Time and Frequency Transfer Using GNSS

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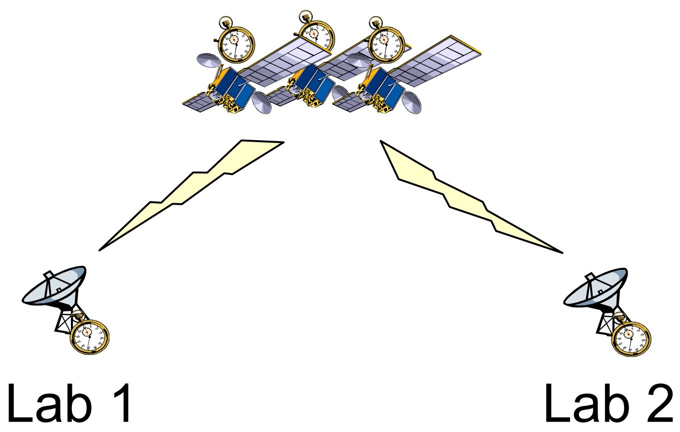
Introduction (1)



Common View technique presently used at ROB :

Simultaneous observation of satellites using
geodetic receivers connected to High Frequency Standards

➔ Standardized processing of GPS pseudoranges, following BIPM schedule, using P3 and IGS orbits
(RINEX-CGGTTS conversion software developed at ROB)

➔ combined code-carrier phase analysis (Bernese)

Introduction (2)

Influence of ambient temperature variations on the TT results

Tests of geodetic receivers suitable for time/frequency transfer

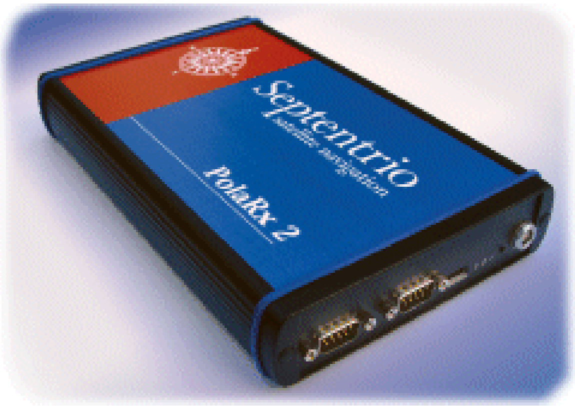
Ashtech Z-XII3T
Topcon Legacy-E (Javad)
Septentrio PolaRx2

Time transfer with GLONASS

Implementation with Galileo

Availability of more simultaneously visible satellites
Smaller time error [TE(95%)]

➡ **Higher Accuracy**

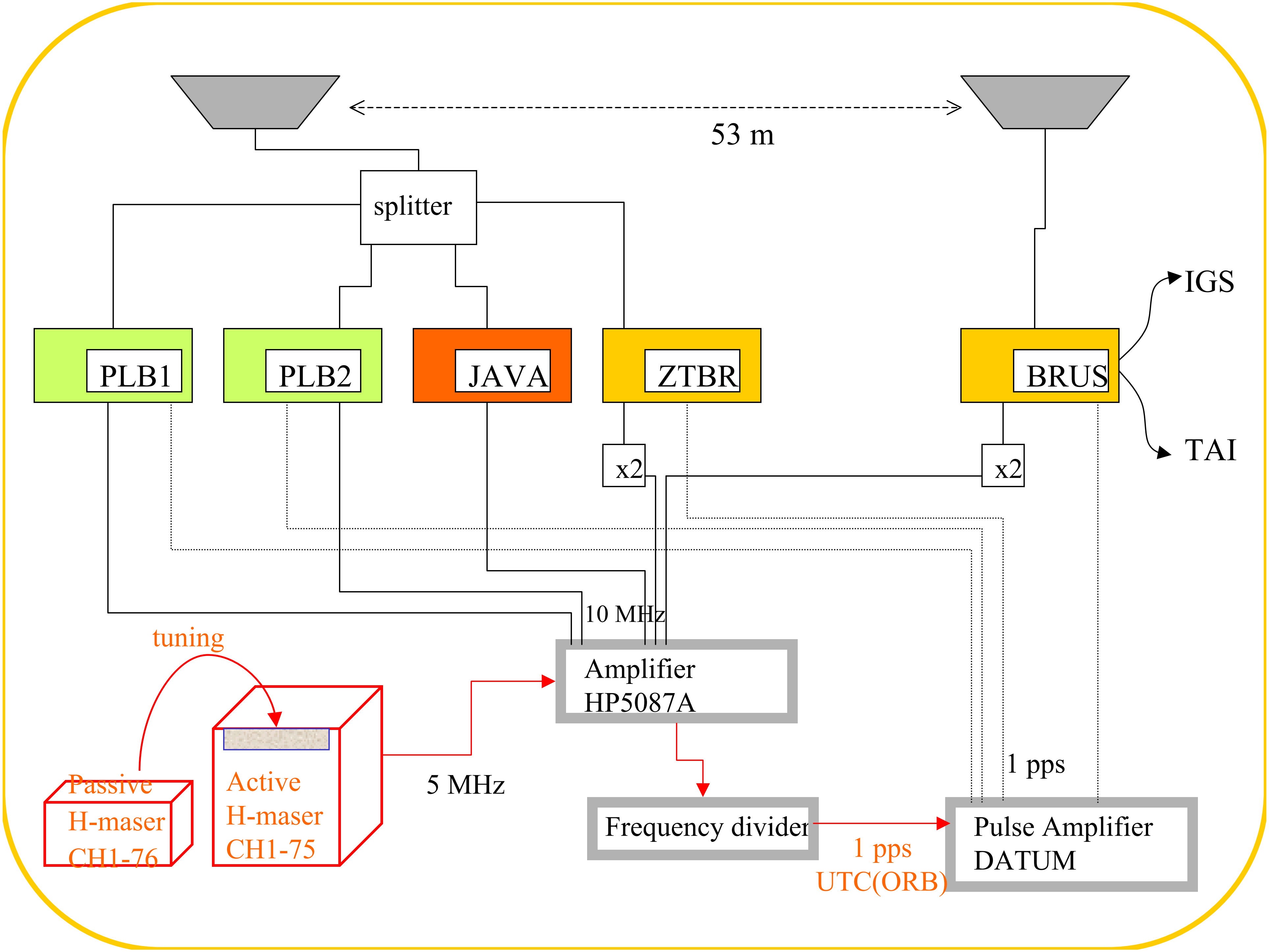


PolaRx2 receiver (Septentrio)

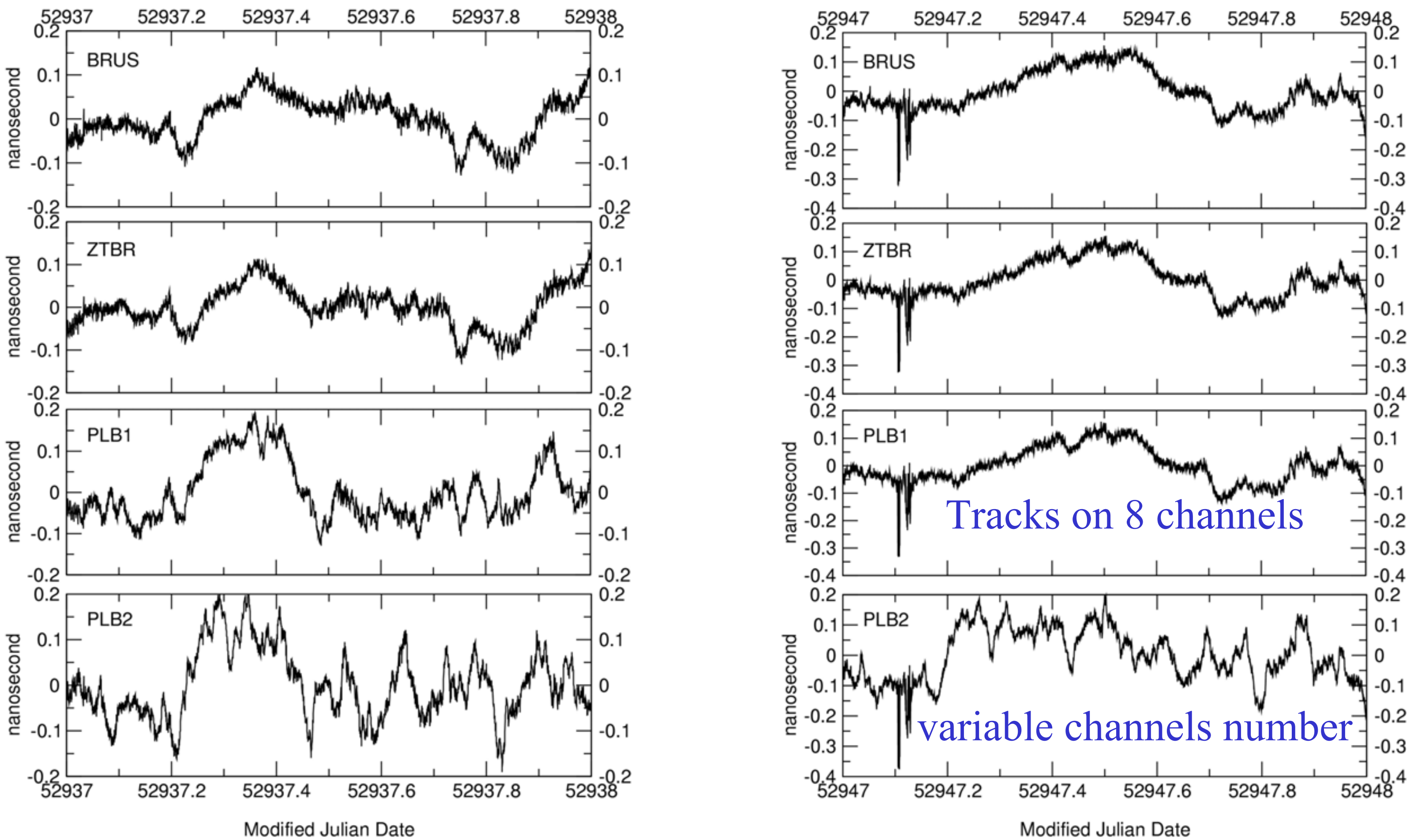
www.septentrio.com

- dual-frequency tracking of the GPS signal;
- simultaneous tracking of up to 6 SBAS satellites;
- accepts a 10 MHz external frequency and an associated 1 pps input;
- synchronization of the internal clock on the 1 pps input with an ambiguity of a multiple of 8.33 ns;
- 1 pps output synchronized on the internal clock

→ allows differential calibration

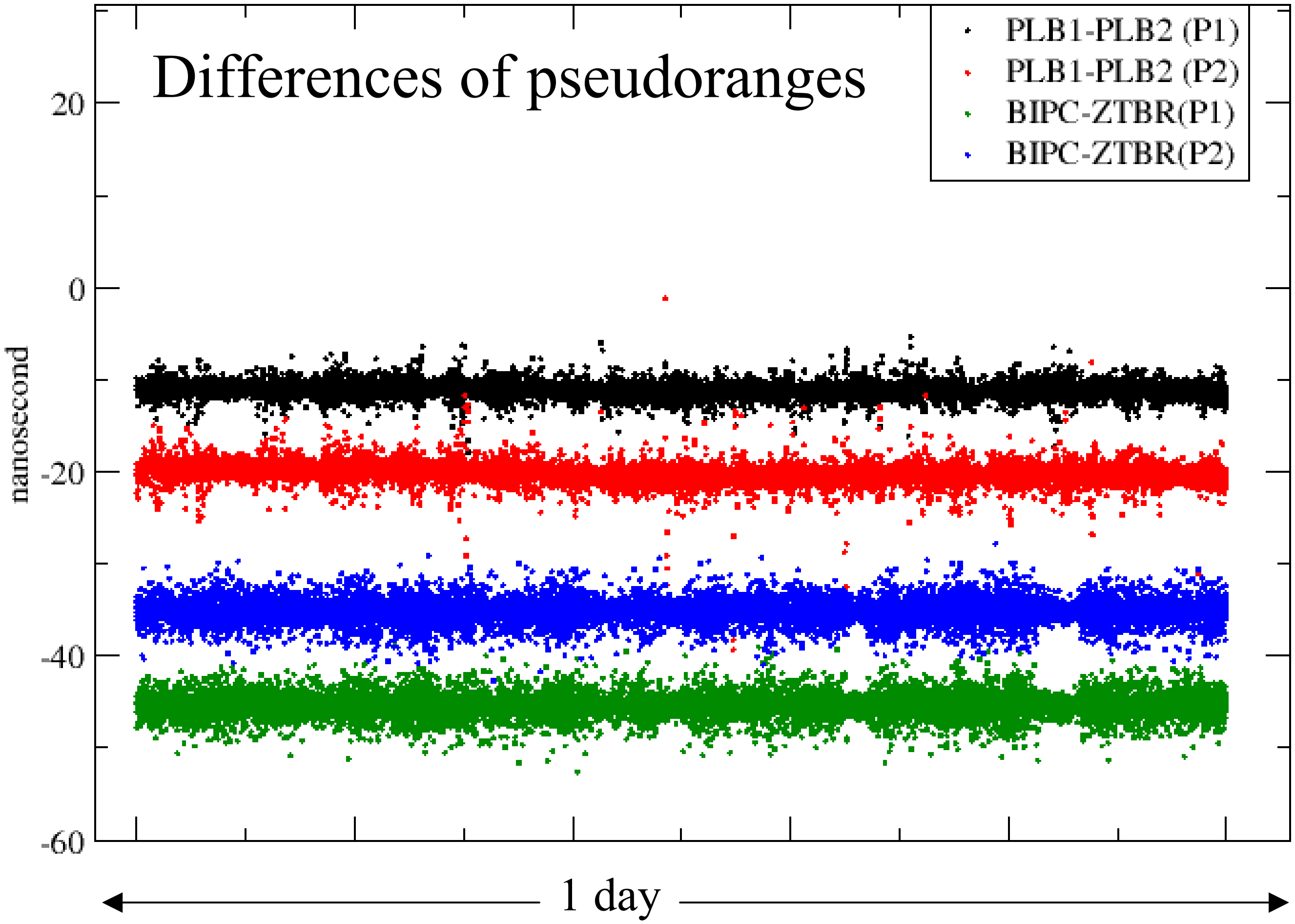

53 m
splitter
IGS
PLB1
PLB2
JAVA
ZTBR
BRUS
TAI
x2
x2
10 MHz
tuning
Amplifier
HP5087A
Passive
H-maser
CH1-76
Active
H-maser
CH1-75
5 MHz
1 pps
Frequency divider
Pulse Amplifier
DATUM
1 pps
UTC(ORB)

Time links UTC(ORB)-USNO(MC3)
Bernese code+carrier-phase analysis



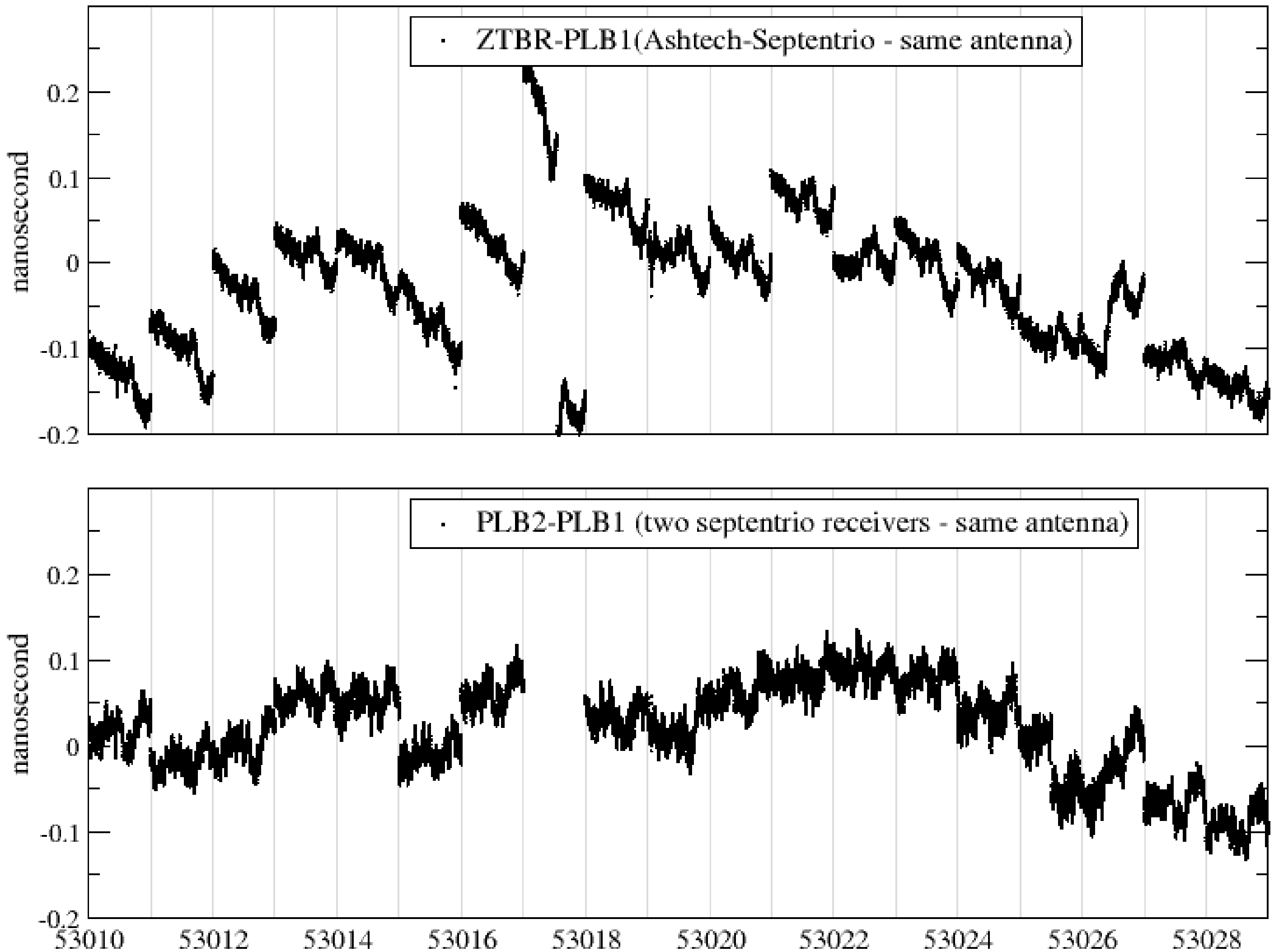
Code noise level

2 Septentrio receivers	2 Ashtech receivers
Rms : PLB1-PLB2 P1: 0.6 ns	Rms : BIPC-ZTBR P1: 1.1 ns
P2: 0.9 ns	P2: 1.1 ns



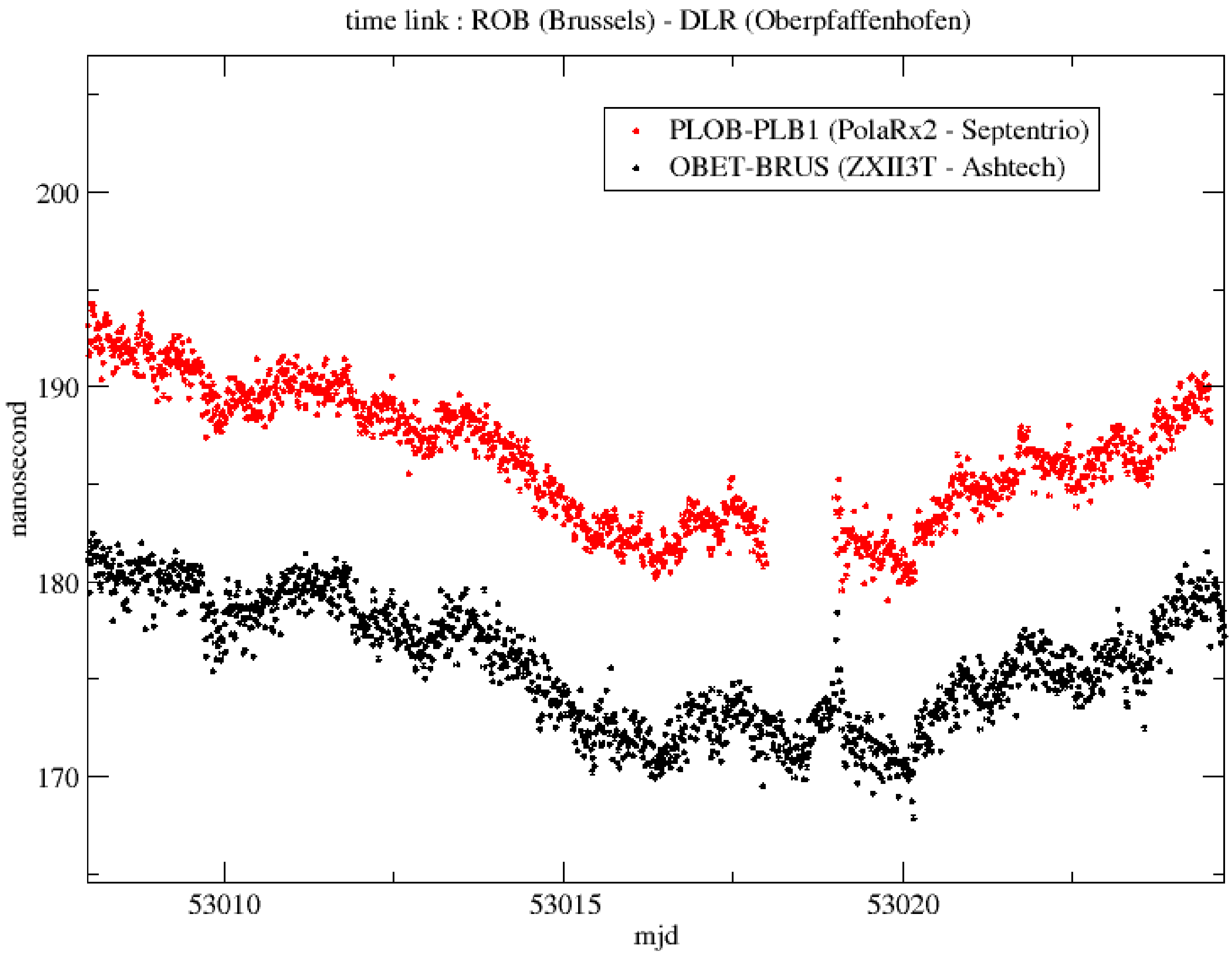
Septentrio :

Reduced jumps at the day boundaries

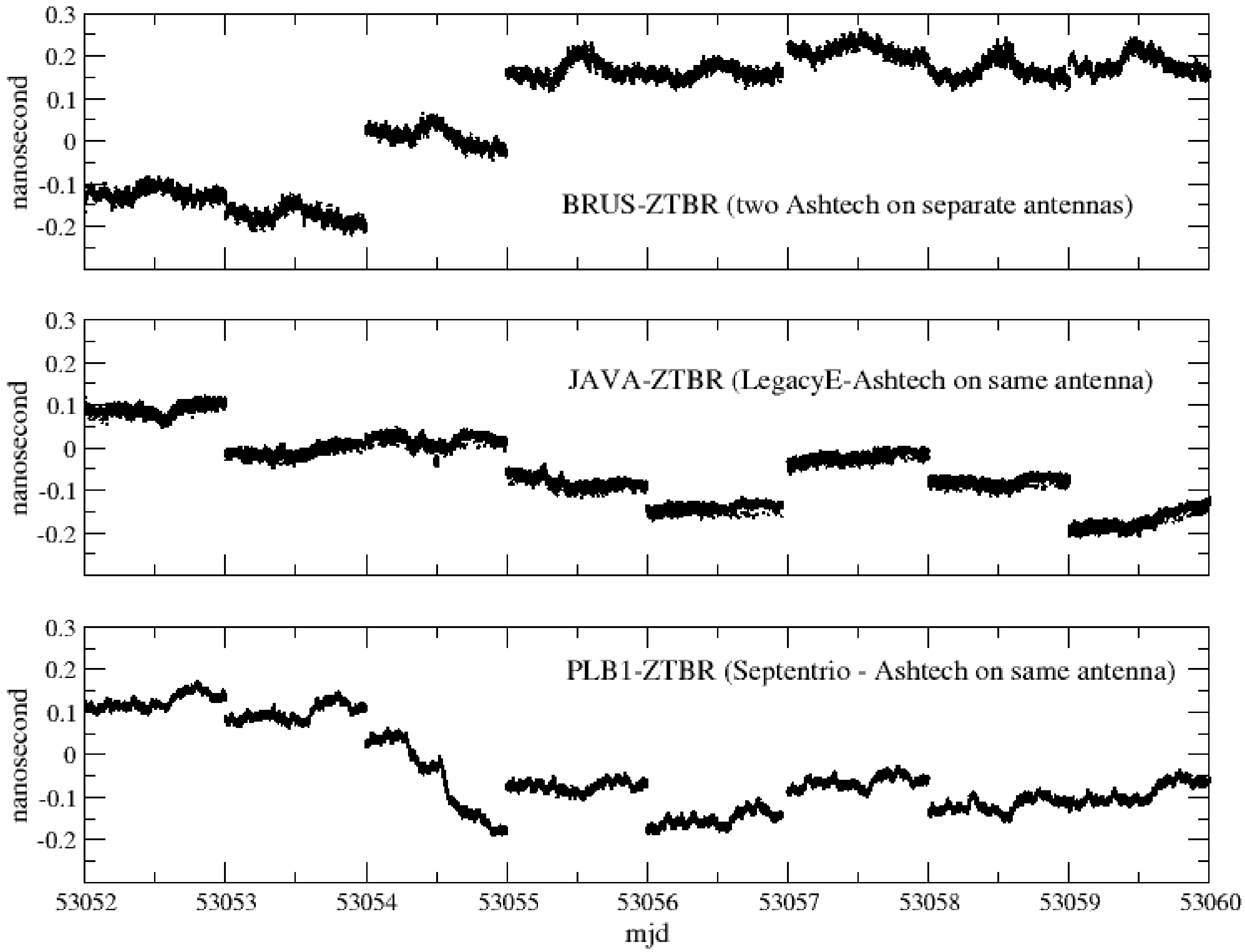


Time transfer for TAI :

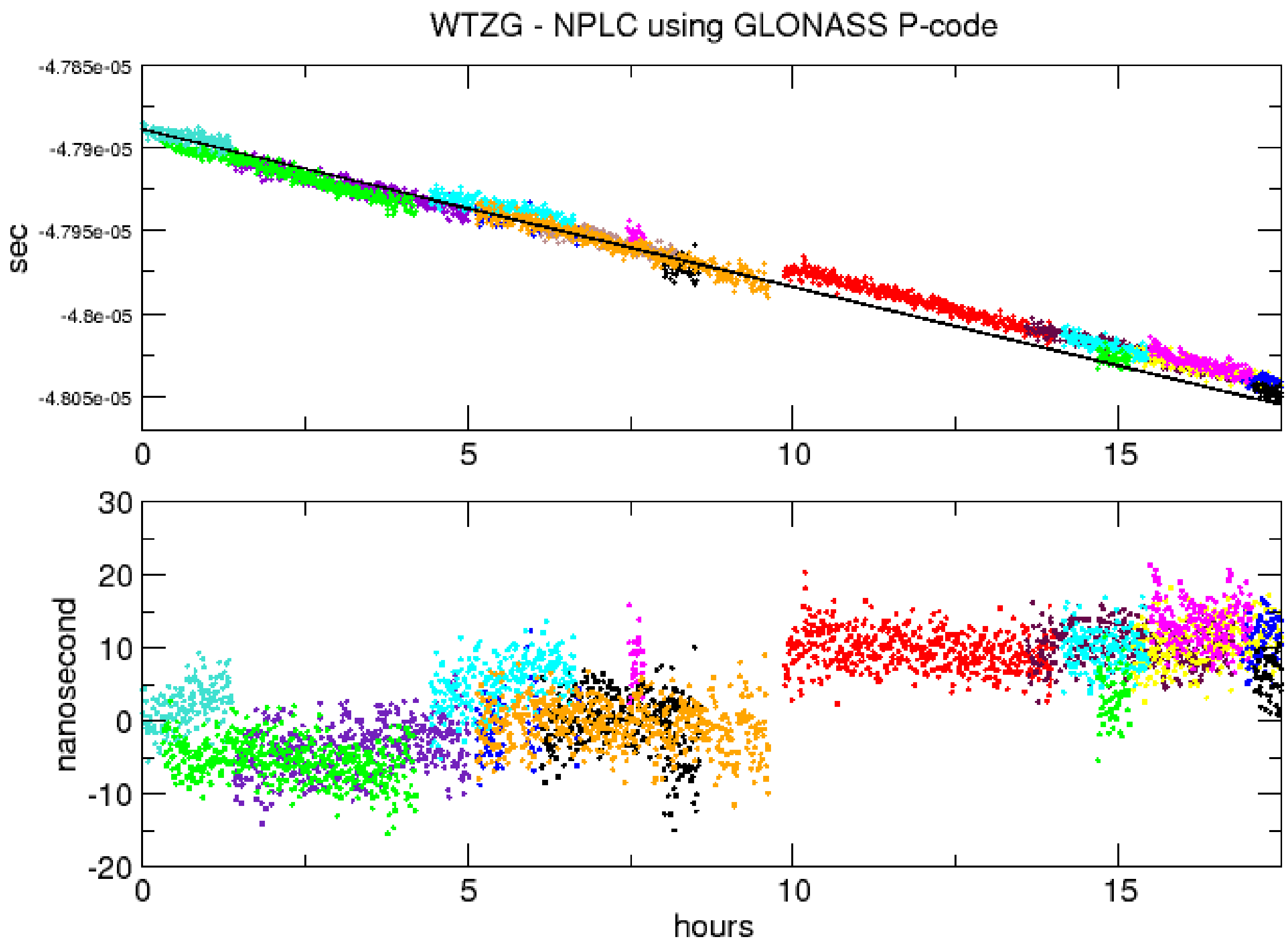
RINEX-CGGTTS using P3 and IGS orbits



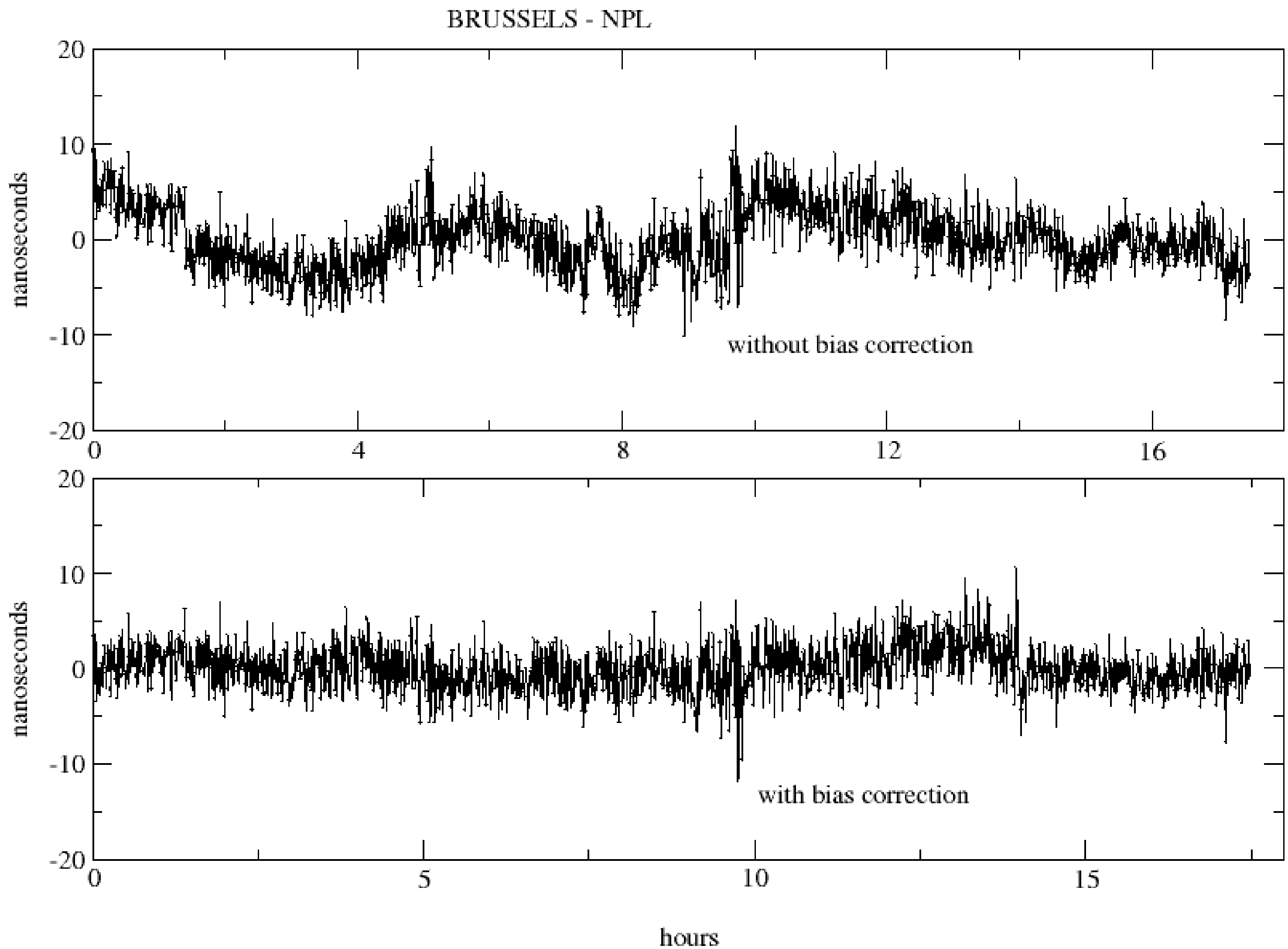
Comparison of receivers
ASHETCH – JAVAD – SEPTENTRIO



Time transfer with GLONASS P-code



Time transfer with GLONASS P-code (2)



Time transfer with Galileo

Clock offset

$$\Delta t^{k}_{i,GPS} = t_i - GPStime + \Delta t^{k}_{GPSsat} + \varepsilon^{k}_{i,GPS}$$

$$\Delta t^{l}_{i,Gal} = t_i - GST + \Delta t^{l}_{Galsat} + \varepsilon^{l}_{i,Gal}$$

Common view (single difference)

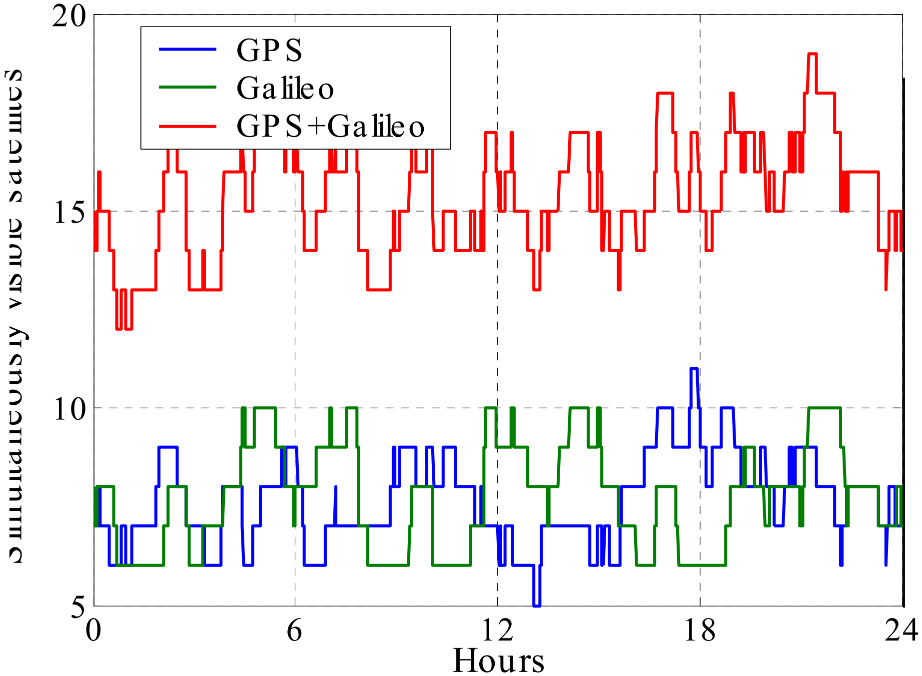
$$\Delta t^{k}_{12,GPS} = \Delta t^{k}_{1,GPS} - \Delta t^{k}_{2,GPS} = t_1 - t_2 + \Delta\varepsilon^{k}_{12,GPS}$$

$$\Delta t^{l}_{12,Gal} = \Delta t^{l}_{1,Gal} - \Delta t^{l}_{2,Gal} = t_1 - t_2 + \Delta\varepsilon^{l}_{12,Gal}$$

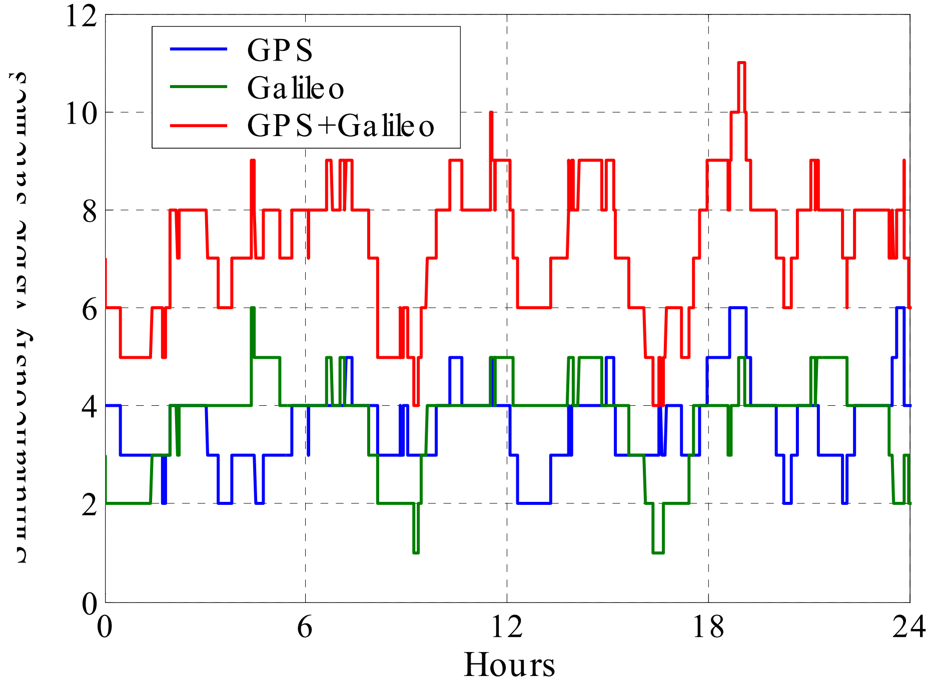
No term related to the offset GPStime - GST

$$\overline{t_1 - t_2} = \frac{\sum_{k=1}^{M} \Delta t^{k}_{12,GPS} + \sum_{l=1}^{N} \Delta t^{l}_{12,Gal}}{M + N}$$

Time Transfer with Galileo: Satellite Availability



Simultaneously visible satellites
for PTB – DLR link (Germany)



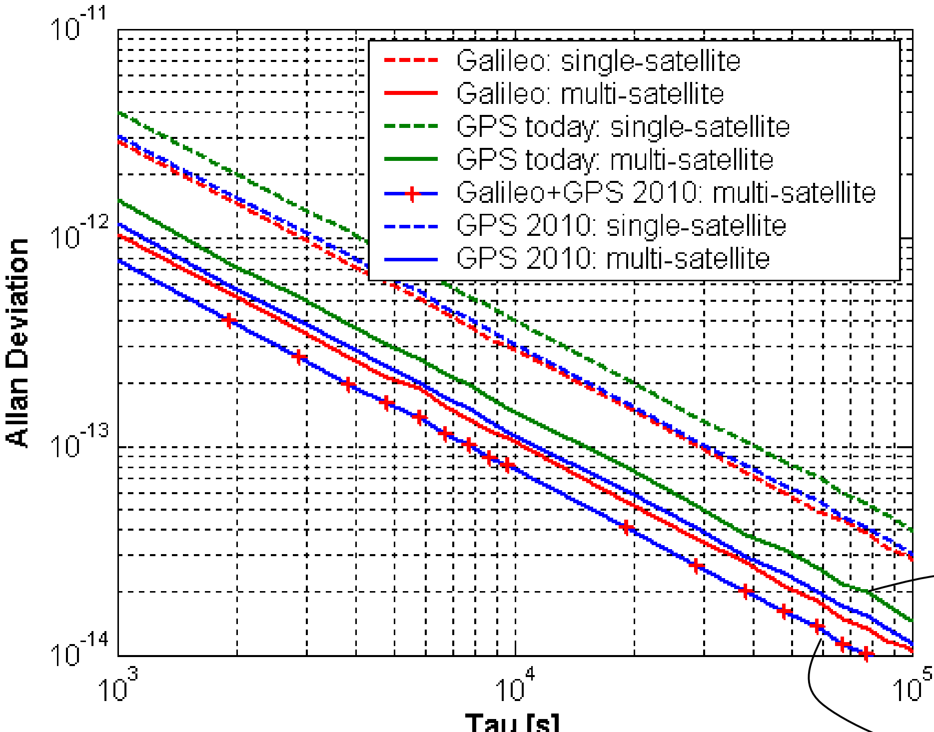
Simultaneously visible satellites
for US Naval Observatory – DLR link

Average number of simultaneously visible satellites

7.6	GPS	3.6
7.7	Galileo	3.7
15.3	GPS+Galileo	7.3

Time Transfer with Galileo:
Simulated Common View between PTB and DLR

effect of the combination GPS+GALILEO



Simulated Common View errors:

orbit,
ionosphere,
troposphere,
receiver noise errors

No Simulated clocks

About 2 times better

Common View procedure: P. Defraigne (ORB) and G. Petit (BIPM) : RINEX-CGGTTS using P3 – broadcast orbits

Conclusions

- ✓ Septentrio receiver PolaRx2 suitable for time and frequency transfer (when the ambiguity of 8.33 ns will be solved)

- ✓ Topcon receiver LegacyE suitable for frequency transfer (but not for absolute timing, no synchronization of the clock)

  BUT

  To see exactly how the receivers reproduces the frequency changes : two separate clocks monitored by another way

- ✓ GLONASS time transfer limited due to differential biases

- ✓ Galileo + GPS time transfer with code only: about 2 times better than GPS now