METODE Experiments 2013-III

-- MEasurement of TOtal DElay for UTC Time Link Calibration

Phase III: Measurements at and between BIPM, OP and PTB

BIPM group: Zhiheng Jiang, Laurent Tisserand
PTB group: Andreas Bauch, Dirk Piester, Ekkehard Peik, Thomas Polewka

***Résumé**: One of the major goals of this experiment is to study the attainable uncertainty and the characters of the METODE calibration scheme for the UTC time links [2,11]. Measurements were made at and between BIPM and PTB during MJD 56450-56476, of which the calibrator was installed at PTB between 56465-56470. This TM is not a research paper but a technical document giving descriptions of the experiment setups and measurements. The results given here are preliminary not for publication. More details can be found in [5]. In Aug. 2014, the StdB re-visited PTB to have a closure measurement. The closure is less than 0.3 ns [37].*

Notation

METODE: MEasurement of TOtal DElay, a scheme with related methods and equipments proposed by BIPM for UTC time link calibration

u_A,u_B: type A and type B uncertainties

Link: a time link is a clock comparison result using a particular technique, e.g., a link of GPS C/A, P3, PPP or GLN or TWSTFT. A UTC link is a time link between a UTC Lab(*k*) and PTB

Baseline: a baseline between two clocks or laboratories may be measured by several links using different techniques. A baseline may be short in a same laboratory or long between two continents

CC: common clock(s); **SCC/DCC:** single/double CC; **CCD**: CC difference; **CCB/CCL**: CC baseline/link;

DCD : double clock difference

$Dly_{R/i}$: the total delay of a *receiver* system at Lab(*i*), *i* = BIPM, PTB, Lab(*k*), …

$Dly_{L/ij}$: the total delay of a time *link* system which is defined as the difference of Dly_{Ri} and Dly_{Rj}

Ref_i: the reference or mast receiver at Lab(*i*)

Std_B: the BIPM standard traveling calibration station (calibrator) consisting of N ≥2 GNSS receivers+antennas+pps/freq.distributors+cables. It is a black box calibrator with unknown but a constant delay during a calibration tour. The output is Z12T0

RCV0: mean value of two receiver measurements: Rcv0=½[Rcv1+Rcv2]. Z12T0 is that of the two Z12Ts receivers used as the BIPM stationary reference and GRT0 is that of the two GTR50 traveling receivers in the Std_B.

$UTCP_i$: the UTC point at Lab(*i*)

$CLBP_i$: the calibration point at Lab(*i*). The $Dly_{R/i}$ is the total delay between this point and the phase center of the antenna at laboratory *i*

Δ_i=$CLBP_i$–$UTCP_i$ is the delay between the UTCP and CLBP. Δ is considered as known in the following discussion.

I. Summary

1.1 General

The UTC generation requires the UTC '*link*' Lab(*k*)-PTB but the receivers to be calibrated. METODE is a scheme to calibrate the UTC time links. To do this, we do not need, as do the classic methods, to calibrate any GNSS receivers involved at Lab(*k*), PTB including BIPM traveling standard calibrator StdB. We do not need to know neither the internal delays due to the cables, antennas or any devices at anywhere [10,11,15]. We need only the calibration system to be stable during a calibration tour, saying 3 months.

For the 2013 Experiments, *k* = OP, AOS, PL, TL, NICT as well as PTB and BIPM [2-9]. During the experiments in Poland and in Taiwan, the METODE were compared respectively with the optical fibre baseline between UTC(AOS)-UTC(PL) and a Cs mobile atomic standard between UTC(TL) and TLPI. The difference of the optical fibre self-calibration and that of the METODE is 0.6 ns [9].

During 21-27 June 2013, MJD 56464-56470, the BIPM METODE calibrator was installed at PTB. We can then compute the calibration corrections for the UTC time links Lab(*k*)-PTB according to the scheme given in section 2.2 and the equation 2.2.1.

We use the PPP solutions for all the calibration computations.

The calibration results are of the StdB alignment corrections vs. the PTBB and the Lab(*k*)-PTB time link corrections. Before the visit to PTB, the calibrator had been to OP during 12-22 April, MJD 56394-56404 [2,14]. We there fore gave in this report the results of the UTC time link calibration corrections between OP-PTB. Other results after the PTB visit can be found in [6-9].

1.2 Main results

The visit to PTB allows the StdB to be aligned to the PTBB, the master receiver of PTB which is in fact the pivot of the GPS PPP network, a part of the UTC/TAI international time and frequency transfer network. The alignment results are given in Table 1.1a.

Together with the starting and closure measurements at the BIPM, we can compute the calibration corrections for the UTC time link OP-PTB with the METODE scheme [11] and the measurements at OP [3]. We use the PPP final solutions for all the calibration computations. The setup requirement for PTB is given in [13].

The METODE calibration result is the time link calibration correction, which should be used for all the GNSS (PPP, C/AL1C, P3) links and the TWSTFT links on the baseline LAB(*k*)-PTB, *k*=OP. The results are given in Tables 1.1b and 1.1c.

Table 1.1a The alignment correction for the BIPM StdB GNSS receivers vs. the PTB master receiver

Rcv/Link	Alignment correction /ns
GPS: BP0U-PTBB	5.2*
GPS: BP1C-PTBB	3.6*

Table 1.1b The total delay correction for the UTC GNSS and TW time links of OP-PTB

Rcv/Link	Total delay correction /ns
GPS: OPMT-PTBB	2.2*
TW: OP-PTB	-1.4*

* V5. The closure at PTB between 15 months is 0.3 ns, largely inferior of the uncertainty. The visits to OP and the first to PTB were within one month. The closure correction is negligible.

Table 1.1c The total delay correction for the non UTC GNSS time links of OP-PTB

Labo	Time link	Total delay correction /ns
PTB GPS		
PTB GLONASS		
OP GPS		
OP GLONASS		

1.3 Uncertainty

Based on this and the experiments [2-9,14-16,22], the *total uncertainty* of the *total delay* in the METODE link calibration is composed of (values on average are given here):

- Measurement uncertainty (u_A): about 0.1 ns~0.3 ns (u_A of PPP link);
- Calibration measurement uncertainty of the calibrator Std_B: 0.3~1.0 ns;
- Instability of the reference and travel receivers: 0.5~0.8 ns;
- Uncertainty relating to the measurements of UTCp-CLBp: 0.2~0.5 ns;
- Others 0.3~0.6 ns (unexpected)

The total uncertainty of METODE U_M is hence 0.8~1.5 ns (1σ). This uncertainty does not include that of the cable/devices measurements in lab(k) nor long-term variations.

Given the relations between the master (UTC) time link (e.g. GPSPPP TL-PTB) and other time links, we can compute the required calibration corrections. As discussed and computed in [11,15], the total delay can be converted to the classical differential receiver calibration results.

Similar discussions about the link calibrations by different authors using different schemes can be found in [12,18,19]. It is no need to repeat all here.

II. Experiment setups and initial parameters

2.1 The BIPM METODE calibrator StdB

The BIPM METODE UTC time link calibration system is composed mainly two "*black* boxes", one fixed and the other mobile, cf. Figure 2.1.2. "*Black*" here means the internal delays are unknown and not needed to be known[1]. The basic require in the METODE scheme [11] is the short term stability of the whole system during the calibration tour of typically three months. We observed the instability in the relative variations of about 1 ns over 10 days for two side by side receivers under laboratory condition, see section 4.1.

The right plot in Figurer 2.1.2 illustrates the BIPM calibrator in its shipping and working condition with a pps distributor and a 10 MHz frequency distributor, two GTR50 GPS receivers and a Polarx3 GPS-GLONASS receiver as well as the related antennas, cables etc. Each receiver has its proper antenna and connecting cables hence is an independent measurement system. The enforced shipping container severs as both the shipment box and the operational setup, see Figures 2.1.2 and 2.1.3. The devices are pre-cabled in the container. The internal delays are fixed (except for the PolarX of which the receiver reference delay depends on the input

[1] Except the Sept. Polarx, it needs the 'latching measurement' for each setup and this is the only measure to make

frequency forms. Ideally, to reduce the systematic error by the TIC [22], a BIPM SR620 TIC[2] is shipped together with the Polarx to measure the PPS in-out delay).

The dimension of the container is 106 cm in height (with the wheels), 92 cm in length and 70 cm in width. It weights about 110 kg with the three GNSS receiver systems. The calibrator requires an input of the reference frequency and an input of the reference pps. The antenna support can hold three antennas and needs one male to be fixed on, as shown in Figure 2.1.3. The inter-impacts between the three antennas have been carefully studied and are within 30 ps which is practically negligible in the METODE calibration, see [21] for details.

Above is the standard composition of the BIPM StdB. For the PTB tour, only two GNSS receivers were installed: a GTR50 (BP0U) and a Sept. PolarX3 (BP1C). A TIC is installed in the StdB shipping box.

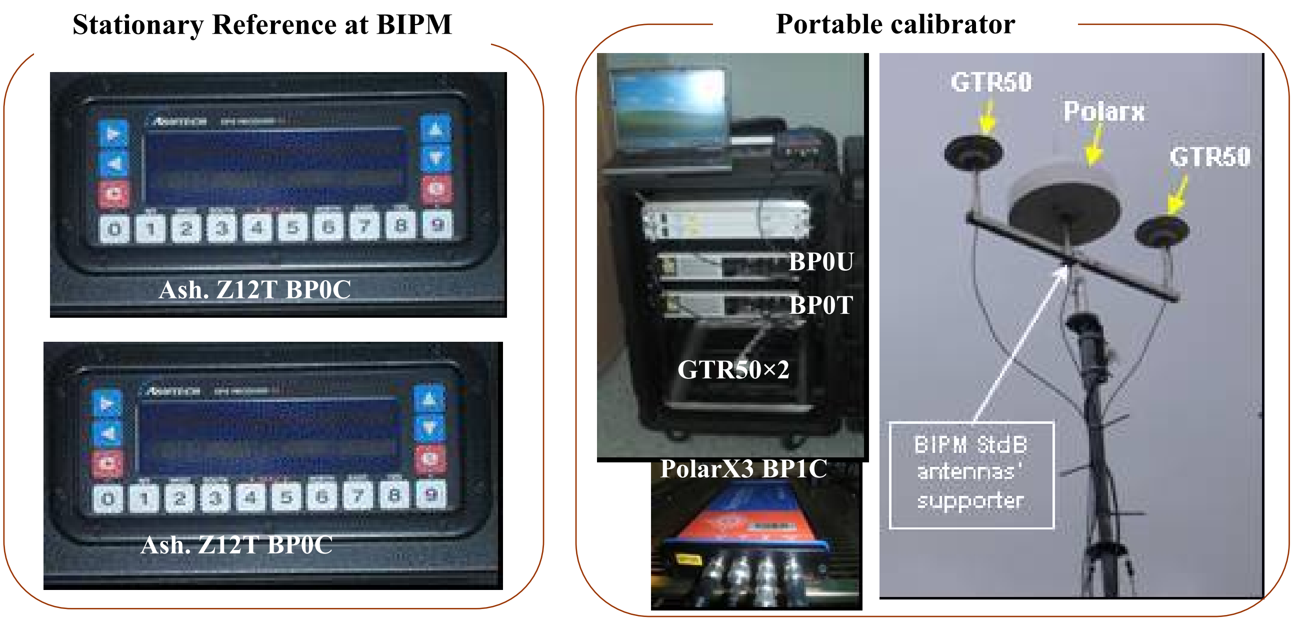

Figure 2.1.2 The BIPM calibration system

Two Pre-cabled black boxes with unknown delays require only to be stable during calibration period (~3 months): 1) The stationary reference system fixed at BIPM.: 2) The portable calibrator with N≥2 receivers: usually 2 GTR50 GNSS and enforced with a Sept. PolarX. The BIPM antenna support can hold three antennas.

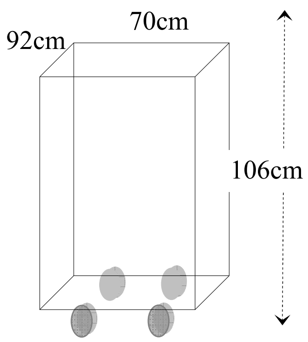

Figure 2.1.3 The shipping/working container of the BIPM calibrator

with two GTR50 GPS receivers and a Polarx3 GPS-GLONASS receiver as well as the related antennas, cables etc. in an operational setup in the enforced shipping container, 106 cm in height (with the wheels), 92 cm in length and 70 cm in width

[2] The SR620 TIC shipped with Polarx3 is to reduce possible systematical error in different SR620 TICs in the PPS in-out measurements. This may be up to 0.5 ns according to the manufacture's notice. In case the BIPM SR620 TIC is not shipped, we ask the laboratory to measure the delays of at least two cables of the BIPM calibrator to validate the possible systematic biases of the TICs, e.g. the cables C151 and C157. Their delays are 10.1 ns by the BIPM SR620 TIC

The fully operational calibrator is comprised of three GNSS receivers: two GTR50 BP0U and BP0T and a third receiver either a TTS4 or a Septontrio PolarX (BP0C or BP1C). Table 2.1.1 gives the total delay values for BIPM reference and traveling receivers aligned to the reference receiver Ash. Z12T BP0M. The later was differentially calibrated with respect to BP0C which was absolutely calibrated in 2001 [24-28]. Since then the two receivers have gradually a difference which becomes 1.629 ns.

Table 2.1.1 Total delays of the BIPM reference and traveling receivers vs. the Ash. Z12T BP0M and PTB [3,5]

Receiver	Type	Tsoft acronym	Total delay /ns	Correction 1 /ns CLB_GNSS.Lst	Note
BP0M	Ash. Z12T	BZM3	-338.418		TM215
BP0C	Ash. Z12T	BZC3	-425.717	1.629[3]	TM215
BP0U	GTR50	BGU3	20.781		
BP0T	GTR50	BGT3	17.670		
BP1C	Sept. PolarX3	BPC3	-225.184[4]		

2.2 The BIPM METODE scheme for the UTC time link Lab(k)-PTB

By the definition of the METODE scheme [11], we have the following steps for a UTC time link calibration Lab(*k*)-PTB:

- We set the PTBB to be the fixed master GNSS receiver and its calibration correction to be zero;
- We align the StdB to PTBB, i.e. the BP0U and BP1C (the alignment corrections for this visit are -5.22 ns and -3.59 ns respectively;
- The StdB goes to the Lab(*k*), *k*=OP, AOS, PL, TL and NICT …, and make a side by side measurement with the master receiver of Lab(*k*);
- We compute the double clock difference:

  DCD=[StdB-UTC(PTB)]-[UTC(k)-UTC(PTB)] (2.2.1)

  Equation (2.2.1) is the basic equation for the METODE time link calibration. The second part can be any kinds of the time links including GPS, GLN and TWSTFT etc. Note here that, the StdB keeping the calibration of PTBB is now at Lab(*k*) and driven by the master clock of Lab(*k*). The first term is therefore the true clock difference without the calibration impact. The second term can be a GPS PPP or P3 or C/A or TWSTFT link which should be equal to the first one theoretically;
- The no-zero DCD is the calibration correction to the master GNSS receiver of Lab(*k*).
  Remark: *This DCD correction should be subtract from the total delay of the GNSS master receiver and added to the CALR of the TW link Lab(k)-PTB.*

Tables 2.2.1 and 2.2.2 give the 'old' calibration values for the master GPS receivers given in the header of the CGGTTS data file[5]. See section 4.2 for the application of the METODE correction in CGGTTS header.

Table 2.2.1 Total delays of the PTBB/PTBG at PTB and OPMT at OP
The delay values are from the CGGTTS header files or calibration info available on the BIPM ftp sites [1-3]

[3] Correction to BP0C vs. BP0M
[4] 225.184 ns=-64.284+44.0-213.6+8.7. This was used when the visit to PTB and should be added by the local latching delay correction. An dit needed the collaboration correction : -3.592 ns in CLB_GNSS.Lst.
[5] Theoretically, the METODE does not need any known delay as reference. However, all the UTC time links should have been calibrated. Therefore we compute the calibration *correction* to the existing calibration. P3 and PPP have the same calibration. The relation of the P1, P2 and P3 is given by the equation: Dly(P3)=2.545*Dly(P1)-1.545*Dly(P2) = Dly(P1)+1.545*Dly(P1-P2). The classic calibration results are the delays of the receiver and the antenna (XR+XS). The total delay can be presented in the form of the total delay of P1 and P2 code. For example, for the BP0C. BP0C GPS P1: -XP-XO+XR1+XC+XD+XS1 = 515.6 ns; BP0C GPS P2: -XP-XO+XR2+XC+XD+XS2 = 531.9 ns

Rcv/Sys	P1	P2	P1-P2	P3(XR+XS)	XC	XD	XO	XO'	XP	Total Dly	Note
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	
PTBB/PZB3	304,5	318,9	-14,4	282,252	301,7	0,0			75,3	508,652	TM172
PTBG/PZG3	279,6	263,9	15,7	303,857	251,4	0,0			84,2	471,057	TM172
OPMT/OZT3	311,3	323,3	-12,0	**292,760**	156,5	0			117,2	332,060	TM204

Table 2.2.2 The calibration value CALR in the ITU TWSTFT data file on MJD 56500

TW link	ITU file	CALR/ns	ESDVAR/ns	ID
OP-PTB	TWOP56.500			
PTB-OP	TWPTB56.500			

The calibrator contains the BP0U and the Sept. PolarX3 BP1C. Unlike the GTR50, the PolarX requires measuring the 1 pps pin point with respect to the local frequency forms and this is done with a TIC SR620. To evade the impact of the systematical offset in the TIC, it is better to use the same TIC for each setup.

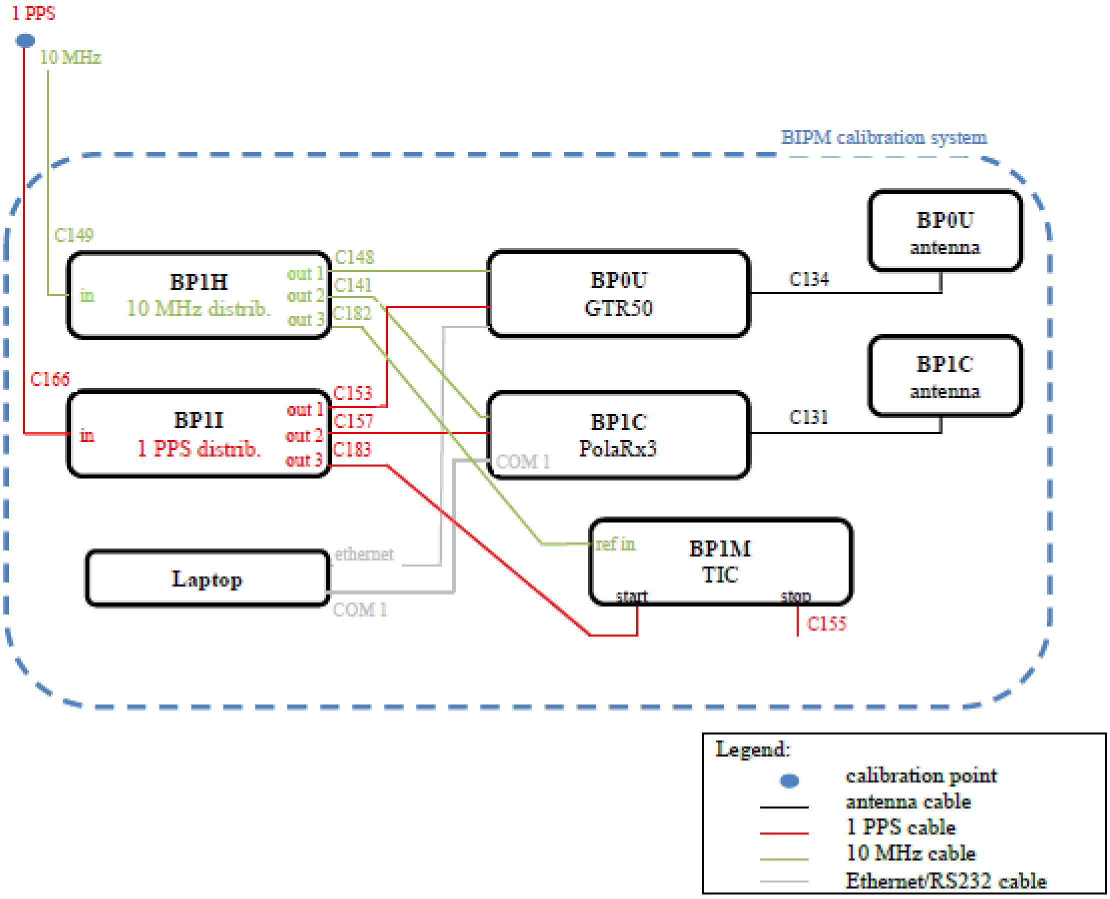

Figure 2.2.1 The calibrator setups at the BIPM and PTB [10]

The setups of the GTR50 BP0U and the PolarX3 BP1C with respected to the reference clock (UTC(TL) or others) are illustrated in the Figure 2.2.1. If only for the METODE link calibration, we do not need to know the configuration and the internal delays of the calibrator with respect to the BIPM reference receiver system. However, to be able to compare the link calibration result and that of the classic method, we carefully measured the delays using two methods: the TIC and the BIPM fixed reference receivers vs. the portable calibrator. The fixed reference can be used also for the closure measurements after the calibrator coming back to BIPM to verify its stability.

The setup of the BIPM time link calibrator StdB is kept always the same, that is, the internal delays are kept no change since its visit to PTB so that the equation 2.2.1 can be used directly.

III. The METODE measurements

The METODE measurements were made between 21-27 June 2013, MJD 56464-56470 at PTB and during 12-22 April, MJD 56394-56404 at OP. See cf. [3] for details at OP. A closure measurement after the visits and the closures were 0.3 ns on average, ignorable vs. the UM.

We computed the calibrations using the receiver and link methods. We use the equation (2.2.1), i.e., the METODE link calibration, for the final result.

The Tables 3.1-3.4 are the summaries of the results demonstrated in the Figures in the sections 3.1 and 3.2. Here the PTBB and OPMT stand for master GNSS receivers of PTB and OP. CCD is the common clock differences of the Lab(*k*) master receiver and one of the StdB receivers. Link is the time link between the StdB, Lab(k) and PTB. As mentioned above, the BP0U and BP1C are to be aligned to the PTBB.

Table 3.1 Correction to align the StdB to PTBB MJD 56464-56470 setup at PTB (Figures 3.1.2-3.1.3)

CCD	Average±σ /ns	Closure correction	Align correction /ns	weight
BP0U-PTBB	5.192±0.038	0.03	5.22	1
BP1C-PTBB	3.562±0.017	0.03	3.59	1
Weight mean	4.377±0.028		4.38	

Table 3.2 summary of the Tables 3.3 and 3.4

Lab(k)	Setup	Calibration type	MJD	Result	weight	Weight-mean /ns	Remark of weight
OP	1	Receiver	56394-404	-0.57±0.075	0		
	1	Link	”	-0.48±0.088	1		Use the Link

Table 3.3 Setup at OP: Receiver calibration between 56394-56404 (Figures 3.2.1-3.2.2)

CCD	Average±σ /ns	Cor* /ns	Average±σ /ns	weight
BP0U-OP	-0.536±0.072	+2.67	2.13±0.07	1
BP0T-OP	-0.602±0.078	+2.67	2.07±0.08	1
Weight mean	-0.569±0.075	+2.67	2.10±0.075	

* Sept 2014

Table 3.4 Setup at OP: Link calibration between 56394-56404 (Eq. 2.2.1, Figures 3.2.3-3.2.5)

Link	Average /ns	DCD /ns	Cor* /ns	Average±σ /ns	weight
OP-PTBB	2.958				
BP0U-PTBB	2.511	-0.447	+2.67	2.22	1
BP0T-PTBB	2.447	-0.511	+2.67	2.16	1
Weight mean		-0.479±0.075	+2.67	2.19±0.08	

* Sept 2014

3.1 The alignment measurement setup at PTB

The setups of the METODE StdB and the devices of the PTB are shown in Figures 2.1.2, 2.2.1 and 3.1.1.

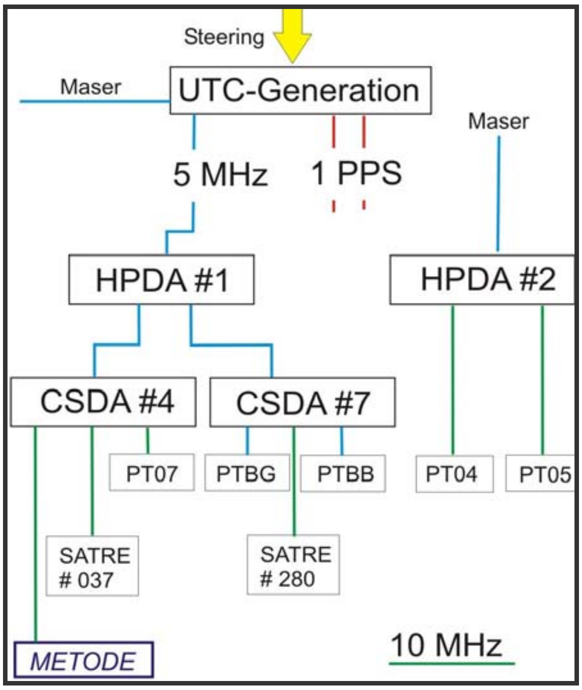

Figure 3.1.1 The BIPM calibrator setup vs. other equipments at PTB on MJD 56463-56467
Left: 1 PPS and *right*: 5-10 MHz. PD is pulse distribution amplifier. HPDA is High-performance distribution amplifier. But some of the units include a multiplier form 5 MHz to 10 MHz. CSDA is clock signal distribution amplifier which is a 19" 2 HE model that distributes 1 PPS (5 out), 5 MHZ (5 out) and generates 10 MHz (5 out). So the same device may appear in both configuration plots.

The calibration information is stored in the file X:\TaN\ CLB_GNSS.Lst. Raw Rinex data are used for the PPP solutions and then used for the time link computation after the calibration using the Tsoft menu yB/f313 and the parameters in CLB_GNSS.Lst as given below. The plots followed are the commutation results and keeps most of the calibration output information.

The Calibration corrections to the Lab RefGps (CLB_GNSS.Lst), cf. the Section 2.2:

```
--- Calibration to Lab RefGps:
   1: PZB3 -508.652,                Total=  -508.652 ns
   2: BGU3  20.781 8.85,            Total=    29.631 ns
   3: BPC3 -225.184 8.85 187.904,   Total=   -28.430 ns
   4: OZT3 -332.060,                Total=  -332.060 ns
   5: BGT3   17.670,                Total=    17.670 ns
   6: BZM3 -338.418,                Total=  -338.418 ns
   7: BZC3 -425.717 1.629,          Total=  -424.088 ns
   8: PZG3 -471.057,                Total=  -471.057 ns
```

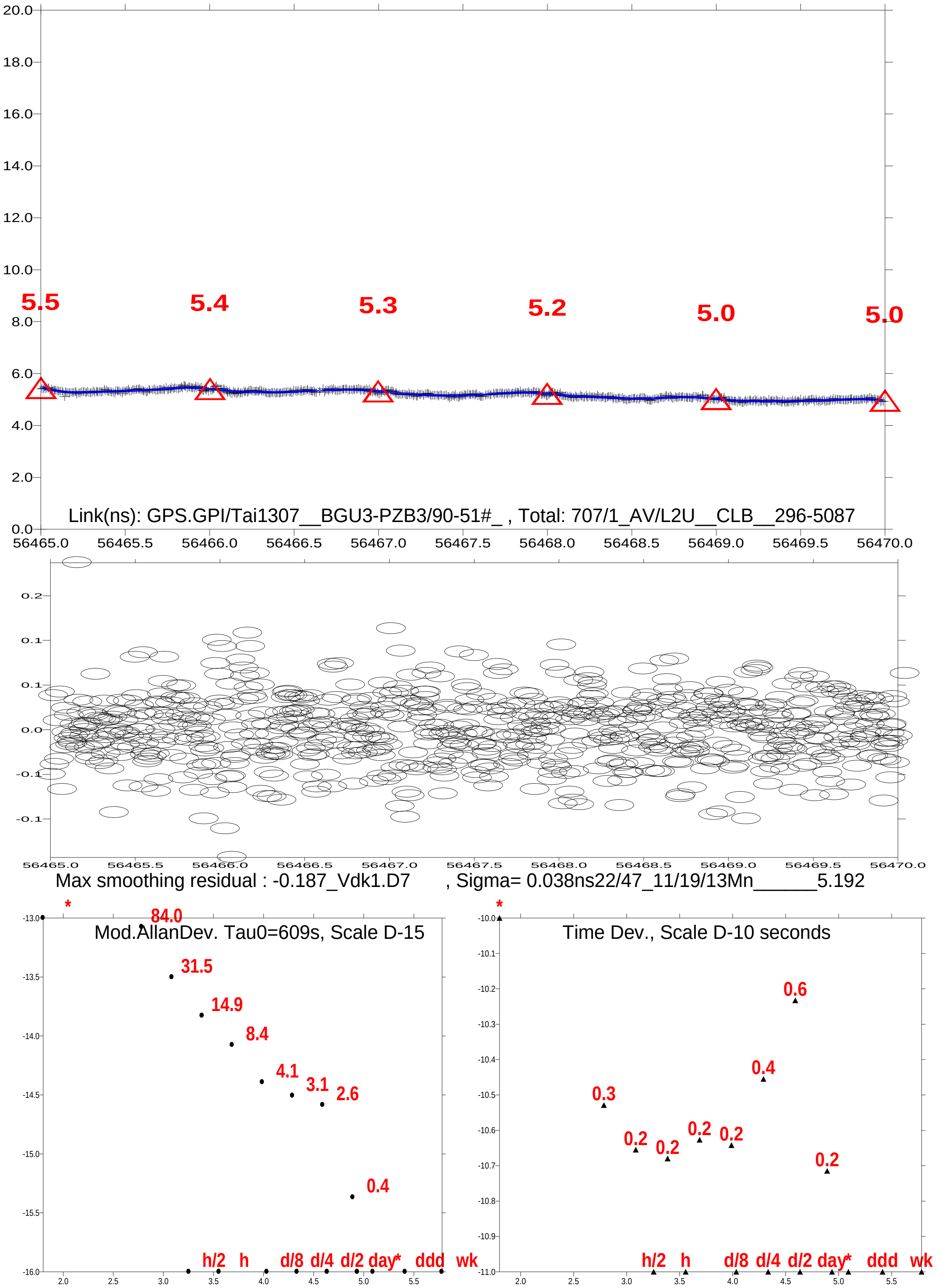

Figure 3.1.2 CCD BP0U-PTBB av=(5.192±0.038) ns

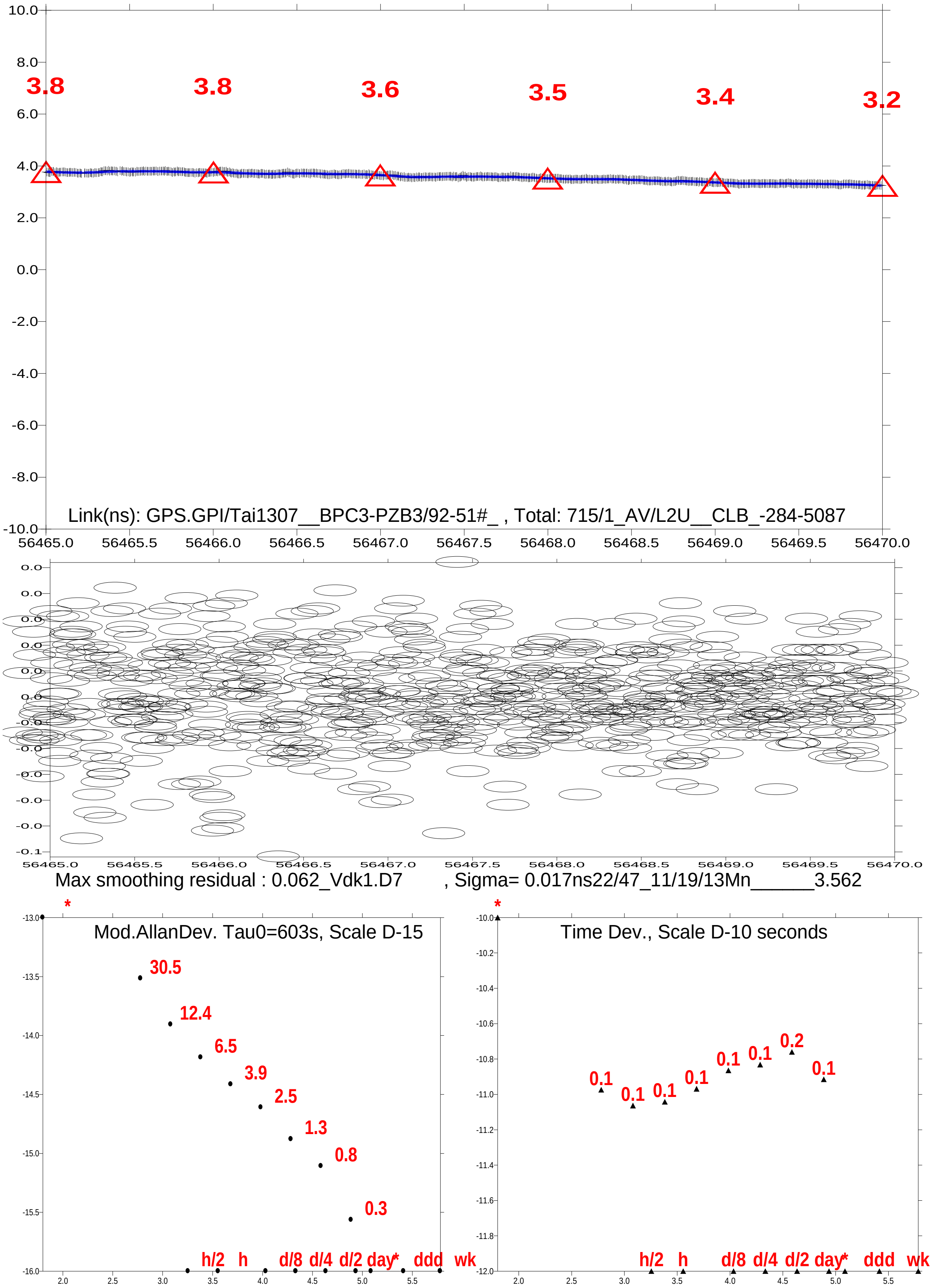

Figure 3.1.3 CCD BP1C-PTBB av=(3.562±0.017) ns

3.2 The calibration setup at OP

The BP0T did not participate in the alignment measurements as did the BP0U and BP1C. However, several inter-comparisons of the BP0T to BP0U and BP1C prove that the BP0T agrees with the BP0U and BP1C within 0.3 ns and we can use the same alignment correction of 5.221 ns for both BP0U and BP0T.

The Calibration corrections to the Lab RefGps (CLB_GNSS.Lst):

```
--- Calibration to Lab RefGps:
   1: OZT3 -332.060,                                Total=  -332.060 ns
   2: BZM3 -338.418,                                Total=  -338.418 ns
   3: BZC3 -425.717 1.629,                          Total=  -424.088 ns
   4: BGU3   20.781 * 289.958 -5.221,               Total=   305.518 ns
   5: BGT3   17.670 * 289.958 -5.221,               Total=   302.407 ns
   6: PZB3 -508.652,                                Total=  -508.652 ns
```

* V5

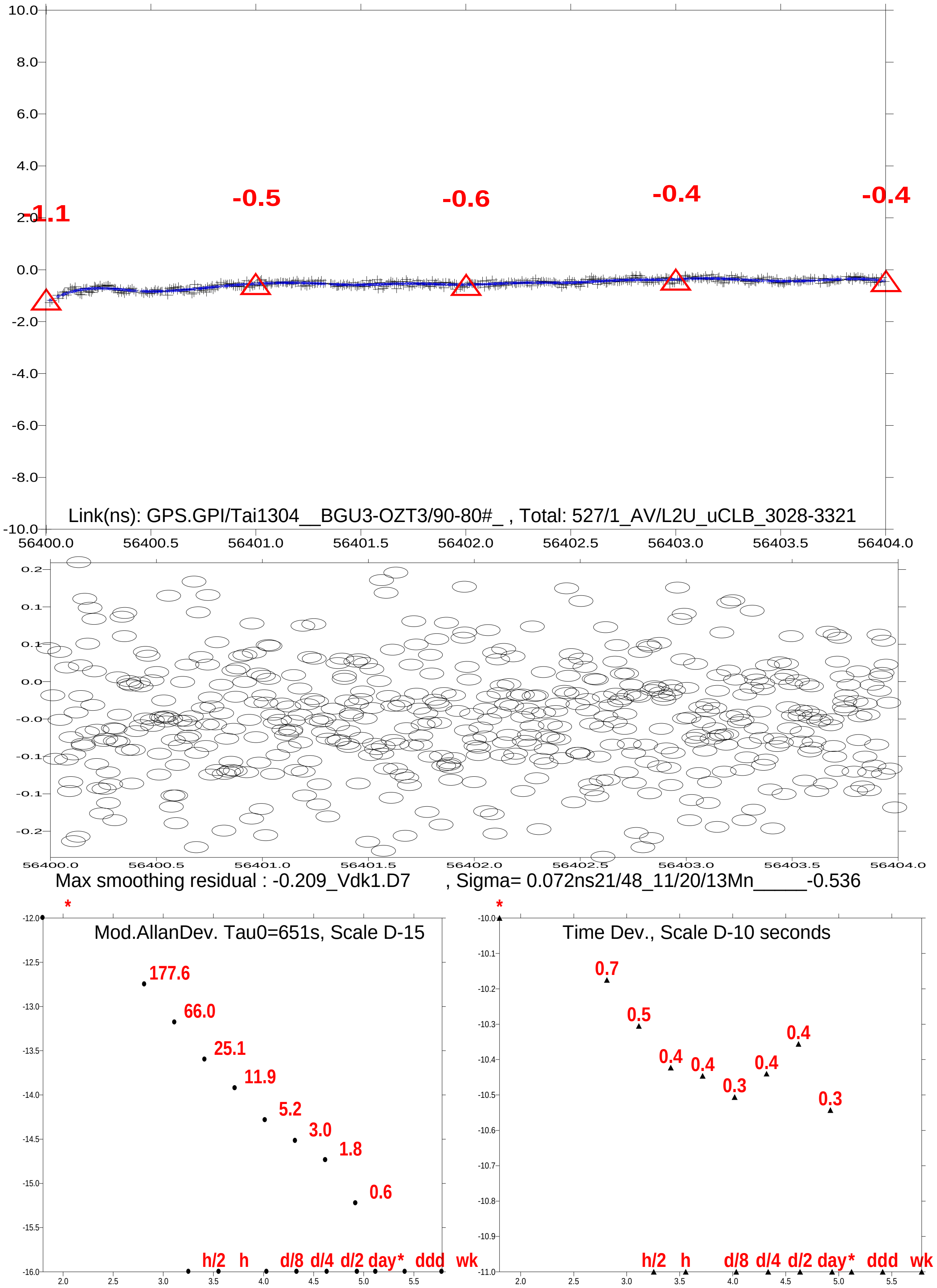

Figure 3.2.1 CCD BP0U-OPMT av=(-0.536±0.072) ns

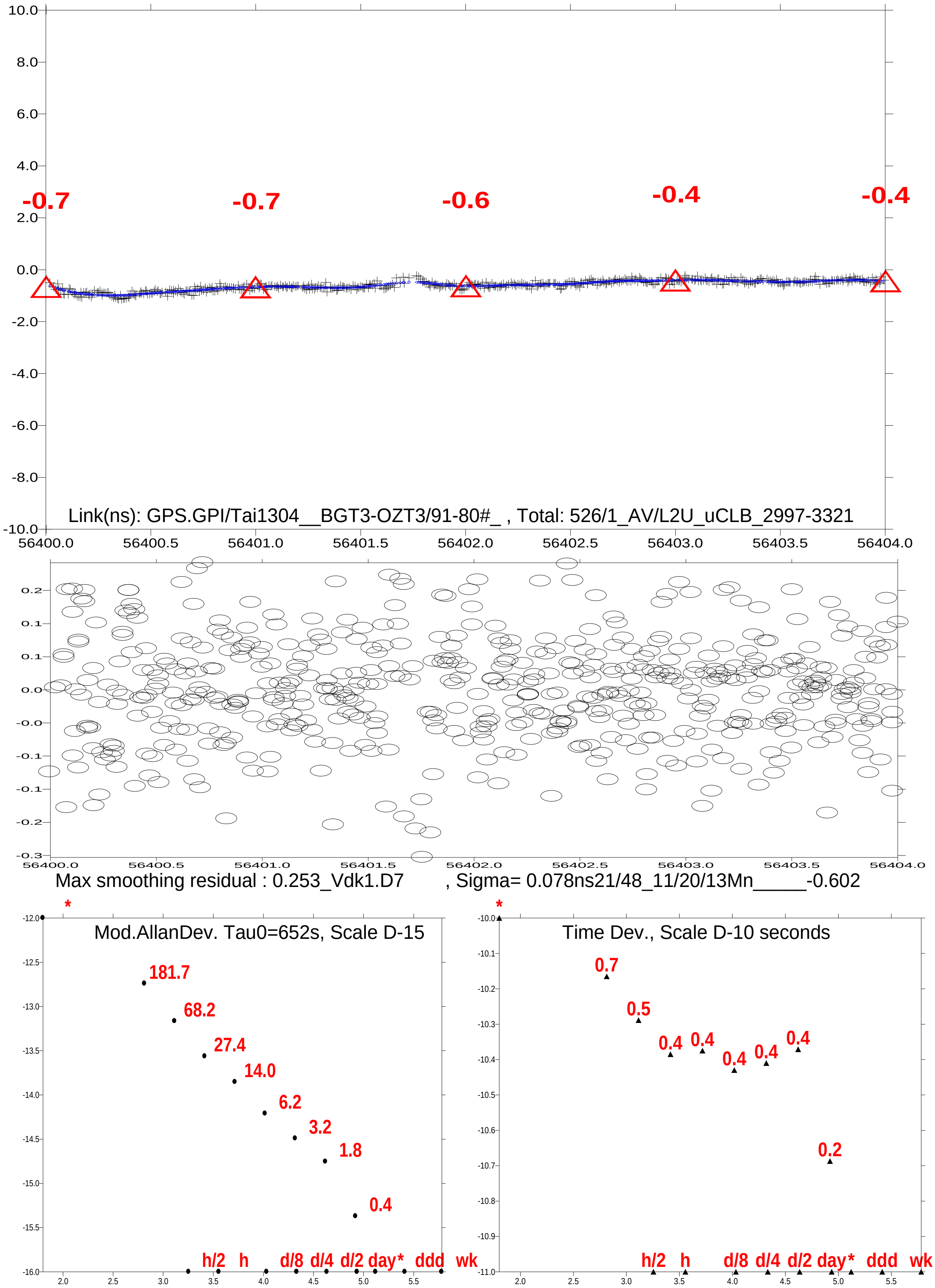

Figure 3.2.2 CCD BP0T-OPMT av=(-0.602±0.078) ns

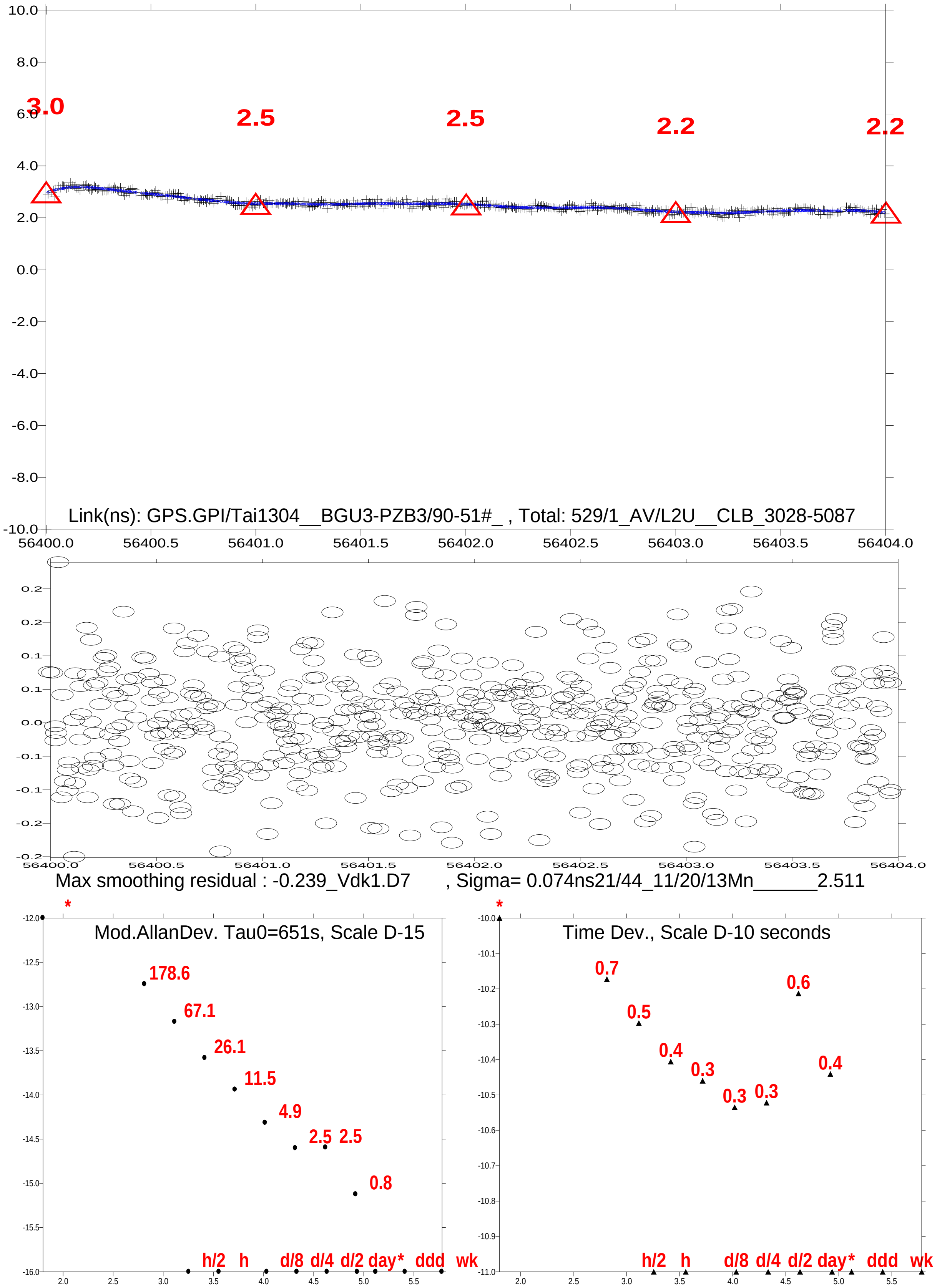

Figure 3.2.3 Link BP0U-PTBB av=(2.511±0.074) ns

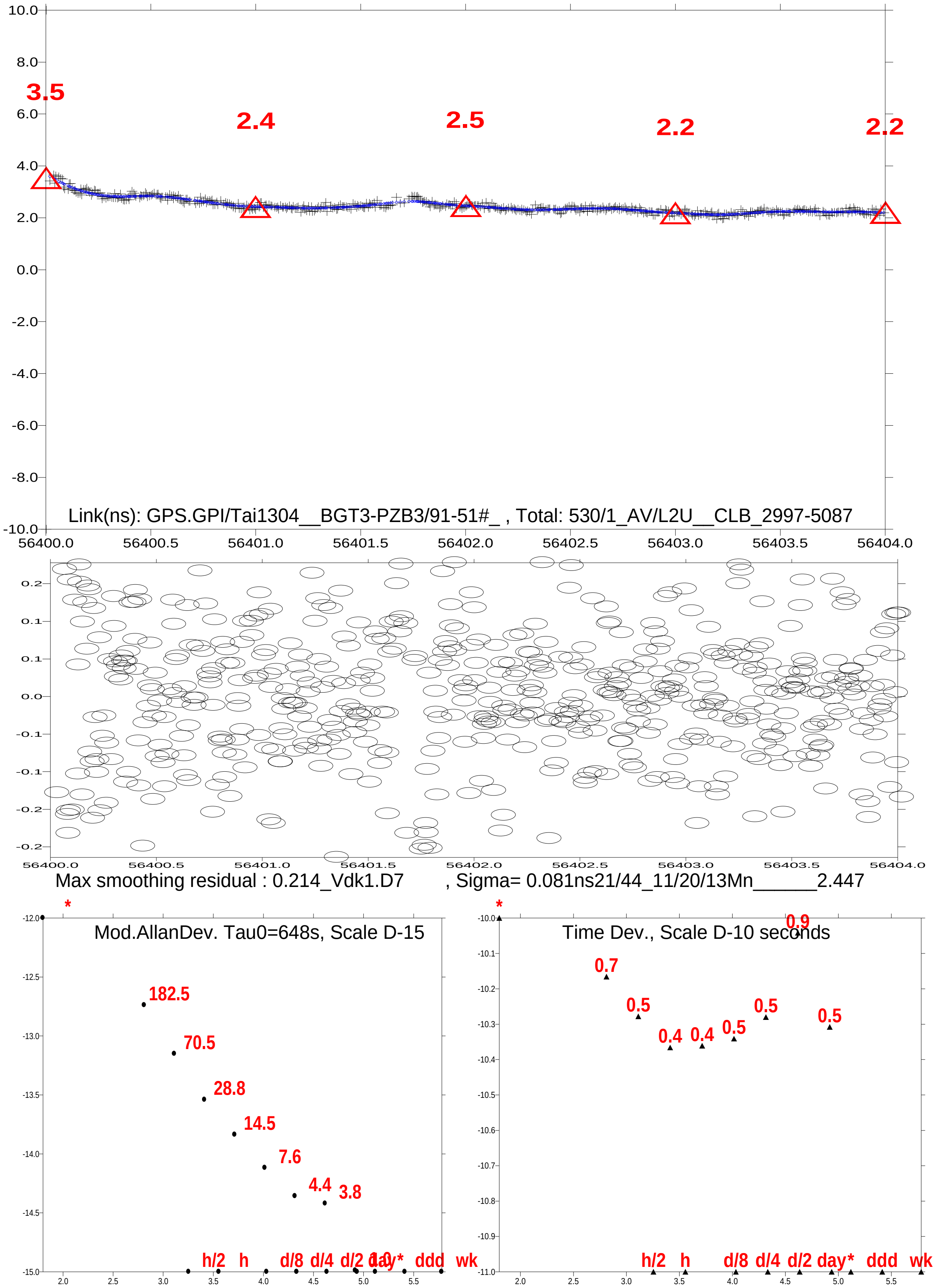

Figure 3.2.4 Link BP0T-PTBB av=(2.447±0.081) ns

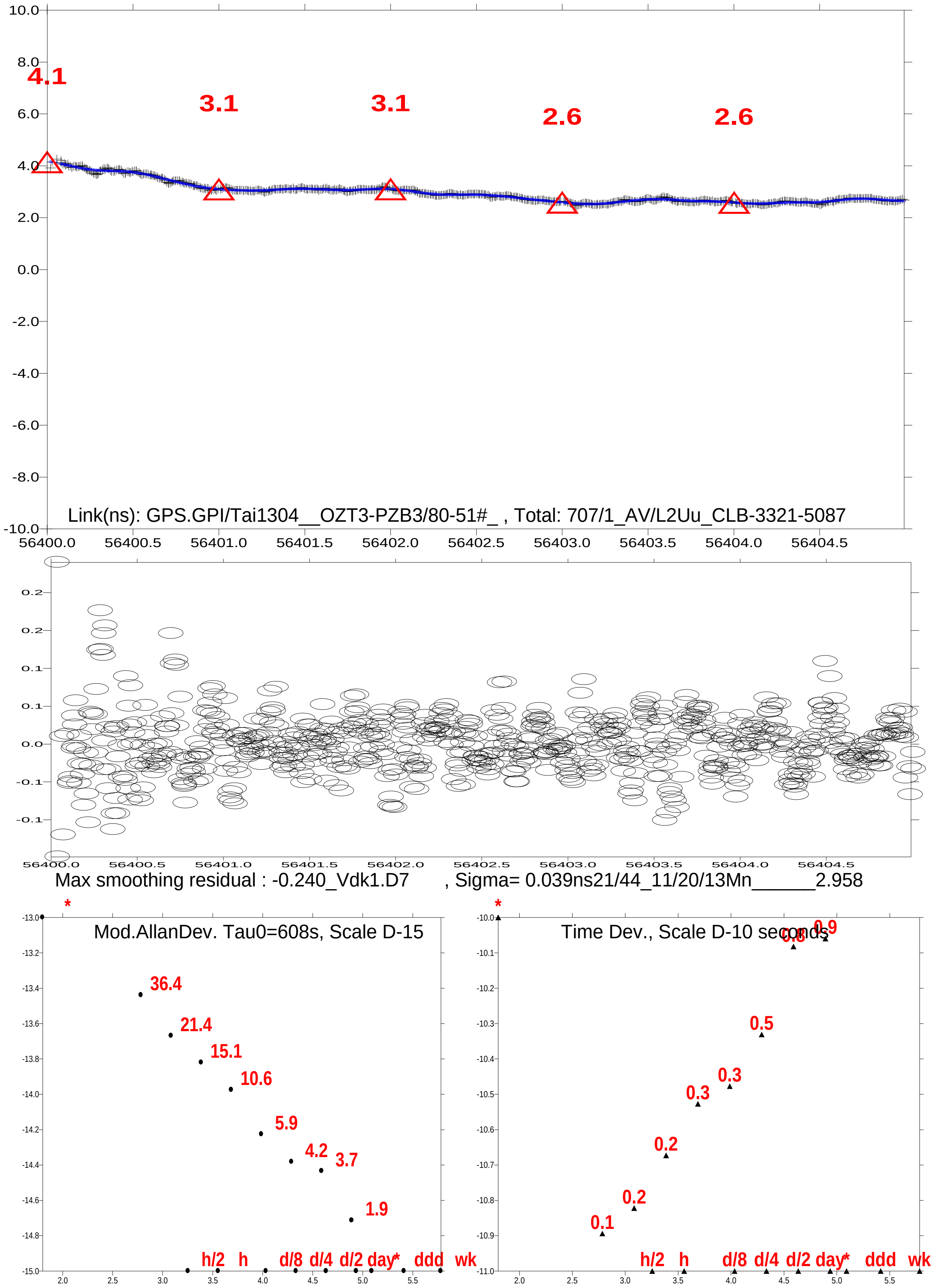

Figure 3.2.5 Link OPMT-PTBB av=(2.958±0.039) ns

3.4 The calibration of the TWSTFT link OP-PTB[6]

The METODE calibration correction for the GPS link OP-PTB is =+0.5 ns. Use the corrected GPS link, we can calibrate the TW link by the double clock difference of the links TW-GPS.

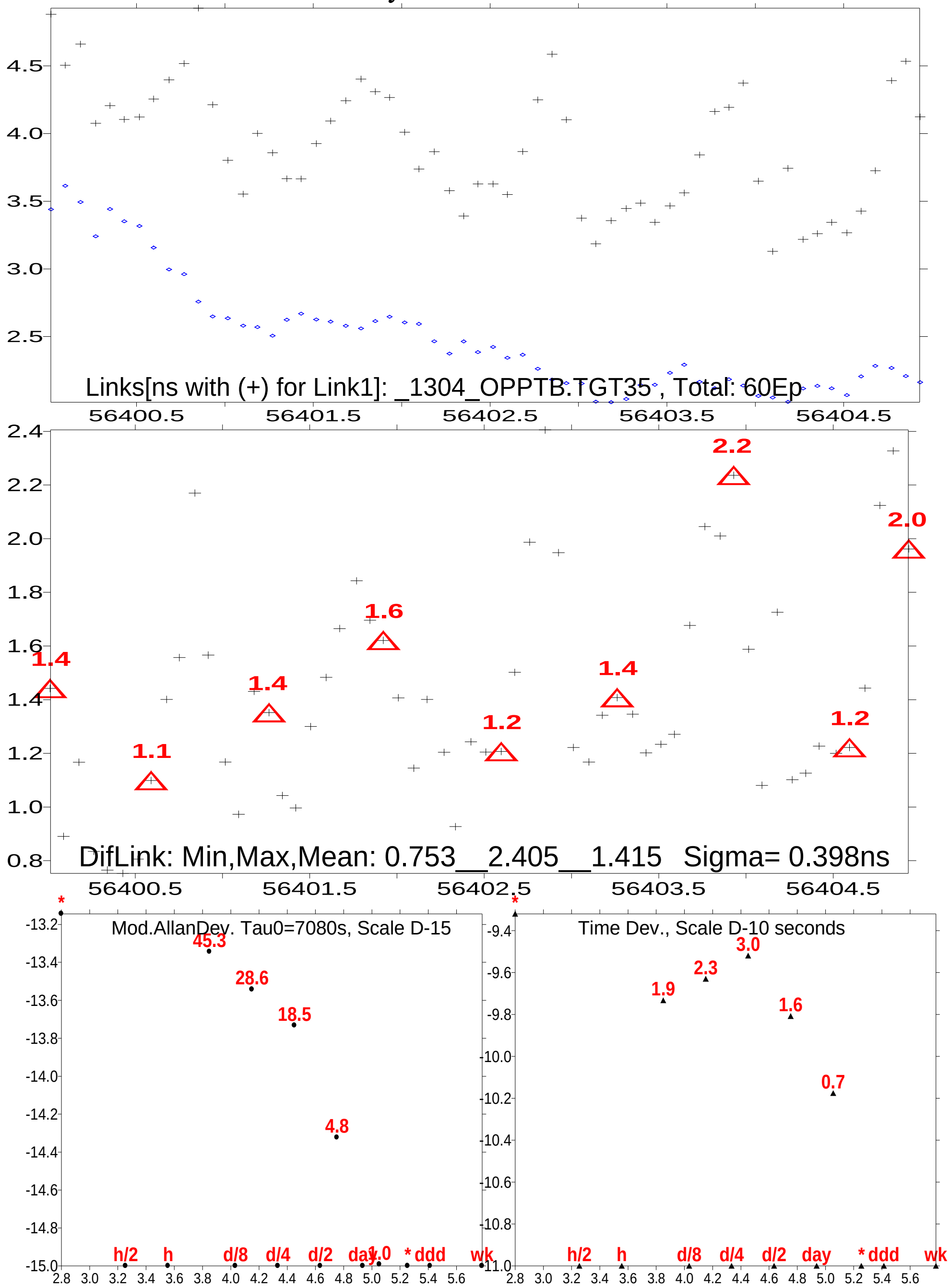

Figure 3.4.1 Comparison of TW-GPSPPP link 1304: the difference is (1.415±0.398) ns (after METODE correction)

TW link is usually noisy and diurnal signals present as can be seen in the Figure 3.4.1. The difference is 1.415±0.398 ns which is the calibration correction for the TW link TL-PTB.

[6] Updated 9 Sept. 2014. C_M= -0.5 ns should be substracted from the GPS OPMT data (-C_M from the RefGPS in CGGTTS or CLB_GNSS.Lst)

IV. Discussion

4.1 The temperature impacts over the uncertainty

The crucial issue is the instabilities of the stationary and traveling receiver-systems involved in the METODE. By the principle of the METODE, we do not require the long-term (longer than a closure calibration tour) stability of the StdB. But the short-term instability of a calibration setup at a lab, about a week, will impact the calibration results. One of the major disturbing sources is the temperature variations.

As seen the variations in the reference receiver-system. Figures 4.1.1 and 4.1.2 demonstrate the relative variations in CCD (common clock differences) of P3 and PPP between the two Z12T of the BIPM reference receivers (BP0C and BP0M) over two 10-day periods. Both are maintained in the air-conditioned time laboratory. The variations are bigger than 1 ns. The temperature sensibilities are different for different receivers. This implies the necessity of the closure measurements and the use of the double receiver-cable-antenna systems for both the fix and travel equipments.

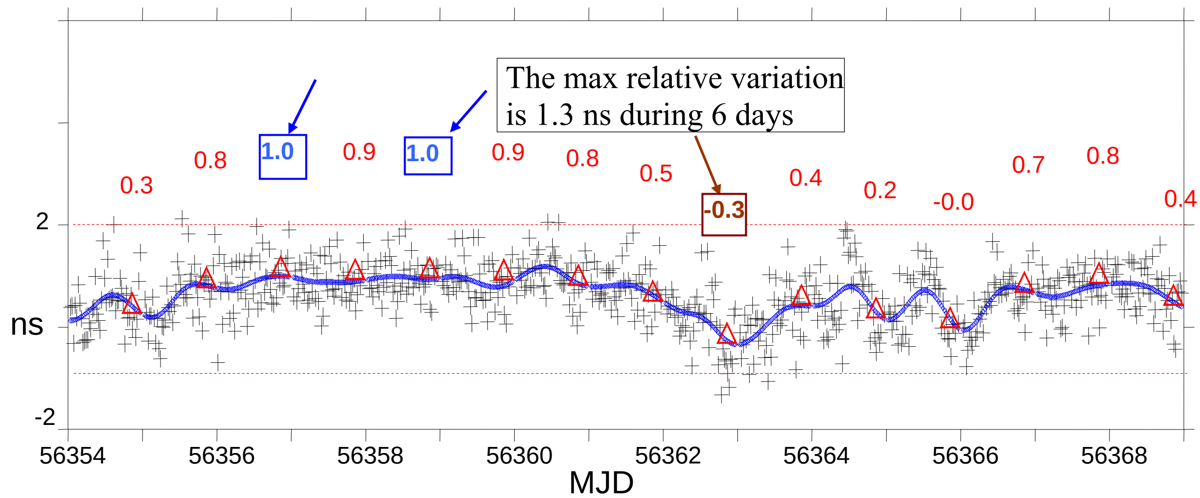

Figure 4.1.1 P3 CCD of BP0M-BP0C between 56354-56369

The GTR50 [23] is chosen in the calibrator Std_B thanks to its facility in application and the easier traveling condition. One of its advantages is its self-temperature control system. Unlike the Z12T and the PolarX receivers, it is impacted less by the environmental temperature variations. It requires only the PPS signal inputs and no additional latching determination with a TIC is needed at Lab(*k*). One assumption is that the trigger error of each reboot is near constant so as to be partially cancelled in the METODE differential setups. This is proven in our tests.

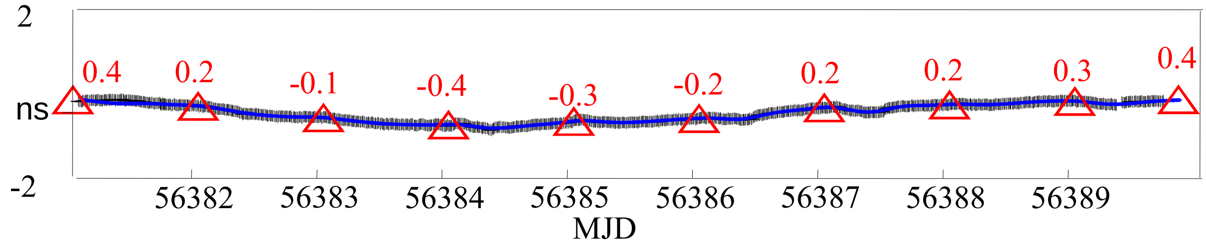

Figure 4.1.2 PPP CCD of BP0M-BP0C between 56381-56390

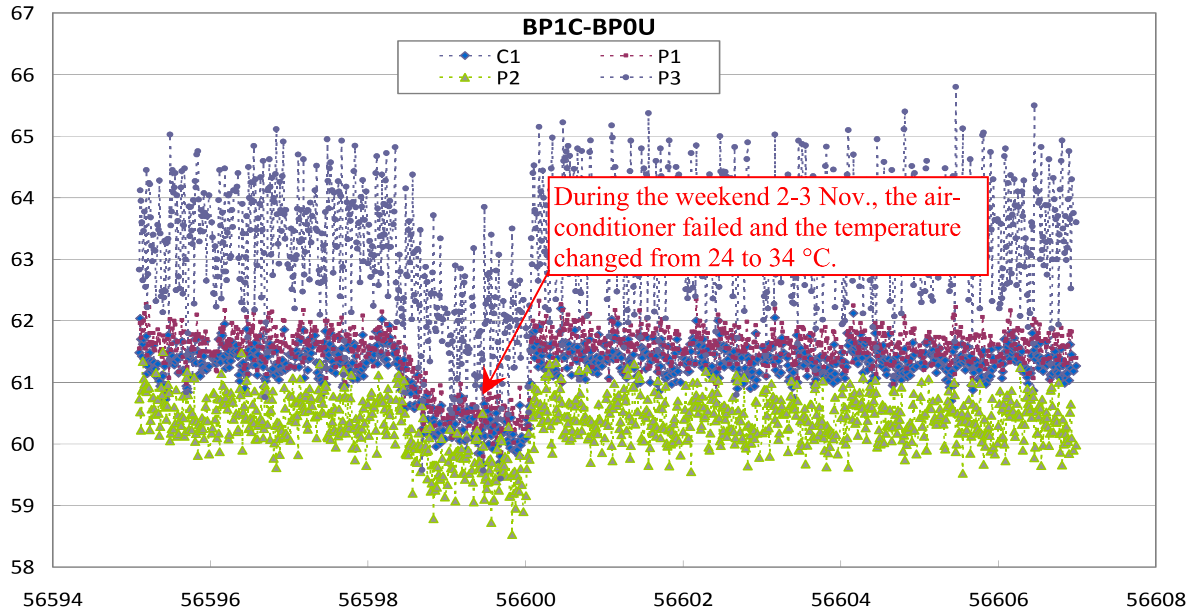

Figure 4.1.3 CCD of the two receivers in the BIPM calibrator StdB at the TL UTC time laboratory room

Another typical example is that during the setup of the StdB at TL in the weekend of 2-3 Nov., the air-conditioner failed and the temperature increased from 24 to 34 °C. The GTR50 is self-air-conditioned so was almost not influenced by the environmental temperature variations and taken as the reference receiver in Figure 4.1.3. While the Sept. PolarX and the Ash. Z12 have not a self temperature control system and are very sensible to the external temperature changes and produced about 1.5 ns variation in the measurements, which however went back after the temperature became normal. Instability may occur due to other causes during mobile conditions. This is one of the basic considerations for which we need N≥2 receivers in the traveling calibrator in order to guaranty the total u_B to be inferior of 2 ns. It is hardly to believe than a single-receiver calibrator is able to do better than 2 ns.

4.2 Implementation of the METODE total delay correction in the CGGTTS format V02

In the UTC time transfers and many other practices, the header CGGTTS format version V02 is used for the GNSS P3 (and PPP) data, e.g. the header of TWTF of TL:

```
CGGTTS GPS/GLONASS DATA FORMAT VERSION = 02
REV DATE = 2005-04-21
RCVR = Z-XII3T
CH = 12 (GPS)
IMS = Z-XII3T
LAB = TL
X = -2994428.02 m (GPS)
Y = +4951309.28 m (GPS)
Z = +2674496.91 m (GPS)
FRAME = ITRF                                                s
COMMENTS = TAIPPP PILOT EXPERIMENT
INT DLY =  304.3 ns (GPS P1),  315.6 ns (GPS P2)  calibration in 2005
CAB DLY =  119.8 ns (GPS)
REF DLY =   52.0 ns
REF = UTC(TL)
COMMENTS = PsdGPS with CggttsHeader based on: X:\TaN\1310\Obs\TL31310.U0 at 11:04:43/11/04/13
COMMENTS = Total_DLY/Mjd,DLY_P1,P2,Cab,Ref: 1 354.642 54497 304.3 315.6 119.8 52.0 ins.by F30192
```

As shown above, the so far BIPM calibration results are given by the values of the internal delay (INT DLY) in P1 and P2. While the cable and reference delays are supplied by the local laboratory. If we review the historical calibration results, we can easily find the changes of the INT DLY values are often up to several ns, e.g., that of the internal delay values for TWTF of TL in 2002 are:

```
INT DLY =  307.5 ns (GPS P1),  317.7 ns (GPS P2)   calibration in 2002
```

The internal delay changed 4.9 ns in P3 [35] between 2002 and 2005, hardly to be true. Similar, that of the NMIJ is up to 5.7 ns [36]. Both are the Ash. Z12T double frequency geodetic receivers quiet new at that epoch (purchased in 2001). As we know that the P3 but not the P1 or P2 code supplies the absolute scale, i.e. the calibration, for P3 and PPP UTC time transfers. The internal delay values impact the P3 scale through the relation: Dly(P3)=2.545*Dly(P1)-1.545*Dly(P2) = Dly(P1)+1.545*Dly(P1-P2) . However, no proof proves that the internal delay could be able to change so much: 5 ns during 3 years. In contrast, it is easy to prove the mal-measurements of the cable delay, e.g. in the Table I in [11] which shows the discrepancies of the BIPM antenna cable delay and its delay values measured by 18 laboratories. The maximum difference is 6.6 ns. The standard deviation is 1.6 ns. This is only a simple cable. For other complex equipment, the discrepancies of the measured delays would be worse. Unfortunately, the present calibration procedure accounts all the errors in the cable-device delay measurements into the P1 and P2 internal delays and this is obviously not reasonable.

The more reasonable explanation is that the difference obtained by the classic receiver calibrations in the internal delay is rather the delay measurement errors due to the changes of setups or the laboratory's cable-devices. This should not be taken into account in the internal delay anyway.

Therefore, it is proposed the METODE calibration total delay correction to be added to the cable delay (**CAB DLY**) instead of the 'internal delays'.

A comment line should be inserted to declare the calibration correction applied and the identifier of the calibration. Take the above example, suppose there is a calibration correction of 5.7 ns, the calibration information lines become:

```
INT DLY =  304.3 ns (GPS P1),  315.6 ns (GPS P2) ! calibration in 2005
CAB DLY =  114.1 ns (GPS)
REF DLY =   52.0 ns
COMMENT = original CAB DLY=119.8 ns. METODE correction 5.7 ns subtracted. ID 01-30-05-13-04[7]
```

The total delay corrections should be *subtract*[8] from the CAB DLY of the GNSS receiver to be calibrated. However the TW calibration correction should be *added* to the present CLAR value of the TWSTFT link OP-PTB[9].

Acknowledgement

We thank the support of the OP and PTB groups for the cooperation during the experiments. We thank also the NRCan group for the use of the PPP software and the technical support.

[7] ID, the identifier of the calibration : A CLB Id code is a 9 or 10-number/letter-chain as: AA-BB-CC-YY-XX (here the '-' is a separator only for clearly showing the meaning of the numbers and should not be used in practice to easy the computer program reading, i.e. Tsoft). AA: is one or two numbers or letters to identify the nature of the calibration: e.g. BIPM groups or RMO or others; BB: is the Lab code in the UTC/TAI computation (for Lab2 of the link Lab2-Lab1); CC: is the Lab code in the UTC/TAI computation (for Lab1 of the link Lab2-Lab1); YY: the year of calibration; XX: sequential number of the calibrations in the year YY. For more information, cf. Annex 1 of TM214 [2]

[8] keep the sign in GNSS_CLB.Lst file

[9] For example, the CALR in the raw data file: TWOP56.437 is -7300.704 for OP01 PTB01 14 56437 001900. The correction in Table 1.1 for TW OP-PTB is -1.4. The calibrated CALR is equal to -7300.704+(-1.4)=-7302.104. Accordingly, the CALR for PTB-OP is +7302.104

Reference

1. Śliwczyński Ł., Krehlik P., Czubla A., Buczek Ł., Lipiński M.: Dissemination of time and RF frequency via stabilized fiber optic link over the distance of 420 km, *Metrologia*, vol. 50, pp. 133-145, 2013
2. Jiang Z., Tisserand L., Petit G. and Lin S.Y., **TM214**, METODE Experiments 2013-I, -- MEasurement of TOtal DElay for UTC Time Link Calibration, Phase I: Tests at BIPM and TL Apr 2013
3. Jiang Z. et al. **TM215**, METODE Experiments 2013-II, -- MEasurement of TOtal DElay for UTC Time Link Calibration, Phase II: Tests at and between BIPM and OP, May 2013
4. Jiang Z. et al. **TM216**, METODE Experiments 2013-II, -- MEasurement of TOtal DElay for UTC Time Link Calibration, Phase III: Tests at and between BIPM, OP and PTB, July 2013
5. Jiang Z. **TM216bis**, METODE Experiments 2013-II, -- MEasurement of TOtal DElay for UTC Time Link Calibration, Phase III: Tests at and between BIPM, OP and PTB, July 2013
6. Jiang Z. et al. **TM217**, METODE Experiments 2013-III, -- MEasurement of TOtal DElay for UTC Time Link Calibration, Phase III: Tests at and between BIPM, PTB, AOS and PL July 2013
7. Jiang Z. et al. **TM218**, METODE Experiments 2013-IV, -- MEasurement of TOtal DElay for UTC Time Link Calibration, Phase IV: Tests at and between BIPM, PTB and TL Nov. 2013
8. Z. Jiang, W. Lewandowski, L. Robertsson, J. Nawrocki, A. Czubla and W.H. Tseng, TM219, Evaluation of the first optical fiber time link between the UTC laboratories AOS and PL- Review of the TWOTFT and Consideration for the Mise En Pratique in UTC, May 2013
9. Z Jiang, J Nawrocki, A Czubla, P. Dunst, L Tisserand and W Lewandowski **TM221,** Calibration comparison on the UTC AOS-PL baseline between the AGH optical fiber self-calibration and the BIPM METODE calibration, Aug. 2013
10. Jiang Z., F. Arias, W. Lewandowski, G. Petit, *Toward new procedures in TWSTFT and GNSS delay characterization for UTC time transfer*, Proc. EFTF 2010
11. Jiang Z., Arias F., Lewandowski W., Petit G., *BIPM Calibration Scheme for UTC Time Links*, Proc. EFTF 2011, pp 1064-1069
12. Lewandowski W. and L Tisserand, Relative characterization of GNSS receiver delays for GPS and GLONASS C/A codes in the L1 frequency band at the OP, SU, PTB and AOS, Rapport BIPM-2010/04
13. L Tisserand, Notice for the BIPM calibration scheme « METODE » *MEasurement of TOtal Delay* Draft 0.6 (14/06/2013)
14. Jiang Z, G Petit, L Tisserand, P Uhrich, G D Rovera and S Y Lin,˙ Progress in the link calibration for UTC time transfer, EFTF 2013
15. Jiang Z. et N. A. Niessner, *Calibrating GPS with TWSTFT for Accurate Time Transfer*, Proc. PTTI 2008
16. Niessner N. A., W. Mache, B. Blanzano, O. Koudelka, J. Becker, D. Piester, Z. Jiang, and F. Arias, *Calibration of the BEV GPS receiver using TWSTFT*, Proc. PTTI 2008
17. Arias E.F. and Z. Jiang, *Considerations on unifying the TWSTFT and GPS Calibration for UTC time transfer*, CCTF WG on TWSTFT Workshop 2008, http://www.bipm.org/wg/AllowedDocuments.jsp
18. Esteban H., J. Palacio, F. J. Galindo, T. Feldmann, A. Bauch, D. Piester, *A GPS calibration trip experience between ROA and PTB*, Proc. EFTF 2009
19. Feldmann T., Bauch A., Piester D., Stefanov A.; Bernier L.G., Schlunegger C., Liang K., *On Improved GPS-Based Calibration of the Time Links between METAS and PTB*, Proc. EFTF 2010
20. Jiang Z., D. Matsakis, S. Mitchell, L. Breakiron, A. Bauh, D. Piester, H. Maeno and L.G. Bernier, *Long-term Instability of GPS-based Time Transfer and Proposals for Improvements*, Proc. PTTI 2011
21. Jiang Z., L. Tisserand and G. Petit, Tests of the BIPM portable calibration station - METODE: MEasurement of TOtal Delay, CD Proc. PTTI 2012
22. MODEL SR620, Universal Time Interval Counter, http://ilrs.gsfc.nasa.gov/docs/timing/sr620_manual.pdf
23. GTR50 - Time and frequency transfer receive, http://www.dicom.cz/en/product/873-time-frequency-transfer-receiver
24. Petit G., Jiang Z., Moussay P., White J., Powers E., Dudle G, Uhrich P., Progresses in the calibration of geodetic like GPS receivers for accurate time comparisons, Proc. 15th EFTF, p.164, 2001a
25. Petit G., Jiang Z., White J., Beard R., Powers E., "Absolute calibration of Ashtech Z12-T GPS receiver", *GPS Solutions* 4 (4), 41, 2001b.
26. White J., Beard R., Landis G., Petit G., Powers E., Dual frequency absolute calibration of a geodetic GPS receiver for time transfer, Proc. 15th EFTF, p. 167, 2001
27. Petit G., TM116, July 2002, Estimation of the values and uncertainties of the BIPM Z12-T receiver and antenna delays, for use in differential calibration exercise, ftp://tai.bipm.org/TFG/CALIB_GEO/tm116.pdf
28. Petit G. et al 2011 The time stability of PPP links for TAI, Proc. EFTF 2011
29. Jiang Z., W. Lewandowski, G. Panfilo and G. Petit (2011) *Reevaluation of the Measurement Uncertainty of the UTC Time Transfer*, Proc. PTTI 2011 pp 133-140
30. Lewandowski W., D. N. Matsakis, G. Panfilo and P. Tavella 2005 *On the Evaluation of the Uncertainties in UTC-UTC(k)*, Proc. EFTF 2005, March 2005, Besançon, France, p. 83
31. Piester D., Bauch A., Breakiron L., Matsakis D., Blanzano B. and Koudelka O. 2008 Time transfer with nanosecond accuracy for the realization of International Atomic Time *Metrologia* 45 pp 185–98
32. M. Weiss, V. Zhang, J. White, K. Senior, D. Matsakis, S. Mitchell, P. Uhrich, D. Valat, W. Lewandowski, G. Petit, A. Bauch, T. Feldman and A. Proia, « Coordinating GPS Calibrations Among NIST, NRL, USNO, PTB, and OP », Proc. of the Joint Meeting of the 25th European Frequency and Time Forum (EFTF) and the IEEE Frequency Control Symposium, San Francisco, USA, 2-6 May 2011, pp 1070-1075
33. Jiang Z. and Lewandowski W*, Some remarks on the CCTF CGGTTS format*, **Proc. EFTF 2011**, pp 317-322
34. BIPM *Circular T 303*, ftp://ftp2.bipm.org/pub/tai/publication/cirt.303
35. http://www.bipm.org/utils/common/TimeCalibrations/GPS_P3/P3_calib_TL.pdf
36. http://www.bipm.org/utils/common/TimeCalibrations/GPS_CA_code/TL.pdf
37. TM235, UTC calibration report-- *MEasurement of TOtal DElay for UTC Time Link Calibration,* Phase VIII: Measurements at and between PTB and ROA