Timing performance evaluation of BDS-3 early constellation using receivers located in time laboratories

IGS INTERNATIONAL GNSS SERVICE

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Introduction

The third generation of BeiDou satellite navigation system, BDS-3, is a global system and is planned to provide basic service by the end of 2018. Until Aug. 24, 2018, there have been 12 satellites in the BDS-3 constellation. Despite being flagged as "unhealthy", navigation signals of these satellites could be tracked by some receivers of iGMAS and IGS network. Measurements from receivers located in three time laboratories, NTSC, PTB, USNO, are used to evaluate the possible global timing performance of this early BDS-3 constellation.

Data and Method

The time span of observations is 140 days, from May 11(DOY 131/2018) to Sep 27 (DOY 270/2018) . Receiver information is described in Table 1. While BRCH has the longest observation arc, USN7, which starts from DOY 240/2018, has the shortest. As the iGMAS stations, BRCH and XIA5 could track all the BDS-3 open signals. However, by using Septentrio PolaRx5TR receivers, the XIA6 and USN7 station could only track the legacy signals B1I / B3I currently.

Table 1 Station information

Station name	Time Lab	Receiver type	Tracked BDS-3 Signals	Note
XIA5	NTSC(Xi'an, China)	CETC-54-GMR-4011	B1I/B3I/B1C/B2a	iGMAS
XIA6	NTSC(Xi'an, China)	SEPT POLARX5TR	B1I/B3I	
NTP1	NTSC(Xi'an, China)	SEPT POLARX4TR	/	UTC
BRCH	PTB (Braunschweig, Gernany)	CETC-54-GMR-4011	B1I/B3I/B1C/B2a	iGMAS
PTBB	PTB (Braunschweig, Gernany)	ASHTECH Z12T	/	IGS/UTC
USN7	USNO(Washington, DC, USA)	SEPT POLARX5TR	B1I	IGS
USN6	USNO(Washington, DC, USA)	NovAtel ProPak-V3	/	UTC

Eight BDS-3 satellites were processed, including C19, C20, C21, C22, C27, C28, C29, and C30. Signal available time of these satellites is displayed in Fig. 1.

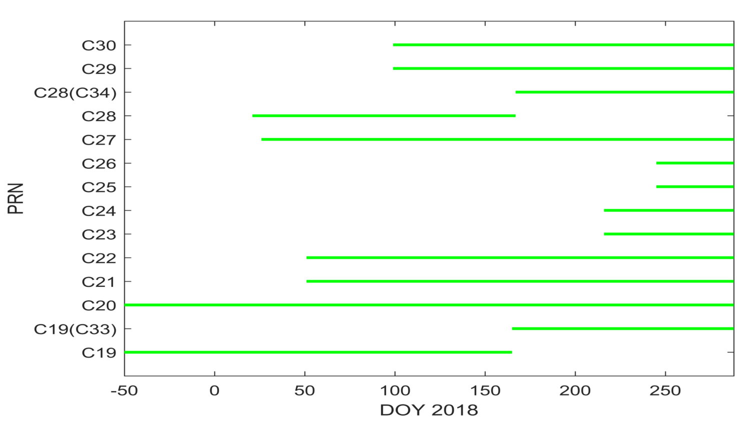

Figure 1 Signal transmission status of BDS-3 satellites

Firstly, we use the GPS PPP method with IGR products to calibrate the BDS-3 available receivers XIA5, XIA6, BRCH, and USN7. The UTC time transfer receivers NPT1, PTBB, and USN6 are selected as the calibration reference. Then, Standard Point Positioning is used to compute the receiver clocks with only BDS-3 signals. Timing performance is evaluated by the stander deviation (STD) of receiver clock time series.

Preliminary Receiver Calibration

Calibration was conducted in the relative mode. GPS P1/P2 ionosphere-free combination total delay (TOT DLY) of BDS-3 available receivers are compute from the clock differences respect to UTC receivers and the corresponding TOT DLY, which were published by BIPM.

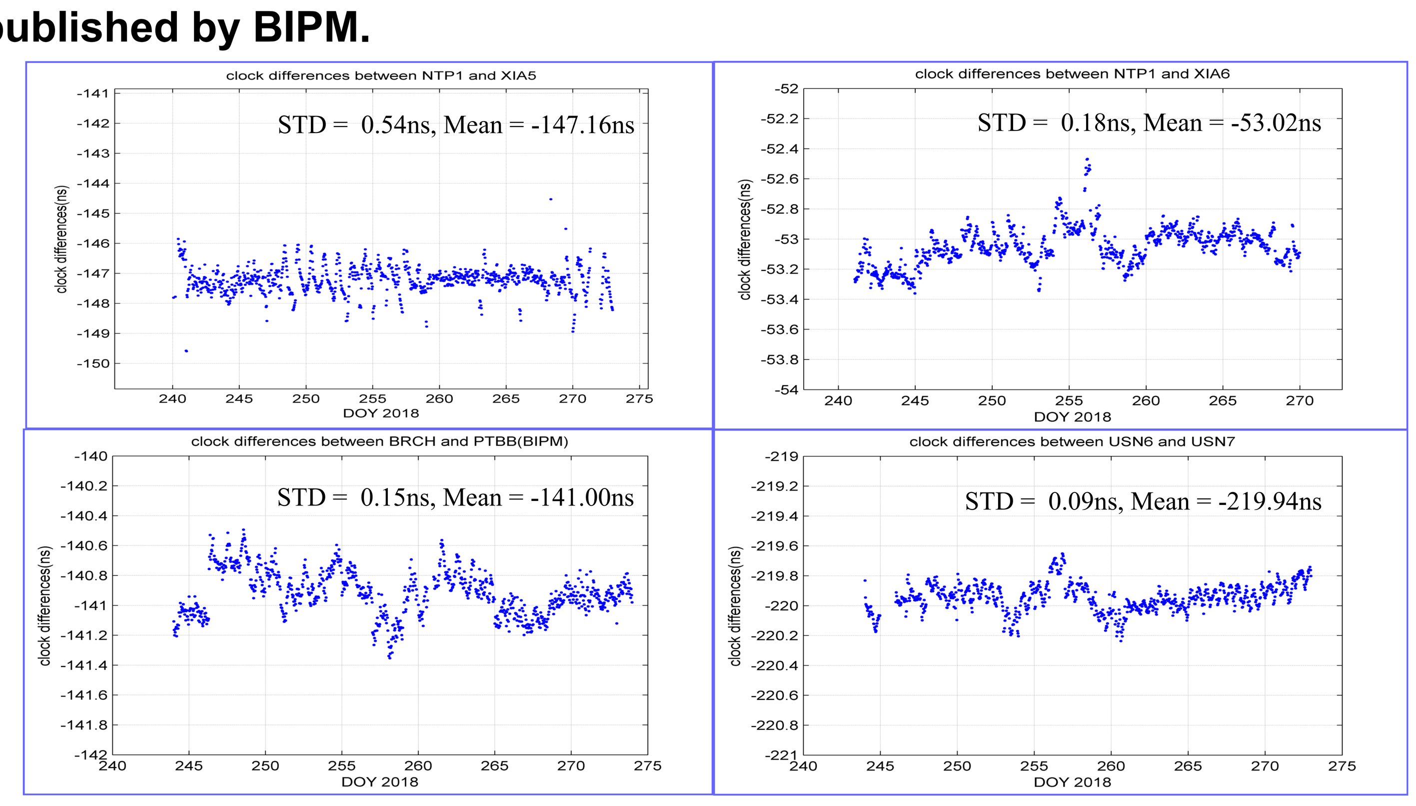

Figure 2 clock differences of September 2018 between BDS-3 available receivers and UTC time transfer receivers at NTSC, PTB and USNO

Fig. 2 shows the clock differences of each calibration link. The STD of XIA5-NTP1 link is 0.54ns, that of the other three links are all below 0.2ns. It indicates that the hardware delays in the links are quite stable during one month.

Table 2 GPS P1/P2 ionosphere-free combination total delay (TOT DLY) of receivers

Station name	XIA5	XIA6	BRCH	USN7	NTP1	PTBB	USN6
TOT DLY (ns)	38.98	-55.15	367.73	218.25	-108.17	508.73	-1.68
Note	XIA5-NTP1	XIA6-NTP1	BRCH-PTBB	USN7-USN6	From BIPM	From BIPM	From BIPM

GPS P1/P2 ionosphere-free combination TOT DLY of BDS-3 available receivers are listed in Table 2. Considering that the internal delay of each signal in receiver and antenna are quite stable, we could introduce these GPS TOT DLY values into BDS receiver clocks to investigate the BDS timing variation.

Timing Results

After TOT DLY and UTC-UTC(k) corrections, the BDS-3 receiver clocks are converted to the differences between UTC time and BDT. Because the TOT DLY values are not referred to corresponding BDS-3 signals, we could only use these time differences to evaluate the precision not the accuracy of BDS-3 timing.

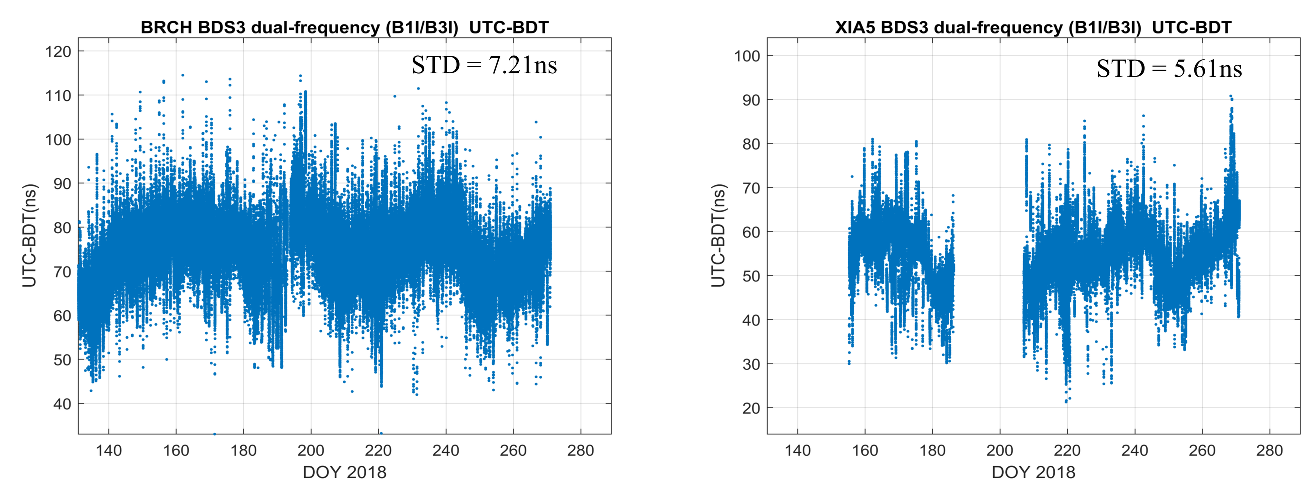

Figure 3 Timing results with B1I/B3I ionosphere-free combination

The B1I/B3I dual-frequency timing results are illustrated in Fig. 3. Fig. 4 and Fig. 5 are results of single-frequency B1I and B3I respectively. While BRCH is a little more noisy, similar fluctuation trend could be found in results of different receivers and difference time laboratories.

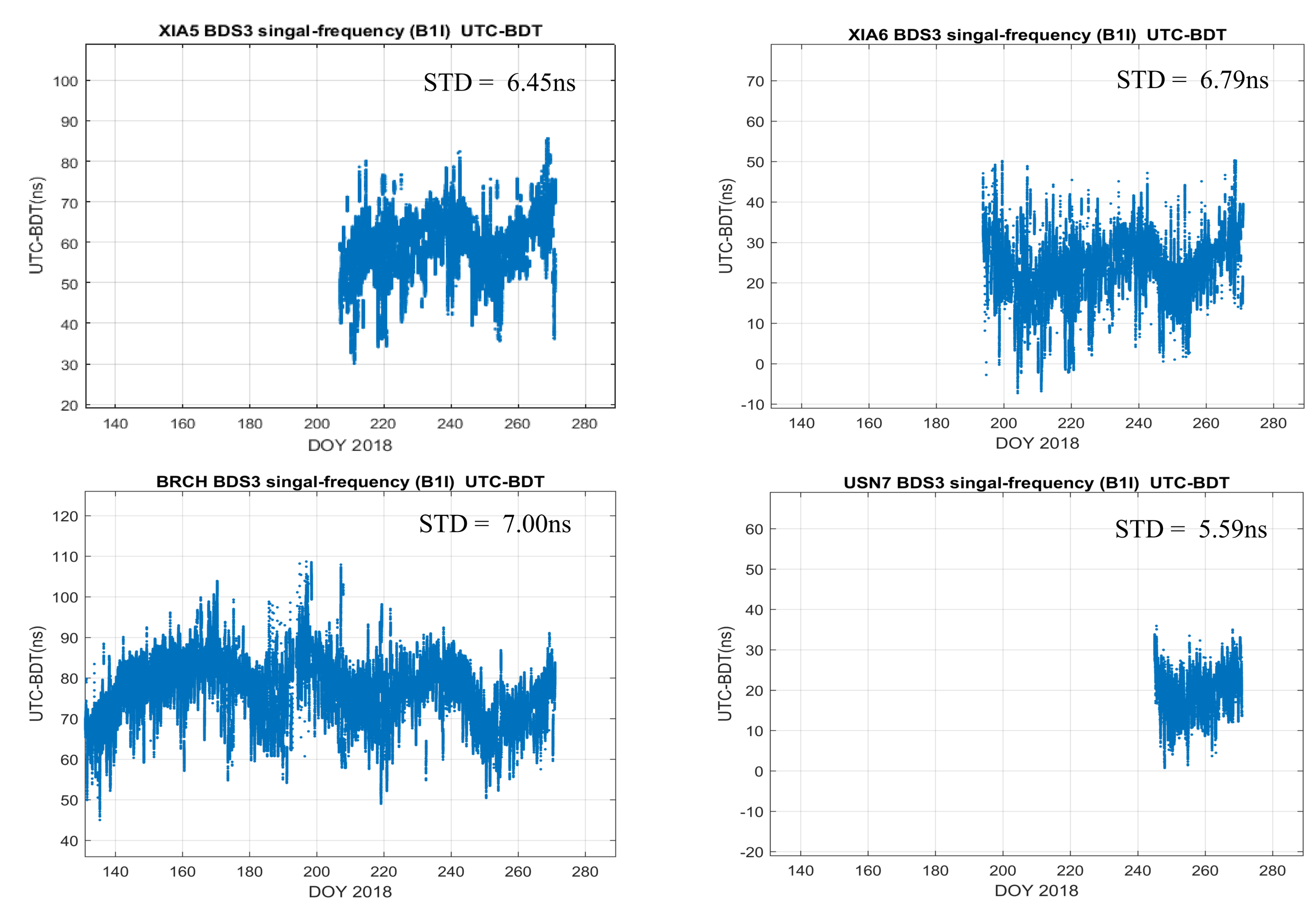

Figure 4 Timing results with B1I

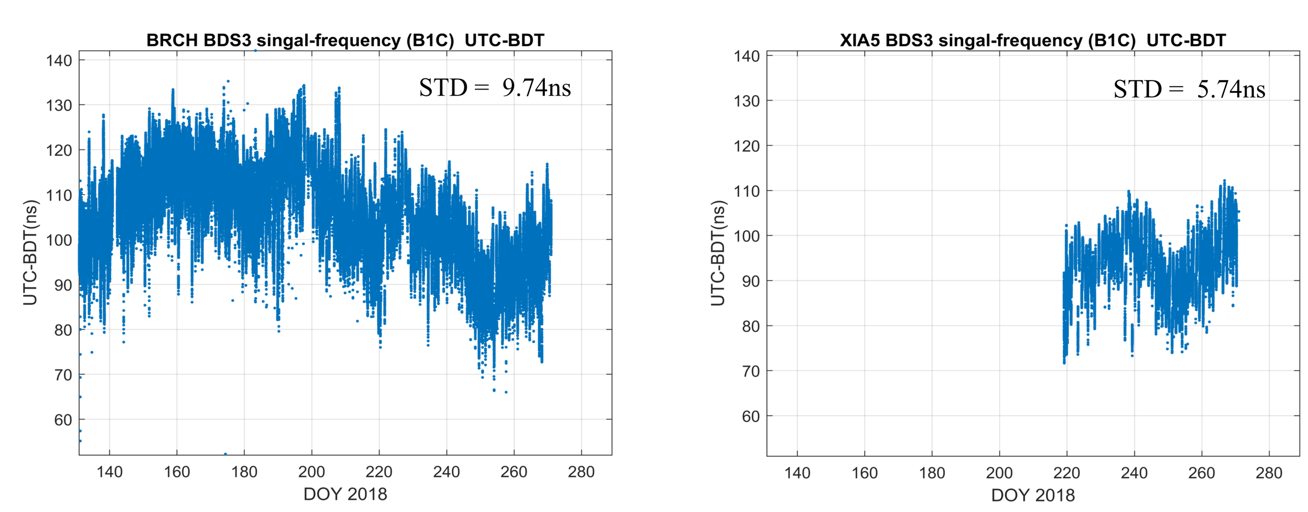

Figure 5 Timing results with B1C

Summary and Outlook

- Four receivers located in three globally distributed timing laboratories were used to evaluate the timing performance of the BDS-3 early constellation.
- The preliminary calibration results show that the GPS P1/P2 total delays of these four BDS-3 available receivers are stable better than 1ns.
- The STD of time differences between UTC and BDT is less than 10ns over 140 days.
- BDS signals total delay would be calibrated in future.

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