Galileo OS timing performances

ICG-12

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Context

Galileo System Time (GST) is

- the reference time for the Galileo system
- under responsibility of the Galileo Mission Segment (GMS)
- computed on the ground at the Galileo Control Centre in Fucino (Italy) using the atomic clocks located at the Precise Timing Facility
- steered to UTC
- fully described in the corresponding ICG timing template

Context

- In order to better support timing applications based on UTC, the Galileo OS nav msg includes additional parameters that enable users to obtain a UTC realization by applying a correction to GST → UTC_SiS

- In order to insure interoperability between GPS and Galileo, their time difference, known as GPGA (or GGTO), is broadcast in the Galileo nav msg allowing users to benefit from a combined GPS/Galileo positioning
- GPGA can also be estimated by receivers if enough satellites are in view

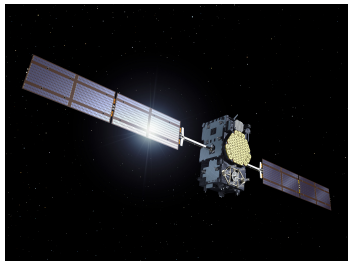
Context

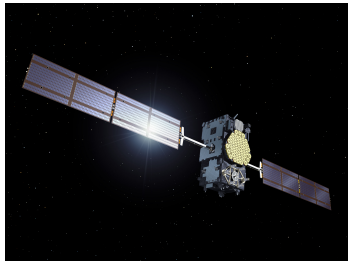
Three Key Performance Indicators (KPI) are monitored :

- ✓ The offset between the Galileo System Time and UTC : UTC – GST
- ✓ the OS dual-frequency UTC dissemination accuracy : UTC – UTC_SiS
- ✓ the GGTO accuracy

… since the Initial Services declaration

METHODOLOGY

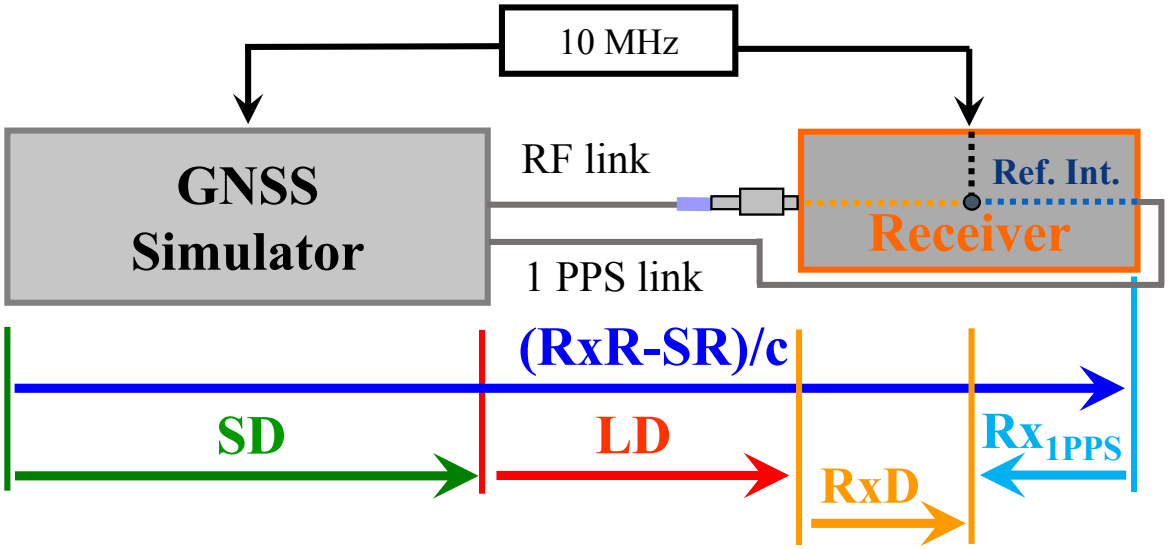




Positioning computation
taking into station delays
provides
GNSS_time – UTC(k)
that can be compared to
broadcast messages

>> this requires calibration of
the station

Absolute calibration of the receiver



Receiver internal delay RxD = (RxR-SR)/c - SD - LD + Rx_{1PPS}

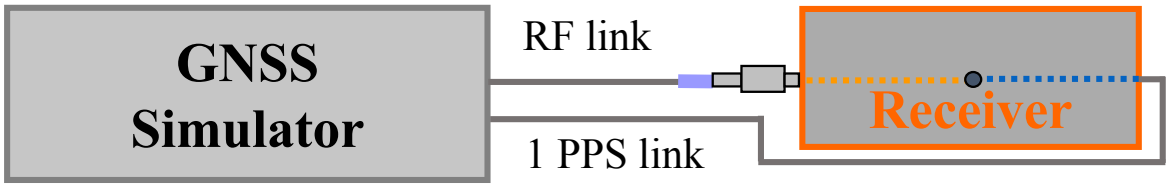
RxR-SR : difference of simulator and receiver pseudo ranges

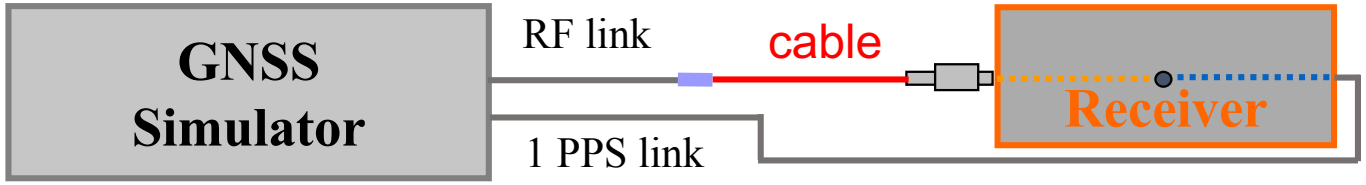
SD : simulator internal delay

LD : 1 PPS and RF links delay difference

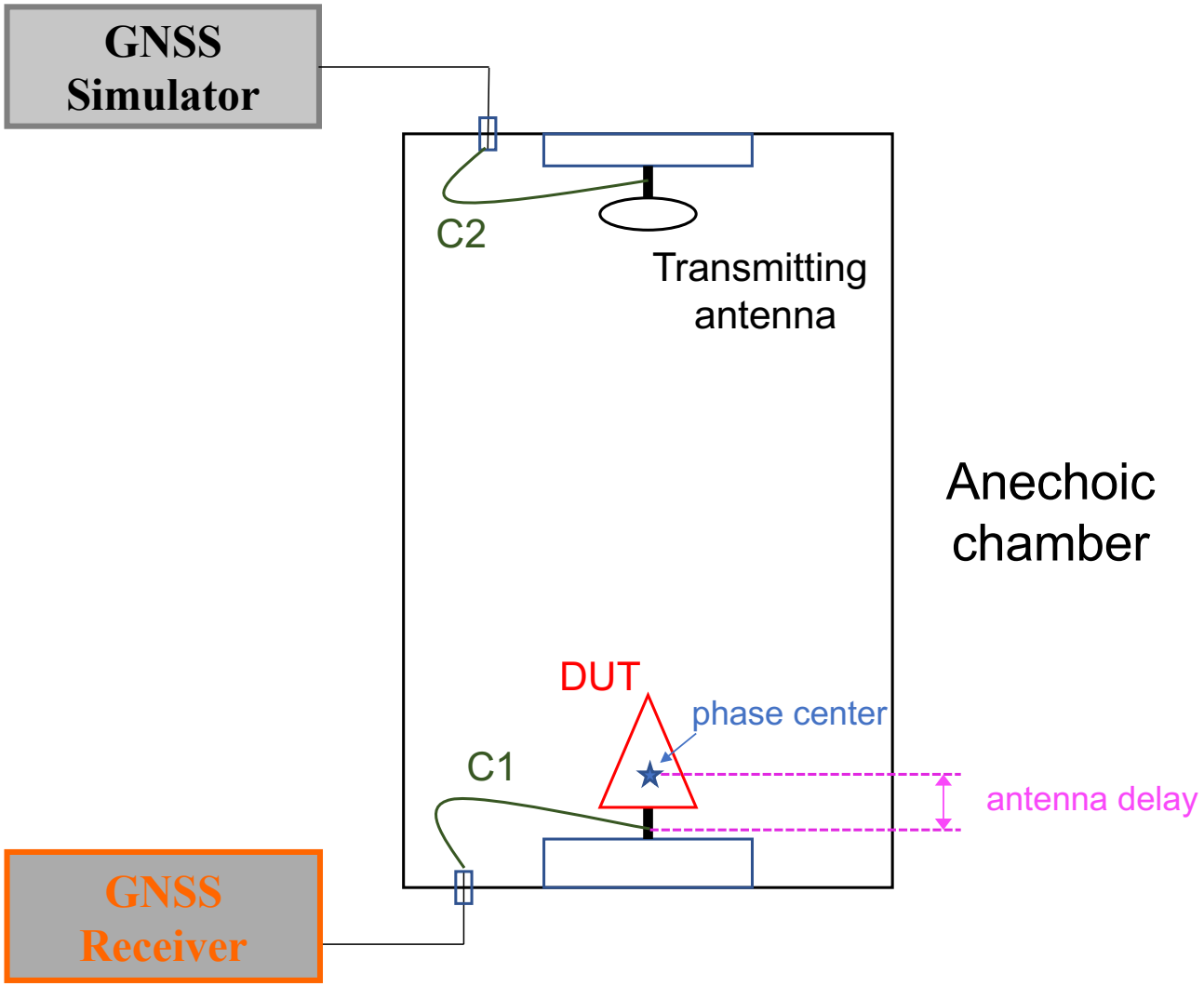
Rx_{1PPS} : delay between internal reference of the receiver and the external 1PPS

Absolute calibration of the cable

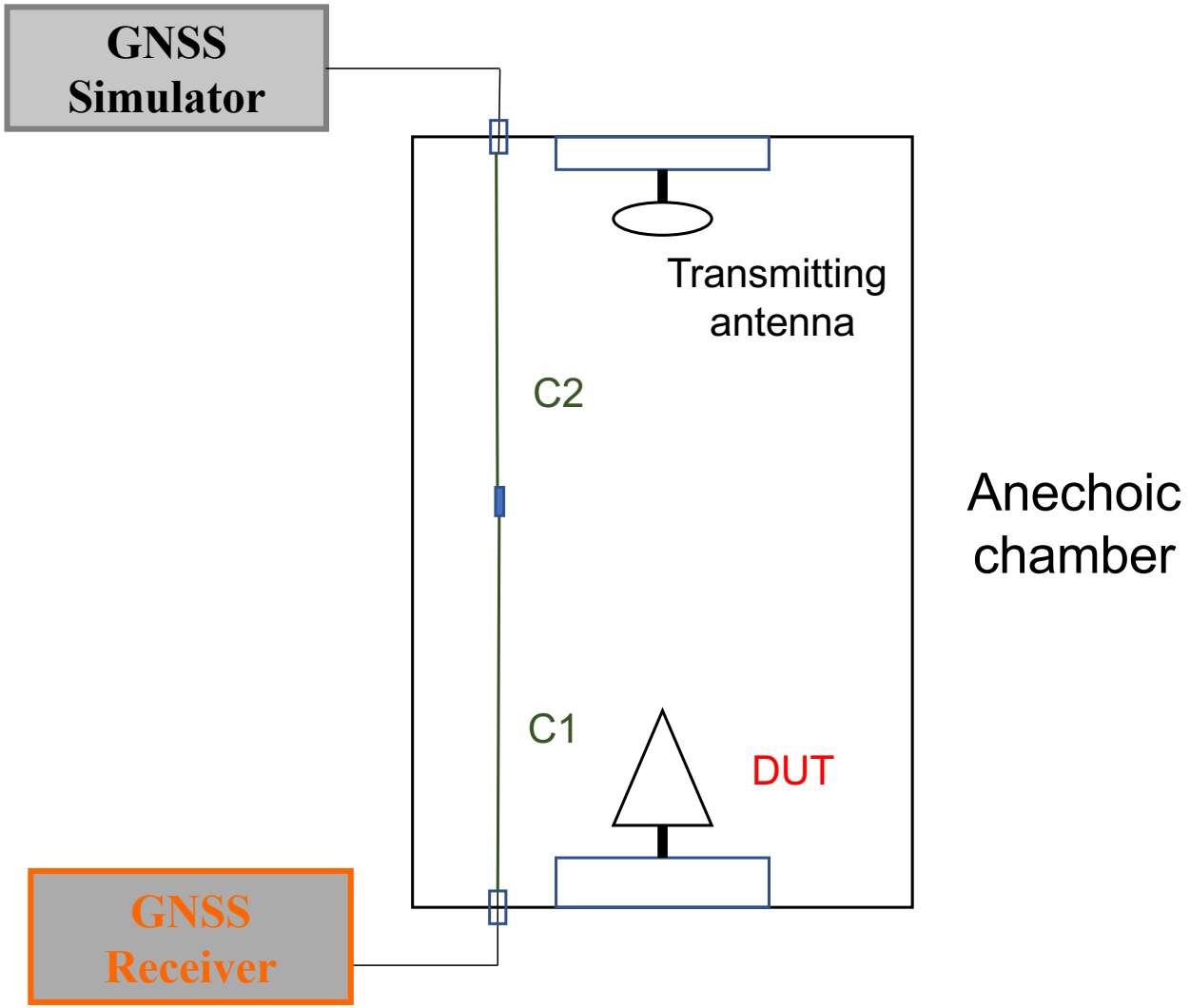




Absolute calibration of the antenna



Absolute calibration of the antenna



Absolute calibration - results

Results for a Septentrio PolaRx4 TR PRO using 2 different simulators :

	Spirent 4760	Spectracom GSG-6
GPS P1	36.5 ns (σ = 0.5)	36.0 ns (σ = 0.5)
GPS P2	35.2 ns (σ = 0.5)	35.3 ns (σ = 0.9)
GPS C5	-	42.6 ns (σ = 0.4)
Galileo E1	-	36.1 ns (σ = 0.4)
Galileo E5a	-	43.0 ns (σ = 0.4)

Both results agree within 0.5 ns for GPS P1 and P2

Absolute calibration - results

Results for an Aeroantenna Sepchoke B3E6

	Spectracom GSG-6
GPS P1	21.6 ns (σ = 0.3)
GPS P2	18.8 ns (σ = 0.3)
GPS C5	20.3 ns (σ = 0.4)
Galileo E1	21.6 ns (σ = 0.3)
Galileo E5a	20.3 ns (σ = 0.3)

DATA PROCESSING

- **Software**
  - R2CGGTTS : ORB software that provides clock solutions for GNSS time transfer in the CGGTTS format
  - SPRING : CNES software dedicated to advanced display, analysis and simulations around systems integrating GNSS positioning

  - Both software provide GNSS_time – local_time
    every 13 minutes for R2CGGTTS
    30 seconds for SPRING

DATA PROCESSING

- **Stations**
  - BRUX connected to UTC(ORB)
    - GPS P1, P2 : relative calibration vs. OP travelling chain
    - Galileo E1 considered as equal to GPS P1 (1)
    - Galileo E5a : calibrated using the original technique developed by ORB (2)
  - CS11 connected to UTC(CNES).
    - GPS P1, P2 and Galileo E1, E5a : absolute calibration by CNES (starting from the 7th of June)

(1) « Progress on absolute calibrations of GNSS reception chains at CNES », J. Delporte et al. , Proc. of IFCS 2016

(2) « Advances on the use of Galileo signals in time metrology: calibrated time transfer and estimation of UTC and GGTO using a combined commercial GPS-Galileo receiver », P. Defraigne et al., Proc. of PTTI 2013

KPI#1 : UTC-GST offset

- **GAUT = UTC – GST**

GAUT = (UTC – UTC(k)) + (UTC(k) – GST)

from BIPM circular T
(daily values obtained by interpolation)

computed at 00:00:00
(by linear regression)
using both software and both stations

KPI#1 : UTC-GST offset
BRUX station (01/01 to 30/06/2017)

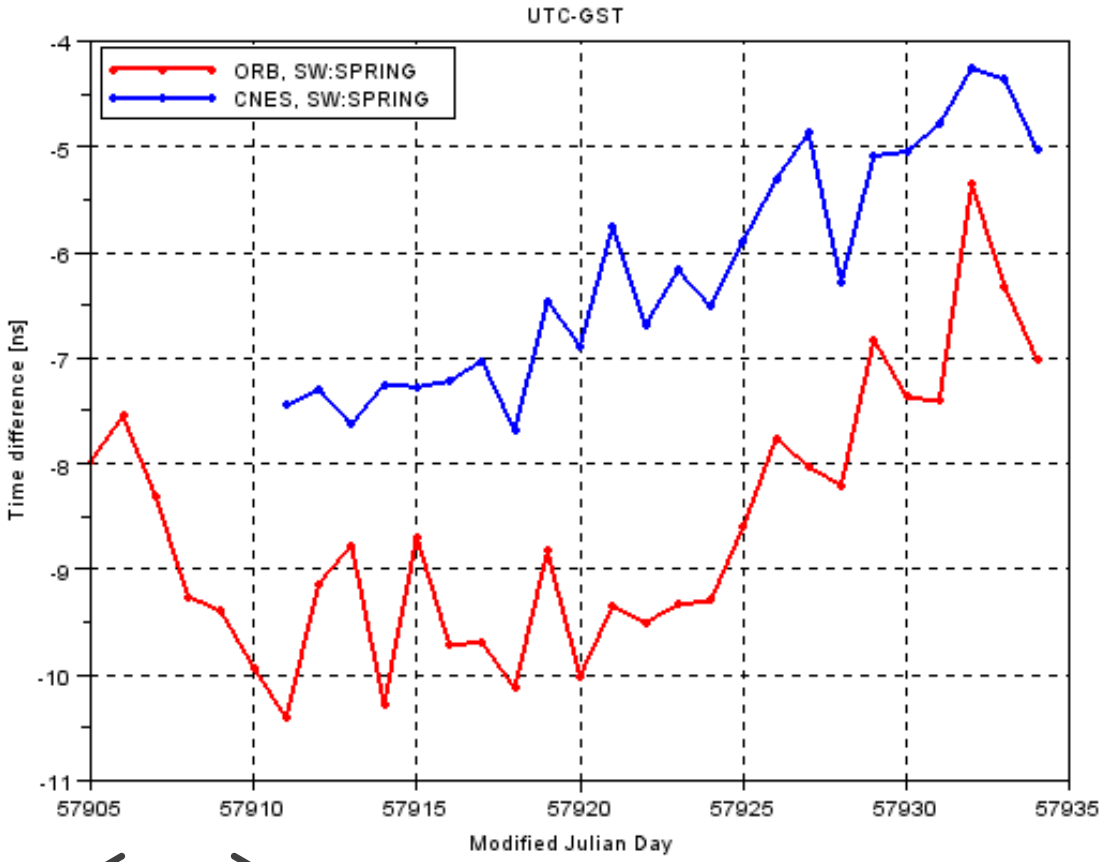
MISSION REQUIREMENT

< 50 ns, 95% of any period of one year

Mean : -3.9 ns
Std : 4.0 ns
95% : 10.1 ns

OK ☑

KPI#1 : UTC-GST offset : BRUX vs. CS11



~3 ns bias due to the difference in calibration values

consistent with the cumulated uncertainties of CNES and ORB calibration techniques

KPI#2 : UTC - UTC_SiS offset

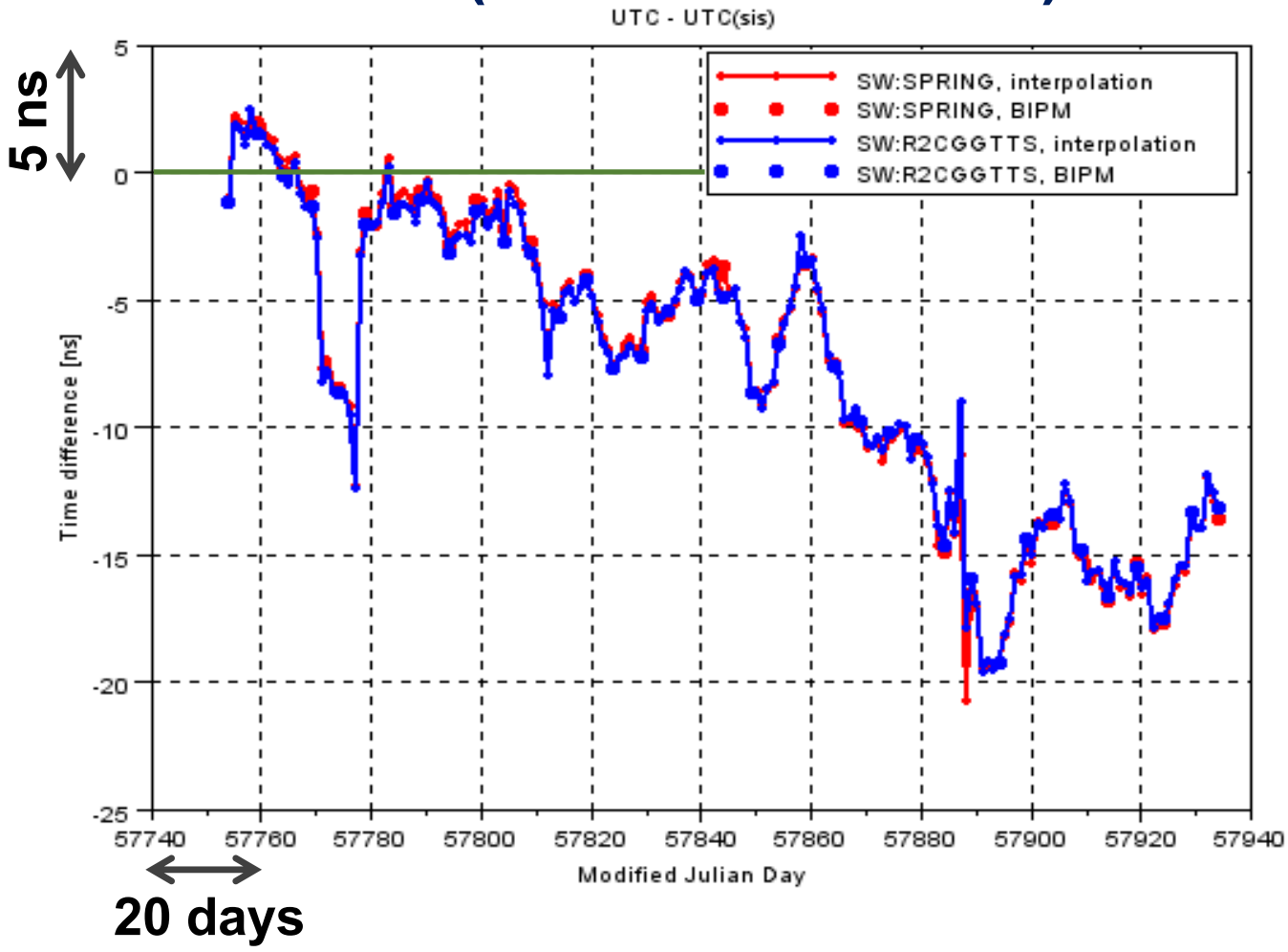
UTC – UTC_SiS = (UTC – GST) – (UTC_SiS – GST)

computed as previously explained

from GAUT broadcast values in the Galileo RINEX nav file

KPI#2 : UTC - UTC_SiS offset

BRUX station (01/01 to 30/06/2017)



Initial Services Requirement

< 30 ns, 95 % over all age of data, normalised annually

Mean : -7.7 ns
Std : 5.9 ns
95% : 17.6 ns

OK ☑

KPI#3 : GGTO accuracy

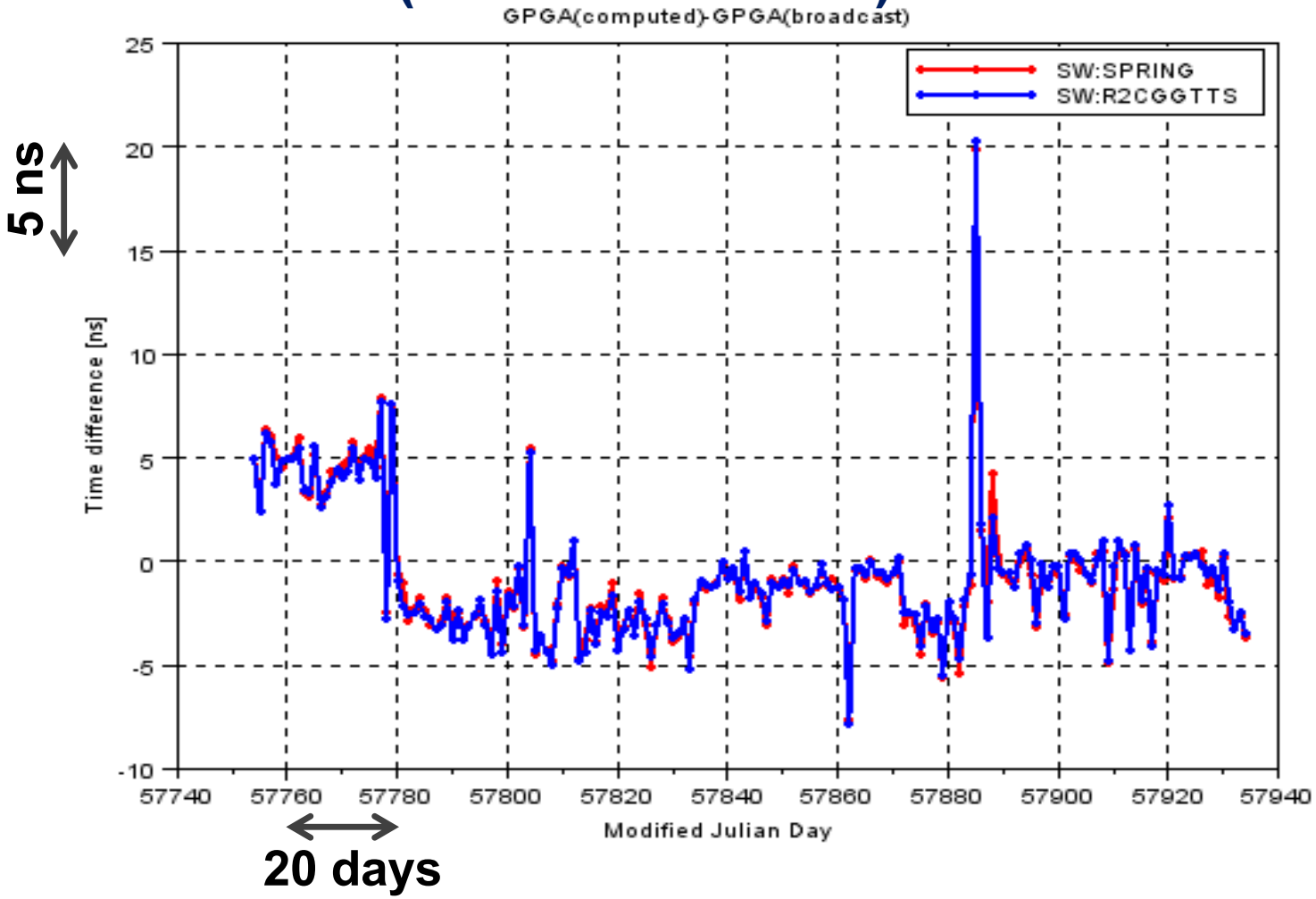
GGTO accuracy = (GST – GPST) – (GST– GPST)

computed as :
(GST – UTC(k)) – (GPST – UTC(k))

from GPGA broadcast values in the RINEX nav file

KPI#3 : GGTO accuracy

BRUX station (01/01 to 30/06/2017)



Initial Services Requirement

< 20 ns, 95% of average daily offset, normalised annually

Mean : -0.7 ns
Std :3.2 ns
95% : 5.5 ns

OK ☑

SUMMARY

- For the 3 KPIs, R2CGGTTS and SPRING provide very similar results (difference < 1 ns)
- For the 3 KPIs, CNES and ORB calibrated stations provide similar results (difference < 4 ns)
- The 3 KPIs are compliant with Galileo Open Service Time requirements

Thank you for your attention

Questions ?

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