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DFMC SBAS SARPs Sub Group (DS2)

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DFMC SBAS SARPs - PART A VERSION 2.2

SUMMARY

This paper contains proposed SARPs amendments to introduce DFMC SBAS within chapter 3.7.

Part A version 2.2 with Part B version 2.0 constitute the technical baseline endorsed during NSP/5.

1. INTRODUCTION

1.1 This paper contains proposed SARPs amendments to introduce DFMC SBAS within chapter 3.7.

1.2 This version was developed and endorsed during NSP/5 on 15 November 2018.

2. PROPOSED AMENDMENTS

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:

~~Text to be deleted is shown with a line through it.~~	text to be deleted
New text to be inserted is highlighted with grey shading.	new text to be inserted
~~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

Yellow shading refers to sections to be developed in SARPs Annex 10 for core constellations.

NAVIGATION AIDS

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

3.7.1 Definitions

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

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

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

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

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

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.

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

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

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

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

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

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

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

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

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

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

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

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

3.7.2 General

3.7.2.1 Functions

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

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

3.7.2.2 GNSS elements

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

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

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

c) Galileo that provides an open service (OS) as defined in 3.7.3.x;

d) BDS that provides an open service (OS) as defined in 3.7.3.y;

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

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

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

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

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

3.7.2.3 Space and time reference

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

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

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

3.7.2.4 Signal-in-space performance

3.7.2.4.1 The combination of GNSS elements and a fault-free GNSS user receiver shall meet the signal-in-space requirements defined in Table 3.7.2.4-1 (located at the end of section 3.7).

Note 1.— The concept of a fault-free user receiver is applied only as a means of defining the performance of combinations of different GNSS elements. The fault-free receiver is assumed to be a receiver with nominal accuracy and time-to-alert performance. Such a receiver is assumed to have no failures that affect the integrity, availability and continuity performance.

Note 2.— For GBAS approach service (as defined in Attachment D, 7.1.2.1) intended to support approach and landing operations using Category III minima, performance requirements are defined that apply in addition to the signal-in-space requirements defined in Table 3.7.2.4.-1.

3.7.3

3.7.3.1

3.7.3.2

3.7.3.3

3.7.3.4 *Satellite-based augmentation system (SBAS)*

Note.— All SBAS have to fulfil the requirements introduced in section 3.7.3.4 and Appendix B section 3.5 except when a specific condition is mentioned in the requirement such as the provision of optional functions.

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

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

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

Note. — For L1 SBAS, message types 27 or 28 can be used to comply with the integrity requirements in the coverage area, additional g~~G~~uidance on the rationale and interpretation of this requirement is provided in Attachment D, section 3.3.

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 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) DFMC SBAS ranging: provide an additional ionosphere-free ~~pseudo-range~~ ranging signal (using SBAS L1 and L5) (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).

Note 1—For single frequency users, if the functions (b) and (c) in 3.7.3.4.2 are provided, SBAS in combination with core satellite constellation(s) can support departure, en-route, terminal and non-precision approach operations, and if the 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 the function (f) is provided, SBAS in combination with core satellite constellation(s) can support departure, en-route, terminal, non-precision approach operations, and approach operations including Category I.

Note 3—In order to provide function (e) in 3.7.3.4.2, 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 section 3.5.15.1.1.2.

3.7.3.4.3~~*3.7.3.4.2.1*~~ *Ranging:* When SBAS is providing a ranging service then the following sub-paragraphs shall apply:

3.7.3.4.3.1 ~~3.7.3.4.2.1.1~~ Excluding atmospheric effects, the range error for the ranging signal from SBAS satellites shall not exceed 25 m (82 ft) (95 per cent).

3.7.3.4.3.2 ~~3.7.3.4.2.1.2~~ 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 ~~3.7.3.4.2.1.3~~ The probability of unscheduled outages of the ranging function from an SBAS satellite in any hour shall not exceed 10^{-3}.

3.7.3.4.3.4 3.7.3.4.2.1.4 The range rate error shall not exceed 2 m (6.6 ft) per second.

3.7.3.4.3.5 3.7.3.4.2.1.5 The range acceleration error shall not exceed 0.019 m (0.06 ft) per second-squared.

3.7.3.4.4 *3.7.3.4.3* *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. such as APV-I, and Category-I, etc.).

Note 2.— The coverage area is that area within which the SBAS broadcast can be received (i.e. that is 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 3.7.3.4.4 *RF characteristics for the L1 SBAS signal.*

Note.— Detailed RF characteristics are specified in Appendix B, 3.5.2 for L1

3.7.3.4.5.1 *3.7.3.4.4.1L1 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 3.7.3.4.4.2 *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.

3.7.3.4.5.3 3.7.3.4.4.3 *L1 SBAS satellite signal power level.*

3.7.3.4.5.3.1 3.7.3.4.4.3.1 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 3.7.3.4.4.3.2 Each SBAS satellite 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 satellite (GEO) 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-88, 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 3.7.3.4.4.4 *Polarization.* The broadcast signal on L1 shall be right-hand circularly polarized.

3.7.3.4.5.5 3.7.3.4.4.5 *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 L5 SBAS 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 to 24 MHz

3.7.3.4.6.3 *L5 Signal power level.* Each DFMC SBAS satellite shall comply with the following additional requirements:

a) The DFMC SBAS geostationary and non-geostationary satellite shall broadcast additional 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 RHCP antenna located near the ground shall not exceed –150.5 dBW.

d) The ellipticity on L5 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 centered 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 Modulo-2 addition of the navigation message at a rate of 500 symbols per second and the 10 230 bit pseudo-random noise code. The resulting code shall then be bi-binary encoded with a code synchronised with the code epoch period and shall then be BPSK-modulated onto the carrier at a rate of 10.23 megachips per second.

Note.— Details to the L5 modulation are specified in Appendix B, 3.5.9 for L5.

3.7.3.4.7 ~~*3.7.3.4.5*~~*Timing*

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

3.7.3.4.7.2 *SBAS network time (SNT) for DFMC SBAS.* The difference between the 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 50 nanoseconds.

3.7.3.4.8 ~~*3.7.3.4.6*~~ *L1 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 *L5 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;

f) time transfer to UTC (optional); and

Note.— Structure and contents of data are specified in Appendix B, 3.5.10 and 3.5.11, respectively.

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