and applicability of active SBAS data. During this monitoring, the SBAS is required to maintain integrity. For some monitored behaviours, like a clock run-off, if the errors are consistent with the SBAS system design and integrity analysis and the errors continue to be bounded by the active previously broadcast DFREs in combination with the degradation parameters, the SBAS should not broadcast an alert in order to maintain continuity. If the SBAS determines that old but active data with the degradations applied will not meet the integrity requirement, then the SBAS will broadcast an alert for that satellite. The alert could be in the form of larger DFREIs, up to and including the value indicating "Do Not Use in SBAS Mode". For other monitored cases, like detection of abnormal signal quality, the SBAS may be better served to broadcast an alert for the satellite directly to "Do Not Use in SBAS Mode".

6.7.4.2 *Mechanism.* There are several means to provide an alert. The alert sequence consists of a broadcast of at least four consecutive instances of data that will mitigate the misleading information. For individual satellites, it is often sufficient to broadcast larger DFREs to bound the error. This provides protection for all satellite data including that with longer time-out periods. Through this use of DFREs to alert, once the alerting condition has cleared, the nominal performance can be restored quickly by broadcasting nominal DFREs. The SBAS should expect that the user will miss messages and could be using any data that was previously broadcast that has not yet reached its time-out. When sending larger DFRE data to mitigate the misleading information, the SBAS sends the new DFRE in at least four consecutive messages. Since the DFRE terms are found in several different messages, it is possible to mix messages to achieve this repetition, such as four consecutive Type 32 messages or four consecutive Type 34/35/36 messages, or a combination of four consecutive Type 32 and integrity messages.

6.7.4.3 *Use of Type 0 message for alerts.* If necessary, to remove active data from the user receiver, SBAS can broadcast Type 0 messages. If the active data results in misleading information, the SBAS may use Type 0 message as an alert and send it in four consecutive messages. The reception of Type 0 messages will result in users dropping L5 data sent by the broadcasting satellite on the respective link. The use of Type 0 messages to alert individual satellites is generally not necessary as the use of larger DFREIs can provide for satellite alerts with less impact to the SBAS service.

6.7.4.4 *Missed messages and use of Type 0 messages.* Since the alert is required to be sent four times, a receiver might miss an alert if it misses four consecutive messages. For safety during approach operations, when the receiver misses four messages, it is required to invalidate all DFREIs/DFRECIs (see Appendix B, 3.5.15.1.4.15). The receiver could resume using correction data upon reception of an appropriate set of DFREIs with no other changes, as might occur with the reception of a Type 35 or Type 36 message. The SBAS should consider the possibility that the user receiver missed an alert sequence and should continue to broadcast DFREIs or DFRECIs consistent with the alerted value for all correction data that remains valid. This is also true following broadcast of a Type 0 message. If the user misses four or more messages, the user will only time out the DFREIs/DFRECIs and not remove other data. Therefore, the SBAS should consider how to resume nominal broadcast sequence following a Type 0 message alert sequence. The SBAS could continue to broadcast Type 0 messages or make impacted satellites unavailable until the misleading broadcast data has timed out. Transition from alerting through Type 0 messages to alerting through "Do Not Use for SBAS" may permit the receiver to use new SBAS data sooner.

6.7.5 *Integrity data*

6.7.5.1 *Integrity messages.* The DFMC SBAS concept defined three message types to provide integrity information with a repetition not to exceed six seconds. DFMC SBAS will broadcast integrity data for all satellites set in the satellite mask (Type 31 message), and can use any combination of these messages. The integrity messages are Types 34, 35 and 36. The Type 35 message provides DFREI information for the first 53 satellites in the Type 31 mask message and can be the sole message used when the SBAS augments 53 or fewer satellites. The Type 36 message is similar to the Type 35 message and is used together with the Type 35 message to broadcast DFREI information for satellites 54 to 92. Using a paired Type 35/36 message doubles the number of integrity messages being sent and might reduce the ability to send other information (e.g. correction information) more frequently compare to the minimum required. The Type 34 message is an option to provide integrity information for up to 92 satellites in a single SBAS message.

6.7.5.2 *Use of the integrity message.* The Type 34 message gives a means to provide integrity information for up to 92 satellites in a single message through the use of a 2-bit DFRE change indicator (DFRECI) instead of a 4-bit DFREI for each satellite. The Type 32 message provides the actual DFREI. For most operations, the DFREI will stay the same or only change by one increment during the time-out period of the DFREI. Therefore, the two-bit indicator has only four states indicating the following: 1) no change in DFREI, used to indicate that all broadcast, valid DFREIs remain valid; 2) increase the DFREI by one step (bump); 3) the Type 34 message will provide a new DFREI in one of seven slots allocated for DFREI updates in the message; or 4) indicate that the satellite is "Do Not Use for SBAS". The user could apply the indicator to the last received DFREI that has not timed out. The SBAS system design accounts for the user missing prior broadcast DFREI and/or DFRECI values. The SBAS cannot expect the user to have the most recent DFREI and monitors all old but active data transmitted to comply with the integrity requirement in Appendix B, 3.5.14.3.1. The SBAS can provide seven DFREIs in the Type 34 message. If the SBAS provider needs to increase more than seven DFREIs by more than one DFREI value, then the SBAS provider has two options, either set satellites that cannot be coded in the DFREI field to "Do Not Use for SBAS", or provide DFREIs using the Type 35 or Type 36 message. The SBAS provider can broadcast a DFRECI set to 0 corresponding to an existing higher DFREI value when a lower one could be broadcast. The DFRECI bump is not cumulative and can apply to any broadcast DFREI that could still be valid. Each Type 32 satellite correction message contains a DFREI. Any DFREI sent in a Type 32 message is valid until its time-out unless a new DFREI has been sent in multiple consecutive Types 34, 35 or 36 messages. When SBAS sends a new DFREI in all integrity messages broadcast during the DFREI validity period, SBAS can consider that the user will have the new DFREI and that the DFREI value broadcast in the previous Type 32 message has been replaced.

6.7.5.3 *Use of DFMC SBAS integrity message for alerting.* When an SBAS augments 53 or fewer satellites or uses the Type 34 message, the SBAS can send an alarm sequence using consecutive Type 34 or Type 35 messages and meet the alarm requirement. When an SBAS augments more than 53 satellites and chooses to use the Type 35/36 message pair, the alert logic becomes more complex. If all the satellites for which an alert needs to be sent are in the same message type, then that message type could be broadcast multiple times to meet the alert requirement. If the satellites that require an alert are contained across both the Type 35 and Type 36 messages, then it will be necessary to transition to use the Type 34 message or a Type 0 message to alert these satellites. The use of the Type 34 message is the preferred option to limit service disruption since the use of Type 0 message requires recovery of all SBAS data.

6.7.6 *DFREI scale table update*. The Type 37 message contains integrity related parameters which are used in the DFMC SBAS HPL and VPL equations. In particular, the Type 37 message contains a DFREI scale table which provides the link between broadcast DFREI values and the associated dual-frequency range error sigma value to use in the protection level computation. Since the Type 37 message content is related to SBAS design, the expectation is that the Type 37 message parameters will change rarely. However, when the Type 37 message content does change, the SBAS provider will need to ensure that SBAS receivers maintain integrity during the change. The SBAS provider can achieve this through the broadcast of Type 0 message to clear SBAS receivers of the old Type 37 message data, through the inflation of broadcast DFREI values for all satellites, by alerting specific satellites that might not maintain integrity, or with no change if SBAS receivers will maintain integrity when using any valid broadcast Type 37 message data.

6.7.7 *Time-to-alert*. Figure D-2 also provides explanatory material in the frame of DFMC SBAS for the allocation of the total time-to-alert defined in Chapter 3, Table 3.7.2.4-1.

6.7.8 *Tropospheric function*. A tropospheric delay estimate for precision approach is described in 6.5.4.

6.7.9 *Multipath considerations*. Multipath is the largest contributors to positioning errors for DFMC SBAS affecting both ground and airborne elements in particular due to ionosphere-free combination of SBAS corrected dual-frequency measurements. Mitigation techniques for SBAS ground elements, described in 6.5.5, are also valid in DFMC SBAS.

6.7.10 Week number rollover. The week number rollover count ($WNRO_{count}$) value of 15 indicates that parameter is not valid. The DFMC SBAS receiver may use the $WNRO_{count}$ parameter to solve the possible ambiguity of the truncated week number value (WN_x) transmitted through the GNSS navigation data if the SBAS broadcast a $WNRO_{count}$ between 0 and 14. In this case, the $WNRO_{count}$ is processed as follows:

- If the current truncated week number (WN_x) of the GNSS constellation designated by a Type 37 message is equal to the maximum value $\overline{WN} - 1$, and the current day number of week is 7 and the reference time t_a corresponds to day number of week 1 in the GNSS constellation reference time, the total number of weeks (WN) elapsed since the beginning of the GNSS reference time is given by:

$$WN = (WNRO_{count} - 1) \times \overline{WN} + WN_x = WNRO_{count} \times \overline{WN} - 1$$

- If the current truncated week number (WN_x) of the GNSS constellation designated by a Type 37 message is 0, and the current day number of week is 1 and the reference time t_a corresponds to day number of week 7 in the GNSS constellation reference time, the total number of weeks (WN) elapsed since the beginning of the GNSS constellation reference time is given by:

$$WN = (WNRO_{count} + 1) \times \overline{WN} + WN_x = (WNRO_{count} + 1) \times \overline{WN}$$

- Otherwise:

$$WN = WNRO_{count} \times \overline{WN} + WN_x$$

6.7.11 *Day crossovers considerations.* The parameters t_d, t_a and t_e are expressed in seconds of day, adjusted for day crossovers. The following mechanism can be used at the user level to determine the reference day for a t_d, t_a or t_e parameter received in a message broadcast at epoch t. Taking the case of a t_d parameter, with t and td expressed in seconds of day:

- If $-43\,200 \leq (t_d - t) \leq 43\,199$, t_d is expressed in seconds of the message broadcast day;
- If $(t_d - t) < -43\,200$, t_d is expressed in seconds of the next day of the message broadcast day; and
- If $(t_d - t) > 43\,199$, t_d is expressed in seconds of the previous day of the message broadcast day;

The previous mechanism can be applied to t_a and t_e, replacing t_d by t_a or t_e.

6.7.12 *Position computation in DFMC SBAS.* Appendix B, 3.5.12.4 provides the protocol to compute SBAS position out of two augmented constellations by an SBAS. Assuming that an SBAS augments N number of constellations, N being equal to three or more, the linearized weighted least square estimate X includes N - 2 additional elements for the time offsets between the additional constellation and the reference constellation 1. In addition, the observation matrix G, described in Appendix B, 3.5.12.4 c), is modified to integrate N - 2 additional columns of time parameters. Those time parameters equal 1 for all satellites of this specific constellation when setting the parameter for the column number corresponding to the time offset column of this constellation in X. Those time parameters equal 0 otherwise.

6.7.12.1 *Alternative observation matrix G.* The DFMC SBAS navigation solution can be computed with the following observation matrix G as an alternative to the one defined in Appendix B, 3.5.12.4:

$$G_i = [-\cos El_i \cdot \sin Az_i \quad -\cos El_i \cdot \cos Az_i \quad -\sin El_i \quad n_{i,1} \quad n_{i,2}] = i^{th} \text{ row of } G$$

where

$n_{i,1}$ is "1" if the satellite is part of reference constellation C1 or "0" if the satellite is part of constellation C2;

$n_{i,2}$ is "0" if the satellite is part of reference constellation C1 or "1" if the satellite is part of constellation C2;

If the i^{th} row of G corresponds to a SBAS ranging measurement:

$n_{i,1}$ is "1" if C1 is GPS or "0" otherwise;

$n_{i,2}$ is "1" if C2 is GPS or "0" otherwise.

If the SBAS providing SBAS ranging measurement is not augmenting GPS, the SBAS clock offset needs to be solved by an additional unknown:

$n_{i,3}$ is "1" if C1 and C2 are different than GPS (additional unknown to solve the clock offset of the SBAS satellite ranging constellation).

The navigation solution vector obtained with the alternative observation matrix is:

$$X = [x, y, z, ct_{C1}, ct_{C2}]$$

where

t_{C1} is the clock bias of the receiver with respect to constellation 1 reference time;

t_{C2} is the clock bias of the receiver with respect to constellation 2 reference time.

6.7.13 *Dual PRNs from one SBAS satellite*

6.7.13.1 *Assignment of SBAS PRN codes to satellites*. For vertically-guided approach operations, the system safety analysis expects user equipment to track two different satellites (as identified by PRN code), if available, to improve continuity of the operation. The broadcast of two PRNs from the same SBAS satellite introduces the SBAS satellite as a common failure between the two SBAS PRNs and might not provide the same level of continuity for these operations.

6.7.13.2 *Multiple SBAS range from the same satellite*. A concern with the broadcast of two ranging PRNs from the same SBAS satellite is that user equipment will use both ranging sources as if they were independent. If there are two ranging PRNs from the same SBAS satellite, the DFMC SBAS mask can prohibit use of both ranging signals in the same position solution for the DFMC SBAS user since the DFMC SBAS user is required to use all information from a single SBAS PRN. Therefore, an SBAS should preclude use of the second SBAS ranging signal from the same satellite by ensuring that the second ranging SBAS PRN satellite slot number is not set to "1" in the satellite mask received from the first SBAS PRN signal and vice-versa.

6.7.14 *Test operations*. Prior to certification for aviation use, SBAS broadcasts a Type 0 Do Not Use message. Aviation equipment will process this Type 0 message by clearing SBAS data received from that SBAS satellite. During pre-operational testing when the SBAS is able to compute valid data, some SBAS providers can broadcast valid data in the Type 0 message. Non-safety of life receivers might decide to use this data to calculate SBAS position solutions. For the L1 messages, some SBAS providers populated the Type 0 message with Type 2 data content. For the L5 message, SBAS providers may populate the Type 0 message with the content of Type 34, Type 35 or Type 36 messages. To identify which of these three integrity messages content is broadcast under Type 0 message, SBAS providers can use bits 222 and 223, with the following convention:

"00"	No integrity data.
"01"	Type 34 data content.
"10"	Type 35 data content.
"11"	Type 36 data content.

SBAS providers may choose a different coding of Type 0 messages in test operation.

6.7.15 *Non-geostationary satellite consideration.* There are several considerations for non-geostationary satellites. With higher satellite eccentricity, the deviations in power and Doppler shift require more consideration from the SBAS provider. Based on analysis, when the eccentricity exceeds 0.15, then the power differential from the orbit will exceed 3 dB and require some onboard power control function. The range change in the orbit will cause a constant power satellite bus to have broadcast power outside of either the maximum or minimum required power at some point during the orbit. When the eccentricity is above 0.3, the satellite Doppler shift at perigee will exceed the maximum specified Doppler shift. Some user equipment might no longer be able to track this satellite at perigee. Generally, highly eccentric orbits are used to increase satellite dwell time over a particular region during the apogee portion of the orbit. Therefore, the inability of user equipment to track the satellite around perigee might not impact the intended SBAS service. The Doppler shift for non-GEO SBAS is set to ± 7 kHz in Appendix B, 3.5.14.1.4, in line with these analyses.

6.7.16 *SNT-to-UTC conversion*

6.7.16.1 Users compute the time referenced in SNT at each epoch by solving the DFMC SBAS navigation solution. The optional Type 42 message provides the parameters to convert the time referenced in SNT into time referenced in UTC.

6.7.16.2 SNT is aligned on the core constellation time identified by the SBAS time reference identifier broadcast in the Type 37 message. The core constellation broadcasts parameters to convert the core constellation time into UTC, without an associated validity period. An SBAS service provider can broadcast a Type 42 message with UTC conversion parameters corresponding to the ones broadcast by the reference core constellation, without guarantee on the validity period by setting the validity period parameter to “000”. SBAS service providers can broadcast a Type 42 message with other validity period values to provide a more accurate UTC conversion service (see Appendix B, 3.5.11.6).

6.7.16.3 Under nominal operation, the UTC conversion parameters broadcast in the Type 42 message are valid during a period of time equal to the validity period parameter. The UTC offset status parameter provides a mechanism to invalidate parameters broadcast in the previous Type 42 message and for which the validity period (VP) has not timed out. In that case, users should discard the UTC conversion parameters from the previous Type 42 message and start using the parameters contained in the latest received Type 42 message, if any provided (i.e. UTC standard identifier not set to 7).

End of new text.

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9. STATUS MONITORING AND NOTAM

9.1 System status

9.1.1 Degradation of GBAS usually has local effects and affects mainly approach operations. System degradation of GBAS is to be distributed as approach-related information.

9.1.2 Degradation of core satellite constellation(s) or SBAS can be limited to ~~usually has not only~~ local effects affecting mainly approach operations, but can also impact ~~additional consequences for~~ a wider area, and may directly affect en-route operations in the SBAS service area(s). System degradation impacting en-route or wider area SBAS operations ~~of these elements~~ is to be distributed as area-related information. An example is an ionosphere storm that removes all vertically-guided approach capability. System degradation impacting limited approaches can be distributed as approach-related information.

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11. RECORDING OF GNSS PARAMETERS

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11.4 For SBAS the following monitored items should be recorded for all ~~geostationary~~ SBAS satellites in view in addition to the GNSS core system monitored items listed above:

a) observed ~~geostationary~~ SBAS satellite carrier-to-noise density (C/N_0);

b) observed ~~geostationary~~ SBAS satellite raw pseudo-range code and carrier phase measurements;

c) broadcast SBAS data messages; and

d) relevant receiver status information.

Origin:	*Rationale*:
NSP/6	This proposal introduces Annex provisions to support the evolution of SBAS. SBAS is a wide-coverage GNSS augmentation system in which the user receives augmentation information from a satellite-based transmitter. It is currently in service worldwide using signals transmitted on the L1 frequency, already standardized by ICAO. The proposal includes amendments to the existing SBAS SARPs to add a signal transmitted on the L5 frequency and to enhance the ability of SBAS to augment multiple constellations (up to 92 satellites). As a result of these features, DFMC SBAS service can be provided even in regions of active ionosphere where availability of an L1 SBAS service would be low, and DFMC SBAS users will benefit from improved availability, continuity and accuracy compared to the existing L1 SBAS service. Backward compatibility will be preserved, as existing L1 SBAS avionics will continue to function with the existing L1 SBAS service, which is not modified by the proposed amendment.

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CHAPTER 3. SPECIFICATIONS FOR RADIO NAVIGATION AIDS

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3.7 Requirements for the Global Navigation Satellite System (GNSS)

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3.7.3.2 *Reserved*

3.7.3.3 *Aircraft-based augmentation system (ABAS)*

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

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

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3.7.3.6 *Aircraft GNSS receiver*

3.7.3.6.1 The aircraft GNSS receiver shall process the signals of those GNSS elements that it intends to use as specified in Appendix B, 3.1.1 (for GPS), Appendix B, 3.1.2 (for GLONASS), Appendix B, 3.1.3 (for Galileo), Appendix B, 3.1.4 (for BDS), Appendix B 3.3 (for combined ~~GPS and GLONASS~~ core satellite constellations), Appendix B, 3.4 (for ABAS), Appendix B, 3.5 (for SBAS) and Appendix B, 3.6 (for GBAS and GRAS).

3.7.4 Resistance to interference

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

Note.— GPS and GLONASS GNSS elements operating within the frequency bands 1 164 – 1 215 MHz and 1 559 – 1 610 MHz are classified by the ITU as operating in the providing a radionavigation-satellite service (RNSS). Those frequency bands also include global allocations to the and aeronautical radionavigation service (ARNS). Both aeronautical uses of those services are considered "safety services" and are afforded special spectrum protection status for RNSS in the ITU radio regulations. In order to achieve the performance objectives for precision approach guidance to be supported by the GNSS and its augmentations, RNSS/ARNS is intended to remain the only global allocation in the 1 164 – 1 215 MHz and 1 559 – 1 610 MHz band and emissions from systems in this and adjacent frequency bands are intended to be tightly controlled by national and/or international regulation.

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

3. GNSS ELEMENTS

3.1 Core constellations

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3.2 (Reserved)

3.3 Combined uUse of GPS and GLONASS multiple core satellite constellations

3.3.1 AIRCRAFT ELEMENTS

3.3.1.1 *Combined Multi-constellation GNSS receiver*. The combined multi-constellation GNSS receiver shall process signals from GPS and GLONASS two or more core satellite constellations in accordance with the requirements specified in 3.1.1.3.1, GPS (GNSS) receiver, and 3.1.2.3.1, GLONASS (GNSS) receiver, 3.1.3.3.1, Galileo receiver and 3.1.4.3.1, BDS receiver.

3.3.1.1.1 *Resistance to interference*. The combined multi-constellation GNSS receiver shall meet the individual requirements for GPS and GLONASS the core satellite constellations processed as specified in 3.7.

3.3.1.2 *Antenna(e)*. GPS and GLONASS Core satellite constellation signals shall be received through one or more antennae.

Note.— Performance characteristics of GNSS receiver antennae are defined in 3.8.

3.3.1.3 *Conversion between coordinate systems.* Position information provided by a combined multi-constellation GPS and GLONASS GNSS receiver shall be expressed in WGS-84 earth coordinates.

3.3.1.3.1 Recommendation.— *The GLONASS satellite position, obtained in PZ-90 coordinate frame, should be converted to account for the differences between WGS-84 and PZ-90, as defined in 3.2.5.2.*

3.3.1.4 ~~*GPS/GLONASS time.*~~ When combining measurements from ~~GLONASS and GPS~~ core satellite constellations, the difference ~~between GLONASS time and GPS time~~ among each core satellite constellation reference time shall be taken into account.

3.3.1.4.1 ~~GPS/GLONASS~~ Multi-constellation GNSS receivers shall solve for the time offset between the core constellations as an additional unknown parameter in the navigation solution and not only rely on the time offset broadcast in the navigation messages.

3.4 Aircraft-based augmentation system (ABAS)

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

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3.7 Resistance to interference

3.7.1 PERFORMANCE OBJECTIVES

Note 1.— For ~~unaugmented GPS and GLONASS~~ GNSS receivers not using differential corrections from an augmentation system, the resistance to interference is measured with respect to the following core satellite constellation performance parameters:

	Tracking error (1 sigma)
GPS L1 (single-frequency equipment)	*0.36 m*
GPS L1 (dual-frequency equipment)	*0.15 m*
GPS L5	*0.15 m*
*GPS L1-L5***	*0.40 m*
GLONASS L1OF	*0.80 m*
GLONASS L1OC	*0.30 m*
GLONASS L3OC	*0.10 m*
*GLONASS L1OC-L3OC***	*0.65 m*
*Galileo E1-E5a***	*0.40 m*
Galileo E1	*0.15 m*
Galileo E5a	*0.15 m*
BDS B1I	*0.60 m*
BDS B1C	*0.20 m*
BDS B2a	*0.15 m*
*BDS B1C-B2a***	*0.40 m*

** The accuracy budget for the tracking error is specified for smoothed measurements.*
*** Refers to dual-frequency ionosphere-free pseudo-range measurements.*

Note 2.— This tracking error neither includes contributions due to signal propagation such as multipath, tropospheric and ionospheric effects nor ephemeris and GPS, ~~and~~ GLONASS, Galileo and BDS satellite clock errors.

Note 3.— For SBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.5.8.2.1, ~~and~~ 3.5.8.4.1, and 3.5.15.3.2.

Note 4.— For GBAS receivers, the resistance to interference is measured with respect to parameters specified in 3.6.7.1.1 and 3.6.8.2.1.

Note 5.— The signal levels specified in this section are defined at the antenna port. Assumed maximum aircraft antenna gain in the lower hemisphere is –10 dBic.

Note 6.— The performance requirements are to be met in the interference environments defined below. This defined interference environment is relaxed during initial acquisition of GNSS signals when the receiver cannot take advantage of a steady-state navigation solution to aid signal acquisition.

Note 7.— If not specified, the equipment performance objectives and requirements specified for a particular constellation apply whether the equipment supports only that constellation (single constellation equipment) or that constellation and other constellation(s) (multiple constellation equipment).

3.7.2 CONTINUOUS WAVE (CW) INTERFERENCE

3.7.2.1 *GPS L1 AND SBAS L1 RECEIVERS*

Note.— Less interference power is tolerated by the interference thresholds for GPS L1 and SBAS L1 receivers than for the dual-frequency L1/L5 receivers in the band 1 480 – 1 565 MHz described in 3.7.2.3.

3.7.2.1.1 After steady-state navigation has been established, GPS L1 and SBAS L1 receivers shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-83 and shown in Figure B-15 and with a desired GPS L1 and SBAS L1 signal level of –164 dBW at the antenna port.

3.7.2.1.2 During initial acquisition of the GPS L1 and SBAS L1 signals prior to steady-state navigation, GPS L1 and SBAS L1 receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table B-83.

3.7.2.2 *GLONASS RECEIVERS*

3.7.2.2.1 After steady-state navigation has been established, GLONASS FDMA signals receivers in L1 band (except those identified in 3.7.2.2.1.1) shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table B-84 and shown in Figure B-16 and with a desired signal level –166.5 dBW at the antenna port.

Table B-83. CW interference thresholds for GPS L1 and SBAS L1 receivers in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers in steady-state navigation
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ 1 500 MHz	Linearly decreasing from –4.5 dBW to –38 dBW
1 500 MHz < $f_i \leq$ 1 525 MHz	Linearly decreasing from –38 dBW to –42 dBW
1 525 MHz < $f_i \leq$ 1 565.42 MHz	Linearly decreasing from –42 dBW to –150.5 dBW
1 565.42 MHz < $f_i \leq$ 1 585.42 MHz	–150.5 dBW
1 585.42 MHz < $f_i \leq$ 1 610 MHz	Linearly increasing from –150.5 dBW to –60 dBW
1 610 MHz < $f_i \leq$ 1 618 MHz	Linearly increasing from –60 dBW to –42 dBW~~*~~
1 618 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
~~1 610~~ 1 618 MHz < $f_i \leq$ 1 626.5 MHz	Linearly increasing from –42 dBW to –22 dBW**
1 626.5 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
f_i > 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there ~~is~~are on-board satellite communications.

3.7.2.2.1.1 After steady-state navigation has been established, GLONASS FDMA signals receivers in L1 band used for all phases of flight (excluding those used for the precision approach phase of flight) and put into operation before 1 January 2017 shall meet the performance objectives with CW interfering signals present with a power level at the antenna port 3 dB less than the interference thresholds specified in Table B-84 and shown in Figure B-16 and with a desired signal level of –166.5 dBW at the antenna port.

Table B-84. CW interference thresholds for GLONASS FDMA signals receivers in L1 band in steady-state navigation

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Editorial note.— Insert new text as follows:

3.7.2.2.1.2 After steady-state navigation has been established, GLONASS CDMA signals receivers in L1 and L3 bands shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Tables TAB-01 and TAB-02 and shown in Figures FIG-01 and FIG-02 and with a desired signal level of –161.5 dBW at the antenna port.

Table TAB-01. CW interference thresholds for GLONASS CDMA signals receivers in L1 band in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers in steady-state navigation
$f_i \leq$ 1 315 MHz	–4.5 dBW
1 315 MHz < $f_i \leq$ 1 562.15625 MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 562.15625 MHz < $f_i \leq$ 1 583.65625 MHz	Linearly decreasing from –42 dBW to –80 dBW
1 583.65625 MHz < $f_i \leq$ 1 592.9525 MHz	Linearly decreasing from –80 dBW to –149 dBW
1 592.9525 MHz < $f_i \leq$ 1 609.36 MHz	–149 dBW
1 609.36 MHz < $f_i \leq$ 1 613.65625 MHz	Linearly increasing from –149 dBW to –80 dBW
1 613.65625 MHz < $f_i \leq$ 1 635.15625 MHz	Linearly increasing from –80 dBW to –42 dBW*
1 613.65625 MHz < $f_i \leq$ 1 626.15625 MHz	Linearly increasing from –80 dBW to –22 dBW**
1 635.15625 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 626.15625 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
f_i > 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there are on-board satellite communications.

Table TAB-02. CW interference thresholds for GLONASS CDMA signals receivers in L3 band in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers in steady-state navigation
$f_i \leq$ 908 MHz	–4.5 dBW
908 MHz < $f_i \leq$ 1 155.775 MHz	Linearly decreasing from –4.5 dBW to –42 dBW
1 155.775 MHz < $f_i \leq$ 1 178.775 MHz	Linearly decreasing from –42 dBW to –73 dBW
1 178.775 MHz < $f_i \leq$ 1 191.775 MHz	Linearly decreasing from –73 dBW to –143 dBW
1 191.775 MHz < $f_i \leq$ 1 212.275 MHz	–143 dBW
1 212.275 MHz < $f_i \leq$ 1 224.875 MHz	Linearly increasing from –143 dBW to –73 dBW
1 224.875 MHz < $f_i \leq$ 1 244.375 MHz	Linearly increasing from –73 dBW to –42 dBW
1 244.375 MHz < $f_i \leq$ 1 492.125 MHz	Linearly increasing from –42 dBW to –4.5 dBW
f_i > 1 492.125 MHz	–4.5 dBW

Editorial note.— End of new text

3.7.2.2.2 During initial acquisition of the GLONASS FDMA signals in L1 band prior to steady-state navigation, GLONASS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table B-84.

Editorial note.— *Insert* new text as follows:

3.7.2.2.2.1 During initial acquisition of the GLONASS CDMA signals in L1 and L3 bands prior to steady-state navigation, GLONASS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Tables TAB-01 and TAB-02.

3.7.2.3 *GPS L1/L5, GALILEO E1/E5A AND DFMC SBAS receivers*

3.7.2.3.1 During initial L5/E5a acquisition prior to steady-state navigation, and after steady-state navigation has been established, DFMC SBAS receivers processing signals centred on L1/E1 and L5/E5a frequencies shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table TAB-03 and shown in Figure FIG-03, and with a desired SBAS L5 signal level of –162.5 dBW, with a desired GPS L5 signal level of –159.4 dBW, and with a desired Galileo E5a signal level of –160.4 dBW at the antenna port.

3.7.2.3.2 After steady-state navigation has been established, DFMC SBAS receivers processing signals centred on L1/E1 and L5/E5a frequencies shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table TAB-03 and shown in Figure FIG-03, and with a desired GPS L1 and SBAS L1 signal level of –163 dBW and with a desired Galileo E1 signal level of –162.25 dBW at the antenna port. During initial L1/E1 acquisition, DFMC SBAS receivers shall meet the performance objectives with interference levels that are 6 dB below what is specified in Table TAB-03.

Note.— CW interference thresholds for DMFC SBAS receivers determine the interference power levels applicable for the frequency ranges defined in Table TAB-03.

Table TAB-03. CW interference thresholds for GPS L1/L5, Galileo E1/E5a and DFMC SBAS receivers

Frequency range f_i of the interference signal	Interference thresholds for receivers
$f_i \leq$ 1 000 MHz	–21 dBW
1 000 MHz < $f_i \leq$ 1 100.45 MHz	Linearly decreasing from –21 dBW to –44 dBW
1 100.45 MHz < $f_i \leq$ 1 148.45 MHz	Linearly decreasing from –44 dBW to –54 dBW
1 148.45 MHz < $f_i \leq$ 1 166.45 MHz	Linearly decreasing from –54 dBW to –145 dBW
1 166.45 MHz < $f_i \leq$ 1 186.45 MHz	–145 dBW
1 186.45 MHz < $f_i \leq$ 1 205.45 MHz	Linearly increasing from –145 dBW to –54 dBW
1 205.45 MHz < $f_i \leq$ 1 252.45 MHz	Linearly increasing from –54 dBW to –43 dBW
1 252.45 MHz < $f_i \leq$ 1 315 MHz	Linearly increasing from –43 dBW to –39 dBW
1 315 MHz < $f_i \leq$ 1 525 MHz	Linearly increasing from –39 dBW to –31.5 dBW
1 525 MHz < $f_i \leq$ 1 531 MHz	Linearly decreasing from –31.5 dBW to –34 dBW
1 531 MHz < $f_i \leq$ 1 536 MHz	Linearly decreasing from –34 dBW to –65 dBW
1 536 MHz < $f_i \leq$ 1 565.42 MHz	Linearly decreasing from –65 dBW to –150.5 dBW
1 565.42 MHz < $f_i \leq$ 1 585.42 MHz	–150.5 dBW
1 585.42 MHz < $f_i \leq$ 1 610 MHz	Linearly increasing from –150.5 dBW to –60 dBW
1 610 MHz < $f_i \leq$ 1 618 MHz	Linearly increasing from –60 dBW to –42 dBW
1 618 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –12 dBW*
1 618 MHz < $f_i \leq$ 1 626.5 MHz	Linearly increasing from –42 dBW to –22 dBW*
1 626.5 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –12 dBW**
f_i > 2 000 MHz	–12 dBW**

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there are on-board satellite communications.

3.7.2.4 *BDS RECEIVERS*

3.7.2.4.1 After steady-state navigation has been established, BDS B1I receivers shall meet the performance objectives with CW interfering signals present with a power level at the antenna port equal to the interference thresholds specified in Table TAB-04B and shown in Figure FIG-04A and with a desired BDS signal level of –164.5 dBW at the antenna port. During initial acquisition prior to steady-state navigation, BDS B1I receivers shall meet the performance objectives with 6 dB less than those specified in Table TAB-04B.

3.7.2.4.2 After steady-state navigation has been established, BDS B1C/B2a receivers shall meet the performance objectives with a power level at the antenna port equal to the interference thresholds specified in Table TAB-04C and shown in Figure FIG-04B and with desired BDS signal levels of –163.5 dBW for B1C and –160.5 dBW for B2a at the antenna port. During initial acquisition prior to steady-state navigation, BDS B1C/B2a receivers shall meet the performance objectives with 6 dB less than those specified in Table TAB-04C.

Table TAB-04B. CW interference thresholds for BDS B1I receivers in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers in steady-state navigation
$f_i \leq$ 1 465 MHz	–18 dBW
1 465 MHz < $f_i \leq$ 1 528 MHz	Linearly decreasing from –18 dBW to –30 dBW
1 528 MHz < $f_i \leq$ 1 559.052 MHz	Linearly decreasing from –30 dBW to –150.5 dBW
1 559.052 MHz < $f_i \leq$ 1 563.144 MHz	–150.5 dBW
1 563.144 MHz < $f_i \leq$ 1 610 MHz	Linearly increasing from –150.5 dBW to –60 dBW
1 610 MHz < $f_i \leq$ 1 618 MHz	Linearly increasing from –60 dBW to –42 dBW*
1 618 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 610 MHz < $f_i \leq$ 1 626.5 MHz	Linearly increasing from –60 dBW to –22 dBW**
1 626.5 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
f_i > 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there are on-board satellite communications.

Table TAB-04C. CW interference thresholds for BDS B1C/B2a receivers in steady-state navigation

Frequency range f_i of the interference signal	Interference thresholds for receivers
$f_i \leq$ 1 000 MHz	–24 dBW
1 000 MHz < $f_i \leq$ 1 100.45 MHz	Linearly decreasing from –24 dBW to –44 dBW
1 100.45 MHz < $f_i \leq$ 1 148.45 MHz	Linearly decreasing from –44 dBW to –54 dBW
1 148.45 MHz < $f_i \leq$ 1 166.45 MHz	Linearly decreasing from –54 dBW to –145 dBW
1 166.45 MHz < $f_i \leq$ 1 186.45 MHz	–145 dBW
1 186.45 MHz < $f_i \leq$ 1 205.45 MHz	Linearly increasing from –145 dBW to –54 dBW
1 205.45 MHz < $f_i \leq$ 1 252.45 MHz	Linearly increasing from –54 dBW to –43 dBW
1 252.45 MHz < $f_i \leq$ 1 315 MHz	Linearly increasing from –43 dBW to –39 dBW
1 315 MHz < $f_i \leq$ 1 525 MHz	Linearly increasing from –39 dBW to –31.5 dBW
1 525 MHz < $f_i \leq$ 1 531 MHz	Linearly decreasing from –31.5 dBW to –34 dBW
1 531 MHz < $f_i \leq$ 1 536 MHz	Linearly decreasing from –34 dBW to –65 dBW
1 536 MHz < $f_i \leq$ 1 565.42 MHz	Linearly decreasing from –65 dBW to –150.5 dBW
1 565.42 MHz < $f_i \leq$ 1 585.42 MHz	–150.5 dBW
1 585.42 MHz < $f_i \leq$ 1 610 MHz	Linearly increasing from –150.5 dBW to –60 dBW
1 610 MHz < $f_i \leq$ 1 618 MHz	Linearly increasing from –60 dBW to –42 dBW*
1 618 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –42 dBW to –8.5 dBW*
1 618 MHz < $f_i \leq$ 1 626.5 MHz	Linearly increasing from –60 dBW to –22 dBW**
1 626.5 MHz < $f_i \leq$ 2 000 MHz	Linearly increasing from –22 dBW to –8.5 dBW**
f_i > 2 000 MHz	–8.5 dBW

* Applies to aircraft installations where there are no on-board satellite communications.
** Applies to aircraft installations where there are on-board satellite communications.

Editorial note.— End of new text.

3.7.3 BAND-LIMITED NOISE-LIKE INTERFERENCE

3.7.3.1 *GPS L1 AND SBAS L1 RECEIVERS*

3.7.3.1.1 After steady-state navigation has been established, GPS L1 and SBAS L1 receivers shall meet the performance objectives with noise-like interfering signals present in the frequency range of 1 575.42 MHz ±Bw_i/2 and with power levels at the antenna port equal to the interference thresholds specified in Table B-85 and shown in Figure B-17 and with the desired signal level of –164 dBW at the antenna port.

Note.— Bw_i is the equivalent noise bandwidth of the interference signal.

3.7.3.1.2 During initial acquisition of the GPS and SBAS signals prior to steady-state navigation, GPS L1 and SBAS L1 receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table B-85.

3.7.3.2 *GLONASS RECEIVERS*

3.7.3.2.1 After steady-state navigation has been established, GLONASS FDMA signals receivers in L1 band (except those identified in 3.7.3.2.1.1) shall meet the performance objectives while receiving noise-like interfering signals in the frequency band f_k ±Bw_i/2, with power levels at the antenna port equal to the interference thresholds specified in Table B-86 and shown in Figure B-18 and with a desired signal level of –166.5 dBW at the antenna port.

3.7.3.2.1.1 After steady-state navigation has been established, GLONASS FDMA signals receivers in L1 band used for all phases of flight (excluding those used for the precision approach phase of flight) and put into operation before 1 January 2017 shall meet the performance objectives while receiving noise-like interfering signals in the frequency band f_k ±Bw_i/2, with power levels at the antenna port 3 dB less than the interference thresholds specified in Table B-86 and shown in Figure B-18 and with a desired signal level of –166.5 dBW at the antenna port.

Note.— f_k is the centre frequency of a GLONASS channel with f_k = 1 602 MHz + k × 0.5625 MHz and k = –7 to + 6 as defined in Table B-16 and Bw_i is the equivalent noise bandwidth of the interference signal.

3.7.3.2.1.2 After steady-state navigation has been established, GLONASS CDMA signals receivers in L1 and L3 bands shall meet the performance objectives while receiving noise-like interfering signals in the frequency band f_k ±Bw_i/2, with power levels at the antenna port equal to the interference thresholds specified in Tables TAB-05 and TAB-06 and shown in Figures FIG-05 and FIG-06 and with a desired signal level of –161.5 dBW at the antenna port.

3.7.3.2.2 During initial acquisition of the GLONASS FDMA signals in L1 band prior to steady-state navigation, GLONASS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table B-86.

Editorial note.— Insert new text as follows:

3.7.3.2.2.1 During initial acquisition of the GLONASS CDMA signals in L1 and L3 bands prior to steady-state navigation, GLONASS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Tables TAB-05 and TAB-06.

Table TAB-05. Interference threshold for band-limited noise-like interference to GLONASS CDMA L1 signals receivers in L1 band in steady-state navigation

Interference bandwidth	Interference threshold
0 Hz < Bw_i ≤ 1 kHz	–149 dBW
1 kHz < Bw_i ≤ 10 kHz	Linearly increasing from –149 to –143 dBW
10 kHz < Bw_i ≤ 0.5 MHz	–143 dBW
0.5 MHz < Bw_i ≤ 10 MHz	Linearly increasing from –143 to –130 dBW
10 MHz < Bw_i	–130 dBW

Table TAB-06. Interference threshold for band-limited noise-like interference to GLONASS CDMA signals receivers in L3 band in steady-state navigation

Interference bandwidth	Interference threshold
0 Hz < Bw_i ≤ 1 kHz	–143 dBW
1 kHz < Bw_i ≤ 1 MHz	Linearly increasing from –143 to –140 dBW
1 MHz < Bw_i ⩽ 20 MHz	Linearly increasing from –140 to –126.9 dBW
20 MHz < Bw_i	–126.9 dBW

3.7.3.3 *GPS L1/L5, GALILEO E1/E5A AND DFMC SBAS RECEIVER*

3.7.3.3.1 During initial L5/E5a acquisition prior to steady-state navigation, and after steady-state navigation has been established, GPS L1/L5, Galileo E1/E5a and DFMC SBAS receivers processing signals centred on L1/E1 and L5/E5a frequencies shall meet the performance objectives with noise-like interfering signals present in the frequency range of 1 176.45 MHz ±Bwi/2 and with power levels at the antenna port equal to the interference thresholds specified in Table TAB-07 and shown in Figure FIG-07 and with a desired SBAS L5 signal level of –162.5 dBW, with a desired GPS L5 level of –159.4 dBW and with a desired Galileo E5a level of –160.4 dBW at the output of the antenna.

Note.— Bw_i is the equivalent noise bandwidth of the interference signal.

3.7.3.3.2 After steady-state navigation has been established, GPS L1/L5, Galileo E1/E5a and DFMC SBAS receivers processing signals centred on L1/E1 and L5/E5a frequencies shall meet the performance objectives with noise-like interfering signals present in the frequency range of 1 575.42 MHz ±Bw_i/2 and with power levels at the antenna port equal to the interference thresholds specified in Table B-85 and shown in Figure B-17 and with the desired GPS and SBAS L1 signal levels of –163 dBW and with the desired Galileo E1 signal level of –162.25 dBW at the antenna port. During initial L1/E1 acquisition, DFMC SBAS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table B-85.

Note.— Bw_i is the equivalent noise bandwidth of the interference signal.

Table TAB-07. Interference threshold for band-limited noise-like interference to GPS L1/L5, Galileo E1/E5A and DFMC SBAS receivers

Interference bandwidth	Interference threshold for receivers
0 Hz < Bw_i ≤ 1kHz	–145.0 dBW
1 kHz < Bw_i ≤ 10 kHz	Linearly increasing from –145.0 to –137.5 dBW
10 kHz < Bw_i ≤ 100 kHz	Linearly increasing from –137.5 to –133.9 dBW
100 kHz < Bw_i ≤ 1 MHz	Linearly increasing from –133.9 to –133.0 dBW
1 MHz < Bw_i ≤ 10 MHz	Linearly increasing from –133.0 to –131.7 dBW*
10 MHz < Bw_i ≤ 40 MHz	Linearly increasing from –131.7 to –127.0 dBW*

* The interference threshold is not to exceed –134.0 dBW/MHz in the frequency range 1 176.45 ±10 MHz.

3.7.3.4 *BDS RECEIVERS*

3.7.3.4.1 After steady-state navigation has been established, BDS B1I receivers shall meet the performance objectives with noise like interfering signals present in the frequency range of 1561.098 MHz $\pm Bw_i/2$ and with power levels at the antenna port equal to the interference thresholds specified in Table TAB-08A and shown in Figure FIG-08A and with a desired B1I signal level of –164.5 dBW at the output of the antenna. During initial acquisition of the BDS B1I signals prior to steady-state navigation, BDS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table TAB-08A.

Note.— Bw_i is the equivalent noise bandwidth of the interference signal.

3.7.3.4.2 After steady-state navigation has been established, BDS B1C receivers shall meet the performance objectives with noise-like interfering signals present in the frequency range of 1 575.42 MHz ±Bwi/2 and with power levels at the antenna port equal to the interference thresholds specified in Table TAB-08B and shown in Figure FIG-08B and with a desired B1C signal level of –163.5 dBW at the output of the antenna. During initial acquisition of the BDS B1C signals prior to steady-state navigation, BDS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table TAB-08B.

Note.— Bwi is the equivalent noise bandwidth of the interference signal.

Table TAB-08A. Interference threshold for band-limited noise-like interference to BDS B1I receivers in steady-state navigation

Interference bandwidth	Interference threshold for receivers in steady-state navigation
$0 \text{ Hz} < Bw_i \leq 700 \text{ Hz}$	–150.5 dBW
$700 \text{ Hz} < Bw_i \leq 10 \text{ kHz}$	Linearly increasing from –150.5 dBW to –143.5 dBW
$10 \text{ kHz} < Bw_i \leq 100 \text{ kHz}$	Linearly increasing from –143.5 dBW to –140.5 dBW
$100 \text{ kHz} < Bw_i \leq 1 \text{ MHz}$	–140.5 dBW
$1 \text{ MHz} < Bw_i \leq 4.096 \text{ MHz}$	Linearly increasing from –140.5 dBW to –134.4 dBW
$4.096 \text{ MHz} < Bw_i \leq 10 \text{ MHz}$	Linearly increasing from –134.4 dBW to –126 dBW
$10 \text{ MHz} < Bw_i$	–126.0 dBW

* The interference threshold is not to exceed –140.5 dBW/MHz in the frequency range 1 561.098 ± 2.046 MHz.

Table TAB-08B. Interference threshold for band-limited noise-like interference to BDS B1C receivers in steady-state navigation

Interference bandwidth	Interference threshold for receivers in steady-state navigation
0 Hz < Bw_i ⩽ 700 Hz	–150.5 dBW
700 Hz < Bw_i ⩽ 10 kHz	Linearly increasing from –150.5 to –143.5 dBW
10 kHz < Bw_i ⩽ 100 kHz	Linearly increasing from –143.5 to –140.5 dBW
100 kHz < Bw_i ⩽ 1 MHz	–140.5 dBW
1 MHz < Bw_i ⩽ 20 MHz	Linearly increasing from –140.5 to –127.5 dBW*
20 MHz < Bw_i ⩽ 30 MHz	Linearly increasing from –127.5 to –121.1 dBW*
30 MHz < Bw_i ⩽ 40 MHz	Linearly increasing from –121.1 to –119.5 dBW*
40 MHz < Bw_i	–119.5 dBW*

* The interference threshold is not to exceed –140.5 dBW/MHz in the frequency range 1 575.42 ±10 MHz.

3.7.3.4.3 After steady-state navigation has been established, BDS B2a receivers shall meet the performance objectives with noise-like interfering signals present in the frequency range of 1 176.45 MHz ±Bwi/2 and with power levels at the antenna port equal to the interference thresholds specified in Table TAB-08C and shown in Figure FIG-08C and with a desired B2a signal level of –160.5 dBW at the output of the antenna. During initial acquisition of the BDS B2a signals prior to steady-state navigation, BDS receivers shall meet the performance objectives with interference thresholds 6 dB less than those specified in Table TAB-08C.

Note.— Bw_i is the equivalent noise bandwidth of the interference signal.

Table TAB-08C. Interference threshold for band-limited noise-like interference to BDS B2a receivers in steady-state navigation

Interference bandwidth	Interference threshold for receivers in steady-state navigation
0 Hz < Bw_i ≤ 1kHz	–145.0 dBW
1 kHz < Bw_i ≤ 10 kHz	Linearly increasing from –145.0 to –137.5 dBW
10 kHz < Bw_i ≤ 100 kHz	Linearly increasing from –137.5 to –133.9 dBW
100 kHz < Bw_i ≤ 1 MHz	Linearly increasing from –133.9 to –133.0 dBW
1 MHz < Bw_i ≤ 10 MHz	Linearly increasing from –133.0 to –131.7 dBW*
10 MHz < Bw_i ≤ 40 MHz	Linearly increasing from –131.7 to –127.0 dBW*

* The interference threshold is not to exceed –134.0 dBW/MHz in the frequency range 1 176.45 ±10 MHz.

Editorial note.— End of new text.

~~3.7.3.3~~ 3.7.3.5 *Pulsed interference*. After steady-state navigation has been established, the GNSS receiver shall meet the performance objectives while receiving pulsed interference signals with characteristics according to Table B-87 where the interference threshold is defined at the antenna port.

~~3.7.3.4~~ 3.7.3.6 ~~SBAS and GBAS~~ GNSS receivers shall not output misleading information in the presence of interference including interference levels above those specified in 3.7.

Note.— Guidance material on this requirement is given in Attachment D, 10.5

3.8 GNSS aircraft satellite receiver antenna

3.8.1 *Antenna coverage*. The GNSS antenna shall meet the performance requirements for the reception of GNSS satellite signals from 0 to 360 degrees in azimuth and from 0 to 90 degrees in elevation relative to the horizontal plane of an aircraft in level flight.

3.8.2 *Antenna gain*. The minimum passive antenna element gain for single-frequency antennas shall not be less than that shown in Table B-88A for the specified elevation angle above the horizon. For these antennas, ~~T~~the maximum passive antenna element gain shall not exceed +4 dBic for elevation angles above 5 degrees. The minimum passive antenna element gains at both frequencies for dual-frequency antennas shall comply with Table B-88B for the specified elevation angles above the horizon. For these antennas, the maximum passive antenna element gain shall be limited to +4 dBic for elevation angles above 75 degrees.

3.8.3 *Polarization*. The GNSS antenna polarization shall be right-hand circular (clockwise with respect to the direction of propagation).

3.8.3.1 *Axial ratio.* For single-frequency antennas, ~~T~~the axial ratio shall not exceed 3.0 dB as measured at boresight. For dual-frequency antennas, the axial ratio shall be less than or equal to 3 dB over the operating frequency range as measured in a region extending from boresight down to 40 degrees off boresight across all azimuth angles.

Table B-85. Interference threshold for band-limited noise-like interference to GPS L1 and SBAS L1 receivers in steady-state navigation

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Table B-86. Interference threshold for band-limited noise-like interference to GLONASS FDMA signals receivers in L1 band in steady-state navigation

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Table B-87. Interference thresholds for pulsed interference

	GPS L1, Galileo L1 and SBAS L1	GLONASS FDMA	GLONASS CDMA	BDS B1C	BDS B1I
Frequency range for in-band and near-band	1 575.42 MHz ± 20 MHz	1 592.9525 MHz to 1 609.36 MHz	1 191.775 MHz to 1 212.275 MHz/ 1 592.9525 MHz to 1 609.36 MHz	1 575.42 MHz ± 20 MHz	1 561.98 MHz ± 2.046 MHz
Interference threshold (Pulse peak power) for in-band and near-band interference	–20 dBW	–20 dBW	–20 dBW / –20 dBW	–20 dBW	–20 dBW
Interference threshold (Pulse peak power) outside the in-band and near-band frequency ranges (out-of-band interference)	0 dBW(*)	0 dBW	0 dBW / 0 dBW	0 dBW	0 dBW
Pulse width	≤125 µs	≤250 µs	≤250 µs / ≤250 µs	≤125 µs	≤125 µs
Pulse duty cycle	≤1%	≤1%	≤2% / ≤1%	≤1%	≤1%
Interference signal bandwidth for in-band and near-band interference	≥1 MHz	≥500 kHz	≥1 MHz / ≥500 kHz	≥1 MHz	≥1 MHz

Note 1.— The interference signal is additive white Gaussian noise centred around the carrier frequency and with bandwidth and pulse characteristics specified in the table.

Note 2.— In-band, near-band and out-of-band interference refers to the centre frequency of the interference signal.

Note 3.— Out-of-band interference is interference, the centre frequency of which is located on either side from the centre frequency of the frequency range for in-band and near-band at a distance of at least 250 per cent of the bandwidth of this frequency range.

Note 4.— The signal bandwidth specifies the minimum bandwidth of the noise-like signal with a power as large as the interference threshold that is pulsed with the specified pulse width and duty cycle.

Note 5.— (*) When considering the L1 channel of an L1/L5 receiver, this value is related to non-aeronautical pulsed interferences with a carrier frequency within 1 215 MHz – 2 000 MHz. This table does not describe non-aeronautical pulsed interferences in the environment to be considered for the L5 channel in an L1/L5 receiver (see Attachment D, 4.4.5 for further guidance).

Table B-88A. Minimum antenna gain — single-frequency antennas for GPS (L1), GLONASS (L1OF), BDS (B1C), BDS (B1I), and/or SBAS L1

Elevation angle degrees	Minimum gain dBic
0	–7.0
5	–5.5
10	–4.0
15 to 90	–2.5

~~*Note.— The –5.5 dBic gain at 5 degrees elevation angle is appropriate for an L1 antenna. A higher gain may be required in the future for GNSS signals in the L5/E5 band.*~~

Table B-88B. Minimum antenna gain — dual-frequency antennas for GPS (L1/L5), GLONASS (L1OC/L3OC), Galileo (E1/E5a), BDS (B1C/B2a) and/or SBAS (L1/L5)

Elevation angle degrees	Minimum gain dBic
0	–7.0
5	–4.5
10	–3.0
15	–1.5
30	0.5
≥ 75	1.5

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Figure B-15. CW interference thresholds for GPS L1 and SBAS L1 receivers in steady-state navigation

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Figure B-16. CW interference thresholds for GLONASS FDMA signals receivers in L1 band in steady-state navigation

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Figure B-17. Interference thresholds versus bandwidth for GPS L1 and SBAS L1 receivers

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Figure B-18. Interference thresholds versus bandwidth for GLONASS FDMA signals receivers in L1 band

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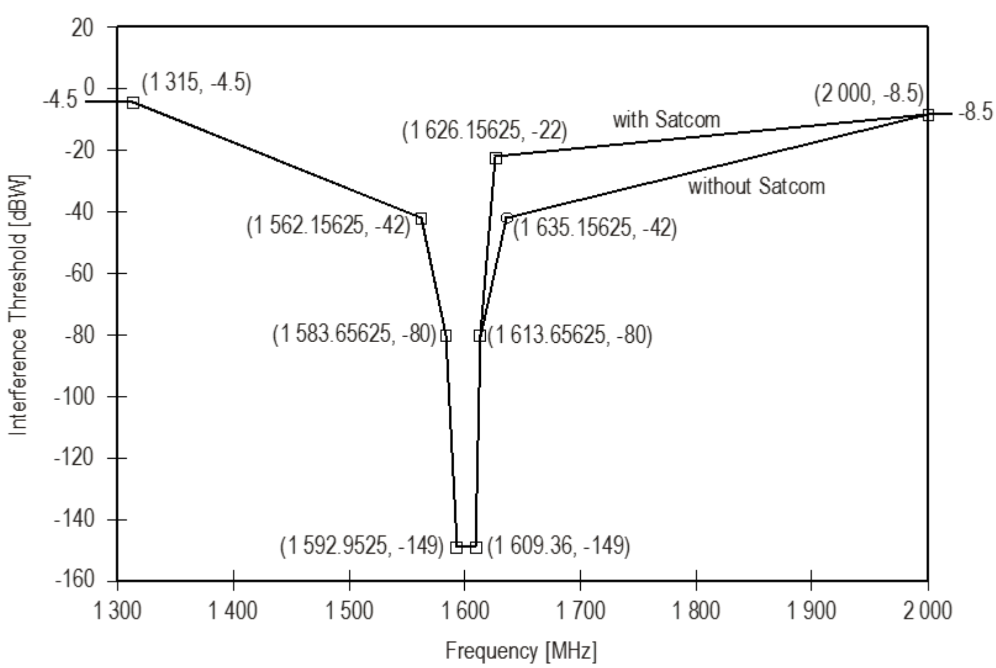

Figure FIG-01. CW interference thresholds for GLONASS CDMA signals receivers in L1 band in steady-state navigation

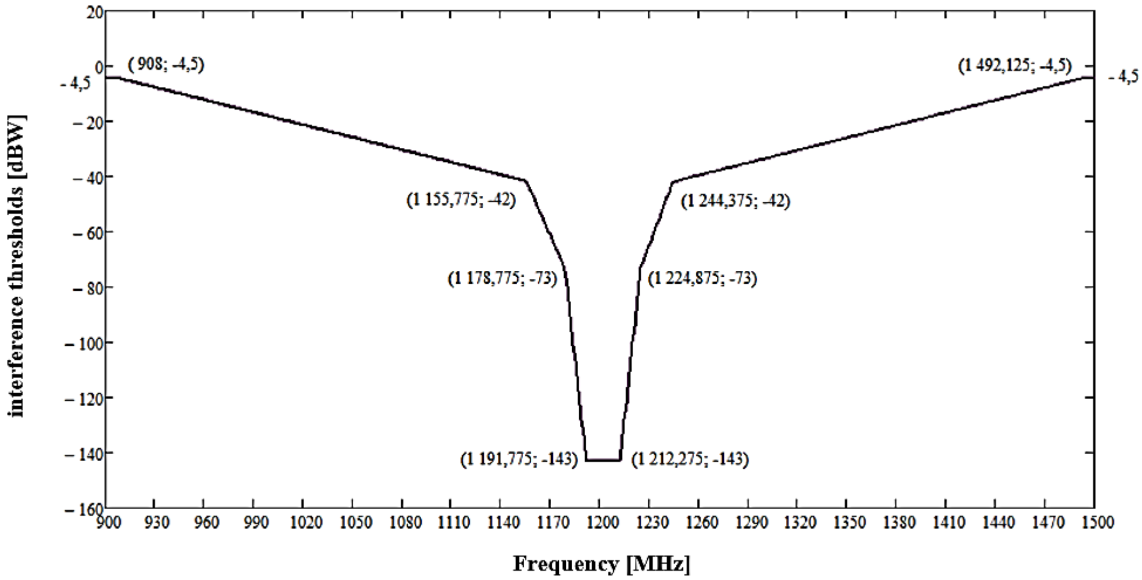

Figure FIG-02. CW interference thresholds for GLONASS CDMA signals receivers in L3 band in steady-state navigation

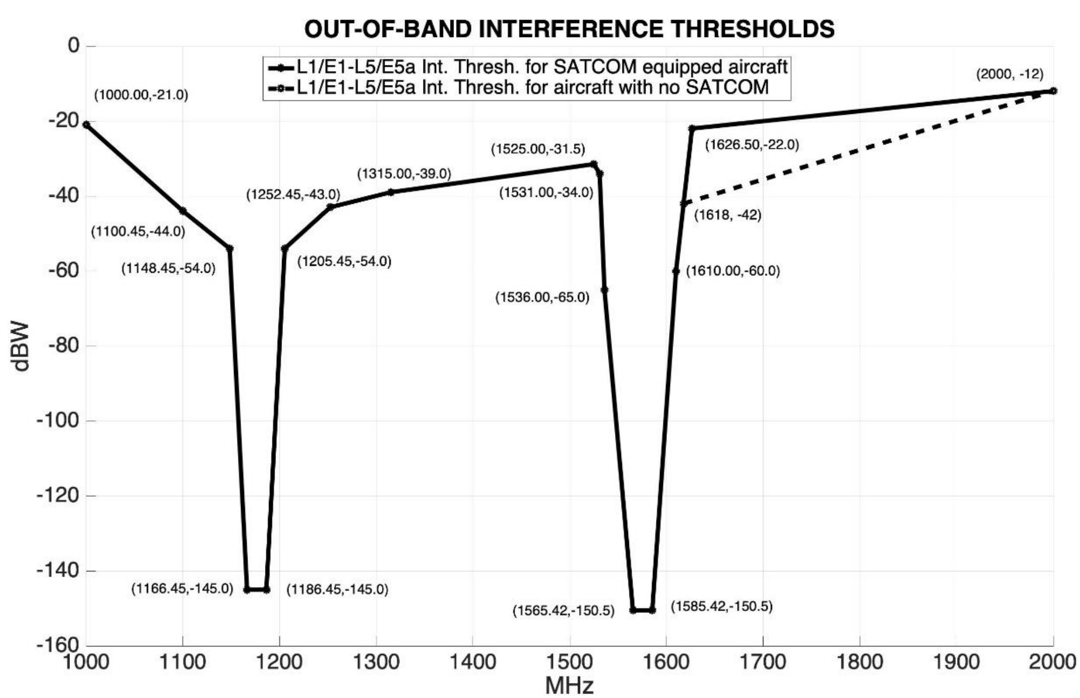

Figure FIG-03. CW interference thresholds for GPS L1/L5, Galileo E1/E5A and DFMC SBAS receivers

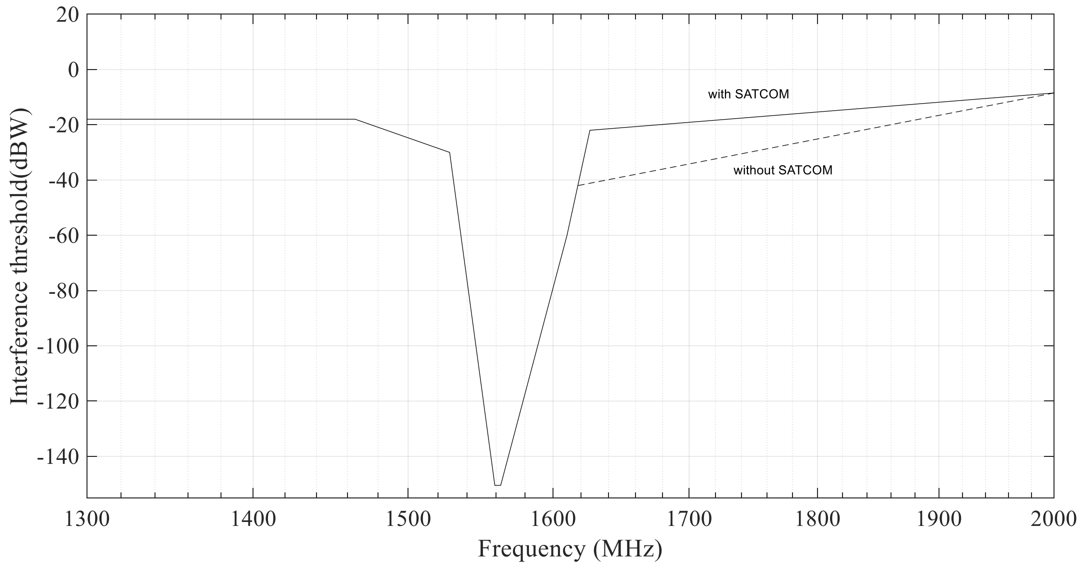

Figure FIG-04A. CW interference thresholds for BDS B1I receivers in steady-state navigation

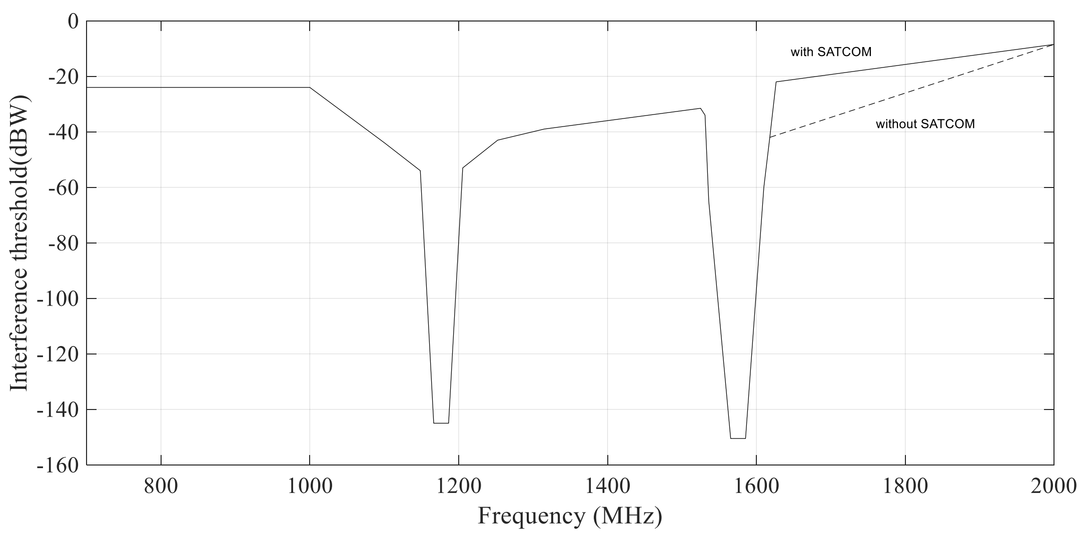

Figure FIG-04B. CW interference thresholds for BDS B1C/B2a receivers in steady-state navigation

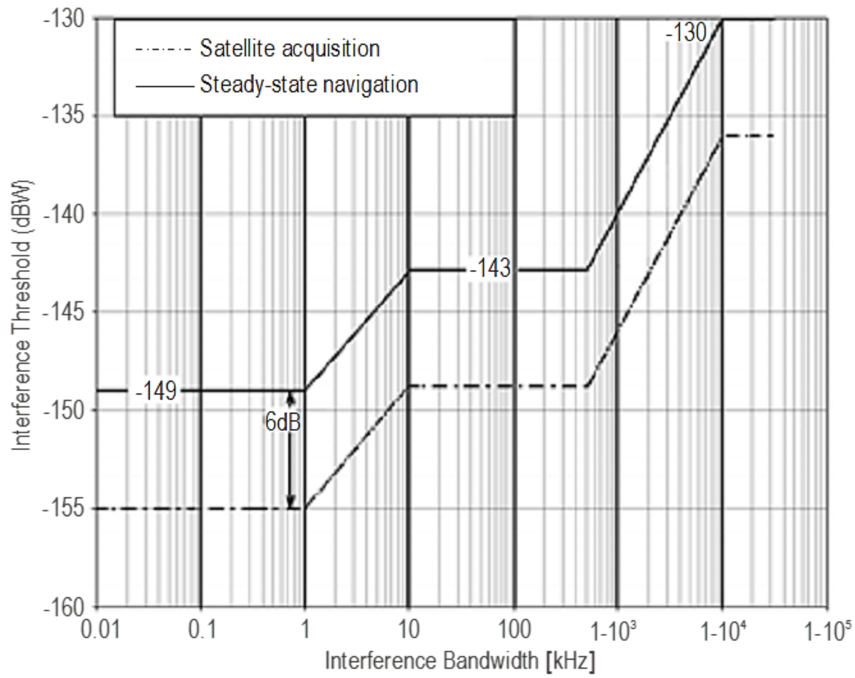

Figure FIG-05. Interference thresholds versus bandwidth for GLONASS CDMA signals receivers in L1 band

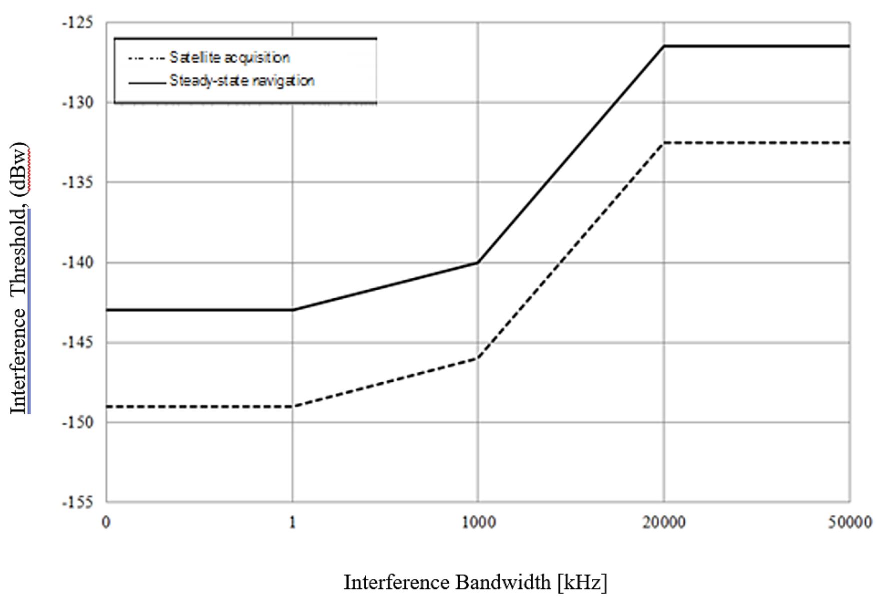

Figure FIG-06. Interference thresholds versus bandwidth for GLONASS CDMA signals receivers in L3 band

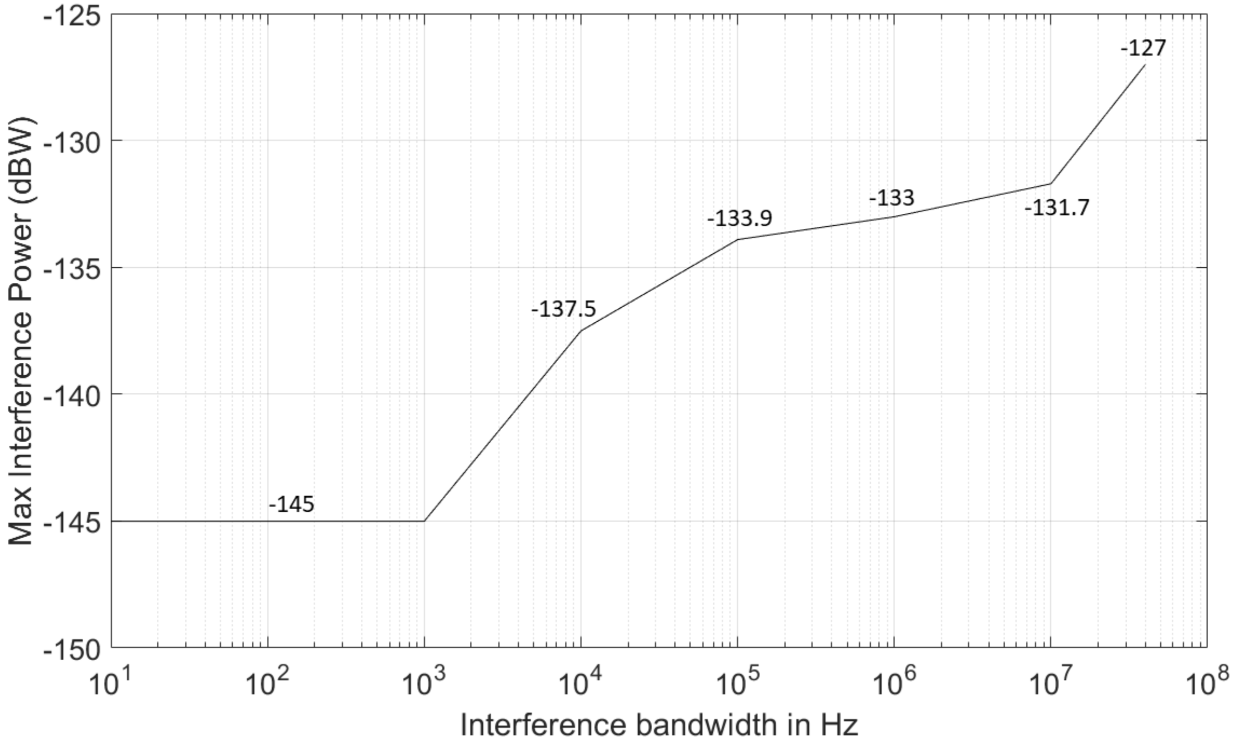

Figure FIG-07. Interference thresholds versus bandwidth for GPS L1/L5, Galileo E1/E5A and DFMC SBAS receivers

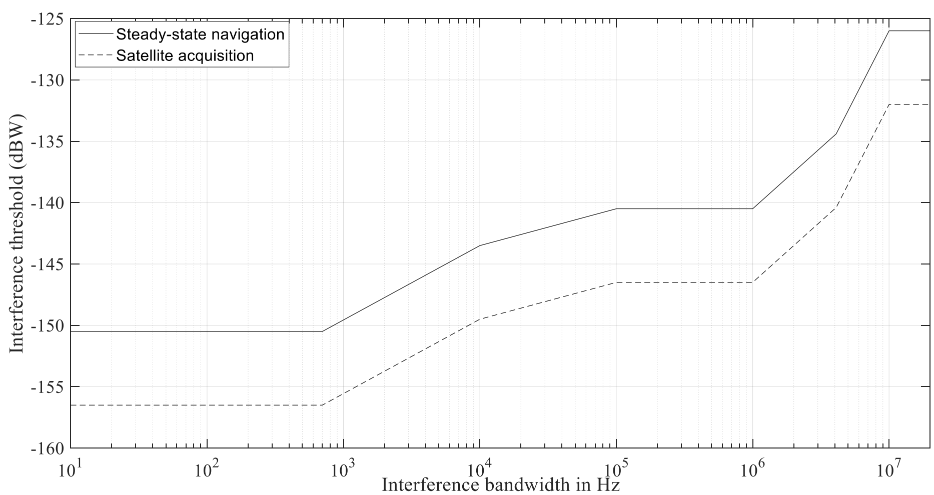

Figure FIG-08A. Interference thresholds versus bandwidth for BDS B1I receiver

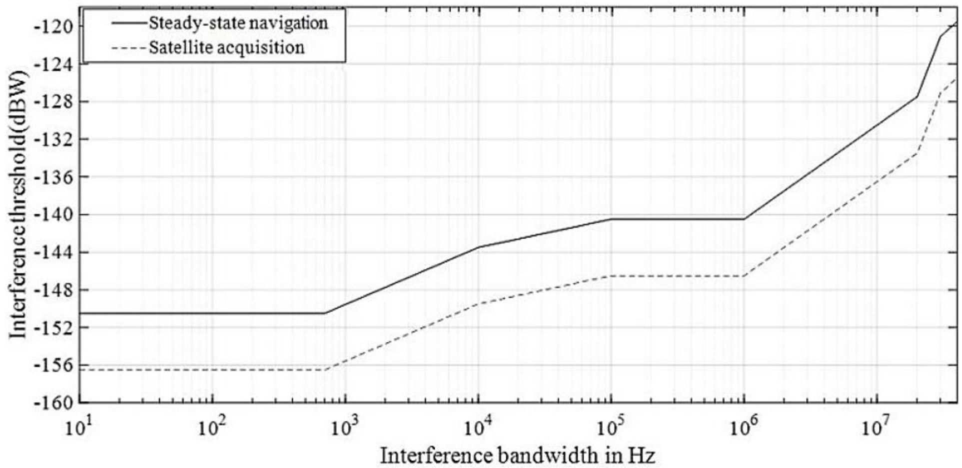

Figure FIG-08B. Interference thresholds versus bandwidth for BDS B1C receiver

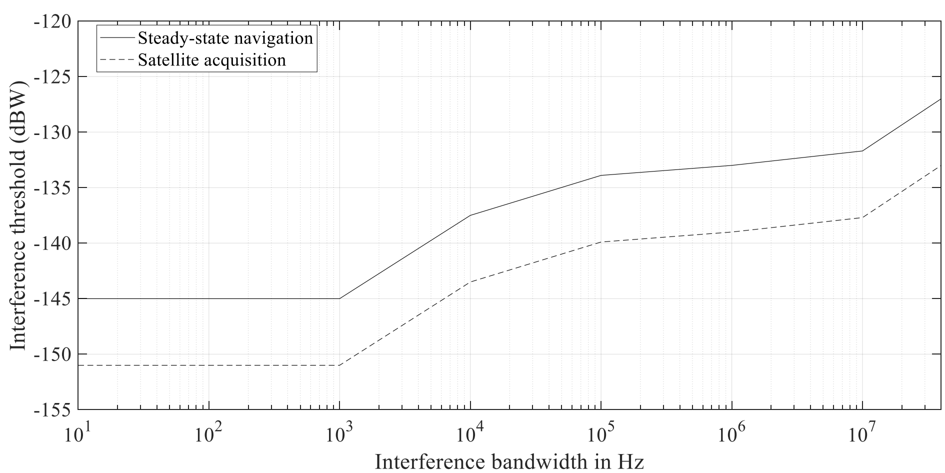

Figure FIG-08C. Interference thresholds versus bandwidth for BDS B2a receiver

ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

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3.5.6 *Determining GNSS availability*

Note.— Additional guidance material pertaining to reliability and availability of radio communications and navigation aids is contained in Attachment F.

3.5.6.1 The availability of GNSS is complicated by the movement of satellites relative to a coverage area under consideration and the potentially long time needed to restore a satellite in the event of a failure. Accurately measuring the availability would require many years to allow for a measurement period longer than the MTBF and repair times. The availability of GNSS should be determined through design, analysis and modelling, rather than measurement. The availability model should account for the ionospheric, tropospheric and receiver error models used by the receiver to verify integrity (e.g. HPL, LPL and VPL calculations). The availability specified in Chapter 3, 3.7.2.4, applies to the design availability.

3.5.6.2 The availability of ABAS, GBAS and SBAS must be evaluated by comparing the augmented performance to the operational requirements of Chapter 3, 3.7.2.4. The availability of ABAS, GBAS and SBAS does not directly relate to the core constellation service availability standards in Chapter 3. Availability analysis is based on the number of usable satellites from the core constellation(s) and the performance of the augmentation system(s). Information on the operational satellites/slots is given in the satellite/slot/constellation availability standards or guidance material for each core constellation.

~~*Note.— Additional guidance material pertaining to reliability and availability of radio communications and navigation aids is contained in Attachment F.*~~

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5. AIRCRAFT-BASED AUGMENTATION SYSTEM (ABAS)

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5.2 ABAS includes processing schemes that provide:

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d) accuracy aiding through filtering techniques and/or estimation of remaining errors in determined ranges.

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8. SIGNAL QUALITY MONITOR (SQM) DESIGN

8.1 The objective of the signal quality monitor (SQM) is to detect satellite signal anomalies in order to prevent aircraft receivers from using misleading information (MI). MI is an undetected aircraft pseudo-range differential error greater than the maximum error (MERR) that can be tolerated. These large pseudo-range errors are due to ~~C/A~~ code correlation peak distortion caused by satellite payload failures. If the reference receiver used to create the differential corrections and the aircraft receiver have different measurement mechanizations (i.e. receiver bandwidth and tracking loop correlator spacing), the signal distortion affects them differently. The SQM must protect the aircraft receiver in cases when mechanizations are not similar. SQM performance is further defined by the probability of detecting a satellite failure and the probability of incorrectly annunciating a satellite failure.

8.2 The signal effects that might cause a GBAS or SBAS to output MI can be categorized into three different effects on the correlation function as follows:

a) *Dead zones:* If the correlation function loses its peak, the receiver's discriminator function will include a flat spot or dead zone. If the reference receiver and aircraft receiver settle in different portions of this dead zone, MI can result.

b) *False peaks:* If the reference receiver and aircraft receiver lock to different peaks, MI could exist.

c) *Distortions:* If the correlation peak is misshapen, an aircraft that uses a correlator spacing other than the one used by the reference receivers may experience MI.

8.3 The threat model proposed for use in assessment of SQM has three parts that can create the three correlation peak pathologies listed above.

8.4 Threat Model A consists of the normal ~~C/A~~ code signal except that all the positive chips, and positive/negative sub-carrier chips for Galileo E1-C signal and BDS B1C_pilot signal, have a falling edge that leads or lags relative to the correct end-time for that chip. This threat model is associated with a failure in the navigation data unit (NDU), the digital partition of a ~~GPS or GLONASS~~ satellite. The occurrences of Threat Model A on GPS L1 C/A and on GPS L5 Q5 signals are independent events. If overlapping in time, the signs and sizes of leads and lags may be different on L1 C/A and L5 Q5 signals.

8.4.1 Threat Model A for GPS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in ~~fractions of a chip~~ microseconds. The range for this parameter is $-0.12 \leq \Delta \leq 0.12$ for the L1 C/A code signal. The range for this parameter is $-0.1 \leq \Delta \leq 0.1$ for the GPS L5 Q5 signal. Threat Model A for GLONASS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in ~~fractions of a chip~~ microseconds. The range for this parameter is ~~$-0.11 \leq \Delta \leq 0.11$~~ $-0.22 \leq \Delta \leq 0.22$ for GLONASS L1OF signal. The range for this parameter is $-0.1 \leq \Delta \leq 0.1$ for GLONASS L1OC signal and $-0.1 \leq \Delta \leq 0.1$ for GLONASS L3OC. Threat Model A for Galileo has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in microseconds. The range for this parameter is $-0.12 \leq \Delta \leq 0.12$ for Galileo E1-C signal. The range for this parameter is $-0.1 \leq \Delta \leq 0.1$ for Galileo E5a-Q signal. Threat Model A for BDS has a single parameter Δ, which is the lead ($\Delta < 0$) or lag ($\Delta > 0$) expressed in microseconds. The range for this parameter is $-0.05 \leq \Delta \leq 0.05$ for BDS B1C_pilot signal. The range for this parameter is $-0.05 \leq \Delta \leq 0.05$ for BDS B2a_pilot signal.

8.4.2 Within this range, threat Model A generates the dead zones described above. (Waveforms with lead need not be tested, because their correlation functions are simply advances of the correlation functions for lag; hence, the MI threat is identical.)

8.5 Threat Model B introduces amplitude modulation and models degradations in the analog section of the ~~GPS or GLONASS~~ core constellation satellite. More specifically, it consists of the output from a second order system when the nominal ~~C/A~~ code baseband signal is the input. Threat Model B assumes that the degraded satellite subsystem can be described as a linear system dominated by a pair of complex conjugate poles. These poles are located at $\sigma \pm j2\pi f_d$, where σ is the damping factor in 10^6 nepers/second and f_d is the resonant frequency with units of 10^6 cycles/second.

8.5.1 The unit step response of a second order system is given by:

$$e(t) = \begin{cases} 0 & t \leq 0 \\ 1 - \exp(-\sigma t)\left[\cos\omega_d t + \frac{\sigma}{\omega_d}\sin\omega_d t\right] & t \geq 0 \end{cases}$$

where $\omega_d = 2\pi f_d$.

8.5.2 Threat Model B for GPS corresponding to second order anomalies uses the following ranges for the parameters Δ, f_d and σ:

$\Delta = 0$; $4 \leq f_d \leq 17$; and $0.8 \leq \sigma \leq 8.8$.

The occurrence of Threat Model A on the GPS L1 C/A signal, the occurrence of Threat Model B on GPS L1 C/A signal, the occurrence of Threat Model A on the GPS L5 Q5 signal and the occurrence of Threat Model B on the GPS L5 Q5 signal are independent events. The parameters characterizing the leads, lags, ringing frequency f_d, and decay parameter σ are not constrained to be the same size or sign on GPS L1 C/A and GPS L5 Q5 signals.

Threat Model B for GLONASS corresponding to second order anomalies uses the following ranges for the parameters defined above:

L1OF signal: $\Delta = 0$; $10 \leq f_d \leq 20$; and $2 \leq \sigma \leq 8$.
L1OC signal: $\Delta = 0$; $0.1 \leq f_d \leq 14$; and $0.1 \leq \sigma \leq 24$.
L3OC signal: $\Delta = 0$; $0.1 \leq f_d \leq 8$; and $0.1 \leq \sigma \leq 15$.

Threat Model B for Galileo corresponding to second order anomalies uses the following ranges for the parameters defined above:

E1-C signal: $\Delta = 0$; $0.1 \leq f_d \leq 18$; and $0.1 \leq \sigma \leq 63$.
E5a-Q signal: $\Delta = 0$; $0.1 \leq f_d \leq 8$; and $0.1 \leq \sigma \leq 23$.

Threat Model B for BDS corresponding to second order anomalies uses the following ranges for the parameters defined above:

B1C_pilot signal: $\Delta = 0$; $1.5 \leq f_d \leq 18$; and $0.1 \leq \sigma \leq 20$.
B2a_pilot signal: $\Delta = 0$; $4 \leq f_d \leq 18$; and $0.1 \leq \sigma \leq 18$.

8.5.3 Within these parameter ranges, Threat Model B generates distortions of the correlation peak as well as false peaks.

8.6 Threat Model C introduces both lead/lag and amplitude modulation. Specifically, it consists of outputs from a second order system when the C/A code signal at the input suffers from lead or lag. This waveform is a combination of the two effects described above.

8.6.1 Threat Model C for GPS includes parameters Δ, fd and σ with the following ranges:

L1 signal: $-0.12\ \mu s \le \Delta \le 0.12\ \mu s$; $7.3 \le f_d \le 13$; and $0.8 \le \sigma \le 8.8$.
L5 signal: $-0.10\ \mu s \le \Delta \le 0.10\ \mu s$; $7.3 \le f_d \le 13$; and $0.8 \le \sigma \le 8.8$.

Threat Model C for GLONASS includes parameters Δ, f_d and σ with the following ranges:

L1OF signal: ~~$-0.11 \le \Delta \le 0.11$~~ $-0.22\ \mu s \le \Delta \le 0.22\ \mu s$; $10 \le f_d \le 20$; and $2 \le \sigma \le 8$.
L1OC signal: $-0.1\ \mu s \le \Delta \le 0.1\ \mu s$; $0.1 \le fd \le 14$; and $0.1 \le \sigma \le 24$.
L3OC signal: $-0.1\ \mu s \le \Delta \le 0.1\ \mu s$; $0.1 \le fd \le 8$; and $0.1 \le \sigma \le 15$.

Threat Model C for Galileo includes parameters Δ, f_d and σ with the following ranges:

E1-C signal: $-0.12\ \mu s \le \Delta \le 0.12\ \mu s$; $0.1 \le f_d \le 18$; and $0.1 \le \sigma \le 63$.
E5a-Q signal: $-0.1\ \mu s \le \Delta \le 0.1\ \mu s$; $0.1 \le f_d \le 8$; and $0.1 \le \sigma \le 23$.

Threat Model C for BDS includes parameters Δ, f_d and σ with the following ranges:

B1C_pilot signal: $-0.05 \le \Delta \le 0.05$; $1.5 \le f_d \le 18$; and $0.1 \le \sigma \le 20$.
B2a_pilot signal: $-0.05 \le \Delta \le 0.05$; $4 \le f_d \le 18$; and $0.1 \le \sigma \le 18$.

8.6.2 Within these parameter ranges, threat Model C generates dead zones, distortions of the correlation peak and false peaks.

8.7 Unlike ~~GPS and GLONASS~~ core constellation signals, the SBAS ranging signal is commissioned and controlled by the service provider. Moreover, the service provider also monitors the quality of the signal from the SBAS. To this end, the threat model will be specified and published by the service provider for each SBAS satellite. The SBAS SQM will be designed to protect all avionics that comply with Table D-12. Publication of the threat model is required for those cases where a service provider chooses to allow the SBAS L1 ranging signal from a neighbouring service provider to be used for precision approach by SBAS or GBAS. In these cases, the service provider will monitor the SBAS ranging signal from the neighbouring satellite.

8.8 In order to analyse the performance of a particular monitor design, the monitor limit must be defined and set to protect individual satellite pseudo-range error relative to the protection level, with an allocation of the ground subsystem integrity risk. The maximum tolerable error (denoted as MERR) for each ranging source *i* can be defined in GBAS, L1 SBAS and DFMC SBAS as:

$$MERR_{GBAS} = K_{ffmd}\sigma_{pr\_gnd,i} \text{ and}$$

$$MERR_{L1\ SBAS} = K_{V,PA}\sqrt{\sigma^2_{i,UDRE} + \min\{\sigma^2_{i,UIRE}\}}$$

$$MERR_{DFMC\ SBAS} = K_{V,PA}\sqrt{\sigma^2_{i,DFRE}}$$

for SBAS, and in particular for L1 SBAS APV and precision approach where min $\{\sigma^2_{i,UIRE}\}$ is the minimum possible value for any user., MERR is evaluated at the output of a fault-free user receiver and varies with satellite elevation angle and ground subsystem performance.

8.9 The SQM is designed to limit the worst differential error UDRE to values below the MERR in the case of a satellite anomaly. Typically, the SQM measures various correlation peak values and generates spacing and ratio metrics that characterize correlation peak distortion. Figure D-18 illustrates typical points at the top of a fault-free, unfiltered correlation peak.

8.9.1 A correlator pair is used for tracking. All other correlator values are measured with respect to this tracking pair.

8.9.2 Two types of test metrics are formed: early-minus-late metrics (D) that are indicative of tracking errors caused by peak distortion, and amplitude ratio metrics (R) that measure slope and are indicative of peak flatness or close-in, multiple peaks.

8.9.3 It is necessary that the SQM has a precorrelation bandwidth that is sufficiently wide to measure the narrow spacing metrics, so as not to cause significant peak distortion itself and not to mask the anomalies caused by the satellite failure. Typically, the SQM receiver must have a precorrelation bandwidth of at least 16 MHz for GPS L1 and at least 24 MHz for L5, and at least 15 MHz for GLONASS, at least 24 MHz for Galileo and at least 24 MHz for BDS.

8.9.4 The test metrics are smoothed using low-pass digital filters. The time constant of these filters are to be shorter than those used jointly (and standardized at 100 seconds) by the reference receivers for deriving differential corrections and by the aircraft receiver for smoothing pseudo-range measurements (using carrier smoothing) (and standardized at 100 seconds). The smooth metrics are then compared to thresholds. If any one of the thresholds is exceeded, an alarm is generated for that satellite.

8.9.5 The thresholds used to derive performance are defined as minimum detectable errors (MDEs) and minimum detectable ratios (MDRs). Fault-free false detection probability and missed detection probability are used to derive MDEs and MDRs. The noise in metrics (D) and (R), as denoted $\sigma_{D,test}$ and $\sigma_{R,test}$ below, is dominated by multipath errors. Note that the metric test can also have a mean value (µtest) caused by SQM receiver filter distortion. Threshold tests must also account for the mean values.

8.9.6 The MDE and MDR values used in the SQM performance simulations are calculated based on the following equations:

$$MDE = (K_{ffd} + K_{md})\ \sigma_{D,test} \text{ and}$$
$$MDR = (K_{ffd} + K_{md})\ \sigma_{R,test}$$

where

$K_{ffd} = 5.26$ is a typical fault-free detection multiplier representing a false detection probability of 1.5×10^{-7} per test. The false detection probability may be allocated to each metric used in the SQM depending on the number of metrics implemented;

$K_{md} = 3.09$ is a typical missed detection multiplier representing a missed detection probability of 10^{-3} per test. The allocation of the missed detection probability can be further optimised considering the probability of integrity risk induced by each distortion (given its differential bias) and the probability of integrity failure allocated to the signal distortion event;

$\sigma_{D,test}$ is the standard deviation of measured values of difference test metric D; and

$\sigma_{R,test}$ is the standard deviation of measured values of ratio test metric R.

8.9.7 If multiple independent SQM receivers are used to detect the failures, the sigma values can be reduced by the square root of the number of independent monitors.

8.9.8 A failure is declared if

$$| D,test - \mu_{D,test} | \geq MDE \text{ or}$$
$$| R,test - \mu_{R,test} | \geq MDR$$

for any of the tests performed, where $\mu_{X,test}$ is the mean value of the test X that accounts for fault-free SQM receiver filter distortion, as well as correlation peak distortion ~~peculiar to~~ associated with the specific ~~C/A~~ code ~~PRN~~. (~~Not all C/A c~~Code correlation peaks can have ~~the same~~ different slopes across different codes within the same code family. In a simulation environment, however, this ~~PRN~~ code distortion can be ignored, and a perfect correlation peak can be used, except for simulated filter distortion.)

8.10 The standard deviations of the test statistics, $\sigma_{D,test}$ and $\sigma_{R,test}$ can be determined via data collection on a multicorrelator receiver in the expected operating environment. The data collection receiver utilizes a single tracking pair of correlators and additional correlation function measurement points which are slaved to this tracking pair, as illustrated in Figure D-18 for GPS and GLONASS and in Figure FIG-09 for Galileo and BDS. Data is collected and smoothed for all available measurement points in order to compute the metrics. The standard deviation of these metrics define $\sigma_{D,test}$. It is also possible to compute these one sigma test statistics if a multipath model of the installation environment is available.

8.10.1 The resulting $\sigma_{D,test}$ is highly dependent on the multipath environment in which the data are collected. The deviation due to multipath can be an order of magnitude greater than that which would result from noise even at minimum carrier-to-noise level. This aspect illustrates the importance of the antenna design and siting criteria which are the primary factors in determining the level of multipath that will enter the receiver. Reducing multipath will significantly decrease the resulting MDEs and thus improve the SQM capabilities.

8.10.2 Mean values $\mu_{D,test}$ and $\mu_{R,test}$, on the other hand, are determined in a relatively error-free environment, such as through the use of ~~GPS and GLONASS~~ core constellation satellite signal simulator as input. These mean values model the nominal SQM receiver's filter distortion of the autocorrelation peak, including the effects of distortion due to adjacent minor autocorrelation peaks. The mean values can differ for the various PRNs based on these properties.

8.10.3 The presence of nominal signal deformation biases may cause the distribution of the monitor detectors to have non-zero mean. These biases can be observed by averaging measurements taken from a real-world data collection. Note that the nominal biases may depend on elevation and they typically change slowly over time. For example, nominal GPS deformations are leads and lags that are present in unfaulted conditions and thus may exist all the time. The nominal GPS deformation is in the range $-0.01\ \mu s \leq \Delta \leq +0.01\ \mu s$.

8.10.4 The SQM for SBAS is validated for the signal distortions defined by the GPS, GLONASS, Galileo and BDS TM-A/B/C threat space only for a vertical alert limit greater or equal to 35 m.

Editorial note.— Proposals to change this section need to bring additional validation material, including the sufficiency of the monitor form herein.

8.11 In order for the ground monitor to protect users against the different threat models described above, it is necessary to assume that aircraft receivers have specific characteristics. If no such constraints were assumed, the complexity of the ground monitor would be unnecessarily high. Evolution in the technology may lead to improved detection capability in the aircraft receiver and may alleviate the current constraints.

8.11.1 For double-delta correlators, the aircraft receiver tracks the strongest correlation peak over the full code sequence for every ranging source used in the navigation solution.

8.11.2 For double-delta correlators, the precorrelation filter rolls off by at least 30 dB per octave in the transition band. For GBAS receivers, the resulting attenuation in the stop band is required to be greater than or equal to 50 dB (relative to the peak gain in the pass band).

8.11.3 The following parameters are used to describe the tracking performance specific to each type of satellite:

a) the instantaneous correlator spacing is defined as the spacing between a particular set of early and late samples of the correlation function;

b) the average correlator spacing is defined as a one-second average of the instantaneous correlator spacing. The average applies over any one-second time frame;

c) the discriminator Δ is based upon an average of early-minus-late samples with spacings inside the specified range, or is of the type $\Delta = 2\Delta_{d1} - \Delta_{2d1}$, with both d_1 and $2d_1$ in the specified range. Either a coherent or non-coherent discriminator is used;

d) the differential group delay applies to the entire aircraft system prior to the correlator, including the antenna. The differential group delay is defined as:

$$\left| \frac{d\phi}{d\omega}(f_c) - \frac{d\phi}{d\omega}(f) \right|$$

where

f_c is the precorrelation band pass filter centre frequency;

f is any frequency within the 3dB bandwidth of the precorrelation filter;

ϕ is the combined phase response of precorrelation band pass filter and antenna; and

ω is equal to $2\pi f$.

8.11.4 For aircraft receivers supporting single-frequency L1 using early-late correlators and tracking GPS L1 C/A satellites signal, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-11, except as noted below.

8.11.4.1 For GBAS airborne equipment using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges defined in Table D-11, except that the region 1 minimum bandwidth will increase to 4 MHz and the average correlator spacing is reduced to an average of 0.21 chips or instantaneous of 0.235 chips.

8.11.4.2 For GBAS airborne equipment class D (GAEC D) receivers using early-late correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-11, regions 2, 3 or 4 only. In addition, in region 2 the range of average correlator spacing is 0.045 – 0.12 chips, and the instantaneous correlator spacing is 0.04 – 0.15 chips.

8.11.4.3 For SBAS airborne equipment using early-late correlators and tracking GPS L1 C/A satellites signal, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay (including the contribution of the antenna) are within the ranges of the first three regions defined in Table D-11 for L1 signal.

8.11.5 For aircraft receivers supporting single-frequency L1 using early-late correlators and tracking GLONASS satellites, the precorrelation bandwidth of the installation, the correlator spacing, and the differential group delay are within the ranges as defined in Table D-12.

8.11.5.1 For GBAS airborne equipment class D (GAEC D) aircraft receivers using early-late correlators and tracking GLONASS satellites, the precorrelation bandwidth of the installation, the correlator spacing, and the differential group delay are within the ranges as defined in Table D-12, regions 2 and 3 only. In addition, in region 2 the range of average correlator spacing is 0.05 – 0.1 chips, and the instantaneous correlator spacing is 0.045 – 0.11 chips.

8.11.6 For aircraft receivers supporting single-frequency L1 using double-delta correlators and tracking GPS L1 C/A satellites signal, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Tables D-13A and D-13B.

8.11.6.1 For GBAS airborne equipment class D (GAEC D) receivers using double-delta correlators and tracking GPS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-13, regions 2 and 3 only.

8.11.7 For aircraft receivers supporting single-frequency L1 and using the early-late or double-delta correlators and tracking SBAS L1 satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-14.

8.11.7.1 For GBAS airborne equipment class D (GAEC D) receivers using the early-late or double-delta correlators and tracking SBAS satellites, the precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table D-14, region 2 only. In addition, for GAEC D receivers using early-late correlators and tracking SBAS satellites, the average correlator spacing is 0.045 – 0.12 chips, and the instantaneous correlator spacing is 0.04 – 0.15 chips.

8.11.8 For aircraft receivers designed for DFMC SBAS, the L5 (or L3) signal tracking precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table TAB-09 using the early-late correlators and tracking the GPS, Galileo, GLONASS, BDS or SBAS L5 signals identified in Attachment B, section 3.5.11.1.

8.11.9 For aircraft receivers designed for DFMC SBAS, the L1 signal tracking precorrelation bandwidth of the installation, the correlator spacing and the differential group delay are within the ranges defined in Table TAB-10 using the early-late correlators and tracking the GPS, Galileo, GLONASS, BDS or SBAS L1 signals identified in Attachment B, section 3.5.11.1.

8.11.10 The instantaneous correlator spacing may be larger than the average correlator spacing range provided in Table TAB-09 and Table TAB-10 accounting for noise or jitter in the correlator spacing.

. . .

Table D-13A. GPS tracking constraints for GRAS and SBAS airborne receivers with double-delta correlators

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (X) (chips)	Instantaneous correlator spacing (chips)	Differential group delay
. . .	. . .	. . .	. . .	. . .
3	14 < BW ≤ (133.33 × X) + 2.667 MHz	0.07 – 0.24	0.06 – 0.26	≤ 150 ns

. . .

Table TAB-09. DFMC SBAS tracking constraints for early-late correlators tracking the L5, E5a or L3OC signals

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Differential group delay
1	12 < BW ≤ 24 MHz	0.9 – 1.1	≤ 150 ns

Table TAB-10. DFMC SBAS tracking constraints for early-late correlators tracking the L1, E1 or L1OC signals

Region	3 dB precorrelation bandwidth, BW	Average correlator spacing (chips)	Differential group delay
1	12 < BW ≤ 24 MHz	0.08 – 0.12	≤ 150 ns

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10. INTERFERENCE

10.1 Potential for interference

Satellite radio navigation systems such as GPS ~~and~~, GLONASS, Galileo and BDS feature relatively weak received signal power, meaning that an interference signal could cause loss of service. In order to maintain service, it will be necessary to ensure that the maximum interference levels specified in the SARPs are not exceeded.

10.2 In-band interference sources

A potential source of in-band harmful interference is Fixed Service operation in certain States. There is a primary allocation to the fixed service for point-to-point microwave links in certain States in the frequency band used by GPS ~~and~~, GLONASS, Galileo and BDS.

10.3 Out-of-band interference sources

Potential sources of out-of-band interference include harmonics and spurious emissions of aeronautical VHF and UHF transmitters. Out-of-band noise, discrete spurious products and intermodulation products from radio and TV broadcasts can also cause interference problems.

10.4 Aircraft generated sources

10.4.1 The potential for harmful interference to GPS ~~and~~, GLONASS, Galileo and BDS on an aircraft depends on the type of aircraft, its size and the transmitting equipment installed. The GNSS antenna location should take into account the possibility of on-board interference (mainly SATCOM).

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10.5 Integrity in the presence of interference

The requirement that ~~SBAS and GBAS~~ GNSS receivers do not output misleading information in the presence of interference is intended to prevent the output of misleading information under unintentional interference scenarios that could arise. It is not intended to specifically address intentional interference. While it is impossible to completely verify this requirement through testing, an acceptable means of compliance can be found in the appropriate receiver Minimum Operational Performance Standards published by RTCA and EUROCAE.

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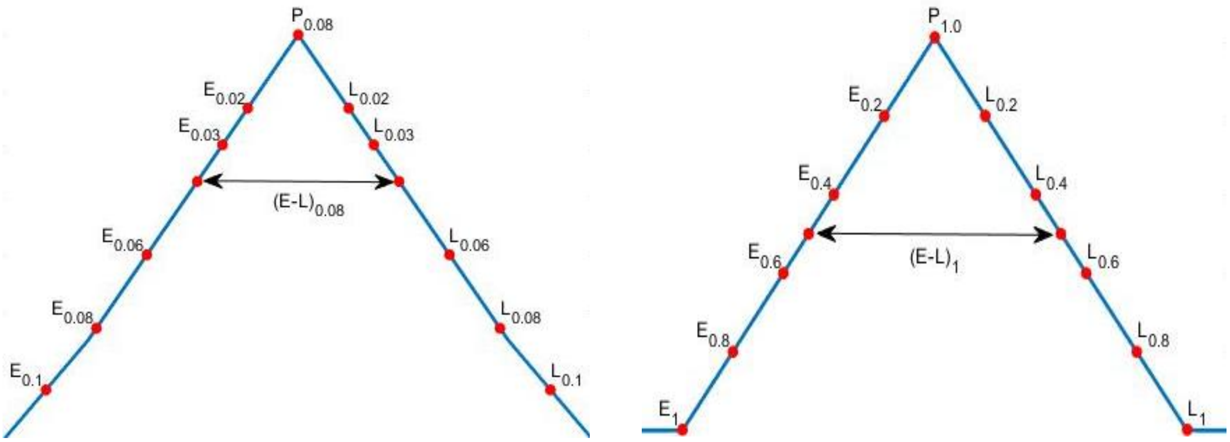

Figure FIG-09. Correlator outputs for Galileo E1-C or BDS B1C_pilot (left) and Galileo E5a-Q or BDS B2a_pilot (right)

Origin:	*Rationale*:
NSP/6	This proposal addresses Annex provisions that cover common aspects of all GNSS elements and need to be updated to reflect the introduction of DFMC GNSS. It includes amendments to the provisions for ABAS, aircraft receivers, resistance to interference, receiver antenna characteristics and signal quality monitor design, which in the Annex are mostly located after the provisions for individual GNSS elements. (Additional common aspects are covered in Initial Proposal 1.)

INITIAL PROPOSAL 8
Ground-based augmentation system (GBAS)

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

3. GNSS ELEMENTS

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

3.6.1 GENERAL

The GBAS shall consist of a ground subsystem and an aircraft subsystem. The GBAS ground subsystem shall provide data and corrections for the GNSS ranging signals over a digital VHF data broadcast to the aircraft subsystem. The GRAS ground subsystem shall consist of one or more GBAS ground subsystems.

Note 1.— Guidance material is provided in Attachment D, 7.1.

Note 2.— GBAS SARPs have not yet been updated to support dual-frequency multi-constellation (DFMC) use. These SARPs are applicable to GPS L1 C/A and GLONASS L1OF only. Throughout the GBAS SARPs (Appendix B, 3.6) and in the GBAS sections of Attachment D, the term GLONASS should be understood to refer to GLONASS L1OF signals and services only, and the term GPS should be understood to refer to GPS L1 C/A signals and services only.

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3.6.7.3.4 *Ionospheric gradient mitigation*

For FAST D ground subsystems, the probability of an error (|Er|) in the 30-second smoothed corrected pseudo-range at the landing threshold point (LTP) for every GAST D supported runway that: a) is caused by a spatial ionospheric delay gradient, b) is greater than the E_{IG} value computed from a broadcast Type 2 message, and c) is not detected and reflected in the broadcast Type 11 message within 1.5 seconds shall be less than 1×10^{-9} in any one landing. The FAST D ground subsystem shall limit the Type 2 broadcast parameters to ensure that the maximum E_{IG} at every LTP supporting GAST D operations shall not exceed 2.75 metres, except when operational requirements are demonstrated to permit it.

Note 1.— The total probability of an undetected delay gradient includes the prior probability of the gradient and the monitor(s) probability of missed detection.

Note 2.— Validation guidance for ionospheric gradient mitigation ~~this requirement~~ can be found in 7.5.6.1.8.

Note 3.— To broadcast Type 2 parameters such that E_{IG} exceeds 2.75 m for a specific LTP supporting GAST D operations, a tailored analysis will demonstrate that the resulting GAST D continuity and availability supports the intended operation. Guidance for assessing acceptability of E_{IG} exceeding 2.75 m can be found in 7.5.13.1.

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ATTACHMENT D. INFORMATION AND MATERIAL FOR GUIDANCE IN THE APPLICATION OF THE GNSS STANDARDS AND RECOMMENDED PRACTICES

. . .

7.5.6.1.6 *Requirements for FAST D ground subsystems to support mitigation of errors caused by ionospheric anomalies*. Although much of the responsibility for mitigation of ionospheric errors is allocated to the airborne segment, there is a requirement for FAST D ground subsystems that is necessary to support mitigation of such effects. Appendix B, 3.6.7.3.4 specifies that the ground subsystem is responsible for ensuring mitigation of ionospheric spatial delay gradients. The ground subsystem ensures that the value of the maximum corrected pseudo-range error (E_{IG}) computed from the Type 2 data does not exceed 2.75 metres at all LTPs associated with runways that support GAST D procedures. One option available to the manufacturer is to restrict the distance between the GBAS reference point and the LTP. It may, in some cases, be desirable to allow GAST D service at LTPs where E_{IG} exceeds 2.75 m. This could have an impact on the availability of the GAST D service for that particular approach. The service provider should then evaluate whether the expected performance is adequate for the intended service. See 7.5.13.1 for guidance on how availability assessment can be done.

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7.5.10.1 The monitor design (for example, its smallest detectable error) is to be based upon the integrity risk requirements and the failure model the monitor is intended to protect against. A bound on the GPS ephemeris failure rate can be determined from the reliability requirements defined in Chapter 3, 3.1.7.3.1.~~3~~4, since such an ephemeris error would constitute a major service failure.

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7.5.13 *Ground subsystem requirements and airworthiness performance assessment.* Airworthiness certification of autoland systems, for use in Category II/III operations, requires an assessment of landing performance under fault-free and faulted conditions. More information, describing how the technical standards can be used to support an assessment, may be found in RTCA document DO-253D, "Minimum Operational Performance Requirements for Airborne Equipment using the Local Area Augmentation System", Appendix J".

7.5.13.1 *Estimating availability.* It may, in some cases, be necessary to estimate the expected availability for an airport or a runway end. Examples are cases where the mask angles are high or E_{IG} exceeds 2.75 m. When the maximum value of 2.75 m is established for the E_{IG}, this is based on availability simulations where conservative assumptions are used for the constellation and aircraft performance, and the target is to provide the GAST D service with an availability of 0.999 for Category III airports around the world. Therefore, the E_{IG} limit of 2.75 m guarantees an availability that is higher than 0.999 under the worst-case assumptions, when only the residual ionospheric component is considered. However, for many locations, the availability may still be within this limit for E_{IG} > 2.75 m. Also, Chapter 3, Table 3.7.2.4-1 specifies a range of availability requirements, and the service provider must assess which availability is needed for the operation in question. In case GAST D service is provided to an LTP where E_{IG} exceeds 2.75 m, no assumptions can be made on availability, and the service provider is then responsible for estimating the availability according to the guidance outlined below, making assumptions on airborne performance. The maximum allowable undetected airborne error in the position domain (maxEv, maxE_L) as derived from the touchdown airworthiness requirements, can be assumed to be 10 m or higher.

7.5.13.2 In general, availability at a given approach can be estimated by taking into account the ground station parameters transmitted under normal conditions, to compute airborne VEB/LEB and VPL/LPL and to compare against VALs/LALs for a particular approach. The result of the airborne geometry screening is a separate component of the availability. For cases where E_{IG} exceeds 2.75 m, it is sufficient to consider the availability resulting from airborne geometry screening, which will drive availability rather than protection levels.

7.5.13.3 At a minimum, the duration of the simulation must consider all constellation states (24 hours for GPS). When taking additional probabilistic considerations into account, e.g. scintillation probability, longer simulation durations may be required.

7.5.13.4 VPL/LPL should be compared against VAL/LAL at 200 ft (or at the threshold if that is further away from the GBAS reference point).

7.5.13.5 VEB/LEB should be compared against VAL/LAL at 23 NM or wherever the approach is intended to start.

7.5.13.6 The constellation to be used is the standard expandable (27 SV) constellation, as defined in the *GPS Standard Positioning Service (SPS) Performance Standard, Fourth Edition* with N-1 and N-2 state probabilities as given in Table D-XX.

7.5.13.7 If the availability requirement is met under these conditions, no further analysis is required. If additional analysis is needed, a less conservative constellation can be used, e.g. a contemporary Yuma almanac. The same constellation state probabilities may be used, or, if possible, probabilities applicable to that constellation.

Table D-XX. GPS constellation state probabilities

GPS constellation state	**N satellites operating**	**N-1**	**N-2**	**N-3**	**N-4**
Probability	0.95	0.035	0.015	0	0

7.5.13.8 The ground station parameters are those transmitted by the particular ground subsystem.

7.5.13.9 The assumptions for airborne parameters are:

- AAD B;
- aircraft speed: 160 kts;
- σ_{divg} : 0 (assumes smoothing filter steady state);
- σ_{noise} : 0.15 (worst-case within AAD B);
- $MaxE_{v,}$ $MaxE_L$: 10 m;
- $MaxS_{vert} = MaxE_{v\,/}\, E_R$;
- $MaxS_{Lat} = MaxE_{L\,/}\, E_R$;
- $MaxS_{vert2} = MaxE_{v\,/}$ max (E_{IG});
- $MaxS_{Lat2} = MaxE_{L\,/}$ max (E_{IG});
- E_R is the maximum undetected pseudo-range error for the GAST D approach, either 1.6 m or EIG for the approach, whichever is larger; and
- the airborne receiver is capable of simultaneously tracking and continuously decoding the associated navigation data for at least 12 ranging sources.

Origin:	*Rationale*:
NSP/6	This proposal is intended to address potential restrictions on the use of a single GBAS ground station to support multiple runways that could be caused by the current limit on E_{IG} (2.75 m). E_{IG} is proportional to the distance between the GBAS ground station and the runway threshold(s) served by that station. Thus, setting a limit on E_{IG} implicitly sets a limit on the maximum distance allowed between the ground station and the threshold(s). This distance limit constrains the siting of the station and imposes significant restrictions on the use of a single GBAS station to support multiple runways. Relaxing the E_{IG} limit can alleviate the restrictions without any impact on safety, as system integrity is not affected, but could decrease availability of service under certain conditions. Accordingly, the proposal maintains the original limit as a general provision, but allows deviations for airports in which availability remains acceptable if the limit is increased. The proposal also contains guidance material on availability estimation to assist the availability trade-off analysis.

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ATTACHMENT C to State letter AN 7/62.1.4-21/41

RESPONSE FORM TO BE COMPLETED AND RETURNED TO ICAO TOGETHER WITH ANY COMMENTS YOU MAY HAVE ON THE PROPOSED AMENDMENT

To: The Secretary General
International Civil Aviation Organization
999 Robert-Bourassa Boulevard
Montréal, Québec
Canada, H3C 5H7

(State) ____

Please make a checkmark (✓) against one option for each amendment. If you choose options "agreement with comments" or "disagreement with comments", **please provide your comments on separate sheets**.

	Agreement without comments	*Agreement with comments**	*Disagreement without comments*	*Disagreement with comments*	*No position*
Amendment to Annex 10 — *Aeronautical Telecommunications*, Volume I — *Radio Navigation Aids* (Attachment B refers)					

*"Agreement with comments" indicates that your State or organization agrees with the intent and overall thrust of the amendment proposal; the comments themselves may include, as necessary, your reservations concerning certain parts of the proposal and/or offer an alternative proposal in this regard.

Signature: ________________________________ Date: ____________________________________

— END —