GNSS CALIBRATION REPORT

G1G2_1014_2018

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REFERENCES

REFERENCES	
RD01	**BIPM report 1001-2016, 2016 Group 1 GPS calibration trip BV 1.1 2017-01-18**
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	**PTB GNSS calibration reportG1G2_1012_2016**
RD07	**P. Defraigne and G. Petit, "CGGTTS-Version 2E: an extended standard for GNSS time transfer, Metrologia 52 (2015) G1**

ACRONYMS

ACRONYMS	
AOS	**Astrogeodynamical Observatory, Space Research Centre PAS, Borowiec, Poland**
BIPM	**Bureau International de Poids et Mesures, Sèvres, France**
CGGTTS	**CCTF Generic GNSS Time Transfer Standard**
CV	**Common-View (GNSS data analysis)**
EURAMET	**The European Association of National Metrology Institutes**
IGS	**International GNSS Service**
FTMC	**Center for Physical Sciences and Technology, Lithuania**
GNSS	**Global Navigation Satellite System**
GUM	**Central Office of Measures, Warsaw, Poland**
ORB	**Observatoire Royal Belgique**
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**
TDEV	**Time deviation**
TIC	**Time interval counter**

EXECUTIVE SUMMARY

As part of the support of the BIPM Time and Frequency Group by EURAMET, PTB conducted a relative calibration of the GNSS equipment of FTMC, Vilnius, Lithuania, GUM, Warsaw, Poland and AOS, Borowiec, Poland,with respect to the calibration of PTB receiver PT02, whose last calibration was reported with Cal_Id=1001-2016 [RD01]. PTB provided its receiver PTBT for the purpose as travelling equipment.

The current campaign followed as much as possible the BIPM Guide [RD02] and results will be reported using Cal_Id 1014_2018. Results provided are the visited receivers' internal delays for GPS P-code signals on the two frequencies L1 and L2 (INT DLY (P1), and INT DLY(P2)). In addition, the internal delays for L1C signals were determined by aligning common-view results between the visited receivers and a reference receiver at PTB. The delays for GLONASS signals were not determined during this campaign.

The final results are included in Table 11-1. The internal delays of 3 receivers were determined with an uncertainty of about 1 ns for P1 and P2, respectively. The uncertainty for P3 time transfer links to PTB is of the order 1.3 ns. This value is quite low, but in line with previous "succesfull" campaigns during which no apparent change in the delays of the travelling equipment during its journey was noted.

In Table 11-2 we report the results of the determination of L1C signal delays in the 3 receivers. Here PTB receiver PT07 served as reference as this receiver is routinely used by BIPM for the remaining L1C-links in the generation of TAI.

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

Following instructions from the PTB quality management responsibles, we want to stress that the correctness of all results and of the stated uncertainty values relies partly 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, PTB conducted a relative calibration of the GNSS equipment of FTMC, Vilnius, Lithuania, GUM, Warsaw, Poland, and AOS, Borowiec, Poland, with respect to the calibration of PTB receiver PT02, whose last calibration was reported with Cal_Id=1001-2016 [RD01]. PTB provided its receiver PTBT for the purpose as travelling equipment. This report documents the installation, data taking and evaluation during the campaign.

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

At first (Common-Clock 1, CC1), the travelling receiver (PTBT) is compared to the “golden” receiver (PT02), and the offset between the actual and the assumed PTBT delay values is determined.

After that, the receiver is installed at the three institutes in sequence and the internal delay values of the devices under test and their statistical properties are determined.

Finally, the stability of the PTBT delay is assessed by a second Common-Clock measurement (CC2) in PTB. Based thereon, the “final” INT DLY values of the visited receivers and their uncertainty values are calculated.

A similar approach was taken for determination of L1C signal delays in the three visited receivers. Here PTB receiver PT07 served as reference as this receiver is routinely used by BIPM for the remaining L1C-links in the generation of TAI.

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 the three sites. The final results and the uncertainty discussion close the report. In the Annex the BIPM information tables are reproduced.

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
FTMC	Rimantas Miškinis Tel +370 5 262 0194 Rimantas.miskinis@ftmc.lt	FTMC, Metrology dep. Lukiškiustr. 9, 01108 Vilnius, Lithyania
GUM	Albin Czubla Tel +48 581 9156 albin.czubla@gum.gov.pl	GUM, pok.20 Elektoralna 2 00139 Warszawa, Poland
AOS	Jerzy Nawrocki Tel. +48 61 8170 187 nawrocki@cbk.poznan.pl	Astrogeodynamical Observatory (AOS) Drapalka 4 62-037 Kornik, Poland

Table 2-2: Schedule of the campaign

Date	Institute	Action	Remarks
2018-06-04 08:02 until 2018-06-1105:54	PTB	First common-clock comparison between PTBT, PT02, and PT07	795 data points
2018-06-20 until 2018-07-09	FTMC	Common – clock comparison between PTBT and LT02	Data used MJD 58303 – 58307 (DOY 185 – 189 (5 days)
2018-07-13 until 2018-07-31	GUM	Common – clock comparison between PTBT and PL_3	Data used MJD 58325– 58329 (DOY 207 – 211 (5 days)
2018-08-10 until 2018-08-19	AOS	Common - clock Comparison between PTBT and AO_4	Data used MJD 58342– 58348 (DOY 224 – 230 (7 days)
2018-08-29 Until 2018-09-5	PTB	Operation of PTBT after return	Data used MJD 58359 – 58366, DOY 241 - 248

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

3. CALIBRATION PROCEDURE

The calculation of P1 and P2 INT DLY values for the receiver to be calibrated follows the description given in BIPM TM.212 [RD03] and has been coded in software routine cv.py written by Julia Leute of PTB. The following text piece that describes its function is generated via copy-paste from [RD03] with small changes of the designation of quantities.

When dealing with G1G2 calibrations, in principal we distinguish receivers V, T, and G: V for visited, T for travelling, and G for golden_reference. G1 labs committed to ship their T to the other sites. In the current campaign, PT02 (named PTBB when referred to as IGS station) serves as the reference receiver G, its internal delays were determined by BIPM in the second G1 campaign with the identifier Cal_Id=1001-2016. PTBT served as the travelling 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. We distinguish the two quantities for the two frequencies, 1 and 2.

INT DLY(P1) and INT DLY(P2) of receiver V are the basic quantities that are determined during the relative calibration. For calculating ionosphere-free observation data, INT DLY(P3) is calculated as 2.54×INT DLY(P1) - 1.54×INT DLY(P2).

The following terms are considered frequency independent, i. e. no distinction is made for P1 and P2 and other signal frequencies.

(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 Ashtech Z12-T: The first positive zero crossing of the inverted 20 MHz-in following the 1PPS-in, delayed by 15.8 ns,
- For Septentrio PolaRx2: The 1PPS-out, delayed by 8.7 ns,

- For Septentrio PolaRx4: The 1 PPS-out, no further correction
- For DICOM GTR50 and GTR51: The 1PPS-in, i.e. $X_O = 0$,
- For Javad/Topcon: The first positive zero crossing of the 5/10 MHz-in following the 1PPS-in.
- For TTS-4: RD02, Section 2.3.2, and Annex G specify the procedure for TTS-4, which in detail depends on the software version.

Details of the measurement procedures for the Ashtech Z12-T are given in the BIPM calibration guideline [RD02], but the parameters of PT02 were not determined again on occasion of the current campaign.

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 taken into accountonly 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 by PTB, valid CGGTTS files with dual frequency observation (L3P) data (including correct, accurate antenna coordinates) are needed. As a reminder,

$$\text{REFGPS}(k) = [\text{REFGPS}_{\text{RAW}}(k) - \text{CAB DLY}_F - \text{INT DLY(P3)} + \text{REF DLY}_F], \quad (1)$$

where REFGPS(k) is reported in column 10 of the standard CGGTTS files, $\text{REFGPS}_{\text{RAW}}$ designates the uncorrected measurement values, INT DLY(P3) is calculated as $2.54\times\text{INT DLY(P1)}_F - 1.54\times\text{INT DLY (P2)}_F$, and the values designated as "Q_F" are reported in the CGGTTS file header.

The software cv.py in calibration mode is used to calculate:

$$\text{REFGPS}_{P1}(j) = \text{REFGPS}(j) + \text{MDIO}(j) \quad (2a)$$

$$\text{REFGPS}_{P2}(j) = \text{REFGPS}(j) + \text{MDIO}(j) + (f_1/f_2)^2 \times \text{MDIO}(j), \quad (2b)$$

where $(f_1/f_2)^2 = 1.647$ for GPS for each satellite observation j and REFGPS(j) and MDIO(j) are from the line in the CGGTTS file that reports the observation j. Eq. 2a and 2b build on the rules how CGGTTS L3P data lines are generated.

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

$$\Delta Pi := \text{REFGPS}_{Pi}(T) - \text{REFGPS}_{Pi}(G) \quad (3)$$

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

cv.py at the end of the computation edits the median value of all individual observations ΔPi for P1 and P2, and the number of data points used. In addition cv.py generates a file deltap_stats that contains observation epoch (MJD.frakt) and the average ΔP1, ΔP2 of all satellite observations at that epoch. Such values are plotted throughout the report in the various figures.

The calculation of the INT DLY values comprises two steps:

Step 1: $$\text{INT DLY(Pi)\_T\_corr} = \Delta\text{Pi(T,G)} + \text{INT DLY(Pi)\_T\_F}, \quad (4)$$

where the last summand >_F < is the value reported in the CGGTTS file.

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

$$\text{INT DLY(Pi)\_V\_new} = \Delta\text{Pi(V,T)} + \langle\Delta\text{Pi(T,G)}\rangle + \text{INT DLY(Pi)\_V\_F}, \quad (5)$$

where <ΔPi(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 (5) 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.

The determination of th receiver delay for signals of type L1C is de facto a transfer of the delay assumed valid for a receiver in PTB to the visited receiver. The transfer is based on common-view common-clock data analysis as explained in Section 11.

4. CHARACTERIZATION OF PTB EQUIPMENT

The receiver PTBT had been used during campaign G1G2_1016_2017 which ended only at 2018-05-09. After that it was operated for a few weeks in PTB intermittently in a small campaign for surveying different antenna posts. The L3P comparison results against another receiver of the same brand are shown in Figure 4-1. One day contains some outliers, likely due to antenna position mismatch. There is no indication of any deficiency of the travelling equipment before doing the first common clock campaign.

The installation of the receivers in PTB is depicted in Figure 4-2 for 1 PPS signals and in Figure 4-3 for 5 MHz signals. The PT02 and PT03 receivers are supplied with 20 MHz from a times 4 multiplier.

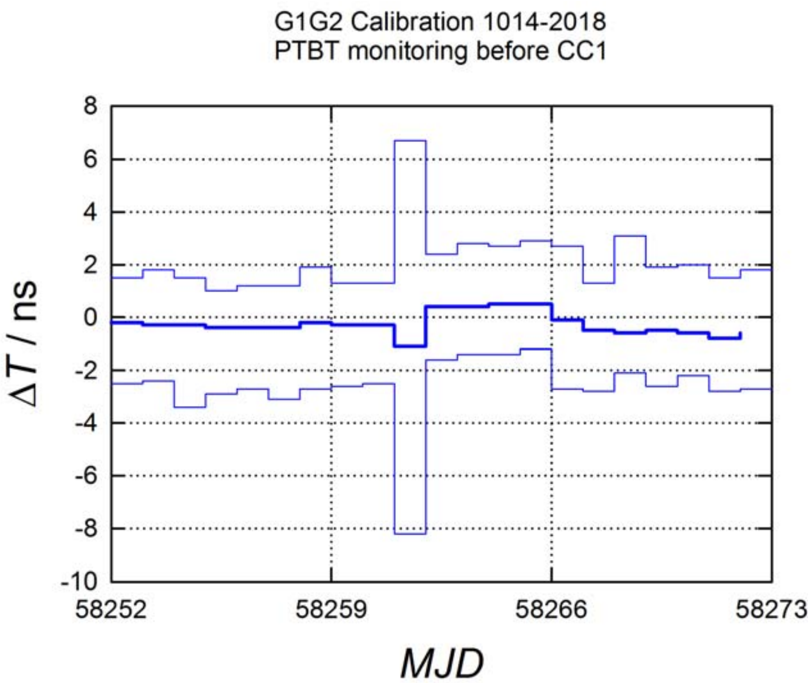


Figure 4-1: Common-clock common-view L3P comparison between PTBT and PT07 at PTB, daily mean values (bold) and minimum and maximum of individual 16-min avg data (thin)

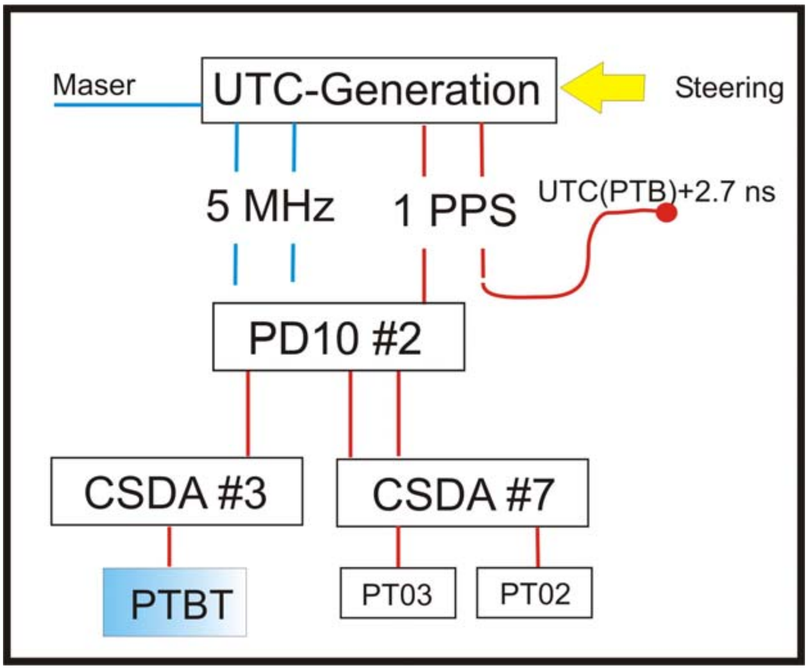


Figure 4-2: UTC(PTB) reference point and 1 PPS signal distribution to PT02, PT03 and PTBT; PD10 stands for pulse distributor, CSDA stands for clock signal distribution amplifier

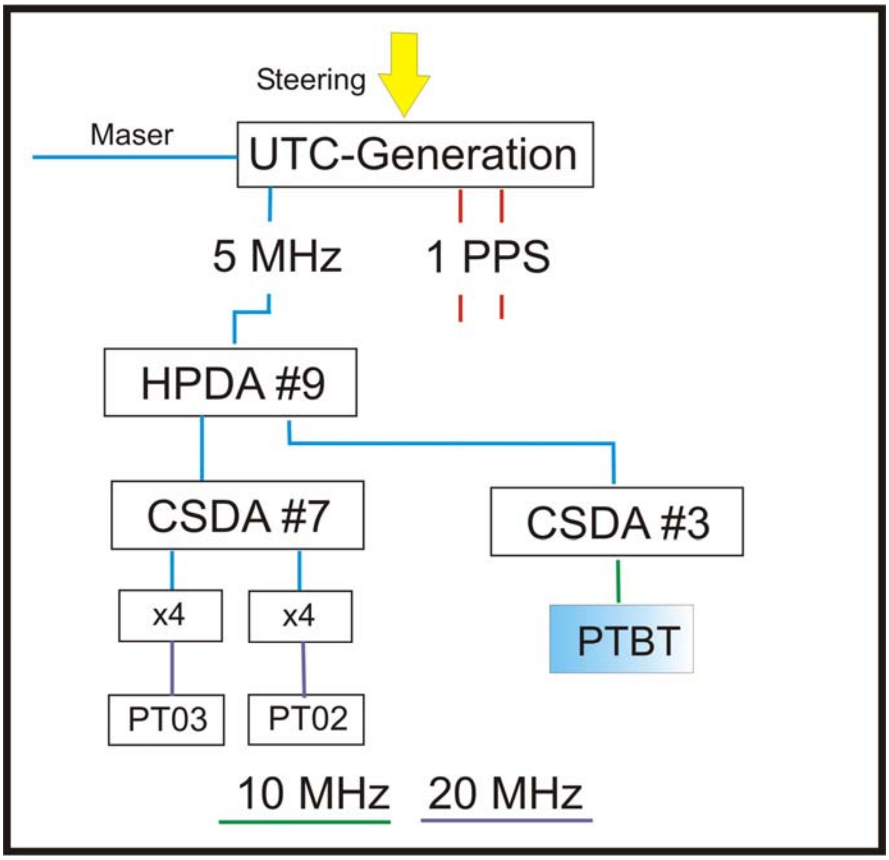


Figure 4-3: UTC(PTB) signal distribution (5 MHz, 10 MHz, 20 MHz) to PT02, PT03 and PTBT, HPDA stands for High-precision distribution amplifier (for rf frequencies)

Figure 4-4: Installation of GNSS antennas at PTB

Figure 4-4 illustrates the installation of GNSS antennas on the roof of the PTB time laboratory (clock hall) and was taken during the CC1 period of the current campaign. The two Ashtech SNOW antennas (with dome) belong to PT03 (left) and PT02 (middle). The PTBT antenna is seen on the pole to the right of PT03 in the foreground.

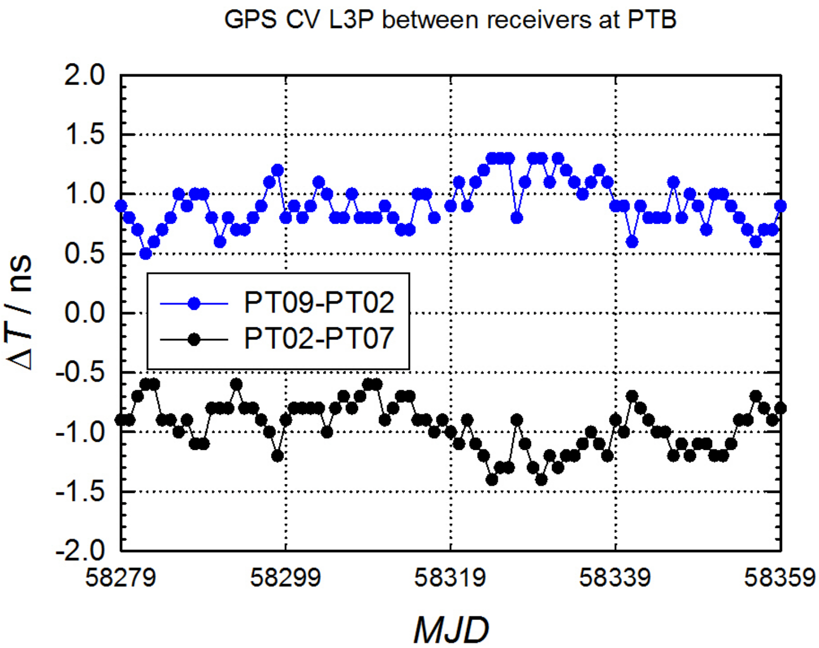


Figure 4-5: Daily mean time difference ΔT between the PTB receivers, PT02 – PT07 and PT09-PT02, during the period of the calibration campaign.

The campaign stretched over 2.5 months. In Figure 4-5, the common-view common-clock time differences between PT07 (Mesit GTR50), PT09 (Septentrio PolaRx 4) and PT02 during this period is shown. We note that variations of PT02 during this period are at the 0.5 ns-level and thus covered by the calibration uncertainty.

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

The period 58273 to 58280 (about 7 days) was chosen to determine the initial PTBT INT DLY values (CC1). The result of comparison with PT02 as the reference are shown in Figure 5-1 illustrating in total 610 ∆Pi (see eq. 3) values obtained as mean over all common view observations at a given epoch. The time instability (TDEV) plots for the two data sets follow as Figure 5-2. The numerical results are given in the Summary sub-section at the end of the report on CC2 in PTB.

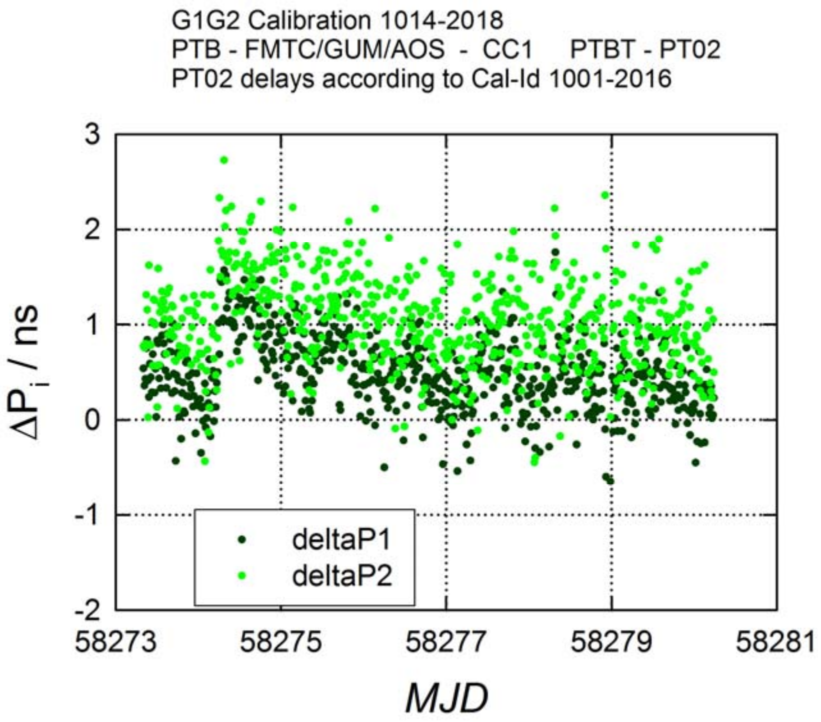


Figure 5-1: ∆P1 (dark green) and ∆P2 (light green) values obtained during the first common-clock set-up in PTB.

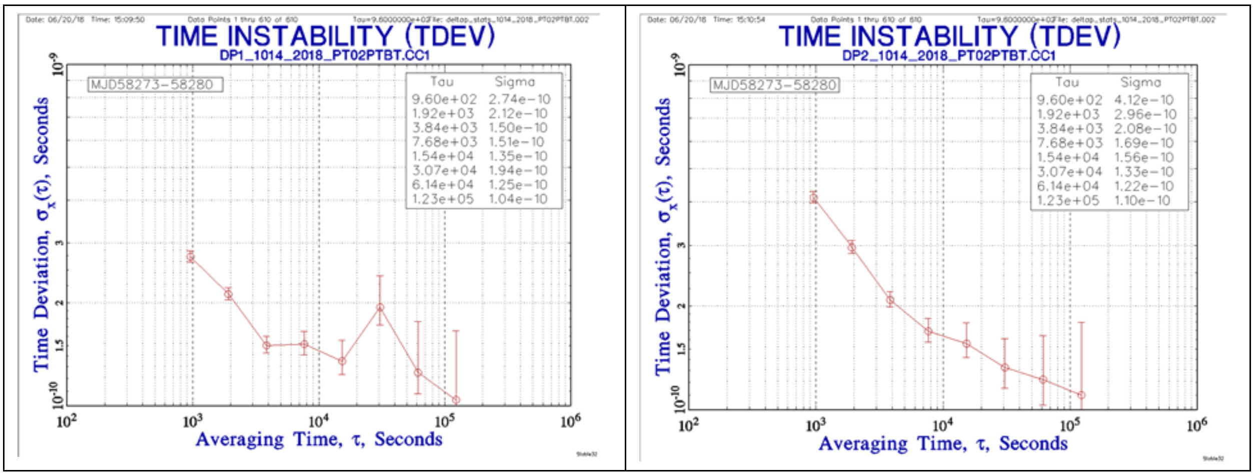


Figure 5-2: TDEV obtained for the two data sets shown in, ∆P1 left, ∆P2 right.

The INT DLY(Pi) of PTBT have not been corrected for the offsets shown in Figure 5-1 before shipment. Instead, the individual value found for the visited receivers were corrected for the mean value obtained after the second common-clock set-up (see eq. 5)).

5.1. DETERMINATION OF L1C DELAY

On suggestion of GUM and AOS, the internal delays of the three receivers for L1C signals were determined with respect to the PTB receiver that is routinely used by BIPM for single frequency GPS comparisons. This PTB receiver is of type Mesit GTR50 and designated as PT07. The L1C internal delay of receiver PT07 was adjusted to results obtained in the campaign 1001-2016 and reported in BIPM TM.266 Annex 2 on date 2017-02-06.

We determine the cv difference between PTBT and PT07 during CC1 and CC2 (see Section 9.) and take the mean for further evaluation. The differences between PTBT, and PL_3 and AO_4, respectively is then determined in common view as well. This allows an estimate of the GPS L1C delay values in the respective receivers to be made. The results of the comparison during CC1 are shown in Figure 5-3.

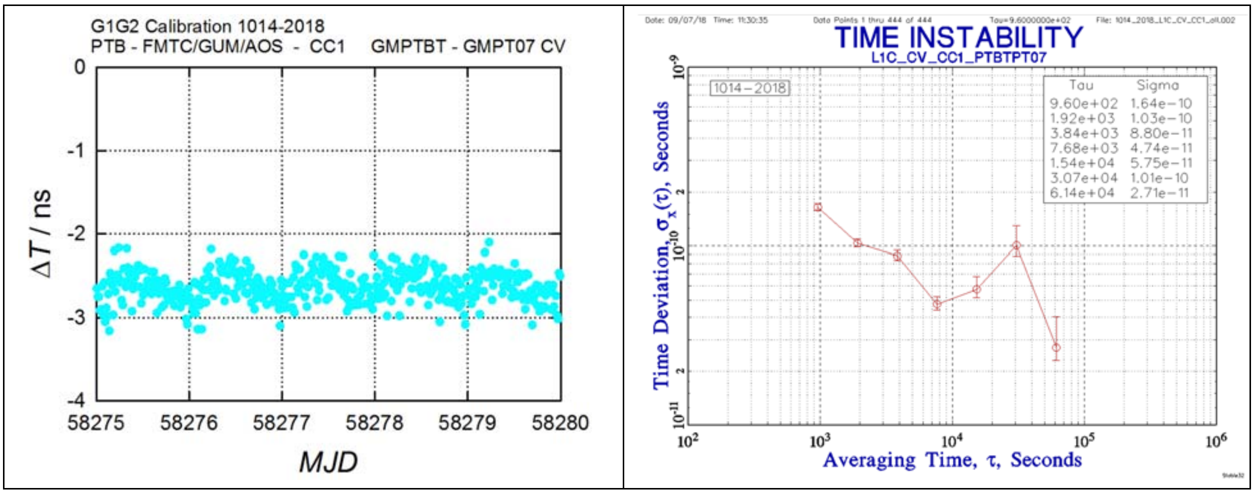


Figure 5-3 CV between receivers PTBT and PT07 using L1C data, time differences (left) and TDEV (right) during CC1

See Section 9.1 11. for further analysis of the data.

6. OPERATION OF PTBT AT FTMC, VILNIUS

PTBT was in the hands of FTMC for about three weeks, but the calibration of receiver LT02 (Type TTS-5, S/N-1020) was performed on the FTMC campus only after new antenna coordinates had been determined and entered in the PTBT operations software.

6.1. CALIBRATION OF RECEIVER LT02

Five days between MJD 58303 and 58307 (2018-07-04 – 2018-07-09) were used for the data analysis of receiver LT02. CGGTTS data of this receiver were generated using r2cggtts V 5.1 and named GZLT0258.303 – GZLT0258.307. In the files generated autonomously by the receiver of type PIKTIME TTS-5 (GMLT02MJ.DDD) the columns MDIO and MSIO are not populated as assumed when deriving eq. 2a and 2b, respectively. Also for PTBT new cggtts files were produced based on RINEX files and compared with the files generated by the receiver software autonomously. The mean difference in common-view as well the ∆Pi-delays was < 0.1 ns and below the statistical fluctuations. Results shown for FTMC and GUM are thus based on original PTBT files. New GZPTBT files with new coordinates were generated for the period of operation at AOS.

Details on the receiver and its installation are given in the Annex. All antenna coordinates (antenna phase center) had been determined consistently using NRCan PPP immediately before the period of data taking that is stated in Table 2-2.

The installation of the receivers PTBT and LT02 at FTMC is illustrated in Figure 6-1. The mounting of the antennas is shown in Figure 6-2. In Figure 6-3 common-clock common-view comparison results are shown. We note that the measurement noise for L3P CV comparisons is larger at FTMC than it used to be when PTBT was operated in PTB (CC1). Plots of individual satellite observation results (REFSYS) are shown in Figure 6-4. Without proof, we assume that the type of mounting of the PTBT antenna as shown in Figure 6-2 was sub-optimal.

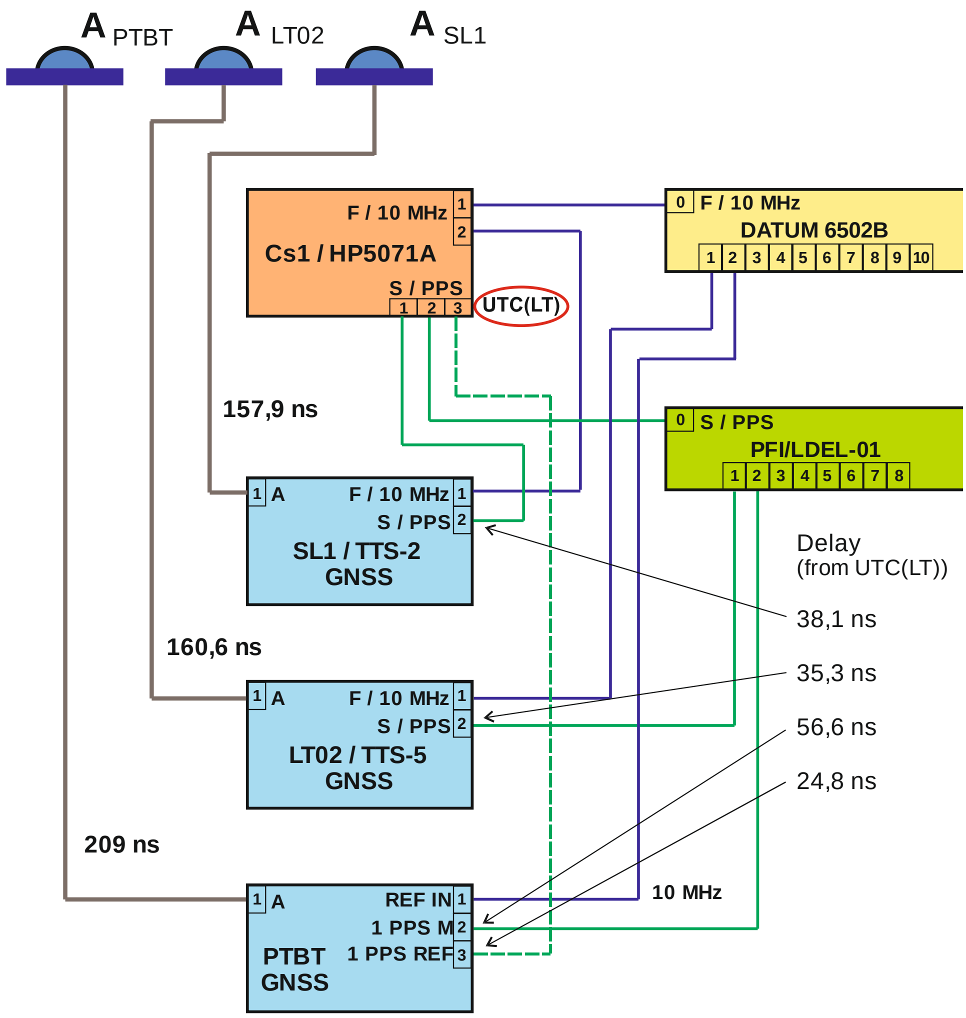
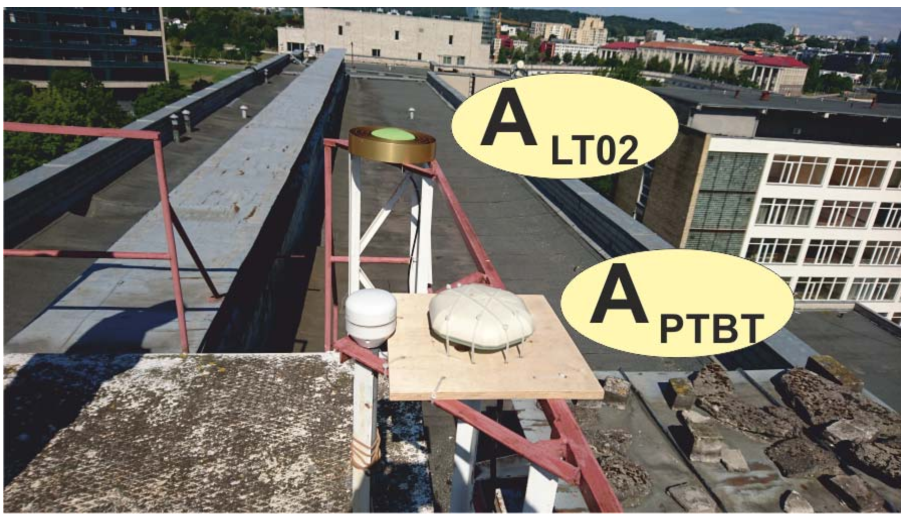


Figure 6-1 Signal distribution at FTMC



LT02:
X(m) = +3341116.78
Y(m) = +1577001.49
Z(m) = +5181850.71

PTBT:
X(m) = +3341116,50
Y(m) = +1577002,85
Z(m) = +5181850,51

Figure 6-2: Antenna position on the FTMC building

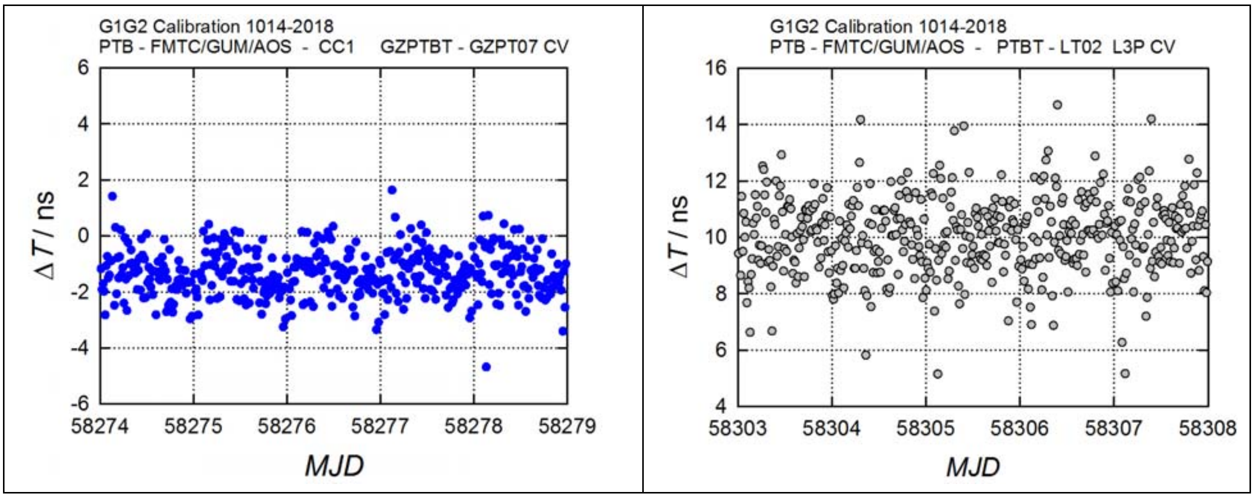


Figure 6-3 Common-view common-clock time comparison between PTBT and PT07 (Mesit GTR50), left and LT02 (right)

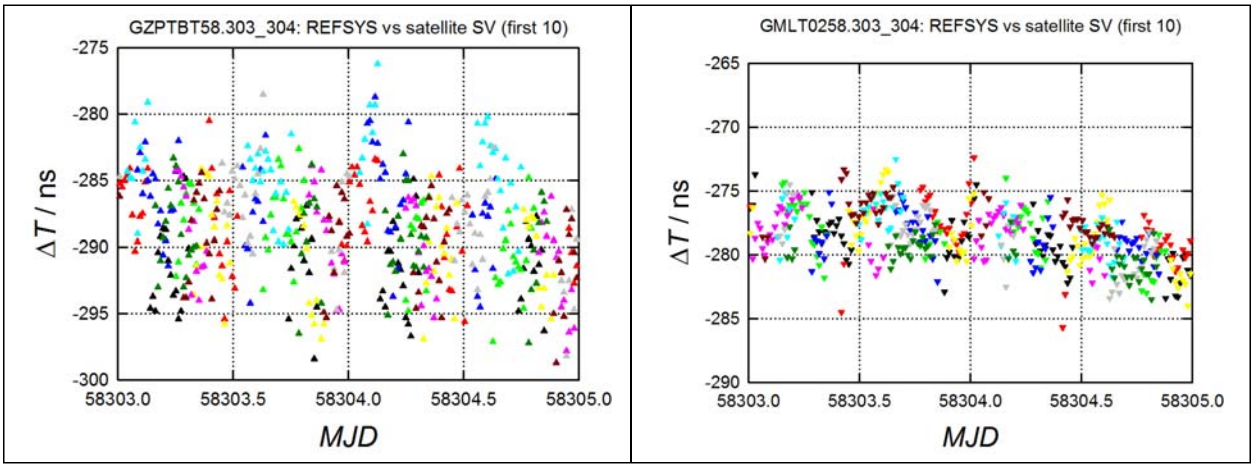


Figure 6-4 Time transfer results UTC(LT)-GPS (REFSYS) for ten satellites (different colours) collected during the calibration with receiver PTBT (left) and LT02(right)

In Figure 6-5, the ΔPi (3) derived from the raw data are depicted and the result are summarized in Table 6-1, including their statistical uncertainty. The corresponding TDEV plots are shown in Figure 6-6. As a statistical measurement uncertainty the TDEV at τ equal to about one tenth of the total measurement time (about 40 000 s) is chosen, cum grano salis, to be not too optimistic.

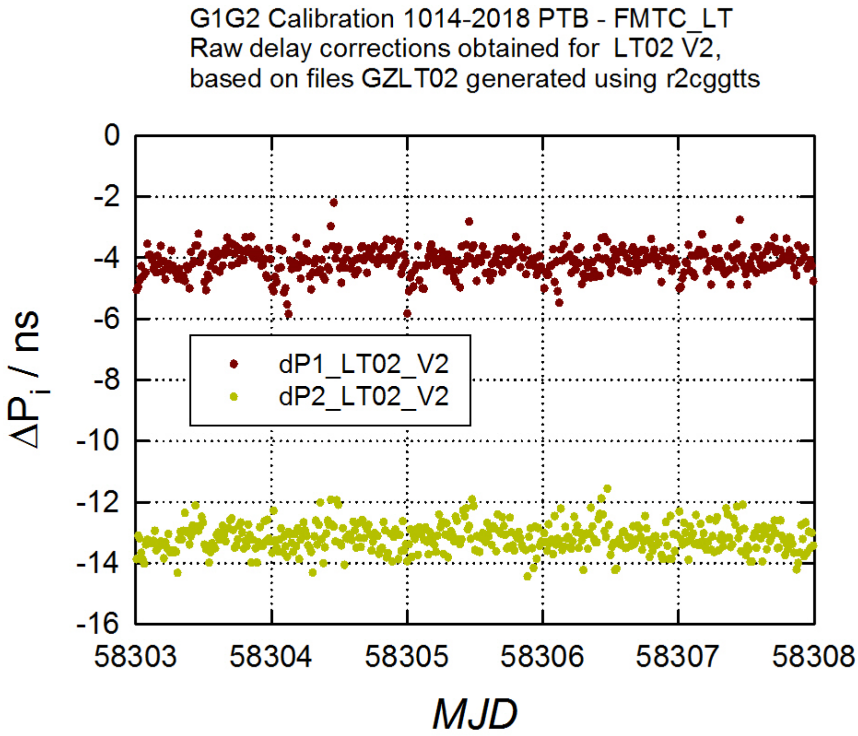


Figure 6-5 ΔP1 (dark red) and ΔP2 (olive) values obtained comparing receiver LT02 (file name GZLT0258.30X) and PTBT.

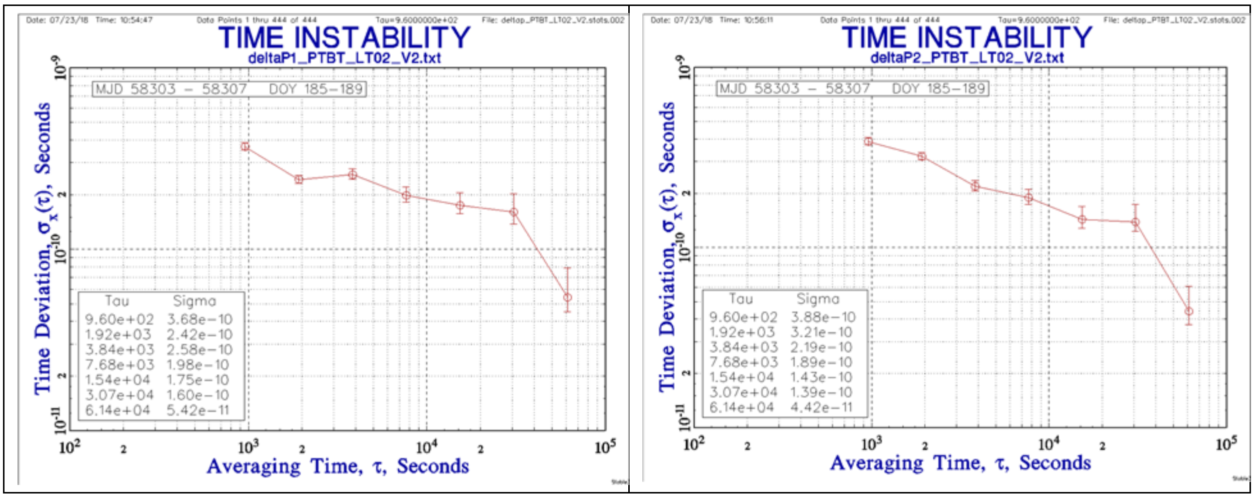


Figure 6-6 TDEV obtained for the two data sets shown inFigure 6-5, ΔP1 left, ΔP2 right.

Table 6-1: ΔINT DLY(Pi) values and statistical properties (in ns) obtained initially.

ΔINT DLY (Pi) for receivers at FTMC	Mean (ns)	Median (ns)	Std.Dev. (ns)	TDEV (ns)	Number of 16-min epochs
LT02 P1	-4.13	-4.10	0.44	0.2	444
LT02 P2	-13.18	-13.19	0.45	0.15	444

In Figure 6-7 we show the results of a CV data analysis between L1C data of PTBT and LT02. The mean difference amounts to -1.07 ns, with a standard deviation of 0.44 ns. The result was used to determine the LT02 L1C delay wrt to the L1C delay of receiver PT07. Results are discussed in Section 11.

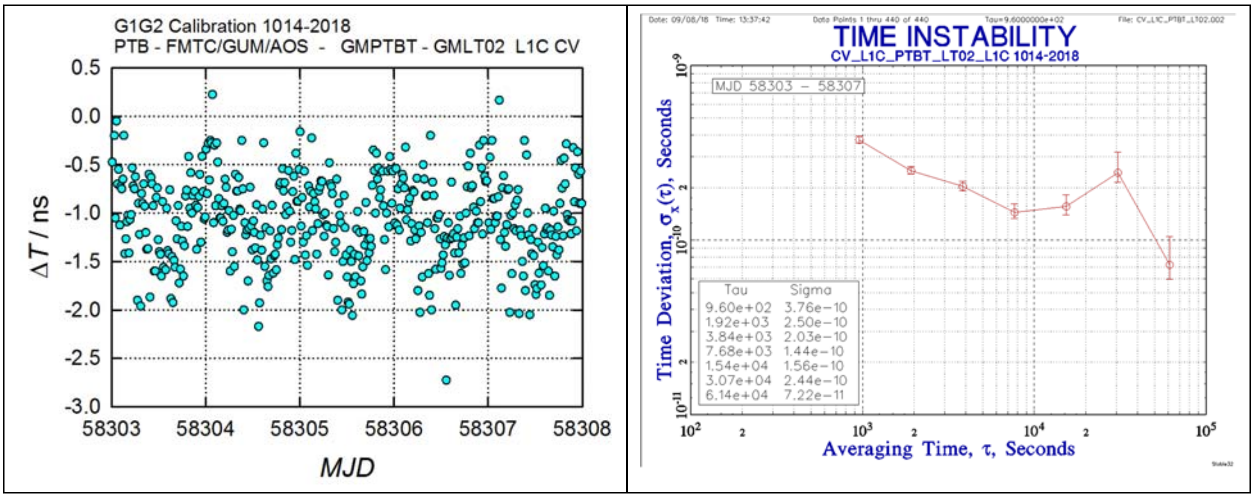


Figure 6-7 Results of CV data analysis between L1C data of PTBT and LT02, time difference (left) and TDEV (right)

7. OPERATION OF PTBT AT GUM

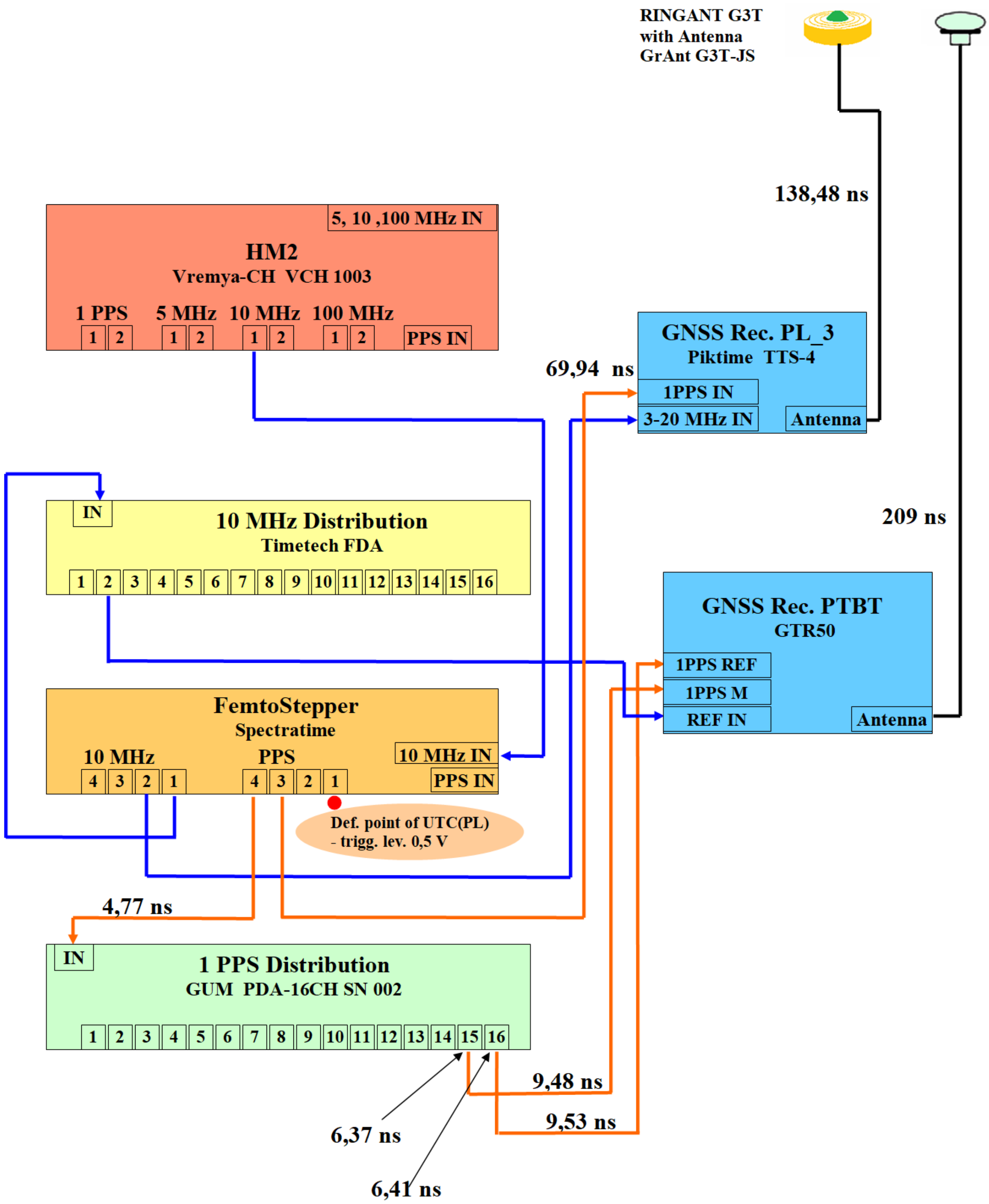


Figure 7-1 Signal distribution and installation of the receivers PTBT and PL_3 at GUM

Five days between MJD 58325 and 58329 (2018-07-26 – 2018-07-31) were used for the data analysis of receiver PL_3. L3P CGGTTS data of this receiver were generated from RINEX files

GUM4DOY0.18O and appropriate navigation files using R2CGGTTS v5.1 and have been designated as GZPL_3MJ.DDD. Details on the receiver and its installation are given in the Annex. Antenna coordinates (APC) were determined consistently using NRCan PPP immediately before the period of data taking. The installation of the receivers PTBT and PL_3 at GUM is illustrated in Figure 7-1. The graph details the delays of cables connecting the source of UTC(PL) and the distribution equipment and further to the GNSS receivers. It also shows the delay between input and output of the PPS distribution unit. The mounting of the antennas is illustrated in Figure 7-2. Triggered by the results obtained at FTMC, a plot of individual satellite observations (REFSYS) of the two receivers involved at GUM was made and is shown in, alike to Figure 6-4, at the very first days of PTBT installation at GUM, to ensure its proper function.

Figure 7-2 Mounting of GNSS antennas on the roof of GUM during data taking:PTBT antenna (left), PL_3 antenna (right) and TTS-2 antenna (middle)

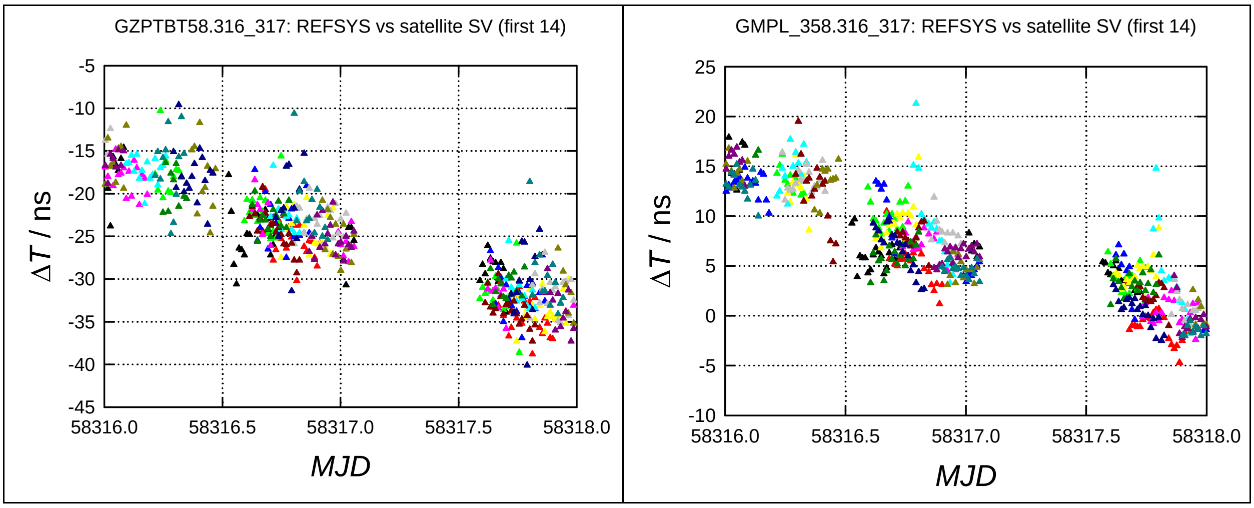


Figure 7-3 Time transfer results UTC(PL)-GPS (REFSYS) for 14 satellites (different colours) collected prior to the calibration with receiver PTBT (left) and PL_3 (right)

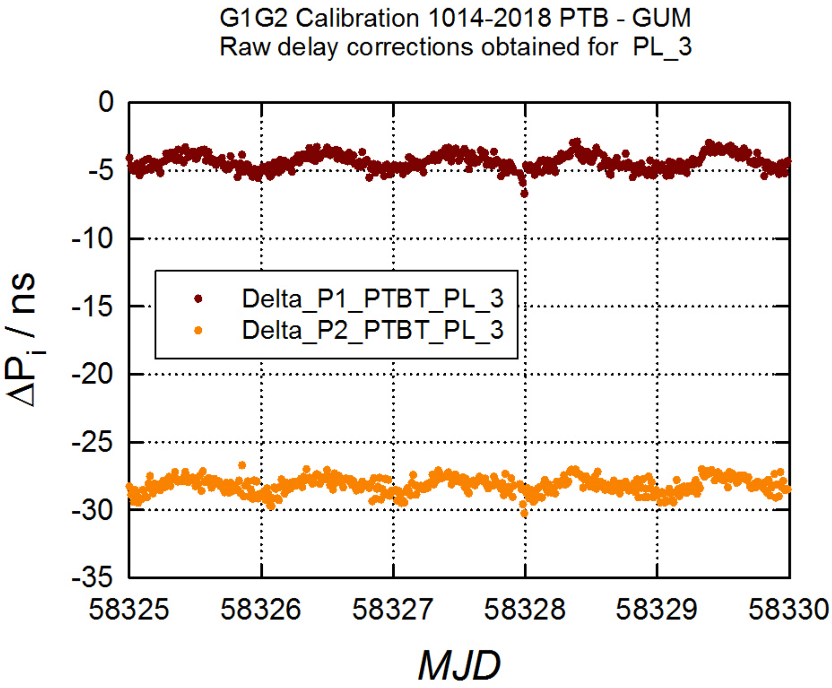


Figure 7-4 ΔP1 (brown) and ΔP2 (orange) values obtained comparing receiver PL_3 (file name GZPL_3MJ.DDD) and PTBT.

In Figure 7-4, the ΔPi (3) derived from the raw data are depicted and the result are summarized in Table 7-1, including their statistical uncertainty. The corresponding TDEV plots are shown in Figure 7-5. As a statistical measurement uncertainty the value of TDEV at τ equal to about one tenth of the total measurement time (about 40 000 s) is chosen, cum grano salis, to be not too optimistic.

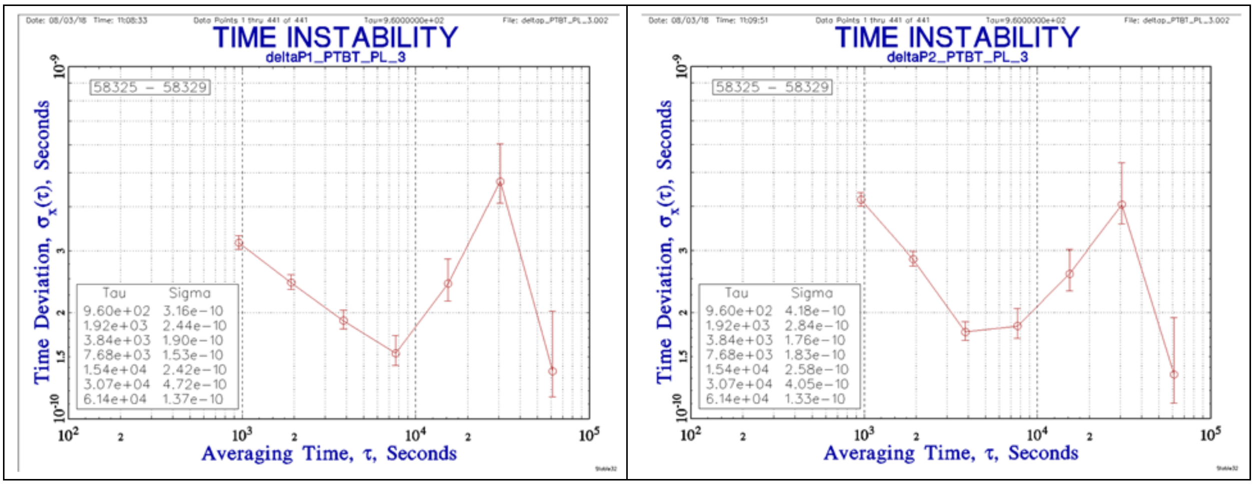


Figure 7-5 TDEV obtained for the two data sets shown in Figure 7-4, ΔP1 left, ΔP2 right.

A clear diurnal varation of the delay differences is noted which is also reflected in the TDEV values.

By doing L3P common view time comparison between GUM and PTB, using PL_3 and PTBT at GUM and PT02 at PTB we can show that the diurnals are mostly caused by receiver PL_3. The results are shown in Figure 7-6 as evidence.

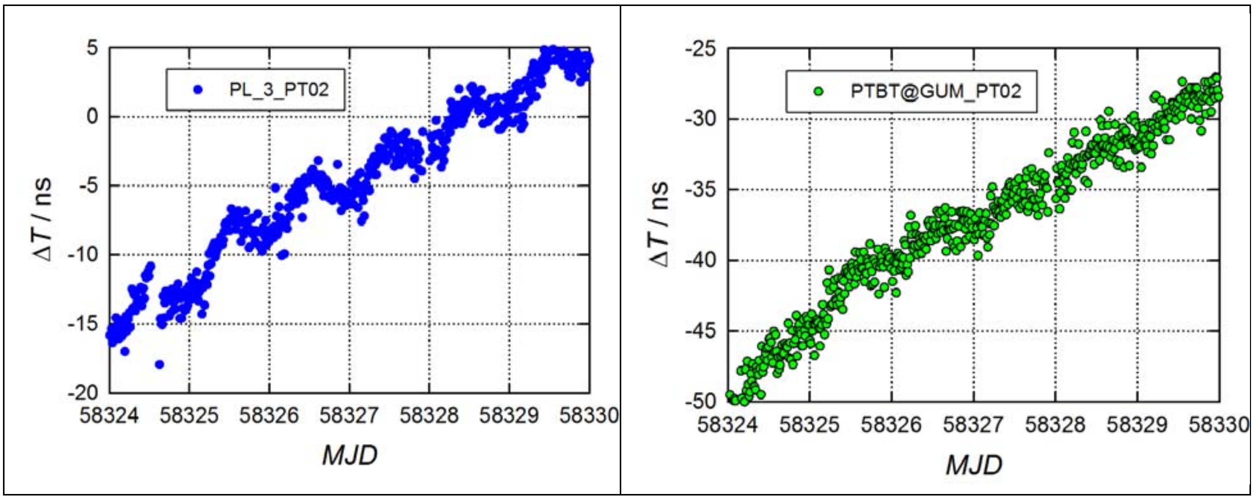


Figure 7-6 Results of GPS L3P CV time comparison between UTC(PL) and UTC(PTB) using receiver PL_3 (left) and PTBT at GUM operated in common clock at the same time.

Table 7-1 ΔINT DLY(Pi) values and statistical properties (in ns) including corrections for erroneous cggtts files.

ΔINT DLY (Pi) for receivers at GUM	Mean (ns)	Median (ns)	Std.Dev. (ns)	TDEV (ns)	Number of 16-min epochs
PL_3 P1	-4.36	-4.37	0.57	0.3	441
PL_3 P2	-28.17	-28.13	0.57	0.3	441

7.1. DETERMINATION OF L1C DELAY

In Figure 7-7 we show the results of a CV data analysis between L1C data of PTBT and PL_3. The mean difference amounts to -0.33 ns, with a standard deviation of 0.48 ns. The result was used to determine the PL_3 L1C delay wrt to the L1C delay of receiver PT07. Results are discussed in Section 11.

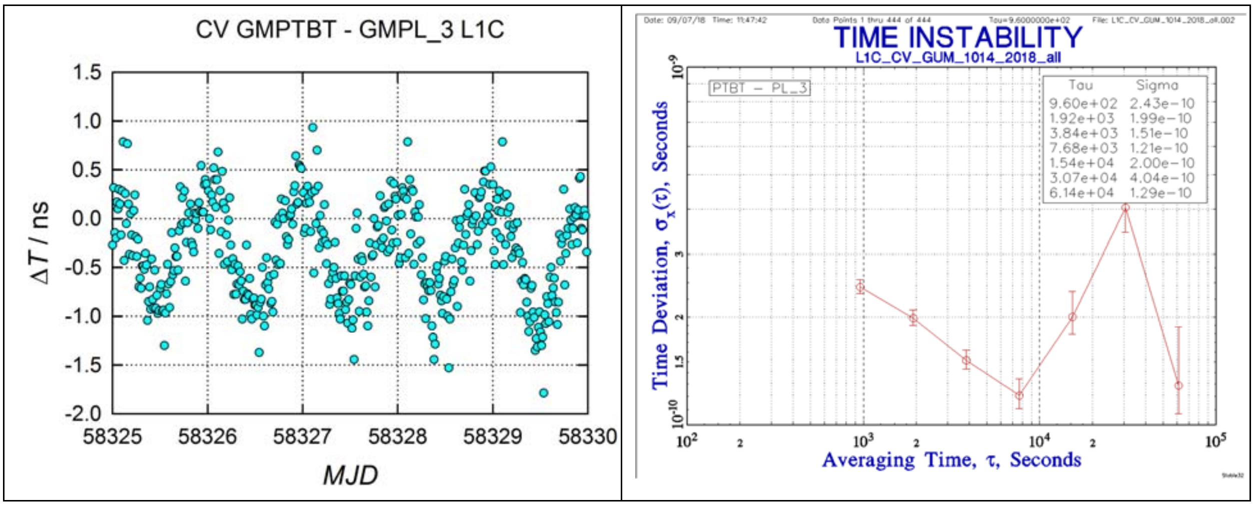


Figure 7-7 Results of CV data analysis between L1C data of PTBT and PL_3, time difference (left) and TDEV (right)

8. OPERATION OF PTBT AT AOS

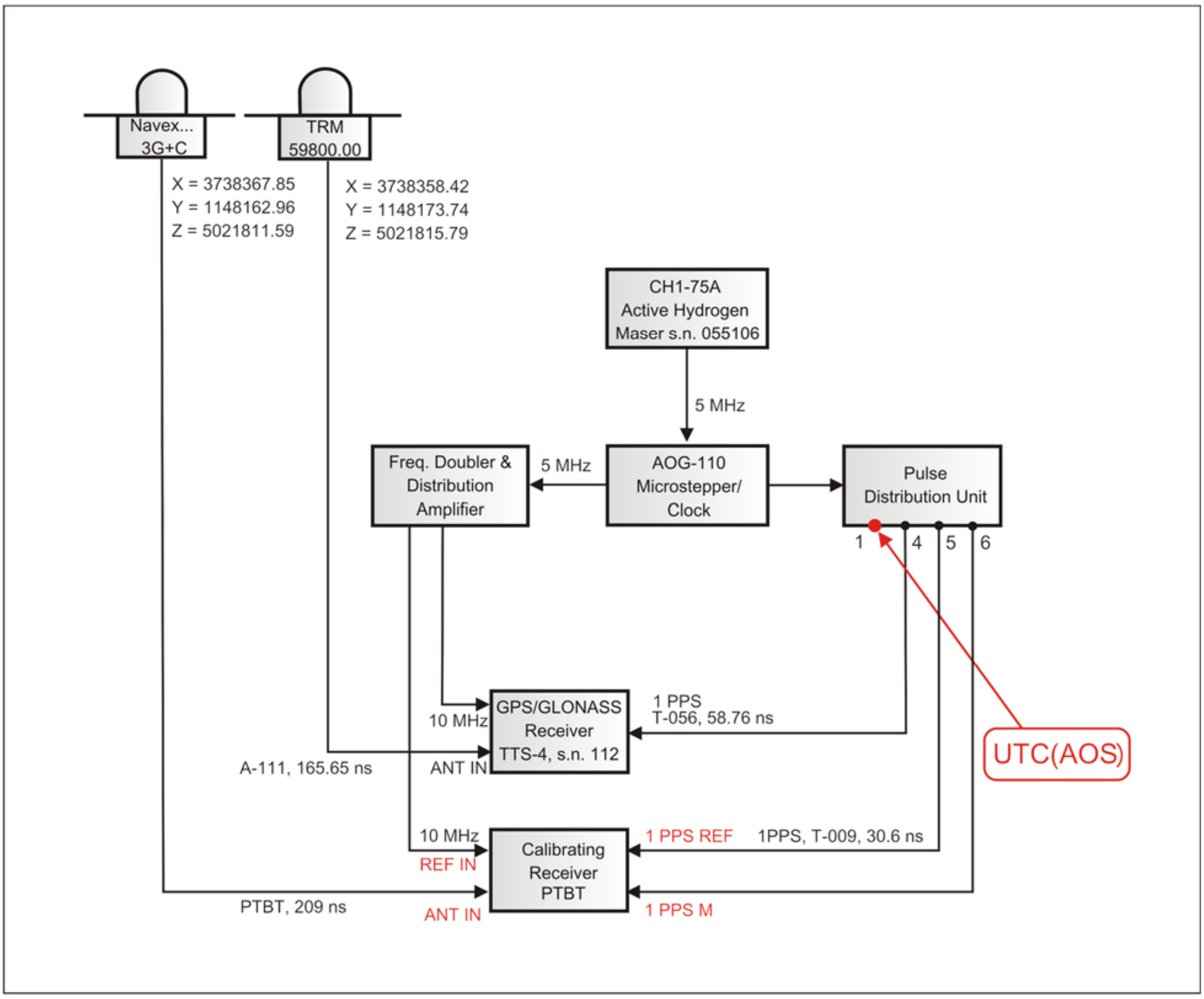


Figure 8-1 Signal distribution and installation of the receivers PTBT and AO_4 at AOS

Seven days between MJD 58342 and 58348 (2018-08-12 – 2018-08-19) were used for the data analysis of receiver AO_4. L3P CV time comparison between AOS and PTB provided evidence that the interval was free of outliers, time steps etc. as demonstrated in Figure 8-2. Antenna coordinates for AO_4 and PTBT were determined consistently using NRCan PPP from the first days of operation at AOS. New L3P CGGTTS data for both receivers were generated from RINEX files AO_4DOY0.18O and PTBTDOY0.18O, respectively, and appropriate navigation files using R2CGGTTS v5.1. Details on the receiver and its installation are given in the Annex. The installation of the receivers PTBT and AO_4 at AOS is illustrated in Figure 8-1. Note that the coordinates reported in Figure 8-1 represent the "initial" values, based on a previous determination. The graph details the delays of cables connecting the source of UTC(AOS) and the distribution equipment and further to the GNSS receivers. The mounting of the antennas is illustrated in Figure 8-3. The PTBT antenna was later mounted on the empty pole.

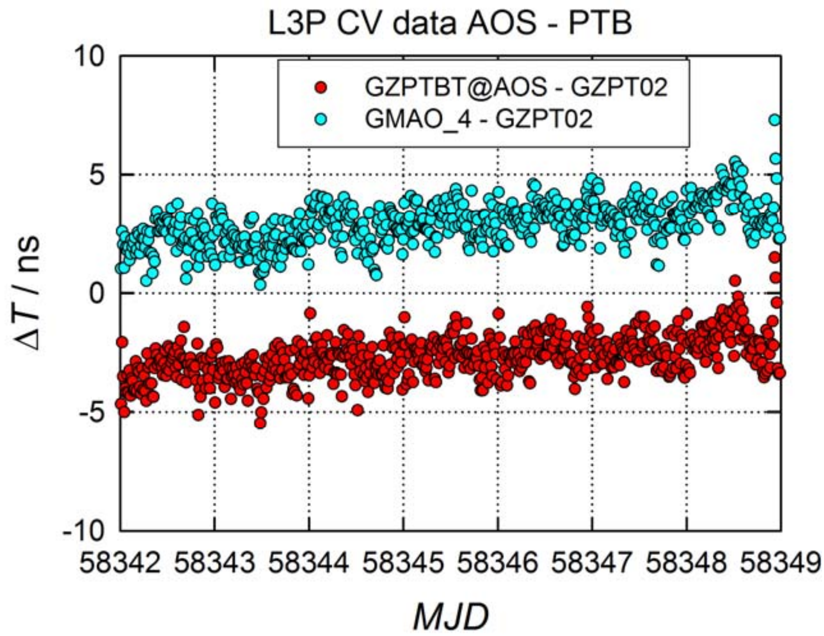


Figure 8-2 L3P time comparison between AOS and PTB (initial delay values, initial antenna coordinates)

Figure 8-3 Mounting of GNSS antennas on the roof of AOS

In Figure 8-4, the ΔPi (3) derived from the raw data are depicted and the result are summarized in Table 8-1, including their statistical uncertainty. The corresponding TDEV plots are shown in Figure 8-5. As a statistical measurement uncertainty the value of TDEV of 0.1 ns is chosen. Any lower value would not have an impact on the overall calibration uncertainty.

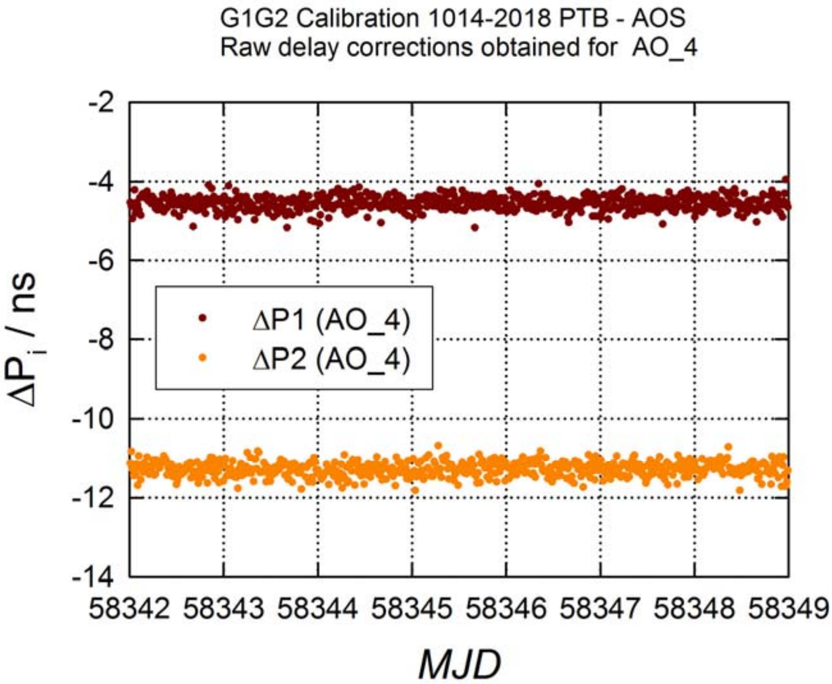


Figure 8-4 P1 (brown) and ΔP2 (orange) values obtained comparing receiver AO_4 (file name GZAO_4MJ.DDD) and PTBT.

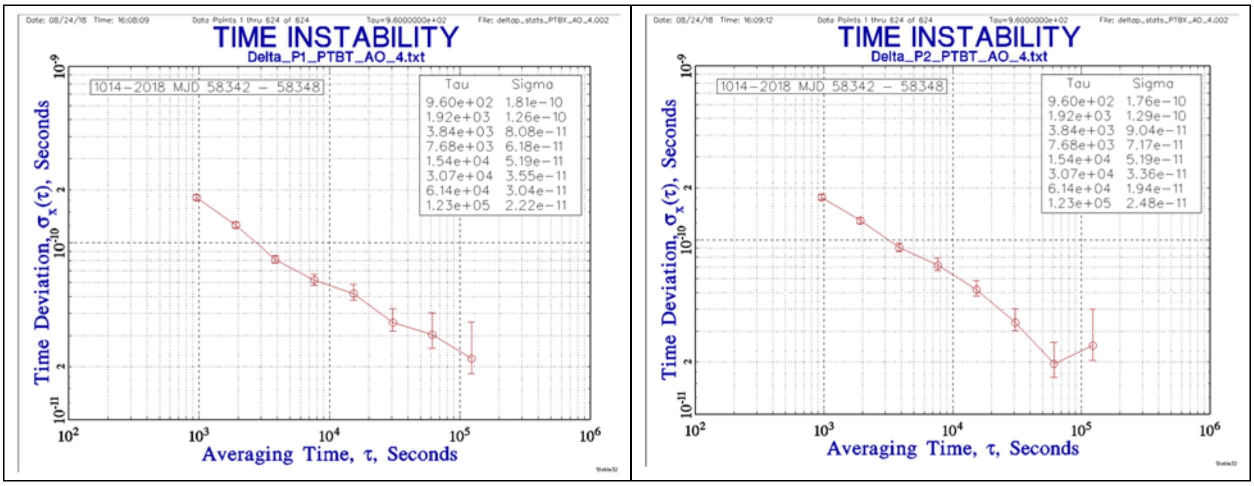


Figure 8-5 TDEV obtained for the two data sets shown in Figure 8-4, ΔP1 left, ΔP2 right.

Table 8-1 ΔINT DLY(Pi) values and statistical properties (in ns) for receiver AO_4

ΔINT DLY (Pi) for receivers at AOS	Mean (ns)	Median (ns)	Std.Dev. (ns)	TDEV (ns)	Number of 16-min epochs
AO_4 P1	-4.55	-4.54	0.18	0.1	624
AO_4 P2	-11.28	-11.28	0.18	0.1	624

8.1. DETERMINATION OF THE L1C DELAY

In Figure 8-6 we show the results of a CV data analysis between L1C data of PTBT and AO_4. The mean difference amounts to -0.24 ns with a standard deviation of 0.36 ns. The result was used to determine the AO_4 L1C delay wrt to the L1C delay of receiver PT07. Results are discussed in Section 11.

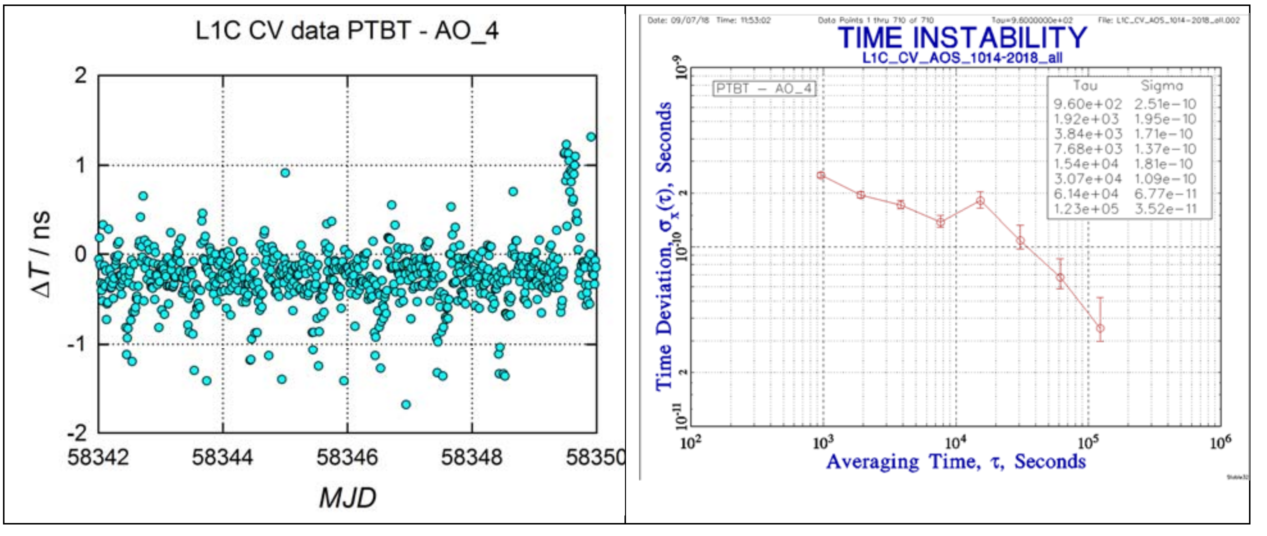


Figure 8-6 Results of CV data analysis between L1C data of PTBT and AO_4, time differences (left) and TDEV (right)

9. OPERATION OF PTBT AT PTB: SECOND PERIOD

The period 58359 to 58366 (8 days) was chosen to determine PTBT INT DLY values during the common clock period CC2. The result of comparison with PT02 as the reference are shown in Figure 9-1, illustrating in total 708 ΔPi (see eq. 3) values obtained as mean over all common view observations at a given epoch. The time instability (TDEV) plots for the two data sets follow as Figure 9-2.

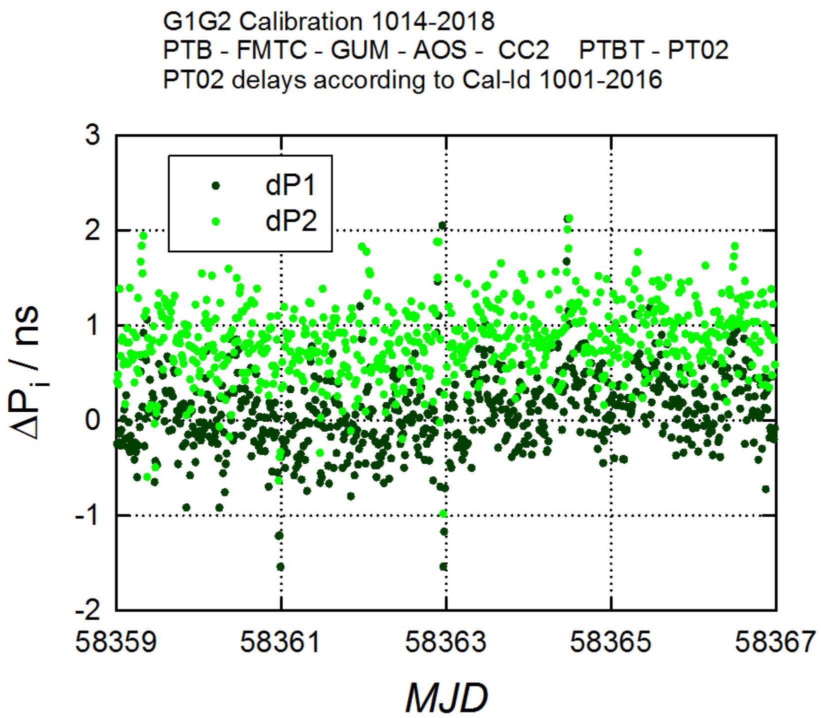


Figure 9-1. ΔPi values obtained during the second common-clock set-up in PTB.

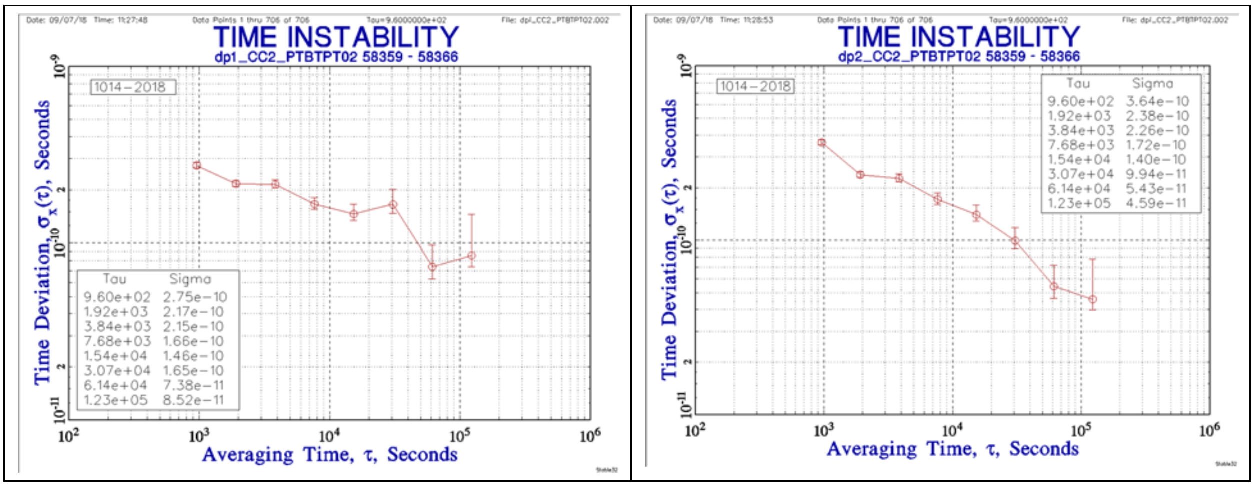


Figure 9-2. TDEV obtained for the two data sets shown in Figure 9-1, ΔP1 left, ΔP2 right.

We determine the cv difference between PTBT and PT07 as in CC1. The results are shown in Figure 9-3.

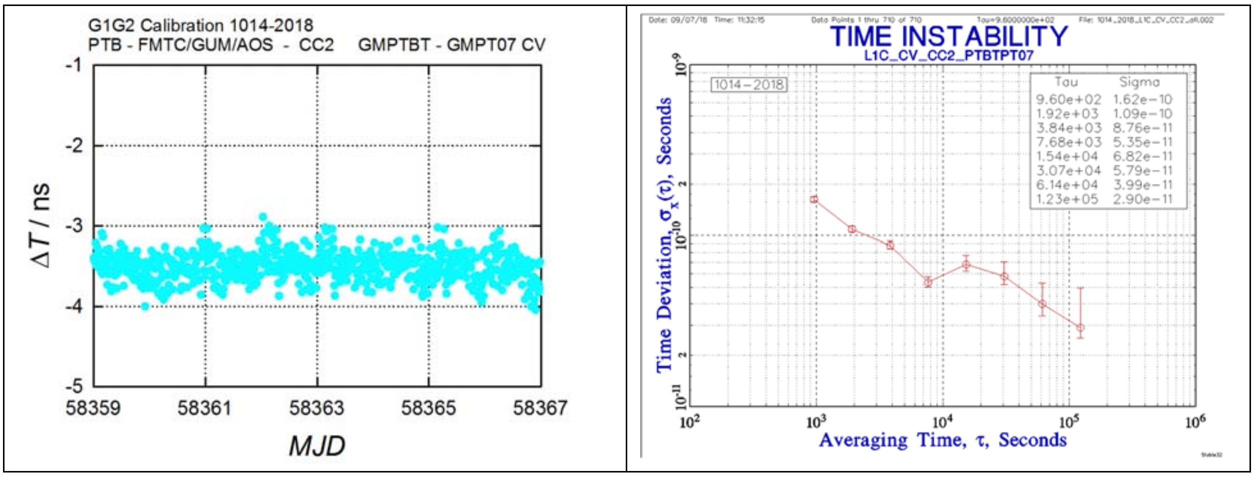


Figure 9-3 CV between receivers PTBT and PT07 using L1C data, time differences (left) and TDEV (right) during CC2

9.1. SUMMARY

The numerical result of the two common-clock campaigns at PTB are given in Table 9-1. The largest change noted between CC1 and CC2 amounts to 0.87 ns for the L1C comparison. For the evaluation of the delays of the visited receivers the mean values for ΔP1, ΔP2, and ΔT, respectively, are used. The estimate of the uncertainty contribution is given in Section 10.

Table 9-1: Result of common clock measurements at PTB

Quantity	Median (ns)	Sigma (ns)	TDEV (ns)
ΔP1 (CC1)	0.49	0.39	0.15
ΔP2 (CC1)	1.05	0.47	0.15
ΔP3 (CC1)	-0.37		
ΔP1 (CC2)	0.1	0.43	0.15
ΔP2 (CC2)	0.86	0.44	0.15
ΔP3 (CC2)	-1.07		
ΔT(PTBT-PT07)_L1C (CC1)	-2.63	0.18	0.1
ΔT(PTBT-PT07)_L1C (CC2)	-3.50	0.18	0.1
Mean values used for evaluation of internal delays of the visited receivers			
ΔP1	0.25		
ΔP2	0.96		
ΔT(PTBT-PT07)_L1C	-3.06		

10. INT DLY UNCERTAINTY EVALUATION

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

$$u_{CAL} = \sqrt{u_a^2 + u_b^2}\,, \qquad (6)$$

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 the individul sites and PTB, respectively. The systematic uncertainty is given by

$$u_b = \sqrt{\sum_n u_{b,n}}\,. \qquad (7)$$

The contributions to the sum (7) are listed and explained subsequently. In the table, extra lines (a, b,) are introduced for the different receivers calibrated at the individual sites if needed.

Values in column P3 are calculated according to $u(P3) = \sqrt{\{u(P1)^2 + (1.54 \times u(P1-P2))^2\}}$.

Note that the uncertainty of the INT DLY values of PTB's fixed receiver PT02 (G) which served as the reference is not included.

Table 10-1: Uncertainty contributions for the calibration of receiver delays

	Uncertainty	Value P1 (ns)	Value P2 (ns)	Value P1-P2 (ns)	Value P3 (ns)	Description
1	u_a (PTB)	0.15	0.15	0.21	0.35	CC measurement uncertainty at PTB, TDEV max. of the two CC campaigns
2a	u_a(FTMC)	0.2	0.15	0.25	0.43	CC measurement uncertainty, receiver
2b	u_a(GUM)	0.3	0.3	0.42	0.71	CC measurement uncertainty, receiver
2c	u_a(AOS)	0.1	0.1	0.14	0.23	CC measurement uncertainty, receiver
Result of closure measurement at PTB						
3	$u_{b,1}$	0.21	0.21	0.30	0.51	Misclosure, see Table 9-1
Systematic components due to antenna installation						
4	$u_{b,11}$	0.1	0.1	0.14	0.23	Position error at PTB
5	$u_{b,12}$( )	0.1	0.1	0.14	0.23	Position error at all sites
6	$u_{b,13}$	0.1	0.1	0.14	0.23	Multipath at PTB
7a	$u_{b,14}$	0.2	0.2	0.28	0.47	Multipath at FTMC
7b	$U_{b,14}$	0.1	0.1	0.14	0.23	Multipath at GUM and AOS
Installation of PTBT and visited receivers						
8	$u_{b,21}$	0.2	0.2	0	0.2	Connection of PTBT to UTC(PTB) (REF DLY)
9	$u_{b,22}$	0.5	0.5	0	0.5	Connection of PTBT to UTC(k) (REF DLY)
10	$u_{b,23}$	0.5	0.5	0	0.5	Connection of receivers at "k" to UTC(k) (REF DEL)
11	$u_{b,24}$	0.1	0.1	0	0.1	TIC nonlinearities at PTB
12	$u_{b,25}$	0.1	0.1	0	0.1	TIC nonlinearities at all sites
Antenna cable delay						
13	$u_{b,31}$(PTB)	0.0	0.0	0	0.0	Uncertainty estimate for the PTBT CAB DLY when installed at PTB
14	$u_{b,32}$(k)	0.2	0.2	0	0.2	Uncertainty estimate for the PTBT CAB DLY when installed at lab "k"
15	Ub,33	0.5	0.5	0	0.5	Uncertainty estimate for the local receiver CAB DLY at each site

The uncertainty contribution $u_{b,1}$ is based on the difference between the two common clock campaigns in the following way. The standard deviation of the two values around the mean value is considered as measure for the uncertainty, and they are treated as statistically independent contributions. If this value is smaller than the combined statistical uncertainty of the two CC-data sets, then the latter value is used. This situation prevailed in the current campaign.

For the generation of the CGGTTS data the PTBT antenna position is manually entered into the processing software in ITRF coordinates before the CCD measurements. These positions could in principle differ from the "true" positions in a different way in each laboratory. This is taken into account 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. As a matter of fact, a position error in general could even affect the P1 and P2 delays in a slightly different way, if the distinction between Antenna Reference Point (ARP) and Antenna Phase Centre (APC) is not accurately made. It has been reported that the difference between the two quantities is different for each antenna type but in addition also for the two frequencies received. To be on the safe side, $u_{b,11}$ and $u_{b,12}$ are very conservatively estimated. For other entries, where a frequency dependence can be safely excluded, the entry for P1-P2 is set to zero.

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 the multipath error need not be considered to be more significant than reported here. Because of the likely unfavourable mounting at FTMC the contribution has been enlarged for this institute.

The uncertainties of the connection of the receivers to the local time scales ($u_{b,21}$, $u_{b,22}$, $u_{b,23}$) are equal but of different origin. As the same counter is employed for the PTBT REF DLY measurements at all sites, the counter's internal measurement uncertainty for time interval need not be considered. $u_{b,21}$ was estimated by PTB: The cable connecting UTC(PTB) to PTBT is repeatedly controlled and has been used in many calibration exercises. The uncertainty of the connection of PTBT and the local receivers to the local time scale is based on the assumption that a high-quality counter is used to determine the value and included as $u_{b,22}$, $u_{b,23}$.

The uncertainty contributions $u_{b,24}$ and $u_{b,25}$ are related to imperfections in the TIC in conjunction with the relationship between the zero-crossings of the external reference frequency and the 1 PPS signals. This "nonlinearity" is probably caused by the internal interpolation process. By connecting the travelling TIC successively to 5 MHz and 10 MHz generated by different clocks (masers, commercial caesium clocks), respectively, the effect was estimated to be at most 0.1 ns if 1 PPS signals with a slew rate of approximately 0.5 V/ns are used.

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 in both CC and at the three sites. The CAB DLY was measured at PTB before CC1 and before CC2, 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. Therefore no uncertainty contribution arises a priori from the PTBT antenna cable delay. The contribution $u_{b,32}$ reflects the potential change of the CAB DLY due to the high temperatures encountered during this summer (see periodc variations at GUM). For the stationary antenna cables at the three sites we conservatively assume 0.5 ns for the uncertainty of the delay value.

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

11. FINAL RESULTS

The results of the calibration campaign G1G2_1014_2018 are summarized in Table 11-1. It contains the designation of the visited receiver, the INT DLY values hitherto used, the offsets ΔPi(V,T) and ΔPi(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 10-1, individually for P1, P2, and combined for P3, were used. Intermediate delays and uncertainties are reported here with two decimal points. According to [RD07], 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 11-1. Results of the Calibration Campaign G1G2_1014_2018, all values in ns

Receiver	INT DLY(P1), old	INT DLY(P2); old	ΔP1 (V,T)	ΔP2 (V,T)	ΔP1 (T,G)	Δ(P2) (T,G)	INT DLY(P1), new	u_{cal}, P1	INT DLY(P2), new	u_{cal}, P2	u_{cal}, P3
FTMC, LT02	41.9	46.0	-4.13	-13.19	0.25	0.96	38.02	1.02	33.77	0.99	1.32
GUM, PL_3	765.8	765.8	-4.36	-28.17	0.25	0.96	761.69	1.04	738.59	1.05	1.41
AOS, AO_4	-5.1	-5.1	-4.55	-11.28	0.25	0.96	-9.4	1.00	-15.42	1.01	1.26

In a similar way we obtain from equation (1) corrected values of the L1C signal delay in receiver PL_3 and AO_4 as
INT DLY(L1C);new = INT DLY(L1C);old + ΔT(T-R) - Δ(T-V), where R designates the receiver PT07 chosen as reference for this action. We estimate the uncertainty of the new value to 1.5 ns.

Table 11-2 Results of L1C calibration during ca,paign 1014-2018, all values in ns

Receiver	INT DLY(L1C), old	ΔT (T-V))	ΔT (T-R)	INT DLY(L1C), new	u_{cal}, L1C
FTMC, LT02	41.51	-1.07	-3.06	39.52	1.5
GUM, PL_3	765.8	-0.33	-3.06	763.07	1.5
AOS, AO_4	-5.14	-0.24	-3.06	-7.96	1.5

ANNEX: BIPM CALIBRATION INFORMATION SHEETS

First common clock measurement at PTB

Laboratory:	**PTB**
Date and hour of the beginning of	2018-06-04 08:00 UTC (MJD 58273)
Date and hour of the end of measurements:	2018-06-11 05:42 UTC (MJD 58280)

Information on the system		
	Local:	**Travelling:**
4-character BIPM code	**PTBB**	**PTBT**
Receiver maker and type: Receiver serial number:	ASHTECH Z-XII3T (S/N RT820013901)	Dicom GTR50 0708522 1.7.7
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	Nokia RG214	Andrews FSJ-1 (N)
Length outside the building /m:	approx. 25	25
Antenna maker and type: Antenna serial number:	Ashtech ASH700936 SNOW (S/N CR15930)	Navexperience 3G+C NA0164
Temperature (if stabilised) /°C		

Measured delays / ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	19.9± 0.1 (**)	-2.7 ± 0.1 (to port 1 PPS REF)
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	38.2± 0.1 (**) + 15.8	N/A
Antenna cable delay: (X_C) / ns	301.7	209.0± 0.1
Splitter delay (if any):	N/A	
Additional cable delay (if any):	N/A	

Data used for the generation of CGGTTS files				
	LOCAL:		Travelling	
☐ INT DLY (or X_R+X_S) (GPS) /ns:	304.5 (P1), 319.8 (P2)(**)		-42.6 (P1) -49.1 (P2) (***)	
☐ INT DLY (or X_R+X_S) (GLONASS) /ns:				
☐ CAB DLY (or X_C) /ns:	301.7		209.0	
☐ REF DLY (or X_P+X_O) /ns:	73.9 (**)		59.6	
☐ Coordinates reference frame:	ITRF (*)		ITRF (***)	
X /m:	+3844059.89 (*)	Mast P10	+3844065.77 (***)	Mast P1
Y /m:	+709661.48 (*)		+709658.27 (***)	
Z /m	+5023129.73 (*)		+5023125.32 (***)	

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 0.6°C

Notes:

(*) values provided by BIPM as part of coordinate alignment 2014 and G1 calibration Cal_Id=1001-2014

(**) values provided by BIPM Cal_Id 1001-2016/ local measurements not repeated
(***) BIPM campaign 1001-2014 provided new INT DLY values for PTB receiver PT02. PTBT INT DLY were adjusted in August 2015 so that PTBT – PT02 were close to zero for convenience.

Coordinates of mast P2 had been determined in the period before CC1 using NRCan PPP.

Names of files to be used in processing for site PTB CC1

Local receiver: GZPT02MJ.DDD

Travelling receiver GZPTBTMJ.DDD

The value REF DLY in PTBT cggtts files is calculated by the PTBT operational software based on the input of the measured delay from local UTC to the input 1 PPS REF to the PTBT rack.

PTBT operation at FTMC: Receiver LT02

Laboratory:	**FTMC**	
Date and hour of the beginning of measurements:	58303 0:00 UTC	
Date and hour of the end of measurements:	58307 24:00 UTC	
Information on the system		
	Local:	**Travelling:**
4-character BIPM code	**LT02**	**PTBT**
Receiver maker and type: Receiver serial number:	PikTime TTS-5, S/N 1020	Dicom GTR50 0708522 1.7.4
1 PPS trigger level /V:	1.0	1.0
Antenna cable maker and type: Phase stabilised cable (Y/N):	PikTime, Andrew Heliax FSJ1-50A. Phase stabilised cable	N-type, LMR400
Length outside the building /m:	10	10
Antenna maker and type: Antenna serial number:	Javad Choke Ring, RinGant G3T sn.: 000656	Navexperience 3G+C NA0164
Temperature (if stabilised) /°C	-	
Measured delays / ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	35.3	24.8 ns (to port 1 PPS REF)
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	1.5	53.2
Antenna cable delay: (X_C) / ns	160.6	209.0
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:	Travelling
☐ INT DLY (or X_R+X_S) (GPS) /ns:	41.88 (P1) 46.02 (P2)	-42.6 (P1) -49.1 (P2)
☐ INT DLY (or X_R+X_S) (GLONASS) /ns:	N/A	N/A
☐ CAB DLY (or X_C) /ns:	160.6	209.0
☐ REF DLY (or X_P+X_O) /ns:	36.8	53.2
☐ Coordinates reference frame:	ITRF	ITRF
X /m:	+3341116.78	+3341116.50
Y /m:	+1577001.49	+1577002.85
Z /m	+5181850.71	+5181850.51

General information

☐ Rise time of the local UTC pulse:	5 ns
☐ Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	23+/-0.5 °C

Names of files to be used in processing for site Ifag:

Local receiver: GZLT0258.303; GZLT0258.304; GZLT0258.305; GZLT0258.306; GZLT0258.307, files generated using r2cggtts V5.2 from LT02 RINEX files.

Travelling receiver GZPTBT58.303; GZPTBT58.304; GZPTBT58.305; GZPTBT58.306; GZPTBT58.307

The value REF DLY in PTBT cggtts files is calculated by the PTBT operational software based on the input of the measured delay from local UTC to the input 1 PPS REF to the PTBT rack.

Notes:

All coordinates determined consistently using NRCan PPP immediately before the period of data taking

PTBT operation at GUM: Receiver

Laboratory:	**GUM**
Date and hour of the beginning of measurements:	58325 0:00 UTC
Date and hour of the end of measurements:	58329 24:00 UTC

Information on the system		
	Local:	**Travelling:**
4-character BIPM code	**PL_3**	**PTBT**
Receiver maker and type: Receiver serial number:	PikTime TTS-4, S/N 108	Dicom GTR50 0708522 1.7.4
1 PPS trigger level /V:	1.0	1.0
Antenna cable maker and type: Phase stabilised cable (Y/N):	PikTime, Andrew Heliax FSJ1-50A. Phase stabilised cable	N-type, LMR400
Length outside the building /m:	5 m	5 m
Antenna maker and type: Antenna serial number:	Javad Choke Ring, RinGant G3T sn.: 000649 with antenna GrAnt G3T-JSsn.: 02726	Navexperience 3G+C NA0164
Temperature (if stabilised) /°C		

Measured delays / ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	69.94	20.71 (to port 1 PPS REF)
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	3.51	
Antenna cable delay: (X_C) / ns	138.48	209.0
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:	Travelling
☐ INT DLY (or X_R+X_S) (GPS) /ns:	765.77 (P1) 765.77 (P2)	-42.6 (P1) -49.1 (P2)
☐ INT DLY (or X_R+X_S) (GLONASS) /ns:	765.77 (P1) 765.77 (P2)	N/A
☐ CAB DLY (or X_C) /ns:	138.48	209.0
☐ REF DLY (or X_P+X_O) /ns:	73.45	18.0
☐ Coordinates reference frame:	ITRF	ITRF
X /m:	+3653846.82	+3653847.24
Y /m:	+1402629.30	+1402628.15
Z /m	+5019465.16	+5019465.52

General information	
☐ Rise time of the local UTC pulse:	< 1 ns
☐ Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	23+/-0.5 °C

Names of files to be used in processing for site GUM

Local receiver: GZPL_3MJ.DDD

Travelling receiver GZPTBTMJ.DDD

The value REF DLY in PTBT cggtts files is calculated by the PTBT operational software based on the input of the measured delay from local UTC to the input 1 PPS REF to the PTBT rack and the 1 PPS measurement results between 1 PPS REF and 1 PPS_M.

Notes:

All coordinates determined consistently using NRCan PPP immediately before the period of data taking

PTBT operation at AOS: Receiver

Laboratory:	**AOS**
Date and hour of the beginning of measurements:	12. 08. 2018, 00:00 UTC
Date and hour of the end of measurements:	18. 08. 2018, 24:00 UTC

Information on the system		
	Local:	**Travelling:**
4-character BIPM code	**AO_4**	**PTBT**
Receiver maker and type: Receiver serial number:	PikTime TTS-4 112	Dicom GTR50 0708522 1.7.4
1 PPS trigger level /V:	0.5	1.0
Antenna cable maker and type: Phase stabilised cable (Y/N):	Heliax, FSJ1-50A Y	N-type, LMR400
Length outside the building /m:	0.5 m	5 m
Antenna maker and type: Antenna serial number:	Trimble GNSS Choke Ring (Dorne-Margolin) TRM59800.00 sn. 5421355014	Navexperience 3G+C NA0164
Temperature (if stabilised) /°C	N/A	

Measured delays / ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	59.90	30.6 (to port 1 PPS REF)
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	-1.14	N/A
Antenna cable delay: (X_C) / ns	165.65	209.0
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:	Travelling
☐ INT DLY (or X_R+X_S) (GPS) /ns:	-5.14 (P1), -5.14 (P2)	-42.6 (P1) -49.1 (P2)
☐ INT DLY (or X_R+X_S) (GLONASS) /ns:	-5.92 (P1), 3.53 (P2)	N/A
☐ CAB DLY (or X_C) /ns:	165.65	209.0
☐ REF DLY (or X_P+X_O) /ns:	58.76	79.9
☐ Coordinates reference frame:	ITRF88	ITRF88
X /m:	+3738358.23	+3738367.63
Y /m:	+1148173.92	+1148163.07
Z /m	+5021815.89	+5021811.58

General information	
☐ Rise time of the local UTC pulse:	1 ns
☐ Is the laboratory air conditioned:	Yes
Set temperature value and uncertainty:	22 +/-0.5 °C

Names of files to be used in processing for site AOS

Local receiver: GZAO_4MJ.DDD
Travelling receiver GZPTBXMJ.DDD

Notes:

Antenna coordinates wer determined using NRCan PPP routines based on the first two days of operation at AOS.

Files GZAO_4MJ.DDD were generated with new coordinates, and the new values are reported in the table.

Files GZPTBXMJ.DDD were generated with new coordinates, and the new name was given in order to avoid confusion with existing files.

The value REF DLY in PTBT cggtts files is calculated by the PTBT operational software based on the input of the measured delay from local UTC to the input 1 PPS REF to the PTBT rack and the 1 PPS measurement results between 1 PPS REF and 1 PPS_M.

Second common clock measurement at PTB

Laboratory:	**PTB**	
Date and hour of the beginning of measurements:	58359 0:00 UTC	
Date and hour of the end of measurements:	58366 24:00 UTC	
Information on the system		
	Local:	**Travelling:**
4-character BIPM code	**PTBB**	**PTBT**
Receiver maker and type: Receiver serial number:	ASHTECH Z-XII3T (S/N RT820013901)	Dicom GTR50 0708522 1.7.4
1 PPS trigger level /V:	1 V	1 V
Antenna cable maker and type: Phase stabilised cable (Y/N):	Nokia RG214	Andrews FSJ-1 (N)
Length outside the building /m:	approx. 25 m	25 m
Antenna maker and type: Antenna serial number:	Ashtech ASH700936 SNOW (S/N CR15930)	Navexperience 3G+C NA0164
Temperature (if stabilised) /°C		
Measured delays / ns		
	Local:	**Travelling:**
Delay from local UTC to receiver 1 PPS-in (X_P) / ns	19.9 ± 0.1 (**)	-2.7 ± 0.1 (to port 1 PPS REF)
Delay from 1 PPS-in to internal Reference (if different): (X_O) / ns	38.2 ± 0.1 (**) + 15.8	N/A
Antenna cable delay: (X_C) / ns	301.7	209.0
Splitter delay (if any):	N/A	N/A
Additional cable delay (if any):	N/A	N/

Data used for the generation of CGGTTS files				
	LOCAL:		Travelling	
☐ INT DLY (or X_R+X_S) (GPS) /ns:	304.5 (P1), 319.8 (P2)(**)		-42.6 (P1) -49.1 (P2) (***)	
☐ INT DLY (or X_R+X_S) (GLONASS) /ns:				
☐ CAB DLY (or X_C) /ns:	301.7		209.0	
☐ REF DLY (or X_P+X_O) /ns:	73.9 (**)		59.6	
☐ Coordinates reference frame:	ITRF (*)		ITRF	
X /m:	+3844059.89 (*)	Mast P10	3844063.48	Mast P4
Y /m:	+709661.48 (*)		709658.72	
Z /m	+5023129.73 (*)		5023127.31	

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 0.6° C

Notes:

(*) values provided by BIPM as part of coordinate alignment 2014 and G1 calibration Cal_Id=1001-2014

(**) values provided by BIPM Cal_Id 1001-2016/ local measurements not repeated
(***) BIPM campaign 1001-2014 provided new INT DLY values for PTB receiver PT02. PTBT INT DLY were adjusted in August 2015 so that PTBT – PT02 were close to zero for convenience.

Names of files to be used in processing for site PTB CC2

Local receiver: GZPT02MJ.DDD

Travelling receiver GZPTBTMJ.DDD

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