

Results of the BIPM 2017 TWSTFT calibrations for UTC and Non-UTC links

Summary

Zhiheng Jiang¹, Victor Zhang² and Dirk Piester³

1. BIPM: Time Department, Bureau International des Poids et Mesures

2. NIST: National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305, USA

3. PTB: Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

This is the summary of the results of the TWSTFT calibrations carried out in 2016-2017. All the results and analysis are reported in the BIPM Technical Memorandum [TM268V2](#). Only the SATRE calibration corrections are re-computed and given here. The CIs, CALRs and the uncertainties of the UTC links are kept the same.

- The CALR values are given in **Tables 1 and 2**. The date of the implementation of this new calibration result is proposed on the **MJD 57997 or the 1 September 2017** at 0h UTC;
- The latest 1707 (July 2017) data were used;
- The Annex, added in Version 2 of TM270, is the report of PTB explaining the transition from the previous calibration of PTB01 to PTB05;
- As agreed by the CCTF Working Group on TWSTFT, the minimum conventional calibration uncertainty u_{Cal} used in the Circular T is 1.0 ns, that is, if a value u_{Cal} is estimated smaller than 1.0 ns, $u_{\text{Cal}} = 1.0$ ns should be used. Otherwise the real u_{Cal} should be used.

Version history:

- The TM270 version V1 was edited in 1 August 2017 and based on the [TM268V2](#) as its summary;
- In version V2, 12 Dec. 2017, the Annex has been added. Table 2 of the Annex has been edited to include hyperlinks to the original calibration reports for the respective Calibration Identifiers.

Table 1 The BIPM SATRE CALR/ESDVAR for AOS and NPL (cf. Table 1b [2])

CI	Type	uB	Lab _i	Lab _j	S	CALR	ESDVAR	StDev
449	LC (GPS)	2.7	AOS01	PTB05	1	33.1	0.0	0.020
			PTB05	AOS01	1	-33.1	0.0	
450	LC (GPS)	7.1	NPL02	PTB05	1	728.1	0.0	0.020
			PTB05	NPL02	1	-728.1	0.0	

Table 2 The new CALR Values for non UTC SATRE links to be implemented in the TW ITU data files
 (The values in this table are reported for information and were implemented on MJD 57997. This table is not updated by the BIPM for later changes)

CI	Type	uB	Labi	Labj	S	CALR	ESDVAR	StDev	No
451	TCC	3.0	AOS01	CH01	1	37.590	00000.000	0.121/0.024	1
			CH01	AOS01	1	-37.590	00000.000	0.121/0.024	1
452	TCC	3.0	AOS01	IT02	1	304.563	00000.000	0.115/0.023	2
			IT02	AOS01	1	-304.563	00000.000	0.115/0.023	2
453	TCC	3.0	AOS01	NIST01	1	-232.515	00000.000	0.154/0.030	3
			NIST01	AOS01	1	232.515	00000.000	0.154/0.030	3
454	TCC	7.1	AOS01	NPL02	1	-695.477	00000.000	0.265/0.052	4
			NPL02	AOS01	1	695.477	00000.000	0.265/0.052	4
455	TCC	3.0	AOS01	OP01	1	7143.848	00000.000	0.143/0.028	5
			OP01	AOS01	1	-7143.848	00000.000	0.143/0.028	5
456	TCC	3.0	AOS01	ROA01	1	-1.751	00000.000	0.189/0.037	6
			ROA01	AOS01	1	1.751	00000.000	0.189/0.037	6
457	TCC	3.0	AOS01	SP01	1	31.684	00000.000	0.162/0.032	7
			SP01	AOS01	1	-31.684	00000.000	0.162/0.032	7
458	TCC	3.0	AOS01	USNO01	1	-178.008	00000.000	0.171/0.034	8
			USNO01	AOS01	1	178.008	00000.000	0.171/0.034	8
459	TCC	3.0	AOS01	VSL01	1	309.468	00000.000	0.284/0.056	9
			VSL01	AOS01	1	-309.468	00000.000	0.284/0.056	9
460	TCC	2.0	CH01	IT02	1	266.645	00000.000	0.181/0.036	10
			IT02	CH01	1	-266.645	00000.000	0.181/0.036	10
461	TCC	2.0	CH01	NIST01	1	-267.869	00000.000	0.115/0.022	11
			NIST01	CH01	1	267.869	00000.000	0.115/0.022	11
462	TCC	7.1	CH01	NPL02	1	-733.262	00000.000	0.178/0.035	12
			NPL02	CH01	1	733.262	00000.000	0.178/0.035	12
463	TCC	2.0	CH01	OP01	1	7106.131	00000.000	0.134/0.026	13
			OP01	CH01	1	-7106.131	00000.000	0.134/0.026	13
464	TCC	2.0	CH01	ROA01	1	-39.099	00000.000	0.150/0.029	14
			ROA01	CH01	1	39.099	00000.000	0.150/0.029	14
465	TCC	2.0	CH01	SP01	1	-6.121	00000.000	0.184/0.036	15
			SP01	CH01	1	6.121	00000.000	0.184/0.036	15
466	TCC	2.0	CH01	USNO01	1	-212.577	00000.000	0.123/0.024	16
			USNO01	CH01	1	212.577	00000.000	0.123/0.024	16
467	TCC	2.0	CH01	VSL01	1	271.808	00000.000	0.249/0.049	17
			VSL01	CH01	1	-271.808	00000.000	0.249/0.049	17
468	TCC	2.0	IT02	NIST01	1	-535.935	00000.000	0.134/0.026	18
			NIST01	IT02	1	535.935	00000.000	0.134/0.026	18
469	TCC	7.1	IT02	NPL01	1	-1000.376	00000.000	0.156/0.031	19
			NPL02	IT02	1	1000.376	00000.000	0.156/0.031	19
470	TCC	2.0	IT02	USNO01	1	-480.173	00000.000	0.204/0.040	23
			USNO01	IT02	1	480.173	00000.000	0.204/0.040	23
471	TCC	2.0	IT02	VSL01	1	5.247	00000.000	0.178/0.035	24
			VSL01	IT02	1	-5.247	00000.000	0.178/0.035	24
472	TCC	2.0	NIST01	OP01	1	7374.039	00000.000	0.112/0.022	25
			OP01	NIST01	1	-7374.039	00000.000	0.112/0.022	25
473	TCC	2.0	NIST01	ROA01	1	229.247	00000.000	0.149/0.029	26
			ROA01	NIST01	1	-229.247	00000.000	0.149/0.029	26
474	TCC	2.0	NIST01	SP01	1	261.555	00000.000	0.132/0.026	27
			SP01	NIST01	1	-261.555	00000.000	0.132/0.026	27
475	TCC	2.0	NIST01	VSL01	1	540.132	00000.000	0.226/0.044	28
			VSL01	NIST01	1	-540.132	00000.000	0.226/0.044	28
476	TCC	7.1	NPL02	OP01	1	7838.913	00000.000	0.267/0.052	29
			OP01	NPL02	1	-7838.913	00000.000	0.267/0.052	29
477	TCC	7.1	NPL02	ROA01	1	693.464	00000.000	0.159/0.031	30
			ROA01	NPL02	1	-693.464	00000.000	0.159/0.031	30
478	TCC	7.1	NPL02	SP01	1	726.638	00000.000	0.243/0.048	31
			SP01	NPL02	1	-726.638	00000.000	0.243/0.048	31
479	TCC	7.1	NPL02	VSL01	1	1005.211	00000.000	0.207/0.041	32
			VSL01	NPL02	1	-1005.211	00000.000	0.207/0.041	32
480	TCC	2.0	OP01	USNO01	1	-7319.015	00000.000	0.155/0.030	35
			USNO01	OP01	1	7319.015	00000.000	0.155/0.030	35
481	TCC	2.0	OP01	VSL01	1	-6834.203	00000.000	0.206/0.040	36
			VSL01	OP01	1	6834.203	00000.000	0.206/0.040	36
482	TCC	2.0	ROA01	USNO01	1	-174.229	00000.000	0.187/0.037	38
			USNO01	ROA01	1	174.229	00000.000	0.187/0.037	38
483	TCC	2.0	ROA01	VSL01	1	310.918	00000.000	0.199/0.039	39
			VSL01	ROA01	1	-310.918	00000.000	0.199/0.039	39
484	TCC	2.0	SP01	USNO01	1	-207.206	00000.000	0.172/0.034	40
			USNO01	SP01	1	207.206	00000.000	0.172/0.034	40
485	TCC	2.0	SP01	VSL01	1	277.656	00000.000	0.281/0.055	41
			VSL01	SP01	1	-277.656	00000.000	0.281/0.055	41
486	TCC	2.0	USNO01	VSL01	1	485.013	00000.000	0.230/0.045	42
			VSL01	USNO01	1	-485.013	00000.000	0.230/0.045	42

Annex

Report on Switching Operation of PTB's TWSTFT Ground Station PTB01 to PTB05

Dirk Piester and Andreas Bauch

Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

On 10th May 2017 (MJD 57883) PTB's TWSTFT ground station PTB01 was replaced by PTB05. The operation was stopped after 26 years of use in experimental and regular TWSTFT measurements within Europe and on transatlantic baselines. PTB01 was used as PTB's main operational station in the Europe/USA TWSTFT network providing daily data files to BIPM for computation of UTC. To maintain calibrated time transfer between PTB and remote stations, PTB05 was calibrated in a two-step process relatively with respect to PTB01 [1]. First, the delay difference between PTB01 and PTB05 was measured in a common clock setup. During this measurement PTB05 was operated with the same calibration parameters (CALR, CI, S) as PTB01. Finally, PTB05 was aligned by setting its ESDVAR with respect to PTB01. The estimated ESDVAR change was -7.14 ns. This pre-calibrated station was then operated to a selection of participating stations in Europe and the United States for ten days during the odd hours in parallel to the regular sessions of PTB01 during the even hours to determine the residual delay difference:

$$[\text{PTB01} - \text{PTB05}]_k = [\text{PTB01} - \text{remote station } k] - [\text{PTB05} - \text{remote station } k].$$

Examples of these parallel operations are depicted in Fig. 1 and the results are summarized in Table 1.

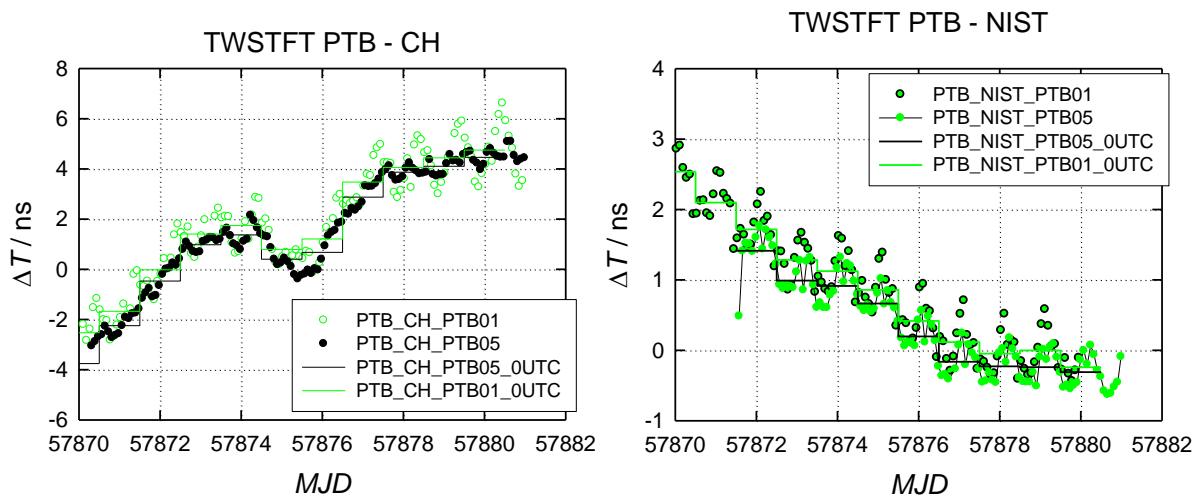


Figure 1: Two examples of parallel operation $[\text{PTB01} - \text{remote station } k]$ and $[\text{PTB05} - \text{remote station } k]$ with $k = \text{CH}$ (left) and $k = \text{NIST}$ (right).

Table 1: Residual delay differences PTB01 – PTB05

PTB01 – PTB05 via	dD (ns)	SD (ns)
CH	0.41	0.13
NIST	0.22	0.07
OP	1.07	0.08
ROA	0.77	0.11
USNO	0.53	0.11
VSL	0.65	0.16

The mean is $[\text{PTB01} - \text{PTB05}]_{\text{mean}} = 0.61$ ns with a standard deviation $\text{SD} = 0.29$ ns. The SD value is considered as the uncertainty of the adjustment. Finally, the combined uncertainties for the PTB05 links are the geometric sums of the current particular link uncertainties with PTB01 and the adjustment uncertainty. The correction applied to the ESDVAR values of PTB05 is then

$$\text{dESDVAR}(\text{PTB05}) = 2 \cdot [\text{PTB01} - \text{PTB05}]_{\text{mean}} = + 1.22 \text{ ns} \pm 0.59 \text{ ns}.$$

With this procedure TWSTFT calibrations of PTB01 (see e.g. [2,3]) are maintained over the switch to PTB05 with a slight increase of the link uncertainties. As no new calibration with respect to a portable reference station or other means were used, this bridging procedure is not considered as a common calibration [4], and thus all calibration parameters (CALR, CI, S) have been kept and remain the same until new results will be provided from a future campaign. In Table 2 parameter changes in PTB's TW... files are listed. Note, the pre-adjustment of PTB05 already introduced ESDVAR values different from the PTB01 values. E.g. for the link to IT02, the intermediate value was $\text{ESDVAR}(\text{PTB05}, \text{IT02})_{\text{int}} = -7.14$ ns, which leads to the final value $\text{ESDVAR}(\text{PTB05}, \text{IT02}) = \text{ESDVAR}(\text{PTB05}, \text{IT02})_{\text{int}} + \text{dESDVAR}(\text{PTB05}, \text{IT02}) = -7.14 \text{ ns} + 1.22 \text{ ns} = -5.92$ ns.

Table 2: Parameter changes in PTB's TW... files over the switch from PTB01 to PTB05¹

Remote station	CI Cal_Id PTB01/PTB05	S	CALR (ns)	ESDVAR (ns)		ESIG (ns)	
				PTB01	PTB05	PTB01	PTB05
IT02	0434-2016	1	274.900	0.000	-5.920	0.000	0.600
ROA01	0440-2016	1	-31.600	0.000	-5.920	0.000	0.600
OP01	0437-2016	1	7113.800	0.000	-5.920	0.000	0.600
NPL02	0450-2017	9	99999999	-1412.656	-1418.580	0.000	0.600
VSL01	0295-2015	1	986.300	-1412.656	-1418.580	0.000	0.600
SP01	0441-2016	1	1.600	0.000	-5.920	0.000	0.600
CH01	0284-2012	1	713.400	-1412.656	-1418.580	0.000	0.600
AOS01	0449-2017	1	164.141	-377.656	-383.580	2.800	2.870
USNO01	0395-2016	1	-205.080	0.000	-5.920	0.000	0.600
NIST01	0393-2015	1	716.776	-1412.656	-1418.580	0.000	0.600

¹ Table 2 has been edited by the BIPM to replace the original TW code CI by the full BIPM Calibration Identifiers with hyperlinks to the original calibration reports.

Two typical examples of operational UTC links over the switch from PTB01 to PTB05 are depicted in Fig. 2 displaying the successful application of the procedure.

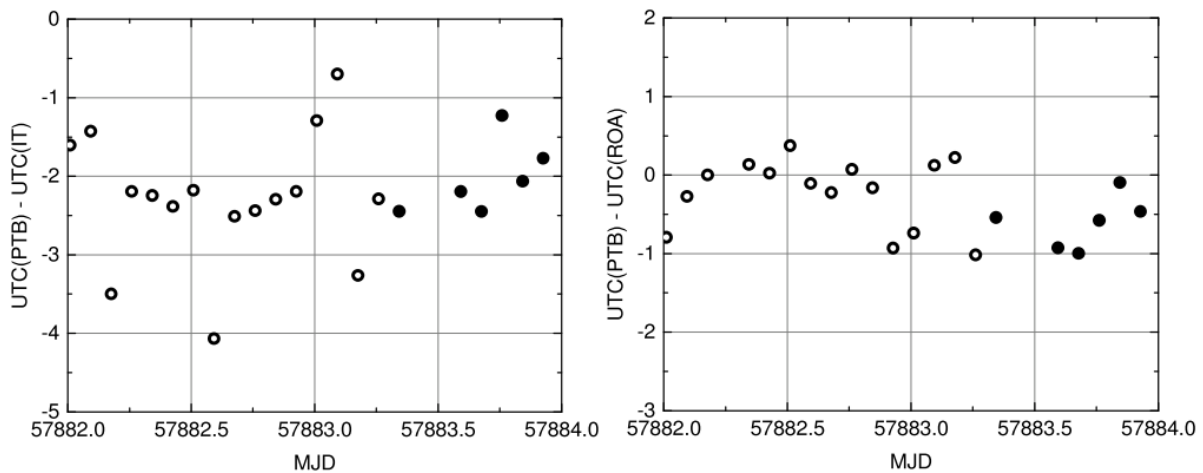


Figure 2: Two examples of operational UTC links over the switch from PTB01 (circles) to PTB05 (full dots).

References

- [1] D. Piester: **Update on TWSTFT Activities at PTB**, Laboratory Report to the 25th Meeting of the CCTF Working Group on TWSTFT, 17-18 May 2017, NTSC, Xian, China.
- [2] F. J. Galindo, A. Bauch, D. Piester, H. Esteban, I. Sesia, J. Achkar, K. Jaldehag: **European TWSTFT Calibration Campaign 2016**, Calibration Report, 2017.
- [3] D. Piester, A. Bauch, J. Becker, J. Leute, T. Polewka, F. Riedel, D. Sibold, E. Staliuniene, S. Weyers: **PTB's Time and Frequency Services 2015 – 2016**; Proc. 2017 Precise Time and Time Interval Meeting – ION PTTI 2017, 30 Jan – 2 Feb 2017, Monterey, CA, USA, pp. 53-61, 2017.
- [4] **TWSTFT Calibration Guidelines for UTC Time Links**, V2016