Physikalisch-Technische Bundesanstalt
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Calibration report

ESOC's time transfer system at PTB, Braunschweig, Mai 2015

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Summary

This document reports on the relative GPS calibration of GNSS equipment owned by ESOC. The equipment (receiver, antenna and antenna cables) was shipped to PTB and calibrated against PTB's permanently installed reference station PT02.

PTB has been selected as one of the G1 laboratories in EURAMET in the new scheme of GNSS calibrations that is applicable for laboratories and institutes collaborating with BIPM in the realization of Coordinated Universal Time UTC [1].

ESOC has declared its interest to collaborate with BIPM and realize a UTC(ESOC) time scale adhering to the standards. The ESOC GNSS receiver has been calibrated for the first time. The partners agreed to the calibration on short notice, and BIPM was informed about the upcoming activity by mail on 30 April 2015. In the terminology of [1] this is a “golden system calibration” which comprises just one period of data taking at PTB.

The ESOC was put into operation on April 30th. Data for the calibration were gathered during four days, May 1st to May 4th 2015 (MJD 57143 to 57146).

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Description of equipment and operations

In this calibration the “traveling” system ESOC is the system under study that is going to be calibrated against the Group 1 reference PT02. The traveling system consists of a Septentrio PolaRx4TR receiver, a Septentrio Sepchoke GNSS antenna, a GPS Networking ALDCBS1X4 splitter, a lightning arrestor and two antenna cables. The reference system PT02 consists of a Ashtech Z-XII3T receiver, an Ashtech ASH700936E antenna and an antenna cable. The traveling system was installed at PTB and connected to UTC(PTB), therefore operated in a common-clock installation with PT02 from MJD 57143 to 57146.

This calibration was performed before the most recent G1 calibration results provided by BIPM and new coordinates for the two involved antenna mast were applied in September 2015.

A detailed “information sheet” describing the equipment is provided in Annex A.

Institute	Status	Dates of measurement	Receiver type	BIPM code	RINEX name
PTB	Group 1 reference	57143-57146	Ashtech Z-XII3T	PT02	PTBB
ESOC	Traveling	57143-57146	Septentrio PolaRx4TR	ESOC	ESOC

Table 1: Summary information on the calibration equipment

Data used

For PT02 CGGTTS files generated using R2CGGTTS v5.1 were used. For ESOC the CGGTTS files generated by the receiver control software RxControl were used (RxControl uses R2CGGTTS v5.1 internally). Processing parameters for both stations are described in Annex A.

Results of raw data processing

A python implementation of the method described in [2] written at PTB was used to process the raw data, the results are shown in Figure 1 and summarized in 2.

Pair	Date	RAWDIF(L1)	Uncertainty	RAWDIF(L2)	Uncertainty
ESOC-PT02	57143-57146	-524.5	0.1	-538.9	0.1

Table 2: Summary information of the raw calibration results (all values in ns)

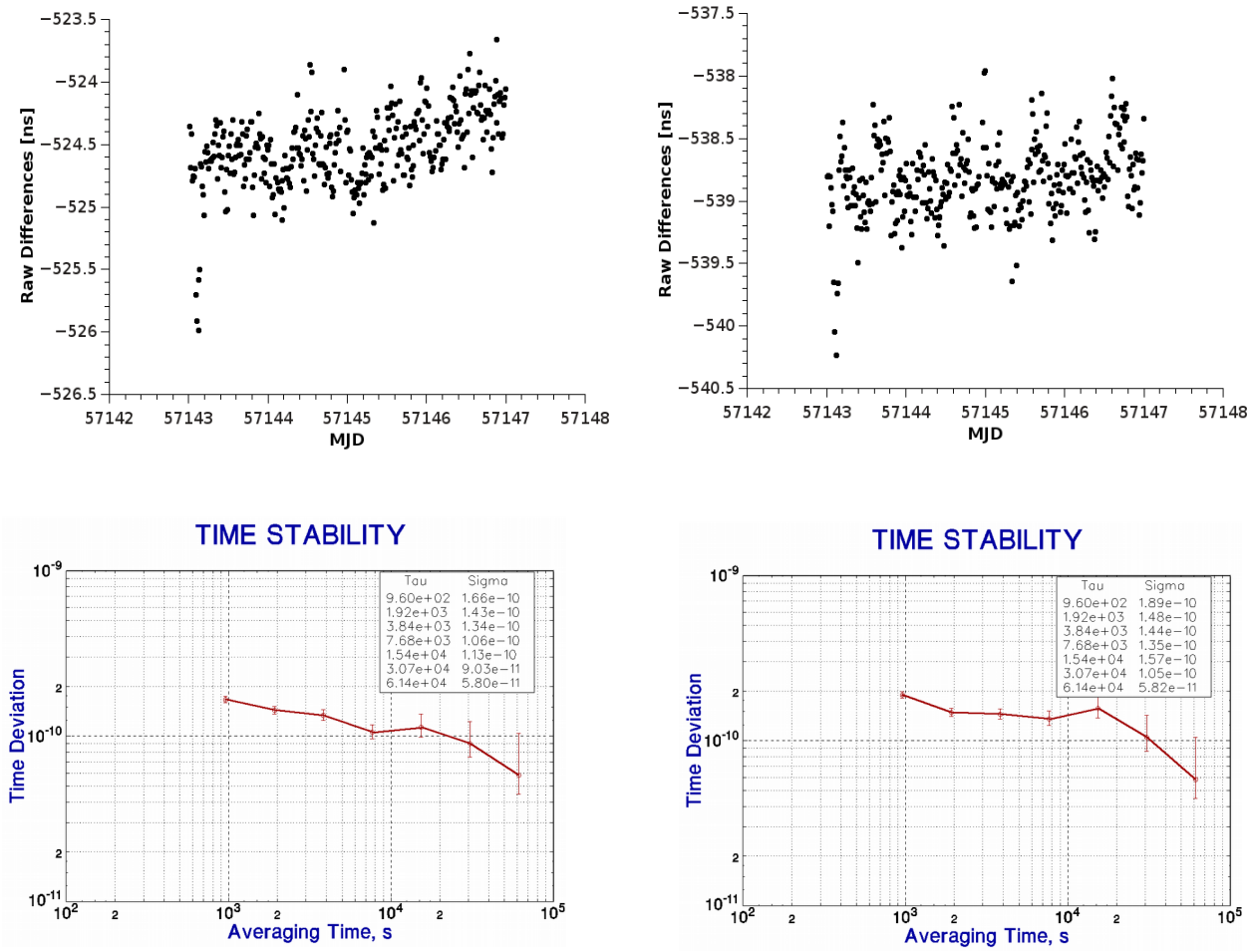

Figure 1: Time series of raw data differences RAWDIF for L1 (left) and L2 (right) and their time stability (below).

Calibration results

We follow the notations in the CGGTTS format where

- CABDLY is the combined antenna cable delay;
- REFDLY represents the offset between the UTC(PTB) reference point and the receiver;
- INTDLY is the internal signal delay (antenna + receiver internal).

Since the delay of the ESOC antenna signal splitter was not measured, this delay goes into the INTDLY as well.

The REFDLY for the ESOC Septentrio PolaRx4TR was measured according to Annex C.3 in [1]. The REFDLY for the reference station PT02 was treated as given from previous

calibration campaigns (see Annex A for details).

In addition we use the following notations:

- SYSDLY = INTDLY + CABDLY
- TOTDLY = SYSDLY – REFDLY.

For a direct calibration of a traveling system T against a reference system R without an intermediate system we define

- $\Delta CABDLY_{T\text{-}R} = CABDLY_T - CABDLY_R$
- $\Delta REFDLY_{T\text{-}R} = REFDLY_T - REFDLY_R$.

Therefore

- $\Delta SYSDLY_{T\text{-}R} = RAWDIF_{T\text{-}R} + \Delta REFDLY_{T\text{-}R}$
- $\Delta INTDLY_{T\text{-}R} = \Delta INTDLY_T - \Delta INTDLY_R = RAWDIF_{T\text{-}R} + \Delta REFDLY_{T\text{-}R} - \Delta CABDLY_{T\text{-}R}$

with $INTDLY_R$ given as 304.5 ns (L1) and 318.9 ns (L2). Calibration results are summarized in 3.

Pair	Date	ΔREFDLY	ΔCABDLY	L1		L2	
				RAWDIF	ΔSYSDLY	RAWDIF	ΔSYSDLY
ESOC-PT02	57143-57146	140.6	-137.0	-524.5	-383.9	-538.9	-398.3

Table 3: Calibration results: Traveling system vs. reference system T-R (all values in ns)

Uncertainty Estimation

The overall uncertainty of the INTDLY values is given by

$$u_{cal} = \sqrt{u_a^2 + u_b^2}$$

with the statistical uncertainty u_a and the systematic uncertainty u_b. All values are considered to be 1-sigma. The statistical uncertainty u_a originates from the RAWDIF (ΔP1 and ΔP2) and is given by the statistical analysis of the raw code differences. Since the traveling system is the system under study, there are no additional uncertainties from an intermediate system. The systematic uncertainty is given by

$$u_b = \sqrt{\sum_n u_{b,n}^2} \quad .$$

Contributions to the sum are listed in 4.

Uncertainty	Value L1	Value L2	Value L1-L2	Value L3	Description
u_a (T-R)	0.1	0.1	0.1		RAWDIF (traveling-reference)
u_a	0.1	0.1	0.1	0.2	
Components related to the link to the local references UTC(k)					
$u_{b,1}$	0.5	0.5	0		REFDLY (reference at PTB)
$u_{b,2}$	0.5	0.5	0		REFDLY (traveling at PTB)
Components related to the antenna cable delays					
$u_{b,11}$	0.5	0.5	0		CABDLY (traveling)
Components related to RAWDIF					
$u_{b,13}$	0.3	0.3	0.4		Multipath at PTB on reference receiver
$u_{b,14}$	0.3	0.3	0.4		Multipath at PTB on traveling receiver
u_b	1.0	1.0	0.6	1.4	
U_{CAL}	1.0	1.0	0.6	1.4	

Table 4: Uncertainty contributions (all values in ns)

Pair	Date	L1		L2		L1-L2	
		ΔINTDLY	Uncertainty	ΔINTDLY	Uncertainty	ΔINTDLY	Uncertainty
ESOC-PT02	57143-57146	-246.9	1.0	-261.3	1.0	14.4	0.6

Table 5: Summary of results: Traveling system vs. reference system T-R (all values in ns)

The uncertainty U_{cal}(L3) does not include the calibration uncertainty of PT02.

Final results for the traveling system

Reference system	Cal_Id	Date		INTDLY L1 /ns	INTDLY L2 /ns
PT02				304.5	318.9
Traveling system	Cal_Id	Date	U_{CAL} (L3) /ns	INTDLY L1 /ns	INTDLY L2 /ns
ESOC			1.4	57.6	57.6

Table 6: Summary of final results

References

[1] BIPM guidelines for GNSS calibration, V3.0, April 2015

[2] G. Petit, “Computation and report of the results of GPS P3 differential calibration of geodetic receivers”, BIPM TM.212, November 2012

Annex A: Detailed BIPM information sheets

Laboratory:	PTB
Date and hour of the beginning of measurements:	57143 0 a.m.
Date and hour of the end of measurements:	57146 12 p.m.

	Local: PT02	Traveling: ESOC
Information on the system		
Receiver maker:	Ashtech	Septentrio
Receiver type:	Z-XII3T	PolaRx4TR
Receiver serial number:	RT820013901	3102129
1 PPS trigger level /V:	1 V	1 V
Antenna cable maker:	Nokia	Times Microwave Systems
Antenna cable type :	RG214	LMR600
Phase stabilised cable (Y/N):		Y
Length outside the building /m:	25 m	25 m
Antenna maker:	Ashtech	Septentrio
Antenna type:	ASH700936E	Sepchoke GNSS antenna
Antenna serial number:	CR15930	5380
Temperature (if stabilised) /°C	no	no
Measured delays /ns		
Delay from local UTC to receiver 1 PPS-in (X_P)	23.3 ns†	82.6 ns
Delay from 1 PPS-in to internal Reference (if different): (X_O)	36.2 ns†‡	133.3 ns
Antenna cable delay: (X_C)	301.7 ns	162.5 ns
Splitter delay (if any):	no splitter	unknown
Additional cable delay (if any):		2.2 ns (X_D, add. ant. cable)
Data used for the generation of CGGTTS files and / or in the following analysis		
INT DLY (or X_R+X_S) (GPS) /ns:	304.5 ns (P1), 318.9 ns (P2)	0 ns (P1), 0 ns (P2)
INT DLY (or X_R+X_S) (GLONASS) /ns:		
CAB DLY (or X_C+X_D) /ns:	301.7 ns	164.7 ns
REF DLY (or X_P+X_O) /ns:	75.3 ns	215.9 ns
Coordinates reference frame:	ITRF	ITRF
Antenna post:	KOP P10	KOP P11
Latitude or X /m:	3844059.94 m	3844057.86 m
Longitude or Y /m:	709661.39 m	709663.12 m
Height or Z /m:	5023129.65 m	5023131.03 m

General information	
Rise time of the local UTC pulse:	< 5 ns
Is the laboratory air conditioned:	yes
Set temperature value and uncertainty:	23 °C ± 0.5 °C
Set humidity value and uncertainty:	

† Measurement 29.09.2010.

‡ Corrected in exchange with BIPM, 20.10.2010.