ICG-16 – 11 Oct 2022

Galileo timing performances monitored by the GRC-MS

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OUTLINE

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- GRC and GRC-MS
- Main results
- Conclusions

Context

Galileo has officially started delivering services to worldwide users since the Initial Services Declaration on the 15th of December 2016

Galileo System Time (GST) is

- **the reference time for the Galileo system**
- **computed on the ground in a Galileo Precise Timing Facility**
- **steered to UTC on a daily basis**

In its navigation message, Galileo includes an estimation of its offset to UTC (referred to as GAUT) and to GPS time (referred to as GGTO)

>> see Galileo timing template on ICG website for details

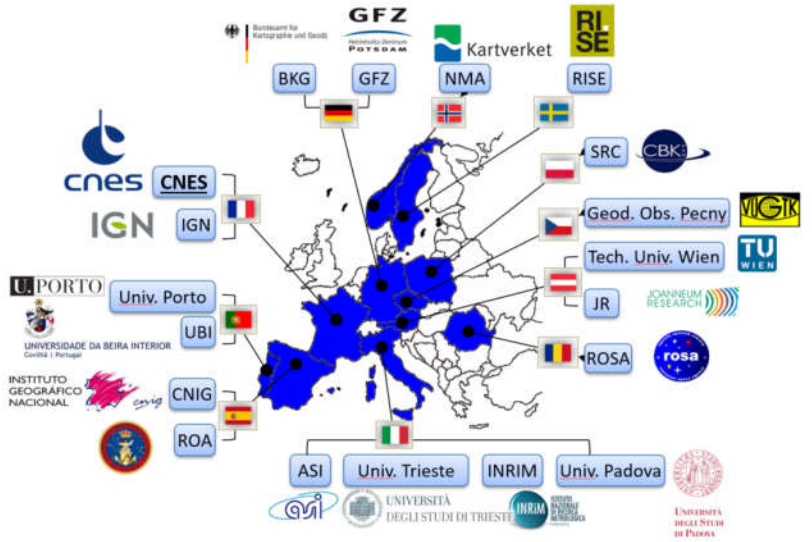
GRC and GRC-MS

Main task of GRC is to provide EUSPA 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 EUSPA) and EU member states contributions (GRC-MS)

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

- **coordinator = CNES**
- **19 partners from 11 countries**
- **Start = 11th Sept 2018**



GRC-MS and timing

Dedicated Work Package on timing with CNES as coordinator and 3 partners (INRiM, RISE and ROA)

Objective: monitoring of Galileo timing performances

- ✓ **Offset between UTC and Galileo System Time : UTC – GST**
- ✓ **UTC dissemination accuracy : UTC – bUTC_Galileo**

  (bUTC_Galileo is the UTC information broadcast by Galileo)
- ✓ **Frequency of UTC dissemination accuracy : freq(UTC – bUTC_Galileo)**
- ✓ **GGTO accuracy**
- ✓ **Availability of GAUT and GGTO information**
- ✓ **Performance of on-board clocks**

Calibration and processing

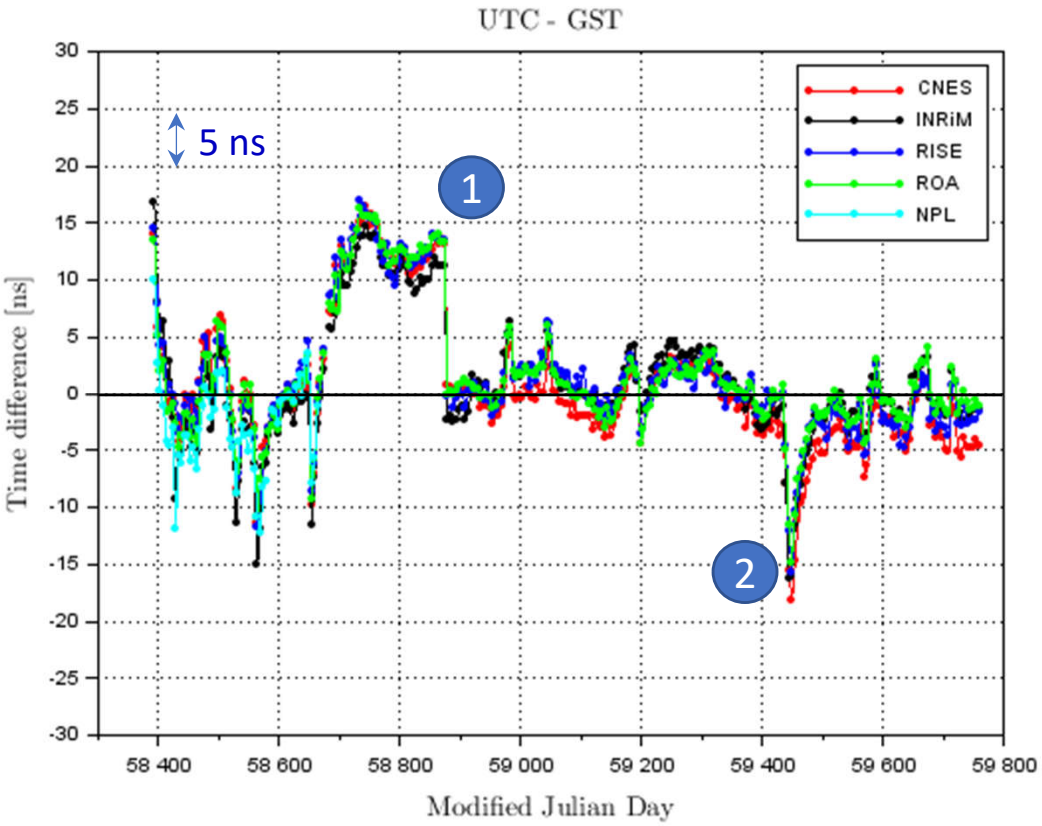
To determine GNSS_time – UTC, it is mandatory to use a calibrated GNSS receiver chain connected to a UTC(k)

Our stations use different calibration methods and processing :

	CNES	INRiM	RISE	ROA
GPS Calibration	absolute	Relative GPS G1/G2 calibration campaign	Relative GPS G1/G2 calibration campaign	Relative GPS G1 calibration campaign
Galileo Calibration	absolute	iono (*) then relative G1/G2 calibration campaign	iono (*) then relative G1/G2 calibration campaign	iono (*) then relative G1 calibration campaign
SW to convert RINEX to CGGTTS	SPRING	RISEGNSS	RISEGNSS	ROARIN2CGGTTS

(*) P. Defraigne et al., Calibration of Galileo signals for time metrology, *IEEE transactions on UFFC*, 12/2014 61(12):1967-75

Results : UTC – GST



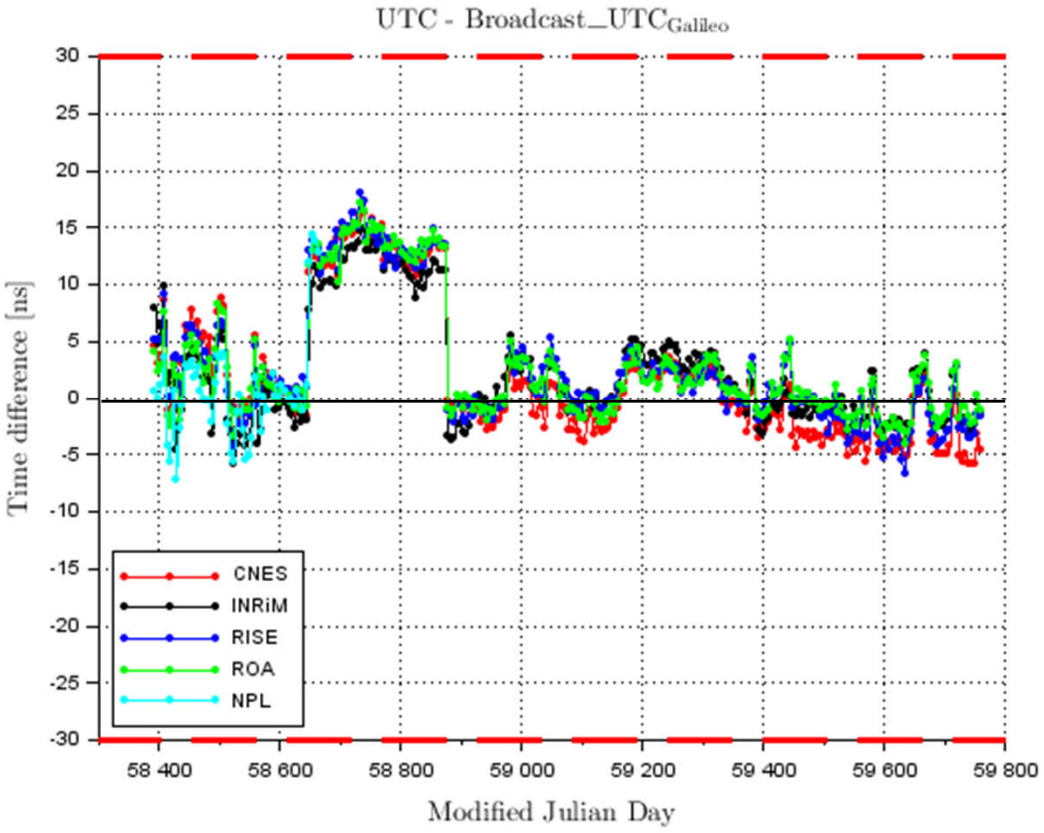
Oct 2018 ⟶ Jun 2022

Computed as [UTC – UTC(k)] + [UTC(k) – GST]

Good consistency for the different stations

1. Rapid correction of 10-15 ns at the end of Jan 2020
2. Slow correction of 15-20 ns in Sept 2021

Results : UTC – bUTC_Galileo



Oct 2018 ⟶ Jun 2022

Computed as [UTC – GST] – [bUTC_GAL – GST]

Offset of ~10-15 ns from Jun 2019 to Jan 2020

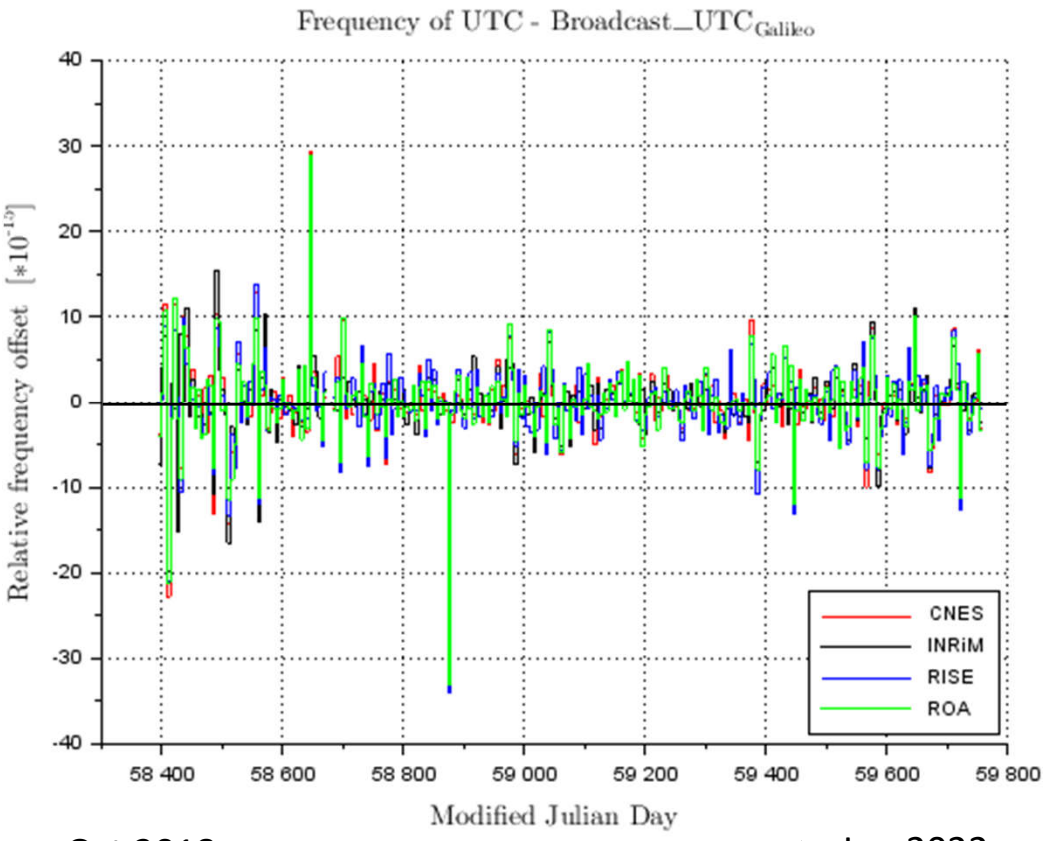
Result at 95 % on any 1-month window < 16 ns

within the specifications (*) ☑

(30 ns, 95 %, normalized monthly)

(*) Galileo OS Service Definition Document, v1.2

Results : Frequency of UTC – bUTC_Galileo



Oct 2018 ⟶ Jun 2022

Computed as Δ(UTC – bUTC_Galileo) / 5 d

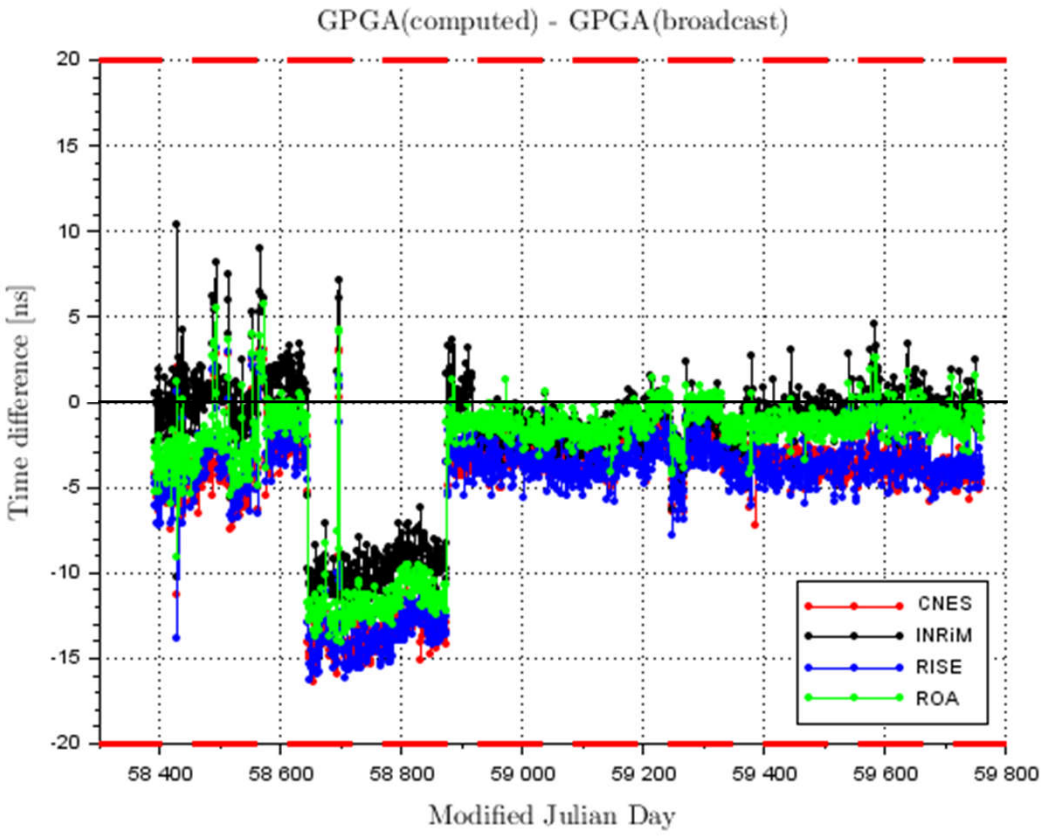
Result at 95 % on any 1-month window < 2e-14

within the specifications (*) ☑

(3e-13, 95 %, normalized monthly)

(*) Galileo OS Service Definition Document, v1.2

Results : GGTO accuracy



Oct 2018 ⟶ Jun 2022

Computed as

$[GST - GPST]_{computed} - [GST - GPST]_{broadcast}$

Offset of ~10-15 ns from Jun 2019 to Jan 2020

Result at 95 % on any 1-month window < 16 ns

within the specifications (*) ☑

(20 ns, 95 %, normalized annually)

(*) Galileo OS Service Definition Document, v1.2

Results : GAUT and GGTO availabilities

Availability of the Galileo OS UTC time dissemination service (referred to as GAUT availability here)

>= 95 % of time a user is provided at least 1 healthy SIS (*)

Calculated over 30 d, elevation > 5°, from any point in the service coverage, incl. planned and unplanned outages

Availability of GST-GPS time offset determination (referred to as GGTO availability here)

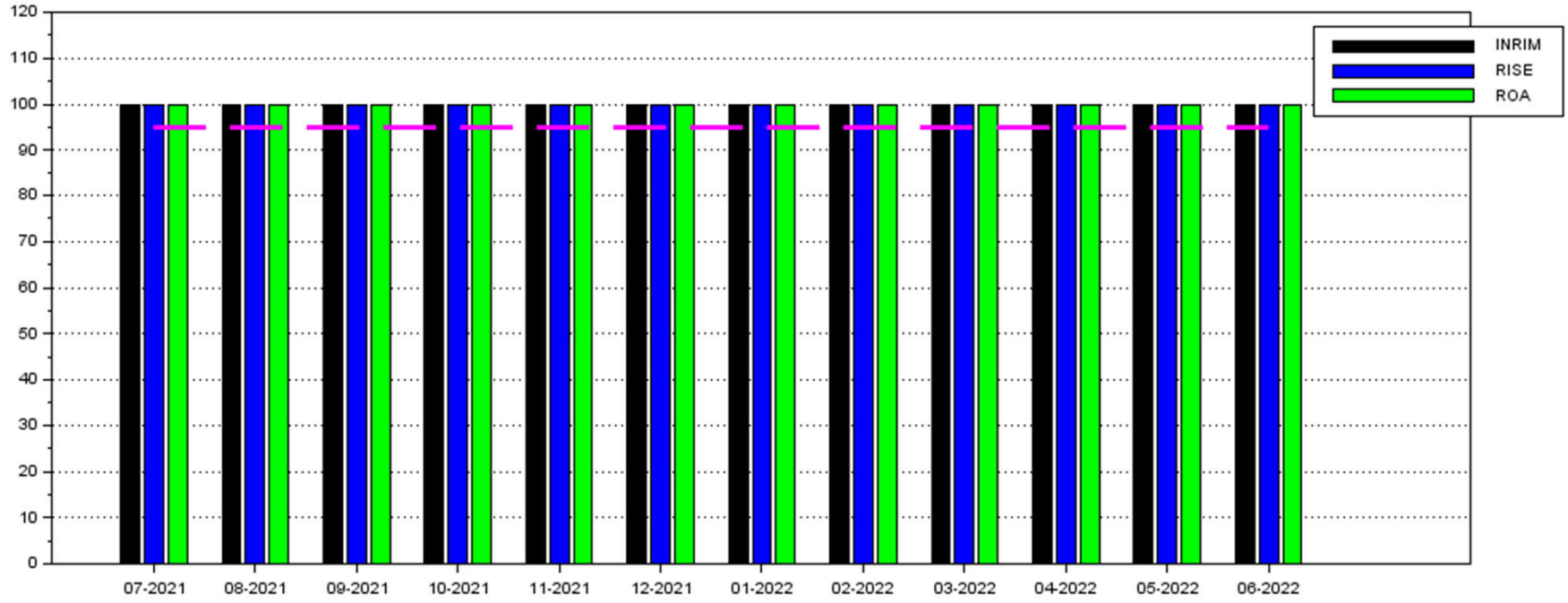
>= 80 % of time that GGTO is broadcast by at least 1 healthy SIS (*)

Calculated over 30 d, elevation > 5°, from any point in the service coverage, incl. planned and unplanned outages

In GRC-MS, GAUT and GGTO availabilities are computed for FNAV and INAV independently, only for a single station (no global computation)

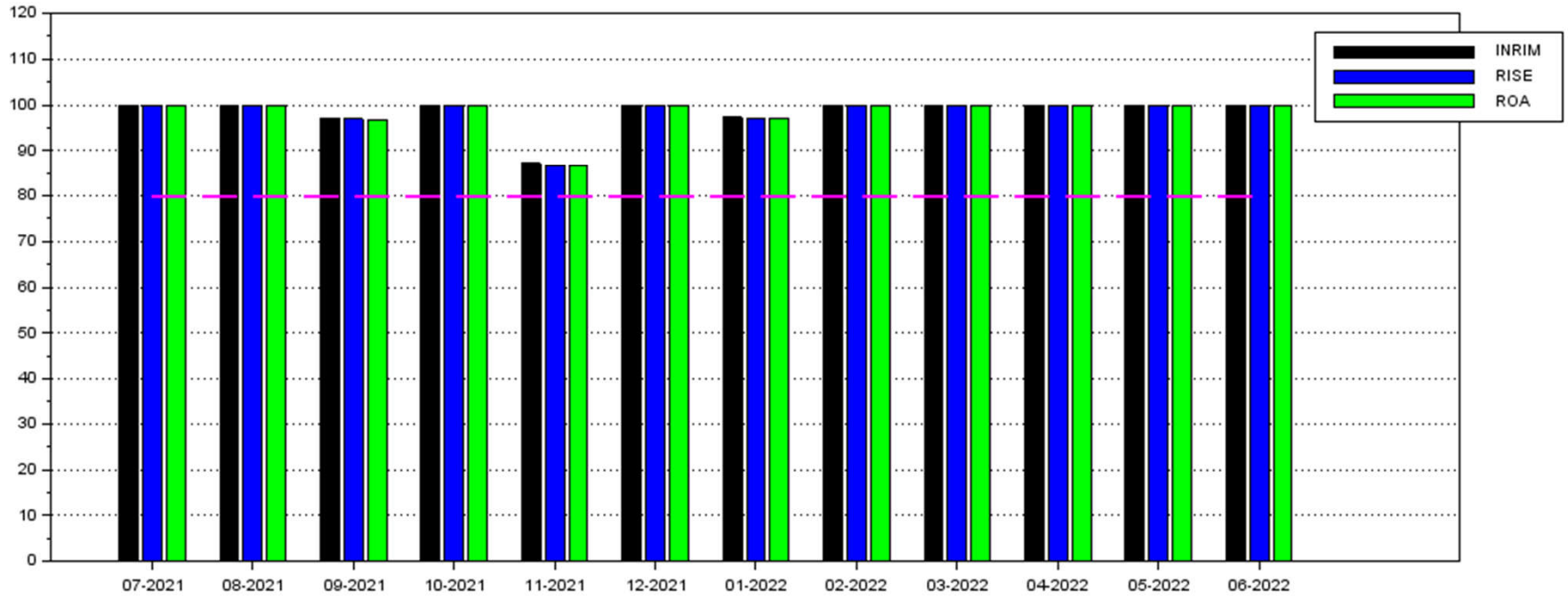
(*) Galileo OS Service Definition Document, v1.2

Results : GAUT availability for FNAV



100 % for the 3 stations between July 2021 and June 2022 ☑

Results : GGTO availability for FNAV

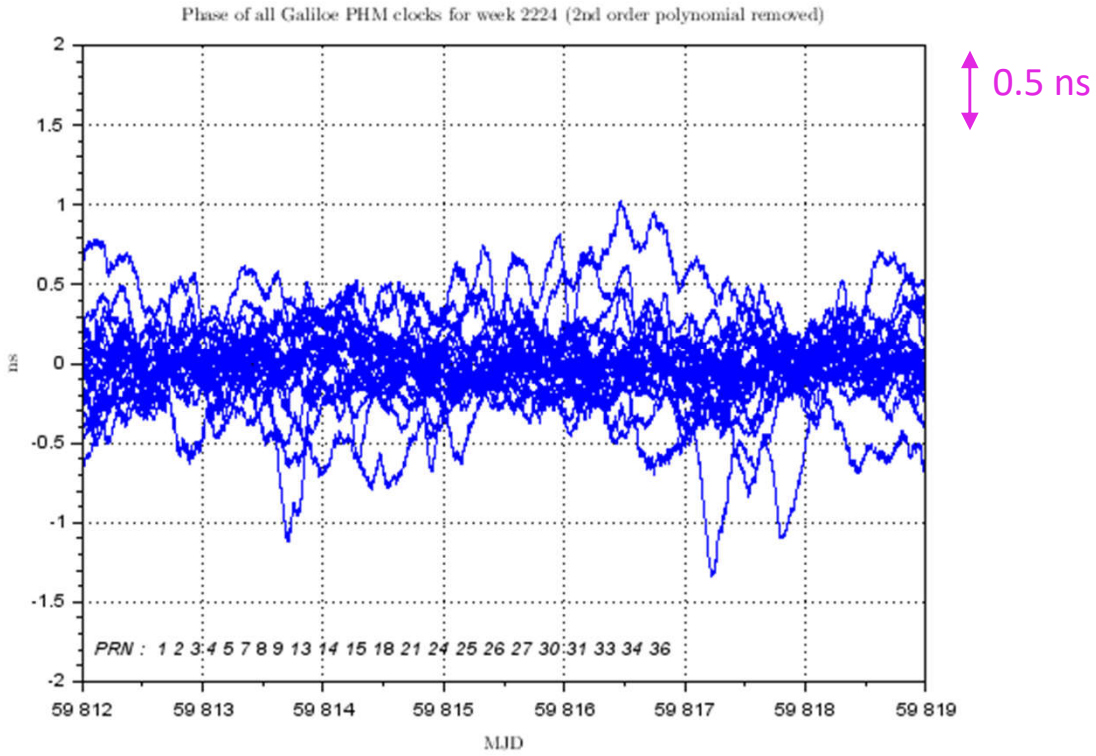


> 85 % for the 3 stations between July 2021 and June 2022 ☑

Results : on-board clocks

All Galileo satellites currently driven by a PHM except E11, E12 and E19 (RAFS)

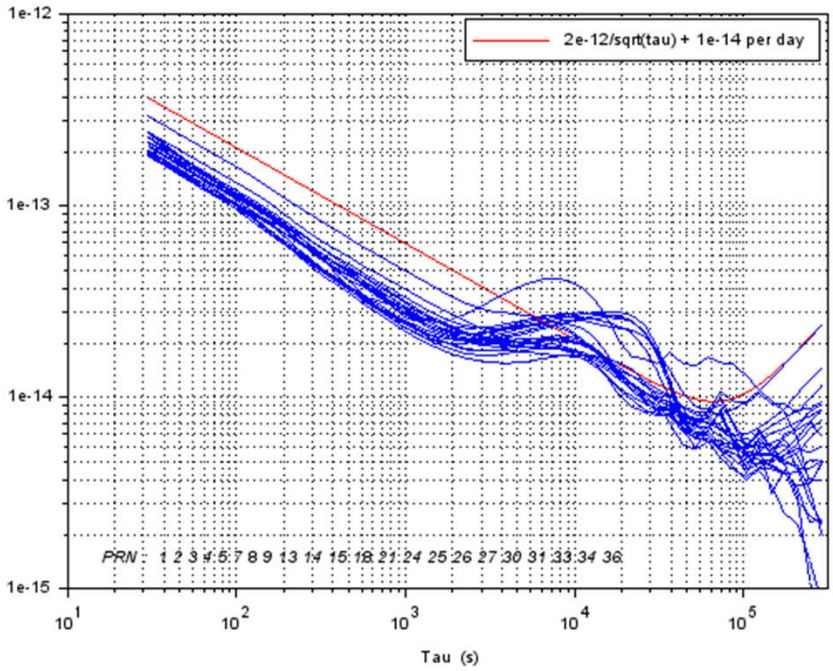
Example of 2nd-order phase residuals of all Galileo PHM over 1 week with GRG clk products :



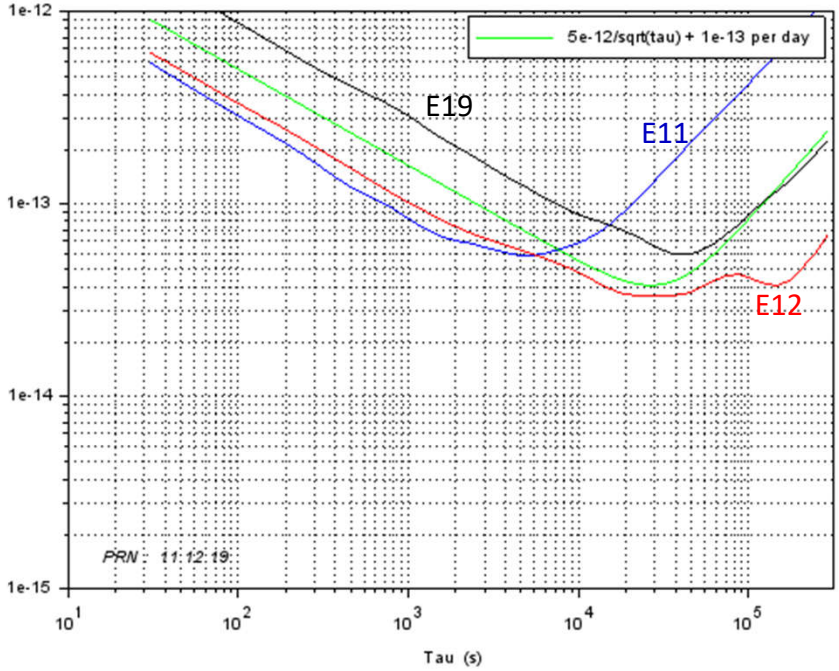
Results : on-board clocks

Stability of Galileo clocks on 1 week using GRG clk products :

PHM



RAFS



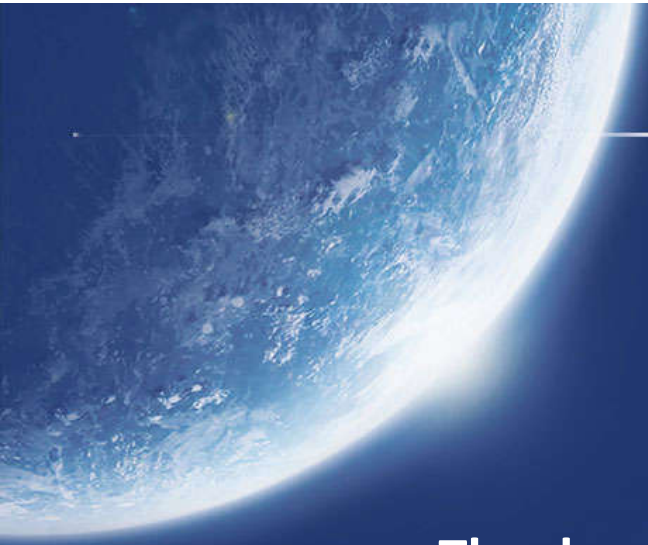
Conclusions

The GRC-MS monitors the Galileo timing performances since Q4 2018

The Galileo timing requirements are met ☑

Galileo on-board PHM show very good performances

Galileo on-board RAFS have very different behavior from one another, with no significant impact on the SIS Range Error thanks to the rapid updates of clock coefficients



Thank you for your attention

Questions ?

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