Bureau International des Poids et Mesures

# Calibration of the NIST01-PTB05 TW links through GNSS calibration transfer

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# Reference documents

[1] BIPM. *1022 Group 1 GNSS calibration trip*. Tech. rep. BIPM, 2022. URL: https://webtai.bipm.org/ftp/pub/tai/publication/time-calibration/Current/1001-2022_GPSP3C1-GALE3-BDSB3_Group1-trip_V1-1.pdf.

[2] ITU-R. *Recommendation ITU-R TF.1153-4 The operational use of two-way satellite time and frequency transferemploying pseudorandom noise codes*. Tech. rep. ITU, Aug. 2015. URL: https://www.itu.int/dms_pubrec/itu-r/rec/tf/R-REC-TF.1153-4-201508-I!!PDF-E.pdf (visited on 03/03/2023).

[3] F Meynadier, C Rieck, and D. Piester. *Calibration bridging for the June and July 2021 satellite transponder frequency changes for european and transatlantic TWSTFT links*. Tech. rep. BIPM, 2022. URL: https://webtai.bipm.org/ftp/pub/tai/publication/twstft-calibration/0533-2021_TW_BIPM_v1-0.pdf.

[4] B Patla et al. *UTC link calibration report*. Tech. rep. NIST and BIPM, 2015. URL: https://webtai.bipm.org/ftp/pub/tai/publication/time-calibration/Current/0393-2015_TW_NIST_v2-0.pdf.

# 1 Context

The NIST01-PTB05 Two Way link has been calibrated in 2015 using the METODE procedure, taking advantage of a GNSS G1 calibration trip (CALID 393, [4]). This calibration was then bridged due to transponder changes occuring in 2021 (CALID 533, [3]).

In 2022 a new G1 calibration campaign included NIST [1], which prompts for an update of the values.

# 2 Data

In order to stay as coherent as possible between possible UTC links, we choose to use recent data from the receiver currently used for calculating the "UTC backup" GPS PPP link, i.e. the link between NISX (Septentrio PolaRx5TR, S/N 3069423) and PT13 (Septentrio PolaRx5TR, S/N 3034575). Period runs from MJD 60460 (introduction of the 1001-2022 G1 calibration) to MJD 60550. The files that have been used are the ones regularly uploaded to the BIPM FTP server by NIST and PTB.

# 3 Processing

The current calibration of the TW links uses CALID 533 and the latest ESDVAR values:

Table 1: Summary of previous calibration values

| CI | loc | rem | calr ns | est. unc. ns | esdvar ns | esig ns | MJD |
|---|---|---|---|---|---|---|---|
| 533 | NIST01 | PTB05 | -447.980 | 1.600 | 28.120 | 0.500 | 59361 |
| 533 | PTB05 | NIST01 | 447.980 | 1.600 | -1406.260 | 0.640 | 59361 |

Comparison to PPP shows a separation over 1ns between the two links (see fig. 1).

Diurnals with peak-to-peak amplitude of around 0.5 ns are steadily visible on the TWSTFT link throughout the whole period. Otherwise data is fairly continuous and uneventful, and suitable for a direct comparison.

PPP processing is performed through the Tsoft pipeline, relying on BIPM's version of NRCan software for GPS PPP, during the monthly calculation of Circular T.

TWSTFT data is processed through custom software allowing to bypass CALR and ESDVAR values while applying the standard TW formula [2]. This allows to set both CALR and ESDVAR value to 0 in further calculations, in which case the residuals after substraction of the GNSS PPP

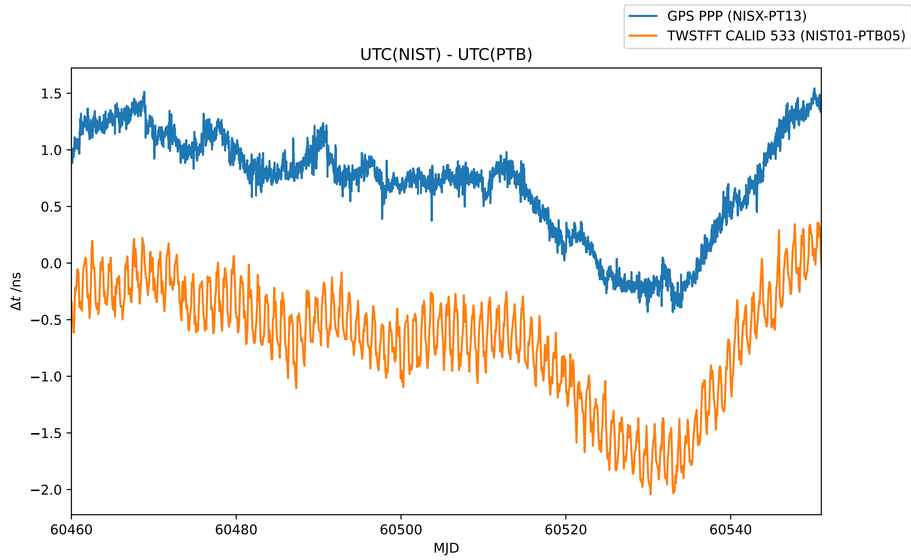


Figure 1: Plots of the two links, GPS PPP and TWSTFT, with the current calibrations

data should correspond to the new CALR value.

GPS PPP link is sampled with one point every 5 minutes, whereas TWSTFT links has one point of measurement every 2h. The difference between the two links is therefore obtained by interpolating (linearly) the TWSTFT data for each epoch of the GPS PPP data.

The result of this procedure is shown on fig. 2.

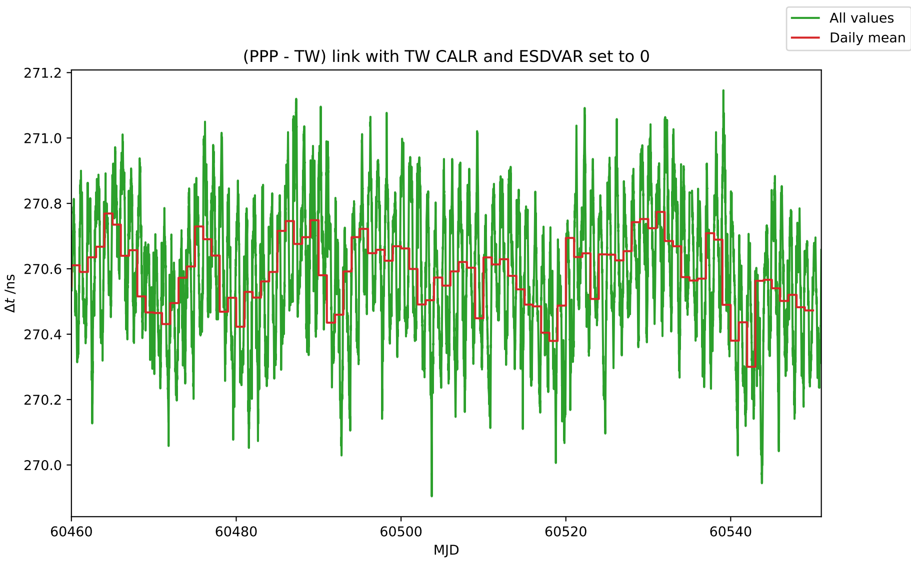


Figure 2: Difference between GPS PPP and TW link with both CALR and ESDVAR set to 0

The resulting plot corresponds to the CALR values that would align the TW link with the calibrated GNSS link, hence transferring the calibration of the GNSS link to TW. Over the 100-day period, one can observe that 1-d variations (diurnals) and few days variations have comparable amplitude, around 0.5 ns peak-to-peak. As customary for TW calibration, daily values are calculated to filter out the diurnals.

# 4 Results

CALR is determined from the data plotted in fig. 2 by averaging the daily values. Diurnals are taken into account by associating a standard deviation to each daily value, and retain the maximum value. Then a standard deviation of the daily values themselves is also calculated. We assume the quadratic sum of both to be an acceptable estimator on the uncertainty of the CALR estimation. This leads to the values shown in table 2 :

Table 2: Results

| | |
|---|---|
| Mean CALR | 270.586 ns |
| Max CALR daily $\sigma$ | 0.236 ns |
| CALR daily values $\sigma$ | 0.102 ns |
| Quadratic sum of the above values | 0.257 ns |

Uncertainty on the PPP link calibration itself is the $u_{CAL}$ value associated to P3 values (see table 18 in [1]), i.e. 1.8 ns. The conventional formula for ageing ($0.4 \times \sqrt{n} - 1$, where $n$ is the number of month between calibration and present date) gives $uAG \simeq 0.3$ ns in our case.

Combination of these independant uncertainties is largely dominated by the GPS P3 calibration uncertainty itself. A conventional uncertainty of 2.0 ns is assigned to this calibration. Final values are

Table 3: Summary of calibration values

| CI | loc | rem | calr ns | est. unc. ns | esdvar ns | esig ns | MJD |
|---|---|---|---|---|---|---|---|
| 593 | NIST01 | PTB05 | 270.586 | 2.000 | 0.000 | 0.000 | 60460 |
| 593 | PTB05 | NIST01 | -270.586 | 2.000 | 0.000 | 0.000 | 60460 |