

**Input paper:** ENG21-3.1.2.1

**Input paper for the following Committee(s): Purpose of paper:**

（Select as appropriate）

ARM **X** ENG  PAP **X** Input

DTEC VTS  Information

**Agenda item** [[1]](#footnote-1) n.n

**Technical Domain / Task Number** Task 3.1.2

**Author(s) / Submitter(s)** CHINA MSA

Working Draft of Guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service

# 1 ABSTRACT

Based on the deliberations at the ENG 20 meeting and feedback solicited through offline communication channels, China MSA has sustained its intercessory efforts and revised the working draft of the Guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service for further consideration by ENG 21.

# 2 PURPOSE

The purpose of this document is to propose draft guidelines for GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service. It introduces the GNSS Satellite-based PPP service, describes the service parameters characterizing GNSS satellite-based PPP service for maritime use, and provides recommendations regarding GNSS satellite-based maritime applications.

# 3 BACKGROUND

The inputs ENG 20-3.1.2.5, ENG 20-3.1.2.6, and ENG 20-3.1.2.6.1 concerning the development of Guidelines on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service were examined. The overall framework and Chapters 2-3 were refined and expanded. Meanwhile, Chapters 4-6 and the annex were discussed. Work on the draft guideline progressed through correspondence among interested members. The draft guideline is planned for completion during ENG 21 by a dedicated task group.

# 4 DISCUSSION

The working draft goes through revision processes such as comprehensive review, feedback integration, and content optimization, ultimately forming the official version.Based on this submitted version, discussions will be conducted to formulate guideline documents for submission to the ENG Subcommittee.

# 5 PROPOSAL

It is recommended that the ENG Committee proceed with finalizing the technical guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service, building upon the draft working guideline submitted by the China Maritime Safety Administration (MSA).

# 6 Action requested of the Committee

The Committee is invited to deliberate upon the Working Draft of the Guideline on GNSS Satellite-based Precise Point Positioning (PPP) Maritime Service and to collaboratively enhance the contents of the guideline.

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| iALA Guideline |

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GNSS satellite-based Precise Point Positioning(PPP) MARITIME SERVICE

Edition x.x

Document date

Revisions to this IALA document are to be noted in the

Revisions to this IALA document are to be noted in the table prior to the issue of a revised document.

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1. **Introduction**

Global Navigation Satellite Systems (GNSS) have become the primary means of obtaining Position, Navigation and Timing (PNT) information at sea. Most ships are equipped with GNSS receivers (SOLAS carriage requirement [1]).

Within the realm of GNSS satellite-based Precise Point Positioning Maritime Services, the Precise Point Positioning (PPP) is defined as a method for global absolute positioning that typically combines multi-frequency GNSS phase measurements with provided corrections to the individual error contributions at the user receiver, or error states, such as signal-in-space terms (satellite orbit, clock and signal biases) and atmospheric corrections (ionosphere and troposphere). 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. Once the PPP corrections are calculated, they are delivered to the end users via satellite, Internet or any other dissemination means. These corrections are used by the receivers, resulting in decimetre-level or centimetre-level positioning without the need for communication with close range GNSS reference stations.

PPP can achieve high accurate positioning, but it strongly depends on accurate and uninterrupted satellite orbit and clock error estimations, the number of tracked satellites and the time of continuous phase measurements. The main error sources for PPP are mitigated by Dual-Frequency Operation, External Error Correction Data, Modelling or PPP Filter Algorithms. A typical PPP solution requires a period of time to converge to dm or cm accuracy in order to resolve any local biases such as the atmospheric conditions, multipath environment and satellite geometry. The actual accuracy achieved and the convergence time required is dependent on the quality of the corrections and how they are applied in the receiver.

Currently, there are two types of consolidated PPP implementations. One is to obtain post-processed solutions and the other is to have real-time solutions. Post-processed PPP solutions have been in use for many years and generally achieve better results than real-time solutions. Conventional PPP enjoys the great advantage of scalability; however, it has the great challenge of a slower convergence time than that of RTK (Real-Time Kinematic), typically devoted to estimate the state of the individual error contributions, which is not necessary for RTK. A core feature of PPP is the estimation of the carrier phase measurement ambiguities. In order to solve the ambiguities as an integer number, the PPP algorithm needs the satellite carrier phase biases, in addition to the abovementioned PPP corrections (orbit, clock, code biases). Ambiguity resolution techniques allow a higher accuracy and a faster convergence. If the service provides both accurate ionospheric and tropospheric corrections, allowing the full correction of the atmospheric errors, it is defined as PPP-RTK, which can be a post-processed PPP solution providing almost-instantaneous convergence and cm-level accuracy. The main difference between the two implementations is that, post-processed solutions apply correction after measuring using the corrections provided by the service provider, while real-time solutions require precise orbit information and clock corrections to be sent in real-time to the GNSS receiver location.

A communication channel is continuously needed to broadcast correction parameters. Satellite-based Precision Point Positioning (PPP) services broadcast PPP navigation messages on the public service signals of GNSS satellites. It is an important technology for satellite navigation systems to achieve wide-area high-precision positioning through satellite navigation signals due to its wide signal coverage, uniform accuracy distribution, and small number of ground reference monitoring stations. Especially in the use cases of PPP fields, such as autonomous ship automatic berthing, channel mapping, dredging, cargo loading and unloading, etc., decametre or centimetre level positioning accuracy is very necessary.

## Scope of the document

The guideline provides the description of all the elements of GNSS satellite-based PPP service (including PPP and PPP-RTK)relevant to the maritime administrations or authorities (direct reception of GNSS satellite-based PPP service Signal in Space (SiS) onboard the vessels). This includes some scenarios and the scheme for maritime application.

## Structure of the document

Section 1 is the introduction to this Guideline, including the scope of the document.

Section 2 establishes the IMO Resolution A.1046(27) and A.915(22) operational requirements as the reference for the implementation of GNSS satellite-based PPP maritime service.

Section 3 describes the main elements of a basic GNSS satellite-based PPP service architecture and the existing systems.

Section 4 proposes a list of service parameters to characterize GNSS satellite-based PPP service for maritime use, including their definition.

Section 5 describes the GNSS satellite-based PPP service compatible equipment and maritime application scheme.

And Section 6 describes scenarios of the GNSS satellite-based PPP service in maritime service.

Annex contains descriptive information regarding existing and planned GNSS satellite-based PPP systems.

# IMO Resolution A 1046(27) and a.915(22) Reference Requirements

The IMO Resolution A.1046(27) established the requirements that a radionavigation system needs to be recognized by IMO as a component of the Worldwide RadionNavigation System (WWRNS), which are considered to be the prerequisite reference requirements for the implementation of PPP Service for maritime navigation. Moreover, considering PPP's precision services exhibit strong scenario-specific coupling with maritime applications and operations, the IMO Resolution A.915(22) operational requirements published in 2001 are considered to be the appropriate reference requirements for the implementation of GNSS after GPS and GLONASS.

## IMO Resolution A 1046(27) Requirements

Till 2024, IMO has recognized six GNSS systems (GPS, GLONASS, BDS, Galileo, IRNSS, QZSS) as the WWRNS elements in ocean waters. As one potential capability of the recognized GNSS elements by IMO WWRNS such as BDS, Galileo, QZSS and so on, GNSS satellite-based PPP service should be in compliance with the responsibilities of Governments or organizations and the operational requirements. Meanwhile, with the capability of better than decimeter precise positioning of GNSS satellite-based PPP service, the recognized WWRNS can achieve the levels of performance required in IMO Resolution A.1046(27) for coastal areas and harbour approaches.

The IMO Resolution A.1046(27) establishes the operational requirements that a radionavigation system shall fulfil, which are summarized in the table below:

1. IMO Resolution A.1046(27) operational

|  |  |  |
| --- | --- | --- |
|  | Ocean waters | Harbour entrance, harbour approach and coastal waters |
| Accuracy  (95%) | 100 m | 10 m |
| System Integrity  (Time to alarm) | As soon as practicable by Maritime Safety Information | Within 10s |
| Signal Availability | 99.8% | 99.8% |
| Continuity | N/A | 99.97%(over 15 min) |

Moreover, IMO Resolution A.1046(27) requires that governments or organizations owning and operating the recognized radionavigation systems should comply with the following points:

• The government or organization providing and operating the system has stated formally that the system is operational and available for use by merchant shipping.

• The continued provision of the service is assured.

• The system is able to provide position information within the declared coverage area with a performance not less than that established in the present resolution.

• Adequate arrangements have been made for publication of the characteristics and parameters of the system and of its status.

• Adequate arrangements have been made to protect the safety of navigation should it be necessary to

introduce changes in the characteristics or parameters of the system that could adversely affect the

performance of shipborne receiver equipment.

## IMO Resolution a.915(22) Requirements

The IMO Resolution A.915(22) established general requirements, operational requirements, institutional requirements and transitional requirements for the WWRNS GNSS elements after 2001, the requirements can be summarized below:

• A future GNSS should primarily serve the operational user requirements for general navigation. This includes navigation in harbor entrances and approaches, and other waters in which navigation is restricted.

• A future GNSS should have the operational and institutional capability to meet additional area-specific requirements through local augmentation, if this capability is not otherwise provided. Augmentation provisions should be harmonized worldwide to avoid the necessity of carrying more than one shipborne receiver or other devices.

• A regional satellite navigation system that is fully operational may be recognized as a component of the WWRNS.

Therefore, the administration may consider if the above requirements should be fulfilled and documented by the GNSS satellite-based PPP service provider. This may possibly be achieved by using the appropriate IALA recommended methods.

The list of service parameters required for a complete characterization of a GNSS satellite-based PPP service are derived from the list in IMO Resolution A.915(22) and IALA Guideline 1127.

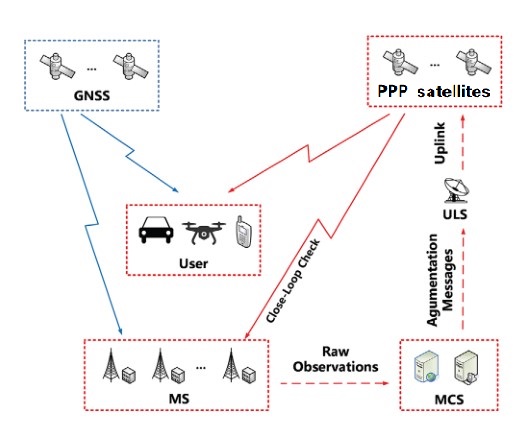
1. IMO Resolution A.915(22) service requirements

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | System level parameters | | | | | Service level parameters | | | |
|  | Accuracy | | Integrity | | | Availability  % per 30 days | Continuity  % over 3hours | Coverage | Fix interval2  (seconds) |
|  | Horizontal  (metres) | Vertical  (metres) | Alert limit (metres) | Time to alarm2(seconds) | Integrity risk (per 3 hours) |
| Operations | Relative accuracy | |  |  |  |  |  |  |  |
| tugs and pushers | 1 |  | 2.5 | 10 | 10^-5 | 99.8 | 99.97 | Local | 1 |
| icebreakers | 1 |  | 2.5 | 10 | 10^-5 | 99.8 | 99.97 | Local | 1 |
|  | Absolute accuracy | |  |  |  |  |  |  |  |
| automatic docking | 0.1 |  | 0.25 | 10 | 10^-5 | 99.8 | 99.97 | Local | 1 |
| Hydrography | 1-2 | 0.1 | 2.5-5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| Marine engineering, construction, maintenance and management |  |  |  |  |  |  |  |  |  |
| dredging | 0.1 | 0.1 | 0.25 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| cable and pipeline laying | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| construction works | 0.1 | 0.1 | 0.25 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| Aids to navigation management | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| Port operations | Absolute accuracy | |  |  |  |  |  |  |  |
| local VTS | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| container/cargo management | 1 | 1 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| law enforcement | 1 | 1 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Local | 1 |
| cargo handling | 0.1 | 0.1 | 0.25 | 1 | 10^-5 | 99.8 | N/A | Local | 1 |
| Casualty analysis | Predictable accuracy | |  |  |  |  |  |  |  |
| port approach and  restricted waters | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| Offshore exploration and  exploitation | Absolute accuracy | |  |  |  |  |  |  |  |
| exploration | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| appraisal drilling | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| field development | 1 | N/A | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| support to production | 1 | N/A^2 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |
| post-production | 1 | N/A^2 | 2.5 | 10 | 10^-5 | 99.8 | N/A | Regional | 1 |

# GNSS satellite-based PPP service

The main elements of a basic GNSS satellite-based PPP service architecture is usually as following:

* **Space segment**: Includes the satellites with payloads aimed to transmit the corrections to the GNSS core constellations.
* **Ground segment**: Includes all the ground elements which provide the PPP navigation messages.
* master control station (MCS)
* uplink stations (ULS)
* monitoring stations (MS)
* **User segment**: Includes the user equipment needed to receive and use the GNSS high accuracy PPP service information.



1. Basic GNSS satellite-based PPP service architecture

## Existing and planned GNSS satellite-based PPP systems

The current institutional service providers of PPP/PPP-RTK are Japan (QZSS), China (BDS), EU (Galileo), Australia/New Zealand (SouthPAN), Russia (GLONASS) and Korea (KPS). At the time of writing this report, only Japan, China and EU provide an operational service: QZSS CLAS [3], BDS PPP [4], and Galileo HAS [5], respectively. Australia/New Zealand is also offering an early open service of PPP via SouthPAN on L5. Russia is offering a ground-based experimental service and developing their satellite-based service . Finally, Korea is developing an open service of PPP-RTK via KPS. All providers offer PPP.The existing and Planned GNSS satellite-based PPP service and their status are shown in Table 3 below:

1. The existing and planned GNSS satellite-based PPP systems

| **Country/Region** | **GNSS satellite-based PPP system** | **Organisation in charge** | **Coverage area** | **Broadcast Signals** | **Status** | **GNSS Augmented** | **CHARGE/FREE** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| China | BDS PPP B2b | China Satellite Navigation Office | Asian-Pacific Area | PPP-B2b | Operational | GPS  BDS  GALILEO  GLONASS | free |
| Europe | Galileo HAS | EUSPA | SL1：GLOBAL  SL2：EUROPEAN AREA | E6-b | Operational  (Initial Service) | GPS  Galileo | free |
| Japan | CLAS  QZSS MADOCA-PPP | cabinet Office of Japanese Government |  | L6-d  L6-e | Operational | QZSS  BDS  GPS  GALILEO  GLONASS |  |
| Australia and New Zealand | PPP via SouthPAN (PVS) | Geoscience Australia and Toitū Te Whenua Land Information New Zealand | Australian and New Zealand | L5 (now)  L5-b(future) | Operational (Initial Operating Capability) OS-PVS-IOC  In-development (Final Operating Capability) OS-PVS-FOC | GPS  Galileo | free |
| KOREA | KPS POINT | Ministry of Oceans and Fisheries, and Korea AeroSpace Administration | Republic of Korea | L6 | Ground-based  Satellite-based(future) | GPS  Galileo  KPS | free |
| Russia | GLONASS PPP | ROSCOSMOS, State Space Corporation, Russian Federation | Russian Federation  Global(furutre) | L3SVO | Ground-based expertise  Satellite-based (future) | GLONASS  GPS  Galileo  BDS |  |

## Correction parameters

PPP Messages are synchronized with their own system time reference through a preamble or synchronization pattern transmitted regularly, as is the case for most GNSS signals. The satellite corrections are linked to the corrected broadcast messages through the broadcast IODs and satellite ID. Error detection and/or correction codes are added in all messages.

Regarding satellite corrections, all corrections are provided for satellite broadcast orbits and clocks. Code biases are provided for between multiple signals, where GPS L1C/A is one of them in all cases. Other corrected signals include L5/E5a, E5b/B2, L2C/L2OF and E6. Phase biases are provided by QZSS and will be provided by Galileo and GLONASS. Note that biases are closed related to satellite antenna phase centers. Usually PPP/PPP-RTK service providers will align their satellite clock products with the satellite center of mass (Ref. CoM) or the satellite antenna phase centers (Ref. APC). Which reference point, CoM or APC, to be used will lead to different code/phase bias corrections, and they are totally incompatible. Therefore, the observations used for code/phase bias estimation are corrected by the APC corrections, in order to reconcile the signal bias to a uniform and frequency-independent reference point for both the server side and the user side. This has been a common practice in bias estimation processes using geometry-related observations (e.g., for ionosphere-free phase bias) for long time, but it was not clear until recently for bias estimation processes using geometry-free observations (e.g., for MW phase bias and differential code bias) . The APC issue should be considered when accounting for the interoperability of PPP bias products.

Regarding atmospheric corrections, ionosphere corrections are already provided by QZSS through STEC (Slant Total Electron Content) and will be provided by Galileo through VTEC (Vertical Total Electron Content) as part of the so-called Service Level 2 in Europe. Other PPP providers have not shared yet any plans to provide ionospheric corrections. QZSS CLAS is the only system providing tropospheric corrections over the Japan area, as part of CLAS. KPS will provide the atmospheric correction for PPP-RTK.

Additional data also provided by some operators includes a confidence level on the corrections, such as URA (User Range Accuracy) or equivalent, integrity, and authentication. URA is provided by QZSS and BDS and confidence values for corrections will be also provided by Galileo (HAS Phase 2). Authentication is not yet provided but foreseen by QZSS, Galileo and GLONASS.

For the supported GNSS for correction, most services support GPS, and their own navigation system, QZSS for QZSS CLAS and QZSS MADOCA-PPP, Galileo for Galileo HAS, BDS for BDS PPP, GLONASS for GLONASS PPP, KPS for KPS POINT. QZSS CLAS also support Galileo, QZSS MADOCA-PPP also support Galileo and GLONASS, and PVS (PPP via SouthPAN) supports GPS and Galileo. For supported navigation message, LNAV is supported for all GPS and QZSS correction providers, I/NAV is supported for Galileo except for PVS. CNAV1 is supported for BDS by BDS PPP.The PPP messages are transmitted at a rate between 2,800 bps (GLONASS PPP) to 448 bps (Galileo HAS) per satellite. Both have been proven sufficient to provide corrections with a high-enough update rate for their intended service.

Correction parameters messages for Satellite-Based PPP are broadcast through GNSS satellites, mainly include satellite orbit correction, clock correction, biases(code and phase) and user range accuracy. shown in Table 4 below.

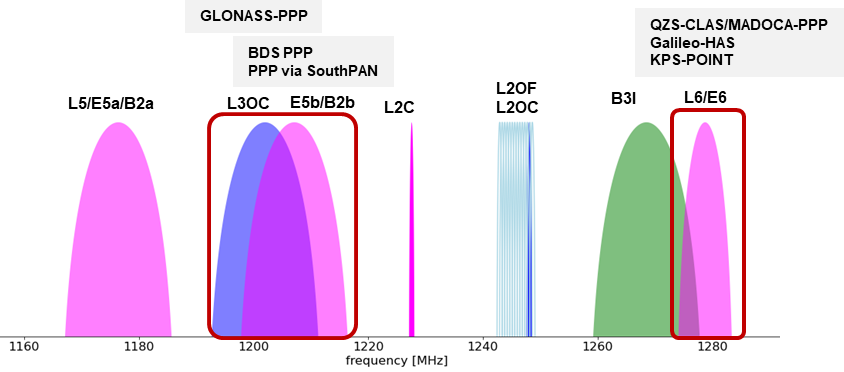
1. Correction parameters for Satellite-Based PPP

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Correction parameters** | **BDS PPP** | **Galileo HAS** | **QZSS MADOCA-PPP** | | | **PPP via SouthPAN** | **KPS POINT** | **GLONASS** |
| **Time** | BDT | GST | QZSST | | CLAS | SNT | KPST | UTC+3h |
| **Reference frame** | BeiDou Coordinate System (BDCS) | Galileo Terrestrial Reference Frame (GTRF) | ITRF | |  | ITRF2014 | Korean Terrestrial Reference Frame (KTRF) | ITRF2014 |
| **Satellite mask** | Y | Y | Y |  | | Y | Y | Y |
| **Satellite orbit correction** | Y | Y | Y |  | | Y | Y | Y |
| **Clock correction** | Y | Y | Y |  | | Y | Y | Y |
| **Code Biases** | Y | Y | Y |  | | N | Y | Y(future) |
| **Phase Biases** | - | Y[[2]](#footnote-2) | Y |  | | N | Y | Y(fufure) |
| **User Range Accuracy** | Y | Y | Y |  | | Y | Y | Y |
| **Atmospheric corrections** | n/a | Available at Service Level 2 | n/a |  | | N | Y | Y(future) |
| **Delivery Channels** | Signal in Space (SiS) | Signal in Space (SiS) and HAS IDD (Internet) | Signal in Space | | | Signal in Space | Signal in Space | Signal in Space |
| **Broadcasting Frequencies** | B2b | E6 | L6 |  | | L5 | L6 | L3SVO |

## Augmented navigation message

PPP/PPP-RTK Messages are synchronized with their own system time reference through a preamble or synchronization pattern transmitted regularly, as is the case for most GNSS signals. The satellite corrections are linked to the corrected broadcast messages through the broadcast IODs and satellite ID. Error detection and/or correction codes are added in all messages, including a checksum by CRC, encoding by LDPC, Reed-Solomon or convolutional codes.

Figure 2 shows the frequency of PPP/PPP-RTK signals. The signal carrier frequencies used for the PPP/PPP-RTK signals coincide with those used for GNSS: 1278.75 MHz (Galileo E6, QZSS L6, KPS L6), 1207.14 (BDS B2b, SouthPAN E5b), or 1202.025 MHz (GLONASS L3). Signal power ranges across the typical GNSS power levels, from -160dBW to -153dBW on earth. All signals are RHCP.

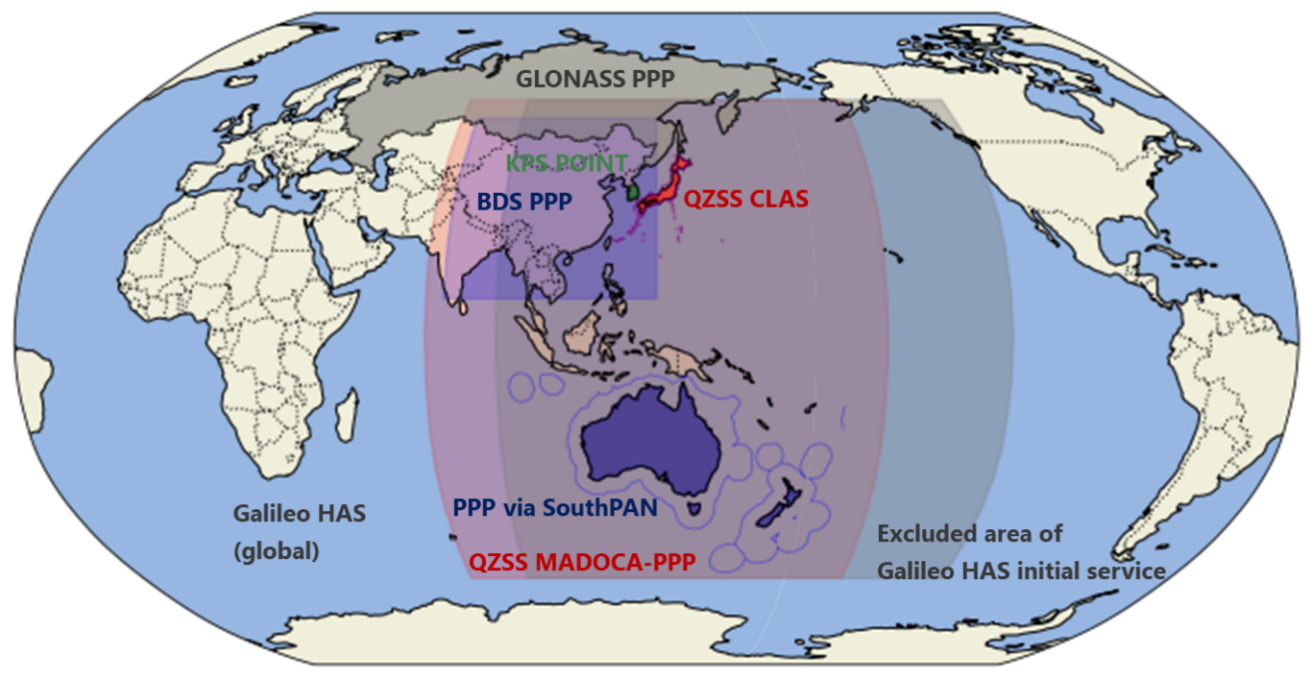


1. Power spectrums vs frequency of the main PPP/PPP-RTK signals

Concerning signal modulation, all signals are DS-SS (Direct Sequence-Spread Spectrum) using BPSK code modulations: BPSK(5) for L6/E6 (QZSS, Galileo) and L3 (GLONASS); and BPSK(10) for E5b-B2b (BDS, SouthPAN). They use shift register (Gold, Kasami) or memory codes, at least in those publicly defined. The correction message is multiplexed with the code in a binary phase-modulated way for all cases but QZSS, which uses Code Shift Keying (CSK) to transform 250 sps into the 2000 bps abovementioned.

## Service Coverage

Regarding coverage, most services are provided regionally: QZSS CLAS for Japan and MADOCA-PPP for the Asia-Oceania region, PPP via SouthPAN in Exclusive Economic Zone of Australia/New Zealand and BDS in China and its surroundings. Only Galileo HAS is provided globally, although with a temporary limitation excluding the Asia-Pacific region from the official service area during the initial service phase (Phase 1). There are plans for a global service also from GLONASS PPP.



1. Service Area of GNSS satellite-based PPP

# GNSS satellite-based PPP service Performance Parameters

This section proposes a list of service parameters to characterize GNSS satellite-based PPP service for maritime use. The paragraphs below detail how these parameters can be understood and measured.

## Positioning accuracy and convergence time

Positioning accuracy is expressed as the horizontal and vertical accuracy [m], both at the 95%. It relates to convergence time which is defined as the time required to permanently[[3]](#footnote-3) reach the specified positioning accuracy, including the time to receive the correction data. The accuracy and convergence time are summarized and provided by each PPP system shown in table 4-1.

1. Positioning accuracy and convergence time for Satellite-Based PPP

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **BDS PPP** | **Galileo HAS** | **QZSS MADOCA-PPP** | **CLAS** | **PPP via SouthPAN** | **KPS POINT** | **GLONASS PPP** |
| **Real-time Horizontal Accuracy** | 30cm (using BDS only)  20cm (BDS+GPS) | 20cm | 30cm | 12cm horizontal, 24cm vertical (kinematic)  6cm horizontal, 12cm vertical (static) | 37.5 cm | 10cm | 20cm horizontal |
| **Real-time**  **Vertical Accuracy** | 60cm  (using BDS only)  40cm (BDS+GPS) | 40cm | 50cm  (static) |  | 52.5 cm | 20cm | 30cm vertical |
| **Convergence time** | 30 mins  (using BDS only)  20 mins (BDS+GPS) | 300 sec(L1)  100 sec(L2) | 30mins | 60 sec (Including time to receive correction data) | OS-PVS-IOC =< 80 minutes (average 45-55 minutes)  OS-PVS-FOC =< 40 minutes | TBD | 1200 sec |

## SIGNAL Availability

The signal is considered available when provided according to its specification. For maritime, Signal Availability is the percentage of time the SiS is provided by the GNSS throughout the specified service coverage area.

## Service Availability

Service Availability is the probability of the system providing the necessary information that would enable the

user to determine their position, with the specified accuracy within the service coverage area.

## Service Continuity [[4]](#footnote-4)

The probability that, assuming a fault-free receiver , a user will be able to determine position without any interruption under specified accuracy applicable for a particular operation within the service coverage area.

## Integrity

The ability to provide users with warnings within a specified time when a system should not be used for navigation. The minimum operational requirements of integrity of PPP/PPP-RTK depends on the use cases.

## SERVICE COVERAGE AREA

The maritime service coverage area is a designated geographical area where, taking into account the radio

frequency environment, PPP/PPP-RTK is adequate to provide required service performance throughout a phase of

navigation according to the specific operations.

1. **GNSS satellite-based PPP MARITIME Service Provision Scheme**

A scheme for providing the users with the appropriate GNSS satellite-based PPP maritime service should be established, including the provision of maritime safety related information to the end users.

This section describes an example of this scheme, with relevant stakeholders involved, including the interfaces between them and the provision of GNSS satellite-based PPP service related Maritime Safety Information (MSI) to the end users. The picture below presents schematically this High level Service provision model:



Figure 4 GNSS Satellite-based PPP Maritime Service Provision Scheme

This example considers the reception of the PPP SiS directly on-board the vessels equipped with type approved receivers. The stakeholders involved in this high-level service provision model, including their expected roles and responsibilities, are described below:

## THE PPP SERVICE PROVIDER

The PPP Service Provider will be the entity which provides the PPP Maritime Service. The PPP Service Provider

will also be responsible for establishing and supporting all the required operational interfaces with the other

stakeholders (end users, Marine Aids to Navigation Competent Authorities and MSI Providers)[[5]](#footnote-5), including the

generation of any PPP MSI proposals to be distributed by the MSI providers to the end users of the service.

### PPP SERVICE PROVIDER RESPONSIBILITIES

The PPP Service Provider responsibilities may be structured in four main blocks, as follows:

#### Operation and Maintenance:

The PPP Service Provider should continuously monitor the service to detect and manage service disruptions and

performance degradations and inform the users. The information regarding planned and unintended PPP service

degradations and unavailability is delivered to the MSI provider.

* + - 1. **Performance Verification:**

The PPP service provider should verify that the service is performing according to its specifications.

* + - 1. **Publication of information:**

The PPP service provider should make publicly available the description of the service and also report scheduled

maintenance activities and planned unavailability. The PPP service provider could also provide service performance reporting and support to all the users.

* + - 1. **Working agreements:**

The formalisation of PPP Service Provider commitment to provide the service and the engagement with

administrations could be done by establishing working agreements, including:

• Roles, responsibilities and liability [[6]](#footnote-6)scheme,

• Assurance of the long-term operation of the PPP service and backwards compatibility,

• Service offered and its characteristics,

• Service performance in compliance to the IMO Requirements and maritime service coverage area,

• PPP MSI provision (generation and distribution procedure),

• Costs of the service – (e.g. free of charge),

• Legal data recording needs.

* + 1. **AIDS TO NAVIGATION AUTHORITIES**

Aids to Navigation authorities are encouraged to work with the PPP maritime service provider through

mutual cooperation and consider any additional responsibility for the authorities for the delivery of the service or

the maritime safety information, beyond their existing roles. Authorities are encouraged to monitor the service

and ensure that appropriate MSI is being conveyed to the user.

For MSI existing internationally agreed procedures should be followed.

## END USERS

The end users are the mariners/vessels using the PPP Maritime Service SiS. End users that wish to use this

service need to use a type approved receiver, once the appropriate standards are in place. The end users are also

the recipient of the MSI related to PPP.

## MSI PROVIDER

The MSI provider is encouraged to promulgate to the users, using approved procedures, the MSI related to PPP

Maritime Service status and degradations.

The PPP Service Provider should send details of the PPP MSI (e.g. service performance degradations) to the MSI

provider, in a format agreed between these parties. The MSI provider will use the procedures and channels

already in place for the transmission of MSI to the vessels. Depending on the specific characteristics of the PPP MSI, the MSI provider will distribute the information as Navigational warnings (NAVAREA, coastal or local

warnings)[[7]](#footnote-7)[[8]](#footnote-8) or Notices to Mariners (NtM)[[9]](#footnote-9).

1. **User Segment Approach**

[Including specific scenarios for maritime usage]

Specific scenarios for maritime usage could involve various operations and routes taken by the vessels. The User Segment Approach should consider the diverse range of maritime operations and the specific needs of different user groups, ensuring that the PPP Maritime Service is designed and delivered in a way that supports safe, efficient, and sustainable maritime navigation.

## MASS

Maritime Autonomous Surface Ships (MASS) is defined by IMO as being: *A ship which, to a varying degree, can operate independently of human interaction.* The MASS should be able to navigate to minimise risk of grounding, collision and environmental impact and to communicate its limitations and navigational intentions to other vessels. Navigational systems should identify all navigation hazards, fixed or mobile, and measure and interpret environmental data. The navigational systems should be designed and constructed to:

1. Enable their operation in all Reasonably Foreseeable Operating Conditions;

(b) Operate in a predictable manner with a level of integrity commensurate with operational and safety requirements;

(c) Meet requirements for watertight, weathertight and fire integrity;

(d) Minimise the risk of initiating fire and explosion;

(e) Enable the maintenance and repair in accordance with the maintenance philosophy.

(f) allow for automated docking.

Satellited-based PPP provide high accuracy of operation of MASS for navigation in harbour entrances, harbour approaches without assistance of the ground broadcasting system. Once the PPP service converges, it can provide stable and continuous high-precision location service at centimetre level. This will be critical in enabling MASS to navigate safely and manoeuvre as required by international regulations.

## OFFSHORE OPERATIONS

PPP can support offshore drilling and construction through provision of an accurate and reliable method of maintaining precise locations, which is essential for the safety and efficiency of these operations.

Critical for Complex Offshore Activities. Offshore operations like pipe-laying, drilling, and maintenance require high levels of accuracy to ensure proper alignment and avoid costly errors. PPP provides centimeter-level precision, which is essential when exact positioning is critical.

Support for Dynamic Positioning Systems. Many offshore vessels and platforms use dynamic positioning (DP) systems to maintain their location without the need for anchors. PPP enhances these systems by supplying highly accurate geospatial data, allowing vessels to remain in a fixed position even when affected by currents, waves, or wind. This stability is especially important during complex and high-stakes activities such as drilling or construction in challenging sea conditions.

Minimizing the Risk of Drifting. For vessels like survey ships, floating production systems, or support vessels, precise station-keeping is necessary to avoid drifting, which could lead to accidents or disruptions in operations. PPP ensures that vessels remain within defined positional limits, reducing the risk of collisions, environmental damage, or costly downtime due to repositioning.

Increased Operational Efficiency and Safety. By providing precise and continuous positioning data, PPP helps reduce the margin for error in offshore operations. This improved accuracy enhances both operational efficiency and safety, preventing incidents that could compromise the integrity of critical infrastructure or endanger personnel. In unpredictable and often harsh ocean environments, this level of precision is indispensable.

## PORT AND HARBOUR OPERATIONS

Port and harbour operations require accuracy of position to enhance safety and efficiency in critical activities, such as:

Safe and Efficient Docking for Large Vessels. Large ships, such as container vessels and cruise liners, require precise navigation when entering or leaving ports, especially in crowded harbours or during challenging weather conditions. PPP provides highly accurate positioning, allowing these vessels to dock safely and efficiently, minimizing the risk of collisions or grounding, even in narrow or congested areas.

Accurate Dredging Operations. Maintaining safe depths in ports and harbours is essential for accommodating large vessels. PPP ensures precise positioning during dredging operations, which is critical for removing sediment and maintaining the necessary depths for vessel passage. Accurate dredging also optimizes costs by ensuring only the necessary areas are dredged and to the required depth.

Precision in Harbour Infrastructure Construction. Building breakwaters, piers, and other harbour structures requires a high degree of accuracy to ensure structural stability and alignment. PPP supports precise construction by providing accurate location data for construction teams, ensuring that these structures are built to the correct specifications and in the right positions.

Enhanced Automation in Port Machinery. Modern ports increasingly rely on automated systems such as cranes and transport vehicles to handle containers and other cargo. PPP enhances the precision of these automated systems by ensuring accurate positioning of cranes and machinery, enabling efficient loading and unloading of goods. This not only streamlines port operations but also reduces human error and improves overall safety.

Weather-Independent Operations. PPP remains reliable even in challenging weather conditions, providing continuous and accurate data. This allows for uninterrupted port operations regardless of reduced visibility or adverse environmental factors, further ensuring the safety and efficiency of vessel movements and cargo handling.

## SURVEY OPERATIONs

Accurate Seabed Mapping for Navigation. Hydrographic surveys rely on high-precision positioning to map the seabed, coastal areas, and underwater hazards. PPP ensures that these surveys provide the necessary detail to support safe navigation, identifying potential obstacles or changes in the seabed that could pose risks to vessels. This level of accuracy is crucial for charting safe shipping routes and preventing accidents.

Supporting Port Development. Accurate hydrographic data is vital for the planning and development of ports and harbours. PPP ensures the precise mapping of underwater features and topography, aiding in the design of new infrastructure such as piers, docks, and dredging zones. With PPP, engineers can make informed decisions based on reliable data, ensuring that development projects proceed smoothly and safely.

Critical for Environmental Assessments. Environmental assessments often require precise mapping of coastal and underwater areas to monitor ecosystems, assess the impact of construction, and detect changes in marine environments. PPP enhances the accuracy of hydrographic surveys used for these assessments, providing data that is vital for protecting marine life and coastal habitats, ensuring that development or industrial activities are environmentally sustainable.

Supporting Underwater Installations. Pipelines, cables, and other underwater installations rely on precise mapping and monitoring to ensure their integrity. PPP allows for highly accurate surveys and monitoring systems, enabling precise placement of these critical infrastructures. Additionally, PPP supports maintenance operations by providing exact positional data for inspecting and repairing underwater assets, minimizing the risk of damage and reducing downtime.

Improving Safety and Efficiency in Surveying. Hydrographic surveys conducted with PPP improve both safety and efficiency. By providing real-time, highly accurate positioning data, surveyors can avoid costly errors, complete surveys more quickly, and reduce the likelihood of revisiting sites due to inaccurate data. This is particularly important in complex environments where precision is vital to avoid hazards or disruption to marine operations.

## SEARCH AND RESCUE

In search and rescue operations, PPP provides rescue vessels and aircraft with highly accurate location data, enabling quicker response times and more effective rescue efforts, particularly in bad weather or poor visibility. The system supports real-time tracking of vessels in distress, providing rescuers with accurate, up-to-date information for planning and coordination.

Dredging is the removal of sediments and debris from the bottom of lakes, rivers, harbors, and other water bodies. It is a routine necessity in waterways around the world because sedimentation—the natural process of sand and silt washing downstream—gradually fills channels and harbors. Dredging often is focused on maintaining or increasing the depth of navigation channels, anchorages, or berthing areas to ensure the safe passage of ships. Vessels require a certain amount of water in order to float and not touch bottom. A Dredge Positioning System is often used combined with GNSS Real-time kinematic (RTK) positioning devices to show a superimposed view of the dredge location in real-time over the survey. GNSS satellite-based PPP service can provide real-time high accuracy location without extra augmentation GNSS devices. It precisely identifies the location of the attachment at the end of the excavator boom/stick assembly. And together with the dredge positioning system, displays a survey or map of an as-built color bathometric surface of the area to be dredged. It decreases the potential for damage by increasing situational awareness, keeping the operator alerted when the digging attachment is positioned too close to environmental borders, infrastructure, or any other areas where the digging attachment can cause undesired damage.

1. **Acronyms**

BEIDOU Chinese Global Navigation Satellite System

CHAYKA Russian long range navigation system

CLAS Centimetre Level Augmentation Service

DGNSS Differential GNSS

EGNOS European Geostationary Navigation Overlay Service

Galileo European GNSS

GLONASS Russian Global Navigation Satellite System

GMDSS Global Maritime Distress and Safety System

GNSS Global Navigation Satellite System such as Galileo, GPS, GLONASS or BEIDOU.

GPS U.S. Global Positioning System

IALA International Association of Marine Aids to Navigation and Lighthouse Authorities

IEC International Electrotechnical Commission

IGS International GNSS Service

IMO International Maritime Organization

IRNSS Indian Regional Navigation Satellite System

MADOCA-PPP Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning

PNT Position, Navigation, and Time

PPP Precise Point Positioning

QZSS Quasi-Zenith Satellite System

RTK Real Time Kinematic

SBAS Satellite-based Augmentation System

SDCM System of Differential Correction and Monitoring

WWRNS World Wide Radio Navigation Systems

1. **References**
2. Service Definition Document for Signal-In-Space Open Services, <https://www.ga.gov.au/__data/assets/pdf_file/0011/123320/SBAS-STN-0001_03_SouthPAN-SDD-for-SIS-OS.pdf>
3. Galileo augmented navigation message[Reference: Galileo HAS SIS ICD, Issue 1.0, May 2022]
4. European Union, “Galileo High Accuracy Service - Service Definition Document (HAS SDD) v1.0,” EUSPA, Jan 2023.]
5. Galileo HAS SL1 and SL2 are described in the Galileo HAS info note available at: https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo\_HAS\_Info\_Note.pdf
6. Galileo HAS SERVICE DEFINITION DOCUMENT (SDD): https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo-HAS-SDD\_v1.0.pdf
7. Galileo HAS SIGNAL-IN-SPACE INTERFACE CONTROL DOCUMENT (SIS ICD): https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo\_HAS\_SIS\_ICD\_v1.0.pdf
8. Galileo HAS Internet Data Distribution (IDD): https://www.gsc-europa.eu/galileo/services/galileo-high-accuracy-service-has/internet-data-distribution
9. IMO Resolution A.1046(27), Adopted on 30 November 2011, WORLDWIDE RADIONAVIGATION SYSTEM.
10. IMO Resolution A.915(22), Adopted on 29 November 2001 , REVISED MARITIME POLICY AND REQUIREMENTS FOR A FUTURE GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS).
11. IALA Guidelines 1180,RESILIENT PNT
12. IALA Guidelines 1152, SBAS MARITIME SERVICE
13. IALA Guideline G1112 Performance and Monitoring Of DGNSS Services in the Frequency Band 283.5 – 325
14. IALA Guidelines 1127, SYSTEMS AND SERVICES FOR HIGH ACCURACY POSITIONING AND RANGING
15. IALA Guidelines 1129, THE RETRANSMISSION OF SBAS CORRECTIONS USING MF-RADIO BEACON AND AIS
16. IALA Recommendation 1022 PROVISION OF GNSS AUGMENTATION SERVICE FOR MARITIME APPLICATION
17. IALA NAVGUIDE 2023.
18. IMO Guideline MSC.1/Circ.1575, GUIDELINES FOR SHIPBORNE POSITION, NAVIGATION AND TIMING (PNT) DATA PROCESSING.
19. IALA World Wide Radio Navigation Plan, Edition 2, December 2012.

ANNEX A existing and planned GNSS satellite-based PPP systems

A.1 ANNEX BDS PPP B2b

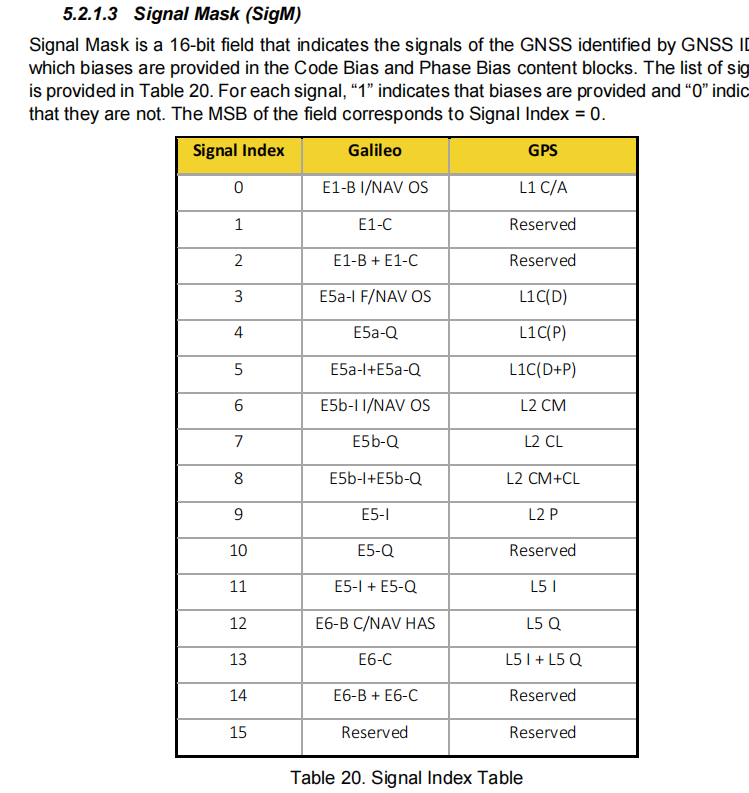
The BDS PPP-B2b signal is designed to provide PPP service for GNSS and their combinations. For each satellite navigation system, the reference broadcast navigation messages corresponding to various corrections are:

1) BDS: PPP-B2b information is used to correct the CNAV1 navigation messagesofB1C signal.

2) GPS: PPP-B2b information is used to correct the LNAV navigation messages.

3) Galileo: PPP-B2b information is used to correct the I/NAV navigation messages.

4) GLONASS: PPP-B2b information is used to correct the L1OCd navigation messages



A.2 ANNEX Galileo HAS

On January 24th 2023, the Galileo HAS Initial Service was declared operational and Galileo became the first Global Navigation Satellite System (GNSS) to provide free-of-charge, high accuracy Precise Point Positioning (PPP) corrections worldwide, both through the Galileo signal in space (E6-B) and over the internet through Galileo HAS IDD.

The HAS Initial Service, enabled by the current Galileo infrastructure, allows the provision of the so-called HAS Service Level 1 (not all SL1 products are available at Initial Service, certain areas are not covered). Even if the HAS Initial Service performances do not reach the HAS Full Service targets yet, the Galileo HAS Initial Service provides decimeter level as a typical accuracy performance. The full description of the HAS Initial Service, including performance levels and coverage, is provided in the HAS Service Definition Document (SDD).

In the near future, the Galileo HAS Full Service will provide two Service Levels. It will expand the Initial Service version of the so-called SL1 to support more demanding performance targets and achieve a global service area. Additionally, the Galileo HAS Full Service will provide a regional, European centric, Service Level (SL2). Their main features are included hereafter:

SL1:

Service area: global coverage, hence addressing the areas currently excluded from the HAS service area,

Products: orbits and clocks corrections, code and phase biases.

Delivery channels: HAS Signal-In-Space (SIS) and HAS Internet Data Distribution (IDD),

User performance accuracy (95%): 20 cm (horizontal) and 40 cm (vertical),

Availability target: 99%,

User performance convergence time: 300 seconds.

SL2:

Service area: European coverage,

Products: SL1 products and atmospheric corrections,

Delivery channels: HAS SIS and HAS IDD,

User performance accuracy targets (95%): 20 cm (horizontal) and 40 cm (vertical),

Availability target: 99%,

User performance convergence time: 100 seconds.

A.3 ANNEX CLAS

The CLAS (Continuous Learning and Adaptation System) is a key component in the evolution and enhancement of Galileo HAS. It is designed to continuously monitor and improve the service based on user feedback and operational data. By incorporating machine learning algorithms, CLAS can adapt to changing conditions and user needs, ensuring that Galileo HAS remains at the forefront of navigation technology. This continuous improvement cycle will play a crucial role in the long-term success and reliability of the Galileo HAS service.

Moreover, the integration of CLAS with Galileo HAS fosters a collaborative environment among users and providers. Users can report anomalies or suggest improvements, which are then analyzed by CLAS to adjust and optimize the service. This two-way communication ensures that Galileo HAS evolves in tandem with technological advancements and emerging user requirements.

Furthermore, the CLAS system is instrumental in anticipating and mitigating potential disruptions. By continuously analyzing operational data, CLAS can detect early signs of issues such as satellite malfunctions or signal interference. This proactive approach allows for swift corrective actions, minimizing downtime and maintaining the high availability and reliability of Galileo HAS.

In conclusion, the implementation of CLAS within Galileo HAS underscores a commitment to excellence and innovation. It not only enhances the current capabilities of the service but also paves the way for future advancements, ensuring that Galileo HAS remains a leader in precise point positioning technology for years to come.

# A.4 ANNEX QZSS MADOCA-PPP

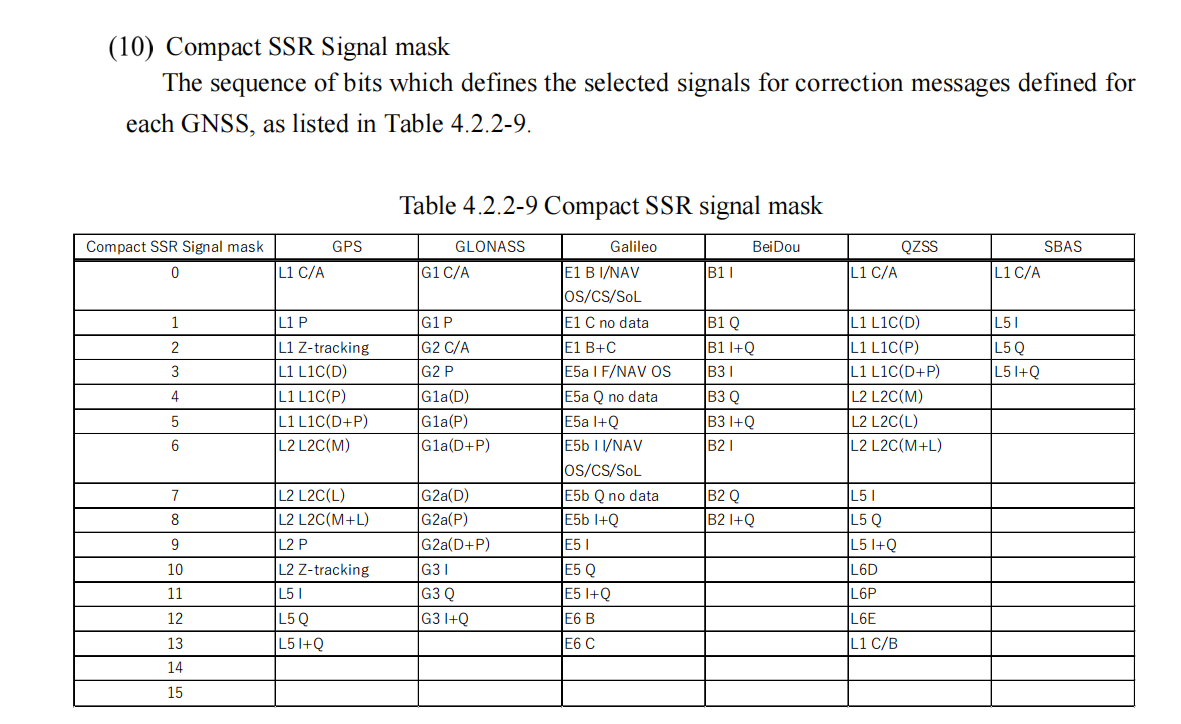
[Reference: Quasi-Zenith Satellite System Interface Specification Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning (IS-QZSS-MDC-002)- (November 2023) Cabinet office]

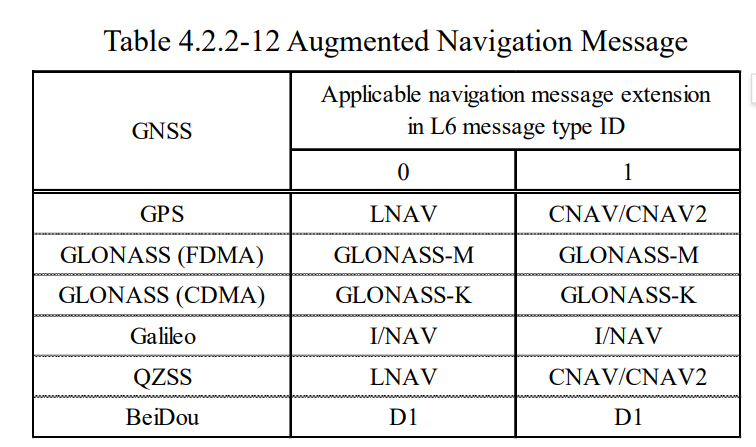
QZSS MADOCA-PPP leverages the Quasi-Zenith Satellite System (QZSS) to provide advanced orbit and clock augmentation for Precise Point Positioning (PPP). This system aims to enhance the accuracy and reliability of PPP services, particularly in regions where traditional GNSS signals may be weak or unavailable. By utilizing the unique geometry of the QZSS satellites, MADOCA-PPP is able to offer corrections that significantly improve positioning performance.

One of the key advantages of QZSS MADOCA-PPP is its ability to provide regional enhancements. Unlike some global PPP services, QZSS MADOCA-PPP focuses on improving positioning accuracy within specific geographic areas, such as Japan and surrounding regions. This regional focus allows for more tailored corrections and improved performance in these critical areas.

In addition to regional enhancements, QZSS MADOCA-PPP also supports multi-GNSS capabilities. This means that it can utilize signals from multiple global navigation satellite systems, including GPS, Galileo, and GLONASS, to provide even more accurate and reliable positioning. By combining signals from multiple systems, MADOCA-PPP is able to mitigate the impact of signal outages and multipath errors, further enhancing its performance.

Overall, QZSS MADOCA-PPP represents a significant advancement in PPP technology. Its focus on regional enhancements and multi-GNSS capabilities make it an ideal solution for applications that require high-accuracy positioning, such as aviation, marine navigation, and surveying. As the technology continues to evolve, QZSS MADOCA-PPP is poised to play an increasingly important role in the future of precise point positioning.





# A.5 ANNEX PPP via SouthPAN (PVS)

[Geoscience Australia, Land Information New Zealand, “Service Definition Document for Open Services (Revision 02),” December 2022. Available: <https://www.ga.gov.au/__data/assets/pdf_file/0011/123320/SBAS-STN-0001_02_SDD-OS.pdf.>]

South-PAN, which stands for Southern Positioning Augmentation Network, offers an augmented navigation message that enhances the precision and reliability of PPP services in southern regions. By leveraging a network of ground stations and advanced algorithms, South-PAN provides corrections to the standard GNSS signals, significantly improving positioning accuracy.

One of the notable features of PPP via South-PAN (PVS) is its ability to provide real-time corrections. These corrections are transmitted to users via satellite, ensuring that they receive the most up-to-date and accurate positioning information. This real-time capability is crucial for applications that require high precision and reliability, such as aviation, marine navigation, and surveying.

Moreover, South-PAN is designed to be interoperable with other global navigation satellite systems, including GPS, Galileo, and QZSS. This interoperability allows users to benefit from the combined strengths of multiple systems, further enhancing the accuracy and reliability of PPP services. By utilizing signals from multiple systems, South-PAN can mitigate the impact of signal outages and multipath errors, providing a more robust and reliable positioning solution.

In addition to real-time corrections and interoperability, PPP via South-PAN (PVS) also offers high availability and performance convergence time. With an availability target of 99% and a user performance convergence time of 100 seconds, South-PAN ensures that users can rely on accurate and reliable positioning information even in challenging environments.

Overall, PPP via South-PAN (PVS) represents a significant advancement in PPP technology for southern regions. Its real-time corrections, interoperability with multiple systems, and high availability make it an ideal solution for applications that require high-accuracy positioning. As the technology continues to evolve, PPP via South-PAN (PVS) is poised to play an increasingly important role in the future of precise point positioning in southern regions.

# A.6 ANNEX KPS POINT

KPS POINT is another notable contribution to the field of PPP technology. This system leverages advanced algorithms and a dense network of ground stations to provide highly accurate and reliable positioning services. Similar to QZSS MADOCA-PPP, KPS POINT focuses on enhancing positioning accuracy within specific geographic areas, particularly in Korea and surrounding regions.

One of the key features of KPS POINT is its ability to provide real-time corrections and updates. These corrections are transmitted to users via satellite, ensuring that they always have access to the most current and accurate positioning information. This real-time capability is essential for applications that require high precision, such as aviation, marine navigation, and surveying, where up-to-date positioning data is crucial for safety and efficiency.

In addition to real-time corrections, KPS POINT also supports multi-GNSS capabilities. This means that it can utilize signals from multiple global navigation satellite systems, including GPS, Galileo, GLONASS, and QZSS, to provide even more accurate and reliable positioning. By combining signals from multiple systems, KPS POINT is able to mitigate the impact of signal outages and multipath errors, further enhancing its performance and robustness.

Moreover, KPS POINT is designed to be interoperable with other PPP services and systems. This interoperability allows users to seamlessly integrate KPS POINT with their existing positioning infrastructure, further expanding its potential applications and use cases. Whether users are in Korea or other regions, KPS POINT offers a high-accuracy, reliable, and versatile positioning solution that meets the demands of modern positioning technology.

# A.7 ANNEX GLONASS PPP

GLONASS, the Russian global navigation satellite system, has also made significant strides in precise point positioning technology. GLONASS PPP leverages the constellation of GLONASS satellites and a network of ground stations to provide highly accurate positioning services. Similar to South-PAN and KPS POINT, GLONASS PPP offers real-time corrections that are transmitted to users via satellite, ensuring they receive the most up-to-date and precise positioning information.

These real-time corrections are crucial for applications that require high precision and reliability, such as aviation, marine navigation, and surveying. By incorporating real-time data, GLONASS PPP can adapt to changing conditions and provide continuous, accurate positioning, even in challenging environments.

In addition to real-time corrections, GLONASS PPP supports multi-GNSS capabilities. This means it can utilize signals from multiple global navigation satellite systems, including GPS, Galileo, and QZSS, to further enhance positioning accuracy and reliability. By combining signals from these different systems, GLONASS PPP can mitigate the impact of signal outages and multipath errors, providing a more robust and reliable positioning solution.

Furthermore, GLONASS PPP is designed to be interoperable with other PPP services and systems. This interoperability allows users to seamlessly integrate GLONASS PPP with their existing positioning infrastructure, expanding its potential applications and use cases. Whether users are in Russia or other regions, GLONASS PPP offers a high-accuracy, reliable, and versatile positioning solution that meets the demands of modern positioning technology. As the technology continues to evolve, GLONASS PPP is poised to play an increasingly important role in the future of precise point positioning globally.

1. [↑](#footnote-ref-1)
2. (Not available at Initial Service) [↑](#footnote-ref-2)
3. The term *permanently* is added to clarify that if the positioning error reaches the accuracy specification but then it raises above it during the convergence process, the receiver positioning error should not be considered as converged. [↑](#footnote-ref-3)
4. Note: This definition is not completely in line with that provided in the IMO Resolution a.915(22) Requirements. [↑](#footnote-ref-4)
5. Orange and red arrows in Figure 5-1. [↑](#footnote-ref-5)
6. Including technical, operational and legal aspects [↑](#footnote-ref-6)
7. NAVAREA warning is the MSI of temporary nature applicable to one of the 21 navigational areas in the world. [↑](#footnote-ref-7)
8. Coastal or local warnings are the MSI of temporary nature applicable to a coastal or local area. [↑](#footnote-ref-8)
9. Notices to Mariners (NtM) is the MSI permanent information published by the National Hydrographic Office. [↑](#footnote-ref-9)