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SBAS/EGNOS Enabled Devices in Maritime

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ABSTRACT: Nowadays, it is a fact that Global Navigation Satellite Systems (GNSS) have become the primary means of obtaining Position, Navigation and Timing (PNT) information at sea. Most of the ships in the world are equipped with GNSS receivers. And currently these users take advantage of different augmentation systems such as DGNSS or SBAS/EGNOS, as they provide an adequate answer, especially in terms of accuracy and integrity.
To take advantage of this improved accuracy, direct access to EGNOS in vessels can be achieved through EGNOS-enabled navigation receivers and EGNOS-enabled AIS transponders. Therefore, the natural question is: Are those GNSS receivers SBAS (EGNOS) enabled? In most cases they are; SBAS is being used. This paper provides an analysis of the number of onboard devices, mainly devoted to navigation purposes and AIS transponders, which are SBAS compatible.

1 INTRODUCTION

The maritime sector was one of the first communities that recognized and exploited the opportunities and advantages provided by GNSS systems. In fact, the introduction of GNSS represented a great revolution in the maritime field.

GNSS positioning has progressively acquired more and more relevance in all ships sailing around the globe. At the beginning, GNSS was only used as a way to know the current position, but today GNSS receivers are connected and integrated with other different functions such as Integrated Bridge Systems, ECDIS, ARPA, GMDSS, AIS, LRIT or VDR.

It is recognised that Global Navigation Satellite Systems (GNSS) have become the primary means of obtaining Position, Navigation and Timing (PNT) information at sea. Most of the ships in the world (even in the recreational and leisure field) are equipped with GNSS receivers (SOLAS carriage requirement). And nowadays these users take advantage of different augmentation systems such as DGNSS or SBAS/EGNOS, as they provide an adequate answer, especially in terms of accuracy and integrity.

The question is: how many of the GNSS onboard equipment are SBAS ready? To answer this question, this paper presents the results of the survey that has been done among a large set of approved maritime devices including a GNSS receiver.

1.1 *What is EGNOS?*

Satellite navigation systems are designed to provide a positioning and timing service over vast geographical areas (typically continental or global coverage) with high accuracy performance. However, a number of events may lead to positioning errors. Satellite-Based Augmentation Systems (SBAS) are designed to augment the navigation system constellations by broadcasting additional signals from geostationary (GEO) satellites. EGNOS (European Geostationary Navigation Overlay Service) is the European SBAS providing an augmentation service to the Global Positioning System (GPS).

EGNOS has been designed to broadcast a GPS-like ranging signal in Europe with embedded corrections, providing improved performances over GPS. With EGNOS, all navigation receivers will benefit from enhanced accuracy, availability and continuity over GPS.

The EGNOS coverage area is Western Europe, but could be readily extended to include other regions within the broadcast area of the geostationary satellites, such as Africa. EGNOS is the first element of the European satellite-navigation strategy and a major stepping-stone towards Galileo, Europe's own global satellite navigation system for the future.

In addition to EGNOS, there are other SBAS around the world with similar characteristics and compatible among them. Figure 1 presents the coverage of the different SBAS systems in the world.

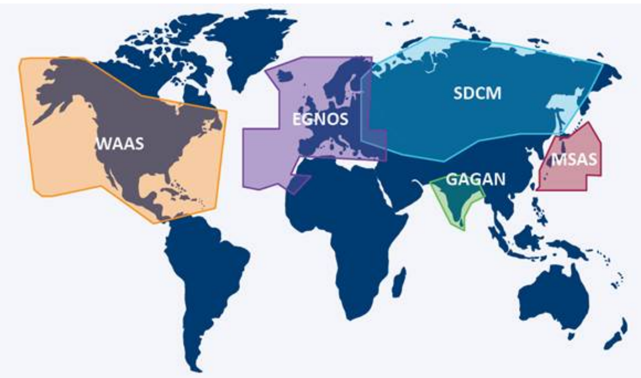


Figure 1. Existing and planned SBAS systems

The main objective of the EGNOS Open Service (EGNOS OS) is to improve the achievable positioning accuracy by correcting several error sources affecting the GPS signals. The corrections freely transmitted by EGNOS geostationary satellites contribute to mitigate the ranging error sources related to satellite clocks, satellite position and ionospheric effects. The EGNOS OS minimum accuracy is specified in the following table [1].

Table 1. EGNOS OS Horizontal and Vertical Accuracy

Accuracy	Definition	Value
Horizontal	Corresponds to a 95% confidence bound of the 2-dimensional position error in the horizontal local plane for the Worst User Location	3m
Vertical	Corresponds to a 95% confidence bound of the 1-dimensional unsigned position error in the local vertical axis for the Worst User Location	4m

2 ONBOARD GNSS RECEIVERS - SOLAS CONVENTION

To have a picture of what kind of navigation equipment can be found onboard vessels, SOLAS Convention [2] must be consulted. The SOLAS Convention is considered as the most important of all international treaties concerning the safety of merchant ships. Chapter V within SOLAS Convention deals with safety of navigation; it identifies navigation safety services which should be provided by Contracting Governments and sets forth operational provisions applicable in general to all ships on all voyages. Of special interest is Regulation 19 within chapter V, which establishes the carriage requirements for shipborne navigational systems and equipment.

2.1 *Satellite Navigation Equipment*

According to that Regulation, all ships irrespective of size are required to be fitted with a GNSS receiver. This will probably be a GPS receiver using the US Global Positioning System which may or may not be equipped to provide differential corrections, since the carriage of a DGPS receiver or an SBAS enabled receiver is not mandatory. The question is: Does a simple GPS receiver fulfil the IMO requirements in all navigation phases?

The most common system used as primary means of navigation is GNSS, however currently available GNSS do not fulfil IMO requirements in regards to accuracy and integrity in all the navigation phases. According to Resolution A.915(22) [3] on the "Revised maritime policy and requirements for a future Global Navigation Satellite System (GNSS)" GPS (and GLONASS) has been recognized as a component of the World Wide Radionavigation System[1] (WWRNS) for navigational use in waters other than harbour entrances and approaches and restricted waters. That is, GPS alone, without augmentation is not enough in these situations.

A.915(22) recognises that differential corrections can enhance accuracy (in limited geographic areas) to 10 m or less (95%) and also offer external integrity monitoring. In this sense, this Resolution mentions the following techniques that can improve the accuracy and/or integrity of GPS and GLONASS by augmentation[2]:

- Differential correction signals from stations using the appropriate maritime radionavigation frequency band between 283.5 and 325 kHz for local augmentation.
- Craft or receiver autonomous integrity monitoring.
- Integrated receivers combining signals from GPS, GLONASS, LORAN-C and/or Chayka (a Russian

[1] In May 2016, the IMO recognised also Galileo as part of the World Wide Radio Navigation System.
[2] To take into account that Resolution A.915(22) was adopted on 29 November 2001 and consequently it is not updated. Some of the systems have been decommissioned, for instance LORAN-C, and technological advances are not considered.

terrestrial radionavigation system, similar to LORAN-C).
– Wide area augmentation systems using differential correction signals from geostationary satellites such as EGNOS for Europe, WAAS for the United States and MSAS for Japan.

A more recent IMO Resolution, A.1046(27) [4] on the "Worldwide Radionavigation System" refers to Chapter V of the SOLAS Convention, Regulation 13, when talking about navigation in harbour entrances, harbour approaches and coastal waters. At the same time, IMO Res. 1046 establishes that: *where a radionavigation system is used to assist in the navigation of ships in such waters, the system should provide positional information with an error not greater than 10 m with a probability of 95%.* It is important to note that this is a requirement to be accomplished by the radionavigation system.

The provision of differential corrections, understood as aids to navigation to be provided by maritime authorities, is not mandatory. It is up to the Contracting Governments to decide to provide this service based on the volume of traffic and the degree of risk. Hence, when navigating in waters without a maritime DGNSS service, it is of special interest the access to SBAS corrections or even as a backup when this DGNSS service is provided.

2.2 *AIS onboard devices*

Automatic Identification System (AIS) is an autonomous and continuous broadcast system, operating in the VHF maritime mobile band. The objective of AIS is to exchange navigation data such as vessel identification, position, course, speed, etc. between participating vessels and shore stations.

Section 4.1.1 of the IALA Guideline 1082 [5] is devoted to shipborne AIS, that is, Class A and Class B devices. According to that Guideline and the AIS Technical Standards (ITU-R M.1371), Class A equipment complies with the IMO AIS performance standards. Whilst the Class B are compatible with Class A, they are not fully compliant with IMO requirements and report less frequently than Class A.

AIS uses an absolute referencing system to determine position. This position is normally derived from a GNSS receiver. AIS Class A devices can obtain position information from an internal GNSS receiver or from the vessel's primary GNSS receiver. However, Class B equipment only uses the AIS internal GNSS sensor to obtain the position information.

According to the SOLAS Convention, AIS carriage (Class A) is mandatory for ships of 300 gross tonnage and upwards engaged on international voyages and cargo ships of 500 gross tonnage and upwards not engaged on international voyages and passenger ships irrespective of size. In addition, EU Directive 2002/59/EC [6] states that fishing vessels with a length of more than 15 metres overall shall be fitted with an AIS (Class A) which meets the performance standards drawn up by the IMO.

3 SURVEY RESULTS

A survey has been done to have an overview of the percentage of onboard GNSS devices which are SBAS enabled. The statistical analysis took as basis the satellite navigation equipment and AIS devices approved to be used in SOLAS and non-SOLAS vessels. As a starting point, the list of receivers and their characteristics sheets were gathered.

The receiver equipment and AIS devices list took as reference was extracted from the data base published by the Spanish Merchant Marine, as can be found in the Spanish Ministry of Transport website [7]. This inventory catalogues SOLAS and non-SOLAS authorised devices including brand, model and dates of homologation and expiration for each equipment.

The analysis of the characteristics sheets, brochures, owner's manuals, webpages or technical specifications of the listed receivers and AIS devices has led to know if the device is SBAS compatible and, among the SBAS compatible ones, if EGNOS is explicitly mentioned.

3.1 *Satellite Navigation Equipment Survey*

3.1.1 *SOLAS*

24 satellite navigation devices authorised for SOLAS vessels were analysed, from 7 different brands, according to the published list by the Spanish Ministry of Transport.

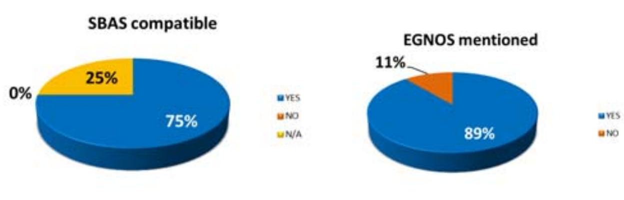
It is important to note than a 100% of the authorised manufacturers to provide SOLAS GNSS-based equipment have at least 1 SBAS-enabled receiver and 71% mentioned their equipment was EGNOS compatible.

The analysis yielded the following results:

Table 2. SBAS compatible device analysis – SOLAS satellite navigation equipment

	SBAS compatible equipment	Percentage
YES	18	75%
NO	0	0%
N/A	6	25%
	EGNOS mentioned	Percentage
YES	16	89%
NO	2	11%

N/A: Navigation system to be used in combination with external antennas. The compatibility with SBAS depends on the chosen antenna.



3.1.2 *Non-SOLAS*

432 satellite navigation devices authorised for non-SOLAS vessels were analysed, from 27 different brands, according to the published list by the Spanish

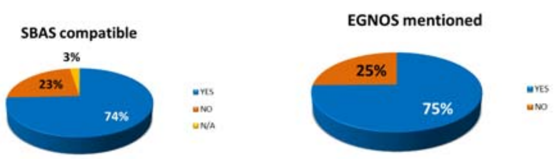
Ministry of Transport. To be noted that **92%** of the authorised manufacturers to provide non-SOLAS GNSS-based equipment have at least 1 SBAS-enabled receiver and 83% mentioned their equipment was EGNOS compatible.

The analysis yielded the following results:

Table 3. SBAS compatible device analysis – non-SOLAS satellite navigation equipment

	SBAS compatible equipment	Percentage
YES	321	74%
NO	100	23%
N/A	11	3%
	EGNOS mentioned	Percentage
YES	240	75%
NO	81	25%

N/A: No built-in GPS or no information available on these models



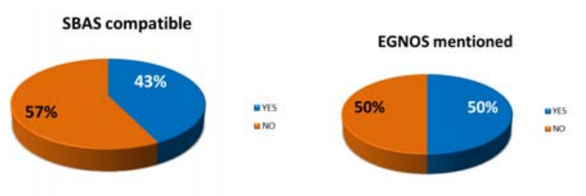
3.2 *AIS Equipment Survey*

3.2.1 *SOLAS*

There are 14 AIS devices authorised for SOLAS vessels, from 12 different brands, according to the published list by the Spanish Ministry of Transport. The analysis of the specifications of these onboard AIS devices resulted as follows:

Table 4. SBAS compatible device analysis – AIS SOLAS

	SBAS compatible equipment	Percentage
YES	6	43%
NO	8	57%
	EGNOS mentioned	Percentage
YES	3	50%
NO	3	50%



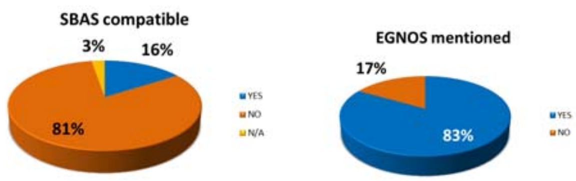
3.2.2 *Non-SOLAS*

The characteristics sheets of 38 AIS devices authorised for non-SOLAS vessels were analysed, from 19 different brands, according to the published list by the Spanish Ministry of Transport. The following results were obtained:

Table 5. SBAS compatible device analysis – AIS non-SOLAS

	SBAS compatible equipment	Percentage
YES	6	16%
NO	31	82%
N/A	1	3%
	EGNOS mentioned	Percentage
YES	5	83%
NO	1	17%

N/A: No information available on these models



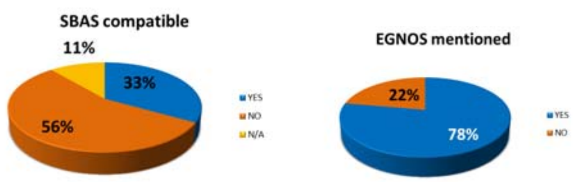
3.2.3 *Inland AIS*

There are 27 approved Inland AIS devices, according to the "List of approved Inland AIS equipment in accordance with the Rhine Vessel Inspection Regulations" [8]. These devices were analysed with the following results:

Table 6. SBAS compatible device analysis – Inland AIS

	SBAS compatible equipment	Percentage
YES	9	33%
NO	15	56%
N/A	3	11%
	EGNOS mentioned	Percentage
YES	7	78%
NO	2	22%

N/A: No information available on these models



4 CONCLUSIONS

Many GNSS receivers currently available on the market are able to receive and process EGNOS signals and can be used to support numerous applications. As a result of using EGNOS, a better position performance can be obtained.

According to the EGNOS OS SDD [1], the EGNOS OS horizontal minimum accuracy, corresponding to a 95% confidence bound of the 2-dimensional position error in the horizontal local plane for the Worst User Location, is 3 meters. Therefore the accuracy requirement established in IMO Res. 1046 about navigation in harbour entrances, harbour approaches and coastal waters *with an error not greater than 10 m with a probability of 95%* is fulfilled by far when the GNSS receiver is EGNOS enabled. It is also important to remark that IMO Resolution A.915(22) considers

SBAS/EGNOS as one of the techniques that can improve the accuracy of GPS.

To take advantage of this improved accuracy, direct access to EGNOS in vessels can be achieved through:

- EGNOS-enabled navigation receivers:
  75% of the GNSS-based equipment authorised to be used in SOLAS vessels are SBAS/EGNOS compatible. A similar percentage, 74%, of the GNSS-based equipment authorised to be used in non-SOLAS vessels are EGNOS compatible.
- EGNOS-enabled AIS transponders:
  43% of the AIS devices authorised to be used in SOLAS vessels are SBAS/EGNOS compatible. This percentage is lower in the AIS non-SOLAS devices, around 16%.

The analysis of the list of approved Inland AIS equipment in accordance with the Rhine Vessel Inspection Regulations results in 9 SBAS-enabled AIS transponders out of 27. Therefore a 33% of the approved inland AIS transponders are EGNOS compatible.

Choosing SBAS/EGNOS-enabled receivers leads to accurate position information; this is directly related with an improvement in safety in navigation and an enhancement of those services based on position information.

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