GNSS CALIBRATION REPORT

PT14 INTERNAL

Prepared by: Andreas Bauch (PTB)
Head, Time Dissemination
Working Group

Approved by: Jürgen Becker (PTB)
QM-representative of
Time and Frequency
Department of PTB

Authorized by: BIPM

Project:	PTB_PT14_internal
Code:	1001-2020_transf.
Version:	1.0
Safe date:	28.03.2022 16:59

PHYSIKALISCH-TECHNISCHE BUNDESANSTALT, BRAUNSCHWEIG, MARCH 2022

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

REFERENCES

REFERENCES	
RD01	**BIPM report 2021 1001-2020_GPSP3C1-GALE3_Group1-trip_V1-2**
RD02	**BIPM guidelines for GNSS calibration, V4.0, 05/08/2021**
RD03	**J. Kouba, P. Heroux, 2002, *"Precise Point Positioning Using IGS Orbit and Clock Products,"* GPS Solutions, Vol 5, No. 2, 12-28**

ACRONYMS

ACRONYMS	
BIPM	**Bureau International de Poids et Mesures, Sèvres, France**
CGGTTS	**CCTF Generic GNSS Time Transfer Standard**
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**
TDEV	**Time deviation**
TIC	**Time interval counter**

SUMMARY

PTB is preparing operation of receiver PT14, PolaRx5TR (5.4.0) 3078762, as part (back-up) of its GNSS infrastructure. The receiver was installed for the first time beginning of March 2022. The final location has not yet been decided. The transfer of internal delays from PT13 (PTBB) to PT14 is described. Results provided are the new receiver's internal delays for GPS P-code signals on the two frequencies L1 and L2 (INT DLY (P1), and INT DLY(P2)), on GPS C/A-code signals (INT DLY (L1C)), and Galileo E1 and E5a.

As a reminder: All uncertainty values reported in this document are 1-σ values. In the Annex the BIPM information table is added.

1. RECEIVER INSTALLATION AT PTB

The installation of the receivers in PTB is depicted in Figure 1-1 for 1 PPS signals and in Figure 1-2 for 5 MHz signals. PTB's mobile receiver PTBT is mentioned in the pictures but was not involved in the current exercise. The Calibration Information Sheet in the Annex gives all details.

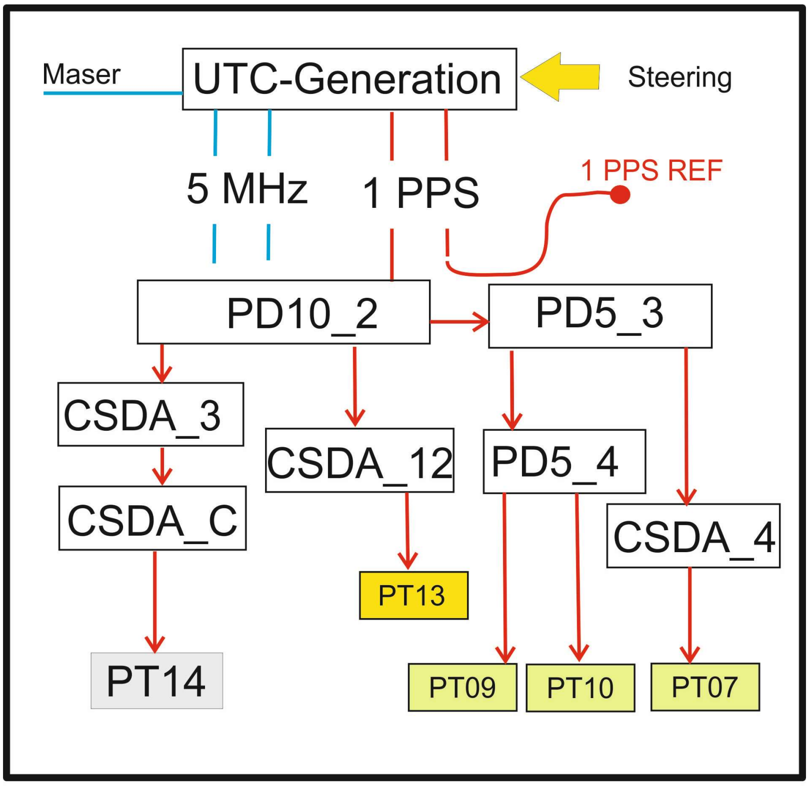

Figure 1-1: UTC(PTB) reference point and 1 PPS signal distribution to PTB GNSS receivers; PD5 and PD10 stand for pulse distributor, CSDA stands for clock signal distribution amplifier

Figure 1-3 illustrates the installation of GNSS antennas on the roof of the PTB time laboratory (clock hall). The PT13 antenna is marked with a yellow arrow, the PT09 antenna is the geodetic antenna next to the right, the PT10 antenna is the next one (NavXperience 3G+C) to the right.

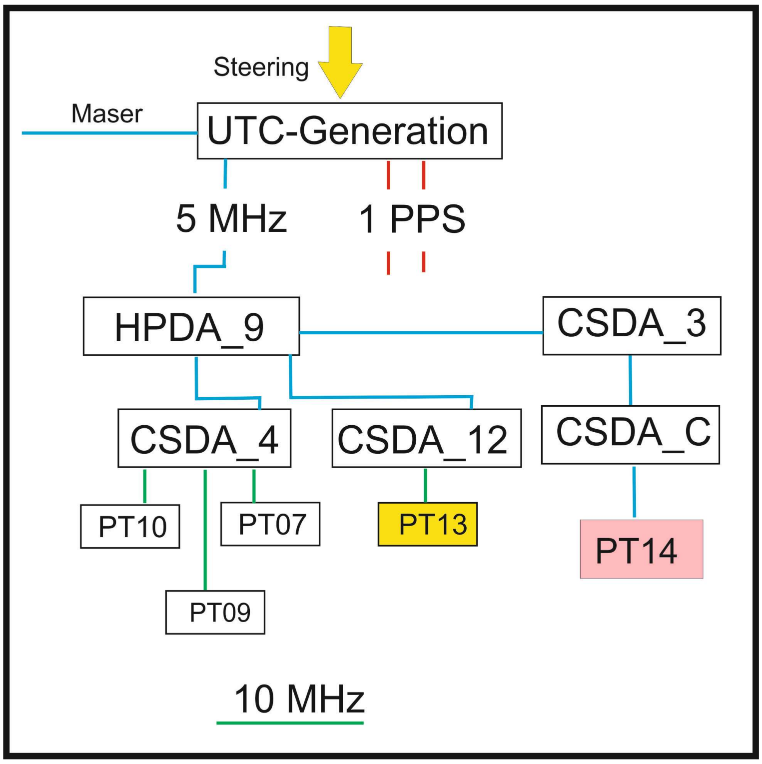

Figure 1-2: UTC(PTB) signal distribution (5 MHz, 10 MHz) to PTB GNSS receivers; HPDA stands for High-precision distribution amplifier (for rf frequencies)

Figure 1-3: Installation of GNSS antennas at PTB, the PTBB/PT13 antenna marked yellow, the PT14 antenna red

2. RESULTS OF COMMON-CLOCK DATA TAKING

2.1. DETERMINATION OF PT14 INT DELAYS MARCH 2022

The period 59657 to 59662 (6 days) was chosen to determine the PT14 INT DLY values. PT13 served as reference. The results are given in Table 2-1.

Table 2-1 INT DLY values in ns determined for receiver PT14 in March 2022

Signal	Mean	Median	SigmaE	Nepoch
GPS P1	19.34	19.35	0.19	535
GPS P2	18.52	18.54	0.23	535
GPS L1C	21.60	21.60	0.17	535
Galileo E1	21.59	21.58	0.19	535
Galileo E5a	19.14	19.14	0.22	535

All results are shown in one plot as Figure 2-1.

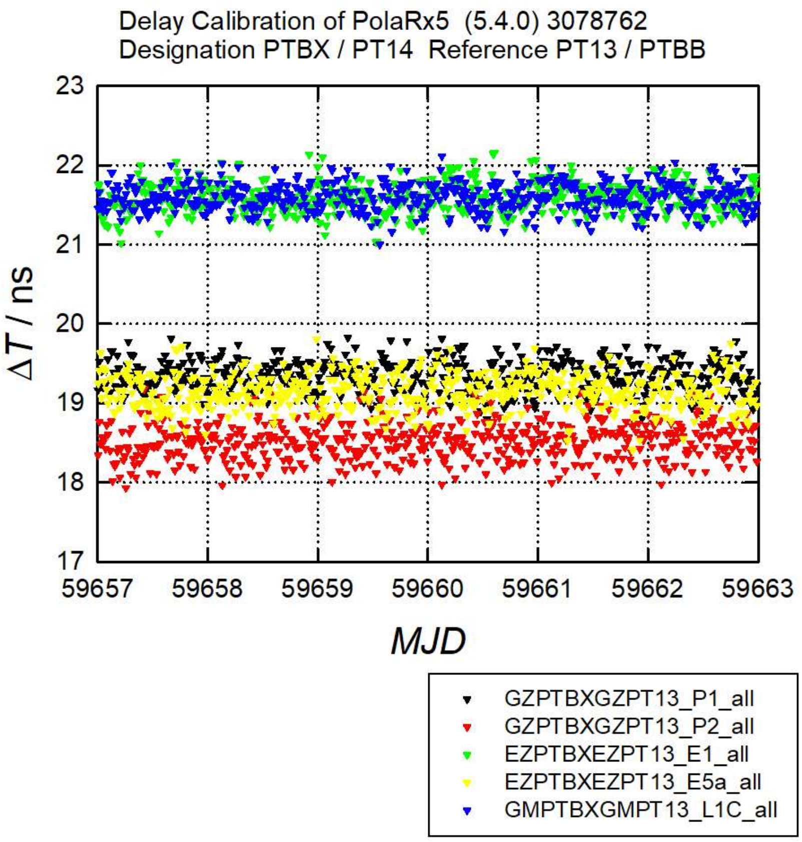

Figure 2-1 Delay values obtained for PT14 during the common-clock set-up in PTB

3. 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 PTB. The systematic uncertainty is given by

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

Values in column f3 are calculated according to u(f3) = √{u(f1)² +(1.54 × u(f1-f2))² } for GPS and for the Galileo delays according to √{u(f1)² +(1.26 × u(f1-f2)²}.

Table 3-1: Uncertainty contributions for the GPS calibration of receiver delays

	Uncertainty		Value f1 (ns)	Value f2 (ns)	Value f1-f2 (ns)	Value f3 (ns)	Description
1	u_a (PTB)		0.1	0.1	0.14	0.23	CC measurement uncertainty at PTB, TDEV
	Systematic components due to antenna installation						
2	$u_{b,11}$		0.1	0.1	0.14	0.28	Position error at PTB
3	$u_{b,13}$		0.2	0.2	0.0	0.20	Multipath at PTB(as agreed by CCF WG GNSS)
4	$u_{b,14}$		0.5	0.5	0.0	0.5	Antenna cable delay measurement
	Installation of receivers to UTC(PTB)						
5	$u_{b,21}$		0.2	0.2	0	0.2	Connection of receivers to UTC(PTB) (REF DLY)
6	$u_{b,24}$		0.1	0.1	0	0.1	TIC nonlinearities at PTB

All uncertainties considered are small compared to the “standard” uncertainty attributed to a link between PTB and any laboratory contributing to TAI. The slightly different frequency ratio in case of Galileo compared to GPS results in slightly different values, but after rounding to 0.1 ns the differences are negligible.

ANNEX: BIPM CALIBRATION INFORMATION SHEETS

Common clock measurement at PTB

Laboratory:	**PTB**
Date and hour of the beginning of	2022-03-19 0:00 UTC (MJD 59657)
Date and hour of the end of	2022-03-24 24:00 UTC (MJD 59662)

Information on the system		
	Reference:	**DUT:**
4-character BIPM code	**PT13**	**PT14**
Receiver maker and type: Receiver serial number:	PolaRx5TR (5.2.0) S/N 470 1292	PolaRx5TR (5.4.0) 3078762
1 PPS trigger level /V:	1	1
Antenna cable maker and type: Phase stabilised cable (Y/N):	ECOFLEX 15plus	LMR-400
Length outside the building /m:	approx. 25	Approx.25
Antenna maker and type: Antenna serial number:	LEICA AR25 726333, Calib Geo++ 18.08.2015	Navexperience 3G+C REFERENCE S/N RE 0661
Temperature (if stabilised) /°C		

Measured delays /ns		
	Reference:	**DUT:**
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 (#)	Determined automatically by receiver software
Antenna cable delay: (X_C) / ns	198.7 ± 0.1	208.7 ± 0.5
Splitter delay (if any):	N/A	

Data used for the generation of CGGTTS files				
	Reference:		**DUT**	
☐ INT DLY (or X_R+X_S) (GPS) /ns:	31.6 (P1), 29.3 (P2), 33.6 (C1) (*)		0.0 for all	
☐ INT DLY (or X_R+X_S) (GALILEO) /ns:	33.6 (E1), 33.6 (E5a) (*)		0.0 (E1) 0.0 (E5a)	
☐ INT DLY (or X_R+X_S) (GLONASS) /ns:				
☐ 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	+3844062.49(**)	Mast P7
Y /m:	+709661.56 (***)		+709659.56(**)	

Z /m	+5023129.87 (***)		+5023127.89(**)	

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, peakt-to-peak variations 0.3° C

Notes:

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

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

(**) APC determined using NRCan PPP free software [RD03]

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

Names of files to be used in processing:

DUT:	GZPT14MJ.DDD	GMPT14MJ.DDD	EZPT14MJ.DDD
Reference receiver:	GZPT13MJ.DDD	GMPT13MJ.DDD	EZPT13MJ.DDD

END of DOCUMENT