BS IEC 61108-7:2024

BSI Standards Publication

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

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The UK participation in its preparation was entrusted to Technical Committee EPL/80, Maritime navigation and radiocommunication equipment and systems.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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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

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

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

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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/publications.

A list of all parts in the IEC 61108 series, published under the general title *Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS)*, can be found on the IEC website.

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

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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:2023). 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 has 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 document 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.

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).

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This document 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, harbour entrances, harbour approaches and coastal waters, 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:2023).
- 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.

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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

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, harbour entrances, harbour approaches and coastal waters.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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 interconnection*

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

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

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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*

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

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

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 Resolution A.915(22)]

3.1.2
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 Resolution A.915(22)]

3.1.3
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 Resolution A.915(22)]

3.1.4
horizontal alert limit
HAL
maximum allowable horizontal error in the measured position – during integrity monitoring – before an alert is triggered

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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
HPL
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

Note 1 to entry: 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 document 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

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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
HDOP	horizontal dilution of precision
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

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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 operating on the L1 signal and C/A code.

NOTE 2 IEC 61108-1 covers the basic requirements of position fixing for navigation purposes only and does not cover other computational facilities which can 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-229F:2020, 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.

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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.

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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 source 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] IEC 61162-1 applies.

[b] Annex B applies.

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

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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 IEC 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.

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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.

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 3 s. When the unwanted signals are 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.

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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 used 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 4.3.9.3) 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

4.3.9.1 General

(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).

4.3.9.2 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.

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4.3.9.3 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 Clause 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 Clause 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 Clause 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

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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.

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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;
- 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. In addition to the SBAS status indication, the EUT shall present an alert as defined in Annex D, and additionally transmit it with the corresponding alert ID in Annex D.

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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 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 not greater than HAL for the selected accuracy level (HPL $\leq$ 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 can 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 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.

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