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GPS based link calibration between BKG Wettzell and PTB

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Result for the time transfer link currently used by BIPM between BKG and PTB

Executive summary

The Bundesanstalt für Kartographie und Geodäsie (BKG) and the Physikalisch.Technische Bundesanstalt, Braunschweig, Germany, contribute with their clocks and time transfer data to the realization of International Atomic Time. BKG clocks are operted at the Fundamentalstation Wettzell, and for historical reasons the local realization of UTC is named UTC(IFAG) (IFAG: institut für angewandte Geodäsie). Routinely, the BIPM uses data generated with the two fixed receivers (FR) with the designation WTZA and PTBB, respectively.

The time difference is determined as

$$[\mathrm{UTC(IFAG)} - \mathrm{UTC(PTB)}]_{\mathrm{GPS}} = \mathrm{FR(IFAG)} - \mathrm{FR(PTB)} - \mathrm{C}_{\mathrm{GPS}} .$$

The differential correction C_{GPS} obtained with the two fixed receivers (FR) is C_{GPS} = -2.27 ns, and the calibration uncertainty (1 σ) amounts to 2.18 ns. (see Table 3).

Details of the data evaluation and uncertainty estimation are given in the following sections. Information on the installation of the travelling receiver and on the fixed receivers at BKG and PTB, respectively, are given in Annex 1 and Annex 2.

Further work

Additionally the offsets of the time reference points in the very large baseline interferometry (VLBI) building and the satellite laser ranging (SLR) building have been measured with respect to UTC(IFAG). At the moment of the measurement (MJD 55812) the offsets were VLBI – UTC(IFAG) = (23670.65 ± 2.73) ns and SLR – UTC(IFAG) = (734,98 ± 2.72) ns, respectively.

Equipment and calibration procedure

The relative calibration of the GPS link between BKG´s geodetic observatory and PTB was performed with the PTB´s calibration set-up (see Figure 1), consisting of a GTR50 receiver, a SR620 time interval counter (TIC) and a monitor/keyboard. The devices are integrated in a transportable rack. Becasue of the use of a traveling TIC for the determination of the local UTC reference points at both sites, a systematic error related to internal delay differences between different counters does not exist.

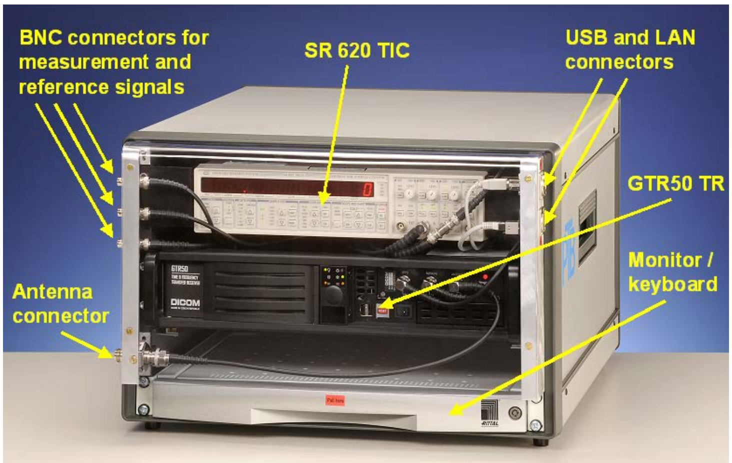

Figure 1. PTB’s calibration set-up.

The travelling receiver (TR) is operated together with the fixed GPS receivers in a common-clock very short baseline at both labs. It is referenced to the local UTC realization by the TIC measurements.

By differencing the common-clock difference (CCD) results of both labs, the contributions of the TR cancels out and the calibration values for the links between the fixed receivers (FR) can be calculated according to

$$\langle TR@PTB - FR(PTB) \rangle - \langle TR@BKG - FR(BKG) \rangle = C_1 - C_2 = C_{GPS}\,, \qquad (1)$$

where <…> stands for the mean value over a certain period. The mean values are obtained by first calculating the time deviation (TDEV) of the CCD measurements. Then an averaging period is determined from the global minimum of the time deviation (TDEV) of the CCD measurement data, in order to get rid of the white phase noise. The averaged data are used to calculate the mean value of the CCD.

Only the offset of the 1 PPS signal connected to the TR has to be measured with respect to the local UTC, the delays of the FRs are included in the calibration values. The operational link has to be corrected according to

$$[UTC(IFAG) - UTC(PTB)]_{GPS} = FR(BKG) - FR(PTB) - C_{GPS}\,. \qquad (2)$$

UTC(IFAG) is the local UTC realization at BKG. Table 1 lists the two FRs at PTB and BKG which are used for the operational TAI link by the BIPM. The nomenclature used here takes into account that one receiver produces different kinds of data.

Table 1. Receivers at PTB and BKG and their designation when providing data of different kind.

Institute	Receiver	P3	RINEX
PTB	Ashtech Z12-T	PT02	PTBB
BKG	Ashtech Z12-T	IF13	WTZA

UTC reference points

At PTB the local UTC reference is available at the BNC connector of a cable inside the measurement room with a known offset to UTC(PTB), which is a virtual point inside the central measurement system (see Annex 1).

At BKG the local timescale UTC(IFAG) is represented by the signal at the output connectors of a 1 PPS distribution amplifier. This amplifier is located in the basement of a building nearby the commercial caesium clock which is used for providing the UTC(IFAG) frequency and the clock module which generates the 1 PPS (see Annex 2). The UTC(IFAG) frequency is also provided to the GPS building by a long underground cable. In this building the GPS receiver IF13/WTZA is located which is used for the TAI link. A second clock module generates a 1 PPS signal. Via a distribution amplifier it is connected to the GPS receiver and additionally send to the UTC(IFAG) generation basement by another long cable where it can be measured with respect to UTC(IFAG). The same is done with the 1 PPS output signal of the receiver.

The calibration set-up was also placed in the GPS receiver building and provided with the 1 PPS signal of the local clock module. To reference the TR to UTC(IFAG) a long cable to the UTC(IFAG) generation basement was temporarily used. 1800 single measurements were performed with the travelling TIC. In order to cancel out the delay of this cable it was also used at PTB and connected to the UTC(PTB) reference cable with an adapter. Here also 1800 measurements were recorded. The results of these measurements and the related standard deviations (SD) are listed in Table 2.

Table 2. Results of the UTC reference measurements at PTB and BKG.

Measurement	**Mean / ns**	**SD / ns**
UTC(PTB) + long cable + internal cables – 1 PPS ref.	-399.04	0.47
UTC(IFAG) + long cable + internal cables – 1 PPS ref.	129.92	0.14

These values have to be added to the GPS measurements. The delay of the long cable and of the internal cables inside the calibration set-up cancel out in equation (1).

Uncertainty Estimation

The overall uncertainty of the GPS link calibration is given by

$$\mathrm{U_{GPS}} = \sqrt{\mathrm{u_a^2} + \mathrm{u_b^2}}\,, \tag{3}$$

with the statistical uncertainty u_a and the systematic uncertainty u_b. The statistical uncertainty is related to the standard deviation (SD) of the averaged CCD data. The systematic uncertainty is given by

$$\mathrm{u_b} = \sqrt{\sum_n \mathrm{u}_{\mathrm{b},n}}\,. \tag{4}$$

The contributions to the sum are listed in Table 3 and explained below.

The uncertainties due to the instabilities of the connection to the local UTC sites ($u_{b,1}$, $u_{b,2}$) [1] are estimated from long term laboratory experience and are supported by a repetition of the TIC measurement at PTB after finishing the GPS measurements.

According to the manufacturer specifications the trigger level timing error of the travelling SR620 TIC ($u_{b,3}$, $u_{b,4}$) is given by [2]

$$\text{Trigger level timing error} = \frac{15\text{ mV} + 0.5\text{ \% of trigger level}}{1\text{ PPS slew rate}} \tag{5}$$

for start and stop channel, respectively. At both labs a trigger level of 1 V at both channels was used. The 1 PPS slew rate can be estimated to be approximately 0.5 V/ns for a signal at the endpoint of a relatively short cable. This was checked by using a scope at PTB. Thus the error is 0.04 ns for the stop channel at both labs. A second scope measurement showed that the pulse is distorted at the end of the long cable and the slew rate is just 0.1 V/ns. The error for the start channel is 0.20 ns. By geometrically adding the two errors the total trigger level timing error at both labs is 0.20 ns.

The trigger level timing error of the TR´s internal TIC ($u_{b,5}$, $u_{b,6}$) is estimated, according to information given by the manufacturer [3], as 10 mV / (1 PPS slew rate) per channel. The error of the stop channel cancels out, because it is always provided with the signal of the receiver board. The TR was provided with the signal with the high slew rate in both cases.

Table 3. Systematic uncertainty contributions. Values are determined either by measurements or by estimation and rounded to the second decimal. The contributions marked with an asterisk are only applied to special measurements (see text).

Uncertainty	Value / ns	Description
$u_{b,1}$	0.10	Instability of the connection to UTC(PTB)
$u_{b,2}$	0.10	Instability of the connection to UTC(IFAG)
$u_{b,3}$	0.20	TIC trigger level timing error at PTB
$u_{b,4}$	0.20	TIC trigger level timing error at BKG
$u_{b,5}$	0.02	TR trigger level timing error at PTB
$u_{b,6}$	0.02	TR trigger level timing error at BKG
$u_{b,7}$	1.00	TIC nonlinearities at PTB
$u_{b,8}$	1.00	TIC nonlinearities at BKG
$u_{b,9}$	0.47	Jitter of the TIC measurement at PTB
$u_{b,10}$	0.14	Jitter of the TIC measurement at BKG
$u_{b,11}$	0.02	Determination of the UTC reference point at PTB
$u_{b,12}$	2.30	Uncertainty of the UTC(IFAG) reference points
$u_{b,13}$	0.30	Multipath
$u_{b,14}$	0.18	Antenna cable and antenna
$u_{b,15}$*	0.51	Position error at PTB
$u_{b,16}$*	0.99	Position error at BKG
$u_{b,17}$*	0.30	Uncertainty of the ambiguity estimation

The uncertainty contributions $u_{b,7}$ and $u_{b,8}$ 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 traveling TIC 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. In case of distorted signals this effect can be at the order of a nanosecond. Since the TR´s internal TIC uses a surface acoustic wave (SAW) filter as interpolator, its nonlinearity effect can be neglected, because it is of the order of a few picoseconds (see reference [4]).

Although the TIC jitter (SD) is the statistical uncertainty of the TIC measurements, it becomes a systematic uncertainty in terms of the GPS measurements ($u_{b,9}$, $u_{b,10}$), because the results of the TIC measurements affect all GPS measurements in the same way.

As mentioned above the UTC(PTB) reference point is a virtual point inside the central measurement system. The delay of the reference cable was checked before the measurement with the calibration set-up´s TIC. The uncertainty is 0.01 ns. This has to be combined with the uncertainty of the delay measurement of the adapter which is used to connect the long cable. It is 0.02 ns. The combined uncertainty $u_{b,11}$ is 0.02 ns.

For the generation of the CGGTTS data the antenna positions of the TR is manually entered into the processing software in ITRF coordinates before the CCD measurements. These positions could differ from the "true" positions in a different way in each laboratory. This is taken into account by the contributions $u_{b,15}$ and $u_{b,16}$ in case of the code based link calibration, because the position has an effect on the total delay. Since these effect is dominant in the height and linear for position errors up to 30 m [1], the absolute deviation of the manually entered position from the "true" position is multiplied with a coefficient which reflects the effect of the height error at each laboratory. The "true" position of the TR at PTB and BKG is estimated with the help of the RINEX data and the NRCan-PPP software [7]. The PPP method guarantees consistency. Thus the PPP position can be named "true" position. The height error coefficients at each site are evaluated by comparing P3 CGGTTS data from two receivers in a common-clock short baseline setup generated with the R2CGGTTS software [8] developed at ORB from RINEX data and then regenerating the data of one of the two receivers with virtual height shifts of ±1 m. This is exemplarily depicted for the site BKG in Figure 2.

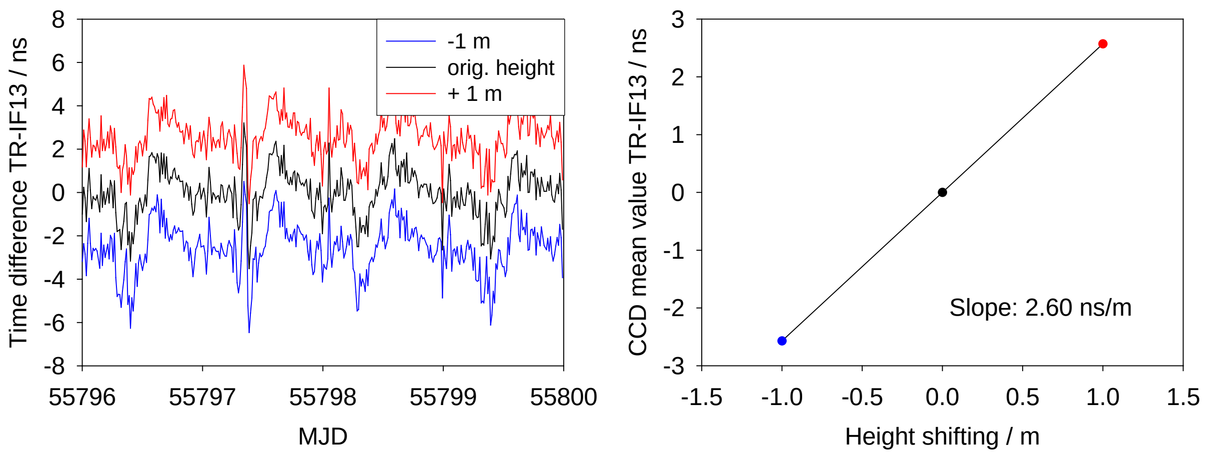

Figure 2. Determination of the position error coefficient at BKG. All data are normalized with the mean value of the original height data.

The black graph on the left-handed plot shows the CCD between TR and IF13 with the same position which are used by the internal processing software. The blue and the red graph depict the CDD between the two receivers using exactly the same data, but with a (fictive) height shift applied to the TR of ±1 m, respectively. The right-handed plot shows the CCD mean value with respect to the height shift. The absolute value of the slope of the line which connects the three points is used as position error coefficient e_h(BKG) = 2.60 ns/m. A similar study was performed at PTB and the coefficient was calculated to be e_h(PTB) = 2.22 ns/m. The absolute value of the difference between "true" and manually entered position of the TR is 0.23 m at PTB and 0.38 m at BKG.

The uncertainty contribution $u_{b,17}$ of 0.3 ns is applied to the PPP link calibration, according to reference [9], where a typical phase discontinuity of 0.15 ns per receiver was found for PPP batch processing with the NRCan-PPP software [7], independent of the length of the processed batch. This adds up geometrically to 0.21 ns for a CCD comparison between a pair of receivers and to 0.3 ns for the two CCD measurements.

Results

In Figure 3 on the left hand side the P3 and PPP results of the CCD measurement at BKG are depicted. Before plotting the P3 data were cleaned from outliers by a 3σ filter. The plot on the right hand side shows the related time deviations.

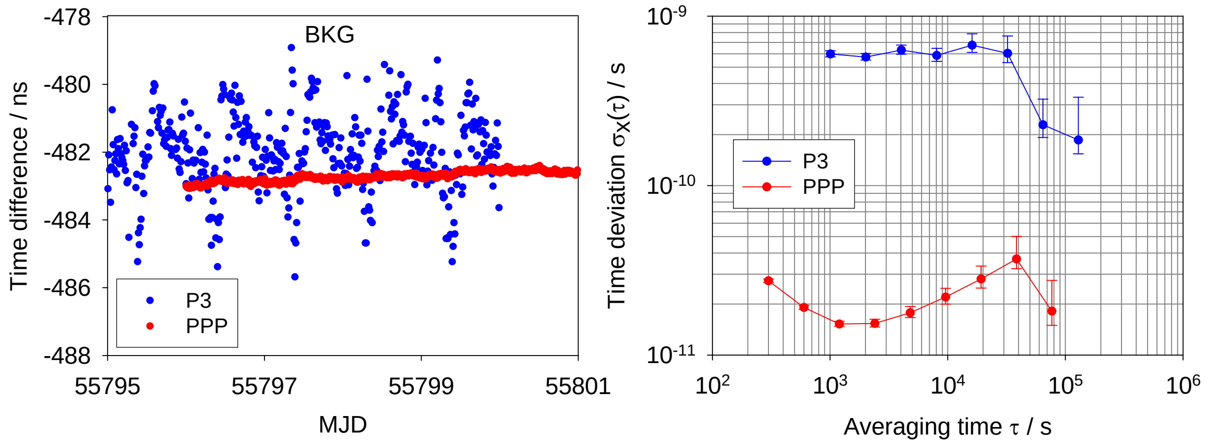

Figure 3. CCD measurements between the TR and the IF13/WTZA receiver and related time deviations.

The measurement at PTB between the TR and PT02/PTBB receiver is shown in Figure 4 together with the related time deviation.

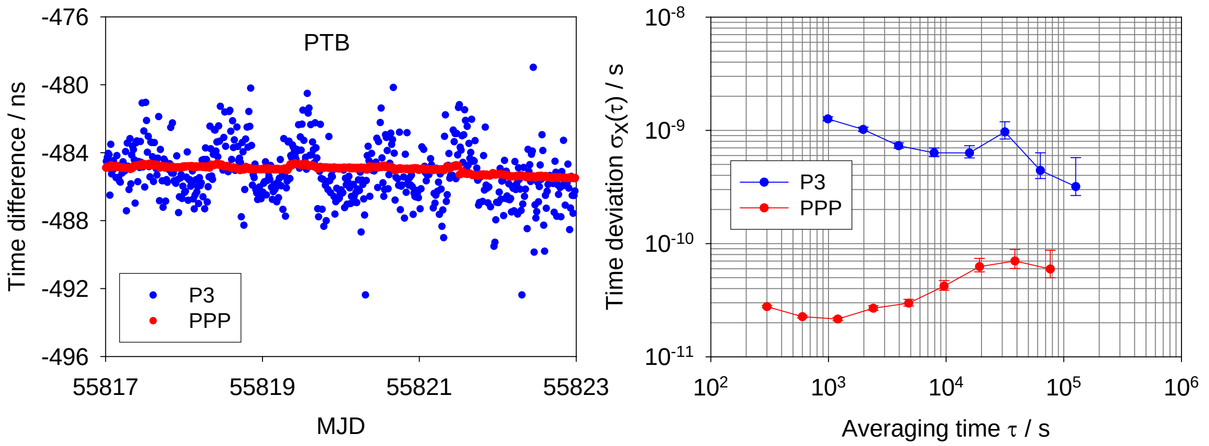

Figure 4. CCD measurements between the TR and the PT02/PTBB receiver and related time deviations

In contrast to the GTR50 receiver the Ashtech Z-12 receivers at PTB do not apply the internal delays, the antenna cable delay, and the reference delay to the RINEX files. The CGGTTS P3 data are calculated from the RINEX files with the R2CGGTTS software [8] developed at ORB and the delay settings are made in this software. Thus the results of the PPP analysis are corrected by

$$D = \frac{154^2 D_{\mathrm{P1}} - 120^2 D_{\mathrm{P2}}}{9316} + D_{\mathrm{Cab}} - D_{\mathrm{Ref}}, \tag{6}$$

where D is the total delay which has to be subtracted from the PPP calibration values. D_{P1} and D_{P2} are the internal delays on the two GPS frequencies, D_{Cab} is the antenna cable delay, and D_{Ref} is the delay with respect to the UTC reference point. The values are taken from the CGGTTS file header.

In order to avoid underestimation the minimum of the upper error bar of the time deviation estimates is used to determine an interval for data averaging. The error bars are representing the confidence interval of the time deviation estimates. Furthermore, the maximum averaging interval was limited to one day. Each time deviation estimate is calculated in a way that the averaging time of the preceding estimate is doubled (except the first estimate).

The results of the CCD measurement and the related SD are listed in Table 4, together with the number of averaged data. For example, a 64 in case of P3 data means that 64 consecutive 16 min spaced data are averaged. In case of PPP the data spacing is 300 s.

Table 4. Results of the CCD measurement. The calibration values C_1 and C_2 are calculated as the mean value of the averaged data. The SD is used as the statistical uncertainty. All values are rounded to the second decimal.

Lab	**Type**	**# of averaged data**	**C_1, C_2 / ns**	**SD / ns**
BKG	P3	64	-482.00	0.30
	PPP	4	-482.72	0.14
PTB	P3	daily averages	-485.19	0.54
	PPP	4	-484.99	0.24

The result of the calibration is

$$C_{GPS,P3} = (-3.19 \pm 3.06)\ \text{ns} \quad (7)$$

for the P3 link between IF13 and PT02 and

$$\boxed{C_{GPS,PPP} = (-2.27 \pm 2.81)\ \text{ns}} \quad (8)$$

for the PPP link WTZA-PTBB. The PPP link is the relevant link used for TAI generation by the BIPM. The P3 result can be considered as a crosscheck. P3 and PPP diverge by 0.92 ns but agree within the combined uncertainty.

Closure measurement

It has to be verified that the internal delays of the travelling equipment have not significantly changed during the calibration campaign. For this purpose the travelling receiver was compared to a fixed receiver at PTB before and after the calibration trip to BKG. The fixed receiver is a GTR50 receiver (PT08, as designated by the BIPM). The delay of the 1 PPS signal connected to PT08 is referenced to UTC(PTB) and the internal delays as well as the cable delay was calibrated by the manufacturer. With the internal TIC of the calibration set-up the GPS measurements were referenced to the UTC(PTB) reference cable (without the long cable used at BKG). The P3 data of one day before (MJD 55749) and one day overlapping with the BKG calibration (MJD 55817) were compared to the data of PT08. The individual P3 common-views of the two CCD measurements at PTB and the mean values are depicted in Figure 5.

The first CCD yields 9.40 ns and the second one 9.36 (The results are not nearby zero, because the internal cabling of the calibration set-up is not taken into account). The difference between the two measurements is 0.04 ns. Thus it has been proven that the internal delays of the calibration set-up have not significantly changed 68 days.. Since the difference of 0.04 ns is far below the statistical uncertainty of the CCD measurements at BKG and PTB (Table 4), it has not to be taken into account in the uncertainty budget.

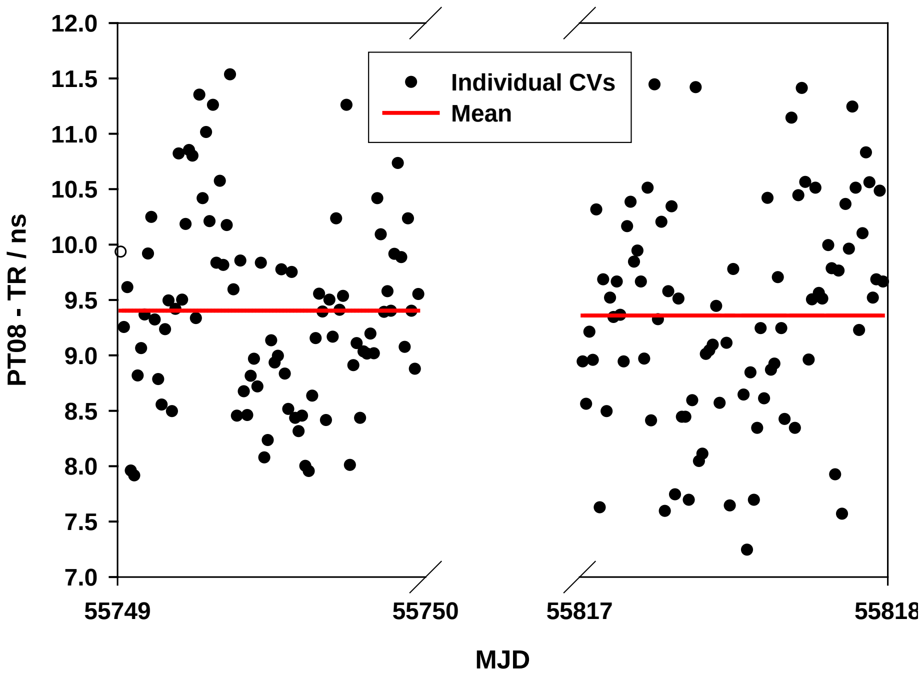

Figure 5. Closure measurements at PTB

Calibration of different reference points at BKG

At the BKG site at Wettzell a calibrated time signal is needed for very large baseline interferometry (VLBI) as well as for satellite laser ranging (SLR). The VLBI and the SLR building are provided with a 1 PPS signal generated by an active hydrogen maser and transmitted by long underground cables.
The internal TIC of the calibration set-up was used to relate selected points at the VLBI and SLR sites to UTC(IFAG). For this purpose the calibration set-up was relocated to the UTC(IFAG) generation basement. The measurement steps are depicted in Figure 6.

At first the start channel of the internal TIC were connected to UTC(IFAG) by the long cable which was also used to measure the delay between the 1 PPS in the GPS building and UTC(IFAG). The stop channel was also provided with UTC(IFAG) using a short cable. In the second step the long cable was connected to the reference points at the VLBI and the SLR building, respectively. In each measurement 1800 single data points were taken. The frequency of the maser providing the signal for VLBI and SLR was kept in close agreement to the UTC(IFAG) frequency and no drift was detected during the measurements.

To relate the reference points at VLBI and SLR to UTC(IFAG) the results of the measurements are differenced according to

$$\begin{aligned} &<(\mathrm{VLBI/SLR} + \text{long cable}) - (\mathrm{UTC(IFAG)} + \text{short cable})> \\ &- <(\mathrm{UTC(IFAG)} + \text{long cable}) - (\mathrm{UTC} + \text{short cable}> \\ &= \mathrm{VLBI/SLR} - \mathrm{UTC(IFAG)}. \end{aligned} \tag{9}$$

Here <…> stands for the mean value of the 1800 single measurements, similar to equation (1). The internal delays inside the calibration set-up due to the cables which connect the TIC to the outside connectors (see Figure 1) are neglected in equation (9), because they cancel out, as well as the internal delay of the TIC itself. The mean values of the measurements are listed in Table 5, together with the related SD of the 1800 single measurements.

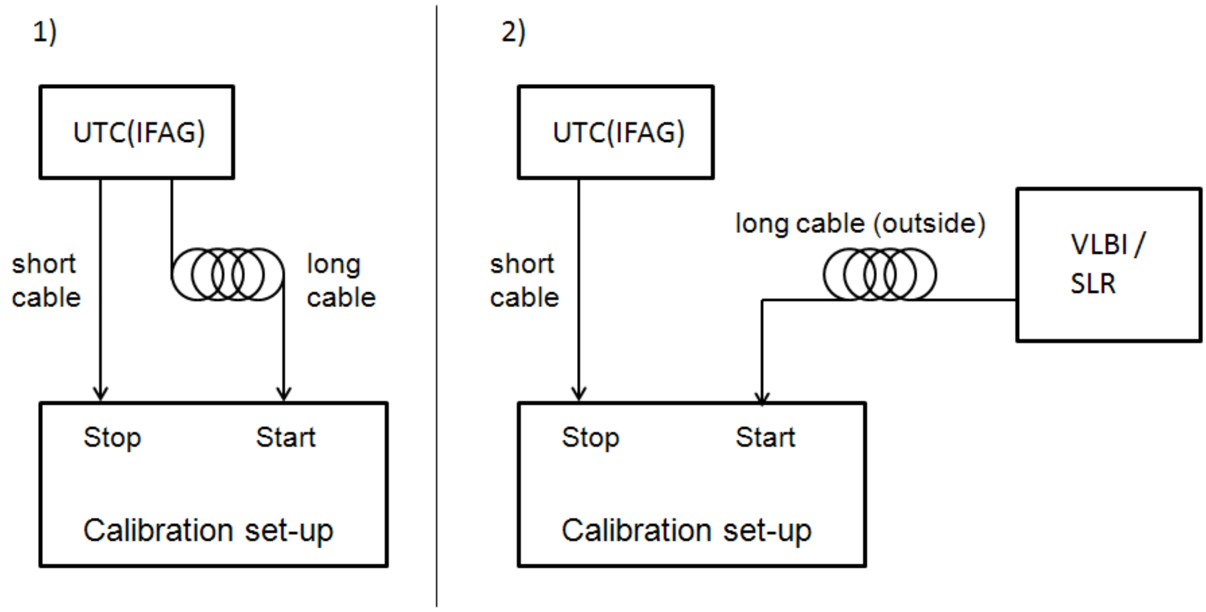

Figure 6. The measurement steps for relating the reference points of VLBI and SLR to UTC(IFAG).

The systematic uncertainty of these measurements consists of the trigger level timing error of the TIC (equation (5)), the nonlinearity effect of the TIC, and the uncertainty of UTC(IFAG) reference signals. Again, the 1 PPS slew rate can be estimated to be 0.5 V/ns at the short cable and 0.1 V/ns at the long cable. According to the usual practice at BKG in case of such measurements the trigger level was set to 0.4 V at both TIC channels. This yield a trigger level timing error of 0.17 ns for the start channel and 0.03 ns for the stop channel, resulting in a total trigger level timing error of 0.17 ns for both channels and 0.24 ns for the two pairs of measurements in equation (9). With an uncertainty due to the nonlinearity effect of 1 ns for each TIC measurement and an uncertainty of UTC(IFAG) of 2.30 ns the total systematic uncertainty of each delay evaluation according to (9) becomes 2.72 ns.

Table 5. Results of the UTC reference measurements at PTB and BKG, performed on MJD 55812 between 7:30 UTC to 11:30 UTC.

Measurement	**Mean / ns**	**SD / ns**
(UTC(IFAG) + long cable) – (UTC(IFAG) + short cable)	457.68	0.02
(VLBI + long cable) – (UTC(IFAG) + short cable)	24123.37	0.24
(SLR + long cable) – (UTC(IFAG) + short cable)	1192.66	0.10

Considering the SD of the measurements as the statistical uncertainty the results for the two reference points are

$$\mathrm{VLBI} - \mathrm{UTC(IFAG)} = (23670.69 \pm 2.73)\ \mathrm{ns} \tag{10}$$

and

$$\mathrm{SLR} - \mathrm{UTC(IFAG)} = (734.98 \pm 2.72)\ \mathrm{ns}. \tag{11}$$

The measurements were conducted on MJD 55812 between 7:30 UTC and 11:30 UTC. Since the 1 PPS at the VLBI and SLR reference points is generated by a hydrogen maser the calibration results (10) and (11) are only valid for this period. In long term the maser´s frequency will be in disagreement with the UTC(IFAG) frequency. Only if the maser is continuously measured against the UTC(IFAG) frequency somewhere at BKG the calibration results (10) and (11) can be calculated at any epoch by adding the accumulated phase difference.

Summary

With PTB´s travelling calibration setup the GPS TAI link between BKG and PTB has been calibrated with an uncertainty of 2.81 ns. Since the new calibration value is -2.27 ns, it is not necessary to apply it to the data of the operational link.

On MJD 55812 the delays of the VLBI and the SLR reference points have been determined with respect to UTC(IFAG), respectively. For the values which are valid at the moment of the measurement see equations (10) and (11).

References

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ANNEX 1

BIPM calibration information sheet

Laboratory:	IFAG
Date and hour of the beginning of measurements:	**2011-08-22 (00:00:00 UTC)**
Date and hour of the end of measurements:	**2011-08-28 (23:59:30 UTC)**

Receiver setup information

	Local:	**Portable: PTBTR**
• Maker:	Ashtech	DICOM
• Type:	Z-XII3T	GTR50
• Serial number:	RT820013902	0708522
• Receiver internal delay (GPS) :	P1 = 292.8 ns, P2 = 307.2	P1 = -28.8 ns, P2 = -22.7 ns,
• Receiver internal delay (GLO) :	N/A	N/A
• Antenna cable identification:	N/A	
Corresponding cable delay :	122.0 ns	223.8 ns
• Delay to local UTC :	435.9 ns	13.9 ns
• Receiver trigger level:	N/A	1.0 V
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	4075578.66	-3942085.67 m
Longitude or Y m	931852.57	+3368256.21 m
Height or Z m	4801569.81	+3702000.74 m

Antenna information

	Local:	**Portable:**
• Maker:	Ashtech	Novatel
• Type:	ASH700936C_M SNOW	NOV702
• Serial number:	12118	7020087
If the antenna is temperature stabilised		
• Set temperature value :	---	---

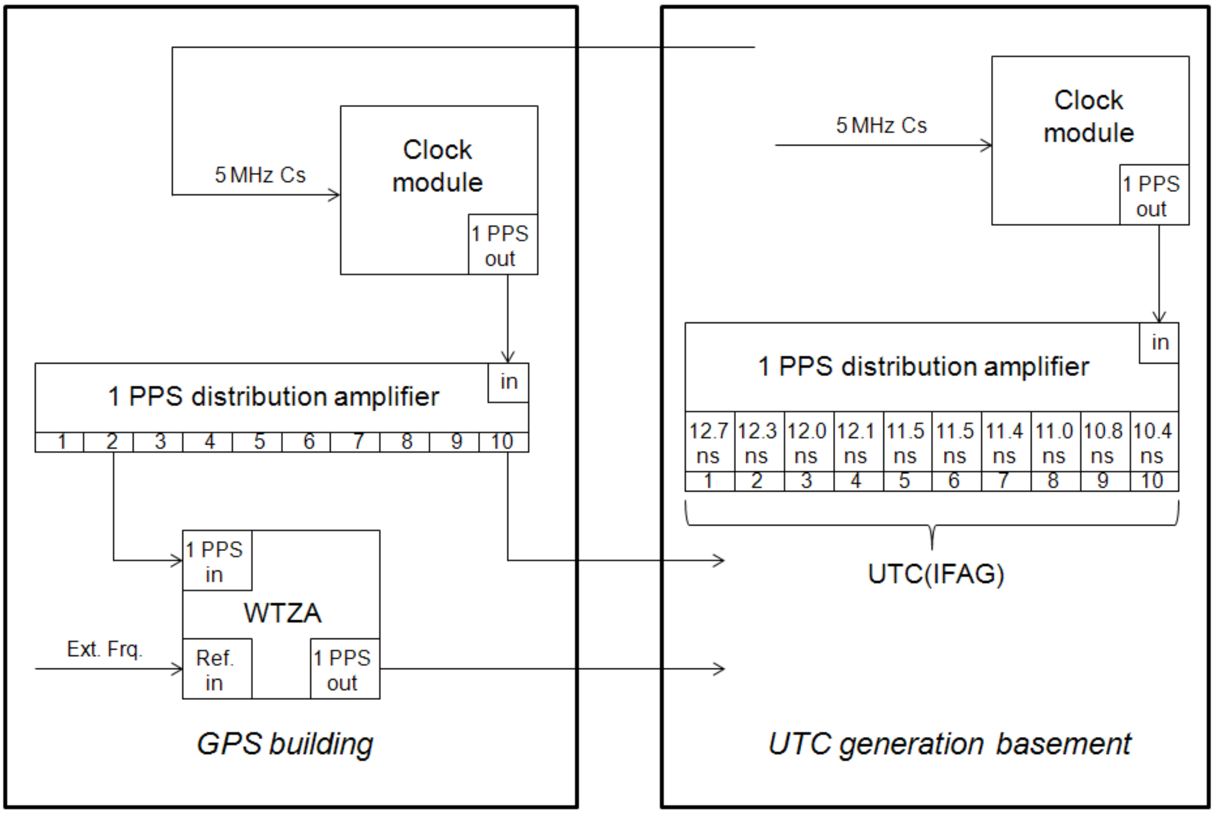
Local antenna cable information

• Maker:	
• Type:	
• Is it a phase stabilised cable:	
• Length of cable outside the building :	

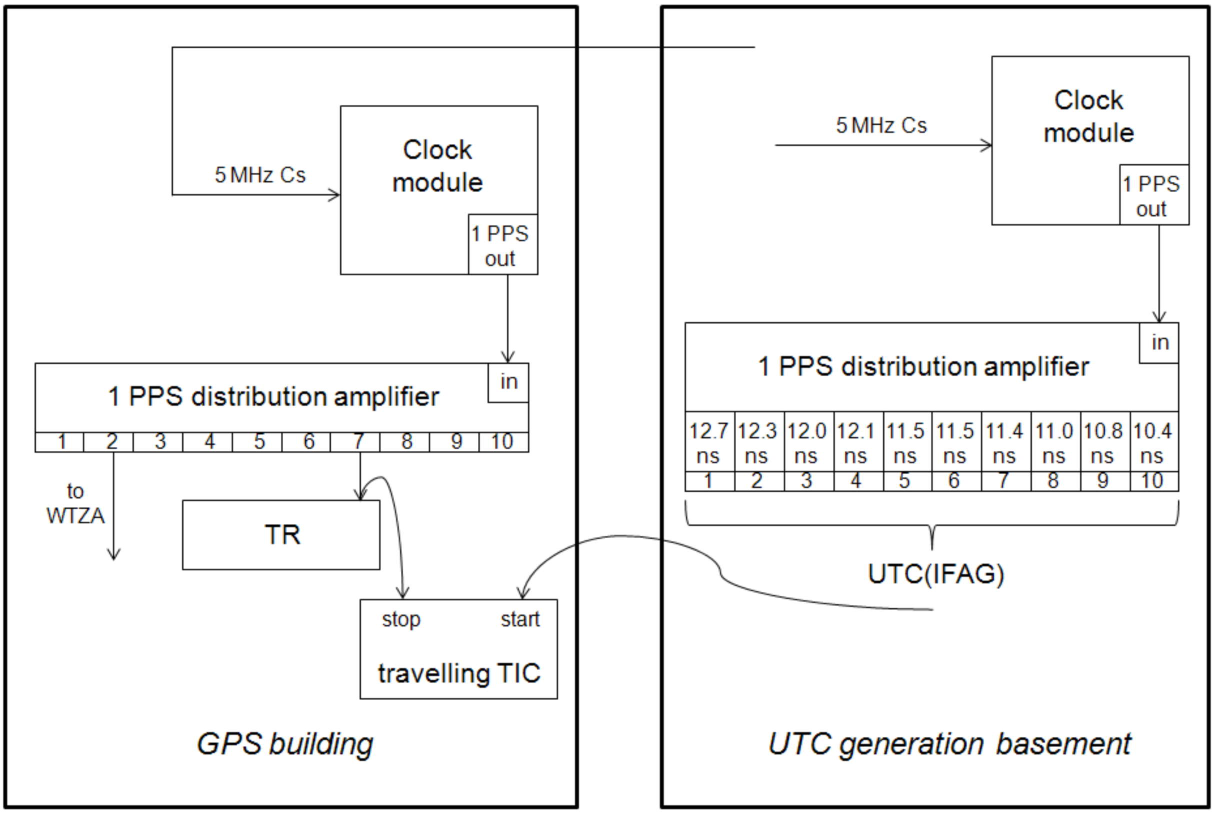
General information

• Rise time of the local UTC pulse:	< 2 ns
• Is the laboratory air conditioned:	no
• Set temperature value and uncertainty :	? deg ± ?deg
• Set humidity value and uncertainty :	? % ± ? %

Installation of fixed receivers at BKG



Installation of TR at BKG



ANNEX 2

BIPM calibration information sheet

Laboratory:	PTB
Date and hour of the beginning of measurements	**2011-09-13 (00:00 UTC)**
Date and hour of the end of measurements	**2011-09-19 (24:00 UTC)**

Receiver setup information

	Local:	**Portable: PTTR**
• Maker:	Ashtech	DICOM
• Type:	Z-XII3T	GTR50
• Serial number:	RT820013901	0708522
• Receiver internal delay (GPS) :	P1 = 304.5 ns, P2 = 318.9 ns	P1 = -28.8 ns, P2 = -22.7 ns, MC = -26.8 ns
• Receiver internal delay (GLO) :	N/A	N/A
• Antenna cable identification:	-	-
Corresponding cable delay :	301.7 ns	223.8 ns
• Delay to local UTC :	65.5 ns	CCD1: 91.0 ns, CCD2: 73.8
• Receiver trigger level:	1 V	1 V
• Coordinates reference frame:	ITRF	ITRF
Latitude or X m	3844059.94 m (PTB mast P2)	3844057.85 m (PTB mast P11)
Longitude or Y m	709661.39 m	709663.12 m
Height or Z m	5023129.65 m	5023131.03 m

Antenna information

	Local:	**Portable:**
• Maker:	Ashtech	Novatel
• Type:	ASH700936E	NOV702
• Serial number:	CR15930	NAE07020087
If the antenna is temperature stabilised		
• Set temperature value :	-	-

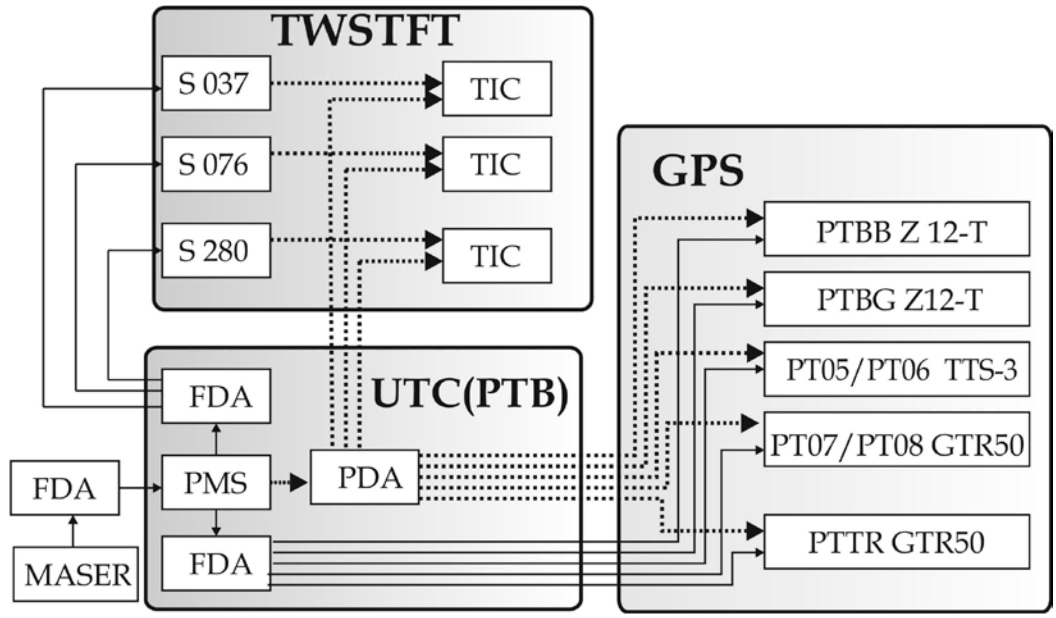
Local antenna cable information

• Maker:	Nokia
• Type:	RG214
• Is it a phase stabilised cable:	No
• Length of cable outside the building :	20 m

General information

• Rise time of the local UTC pulse:	< 5 ns
• **Is the laboratory air conditioned:**	Yes
• Set temperature value and uncertainty :	23,0 ± 0,5 °C
• Set humidity value and uncertainty :	Max. 50 %

Installation of fixed and travelling receivers at PTB



Acronyms:

FDA:	Frequency Distribution Amplifier
PDA:	Pulse Distribution Amplifier
PMS:	Phase Micro Stepper
TIC:	Time Interval Counter
S XXX	SATRE modem serial number