GNSS CALIBRATION REPORT

G1G2_1101-2017

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Real Instituto y Observatorio de la Armada, San Fernando, Spain, April 2018.

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1. INTRODUCTION

1.1. SCOPE OF THE DOCUMENT

In 2014, as a result of a CCTF recommendation of collaboration between the BIPM and the RMOs for GNSS equipment calibration, some National Metrology Institutes (NMIs) and Designated Institutes (DIs), were selected to be G1 laboratories, to function as regional nodes for the GPS calibrations. The mission of these Labs, once calibrated by the BIPM, is to perform new calibration trips between G2 laboratories, under the responsibility of the RMOs.

ROA, as EURAMET G1 laboratory, has this year organized a new GPS receiver relative calibration but, unlike other occasions, the whole JV station (receiver + antenna + antenna cable) was sent to ROA, to perform a differential calibration without closure, with respect to the reference receiver RO_5. This last was calibrated and reported last year (Cal_Id=1001-2016 [RD01]), and has been continuously monitored since then.

1.2. DOCUMENT STRUCTURE

The current campaign has been carried out in accordance with ROA calibration procedures and follows as much as possible the BIPM guidelines for GNSS calibrations [RD02]. The results will be reported using Cal_Id 1101_2017, and they will provide the JV receiver's internal delays for GPS C1, P1 and P2 code signals on the two carrier frequencies L1 and L2 (INT DLY P1/P2).

Section 1 of this document gives the introduction, the document structure and a document baseline (in terms of applicable and reference documents and acronyms used).

Section 2 reports the participating laboratories, dates of visits, and GPS receivers involved in this calibration campaign.

Section 3 presents an overview of the travelling equipment sent by JV.

Section 4 briefly describes the calibration procedure.

Section 5 explains the data processing carried out by ROA using its own software and includes all the necessary tables to present the results.

Section 6 is focused on the uncertainty estimation, listing all the terms taken into account for the uncertainty budget.

Section 7 shows the final results, with the new internal delays, as well as all the information needed to obtain them.

The report concludes with the Annex-A information sheet for each visited receiver, and the Annex-B, which contains all the figures showing the common clock differences (CCD), and their respective time instabilities (TDEV).

1.3. DOCUMENTS

REFERENCES	
RD01	BIPM report 1001-2016 V1.2 / 20170210, subject: 2016 Group 1 GPS calibration trip (Phase 2).
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	J. Kouba, P. Heroux, 2002, Precise Point Positioning Using IGS Orbit and Clock Products, GPS Solutions, Vol. 5, No. 2, pp. 12-28.
RD05	PolaRx5TR user manual version 1.1. Applicable to version 5.1 of the receiver firmware, November 30, 2016.

1.4. ACRONYMS AND ABBREVIATIONS

Table 1-1: List of Acronyms and Abbreviations

Acronym	Definition
BIPM	Bureau International des Poids et Mesures.
CCD	Common clock differences.
CCTF	Consultative Committee for Time and Frequency.
CGGTTS	CCTF Generic GNSS Time Transfer Standard.
DI	Designated Institute.
EURAMET	The European Association of National Metrology Institutes.
GNSS	Global Navigation Satellite System.
GPS	Global Positioning System.
IGS	International GNSS Service.
JV	Justervesenet (Norwegian Metrology Service).
MJD	Modified Julian Date.
NMI	National Metrology Institute.
PPP	Precise Point Positioning.
RINEX	Receiver Independent Exchange Format.
ROA	Real Instituto y Observatorio de la Armada, San Fernando, Spain.
TDEV	Time Deviation, Which is a measure of time instability based on the modified Allan variance.
TIC	Time Interval Counter.
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. PARTICIPANTS AND SCHEDULE

Participating laboratories, dates and GPS receivers involved in the calibration campaign are summarized in Table 2-1 and Table 2-2. Nevertheless, 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: List of participants.

Institute	Point of contact	Postal address
ROA	Héctor Esteban Tel +34 956 54 54 39 hesteban@roa.es	Plaza de las Tres Marinas s/n 11100, San Fernando Spain
JV	Harald Hauglin Tel +47 64 84 84 43 hha@justervesenet.no	Justervesenet (Norwegian Metrology Service) PO Box 170 N-2027 Kjeller Norway

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

Institute	Dates of measurements	Status of equipment	Receiver type	BIPM code	RINEX name
ROA	MJD: 58089-58094 02/12/17-07/12/17	Group 1 reference	DICOM GTR50	RO_5	RO_5
		Group 2	PolaRx5TR	JV02	JV02

3. THE JV TRAVELING STATION

The JV equipment consists of the following items:

- 1 PolaRx5TR receiver SN: 4701240
- 1 PolaNt Choke Ring B3/E6 antenna SN: 5264
- 50 m Ecoflex 10Plus low-loss antenna cable

Figure 3-1: Choke Ring B3/E6 antenna on the roof of ROA laboratory.

Figure 3-2: PolaRx5TR receiver inside the ROA laboratory.

4. CALIBRATION PROCEDURE

The calibration has been performed based in C1, P1 and P2 observations provided in the RINEX V.2.1 observation files, that is, using all the GPS satellites in view, at 30 seconds time intervals. We have also used the satellite ephemeris BRDC files provided by IGS.

The coordinates of the antenna phase centre have been especially computed for the calibration period from RINEX files by using the NRCan PPP (V 1.05 34613) software [RD04], so the time transfer error caused by this factor is nearly negligible.

The calibration method is basically as follows. From the known delays of the reference receiver (RO_5), we have obtained INTDLY(C1), INTDLY(P1) and INTDLY(P2) values for the JV receiver. The calibration procedure consists on building differential pseudo-ranges for each code C1, P1 and P2 between the two receivers in common-clock set-up.

The 10 MHz frequency reference input signal was attenuated to 0.6 Vpp amplitude, in order to enable the ranging from 0.25 Vpp to 1Vpp on 50 ohms load impedance [RD05].

5. DATA PROCESSING

For the calculation process it has been used an ROA-authored program, in which the common clock differences (CCD) are obtained from the differential pseudo-ranges for each code C1, P1 and P2. For JV receiver, the coordinates of the antenna have been carefully calculated for the calibration period from RINEX V.2.1 files.

As was stated before, from the known delays of the reference receiver RO_5, were obtained the internal delays of the PolaRx5TR receiver. The antenna cable delay (CAB DLY) was measured at ROA, with a value of (196.4 ± 0.6) ns. The reference delay (REF DLY) was also measured from the PPS OUT receiver signal, being the only delay value jointly with the antenna coordinates that must be updated, once installed at JV. Table 5-1 summarizes the CCD values.

Table 5-1: Raw common clock differences, all values in ns.

Pair	RAW ΔC1	TDEV (1 day)	RAW ΔP1	TDEV (1 day)	RAW ΔP2	TDEV (1 day)
RO_5-JV02	-31.75	0.08	-29.19	0.07	-28.19	0.07

6. UNCERTAINTY ESTIMATION

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

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

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:

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

The contributions to the sum (2) are listed and explained subsequently in Table 6-1. Note that the uncertainty of the INT DLY values of ROA's fixed receiver RO_5, which served as the reference, is not included.

Table 6-1: Uncertainty contributions for the calibration of receiver delays

	Uncertainty	Value C1(ns)	Value P1 (ns)	Value P2 (ns)	Description
1	$u_{a(ROA)}$	0.08	0.07	0.07	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	Position error of RO_5 receiver
3	$u_{b,12}$	0.05	0.05	0.05	Position error of JV02 receiver
4	$u_{b,13}$	0.10	0.10	0.10	Multipath at RO_5 antenna
5	$u_{b,14}$	0.10	0.10	0.10	Multipath at JV02 antenna
Installation of RO_5 and JV02 receivers					
6	$u_{b,21}$	0.20	0.20	0.20	Connection of RO_5 to UTC(ROA) (REF DLY)
7	$u_{b,22}$	0.60	0.60	0.60	Connection of JV02 to UTC(ROA) (REF DLY)
8	$u_{b,23}$	0.10	0.10	0.10	TIC nonlinearities at ROA

7. FINAL RESULTS

The results of the calibration campaign G1G2_1101_2017 are summarized in Table 7-1. INTDLY and associated uncertainty C1 values have been calculated from Table 5.1 and Table 6.1, respectively, rounded to the tenth of a nanosecond (the same for P1 and P2 codes):

INTDLY C1 = - ΔC1

Table 7-1. Results of the Calibration Campaign G1G2_1014_2017, 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
JV02	-	196.4	31.8	0.7	29.2	0.7	28.2	0.7

8. ANNEX-A

8.1. CALIBRATION INFORMATION SHEET AT ROA

Laboratory:	ROA
Date and hour of the beginning of measurements:	02.12.2017
Date and hour of the end of measurements:	07.12.2017

Information on the system

	Local:	**Travelling:**
4-character BIPM code	RO_5	JV02
• Receiver maker and type: Receiver serial number:	DICOM GTR50 0601012	PolaRx5TR SN: 4701240
1 PPS trigger level /V:	1 V	1 V (PPS OUT)
• Antenna cable maker and type: Phase stabilised cable (Y/N):	LMR-400	Ecoflex 10Plus
Length outside the building /m:	Approximately 8 m	Approximately 16 m
• Antenna maker and type: Antenna serial number:	LEICA AR25 Choke Ring 725232	PolaNt Choke Ring B3/E6 5264

Measured delays /ns

	Local:	**Travelling:**
• Delay from local UTC to receiver 1 PPS-in:	(36.5 ± 0.3) ns	(122.9 ± 0.6) ns
Delay from 1 PPS-in to internal Reference (if different): (see section 2 for details)		(33.8 ± 0.6) ns (can take any value from 20ns to 60ns depending on the phase relationship between the 10 MHz frequency reference and the PPS input signal)
• Delay from local UTC to receiver 1 PPS-out:		(156.7 ± 0.6) ns
• Antenna cable delay: Antenna cable type:	127.5 ns	(196.4 ± 0.6) ns Ecoflex 10Plus

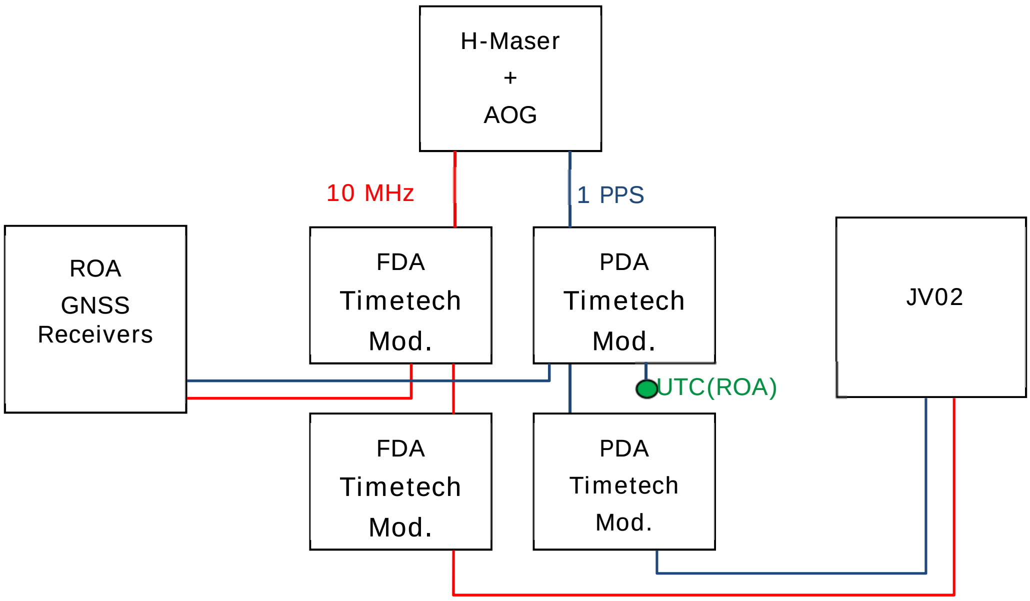
Data used for the generation of RO_5 CGGTTS files

• INT DLY (GPS) /ns:	18.6 ns (GPS C1) 18.5 ns (GPS P1) 32.7 ns (GPS P2)
• INT DLY (GLONASS) /ns:	N/A
• CAB DLY /ns:	127.50 ns
• REF DLY /ns:	36.50 ns
• Coordinates reference frame:	ITRF
Latitude or X /m:	5105510.60 m
Longitude or Y /m:	-555200.98 m
Height or Z /m:	3769791.03 m

General information

• Rise time of the local UTC pulse:	< 3 ns
• Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	(23 ± 2) °C
Set humidity value and uncertainty:	< 70 %

Diagram of the experiment set-up at ROA:



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

Figure 9-1: Common clock differences (CCD) at ROA

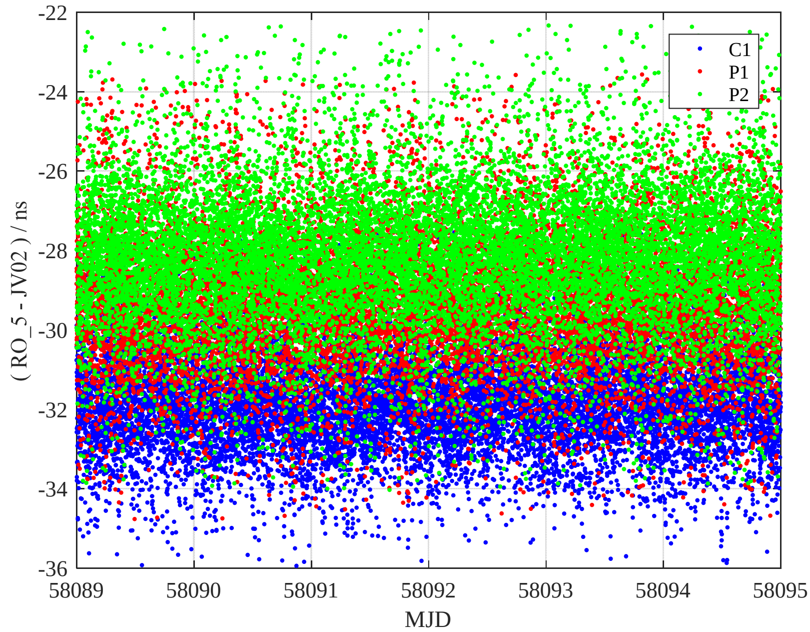
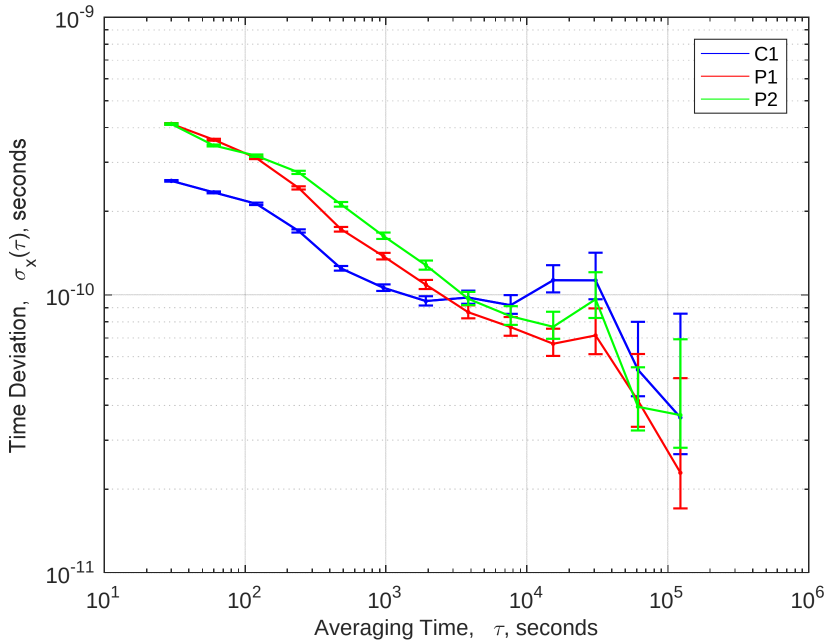


Figure 9-2: Time deviation of CCD



Acknowledgement

We are grateful to Natural Resources Canada (NRCan) for the use of their Precise Point Positioning (PPP) software for positioning computations.

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