2018 BDS&GLONASS SERVICE PORFORMANCE JOINT TEST REPORT

(Chinese Part)

January 2019

CONTENTS

1 OVERVIEW

Under the frame of the "China-Russia Project Committee on Important Strategic Cooperation in Satellite Navigation", Test and Assessment Research Center of China Satellite Navigation Office (CSNO-TARC) and Information and Analysis Center for Positioning, Navigation and Time (IAC PNT) of the Central Research Institute of Machine Building, Federal State Unitary Enterprise (FGUP TSNIIMASH) (hereinafter referred to as "The two parties") have set up a working group to jointly undertake the BeiDou Navigation Satellite System (BDS) and GLONASS cooperation in the field of Monitoring and Assessment.

The two parties started BDS and GLONASS user support cooperation from 2015, to add user support information of BDS and GLONASS at each other's portal website. (www.csno-tarc.cn & www.glonass-iac.ru) One of the most important index parameter of the GNSS user support information is the GNSS service performance, therefore, the two parties carried out GNSS service performance evaluation work along "The Belt & Road" since 2017.

The BDS has been independently constructed and operated by China with an eye to the needs of the country's national security and economic and social development. As a space infrastructure of national significance, BDS provides all-time, all-weather and high-accuracy positioning, navigation and timing services to global users. The BDS is a hybrid navigation constellation consisting of 3 GEO, 3 IGSO and 24 MEO satellites，providing B1I、B1C、B2a、B3I four open signals with the frequency at 1561.098MHz、1575.42MHz、1176.45MHz、 1268.52MHz. Otherwise, BDS has the functions of short message communication, search and rescue services and provides SBAS, PPP services in Asia-Pacific region.

The GLONASS is constructed by Russian government. It has 24 MEO satellites, providing navigation signals at G1/G2 （ G1=1602+0.5625*k(MHz), G2=1246+0.4375*k(MHz)，k is the frequency number of each 1~24 satellite） frequency bands in FDMA.

2 PURPOSE

The two parties are committed to providing better information support to global BDS and GLONASS users, serving industry users, equipment manufacturers, research groups and mass worldwide users. The joint test work aims to jointly test and verify the service performance of BDS and GLONASS in different environments and different regions, with this to provide reference for global users.

3 TEST CONTENTS

3.1 Number of visible satellite

Users need to resolve three positioning parameters and one clock offset parameter when tracking GNSS signal and want to know their positioning information. Therefore, the number of visible satellites is a basic evaluation indicator in the test.

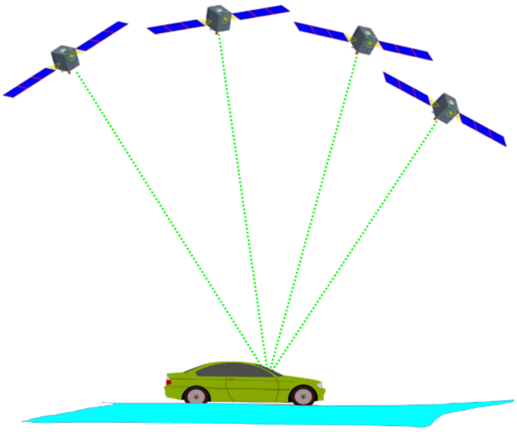

Fig1 Diagram of GNSS positioning

3.2 Dilution of Precision

Dilution of Precision (DOP), the quality of characterizing users and spatial geometry of visible satellites amplify the ranging error. DOP includes several types: Geometry Dilution of Precision (GDOP), Position Dilution of Precision (PDOP), Horizontal Dilution of Precision (HDOP), Vertical Dilution of Precision (VDOP) and Time Dilution of Precision (TDOP).

Assuming that the main diagonal element of the position parameter cofactor matrix $(G^TG)^{-1}$ is σ_{ii} (i=1,2,3,4), then for each independent observation with zero-mean equal precision, the respective DOP values are:

$$GDOP = \sqrt{\sigma_{11} + \sigma_{22} + \sigma_{33} + \sigma_{44}}$$

$$PDOP = \sqrt{\sigma_{11} + \sigma_{22} + \sigma_{33}}$$

$$HDOP = \sqrt{\sigma_{11} + \sigma_{22}}$$

$$VDOP = \sqrt{\sigma_{33}}$$

$$TDOP = \sqrt{\sigma_{44}}$$

3.3 Positioning Accuracy

Positioning Accuracy describes the difference between satellite positioning results and real coordinates. There are many ways to obtain the real coordinates. An order of magnitude higher than positioning accuracy is generally considered as the reference.

Satellite navigation positioning pseudo range observation error can be described as:

$$\mathrm{V_k} = \mathrm{A_k}\hat{\mathrm{X}}_\mathrm{k} - \mathrm{L_k}$$

Where $\mathrm{A_k}$ is the design matrix, $\mathrm{V_k}$ is the residual vector of observation vector $\mathrm{L_k}$, $\hat{\mathrm{X}}_\mathrm{k}$ is the parameter vector assessment of system status. Generally, the calculation method includes Least Square Method, Kalman Filtering and various improvement methods.

After obtaining the positioning results, positioning accuracy root-mean-square error is calculated as:

$$\begin{bmatrix} \Delta x_{\mathrm{rms}} \\ \Delta y_{\mathrm{rms}} \\ \Delta z_{\mathrm{rms}} \end{bmatrix} = \begin{bmatrix} \sqrt{\dfrac{\sum_{k=1}^{n} \Delta x_k^2}{(n-1)}} \\ \sqrt{\dfrac{\sum_{k=1}^{n} \Delta y_k^2}{(n-1)}} \\ \sqrt{\dfrac{\sum_{k=1}^{n} \Delta z_k^2}{(n-1)}} \end{bmatrix}$$

The positioning accuracy is usually categorized as user local coordinates, expressed in three directions, North, East and Up, or in two directions, Horizontal and Vertical.

4 TEST EQUIPMENT

“GNSS Dynamic Service Performance Assessment System” (GNSS-DSPAS) is a GNSS test equipment integrated with full frequency GNSS antenna, GNSS high-precision measurement receiver, control and display terminal, network connection, and power supply, developed by CSNO-TARC. GNSS-DSPAS can collect GNSS data and evaluate the service performance at fixed place or regional area in static or dynamic way.

Fig1 GNSS-DSPAS

The high-precision receivers in GNSS-KSPAS work in parallel. The engineer will select the most reliable one for data processing. Currently the receivers are as follows:

UNICORECOMM UR4B0		BDSB1I/B1C/B2a/B3I、GPS L1/L2/L5、GLONASS G1/G2、Galileo E1/E5a/E5b
ComNav M300Pro		BDSB1I/B1C/B2a/B3I、GPS L1/L2/L5、GLONASS G1/G2、Galileo E1/E5a/E5b

5 TEST DESCRIPTION

Time: From 21 November 2018-22 November 2018.

Route: Urumqi -Horgos – Urumqi, Xinjiang.

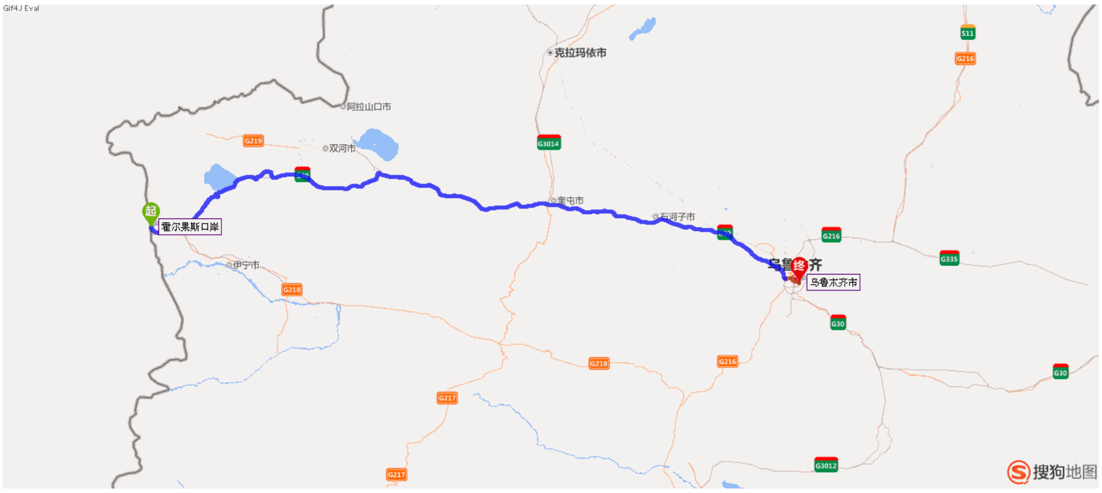

Fig3 Test Route

During the test, there were 40 satellites in orbit including 19 BDS-2, 16 BDS-3 and 5 BDS-3S. 15 BDS-2 satellites (5GEO，7IGSO，3MEO) officially provide services, and all the BDS-3 satellites were under test at that time.

6 RESULTS

6.1 Number of visible satellite and PDOP

The number of visible satellites of BDS is normally between 5 to 12, with an average of 10. But in natural, the surrounding environmental conditions will affect the number of visible satellites, like trees, buildings, mountains lead to less visible satellites.

This test was carried out under the natural conditions, so the result of the number of visible satellites is different from the result on the “China-Russia

Satellite Navigation Monitoring and Assessment Service Platform”. （The number of visible satellites shown on the platform is the prediction result under ideal occlusion with no interference）

PDOP value is corresponding to the number of visible satellites between 2.58 to 6.00. The sudden increase in PDOP value is largely related to the change of the number of satellites and also to the natural environment during the test.

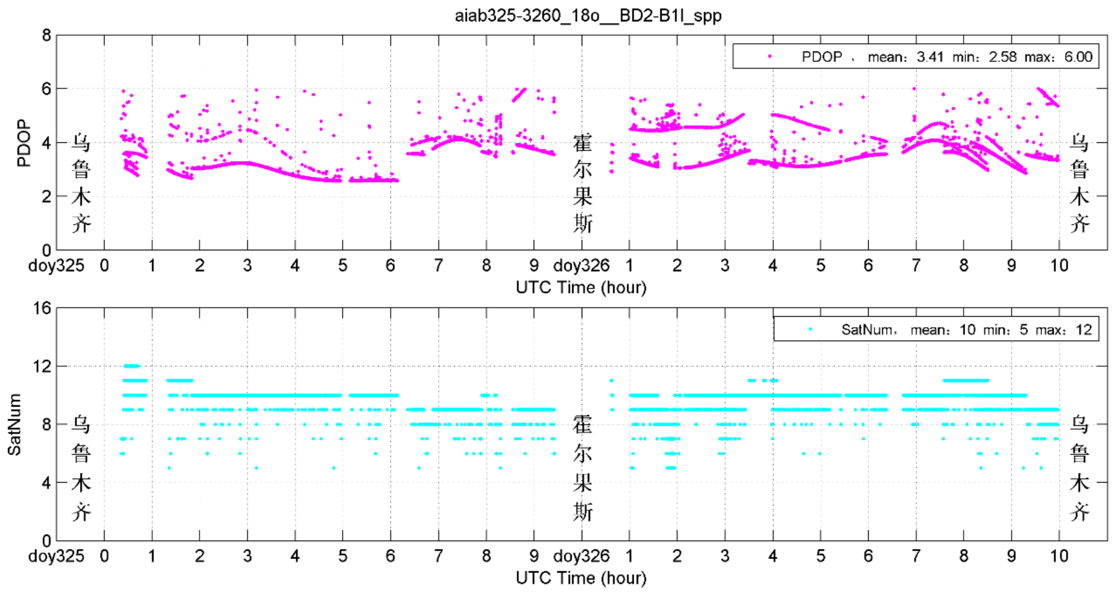

Fig2 The Number of Visible Satellites and PDOP Values of BDS during the test

For GLONASS, the number of visible satellites is between 4 to 9, with an average of 7 during the test. PDOP value is from 1.43 to 6.0, with an average of 2.42.

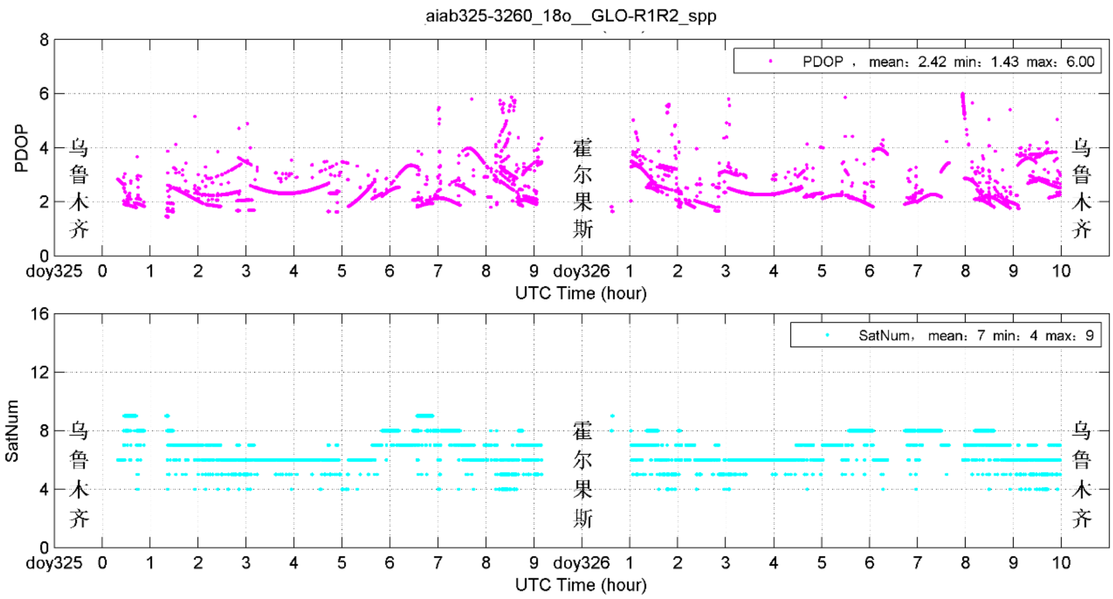

Fig5 The Number of Visible Satellites and PDOP Values of GLONASS during the test

6.2 Positioning Accuracy

The analysis results show that the positioning accuracy of BDS in different frequencies are: B1I single frequency pseudo range (unsmoothed) horizontal direction is 3.12 meters, vertical direction is 4.10 meters (95%); B3I single frequency pseudo range (unsmoothed) horizontal direction is 2.82 meters, vertical direction is 4.45 meters (95%); the combination of B1I and B3I dual-frequency pseudo range (unsmoothed) is 3.79 meters in the horizontal direction and 4.16 meters (95%) in the vertical direction.

In some time periods, the number of visible satellites is reduced due to the signal occlusion, and then the positioning accuracy will decrease. However, the overall positioning accuracy results of BDS are fully satisfying the "BeiDou Navigation Satellite System Open Service Performance Standard (Version 2.0)".

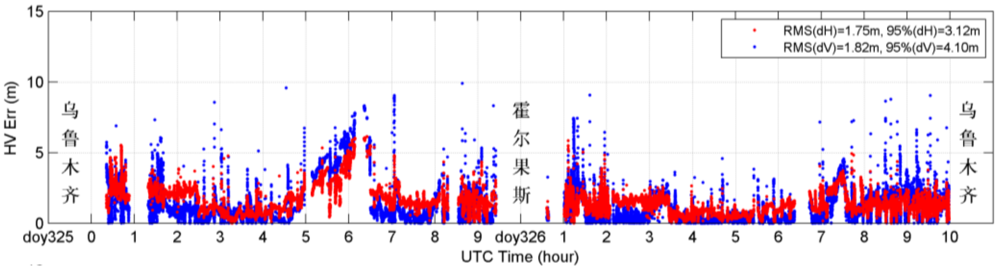

Fig3 BDS B1I Positioning Error

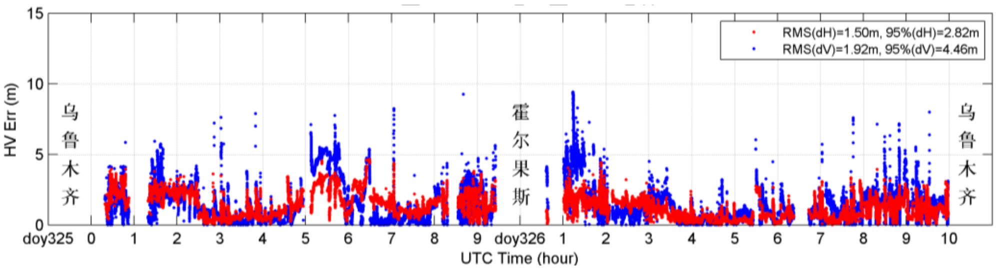

Fig7 BDS B3I Positioning Error

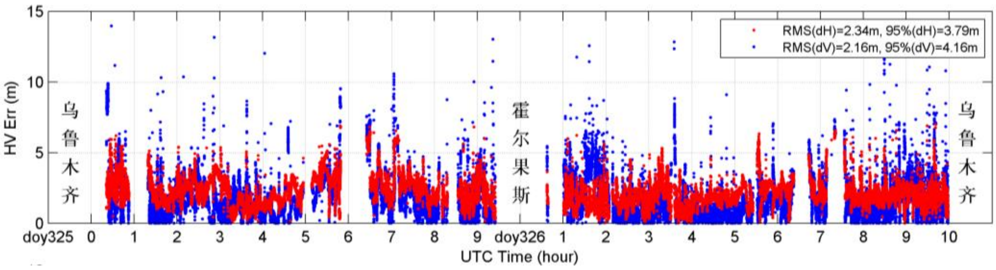

Fig8 BDS B1I&B3I Positioning Error

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