The August 2016 calibration of the link UTC(USNO) – UTC(PTB) by means of USNO's portable X-band TWSTFT station

Report

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From 9 to 11 August 2016 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 a Circular T value (orange) are shown.

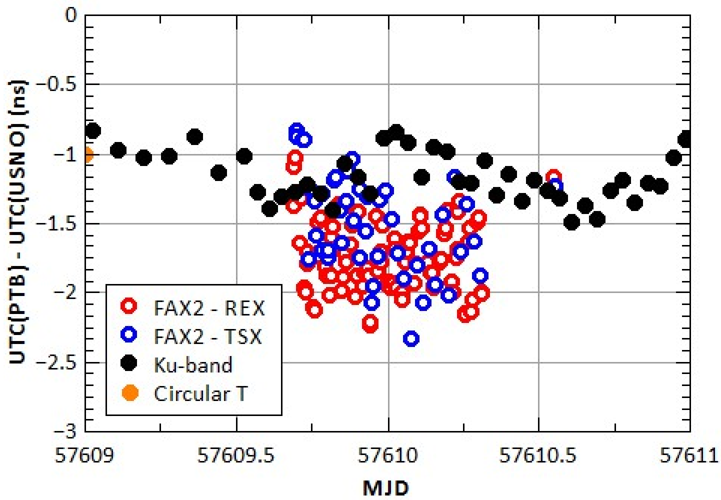

Fig. 1: UTC(PTB) – UTC(USNO) via 3 different links: Operational Ku-band TWSTFT (black), the established X-band TWSTFT link configurations (blue and red) and Circular T (orange).

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 $[\mathrm{UTC(PTB)} - \mathrm{UTC(USNO)}]_{\text{X-band TWSTFT}} - [\mathrm{UTC(PTB)} - \mathrm{UTC(USNO)}]_{\text{Ku-band TWSTFT}}$ 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 value represents 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 $[\mathrm{UTC(PTB)} - \mathrm{UTC(USNO)}]_{\text{Ku-band TWSTFT}}$ the link results would represent the calibrated and thus true time scale difference UTC(PTB) – UTC(USNO).

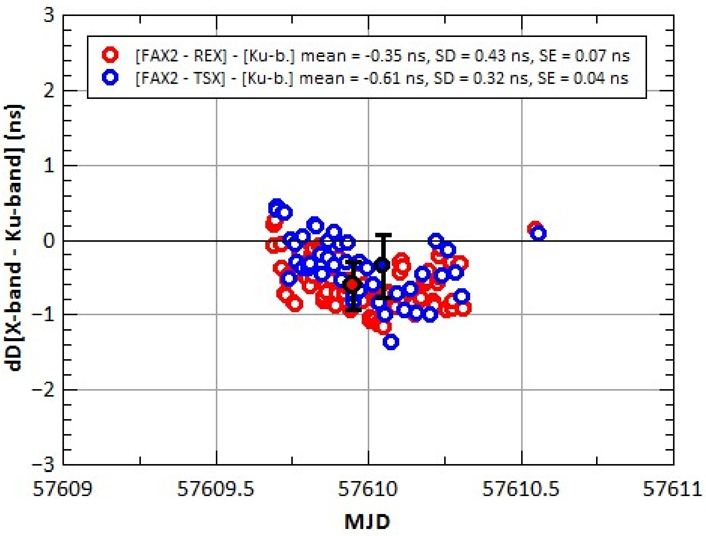

Fig. 2: Double differences X-band – Ku-band of the link UTC(PTB) – UTC(USNO).

Table 1: Results of the double differences.

	weighted mean (ns)	Sigma (ns)
X-band - Ku-band	-0.517	0.253

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

$u_{B,1}$ (mobile station): 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 = 0.175 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 present rms value is smaller than the uncertainty of the rms (u_{rms} = 0.261 ns as determined with the propagation of error formula) and thus u_{rms} of the closure measurements is considered as an appropriate means to state the uncertainty.

Table 2: Common clock difference closure (pre-campaign minus post-campaign) measurements at USNO.

	Closure (ns)	Sigma (ns)
FAX2 - TSX	-0.13	0.303
FAX2 - REX	-0.21	0.392

We take further into account an influence of the environmental temperature on the portable station, which is estimated to be smaller than 0.2 ns. In total we get $u_{B,1}$ = 0.329 ns.

$u_{B,2}$ (fixed stations): The second term is a possible systematic instability of the fixed stations and the local frequency and time distribution systems, which is estimated to be less than 0.1 ns.

$u_{B,3}$ (interface): The third term is the uncertainty of the connected 1pps to the local UTC realization, which is conservatively estimated to be 0.5 ns according to time interval counter specifications.

$u_{B,4}$ (satellite): The calibration campaign is performed in the LINK mode. The uncertainty of all other effects should be below a tenth of a nanosecond and are summarized in a small contribution $u_{B,4}$ = 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)	$u_{B,4}$ (ns)	U (ns)
X-band - Ku-band	-0.517	0.253	0.329	0.1	0.5	0.1	0.67

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: 57662  EST. UNCERT.:    0.630 ns
```

The MJD is the proposed day (1 October 2016) of implementation. The current CALR value reported in PTB ITU files is 501.770 ns. The TWPTB… files contain a nonzero value for the ESDVAR(USNO), it is -1412.656 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)= -1412.656 ns, ESDVAR(USNO)= 0]

+ ½ (-1412.656 ns) – ½ (0.000 ns)

+ (-0.517 ns)

= -205.075 ns ≈ -205.08 ns

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

= $CALR(USNO)_{old,}$[ESDVAR(PTB)= -1412.656 ns, ESDVAR(USNO)= 0]

– ½ (-1412.656 ns) + ½ (0.000 ns)

– (-0.517 ns)

= 205.075 ns ≈ 205.08 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…	**395**	1	501.770	-205.080	-1412.656	00000.000	0.000	0.000
TWUSNO…	**395**	1	-501.770	205.080	00000.000	00000.000	0.000	0.000

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