Update on BeiDou time system and its performance evaluation

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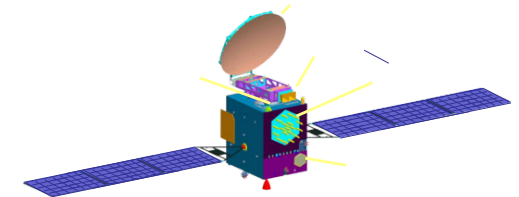
Beijing Satellite Navigation Centre

Outline

1. The definition and realization of the BDT

BeiDou Time

The coordinate time of BeiDou Navigation Satellite System, used as the time reference for *time synchronization* and *orbital determination.*
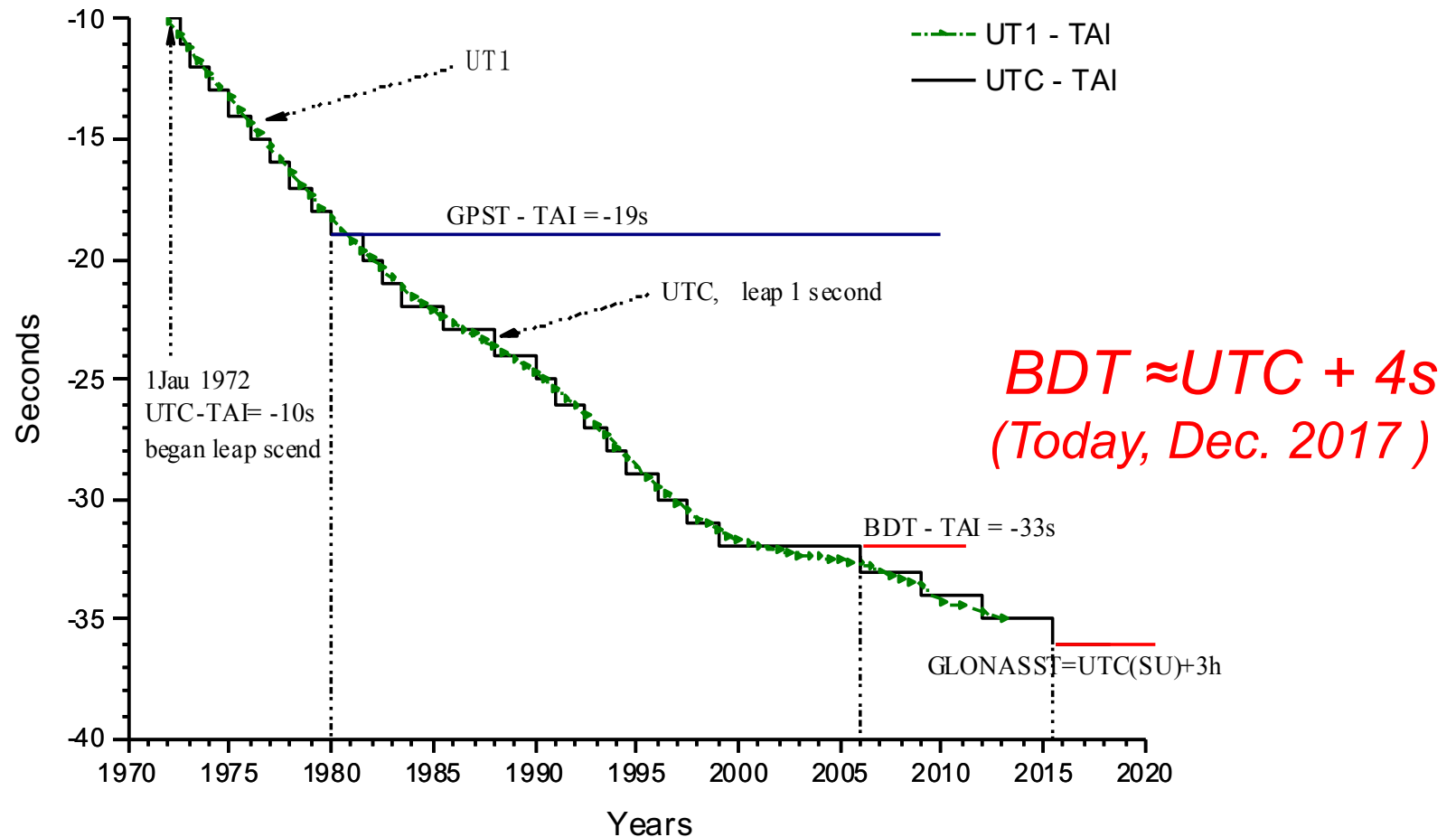
- BDT are counted by Week Number (WN) and Second of Week (SoW).
- The zero point is **Jan 1,2006 UTC00:00:00**
- *BDT and GPST are different realizations of TT.*

$$GPST \approx TAI -19s = TT- 51.184s$$
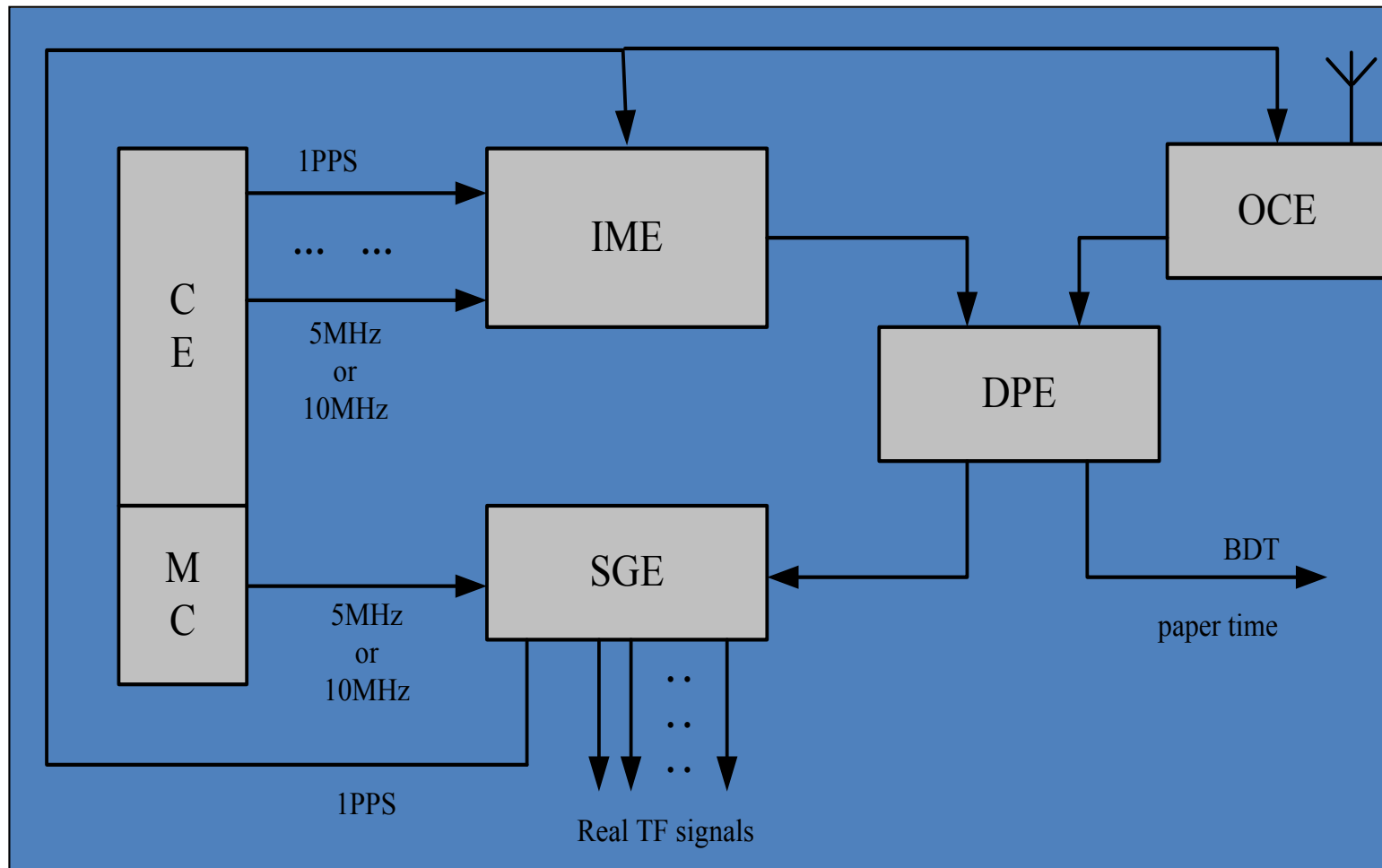
$$BDT \approx TAI -33s = TT- 65.184s$$

1. The definition and realization of the BDT

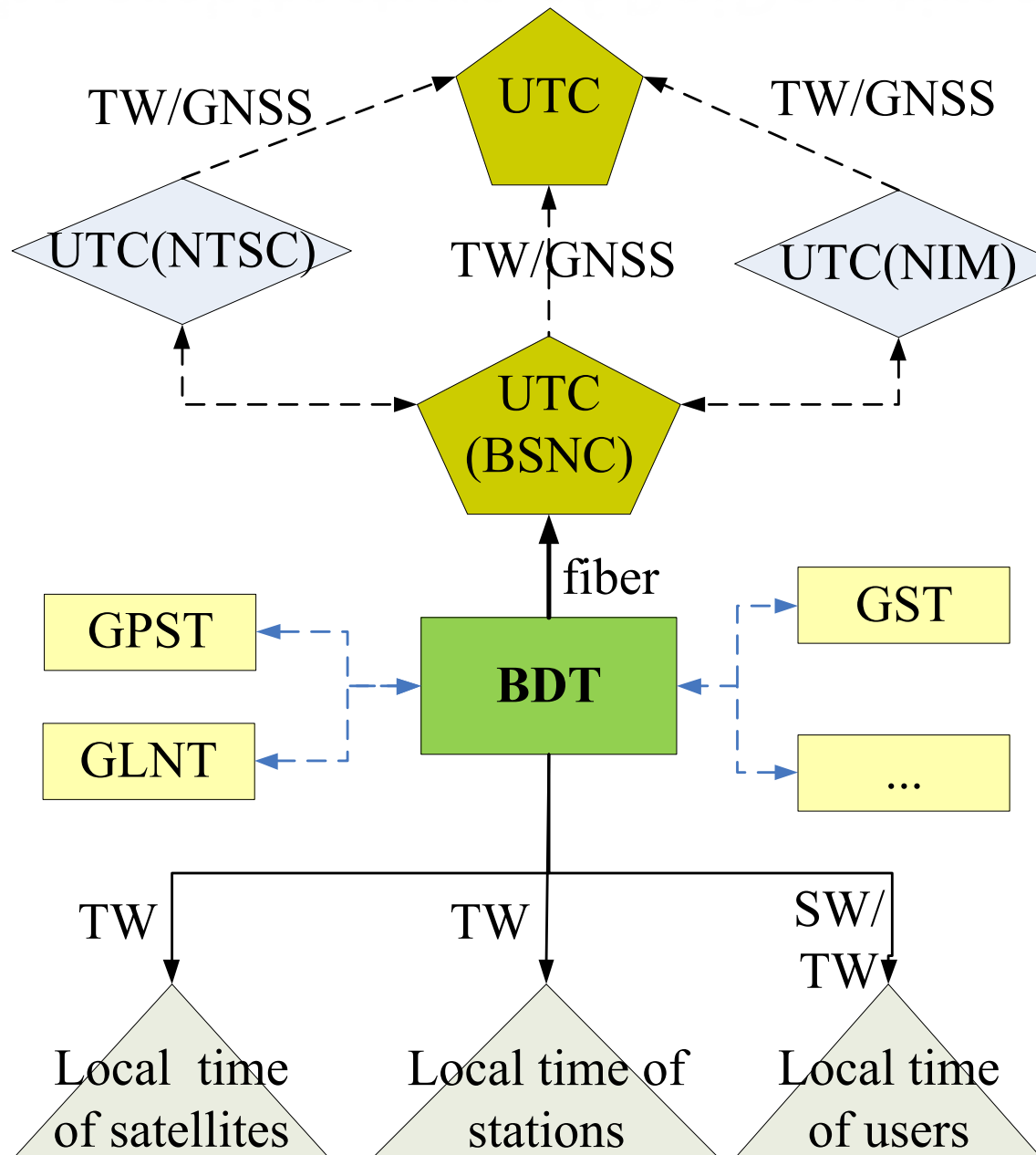## The relation among BDT and other time systems

BDT ≈UTC + 4s
(Today, Dec. 2017)

1. The definition and realization of the BDT

Structure of TFS(Time and Frequency System)

2. The architecture of BeiDou time system
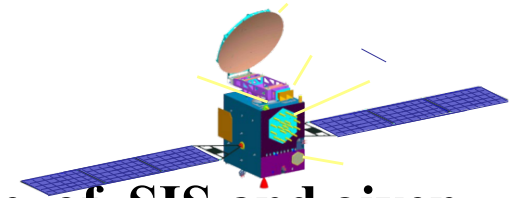
➢ **Satellite Time**

The local time of a satellite, used for the time reference of SIS and given by the master clock of the satellite.

● The time offset of the satellite $|T_s\text{-}BDT|< 1ms$

● The time accuracy of satellite clocks is better than 5E-10.

● The stability of the satellite clocks for one day is better than 1E-13.

➢ **Station Time**

The local reference time of a station, used for the ground station mission and given by the master clock of the station.

● The time offset of the Uplink Station $|T_u\text{-}BDT|< 1\mu s$

● The time accuracy of the Uplink Station is better than 5E-13.

➢ **Time Service**

Standard Time :UTC

Nav. Data: UTC parameters

number of leap seconds: Δt_{LS}

time offset parameters (modulo 1s)

$$\Delta t_{ST} = T_{GNSS} - UTC = A_0 + A_1 （T - T_0）$$
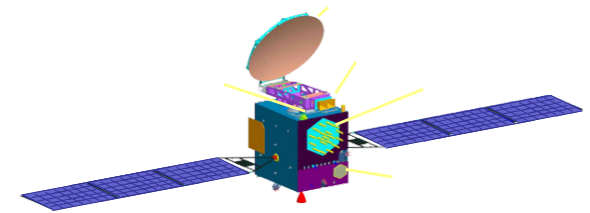
$$UTC = T_{GNSS} - \Delta t_{LS} - \Delta t_{ST}$$

for example:

$$UTC （USNO） = GPST - \Delta t_{LS}^{GPS} - \Delta t_{ST}^{GPS}$$
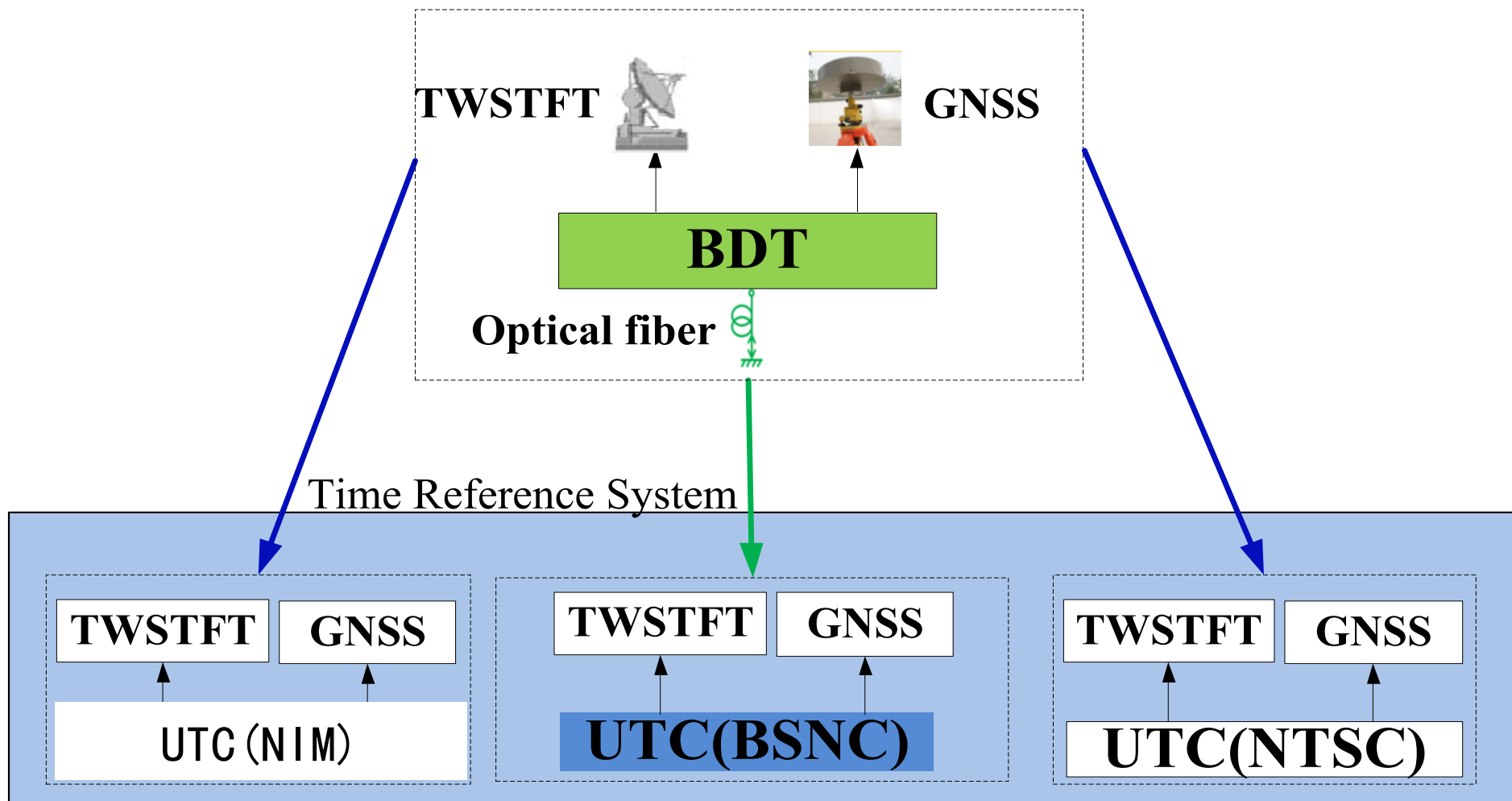
$$UTC （BSNC） = BDT - \Delta t_{LS}^{BDS} - \Delta t_{ST}^{BDS}$$

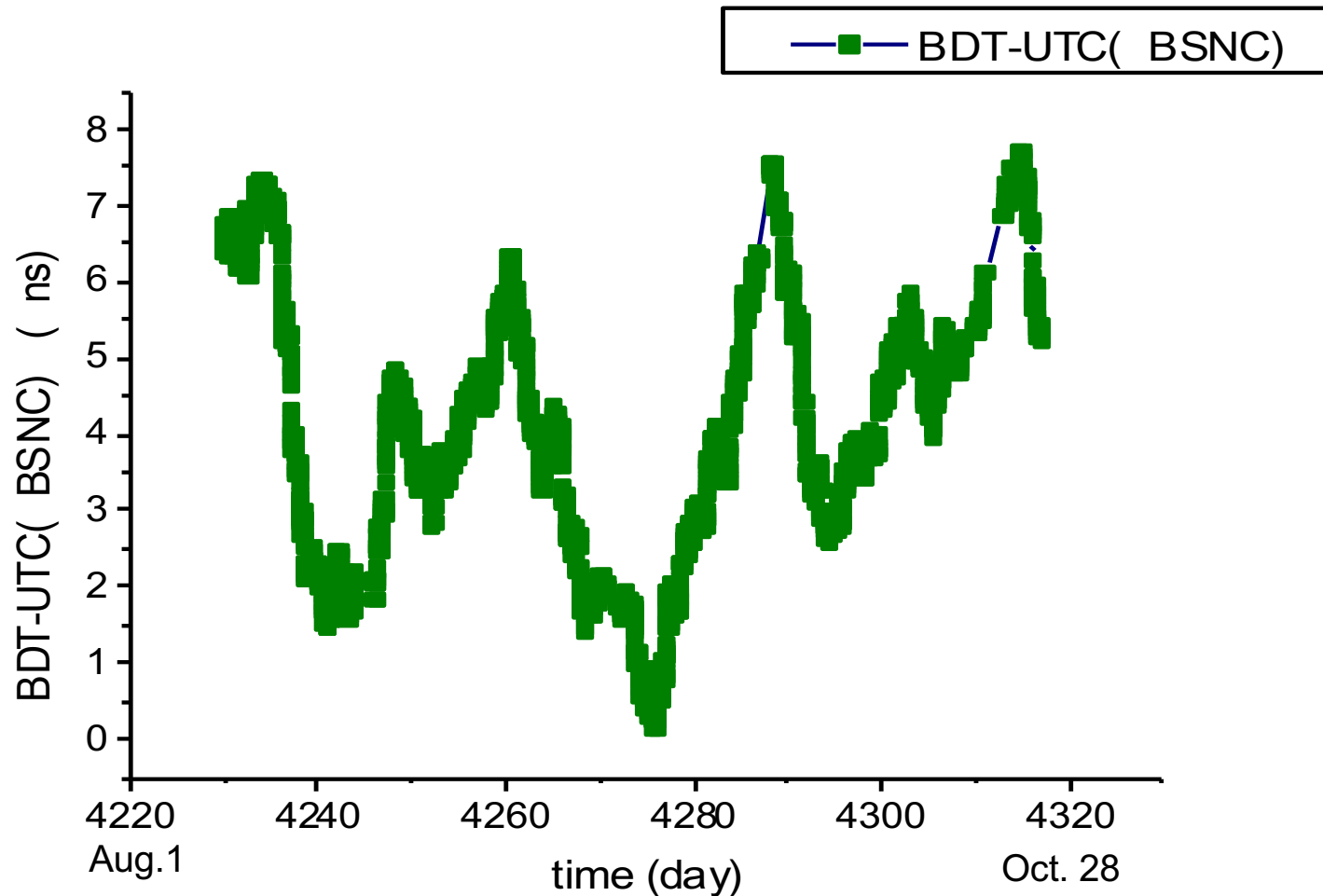$$（ UTC(BSNC) - UTC < 100ns)$$

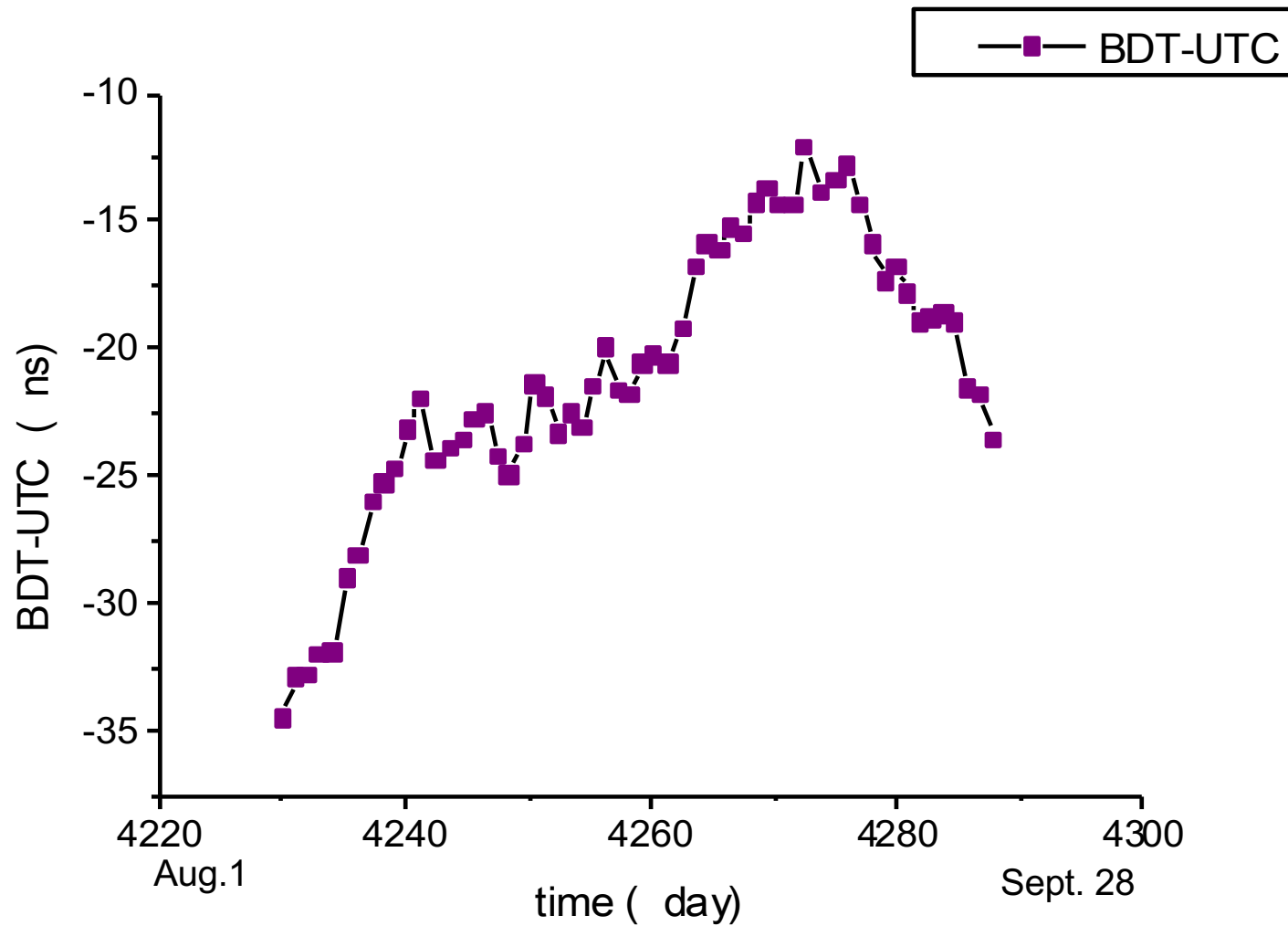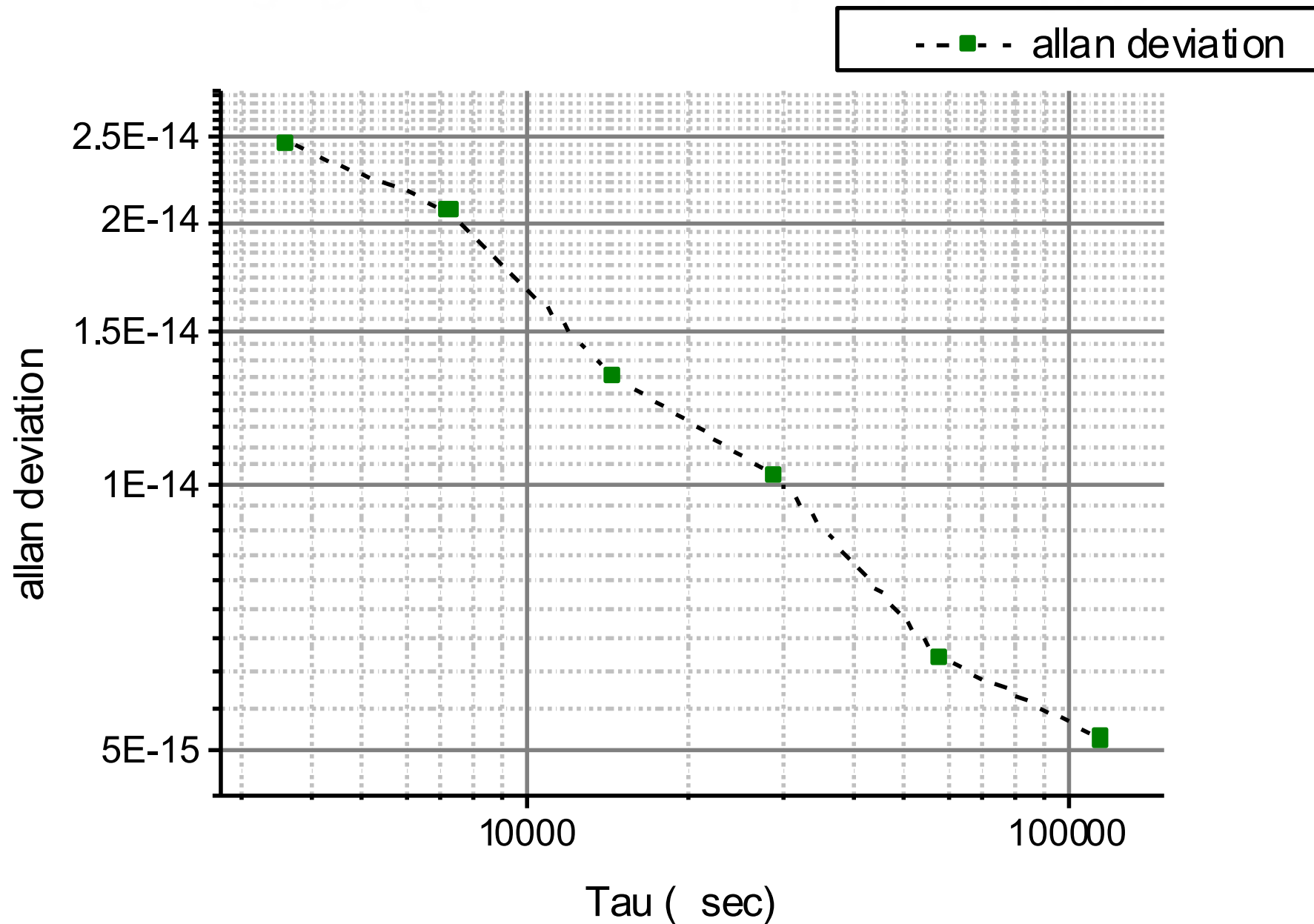*BSNC: Beijing Satellite Navigation Center*

Time Links for BDT performance evalutation

time offset between BDT and UTC(BSNC)

time offset between BDT and UTC

3. Performance evaluation of BDT

frequency stability of BDT

Three Methods are considered to get the time offset among BDT and other GNSST (GPST, GLNT, GST) which is called "BGTO"

#1 Local timing method: to get the time offset from the high precision GNSS timing receivers deployed in the MCS of BDS

#2 Common View Method: to get the time offset from the CV receivers deployed in both MCS

#3 Two Way Method: to get the time offset from the TWSTFT devices deployed in both MCS

4. Monitor and broadcast of GNSST
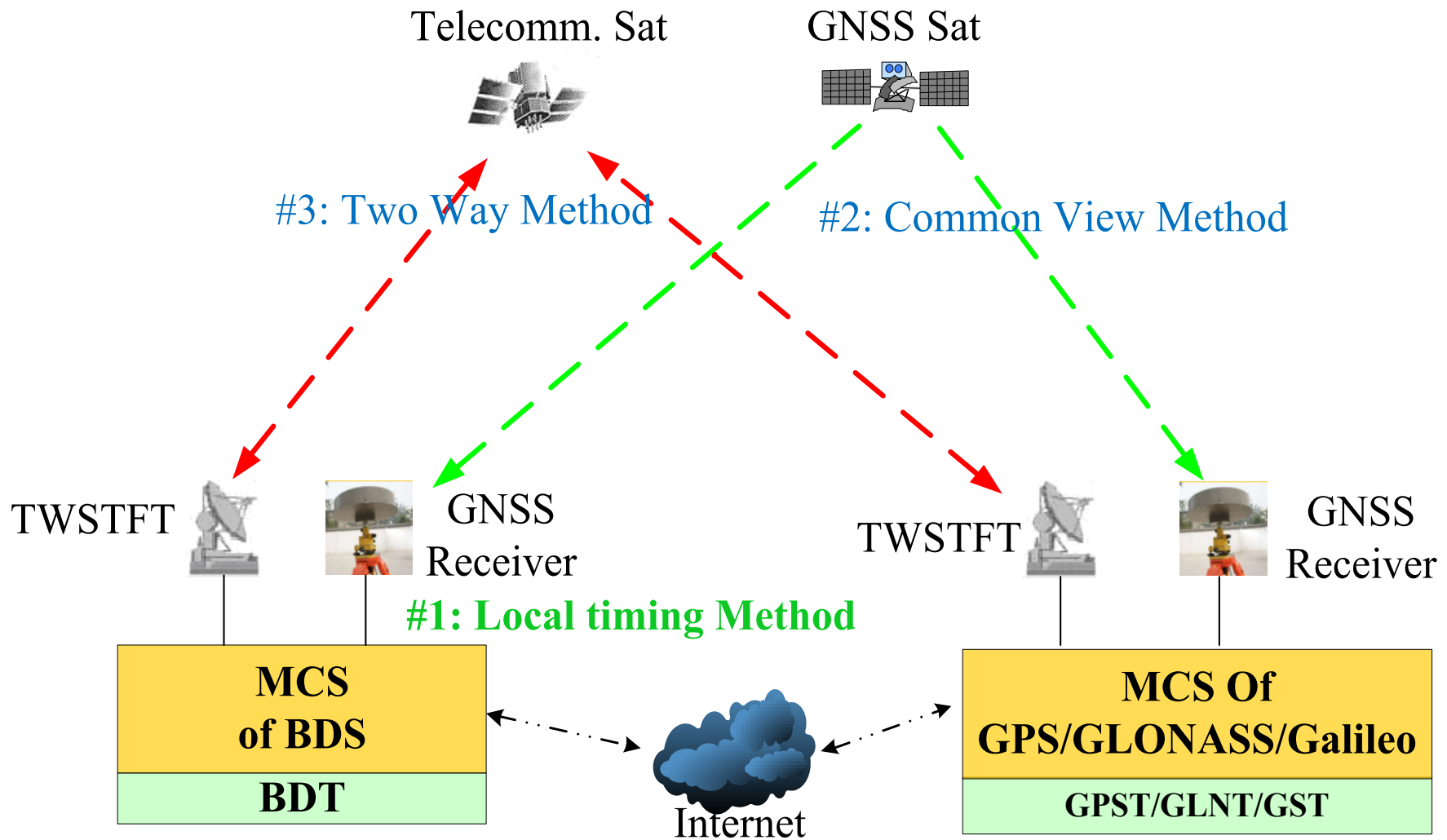
Time Links for monitoring BGTO

time offset between BDT and GPST (local timing method)

The new experimental satellites of BDS have broadcast the GNSST parameters.

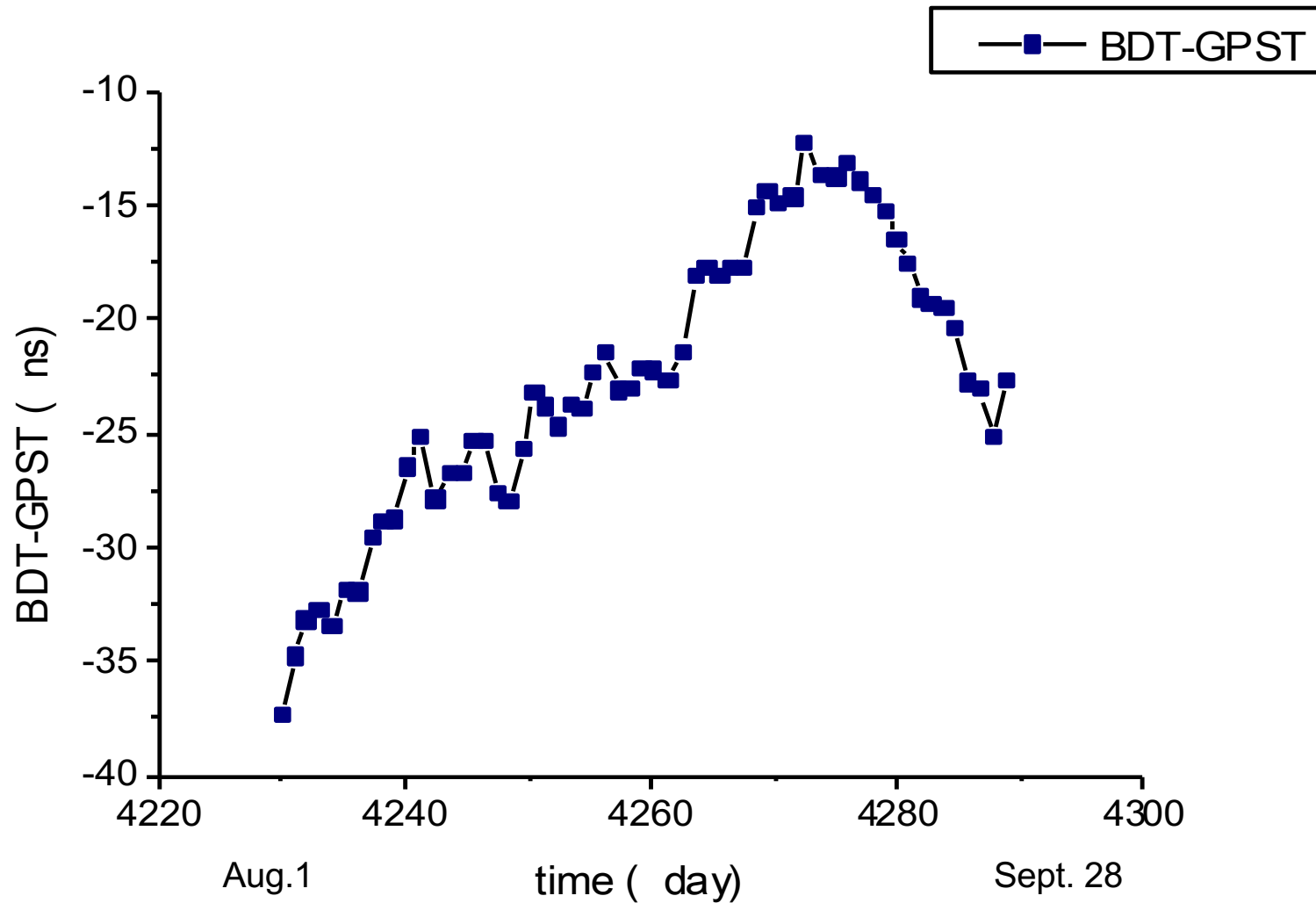The formation of time parameters among BDT and other GNSST could be inquired in the ICD document of BDS.

BeiDou Navigation Satellite System
Signal In Space
Interface Control Document

Open Service Signal (Version 2.0)

China Satellite Navigation Office

December 2013

5.2.4.18 Time Parameters relative to GPS time （A_{0GPS}, A_{1GPS}）

These parameters indicate the relationship between BDT and GPS time as in Table 5-17. (Not broadcast temporarily)

Table 5-17   Time parameters relative to GPS time

Parameter	No. of Bits	Scale factor (LSB)	Units
A_{0GPS}	14*	0.1	ns
A_{1GPS}	16*	0.1	ns/s

* Parameters so indicated are two's complement, with the sign bit (+ or −) occupying the MSB.

A_{0GPS}: BDT clock bias relative to GPS time;

A_{1GPS}: BDT clock rate relative to GPS time.

The relationship between BDT and GPS time is as follows:
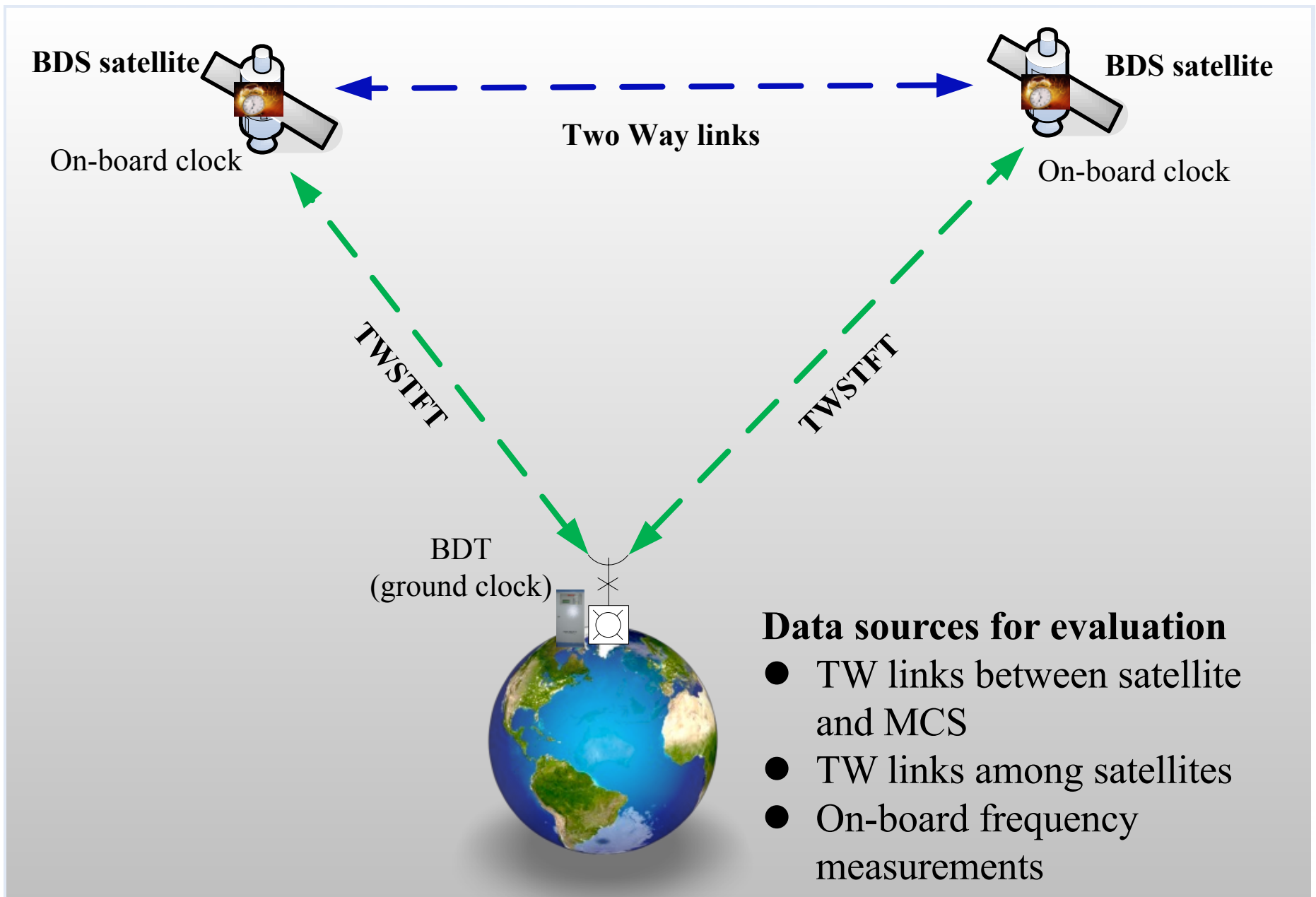
$$t_{GPS} = t_E - \Delta t_{GPS}$$

where, $\Delta t_{GPS} = A_{0GPS} + A_{1GPS} \times t_E$;

t_E is the SOW in BDT computed by user.

5.2.4.19 Time Parameters relative to Galileo time (A_{0Gal}, A_{1Gal})

These parameters indicate the relationship between BDT and Galileo time as in Table 5-18. (Not broadcast temporarily)

BDS satellite

On-board clock

Two Way links

BDS satellite

On-board clock

TWSTFT

TWSTFT

BDT
(ground clock)

Data sources for evaluation
- TW links between satellite and MCS
- TW links among satellites
- On-board frequency measurements

The basic model for performance evaluation

Data from TW links between satellite and MCS

$$\Delta \tau_{obs}(t_i) \equiv T_{satclk}(t_i) - t_i + \varepsilon_{link}(t_i)$$
$$= T_{satclk}(t_i) - BDT(t_i) + \varepsilon_{link}(t_i)$$
$$= a_0 + a_1(t_i - t_0) + a_2(t_i - t_0)^2 + \delta_{satclk} + \varepsilon_{link}(t_i)$$
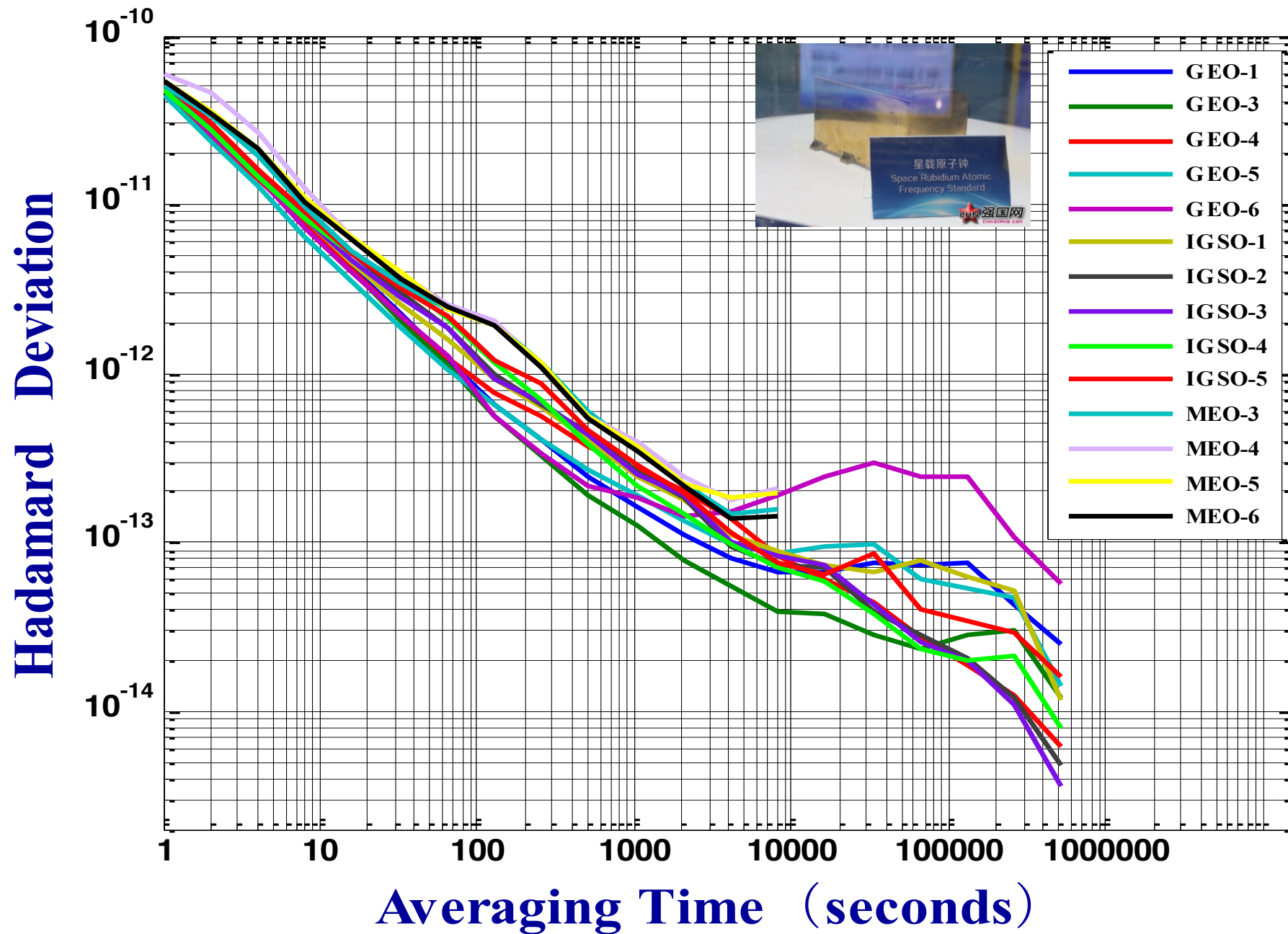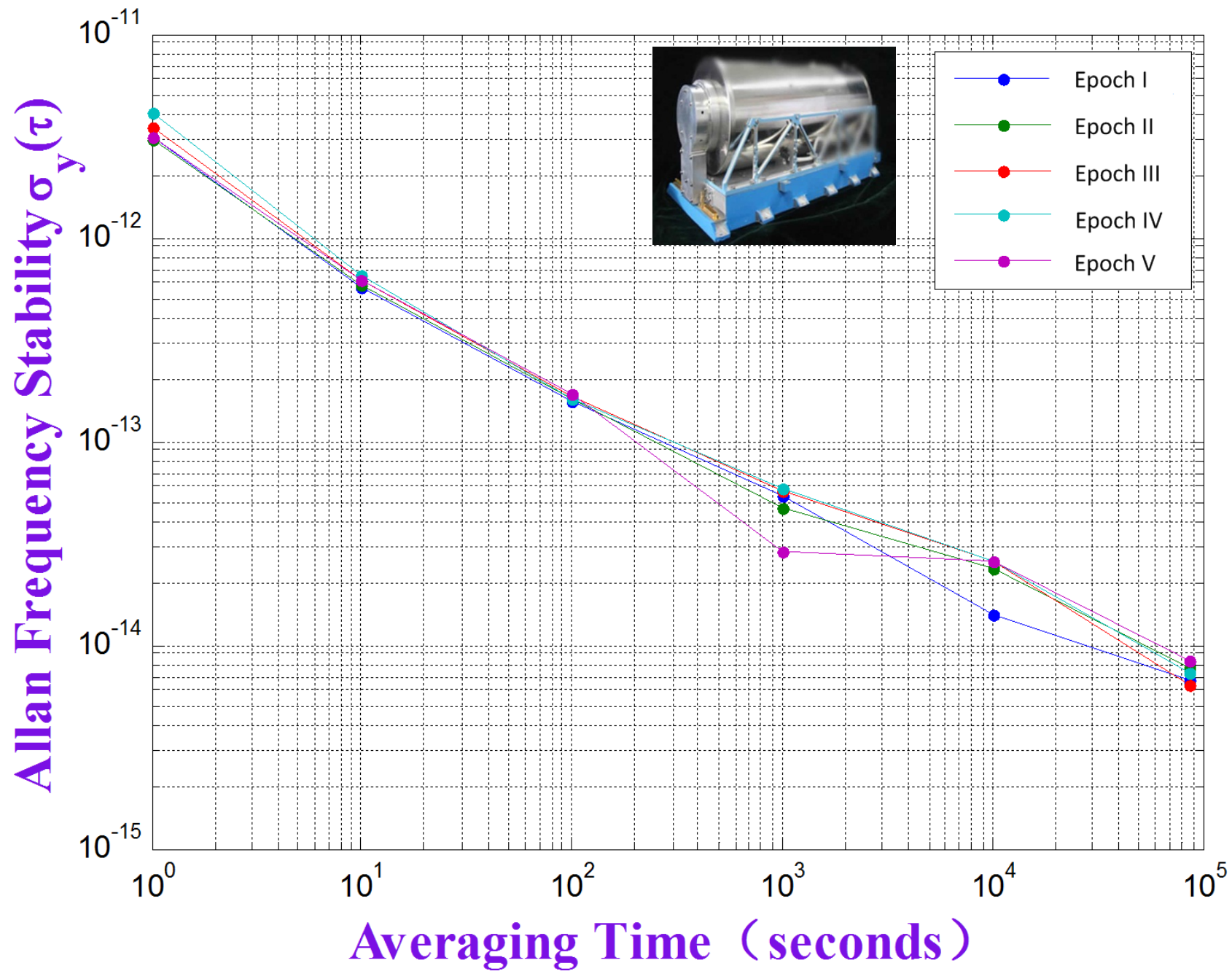
Frequency drift   Allan deviation

Stability of traditional Rubidium Clocks of BDS

Stability of the new hydrogen clocks of BDS

6. Summary

1. **BDT is defined as a kind of atomic time and realized by an ensemble of hydrogen clocks. The stability of BDT is about 5E-15 in this year.**

2. **BDT is steered to UTC/UTC(BSNC) and the time offset between BDT and UTC(BSNC) is less than 10ns this year.**

3. **The BGTO parameters are monitored and the parameters BGTO(BDT-GPST) have been broadcast in the new experimental satellites.**

4. **The onboard satellite clocks work well and the stability of traditional Rb satellite clocks is about 5E-14/day.**

5. **The new hydrogen clocks were tested on the new experimental satellites and their stabilities are about 6~8E-15/day.**

Thank you for your attention !