Experimental research on BeiDou time transfer using the NIM made GNSS time and frequency receivers at the BIPM in Euro-Asia link

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Motivation

BDS system is developing fast; 27 navigation satellites have been launched. In fact, there are 14 satellites including 5 GEO, 5 IGSO and 4 MEO satellites for use of position, navigation and timing. Since 2012, at the National Institute of Metrology (NIM, Beijing, China) BDS time and frequency transfer systems have been constructed using two OEM (Original Equipment Manufacturer) boards that are able to receive both BDS and GPS (Global Positioning System) signals. The experiments have been implemented using the BDS observations of a certain 'P3-type' code formed as the iono-free combination of B1 code and so called P2 code, and carrier phase. Compared to GPS P3 code and carrier phase measurements, the performance of time and frequency transfer by BDS has been evaluated and analyzed.

A new multi-GNSS (Global Navigation Satellite System) version, NIM-TF-GNSS-3, has been developed at NIM and finished in the middle of 2016, compatible with GPS, GLONASS (GLObal NAvigation Satellite System) and BDS systems. Three of these new systems have been installed at the BIPM in 2017 to investigate the transfer performances over long baselines, in particular, the Euro-Asia link.

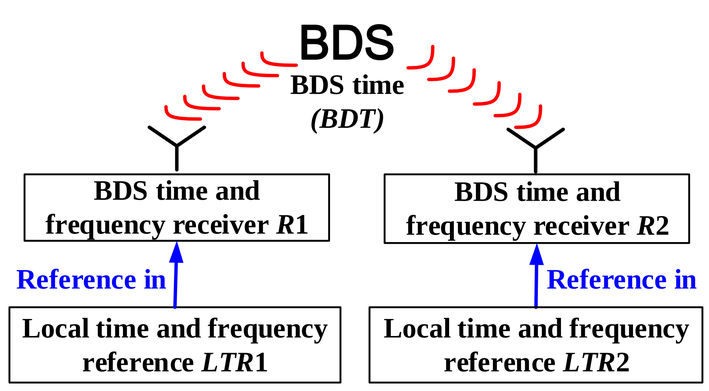
Time Transfer by BDS

BDS System

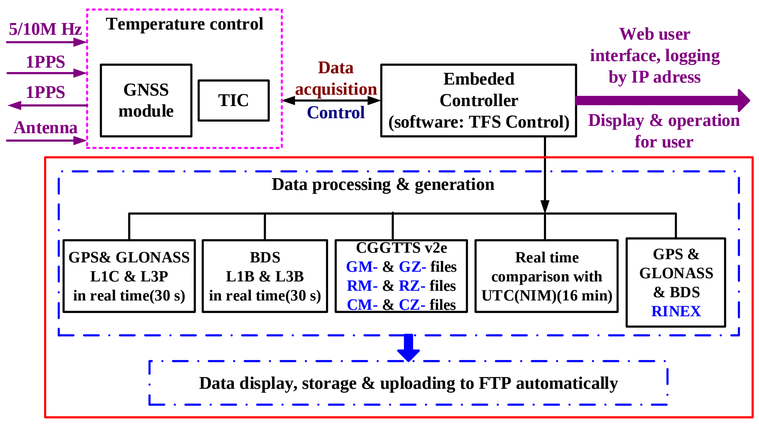
The space segment of BDS involves the three types, GEO, IGSO and MEO satellites. GEO and IGSO satellites with one-day cycle around the earth are about more than 36000 kilometers away from the terminal receivers, and MEO satellites, which return cycles are 7 days with 13 rounds around the earth, are about more than 20000 kilometers from the terminal receivers.

Principle for Time and Frequency Transfer by BDS

Time and frequency transfer methods by BDS can be of three types that are B1 code, B3 code and carrier phase time and frequency transfer according to the measurement signals. The basic principle is shown in the right figure.



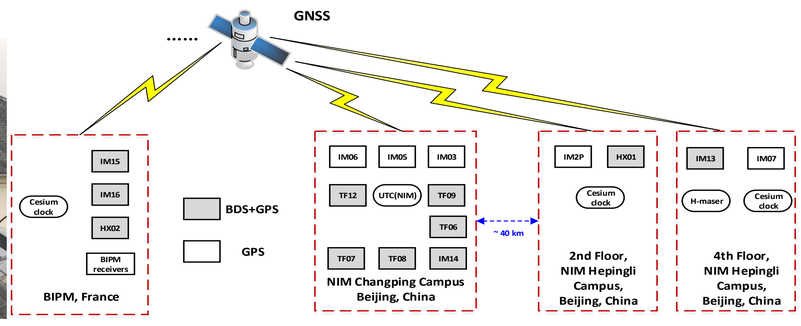
Scheme of the NIM-TF-GNSS-3 Receiver



A new type (NIM-TF-GNSS-3) of GNSS time and frequency transfer receiver compatible with GPS, GLONASS and BDS has been developed at NIM.

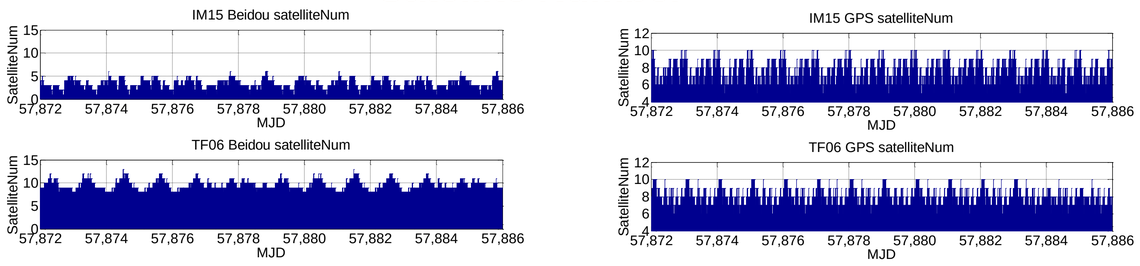
Experiments Setups

Two new self-developed NIM-TF-GNSS-3 receivers (IM15 and IM16) and one compact GNSS receiver compatible with both GPS and BDS systems were sent to BIPM where they had been installed and the experiment setups are shown in the below figures.



Satellite Signal Coverage Statistics

Satellite Number



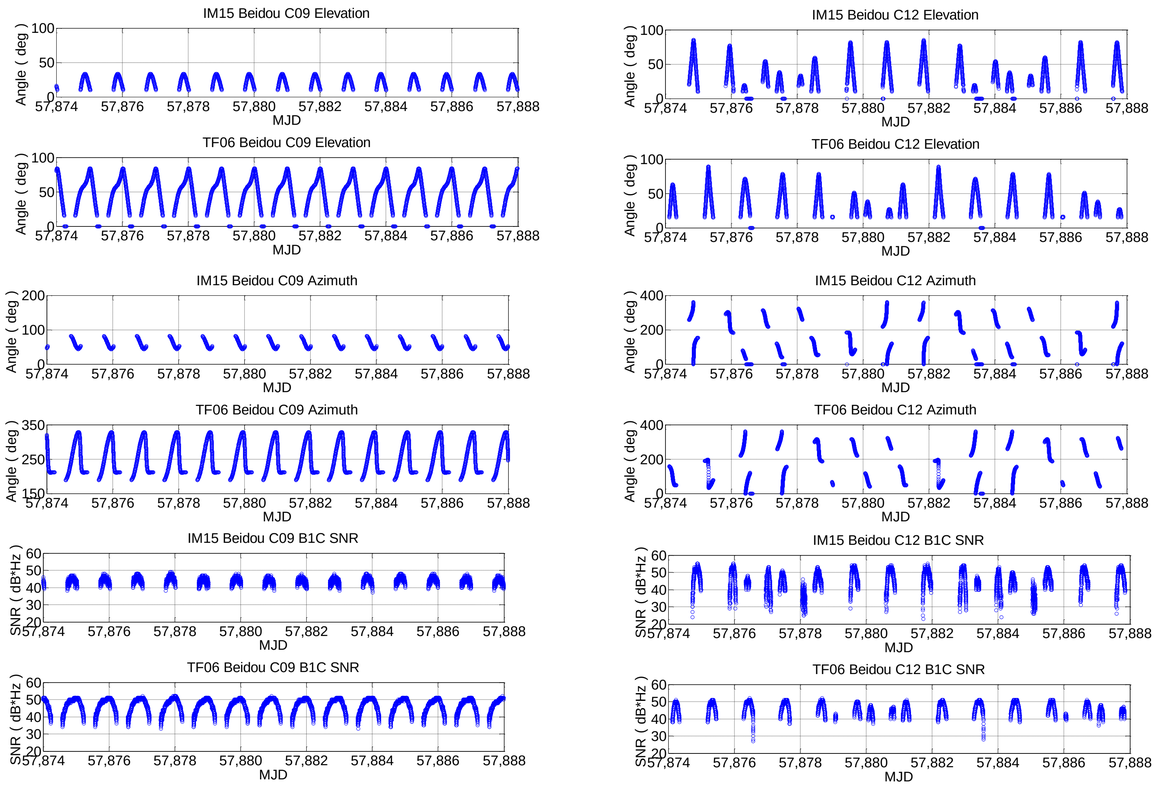
Satellite Elevation, Azimuth and Signal to Noise Ratio

IM15 at BIPM

TF06 at NIM

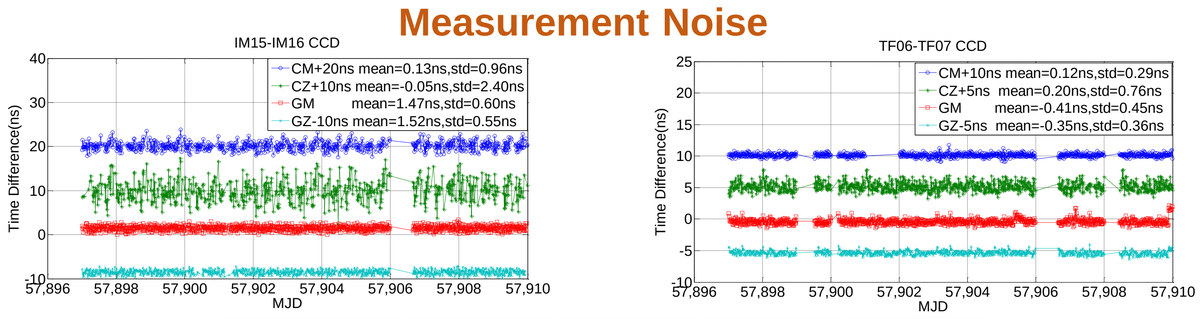
C09 IGSO

C12 MEO



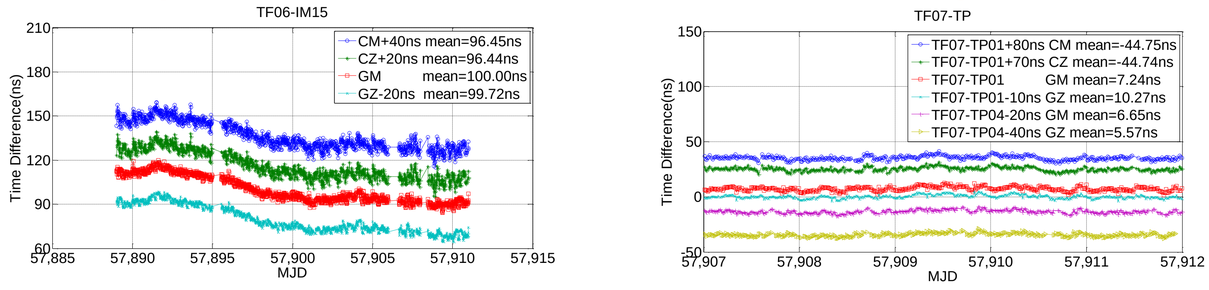
Stability and Accuracy

Measurement Noise

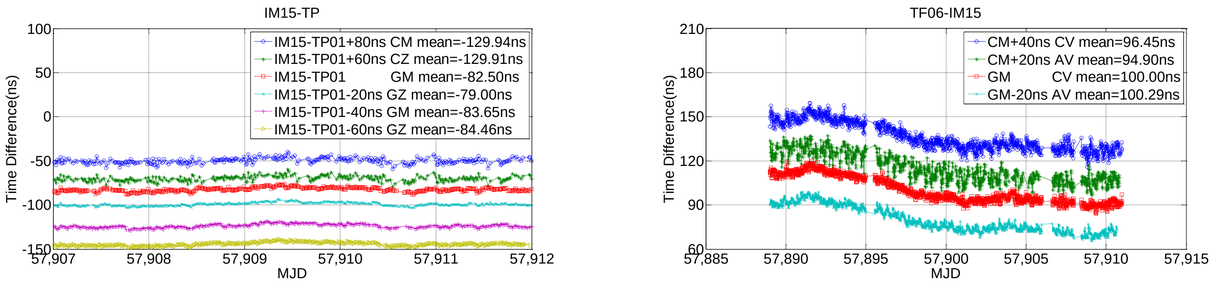


Receiver pair	CM (ns)	CZ (ns)	GM (ns)	GZ (ns)
IM15-IM16	1.0	2.4	0.6	0.6
TF06-TF07	0.3	0.8	0.5	0.4

Comparison with the Difference Sources in Long Baselines



All-in View vs Common View



Accuracy

	CM (ns)	CZ (ns)	GM (ns)	GZ (ns)
IM15	-3.2	4.89	-7.1	-10.9
IM16	-3.3	4.80	-5.1	-8.9
TF06	-	-	-12.4	-16.1
TF07	0.3	6.24	-3.8	-6.9
TF08	1.1	4.39	-13.6	-16.9
TF09	0.2	9.88	-4.9	-8.4
TF12	-2.8	3.87	-6.2	-9.7
IM03	-	-	-40.3	-44.4
IM05	-	-	74.0	62.1
IM06	-	-	-30.4	-31.3
IM07	-	-	-24.2	-27.1
IM13	-14.6	139.1	-44.2	-47.0

Time transfer results

	CM (ns)	CZ (ns)	GM (ns)	GZ (ns)	Calibrated
IM06-BP0R	-	-	-	101.4	IM06 GZ /BP0R GZ
IM06-BP0T	-	-	-	101.4	IM06 GZ /BP0T GZ
IM06-BP1B	-	-	-	102.2	IM06 GZ /BP1B GZ
IM06-BP1J	-	-	-	100.3	IM06 GZ /BP1J GZ
TF06-IM15	99.9	99.9	100.0	99.7	TF06 All / IM15 All

Summary

One new time and frequency transfer system compatible with BDS system has been developed, and the measurement noise of the NIM time and frequency transfer receivers has been evaluated as less than 1 ns by CCD experiments.

The worse satellites signal coverage statistics in the area at BIPM has been seen with the satellite number, elevation and azimuth and SNR. The short and long-term stabilities and the effects in AV and CV modes by BDS in the European and Asian baselines have been assessed.

Agreement between BDS and GPS time and frequency transfer results could be seen. With the time transfer link calibration, the accuracy of the time transfer by BDS has been observed and the difference from the results by GPS is within 2.5 ns.

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