GNSS CALIBRATION REPORT

RO_8, RO10 Internal - Cal Id: 1101-2021

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1. INTRODUCTION

1.1. SCOPE OF THE DOCUMENT

RO_8 and RO10 receivers were calibrated 1n 2018 (Cal_Id=1001-2018 [RD01]). Last year a new Antcom's G5Ant-72CA4T1 antenna and a new firmware (from v1.9.4 to v1.10.7) were installed to RO_8 receiver which required a new determination of GPS and Galileo internal delays. During this same year, a change in the antenna signal distribution of RO10 receiver was also carried out.

Figure 1-1: Choke Ring Antcom's G5Ant-72CA4T1 antenna on the roof of ROA laboratory.

With publication of V2 of [RD01] in June 2020, Galileo delay values for the G1 laboratories were published. In this report, new internal delay GPS C1, P1, P2 and Galileo E1, E5a values for RO_8 and RO10 receivers are shown.

1.2. DOCUMENTS

REFERENCES	
RD01	BIPM report 1001-2018 V2.0 / 20200620, subject: 2018 Group 1 GPS calibration trip.
RD02	BIPM guidelines for GNSS calibration, V3.2, 15/02/2016.
RD03	G. Petit, Z. Jiang, P. Moussay, J. White, E. Powers, G. Dudle, P. Uhrich, 2001, Progresses in the calibration of geodetic like GPS receivers for accurate time comparisons, Proc. 15th EFTF, pp. 164-166.

RD04	PolaRx5TR user manual version 1.1. Applicable to version 5.1 of the receiver firmware, November 30, 2016.

1.3. ACRONYMS AND ABBREVIATIONS

Table 1-1: List of Acronyms and Abbreviations

Acronym	Definition
BIPM	Bureau International des Poids et Mesures.
CGGTTS	CCTF Generic GNSS Time Transfer Standard.
EURAMET	The European Association of National Metrology Institutes.
GPS	Global Positioning System.
MJD	Modified Julian Date.
RINEX	Receiver Independent Exchange Format.
ROA	Real Instituto y Observatorio de la Armada, San Fernando, Spain.
TDEV	Time Deviation, measure of time instability based on the modified Allan variance.
UTC	Coordinated Universal Time.
UTC(k)	Version of UTC realized at each of the contributing NMI(k)s.
	CGGTTS specific acronyms
CAB DLY	Field present in the CGGTTS header. It is the group delay inside the antenna cable, including both end connectors.
INT DLY	Field present in the CGGTTS header. It is the code- and frequency-dependent combined electric delay of the GNSS signal inside the antenna and the receiver. See also [RD03].
REF DLY	Field present in the CGGTTS header. It is the time offset between the receiver internal clock (or its conventional realization by an external signal) and the local clock at the station. See also [RD03].

2. RECEIVERS AND DATES

Dates and receivers involved in the calibration are summarized in Table 2-1¡Error! No se encuentra el origen de la referencia.. A complete information related with the receiver set-up and the signal distribution system have been provided by all Labs (see relevant Annex-A).

Table 2-1: Schedule of the campaign and involved receivers.

Institute	Dates of measurements	Status of equipment	Receiver type	BIPM (CGGTTS)	RINEX name
ROA	MJD: 59264-59268 19/02/21-24/02/21	Group 1 Reference	Septentrio PolaRx4TR PRO	RO_9	RO_9
		Group 1 Alignment	Septentrio PolaRx5TR	RO10	ROAG
		Group 1 Alignment	MESIT GTR51	RO_8	RO_8

3. CALIBRATION PROCEDURE AND RESULTS

The calibration has been performed based on C1, P3 GPS and E1, E3 CGGTTS Galileo files. The reference delay (REF DLY) was also measured in both directly from the PPS IN signal, once selected 'auto' mode in RO10 (which enable automatic PPS IN internal delay compensation for this receiver). Table 3-1 and 5-2 summarize the common clock differences (CCD) values.

Table 3-1: GPS raw common clock differences, all values in ns.

Pair	RAW ΔC1	Sigma	RAW ΔP1	Sigma	RAW ΔP2	Sigma
RO_9-RO_8	-31.32	0.52	-29.57	0.44	-27.87	0.61
RO_9-RO10	-30.72	0.30	-28.95	0.36	-26.26	0.31

Table 3-2: Galileo raw common clock differences, all values in ns.

Pair	RAW ΔE1	Sigma	RAW ΔE5a	Sigma
RO_9-RO_8	-32.61	0.38	-24.57	0.58
RO_9-RO10	-30.62	0.26	-30.45	0.20

4. UNCERTAINTY ESTIMATION

The overall uncertainty of the INT DLY values obtained as a result of the calibration is given by:

$$u_{CAL} = \sqrt{u_a^2 + u_b^2}\ , \qquad (1)$$

with the statistical uncertainty u_a and the systematic uncertainty u_b. The statistical uncertainty is related to the instability of the common clock data collected at each site and collected at ROA when the INT DLY of the travelling equipment was determined. The systematic uncertainty is given by:

$$u_b = \sqrt{\sum_n u_{b,n}^2} \qquad (2)$$

The contributions to the sum (2) are listed and explained subsequently in Table 4-1. Note that the uncertainty of the INT DLY values of ROA's fixed receiver RO_9, which served as the reference, is not included.

Table 4-1: Uncertainty contributions for the calibration of receiver delays

	Uncertainty	Value C1 ns	Value P1 ns	Value P2 ns	Value E1 ns	Value E5a ns	Description
1	$u_{a(ROA)}$	0.10	0.10	0.10	0.10	0.10	CCD uncertainty at ROA, TDEV at τ = 1 day
Systematic components due to antenna installation							
2	$u_{b,11}$	0.05	0.05	0.05	0.05	0.05	Position error of RO_9 receiver
3	$u_{b,12}$	0.05	0.05	0.05	0.05	0.05	Position error of RO_8/RO10 receiver
4	$u_{b,13}$	0.10	0.10	0.10	0.10	0.10	Multipath at RO_9 antenna
5	$u_{b,14}$	0.10	0.10	0.10	0.10	0.10	Multipath at RO_8/RO10 antenna
Installation of RO_9 and SMDC receivers							
6	$u_{b,21}$	0.50	0.50	0.50	0.50	0.50	Connection of RO_9 to UTC(ROA) (REF DLY)
7	$u_{b,22}$	0.50	0.50	0.50	0.50	0.50	Connection of RO_8/RO10 to UTC(ROA) (REF DLY)
10	$u_{b,23}$	0.10	0.10	0.10	0.10	0.10	TIC nonlinearities at ROA

5. FINAL RESULTS

The results of the internal calibration are summarized in Table 5.1-2. INTDLY and associated uncertainty C1 values have been calculated from Table 3.1-2 and Table 4.1, respectively, rounded to the tenth of a nanosecond (the same for GPS C1, P1, P2 and Galileo E1, E5a codes):

$$\text{INTDLY C1} = -\Delta C1$$

Table 5-1. GPS calibration results, all values in ns.

Receiver	REF DLY	CAB DLY	INTDLY C1	u_{cal} C1	INT DLY P1	u_{cal} P1	INT DLY P2	u_{cal} P2
RO_8	20.4	197.1	31.3	0.8	29.6	0.8	27.9	0.8
RO10	5.1*	199.0	30.7	0.8	29.0	0.8	26.3	0.8

Table 5-2. Galileo calibration results, all values in ns.

Receiver	REF DLY	CAB DLY	INTDLY E1	u_{cal} E1	INT DLY E5a	u_{cal} E5a
RO_8	20.4	197.1	32.6	0.8	24.6	0.8
RO10	5.1*	199.0	30.6	0.8	30.5	0.8

* RO10 in auto-compensation PPS IN internal delay mode operation.

6. ANNEX-A

6.1. CALIBRATION INFORMATION SHEET AT ROA

Laboratory:	ROA
Date and hour of the beginning of measurements:	19.02.2021
Date and hour of the end of measurements:	24.02.2021

Information on the system		
	Reference:	**DUT:**
4-character BIPM code	RO_9	RO_8
• Receiver maker and type: Receiver serial number:	Septentrio PolaRx4TR PRO 3008013	MESIT GTR51 v1.9.4 1509257
1 PPS trigger level /V:	1 V	1 V
• Antenna cable maker and type: Phase stabilised cable (Y/N):	LDF1RK-50	LDF1RK-50
Length outside the building /m:	Approximately 20 m	Approximately 20 m
• Antenna maker and type: Antenna serial number:	LEICA AR25 726363	ANTCOM G5Ant-72CA4T1 448359

Measured delays /ns		
	Local:	**Travelling:**
• Delay from local UTC to receiver 1 PPS-in:		20.4 ns
Delay from 1 PPS-in to internal Reference (if different): (see section 2 for details)		
• Delay from local UTC to receiver 1 PPS-out:	451.8 ns	
• Antenna cable delay: Antenna cable type:	59.7 ns	197.1 ns

Data used for the generation of CGGTTS files		
	Reference:	**DUT:**
• INT DLY (GPS) /ns:	56.9 ns C1, 55.5 ns P1, 54.4 ns P2	31.3 ns C1, 29.6 ns P1, 27.9 ns P2
• INT DLY (GALILEO) /ns:	56.2 ns E1, 65.3 ns E5a	32.6 ns E1, 24.6 ns E5a
• CAB DLY /ns:	451.8 ns	197.1 ns
• REF DLY /ns:	59.7 ns	20.4 ns
• Coordinates reference frame:	ITRF	ITRF
Latitude or X /m:	5105582.90 m	5105576.84 m
Longitude or Y /m:	-555191.22 m	-555197.14 m
Height or Z /m:	3769703.66 m	3769710.69 m

General information	
• Rise time of the local UTC pulse:	0.5 ns
• Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(22 ± 2) °C
Set humidity value and uncertainty:	< 70 %

Laboratory:	ROA
Date and hour of the beginning of measurements:	19.01.2021
Date and hour of the end of measurements:	24.02.2021

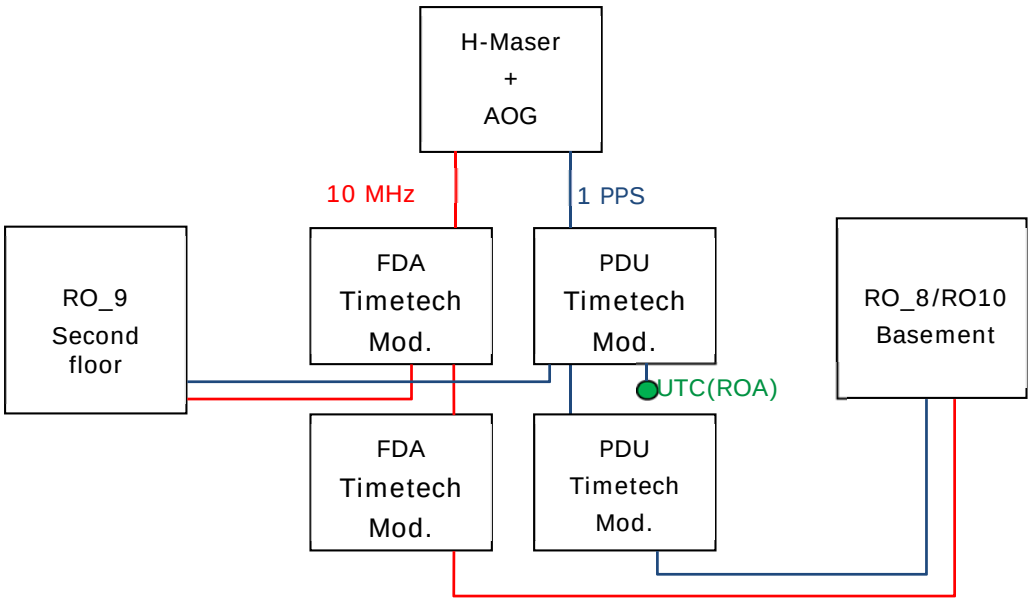
Information on the system		
	Local:	**DUT:**
4-character BIPM code	RO_9	RO10
• Receiver maker and type: Receiver serial number:	Septentrio PolaRx4TR PRO 3008013	Septentrio PolaRx5TR v5.3.2 4701187
1 PPS trigger level /V:	1 V	1 V
• Antenna cable maker and type: Phase stabilised cable (Y/N):	LDF1RK-50	LDF1RK-50
Length outside the building /m:	Approximately 20 m	Approximately 37 m
• Antenna maker and type: Antenna serial number:	LEICA AR25 726363	LEICA AR25 726362

Measured delays /ns		
	Local:	**Travelling:**
• Delay from local UTC to receiver 1 PPS-in:		5.1 ns Auto-compensation PPS IN: ON
Delay from 1 PPS-in to internal Reference (if different): (see section 2 for details)		
• Delay from local UTC to receiver 1 PPS-out:	451.8 ns	
• Antenna cable delay: Antenna cable type:	59.7 ns	199.0 ns

Data used for the generation of CGGTTS files		
	Reference:	**DUT:**
• INT DLY (GPS) /ns:	56.9 ns C1, 55.5 ns P1, 54.4 ns P2	30.7 ns C1, 29.0 ns P1, 26.3 ns P2
• INT DLY (GALILEO) /ns:	56.2 ns E1, 65.3 ns E5a	30.6 ns E1, 30.5 ns E5a
• CAB DLY /ns:	451.8 ns	199.0 ns
• REF DLY /ns:	59.7 ns	5.1 ns
• Coordinates reference frame:	ITRF	ITRF
Latitude or X /m:	5105582.90 m	5105577.48 m
Longitude or Y /m:	-555191.22 m	-555208.94 m
Height or Z /m:	3769703.66 m	3769714.20 m

General information	
• Rise time of the local UTC pulse:	0.5 ns
• Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(22 ± 2) °C
Set humidity value and uncertainty:	< 70 %

Diagram of the experiment set-up at ROA:



7. ANNEX-B: CCD and TDEV analysis at ROA

Figure 7-1: RO_9 and RO_8 GPS common clock differences (CCD)

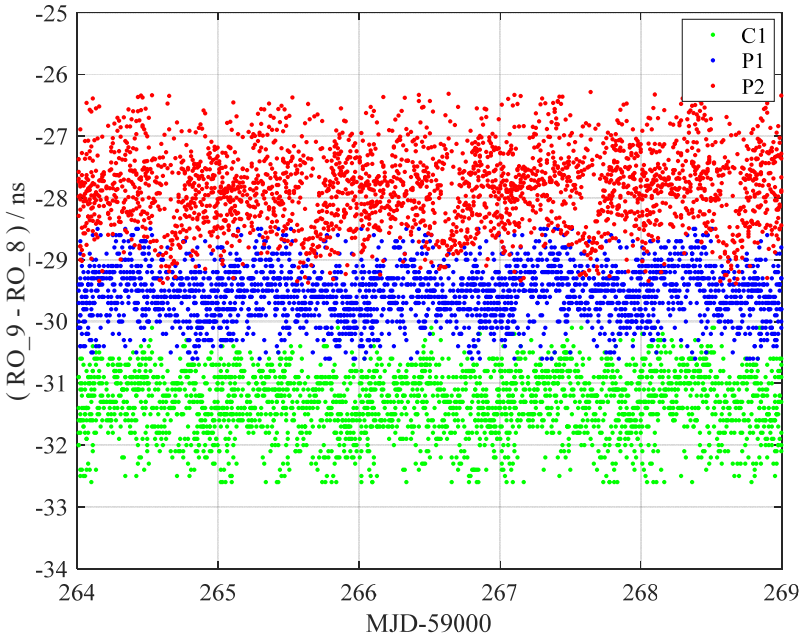


Figure 7-2: RO_9 and RO_8 Galileo common clock differences (CCD)

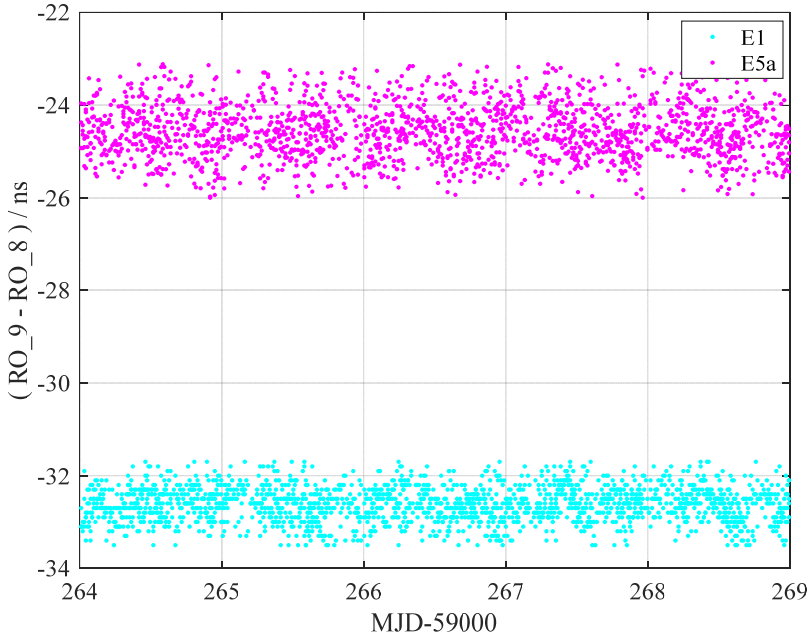


Figure 7-3: RO_9 and RO_10 GPS common clock differences (CCD)

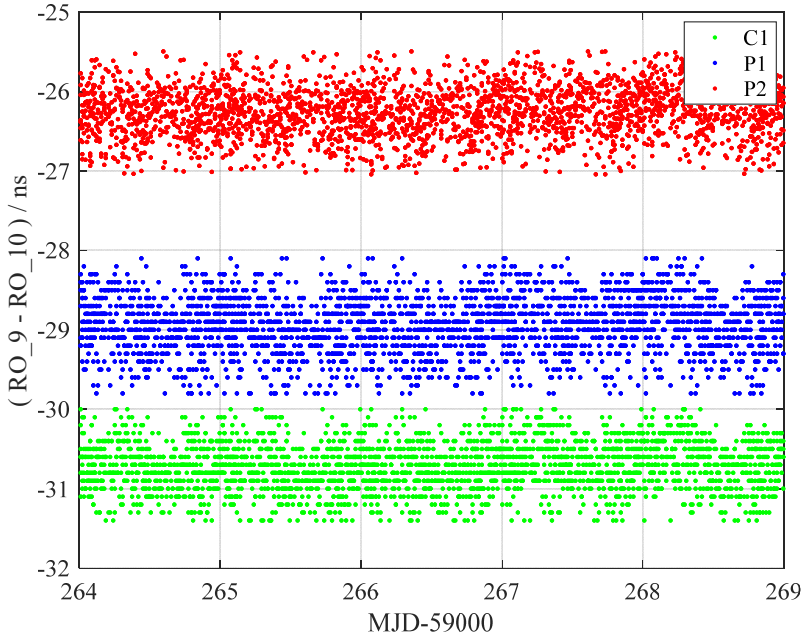
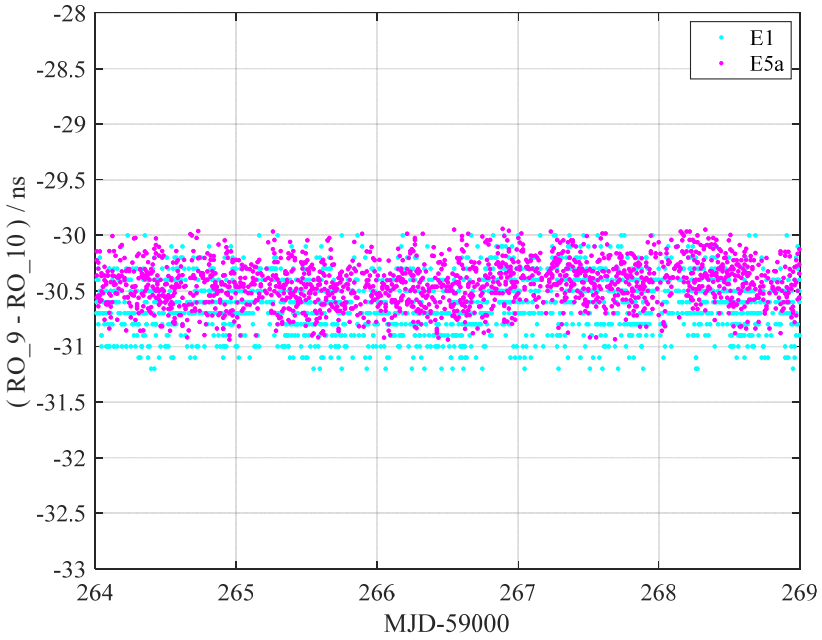


Figure 7-4: RO_9 and RO_10 Galileo common clock differences (CCD)



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