*--- V2 is the updated version of V1 with **PTB01** replaced by **PTB05** [12]. The latest 1707 (July 2017) data were used. Only the SATRE calibration corrections are re-computed and given. See the changes below in blue colour.*

# BIPM 2017 TWSTFT SATRE/SDR calibrations for UTC and Non-UTC links

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**Summary:**

- The TCC technique was approved by the CCTF WG on TWSTFT in 2015 and the SDR TWSTFT is under validation;
- A SDR link calibration is obtained by aligning it to the corresponding SATRE link of the same baseline;
- The conventional uA of SATRE and SDR links are 0.5 ns and 0.3 ns;
- The uncertainty of SDR is the combination of the calibration uncertainty (not the conventional ones but the true values in the Calibration Report) of SATRE and SDR links. Because the number of the common points of SATRE and SDR is big (~ 360 per month), measurement noise is averaged out and the influence of uA are negligible. The conventional calibration uncertainty of SDR link equals to that of the SATRE link, that is, 1.0 ns, 1.5 ns and 2.0 ns for the calibrations using the TW MB station, the GPS calibrator and the TCC respectively;
- The CALR values are given in **Tables 4.1.2, 4.2.1a** ~~**and 4.2.1b**~~. The date of the implementation of this new calibration result is proposed on the **MJD 57997 or the 1 September 2017** at 0h UTC. SDR and Asia links will not be implemented;
- Comparisons between the calibrated TW and GPS links are made.

## Introduction

Organizing and maintaining the metrological calibration of the time transfer facilities in laboratories contributing to UTC is among the responsibilities of the BIPM[1] [1].

TWSTFT (Two Way Satellite Time and Frequency Transfer, TW here after) is the primary time transfer technique used for UTC generation. All the TW links used in the calculation of UTC should be calibrated. The calibration value is listed in the column CALR of the ITU data file. Sometimes a modification of the calibration value is made and the corresponding correction is given in term of ESDVAR. During the Circular T time link computation, both values of CALR and ESDVAR are to be used. There are a number of TW observations (refer to as non-UTC links) that are not directly used in the generation of UTC. They provide the redundant or backup links or other scientific applications.

Calibration is a key issue of the UTC time transfer and related technical and scientific applications.

TWSTFT calibrations by using Triangle Closure Calibration (TCC) was proposed in 2008 [2] and highlighted by Klepczynski as one of the four *milestones* in TWSTFT history [3]. And in Sept. 2015, the TCC has been authorized by the recently approved TW calibration guidelines [4,5] as a formal technique for the TW link calibrations.

On one side, there were new Europe/RMO and BIPM 2016 calibrations [8,9]. On the other side, in Feb. 2016, the BIPM and CCTF WG on TWSTFT a launched a pilot project on the use of the Software-Defined Radio (SDR) receiver for TW [7] in the UTC time link computation. Advantage of the SDR is to significantly reduce the diurnal bias in the TW links, which is the major uncertainty source in the TWSTFT. The result of the pilot study is very encouraging so far. In most cases, it may reduce the uncertainty by a factor of 2 or 3. Most of the UTC TW participating laboratories have installed the SDR facility and perform the time and frequency transfers. The annual TW WG meeting held in May at NTSC will recommend it for the use in UTC generation [10].

To identify the TW ***SDR links***, we name the present UTC TW links, the TW ***SATRE links*** in this TM.

As the SATRE links, the SDR links need to be calibrated before its application in UTC. At present the official UTC calibrations are all of the SATRE links by using the MB and TCC techniques. A SDR link should be therefore calibrated by the alignment with the corresponding SATRE link.

The latest SATRE link MB calibration has been made in summer 2016 [6], cf. the Table Ia below.

**Table 1a** The 2016 European MB CALR calibration results [6]

| CI | Link | 1 | CALR/ns | uB/ns | Implementation MJD |
|---|---|---|---|---|---|
| 433 | IT02_OP01 | 1 | 6839.1 | 0.9 | 57842. |
| 435 | IT02_ROA01 | 1 | -306.4 | 0.9 | 57842. |
| 436 | IT02_SP01 | 1 | -271.9 | 1.0 | 57842. |
| 437 | OP01_PTB01 | 1 | -7113.8 | 0.7 | 57842. |
| 438 | OP01_ROA01 | 1 | -7145.6 | 0.7 | 57842. |
| 439 | OP01_SP01 | 1 | -7112.2 | 0.7 | 57842. |
| 440 | PTB01_ROA01 | 1 | -31.6 | 0.8 | 57842. |
| 441 | PTB01_SP01 | 1 | 1.6 | 0.8 | 57842. |
| 442 | ROA01_SP01 | 1 | 33.6 | 0.7 | 57842. |
| 443 | IT01_OP01 | 1 | 7112.2 | 0.9 | 57842. |
| 444 | IT01_PTB01 | 1 | -1.7 | 1.0 | 57842. |
| 445 | IT01_ROA01 | 1 | -33.9 | 0.7 | 57842. |
| 446 | IT01_SP01 | 1 | -0.3 | 1.0 | 57842. |

### PTB01 replaced by PTB05 and PTB05 calibration adjustment

Calibration transfer from PTB01 to PTB05 has been made by PTB and by adjusting the ESDVAR(PTB05) from common clock data PTB01-PTB05 [12]. PTB05 vs. a number of EUR and USA participating stations was carried out for 10 days during the odd hours.

dESDVAR(PTB05) = + 1.22 ns ± 0.59 ns (applied to all PTB05 links), corresponding to a quadratic increase of link uncertainties by 0.29 ns. The results are given in the following table. All CALR values and CIs to remote links remain the same.

[1] 'When necessary, the BIPM will perform the global network calibration through the TCC technique' – Point 5 of the Section IV, The Role of the BIPM, TWSTFT Calibration Guidelines for UTC Time Links V2016 [3]

**Table 1a′** Calibration transfer correction (*d*) from PTB01 to PTB05 by adjustment of ESDVAR(PTB05)

| **PTB01–PTB05** via | ***d***/ns | **σ**/ns |
|---|---|---|
| CH-PTB | 0.41 | 0.13 |
| NIST-PTB | 0.22 | 0.07 |
| OP-PTB | 1.07 | 0.08 |
| ROA-PTB | 0.77 | 0.11 |
| USNO-PTB | 0.53 | 0.11 |
| VSL-PTB | 0.65 | 0.16 |
| mean | 0.61 | 0.29 |

As seen in the table, the corrections due to the switch from PTB01 to PTB05 are between 0.4 to 1.1 ns. A new calibration computation is necessary.

To maintain the continuity of the UTC-UTC(k), the BIPM adds from time to time a time link correction in the Circular T computation, namely the 'Link to UTC' or 'L2U'. This operation may be applied to both a TWSTFT link and a GNSS link. At present, the only TW L2U are for AOS -5.4 ns and for NPL -18.8 ns, cf. the Section 5 of the BIPM Circular T [1]. Please note, here the difference between PTB01 and PTB05 has been taken into account in ESDVAR..

Conventionally, for a new CALR, we set the ESDVAR=0. The relation of the new CALR can be obtained by the equation:

CALR1(new)= -CALR2(new)={CALR1(old) - BIPM Correction - ( [ESDVAR2-ESDVAR1]/2 ) }

Table 1b gives the values of the ESDVAR, the old and new CALR for AOS-PTB and NPL-PTB. They have been used in UTC and this computation and should be implemented in the AOS and NPL ITU data files.

**Table 1b** The BIPM CALR/ESDVAR for AOS and NPL (1707)

| Link | CALR_Old ns | BIPM Correction ns | ESDVAR ns | CALR0 ns | CALR_new ns |
|---|---|---|---|---|---|
| AOS01-PTB05 | -164,141 | -5,4 | -383,58 | -197,2 | 33,1 |
| NPL02-PTB05 | 0 | -18,8 | -1418,58 | 18,8 | 728,1 |

In July 2016, the BIPM GPS calibrator passed to NIM and NTSC to make the link calibrations. NIM-PTB and NTSC-PTB were carried out [8,9], cf. Table Ic that gives the values of CALR and ESDVAR.

**Remark:** Because new satellite are to be used  for the Asia-Europe, the Asian TW link calibrations are not necessary to be implemented.

**Table 1c** The 2016 BIPM CALR/ESDVAR for NIM and NTSC [8,9]

| Link | CALR ns | ESDAVR ns | ESDVAR/PTB ns | NOTE |
|---|---|---|---|---|
| NIM01-PTB03 | 2319.7 | 0 | -3.6 | |
| NTSC02-PTB03 | 2242.9 | -11.98 | -3.6 | |

Above the TW SATRE link calibrations. The TW SDR links will be aligned to the SATRE links for their calibrations.

This TM reports the calibration results for the calibrations of UTC and non-UTC links through TCC and alignment for both the SATRE and SDR links. We first review quickly the TCC and SDR methods, then the UTC data set 1703 (March 2017) used for the computation. Users may get into directly the Section 4 for the final result, the CI and the related uncertainty[2], as well as the implementation information. In the last section, we compared the TW and GPS links.

[2] The uncertainty of the TW mobile station calibration is $u_B$≈1 ns, that of GPS calibrator is $u_B$≈1.5 ns [4-10] and that of the TCC is ≤ 2 ns (see section 4 below).

# 1. The TCC and SDR

## *1.1 The TW TCC Calibration*

We introduce briefly the TW triangle closure calibration (TCC) [2].

Taking NIM and NTSC as examples, the principle of the TCC can be described simply that, in a triangle we can calibrate the TW link NIM-NTSC if the other two adjacent links NIM-PTB and NTSC-PTB are calibrated (Fig. 1.1). Because all the TW links with the PTB (the pivot of the UTC network) are calibrated, any non UTC link between two non-pivot laboratories can be calibrated with the so called triangle closure calibration: *a triangle closure should be equal to zero*. Such one by one, all the links in the network can be calibrated, cf. Figure 2.1.

Taken the example of Fig. 1.1, we want to calibrate the non UTC link between NIM and NTSC. After the calibration, the triangle closure is expected to be zero, that is:

$$[UTC(NIM)-UTC(PTB)] - [UTC(NTSC)-UTC(PTB)] + [UTC(NTSC)-UTC(NIM)] = Closure \equiv 0 \quad (1)$$

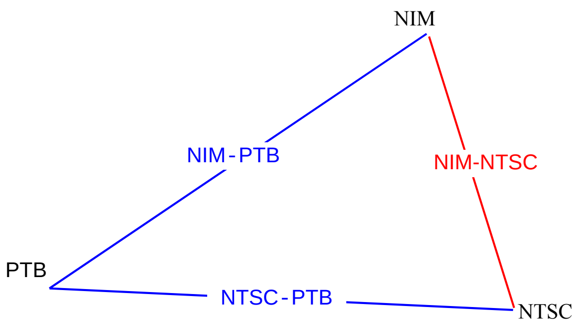



**Fig. 1.1** Non UTC TW link calibration via triangle closure calibration (TCC)

CALR(NTSC-NIM)=[UTC(NIM)-UTC(PTB)]-[UTC(NTSC)-UTC(PTB)]+[UTC(NTSC)-UTC(NIM)]

If all of the three links are calibrated, the non-zero closure should be nothing but the measurement noise. Because the UTC links are calibrated, we have the non-zero-closure = CALR+/-Std, if we set ESDVAR=0. When a non-zero ESDVAR values should be kept, for a link with the two end laboratories Lab1 and Lab2, we have, CALR1= -CALR2 =Closure+(ESDVAR2-ESDVAR1)/2. The final calibration value is the average for a period: typically a UTC month (12 measurements per day over 30 days or about 360 measurements for a UTC month). To have observations at common dates, values are interpolated at the nearest common TW scheduled epochs and then the closures are calculated. The uncertainty of the calibration can be estimated by the following equation:

$$u(CloseCalib)=\sqrt{u_{NIM}^2 + u_{NTSC}^2+S^2} \quad (2)$$

Here:

$u_{NIM}$=u[UTC(NIM)-UTC(PTB)]
$u_{NTSC}$=u[UTC(NTSC)-UTC(PTB)]
S=Std√N where Std is Standard deviation of the triangle closures and N= number of triangle closures

Values of Std are listed in the tables of section 4. They are used to estimate the calibration uncertainty by using the equation (2). The value S is very small with an order of uA/√N. uA are about 0.5 ns (SATRE) and 0.3 ns (SDR) with N is about 360 for a UTC monthly data set. The S is then less than 0.03 ns, completely negligible. Introducing these values and taking into account of the TW calibration uncertainty $u_B \leq 1$ ns [1,2,4,5] and by using equation (2), the TCC uncertainty of a TW-TW triangle calibration is ≤ 1.4 ns in total, not too much bigger than that of the traditional UTC calibrated links. For the GPS link calibration, we have $u_B \leq 1.5$ ns [4,5], the TCC uncertainty of a TW-GPS triangle calibration is ≤ 1.8 ns in total. In the BIPM Circular T computation, conventional values are assigned and used, cf. the Section 4.4.

## ***1.2 The SDR*** *[7]*

The measurement uncertainty ($u_A$) of the TWSTFT link may attain at most 0.2 ns. The dominant instability source in TW is the diurnal signals of which amplitudes are recorded to be ±1 ns or even bigger in some extreme cases, 0.5 ns on average. Efforts have been made in last decade to investigate the physical causes of the diurnal but no convincing conclusion has been obtained. Since 2009, the combination of the TW and GPS carrier phase (through GPSPPP solution, PPP for short) has been used for the UTC time links [7], profiting of the advantage of the long-term stability in

TW and the short-term stability of the GPS carrier phase. In the later, diurnals do not exist. The combination technique is successful in both that the diurnal and the white noise are significantly reduced meanwhile the TW link calibration is kept. The TW community continues investigating on the origin of the diurnals. The latest development is the SDR receiver for TW [6].

TW with a SDR is a technique under validation, which can significantly reduce the diurnal signals observed in most TW links. The diurnal increases the TW uncertainty, and is one of its major sources. The goal of the pilot project, jointly organized by BIPM and the CCTF WG on TWSTFT and started in February 2016, is to validate the SDR receiver in view of its use in UTC generation. The validation requests that adapted equipment is installed in TW UTC participating stations (PS) and that they provide regularly data along the project. The role of the BIPM is to coordinate with the pilot study participants to collect the data and perform the analysis to assess the capacity of the SDR to reduce the diurnals and improve the short-term stability. After this first step, feedback will be given to the CCTF WG on TWSTFT. A second discussion, which might be beyond the scope of this paper, would take place at the CCTF, with a possible proposal for inclusion of data obtained with the SDR receiver for the computation of UTC. We hope that this study will have positive impact on the equipment manufacturers, motivated by this new competitive technique.

Our experience is that in most inner-continental links, the SDR TW significantly reduces the diurnals in the TW links and improves the time stability by a factor of maximum 3 (from 100~120 ps to 30~40 ps). However, for some trans-continental long distance links, the gain is not as significant as for short continental links. Further investigation is required. The software currently used at the BIPM for the computation of UTC has been adapted to process both the SATRE and the SDR data together with the monthly computation of *Circular T*.

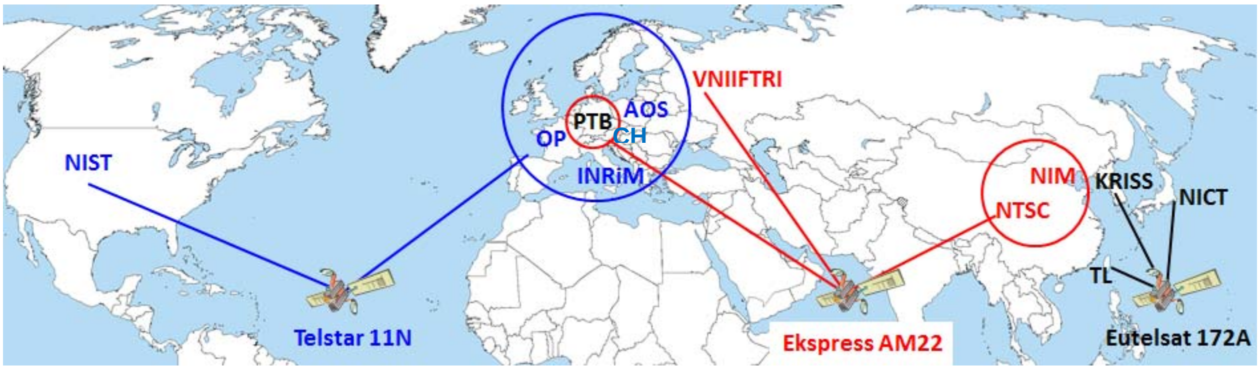



**Figure 1.2.1** Satellite coverage of the 12 UTC TW laboratories that are installed and operate the SDR receivers (KRIS, NICT, TL, NIM, NTSC, SU, AOS, IT, OP, CH, NIST and PTB)

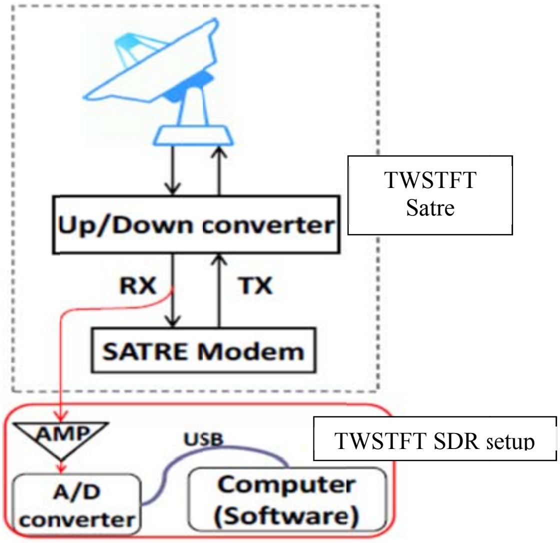
Detailed discussions are given in in [6]. Here we present the results of SDR receiver applied to (Figure 1.2.1):

- The Asia-Asia links between the laboratories of KRISS, TL and NICT, where the satellite Eutelsat 172A is used;
- The Asia-Europe links between PTB, NTSC, NIM and VNIIFTRI (SU), where the satellite Ekspress–AM22 is used;
- The Europe-Europe and Europe-USA links between PTB, OP, INRiM (IT), SU, CH, AOS and NIST, where the Telstar 11N is used.

We observe that the gains of the SDR depend a lot on the regions or the satellite coverage. In general, we concluded that gains on links between stations in the same region are more significant than those on baselines linking different regions. Therefore, the analyses in this paper are grouped into different regions and between them: Asia-Asia, Asia-Europe, Europe-Europe and Europe-USA.

Since 2014, we investigated the TWSTFT SATRE and SDR, and compared them with the GPSPPP results. The indicators used to validate the SDR are the Time Deviation ($\sigma_x$), the standard deviation of the measurement noise σ, the triangle closures, the differences between the two independent techniques TW and PPP (or double clock difference DCD), the gain factor, that can be estimated and defined as the ratio of the standard deviations of SATRE and SDR $\sigma_{SATRE}/\sigma_{SDR}$, and/or as the ratio of the Time Deviations.

Now let us have a quick look at the SDR setup. New developments of TWSTFT technique may drive considerable improvement of the stability at averaging times of one day and less, e.g., employing dual pseudo-random noise (DPN) codes and carrier-phase (CP) based TWSTFT. As well known, the precision of the current TW links involved in UTC computation is still limited due to instabilities of the signal arrival time that suffers from diurnal disturbances. The sources of diurnals are still unclear, and may be not only the variation of the physical propagation delay, but also a composition involving signal interferences and imperfection of TW equipment. The software-defined radio (SDR) receiver was originally designed for implementing the DPN-based or CP-based TWSTFT. In the scope of the pilot project it is used to precisely measure the arrival time of code signal transmitted by the SATRE modem. In fact, it has been observed that in some cases the SDR receiver has the capacity to considerably reduce the diurnal variations. Figure 1.2.2 shows the setup configuration of the SDR in a TWSTFT system equipped with a SATRE modem.




A/D converter: analogue-to-digital converter; AMP: amplifier for optimizing the power level of the intermediate frequency signal.

**Figure 1.2.2** Setup of the SDR in a TWSTFT Earth station.

There is no change in the standard TW ground station except for a splitter which is added to drive the arriving signal to both SDR and SATRE modem. The SDR consists of an amplifier for optimizing the power level of the intermediate frequency (IF) signal, an analogue-to-digital (A/D) converter for sampling the reception signal, and a personal computer for collecting the samples and performing the measurement by the software. In the software, some digital signal processing (DSP) algorithms are applied to measure the time of arrival (TOA) by code phase and carrier phase. Thanks to DSP, the multiple channels can be easily realized to measure more than one TOA at the same time. Since the setup enables independent operation from the SATRE modem to the SDR, two parallel TW measurements can be performed and recorded simultaneously.

Since 2015, three laboratories in the Asia region, TL in Chung-Li (Chinese Taipei), NICT in Tokyo (Japan) and KRISS in Daejeon (South Korea), have experimentally operated SDRs in their TW systems. The results of these laboratories' observations gave the indication that the SDR could significantly reduce the diurnal signal and the measurement noise.

Based on this promising result, the BIPM and the CCTF WG on TW launched jointly a pilot study to validate the SDR technique towards its use in the computation of UTC time links. At present, the SDR facility has been installed and operated in 12 TW laboratories, cf. the Figure 1.2.1.

The rest UTC TW laboratories are coming.

Now we look at the calibration method and the uncertainty.

The same as the SATRE links, the SDR links need to be calibrated before its application in UTC. At present the official UTC calibrations are all of the SATRE links by using the MB and TCC techniques. A SDR link should be therefore calibrated by the *alignment* with the corresponding SATRE link.

The uncertainty of SDR is the combination of the calibration uncertainty (not the conventional ones but the true values in the Calibration Report) of SATRE and SDR links. Because the number of the comment points of SATRE and SDR is big (> 300 per month), the influence of uA are negligible. Therefore conventional calibration uncertainty of SDR link are quais-equal to that of the SATRE link, that is, 1.0 ns, 1.5 ns and 2.0 ns for respectively using the TW MB station, the GPS calibrator and the TCC.

# 2. The Data Set UTC1703 (March 2017)

## *2.1 The TW SATRE data*

The latest UTC1703 (March 2017) TW data are used. There are 11 TW laboratories involved (Table 2.1). The Figure 2.1 shows the independent link availability. Here, 'independent' stands for that a measurement, a link or a triangle, cannot be derived by other links or triangles.

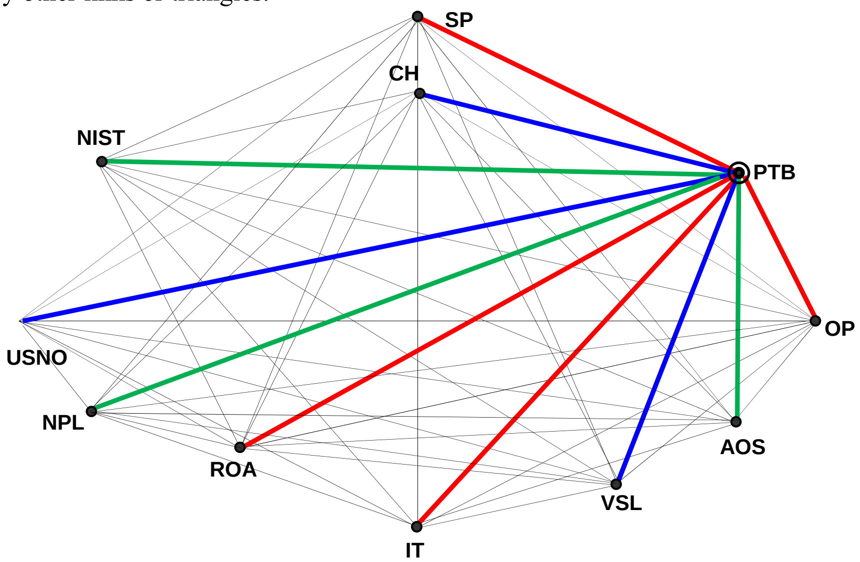



**Fig. 2.1** The UTC time links (**red** or **blue** or **green** lines) and the redundant/non-UTC links (**black** lines)
The **red** and **blue** links are calibrated with the TW mobile station ($u_B \leq 1$ ns), the red links calibrated in 2016 and the blue before. The **green** links are calibrated with the GPS calibrator ($u_B \leq 1.5$ ns)

**Table 2.1** Laboratories in the UTC time link network of UTC1703 in Europe-US network.

| No | Labo | Code |
|---|---|---|
| 1 | NIST | 10002 |
| 2 | PTB | 10005 |
| 3 | USNO | 10007 |
| 4 | OP | 10008 |
| 5 | IT | 10011 |
| 6 | ROA | 10014 |
| 7 | VSL | 10024 |
| 8 | CH | 10057 |
| 9 | SP | 10072 |
| 10 | NPL | 10017 |
| 11 | AOS | 10046 |

Theoretically, the number of the total independent links (Lab2-Lab1) can be calculated by the formula {N(N-1)/2}. With N=11, we have 55 independent links. However, there are no measurements between NIST-USNO, NPL-NIST and NPL-USNO. Therefore there are in total 52 independent links.

Similarly the number of total independent triangles (Lab1-Lab2-Lab3) is calculated by $\{(N^2-3N+2)/2\}=45$. As mentioned above, there are 3 links not available. There are 42 independent TCC triangles or links to calibrate for the Europe-US network.

Finally, we have also a unique Europe-Asia triangle: PTB-NIM-NTSC.

## *2.2 The TW SDR data*

First, this analysis is towards the UTC computation using the BIPM standard Circular T procedure, the Software Tsoft and the ITU data files. 12 labs have installed and are operating the SDR. However, it seems not all the SDR facilities work normally and continually in the UTC month 1703. We collected only the 6 labs (PTB, CH, NIST, IT, AOS and OP) that have the SDR UTC links and some of the non-UTC links, as shown in the Figure 2.2. None of the Asian labs have the completed data during this period. Cf. the Figure 2.1.

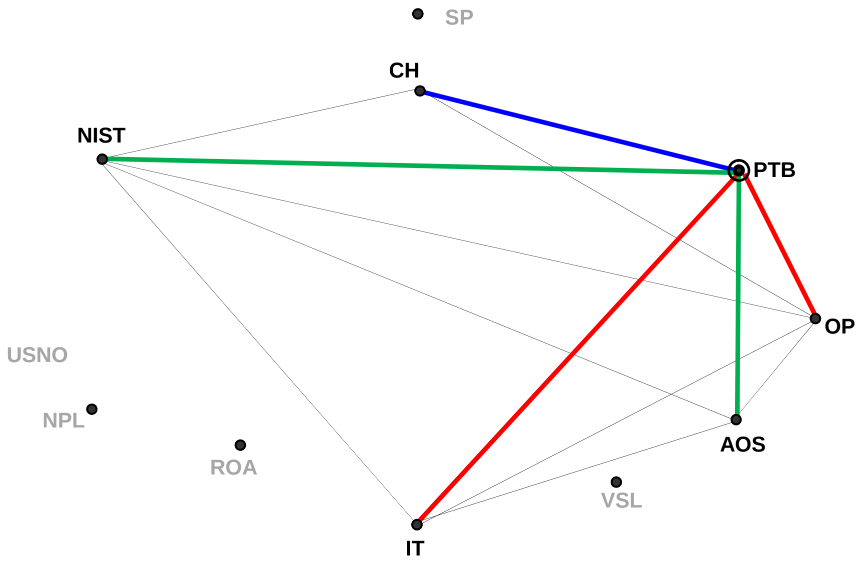



**Fig. 2.2** The TW SDR UTC time links (**red** or **blue** or **green** lines) and the redundant/non-UTC links (**black** lines)

**Table 2.2** Laboratories in the UTC SDR time link network of UTC1703 in Europe-US network.

| No | Labo | Code |
|---|---|---|
| 1 | NIST | 10002 |
| 2 | PTB | 10005 |
| 3 | OP | 10008 |
| 4 | IT | 10011 |
| 5 | CH | 10057 |
| 6 | AOS | 10046 |

# 3. The computation of the TCC calibration of the SATRE/SDR network

## *3.1 The SATRE links*

The full data set 1703 were used for the TCC calibration. The measurement interval is two hours. So there are 12 points per day or about 360 point per months per link. In the normal cases, there are 360 closures per month per triangle and we take the mean value as the result. As discussed in the Section 2, the non-zero closure is the CALR of the non-UTC link of the triangle.

To be simple, we first use only the data of the 6 standard MJDs to first verify the triangles with the values of CALR and ESDVAR in the TWSTFT ITU files and they should be zero if the CALR/ESDVAR values are correct. The non-zero closures are the calibration values. We use the fully-automatic procedure installed in the UTC Software Tsoft for this computation. The related jobs and parameters are given in the Annex I.

Table 3.1 is the 43 independent triangle closures composed by the 13 TW labs using the actual ITU data. For a demonstration here, only the triangle closures on the six standard MJDs are shown. In Table 3.1, the 'Mean' is the mean of the 6 closures and StdD is the standard deviation giving the noise level, of which the biggest is less than 0.3 ns except of the only Europe-Asia triangle PTB-NIM-NTSC. It is rather big, 1.3 ns. There seems a setup delay about 6 ns changed in the link NIM-NTSC. '*' stands for values which are corrected but too big to be held in the table. This does not affect our analysis.

**Table 3.1** The 43 triangle closures in ns (without calibration for the non-UTC links)

| No | Triangle | N | Min | Max | Mean | StdD | 57814 | 57819 | 57824 | 57829 | 57834 | 57839 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | T PTB AOS CH | 6 | 37.60 | 37.80 | 37.67 | 0.07 | 37.7 | 37.8 | 37.6 | 37.6 | 37.7 | 37.6 |
| 2 | T PTB AOS IT | 6 | 305.00 | 305.30 | 305.13 | 0.11 | 305.2 | 305.0 | 305.1 | 305.0 | 305.3 | 305.2 |
| 3 | T PTB AOS NIST | 6 | -232.80 | -232.20 | -232.42 | 0.20 | -232.8 | -232.4 | -232.5 | -232.4 | -232.2 | -232.2 |
| 4 | T PTB AOS NPL | 6 | -695.20 | -694.80 | -695.05 | 0.15 | -695.2 | -695.1 | -695.1 | -695.2 | -694.8 | -694.9 |
| 5 | T PTB AOS OP | 6 | 7144.30 | 7144.80 | 7144.47 | 0.18 | 7144.3 | 7144.3 | 7144.4 | 7144.4 | 7144.6 | 7144.8 |
| 6 | T PTB AOS ROA | 6 | -1.50 | -1.00 | -1.28 | 0.20 | -1.4 | -1.4 | -1.0 | -1.5 | -1.0 | -1.4 |
| 7 | T PTB AOS SP | 6 | 32.00 | 32.40 | 32.25 | 0.14 | 32.3 | 32.2 | 32.4 | 32.0 | 32.4 | 32.2 |
| 8 | T PTB AOS USNO | 6 | -177.60 | -176.90 | -177.22 | 0.21 | -177.6 | -177.3 | -177.2 | -177.1 | -176.9 | -177.2 |
| 9 | T PTB AOS VSL | 6 | 310.00 | 310.80 | 310.30 | 0.28 | 310.0 | 310.0 | 310.3 | 310.2 | 310.8 | 310.5 |
| 10 | T PTB CH IT | 6 | 267.30 | 267.70 | 267.52 | 0.13 | 267.3 | 267.5 | 267.7 | 267.4 | 267.6 | 267.6 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | T | PTB | CH | NIST | 6-267.90-267.70-267.80 | 0.08 | -267.9 | -267.7 | -267.9 | -267.8 | -267.7 | -267.8 |
| 12 | T | PTB | CH | NPL | 6-732.40-732.00-732.17 | 0.14 | -732.1 | -732.1 | -732.3 | -732.4 | -732.0 | -732.1 |
| 13 | T | PTB | CH | OP | 67106.907107.107107.03 | 0.07 | 7106.9 | 7107.1 | 7107.0 | 7107.1 | 7107.0 | 7107.1 |
| 14 | T | PTB | CH | ROA | 6 -38.90 -38.50 -38.73 | 0.14 | -38.8 | -38.6 | -38.5 | -38.8 | -38.8 | -38.9 |
| 15 | T | PTB | CH | SP | 6 -5.60 -5.20 -5.48 | 0.13 | -5.5 | -5.5 | -5.6 | -5.5 | -5.6 | -5.2 |
| 16 | T | PTB | CH | USNO | 6-211.80-211.60-211.72 | 0.09 | -211.8 | -211.7 | -211.8 | -211.6 | -211.6 | -211.8 |
| 17 | T | PTB | CH | VSL | 6 272.10 273.10 272.70 | 0.37 | 272.8 | 272.9 | 272.3 | 272.1 | 273.0 | 273.1 |
| 18 | T | PTB | IT | NIST | 6-536.80-536.60-536.72 | 0.09 | -536.8 | -536.7 | -536.8 | -536.6 | -536.8 | -536.6 |
| 19 | T | PTB | IT | NPL | 6*******-999.50-999.65 | 0.17 | -999.5 | -999.7 | -1000.0 | -999.5 | -999.6 | -999.6 |
| 20 | T | PTB | IT | OP | 66839.106839.506839.28 | 0.12 | 6839.3 | 6839.3 | 6839.1 | 6839.2 | 6839.3 | 6839.5 |
| 21 | T | PTB | IT | ROA | 6-306.60-305.90-306.28 | 0.26 | -305.9 | -306.1 | -306.5 | -306.5 | -306.1 | -306.6 |
| 22 | T | PTB | IT | SP | 6-272.30-272.00-272.18 | 0.11 | -272.3 | -272.3 | -272.2 | -272.1 | -272.2 | -272.0 |
| 23 | T | PTB | IT | USNO | 6-480.40-479.70-480.00 | 0.26 | -479.9 | -480.4 | -480.1 | -479.7 | -480.2 | -479.7 |
| 24 | T | PTB | IT | VSL | 6 5.00 5.50 5.23 | 0.18 | 5.5 | 5.1 | 5.1 | 5.0 | 5.3 | 5.4 |
| 25 | T | PTB | NIST | OP | 67374.607374.807374.70 | 0.06 | 7374.8 | 7374.7 | 7374.7 | 7374.7 | 7374.6 | 7374.7 |
| 26 | T | PTB | NIST | ROA | 6 229.40 230.10 229.78 | 0.21 | 229.8 | 230.1 | 229.9 | 229.7 | 229.8 | 229.4 |
| 27 | T | PTB | NIST | SP | 6 261.90 262.30 262.07 | 0.15 | 262.1 | 262.2 | 262.3 | 262.0 | 261.9 | 261.9 |
| 28 | T | PTB | NIST | VSL | 6 540.90 541.60 541.38 | 0.25 | 541.6 | 541.5 | 541.2 | 540.9 | 541.6 | 541.5 |
| 29 | T | PTB | NPL | OP | 67838.207839.007838.65 | 0.28 | 7838.9 | 7839.0 | 7838.2 | 7838.8 | 7838.5 | 7838.5 |
| 30 | T | PTB | NPL | ROA | 6 693.10 693.60 693.50 | 0.18 | 693.6 | 693.6 | 693.6 | 693.6 | 693.5 | 693.1 |
| 31 | T | PTB | NPL | SP | 6 726.50 726.90 726.70 | 0.13 | 726.7 | 726.6 | 726.9 | 726.8 | 726.5 | 726.7 |
| 32 | T | PTB | NPL | VSL | 61004.601005.101004.90 | 0.16 | 1005.0 | 1004.9 | 1005.1 | 1004.8 | 1004.6 | 1005.0 |
| 33 | T | PTB | OP | ROA | 6********************* | 0.16 | -7145.7 | -7145.6 | -7145.5 | -7145.8 | -7145.7 | -7146.0 |
| 34 | T | PTB | OP | SP | 6********************* | 0.07 | -7112.4 | -7112.5 | -7112.3 | -7112.4 | -7112.5 | -7112.4 |
| 35 | T | PTB | OP | USNO | 6********************* | 0.20 | -7318.9 | -7318.8 | -7318.7 | -7318.6 | -7318.5 | -7319.1 |
| 36 | T | PTB | OP | VSL | 6********************* | 0.14 | -6833.7 | -6833.9 | -6833.9 | -6834.1 | -6834.1 | -6833.9 |
| 37 | T | PTB | ROA | SP | 6 33.20 33.60 33.32 | 0.15 | 33.3 | 33.2 | 33.2 | 33.4 | 33.2 | 33.6 |
| 38 | T | PTB | ROA | USNO | 6-174.00-173.20-173.63 | 0.25 | -173.7 | -174.0 | -173.8 | -173.5 | -173.6 | -173.2 |
| 39 | T | PTB | ROA | VSL | 6 310.60 311.40 311.12 | 0.25 | 311.3 | 311.2 | 311.1 | 310.6 | 311.1 | 311.4 |
| 40 | T | PTB | SP | USNO | 6-207.10-206.30-206.78 | 0.26 | -207.1 | -206.9 | -207.0 | -206.7 | -206.7 | -206.3 |
| 41 | T | PTB | SP | VSL | 6 277.40 278.00 277.67 | 0.24 | 278.0 | 277.8 | 277.4 | 277.4 | 277.5 | 277.9 |
| 42 | T | PTB | USNO | VSL | 6 484.80 485.50 485.27 | 0.25 | 485.5 | 485.4 | 485.1 | 484.8 | 485.5 | 485.3 |
| 43 | T | PTB | NIM | NTSC | 6 84.70 88.20 86.35 | 1.30 | 84.8 | 84.7 | 88.2 | 86.6 | 87.6 | 86.2 |

Table 3.2 is an example of the triangle closure which is composed of PTB, OP and SP on each MJD. The mean value is only -0.05±0.12 ns (cf. the triangle 34 in Table 3.1).

**Table 3.2** Example of the triangle closure PTB-OP-SP from UTC1703

| | MJD | Closure= | Link1 + | Link2 + | Link3 |
|---|---|---|---|---|---|
| 1 | 57814 | -7112.4= | -0.3 + | 0.9 + | -7111.2 |
| 2 | 57819 | -7112.5= | -0.3 + | 0.8 + | -7111.4 |
| 3 | 57824 | -7112.3= | -0.2 + | 0.6 + | -7111.5 |
| 4 | 57829 | -7112.4= | -0.5 + | 0.7 + | -7111.2 |
| 5 | 57834 | -7112.5= | -0.9 + | 0.9 + | -7111.7 |
| 6 | 57839 | -7112.4= | -1.0 + | 0.9 + | -7111.5 |

## *3.2 The SDR links*

As discussed above, a SDR link should be aligned to the corresponding SATRE link. The uncertainty is as same as the SATRE because the aligned measurement error comes from mainly the measurement noise of the SATRE link (StdDev/√N, N is number of the common point of SATRE and SDR links, about 150) and will be mostly averaged out, less than 0.1 ns in most cases. There are 5 UTC links and 6 non-UTC links (Figure 2.2). The alignment results is the so called double clock differences (DCD), given in the Table 3.2.1, the 'Mean" values. The DCD is the CALR for the SDR link.

**Table 3.2.1** The DCD of the SATRE and **SDR** links over the available 1703 UTC and non-UTC links

| n | Link | N | Min | Max | Mean | StdDev |
|---|---|---|---|---|---|---|
| 1 | AOSPTB.TTTT4 | 144 | -2.546 | 2.095 | 0.000 | 1.331 |
| 2 | CHPTB.TTTT4 | 144 | -1.589 | 1.362 | 0.000 | 0.842 |
| 3 | ITPTB.TTTT4 | 144 | 183.835 | 186.214 | 185.124 | 0.466 |
| 4 | NISTPTB.TTTT4 | 143 | 473.312 | 473.895 | 473.668 | 0.130 |
| 5 | OPPTB.TTTT4 | 144 | -2177.938 | -2176.121 | -2177.127 | 0.437 |
| 6 | NISTAOS.TTTT4 | 143 | 393.232 | 395.553 | 394.218 | 0.585 |
| 7 | NISTCH.TTTT4 | 143 | 325.631 | 327.365 | 326.530 | 0.207 |
| 8 | NISTIT.TTTT4 | 143 | 287.149 | 288.455 | 287.816 | 0.262 |
| 9 | OPNIST.TTTT4 | 143 | -2650.144 | -2649.696 | -2649.920 | 0.075 |
| 10 | OPCH.TTTT4 | 143 | -2324.769 | -2322.474 | -2323.461 | 0.449 |
| 11 | OPIT.TTTT4 | 142 | -2363.752 | -2360.775 | -2362.616 | 0.678 |

# 4. The Results of the TW SATRE and SDR Calibration: CARL and ESDVAR

We use the latest UTC 1703 (2017 March, MJD 57812-57840) data for the computation.
In the following sections, the final calibration results: CALR, ESDVAR, CI, TYPE and the uncertainties will be given for the implementation in the ITU data files.

## *4.1 CALR/ESDVAR for UTC SATRE links*

Table 4.1.1 gives the CALR/Esdvar values used for the SATRE calibration computation.

**Table 4.1.1a** The SATRE CALR/ESDVAR values in the 12 1703 TW ITU data files (no new calibrations)

| LAB1- LAB2 | MJD1- MJD2 | CALR1 | CALR2 | ESDVAR1 | ESDVAR2 | ESIG1 | ESIG2 |
|---|---|---|---|---|---|---|---|
| AOS01-PTB01 | 57807-57846 | 30.1 | -30.1 | 00000.000 | 0.0 | 0.500 | 2.800 |
| CH01-PTB01 | 57807-57846 | -713.400 | 713.400 | -0.850 | -1412.656 | 0.450 | 0.000 |
| IT02-PTB01 | 57807-57846 | -274.9 | 274.9 | 00000.000 | 00000.000 | 99999 | 0.000 |
| NIM01-PTB03 | 57807-57845 | 02319.700 | -2319.700 | 00000.000 | -3.600 | 99999 | 0.800 |
| NIST01-PTB01 | 57807-57845 | -716.776 | 716.776 | 543.200 | -1412.656 | 0.500 | 0.000 |
| NPL02-PTB01 | 57807-57846 | 725.1 | -725.1 | 00000.000 | 0.0 | 99999 | 0.000 |
| NTSC02-PTB03 | 57807-57846 | 2242.900 | -2242.900 | -14.980 | -3.600 | 0.310 | 0.800 |
| OP01-PTB01 | 57807-57846 | -7113.8 | 7113.8 | 00000.000 | 00000.000 | 0.000 | 0.000 |
| PTB01-ROA01 | 57808-57846 | -31.6 | 31.6 | 00000.000 | 00000.000 | 0.000 | 99999 |
| PTB01-VSL01 | 57807-57846 | 986.300 | -986.300 | -1412.656 | 999999999 | 0.000 | 99999 |
| PTB01- SP01 | 57807-57846 | 1.6 | -1.6 | 00000.000 | 00000.000 | 0.000 | 99999 |
| PTB01-USNO01 | 57807-57846 | -205.080 | 205.080 | 00000.000 | 0.000 | 0.000 | 0.000 |

**Table 4.1.1b** The SATRE CALR/ESDVAR values in the 12 **1707** TW ITU data files (PTB05, no new calibrations)

| LAB1- LAB2 | MJD1- MJD2 | CALR1 | CALR2 | ESDVAR1 | ESDVAR2 | ESIG1 | ESIG2 |
|---|---|---|---|---|---|---|---|
| AOS01-PTB01 | 57807-57846 | 164.141 | -164.141 | -383.580 | 0.0 | 0.500 | 2.800 |
| CH01-PTB05 | 57932-57965 | -713.400 | 713.400 | -0.850 | -1418.580 | 0.450 | 0.600 |
| IT02-PTB05 | 57932-57965 | -274.900 | 274.900 | 999999999 | -5.920 | 99999 | 0.600 |
| NIM01-PTB03 | 57932-57932 | 2319.700 | -2319.700 | 00000.000 | -3.600 | 99999 | 0.800 |
| NIST01-PTB05 | 57932-57964 | -716.776 | 716.776 | 543.200 | -1418.580 | 0.500 | 0.600 |
| NPL02-PTB05 | 57932-57965 | 999999999 | 999999999 | 999999999 | -1418.580 | 99999 | 0.600 |
| NTSC02-PTB03 | 57932-57934 | 2242.900 | -2242.900 | -22.480 | -3.600 | 0.310 | 0.800 |
| OP01-PTB05 | 57932-57965 | -7113.800 | 7113.800 | 00000.000 | -5.920 | 0.000 | 0.600 |
| PTB05-ROA01 | 57932-57964 | -31.600 | 31.600 | -5.920 | 999999999 | 0.600 | 99999 |
| PTB05-VSL01 | 57932-57965 | 986.300 | -986.300 | -1418.580 | 999999999 | 0.600 | 99999 |
| PTB05-SP01 | 57932-57965 | 1.600 | -1.600 | -5.920 | 999999999 | 0.600 | 99999 |
| PTB05-SNO01 | 57932-57965 | -205.080 | 205.080 | -5.920 | 0.000 | 0.600 | 0.000 |

**Table 4.1.2** The BIPM SATRE CALR/ESDVAR for AOS and NPL (cf. Table Ib)

| CI | Type | uB | Labi | Labj | S | CARL | ESDVAR | StDev |
|---|---|---|---|---|---|---|---|---|
| 449 | LC(GPS) | 2.5 | AOS01 | PTB05 | 1 | 33.1 | 0.0 | 0.020 |
| | | | PTB05 | AOS01 | 1 | -33.1 | 0.0 | |
| 450 | LC(GPS) | 2.0 | NPL02 | PTB05 | 1 | 728.1 | 0.0 | 0.020 |
| | | | PTB05 | NPL02 | 1 | -728.1 | 0.0 | |

The values in Table 4.1.1 have been implemented in 57842 for 1704 and the values in Table 4.1.2 are planned to be implemented on the date given in Section 4.3.

## *4.2 CALR/ESDVAR for Non-UTC SATRE links and the ~~SDR~~ links*

Table 4.2.1a lists the CALR/ESDVAR TCC calibration result for the non-UTC European-USA and Asia-Asia links. The same values for the SDR links are given in the Table 4.2.1b below. For the later, there are open points: (1) How to incorporate REFDLY in the SDR ITU file and (2) How to adapt for the time step(s) after this calibration computation.

The new calibrations should be implemented. Cf. the equation (2) for the definition of the terms N and S.

**Table 4.2.1a** The new CALR Values for non UTC SATRE links to be implemented in the TW ITU data files

| CI | Type | uB | Labi | Labj | S | CALR | ESDVAR | StDev | No |
|---|---|---|---|---|---|---|---|---|---|
| 451 | TCC | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 | 2.0 | 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 |

Those already calibrated given in [6] are kept the same values, as listed in the column CALR' in the Table 4.2.2. Here the 'Dif.' is the differences between the results of this TM and that given by the 2016 European calibration report [6]. As seen, the Dif. values are between -0.4 and 0.3 ns, that is, the 2016 [6] and this 2017 BIPM calibrations are highly agreed.

**Table 4.2.2** The SATRE CALR Values for non UTC links given by the 2016 MB calibration [6]

| Labi | Labj | S | CALR | ESDVAR | StDev | N | CALR' | Dif. |
|---|---|---|---|---|---|---|---|---|
| IT02 | OP01 | 1 | 6839.315 | 00000.000 | 0.179/0.035 | 20 | 6839.1 | 0.2 |
| OP01 | IT02 | 1 | -6839.315 | 00000.000 | 0.179/0.035 | 20 | | |
| IT02 | ROA01 | 1 | -306.223 | 00000.000 | 0.239/0.047 | 21 | -306.4 | -0.2 |
| ROA01 | IT02 | 1 | 306.223 | 00000.000 | 0.239/0.047 | 21 | | |
| IT02 | SP01 | 1 | -272.173 | 00000.000 | 0.132/0.026 | 22 | -271.9 | 0.3 |
| SP01 | IT02 | 1 | 272.173 | 00000.000 | 0.132/0.026 | 22 | | |
| OP01 | ROA01 | 1 | -7145.704 | 00000.000 | 0.165/0.032 | 33 | -7145.6 | -0.1 |
| ROA01 | OP01 | 1 | 7145.704 | 00000.000 | 0.165/0.032 | 33 | | |
| OP01 | SP01 | 1 | -7112.404 | 00000.000 | 0.109/0.021 | 34 | -7112.2 | -0.2 |
| SP01 | OP01 | 1 | 7112.404 | 00000.000 | 0.109/0.021 | 34 | | |
| ROA01 | SP01 | 1 | 33.262 | 00000.000 | 0.133/0.026 | 37 | 33.6 | -0.4 |
| SP01 | ROA01 | 1 | -33.262 | 00000.000 | 0.133/0.026 | 37 | | . |

From the table 4.2.2, the differences are small, vs. the uncertainty given in [4,5]: 2ns. This suggests:
(1) both of the computations are correct and agree within 0.5 ns (0.05 ns on average and 0.3 ns of r.m.s.). The software, the parameters and data sets were used correctly;
(2) the CALRs are quite stable since more than half years except for the link NIM-NTSC;
(3) if (2) is right and when the differences of GPS-TW go up (Tables 5.1a and 5.1b), the GPS would be less stable ?

The Table 4.2.3 gives the closures after the implementation of the calibration given in the Table 4.2.1. As seen, the closures are all less than 0.1 ns with only one exception: 0.18 ns for the triangle PTB-NIM-NTSC. From the table, the standard deviations are all less than 0.3 ns with only the above exception.

**Table 4.2.3** Closures after implementing the 2017 TCC for non-UTC SATRE link calibration (Tables 4.1.2 and 4.2.1)

| Triangle/Stat./Mjd: | Min | Max | Closure | RMS | StdD | 57814.00 | 57819.00 | 57824.00 | 57829.00 | 57834.00 | 57839.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 T PTB AOS CH | 0.00 | 0.20 | 0.07 | 0.10 | 0.07/ | 0.1 | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 |
| 2 T PTB AOS IT | -0.10 | 0.30 | 0.07 | 0.14 | 0.12/ | 0.1 | -0.1 | 0.0 | 0.0 | 0.3 | 0.1 |
| 3 T PTB AOS NIST | -0.40 | 0.20 | -0.03 | 0.21 | 0.21/ | -0.4 | -0.1 | -0.1 | 0.0 | 0.2 | 0.2 |
| 4 T PTB AOS NPL | -0.20 | 0.30 | -0.02 | 0.17 | 0.17/ | -0.1 | -0.1 | -0.1 | -0.2 | 0.3 | 0.1 |
| 5 T PTB AOS OP | -0.20 | 0.30 | -0.02 | 0.17 | 0.17/ | -0.1 | -0.2 | -0.1 | -0.1 | 0.1 | 0.3 |
| 6 T PTB AOS ROA | -0.20 | 0.30 | -0.05 | 0.22 | 0.21/ | -0.2 | -0.2 | 0.2 | -0.2 | 0.3 | -0.2 |
| 7 T PTB AOS SP | -0.30 | 0.20 | 0.00 | 0.15 | 0.15/ | 0.0 | 0.0 | 0.1 | -0.3 | 0.2 | 0.0 |
| 8 T PTB AOS USNO | -0.50 | 0.30 | -0.07 | 0.24 | 0.24/ | -0.5 | -0.1 | 0.0 | 0.0 | 0.3 | -0.1 |
| 9 T PTB AOS VSL | -0.20 | 0.60 | 0.13 | 0.30 | 0.27/ | -0.2 | -0.1 | 0.2 | 0.0 | 0.6 | 0.3 |
| 10 T PTB CH IT | -0.20 | 0.20 | 0.00 | 0.13 | 0.13/ | -0.2 | 0.0 | 0.2 | -0.1 | 0.0 | 0.1 |
| 11 T PTB CH NIST | -0.20 | 0.00 | -0.07 | 0.12 | 0.09/ | -0.2 | 0.0 | -0.2 | 0.0 | 0.0 | 0.0 |
| 12 T PTB CH NPL | -0.20 | 0.20 | 0.03 | 0.14 | 0.14/ | 0.1 | 0.1 | -0.1 | -0.2 | 0.2 | 0.1 |
| 13 T PTB CH OP | -0.10 | 0.10 | 0.02 | 0.07 | 0.07/ | -0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| 14 T PTB CH ROA | -0.20 | 0.20 | 0.00 | 0.13 | 0.13/ | 0.0 | 0.1 | 0.2 | 0.0 | -0.1 | -0.2 |
| 15 T PTB CH SP | -0.20 | 0.30 | -0.05 | 0.18 | 0.17/ | -0.1 | -0.1 | -0.2 | 0.0 | -0.2 | 0.3 |
| 16 T PTB CH USNO | -0.20 | 0.00 | -0.08 | 0.12 | 0.09/ | -0.1 | 0.0 | -0.2 | 0.0 | 0.0 | -0.2 |
| 17 T PTB CH VSL | -0.50 | 0.50 | 0.03 | 0.37 | 0.36/ | 0.1 | 0.2 | -0.4 | -0.5 | 0.3 | 0.5 |
| 18 T PTB IT NIST | -0.20 | 0.10 | -0.03 | 0.12 | 0.11/ | -0.1 | 0.0 | -0.2 | 0.1 | -0.1 | 0.1 |
| 19 T PTB IT NPL | -0.30 | 0.20 | 0.05 | 0.18 | 0.17/ | -40.9 | -41.1 | -41.4 | -40.9 | -41.0 | -41.0 |
| 20 T PTB IT OP | -0.20 | 0.20 | -0.03 | 0.14 | 0.14/ | 0.0 | 0.0 | -0.2 | -0.2 | 0.0 | 0.2 |
| 21 T PTB IT ROA | -0.40 | 0.30 | -0.08 | 0.27 | 0.26/ | 0.3 | 0.1 | -0.3 | -0.3 | 0.1 | -0.4 |
| 22 T PTB IT SP | -0.10 | 0.20 | 0.00 | 0.12 | 0.12/ | -0.1 | -0.1 | -0.1 | 0.1 | 0.0 | 0.2 |
| 23 T PTB IT USNO | -0.40 | 0.30 | -0.02 | 0.24 | 0.24/ | 0.1 | -0.4 | -0.1 | 0.2 | -0.2 | 0.3 |
| 24 T PTB IT VSL | -0.30 | 0.10 | -0.08 | 0.18 | 0.16/ | 0.1 | -0.2 | -0.2 | -0.3 | 0.0 | 0.1 |
| 25 T PTB NIST OP | 0.00 | 0.10 | 0.07 | 0.08 | 0.05/ | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 |
| 26 T PTB NIST ROA | -0.40 | 0.30 | -0.02 | 0.21 | 0.21/ | 0.0 | 0.3 | 0.1 | -0.1 | 0.0 | -0.4 |
| 27 T PTB NIST SP | -0.10 | 0.30 | 0.08 | 0.18 | 0.16/ | 0.2 | 0.2 | 0.3 | 0.0 | -0.1 | -0.1 |
| 28 T PTB NIST VSL | -0.30 | 0.40 | 0.18 | 0.31 | 0.25/ | 0.4 | 0.3 | 0.0 | -0.3 | 0.4 | 0.3 |
| 29 T PTB NPL OP | -0.40 | 0.40 | 0.05 | 0.28 | 0.28/ | 0.3 | 0.4 | -0.4 | 0.2 | -0.1 | -0.1 |
| 30 T PTB NPL ROA | -0.50 | 0.00 | -0.10 | 0.21 | 0.18/ | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | -0.5 |
| 31 T PTB NPL SP | -0.10 | 0.20 | 0.08 | 0.14 | 0.11/ | 0.1 | 0.0 | 0.2 | 0.2 | -0.1 | 0.1 |
| 32 T PTB NPL VSL | -0.40 | 0.10 | -0.10 | 0.19 | 0.16/ | 0.0 | -0.1 | 0.1 | -0.2 | -0.4 | 0.0 |
| 33 T PTB OP ROA | -0.30 | 0.20 | -0.02 | 0.16 | 0.16/ | 0.0 | 0.1 | 0.2 | -0.1 | 0.0 | -0.3 |
| 34 T PTB OP SP | -0.10 | 0.10 | -0.02 | 0.07 | 0.07/ | 0.0 | -0.1 | 0.1 | 0.0 | -0.1 | 0.0 |
| 35 T PTB OP USNO | -0.50 | 0.20 | -0.10 | 0.25 | 0.23/ | -0.2 | -0.2 | 0.0 | 0.1 | 0.2 | -0.5 |
| 36 T PTB OP VSL | -0.20 | 0.20 | -0.03 | 0.14 | 0.14/ | 0.2 | 0.0 | 0.0 | -0.2 | -0.2 | 0.0 |
| 37 T PTB ROA SP | 0.00 | 0.30 | 0.07 | 0.13 | 0.11/ | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.3 |
| 38 T PTB ROA USNO | -0.30 | 0.40 | 0.05 | 0.23 | 0.22/ | 0.0 | -0.3 | -0.1 | 0.2 | 0.1 | 0.4 |
| 39 T PTB ROA VSL | -0.50 | 0.30 | 0.00 | 0.26 | 0.26/ | 0.2 | 0.1 | -0.1 | -0.5 | 0.0 | 0.3 |
| 40 T PTB SP USNO | -0.30 | 0.50 | -0.02 | 0.27 | 0.27/ | -0.3 | -0.1 | -0.3 | 0.0 | 0.1 | 0.5 |
| 41 T PTB SP VSL | -0.30 | 0.30 | -0.05 | 0.23 | 0.23/ | 0.3 | 0.1 | -0.3 | -0.3 | -0.2 | 0.1 |
| 42 T PTB USNO VSL | -0.40 | 0.30 | 0.10 | 0.27 | 0.25/ | 0.3 | 0.3 | 0.0 | -0.4 | 0.3 | 0.1 |
| 43 T PTB NIM NTSC | -1.30 | 0.40 | -0.18 | 0.60 | 0.57/ | 0.4 | 0.3 | -0.3 | -0.3 | 0.1 | -1.3 |

The double clock differences (DCD) between the SATRE and SDR links in Table 3.2.1 are the CALR values for the corresponding SDR on the same baseline of the SATRE. For example, the DCD between the SATRE and SDR links over the baseline AOS-PTB is +80.496 (cf. Table 3.2.1) and this is the CALR of the link AOS01-PTB01 in the ITU file TWAOSMJ.DDD. All the results are given in the Table 4.2.1b. This is a test calibration for the SDR links, the CI code is 999. Note here that a constant of 50 is added to ground station N°, cf., Section 6 in TM267 [7].

**Table 4.2.1b*** The **SDR** CALR Values for the SDR links to be implemented in the TW ITU data files

| CI | Type | uB | Labi | Labj | S | CARL | ESDVAR | StDev | N |
|---|---|---|---|---|---|---|---|---|---|
| 999 | LC(TW/SATRE) | 1.0 | AOS51 | PTB51 | 1 | 80.496 | 00000.000 | < 0.2 | ~150 |
| | | | PTB51 | AOS51 | 1 | -80.496 | 0.0 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 1.0 | CH51 | PTB51 | 1 | 146.105 | 00000.000 | < 0.2 | ~150 |
| | | | PTB51 | CH51 | 1 | -146.105 | 00000.000 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 1.0 | IT52 | PTB51 | 1 | 185.124 | 00000.000 | < 0.2 | ~150 |
| | | | PTB51 | IT52 | 1 | -185.124 | 00000.000 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 1.5 | NIST51 | PTB51 | 1 | 473.668 | 00000.000 | < 0.2 | ~150 |
| | | | PTB51 | NIST51 | 1 | -473.668 | 0.0 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 1.0 | OP51 | PTB51 | 1 | -2177.127 | 00000.000 | < 0.2 | ~150 |
| | | | PTB51 | OP51 | 1 | 2177.127 | 00000.000 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 2.0 | NIST51 | AOS51 | 1 | 394.218 | 00000.000 | < 0.2 | ~150 |
| | | | AOS51 | NIST51 | 1 | -394.218 | 0.0 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 2.0 | NIST51 | CH51 | 1 | 326.530 | 00000.000 | < 0.2 | ~150 |
| | | | CH51 | NIST51 | 1 | -326.530 | 0.0 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 2.0 | NIST51 | IT51 | 1 | 287.816 | 00000.000 | < 0.2 | ~150 |
| | | | IT51 | NIST51 | 1 | -287.816 | 0.0 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 2.0 | NIST51 | OP51 | 1 | 2649.920 | 00000.000 | < 0.2 | ~150 |
| | | | OP51 | NIST51 | 1 | -2649.920 | 0.0 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 2.0 | OP51 | CH51 | 1 | -2323.461 | 00000.000 | < 0.2 | ~150 |
| | | | CH51 | OP51 | 1 | 2323.461 | 00000.000 | < 0.2 | ~150 |
| 999 | LC(TW/SATRE) | 2.0 | OP51 | IT51 | 1 | -2362.616 | 00000.000 | < 0.2 | ~150 |
| | | | IT51 | OP51 | 1 | 2362.616 | 00000.000 | < 0.2 | ~150 |

* Due to the incomplete SDR data, this table is to be updated before the planned implementation.

### *4.3 Implementation date*

The proposed schedule of the implementation is the **MJD 57997 (1 September 2017)** at 0h UTC. The TW LABs check their own new CALR and the related ESDVAR in Tables 4.1.2, 4.2.1a and ~~4.2.1b~~ and then implement them with the CI codes in their ITU files. The BIPM will use these data for the computation of the coming Circular T 355 (1707).

### *4.4 The uncertainty*

The calibration uncertainty $u_B$ for the PTB/AOS and PTB/NPL links are given in Table 4.1.2. the conventional values are 1.0 ns for using a TW mobile station and 1.5 ns for using the GPS calibrator. By equation (2) and the Table 4.2.1 (s~0.03), the uncertainty $u_B$ of TCC can be estimated as:

for TW link only triangles: $u_{B2} = \sqrt{1^2 + 1^2 + S^2} = 1.4$ ns < **2 ns**
for TW-GPS mixed triangles: $u_{B1} = \sqrt{1.5^2 + 1^2 + S^2} = 1.8$ ns < **2 ns**

We use the conventional value of 2 ns for the uncertainty of all the TCC calibrations for both the SATRE and the SDR links.

The estimation is valuable for both of the SATRE and SDR links.

## 5. Comparisons between the TWSTFTF and the GPSPPP links

Table 5.1a gives the results of the comparisons between the TWSTFT and GPSPPP links over the 12 UTC baselines based on the BIPM/RMO 2016 TW and GPS calibrations. It is important to notice that the most recent calibrations for the TW and GPS links are used.

In the tables, **σ** is the standard deviation of the differences of a link measurement (DCD) between TW and GPS vs. the **Mean** value. It reflects measurement (difference between TW-GPS) noise level. As seen, most of **σ** is less than 1 ns, that is, within the reasonable range.

Taking the calibration uncertainty of TW and GPS are of 1 ns and 1.7 ns, the combined uncertainty in the difference of TW-GPS links are $\sqrt{(1^2+1.7^2)}=1.97$ ns. However, as can be seen, half of the differences ('Mean' in the Table) are bigger than 2 ns ! The values bigger than 2.0 ns, the combined uncertainty, are highlighted with red colour.

**Table 5.1a** Differences between TW (SATRE) and GPSPPP links over the **UTC** baselines (based on the **2016** TW and GPS calibrations)

| Lab2-Lab1 | N | Min | Max | Mean | RMS | σ |
|---|---|---|---|---|---|---|
| AOSPTB | 384 | -2.658 | 1.247 | -0.243 | 0.974 | 0.943 |
| CHPTB | 383 | 1.224 | 4.860 | 3.087 | 3.207 | 0.867 |
| ITPTB | 382 | -4.192 | -0.722 | -2.709 | 2.786 | 0.653 |
| NISTPTB | 383 | -7.005 | -5.447 | -6.210* | 6.218 | 0.311 |
| OPPTB | 382 | -5.822 | -3.522 | -4.715 | 4.742 | 0.505 |
| ROAPTB | 384 | -1.425 | 2.050 | 0.133 | 0.657 | 0.644 |
| SPPTB | 384 | -0.138 | 3.575 | 1.221 | 1.500 | 0.872 |
| VSLPTB | 377 | -2.823 | 0.371 | -1.676 | 1.770 | 0.571 |
| USNOPTB | 338 | 0.808 | 2.248 | 1.549 | 1.567 | 0.238 |
| NPLPTB | 368 | 1.525 | 4.016 | 2.812 | 2.850 | 0.464 |
| NTSCPTB | 933 | -2.282 | 2.694 | -0.063 | 0.679 | 0.676 |
| NIMPTB | 1255 | 1.778 | 5.406 | 3.326 | 3.353 | 0.428 |

Remarks:

* According to [11], there is an error in the total delay used in computation of the TAIPPP for NIST. The total delay is 109.9 ns reported in nist1703.gpi but it should be 116.7 ns after the new calibration implementation on 57506. Counting this 6.8 ns difference, the DCD here become 0.6 ns, more reasonable.

Table 5.1b are the same comparison but based on the BIPM/RMO TW/GPS 2014-2015 calibrations. There the difference between TW and GPS are only of 3 over 8 bigger than 2 ns.

**Table 5.1b** Differences between TW (SATRE) and GPS links over the **UTC** baselines (based on the **2015** TW and GPS calibrations)

| Lab2-Lab1 | N | Min | Max | Mean | RMS | σ |
|---|---|---|---|---|---|---|
| CH-PTB | 354 | -0.594 | 1.882 | 1.153 | 1.197 | 0.321 |
| IT-PTB | 370 | -6.452 | -2.201 | -4.091 | 4.150 | 0.698 |
| NIST-PTB | 380 | -8.996 | -5.930 | -7.748 | 7.773 | 0.617 |
| OP-PTB | 384 | -1.900 | 0.652 | -0.825 | 0.917 | 0.401 |
| ROA-PTB | 381 | 0.089 | 3.408 | 1.732 | 1.808 | 0.517 |
| SP-PTB | 382 | 0.295 | 2.524 | 1.459 | 1.505 | 0.369 |
| USNO-PTB | 382 | 1.802 | 4.447 | 2.628 | 2.642 | 0.275 |
| VSL-PTB | 384 | -2.585 | 1.832 | -0.094 | 0.756 | 0.750 |

Table 5.2 gives the results of the comparisons between the TWSTFT and GPSPPP links over the 54 UTC and non-UTC baselines. Similar conclusion can be obtained, the measurement noise is reasonable but the calibration between TW and GPS do not agree with each other. The values bigger than 2.0 ns, the combined uncertainty, are highlighted with red colour.

It seems the goal of the BIPM/RMO calibrations do not achieve?

**Table 5.2** Differences between TW (SATRE) and GPS links over the **non-UTC** baselines (based on the **2016** TW and GPS calibrations)

| Lab2-Lab1 | N | Min | Max | Mean | RMS | σ |
|---|---|---|---|---|---|---|
| AOSPTB.TGT34 | 384 | -2.658 | 1.247 | -0.243 | 0.974 | 0.943 |
| CHPTB.TGT34 | 383 | 1.224 | 4.860 | 3.087 | 3.207 | 0.867 |
| ITPTB.TGT34 | 382 | -4.192 | -0.722 | -2.709 | 2.786 | 0.653 |
| NISTPTB.TGT34 | 383 | -7.005 | -5.447 | -6.210 | 6.218 | 0.311 |
| OPPTB.TGT34 | 382 | -5.822 | -3.522 | -4.715 | 4.742 | 0.505 |
| ROAPTB.TGT34 | 384 | -1.425 | 2.050 | 0.133 | 0.657 | 0.644 |
| SPPTB.TGT34 | 384 | -0.138 | 3.575 | 1.221 | 1.500 | 0.872 |
| VSLPTB.TGT34 | 377 | -2.823 | 0.371 | -1.676 | 1.770 | 0.571 |
| USNOPTB.TGT34 | 338 | 0.808 | 2.248 | 1.549 | 1.567 | 0.238 |
| NPLPTB.TGT34 | 368 | 1.525 | 4.016 | 2.812 | 2.850 | 0.464 |
| NTSCPTB.TGT34 | 933 | -2.282 | 2.694 | -0.063 | 0.679 | 0.676 |
| NIMPTB.TGT34 | 1255 | 1.778 | 5.406 | 3.326 | 3.353 | 0.428 |
| CHAOS.TGT34 | 379 | 1.998 | 4.924 | 3.412 | 3.450 | 0.513 |
| ITAOS.TGT34 | 380 | -4.315 | -0.095 | -2.433 | 2.631 | 1.002 |
| NISTAOS.TGT34 | 382 | -7.166 | -5.423 | -6.410 | 6.418 | 0.313 |
| OPAOS.TGT34 | 292 | -5.878 | -3.850 | -4.712 | 4.728 | 0.385 |
| ROAAOS.TGT34 | 382 | -0.984 | 2.503 | 0.461 | 0.858 | 0.724 |
| SPAOS.TGT34 | 381 | 0.163 | 2.655 | 1.340 | 1.434 | 0.510 |
| VSLAOS.TGT34 | 375 | -3.463 | 0.800 | -1.661 | 1.959 | 1.038 |
| USNOAOS.TGT34 | 342 | 0.724 | 2.216 | 1.367 | 1.397 | 0.290 |

| | | | | | | |
|---|---|---|---|---|---|---|
| NPLAOS.TGT34 | 365 | 1.454 | 5.543 | 3.028 | 3.147 | 0.859 |
| ITCH.TGT34 | 381 | -7.561 | -4.126 | -5.945 | 5.981 | 0.656 |
| NISTCH.TGT34 | 381 | -10.313 | -8.985 | -9.714 | 9.718 | 0.285 |
| OPCH.TGT34 | 379 | -9.438 | -6.797 | -8.023 | 8.040 | 0.524 |
| ROACH.TGT34 | 382 | -4.480 | -0.762 | -2.828 | 2.946 | 0.825 |
| SPCH.TGT34 | 376 | -3.532 | -0.492 | -2.087 | 2.194 | 0.676 |
| VSLCH.TGT34 | 378 | -6.450 | -2.705 | -5.017 | 5.079 | 0.795 |
| USNOCH.TGT34 | 338 | -3.099 | -0.706 | -1.973 | 2.006 | 0.363 |
| NPLCH.TGT34 | 362 | -1.575 | 0.531 | -0.467 | 0.683 | 0.499 |
| NISTIT.TGT34 | 381 | -5.585 | -2.166 | -3.576 | 3.614 | 0.526 |
| OPIT.TGT34 | 376 | -4.312 | -0.320 | -2.139 | 2.272 | 0.767 |
| ROAIT.TGT34 | 365 | 0.811 | 5.506 | 2.859 | 2.995 | 0.892 |
| SPIT.TGT34 | 379 | 0.914 | 6.659 | 3.715 | 3.887 | 1.145 |
| VSLIT.TGT34 | 371 | -2.461 | 2.453 | 0.802 | 1.126 | 0.790 |
| USNOIT.TGT34 | 337 | 2.221 | 5.645 | 4.080 | 4.126 | 0.620 |
| NPLIT.TGT34 | 362 | 2.279 | 7.056 | 5.450 | 5.510 | 0.806 |
| OPNIST.TGT34 | 381 | 0.892 | 2.408 | 1.651 | 1.678 | 0.299 |
| ROANIST.TGT34 | 383 | 5.662 | 9.075 | 6.552 | 6.574 | 0.541 |
| SPNIST.TGT34 | 382 | 6.946 | 8.505 | 7.636 | 7.641 | 0.279 |
| VSLNIST.TGT34 | 382 | 3.150 | 5.317 | 4.365 | 4.383 | 0.399 |
| OPNPL.TGT34 | 349 | -8.910 | -5.704 | -7.479 | 7.499 | 0.545 |
| ROANPL.TGT34 | 368 | -4.277 | -1.100 | -2.628 | 2.689 | 0.569 |
| SPNPL.TGT34 | 365 | -2.583 | -0.066 | -1.575 | 1.644 | 0.471 |
| VSLNPL.TGT34 | 338 | -6.975 | -2.102 | -4.508 | 4.582 | 0.817 |
| ROAOP.TGT34 | 381 | 3.352 | 6.531 | 5.065 | 5.108 | 0.661 |
| SPOP.TGT34 | 378 | 4.699 | 7.723 | 5.851 | 5.885 | 0.628 |
| VSLOP.TGT34 | 375 | 1.560 | 4.416 | 2.907 | 2.971 | 0.614 |
| USNOOP.TGT34 | 338 | 4.552 | 7.067 | 6.031 | 6.055 | 0.535 |
| SPROA.TGT34 | 383 | -0.948 | 2.458 | 0.948 | 1.198 | 0.732 |
| VSLROA.TGT34 | 369 | -3.828 | 0.236 | -1.972 | 2.181 | 0.933 |
| USNOROA.TGT34 | 337 | 0.413 | 2.069 | 1.241 | 1.279 | 0.311 |
| VSLSP.TGT34 | 374 | -5.127 | -1.059 | -2.871 | 3.052 | 1.036 |
| USNOSP.TGT34 | 346 | -1.409 | 0.992 | 0.192 | 0.413 | 0.366 |
| VSLUSNO.TGT34 | 336 | -5.241 | -1.388 | -3.432 | 3.471 | 0.517 |

## 5. Summary

We first made the TCC calibration for the standard SATRE links and then the alignment calibrations for the SDR links. As done many times in the past and as a standard procedure, the TCC is performed normally. But the SDR data suffer the problem of the data quality. This would be the major obstruct for its application in the UTC computation.

This analysis is towards the UTC computation therefore we used the BIPM standard Circular T procedure, the Software Tsoft and the ITU data files. Although 12 labs have installed and are operating the SDR, it seems not all the SDR facilities work normally and continually in the UTC month 1703. We successfully collected only the 6 labs (PTB, CH, NIST, IT, AOS and OP) between MJD 57828-57842, which have the SDR UTC links and some of the non-UTC links, as shown in the Figure 2.2. None of the Asian labs have the completed data during this period. Cf. the Figure 2.1.

Based on this situation, we propose the following steps in the frame of the Pilot Project on SDR:

1. We discuss and resolve the practical problems during the annual TW meeting in May at NTSC, ;
2. We try to have completed SDR data for June, not only the UTC links with PTB but also all the non-UTC links between a lab to all others;
3. The BIPM will re-do a SDR calibrations and the SDR labs should implement them in their ITU data;
4. BIPM starts to compute the SDR links as the backup in its monthly standard Circular T computation in July 2017. This including to make the comparisons between the SDR against the SATRE and PPP links, as well as publish the link and link comparison results on the BIPM site as usual;
5. The above experience should be continued for at least 3 months, saying between Aug. to Oct. 2017;
6. Analysis and report;
7. If everything is Ok, use the SDR in UTC computation starting from Jan. 2018

**Remark**:

- Due to the change of the TW network pivot station PTB01 was changed to PTB05 in May 2017, this version TM268V2 is an updated version using the 1707/PTB05 data
- SDR calibration is not suggested to be applied this time

## References


[1] BIPM Circular T 351, April 2017, ftp://ftp2.bipm.org/pub/tai//Circular-T/cirthtm/cirt.351.html

[2] Jiang Z, Lewandowski W, Piester D (2008) *Calibration of TWSTFT Links Through the Triangle Closure Condition,* Proc. PTTI 2008

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*--- The Annexes I is for the BIPM staff for the computation using Tsoft.*

# Annex I. TCC by using the Tsoft standard procedure

This section is only for the BIPM time section staff:
1510
We use the Tsoft/F2/F3162 to calculate TCC the calibration following the steps below:
1. run1: Y4 - UTC links with PTB with the options ON: CALR EDSVAR
2. run2: Y4 - Non UTC links (No PTB) with the options OFF: -CALR -EDSVAR
3. run3: F2 - CALR by triangle method, better with the option ON: LKTY4i (Lab1==PTB)
4. run4:Y20 - Set CALR calculated/ESDVAR==0 into TwYYMM.lk (using this file)
5. run5: Y4 - UTC+Non UTC links with the option ON: CALR EDSVAR
6. run6: F2 - Verify if all the triangle closures -- >0

The calibration results are in Table 4 TW Calibrations of CALR and ESDVAR. Certainly, if any of the non-UTC links are hardware calibrated, the values here can be used as a check (cf. section 6).
(Job for F2: 1510 LKTY4i -LKGY3i -ALIGN -ALIGN.G2T -ALIGN.T2G -Out888 OutStep=1 HistScale=1000 HistIntv=50 MjdCol01_09 LinkCol18_30)

If a laboratory wants to keep its ESDVAR value, this value should be subtracted from the originally determined CALR values (X:\TaN\1510\Adj\CALR1510.Tf2) which is computed by F2 supposing ESDVAR==0. The new CALR value with ESDVAR-removed can be computed by:
CALR1(new)= -CALR2(new)={CALR1(old) + ( [ESDVAR2-ESDVAR1]/2 ) }

**Use Y20 option:** RmESDVAR ON to make an iteration to remove ESDVAR from the original file X:\TaN\1510\Adj\CALR1510.Tf2 and then re-establish the big TW file for TAI computation:
1. run1: Type in Link_LAB1_Non-Zero_ESDVAR value in X:\TaN\1510\Adj\CALR1510.Tf2 (note here for a link in CALR1510.Tf2 type in the Lab1 value. For example: USNO01 CH01: S=1 CALR= 425.057 +/-0.426, ESDVAR= -387.250 375 0.022 14
2. run2: Y20 with Calib & RmESDVAR ON. This will read the above copied file in which the ESdVar(sb) should be removed from the listed CALR values: Output new files is X:\TaN\1510\Adj\CALR1510.Tf2.Y20
3. run3: Copy the NewCALR file: X:\TaN\1510\Adj\CALR1510.Tf2.Y20 (present only the non-zero-ESDVAR labs) into the old: X:\TaN\1510\Adj\CALR1510.Tf2
4. run4: Re-do Y20 with Calib ON and RmESDVAR OFF

1108 LKTY4i -LKGY3i -ExtCmb= .Dat -ALIGN -ALIGN.G2T -ALIGN.T2G -Out888 OutStep=1 HistScale=1000 HistIntv=250 MjdCol01_09 LinkCol18_30 !(21+13+32) Use Cor. Lab2Lab1.lkG/T or *.Y3/Y4i to calib., Template list X:\TAN\Tri-Clos.Lst

**Remark:**
Geometrically, if there are N laboratories, we will have:
Number of UTC links = N-1
Number of total links = N(N-1)/2
Number of independent triangles = $N(N-1)/2-(N-1)=(N^2-3N+2)/2$

**Job Y20 (SATRE)**

```
Calib.  AOS01  PTB01: S=1 CALR=    30.1   ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01  AOS01: S=1 CALR=   -30.1   ESDVAR=     0.0     ! Calib setting
Calib.  NPL02  PTB01: S=1 CALR=   725.1   ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01  NPL02: S=1 CALR=  -725.1   ESDVAR=     0.0     ! Calib setting
Calib.   IT02  PTB01: S=1 CALR=  -274.9   ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01   IT02: S=1 CALR=   274.9   ESDVAR= 00000.000   ! Calib setting
Calib.   OP01  PTB01: S=1 CALR= -7113.8   ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01   OP01: S=1 CALR=  7113.8   ESDVAR= 00000.000   ! Calib setting
Calib.  ROA01  PTB01: S=1 CALR=    31.6   ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01  ROA01: S=1 CALR=   -31.6   ESDVAR= 00000.000   ! Calib setting
Calib.   SP01  PTB01: S=1 CALR=    -1.6   ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01   SP01: S=1 CALR=     1.6   ESDVAR= 00000.000   ! Calib setting
```

**Job Y0/Y4/YB**

Y 1706 57909 57934 5 -CALR -ESDVAR CalEsd9=0 MAXHOLE5 -ClearTw Max_Dev99 MaxTwLk8999 -LINK2UTC MJDINTERPL OUTLIER1.5 MARGIN5 PLOT RefDly VDK1.D5 EssIntpl_VDK3 -MES
T_ AOS CH IT NIST NPL OP ROA SP USNO VSL
T_ CH IT NIST NPL OP ROA SP USNO VSL
T_ IT NIST NPL OP ROA SP USNO VSL
T_ NIST NPL OP ROA SP VSL
T_ NPL OP ROA SP USNO VSL
T_ OP ROA SP USNO VSL
T_ ROA SP USNO VSL
T_ SP USNO VSL

T_ USNO VSL
T_ NIM NTSC
END

Y 1706 57909 57934 5 CALR ESDVAR CalEsd9=0 MAXHOLE5 -ClearTw Max_Dev99 MaxTwLk999 -LINK2UTC MJDINTERPL OUTLIER1.5 MARGIN5 PLOT RefDly VDK1.D5 EssIntpl_VDK3 -MES
T_ PTB AOS CH IT NIST NPL OP ROA SP USNO VSL

Y 1706 57909 57934 5 CALR ESDVAR CalEsd9=0 MAXHOLE5 -ClearTw Max_Dev99 MaxTwLk999 -LINK2UTC MJDINTERPL OUTLIER1.5 MARGIN5 PLOT RefDly VDK1.D5 EssIntpl_VDK3 -MES
T_ PTB NIM NTSC
END

**Job F2**

```
T PTB AOS CH        9
T PTB AOS IT
T PTB AOS NIST
T PTB AOS NPL
T PTB AOS OP
T PTB AOS ROA
T PTB AOS SP
T PTB AOS USNO
T PTB AOS VSL
T PTB CH IT         8
T PTB CH NIST
T PTB CH NPL
T PTB CH OP
T PTB CH ROA
T PTB CH SP
T PTB CH USNO
T PTB CH VSL
T PTB IT NIST       7
T PTB IT NPL
T PTB IT OP
T PTB IT ROA
T PTB IT SP
T PTB IT USNO
T PTB IT VSL
T PTB NIST NPL       5  WITHOUY T PTB NIST USNO
T PTB NIST OP
T PTB NIST ROA
T PTB NIST SP
T PTB NIST VSL
T PTB NPL OP         5
T PTB NPL ROA
T PTB NPL SP
T PTB NPL USNO
T PTB NPL VSL
T PTB OP ROA         4
T PTB OP SP
T PTB OP USNO
T PTB OP VSL
T PTB ROA SP         3
T PTB ROA USNO
T PTB ROA VSL
T PTB SP USNO        2
T PTB SP VSL
T PTB USNO VSL       1
T PTB NIM NTSC       1
END -- Tri-Clos.Lst TM268 1703
```

**Job W9/Z4 (SATRE-GPSPPP)**

```
! PTB
T AOSPTB.TTTT_   T  -JUMP -Fr1  To99  !
G AOSPTB.333A_   3  -JUMP -Fr1  To99  OutF=GPS\AOPT

T CHPTB.TTTT_    T  -JUMP -Fr1  To99  !
G CHPTB.333A_    3  -JUMP -Fr1  To99  OutF=GPS\CHPT

T ITPTB.TTTT_    T  -JUMP -Fr1  To99  !
G ITPTB.333A_    3  -JUMP -Fr1  To99  OutF=GPS\ITPT

T NISTPTB.TTTT_  T  -JUMP -Fr1  To99  !
G NISTPTB.333A_  3  -JUMP -Fr1  To99  OutF=GPS\NIPT

T OPPTB.TTTT_    T  -JUMP -Fr1  To99  !
```

```
G OPPTB.333A_    3  -JUMP -Fr1  To99  OutF=GPS\OPPT

T ROAPTB.TTTT_   T  -JUMP -Fr1  To99  !
G ROAPTB.333A_   3  -JUMP -Fr1  To99  OutF=GPS\ROPT

T SPPTB.TTTT_    T  -JUMP -Fr1  To99  !
G SPPTB.333A_    3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLPTB.TTTT_   T  -JUMP -Fr1  To99  !
G VSLPTB.333A_   3  -JUMP -Fr1  To99  OutF=GPS\VSPT

T USNOPTB.TTTT_  T  -JUMP -Fr1  To99  !
G USNOPTB.333A_  3  -JUMP -Fr1  To99  OutF=GPS\USPT

T NPLPTB.TTTT_   T  -JUMP -Fr1  To99  !
G NPLPTB.333A_   3  -JUMP -Fr1  To99  OutF=GPS\NPPT

T NTSCPTB.TTTT_  T  -JUMP -Fr1  To99  !
G NTSCPTB.333A_  3  -JUMP -Fr1  To99  OutF=GPS\NTPT

T NIMPTB.TTTT_   T  -JUMP -Fr1  To99  !
G NIMPTB.333A_   3  -JUMP -Fr1  To99  OutF=GPS\IMPT

! AOS
T CHAOS.TTTT_    T  -JUMP -Fr1  To99  !
G CHAOS.333A_    3  -JUMP -Fr1  To99  OutF=GPS\CHPT

T ITAOS.TTTT_    T  -JUMP -Fr1  To99  !
G ITAOS.333A_    3  -JUMP -Fr1  To99  OutF=GPS\ITPT

T NISTAOS.TTTT_  T  -JUMP -Fr1  To99  !
G NISTAOS.333A_  3  -JUMP -Fr1  To99  OutF=GPS\NIPT

T OPAOS.TTTT_    T  -JUMP -Fr1  To99  !
G OPAOS.333A_    3  -JUMP -Fr1  To99  OutF=GPS\OPPT

T ROAAOS.TTTT_   T  -JUMP -Fr1  To99  !
G ROAAOS.333A_   3  -JUMP -Fr1  To99  OutF=GPS\ROPT

T SPAOS.TTTT_    T  -JUMP -Fr1  To99  !
G SPAOS.333A_    3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLAOS.TTTT_   T  -JUMP -Fr1  To99  !
G VSLAOS.333A_   3  -JUMP -Fr1  To99  OutF=GPS\VSPT

T USNOAOS.TTTT_  T  -JUMP -Fr1  To99  !
G USNOAOS.333A_  3  -JUMP -Fr1  To99  OutF=GPS\USPT

T NPLAOS.TTTT_   T  -JUMP -Fr1  To99  !
G NPLAOS.333A_   3  -JUMP -Fr1  To99  OutF=GPS\NPPT

! CH
T ITCH.TTTT_     T  -JUMP -Fr1  To99  !
G ITCH.333A_     3  -JUMP -Fr1  To99  OutF=GPS\ITPT

T NISTCH.TTTT_   T  -JUMP -Fr1  To99  !
G NISTCH.333A_   3  -JUMP -Fr1  To99  OutF=GPS\NIPT

T OPCH.TTTT_     T  -JUMP -Fr1  To99  !
G OPCH.333A_     3  -JUMP -Fr1  To99  OutF=GPS\OPPT

T ROACH.TTTT_    T  -JUMP -Fr1  To99  !
G ROACH.333A_    3  -JUMP -Fr1  To99  OutF=GPS\ROPT

T SPCH.TTTT_     T  -JUMP -Fr1  To99  !
G SPCH.333A_     3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLCH.TTTT_    T  -JUMP -Fr1  To99  !
G VSLCH.333A_    3  -JUMP -Fr1  To99  OutF=GPS\VSPT

T USNOCH.TTTT_   T  -JUMP -Fr1  To99  !
G USNOCH.333A_   3  -JUMP -Fr1  To99  OutF=GPS\USPT

T NPLCH.TTTT_    T  -JUMP -Fr1  To99  !
G NPLCH.333A_    3  -JUMP -Fr1  To99  OutF=GPS\NPPT
```

```
! IT
T NISTIT.TTTT_   T  -JUMP -Fr1  To99  !
G NISTIT.333A_   3  -JUMP -Fr1  To99  OutF=GPS\NIPT

T OPIT.TTTT_     T  -JUMP -Fr1  To99  !
G OPIT.333A_     3  -JUMP -Fr1  To99  OutF=GPS\OPPT

T ROAIT.TTTT_    T  -JUMP -Fr1  To99  !
G ROAIT.333A_    3  -JUMP -Fr1  To99  OutF=GPS\ROPT

T SPIT.TTTT_     T  -JUMP -Fr1  To99  !
G SPIT.333A_     3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLIT.TTTT_    T  -JUMP -Fr1  To99  !
G VSLIT.333A_    3  -JUMP -Fr1  To99  OutF=GPS\VSPT

T USNOIT.TTTT_   T  -JUMP -Fr1  To99  !
G USNOIT.333A_   3  -JUMP -Fr1  To99  OutF=GPS\USPT

T NPLIT.TTTT_    T  -JUMP -Fr1  To99  !
G NPLIT.333A_    3  -JUMP -Fr1  To99  OutF=GPS\NPPT

! NIST
T OPNIST.TTTT_   T  -JUMP -Fr1  To99  !
G OPNIST.333A_   3  -JUMP -Fr1  To99  OutF=GPS\OPPT

T ROANIST.TTTT_  T  -JUMP -Fr1  To99  !
G ROANIST.333A_  3  -JUMP -Fr1  To99  OutF=GPS\ROPT

T SPNIST.TTTT_   T  -JUMP -Fr1  To99  !
G SPNIST.333A_   3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLNIST.TTTT_  T  -JUMP -Fr1  To99  !
G VSLNIST.333A_  3  -JUMP -Fr1  To99  OutF=GPS\VSPT


! NPL
T OPNPL.TTTT_    T  -JUMP -Fr1  To99  !
G OPNPL.333A_    3  -JUMP -Fr1  To99  OutF=GPS\OPPT

T ROANPL.TTTT_   T  -JUMP -Fr1  To99  !
G ROANPL.333A_   3  -JUMP -Fr1  To99  OutF=GPS\ROPT

T SPNPL.TTTT_    T  -JUMP -Fr1  To99  !
G SPNPL.333A_    3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLNPL.TTTT_   T  -JUMP -Fr1  To99  !
G VSLNPL.333A_   3  -JUMP -Fr1  To99  OutF=GPS\VSPT

! OP
T ROAOP.TTTT_    T  -JUMP -Fr1  To99  !
G ROAOP.333A_    3  -JUMP -Fr1  To99  OutF=GPS\ROPT

T SPOP.TTTT_     T  -JUMP -Fr1  To99  !
G SPOP.333A_     3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLOP.TTTT_    T  -JUMP -Fr1  To99  !
G VSLOP.333A_    3  -JUMP -Fr1  To99  OutF=GPS\VSPT

T USNOOP.TTTT_   T  -JUMP -Fr1  To99  !
G USNOOP.333A_   3  -JUMP -Fr1  To99  OutF=GPS\USPT

! ROA
T SPROA.TTTT_    T  -JUMP -Fr1  To99  !
G SPROA.333A_    3  -JUMP -Fr1  To99  OutF=GPS\SPPT

T VSLROA.TTTT_   T  -JUMP -Fr1  To99  !
G VSLROA.333A_   3  -JUMP -Fr1  To99  OutF=GPS\VSPT

T USNOROA.TTTT_  T  -JUMP -Fr1  To99  !
G USNOROA.333A_  3  -JUMP -Fr1  To99  OutF=GPS\USPT

! SP
T VSLSP.TTTT_    T  -JUMP -Fr1  To99  !
G VSLSP.333A_    3  -JUMP -Fr1  To99  OutF=GPS\VSPT

T USNOSP.TTTT_   T  -JUMP -Fr1  To99  !
```

```
G USNOSP.333A_   3  -JUMP -Fr1  To99  OutF=GPS\USPT

! USNO
T VSLUSNO.TTTT_  T  -JUMP -Fr1  To99  !
G VSLUSNO.333A_  3  -JUMP -Fr1  To99  OutF=GPS\UVSLT

END --- TM268 BIPM 2017 TCC SATRE+SDR CALIBRATIONS
```

**Job Y20 (SDR)**

```
Calib. ______ ______: S=1 CALR= 00000.000 ESDVAR= 00000.000   ! Calib setting
Calib.  AOS01  PTB01: S=1 CALR=    80.496 ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01  AOS01: S=1 CALR=   -80.496 ESDVAR=     0.0     ! Calib setting
Calib.   CH01  PTB01: S=1 CALR=   146.105 ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01   CH01: S=1 CALR=  -146.105 ESDVAR= 00000.000   ! Calib setting
Calib.   IT02  PTB01: S=1 CALR=   185.124 ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01   IT02: S=1 CALR=  -185.124 ESDVAR= 00000.000   ! Calib setting
Calib. NIST01  PTB01: S=1 CALR=   473.668 ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01 NIST01: S=1 CALR=  -473.668 ESDVAR=     0.0     ! Calib setting
Calib.   OP01  PTB01: S=1 CALR= -2177.127 ESDVAR= 00000.000   ! Calib setting
Calib.  PTB01   OP01: S=1 CALR=  2177.127 ESDVAR= 00000.000   ! Calib setting
Calib. NIST01  AOS01: S=1 CALR=   394.218 ESDVAR= 00000.000   ! Calib setting
Calib.  AOS01 NIST01: S=1 CALR=  -394.218 ESDVAR=     0.0     ! Calib setting
Calib. NIST01   CH01: S=1 CALR=   326.530 ESDVAR= 00000.000   ! Calib setting
Calib.   CH01 NIST01: S=1 CALR=  -326.530 ESDVAR=     0.0     ! Calib setting
Calib. NIST01   IT01: S=1 CALR=   287.816 ESDVAR= 00000.000   ! Calib setting
Calib.   IT01 NIST01: S=1 CALR=  -287.816 ESDVAR=     0.0     ! Calib setting
Calib. NIST01   OP01: S=1 CALR=  2649.920 ESDVAR= 00000.000   ! Calib setting
Calib.   OP01 NIST01: S=1 CALR= -2649.920 ESDVAR=     0.0     ! Calib setting
Calib.   OP01   CH01: S=1 CALR= -2323.461 ESDVAR= 00000.000   ! Calib setting
Calib.   CH01   OP01: S=1 CALR=  2323.461 ESDVAR= 00000.000   ! Calib setting
Calib.   OP01   IT01: S=1 CALR= -2362.616 ESDVAR= 00000.000   ! Calib setting
Calib.   IT01   OP01: S=1 CALR=  2362.616 ESDVAR= 00000.000   ! Calib setting
END -- SDR aligned to SATRE 1703 57828-840
```

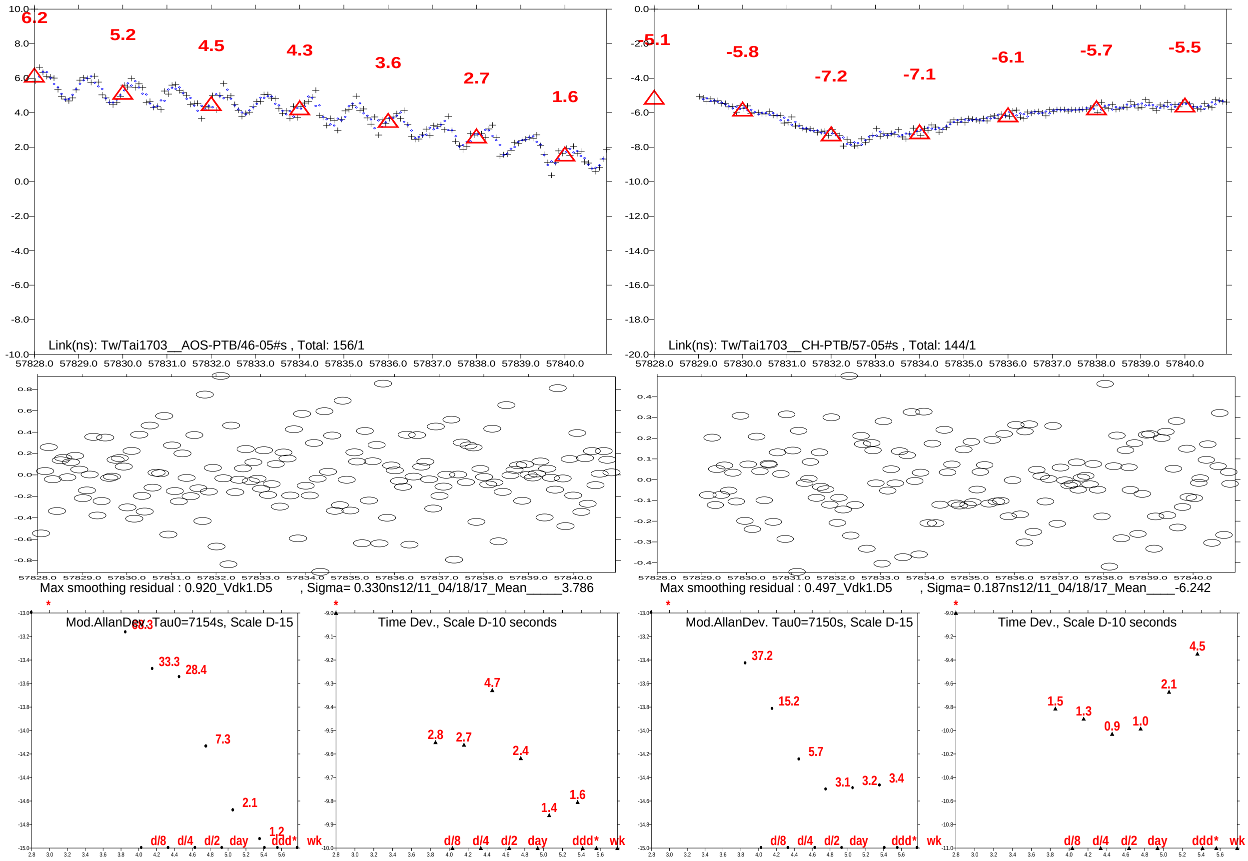
**Job W9/Z4 (SATRE-SDR)**

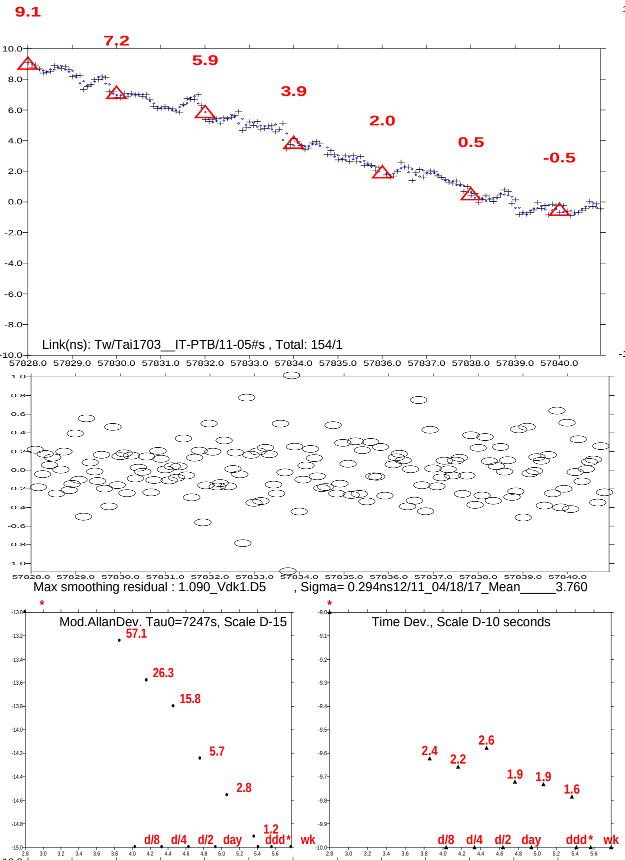
```
! TM268 SATRE6SDR BIPM 2017 TCC SATRE+SDR CALIBRATIONS

! PTB
T AOSPTB.TTTT_   T  -JUMP -Fr1  To99  !
T AOSPTB.TTTTs   T  -JUMP -Fr1  To99  !

T CHPTB.TTTT_    T  -JUMP -Fr1  To99  !
T CHPTB.TTTTs    T  -JUMP -Fr1  To99  !

T ITPTB.TTTT_    T  -JUMP -Fr1  To99  !
T ITPTB.TTTTs    T  -JUMP -Fr1  To99  !

T NISTPTB.TTTT_  T  -JUMP -Fr1  To99  !
T NISTPTB.TTTTs  T  -JUMP -Fr1  To99  !

T OPPTB.TTTT_    T  -JUMP -Fr1  To99  !
T OPPTB.TTTTs    T  -JUMP -Fr1  To99  !

! NIST
T NISTAOS.TTTT_  T  -JUMP -Fr1  To99  !
T NISTAOS.TTTTs  T  -JUMP -Fr1  To99  !

T NISTCH.TTTT_   T  -JUMP -Fr1  To99  !
T NISTCH.TTTTs   T  -JUMP -Fr1  To99  !

T NISTIT.TTTT_   T  -JUMP -Fr1  To99  !
T NISTIT.TTTTs   T  -JUMP -Fr1  To99  !

T OPNIST.TTTT_   T  -JUMP -Fr1  To99  !
T OPNIST.TTTTs   T  -JUMP -Fr1  To99  !

! OP
T OPCH.TTTT_     T  -JUMP -Fr1  To99  !
T OPCH.TTTTs     T  -JUMP -Fr1  To99  !

T OPIT.TTTT_     T  -JUMP -Fr1  To99  !
T OPIT.TTTTs     T  -JUMP -Fr1  To99  !

END --- TM268 SATRE-SDR
```

```
T NTSCPTB.TTTT_   T  -JUMP -Fr1  To99  !
T NTSCPTB.TTTTs   T  -JUMP -Fr1  To99  !

T NIMPTB.TTTT_    T  -JUMP -Fr1  To99  !
T NIMPTB.TTTTs    T  -JUMP -Fr1  To99  !

END
```

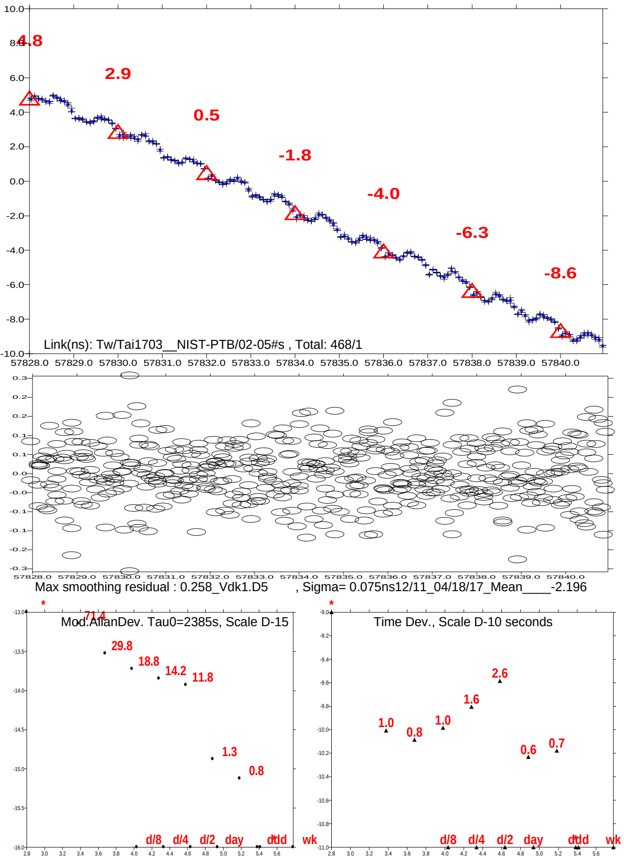
# Annex II. SDR links and link comparisons

## AII.1 SDR links

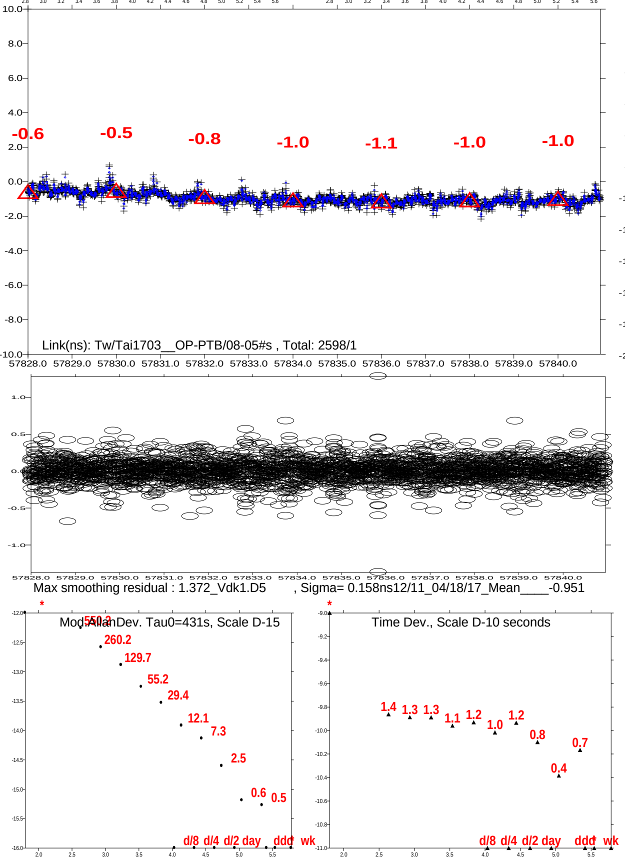




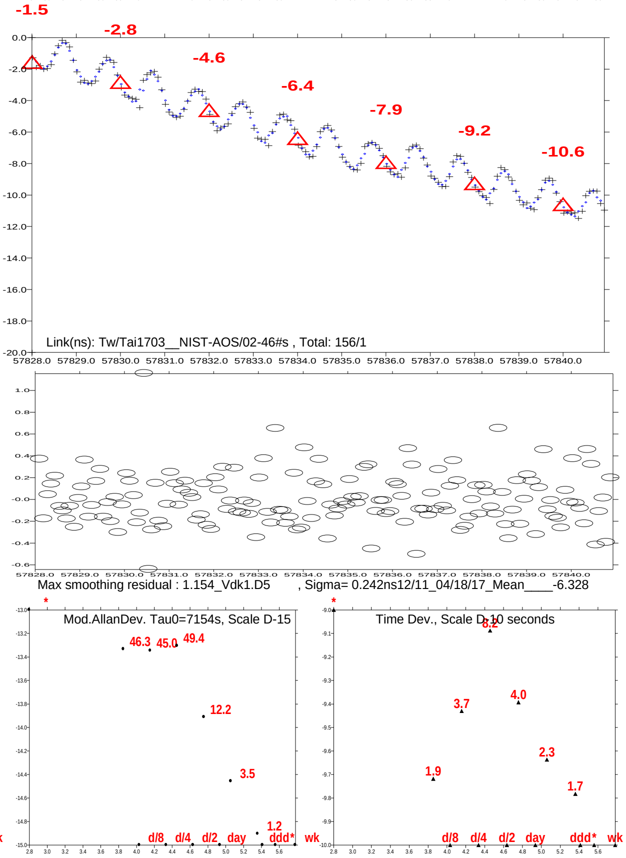
Link(ns): Tw/Tai1703__IT-PTB/11-05#s , Total: 154/1
9.1
7.2
5.9
3.9
2.0
0.5
-0.5
Max smoothing residual : 1.090_Vdk1.D5
, Sigma= 0.294ns12/11_04/18/17_Mean_____3.760
Mod.AllanDev. Tau0=7247s, Scale D-15
57.1
26.3
15.8
5.7
2.8
1.2
Time Dev., Scale D-10 seconds
2.4
2.2
2.6
1.9
1.9
1.6
d/8
d/4
d/2
day
ddd*
wk



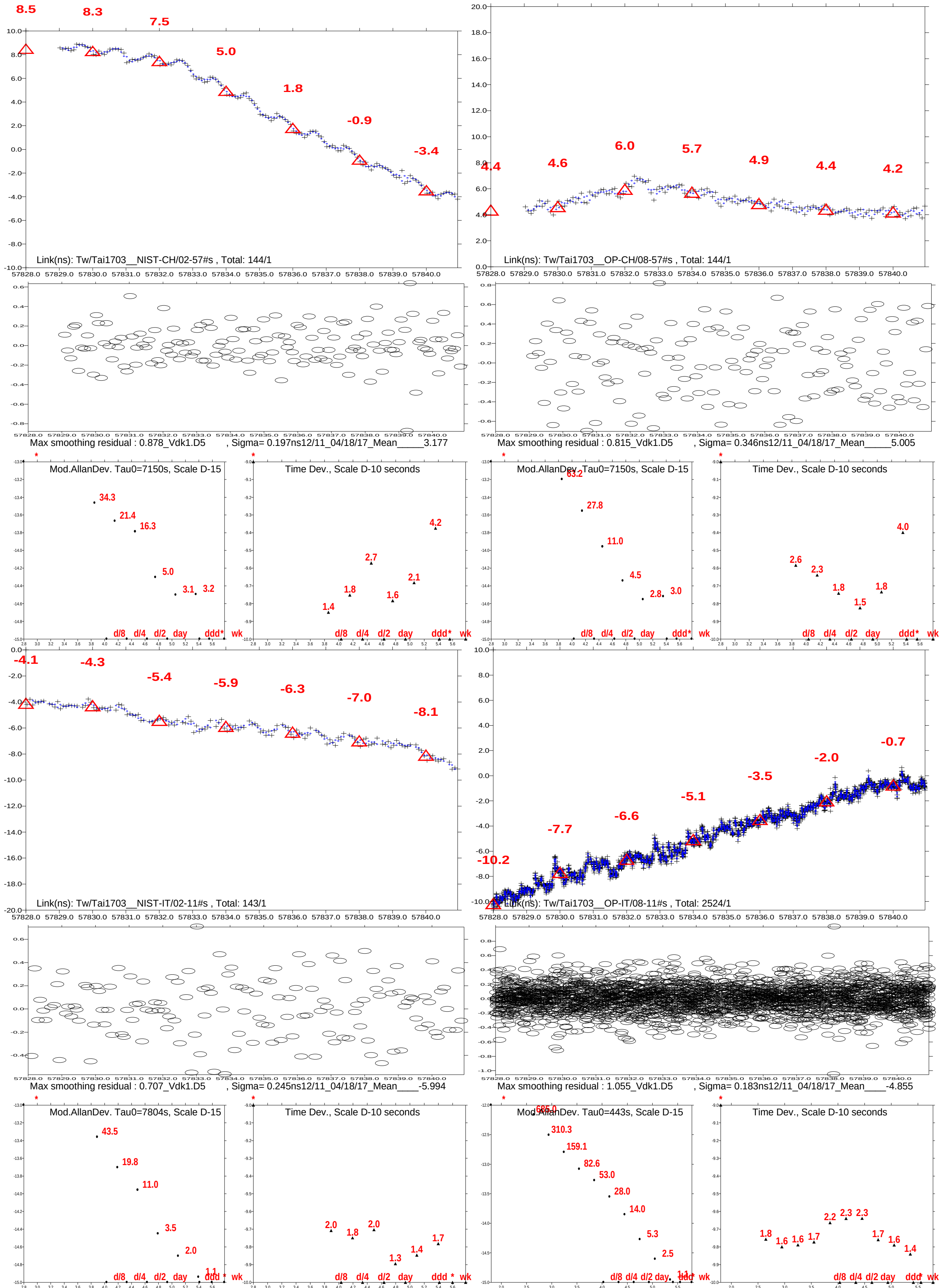
Link(ns): Tw/Tai1703__NIST-PTB/02-05#s , Total: 468/1
4.8
2.9
0.5
-1.8
-4.0
-6.3
-8.6
Max smoothing residual : 0.258_Vdk1.D5
, Sigma= 0.075ns12/11_04/18/17_Mean____-2.196
Mod.AllanDev. Tau0=2385s, Scale D-15
71.4
29.8
18.8
14.2
11.8
1.3
0.8
Time Dev., Scale D-10 seconds
1.0
0.8
1.0
1.6
2.6
0.6
0.7
d/8
d/4
d/2
day
ddd
wk

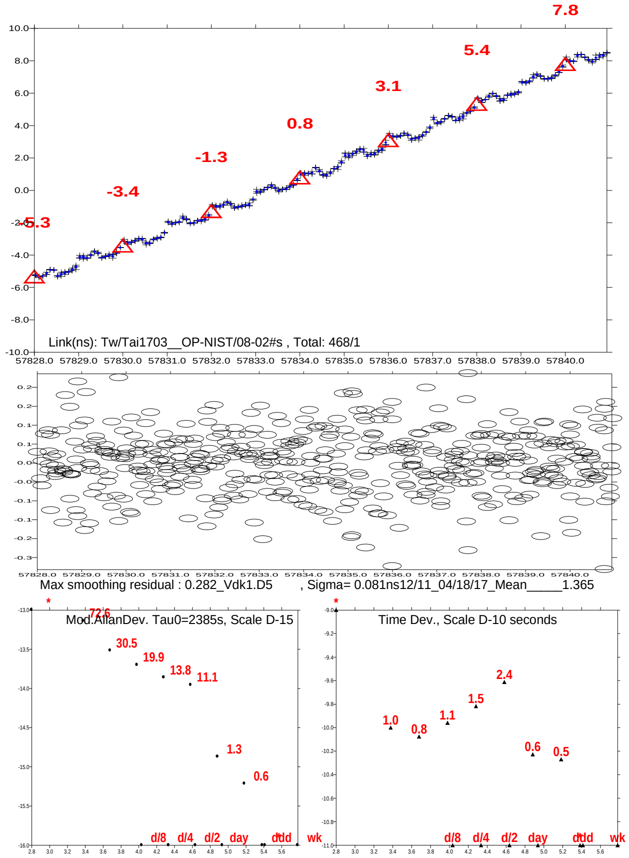


Link(ns): Tw/Tai1703__OP-PTB/08-05#s , Total: 2598/1
-0.6
-0.5
-0.8
-1.0
-1.1
-1.0
-1.0
Max smoothing residual : 1.372_Vdk1.D5
, Sigma= 0.158ns12/11_04/18/17_Mean____-0.951
Mod.AllanDev. Tau0=431s, Scale D-15
550.2
260.2
129.7
55.2
29.4
12.1
7.3
2.5
0.6
0.5
Time Dev., Scale D-10 seconds
1.4
1.3
1.3
1.1
1.2
1.0
1.2
0.8
0.7
0.4
d/8
d/4
d/2
day
ddd
wk

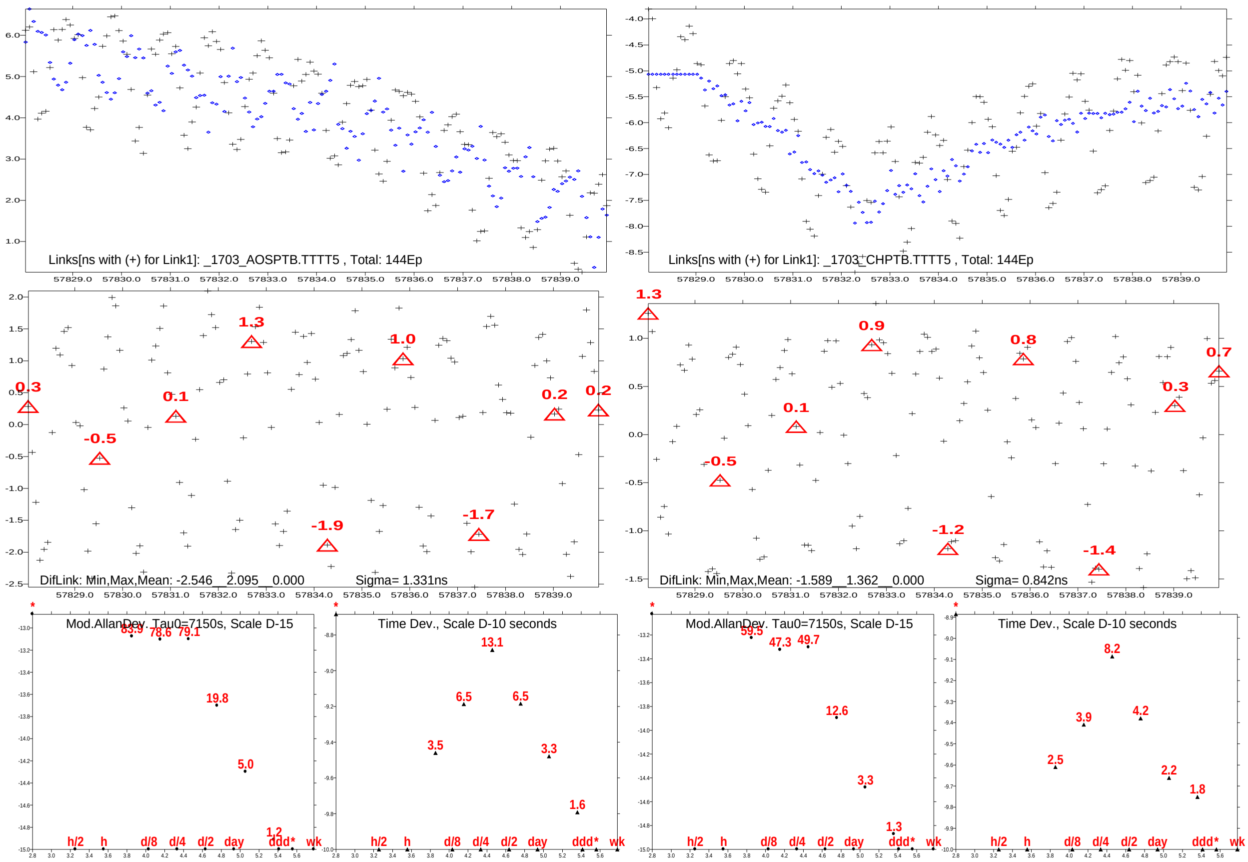


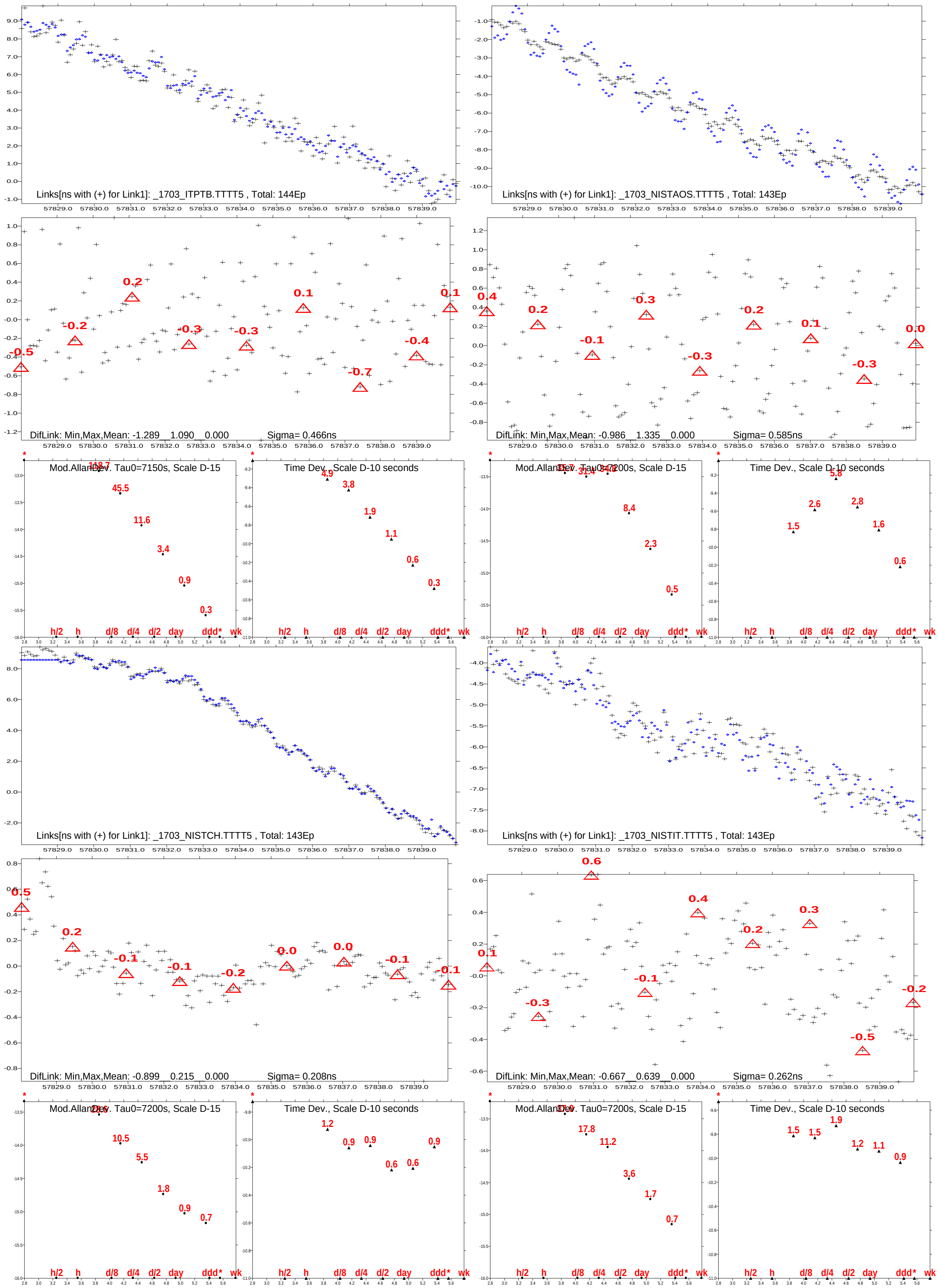
Link(ns): Tw/Tai1703__NIST-AOS/02-46#s , Total: 156/1
-1.5
-2.8
-4.6
-6.4
-7.9
-9.2
-10.6
Max smoothing residual : 1.154_Vdk1.D5
, Sigma= 0.242ns12/11_04/18/17_Mean____-6.328
Mod.AllanDev. Tau0=7154s, Scale D-15
46.3
45.0
49.4
12.2
3.5
1.2
Time Dev., Scale D-10 seconds
6.2
3.7
4.0
1.9
2.3
1.7
d/8
d/4
d/2
day
ddd*
wk

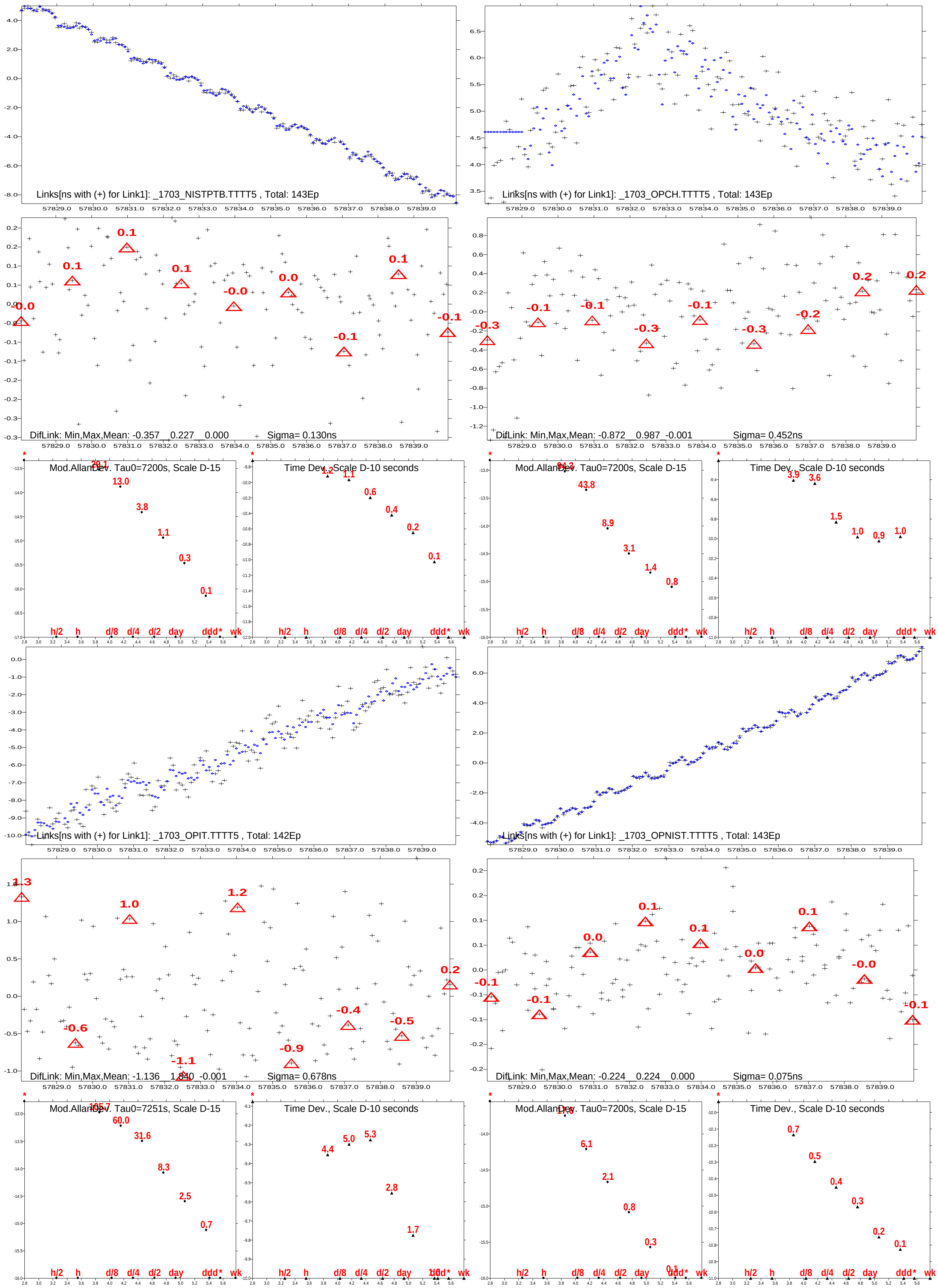

Link(ns): Tw/Tai1703__NIST-CH/02-57#s , Total: 144/1
Link(ns): Tw/Tai1703__OP-CH/08-57#s , Total: 144/1
Max smoothing residual : 0.878_Vdk1.D5 , Sigma= 0.197ns12/11_04/18/17_Mean_____3.177
Max smoothing residual : 0.815_Vdk1.D5 , Sigma= 0.346ns12/11_04/18/17_Mean_____5.005
Mod.AllanDev. Tau0=7150s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7150s, Scale D-15
Time Dev., Scale D-10 seconds
Link(ns): Tw/Tai1703__NIST-IT/02-11#s , Total: 143/1
Link(ns): Tw/Tai1703__OP-IT/08-11#s , Total: 2524/1
Max smoothing residual : 0.707_Vdk1.D5 , Sigma= 0.245ns12/11_04/18/17_Mean____-5.994
Max smoothing residual : 1.055_Vdk1.D5 , Sigma= 0.183ns12/11_04/18/17_Mean____-4.855
Mod.AllanDev. Tau0=7804s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=443s, Scale D-15
Time Dev., Scale D-10 seconds

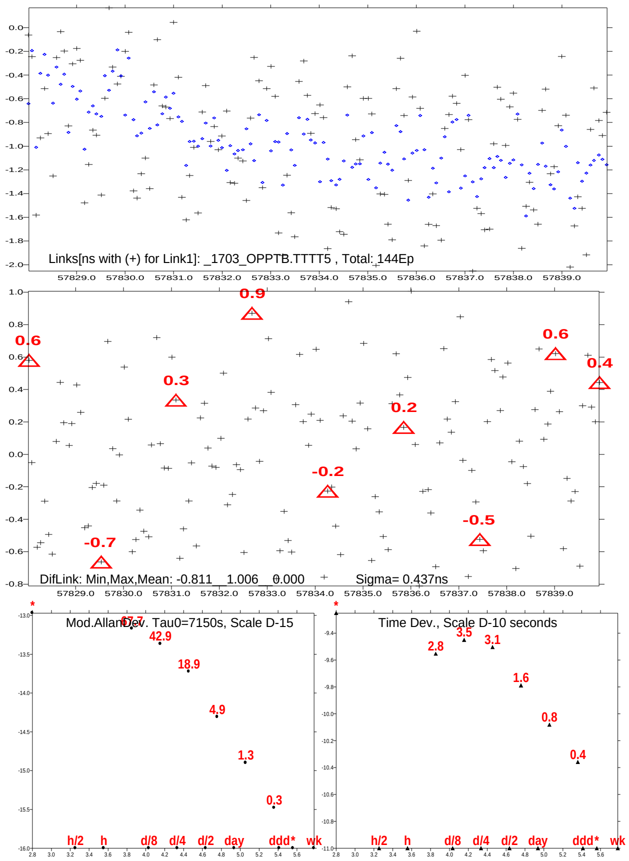



## AII.2 Comparison SATRE-SDR




Links[ns with (+) for Link1]: _1703_ITPTB.TTTT5 , Total: 144Ep
Links[ns with (+) for Link1]: _1703_NISTAOS.TTTT5 , Total: 143Ep
DifLink: Min,Max,Mean: -1.289 1.090 0.000
Sigma= 0.466ns
DifLink: Min,Max,Mean: -0.986 1.335 0.000
Sigma= 0.585ns
Mod.AllanDev. Tau0=7150s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds
Links[ns with (+) for Link1]: _1703_NISTCH.TTTT5 , Total: 143Ep
Links[ns with (+) for Link1]: _1703_NISTIT.TTTT5 , Total: 143Ep
DifLink: Min,Max,Mean: -0.899 0.215 0.000
Sigma= 0.208ns
DifLink: Min,Max,Mean: -0.667 0.639 0.000
Sigma= 0.262ns
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds


Links[ns with (+) for Link1]: _1703_NISTPTB.TTTT5 , Total: 143Ep
Links[ns with (+) for Link1]: _1703_OPCH.TTTT5 , Total: 143Ep
DifLink: Min,Max,Mean: -0.357 0.227 0.000
Sigma= 0.130ns
DifLink: Min,Max,Mean: -0.872 0.987 -0.001
Sigma= 0.452ns
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds
Links[ns with (+) for Link1]: _1703_OPIT.TTTT5 , Total: 142Ep
Links[ns with (+) for Link1]: _1703_OPNIST.TTTT5 , Total: 143Ep
DifLink: Min,Max,Mean: -1.136 1.840 -0.001
Sigma= 0.678ns
DifLink: Min,Max,Mean: -0.224 0.224 0.000
Sigma= 0.075ns
Mod.AllanDev. Tau0=7251s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds


Links[ns with (+) for Link1]: _1703_OPPTB.TTTT5 , Total: 144Ep
DifLink: Min,Max,Mean: -0.811 1.006 0.000
Sigma= 0.437ns
Mod.AllanDev. Tau0=7150s, Scale D-15
Time Dev., Scale D-10 seconds
h/2
h
d/8
d/4
d/2
day
ddd*
wk