Calibration for GNSS one-way timing link and real-time GNSS system time monitoring

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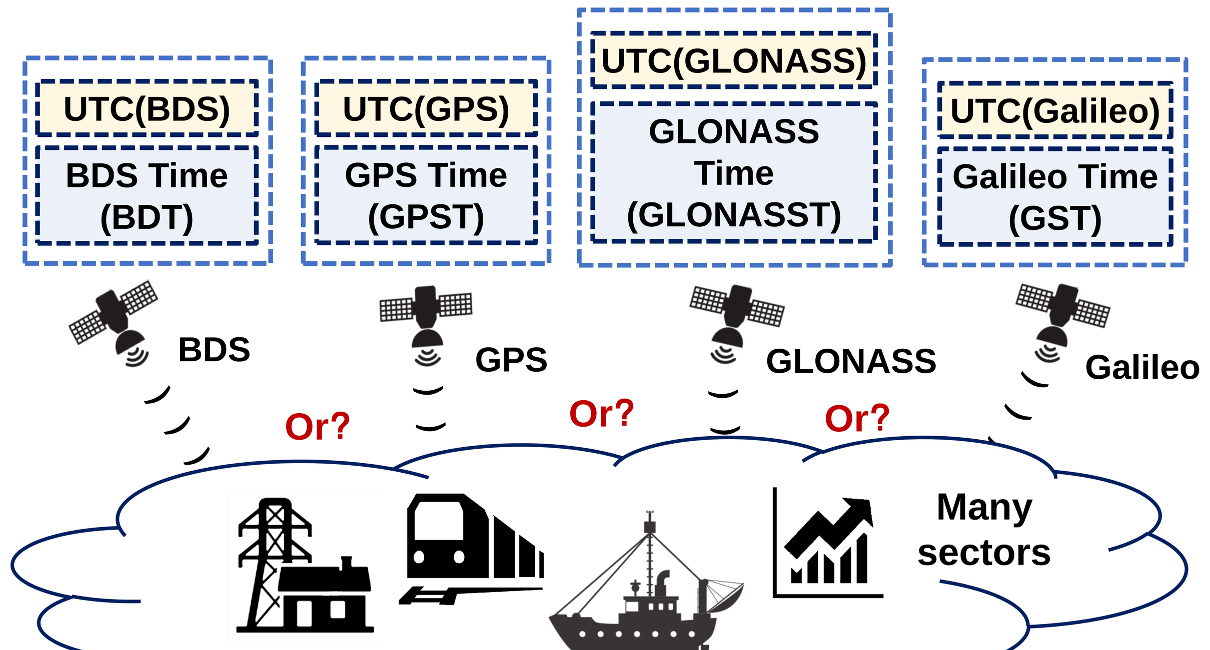
Motivation

The method of GNSS one-way timing has been most commonly used in many sectors that rely on real-time time and frequency values. The GNSS receiver which can provide real-time signals (e.g. 1 PPS and 10 MHz) is employed as a time and frequency standard. To make the systems in these sectors more stable and reliable, the collaboration of multiple systems and the introduction of new technologies impose a demand for higher precision in time synchronization.



E.g. The requirements in 5th Generation Mobile Communication Technology:

- Multiple-Input Multiple-Output: 65 ns
- Meter-level positioning based on 5G base staion: 3 ns

The limitations of GNSS one-way timing, which constrain the advancement of the systems are revealed :

- The output signals from the uncalibrated receiver with the uncorrected hardware delays provide the inaccurate time quantity value.
- The time and frequency values obtained from the receiver are not accurately traceable to UTC.
- The time signals output from the different receivers with the different configurations are multiple (e.g. BDS system time (BDT) and GPS system time (GPST)).

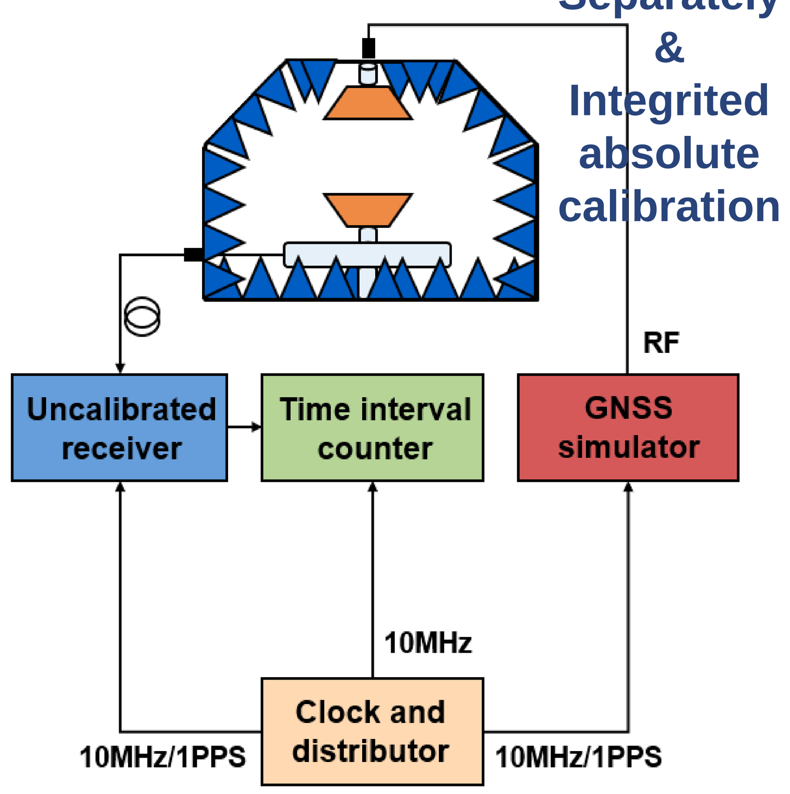
Targets for study

- Calibration method for GNSS one-way timing receiver.
- The real-time monitoring method for the GNSS system time (GNSST), differences among different GNSS system time and the predictions of UTC by different GNSS (UTC(GNSS)).

Principles & Experiments & Results

GNSS one-way timing receiver calibration

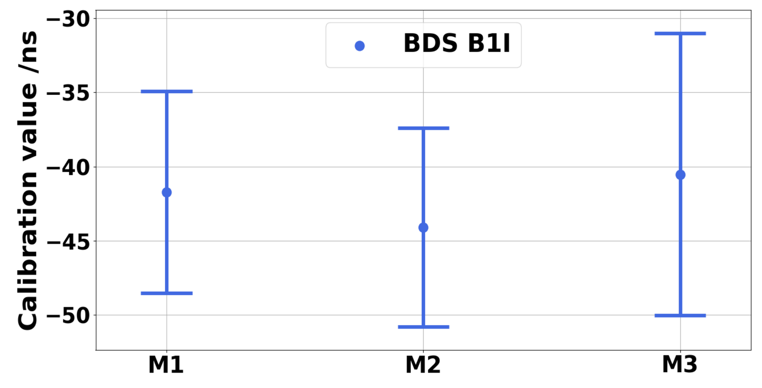
Principles



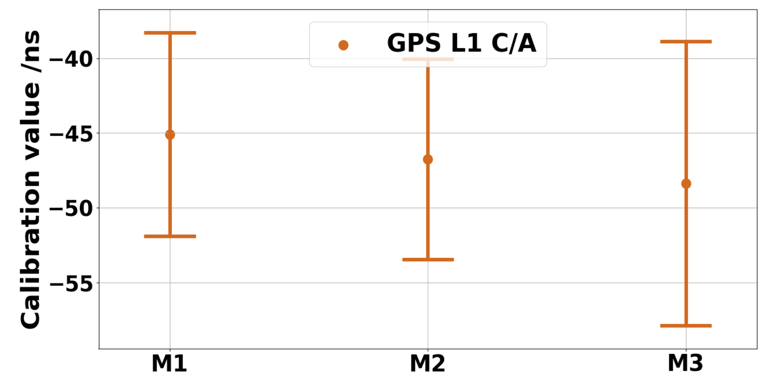
Experiments

Results

The calibration results of the GNSS one-way timing receiver for BDS B1I and GPS L1 C/A are validated successfully by three methods. The separately absolute, integrated absolute, and differential calibration uncertainties are 6.80 ns, 6.70 ns, and 9.50 ns, respectively, which can meet the requirements of the Beidou Open Service Specification for one-way timing accuracy (20 ns).



Calibration results for B1I



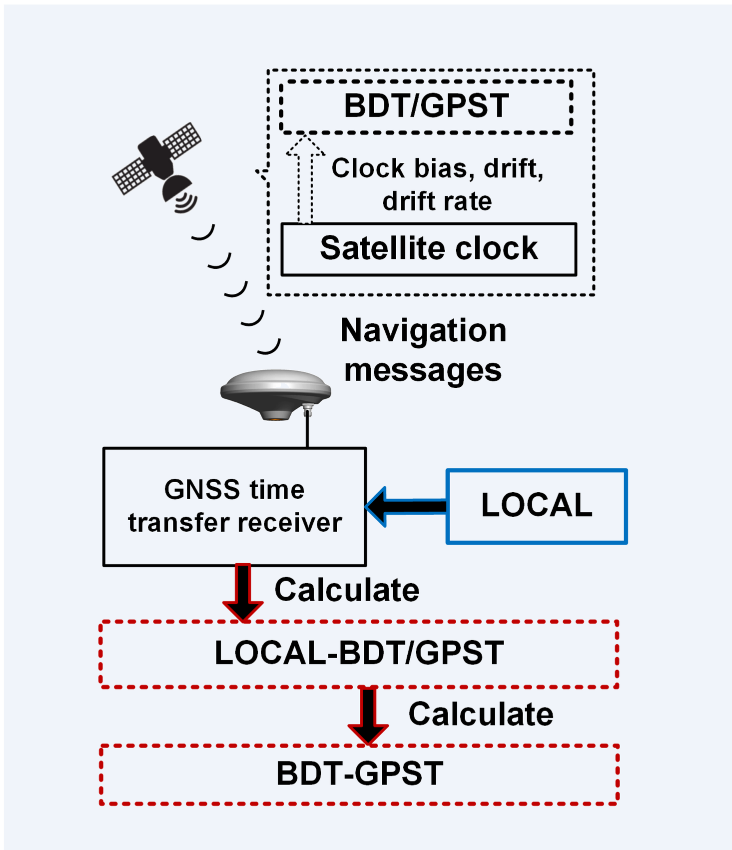
Calibration results for L1 C/A

M1: separately absolute calibration M2: integrited absolute calibration
M3: differential calibration

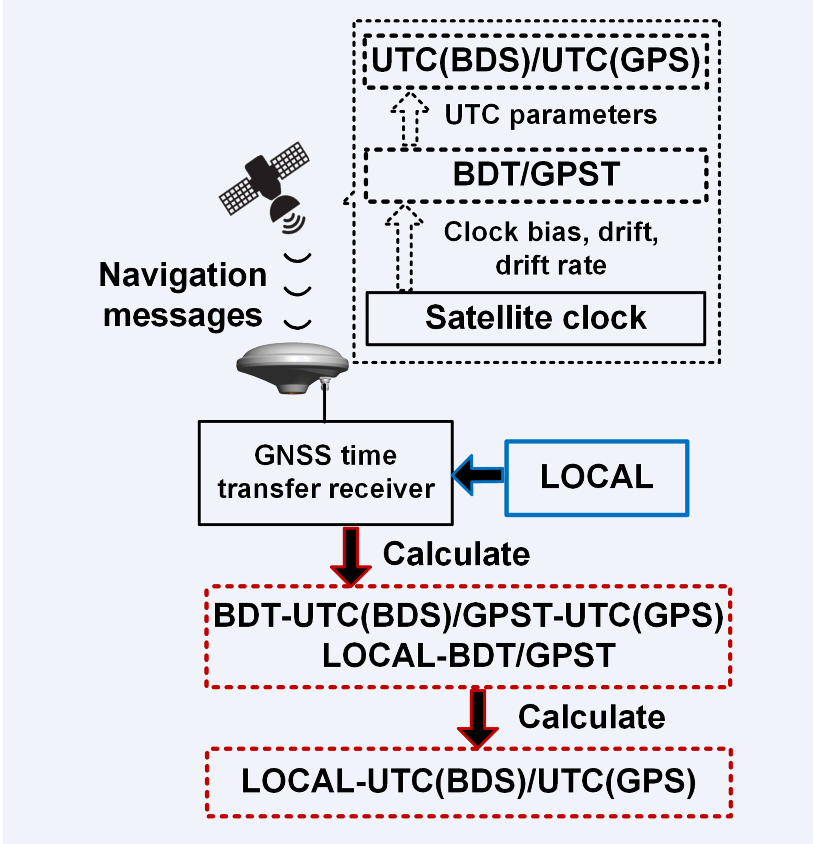
Real-time monitoring

Principles

The link with a remote UTC(k) that can measure the difference between the local time scale LOCAL and remote UTC(k).



BDT/GPST and BDT-GPST



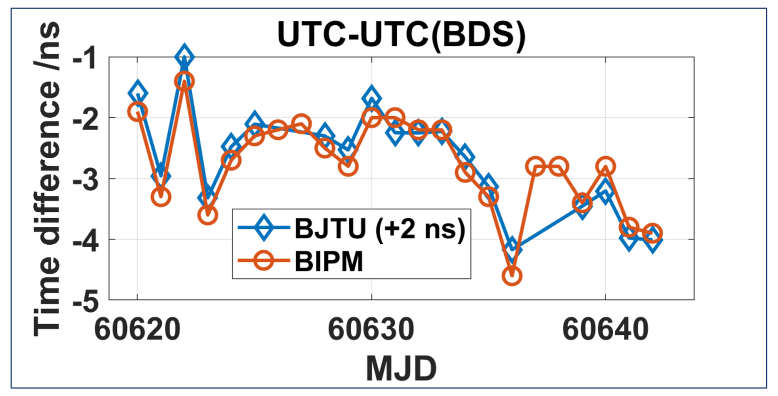
UTC(BDS)/UTC(GPS)

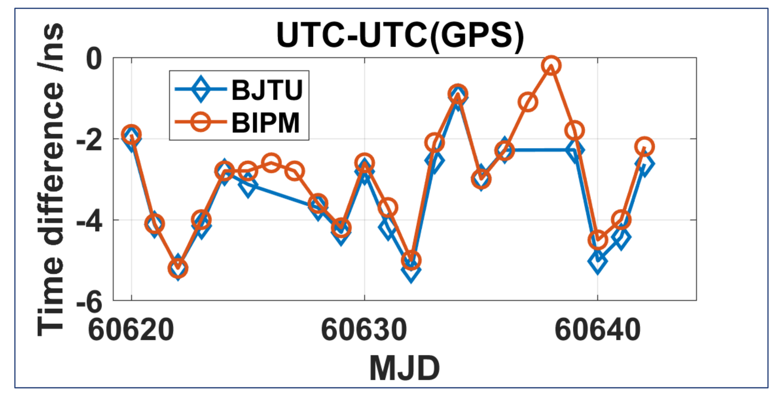
Experiments

The real-time monitoring platform is constructed based on a calibrated receiver and an atomic time scale TS(BJTU) kept by our laboratory, which is connected to UTC(NIM) in real time. The real-time monitoring experiments are conducted from MJD 60619 to MJD 60644.

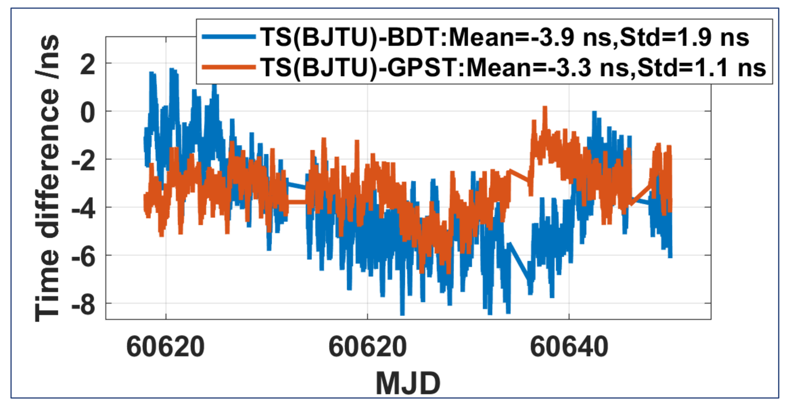
Results

The monitoring results of UTC-UTC(BDS)/UTC(GPS) based on TS(BJTU) are compared with those from BIPM Circular T to verify the validity of the real-time monitoring method.

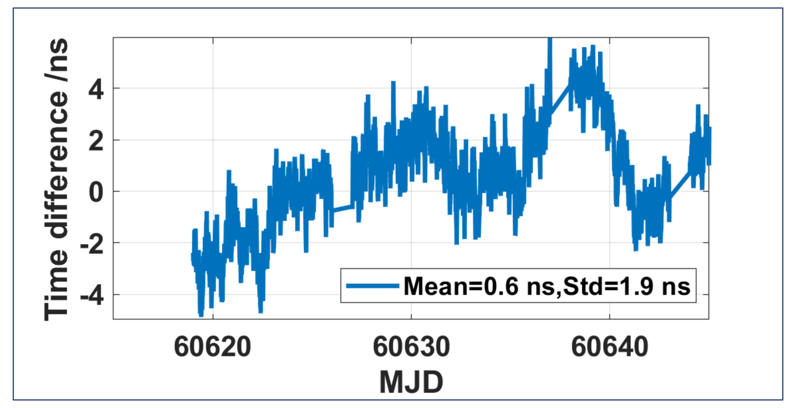




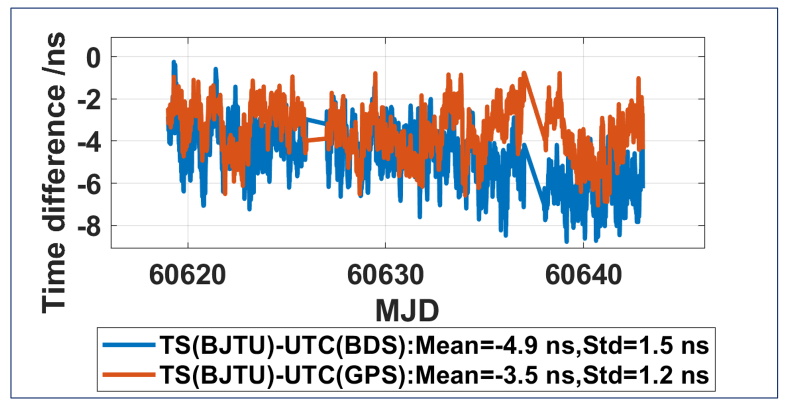
(Results of UTC-UTC(BDS) from BJTU were shifted by 2 ns, which is within the uncertainty of 5 ns given by BIPM Circular T.)



Real-time monitoring of BDT/GPST



Real-time monitoring BDT-GPST



Real-time monitoring of UTC(BDS)/UTC(GPS)

The monitoring results of TS(BJTU)-BDT/GPST/UTC(BDS) /UTC(GPS) and BDT-GPST are less than 5 ns. The mean value of BDT-GPST is 0.6 ns, although the time difference greater than 4 ns occurs in some cases.

Conclusions & Outlook

The absolute calibration method for the GNSS one-way timing receiver is proposed. The separately absolute, integrated absolute, and differential calibration uncertainties are 6.80 ns, 6.70 ns, and 9.50 ns, respectively.

The methods of real-time monitoring based on non-UTC(k) laboratory are proposed. The monitoring results based on TS(BJTU) are well consistent with the results of BIPM Circular T, demonstrating the effectiveness of the real-time monitoring method of TS(BJTU). The results of TS(BJTU)-BDT/GPST/UTC(BDS)/UTC(GPS) and BDT-GPST are less than 5 ns. The offset between BDT and GPST is 0.6 ns.

In the future, research will be conducted including the methods to evaluate the performance of GNSS one-way timing; the monitoring methods of the Galileo system time; and the monitoring methods based on multi-GNSS time transfer receivers.

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