Absolute Calibration activities at CNES

CCTF WG GNSS TT – 28th Nov 2018

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OUTLINE

- **Absolute calibration of the receiver**
- **Absolute calibration of the antenna**
- **Some results**
- **GRC-MS**
- **Summary**

Absolute calibration of the receiver

GNSS-like signals

GNSS simulator

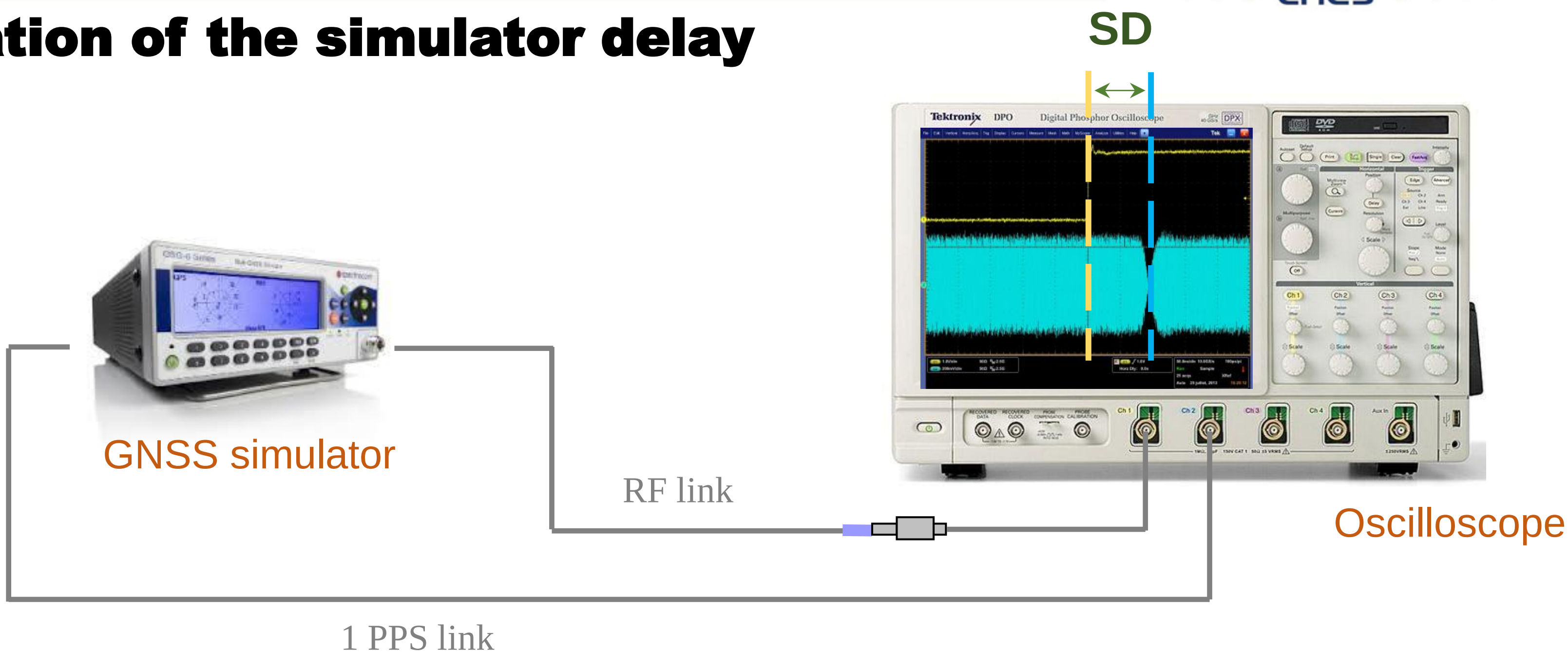
GNSS receiver

Delay of the receiver = PR of the receiver – PR of the simulator

Corrected by :

- the simulator delay
- the delay of the cables/attenuators/amplifier/adaptors
- the delay between the internal reference of the receiver and the external 1 pps

Estimation of the simulator delay



Simulator delay (SD) = time offset between the beginning the GNSS code and the 1 pps

Estimated :

- **with a dedicated simulator mode** (Signal Generator for Spectracom, Single Channel Utility for Spirent)
- **using a dedicated correlation software**
- **with 10 measurements before and 10 measurements after the calibration of the receiver**

Estimation of the simulator delay : validation

<u>Validation #1</u> : check that scenario mode and signal generator mode have no bias

- **dedicated scenario with only one GEO**

10 measurements of SD in both modes for L1C/A :

	Scenario mode	Signal Generator mode
Mean	-29.56 ns	-29.59 ns
Std deviation	0.05 ns	0.05 ns

No offset between these 2 modes
This validates the use of the Signal Generator mode to determine the SD

Estimation of the simulator delay : validation

Validation #2 : validation of the correlation software

- **Use of simulated data (i.e. created by software) with known delay**

Difference between this known delay and the result provided by our correlation software for 10 simulated data sets :

	L1C/A	L2C	E1BC	E5a	E5b
Mean	-0.09 ns	0.01 ns	0.03 ns	-0.05 ns	-0.02 ns
Std deviation	0.11 ns	0.19 ns	0.18 ns	0.08 ns	0.05 ns

This validates our correlation software at the 0.1-0.2 ns level

Absolute calibration of the simulator : uncertainty budget

Typical uncertainty budget for the simulator delay :

Uncertainty	Type	Origin	Typ. value
u_{SD_mean}	A	Std deviation of the 10 SD values	0.1 to 0.3 ns
$u_{SD\_closure}$	B	Related to the difference btw SD_{before} and SD_{after} Estimated by rectangular law	0.01 to 0.2 ns
$u_{SD\_SG2SCEN}$	B	Difference between Single Generator mode and Scenario mode	0.05 ns
u_{SD_IBB}	B	Simulator Inter-Channel Bias	0.1 ns

Typical uncertainty on the simulator delay = 0.2 to 0.4 ns

Absolute calibration of the receiver : uncertainty budget

Typical uncertainty budget for the receiver delay :

Uncertainty	Type	Origin	Typ. value
u_{CV}	A	Std deviation of the difference of the pseudo-ranges	0.05 to 0.2 ns
u_{SD}	B	Simulator delay	0.2 to 0.4 ns
u_{LD}	B	Configuration setup differences (amplifier, attenuator, adaptors) between SD set-up and RxD set-up	0.2 ns
u_{Rx1pps}	B	Time delay between the receiver internal reference and the external 1 PPS	0.1 to 0.2 ns
u_{Power}	B	Difference of GNSS signal power between cal and natural reception.	0.1 ns

Typical uncertainty on the receiver delay = 0.3 to 0.6 ns

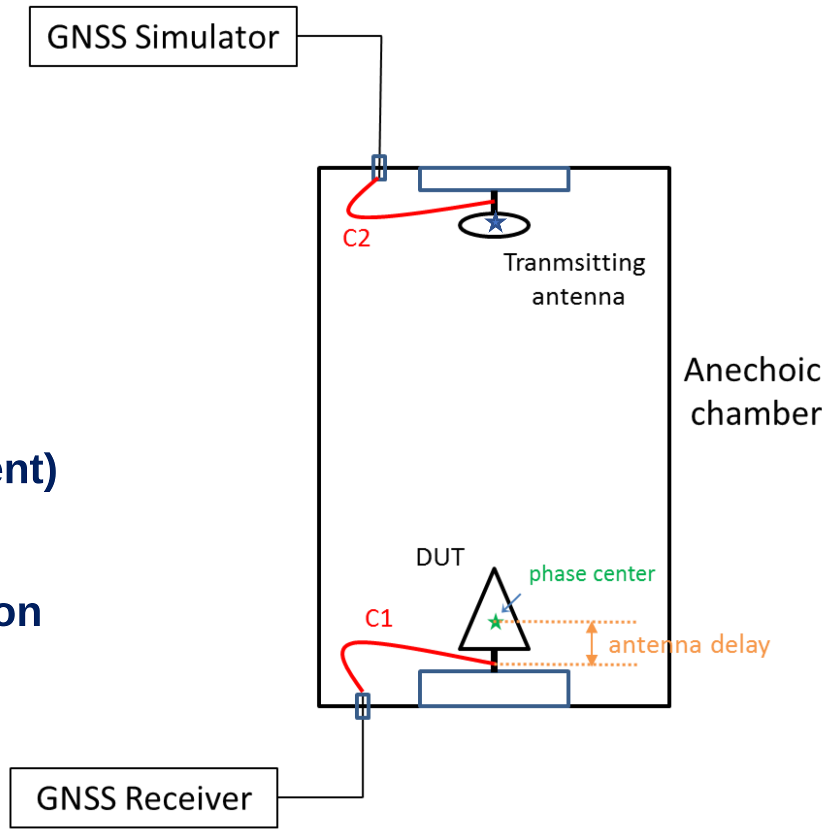
Absolute calibration of the antenna

Use of a GNSS simulator (instead of VNA)

Advantages:

- **signals similar to natural reception**
- **single, integrated value per GNSS signal**
- **no simulator calibration required (differential measurement)**

Transmitting antenna calibrated by triangulation



Absolute calibration of the antenna : uncertainty budget

Typical uncertainty budget for the antenna delay determination by triangulation :

Uncertainty	Type	Origin	Typ. value
u_{Tare_mean}	A	Std deviation of the pseudo-ranges in tare configuration	0.1 to 0.3 ns
$u_{Tare\_closure}$	B	Related to the difference btw SD_{before} and SD_{after} Estimated by rectangular law	0.01 to 0.03 ns
$u_{CV\_Em1\_DUT}$	A	Std deviation of the difference of the pseudo-ranges	0.1 to 0.3 ns
$u_{CV\_Em1\_Em2}$	A	Std deviation of the difference of the pseudo-ranges	0.2 to 0.6 ns
$u_{CV\_Em2\_DUT}$	A	Std deviation of difference of the pseudo-ranges	0.1 to 0.3 ns
$u_{Distance}$	B	Distance between the phase centers	0.1 ns
u_{Conf}	B	Configuration setup differences btw tare and measurement	0.1 ns
u_{Power}	B	Difference of GNSS signal power btw cal and natural reception.	0.1 ns
u_{AZEL}	B	Phase center position w.r.t. elevation/azimuth of the satellites	0.05 ns

Typical uncertainty on the antenna delay = 0.3 to 0.8 ns

Absolute calibration of a GPS/BeiDou reception chain (NIM)

Delay of the receiver

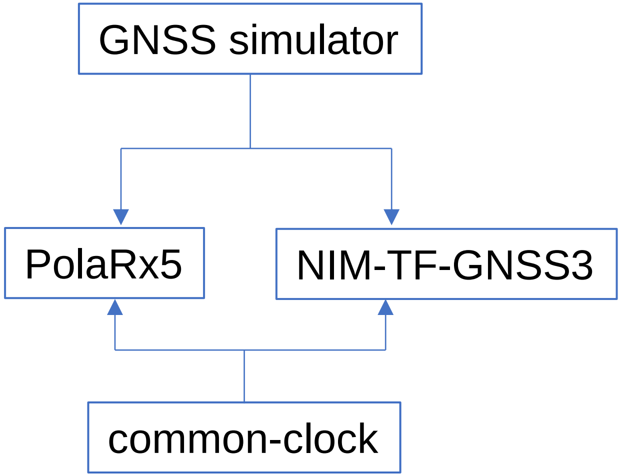
(ns)	RxD	AD
C1	-45.5 (σ = 0.6)	20.0 (σ = 0.6)
P1	-44.9 (σ = 0.4)	20.7 (σ = 0.7)
P2	-49.6 (σ = 0.9)	14.8 (σ = 0.3)
B1	-45.8 (σ = 0.9)	22.4 (σ = 0.9)
B2	-40.4 (σ = 0.6)	14.6 (σ = 0.7)

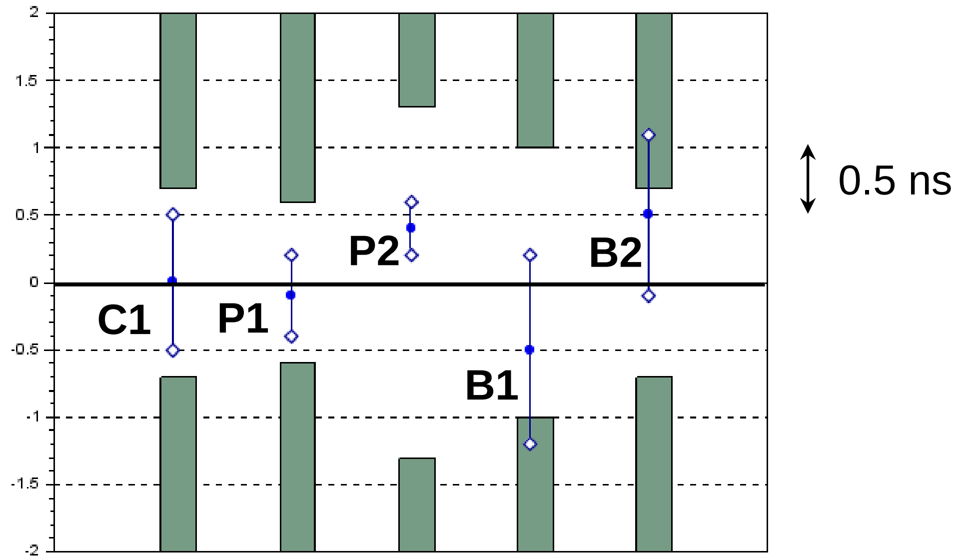
Delay of the antenna

Receiver NIMTFGNSS-3
Antenna HARXON CSX 601A

Absolute calibration of a GPS/BeiDou receiver

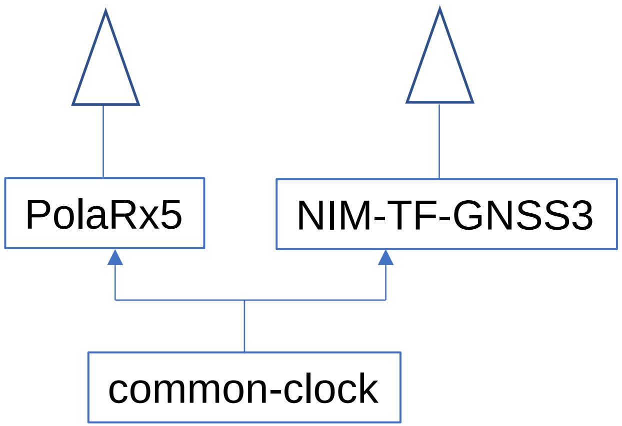
RxD validation in CV using a simulator

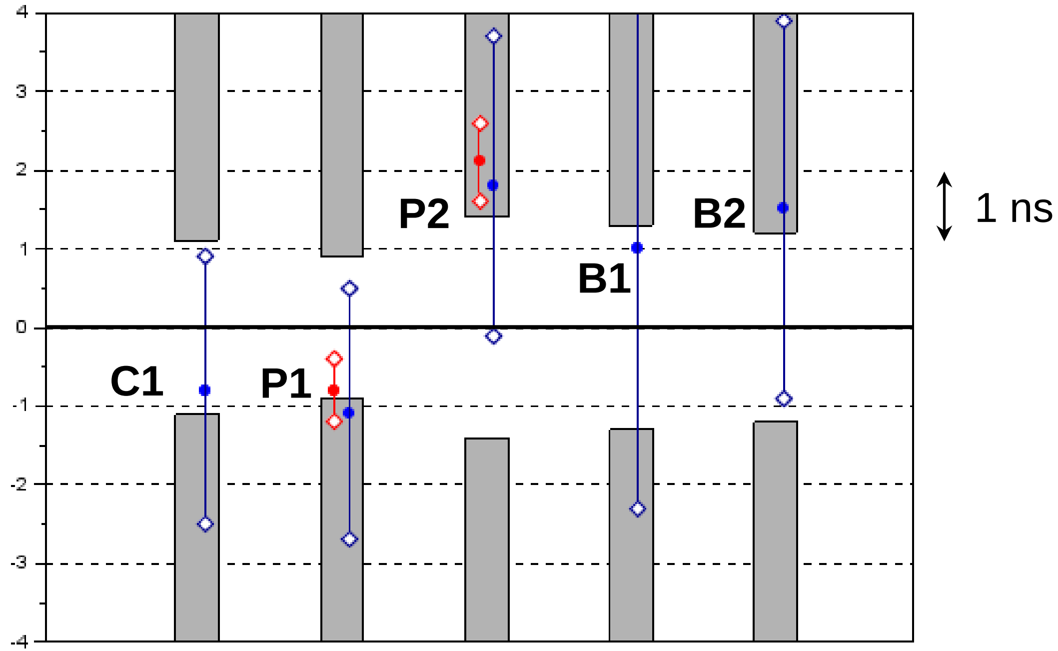




Absolute calibration of a GPS/BeiDou receiver

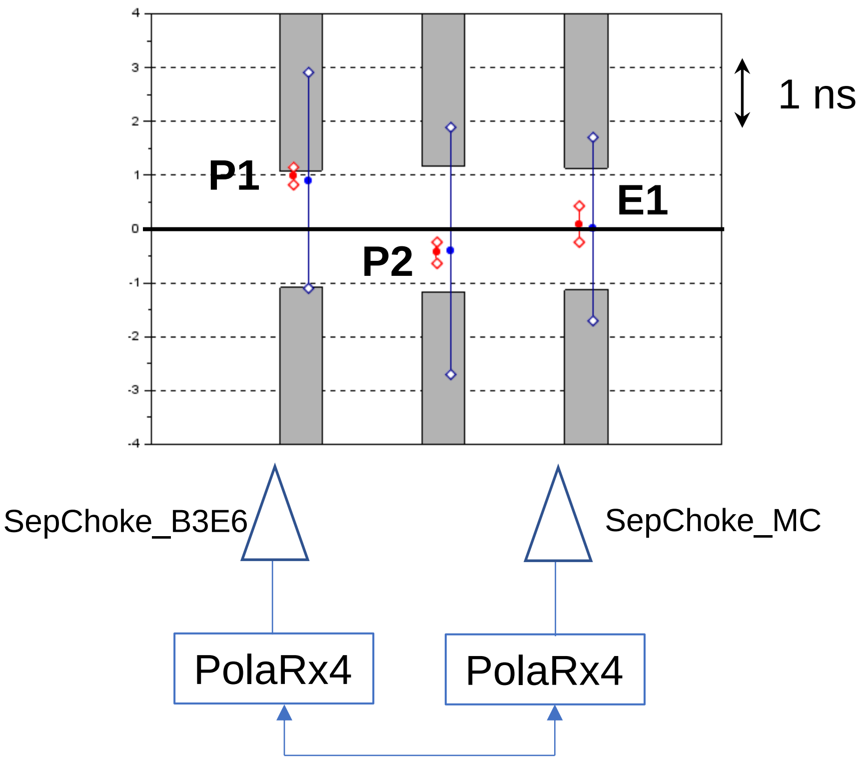
Overall validation in CV (CGGTTS and PR) using real signals

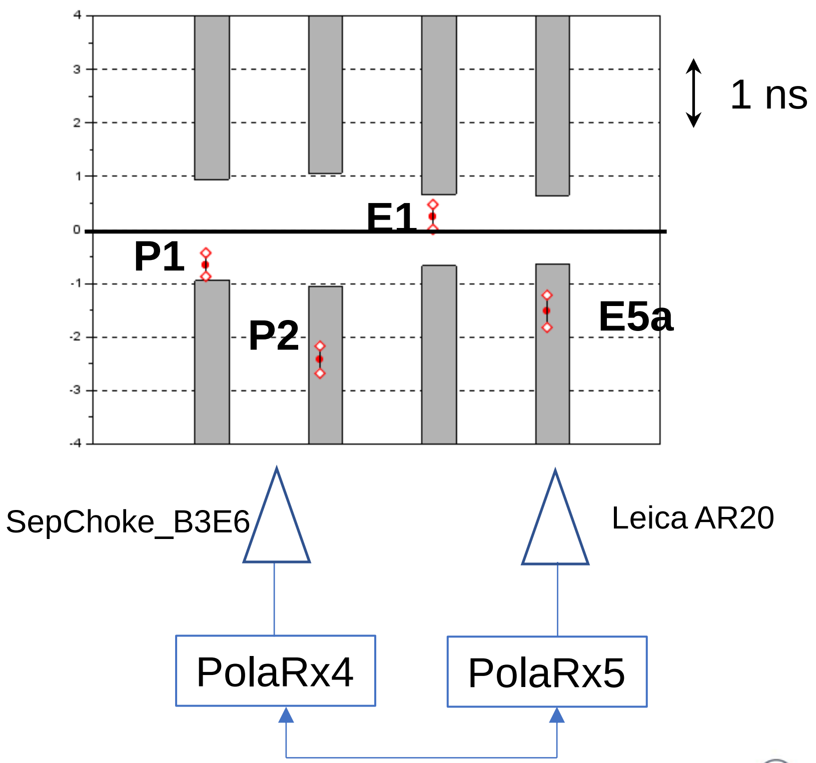




Absolute calibration of a GPS/Galileo receivers

Similar validation test with different pairs of Septentrio receivers using real signals





GRC and GRC-MS

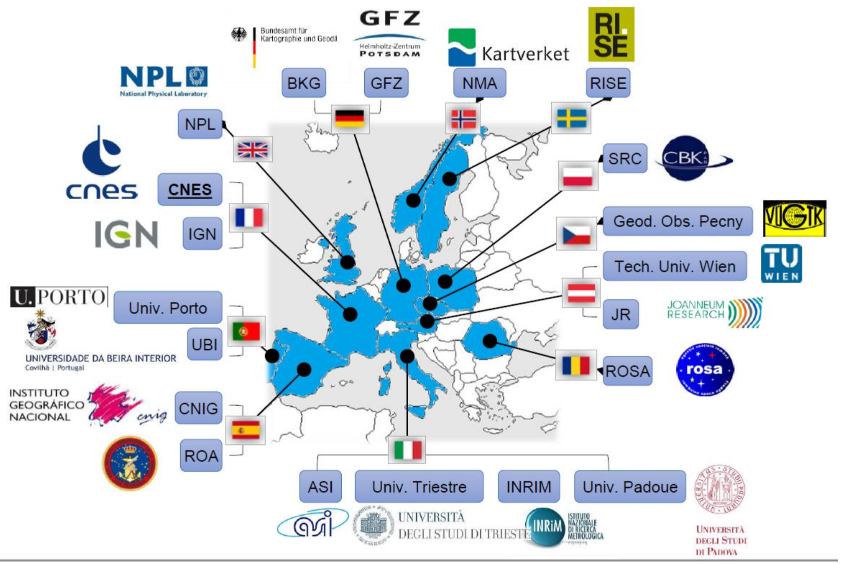
GRC MS

Main task of GRC is to provide the GSA with a means for <u>independent</u> monitoring and assessment of the quality of Galileo Services

The GRC consists of a core facility operated by the GSA and EU member state contributions (GRC-MS)

GRC-MS is a contribution to the Galileo Reference Center by EU member states and associated states :

- **coordinator = CNES**
- **20 partners from 12 countries**
- **Specific Grant #1 KO = 11th Sept 2018**



European Global Navigation Satellite Systems Agency

GRC-MS and timing

Dedicated Work Package on timing with CNES as coordinator and 4 partners (INRiM, NPL, ROA and RISE)

First quarter analysed is Q4 2018 ► no consortium results to show yet

CNES already monitors (since the Initial Services declaration) three Key Performance Indicators (KPI) :

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

SUMMARY

- CNES has been working on absolute calibration for several years and has published several proceedings papers (IFCS 2016, EFTF 2014, PTTI 2014, EFTF-IFCS 2011, …), with a special focus on Galileo

- CNES uses its GNSS reception chains with an absolute calibration for Galileo timing performance monitoring in the GRC-MS frame

- CNES is willing to pursue this activity and to compare absolute calibration results with other interested labs

Thank you for your attention

Questions ?

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