GNSS CALIBRATION REPORT

G1G2_1019_2021

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REFERENCES

REFERENCES	
RD01	**BIPM report 2021**
RD02	**BIPM guidelines for GNSS calibration, V3.0, 02/04/2015**
RD03	**BIPM TM.212 (G. Petit), Nov. 2012**
RD04	**J. Kouba, P. Heroux, 2002, *"Precise Point Positioning Using IGS Orbit and Clock Products,"* GPS Solutions, Vol 5, No. 2, 12-28**
RD05	**W. Lewandowski, C. Thomas, 1991, *"GPS Time transfers,"* Proc. IEEE, Vol. 79, No. 7, 991-1000**
RD06	**P. Defraigne and G. Petit, "CGGTTS-Version 2E: an extended standard for GNSS time transfer", Metrologia 52 (2015) G1**

ACRONYMS

ACRONYMS	
BIPM	**Bureau International des Poids et Mesures, Sèvres, France**
CGGTTS	**CCTF Generic GNSS Time Transfer Standard**
EMI	**Emirates Metrology Institute**
ESA	**European Space Agency**
EURAMET	**The European Association of National Metrology Institutes**
IGS	**International GNSS Service**
GNSS	**Global Navigation Satellite System**
PPP	**Precise Point Positioning**
PTB	**Physikalisch-Technische Bundesanstalt, Braunschweig, Germany**
RINEX	**Receiver Independent Exchange Format**
R2CGGTTS	**RINEX-to CGGTTS conversion software, provided by ORB / BIPM**
UAE	**United Arab Emirates**
TDEV	**Time Deviation**
TIC	**Time Interval Counter**

EXECUTIVE SUMMARY

As part of the support of the BIPM Time and Frequency Group by EURAMET G1 laboratories, PTB conducted a relative calibration of GPS equipment of EMI, United Arab Emirates, with respect to the calibration of PTB receiver PT13, which currently serves as the reference receiver in all GNSS time links to PTB in the context of realization of TAI. The PT13 signal delays for GPS and Galileo were determined by BIPM as reported with CAL_ID 1001-2020 [RD01]. PTB provided its receiver PTBT for the purpose as traveling equipment. PTBT is a GPS-only receiver, adapted to the situation of EMI where a single-frequency (L1C) receiver is operated. The current campaign followed as much as possible the BIPM Guide [RD02] and results will be reported using Cal_Id 1019-2021. Primary result provided is the visited receiver's internal delay for GPS C/A code signals on frequency L1.

The results are included in Table 9-1. The internal delay of the receiver involved was determined with an uncertainty of 1.5 ns for single frequency observations.

As a reminder: All uncertainty values reported in this document are 1-σ values.

PTB quality management responsible gave the advice to stress in this report that the correctness of all results and of the stated uncertainty values relies partially on the correctness of the entries in the installation report (BIPM information tables) provided by the visited institute.

1. CONTENTS OF THE REPORT

As part of the support of the BIPM Time and Frequency Group by EURAMET G1 laboratories, PTB conducted a relative calibration of GPS equipment of EMI, United Arab Emirates, with respect to the calibration of PTB receiver PT13, which currently serves as the reference receiver in all GPS time links to PTB in the context of realization of TAI. The PT13 signal delays for GPS were determined by BIPM as reported with CAL_ID 1001-2020 [RD01]. PTB provided its receiver PTBT for the purpose as traveling equipment. PTBT is a GPS-only receiver, adapted to the situation of EMI where a single-frequency (L1C) receiver is operated. The current campaign followed as much as possible the BIPM Guide [RD02] and results will be reported using Cal_Id 1019-2021. Primary result provided is the visited receiver's internal delay for GPS C/A code signals on frequency L1.

This report documents the installation, data taking and evaluation during the campaign.

The determination of the internal delay values of the receiver at the visited site is a three-step process.

At first (Common-Clock 1, CC1), the traveling receiver, PTBT, was compared to the "golden" receiver, PT13, and the offset between the actual and the assumed PTBT delay value was determined.

After that, the receiver was installed at the visited site and the internal delay value of the device under test and its statistical properties were determined with respect to PTBT.

Finally, the stability of the PTBT delays was assessed by a second Common-Clock measurement (CC2) in PTB. Based thereon, the "final" INT DLY value of the visited receiver and its uncertainty value were calculated.

The structure of this report follows this sequence of work. After presentation of the participants and schedule, a general section follows that contains the (mathematical) calibration procedure, followed by a report of data collection at PTB and EMI. The final result and the uncertainty discussion close the report. In the Annex the BIPM information tables are reproduced.

1.1. CHANGE LOG

Version	Date	Changes
01	08.11.2021	Version 01, all new
02	16.02.2022	Version 02, including results obtained at EMI, UAE
1	24.02.2022	Update from EMI, CC2 results included
1.1	09.03.2022	Typos corrected, information on local receiver improved

2. PARTICIPANTS AND SCHEDULE

Table 2-1 List of participants

Institute	Point of contact	Site address
PTB	Thomas Polewka Tel +49 531 592 4418 Thomas.polewka@ptb.de	PTB, AG 4.42 Bundesallee 100 38116 Braunschweig, Germany
EMI	Jon Bartholomew Office +97124066525 Fax +97124066677 Mobile +97150386267 Jon.Bartholomew@qcc.gov.ae	Emirates Metrology Institute Abu Dhabi Quality and Conformity Council Kryptolabs Building Masdar City Abu Dhabi UAE

Table 2-2 Schedule of the campaign

Date	Institute	Action	Remarks
2021-10-17 until 2021-10-23	PTB	First common-clock comparison between PTBT and PT13	7 days used for determination of delays, MJD 59504 – 59510
2022-01-19 until 2022-01-24	EMI	Operation of PTBT in parallel with local equipment	7 days used for determination of delays. MJD 59598 - 59604
2022-02-16 until 2022-02-21	PTB	Operation of PTBT after return	days used for determination of delays, MJD 59626 - 59631

Information on the receivers at each site is contained in individual information tables which can be found in the Annex.

3. CALIBRATION PROCEDURE

3.1. GENERAL DESCRIPTION

The calculation of INT DLY values for the receiver to be calibrated follows to the extent possible the description given in BIPM TM.212 [RD03]. When dealing with G1G2 calibrations, in principle we distinguish receivers V, T, and G: V for visited, T for traveling, and G for golden_reference. G1 labs committed to ship their T to the other sites. In the current campaign, PT13 (named PTBB when referred to as IGS station) serves as the reference receiver G. Its delays were determined recently by BIPM, Cal_Id=1001-2020 [RD01]. PTBT served as the traveling receiver T.

Conventionally, the receiver delay D is considered as the sum of different terms that are defined subsequently:

(1) INT DLY

The sum $X_R + X_S$ represents the “INT DLY” field in the CGGTTS header:
X_R represents the receiver hardware delay, between a reference point whose definition depends on the receiver type and the internal time reference of the measurements. X_S represents the antenna delay, between the phase center and the antenna cable connector at the antenna body.

As the equipment at EMI contains a C/A-code L1 GPS multichannel receiver only, the only one delay is

The following terms are considered frequency independent, i. e. no distinction is made for f1 and f2.

(2) CAB DLY

The sum $X_C + X_D$ represents the “CAB DLY” field in the CGGTTS header.
X_C corresponds to the delay of the long cable from the antenna to the input connector at either the antenna splitter or the receiver body directly. If a splitter is installed, X_D corresponds to the delay of the splitter and the small cable up to the receiver body. For a simple set-up with just an antenna cable, $X_D = 0$.

(3) REF DLY

The sum $X_P + X_O$ represents the “REF DLY” field in the CGGTTS header.
X_P corresponds to the delay of the cable between the laboratory reference point for local UTC and the 1 PPS-in connector of the receiver.
X_O corresponds to the delay between the 1PPS-in connector and the receiver internal reference point, the latter depending on the receiver type:

- For Septentrio PolaRx4: Xo available at the the 1 PPS-out socket of the receiver
- For Septentrio PolaRx5TR (PT13): optionally Xo is determined autonomously by the receiver or it can be determined alike to the PolaRx4.
- For DICOM GTR50 (PTBT), GTR51 and GTR55: $X_O = 0$,

For clarity, `Figure 3-1` shows the traveling equipment in two views, in idle modus, left and with indications of the cable connections. A detailed operations guide has been distributed beforehand.

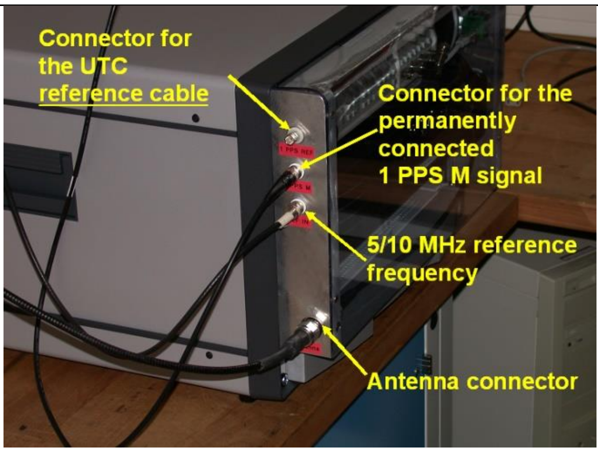

Figure 3-1 PTBT: views of the device.

The distinction of the individual components of the receiver delay reflects the fact that two of them, 2 and 3, can in principle be measured with standard laboratory equipment. Changes of the receiver installation typically affect cabling and thus such delays.

The quantity to be determined by the relative calibration is INT DLY. 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 INT DLY of T may need to be adjusted so that T and G match, but in practice the small correction needed is considered only when INT DLY of V is adjusted to G, using T as intermediate for the measurements made at the different sites.

In the process followed in the current campaign, valid CGGTTS files with single-frequency C/A-code observations are needed. As a reminder,

$$REFSYS(j) = [REFSYS_{RAW}(j) - CAB\ DLY_F - INT\ DLY(L1C)_F + REF\ DLY_F] \quad (1)$$

for reporting results of observation of satellite “j” is valid and reported in column 10 of the standard CGGTTS files. $REFSYS_{RAW}$ designates the uncorrected measurement values, and the values designated as “Q_F” are reported in the CGGTTS file header.

If the common-view condition is fulfilled for the observations with T and G, the differences

$$\Delta ID(L1C)\ (T,G) := REFSYS(T) - REFSYS(G) \quad (2)$$

are calculated and represent the difference delay(new) – delay(old) for receiver T. The example here involves T and G: Equivalent relations hold for the pair of receivers T and V.

The software provides the median value of all individual observations ΔID(L1C) for C/A code L1 CV differences, and the number of data points used. In addition, a file that contains observation epoch

(MJD.frakt) and the average ΔID(L1C) of all satellite observations at that epoch (duration 13 minutes) is generated. Such values are plotted throughout the report in the various figures.

The calculation of the INT DLY values comprises two steps:

Step 1: INT DLY_T_corr = ΔID(T,G) + INT DLY_T_old, (3)

where the last summand >_old < is the value reported in the CGGTTS file up to now.

Step 2: The final results for receiver V is to be calculated as

INT DLY_V_new = ΔID (V,T) + <ΔID(T,G)> + INT DLY_V_old, (4)

where <ΔID(T,G)> is the mean value obtained during CC1 and CC2. Another option would have been to adjust the INT DLY of receiver T after CC1, but this was not done.

The third summand in (4) on the right represents the INT DLY value that was reported previously in the CGGTTS file of receiver V. In some cases, this value may be reported initially as zero.

4. CHARACTERIZATION OF PTB EQUIPMENT

PTBT had been idle for several months as recently G1G2 calibrations should be performed using a GNSS travelling receiver that is able to track Galileo. No recent long-term observations are available. In the past PTBT had been employed in many G1G2 campaigns, the last one was reported with Cal_ID 1013-2019.

The installation of the receivers in PTB is depicted in Figure 4-1 for PPS signals and in Figure 4-2 for 5 MHz (and 10 MHz) signals.

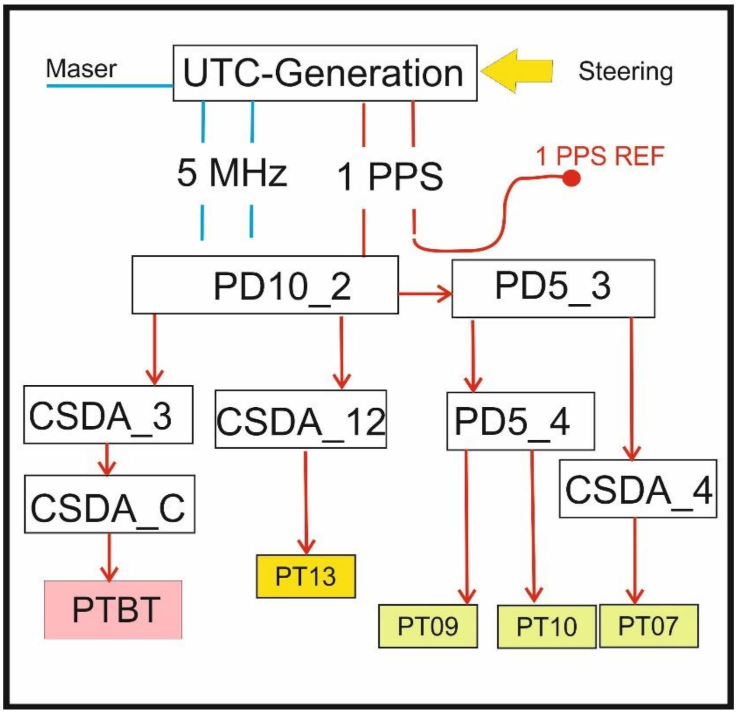

Figure 4-1 UTC(PTB) reference point and 1 PPS signal distribution to PT13, PTBT, and other receivers; PD10 stands for pulse distributor, CSDA stands for clock signal distribution amplifier

A clarification may be helpful regarding the 1 PPS REF point. When measuring with a TIC the time difference between Port A = UTC(PTB), and Port B = 1 PPS REF, then the result is +2.7 ns. Figure 4-3 illustrates the installation of GNSS antennas on the roof of the PTB time laboratory (clock hall) during CC1.

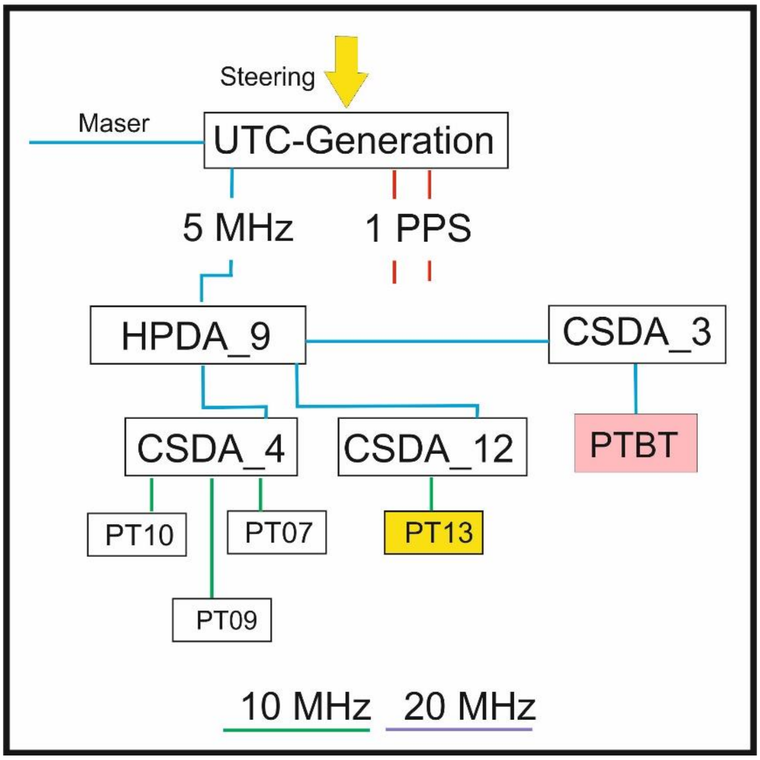

Figure 4-2 UTC(PTB) signal distribution (5 MHz, 10 MHz) to PT13, PTBT, and other receivers
HPDA stands for High-precision distribution amplifier (for rf frequencies)

Figure 4-3 Installation of GNSS antennas at PTB, PT13 antenna (yellow) and PTBT antenna during CC1 and CC2 (orange)

5. RESULTS OF COMMON-CLOCK SET-UP IN PTB: PERIOD 1

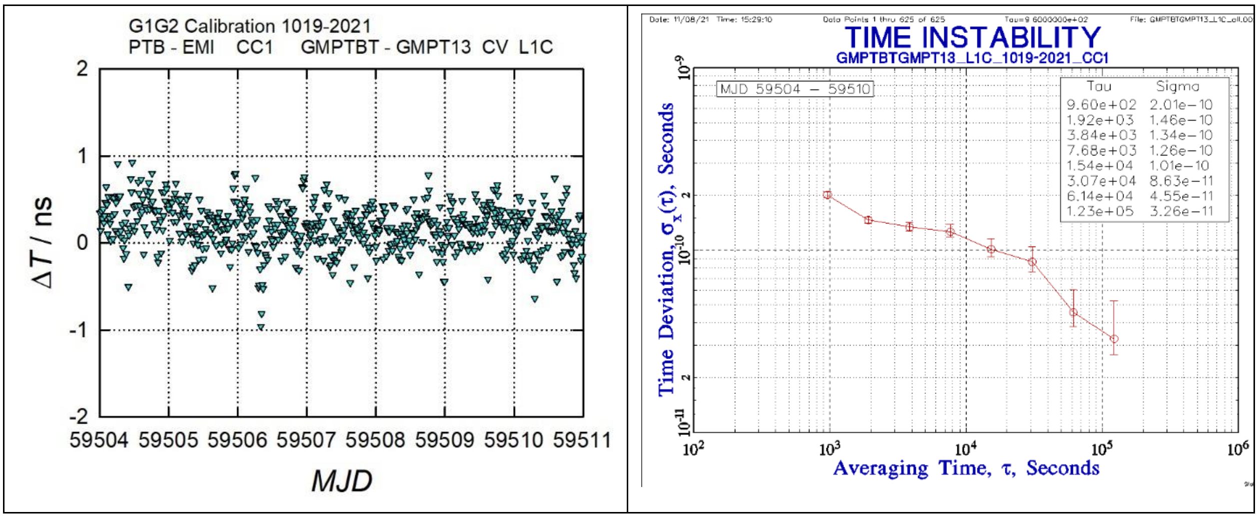

Figure 5-1 Left: Corrections to GPS L1C delay in PTBT during CC1, and TDEV obtained for the data

The period 59504 to 59510 (7 days) was chosen to determine the initial PTBT INT DLY value (CC1). The result of comparison with PT13 as the reference are shown in Figure 5-1 illustrating in total 617 values obtained as mean over all common view observations at a given epoch. The time instability (TDEV) plot for the data set is seen in the right plot.

6. OPERATION OF PTBT AT EMI

PTBT was operated at EMI in January 2022 after a long procedure of getting the device shipped from PTB and released from customs inspection. EMI operates a Primary Time Scale System, manufactured by Symmetricom, Model Number PTSS#0001, Serial Number U22026. Its embedded GPS receiver is a single frequency (L1C) receiver only.

The PPS and 10 MHz signal distribution to receiver PTBT and the EMI receiver is via the backplane connector at the right of the system scheme shown in Figure 6-1 . The PTBT 1 PPS REF input was connected to the cable at J01. This cable is at the defined “on-time point” of the system. The 1 PPS M was connected to J02 through another cable. REF IN (10 MHz) was connected to J12 through a similar cable. The EMI receiver with designation AE__ is hard-wire connected to the backplane without any external cable.

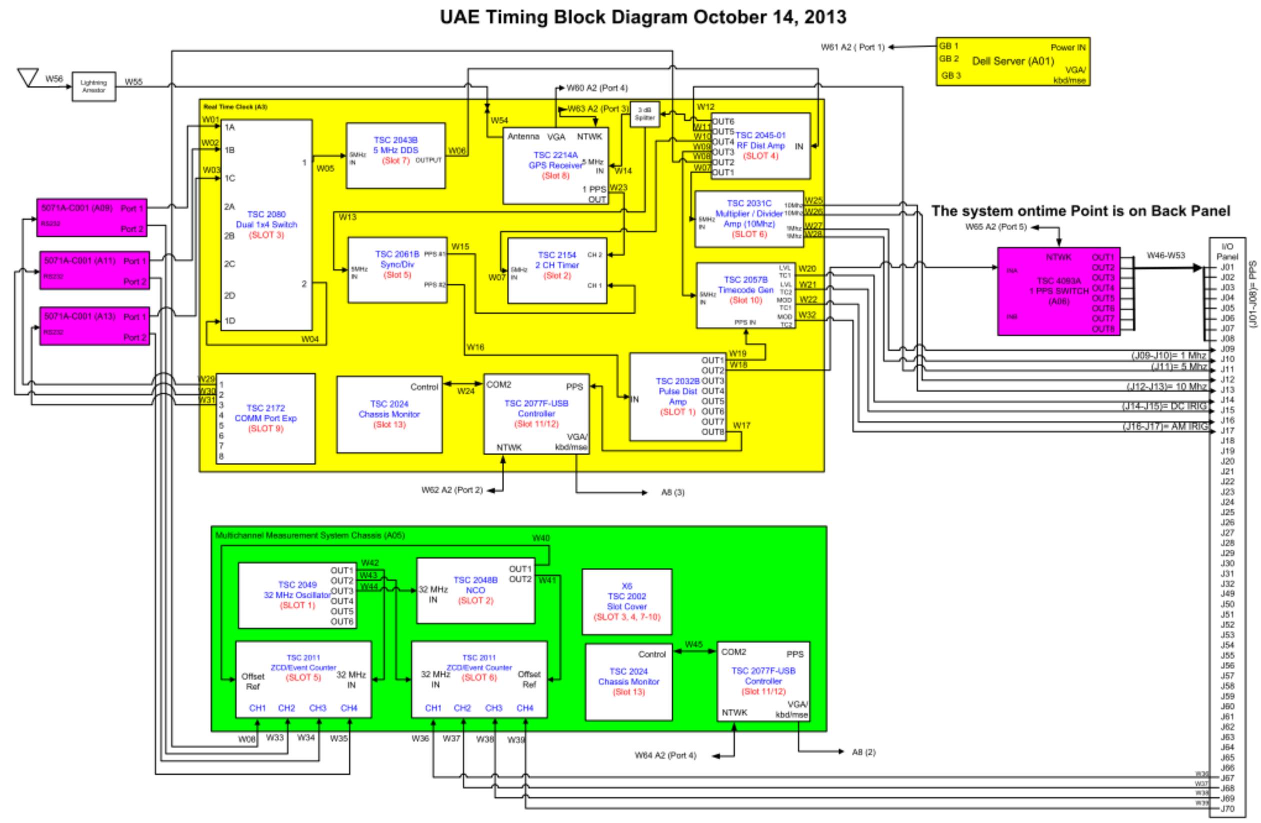

Figure 6-1 EMI Primary Time Scale System

The antenna installation at EMI is illustrated in Figure 6-2. PTBT was operated with its own antenna and antenna cable.

Figure 6-2 Antenna installation at EMI

6.1. CALIBRATION OF L1C RECEIVER DELAY OF THE EMBEDDED RECEIVER

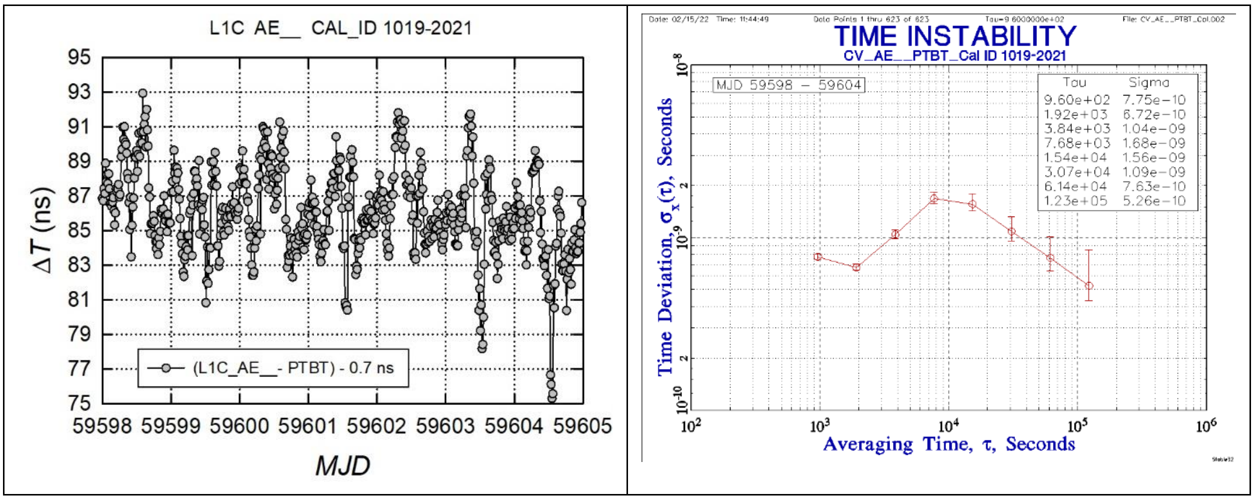

FIGURE 6-3 Left: Corrections to GPS INT DLY (L1C) in AE__, reference PTBT; right: TDEV calculated from the values shown in the left panel.

In FIGURE 6-3 the L1C delay derived from the raw data are depicted. The results are collected in Table 6-1 which contains the mean and the median value, the standard deviation of individual data points and an estimate for the statistical uncertainty which is derived from TDEV at τ = 50 000 s.

Table 6-1 Results obtained at EMI (UAE)

	Mean (ns)	Median (ns)	Sigma (ns)	TDEV (ns)	N
AE__ L1C delay ((ns)	86.05	85.94	2.51	0.8	623

The values were corrected for a flaw in generating the PTBT CGGTTS files with incorrect CAB DLY (0.7 ns too small).

7. OPERATION AT PTB: SECPOND PERIOD

The period 59626 to 59631 (6 days) was chosen to determine the PTBT INT DLY value during the common clock period CC2. The results of comparison with PT13 as the reference are shown in Figure 7-1, illustrating ΔIDi values obtained as mean values over all common view observations at a given epoch. Two data sets are shown overlaid: The pink data result from a standard common-view analysis based on CGGTTS files GM.. in which the REFSYS is corrected for the ionospheric delay (MDIO). Apparently, the software evaluating the GPS navigation message is different in the two receivers. One may safely ignore the ionospheric correction as both antennas are close to each other. This results in the black dots. Results reported are based on this data. The time instability (TDEV) plot is shown in the right of Figure 7-1.

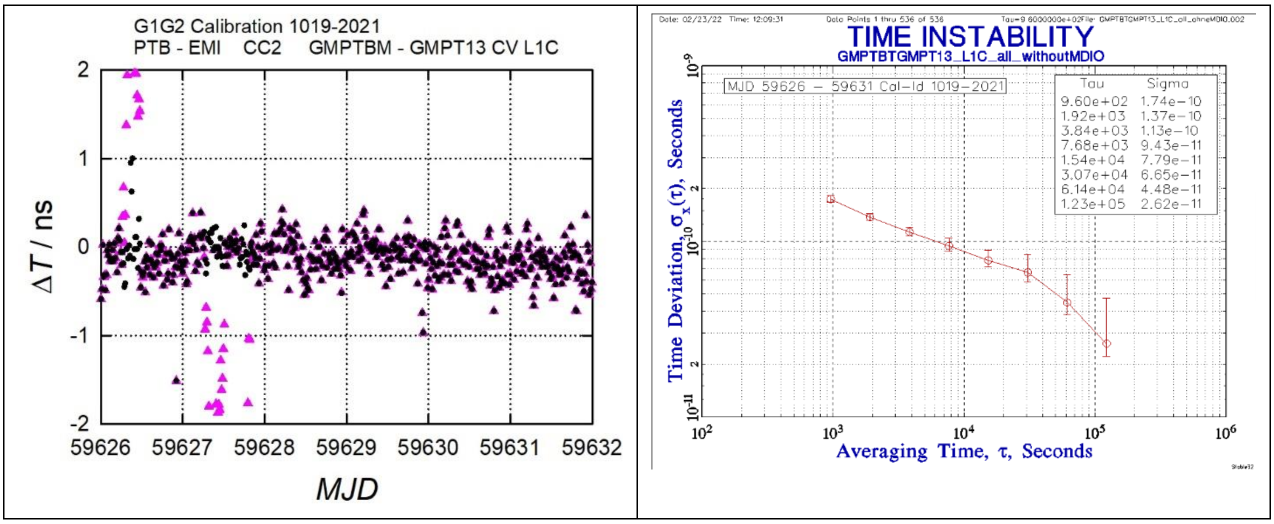

Figure 7-1 PTBT GPS delay (L1C) correction obtained during CC2 and TDEV for the data set

7.1. SUMMARY OF CAMPAIGNS CC1 AND CC2

The numerical results of the two common-clock campaigns at PTB are given in Table 7-1. The change noted between CC1 and CC2 amounts 0.29 ns. For the evaluation of the delays of the visited receiver the mean value is used. The estimate of the uncertainty contribution is given in Section 8.

Table 7-1 Result of common clock measurements CC1 and CC2 at PTB

Quantity	Median (ns)	Sigma (ns)	TDEV (ns)
ΔC1 (CC1)	0.18	0.26	0.1
ΔC1 (CC2)	-0.11	0.22	0.1
Mean values used for evaluation of EMI receiver's internal delays			
ΔC1	0.04		

8. INT DLY UNCERTAINTY EVALUATION

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

$$\mathrm{u_{CAL}} = \sqrt{\mathrm{u_a^2} + \mathrm{u_b^2}}\,, \tag{6}$$

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 EMI and PTB, respectively. The systematic uncertainty is given by

$$\mathrm{u_b} = \sqrt{\sum_n \mathrm{u}_{\mathrm{b},n}}. \tag{7}$$

The contributions to the sum (7) are listed and explained subsequently.

Note that the uncertainty of the INT DLY values of PTB's fixed receiver PT13 (G) which served as the reference is not included.

Table 8-1 Uncertainty contributions for the calibration of receiver delays at EMI

	Uncertainty	Value L1C (ns)	Description
1	u_a (PTB)	0.1	CC measurement uncertainty at PTB, TDEV max. of the two CC campaigns
2	u_a(EMI)	1.0	CC measurement uncertainty, for the EMI receiver
3a	$u_{b,1}$ (GPS)	0.30	Misclosure, see Table 7-1
4	$u_{b,11}$	0.1	Position error at PTB
5a	$u_{b,12}$(EMI)	0.1	Position error at EMI
6	$u_{b,13}$	0.2	Multipath at PTB
7	$u_{b,14}$	0.2	Multipath at EMI
8	$u_{b,21}$	0.2	Connection of PTBT to UTC(PTB) (REF DLY)
9	$u_{b,22}$	0.5	Connection of PTBT to UTC(UAE) (REF DLY)
10	$u_{b,23}$	0.5	Connection of AE__ at EMI to UTC(UAE) (REF DEL)
11	$u_{b,31}$(PTB)	0.5	Uncertainty estimate for the PTBT CAB DLY when installed at PTB
12	$u_{b,32}$(EMI)	0.0	Uncertainty estimate for the PTBT CAB DLY when installed at EMI
13	$u_{b,33}$(EMI)	0.5	Uncertainty estimate for AE__ CAB DLY value

The single-frequency receiver embedded in the Symmetricom Primary Time Scale System provides significantly more noisy data than PTBT. The data scatter is even larger when the MDIO correction is suppressed.

The uncertainty contribution $u_{b,1}$ is based on the difference between the two common clock campaigns involved. The respective differences from the mean value exceed the statistical measurement uncertainty by at least a factor of 2. The difference itself is thus considered as measure for the uncertainty.

For the generation of the CGGTTS data, the PTBT antenna position is manually entered into the processing software in ITRF coordinates before the CC evaluation at both sites. These positions could in principle differ from the "true" positions in a different way in each laboratory. This is considered by the contributions $u_{b,11}$ and $u_{b,12}$. In the current campaign it was confirmed that the antenna coordinates were determined for all masts involved consistently and the contribution is 0.1 ns at maximum.

An uncertainty contribution due to potential multipath disturbance is added as $u_{b,13}$ and $u_{b,14}$. If at a given epoch in time the recorded time differences REFSYS would be biased by multipath, this might change with time due to the change in the satellite constellation geometry. [RD05] gives an estimate that has often been referred to. It was agreed at the 2017 meeting of the CCTF WG on GNSS that a 0.2 ns-uncertainty should be attributed to the multipath effect.

The uncertainties of the connection of the receivers to the local time scales ($u_{b,21}$, $u_{b,22}$, $u_{b,23}$) has been estimated 0.2 ns for the internal set-up at PTB and as 0.5 ns at EMI.

The measurement of antenna cable delays causes contributions $u_{b,31}$, $u_{b,32}$ and $u_{b,33}$. During the current campaign the same PTBT cable was employed at each occasion. CAB DLY values were measured at PTB in previous campaigns, with the cable rolled out and also with the cable on the spool. Each measurement was made with a differential method so that the TIC-internal error should be small anyway. All results agreed within 0.1 ns as long as the same PPS signal source was used. Differences up to 0.5 ns were noted when the slew rate of the pulse was significantly different. We retain an uncertainty contribution $u_{b,31}$ of 0.5 ns. For the stationary antenna cable at EMI we conservatively assume the same uncertainty of the delay value.

Note anyway that this uncertainty contribution $u_{b,33}$ a priori has no impact on the uncertainty of the time transfer link between PTB and the visited institute. If the stated CAB DLY for the visited fixed receiver(s) would be erroneous, this would be absorbed in the INT DLY values produced as a result of the campaign.

9. FINAL RESULTS

The results of the calibration campaign G1G2_1019_2021 are summarized in Table 9-1. They contain the designation of the visited receiver, the INT DLY values hitherto used, the offsets ΔIDi(V,T) and ΔIDi(T,G) (see Section 5, (5)), the new INT DLY values to be used with consent by BIPM, and the uncertainty with which the new values were determined. For calculation, the respective entries from Table 8-1 were used. Intermediate delays and uncertainties are reported here with two decimal points. According to [RD06], in CGGTTS V2E file headers all delays should be reported with one decimal only. So the final results to be reported are rounded to one decimal.

Table 9-1 Results of the Calibration Campaign G1G2_1019_2021: GPS delays, all values in ns

Receiver	INT DLY(L1C), old	Δ(L1C) (V,T)	Δ(L1C) (T,G)	INT DLY(L1C), new	u_{cal},L1C
AE__	0.0	85.94	0.04	85.98	1.50

ANNEX: BIPM CALIBRATION INFORMATION SHEETS

First common clock measurement at PTB

Laboratory:	**PTB**
Date and hour of the beginning of	2021-10-17 0:00 UTC (MJD 59504)
Date and hour of the end of measurements:	2021-10-23 24:00 UTC (MJD 59510)

Information on the system		
	Local:	**Traveling:**
4-character BIPM code	**PT13**	**PTBT**
Receiver maker and type: Receiver serial number:	PolaRx5TR (5.2.0) S/N 470 1292	Dicom GTR50 0708522 1.7.7
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	ECOFLEX15	LMR-400 (N)
Length outside the building /m:	approx. 25	25
Antenna maker and type: Antenna serial number:	LEICA AR25 726333, Calib Geo++ 18.08.2015	Navexperience 3G+C NA 0164
Temperature (if stabilized) /°C		

Measured delays /ns		
	Local:	**Traveling:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	9.59 ± 0.1 (#)	44.3
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	46.63 ± 0.1 (#)	N/A
Antenna cable delay: (X_C) / ns	205.7 ± 0.1	208.7 ± 0.5
Splitter delay (if any):	N/A	

Data used for the generation of CGGTTS files				
	LOCAL:		Traveling	
☐ INT DLY (or X_R+X_S) (GPS) /ns:	33.6 (C1)*		-36.0 (C1) (****)	
☐ CAB DLY (or X_C) /ns:	205.7		208.7	
☐ REF DLY (or X_P+X_O) /ns:	56.2		44.3	
☐ Coordinates reference frame:	ITRF		ITRF	
X /m:	+3844059.86 (***)	Mast P10	+3844062.56 ($)	Mast P7
Y /m:	+709661.56 (***)		+709658.49 ($)	
Z /m	+5023129.87 (***)		+5023127.88 ($)	

General information	
☐ Rise time of the local UTC pulse:	3 ns

☐ Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	23.0 °C, peak-to-peak variations 0.5° C

Notes valid for CC1 – CC2:

(#) Local measurements repeated on occasion of campaign 1001-2020.

($) Coordinates of mast P7 (APC) were determined on 26.05.2020 using NRCan PPP

(*) values based on G1 calib 1001-2020 [RD01]]

(***) values provided by BIPM via Mail 2019-08-07
(****) PTBT INT DLY were adjusted so that PTBT – PT13 for GPS is close to zero for convenience.

Names of files to be used in processing for site PTB
Travelling receiver GMPTBTMJ.DDD
Reference receiver GMPT13MJ.DDD

PTBT operation at EMI: Receiver AE__

Laboratory:	**EMI**
Date and hour of the beginning of measurements:	2022-01-19 00:00 UTC (59598)
Date and hour of the end of measurements:	2022-01-25 24:00 UTC (59604)

Information on the system		
	Local:	**Travelling:**
4-character BIPM code	**AE__**	**PTBT**
Receiver maker and type: Receiver serial number:	NovAtel "L12LV" "DAB12480079" 2013 "3.907"	DICOM GTR50 0708522 1.7.7
1 PPS trigger level /V:		1.0
Antenna cable maker and type: Phase stabilised cable (Y/N):	N-type, LMR400	N-type, LMR400
Length outside the building /m:	15	??
Antenna maker and type: Antenna serial number:	Mira Vista Technologies, Model Number MVT-TSA-110M, Serial Number E910	Navexperience 3G+C NA 0164
Temperature (if stabilised) /°C	Yes 40.6 °C (105 F)	No

Measured delays /ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	0.0(#)	10.8
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	N/A	N/A***
Antenna cable delay: (X_C) / ns	127.0	208.0 ++
Splitter delay (if any):	N/A	N/A
Additional cable delay (if any):	N/A	N/A

Data used for the generation of CGGTTS files		
	LOCAL:	
☐ INT DLY (or X_R+X_S) (GPS) /ns:	(C/A L1C) 0.0	-36.0 (C1)
☐ CAB DLY (or X_C) /ns:	127.0	208.7
☐ REF DLY (or X_P+X_O) /ns:	0.0	10.8
☐ Coordinates reference frame:	ITRF	ITRF
X /m:	3364701.70	+3364697.50
Y /m:	4736632.07	+4736634.92
Z /m	2622434.62	+2622431.16

General information	
☐ Rise time of the local UTC pulse:	~2 ns
☐ Is the laboratory air conditioned:	yes

Set temperature value and uncertainty:	23 °C ± 1 °C

All coordinates (APC) checked before the start of data taking using RINEX files and NRCan PPP routine. Deviations from the values in the files < 2 cm.

AE__ is hard-wire connected to the backplane without any external cable. The REF DLY is thus zero by design.

++ GMPTBT files were generated with the wrong entry for CAB DLY, 208.0 ns instead of 208.7 ns. Results shown in Section 6 and thereafter have been corrected for the flaw.

Names of files to be used in processing for AE__

Traveling receiver GMPTBTMJ.DDD, DUT: GMAE__MJ.DDD

Second common clock measurement at PTB

Laboratory:	**PTB**		
Date and hour of the beginning of	2022-02-16 0:00 UTC (MJD 59626)		
Date and hour of the end of measurements:	2022-02-21 24:00 UTC (MJD 59631)		
Information on the system			
	Local:	**Traveling:**	
4-character BIPM code	**PT13**	**PTBT**	
Receiver maker and type: Receiver serial number:	PolaRx5TR (5.2.0) S/N 470 1292	Dicom GTR50 0708522 1.7.7	
1 PPS trigger level /V:	1	1	
Antenna cable maker and type: Phase stabilised cable (Y/N):	ECOFLEX15	LMR-400 (N)	
Length outside the building /m:	approx. 25	25	
Antenna maker and type: Antenna serial number:	LEICA AR25 726333, Calib Geo++ 18.08.2015	Navexperience 3G+C NA 0164	
Temperature (if stabilized) /°C			
Measured delays /ns			
	Local:	**Traveling:**	
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	9.33 ± 0.1 (#)	43.2 +/- 0.2	
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	45.0 ± 0.1 (#)	44.3	
Antenna cable delay: (X_C) / ns	205.7 ± 0.1	208.7 ± 0.5	
Splitter delay (if any):	N/A		

Data used for the generation of CGGTTS files				
	LOCAL:		Traveling	
☐ INT DLY (or X_R+X_S) (GPS) /ns:	29.7 (P1), 27.2 (P2), 31.7 (C1)		-36.0 (C1)	
☐ CAB DLY (or X_C) /ns:	205.7		208.7	
☐ REF DLY (or X_P+X_O) /ns:	54.3		44.3	
☐ Coordinates reference frame:	ITRF		ITRF	
X /m:	+3844059.86 (***)	Mast P10	+3844062.56 ($)	Mast P7
Y /m:	+709661.56 (***)		+709658.49 ($)	
Z /m	+5023129.87 (***)		+5023127.88 ($)	

General information	
☐ Rise time of the local UTC pulse:	3 ns
☐ Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	23.0 °C, peak-to-peak variations 0.5° C

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END of DOCUMENT