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SECRETARIAT: United Kingdom		SECRETARY: Mr Kim Fisher	
OF INTEREST TO THE FOLLOWING COMMITTEES:		PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.	
FUNCTIONS CONCERNED:			
☐ EMC	☐ ENVIRONMENT	☐ QUALITY ASSURANCE	☐ SAFETY
☐ SUBMITTED FOR CENELEC PARALLEL VOTING		☒ NOT SUBMITTED FOR CENELEC PARALLEL VOTING	

This document is still under study and subject to change. It should not be used for reference purposes.

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TITLE:

Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) – Part 7: Satellite Based Augmentation System (SBAS) L1 – Receiver Equipment – Performance standards, methods of testing and required test results

PROPOSED STABILITY DATE: 2026

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MARITIME NAVIGATION AND RADIOCOMMUNICATION EQUIPMENT AND SYSTEMS – GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS) –

Part 7: Satellite Based Augmentation System (SBAS) L1 – Receiver equipment – Performance standards, methods of testing and required test results

FOREWORD

IEC 61108-7 has been prepared by IEC technical committee 80: Maritime navigation and radiocommunication equipment and systems. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
80/XXXX/FDIS	80/XXXX/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

Satellite Based Augmentation System (SBAS) is designed to augment Global Navigation Satellite System (GNSS) by broadcasting additional signals from geostationary (GEO) satellites. The basic scheme is to use a set of ground monitoring stations (at precisely surveyed locations) to receive GNSS signals that are processed and transmitted to the master station(s) which formulates the correction messages applicable to users within the service area (i.e. ionospheric errors, satellite position/clock errors, etc.). These corrections are then transmitted to navigation payloads via uplink stations on GEO satellites. The GEO satellites then transmit these corrections in a GNSS-like signal across the service area. An integrity message is also broadcasted enabling receivers to remove errors in the GNSS signal for increased position accuracy and integrity. Users are notified within a few seconds of information that could lead to position error.

SBAS are civil aviation safety-critical system and are designed according to an international standard (SARPs:2020). So far, SBAS have already been commissioned by the US (Wide Area Augmentation System – WAAS), Europe (European Geostationary Navigation Overlay Service - EGNOS), Japan (Michibiki Satellite Augmentation System – MSAS) and India (GPS Aided GEO Augmented Navigation – GAGAN). At September 2022, analogous systems are under commissioning or development in other regions of the world such as BeiDou Satellite Based Augmentation System – BDSBAS in China, System of Differential Correction and Monitoring – SDCM in Russia, Korea Augmentation Satellite System – KASS in Republic of Korea, Southern Positioning Augmentation System – SouthPAN in Australia and New Zealand, Augmented Navigation for Africa - ANGA and the Solución de Aumentación para Caribe, Centro y Sudamérica – SACCSA in South/Central America and the Caribbean.

The maritime community is interested in using SBAS for ocean waters, coastal waters and harbour entrances/approaches in order to fulfil the agreed international operational performance requirements (IMO Resolution A.1046(27)), especially where there is no other augmentation service available (i.e. DGPS/DGLONASS) or in poorly covered environments. Besides, when Ground Based Augmentation Systems (GBAS) are available, SBAS could become either the primary augmentation system or could act as a back-up. SBAS aims at providing satellite clock/ephemeris corrections, ionospheric corrections and integrity information to GNSS signals that meet maritime requirements, enhanced accuracy and integrity information.

IMO MSC.401(95) and IEC 61108-4 (Shipborne DGPS and DGLONASS maritime radio beacon receiver equipment) allow the use of different augmentation signals in shipborne receivers but there is neither an IMO or IEC standard on how to process and implement SBAS signals in shipborne receivers. One of the operational and functional requirements (Module B) of IMO Resolution MSC.401(95) is that the equipment should have the facilities to process augmentation data in accordance with the appropriate methods, e.g. Recommendation ITU-R M.823, RTCM 10410, or other relevant standards, already existing or still to be developed in particular for Satellite Based Augmentation System (SBAS) adoption. This IEC 61108-7 provides the requested standard for SBAS L1 augmenting GPS L1.

Most of recent maritime GNSS receiver models are SBAS compatible but present important differences in their performance since they are not certified according to any specific test standard.

As highlighted in the IALA Guidelines G-1152 on SBAS Service, in order to ensure a safe use of SBAS by all shipborne receivers, a test standard for SBAS receiver should be published.

IEC 61108 is a series of IEC standards for "Maritime navigation and radio-communication equipment and systems - Global navigation satellite systems (GNSS)". IEC has published International Standards for the following GNSS systems: IEC 61108-1 for GPS, IEC 61108-2 for GLONASS, IEC 61108-3 for Galileo, IEC 61108-5 for BDS and IEC 61108-6 for IRNSS. In addition, IEC has published International Standard IEC 61108-4 for DGPS and DGLONASS which are Differential Global Navigation Satellite System (DGNSS) enhancing the primary GNSS constellations (GPS and GLONASS).

This new IEC 61108-7 includes the minimum performances for the shipborne receivers, using SBAS L1 signals augmenting GPS L1, in order to be compliant with the IMO Resolution A.1046(27) operational requirements for ocean waters, coastal waters and harbour entrances/approaches, along with the methods of testing and required test results.

Satellite Based Augmentation Systems (SBAS) are available in several regions worldwide to augment GPS L1 frequency by broadcasting additional SBAS L1 signals:

- SBAS are designed according to the same international standard (SARPs:2020).
- GPS L1 signal specification is presented in the GPS Interference Specification (IS-GPS-200).

A description of the GPS Standard Positioning Service Performance Standard (GPS-SPS-PS) is available at https://www.gps.gov.

NOTE A standard including dual-frequency multi-constellation (DFMC) SBAS services will be considered when appropriate.

MARITIME NAVIGATION AND RADIOCOMMUNICATION EQUIPMENT AND SYSTEMS – GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS) –

Part 7: Satellite Based Augmentation System (SBAS) L1 – Receiver equipment – Performance standards, methods of testing and required test results

1 Scope

This part of IEC 61108 specifies the minimum performance standards, methods of testing and required test results for Satellite Based Augmentation System (SBAS) shipborne receiver equipment, which uses L1 signals from GPS and Satellite Based Augmentation System (SBAS) in order to improve the estimated GPS position.

This document addresses the use of SBAS L1 to provide augmentation to the GPS shipborne receiver (IMO Resolution MSC.112(73)). This document includes the minimum performances for SBAS L1 maritime receivers to be obtained by the receiver equipment under coverage of SBAS service in order to be compliant with the IMO Resolution A.1046(27) describing operational requirements for ocean waters, coastal waters and harbour entrances/approaches.

2 Normative references

Reference documents listed below are cited in this document where some or all their content constitutes a requirement. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60721-3-6:1987; *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Ship environment.*

IEC 60945; *Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results.*

IEC 61108-1: 2003; *Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS) – Part 1: Global positioning system (GPS) – Receiver equipment – Performance standards, methods of testing and required test results*

IEC 61162-1: *Maritime navigation and radiocommunication equipment and systems - Digital interfaces - Part 1: Single talker and multiple listeners*

IEC 61162-2; *Maritime navigation and radiocommunication equipment and systems - Digital interfaces - Part 2: Single talker and multiple listeners, high-speed transmission*

IEC 61162-450*, Maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 450: Multiple talkers and multiple listeners – Ethernet connection*

IEC 62923-1: *Maritime navigation and radiocommunication equipment and systems – Bridge alert management – Part 1: Operational and performance requirements, methods of testing and required results.*

IEC 62923-2: *Maritime navigation and radiocommunication equipment and systems – Bridge alert management – Part 2: Alert and cluster identifiers and other additional features.*

IEC 62288; *Maritime navigation and radiocommunication equipment and systems – Presentation of navigation-related information on shipborne navigational displays – General requirements – Methods of testing and required test results*

IMO Resolution A.1046(27) Worldwide Radionavigation System, 30 November 2011.

RTCA DO-229 Revision F:2020, *Minimum Operational Performance Standards (MOPS) for Global Positioning System/Satellite-Based Augmentation System Airborne Equipment.*

ICAO *Standards and Recommended Practices (*SARPs*) Annex10 Volume I Amendment 92 (Radio Navigation Aids):*2020

3 Terms, definitions and abbreviations

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions

3.1.1
accuracy
degree of conformance between the estimated or measured parameter of a craft at a given time and its true parameter at that time

Note 1 to entry: Parameters in this context may be position coordinates, velocity, time, angle, etc.

Note 2 to entry: In particular, relative accuracy is the accuracy with which a user can determine position relative to that of another user of the same navigation system at the same time.

[SOURCE: IMO Res A.915(22)]

3.1.2
alert limit

maximum allowable error in the measured position – during integrity monitoring – before an alarm is triggered.

Note 1 to entry: This definition corresponds with HAL within the document.

[SOURCE: IMO Res A.915(22)]

3.1.3
augmentation
any technique of providing enhancement to the GNSS in order to provide improved navigation performance to the user

Note 1 to entry: Satellite Based Augmentation System (SBAS) is a system providing additional satellite signals in order to enhance the performance of the GNSS service.

Note 2 to entry: Differential Global Navigation Satellite System (DGNSS) is a system providing additional signals from a ground-based station in order to enhance the performance of the GNSS service.

[SOURCE: IMO Res A.915(22)]

3.1.4
availability
percentage of time that an aid, or system of aids, is performing a required function under stated conditions. The non-availability can be caused by scheduled and/or unscheduled interruptions

Note 1 to entry: Signal availability is the availability of a radio signal in a specified coverage area.

Note 2 to entry: System availability is the availability of a system to a user, including signal availability and the performance of the user's receiver.

[SOURCE: IMO Res A.915(22)]

3.1.5
horizontal accuracy 95%
95 percentile of the Horizontal Position Error (HPE) distribution, where HPE is the 2D radial error of the instantaneous measured position with respect to the true instantaneous position.

Note 1 to entry: This definition corresponds with position error (percentile 95%) within the document.

3.1.6
horizontal protection level
radius of a circle in the horizontal plane with its centre being at the true position, which specifies the region assured to contain the indicated horizontal position. It is the horizontal region for which the missed alert requirement can be met.

3.1.7
integrity
ability to provide users with warnings within a specified time when the system should not be used for navigation and the horizontal accuracy is not within the selected accuracy level specified in 4.3.10.1.

3.1.8
integrity monitoring
process of determining whether the system performance (or individual observations) allow use for navigation purposes.

NOTE 1 to entry: Overall GNSS system integrity is described by three parameters: the threshold value or alert limit, the time to alarm and the integrity risk.

NOTE 2 to entry: The output of integrity monitoring is that individual (erroneous) observations or the overall GNSS system cannot be used for navigation.

NOTE 3 to entry: Integrity risk is the probability that a user will experience a position error larger than the threshold value without an alarm being raised within the specified time to alarm at any instant of time at any location in the coverage area.

3.1.9
SBAS position
position computed by a GNSS shipborne receiver equipment using GNSS satellite constellation(s) augmented by SBAS

3.1.10
SBAS L1 receiver equipment
all the components and units necessary for the system to properly perform its intended functions, which includes the use case when a shipborne receiver provides a position using GPS satellite constellation augmented by SBAS L1

NOTE 1 to entry: When the same GNSS shipborne receiver equipment provides a PVT solution not augmented, this standard is not applicable.

3.2 Abbreviated terms

BAM	Bridge Alert Management
BDS	BeiDou Navigation Satellite System
C/A	Coarse/Acquisition
COG	Course Over Ground
DGPS	Differential GPS
EGNOS	European Geostationary Navigation Overlay Service
EUT	Equipment Under Test
Galileo	European global navigation satellite system
GBAS	Ground Based Augmentation Systems
GEO	GEOstationary satellite
GIVEI	Grid Ionospheric Vertical Error Indicator
GNSS	Global Navigation Satellite System
GLONASS	Global'naya Navigatsionnaya Sputnikovaya Sistema
GPS	Global Positioning System

HAL	Horizontal Alert Limit
HDOP	Horizontal Dilution of Precision
HPL	Horizontal Protection Level
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IGP	Ionospheric Grid Point
IMO	International Maritime Organization
IODF	Issue of Data Fast corrections
IODI	Issue of Data IGP Mask
IODP	Issue of Data PRN Mask
ITU-R	International Telecommunication Union-Radiocommunication
L1	GPS frequency 1 575,42 MHz
MKD	Minimum Keyboard and Display
MT	Message Type
NavIC(IRNSS)	Navigation with Indian constellation
PDOP	Position Dilution of Precision
PNT	Position, Navigation and Timing
PRN	Pseudo Random Noise
PVT	Position Velocity Time
QZSS	Quasi-Zenith Satellite System
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
RTCM	Radio Technical Commission for Maritime Services
SBAS	Satellite Based Augmentation System
SIS	Signal in Space
SNR	Signal-to-Noise Ratio
SOG	Speed Over Ground
SPS	Standard Positioning Service
UDRE	User Differential Range Error
UDREI	User Differential Range Error Indicator
UTC	Coordinated Universal Time

4 Minimum GNSS and SBAS performance standard

4.1 General

This document contains the basic minimum performance standard of SBAS L1 receiver equipment for navigational PVT solution.

SBAS is designed to provide satellite clock, ephemeris and ionospheric corrections and integrity information to the GNSS signals, obtaining enhanced accuracy and integrity information. This document covers the SBAS L1 services augmenting GPS L1 signals.

NOTE 1 SBAS is referenced as an augmentation system in MSC.401(95) and its amendment MSC.432(98).

The SBAS L1 receiver equipment shall comply with GPS receiver equipment IEC 61108-1:2003 operating on the L1 signal and C/A code.

NOTE 2 IEC 61108-1:2003 covers the basic requirements of position fixing for navigation purposes only and does not cover other computational facilities which may be provided in the equipment. Other computational activity, input/output activity or extra display functions if provided do not degrade the performance of the equipment below the minimum required performance.

NOTE 3 An SBAS L1 receiver equipment operating without SBAS augmentation is able to provide standard PVT solution for a GNSS system.

4.2 SBAS L1 receiver equipment

(See 6.10.1)

4.2.1 Minimum facilities

The SBAS L1 receiver equipment shall include the following minimum facilities:

a) antenna capable of receiving GPS L1 and SBAS L1 signals;
b) receiver and processor capable of processing GPS L1 and SBAS L1 signals to support SBAS position;
c) means of accessing the computed PVT information;
d) data control and interface;
e) position display and, if required, other forms of output;
f) SBAS indicator when SBAS augmentation is applied in the PVT solution;
g) receiver correlator and front-end characteristics (i.e. 3dB pre-correlation bandwidth, average correlator spacing, instantaneous correlator spacing and equipment differential group delay) as specified in RTCA DO-229:2020 sec. 2.1.4.5.1.; and
h) alert management

If SBAS forms part of an approved Integrated Navigation System (INS), requirements of facilities c) d) e), f) and h) may be provided within the INS.

If SBAS forms part of an approved multi-system PNT, requirements of facilities c) d) e) and f) may be provided within the multi-system PNT.

4.2.2 Configuration

(See 6.10.2)

The SBAS L1 receiver equipment shall provide the facility for the user to enable or disable the SBAS usage to compute the PVT solution.

Besides the automatic capability of the SBAS tracking signals, it is recommended that the SBAS L1 receiver equipment allows the user to manually configure the service provider to be used.

NOTE This optional capability is specifically useful in overlapping areas.

In addition, the following configuration shall be available in the SBAS L1 receiver equipment:

a) automatic mode: When DGPS and SBAS L1 augmentation signals are both available in the receiver, SBAS L1 receiver equipment shall prioritize the use of DGPS corrections over SBAS L1 to compute the PVT solution (DGPS>SBAS).
b) manual mode: SBAS L1 receiver equipment shall provide the facility for the user to select the preferable augmentation signal to be used in the PVT solution, including as options at least DGPS and SBAS L1.

4.2.3 Quality assurance

The equipment shall be designed, produced and documented by manufacturers complying with approved quality systems as applicable.

4.3 Performance standards for SBAS L1 receiver equipment

4.3.1 General

The SBAS L1 receiver equipment shall operate on the GPS L1 C/A signal meeting the requirements of IEC 61108-1.

The SBAS L1 receiver equipment shall operate on the SBAS L1 signal as specified in this document.

The equipment shall have the facilities to process SBAS augmentation data in accordance with the procedure shown in Annex A.

4.3.2 Equipment output

(See 6.10.3 and 6.10.4)

The SBAS L1 receiver equipment shall provide latitude and longitude position information in degrees, minutes and thousandths of minutes referenced to the World Geodetic System (WGS-84) coordinate system, as well as provide time referenced to Coordinated Universal Time (UTC).

The SBAS L1 receiver equipment shall be provided with at least two outputs from which position information can be supplied to other equipment. The physical interface shall be based on IEC 61162-1 or IEC 61162-2 or IEC 61162-450.

When SBAS information is used for positioning reporting purposes, the sentences in Table 1 shall be available in any combination. When SBAS information is not used, the sentences listed in Table 1 shall operate as specified in related equipment standards for operation without SBAS.

Table 1 – Output sentences defined for positioning purposes

Mnemonic	Description	Considerations for SBAS navigation position
GBS[b]	GNSS satellite fault detection	If SBAS satellites are used for ranging in navigation position: **SBAS satellite ID**: The offset from SBAS SV ID to SBAS PRN number is 87.
GNS[b]	GNSS fix data	If SBAS information is used for navigation position: **Navigational status indicator:** S, C, U or V, corresponding to Safe, Caution, Unsafe or Navigational status not valid **Mode indicator:** D (multiple characters). D refers to Differential, Satellite system used in differential mode in position fix **Age of differential data:** For SBAS L1, this value is the oldest age of the most recent fast corrections set in use (received through messages types 2, 3, 4, 5 and 24). **Differential Reference Station ID:** PRN of the SBAS service preceded by 1 (e.g. 1126 for PRN 126). **HDOP:** Calculated HDOP.
RMC[b]	Recommended Minimum Specific GNSS Data	If SBAS information is used for navigation position: **Navigational status:** S, C, U or V, corresponding to Safe, Caution, Unsafe or Navigational status not valid **Mode indicator:** D (single character), indicating differential. **Status: A**, indicating data valid
VTG[b]	Course over ground and ground speed	If SBAS information is used for navigation position: **Mode indicator:** D (single character), indicating differential.
ZDA[a]	Time and date	No specific consideration for SBAS navigation position
GFA[b]	GNSS fix accuracy and integrity	If integrity is provided by RAIM using corrections and integrity data provided by SBAS:

		Integrity status: S, C, U or V, corresponding to Safe, Caution, Unsafe or Integrity status not valid for the first character (RAIM) and the second character (SBAS).
GSN[b]	GNSS SBAS Navigation Message	If SBAS information is used for navigation position.
[a] See 61162-1 [b] See Annex B		

In addition, for integrating with other navigational aids the sentences in Table 2 may be available in any combination.

Table 2 – Output sentences for integration in other navigational aids

Mnemonic	Description	Considerations for SBAS navigation position
GRS[b]	GNSS range residuals	If SBAS satellites are used for ranging in navigation position: **SBAS signal ID:** The offset from SBAS SV ID to SBAS PRN number is 87.
GSA[b]	GNSS DOP and active satellites	If SBAS satellites are used for ranging in navigation position: **SBAS satellite ID:** The offset from SBAS SV ID to SBAS PRN number is 87.
GST[a]	GNSS pseudorange noise statistics	If SBAS information is used for navigation position: Position error estimation after SBAS corrections application. RMS of the pseudorange after SBAS corrections application.
GSV[b]	GNSS satellites in view	If SBAS satellites are in view: **SBAS satellite ID:** The offset from SBAS SV ID to SBAS PRN number is 87.
[a] See 61162-1 [b] See Annex B		

The following sentences shall be used for alert reporting and alert command purposes where required by IEC 62923-1:

- ACN – Alert command
- ALC – Cyclic alert list
- ALF – Alert sentence
- ARC – Alert command refused
- HBT – Heartbeat supervision sentence

4.3.3 Accuracy

4.3.3.1 Static accuracy

(See 6.10.5 and 6.10.6)

The SBAS L1 receiver equipment shall be capable of achieving such static accuracy that the horizontal position of the antenna is determined to within 10 m (percentile 95 %) with HDOP ≤4 (or PDOP ≤ 6).

NOTE 1 This minimum accuracy requirement is compliant with the IMO Resolution A.1046(27) operational requirements for ocean waters, harbour entrances, harbour approaches and coastal waters.

NOTE 2 See Horizontal Accuracy 95% in 3.1.5 for clarification.

4.3.3.2 Dynamic accuracy

(See 6.10.7)

The SBAS L1 receiver equipment shall be capable of achieving such dynamic accuracy that the horizontal position of the ship is determined to within 10 m (percentile 95 %) with HDOP ≤4 (or PDOP ≤ 6) under the conditions of sea state and ship's motion as described in IEC 60721-3-6.

NOTE This minimum accuracy requirement is compliant with the IMO Resolution A.1046(27) operational requirements for ocean waters, harbour entrances, harbour approaches and coastal waters.

4.3.4 Acquisition

(See 6.10.8)

The SBAS L1 receiver equipment shall be capable of determining SBAS position to the required accuracy within 5 min, when the following conditions are met:

- valid almanacs;
- latitude and longitude initialized within 60 nautical miles;
- time and date within 1 minute;
- interference conditions specified in 4.3.11; and
- the signal conditions specified in 4.3.6.

NOTE Equipment operating in areas where the Doppler shift exceeds ±210 Hz are not required to meet SBAS satellite acquisition requirement.

4.3.5 Availability

(See 6.10.5)

After SBAS position acquisition time, the SBAS L1 receiver equipment shall continuously provide SBAS position (with the required position update rate) as long as adequate SBAS services are available (i.e. SBAS signal in space, valid SBAS corrections, at least 4 monitored GPS satellites, etc.).

4.3.6 Dynamic range

(See 6.10.9)

Refer to 4.3.7 in IEC 61108-1:2003 for GPS L1 signals.

The SBAS L1 receiver equipment shall be capable of acquiring SBAS L1 satellite signals with input signals having carrier levels in the range of –130 dBm to –120 dBm as measured at the output of a 3 dBi linear polarized receiving antenna. Once the SBAS L1 satellite signals have been acquired, the equipment shall continue to operate properly with satellite signals having carrier levels down to –133 dBm as measured at the output of a 3 dBi linear polarized receiving antenna.

4.3.7 Effects of specific interfering signals

(See 6.10.10)

The SBAS L1 receiver equipment shall meet the following requirements.

a) In a normal operating mode, i.e. switched on, and with antenna attached, it is subject to radiation consisting of a burst of 10 pulses, each 1,0 μs to 1,5 μs long on a duty cycle of 1 600:1 at a frequency lying between 2,9 GHz and 3,1 GHz at power density of about 7,5 kW/m^2. The condition shall be maintained for 10 min with the bursts of pulses repeated every 3s. When the unwanted signals is removed and the receiver antenna is exposed to the normal GPS and SBAS satellite signals, the receiver shall calculate valid SBAS position fixes within 5 min without further operator intervention.

NOTE 1 This condition is approximately equivalent to exposing the antenna to radiation from a 60 kW “S” Band marine radar operating at a nominal 1,2 μs pulse width at 600 pulses/s using a 4 m slot antenna rotating at 20 r/min with the GPS/SBAS antenna placed in the plane of the bore site of the radar antenna at a distance of 10 m from the centre of rotation.

b) In a normal operating mode, i.e. switched on and with antenna attached, it is subject to radiation of 0,16 W/m^2 at a frequency in the range of 1 626,5 MHz to 1 660,5 MHz for 10 min. During the period, the SBAS L1 receiver equipment shall be able to calculate valid SBAS position fixes.

NOTE 2 This is equivalent to exposing a GPS/SBAS antenna to radiation from an Inmarsat FleetBroadband antenna at 10 m distance along the bore sight.

Advice shall be given in the installation manual for adequate installation of the antenna unit, to minimize interference with other radio equipment such as marine radars, Inmarsat ship earth stations, Iridium ship earth stations, etc.

NOTE 3 Given that Iridium GMDSS ship earth stations and GPS/SBAS L1 receivers operate in adjacent and shared spectrum, the installation manual can include relevant antenna installation warnings and guidelines, including the amount of separation from Iridium ship earth station antennas and other factors necessary to avoid radio frequency interference.

4.3.8 Position update

(See 6.10.11)

After applying SBAS satellite corrections (see Annex A), the SBAS L1 receiver equipment shall compute and output to a display and digital interface (conforming to IEC 61162-1) the SBAS position solution for the primary SBAS satellite selected (see 4.3.9.2) at least once every 1 s for conventional craft and at least once every 0,5 s for high speed craft.

For high speed craft purposes, the equipment shall additionally provide an IEC 61162-2 or IEC 61162-450 interface with a position update rate of 2 Hz.

4.3.9 SBAS input and processing

(See 6.10.12)

The SBAS L1 receiver equipment shall be capable of acquiring, tracking and using the SBAS PRN codes from 120 to 158 (see Table 6).

4.3.9.1 SBAS message processing

(See 6.10.13)

SBAS Message Types 0, 1, 2, 3, 4, 5, 6, 7, 10, 17, 18, 24, 25, 26, 27 and 28 (see Table 8) received from SBAS L1 satellite signal shall be continuously decoded and processed as described in Annex A.

If SBAS ranging is available, it is recommended that SBAS L1 receiver processes Message Type 9.

If an optional message type is used (for instance Message Type 9), the SBAS L1 receiver equipment shall decode it and process it as described in RTCA DO-229.

4.3.9.2 SBAS satellite selection

(See 6.10.14)

The SBAS L1 receiver equipment shall be capable of monitoring (tracking and processing) the data broadcast from at least two SBAS L1 signals (PRN codes) with valid satellite and ionospheric corrections, when available (as described in A.2). A second SBAS L1 signal (PRN code) is necessary to be monitored to ensure continued performance in the event of losing the primary SBAS L1 signal (PRN code) selected.

NOTE 1 Valid GPS satellite corrections are considered the fast and long satellite corrections provided by SBAS L1 (MT2-5, MT24 and MT25) that have not timed out and the associated UDREI for that GPS satellite is below 12 (as described in A.3).

NOTE 2 Valid ionospheric corrections are considered the ionospheric corrections provided by SBAS L1 (MT26) that have not timed out and the associated GIVEI for that IGP is below 15 (as described in A.3).

NOTE 3 The equipment will monitor one SBAS L1 signal if only one SBAS L1 signal, broadcasting valid satellite and ionospheric corrections, is available.

Some recommended methods to select the SBAS L1 signal to be used in the PVT computation and/or when there are more than two SBAS L1 signals available are:

- to select the SBAS satellite that provides best HDOP for the GPS satellites which have valid SBAS corrections; or
- to select the SBAS satellite with highest elevation.

NOTE 4 The two SBAS signals tracked can be from different SBAS service providers.

4.3.10 Navigational status indications

4.3.10.1 General

The SBAS L1 receiver equipment shall provide an indication if the SBAS position calculated is likely to be outside the bounded requirements for general navigation in the ocean, coastal and harbour entrances/approaches as specified in the Table 3. This indication shall also be part of GFA sentence in the output interface.

Table 3 – Required horizontal position accuracy and integrity for general navigation

	Horizontal accuracy (m)	**Horizontal alert limit (HAL) (m)**
Ocean [a]	100 [a]	250 [c]
Coastal [a]	10 [a]	25 [b]
Restricted waters [b]	10 [b]	25 [b]
Harbour/Port approaches [a, b]	10 [a, b]	25 [b]
Harbour entrances [a]	10 a	25 [c]
Inland waterways [b]	10 [b]	25 [b]

[a] Source IMO Resolution A.1046(27)

[b] Source IMO Resolution A.915(22)

[c] Based on 2,5 times horizontal accuracy level

The navigational status for different position accuracy levels shall be expressed in three navigational states:

– “Safe”;

– “Caution”; and

– “Unsafe”

The conditions for a “Safe” navigational state are as follows:

a) the estimated error (95 % confidence) along the major axis of the error ellipse is less than the selected accuracy level corresponding to the actual navigation mode; and

b) integrity is available and within the requirements for the actual navigation mode (HPL < HAL) and the integrity monitoring does not issue alerts at position level; and

c) a new position has been calculated within 1 s for a conventional craft and 0,5 s for a high speed craft.

The conditions for a “Caution” navigational state are as follows:

d) integrity has not been available for a period of at least 3 s; and/or

e) HDOP exceeded – HDOP exceeds the required threshold; and/or

f) SBAS signal not applied – SBAS signals are not being applied to the indicated ship’s position.

The conditions for an “Unsafe” navigational state in alert management are as follows:

g) loss of position – the estimated error (95 % confidence) along the major axis of the error ellipse is greater than the selected accuracy level corresponding to the actual navigation mode; and/or

h) no calculation of position – a new valid position has not been calculated for more than 1 s for a conventional craft and 0,5 s for a high speed craft; and/or

i) integrity status - integrity is available but exceeds the requirements for the actual navigation mode (HPL ≥ HAL) for a period of at least 3 s or the integrity monitoring issue alerts at position level.

The navigational status shall be continuously displayed along with an indication of the accuracy level selected. The navigational status, alert identifier and the accuracy level selected shall be provided to other equipment in accordance with the equipment output requirements in 4.3.2. The classification, presentation, handling and interfacing of alerts, including transmitted alert identifiers shall be as required in Annex D for the purpose of bridge alert management.

The manufacturer may use colours for navigational status indication and if so the following colours shall be used:

- "safe" shall be green;
- "caution" shall be yellow; and
- "unsafe" shall be red.

The manufacturer may use icons for navigational status indication.

NOTE Currently there are no standardised icons for navigational status indication.

A change in the navigational status shall be indicated within 10 s.

For receiver equipment which does not provide information by a dedicated display, the provision of the navigational status indication and the selected accuracy level with an appropriate output interface is required.

The “navigational status indicator” is indicated in the interface sentences:

- GNS: Navigational status indicator: S, C or U;
- RMC: Navigational status: S, C or U.

4.3.10.2 HDOP check

(See 6.10.15.1)

HDOP shall be computed using only the satellites used for the PVT solution.

The equipment shall provide an indication within 5 s if the specified HDOP has been exceeded (HDOP > 4). Under such conditions, the equipment shall provide the last known position and the time of the last valid fix, with explicit indication of this state, so that no ambiguity exists, until normal operation is resumed. The GNS sentence in the interface shall either indicate “value of HDOP” (if SBAS is in use) or change to follow the result from alternative non-SBAS method(s) available in the equipment. If SBAS is in use the “value of HDOP” is indicated in the interface sentence:

- GNS: HDOP = value of calculated HDOP

4.3.10.3 Position data lost

(See 6.10.15.1)

The equipment shall provide an indication within 5 s of loss of position or if a new position has not been calculated for more than 1 s for conventional craft and 0,5 s for high-speed craft. Under such conditions, the equipment shall provide the last known position and the time of the last valid fix, with explicit indication of this state, so that no ambiguity exists, until normal operation is resumed.

The sentences in the interface shall either indicate “position data lost” (if SBAS is in use) or change to follow the result from alternative non-SBAS method(s) available in the equipment. If SBAS is in use the “position data lost” is indicated in the interface sentences:

- GNS: Mode indicator = N (no fix);
- GNS: Navigational status = U (unsafe);

- RMC: Status = V (invalid);
- RMC: Mode indicator = N (no fix);
- RMC: Navigational status = U (unsafe);
- VTG: Mode indicator = N (data not valid).

4.3.10.4 SBAS status indication

(See 6.10.13)

The SBAS L1 receiver equipment shall provide an indication of the SBAS status:

- whether SBAS corrections are being applied to the indicated ship's position; and
- if SBAS corrections are being applied,
- the age of the differential data used; and
- the SBAS PRN used for the PVT computation.

The GNS sentence in the interface shall indicate the SBAS status as described in Annex B. The Alert ID corresponding to SBAS status indication is described in Annex D as "SBAS signal not applied".

4.3.10.5 Integrity using RAIM with SBAS

(See 6.10.15.2)

The SBAS L1 receiver equipment shall incorporate integrity monitoring using fault detection, for example receiver autonomous integrity monitoring (RAIM), or similar means to determine if accuracy is within the performance requirements (see Table 3) and provide an integrity indication.

The RAIM algorithm employed shall be capable of detecting and excluding a faulty range signal from the position solution.

The decision thresholds used to detect and exclude a faulty range signal shall be consistent with requirements stated in Table 3.

NOTE 1 The integrity monitoring mechanism employed to demonstrate compliance to Table 3 performance, including the computation method of estimated error (95 % confidence) and HPL, is responsibility of the receiver equipment.

NOTE 2 Specific algorithms for the estimated error (95 % confidence) and HPL computations are not defined within this document.

Selected accuracy level is the horizontal accuracy as defined in the Table 3 for different areas of navigation. Values of horizontal accuracy level and alert limit for each area of navigation are available in Table 3.

The maximum delay for reaction of the integrity calculation by means of RAIM due to negative changes affecting the integrity status is 10 s.

The integrity indication for different position accuracy levels (10 m and 100 m) shall be expressed in three states.

- Safe: When calculated HPL is less than HAL for the selected accuracy level (HPL < HAL) and the integrity monitoring does not issue alerts at position level. This generally requires at least 5 GPS "healthy" satellites available and in a robust geometry, i.e. the worst 4 satellite geometry is still suitable for navigation.
- Caution: When insufficient information is available to calculate HPL for more than 3 s. Those conditions may occur if an insufficient number of satellites are available, for example 4 or 5 with 2 satellites "close" together in azimuth and elevation, causing the geometry to degrade to the point that the RAIM calculation becomes unreliable. Note that the resulting accuracy based on 4 or 5 satellites in use may be within the selected accuracy level, but the RAIM algorithm cannot verify it.
- Unsafe**:** When calculated HPL exceeds or equals to the HAL for more than 3 s (HPL ≥ HAL) or the integrity monitoring does not issue alerts at position level.

If receiver equipment is providing SBAS PVT solution, SBAS satellite corrections shall be applied to pseudoranges before the pseudoranges are used in the RAIM algorithm.

As part of the integrity monitoring process, the receiver shall estimate pseudorange accuracy (see A.4.3). If the receiver equipment is providing SBAS PVT solution, the SBAS corresponding sigma error estimation per GPS satellite shall be used within the integrity algorithm for HPL computation.

For SBAS-based position, RAIM shall use the integrity information provided by SBAS and the satellite pseudorange residuals after resulting from SBAS position computation. For example, RAIM shall consider only the healthy satellites used in the SBAS navigation solution (healthy being understood as valid SBAS satellite and ionospheric corrections) when providing SBAS PVT solution.

The sentence in the interface shall either indicate "state of integrity" (if SBAS is in use) or change to follow the result from alternative non-SBAS method(s) available in the equipment. If SBAS is in use the "state of integrity" is indicated in the interface sentence:

- GFA: Integrity status for RAIM and SBAS: S, C or U;

4.3.10.6 Self-test

(See 6.10.15.3)

The SBAS L1 receiver equipment shall provide means to perform self-test of major functions either automatically or manually. The major functions of self-test are: antenna interface, BAM interface, MKD interface or other equipment interfaces.

4.3.11 Operation under typical interference conditions

(See 6.10.16)

The SBAS L1 receiver equipment shall be capable of operating properly in typical interference conditions described in 5.7 of IEC 61108-1:2003 and in RTCA DO-229: 2020 Appendix C. Operational situations include static accuracy and reacquisition within 5 min after satellite signals have been masked for 60 s or less by an obstruction, for example a bridge.

The SBAS L1 receiver equipment shall be capable of providing GPS position within 30 s and SBAS position to the required accuracy within 5 min.

Typical GPS L1 and SBAS L1 interference effects can be characterized as being broadband noise-like interference, Continuous Wave Interference (CWI), or pulsed interference. The aviation community has defined interference levels in these three categories as reported in RTCA DO-229. These levels are based upon the interference masks developed within RTCA, which are also described in ITU-R Recommendation M.1903.

Advice shall be given in the operator's manual for enabling the operator to determine when the interference environment is exceeded such that the SBAS can no longer maintain static accuracy or reacquire a signal.

NOTE For example, IMO COMSAR.1/Circ.32/Rev.1, includes the statement: "The presence of interference to GNSS can be quickly checked by switching the unit to the signal-to-noise (SNR) or integrity display mode, and ensuring SNR levels are not reduced when potential interfering devices are activated."

The signal-to-noise ratio (SNR) shall be periodically monitored and the operator notified when the SNR is reduced to a value indicating the likely presence of harmful radio frequency interference.

Annex C gives information on other interference mechanisms.

4.3.12 Output of COG, SOG and UTC

4.3.12.1 Accuracy of COG

(See 6.10.17 and 6.10.18)

The SBAS L1 receiver equipment shall provide COG and SOG outputs. The mode indicator of the GNS and VTG sentence is used for interpretation of validity of COG and SOG.

The error in the COG (the path of the antenna position over ground) due to the actual ship's speed over ground obtained under the various dynamic conditions that could be experienced onboard ships shall not exceed the values in Table 4.

Table 4 – Accuracy of COG

Speed range (knots)	Accuracy of COG output to user
0 to ≤ 1	Unreliable or not available
> 1 to ≤ 17	±3°
> 17	±1°

Due to limitations of SBAS L1 receivers to this document, it is not appropriate to include requirements for COG errors attributed to high dynamic movement. Such limitations shall be stated in the operator's manual.

4.3.12.2 Accuracy of SOG

(See 6.10.17 and 6.10.18)

Errors in the SOG (velocity of the antenna position over ground) obtained under the various dynamic conditions that could be experienced onboard ships shall not exceed 2 % of the actual speed or 0,2 knots, whichever is greater.

4.3.12.3 Availability and validity of time information

(See 6.10.19)

The SBAS L1 receiver equipment digital interface shall provide UTC with resolution of 0,01 s. The GNS sentence mode indicator shall be used for interpretation of validity of digital interface for UTC contained in the ZDA sentence.

5 SBAS technical characteristics

5.1 General

This Clause 5 describes the main characteristics of the SBAS L1 signal-in-space as well as the SBAS L1 messages. For detailed information, refer to the ICAO SARPs:2020 (3.7.3.4 and Appendix B 3.5) or RTCA DO-229:2020 (Appendix A).

An SBAS broadcasts GNSS satellite clock, ephemeris, ionospheric corrections and integrity information to GNSS receivers, providing enhanced accuracy with respect to a GNSS standalone solution and integrity information by SBAS L1 receiver equipment.

NOTE In this SBAS L1 case, the UDREI and GIVEI are the SBAS L1 integrity parameters which ensure timely alerts for satellite clock/ephemeris and ionospheric corrections, respectively. Whenever there is an anomaly in a satellite or Ionospheric Grid Point (IGP), SBAS L1 systems set the corresponding UDREI or GIVEI to 15, which means "do not use". Additionally, SBAS L1 Message Type 0 provides a "do not use" message for the SBAS corrections provided by that specific SBAS PRN, indicating that the SBAS integrity performance cannot be assured.

SBAS are designed according to an international standard, the Standards and Recommended Practices (ICAO SARPs:2020), which is controlled by the International Civil Aviation Organization (ICAO). This standard specifies the type and content of data which is generated and transmitted by an SBAS. Then, SBAS providers broadcast a SBAS Signal in Space (SIS) compliant to this standard in terms of radio-frequency characteristics, and data content and format. In addition, there is another international standard for airborne SBAS L1 receiver equipment, Minimum Operational Performance Standard (MOPS) RTCA DO-229, which is managed by the US Radio Technical Commission for Aeronautics (RTCA). This standard for aviation equipment also includes up-to-date specification of SBAS L1 signal and message processing.

5.2 SBAS L1 SIS RF characteristics

SBAS satellites broadcast SBAS L1 signal-in-space on the same frequency as GPS L1, with the same GPS-type of modulation and Coarse/Acquisition (C/A) PRN code. This allows minimising the modifications needed in a standard GPS receiver hardware to process SBAS signals.

According to this premise, the SBAS broadcasts a single carrier frequency of the GPS L1 central frequency (1575,42 MHz) using right-hand circular polarization (RHCP). Each second, SBAS transmits a SBAS message containing 250 bits of information (described in 5.3). This SBAS message is ½ convolutional encoded with Forward Error Correcting (FEC) Code resulting in a 500 symbols per second data stream, which are added modulo-2 to a 1023-bit PRN code. The message is Bi-Phase Shift Key (BPSK) modulated by a bit train comprising the PRN code and the SBAS data onto the carrier at a rate of 1,023 Mega-chips per second.

The bandwidth of the signal transmitted by a SBAS satellite is at least 2,2 MHz.

The Doppler shift obtained by a stationary user due to the relative motion of the SBAS geostationary satellite is smaller than 40 metres per second (≈ 210 Hz at L1). Doppler shifts experienced at high latitudes and from GEOs with high inclination orbit may be as large as ±450 Hz.

The characteristics are given in Table 5.

Table 5 – SBAS L1 SIS RF characteristics

Characteristic	Description
Frequency	1 575,42 MHz. Same as GPS L1 frequency.
Polarization	Right-Hand Circularly Polarized.
Ranging Code	GPS-type of modulation and Coarse/Acquisition (C/A) PRN code. A 1023 bit PRN Code (Gold code) of 1 millisecond in length at a chipping rate of 1023 kbps, at a rate of 1,023 MHz.
SBAS Data	SBAS data is ½ convolutional encoded with Forward Error Correcting (FEC) Code, resulting in a 500 symbols per second data stream, module-2 (250 effective bits per second).
Modulation	Modulo-2 addition of SBAS data at a rate of 500 symbols per second and the 1023 bit PRN code. It shall then be BPSK-modulated onto the carrier at a rate of 1,023 Mega-chips per second.
Bandwidth	At least 2,2 MHz within L1 ±30,69 MHz. At least 95% of the broadcast power will be contained within the L1 ±12 MHz band.
Power	Range between –161 dBW to –155 dBW when satellite elevation is at least 5 degrees.

5.3 SBAS L1 SIS message characteristics

5.3.1 Identification

The SBAS codes are identified in two ways:

- Pseudo Random Noise (PRN) code. The PRN code is a 1023-bit Gold code that is itself the Modulo-2 addition of two 1023-bit linear patterns, G1 and G2 (see 5.3.2);
- SBAS data. The raw navigation message of the SBAS contains 500 bits (Module-2 encoded), receiving 250 bits of SBAS message per second by the SBAS L1 receiver equipment (see 5.3.3).

5.3.2 L1 C/A PRN Code for SBAS

The SBAS codes used to form the broadcast from SBAS satellites are listed in Table 6. Like the GPS C/A codes, the PRN number is arbitrary, but starting with 120 instead of 1. The actual codes are defined by either the G2 delay or the initial G2 register setting. Detail specification of how to generate PRN code is stated in the last version of the GPS ICD. The ranking of the codes is by the average number of cross correlation peaks when correlating those codes with the 36 different GPS codes with zero Doppler difference.

Receivers shall be designed to acquire and track all of the codes in Table 6.

Table 6 – SBAS Ranging C/A Codes

PRN number	G2 Delay (Chips)	Initial G2 Setting (Octal)	First 10 SBAS Chips (Octal)
120	145	1106	671
121	175	1241	536
122	52	0267	1510
123	21	0232	1545
124	237	1617	0160
125	235	1076	0701
126	886	1764	0013
127	657	0717	1060
128	634	1532	0245
129	762	1250	0527
130	355	0341	1436
131	1012	0551	1226
132	176	0520	1257
133	603	1731	0046
134	130	706	1071
135	359	1216	0561
136	595	0740	1037
137	68	1007	0770
138	386	0450	1327
139	797	0305	1472
140	456	1653	0124
141	499	1411	0366
142	883	1644	0133
143	307	1312	0465
144	127	1060	0717
145	211	1560	0217
146	121	0035	1742
147	118	0355	1422
148	163	0335	1442
149	628	1254	0523
150	853	1041	0736
151	484	0142	1635
152	289	1641	136
153	811	1504	0273
154	202	0751	1026
155	1021	1774	0003
156	463	0107	1670
157	568	1153	0624
158	904	1542	0235

NOTE The assigned SBAS Ranging C/A Codes (PRN allocation system) can be found on https://www.gps.gov/technical/prn-codes/

These SBAS codes belong to the same family of 1023-bit Gold codes as the 37 C/A codes reserved by the GPS system.

5.3.3 SBAS data format

The raw navigation message of the SBAS contains 500 bits. These raw data are ½ convolutional encoded with a Forward Error Correction (FEC) code, which means that 250 bits of information are available every second at user level. The 250 bit message has different parts, including an 8 bit preamble, 24 auxiliary bits to include redundancy and error checking within the message (Cyclic Redundancy Check), 6 bit Message Type identifier to show the SBAS message identifier and the 212 bit data field for the message itself. See Table 7.

Table 7 – SBAS message format

SBAS message: 250 bits – 1 second			
8 bit Preamble	6 bit MT identifier	212 bit Data field	24 bit CRC

The different parts are as follows.

a) Preamble

A unique 8 bit field, distributed over three successive words. The preamble sequence (in three consecutive words) is 01010011 (83) - 10011010 (154) - 11000110 (198). It is assured that the start of the preamble is synchronous with a 6 second GPS sub-frame. Thus, the preamble allows the receiver to achieve frame synchronisation.

b) Message Type Identifier

A 6 bit field, which permits up to 64 different messages (identifiers 0 to 63). Depending on the message type, the information included in the data field has different meaning. Even though 64 type messages are available, only 20 are currently defined in Table 8.

c) Message Data Field

Contains different SBAS corrections and integrity information that depends on the type of message. The specific content of this field is addressed in SARPs:2020 Appendix B and in RTCA DO-229:2020 Appendix A.

d) Parity Information

The 24 bits of the end of the message, Cyclic Redundancy Check (CRC) parity bits, provide protection against burst and random error.

For more information on parity bits algorithm generator see A.4.3.3 of RTCA DO-229:2020.

Table 8 – SBAS Message Types

Message Type	Contents	Purpose
0	Don't Use for Safety Applications	Discard any ranging, corrections and integrity data from that PRN signal for safety applications.
1	PRN Mask assignments	Indicates the slots for GPS and Augmentation satellites provided data.
2-5	Fast corrections	Range corrections and accuracy.
6	Integrity information	Accuracy-bounding information for all satellites in one message.

7	Fast correction degradation factor	Information about the degradation of the fast term corrections.
9	GEO Navigation Message	Information about the SBAS GEO navigation (ephemeris).
10	Degradation parameters	Information about the correction degradation upon message loss.
12	SBAS Network time / UTC offset parameters	Information about time-offset parameters between different time systems.
17	GEO satellite almanacs	Almanacs (satellite and health status as well as rough position) for up to three SBAS GEO satellites.
18	Ionospheric grid point masks	Indicates for which geographical point ionospheric correction data is provided.
24	Mixed fast/long-term satellite error corrections	Fast-term error corrections for up to six satellites and long-term satellite error correction for one satellite in one message.
25	Long-term satellite error corrections	Corrections for satellite ephemeris and clock errors for up to two satellites.
26	Ionospheric delay corrections	Vertical delays/accuracy bounds at given geographical points.
27	SBAS Service Message	Used to increase the UDRE values that are broadcast through messages of type 2 to 5, 6 or 24 over several selected areas. Defines the geographical region of the augmentation service.
28	Clock-Ephemeris Covariance Matrix Message	To provide the relative covariance matrix for clock and ephemeris error. Each covariance matrix is updated on the same order as the long-term corrections. It provides increased availability inside the service area and increased integrity outside.
62	Internal test message	Used to continue using the GEO broadcast data and ranging capabilities.
63	Null message	Broadcast in case no other message is available

A high level procedure for SBAS navigation computation is shown in Annex A which includes the minimum set of SBAS messages that are required to be processed by the SBAS L1 receiver equipment.

6 Methods of testing and required test results

6.1 Test sites

Tests will typically be carried out at test sites.

The manufacturer shall, unless otherwise agreed, set up the SBAS L1 receiver equipment to be tested and ensure that it is operating normally before testing commences.

During the execution of all tests in 6.10, the following information shall be recorded for later evaluation:

- position;
- position mode;
- course over ground;
- speed over ground;
- time;
- indications;
- alerts.

Indications and alerts shall be appropriate to the conditions being experienced by the Equipment Under Test (EUT) at the time of their display.

6.2 Test sequence

The sequence of tests is not specified. Before commencement of testing, the sequence shall be agreed between the test laboratory and the supplier of the equipment.

Where appropriate, tests against different subclauses may be carried out simultaneously. The manufacturer shall provide sufficient technical documentation to permit the SBAS L1 receiver equipment to be operated correctly.

Additional data shall be provided by the manufacturer to cover specific tests which do not form part of the normal user operations.

6.3 Test signals

The tests shall be performed using signals from a navigation system simulator in compliance with the appropriate navigation system ICDs (DO-229 and GPS ICD) except for the static tests described in 6.10.5 and 6.10.6.

The navigation system simulator shall generate signals which have the same characteristics as the GPS and SBAS satellites, as appropriate, and produce signal delays due to normally occurring ionospheric and atmospheric conditions. In addition, the navigation system simulator shall be capable of generating SBAS messages as specified in Clause 5.

The following test signals are defined to introduce programmed modifications in specific SBAS message types to check that the EUT correctly decodes and use the SBAS messages.

Test signal A shall contain SBAS message types required in 4.3.9.1. The SBAS ID (or GEO PRN) of test signal A should be an ID of an SBAS (or GEO) that is stored in the almanac. This signal should present nominal conditions and performance.

Test signal B shall contain SBAS message types required in 4.3.9.1. The SBAS ID (or GEO PRN) of test signal B should be an ID of an SBAS (or GEO) that is not stored in the almanac. This signal should present nominal conditions and performance.

Test signal C shall contain SBAS message types required in 4.3.9.1, but the CRC in each message is invalid.

Test signal D shall contain SBAS message types required in 4.3.9.1, but every MT2 should be replaced by a MT0 (Do Not Use for Safety Applications).

Test signal E shall contain SBAS message types required in 4.3.9.1, but setting UDREI values within Message Types 2, 3, 4, 5, 6 and 24 for all GPS satellites to 12.

Test signal F shall contain SBAS message types required in 4.3.9.1, but setting UDREI values within Message Types 2, 3, 4, 5, 6 and 24 for all GPS satellites to 14 (Not Monitored).

Test signal G shall contain SBAS alerts, including sequences of four consecutive MT6 messages, setting the UDREI values for all GPS satellites to 15 (Do Not Use) with IODF = 3 or with IODF matching the IODF from MT2-5.

Test signal H shall contain Ionospheric alerts, including all IGPs with vertical delays of 63,875 m (111111111) in MT26 messages.

Test signal I shall contain SBAS message types required in 4.3.9.1, but the IODP from MT1 shall be different from the IODP referenced in the rest of SBAS messages where it is used (IODP unmatch).

Test signal J shall contain SBAS message types required in 4.3.9.1, but the IOD from MT25 for at least one satellite monitored shall not match with any of the last three IODEs provided by the corresponding GPS satellite(s).

Test signal K shall contain SBAS message types required in 4.3.9.1, but the MT27 shall be updated to broadcast a service area that not includes the receiver position.

Test signal L shall contain SBAS message types required in 4.3.9.1, but the fast corrections from at least one satellite monitored shall be set to the maximum value allowed (+255,875m).

Test signal M shall contain SBAS message types required in 4.3.9.1, but the IODI referenced in all the MT18 shall be different from the ones included in all the MT26 (IODI unmatch).

Test signal N shall contain SBAS message types required in 4.3.9.1, but the update interval for the MT2-5 shall be set to 60 seconds.

Test signal O shall contain SBAS message types required in 4.3.9.1, but the fast correction degradation factor indicator included in MT7 shall be set to “0” and the update interval for the MT2-5 shall be set to 60 seconds.

Test signal P shall contain MT6 messages, setting the UDREI values for all GPS satellites to 14 (Not Monitored) providing an IODF between “0” and “2” not matching with the IODF included in the MT2-5.

Test signal Q shall contain MT28 (instead of MT27) messages. The content of all the MT28 messages shall be: E11=E22=E33=1, E44=E12=E13=E14=E23=E24=E34=0 and Scale Exp = 5. This will imply a ∂UDRE=1 for each GPS satellites monitored.

Test signal R shall contain MT28 (instead of MT27) messages. The content of all the MT28 messages shall be: E11=E22=E33=E44=511, E12=E13=E14=E23=E24=E34=0 and Scale Exp = 5. This will imply a $\sigma_{i,flt}^2 > 230{,}9661$ for each GPS satellites monitored.

Test signal S shall contain SBAS messages types required in 4.3.9.1, but the Service Provider ID parameter from MT17 shall be modified.

Test signal T shall contain SBAS message types required in 4.3.9.1, but setting UDREI values within Message Types 2, 3, 4, 5, 6 and 24 for all GPS satellites monitored to 11.

Test signal U shall contain SBAS message types required in 4.3.9.1, except MT10.

6.4 Determination of accuracy

The geometric distribution of the satellites will affect the level of position accuracy computed by the SBAS L1 receiver. The HDOP measurement is an indication of the suitability of the constellation in view for use in receiver equipment testing. If the HDOP is ≤4, the test conditions can be considered as suitable. If HDOP is >4 but ≤6, then results may be unreliable. For HDOP > 6, testing shall be delayed until better geometry is established.

The aim of the accuracy tests is to establish that the measurement of position calculated by the EUT under static and dynamic conditions is as good as or better than the performance levels set out in this document. In order to compute the horizontal accuracy 95%, the tester shall compare the instantaneous position provided by the EUT with the true instantaneous position, which shall be known by the tester, and perform the 95 percentile (see 3.1.5).

If a simulator is used, the simulator scenario shall be chosen such that HDOP ≤4 and PDOP ≤6, for the duration of the test.

6.5 Environmental conditions

Normal environmental conditions shall be a convenient combination of +15 °C to + 30 °C temperature and 20 % to 75 % relative humidity.

When it is impractical to carry out the test under the conditions stated above, a note to this effect, stating the actual temperature and relative humidity during the tests, shall be added to the test report.

6.6 General requirements

All the general requirements of IEC 60945 appropriate to the category of the EUT, that is protected or exposed, shall be carried out. The manufacturer shall declare any preconditioning required before environmental checks. For the purposes of this document, the following definitions for performance check and performance test, required by IEC 60945, shall apply.

Performance check – see 6.9.

Performance test – the static accuracy test described in 6.10.5.

6.7 Alert requirements

Confirm by inspection of documented evidence that the EUT complies with IEC 62923-1 and IEC 62923-2.

6.8 Presentation requirements

All the presentation requirements of IEC 62288 shall be carried out as appropriate to the facilities provided with the EUT.

6.9 Performance check

A performance check is defined as a shortened version of the static accuracy test described in 6.10.5 with the following conditions:

- a minimum of 100 SBAS position measurements shall be taken over a period between 5 and 10 minutes, discarding any measurements with HDOP >4;
- the position of the antenna of the EUT shall not be in error compared with the known position >10 m (percentile 95%) using WGS84 as the reference datum.

The required result is that the distribution of the horizontal error for the SBAS position shall be within 10 m (percentile 95%).

6.10 SBAS L1 receiver tests descriptions

6.10.1 SBAS L1 receiver equipment

(See 4.2.1)

The EUT shall be checked for composition by inspection of the equipment and the manufacturer's documentation.

6.10.2 Configuration

(See 4.2.2)

The EUT shall demonstrate that the user can enable or disable the SBAS usage to compute the PVT solution.

The EUT shall demonstrate that the user can select the preferable augmentation mode to be used in the PVT solution if both signals, DGPS and SBAS L1, are available.

The manufacturer's documentation shall be inspected to ensure that, when the SBAS L1 receiver equipment is configured to work in automatic mode, DGPS signal is prioritized over SBAS L1 for the PVT computation.

The EUT shall display the chosen augmentation mode (e.g. DGNSS or SBAS).

6.10.3 Position output

(See 4.3.2)

The EUT shall be checked for the form of the position output by inspection of the manufacturer's documentation.

6.10.4 Equipment output

(See 4.3.2)

The EUT shall demonstrate conformity to IEC 61162-1, IEC 61162-2 or IEC 61162-450 by inspection of the manufacturer's documentation and protocol tests which shall be performed for the sentences required in 4.3.2.

6.10.5 Static accuracy and availability

(See 4.3.3.1 and 4.3.5)

6.10.5.1 Method of testing

SBAS position fix measurements shall be taken at the required sampling interval over a period longer than or equal to 24 h.

The antenna shall be mounted according to the manufacturer's instructions at a height of between 1 m and 1,5 m above the electrical ground in an area providing clear line of sight to the satellites from zenith through to an angle of +5° above horizontal and any heading. The position of the antenna shall be known, with reference to WGS 84 to an accuracy of better than 0,1 m in (x, y, z). Maximum cable lengths as specified by the manufacturer shall be used during testing.

6.10.5.2 Required test results

The distribution of the horizontal error shall be within 10 m (95 %), having discarded measurements taken in conditions of HDOP > 4 and PDOP > 6.

Given a scenario where all the conditions required for SBAS position (i.e. SBAS signal in space, valid SBAS corrections, at least 4 monitored GPS satellites, etc.) are available at 100%, the SBAS L1 receiver equipment shall continuously provide SBAS position after SBAS position acquisition time over the whole test period.

6.10.6 Static accuracy with angular movement of the antenna

(See 4.3.3.1)

The static test specified in 6.10.5 shall be repeated with the antenna performing an angular displacement of +22.5° (simulating roll) in a period of about 8 s during the duration of the tests.

The required results shall be as 6.10.5.

6.10.7 Dynamic accuracy

(See 4.3.3.2)

This test for dynamic accuracy is a practical interpretation of the conditions set out in IEC 60721-3-6:1987, Table V, item e), X – direction (surge) and Y – direction (sway). These are stated as surge 5 m/s^2 and sway 6 m/s^2.

When using a simulator, the simulator characteristics shall accurately represent the GPS and SBAS L1 signals required.

The simulator shall generate the correct signal in space associated with the following dynamic situation:

a) a fully locked and settled EUT travelling in a straight line at 48 knots ± 2 knots for a minimum of 1,2 min which is reduced to 0 knots in the same straight line in 5 s;

b) a fully locked and settled EUT travelling at least 100 m at 24 knots ± 1 knot in a straight line then subjected, for at least 2 min, to smooth deviations either side of the straight line of approximately 2 m at a period of 11 s to 12 s.

For both dynamic situations, the receiver shall remain in lock and the deviation from the programmed simulator positions shall be within the accuracy stated in 6.10.5.2.

For these dynamic situations, the true position will be provided by the simulator.

6.10.8 Acquisition

(See 4.3.4)

Once the EUT has provided SBAS position, the antenna shall be completely masked for a period between 24 h and 25 h.

At the end of the period, a performance check shall be carried out after 5 min.

6.10.9 Sensitivity and dynamic range

(See 4.3.6)

This test is aimed at checking that the receiver is able to track the SBAS signal between the maximum and minimum power levels mentioned in 4.3.6 (–130 dBm to –120 dBm).

The simulator shall adjust the SBAS signal power to -125 dBm ± 5 dBm and inject the generated SBAS signal to the EUT with the maximum and the minimum power in the receiver.

A performance check shall be carried.

The received SBAS signal shall be tracked within the signal range (–130 dBm to –120 dBm).

After the start of transmission and tracking with the nominal transmission level condition, the injected SBAS satellite signal to the EUT shall be attenuated down to -133 dBm.

The EUT shall continue tracking the SBAS signal.

6.10.10 Effects on specific interfering signals

(See 4.3.7)

6.10.10.1 S band interference

In a normal operating mode, using an appropriate signal source, the EUT shall be subjected to radiation consisting of a burst of 10 pulses, each 1,0 µs to 1,5 µs long on a duty cycle of 1600:1 at a frequency in the range of 2,9 GHz to 3,1 GHz at power density of approximately 7,5 kW/m^2. This condition shall be maintained for 10 min with the bursts of pulses repeated every 3 s.

NOTE The peak power density is 7,5 kW/m^2 to be measured at the EUT; this is approximately 4,7 W/m^2 average power at a fixed transmitting antenna.

The signal shall be removed and a successful performance check shall be carried out within 5 min.

6.10.10.2 L band interference from Inmarsat FleetBroadBand

In a normal operating mode, using an appropriate signal source, the EUT shall be subjected to radiation of 0,16 W/m^2 within the frequency range of 1 626,5 MHz to 1 660,5 MHz for 10 min.

During the period, the SBAS L1 receiver equipment shall be able to calculate valid position fixes.

6.10.11 Position update

(See 4.3.8)

6.10.11.1 General

These tests may be carried out by using a simulator.

6.10.11.2 Slow speed update rate

The EUT shall be placed upon a platform, moving in approximately a straight line, at a speed of 5 knots ± 1 knot. The position output of the EUT shall be checked at intervals of 10 s, over a period of 10 min.

The output position shall be observed to be updated on each occasion. The minimum resolution of position, i.e. latitude and longitude shall be checked by observation.

6.10.11.3 High speed update rate

The EUT shall be placed upon a platform, moving in approximately a straight line, at a speed of 50 knots ± 5 knot. The position output of the EUT shall be checked at intervals of 1 s, over a period of 10 min.

The output position shall be observed to be updated on each occasion. The minimum resolution of position, i.e. latitude and longitude shall be checked by observation.

For high speed craft purposes, this test may be carried out by using a simulator with a speed of 70 knots at intervals of 0,5 s.

Record the IEC 61162-2 or IEC 61162-450 output of the EUT during this test and confirm that the received positions at the end of each interval satisfy accuracy requirements (4.3.3) when compared with the real or simulated reference position.

6.10.12 SBAS input and processing

(See 4.3.9)

6.10.12.1 Method of testing

This test is aimed at checking that the receiver is capable of tracking and processing SBAS PRN codes from 120 to 158.

Set up the EUT in a simulation environment providing GPS L1 signals with an HDOP<4 without any SBAS signal available. Then, the method of test is as follows:

1) start transmission of SBAS signal for PRN 120;
2) stop transmission of SBAS signal for PRN 120 and start transmission of SBAS signal for PRN 158;
3) stop transmission of SBAS signal for PRN 158 and start transmission of SBAS signal for an SBAS PRN not already used in previous steps.

6.10.12.2 Required test results

For each step of the above test sequence, observe that EUT provides the corresponding SBAS status indication:

- GNS sentence;
- Mode indicator equal to “D”;
- Reference Station ID equal to “SBAS PRN + 1000”.

6.10.13 SBAS message processing

(See 4.3.9.1 and 4.3.10.4)

6.10.13.1 Method of testing

The manufacturer’s documentation shall be inspected to:

a) confirm that the reception of SBAS signal is indicated;
b) confirm that the application of SBAS signal to the output ship’s position is indicated;
c) confirm which are the SBAS messages ID processed by the receiver.

Additionally, the use of SBAS messages by the receiver shall be verified by the execution of the following tests.

1) Set up the EUT in a simulation environment providing GPS L1 signals with an HDOP<4 without any SBAS signal available. Observe that the status of EUT operation is GNSS without using SBAS corrections.

2) Start the transmission of test signal A (see 6.3). Observe that the indication of SBAS status of EUT operation is given after 5 min.

3) Stop transmission of test signal A. Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 4 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

4) Start the transmission of test signal B (see 6.3). Observe that the indication of SBAS status of EUT operation is given and the related alert is rectified after certain period of time (it is recommended to start transmitting test signal B 10 s after the test signal A has been stopped).

5) Stop transmission of test signal B. Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 4 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

6) Start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is given and the related alert is rectified within 5 min.

7) Stop the transmission of test signal A and immediately start the transmission of test signal C (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 4 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”. Then stop the transmission of test signal C and start again the transmission of test signal A.

8) Stop the transmission of test signal A and immediately start the transmission of test signal D (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 10 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

9) Stop the transmission of test signal D and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified before going to next step.

10) Stop the transmission of test signal A and immediately start the transmission of test signal F (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 10 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

11) Stop the transmission of test signal F and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified within 5 min.

12) Stop the transmission of test signal A and immediately start the transmission of test signal G (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 4 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

13) Stop the transmission of test signal G and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified within 5 min.

14) Stop the transmission of test signal A and immediately start the transmission of test signal H (see 6.3). Observe that GPS satellites used in the solution are progressively removed until the status of EUT operations resumes to GNSS without using SBAS corrections within 10 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056” after the last MT26 setting all IGPs with a vertical delay of 63,875 m.

15) Stop the transmission of test signal H and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified within 5 min.

16) Stop the transmission of test signal A and immediately start the transmission of test signal I (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 18 s due to parameter time out and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

17) Stop the transmission of test signal I and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified within 5 min.

18) Stop the transmission of test signal A and immediately start the transmission of test signal L (see 6.3). Observe that the position error provided by the EUT is bigger than 10 m (percentile

95%) or the status of EUT operations resumes to GNSS without using SBAS corrections and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

19) Stop the transmission of test signal L and start again the transmission of test signal A. Observe that the position error provided by the EUT is within 10 m (percentile 95%).

20) Stop the transmission of test signal A and immediately start the transmission of test signal E (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 10 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

21) Stop the transmission of test signal E and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified within 5 min.

22) Stop the transmission of test signal A and immediately start the transmission of test signal J (see 6.3). Observe that the EUT removes the satellite/s, whose IOD does not match, from the SBAS position solution within 360 s due to parameter time out.

23) Stop the transmission of test signal J and start again the transmission of test signal A. Observe that the impacted satellites are included again in the SBAS position solution.

24) Stop the transmission of test signal A and immediately start the transmission of test signal K (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 10 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

25) Stop the transmission of test signal K and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified within 5 min.

26) Stop the transmission of test signal A and immediately start the transmission of test signal M (see 6.3). Observe that the status of EUT operations resumes to GNSS without using SBAS corrections within 600 s due to parameter time out and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

27) Stop the transmission of test signal M and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified within 5 min.

28) Stop the transmission of test signal A and immediately start the transmission of test signal N (see 6.3). Observe that EUT removes from the SBAS solution the satellites whose fast corrections are timed out.

29) Stop the transmission of test signal N for at least 6 min. Then, start the transmission of test signal O (see 6.3). Observe that EUT no longer removes the satellite from the SBAS solution after test signal O starts to be transmitted.

30) Stop the transmission of test signal O and start again the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered within 5 min.

31) Stop the transmission of test signal A and immediately start the transmission of test signal P (see 6.3). Observe that the indication of SBAS position status is not lost.

32) Stop the transmission of test signal P and immediately start the transmission of test signal D (see 6.3). Once the status of EUT operations resumes to GNSS without using SBAS corrections and the associated alert is raised as defined in Annex D with an alert ID set to “3056”, stop the transmission of test signal D and start the transmission of test signal Q. Observe that the indication of SBAS status of EUT operation is recovered and the related alert is rectified before going to next step.

33) Stop the transmission of test signal Q and immediately start the transmission of test signal R. Observe that EUT starts to remove progressively satellites from the SBAS solution until there are not enough satellites to provide SBAS solution and the status of EUT operations resumes to GNSS without using SBAS corrections and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

34) Stop the transmission of test signal R and start the transmission of test signal A. Observe that the indication of SBAS status of EUT operation is recovered within 5 min. Check GSN sentence to ensure Service Provider ID is correctly decoded.

35) Stop the transmission of test signal A and immediately start the transmission of test signal S (see 6.3). Check GSN sentence and observe Service Provider ID has been updated within 5 min.

36) Stop the transmission of test signal S and immediately start the transmission of test signal U. Observe that the HPL parameter provided within GFA sentence by the EUT is incremented within 360 s due to degradation parameters time out.

The period of time between the different type signals should be large enough (e.g. > 15 min) to not stress the receiver. If necessary due to GNSS simulator constraints, the different signal types could be executed as different scenarios.

If optional messages are processed and used by the EUT, programmed modification in the SBAS Message Type 9 shall be introduced during a time window (additional test signals, not included in this document, shall be defined as done for the mandatory messages) and observe if some changes appear in the EUT status and/or computed position.

6.10.13.2 Required test results

For each step of the above test sequence, check that the modifications proposed impact on the EUT output and observe that the appropriate indication status is provided.

6.10.14 SBAS GEO satellite selection and switching

(See 4.3.9.2)

6.10.14.1 Method of testing

This test is aimed at checking that the receiver is capable of tracking and processing two SBAS data streams if they are available, as well as switching from one stream to another to maximize the continuity of the service.

The method of test is as follows:

1) the EUT shall be set up under simulated conditions where two SBAS signals (different PRN codes), from the same service provider, are available;
2) after nominal SBAS positioning solution is obtained by the EUT, the SBAS signal that is being used by the receiver shall be removed. Observe that the EUT performs the switch to the remaining SBAS signal;
3) repeat steps 1) and 2) but, in this case, the two SBAS signals configured in the simulator shall belong to two different SBAS service providers. The receiver shall be located in an overlapping service area between both service providers.

6.10.14.2 Required test results

The EUT shall continue providing SBAS positioning by switching to the other SBAS signal without service interruption.

6.10.15 Navigational status indications

6.10.15.1 Position/HDOP alert test

(See 4.3.10.2 and 4.3.10.3)

This is tested using a simulator as follows.

a) Set up the EUT in a simulation environment with HDOP < 4 and with at least one SBAS signal available; select a specific EUT HDOP value as an indication threshold more than 4; modify the simulator output until its HDOP is greater than the EUT specified HDOP threshold; observe that an indication is given at the EUT within 5 s and the associated alert is raised as defined in Annex D with an alert ID set to “3056”.

b) Modify the simulator output until HDOP < 4 and observe that the indication is removed and the related alert is rectified.

c) Switch off transmission of simulated signals and observe that the EUT releases an appropriate indication and alert within 5 s.

d) Verify that the navigational status indicator is set to “unsafe” and the associated alert is raised as defined in Annex D with an alert ID set to “3015”.

e) Verify that the last known position and its time stamp are being displayed indicating the loss of position condition; the alert ID is set to “3015”; verify that this mode with the associated alert is provided constantly on display and output interface until removal of the error condition at the simulation environment.

f) Switch on transmission of simulated signals and observe that the EUT resumes normal operation.

6.10.15.2 Test of integrity monitoring using RAIM with SBAS

(See 4.3.10.5)

6.10.15.2.1 General

For RAIM functionality testing, it is recommended that means are provided for real-time display of the actual position error with reference to the simulated position.

During this test, the equipment shall use SBAS for the position solution.

6.10.15.2.2 Testing of “safe” and “caution” status

The EUT shall be set up under simulated conditions, providing 6 "healthy" GPS satellites available and locked and 1 SBAS satellite under test signal A.

1) Select an accuracy level of 10 m.

2) Observe that:

    a) RAIM is indicated as “in operation”, and;

    b) the “S” (safe) status is indicated in navigational status indicator from GNS or RMC sentence and in RAIM integrity status and SBAS integrity status from GFA sentence.

    c) HPL is provided within the corresponding parameter in the GFA sentence.

3) Reduce the number of satellites monitored by the SBAS to 4. Observe that:

    a) RAIM is still indicated as “in operation”, and;

    b) one of the following situations is provided by the receiver within 10 s of the satellite change that caused it

        I. if SBAS solution is provided, the navigational status indication from GNS or RMC sentence switches to “C” (caution), the SBAS integrity status from GFA sentence switches to “C” (caution) and the associated alert is raised as defined in Annex D with an alert ID set to “3013”.

        II. if GPS only solution is provided, the navigational status indication from GNS or RMC sentence is maintained to “S” (safe).

4) Increase the number of monitored satellites by the SBAS to the original value. Observe that:

    a) RAIM is still indicated as “in operation”, and;

b) in the case the navigational status indication was “C” (caution), the navigational status indication from GNS or RMC sentence switches to “S” (safe), the SBAS integrity status from GFA sentence switches to “S” (safe) and the associated alert is rectified within 10 s of the satellite change that prompted it.

For each step of the above test sequence, observe if the appropriate interface output (as per 4.3.10.5) is provided.

6.10.15.2.3 Testing of “unsafe” status

The EUT shall be set up under simulated conditions, providing 6 "healthy" GPS satellites available, acquired and tracked and 1 SBAS satellite under test signal A.

1) Select and accuracy level of 10 m.
2) Observe that:
   a) RAIM is indicated as “in operation”;
   b) the “S” (safe) status is indicated in navigational status indicator from GNS or RMC sentence and in RAIM integrity status and SBAS integrity status from GFA sentence, and;
   c) HPL is provided within the corresponding parameter in the GFA sentence.
3) Reduce the number of healthy satellites to 5 and apply an unsafe simulated test constellation. This can be accomplished in a controlled manner by adding a suitable ramp to the pseudorange signal or by varying the satellite clocks with the result that the position accuracy gradually degrades until it will no longer be inside the selected accuracy level with 95% confidence level. Observe that:
   a) RAIM is indicated as “in operation”; and
   b) the navigational status indication from GNS or RMC sentence switches to “U” (unsafe) and the associated alert is raised as defined in Annex D with an alert ID set to “3012” within 10s of the time of the unsafe simulated test constellation.

NOTE 1 The GPS pseudorange ramp or clock error injected is not included in the differential corrections in the SBAS messages service to maintain the unsafe simulated test constellation.

4) Change the behaviour of the satellites back to nominal behaviour with the result that the position accuracy will be again inside of the selected accuracy level with 95% confidence level. Observe that
   a) RAIM is still indicated as “in operation”; and
   b) the navigational status indication from GNS or RMC sentence switches to “S” (safe) within 10s.
5) Change the UDREI values to 11 within SBAS Message Types 2, 3, 4, 5, 6 and 24 for all the GPS satellites monitored by the SBAS (test signal T, see 6.3). Observe that:
   a) RAIM is indicated as “in operation”, and;
   b) one of the following situations is provided by the receiver within 10s
      i. if SBAS solution is maintained, the HPL values provided within GFA sentence are increased in comparison with step 2.
      ii. if GPS only solution is provided, the navigational status indication from GNS or RMC sentence is maintained to “S” (safe).

NOTE 2 This step is performed to ensure that EUT uses the SBAS sigmas in the HPL computation.

For each step of the above test sequence, observe if the appropriate interface output (as per 4.3.10.5) is provided.

6.10.15.3 Self-test

(See 4.3.10.6)

The EUT shall be checked for provision of a self-check function of antenna interface, BAM interface, MKD interface or other equipment interfaces by inspection of the manufacturer's documentation.

6.10.16 Test for typical interference conditions

(See 4.3.11)

6.10.16.1 Operator's manual check

The operator's manual shall be inspected to confirm that guidelines are provided for enabling the operator to determine when the interference environment described in 4.3.11 is exceeded.

6.10.16.2 Simulator conditions

The simulator conditions shall be as follows.

- One GPS satellite at a maximum level of -120 dBm plus antenna gain at 90° elevation
- One GPS satellite at a minimum level of -130 dBm plus antenna gain at 5° elevation
- Three GPS satellites at a level of -127dBm plus antenna gain at 45° elevation
- One SBAS satellite at a level of -125dBm

6.10.16.3 Navigation solution accuracy test under typical interference condition

6.10.16.3.1 General

Interference conditions, including broadband noise centred at 1 575,42 MHz, continuous wave interference (CWI), and pulsed interference shall be simulated. For the pulsed interference tests, a pulse-modulated carrier (CW) with peak carrier level of −20 dBm and duty factor of 10% shall be used. The interference values are shown in Table 9, Table 10 and Table 11:

Table 9 – Broad-band interference

Noise bandwidth (MHz)	Total RMS power (dBm)
1	-110,5

Table 10 – Pulsed interference

Frequency (MHz)	Pulse width (ms)
1 575,42	1

Table 11 – Continuous wave interference

Frequency (MHz)	Power (dBm)
1 575,42	-120,5
1 605,0	-50,0

6.10.16.3.2 Method of testing

The method of test is as follows:

1) the equipment under test is subjected to one of the interference sources;
2) the simulator scenario shall be engaged and the satellite signals turned on;
3) the equipment under test shall be powered and initialized;
4) while the EUT is providing SBAS position solution, the interference shall be applied to the equipment under test, and the level of the interference shall be adjusted to the required value according to the corresponding Table 9, Table 10 and Table 11;
5) when steady-state accuracy is reached, record a minimum of 100 positions and HDOP values as reported by the EUT at a rate of one sample every 2 min;

6) repeat this cycle for any remaining interference source and receiver frequency defined in Table 9, Table 10 and Table 11.

6.10.16.3.3 Required test results

If the EUT reports a position with a position error greater than 10 m (percentile 95%) or fails to report a position in more than 5% of the samples, a test failure is declared.

6.10.16.4 Re-acquisition test under typical interference condition

6.10.16.4.1 General

The re-acquisition test is designed to simulate a temporary loss of signal, such as passing under a bridge. To determine the re-acquisition pass/fail criteria, consider a single trial where the EUT provides a valid SBAS position fix that is within required accuracy at 5 min from restoration of the satellite signals, and maintains a tracking status for at least the next 60 s. This unit is considered to have passed one trial.

The interference condition to be tested is shown in Table 12. This is a broadband noise value centred at 1 575,42 MHz.

Table 12 – Broad-band interference

Broad-band interference values	
Noise bandwidth (MHz)	Total RMS power (dBm)
1	-110,5

6.10.16.4.2 Method of testing

The method of test is as follows:

1) the equipment under test is subjected to the broadband interference source;
2) the simulator scenario shall be engaged and the satellite signals turned on;
3) the equipment under test shall be powered and initialized;
4) the EUT shall be allowed to reach steady-state accuracy before the satellites are to be switched off;
5) the simulator RF output shall be removed for 60 s;
6) the simulator RF output shall be restored to the EUT;
7) after 5 min record the SBAS position and HDOP value as reported by the EUT. If no SBAS position report has been sent from the receiver, record a trial failure and go to step 9);
8) ensure that the receiver continues position reporting for the next 60 s;
9) go to Step 4) and repeat as required. (Note that if the simulator scenario is reset, some receivers may require purging of all previous data to enable proper operation. This is due to the persistence of time data in the receiver and the inability of the receiver's software to deal with a backward transition in time).

6.10.16.4.3 Required test results

A failure by the EUT to provide SBAS position output after 5 min, reporting an SBAS position outside the given boundaries (10 m at percentile 95%), or failing to continue position reporting for 60 s after sampling indicates a failure mode, will result in the trial being declared as failure.

6.10.17 Accuracy of COG and SOG

(See 4.3.12.1 and 4.3.12.2)

6.10.17.1 Methods of testing

The EUT shall be set up on an appropriate mobile unit or use a simulator, and all outputs indicating SOG or COG shall be monitored as specified by each step.

a) Constant speed for forward direction.
    a) At a constant forward direction, the forward speed shall be within 0 knots to 1 knot.
    b) Ten seconds after being in the range, measurements of SOG and COG shall be made for duration of 2 min.
    c) This cycle shall be repeated for all speed ranges of the Table 4.

b) Change of speed for forward direction.
    a) Apply constant speed of 1 knot for a period of not less than 15 min.
    b) Increase the speed by increments of 1 knot up to speed of 5 knots and thereafter by increments of 5 knots up to the maximum speed for which the equipment is designed at 5 m/s^2 acceleration.
    c) Observe output of SOG after each change speed.

c) Change of course.
    a) Apply constant speed of 1 knot for a period of not less than 15 min.
    b) Change course once per 6 s by increments of 1º or rate of turn of 10º/min up to a course change of 40º.
    c) Observe output of COG after each change of 1º of course.
    d) This cycle shall be repeated for all speed ranges of the Table 4.

6.10.17.2 Required test results

The test results shall be observed on the display and the approved interface.

For SOG tests, no reading of the speed indicator shall differ from the constant speed being applied at the time by more than 2 % of that speed or 0,2 knots, whichever is the greater.

For COG tests, the differences between the reference direction and measured COG in each test cycle shall not exceed the limits of Table 4.

6.10.18 Validity of COG and SOG information

(See 4.3.12.1 and 4.3.12.2)

6.10.18.1 Methods of testing

The mode indicator of the GNS and VTG sentence is used for interpretation of validity of COG and SOG. With the EUT normally operating, preclude invalid position data by reducing the number of received satellites. Investigate the content of the resultant GNS and VTG sentences.

6.10.18.2 Required test results

Observe that the mode indicators of GNS and VTG sentences turn to “N” to indicate no fix.

Observe that the COG and SOG information contained in VTG sentence is replaced by null fields.

6.10.19 Output of UTC

(See 4.3.12.3)

6.10.19.1 Methods of testing

While the EUT is navigating, provoke an invalid position by reducing the number of received satellites to two. Investigate the content of the GNS and ZDA sentences provided.

6.10.19.2 Required test results

Observe that the resolution of UTC information contained in the ZDA sentence is as specified in 4.3.12.3. Observe that the mode indicator of GNS sentence turns to “N” to indicate no fix. Observe that the ZDA sentence remains transmitted carrying complete UTC information.

6.10.20 Validation material for tropospheric model

(See A.3)

Validation material (e.g. maps showing performance comparison) shall be inspected to check that tropospheric model used by the receiver does not degrade the performance obtained with the tropospheric algorithm defined in A.4.2.4 of RTCA DO-229:2020.

Annex A

(normative)

High level procedure for SBAS navigation computation

A.1 GPS L1 signal processing

The equipment tracks GPS satellites, processing the GPS L1 signals and navigation data as performed by GPS receiver equipment. A description of the GPS signal is given in IS-GPS-200N.

The equipment acquires the main C/A code correlation peak for each GPS ranging source used for the navigation solution.

For SBAS-based position, the position determination shall not include satellites (GPS or SBAS) with elevation angles below 5° (a recommended elevation angle for maritime applications is between 7° and 10° considering multipath reflection from the water).

Afterwards, it is recommended to:

– use a smoothing filter to smooth pseudoranges with carrier phase measurements (a recommended time constant is 100 s);

– detect a pseudorange step, excluding that satellite for the position solution (500 m is recommended as step threshold considering vessel speed);

– monitor the quality of the satellite signal, excluding any potential measurements faults (e.g. low carrier power to noise (C/N_0), code carrier phase consistency…).

A.2 SBAS L1 signal processing

The equipment tracks and process SBAS L1 signal meeting the signal processing requirements stated in 2.1.1.3 of RTCA DO-229:2020.

If available, the equipment tracks and process a second SBAS signal to ensure continued performance in the event of losing the SBAS primary signal.

Some recommended methods for SBAS satellite selection are: to select SBAS satellite that provides best HDOP for the GPS satellites which are designated SBAS HEALTHY or to select the SBAS satellite with highest elevation.

A.3 Application of SBAS messages

Detailed specification of SBAS messages, format, data contents and processing is provided in Appendix A of RTCA DO-229:2020.

The following SBAS messages shall be processed.

- Check the non-usability of the SBAS for safety applications through Message Type 0 (see 2.1.1.4.1 of RTCA DO-229:2020).

- Decode and apply the PRN mask of available satellite through Message Type 1 (see 2.1.1.4.2 of RTCA DO-229:2020).

- Decode and apply fast corrections and UDREI information (broadcast through Message Types 2 to 5 and 24 corresponding to satellites selected by Message Type 1) for healthy satellites with UDREI < 12 considering the fast corrections degradation factor indicator (ai_i) from Message Type 7 (see 2.1.1.4.3 of RTCA DO-229:2020)

- Decode and apply long-term satellite corrections (broadcast though Message Types 24 and 25 corresponding to satellites selected by Message Type 1) for healthy satellites with UDREI < 12 (see 2.1.1.4.11 of RTCA DO-229:2020).
- Decode and apply ionospheric corrections and GIVEI indicators (broadcast through Message Type 26 for ionospheric grid points defined by Message Type 18) considering monitored IGPs (GIVEI < 15) (see 2.1.4.9.4 of RTCA DO-229:2020).
- Apply tropospheric error corrections following a tropospheric model (performance shall not degrade those reached by the acceptable algorithm defined in A.4.2.4 of RTCA DO-229:2020).
- Take into account warnings broadcast by the SBAS:
    - satellite alerts (SV set to “Do not Use”/UDREI=15) in Message Types 2 to 6 and 24 (see 2.1.1.4.4 of RTCA DO-229:2020);
    - ionospheric alerts (IGPs set to “Do not Use”/Vertical delay of 63,875 m (111111111)) in Message Type 26.
- Use SBAS messages until they have timed out or a new message for the same message type is received. The SBAS Maritime Navigation Timeouts to be considered are equal to the ones defined as “En route”, “Terminal”, “Approach” (LNAV) Timeout from Table 2-1 of RTCA DO-229:2020.
    - Message Type 7 contains information for computing the timeout interval for fast corrections.
    - In the event of not receiving valid SBAS message for 4 consecutive seconds, all UDREI data from that SBAS satellite are timeout
- If Message Type 27 or 28 is received, the factor for user location δUDRE shall be computed as indicated in RTCA DO-229:2020.
- Satellites with $\sigma_{i,flt}^2 \geq 230{,}9661$ (equivalent to UDREI ≥ 12) shall not be used for the SBAS solution computation (see A.4.3 for $\sigma_{i,flt}^2$ computation).
- decode and output the service provider ID from Message Type 17.
- For the estimation of the SBAS-based standard deviation of satellite pseudorange measurement residual error, use the degradation parameters and the SBAS regional messages (see A.4.3):
    - process Message Types 7, 10, 27 and 28 for the computation of the variance of fast and long term corrections residuals.

Optionally, it is recommended that the receiver:

- process almanac data from SBAS satellites broadcast through Message Type 17 for tracking purposes and estimate the SBAS satellite elevation angle (a potential usage may be SBAS satellite selection);
- is able to configure the service provider to be used;
- if SBAS ranging is available, it is recommended using the augmentation satellite ranging function (broadcast through Message Type 9).

The equipment applies SBAS corrections to each usable satellite pseudorange $\boldsymbol{i}$ (after completed tasks stated in A.1, such as smoothing filter) as:

$$PR_{i,corrected}(t) = PR_{i,measured}(t) + PRC_i(t_{i,of}) + RRC_i(t_{i,of}) \times (t - t_{i,of}) + TC_i + IC_i \quad (1)$$

Where

$PR_{i,measured}$ is the measured pseudorange after smoothing and the associated quality checks,

PRC_i and RRC_i are the Pseudo Range Correction and the Range-Rate Correction computed from Message Types 2-5,

TC_i is the tropospheric correction,

IC_i is the ionospheric correction computed from Message Type 26 and

$t_{i,of}$ is the time of applicability of the most recent fast correction.

A.4 SBAS position computation

A.4.1 General

The equipment applies SBAS corrections (clock, ephemeris and ionospheric corrections) and integrity information extracted from the decoded messages (as explained in A.3) to all smoothed satellite pseudoranges not discarded (as stated in A.1) used to compute SBAS position solution.

Afterwards, the equipment computes SBAS position for the selected SBAS satellite at least once every 1 second.

SBAS position can be computed by iteration using the weighted least-squares algorithm from an initial estimated position, using as weights the inverse of the SBAS-based standard residual error (see A.4.2).

Other methods could be used (e.g. Kalman Filter) if the manufacturer demonstrates that there is no degradation on the accuracy performance and on the integrity performance as described in 4.3.10.5.

A.4.2 Weighted least squares algorithm

Considering $\boldsymbol{x_0} = \left(x_0, y_0, z_0, t_{0,c}\right)$ the initial estimation position and clock, the estimated SBAS position and clocks at every state estimate are given by:

$$\hat{x} = x_0 + \Delta\hat{x}. \tag{2}$$

$$\Delta\hat{x} = (G^T W G)^{-1} G^T W \Delta\rho \tag{3}$$

where

$\hat{x}$ is the SBAS navigation solution after convergence of the weighted least squares algorithm (when $\Delta\hat{x} < \varepsilon$ after iteration),

$\Delta\hat{x}$ is the estimation of the delta receiver's four dimensional position vector with respect the initial position x_0 (dx, dy, dz and clock),

$\Delta\rho = PR_{i,corrected} - \rho_{i,0}$ is an *N* dimensional vector (being N the number of used satellites $\boldsymbol{i}$) containing the SBAS corrected pseudorange measurements (computed in A.3) minus the expected ranging values based on the location of the satellites and the approximate location of the user (x_0),

G is the receiver-satellite geometry matrix, computed per satellite $\boldsymbol{i}$ as:

$$G_i = [-\cos(El_i)\sin(Az_i) \quad -\cos(El_i)\cos(Az_i) \quad -\sin(El_i) \quad 1] = i^{th} \text{ row of G} \tag{4}$$

W is the weighting matrix, using as weights the inverse of the SBAS-based standard residual error per satellite i (σ_i^2 as explained in A.4.3)

$$W = \begin{bmatrix} w_1 & 0 & 0 & 0 \\ 0 & w_2 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & w_N \end{bmatrix}, w_i = 1/\sigma_i^2. \quad (5)$$

A.4.3 SBAS-based standard residual error

A SBAS-based standard residual error of GPS satellite $\boldsymbol{i}$ pseudorange measurements is:

$$\sigma_i^2 = \sigma_{i,flt}^2 + \sigma_{i,UIRE}^2 + \sigma_{i,ship}^2 + \sigma_{i,tropo}^2 \quad (6)$$

Where

$\sigma_{i,flt}^2$ is the fast and long-term correction residual variance derived from Message Type 2-6, 24 and 25, as described in RTCA DO-229**.**

$\sigma_{i,UIRE}^2$ is the is the ionospheric delay estimation error computed from Message Type 26, as described in RTCA DO-229.

$\sigma_{i,ship}^2$ is the of shipborne receiver errors variance estimation.

$\sigma_{i,tropo}^2$ is the tropospheric delay estimation errors.

Residual errors related to clock, orbit and ionosphere shall be derived from sigmas ($\sigma_{i,flt}^2$ and $\sigma_{i,UIRE}^2$) provided by the SBAS messages according to RTCA DO-229, whereas the estimate of remaining residuals are left to the receiver manufacturer.

When Message Type 10 is not available:

$$\sigma_{i,flt}^2 = (\sigma_{i,UDRE} * \delta UDRE + 8m)^2$$

This sigma error estimation per satellite shall be used for:

1) weights of the linearized, weighted least-squares solution (see A.4.2),
2) estimation of the position accuracy
3) integrity monitoring algorithm

Annex B
(normative)

Sentences to support SBAS L1 receiver operation

B.1 General

Annex B describes details of amended sentences used to support SBAS L1 receiver operation and one new sentence GSN.

Refer to IEC 61162-1 for possible later versions of these sentences.

B.2 GBS – GNSS satellite fault detection

This sentence is used to support Receiver Autonomous Integrity Monitoring (RAIM). Given that a GNSS receiver is tracking enough satellites to perform an integrity check of the position solution, a sentence is needed to report the output of this process to other systems to advise the system user. With the RAIM in the GNSS receiver, the receiver can isolate faults to individual satellites and not use them in its position and velocity calculations. Also the GNSS receiver can still track the satellite and easily judge when it is back within tolerance. This sentence is used for reporting this RAIM information. To perform this integrity function, the GNSS receiver should have at least two observables in addition to the minimum required for navigation. Normally, these observables take the form of additional redundant satellites.

If only GPS, GLONASS, Galileo, BDS, QZSS or NavIC (IRNSS) is used for the reported position solution, the talker ID is GP, GL, GA, GB, GQ or GI respectively and the errors pertain to the individual system. If satellites from multiple systems are used to obtain the reported position solution, the talker ID is GN and the errors pertain to the combined solution.

$--GBS, hhmmss.ss, x.x, x.x, x.x, xx, x.x, x.x, x.x, h, h*hh <CR><LF>

GNSS Signal ID 4)
GNSS System ID 3)
Standard deviation of bias estimate
Estimate of bias on most likely failed satellite (in metres)
Probability of missed detection for most likely failed satellite
ID number of most likely failed satellite 2)
Expected error in altitude 1)
Expected error in longitude 1)
Expected error in latitude 1)
UTC time of the GGA or GNS fix associated with this sentence

Comments:

1) Expected error in metres due to bias, with noise = 0.

2) Satellite ID numbers. See table below to determine the meaning of the SV IDs. When the Talker ID is GN, the GNSS System ID provides the only method to determine the meaning of the SVIDs. The GNSS System ID field shall not be null.

3) GNSS System ID identifies a specific GNSS System according to the table below.

4) The GNSS Signal ID identifies the Signal Channel according to the table below, being used for all satellites in this sentence. This field shall not be null.

System	System ID	Satellite ID	Signal ID	Signal/Channel
GPS	1 (GP)	1 to 99	0	All signals
		1 to 63 is reserved for GPS	1	L1 C/A
		64 to 99 is undefined	2	L1 P(Y)
			3	L1 M
			4	L2 P(Y)
			5	L2C-M
			6	L2C-L
			7	L5-I
			8	L5-Q
			9 to F	Reserved
GLONASS	2 (GL)	65 to 99	0	All signals
		65 to 99 is reserved for	1	G1 C/A
		GLONASS	2	G1 P
		To maintain SV ID Legacy support, GLONASS satellites are identified by 64+satellite slot number. The slot numbers are 1 through 24 for the full GLONASS constellation of 24 satellites; this gives a range of 65 through 88.	3 4	G2 C/A GLONASS (M) G2 P
		The numbers 89 through 99 are available if slot numbers above 24 are allocated to on-orbit spares.	5 to F	Reserved
Galileo	3 (GA)	1 to 99	0	All signals
		1 to 36 is reserved for	1	E5a
		Galileo SVs	2	E5b
		65 to 99 is undefined	3	E5 a+b
			4	E6-A
			5	E6-BC
			6	E1-B
			7	E1-C
			8 to F	Reserved
BDS	4 (GB)	1 to 99	0	All signals
		1 to 64 is reserved for BDS	1	B1I
		65 to 99 is undefined	2	B1Q
			3	B1C
			4	B1A

System	System ID	Satellite ID	Signal ID	Signal/Channel
			5 6 7 8 9 A B C D to F	B2a B2b B2 a+b B3I B3Q B3A B2I B2Q Reserved
QZSS	5 (GQ)	0 to 99 0 to 18 and 55 to 63 are reserved for QZSS satellites 19 to 54 and 64 to 99 is undefined QZSS Satellite ID is the 6 LSBs of the 8 bit PRN Number (i.e. Satellite ID of PRN 193 is 1).	0 1 2 3 4 5 6 7 8 9 A B C to F	All signals L1 C/A L1C (D) L1C (P) L1S L2C-M L2C-L L5-I L5-Q L6D L6E L1 C/B Reserved
NavIC (IRNSS)	6 (GI)	1 to 99 1 to 15 is reserved for NavIC (IRNSS) 16 to 32 is undefined 65 to 99 is undefined	0 1 2 3 4 5 6 to F	All signals L5-SPS S-SPS L5-RS S-RS L1-SPS Reserved
SBAS Satellite Based Augmentation System	7	33 - 71 is reserved for SBAS (SBAS PRNs 120 through 158) - 87 = SV ID, i.e. PRN 120 – 87 = SV ID 33 This supports the legacy SV ID values for SBAS.	0 1 2 – 6 7 8 - F	All signals L1 C/A Reserved L5I Reserved
RESERVED	8 to F			

B.3 GFA – GNSS Fix Accuracy and Integrity

This sentence is used to report the results of the data quality and integrity check associated with a position solution to other systems and to advise the system user.

The integrity sources used by the receiver separately or in combination are specified within this GFA sentence by the integrity status field for each of the sources listed in comment 3. There are direct relationships between the values of integrity status of the integrity sources and the navigational status indicator provided by the RMC and GNS sentences, see GFA sentence comment 3.

If only a single constellation (GPS, GLONASS, Galileo, BDS, QZSS or NavIC (IRNSS)) is used for the reported position solution, the talker ID is GP, GL, GA, GB, GQ or GI respectively and the data pertain to the individual system. If satellites from multiple systems are used to obtain the reported position solution, the talker ID is GN and the parameters pertain to the combined solution. This sentence provides the quality data of the position fix and shall be associated with the GNS sentence.

```
$--GFA,hhmmss.ss,x.x,x.x,x.x,x.x,x.x,x.x,x.x,c--c*hh<CR><LF>
         |        |   |   |   |   |   |   |   |
         |        |   |   |   |   |   |   |   └── Integrity status 3)
         |        |   |   |   |   |   |   └── Selected accuracy level (m) 2)
         |        |   |   |   |   |   └── Standard deviation of altitude (m)
         |        |   |   |   |   └── Orientation of semi-major axis of error ellipse (deg) 1)
         |        |   |   |   └── Standard deviation of semi-minor axis of error ellipse (m)
         |        |   |   └── Standard deviation of semi-major axis of error ellipse (m)
         |        |   └── Vertical protection level (m)
         |        └── Horizontal protection level (m)
         └── UTC time of GNS or RMC fix associated with this
```

Comments:

1) Degrees from true north.

2) The selected accuracy level will be in accordance with IMO Res. A.1046(27) for Ocean operations and Appendix 2 of IMO Res. A.915(22) for the rest of operations.

3) The integrity status field is a variable length character field which indicates the status of the various integrity sources. Status of the GNSS position fix solution is dependent upon the value of the RMC or GNS sentence's Navigational Status indicator. Three integrity sources are currently defined; RAIM (first character), SBAS (second character) and GNSS constellation integrity navigation message and Health Status flags (including Galileo integrity channel (GIC) (third character)). If additional integrity sources (i.e. terrestrial broadcast or other satellite system integrity channels) are added to the standard, the Integrity status field will be extended. New integrity sources shall always be added on the right, so the order of characters in the Integrity Status Field is maintained. This field shall not be a null field and the characters shall take one of the following values:

V = Not in use

S = Safe (when integrity is available and HPL<HAL)

C = Caution (when integrity is not available)

U = Unsafe (when integrity is monitored but the condition for the "Safe" status cannot be assured

B.4 GNS – GNSS fix data

Fix data for single or combined satellite navigation systems (GNSS). This sentence provides fix data for GPS, GLONASS, Galileo, BDS, QZSS, NavIC (IRNSS) and possible future satellite systems and systems combining these.

The GFA sentence provides Accuracy and Integrity Status of one or more integrity sources used in the position fix reported by this sentence. The UTC of position is used to link this sentence with a GFA sentence.

This sentence could be used with the talker identification of GP for GPS, GL for GLONASS, GA for Galileo, GB for BDS, GQ for QZSS, GI for NavIC (IRNSS) and GN for GNSS combined systems, as well as future identifiers. Some fields may be null fields for certain applications, as described below.

If a GNSS receiver is capable simultaneously of producing a position using combined satellite systems, as well as a position using only one of the satellite systems, then separate $GPGNS, $GLGNS, etc. sentences may be used to report the data calculated from the individual systems.

If a GNSS receiver is set up to use more than one satellite system, but for some reason one or more of the systems are not available, then it may continue to report the positions using $GNGNS, and use the mode indicator to show which satellite systems are being used.

Navigational status indicator 7)
Differential source ID 6)
Age of differential data 5)
Geoidal separation, m 4)
Antenna altitude, m
re: mean-sea-level (geoid)

$-- GNS, hhmmss.ss,llll.ll,a,yyyyy.yy,a,c--c,xx,x.x,x.x,x.x,x.x,x.x,a*hh<CR><LF>

HDOP 3)
Total number of satellites in use, 00-99 2)
Mode indicator 1)
Longitude, E/W
Latitude, N/S
UTC of position

Comments:

1) Mode indicator. A variable length valid character field type with the first six characters currently defined. The first character indicates the use of GPS satellites, the second character indicates the use of GLONASS satellites and the third indicate the use of Galileo satellites, the fourth character indicates the use of BDS satellites; the fifth character indicates the use of QZSS satellites; the sixth character indicates the use of NavIC (IRNSS) satellites. If another satellite system is added to the standard, the mode indicator will be extended with more characters. New satellite systems shall always be added on the right, so the order of characters in the mode indicator is: GPS, GLONASS, Galileo, BDS, QZSS, NavIC (IRNSS) and other satellite systems in the future. The characters shall take one of the following values:

   A = Autonomous. Satellite system used in non-differential mode in position fix

   D = Differential. Satellite system used in differential mode in position fix. Correction from ground stations or Satellite Based Augmentation Systems (SBAS).

   E = Estimated (dead reckoning) mode

   F = Float RTK. Satellite system used in real time kinematic mode with floating ambiguity estimates

   M = Manual input mode

   N = No fix. Satellite system not used in position fix, or fix not valid

   P = Precise. Satellite system used in precision mode. Precision mode is defined as: no deliberate degradation (such as selective availability) and higher resolution code (i.e. GPS P-code) is used to compute position fix. P is also used for satellite system used in multi-frequency, such as Precise Point Positioning (PPP) mode

   R = Real Time Kinematic. Satellite system used in RTK mode with fixed integers

   S = Simulator mode

   The mode Indicator does not differentiate between single and multi-frequency solutions. The multi-frequency solution is indicated through the reporting of multiple GSA sentences as indicated in GSA sentence's comment 3. The mode indicator shall not be a null field.

   Examples:

   Using GPS receiver:

   $GPGNS,122310.2,3722.425671,N,12258.856215,W,A,14,0.9,1005.543,6.5,5.2,23,S*54<CR><LF>

   Also possible:

   $GPGNS,122310.2,3722.425671,N,12258.856215,W,AN,14,0.9,1005.543,6.5,5.2,23,S*1A<CR><LF>

   $GPGNS,122310.2,3722.425671,N,12258.856215,W,ANN,14,0.9,1005.543,6.5,5.2,23,S*54<CR><LF>

   Using GLONASS receiver:

   $GLGNS,122310.2,3722.425671,N,12258.856215,W,NA,14,0.9,1005.543,6.5,5.2,23,S*06<CR><LF>

   Also possible:

   $GLGNS,122310.2,3722.425671,N,12258.856215,W,NAN,14,0.9,1005.543,6.5,5.2,23,S*48<CR><LF>

   Using Galileo receiver:

   $GAGNS,122310.2,3722.425671,N,12258.856215,W,NNA,14,0.9,1005.543,6.5,5.2,23,S*45<CR><LF

   Using BDS receiver:

   $GBGNS,122310.2,3722.425671,N,12258.856215,W,NNNA,14,0.9,1005.543,6.5,,,S*08<CR><LF>

Using QZSS receiver:

$GQGNS,122310.2,3722.425671,N,12258.856215,W,NNNNA,14,0.9,1005.543,6.5,,,S*55<CR><LF>

Using NavIC (IRNSS) receiver:

$GIGNS,122310.2,3722.425671,N,12258.856215,W,NNNNNA,14,0.9,1005.543,6.5,,,S*03<CR><LF>

Using combined system with GPS and differential GLONASS:

$GNGNS,122310.2,3722.425671,N,12258.856215,W,AD,14,0.9,1005.543,6.5,5.2,23,S*26<CR><LF>

Also possible:

$GNGNS,122310.2,3722.425671,N,12258.856215,W,ADN,14,0.9,1005.543,6.5,5.2,23,S*68<CR><LF>

Using combined system with differential GPS, GLONASS and Galileo:

$GNGNS,122310.2,3722.425671,N,12258.856215,W,DAA,14,0.9,1005.543,6.5,5.2,23,S*67<CR><LF>

In the following example the sentence exceeds the maximum sentence length of 82 characters and shall not be used. The maximum number of all characters in a sentence shall be 82, consisting of a maximum of 79 characters between the starting delimiter "$" or "!" and the terminating <CR><LF>.

Using combined system with differential GPS, GLONASS, Galileo and BDS: In this example, this is an 83 character sentence, where the second character of the checksum “6” is the 80th character, exceeding the 79 character requirement.

$GNGNS,122310.2,3722.425671,N,12258.856215,W,DAAA,14,0.9,1005.543,6.5,5.2,23,S*26<CR><LF>

The following sentences illustrate one way to provide the data without exceeding maximum sentence length, by reporting the Differential Age and Differential source ID in a separate sentence. Another solution could be to reduce the number of decimal digits of the position information:

Using combined system with differential GPS and non-differential GLONASS, Galileo, and BDS:

$GNGNS,122310.2,3722.425671,N,12258.856215,W,DAAA,14,0.9,1005.543,6.5,,,S*0E<CR><LF>

$GPGNS,122310.2,,,,,,07,,,,5.2,23,S*02<CR><LF>

Using combined system with differential GPS and non-differential GLONASS, Galileo, BDS, QZSS, and NavIC (IRNSS):

$GNGNS,122310.2,3722.425671,N,12258.856215,W,DAAAAA,14,0.9,1005.543,6.5,,,S*0E<CR><LF>

$GPGNS,122310.2,,,,,,07,,,,5.2,23,S*02<CR><LF>

2) Total number of satellites in use: The total number of satellites in use includes all satellites used to produce the navigation solution. This includes any SBAS satellites used in ranging mode, identified in the GSA sentence. This number does not include any SBAS satellite used for accuracy and integrity augmentation as identified in the Differential source ID field of this sentence.

3) HDOP calculated using all the satellites (GPS, GLONASS, Galileo, BDS, QZSS, NavIC (IRNSS) and any future satellites) used in computing the solution reported in each GNS sentence. This includes any SBAS satellites used in ranging mode, identified in the GSA sentence. This number does not include any SBAS satellite used for accuracy and integrity augmentation as identified in the Differential source ID field of this sentence.

4) Geoidal separation: the difference between the earth ellipsoid surface and mean-sea-level (geoid) surface defined by the reference datum used in the position solution, “-” = mean-sea-level surface below ellipsoid. The reference datum may be specified in the DTM sentence.

5) Age of differential data:

- For GPS reference station differential source data:

  This value is the average age of the most recent differential corrections in use. When only RTCM 10402 Type 1 corrections are used, the age is that of the most recent Type 1 correction. When RTCM 10402 Type 9 corrections are used solely, or in combination with Type 1 corrections, the age is the average of the most recent corrections for the satellites used. Null field when differential GPS is not used. RTCM 10403 may also be used to provide corrections.

- For GLONASS reference station differential source data:

  This value is the average age of the most recent differential corrections in use. When only RTCM 10402 Type 31 corrections are used, the age is that of the most recent Type 31 correction. When RTCM 10402 Type 34 corrections are used solely, or in combination with Type 31 corrections, the age is the average of the most recent corrections for the satellites used. Null field when differential GLONASS is not used. RTCM 10403 may also be used to provide corrections.

- For Galileo reference station differential source data:

  This value is the average age of the most recent differential corrections in use. When only RTCM 10402 Type 41 corrections are used, the age is that of the most recent Type 41 correction. When RTCM 10402 Type 42 corrections are used solely, or in combination with Type 41 corrections, the age is the average of the most recent corrections for the satellites used. Null field when differential Galileo is not used. RTCM 10403 may also be used to provide corrections.

- The age of differential data for other GNSS constellations, is described in RTCM 10402 and 10403.

- For differential data received from SBAS satellites:

  For SBAS L1, this value is the oldest age of the most recent fast corrections set in use (received through messages types 2, 3, 4, 5 and 24). For example, if MT2, 3 and 4 are used for satellite fast corrections, the age of differential data will be the time frame since the application of the oldest between these 3 messages, MT2, MT3 and MT4.

  For SBAS L5 (Dual Frequency Multi-Constellation), this value is the oldest age of the most recent satellite corrections set in use received from MT32.

6) Differential source ID:

The Differential source ID may be the same or different for the different GNSS systems.

The Differential source ID range for legacy differential reference stations that are not assigned a GBAS PRN number is 0 to 1023.

The Differential source ID range for SBAS satellites is defined to be from 1120 to 1158, where the right most three digits represent the SBAS Satellite's Assigned PRN number. Subtracting 1087 from these SBAS Differential source IDs will yield the corresponding SV ID values shown in the table below for SBAS satellites.

The Differential source ID range for GBAS is defined to be from 1064 to 1119, where the right most three digits represent the GBAS Assigned PRN number.

Differential data may be received from sources other than Reference Stations, GBAS and SBAS, and applies to any source as indicated by the Mode Indicator and Comment 1.

When the talker is GN and more than one of the satellite systems are used in differential mode, then the "Age of differential data" and "Differential source ID" fields shall be null fields. In this case, the "Age of differential data" and "Differential source ID" fields shall be provided in following GNS sentences with talker IDs of GP, GL, GB, GA, GQ, GI, etc. These following GNS messages shall have the latitude, N/S, longitude, E/W, altitude, geoidal separation, mode, and HDOP as null fields. This indicates to the listener that the field is supporting a previous $GNGNS sentence with the same time tag. The "Total number of satellites in use" field may be used in these following sentences to denote the number of satellites used from that satellite system.

Example: A combined GPS/GLONASS receiver using only GPS differential corrections has the following GNS sentence sent.

$GNGNS,122310.2,3722.425671,N,12258.856215,W,DA,14,0.9,1005.543,6.5,5.2,23,S*26<CR><LF>

Example: A combined GPS/GLONASS receiver using both GPS differential corrections and GLONASS differential corrections may have the following three GNS sentences sent in a group.

$GNGNS,122310.2,3722.425671,N,12258.856215,W,DD,14,0.9,1005.543,6.5,,,S*0B<CR><LF>

$GPGNS,122310.2,,,,,,07,,,,5.2,23,S*02<CR><LF>

$GLGNS,122310.2,,,,,,07,,,,3.0,23,S*1A<CR><LF>

7) The navigational status indicator is according to IEC 61108 requirements on 'Navigational (or Failure) warnings and status indications'. This field shall not be a null field and the character shall take one of the following values:

S = Safe when the estimated positioning accuracy (95 % confidence) is within the selected accuracy level corresponding to the actual navigation mode, and integrity is available and within the requirements for the actual navigation mode, and a new valid position has been calculated within 1 s for a conventional craft and 0,5 s for a high speed craft

C = Caution when integrity is not available

U = Unsafe when the estimated positioning accuracy (95 % confidence) is less than the selected accuracy level corresponding to the actual navigation mode, and/or integrity is available but exceeds the requirements for the actual navigation mode, and/or a new valid position has not been calculated within 1 s for a conventional craft and 0,5 s for a high speed craft

V = Navigational status not valid, equipment is not providing navigational status indication.

If the Navigational Status Indicator is set to 'S', at least one Integrity source of those reported in the Integrity Status field in the GFA sentence will be set to 'S' (the decision can depend on the weighting or integrity source selection algorithm within the receiver). See the GFA sentences for more information on Accuracy and Integrity.

System	System ID	Satellite ID	Signal ID	Signal/Channel
GPS	1 (GP)	1 to 99	0	All signals
		1 to 63 is reserved for GPS	1	L1 C/A
		64 to 99 is undefined	2	L1 P(Y)

System	System ID	Satellite ID	Signal ID	Signal/Channel
			3	L1 M
			4	L2 P(Y)
			5	L2C-M
			6	L2C-L
			7	L5-I
			8	L5-Q
			9 to F	Reserved
GLONASS	2 (GL)	65 to 99	0	All signals
		65 to 99 is reserved for	1	G1 C/A
		GLONASS	2	G1 P
		To maintain SV ID Legacy support, GLONASS satellites are identified by 64+satellite slot number. The slot numbers are 1 through 24 for the full GLONASS constellation of 24 satellites; this gives a range of 65 through 88. The numbers 89 through 99 are available if slot numbers above 24 are allocated to on-orbit spares.	3	G2 C/A
			4	GLONASS (M) G2 P
			5 to F	Reserved
Galileo	3 (GA)	1 to 99	0	All signals
		1 to 36 is reserved for	1	E5a
		Galileo SVs	2	E5b
		65 to 99 is undefined	3	E5 a+b
			4	E6-A
			5	E6-BC
			6	E1-B
			7	E1-C
			8 to F	Reserved
BDS	4 (GB)	1 to 99	0	All signals
		1 to 64 is reserved for BDS	1	B1I
		65 to 99 is undefined	2	B1Q
			3	B1C
			4	B1A
			5	B2a
			6	B2b
			7	B2 a+b
			8	B3I
			9	B3Q
			A	B3A
			B	B2I
			C	B2Q
			D to F	Reserved
QZSS	5 (GQ)	0 to 99	0	All signals
		0 to 18 and 55 to 63 are	1	L1 C/A

System	System ID	Satellite ID	Signal ID	Signal/Channel
		reserved for QZSS satellites 19 to 54 and 64 to 99 is undefined QZSS Satellite ID is the 6 LSBs of the 8 bit PRN Number (i.e. Satellite ID of PRN 193 is 1).	2 3 4 5 6 7 8 9 A B C to F	L1C (D) L1C (P) L1S L2C-M L2C-L L5-I L5-Q L6D L6E L1 C/B Reserved
NavIC (IRNSS)	6 (GI)	1 to 99 1 to 15 is reserved for NavIC (IRNSS) 16 to 32 is undefined 65 to 99 is undefined	0 1 2 3 4 5 6 to F	All signals L5-SPS S-SPS L5-RS S-RS L1-SPS Reserved
SBAS Satellite Based Augmentation System	7	33 - 71 is reserved for SBAS (SBAS PRNs 120 through 158) - 87 = SV ID, i.e. PRN 120 – 87 = SV ID 33 This supports the legacy SV ID values for SBAS.	0 1 2 – 6 7 8 - F	All signals L1 C/A Reserved L5I Reserved
RESERVED	8 to F			

B.5 GRS – GNSS Range residuals

This sentence is used to support Receiver Autonomous Integrity Monitoring (RAIM). Range residuals can be computed in two ways for this process. The basic measurement integration cycle of most navigation filters generates a set of residuals and uses these to update the position state of the receiver.

These residuals can be reported with GRS, but because of the fact that these were used to generate the navigation solution they should be recomputed using the new solution in order to reflect the residuals for the position solution in the GNS sentence.

The Mode field indicates which computation method was used. An integrity process that uses these range residuals would also require GNS, the GSA, and the GSV sentences to be sent.

If only GPS, GLONASS, Galileo, BDS, QZSS or NavIC (IRNSS) is used for the reported position solution the talker ID is GP, GL, GA, GB, GQ, GI respectively and the range residuals pertain to the individual system.

If GPS, GLONASS, Galileo, BDS, QZSS or NavIC (IRNSS) are combined to obtain the position solution multiple GRS sentences are produced, one with the GPS satellites, another with the GLONASS satellites, another with Galileo satellites, etc. Each of these GRS sentences shall have talker ID “GN”, to indicate that the satellites are used in a combined solution. The GNSS System ID data field identifies the specific satellite system. It is important to distinguish the residuals from those that would be produced by a GPS-only, GLONASS-only, Galileo-only, etc.

position solution. In general the residuals for a combined solution will be different from the residual for a GPS-only, GLONASS-only, Galileo-only, etc. solution.

```
                                             Signal ID 5) ──┐
                                   GNSS System ID 4) ──┐    │
$--GRS, hhmmss.ss,x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,h,h*hh<CR><LF>
```

- Range residuals for satellites used in the navigation solution 1) 2) Order shall match the order of satellite ID numbers in GSA. When GRS is used, GSA and GSV are generally required. Null fields for unused fields 3)
- Mode: 0 = residuals were used to calculate the position given in the matching GGA or GNS sentence; 1 = residuals were recomputed after the GGA or GNS
- UTC time of the GGA or GNS fix associated with this sentence

Comments:

1) If the range residual exceeds ±99,9 m, then the decimal part is dropped, resulting in an integer (–103,7 becomes –103). The maximum value for this field is ±999.
2) The sense or sign of the range residual is determined by the order of parameters used in the calculation. The expected order is as follows: range residual = calculated range – measured range.
3) When multiple GRS sentences are being sent then their order of transmission shall match the order of corresponding GSA sentences. Listeners shall keep track of pairs of GSA and GRS sentences and discard data if pairs are incomplete.
4) GNSS System ID, see table below.
5) Signal ID identifies the actual ranging signal according to the table below.

System	System ID	Satellite ID	Signal ID	Signal/Channel
GPS	1 (GP)	1 to 99	0	All signals
		1 to 63 is reserved for GPS	1	L1 C/A
		64 to 99 is undefined	2	L1 P(Y)
			3	L1 M
			4	L2 P(Y)
			5	L2C-M
			6	L2C-L
			7	L5-I
			8	L5-Q
			9 to F	Reserved
GLONASS	2 (GL)	65 to 99	0	All signals
		65 to 99 is reserved for	1	G1 C/A
		GLONASS	2	G1 P
		To maintain SV ID Legacy support, GLONASS satellites are identified by 64+satellite slot number. The slot numbers are 1 through 24 for the full GLONASS constellation of 24 satellites; this gives a range of 65 through 88. The numbers 89 through 99 are available if slot numbers above 24 are allocated to on-orbit spares.	3	G2 C/A
			4	GLONASS (M) G2 P
			5 to F	Reserved

System	System ID	Satellite ID	Signal ID	Signal/Channel
Galileo	3 (GA)	1 to 99	0	All signals
		1 to 36 is reserved for	1	E5a
		Galileo SVs	2	E5b
		65 to 99 is undefined	3	E5 a+b
			4	E6-A
			5	E6-BC
			6	E1-B
			7	E1-C
			8 to F	Reserved
BDS	4 (GB)	1 to 99	0	All signals
		1 to 64 is reserved for BDS	1	B1I
		65 to 99 is undefined	2	B1Q
			3	B1C
			4	B1A
			5	B2a
			6	B2b
			7	B2 a+b
			8	B3I
			9	B3Q
			A	B3A
			B	B2I
			C	B2Q
			D to F	Reserved
QZSS	5 (GQ)	0 to 99	0	All signals
		0 to 18 and 55 to 63 are	1	L1 C/A
		reserved for QZSS satellites	2	L1C (D)
		19 to 54 and 64 to 99 is	3	L1C (P)
		undefined	4	L1S
			5	L2C-M
			6	L2C-L
			7	L5-I
			8	L5-Q
			9	L6D
			A	L6E
		QZSS Satellite ID is the 6 LSBs of the 8 bit PRN Number (i.e. Satellite ID of PRN 193 is 1).	B	L1 C/B
			C to F	Reserved
NavIC	6 (GI)	1 to 99	0	All signals
(IRNSS)		1 to 15 is reserved	1	L5-SPS
		for NavIC (IRNSS)	2	S-SPS
		16 to 32 is undefined	3	L5-RS
		65 to 99 is undefined	4	S-RS
			5	L1-SPS

System	System ID	Satellite ID	Signal ID	Signal/Channel
			6 to F	Reserved
SBAS Satellite Based Augmentation System	7	33 - 71 is reserved for SBAS (SBAS PRNs 120 through 158) - 87 = SV ID, i.e. PRN 120 – 87 = SV ID 33 This supports the legacy SV ID values for SBAS.	0 1 2 – 6 7 8 - F	All signals L1 C/A Reserved L5I Reserved
RESERVED	8 to F			

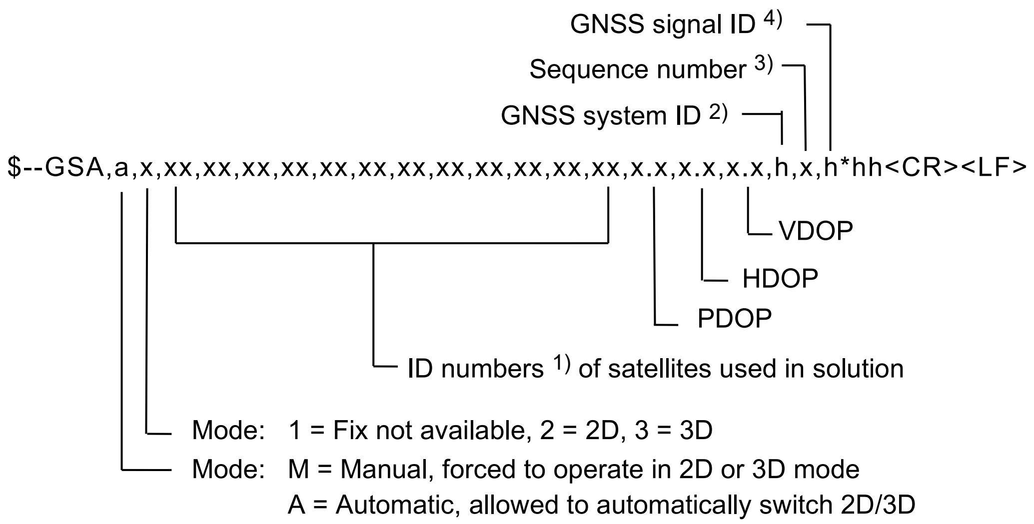
B.6 GSA – GNSS DOP and active satellites

GNSS receiver operating mode, satellites used in the navigation solution reported by the GNS sentence and DOP values. “Active Satellites” includes SBAS satellites used in ranging mode to produce the navigation solution. Any SBAS satellite not used in ranging mode but used for accuracy and integrity augmentation is identified in the GNS and GSN sentences, not in this sentence.

If only GPS, or GLONASS, or Galileo, or BDS, or QZSS, or NavIC (IRNSS) is used for the reported position solution the talker ID is GP, GL, GA, GB, GQ, GI respectively and the DOP values pertain to the individual system. Reporting of SBAS satellites in ranging mode shall use the GN talker ID.

If GPS, GLONASS, Galileo, BDS, QZSS, NavIC (IRNSS), or SBAS satellites used in ranging mode are combined to obtain the reported position solution multiple GSA sentences are produced, one with the GPS satellites, another with the GLONASS satellites, another with Galileo satellites, and another with BDS, etc. Each of these GSA sentences shall have talker ID GN, to indicate that the satellites are used in a combined solution, and each shall have the PDOP, HDOP and VDOP for the combined satellites used in the position. The GNSS System ID data field identifies the specific satellite system.

With advancements in GNSS satellite constellations, there may be more than 12 satellites used from a single GNSS System. When more than 12 satellites are used from a single GNSS system or the navigation solution is based on multiple GNSS systems, multiple GSA sentences are required per measurement cycle. A Sequence Number at the end of the sentence is used to bind multiple GSA sentences together.



Comments:

1) Satellite ID numbers. See table below to determine the meaning of the SV IDs. When the Talker ID is GN, the GNSS System ID provides the only method to determine the meaning of the SVIDs. The GNSS System ID field shall not be null. See Comment 2 for reporting SBAS Satellites used in ranging mode.

2) GNSS System ID identifies a specific GNSS System according to the table below. To report Satellite Based Augmentation System satellites used in ranging mode, use the Talker ID of GN and the GNSS System ID of 7. This field shall not be null.

3) The Sequence number binds multiple GSA sentences together that are related and used in the same measurement cycle for the navigation solution. When GSA sentences are sent, all related GSA sentences have the same Sequence Number value for each set of related GSA sentences. The value is incremented for each consecutive transmission of a set of related GSA sentences. When the maximum value of nine (9) has been used, the Sequence Number is reset so that the next value to be used is zero (0).

   a) This field is required when multiple GSA sentences are necessary to report more than 12 satellites from any single GNSS system, i.e. when the Talker ID is GP, GL, GB, GQ, or GI.

   b) This field is required when multiple systems are being reported with the GN Talker ID, regardless of the number of satellites per system, as this ties all GSA sentences together that are generated during a single measurement cycle.

   c) This field is required when multi-frequencies are used for the same satellites. In this case two or more sentences may be needed, to represent all satellites and their Signal Channel. See Comment 4 & table below.

   d) This field may be null only when a single GSA sentence is needed under the following conditions:

      - when there is only one GNSS system being used with the Taker ID of GP, GL, GB, GQ, or GI,

      - and when there are no more than 12 satellites, all with the same signal ID, being reported for that system.

4) The GNSS Signal ID identifies the Signal/Channel according to the table below, being used for all satellites in this sentence. This field shall not be null.

Examples of multiple GSA sentences:

The example shows three sets of three related GSA sentences, where the Sequence Number value of 0 is the used in the first set, then incremented (See Comment 3) to a value of 1 for the second transmission set. The first and second example shows 13 Galileo satellites and one SBAS EGNOS satellite used in ranging mode to produce the navigation solution reported by the GNS sentence (not shown here). The values shown for DOPs are not real values.

$GAGSA,A,3,01,02,03,04,05,06,07,08,09,10,11,12,99.123,99.123,99.123,3,0,1*hh

$GAGSA,A,3,13,,,,,,,,,,,,99.123,99.123,99.123,3,0,1*hh

$GNGSA,A,3,34,,,,,,,,,,,,99.123,99.123,99.123,7,0,1*hh

$GAGSA,A,3,01,02,03,04,05,06,07,08,09,10,11,12,99.123,99.123,99.123,3,1,1*hh

$GAGSA,A,3,13,,,,,,,,,,,,99.123,99.123,99.123,3,1,1*hh

$GNGSA,A,3,34,,,,,,,,,,,,99.123,99.123,99.123,7,1,1*hh

The third example reflects a combination of Galileo, GPS and SBAS EGNOS satellites used in ranging mode. Note that the GN Talker ID is used per the description of the GSV sentence, and that the Sequence Number has been incremented to the next available value for this transmission (See Comment 3). When GN is used, the GNSS System ID Field value is the only method to determine what GNSS system the satellite number(s) belong to (see table below). The values shown for DOPs are not real values.

$GNGSA,A,3,01,02,03,04,05,06,07,08,09,10,11,12,99.123,99.123,99.123,3,2,1*hh

$GNGSA,A,3,01,06,11,12,21,28,,,,,,,99.123,99.123,99.123,1,2,1*hh

$GNGSA,A,3,34,,,,,,,,,,,,99.123,99.123,99.123,7,2,1*hh

System	System ID	Satellite ID	Signal ID	Signal/Channel
GPS	1 (GP)	1 to 99	0	All signals
		1 to 63 is reserved for GPS	1	L1 C/A
		64 to 99 is undefined	2	L1 P(Y)

System	System ID	Satellite ID	Signal ID	Signal/Channel
			3	L1 M
			4	L2 P(Y)
			5	L2C-M
			6	L2C-L
			7	L5-I
			8	L5-Q
			9 to F	Reserved
GLONASS	2 (GL)	65 to 99	0	All signals
		65 to 99 is reserved for	1	G1 C/A
		GLONASS	2	G1 P
		To maintain SV ID Legacy support, GLONASS satellites are identified by 64+satellite slot number. The slot numbers are 1 through 24 for the full GLONASS constellation of 24 satellites; this gives a range of 65 through 88. The numbers 89 through 99 are available if slot numbers above 24 are allocated to on-orbit spares.	3	G2 C/A
			4	GLONASS (M) G2 P
			5 to F	Reserved
Galileo	3 (GA)	1 to 99	0	All signals
		1 to 36 is reserved for	1	E5a
		Galileo SVs	2	E5b
		65 to 99 is undefined	3	E5 a+b
			4	E6-A
			5	E6-BC
			6	E1-B
			7	E1-C
			8 to F	Reserved
BDS	4 (GB)	1 to 99	0	All signals
		1 to 64 is reserved for BDS	1	B1I
		65 to 99 is undefined	2	B1Q
			3	B1C
			4	B1A
			5	B2a
			6	B2b
			7	B2 a+b
			8	B3I
			9	B3Q
			A	B3A
			B	B2I
			C	B2Q
			D to F	Reserved
QZSS	5 (GQ)	0 to 99	0	All signals
		0 to 18 and 55 to 63 are	1	L1 C/A

System	System ID	Satellite ID	Signal ID	Signal/Channel
		reserved for QZSS satellites 19 to 54 and 64 to 99 is undefined QZSS Satellite ID is the 6 LSBs of the 8 bit PRN Number (i.e. Satellite ID of PRN 193 is 1).	2 3 4 5 6 7 8 9 A B C to F	L1C (D) L1C (P) L1S L2C-M L2C-L L5-I L5-Q L6D L6E L1 C/B Reserved
NavIC (IRNSS)	6 (GI)	1 to 99 1 to 15 is reserved for NavIC (IRNSS) 16 to 32 is undefined 65 to 99 is undefined	0 1 2 3 4 5 6 to F	All signals L5-SPS S-SPS L5-RS S-RS L1-SPS Reserved
SBAS Satellite Based Augmentation System	7	33 - 71 is reserved for SBAS (SBAS PRNs 120 through 158) - 87 = SV ID, i.e. PRN 120 – 87 = SV ID 33 This supports the legacy SV ID values for SBAS.	0 1 2 – 6 7 8 - F	All signals L1 C/A Reserved L5I Reserved
RESERVED	8 to F			

B.7 GSN – GNSS SBAS navigation message

This sentence is used to provide additional information when receiver reports a SBAS position solution.

GSN sentence shall be provided once per second when SBAS position solution is reported by the receiver. If the receiver does not provide SBAS position solution GSN sentence shall not be provided.

The receiver shall provide a GSN sentence with the SBAS augmentation information only from the SBAS PRN used to compute the SBAS position solution. It corresponds when in the GNS sentence the receiver provides Mode Indicator with a “D” as differential solution using corrections from SBAS. This sentence does not include information from SBAS satellites used in ranging mode to produce the navigation solution.

GN talker ID shall be used for all GSN sentences.

$--GSN,hhmmss.ss,xx,h,xx,xx*hh<CR><LF>

SBAS Message Type[4]

SBAS Service Provider ID[3]

Signal ID[2]

ID number of SBAS satellite[1]

UTC time

Comments:

1) ID number of SBAS satellite used as augmentation system to compute the SBAS navigation position solution. See table below to determine the meaning of the SV IDs. This parameter shall not be null.
2) The Signal ID identifies the Signal/Channel according to the table below. This field shall not be null.
3) SBAS Service Provider ID as received from the SBAS Message Type 17 from the SBAS PRN used as augmentation system to compute the SBAS position solution. The Service Provider ID is defined in SARPS:2020. This parameter may be null if Message Type 17 has not been decoded yet.
4) Message Type received for the epoch provided in the GSN sentence from the SBAS PRN used as augmentation system to compute the SBAS navigation position solution. This parameter may be null when there is no SBAS message received for the epoch specified in the GSN.

Example of message when receiver is providing SBAS position solution using EGNOS, SBAS PRN 123, SBAS L1 signal and last message received is a MT=2:

$GNGSN,122310.2,36,1,1,2 *hh<CR><LF>

System	System ID	Satellite ID	Signal ID	Signal/Channel
SBAS Satellite Based Augmentation System	7	33 - 71 is reserved for SBAS (SBAS PRNs 120 through 158) - 87 = SV ID, i.e. PRN 120 – 87 = SV ID 33 This supports the legacy SV ID values for SBAS.	0 1 2 – 6 7 8 - F	All signals L1 C/A Reserved L5I Reserved

B.8 GSV – GNSS Satellites in View

The GSV sentence provides information about all satellites (SV) in view, their satellite ID numbers with their elevation, azimuth, SNR value, signal ID and health status. The satellites reported as “In View” is independent of masks or other configuration settings intended to determine which satellites should be used in the position solution. The GSV sentence contains four satellites maximum per transmission. The total number of sentences being transmitted, and the sentence number being transmitted, are indicated in the first two fields.

The GSV sentence can be used to provide the number of SBAS satellites in view, their SBAS satellite ID numbers with their elevation, azimuth, and SNR value, signal ID, and health status. The talker ID GN shall only be used when reporting SBAS satellites in view. The SBAS satellite IDs shall be in accordance with the System ID of 7 in the table below.

If multiple GPS, GLONASS, Galileo, BDS, QZSS, NavIC (IRNSS) satellites are in view, use separate GSV sentences with Talker ID GP to show the GPS satellites in view, Talker GL to show the GLONASS satellites in view, Talker GA to show the Galileo satellites in view, Talker GB to show the BDS satellites in view, Talker GQ to show the QZSS satellites, and Talker GI to show the NavIC (IRNSS) satellites in view, etc. When more than one ranging signal is used per satellite, also use separate GSV sentences with a Signal ID corresponding to the ranging signal.

To reliably identify when the satellites in view were observed a corresponding transmission of the ZDA sentence is recommended.

Fourth satellite integrity monitoring status 5)
Third satellite integrity monitoring status 5)
Second satellite integrity monitoring status 5)
First satellite integrity monitoring status 5)
Signal ID 4)

$--GSV,x,x,xx,xx,xx,xxx,xx…………..,xx,xx,xxx,xx,h,x,x,x,x*hh<CR><LF>

Fourth satellite in view 2)
Second and third satellites in view 2)
SNR (C/No) 00 to 99 dB-Hz, null field when not tracking
Azimuth, degrees true, 000 to 359
Elevation, degrees, 90° maximum
Satellite ID number 3)
Total number of satellites in view
Sentence number 1), 1 to 9
Total number of sentences 1), 1 to 9

Comments:

1) Satellite information may require the transmission of multiple sentences all containing identical field formats when sending a complete message. The first field specifies the total number of sentences, minimum value 1. The second field identifies the order of this sentence (sentence number), minimum value 1. For efficiency it is recommended that null fields be used in the additional sentences when the data is unchanged from the first sentence.

2) A variable number of "Satellite ID-Elevation-Azimuth-SNR" sets are allowed up to a maximum of four sets per sentence. Null fields shall be used for unused sets when less than four sets are transmitted.

3) Satellite ID numbers. See table below for all SV ID numbers. When the Talker ID is GN, the reported satellites are SBAS and the SBAS satellite IDs shall be in accordance with the System ID of 7 in the table below.

4) Signal ID according to the table below. The Talker ID of the GSV sentence identifies which GNSS System the Signal ID is referenced to within the table below. When the Talker ID is GN, the Signal ID is referenced to the System ID of 7 for SBAS. This field shall not be null.

5) The fixed number of SV Integrity Monitoring Status fields allows expansion of up to four Satellite Information sets with a corresponding Integrity Monitoring Status value. This field shall be null when there is no corresponding Satellite Information set (See Comment 2).
Each field encodes the SV Integrity Monitoring Status using a single digit:
0 = use
1 = do not use
2 = not monitored (no criteria for Integrity Monitoring, or Integrity Monitoring cannot be performed)

The implicit relationship between the Satellite Information sets and the SV Integrity Monitoring Status fields requires that the same Satellite order is used for both.
Sentences that contain less than the maximum of four sets shall have a corresponding null SV Integrity Monitoring Status field (i.e., if there are only two sets of Satellite Information, the first two SV Integrity Monitoring Status fields are populated, and the remaining SV Integrity Monitoring Status fields are set to null).

System	System ID	Satellite ID	Signal ID	Signal/Channel
GPS	1 (GP)	1 to 99	0	All signals
		1 to 63 is reserved for GPS	1	L1 C/A
		64 to 99 is undefined	2	L1 P(Y)
			3	L1 M
			4	L2 P(Y)

System	System ID	Satellite ID	Signal ID	Signal/Channel
			5	L2C-M
			6	L2C-L
			7	L5-I
			8	L5-Q
			9 to F	Reserved

GLONASS	2 (GL)	65 to 99	0	All signals
		65 to 99 is reserved for	1	G1 C/A
		GLONASS	2	G1 P
		To maintain SV ID Legacy support, GLONASS satellites are identified by 64+satellite slot number. The slot numbers are 1 through 24 for the full GLONASS constellation of 24 satellites; this gives a range of 65 through 88. The numbers 89 through 99 are available if slot numbers above 24 are allocated to on-orbit spares.	3 4 5 to F	G2 C/A GLONASS (M) G2 P Reserved

Galileo	3 (GA)	1 to 99	0	All signals
		1 to 36 is reserved for	1	E5a
		Galileo SVs	2	E5b
		65 to 99 is undefined	3	E5 a+b
			4	E6-A
			5	E6-BC
			6	E1-B
			7	E1-C
			8 to F	Reserved

BDS	4 (GB)	1 to 99	0	All signals
		1 to 64 is reserved for BDS	1	B1I
		65 to 99 is undefined	2	B1Q
			3	B1C
			4	B1A
			5	B2a
			6	B2b
			7	B2 a+b
			8	B3I
			9	B3Q
			A	B3A
			B	B2I
			C	B2Q
			D to F	Reserved

QZSS	5 (GQ)	0 to 99	0	All signals
		0 to 18 and 55 to 63 are	1	L1 C/A
		reserved for QZSS satellites	2	L1C (D)
		19 to 54 and 64 to 99 is	3	L1C (P)

System	System ID	Satellite ID	Signal ID	Signal/Channel
		undefined	4	L1S
			5	L2C-M
			6	L2C-L
			7	L5-I
			8	L5-Q
			9	L6D
			A	L6E
		QZSS Satellite ID is the 6 LSBs of the 8 bit PRN Number (i.e. Satellite ID of PRN 193 is 1).	B	L1 C/B
			C to F	Reserved
NavIC	6 (GI)	1 to 99	0	All signals
(IRNSS)		1 to 15 is reserved	1	L5-SPS
		for NavIC (IRNSS)	2	S-SPS
		16 to 32 is undefined	3	L5-RS
		65 to 99 is undefined	4	S-RS
			5	L1-SPS
			6 to F	Reserved
SBAS	7	33 - 71 is reserved for SBAS	0	All signals
Satellite Based Augmentation System		(SBAS PRNs 120 through 158) - 87 = SV ID,	1	L1 C/A
			2 – 6	Reserved
		i.e. PRN 120 – 87 = SV ID 33	7	L5I
		This supports the legacy SV ID values for SBAS.	8 - F	Reserved
RESERVED	8 to F			

B.9 RMC – Recommended minimum specific GNSS data

Time, date, position, course and speed data provided by a GNSS navigation receiver. This sentence is transmitted at intervals not exceeding 2 s and is always accompanied by RMB when a destination waypoint is active.

RMC sentence relationships: The GFA sentence provides Accuracy and Integrity Status of one or more integrity sources used in the position fix reported by this sentence. The UTC of position is used to link this sentence with a GFA sentence.

RMC and RMB are the recommended minimum data to be provided by a GNSS receiver. All data fields should be provided, null fields used only when data is temporarily unavailable.

Navigational status 4)

```
$--RMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,a,x.x,x.x,xxxxxx,x.x,a,a,a*hh<CR><LF>
```

Mode indicator 2) 3)
Magnetic variation, degrees, E/W 1)
Date: dd/mm/yy
Course over ground, degrees true
Speed over ground, knots
Longitude, E/W
Latitude, N/S
Status 3) A = data valid V = navigation receiver warning
UTC of position fix

Comments:

1) E = Easterly variation subtracts from True course
   W = Westerly variation adds to True course
2) Positioning system mode Indicator:
   A = Autonomous. Satellite system used in non-differential mode in position fix;
   D = Differential. Satellite system used in differential mode in position fix. Corrections from ground stations or satellite based augmentation system (SBAS);
   E = Estimated (dead reckoning) mode;
   F = Float RTK. Satellite system used in real time kinematic mode with floating ambiguity estimates;
   M = Manual input mode;
   N = No fix. Satellite system not used in position fix, or fix not valid;
   P = Precise. Satellite system used in precision mode. Precision mode is defined as: no deliberate degradation (such as selective availability) and higher resolution code (i.e. GPS P-code) is used to compute position fix. P is also used for satellite system used in multi-frequency, such as Precise Point Positioning (PPP) mode;
   R = Real time kinematic. Satellite system used in RTK mode with fixed integers;
   S = Simulator mode.
   The Mode Indicator does not differentiate between single and multi-frequency solution. The multi-frequency solution is indicated through the reporting of multiple GSA sentences as indicated in GSA sentence's Comment 3.
3) The positioning system mode indicator field supplements the positioning system status field. The status field shall be set to V = Invalid for all values of the mode indicator except for A (Autonomous), D (Differential), F (Float RTK), P (Precise) and R (Real time kinematic). The positioning system mode indicator and status fields shall not be null fields.
4) The navigational status indicator is according to IEC 61108 requirements on 'Navigational (or Failure) warnings and status indications'. This field shall not be a null field and the character shall take one of the following values:

S =	Safe	when the estimated positioning accuracy (95 % confidence) is within the selected accuracy level corresponding to the actual navigation mode, and/or integrity is available and within the requirements for the actual navigation mode, and/or a new valid position has been calculated within 1 s for a conventional craft and 0,5 s for a high speed craft.
C =	Caution	when integrity is not available.
U =	Unsafe	when the estimated positioning accuracy (95 % confidence) is less than the selected accuracy level corresponding to the actual navigation mode, and/or integrity is available but exceeds the requirements for the actual navigation mode, and/or a new valid position has not been calculated within 1 s for a conventional craft and 0,5 s for a high speed craft.

   V = Navigational status not valid, equipment is not providing navigational status indication.

   If the Navigational Status Indicator is set to 'S', at least one Integrity source of those reported in the Integrity Status field in the GFA sentence will be set to 'S' (the decision can depend on the weighting or integrity source selection algorithm within the receiver). See the GFA sentences for more information on Accuracy and Integrity.

B.10 VTG – Course over ground and ground speed

The actual course and speed relative to the ground.

$--VTG,x.x,T,x.x,M,x.x,N,x.x,K,a*hh<CR><LF>

Mode indicator 2)
Speed over ground, km/h 1)
Speed over ground, knots 1)
Course over ground, degrees magnetic
Course over ground, degrees true

Comments:

1) The speed over the ground shall always be non-negative (positive value).
2) The mode indicator provides status information about the operation of the source device (such as positioning systems, velocity sensors, etc.) generating the sentence, and the validity of data being provided. The possible indications are as follows:

A = Autonomous mode. Satellite system used in non-differential mode in position fix;

D = Differential mode. Satellite system used in differential mode in position fix. Corrections from ground stations or Satellite Based Augmentation System (SBAS);

E = Estimated (dead reckoning) mode;

F = Float RTK. Satellite system used in real time kinematic mode with floating ambiguity estimates.

M = Manual input mode;

N = No fix. Satellite system not used in position fix, or fix not valid.

P = Precise. Satellite system used in precision mode. Precision mode is defined as: no deliberate degradation (such as selective availability) and higher resolution code (i.e. GPS P-code) is used to compute position fix. P is also used for satellite system used in multi-frequency, such as Precise Point Positioning (PPP) mode;

R = Real time kinematic. Satellite system used in RTK mode with fixed integers.

S = Simulator mode;

The mode Indicator does not differentiate between single and multi-frequency solution. The multi-frequency solution is indicated through the reporting of multiple GSA sentences as indicated in GSA sentence’s Comment 3.

The mode indicator field shall not be a null field.

Annex C
(informative)

GNSS interference, jamming and spoofing.

C.1 General

This Annex C provides informative material related to GNSS attacks that can impact SBAS navigation position: interference, jamming and spoofing.

SBAS navigation, as the other satellite based navigation systems (i.e. GPS, Galileo, GLONASS…) is vulnerable to interference, when other radio signals disrupt the GNSS signals impacting accuracy, loss of GNSS position or even integrity failures. GNSS-based positioning is especially vulnerable due to the low power level of the signal at the receiver after traveling from the satellite transmitter to the user receiving antenna and the crowded frequency spectrum.

C.2 Interference

Communication systems transmitting at carrier frequencies close to L1 central frequency (1 575,42 MHz) are potential sources of interference for a GNSS receiver, and even small leakages out of their allocated bandwidth can impact GNSS signals.

As stated in 4.3.11, SBAS L1 receiver equipment shall be capable of operating properly in typical interference conditions. The aviation community has defined interference levels in three categories as reported in RTCA DO-229: broadband noise-like interference, Continuous Wave Interference (CWI), or pulsed interference. These levels are based upon the interference masks developed within RTCA, which are also described in ITU-R Recommendation M.1903.

SBAS L1 receiver equipment should attenuate interfering signals to mitigate interference. Recommended frequency selectivity is shown in section C.3 of RTCA DO-229:2020.

SBAS L1 receiver equipment ensures its nominal operation under typical interfering signals through test specified in 6.10.16.

Additionally, effects on specific interfering signals in the maritime domain for SBAS L1 receiver equipment are checked in the test specified in 6.10.10.

C.3 Jamming

Jamming refers to the intentional interference impacting the accuracy, reliability and availability of a GNSS position.

A jammer is a device that intentionally transmits radiofrequency energy to hinder a navigation service by masking GNSS signals with noise. The malicious objective of jammers is to cause the receiver to lose tracking and to impede signal re-acquisition, being not possible to use the GNSS-based positioning in the jammed area. The use of jammers is prohibited in most countries.

In order to reduce the impact of jamming in GNSS receivers, different countermeasures are typically implemented. Some of the mitigation methods used to reduce the impact of jamming are:

- multi-element antennas (i.e. antenna array) to null the direction of arrival of the jamming source;
- elevation mask angle to limit the reception of signals coming from low elevation sources;
- monitoring of Automatic Gain Control (AGC), carrier to noise density ratio (C/N_0) and/or Doppler shift to detect unusual variations that could imply the reception of jamming signals;

- filtering signals in the adjacent bands;
- pulse blanking to mitigate the effects of pulsed interference;
- multi-navigation system, computing PVT solution using different frequencies or different systems.

C.4 Spoofing

Spoofing is considered the intentional broadcast of GNSS-like or SBAS-like signals with the intention to impair or fool GNSS-based navigation, for example, providing an incorrect position. Within this attack, the receiver may not notice the presence of spoofing as there is no loss in “signal availability” and can wrongly assume that signal availability means reliable position.

In order to reduce the impact of spoofing in GNSS receivers, different countermeasures can be implemented. Some of the mitigation methods that could be used to reduce the impact of spoofing are:

- multi-element antennas (i.e. antenna array) to null the direction of arrival of the spoofing source;
- elevation mask angle to limit the reception of signals coming from low elevation sources;
- monitoring of Automatic Gain Control (AGC), carrier to noise density ratio (C/N_0) and/or Doppler shift to detect unusual variations that could imply the reception of spoofing signals;
- peak monitoring and control loop parametrization, like using several correlators to detect peak forms that may suggest detection of spoofing signals;
- multi-sensor position consistency, comparing PVT solution from different sources (different GNSS systems, frequencies, inertial, etc.);
- step detector and smoothing (see A.1);
- time synchronisation. A recommended solution against SBAS L1 spoofing is that the equipment should discard SBAS L1 signals when the 8-bit preamble block does not match the expected block corresponding to the GPS second of the week. SBAS designed according to SARPS international standard broadcast 24 bit preamble (“01010011 10011010 11000110”) synchronous with a 6 second GPS subframe epoch (SARPs:2020).

In addition, there are additional techniques than can be performed from the service provider side to reduce spoofing impact, like the use of navigation message authentication. For example, Galileo will provide an open service navigation message authentication (OSNMA) and the inclusion of authentication messages in SBAS DFMC dual-frequency multi-constellation services is also under consideration.

Annex D
(normative)

Alert management

The SBAS L1 receiver equipment shall be capable of classifying, handling, displaying and reporting alerts as required in IEC 62923-1 and IEC 62923-2. In the BAM concept, the SBAS L1 receiver equipment acts as an alert source. The SBAS L1 receiver equipment shall be capable of releasing alerts as described in Table D.1.

Table D.1 – Required alerts and their classification

Cause	Alarm	Warning	Caution	CAT A	CAT B	Alert ID
HDOP exceeded			X		X	3056
No calculation of position or loss of position		X			X	3015
SBAS signal not applied			X		X	3056
Integrity status is Unsafe (see 4.3.10.5)		X			X	3012
Integrity has not been available for a period of at least 3 s.			X		X	3013

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