The July 2015 calibration of the link UTC(USNO) – UTC(PTB) by means of the USNO portable X-band TWSTFT station

Report

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From 17 to 21 July 2015 USNO established a calibrated time link to PTB operating a portable X-band TWSTFT station at PTB. The portable station was pre-calibrated at USNO vs. two fixed stations (REX and TSX) in a common clock setup. Two modems (FAX and FAX2) were brought with the portable station but only FAX2 was used, because of a failure in the FAX modem. Thus 2 configurations (FAX2-REX and FAX2-TSX) were available and operated.

In Fig. 1 the temporal X-band TWSTFT link (red and blue), the operational Ku-band TWSTFT link (black) and also Circular T values (orange) are shown.

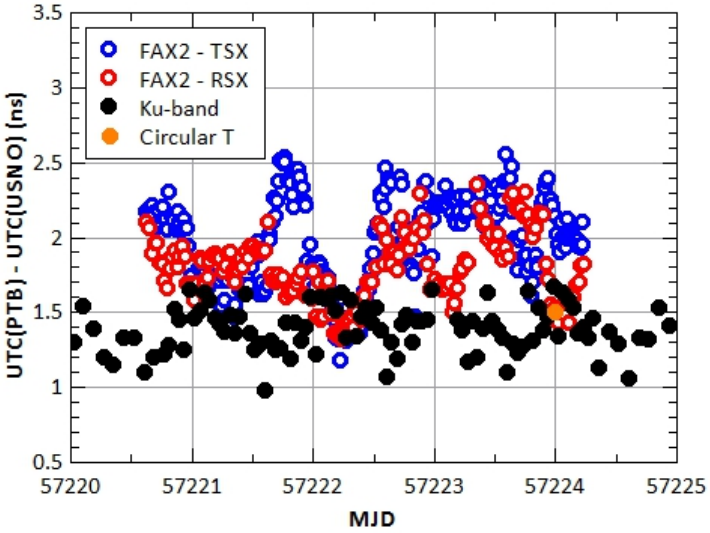

Fig. 1: UTC(PTB) – UTC(USNO) via 3 different links. Operational Ku-band TWSTFT (black), the established X-band TWSTFT link configurations (blue and red) and Circular T (orange).

Assuming the established X-band TWSTFT link represents the true difference UTC(PTB) – UTC(USNO) a correction value for the operational link can be determined. In a first step double differences $[\text{UTC(PTB)} - \text{UTC(USNO)}]_{\text{X-band TWSTFT}} - [\text{UTC(PTB)} - \text{UTC(USNO)}]_{\text{Ku-band TWSTFT}}$ were computed in a way that for each X-band TWSTFT data point the two close-by Ku-band TWSTFT values were interpolated to the epoch of the X-band TWSTFT point and then subtracted. The result is depicted in Fig. 2.

For each setup configuration a mean value and the standard deviation of the single measurements around the mean were calculated. Then the weighted mean and sigma for the two setups were computed. The sigma values represent the statistical uncertainty of the calibration. The results are summarized in Table 1. They are reported in a way that if one adds the weighted mean to $[\text{UTC(PTB)} - \text{UTC(USNO)}]_{\text{Ku-band TWSTFT}}$ the link results would represent the true time scale difference UTC(PTB) – UTC(USNO).

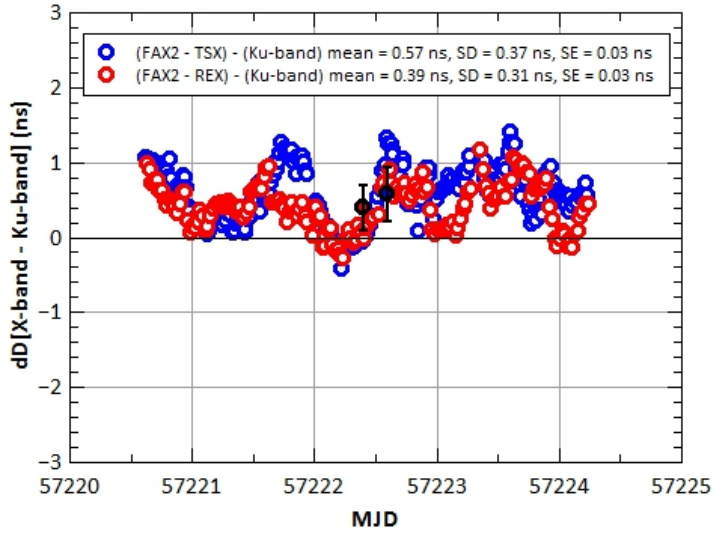

Fig. 2: Double differences X-band – Ku-band and X-band – Circular T of the link UTC(PTB) – UTC(USNO).

Table 1: Results of the double differences.

	weighted mean (ns)	Sigma (ns)
X-band - Ku-band	0.466	0.233

Beside the statistical uncertainty as reported in Table 1 the following contributions from systematic uncertainties exist:

$u_{B,1}$: The most important part is the stability of the portable station all through the campaign. Its uncertainty is estimated by performing common clock difference measurements before and after the campaign at USNO. The differences of the pre-campaign values with respect to the post-campaign values represent the uncertainty due to the long term or transportation instability especially of the portable station. The results of the two hardware configurations are given in Table 2. The rms = 0.522 ns of the two closure values is a measure of the deviation of the single data points from zero as well as the scatter of the data. The actual rms value is bigger than the maximum statistical uncertainty (sigma = 0.510 ns) and thus considered as an appropriate means to state the uncertainty.

Table 2: Common clock difference closure measurements at USNO.

	Closure (ns)	Sigma (ns)
FAX2 - TSX	0.735	0.510
FAX2 - REX	0.066	0.209

$u_{B,2}$: The second term is the uncertainty of the connected 1pps to the local UTC realization, which is estimated to be 0.5 ns according to time interval counter specifications.

$u_{B,3}$: The uncertainty of all other effects should be well below a tenth of a nanosecond and are summarized in a small contribution $u_{B,3}$ = 0.1 ns.

The results are summarized in Table 3.

Table 3: Calibration results

	correction (ns)	u_A (ns)	$u_{B,1}$ (ns)	$u_{B,2}$ (ns)	$u_{B,3}$ (ns)	U (ns)
X-band - Ku-band	0.466	0.233	0.522	0.5	0.1	0.766

Ku-band link calibration: The entries in the ITU formatted TWSTFT data files for the operational Ku-band link should be adjusted with respect as follows:

Header line:

```
* CAL    TBD TYPE: PORT ES REL          MJD: 57220  EST. UNCERT.:    0.770 ns
```

The current CALR value reported in PTB ITU files is 488.884 ns. The TWUSNO… files contain a nonzero value for the ESDVAR(USNO), it is -24.830 ns. The value should be set to 00000.000 and the introduced CALR values should be adjusted accordingly.

$CALR(PTB)_{new,}$[ESDVAR(PTB)=0, ESDVAR(USNO)=0]

= $CALR(PTB)_{old,}$[ESDVAR(PTB)=0, ESDVAR(USNO)= -24.830 ns]

+ ½ (0.000 ns) – ½ (-24.830 ns)

+ 0.466 ns

= 501.765 ns ≈ 501.770 ns

$CALR(USNO)_{new,}$[ESDVAR(PTB)=0, ESDVAR(USNO)=0]

= $CALR(USNO)_{old,}$[ESDVAR(PTB)=0, ESDVAR(USNO)= -24.830 ns]

– ½ (0.000 ns) + ½ (-24.830 ns)

– 0.466 ns

= -501.765 ns ≈ -501.770 ns

Thus, the numbers of the following Table 4 should be used:

Table 4: TW-file entries:

	CI	S	CALR (old)	CALR (new)	ESDVAR (old)	ESDVAR (new)	ESIG (old)	ESIG (new)
TWPTB…	TBD	1	488.884	501.770	00000.000	00000.000	0.000	0.000
TWUSNO…	TBD	1	-488.884	-501.770	-24.830	00000.000	0.060	0.000

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