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The Realization of BeiDou Time Scales

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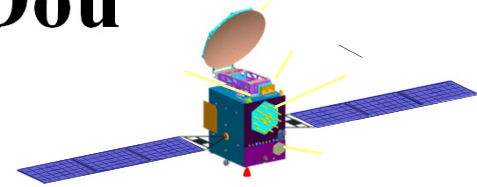


Outline

1. The System Time of BeiDou (BDT)
2. BDT performance evaluation
3. Performance of the BDS Satellite clock
4. BDS Time Service
5. BDS CV
6. Summary



1. The System Time of BeiDou



➤ BeiDou Time--BDT

The system time of BeiDou Navigation Satellite System is 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.*

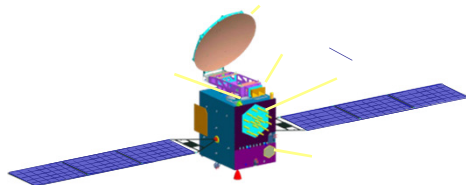
$$GPST \approx TAI - 19s = TT - 51.184s$$

$$BDT \approx TAI - 33s = TT - 65.184s$$

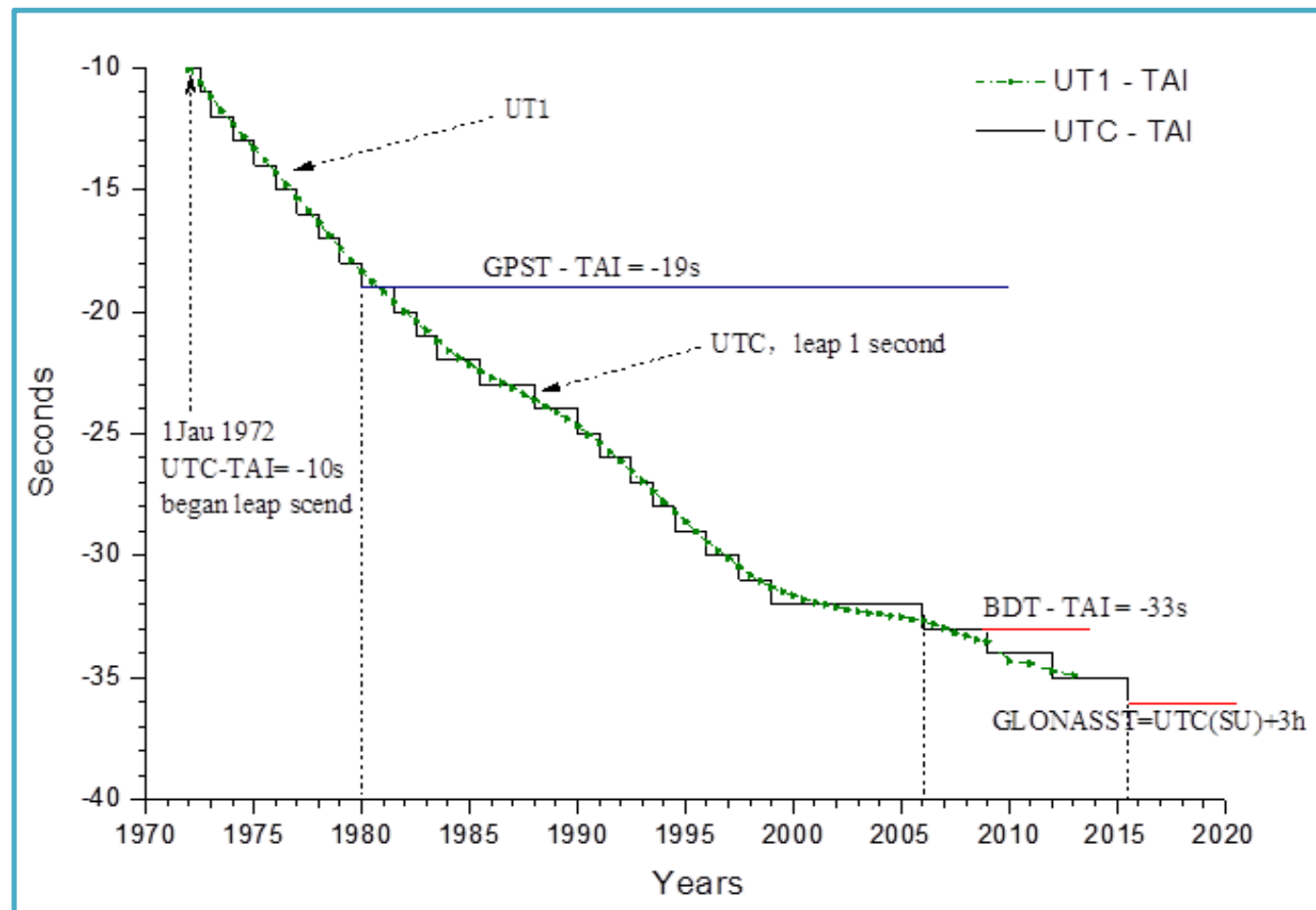


➤ BeiDou Time--BDT

- BDT is maintained by the Master Control Station (MCS) and steered to UTC (BSNC) , the realized Coordinated Universal Time of Beijing Satellite Navigation Center (BSNC) .
- $|BDT-UTC(BSNC)| < 20ns$ (modulo 1s)
- The accuracy of BDT is better than $1E-13$



■ The relation among GNSS time systems and UTC

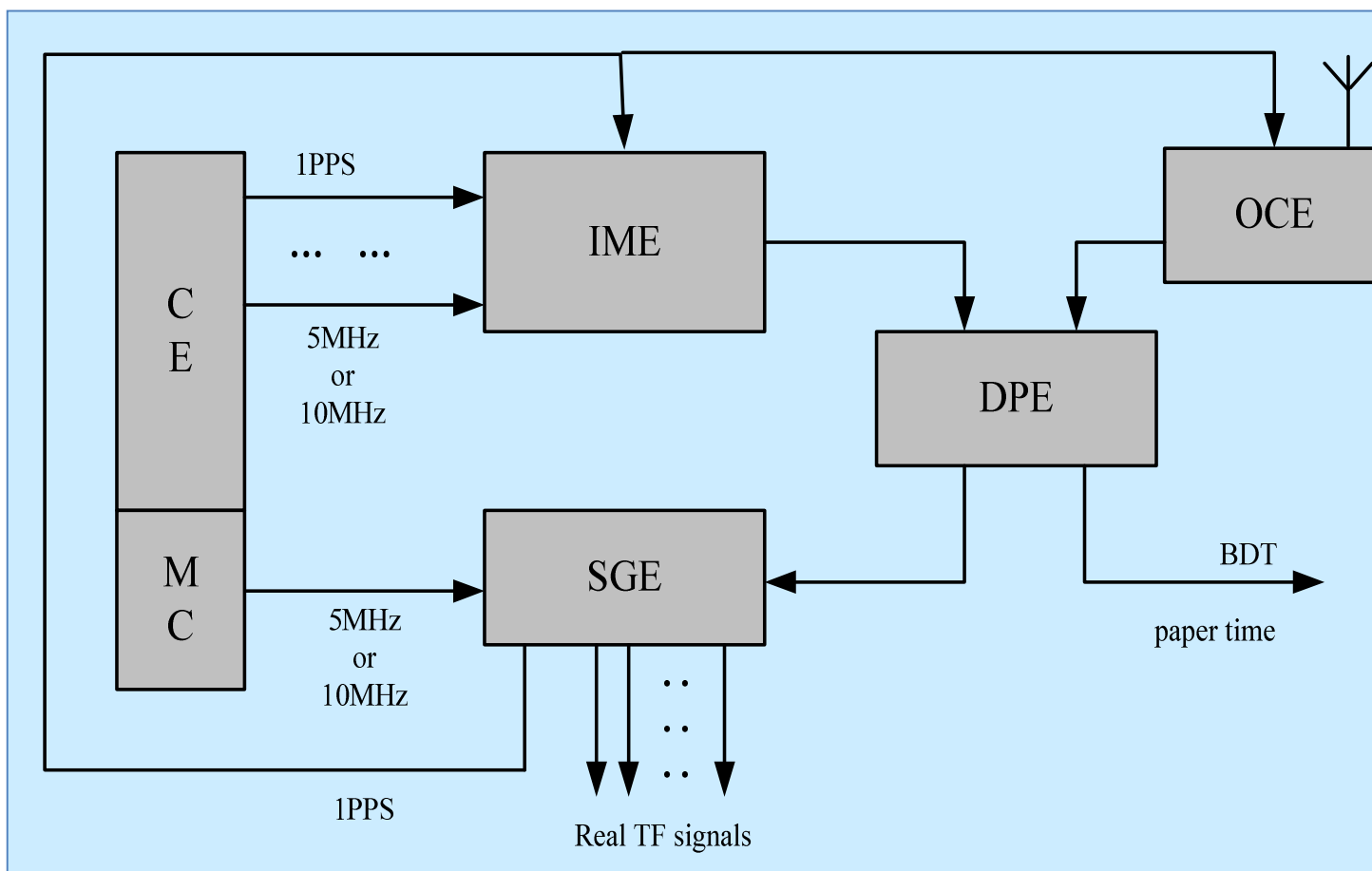


■ Realization of BDT

- **BDT is a composite clock realized by a clock ensemble**
- **BDT is maintained by a time and frequency system (TFS) located at the master control station (MCS)**



■ Structure of TFS(Time and Frequency System)



■ Performance Index of BDT

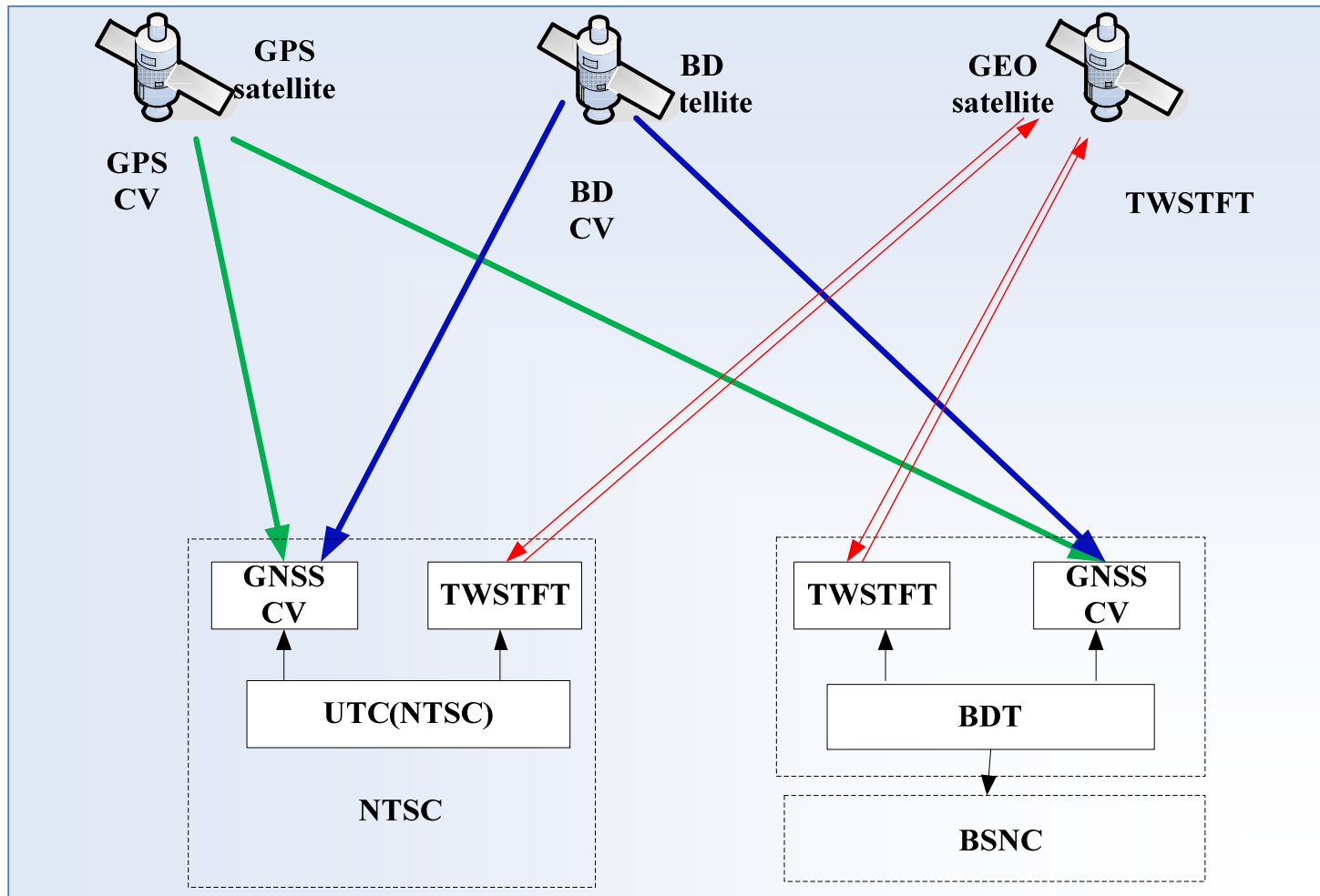
Frequency accuracy : $< 1.0\text{E-}13$

Frequency stability : $< 2.0\text{E-}14$ /1da

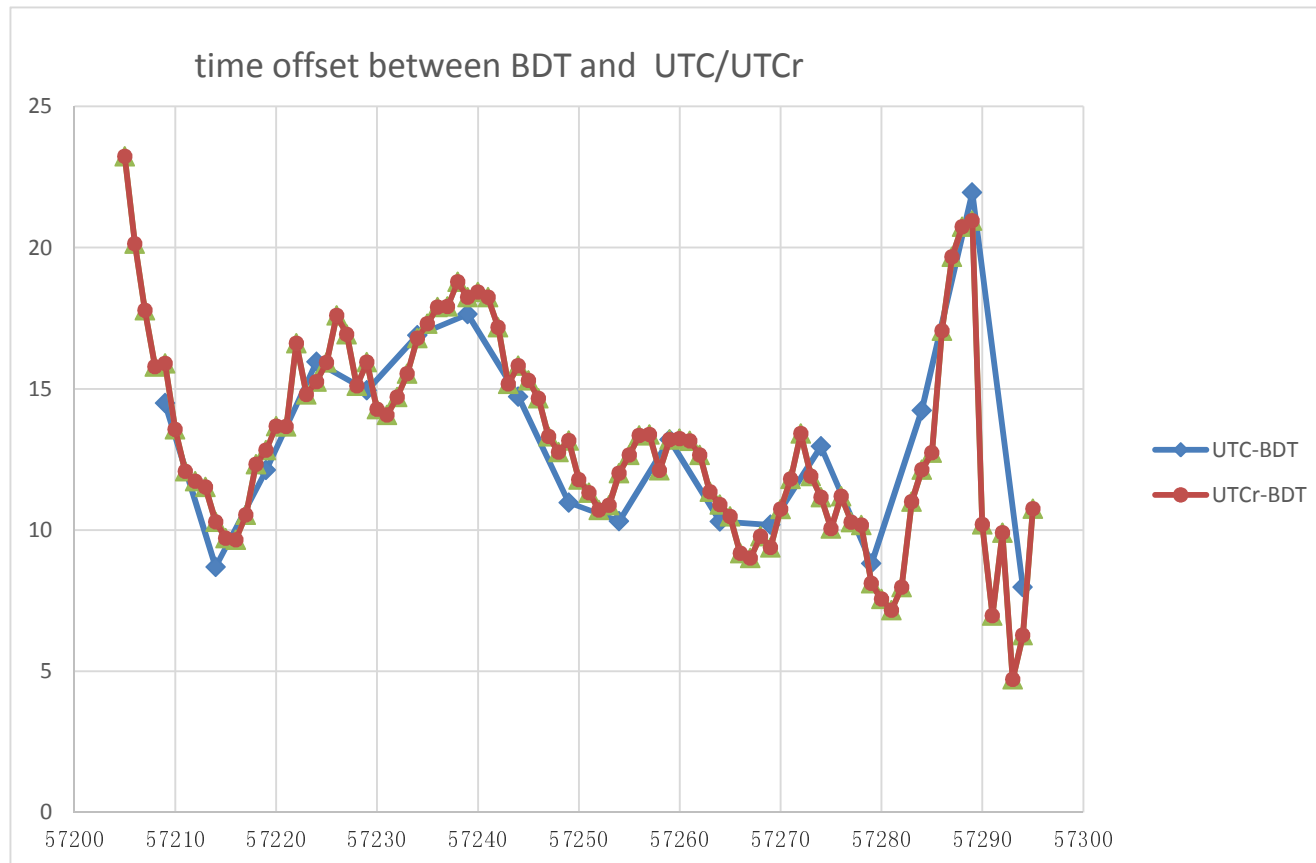


2. BDT performance evaluation

■ BDT time comparison links



■ Time offset between BDT and UTC/UTCr

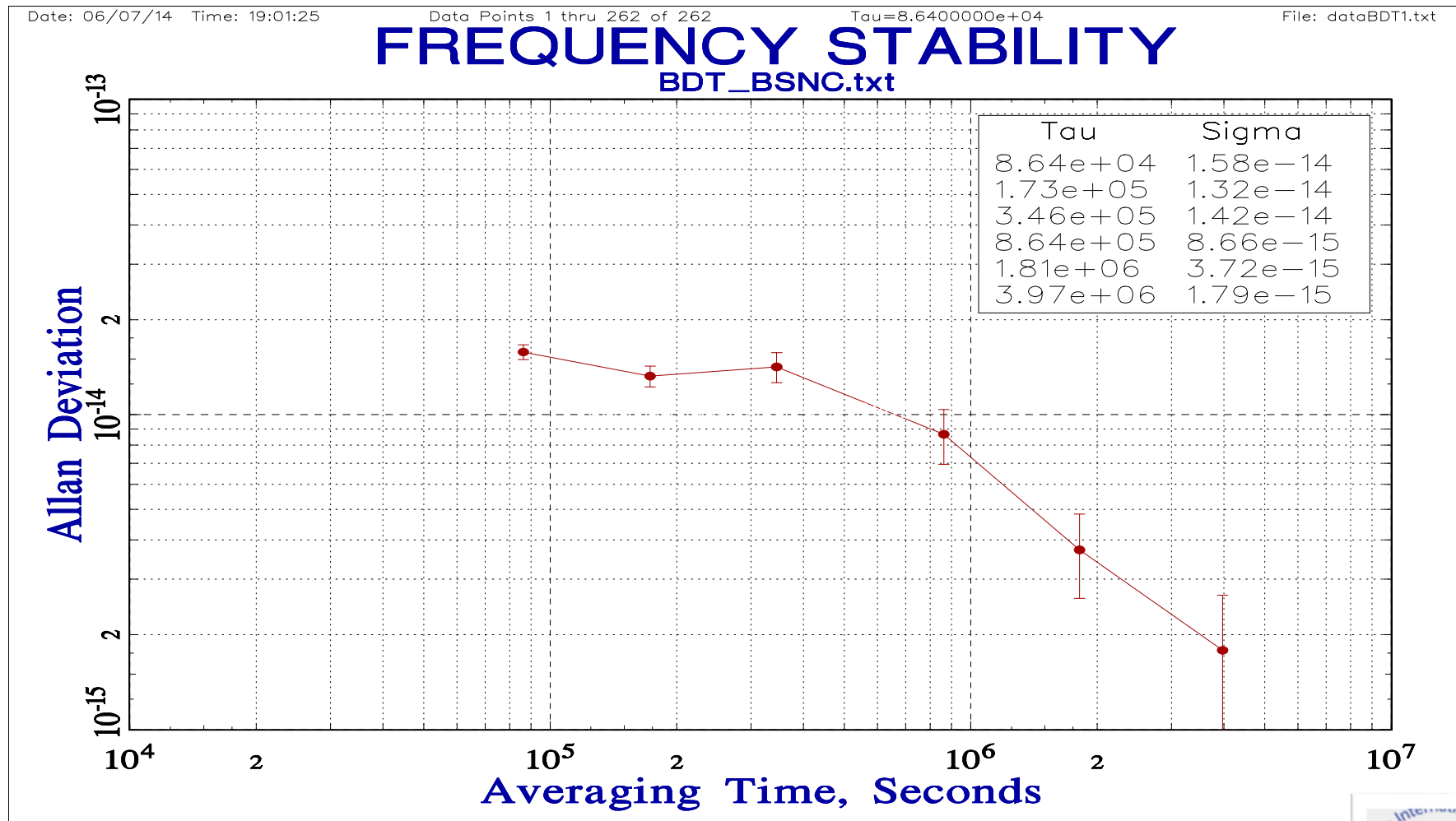


$|\text{BDT}-\text{UTC}| < 100\text{ns}$, control the system time as little as possible

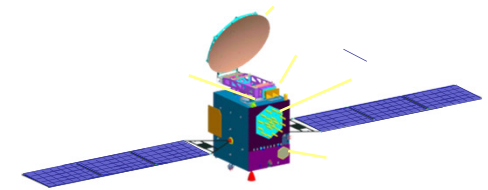
Timelinks: BDT-UTC(BSNC)-UTC(NTSC)-UTC



Performance Evaluation of BDT vs UTC



3. Performance of the BDS Satellite Clock



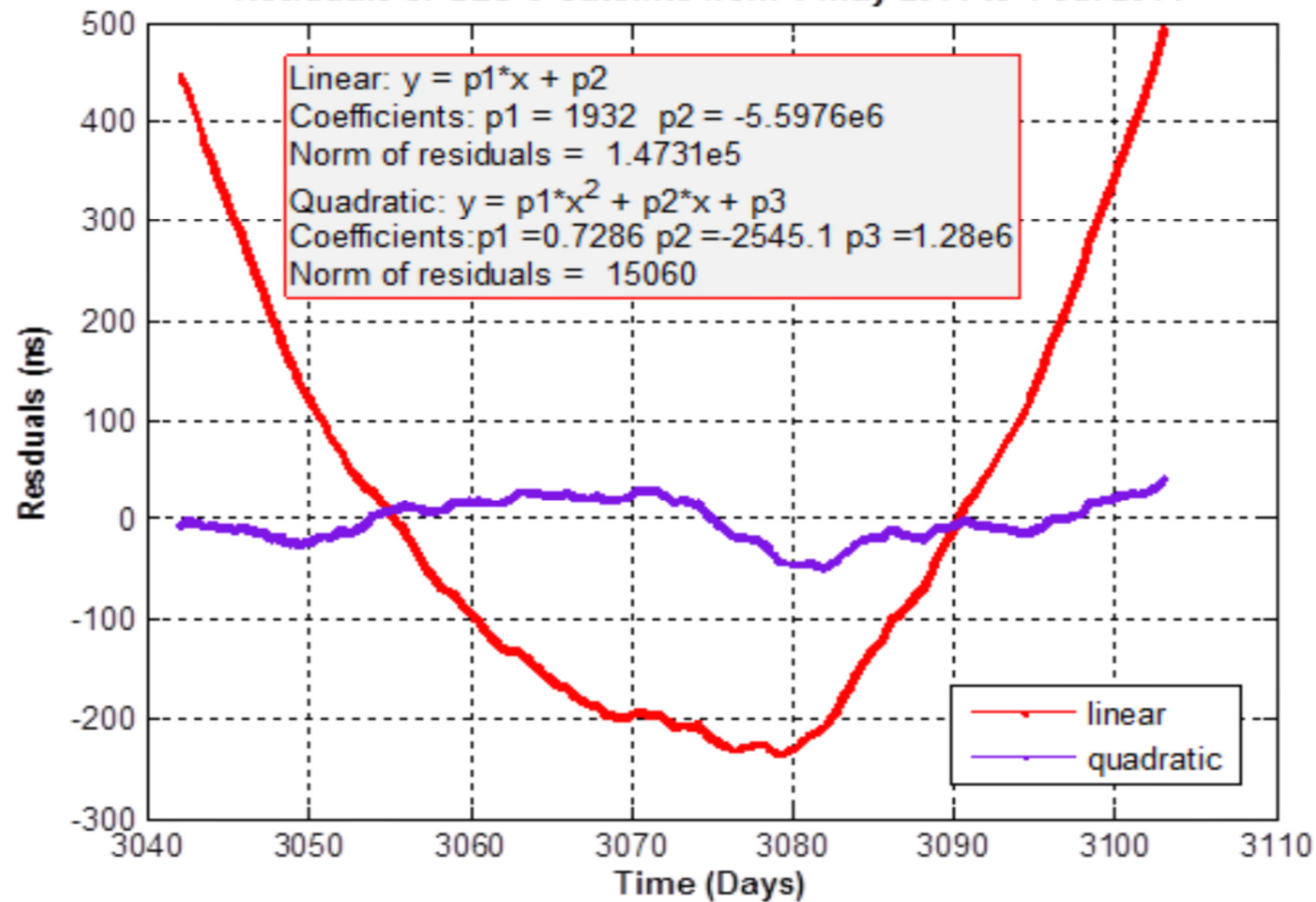
On-board

Actual Measured

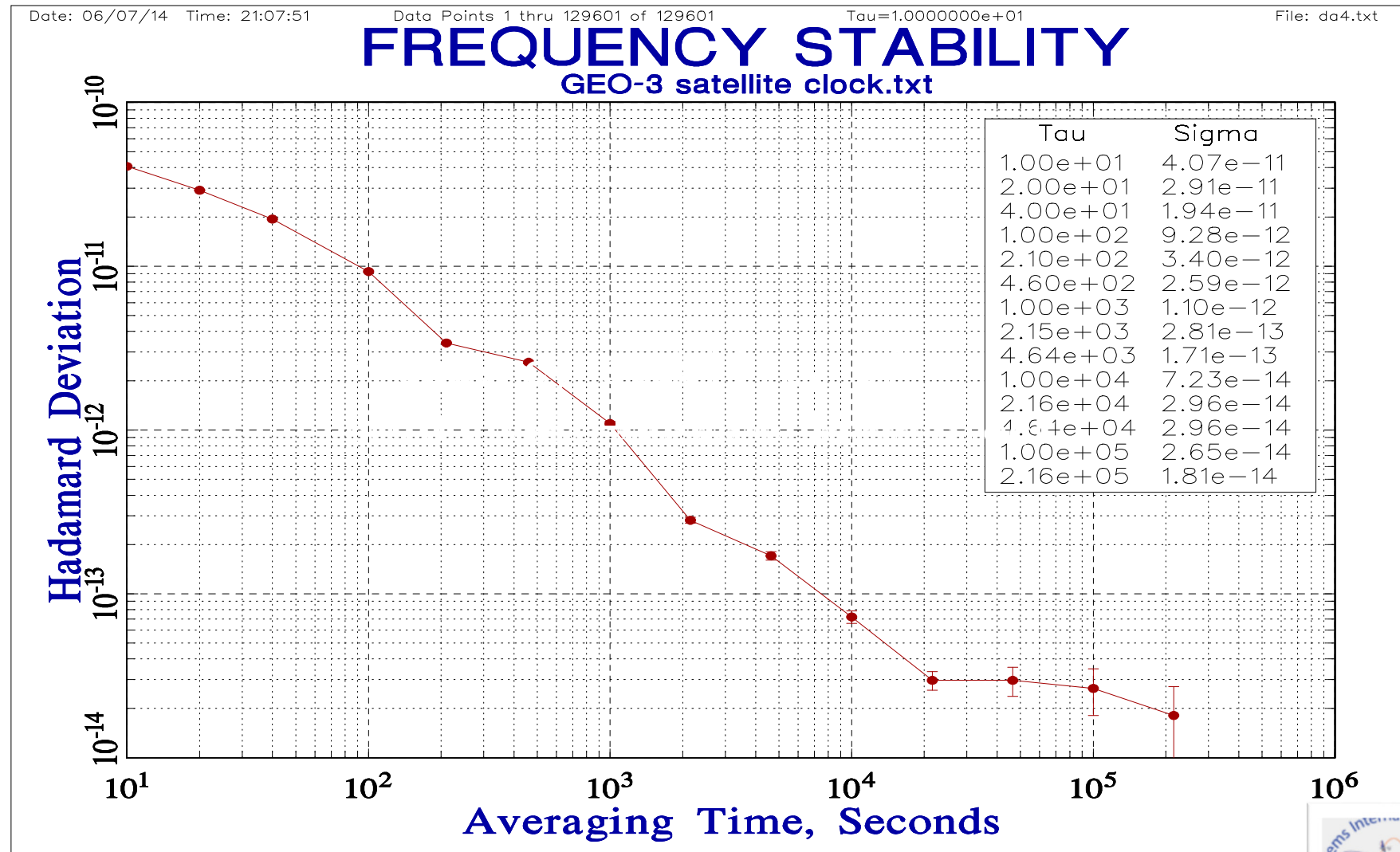
Include :IGSO, GEO and MEO satellites



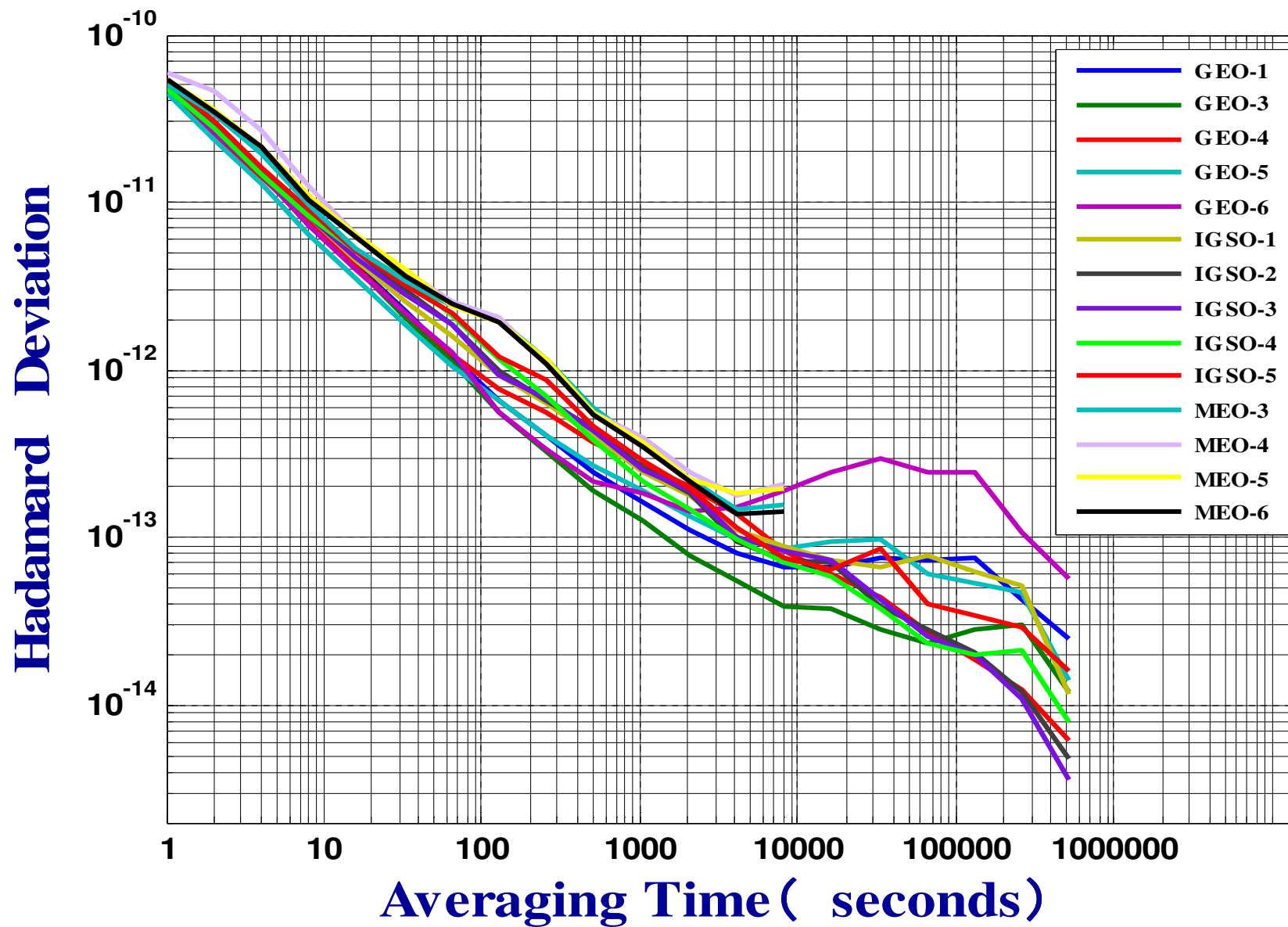
Residuals of GEO-3 Satellite from 1-may-2014 to 1-Jul-2014



Frequency stability of BeiDou GEO-3 satellite clock



Frequency stability of BeiDou satellite clocks



4. BDS Time Service

➤ Time Service

Standard Time :UTC

Nav. Data: UTC parameters

number of leap seconds: Δt_{LS}

time offset parameters (modulo 1s)

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

$$UTC = T_{GNSS} - \Delta t_{LS} - \Delta t_{ST}$$

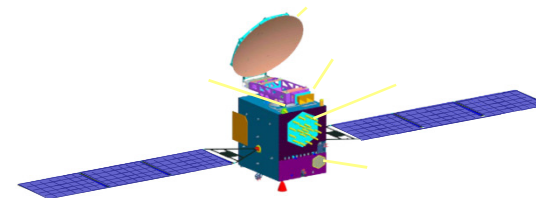
for example:

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

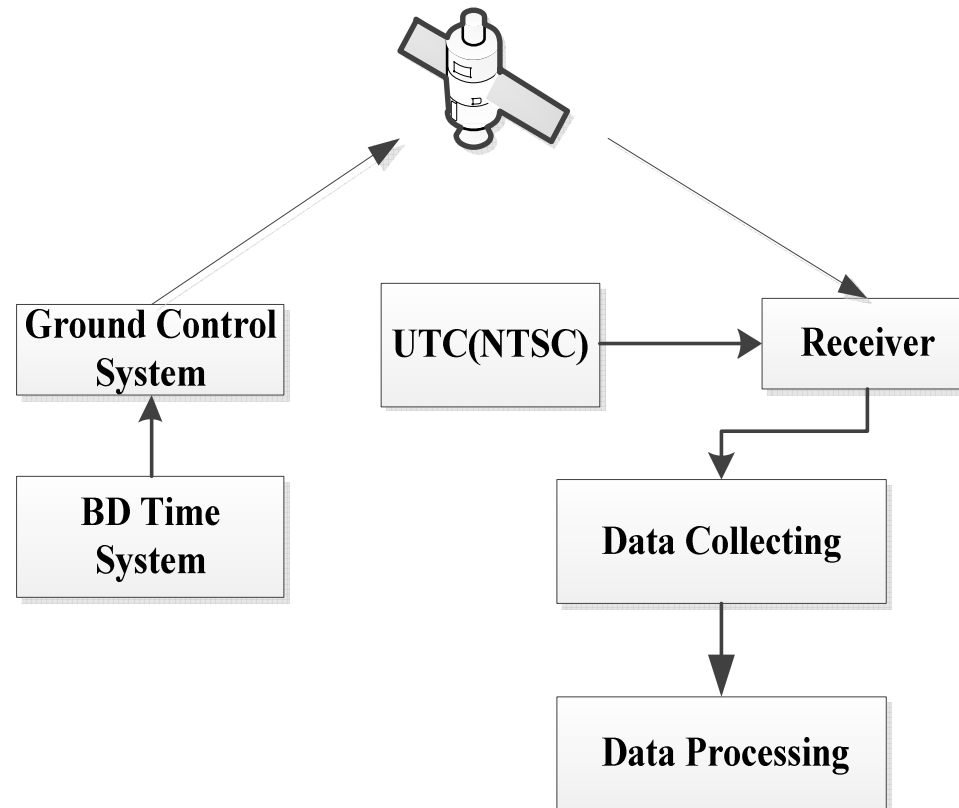
$$UTC (BSNC) = BDT - \Delta t_{LS}^{BDS} - \Delta t_{ST}^{BDS}$$

$$(UTC(BSNC) - UTC < 100ns)$$

BSNC: Beijing Satellite Navigation Center



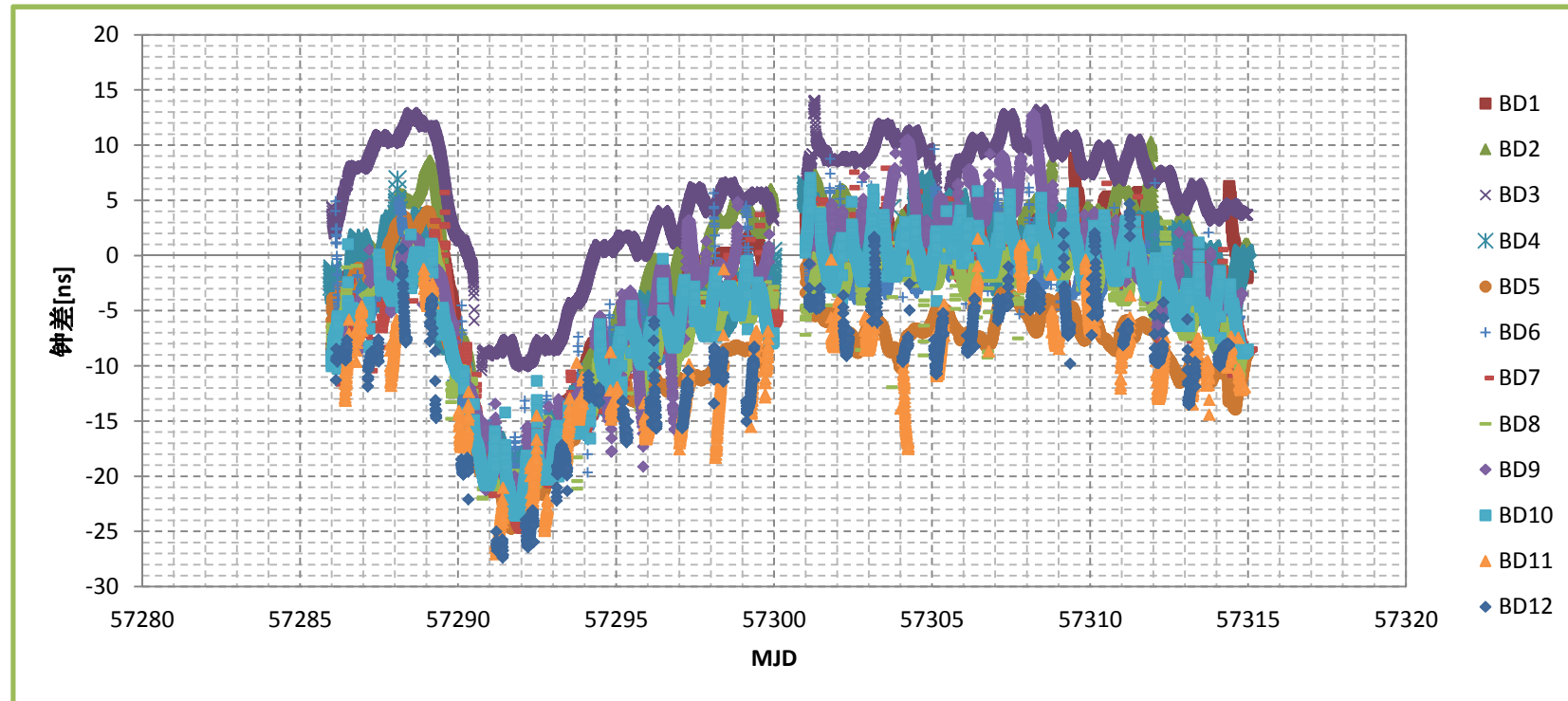
BDS time service monitoring



Time Service performance monitored by the third party (NTSC)



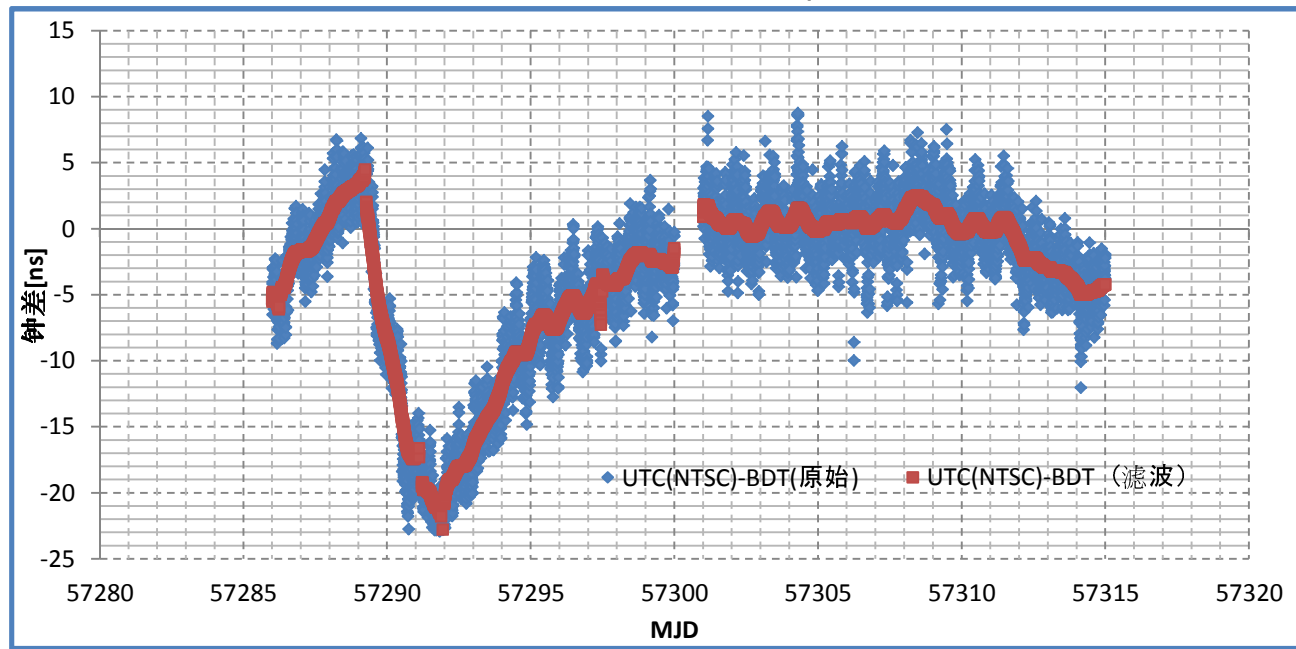
BDS time service monitoring



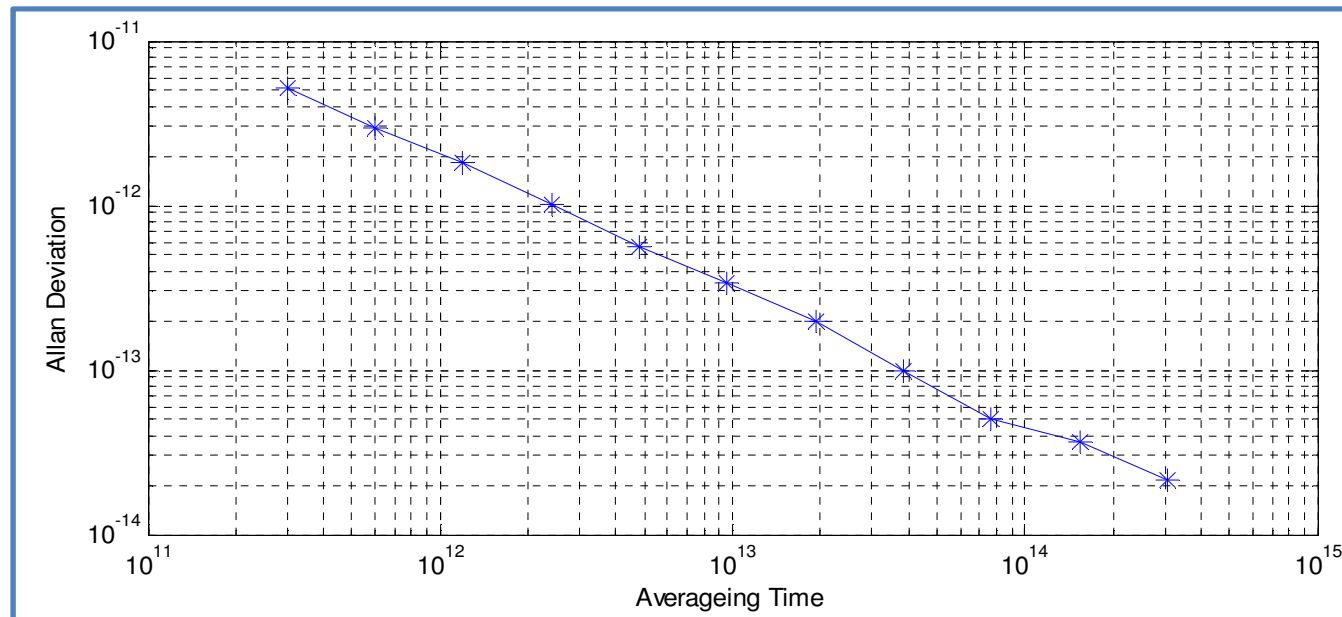
UTC(NTSC)-BDT by GEO(1~5)



UTC(NTSC)-BDT by all satellites

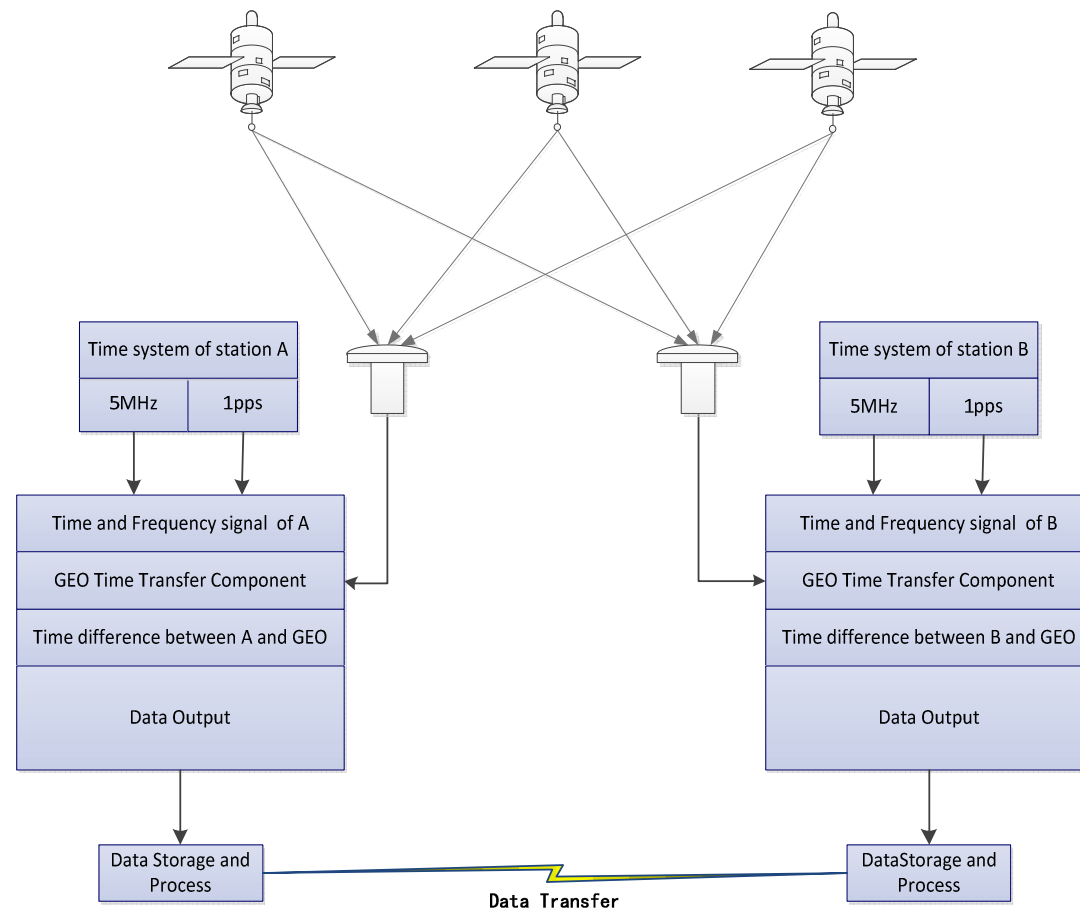


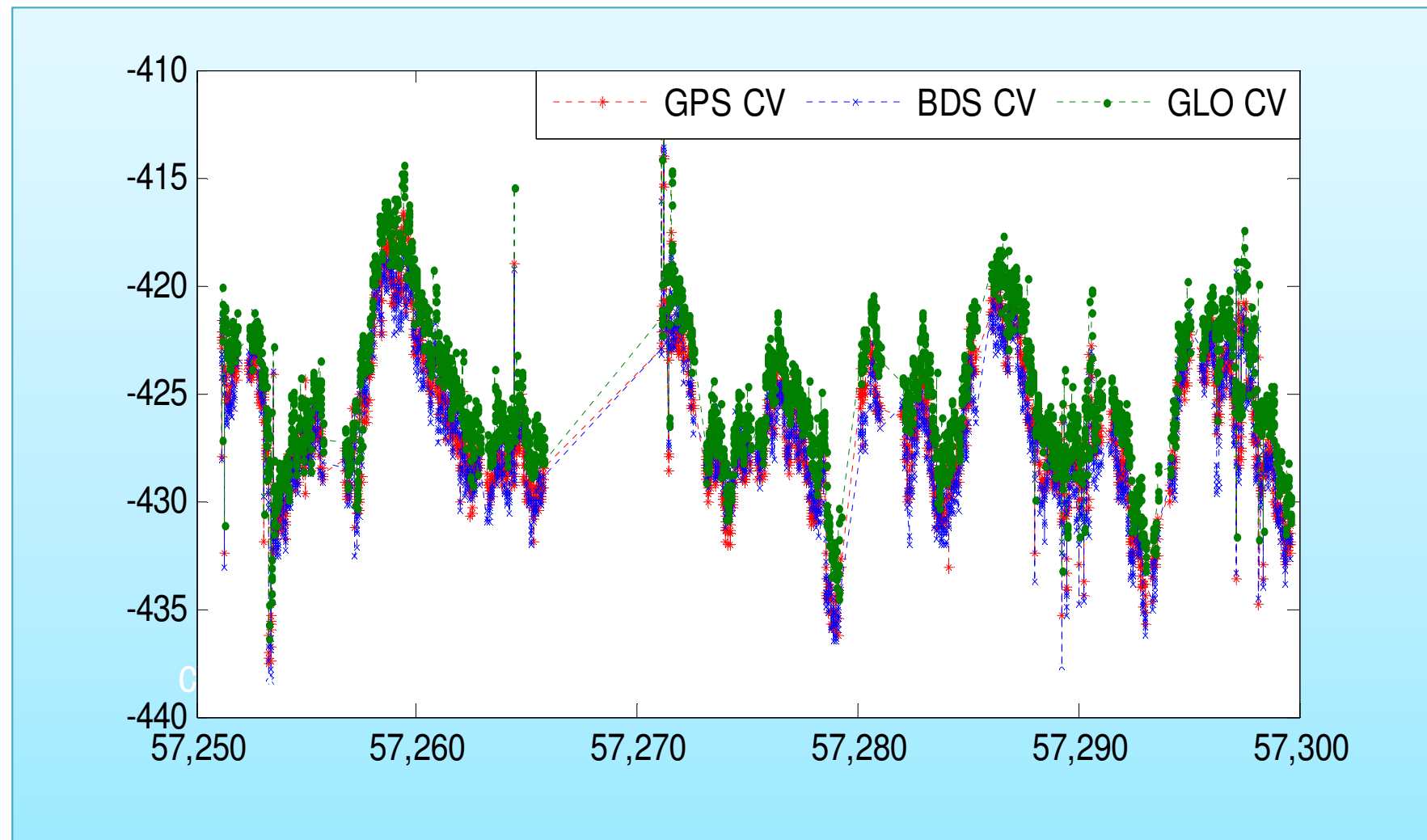
Stability of timing service vs UTC(NTSC)



5. BDS CV Experiment

Based on BDS timing receivers, time transfer experiments of common view were made.





BDS CV Performance Analysis.
The precision of BDS CV is about 1~2ns.



6. Summary

1. BDT is a kind of atomic time. The time offset between BDT and UTC is controlled within 100ns. (The time difference relation among BDT, UTC(k) and other GNSST was described in ICD of BDS).
2. Rb atomic clocks are setup in Beidou satellite. The stability can reach $2E-14$ /day. Hydrogen clock will be adopted in new satellite(launched).
3. UTC service is provided by Beidou system. The time offset between BDT and UTC(BSNC) is broadcasted in navigation message.
4. BDS CV is available and accuracy, which performance is about 1~2ns and almost the same as the other GNSS CV.

Suggest: the BDS should be included in the next version of CGGTTS template.





Thank you for your attention !



BEIDOU NAVIGATION SATELLITE SYSTEM