GNSS CALIBRATION REPORT

TRANSFER OF CALIBRATION BH01-BH02

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REFERENCES

[1] PTB GNSS calibration report G1G2_1011_2019
[2] BIPM guidelines for GNSS calibration, V3.0, 02/04/2015
[3] JCGM 100:2008 Evaluation of measurement data — Guide to the expression of uncertainty in measurement,

ACRONYMS AND ABBREVIATIONS

IMBIH	Institute of metrology of Bosnia and Herzegovina
PTB	Physikalisch-Technische Bundesanstalt
BIPM	Bureau International des Poids et Mesures.
CGGTTS	Generic GNSS Time Transfer Standard.
GNSS	Global Navigation Satellite System
GPS	Global Positioning System.
IGS	International GNSS Service.
ITRF	International Terrestrial Reference Frame.
MJD	Modified Julian Date.
NMI	National Metrology Institute.
NRCan	Natural Resources Canada.
PPP	Precise Point Positioning.
RINEX	Receiver Independent Exchange Format.
TDEV	Time Deviation. Is a measure of time stability 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 NMIs
CAB DLY	Delay inside the antenna cable, including both end connectors.
INT DLY	Delay of the GNSS signal inside the antenna and the receiver
REF DLY	Time offset between the receiver internal clock and the local clock at the station

LIST OF TABLES AND FIGURES

SUMMARY

As part of G1G2 calibration trips, IMBIH receivers BH01 and BH02 were calibrated in 2019 respect to PTB reference PT09 and reported in Cal_Id=1011-2019 [1]. After that, there was a failure on power supply of BH01 GNSS board, and the receiver was sent to the manufacturer for service. As consequence of the repair, internal delays of BH01 are changed, and it was necessary to recalibrate them.

This report documents transfer of calibration from reference receiver BH02 to BH01.
The results will be reported using Cal_Id 1101-2020 and will provide internal delays for BH01 receiver for P1, P2, C1 and C2 GPS signals.

The calibration is declared to the BIPM on April 22 2020, and the measurements are done from MJD 58962 to 58968 (April 23 – April 29 2020). Data analysis and report are finished in May 2020.

1 DESCRIPTION OF EQUIPMENT AND OPERATIONS

Two IMBIH receivers, BH01 (TTS4), and BH02 (GTR51) participated in G1G2 trip Cal_Id=1011-2019, and were calibrated respect to PTB reference. After this trip there was a failure on GNSS board power supply of BH01 and it was sent to manufacturer for service. External antenna power supply is installed, with spliter and additional antenna cable connecting spliter and receiver. As a consequence, INTDLY of BH01 were changed.

This is a transfer of calibration BH02 to BH01. BH02 (GTR51) is a reference receiver (R) and BH01 is a visited receiver (V) – DUT. There is no traveling system (T) involved. Internal delays of BH01 antenna spliter, and cable connecting spliter and receiver were not measured. These delays are assumed to be zero (X_D = 0), and they are included in final INTDLY values. A complete information related with the receivers set-up and the signal distribution system have been provided in Annex-A.

Information about the calibration campaign are summarized in Table 1.

Table 1: Summary information on the calibration trip

NMI	Receiver status	Dates of measurement	Receiver type	BIPM code
IMBH	Reference	-	GTR51	BH02
IMBH	Visited	58962 - 58968	TTS4	BH01

2 DATA USED AND RAW DATA PROCESSING

The current campaign has been carried out following as much as possible the BIPM guidelines for GNSS calibrations [2]. The results will be reported using Cal_Id 1101-2020, and they will provide the visited receiver's internal delays for GPS C1, C2, P1 and P2 code signals on the two carrier frequencies L1 and L2.

The calibration has been performed based on observations provided in the RINEX observation files, using all in view GPS satellites, 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 computed from RINEX files by using the NRCan PPP software.

RAW data proccesing is done using dclrinex software from the BIPM. [1]. Annex 2 of the this report shows pseudorange values from RINEX files and a plot of the statistical analysis (TDEV) for V-R pair and for each code.

The median value, noted RAWDIF, and its uncertainty from the statistical analysis for BH01-BH02 and each code are shown in Table 2.

Table 2: Summary information on the raw calibration results

Code	RAW DIFF (ns)	uA (ns)
P1	37.112	0.2
P2	33.224	0.2
C1	38.596	0.2
C2	34.429	0.2

3 CALIBRATION RESULTS

Since the current campaign is transfer of calibration, we don't utilize traveling receiver (T), BH02 serves as reference (R), and BH01 is a visited one (V).

Receiver delays are defined as:
CABDLY is the delay of the cable from the antenna to the input connector of the receiver
INTDLY is the internal signal delay (antenna + receiver internal)
REFDLY represents the offset between the UTC reference point in the laboratory and the reference point of the receiver.

In addition:
SYSDLY = INTDLY + CABDLY
TOTDLY = SYSDLY – REFDLY

Results of Dclrinex computation for each code are noted as RAW DIFF and are equal to ΔTOTDLY. The quantity to be determined by the relative calibration is INT DLY(V-R) value for each code.

For the pair of systems V-R we note:
ΔSYSDLY(Code) = RAWDIF(Code) + REFDLY(V) – REFDLY(R)

where RAWDIF(Code) is result from dclrinex computation, shown in Table 2, and REFDLY values are taken from the "information sheets" - Annex A of this report.

ΔINTDLY(Code) = ΔSYSDLY(Code) – CABDLY (V) + CABDLY(R)

where the values CABDLY are taken from the "information sheets".

Table 3 shows REFDLY and CABDLY values for both receivers, while Table 4 shows steps to calculate ΔINTDLY for each code.

Table 3: REFDLY and CABDLY values from information sheets

Receiver	**REFDLY (ns)**	**CABDLY (ns)**
BH01	10.81	145.33
BH02	7.60	128.20

Table 4: Steps to calculate ΔINTDLY for BH01-BH02

Code	RAW DIF (ns)	ΔSYSDLY (ns)	ΔINTDLY (ns)
P1	37.11	40.32	23.19
P2	33.22	36.43	19.30
C1	38.60	41.81	24.68
C2	34.43	37.64	20.51

4 UNCERTAINTY ESTIMATION

Uncertainty estimation follows the guidelines described in [3].
The overall uncertainty of the INT DLY values is given by:

$$u_{CAL} = \sqrt{uA^2 + uB^2}$$

where uA represent statistical uncertainty from TDEV (Table 2) and uB represent systematic uncertainty given by

$$u_B = \sqrt{\sum_n u(b,n)^2}$$

All values are considered to be 1-sigma. Values P3 are computed as P1 + 1.545*(P1-P2).
The contributions to the total uncertainty are listed in Table 5.

Table 5: Uncertainty contributions

Uncertainty	Code				Description
	P1 (ns)	P2 (ns)	P1-P2 (ns)	P3 (ns)	
uA	**0.2**	**0.2**	**0.3**	**0.5**	RAWDIF TDEV at 1000s
uB1	0.1	0.1	0.1	0.2	Position error of reference
uB2	0.1	0.1	0.1	0.2	Position error of visited
uB3	0.2	0.2	0.3	0.5	Multipath at reference
uB4	0.2	0.2	0.3	0.5	Multipath at visited
uB5	0.3	0.3	0	0.3	REFDLY(R)
uB6	0.3	0.3	0	0.3	REFDLY(V)
uB7	0.3	0.3	0	0.3	CABDLY(R)
uB8	0.3	0.3	0	0.3	CABDLY(V)
uB9	0.1	0.1	0	0.1	TIC nonlinearities
uB	**0.7**	**0.7**	**0.4**	**1.0**	uB Total
uCAL	**0.7**	**0.7**	**0.5**	**1.1**	Overall uncertainty

5 FINAL RESULTS

INT DLY of the device under test is determined in such a way that the common-clock differences obtained between the device under test and the reference are zero on average.
The final results for receiver V are calculated as:

INTDLY(V)(Code) = INTDLY(R)(Code)+ΔINTDLY(V-R)(Code).

Table 6 shows new INTDLY values for each code to be entered in BH01.

Table 6: Final results

Reference system	Cal_Id	Date		INTDLY P1 (ns)	INTDLY P2 (ns)	INTDLY C1 (ns)	INTDLY C2 (ns)
BH02	1011-2019	2019.09		30.20	29.80	30.20	7.80
Visited system	Cal_Id		U_{CAL}(P3) (ns)	INTDLY P1 (ns)	INTDLY P2 (ns)	INTDLY C1 (ns)	INTDLY C2 (ns)
BH01	1101-2020	2020.04	1.1	53.39	49.10	54.88	28.31

ANNEX A – INFORMATION SHEET

Table 7 Information sheet

Laboratory:	IMBH	
Date and hour of the beginning of measurements:	1	23.04.2020. 00:00:00
Date and hour of the end of measurements:	2	29.04.2020. 23:59:59
Information on the system		
	Local:	**Reference:**
4-character BIPM code	BH01	BH02
• Receiver maker and type:	PikTime Systems, TTS4	Mesit, GTR 51
Receiver serial number:	142	1808032
1 PPS trigger level /V:	1.0	1.0
• Antenna cable maker and type:	FSJ1-50A - 1/4" Andrew Heliax	Belden, 50 Ω, low loss, H155 PVC
Phase stabilised cable (Y/N):	N	N
Length outside the building /m:	Approx. 25	Approx. 25
• Antenna maker and type:	Javad, RingAnt-G3T Antenna	Novatel GNSS-850
Antenna serial number:	00455	NMLK18070098S
Temperature (if stabilised) /°C	47 ± 1	45 ± 1
Measured delays /ns		
	Local:	**Reference:**
• Delay from local UTC to receiver 1 PPS-in:	10.00	7.60
Delay from 1 PPS-in to internal Reference (if different):	0.81 (phase corr.)	
• Antenna cable delay:	144.76	128.20
Splitter delay (if any):	X_D=0	
Additional cable delay (if any):	0.57 (Surge arrester)	
Data used for the generation of CGGTTS files		
• INT DLY (GPS) /ns:	46.74(P1),51.37(P2),46.59(C1),50.90 (C2)	30.20(P1),29.80(P2),30.20(C1),7.80 (C2)
• INT DLY (Galileo) /ns:		
• INT DLY (GLONASS) /ns:		
• CAB DLY /ns:	145.33	128.20
• REF DLY /ns:	10.81	7.60
• Coordinates reference frame:	ITRF	WGS-84
Latitude or X /m:	+4371185.02	4371185.0
Longitude or Y /m:	+1454855.04	1454855.8
Height or Z /m:	+4397063.11	4397062.7
General information		
• Rise time of the local UTC pulse:	1.47 ns	1.47 ns
• Is the laboratory air conditioned:	Yes	Yes
Set temperature value and uncertainty:	23 ± 1 °C	23 ± 1 °C
Set humidity value and uncertainty:	45 ± 10 % RH	45 ± 10 % RH

Figure 1: Diagram of experiment setup

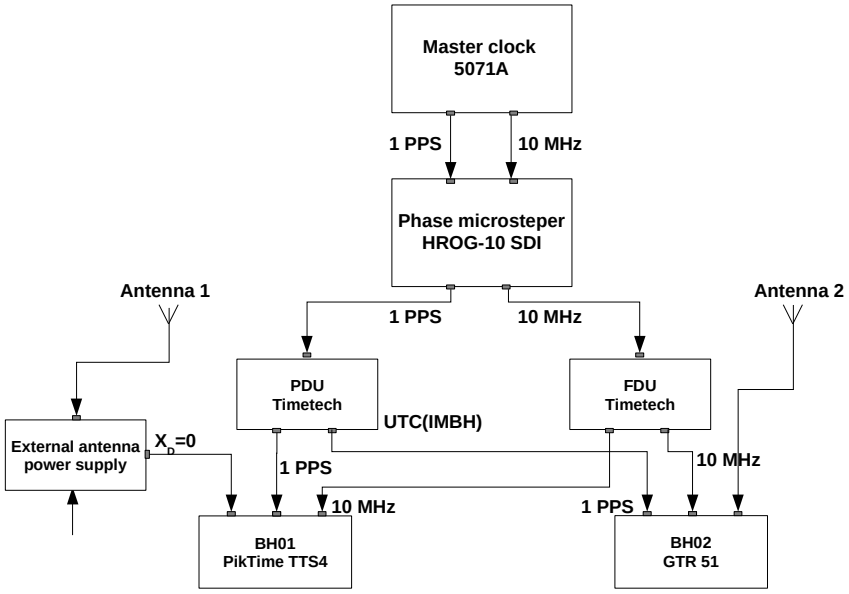
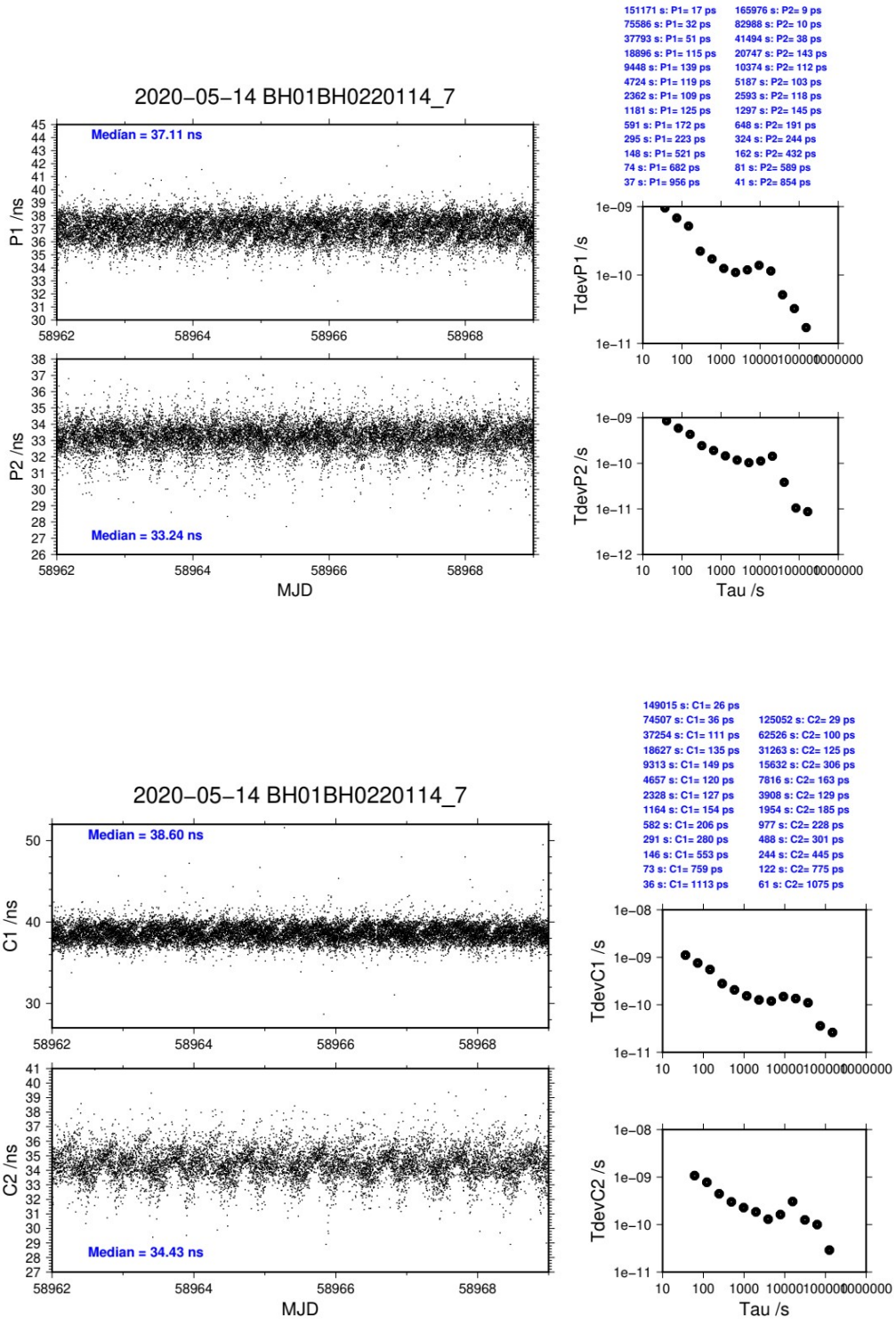


Figure 2: Antenna roof positions

ANNEX B PLOTS OF RAW DATA AND TDEV ANALYSIS

Figure 3: Plots of RAW data and TDEV analysis



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