

# IALA GUIDELINE

G1127

## SYSTEMS AND SERVICES FOR HIGH- ACCURACY POSITIONING AND RANGING

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## 1. PURPOSE, SCOPE AND STRUCTURE OF DOCUMENT

### 1.1. PURPOSE

The purpose of this document is to provide an overview about systems and services enabling high-accuracy positioning or ranging in specific areas such as waterways, traffic separation schemes, traffic zones with limited manoeuvring space, ports and harbours, and congested waters with increased risks of collisions or groundings.

In this Guideline the term “high-accuracy positioning and ranging” refers to accuracies at sub-metre level.

Each high-accuracy system or service will require its own Guideline to clarify the different architecture and system parameters. This document provides a framework for such guidelines to support their consistency.

### 1.2. SCOPE

The document provides guidance to stakeholders, operators, and end users regarding principal aspects, which should be considered for deployment and operation of systems as well as utilisation of services. These include applications, performance requirements, functional principles, and generic descriptions concerning the main aspects that have to be considered during implementation and operation.

### 1.3. STRUCTURE OF DOCUMENT

Chapter 2 provides background information about GNSS as the primary means for worldwide high-accuracy positioning.

Chapter 3 gives an overview of nautical tasks and specific nautical applications to explain conditions under which an increased demand for accuracy of positioning becomes necessary. This approach is compliant with IMO Resolution A.915(22) providing the “Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)” [4] and defining performance requirements in relation to specific navigational phases, nautical applications as well as diversity of maritime professions.

Chapter 4 starts with a short summary about existing performance specifications and general aspects of positioning and ranging. The chapter also discusses performance identifiers.

Chapter 5 gives an overview of technical systems and services supporting positioning and ranging and their capability to provide high-accuracy.

Chapter 6 describes methods for high-accuracy positioning and ranging.

For a harmonised description of high-accuracy systems and services chapter 7 provides a list of implementation and operation aspects which have to be considered.

Chapter 8 and 9 list abbreviations and references used.

An appendix provides further information about positioning and ranging performance parameters.

## 2. BACKGROUND

By using one of the first GNSS (GPS, GLONASS) it was possible to determine horizontal position with an accuracy of several tens of metres. In the 1990s, GNSS augmentation systems such as IALA Beacon DGNSS [1,2] were developed and established to provide correction data for GPS or GLONASS signals. These services made it possible to meet the IMO requirements for position accuracy and integrity for navigation in coastal areas. Where GNSS is not able to provide sufficient positioning accuracy and integrity for more demanding applications, enhanced GNSS augmentation services as well as alternative and complementary localisation systems are suitable approaches for high accurate positioning and ranging.

The demand for systems and services for high-accuracy positioning and ranging results from specific navigational manoeuvres (e.g. automatic docking) as well as specific nautical applications (e.g. automatic track control in

critical areas, dynamic positioning, pilotage). Due to the safety critical aspects of such situations and areas the system and data integrity should be monitored and evaluated.

### 3. APPLICATIONS

Numerous existing and potential navigational applications may only be realised if appropriate systems and services enable high-accuracy positioning and ranging. Navigational applications may require assistance functions supporting bridge teams with respect to situation awareness, evaluation, and management. The partial or complete realisation of navigational tasks by system functions (e.g. automatic docking) represents a more challenging scenario.

An increasing level of automation reduces the potential influence of bridge teams to detect and compensate for uncertainties, inaccuracies, and malfunctions in navigational systems. This reinforces the need for integrity of high-accuracy positioning and ranging.

Each application determines the requirement for either absolute or relative positioning or ranging. For certain applications it may be sufficient to determine the distance to obstacles or other traffic participants.

Table 1 gives example tasks and applications for high-accuracy positioning and ranging and describes the purpose of assistance or system functions. These examples cover a range of activities applicable to coastal, ports and inland waterways.

**Table 1** *Example tasks and applications for high-accuracy positioning and ranging*

Tasks and applications	Purpose of assistance or system function	Ranging approach	Positioning approach
<b>Docking</b>	During docking it is necessary to prevent collision of ship's hull with infrastructures.	Distance measurements to determine ship's hull in relation to infrastructure	Position based determination of attitude of ship hull in relation to infrastructure within georeferenced frame
<b>Locking</b>	During entry and exit of the lock it is necessary to prevent collision of ship's hull with the lock infrastructure.		
<b>Passage of narrow channels</b>	During the passage of narrow channels it is necessary to prevent collision of ship's hull with side of channel.		
<b>Turning</b>	Turning manoeuvres of ships are necessary in port and harbours to arrive or depart the shipping berth. Especially during the turning of large-size vessels in areas with limited manoeuvring space it is necessary to prevent groundings or collisions with harbour infrastructure.	Distance measurements to determine ship's hull in relation to available navigation space	Position based determination of attitude of ship hull in relation to available navigation space within georeferenced frame
<b>Passage under bridges</b>	The size of bridge arches determines the available passage width (similar to passage of narrow channels) as well as the available clearance. Size of bridge arches, varying water levels and load-dependent ship air draughts have		

Tasks and applications	Purpose of assistance or system function	Ranging approach	Positioning approach
	to be taken into account to avoid collision.		
<b>Passage over shallows (under keel clearance)</b>	Varying water levels and load-dependent ship draughts have to be taken into account to avoid groundings.		
<b>Track control</b>	Track control systems serve the automatic steering in a variety of navigational situation ranging from sailing through narrow straits to transoceanic voyages. The demand for accurate positioning may increase to sub-metre level if ship navigation uses track control in areas temporary or permanently restricted by obstacles at sea or on ground.	n/a	Position based determination of achieved position in relation to target position
<b>Dynamic positioning (DP)</b>	A dynamic position system maintains ship's position and heading in relation to a fixed point over ground (absolute) or to the position/attitude of an object (relative).	Distance measurements supporting relative DP	Position and heading reference systems to determine difference between current and required position/attitude

n/a: not applicable

## 4. PERFORMANCE SPECIFICATION

### 4.1. BACKGROUND

#### 4.1.1. IMO STANDARDS

IMO Res. A.1046 (27) [5] provides recommendations on radio navigation systems and services used worldwide for ship positioning: The document specifies for general ship navigation in ocean waters that the horizontal position accuracy (HPA) should be better than 100 m with a probability of 95%. If practicable, integrity warnings should inform about the occurrence of system malfunctions, non-availability or discontinuities by future Maritime Safety Information (MSI) systems. The position error should be below 10 m with a probability of 95%, if radio navigation systems serve the determination of ship's position in harbour entrances, harbour approaches, and coastal waters.

Position accuracies in the sub-metre range are expressed only by IMO Resolution A.915(22) [4] providing the "Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)". The document specifies that the absolute HPA should be better than 1 m for ship's navigation in port areas. The same criteria apply to hydrography, cable and pipeline laying, management of marine aids to navigation (AtoN), and subsidence monitoring of offshore platforms. An increased HPA requirement (< 0.1 m, absolute) is specified for automatic docking, construction and dredging. In addition hydrography, dredging and construction work are application areas, which require vertical position accuracies (VPA, absolute) better than 0.1 m. For the operation of tugs, pushers and icebreakers, resolution A.915(22) [4] specifies a requirement for relative position accuracy better than 1 m. Most of these application scenarios are safety-relevant and encompass additional requirements for integrity. Integrity may be assumed if the position data meets the requirements for data performance e.g. accuracy and latency.

Resolution A.915(22) [4] states integrity monitoring requirements for alert limits (AL), time to alarm (TTA), and integrity risk (IR). Alert limits, the thresholds for tolerated inaccuracy, are defined as two-and-a-half times given HPA and VPA. The TTA (tolerated time delay between the occurrence of a significant error and its indication) should be less than 10 s in all cases. The IR (probability that an alert-relevant event remains undetected or unindicated) should be less than  $10^{-5}$ . The specification of performance parameters is a prerequisite for the implementation of integrity monitoring and the indication of monitoring results.

There may be other tasks and applications, which may benefit from high-accuracy positioning and ranging which are not covered by these IMO standards e.g. rate of turn.

#### 4.1.2. POSITIONING AND RANGING

Absolute positioning provides the position of an object in a specified coordinate system. Each task or application specifies the demand on position either as point in a horizontal plane on the earth surface or as a point in the 3-dimensional space. Relative positioning provides position information of an object in relation to the position of another object.

Ranging stands for techniques to measure the distance between two objects or points. The techniques may use one-way or two-way runtime measurements of electromagnetic waves. Alternatively, distance measurements can be derived from relative or absolute positioning. In both cases the measuring principle as well as environmental conditions determine, if long or short distances are reliably measurable with the intended accuracy.

The performance of systems and services enabling high-accuracy positioning or ranging should be specified in relation to the aimed results. Results at user site may be:

- a absolute position  $X(t)=[x, y, z, t]$  in a defined reference system;
- b relative position  $\Delta X(t)=[\Delta x, \Delta y, \Delta z, t]$  in relation to a static or dynamic reference point in the same reference system;
- c distance  $|\Delta X(t)|$  in relation to a reference point or distance between 2 positions;
- d distances of ship's hull to certain obstacles (e.g. distance to quay wall, clearance to bridge arches).

Systems for high-accuracy positioning and ranging provide data products containing 3-dimensional, horizontal or vertical positions, distance vectors, or distances (see Table 2). These systems are often composed of a combination of a basic system (e.g. GNSS), augmentation systems (e.g. DGNSS services) and user terminals (e.g. GNSS/DGNSS receiver). The chosen system architecture determines which positioning and ranging techniques may be applied and, consequently, whether the system can meet the performance requirements with its data output (demand on data, data rate and data quality taking into account the diversity of intended applications). An unambiguous meaning of provided positions and range measurements may be assumed if the used reference systems and the applied transformation are specified too.

**Table 2 Potential output data of systems for high-accuracy positioning and ranging**

positions			distances			time
component x	horizontal position	3-dimensional position	component dx	distance over ground	3-dimensional distance	reference to UTC
component y			component dy			
component z	vertical position		component dz	altitude, depth, or clearance		

Positioning and ranging are related to each other, from a mathematical as well as a methodical viewpoint:

- A vector is able to describe the absolute as well as the relative position of a point in the 3-dimensional space. Effectively, each vector component indicates the distances in the direction of a single axis to the origin of coordinate system (absolute position) or to a reference point in the same coordinate system (relative



position). Therefore, the magnitude of the vector provides the distance to the origin or to the used reference point.

- For hundred of years combinations of distance and bearing measurements to distinct points (e.g. stars, lighthouse, church steeple) enabled the determination of relative and absolute positions. Today, modern technologies use the interconnection between ranging and positioning as already indicated in chapter 3. A representative example is positioning with GNSS, where the availability of 4 or more distance measurements to GNSS satellites is the prerequisite to determine the coordinates of the unknown spatial antenna position including the offset between GNSS receiver and system time.
- Specialised DGNSS (e.g. real-time kinematic (RTK)) services exploit relative measuring and processing techniques in signal and position domain to support high accurate positioning in their coverage area.

## 4.2. PERFORMANCE PARAMETERS

The performance of systems and services proposed for high-accuracy positioning and ranging should be described unambiguously to enable the identification of suitable solutions in relation to specific needs. Furthermore, monitoring and evaluation of operational systems and services require the specification of suitable performance criteria as well as the provision of methods for their determination.

This section gives an overview of performance terms<sup>1</sup> and parameters, which are used to describe required system or data performance:

- **Accuracy**, specified by the **PROBABILITY** [%] that the data provided is within the specified **ERROR THRESHOLD** [m] (e.g. horizontal position error should be below 10 m in 95% of all provided positions);
- **Latency**, specified as the maximum **TIME DELAY** [s] between data surveying (time point of measuring) and providing (time point of provision or indication);
- **Continuity**, specified as the **PROBABILITY** [%] that in a certain (short) **TIME PERIOD** [s] the data provision is performed continuously and meets the accuracy and integrity requirements;
- **Availability**, specified as the **PERCENTAGE OF TIME** [%] that in a certain (long) **TIME PERIOD** [s] the data provision is performed and meets the accuracy and integrity requirements;
- **Update rate**, specified by the **FIXING INTERVAL** [s] (time increment between data provided successively) to define the time resolution of data determined; and
- **Coverage**, specified as specific area (e.g. **GEO-REFERENCED PARAMETERS, CO-ORDINATES**) where high-accuracy positioning or ranging is required and supported.
- **Alert limit**, specified as the **THRESHOLD** [m] for the maximum allowed error before an alarm is triggered;

Integrity is defined as the ability of a system to provide users with information within a specified time when the system should not be used for navigation [4]. Requirements for integrity monitoring performance parameters are specified by:

- **Time to Alarm**, specified as the tolerated **TIME DELAY** [s] between the occurrence of an error and its indication; and
- **Integrity Risk**, specified as the **PROBABILITY** [%] for a certain (short) **TIME PERIOD** [s] that a violation of accuracy requirements remains undetected.

The provision of positions or distances should be time-synchronised with the provision of associated integrity data.

<sup>1</sup> Various definitions can be found in IMO resolution 915 [4] or IALA dictionary [12].

Further information regarding interdependencies of the performance parameters for latency and accuracy are described in the Appendix.

The performance terms and parameters listed above are sufficient to specify the requirements for system data output. During system development the requirements for the whole system (e.g. availability of output data or accuracy of data content) should be mapped on single system components. During formulation of technical requirements for shore systems and services, the performance terms and parameters should be used.

The fulfillment of specified performance requirements is evaluated either in real time or in relation to a specific time period. Both require suitable indicators for system performance

- to monitor and indicate accuracy and integrity of output data in real time; and
- to validate the operational system performance for relevant time periods.

Due to the diversity of user equipment as well as unknown environmental conditions it is impossible for the system and service provider to determine the accuracy and integrity of data output achieved at the user equipment. At best, systems and services can only provide estimates for accuracy and integrity achieved at system output. The confidence of provided alerts and integrity data depends on the significance and correctness of determined performance indicators.

Most of the performance terms and parameters are probability statements regarding the operational performance of systems and services. Unambiguous specification of them requires information concerning measuring periods and evaluation conditions.

## 5. CLASSIFICATION OF SYSTEMS AND SERVICES

Generally, systems for high-accuracy positioning and ranging comprise several technological components to perform the diversity of functions – from measuring, via analysing to service and data provision. Representative examples of positioning and/or ranging systems are Global Navigation Satellite Systems (GNSS), Radar systems, Lidar systems, or Sonar systems. Augmented GNSS and Laser Ranging Systems are most likely to deliver “high-accuracy” capability. Moreover, augmented GNSS systems are able to provide the user not only with correction data but also with integrity information. In addition, the combined use of different systems (e.g. augmented GNSS and Lidar) is a typical approach to increase continuity and availability of positioning and ranging for a user.

The following Tables 4 and 5 give an overview about the wide range of systems and assigned services used for positioning and ranging in the maritime domain. It should be noted, that not all of the systems listed are able to support high-accuracy positioning or ranging. More information is provided by the IALA NAVGUIDE [9] and IALA World Wide Radio Navigation Plan [11].

**Table 3** Example systems enabling positioning and ranging

Type of system	Primary means for	Examples	Service(s)	Coverage	Provides high-accuracy
Global Navigation Satellite System (GNSS)	Positioning and timing	GPS GLONASS Galileo BEIDOU	SPS, PPS SPS, PPS OS, PRS OS, PRS	Global	No
Regional Navigation Satellite System	Positioning and timing	QZSS NavIC <sup>(a)</sup>	SPS, SLAS, CLAS SPS, PPS	Regional	No, No, Yes No, No
Terrestrial Navigation System	Positioning and timing	LORAN-C, eLORAN, CHAYKA, R-Mode	n/a	Regional	No

Type of system	Primary means for	Examples	Service(s)	Coverage	Provides high-accuracy
Radar	Radio detection and ranging	X-band radar S-band radar	n/a	Local	No <sup>(b)</sup>
Lidar	Light detection and ranging	Laser Ranging	n/a	Local	Yes
Sonar	Sound detection and ranging	Active Sonar Passive Sonar	n/a	Local	No

n/a – not applicable

(a) Former known as IRNSS

(b) May enable high-accuracy in the future.

**Table 4 Example systems improving positioning and ranging**

System	Primary means for	Examples	Service(s)	Coverage	Provides high-accuracy
Satellite Based Augmentation Systems (SBAS)	Provision of GNSS-related correction and integrity data	WAAS EGNOS MSAS GAGAN SDCM	n/a OS, SOL n/a n/a SPS, PPS <sup>(a)</sup>	Regional	No No No No No, Yes <sup>(a)</sup>
Terrestrial augmentation systems – code based DGNSS	Provision of GNSS-related correction and integrity data	IALA Beacon DGNSS	n/a	Regional, Local <sup>(b)</sup>	No, Yes
Terrestrial augmentation systems – phase based DGNSS	Provision of GNSS-related augmentation and integrity data	MGBAS, RTK	n/a	Local <sup>(b)</sup>	Yes
Systems that support Precise Point Positioning (PPP)	Provision of GNSS-related correction and integrity data	IGS	RTS	Global	Yes
Radar Beacon (RACON)	Radio detection and ranging	Lighthouses, Navigation buoys	n/a	Local	No

n/a – not applicable

(a) Restricted service for the area 200 km around base stations

(b) Different communication channels provided by e.g. AIS or VDES could be used

Beside the systems and services mentioned in Table 3 and Table 4 there are commercial systems and services available which can provide high-accuracy positioning and ranging.

## 6. METHODS FOR HIGH-ACCURACY POSITIONING AND RANGING

### 6.1. LASER RANGING

Laser ranging is a method where a bundled light beam is used to measure the distance between an emitter of the light beam and an object which reflects the light beam. With respect to navigational applications runtime measurements are used to calculate a range between emitter and object.

For runtime measurement a light pulse is emitted and the time is measured until the ray of light is reflected to the emitter. The distance  $L$  can be estimated by  $L = c * \Delta t / 2 * n$  (with  $c$  = speed of light,  $\Delta t$  = measured runtime,  $n$  – refraction index). The runtime measurement has a very short reaction time and covers a measurement range up to tens of kilometres. The accuracy is in the range of a few centimetres.

Mirrors and prisms can be used as dedicated reference objects to improve reflection capability of the object and enhance accuracy.

## 6.2. DGNSS AND RTK

DGNSS includes several techniques, which increase accuracy and integrity of user position by decreasing the influence of ranging errors.

IALA Beacon DGNSS is a dedicated code based maritime service providing range and range rate corrections for each GNSS signal received at a reference station. The augmentation data is transmitted to users in the vicinity of the reference station to enable them to correct their own range measurements. Due to spatial decorrelation of propagation effects, the accuracy of correction techniques decreases with increasing distance from the reference station. Although the coverage area of IALA Beacon DGNSS is usually a few 100 km from a reference station, sub-metre accuracies may be possible at close distances.

Real Time Kinematic (RTK) is a phase based differential GNSS technique providing code and carrier measurements for all in-view satellites via a reference station. RTK may operate with single frequency and dual frequency GNSS measurements; however, multi-frequency data processing is expected to become practicable soon. The use of dual frequency RTK should be preferred due to a better mitigation of ionospheric propagation effects, faster ambiguity solution, and consequently an improved availability of high-accurate position results. A successful fixing of unknown ambiguities of phase measurements is a prerequisite for high-accuracy position results. Therefore RTK requires stable receiving conditions of radio signals in order to provide the required performance.

RTK based positioning assumes a high correlation between ranging errors observed at reference station site and ranging errors occurred at user site. Therefore, the preferred application area should be close to a reference station (up to 10 and 20 km) depending on the available radio link for the transmission of RTK augmentation data. Furthermore the application of RTK requires that range and phase measurements at the reference station are transmitted to the user with a sufficient update rate and preferably without significant latencies. The communication channel should have a sufficient bandwidth to distribute RTK augmentation data.

With network RTK approach the decorrelation effects are negligible.

Typically RTK services don't provide any integrity information, however, future methods for RTK integrity monitoring which consider safety relevant maritime applications are being developed.

RTK with fixed ambiguities enables position accuracies better than 0.1 m. With unfixed ambiguities (float solution), the inaccuracy of position may achieve few decimetres.

## 6.3. PPP

Precise Point Positioning (PPP) is a method for global absolute positioning combining usually multi-frequency GNSS phase measurements with provided precise satellite orbits and clock corrections. PPP data products are generated based on the measurements of a global or regional network of GNSS monitoring stations. Local effects have to be compensated at the user side when the PPP service provider does not offer data for regional or local corrections. If single frequency phase measurements are used, additional precise ionosphere models have to be considered.

PPP enables cm accurate positioning, but it strongly depends on precise satellite orbit and clock error estimations, the number of tracked satellites and the time of continuous phase measurements without signal interruption. An accuracy of 10 cm can be reached under good conditions after several minutes.

A communication channel from computation centre to the user is continuously needed.

## 7. SYSTEM IMPLEMENTATION AND OPERATIONAL ASPECTS

This chapter provides guidance for the description of high-accuracy positioning and ranging systems as individual Guideline. Furthermore the implementation principles for harmonised system architectures of shore-based infrastructures written in IALA Guideline 1113 [6] should be taken into account.

### 7.1. SHORE SITE ARCHITECTURE

**Table 5** *Shore Site Architecture*

Topic	Description
Schematic structure of the system and/or service	Block diagram and general description of all required hardware and software components and their functions
Data acquisition and dedicated interfaces	Description of the interfaces and methods for the collection of the required input data (e.g. single site approach or network based approach)
Data processing	Description of methods for the processing of the input data and integrity monitoring
Composition of data products	Description of methods for the provision of all output data

### 7.2. TRANSMISSION SERVICES

**Table 6** *Transmission Services*

Topic	Description
Interfaces	Description of the required hardware interfaces between the system/service and a user device
Protocols and formats	Specification of the used layers, the encapsulation, and protection of data (including data security)
Performance parameter	Description of details concerning the aspects of operational performance specification e.g. bandwidth, latency, coverage, availability, and continuity

### 7.3. TECHNICAL IMPLEMENTATION

**Table 7** *Technical Implementation*

Topic	Description
Components for the acquisition and processing of data	Detailed description concerning the installation of all system and/or service components required for data acquisition and processing
Components for the transmission of data	Detailed description concerning the installation of all system and/or service components required for data transmission
Adjustment of a measuring system	Operations for the calibration of measuring sensors and systems

## 7.4. OPERATIONAL ASPECTS

**Table 8 Operational Aspects**

Topic	Description
System Performance	Specification concerning accuracy, integrity, continuity, availability, coverage of the system and/or service
System Maintenance	Activities (e.g. tests, measurements, replacements, adjustments and repairs) intended to retain or restore the functionality of the system and/or service
System Performance Verification	Activities covering the verification of the offered services by monitoring service performance
Publication of information	Information about the system and/or service (e.g. MSI, handbooks, papers etc.)

## 8. REFERENCES

- [1] IALA Recommendation R-121 on the Performance and Monitoring of DGNSS Services in the Frequency Band 283.5 – 325 kHz, Edition 2.0, May 2015.
- [2] IALA Guideline No. 1112 on Performance and Monitoring Of DGNSS Services in the Frequency Band 283.5 – 325 kHz, Edition 1, May 2015.
- [3] IALA Guideline 1113 on Design and Implementation Principles for Harmonised System Architectures of Shore-based Infrastructure, Edition 1.0, May 2015.
- [4] IMO Resolution A.915(22), Adopted on 29 November 2001 (Agenda item 9), REVISED MARITIME POLICY AND REQUIREMENTS FOR A FUTURE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS).
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- [10] IMO Guideline MSC.1/Circ.1575, GUIDELINES FOR SHIPBORNE POSITION, NAVIGATION AND TIMING (PNT) DATA PROCESSING.
- [11] IALA World Wide Radio Navigation Plan, Edition 2, December 2012.
- [12] IALA Dictionary, URL: <http://www.iala-aism.org/wiki/dictionary/>



## 9. ACRONYMS

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<b>AIS</b>	Automatic Identification System
<b>AL</b>	Alert Limit
<b>AtoN</b>	Marine Aids to Navigation
<b>BEIDOU</b>	Chinese Global Navigation Satellite System
<b>CHAYKA</b>	Russian long range navigation system
<b>CLAS</b>	Centimeter Level Augmentation Service
<b>DGNSS</b>	Differential GNSS
<b>DP</b>	Dynamic Positioning
<b>EGNOS</b>	European Geostationary Navigation Overlay Service
<b>eLORAN</b>	enhanced LORAN
<b>GAGAN</b>	GPS Aided Geo Augmented Navigation
<b>Galileo</b>	European GNSS
<b>GBAS</b>	Ground Based Augmentation Service
<b>GLONASS</b>	Russian Global Navigation Satellite System
<b>GMDSS</b>	Global Maritime Distress and Safety System
<b>GNSS</b>	Global Navigation Satellite System such as Galileo, GPS, GLONASS or BEIDOU.
<b>GPS</b>	U.S. Global Positioning System
<b>HPA</b>	Horizontal Position Accuracy (absolute)
<b>HPE</b>	Horizontal Position Error (absolute)
<b>IALA</b>	International Association of Marine Aids to Navigation and Lighthouse Authorities
<b>IEC</b>	International Electrotechnical Commission
<b>IGS</b>	International GNSS Service
<b>IMO</b>	International Maritime Organisation
<b>IR</b>	Integrity Risk
<b>IRNSS</b>	Indian Regional Navigation Satellite System
<b>LORAN-C</b>	Version three of Long Range Navigation system
<b>MGBAS</b>	Maritime GBAS
<b>MSAS</b>	Multi-functional Satellite Augmentation System
<b>MSI</b>	Maritime Safety Information
<b>NavIC</b>	Navigation with Indian Constellation
<b>OS</b>	Open Service
<b>P</b>	Probability
<b>PNT</b>	Position, Navigation, and Time
<b>PVT</b>	Position, Velocity, and Time
<b>PPP</b>	Precise Point Positioning
<b>PPS</b>	Precise Positioning Service
<b>PRS</b>	Public Regulated Service
<b>QZSS</b>	Quasi-Zenith Satellite System
<b>RACON</b>	Radar Beacon



<b>RTK</b>	Real Time Kinematic
<b>RTS</b>	Real-Time Service
<b>SBAS</b>	Satellite-based Augmentation System
<b>SDCM</b>	System of Differential Correction and Monitoring
<b>SLAS</b>	Sub-meter Level Augmentation Service
<b>SOL</b>	Safety of Life
<b>SPS</b>	Standard Positioning Service
<b>TTA</b>	Time to Alarm
<b>VDES</b>	VHF Data Exchange System
<b>VPA</b>	Vertical Position Accuracy (absolute)
<b>VPE</b>	Vertical Position Error (absolute)
<b>VRS</b>	Virtual Reference Station
<b>WAAS</b>	Wide Area Augmentation System
<b>WWRNS</b>	World Wide Radio Navigation Systems

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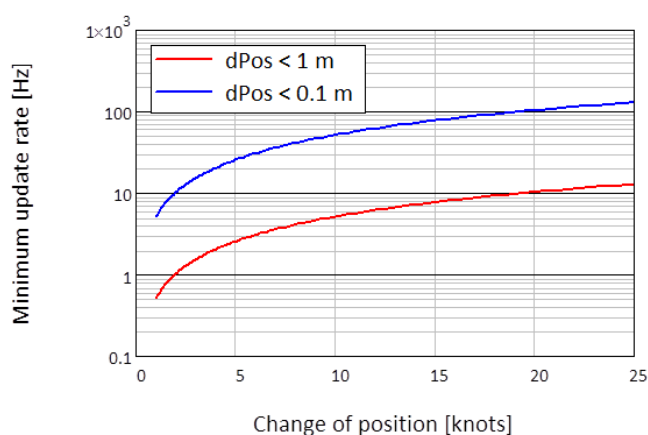
## **ANNEX A FURTHER INFORMATION ABOUT PERFORMANCE PARAMETERS**

### **A 1. LATENCY AND ACCURACY**

High-accuracy positioning and ranging is more sensitive to latencies in processing, provision, utilisation and indication of data.

Moving satellites and users as well as changing environmental conditions are the main reasons that augmentation data provided by DGNSS services are limited to their temporal validity. The applied positioning and ranging method as well as the required accuracy determine the maximum tolerable time delay between generation and use of augmentation data. A correction technique is less sensitive to dynamic errors, if the temporal behaviour of these errors may be described and predicted (e.g. by first coefficients of a Taylor series around a reference time point). It is also understandable that with increasing requirements for accuracy the necessity arises to decrease residual errors by improved determination of dynamic errors and additional mitigation of small-scale errors. Code-based DGNSS are based on range and range rate correction provided for ship positioning in coastal areas. Position accuracies better than 10 meters may be achieved using correction data generated by the DGNSS system few minutes before. In comparison, phase-based DGNSS techniques achieves only position accuracies in the sub-meter level, if at user site single- and double differenced observations may be derived from GNSS ranges and phases measured almost simultaneously at service and user site.

Decision finding in the context of navigational tasks is realised on position data provided and/or indicated by user equipment. Especially the provision of augmentation data (generation at service site and transmission to user site) takes time and leads to the situation that the indicated user position is not the current true position. The difference between both results from error in determined position and user movement during latency time. This should be taken into account, if requirements for position accuracies will be specified. Figure 1 illustrates the problem, whereby the minimum update rate is used as the measure for the inverse of tolerable latency to reach a certain difference between the current and indicated position (below 1 metre or 0.1 metre) for a given change of position. So a vessel with 5 knots speed needs at least a 2.5 Hz position update rate (assumed latency lower than 0.4 s) to provide the nautical staff with an accurate position of at least 1 metre on their displays, assuming an error-free position determination. The demand for higher accuracies (blue vs. red curve) results into requirements for higher update rates or lower latencies.



***Figure 1 Inaccuracies of indicated positions due to latency of information***

### **A 2. REMARKS TO AVAILABILITY**

The term continuity and availability in section 4.2.1 is specified by the probability that data provided over a specific time period has fulfilled defined performance requirements. An availability of 99.8% over 30 days may stand for an interruption of data provision taking not more than 86.4 minutes over 30 days or 2.88 minutes per day (assuming unavailability is equal distributed over the days of a month).

If the availability considers the fulfilment of a certain accuracy level, the 0.2% will be spread across times of interrupted data provision and times of degraded data provision. However, then the 95% accuracy is automatically met. Alternatively, the availability evaluation considers only service level parameter as prerequisite for accurate positioning or allows higher inaccuracies (e.g. alert limit as 2.5 times of desired accuracy).

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