



Fachbereich 4.4
Bundesallee 100, 38116 Braunschweig, Germany

Relative calibration of internal delays of PTB GNSS receivers by
means of B3TS – Campaign 1001-2020

Laboratory:	PTB
Date and hour of the beginning of measurements:	2021-03-30 (approx. 14:00 UTC) 59303 DOY 89(\$)
Date and hour of the end of measurements:	2021-04-08 (24:00 UTC) 59312 DOY 98

Information on the system

	Local: PTBB	Travelling: (1) BP25, (2) BP1C
• Receiver maker:	Septentrio	(1) Mesit, (2) Septentrio
Receiver type:	PolaRx5 TR	(1) GTR55, (2) PolaRx4 TR
Receiver serial number:	470 1292	(1) 1306001, (2) S9000169176
1 PPS trigger level /V:	1 V	1 V
• Antenna cable maker:	SSB electronics GmbH	
Antenna cable type :	ECOFLEX15	(1) C208 (2) C211
Phase stabilised cable (Y/N):		
Length outside the building /m:	approx. 25 m	approx. 25 m
• Antenna maker:	LEICA	(1) Novatel, (2) Ashtech
Antenna type:	AR 25	(1) GPS-703 GG (2) ?
Antenna serial number:	726333	CR6200323008
Temperature (if stabilised) /°C	no	no

Measured delays /ns

	Local:	Travelling:
• Delay from local UTC to receiver 1 PPS-in (X_P)	See Report for details	See Report for details
Delay from 1 PPS-in to internal Reference (if different): (X_O)		
• Antenna cable delay: (X_C)		??
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: P1 / P2 E1 / E5a	Travelling (SS)
• INT DLY (or X_R+X_S) (GPS) /ns:	29.7 / 27.2	0
• INT DLY (or X_R+X_S) (GALILEO) /ns:	32.0 / 31.7	0
• CAB DLY (or X_C) /ns:	205.7 (SSS)	0
• REF DLY (or X_P+X_O) /ns:	54.3 (SSSS)	0
• Coordinates reference frame:	ITRF	ITRF
Latitude or X /m:	3844059.86 (***)	
Longitude or Y /m:	709661.56 (***)	
Height or Z /m:	5023129.87 (***)	

General information

Rise time of the local UTC pulse:	< 3 ns
• Is the laboratory air conditioned:	yes

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v. 0, 2021-04-09, A. Bauch, D. Piester, T. Polewka

Set temperature value and uncertainty:	22.8 °C ± 0.5 °C
Set humidity value and uncertainty:	

Notes:

§ initial operation was with interchanged antenna cables. Corrected 2021-03-30 ca. 13:16 UTC.

§§ no CGGTTS files produced, coordinates (APC) not determined

§§§ measurement not repeated

§§§§ see details on installation below

(***) values provided by BIPM via Mail 2019-08-07

Laboratory:	PTB
Date and hour of the beginning of measurements:	2021-03-30 (approx. 14:00 UTC) 59303 DOY 89(S)
Date and hour of the end of measurements:	2021-04-08 (24:00 UTC) 59312 DOY 98

Information on the system

	Local: (2) PT09 (3) PT10	
• Receiver maker:	(2) Septentrio (3) Dicom (mesit)	
Receiver type:	(2) PolaRx4TR PRO (3) GTR51	
Receiver serial number:	(2) 3001148, (3) 1309042	
1 PPS trigger level /V:	1 V	
• Antenna cable maker:	(2) SSB-electronics GmbH, (3) Belden	
Antenna cable type :	(2) Ecoflex 15plus, (3) 8214 RG-8/U	
Phase stabilised cable (Y/N):	Y	
Length outside the building /m:	approx. 25 m	
• Antenna maker:	(3) Novatel, (4) NavExperience	
Antenna type:	(3) NOV750.R4 NOVS (4) 3G+C	
Antenna serial number:	(3) n/a (4) NA 0121	
Temperature (if stabilised) /°C		

Measured delays /ns

	Local:	Travelling:
• Delay from local UTC to receiver 1 PPS-in (X_P)	See Report for details	
Delay from 1 PPS-in to internal Reference (if different): (X_O)		
• Antenna cable delay: (X_C)		
Splitter delay (if any):	N/A	
Additional cable delay (if any):	N/A	

Data used for the generation of CGGTTS files

	LOCAL: P1 / P2 & E1 / E5a	Travelling
• INT DLY (or X_R+X_S) (GPS) /ns:	(2) 56.7 / 55.7 (3) 34.0 / 31.9	
• INT DLY (or X_R+X_S) (GLONASS) /ns:		
INT DLY (GALILEO)	(2) 57.6 / 66.3 (3) 35.1 / 23.8	
• CAB DLY (or X_C) /ns:	(2) 198.7* (3) 250.0*	
• REF DLY (or X_P+X_O) /ns:	(2) 183.2 (3) 36.8	
• Coordinates reference frame:	ITRF	
Latitude or X /m:	(2) 3844057.34 (3) 3844056.64	
Longitude or Y /m:	(2) 709663.82 (3) 709664.25	
Height or Z /m:	(2) 5023131.76 (3) 5023131.88	

General information

Rise time of the local UTC pulse:	< 5 ns
• Is the laboratory air conditioned:	yes

Set temperature value and uncertainty:	22.8 °C ± 0.5 °C
Set humidity value and uncertainty:	

Note: * not measured in 2021, all antenna coordinates (APC) determined in 2018 using PPP.

Laboratory:	PTB
Date and hour of the beginning of measurements:	2021-03-30 (approx. 14:00 UTC) 59303 DOY 89(S)
Date and hour of the end of measurements:	2021-04-08 (24:00 UTC) 59312 DOY 98

Information on the system

	Local: (4) PT07
• Receiver maker:	(4) Dicom (mesit)
Receiver type:	(4) GTR50
Receiver serial number:	(4) 806091,
1 PPS trigger level /V:	1 V
• Antenna cable maker:	(4) Andrews
Antenna cable type :	(4) FSJ-1
Phase stabilised cable (Y/N):	Y
Length outside the building /m:	approx. 25 m
• Antenna maker:	(4) Novatel
Antenna type:	(4) GPS-702-PP
Antenna serial number:	(4) SN 01017577
Temperature (if stabilised) /°C	

Measured delays /ns

	Local:
• Delay from local UTC to receiver 1 PPS-in (X_P)	See Report for details
Delay from 1 PPS-in to internal Reference (if different): (X_O)	
• Antenna cable delay: (X_C)	
Splitter delay (if any):	N/A
Additional cable delay (if any):	N/A

Data used for the generation of CGGTTS files

	LOCAL: P1 / P2
• INT DLY (or X_R+X_S) (GPS) /ns:	-36.9 / -24.6
• INT DLY (or X_R+X_S) (GLONASS) /ns:	
• CAB DLY (or X_C) /ns:	245.8*
• REF DLY (or X_P+X_O) /ns:	43.4
• Coordinates reference frame:	ITRF
Latitude or X /m:	3844062.43
Longitude or Y /m:	709659.03
Height or Z /m:	5023128.06

General information

Rise time of the local UTC pulse:	< 5 ns
• Is the laboratory air conditioned:	yes

Set temperature value and uncertainty:	22-8 °C ± 0.5 °C
Set humidity value and uncertainty:	

Notes:

* not measured in 2021

The photos show the B3TS antenna installation and the rack in the lab.

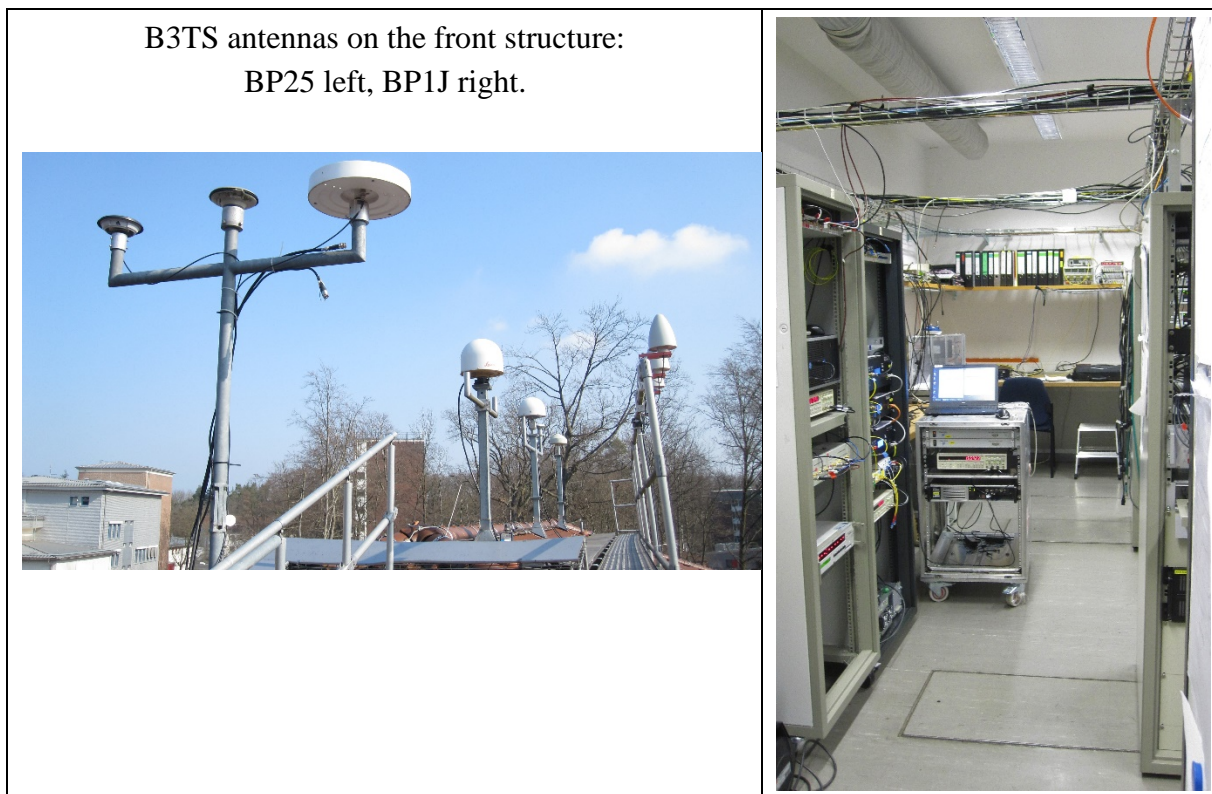


Diagram of the experiment set-up:

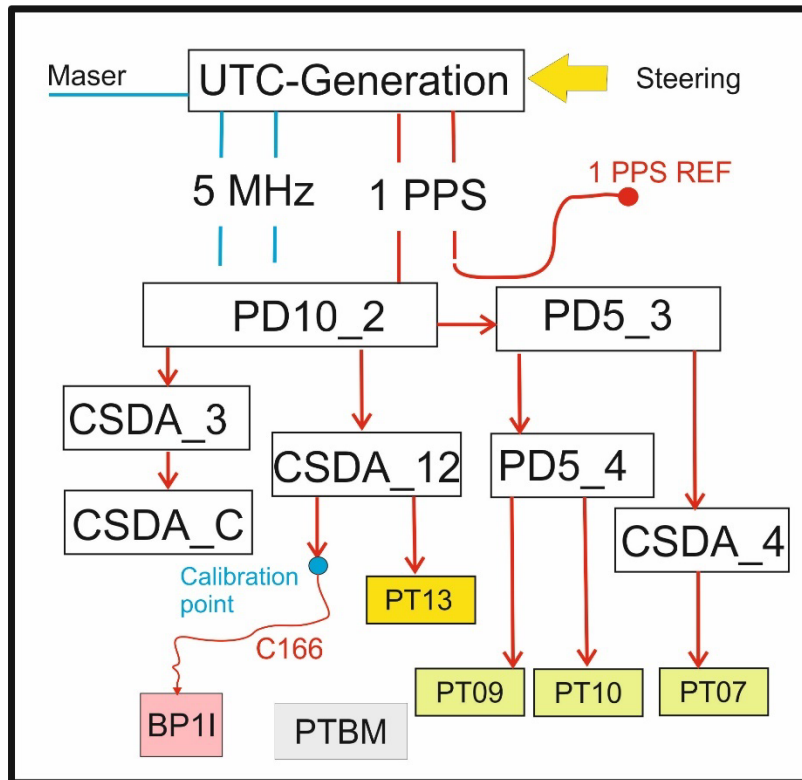


Figure 1: Signal distribution (1pps) to local receivers and B3TS

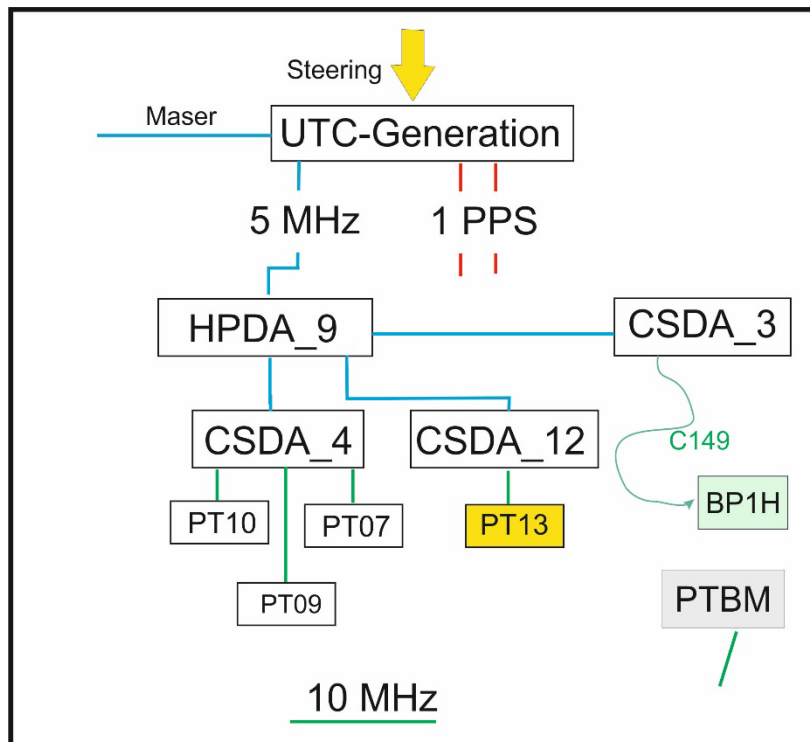


Figure 2: Signal distribution (5 MHz, 10 MHz, 20 MHz) to local receivers and B3TS

PT10 and PT07 are in routine use and can serve for provision of GPS L1C and GLONASS data. PT09 data are provided to BIPM as well. The calibration point was chosen to be connected to the same distribution equipment as PT13, the golden receiver.

Explanation of Acronyms:

HPDA: High Performance Distribution Amplifier (MHz – signals), CSDA: Clock Signal Distribution Amplifier (1PPS and MHz signals)

Additional Information

The following measurements following Annex 1 “Operational procedures for a visit of the travelling equipment” [1] were recorded:

1) Description and operation of the travelling system: B3TS

d. Relating the B3TS to the laboratory reference

Determination of UTC(PTB) – CLBP_k:

The input of cable C166 is the 1pps time reference for both receivers of the setup B3TS. The end of a cable originating in CSDA12 represents the PTB calibration point (CLBP_k). It was measured against UTC(PTB) using a differential method as depicted in Figure 3, and a similar configuration was used to measure all REF DLY values of the receivers involved, complemented by the additional measurements needed for receivers PolaRx4. It was assured that the measurement quantity has always been a small time interval between 5 ns and 800 ns, so that any non-linearities of the counter should be minimal. The 1 PPS AUX cable was thus adapted in length if needed. The counter SR 620 S/N 6096 had been in operation for more than 30 minutes before any data were taken. The Latching delay of receiver BP1J was measured using the BIPM cables and the SR 620 included in the B3TS rack.

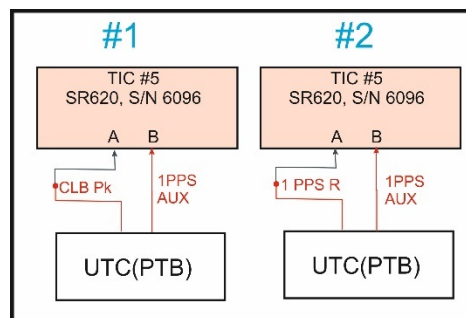


Figure 4: Measurement sequence to determine 1 PPS delays to the receivers, here shown for B3TS

These measurements were carried out before starting and repeated after stopping the operation of B3TS at PTB. The result is:

2021-03-25:

$$\text{UTC(PTB)} - \text{CLBP}_k = 14.969 \text{ ns} \pm 0.1 \text{ ns}$$

2021-04-09:

$$\text{UTC(PTB)} - \text{CLBP}_k' = 15.158 \text{ ns} \pm 0.1 \text{ ns}$$

Mean:

$$\text{UTC(PTB)} - \text{CLBP}_k' = \mathbf{15.064 \text{ ns} \pm 0.2 \text{ ns}}$$

Measurement of the delay between the 1pps input connector and the 1pps output connector of the BP1C PolaRx receiver

The measurement was performed in two steps according to Figures 1 and 2 of Annex E:

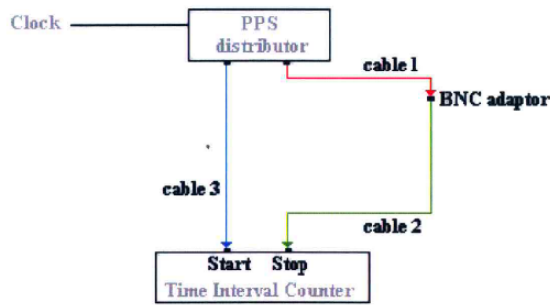


Figure 1: example of tare measurement set-up before and after operation

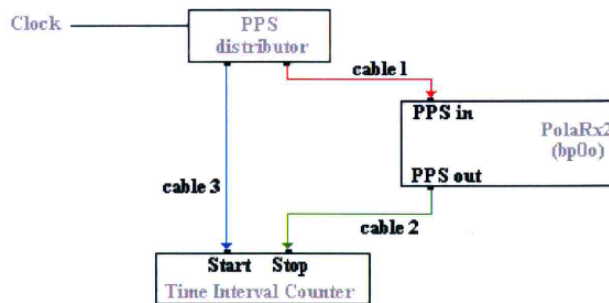


Figure 2: example of delay measurement set-up during operation

Cable 1: C157, Cable 2: C155, Cable 3 : C183

This measurement was carried out before starting and was repeated after some days and also after stopping the operation of B3TS at PTB. The result is:

2021-03-25:

After switch on of the receiver:

“Figure 1” : 15.411 ns ± 0.1 ns

“Figure 2” : 155.587 / 155.603 / 155.719 ns each 100 samples, jitter about 90 ps

After receiver operation for about 1 hour:

“Figure 1” : 15.425 ns ± 0.1 ns

“Figure 2” : 155.579 ns 100 samples, jitter about 104 ps

Latching Delay = “Figure 2” - “Figure 1” = 140.154 ns ± 0.2 ns

2021-04-09:

(receiver in continuous operation, cable not touched all the time)

“Figure 2” : 155.778

“Figure 1” : 15.322 ns ± 0.1 ns

Receiver started once more

“Figure 2” : $155.868 \text{ ns} \pm 0.2 \text{ ns}$

Mean Latching Delay = $\{(155.622 - 15.418) + (155.778 - 15.322)\} / 2 = 140.330 \text{ ns} \pm 0.2 \text{ ns}$

2) Local Equipment at PTB

2.1) REF DLY measurements:

1pps references for all four receivers were measured against UTC(PTB) using the same configuration as described above. Measurements are reported with dates, were done intentionally by different persons with different auxiliary cables and thus raw measurement values recorded with TIC SR 620, S/N 6096.

The results are:

PTBB:

Although PTBB is a new PolaRx5 TR receiver, the optional auto-compensation of the latching delay was deactivated at installation in March 2019 and was not activated now. Initially, the idea was not to interrupt PTBB operation and measure only the 1 PPS out wrt to UTC(PTB)

2021-03-22:

$\text{UTC(PTB)} - 1\text{ppsout(PTBB)} = 56.050 \text{ ns} \pm 0.1 \text{ ns}$

2021-04-07:

$\text{UTC(PTB)} - 1\text{ppsout(PTBB)} = 56.184 \text{ ns} \pm 0.1 \text{ ns}$

This value is to be compared with the current PTBB (PT13) REF DLY: 54.3 ns.

Because of the large discrepancy, the complete method of REF DLY determination was repeated 2021-04-09:

$\text{UTC(PTB)} - 1\text{ppsIn(PTBB)} = 9.591 \text{ ns} \pm 0.1 \text{ ns}$ (March 2019: 9.33 ns)

Latching Delay: (“Figure 2” – “Figure 1”) = $46.629 \text{ ns} \pm 0.1 \text{ ns}$ (March 2019: 45.00 ns)

which results in REF DLY = 56.220 ns in 2021.

PT09 :

The operation of PT09 was not interrupted, and only the 1 PPS out was measured wrt to UTC(PTB):

2021-03-22:

$\text{UTC(PTB)} - \text{PPS(out)} = 182.881 \text{ ns} \pm 0.1 \text{ ns}$

2021-04-07

UTC(PTB) – PPS(out) = 182.887 ± 0.1 ns

This value is to be compared with the current PT09 REF DLY: 183.2 ns

Mean REFDELAY PT09 : 182.884 ns ± 0.2 ns

PT10

2021-03-22

UTC(PTB) - 1ppsIn(PT10) = 36.512 ns ± 0.1 ns

2021-04-07

UTC(PTB) - 1ppsIn(PT10) = 36.599 ns ± 0.1 ns

Mean REFDELAY PT10 : 36.556 ns ± 0.1 ns

PT07

2021-03-22

UTC(PTB) - 1ppsIn(PT07) = 43.315 ns ± 0.1 ns

2021-04-07

UTC(PTB) - 1ppsIn(PT07) = 43.413 ns ± 0.1 ns

Mean REFDELAY PT07 : 43.364 ns ± 0.1 ns