BeiDou Navigation Satellite System

Open Service

Performance Standard

(Version 1.0)

China Satellite Navigation Office

December 2013

Foreword

The space constellation of BeiDou Navigation Satellite System (BDS) will consist of 35 satellites to provide open services to global users. With a space constellation of 14 operational satellites in orbit, BDS has been in full service to provide open services to the most part of the Asia-Pacific region since December 27, 2012.

This document specifies the BDS open service performance standard at the current stage.

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1 Scope

This document specifies the open service performance standard for BDS B1I signal at the current stage.

2 References

BDS-SIS-ICD-2.0 *"BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal(Version 2.0)* "

3   Terms, Definitions and Acronyms

3.1 Terms and Definitions

The BeiDou Navigation Satellite System Open Service is the radio navigation satellite service using the BDS open service signals to determine a user's position, velocity and time, etc.

3.2 Acronyms

The following acronym definitions are applicable to this document:

BDS - BeiDou Navigation Satellite System;

BDT - BeiDou Navigation Satellite System Time;

CGCS 2000 - China Geodetic Coordinate System 2000;

GEO - Geostationary Earth Orbit;

ICD - Interface Control Document;

IGSO - Inclined Geosynchronous Orbit;

MEO - Medium Earth Orbit;

NAV- Navigation (as in "NAV data" or "NAV message");

OS - Open Service;

PDOP - Position Dilution Of Precision;

RF- Radio Frequency;

SIS - Signal In Space;

TGD - Group Delay Time correction;

URAE - User Range Acceleration Error;

URE - User Range Error;

URRE - User Range Rate Error;

UTC - Coordinated Universal Time;

UTCOE - UTC Offset Error.

4 BDS Overview

BDS consists of the space segment, the ground control segment and the user segment.

4.1 Space Segment

The current BDS space segment consists of 5 GEO satellites, 5 IGSO satellites and 4 MEO satellites. The respective positions of satellites are shown in Figure 1.

The GEO satellites are operating in orbit with an altitude of 35,786 kilometers and positioned at 58.75°E, 80°E, 110.5°E, 140°E and 160°E respectively.

The IGSO satellites are operating in orbit with an altitude of 35,786 kilometers and an inclination of 55° to the equatorial plane. The phase difference of right ascensions of ascending nodes of those orbital planes is 120°. The sub-satellite tracks for three of those IGSO satellites are coincided while the longitude of the intersection point is at 118°E. The sub-satellite tracks for the other two IGSO satellites are coincided while the longitude of the intersection point is at 95°E.

The MEO satellites are operating in orbit with an altitude of 21,528 kilometers and an inclination of 55° to the equatorial plane. The satellite recursion period is 13 rotations within 7 days. The phase is selected from the Walker24/3/1 constellation, and the right ascension of ascending node of the satellites in the first orbital plane is 0°. The current 4 MEO satellites are in the 7th and 8th phases of the first orbital plane, and in the 3rd and 4th phases of the second orbital plane respectively.
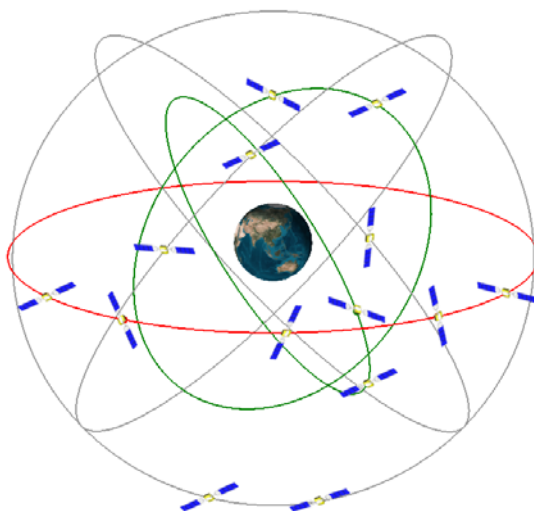

Figure 1 BDS Space Constellation

4.2 Ground Control Segment

The ground control segment is responsible for the BDS operation and control. It consists of the Master Control Station (MCS), Time Synchronization/Upload Stations (TS/US) and Monitor Stations (MS).

The MCS is the operation and control center of BDS with the main tasks including:

a) to collect observation data of NAV signals from each TS/US and MS, to process data, to generate satellite NAV messages;

b) to perform mission planning and scheduling, to conduct system operations, management and control;

c) to observe and calculate the satellite clock bias, to upload satellite NAV messages;

d) to monitor the satellite payload and analyze anomalies, etc.

The main tasks of TS/US are to measure satellite clock biases and to upload satellite NAV messages.

The main tasks of MS are to continuously observe satellite NAV signals, and to provide real-time data to the MCS.

4.3 User Segment

The user segment encompasses various types of BDS terminals, including those compatible with other navigation systems.

4.4 BDS OS Service Volume

The BDS OS service volume is defined as the OS SIS coverage of the BDS satellites where both the BDS OS horizontal and vertical position accuracy are better than 10 meters (probability of 95%). At the current stage, the BDS regional service capability has been achieved, which can provide continuous OS to the area as shown in Figure 2 & Figure 3, including the most part of the region from 55°S to 55°N, 70°E to150°E.
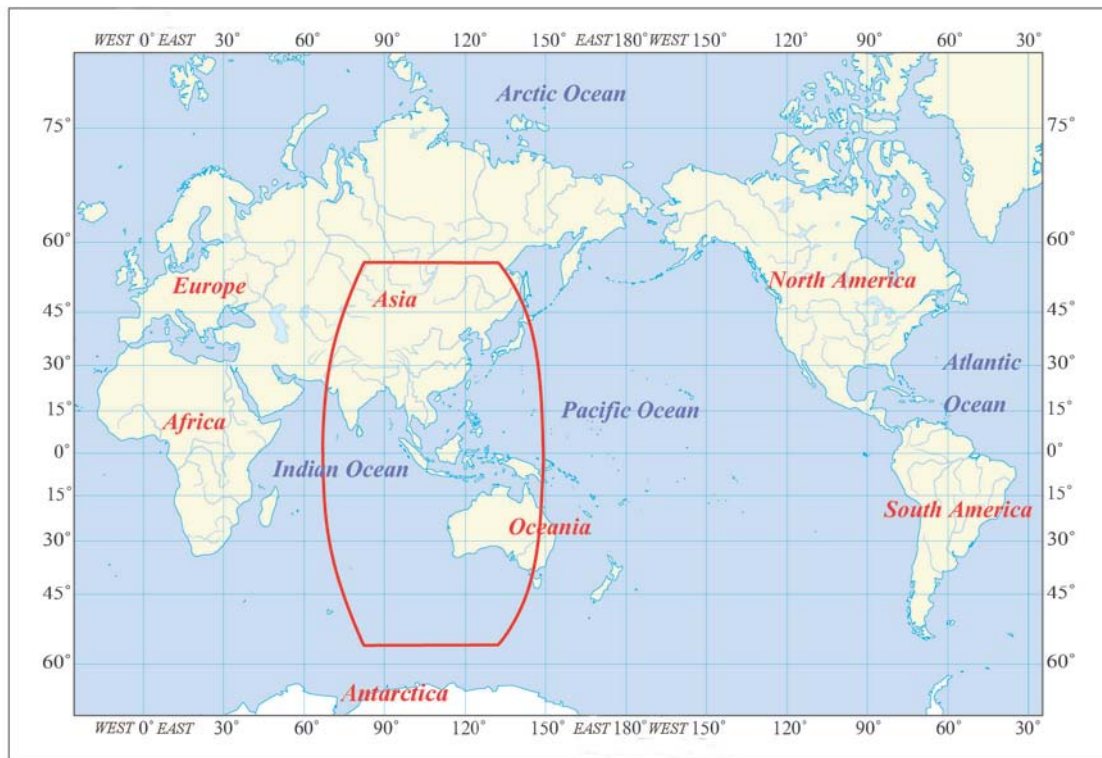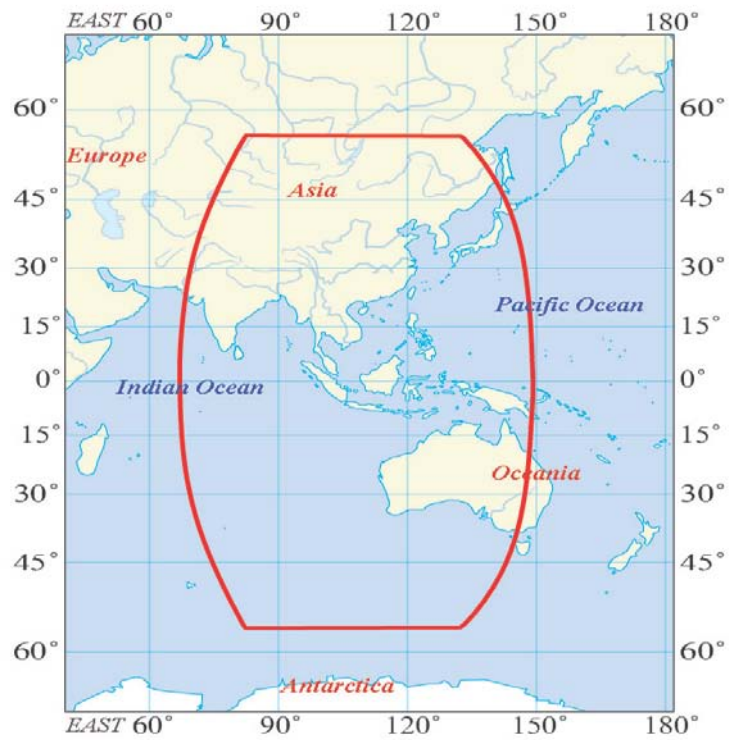
Figure 2 The BDS Service Area

Figure 3 The BDS Service Area(partial enlarged detail)

5   BDS OS SIS Characteristics

5.1 BDS OS SIS Interface Characteristics

5.1.1   BDS OS SIS RF Characteristics

BDS broadcasts right-handed circularly polarized (RHCP) L-band signals. In particular, the B1 frequency has the nominal value of 1561.098MHz, while the signals at this frequency are modulated through Quadrature Phase Shift Keying (QPSK). For more details, please refer to *BDS-SIS-ICD-2.0*.

5.1.2   BDS OS SIS NAV Message Characteristics

5.1.2.1   BDS OS SIS NAV Message Structure

BDS OS SIS NAV messages are formatted in D1 and D2 based on their data rates and structures. D1, with the data rate of 50 bps, is broadcasted by the MEO/IGSO satellites, while D2, with the data rate of 500 bps, is broadcasted by the GEO satellites.

The BDS OS SIS NAV message D1 is broadcasted in the form of superframes. Each superframe consists of 24 frames. Each frame consists of 5 subframes with 10 words in each subframe. It takes 12 minutes to transmit the whole NAV message D1. More specifically, subframes 1 to 3 are used to broadcast fundamental NAV information of the broadcasting satellite; while pages 1 to 24 in subframe 4 and pages 1 to 10 in subframe 5 are used to broadcast the almanac of all satellites and time synchronization information with other navigation systems.

The BDS OS SIS NAV message D2 is broadcasted in the form of superframes. Each superframe consists of 120 frames. Each frame consists of 5 subframes with 10 words in each subframe. It takes 6 minutes to transmit the whole NAV message D2. More specifically, subframe 1 is used to broadcast fundamental NAV information of the broadcasting satellite, while subframe 5 is used to broadcast the almanac of all satellites and time synchronization information with other navigation systems.

The BDS OS SIS NAV message is updated hourly. For the detailed frame format, please refer to *BDS-SIS-ICD-2.0*.

5.1.2.2 BDS OS NAV Message Data

The BDS OS NAV message data mainly includes:

a) satellite ephemeris parameters;

b) satellite clock offset parameters;

c) ionospheric delay model correction parameters;

d) satellite health status;

e) user range accuracy index;

f) constellation status (almanac information), etc.

For more details, please refer to *BDS-SIS-ICD-2.0*.

5.2 BDS OS SIS Performance Characteristics

5.2.1 BDS OS SIS Coverage

The BDS OS SIS coverage is described by the per-satellite coverage, which comprises the portion of the near-Earth region which extends from the surface of the Earth up to an altitude of 1,000 kilometers above the surface of the Earth which is visible from the satellite's orbital position.

5.2.2 BDS OS SIS Accuracy

The BDS OS SIS accuracy is defined as the statistical value of errors (95% probability) for any healthy satellite in normal operation.

The BDS OS SIS accuracy includes four parameters:

a) User Range Error (URE);

b) User Range Rate Error (URRE);

c) User Range Acceleration Error (URAE);

d) UTC Offset Error (UTCOE).

5.2.2.1 BDS OS SIS URE

The BDS OS SIS URE is described by a statistical measurement of the instantaneous SIS URE data.

An instantaneous SIS URE is the difference between the pseudorange measured at a given location

assuming a receiver clock that is perfectly calibrated to BDT and the expected pseudorange as derived from the NAV message data for the given location and the assumed receiver clock. The instantaneous SIS URE includes only those pseudorange data set error budget components assigned to the BDS Space and Ground Control Segments (i.e., not including the error budget components assigned to the BDS User Segment such as the troposphere delay compensation error, multipath, and receiver noise).

5.2.2.2 BDS OS SIS URRE

The BDS OS SIS URRE is defined as the time derivative of the BDS OS SIS URE.

5.2.2.3 BDS OS SIS URAE

The BDS OS SIS URAE is defined as the second time derivative of the BDS OS SIS URE.

5.2.2.4 BDS OS SIS UTCOE

The BDS OS SIS UTCOE is defined as the accuracy of the offset between BDT and UTC. The offset between BDT and UTC is less than 100 nanoseconds.

5.2.3 BDS OS SIS Continuity

The BDS OS SIS continuity is defined as the probability that a healthy BDS OS SIS will continue working without unscheduled interruptions over a specified time interval. The BDS OS SIS continuity is closely correlated to unscheduled interruptions.

5.2.4 BDS OS SIS Availability

The BDS OS SIS availability is described by the per-slot availability, which is defined as the probability that a specific slot in the BDS constellation will be occupied by a BDS satellite transmitting a healthy OS SIS.

6 BDS OS Performance Characteristics

6.1 User Assumptions

The position, velocity and time performance standards in this document are based on the assumption of using a representative BDS OS receiver that:

a) is designed in accordance with *BDS-SIS-ICD-2.0*, which can correctly track and process the BDS OS signals, and conduct position, velocity and time solution;

b) uses a mask angle of 10°;

c) accomplishes satellite position and geometric range computations in CGCS2000;

d) only considers the errors related to the space segment and ground control segment. Those errors include the satellite orbit error, the satellite clock offset error and TGD error.

6.2 BDS OS Accuracy

The BDS OS accuracy includes those of position, velocity and time.

The BDS OS position accuracy is defined as the statistical difference between the user's position derived from BDS OS SIS and its true position, under the BDS user assumptions. The position accuracy includes horizontal and vertical measurements.

The BDS OS velocity accuracy is defined as the statistical difference between the user's velocity derived from the BDS OS SIS and its true velocity, under the BDS user assumptions.

The BDS OS time accuracy is defined as the statistical difference between the user's time derived from BDS OS SIS and that value from UTC, under the BDS user assumptions.

6.3 BDS OS Availability

The BDS OS availability is defined as the percentage of the available service time to the expected service time. The available service time refers to the period when the service accuracy meets the specified performance standards within a given service volume.

The BDS OS availability in this document includes PDOP availability and positioning service availability.

The PDOP availability is defined as the percentage of time when PDOP value meets the

requirements of PDOP threshold, under specified conditions, within a specified time period and service volume.

The positioning service availability is defined as the percentage of time when horizontal and vertical position accuracy meets the specified requirements of accuracy threshold, under specified conditions, within a specified time period and service volume.

7 BDS OS SIS Performance Standards

7.1 BDS OS SIS Coverage Standards

The BDS OS SIS coverage standards are shown in Table 1.

Table 1   The BDS OS SIS Per-Satellite Coverage Standards

Satellite Type	Coverage Standard
GEO/IGSO/MEO	100% of the BDS OS SIS coverage; The minimum user-received signal power is greater than -161 dBW.

7.2 BDS OS SIS Accuracy Standards

7.2.1   BDS OS SIS URE Accuracy Standards

The BDS OS SIS URE accuracy standards are shown in Table 2.

Table 2   The BDS OS SIS URE Accuracy Standards

Satellite Type	SIS Accuracy Standard (95% probability)	Constraints
GEO/IGSO/MEO	URE≤2.5m	For any healthy OS SIS; Neglecting single-frequency ionospheric delay model errors.

Note: When a MEO satellite enters the view of the service volume, the SIS accuracy may deteriorate due to the age of data before the new NAV message is uploaded. It is recommended to use the updated NAV message.

7.2.2   BDS OS SIS URRE Accuracy Standards

The BDS OS SIS URRE accuracy standards are shown in Table 3.

Table 3　The BDS OS SIS URRE Standards

Satellite Type	SIS Accuracy Standard (95% probability)	Constraints
GEO/IGSO/MEO	URRE≤0.006m/s	For any healthy OS SIS; Neglecting single-frequency ionospheric delay model errors; Neglecting all psuedorange step changes caused by NAV message data cutovers.

7.2.3　BDS OS SIS URAE Accuracy Standards

The BDS OS SIS URAE accuracy standards are shown in Table 4.

Table 4　The BDS OS SIS URAE Standards

Satellite Type	SIS Accuracy Standard (95% probability)	Constraints
GEO/IGSO/MEO	URAE≤0.002m/s^2	For any healthy OS SIS; Neglecting single-frequency ionospheric delay model errors; Neglecting all psuedorange step changes caused by NAV message data cutovers.

7.2.4　BDS OS SIS UTCOE Accuracy Standards

The BDS OS SIS UTCOE standards are shown in Table 5.

Table 5　The BDS OS SIS UTCOE Standards

Satellite Type	SIS Accuracy Standard (95% probability)	Constraints
GEO/IGSO/MEO	UTCOE≤2ns	For any healthy OS SIS.

7.3 BDS OS SIS Continuity Standards

The BDS OS SIS continuity standards are shown in Table 6.

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Table 6   The BDS OS SIS Continuity Standards

Satellite Type	SIS Continuity Standard	Constraints
GEO	≥0.995/h	Given that the OS SIS is available from the slot at the start of the hour; Calculated as an annual statistical value for each type of satellite.
IGSO	≥0.995/h	
MEO	≥0.994/h	

7.4 BDS OS SIS Availability Standards

The BDS OS SIS availability standards are shown in Table 7.

Table 7   The BDS OS SIS Availability Standards

Satellite Type	SIS Availability Standard	Constraints
GEO	≥0.98	Calculated as an annual statistical value for each type of satellite
IGSO	≥0.98	
MEO	≥0.91	

8 BDS OS Performance Standards

8.1 BDS OS Service Accuracy

The BDS OS position/velocity/time accuracy standards within its service volume are shown in Table 8.

Table 8　The BDS OS Position/Velocity/Time Accuracy Standards

Service Accuracy		Standard (95% probability)	Constraints
Position Accuracy	Horizontal	≤10m	Calculate the statistical position/velocity/time error for any point in the service volume over any 24-hour interval.
	Vertical	≤10m	
Velocity Accuracy		≤0.2m/s	
Time Accuracy (multi-SISs)		≤50ns	

8.2 BDS OS Service Availability Standards

8.2.1　BDS OS PDOP Availability Standards

The BDS OS PDOP availability standards within its service volume are shown in Table 9.

Table 9　The BDS OS PDOP Availability Standards

Service Availability	Standard	Constraints
PDOP Availability	≥0.98	PDOP≤6; Calculate at any point within the service volume over any 24-hour interval.

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8.2.2 BDS OS Position Service Availability Standards

The BDS OS position service availability standards within its service volume are shown in Table 10.

Table 10 The BDS OS Position Service Availability Standards

Service Availability	Standard	Constraints
Positioning Availability	≥0.95	Horizontal position accuracy≤10m (95% probability); Vertical position accuracy≤10m (95% probability); Calculate at any point within the service volume over any 24-hour interval.

9 Additional Observations

At present, in addition to the specified open service volume, in the most part of the area within 55°S~55°N, 55°E~160°E, the BDS could provide open services with the horizontal and vertical position accuracy better than 20 meters; in the most part of the area within 55°S~55°N, 40°E~180°E, the BDS could provide open services with the horizontal and vertical position accuracy better than 30 meters. As a user moves away from the nominal service volume, the service accuracy and availability will decrease accordingly.