Tests of the BIPM Portable Calibration Station - METODE: MEasurement of TOtal Delay

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Abstract—The dominant part of the total uncertainty budget in the UTC time transfer is from the time transfer link calibration. To improve the calibration, the BIPM is developing a standard calibration procedure in which we use a portable calibration station. It is composed of a 10 MHz distributor, a PPS distributor and two GNSS geodetic systems each including a set of an independent receiver and an antenna. The station is integrated and pre-cabled. The visited laboratory should provide the 10 MHz signal and the 1 PPS signal with a known delay to the laboratory reference. The goal is to provide a link calibration with a 2 ns type B uncertainty for UTC time transfer. In this paper, we outline the first experiments carried out on the common-clock zero and short baselines at the BIPM.

Key words: Calibration, uncertainty, time transfer

I. INTRODUCTION

The UTC link calibration is a classical method to calibrate a time link or keep the calibration continuity in the routine computation practice of the BIPM *Circular* T. We have a typical procedure, namely the alignment, to align or to transfer one link calibration to another link, e.g., from a TWSTFT link calibration to an uncalibrated GPS link [1], and vice versa. In fact, half of the TW links are calibrated by GPS links. The corresponding type B uncertainty (u_B) is also transferred. The type B uncertainty in the calibrations is the dominant part in the total uncertainty budget in the *UTC-UTC*(k) in the *Circular T* [2].

Since 2007, more and detailed issues related to the GNSS link calibrations have been investigated. TW links have already been used to calibrate GPS PPP [1]. The GPS MC link BEV-PTB was the first link for which such a calibration [3,4] was officially applied, with a u_B value of 3 ns . The study [4], proved that we can convert the link calibration to the absolute receiver calibration if at least one of the receivers in the network is absolutely calibrated. Jiang et al.[5] generalized the link calibration to all the *UTC* time link calibrations of different techniques and estimated the reachable u_B. [6,7] carried out link calibrations using a traveling GPS receiver and realized the link calibrations on the baselines ROA-PTB and CH-PTB. The u_B was reported to be less than 2 ns.

The procedure to operationally implement such link calibrations is under development at the BIPM. It also considers the evolution of the u_B values with time after the calibration; cf. [5] for details.

II. THE METODE (MEASUREMENT OF TOTAL DELAY)

A. *The total delay of a GNSS receiver: Dly_R*

The *total delay of a GNSS receiver* (Dly_R) at Lab(k) is the total electronic delay between the phase center of the antenna and the UTC point $UTCP_k$. It is the sum of all the delays of all the pieces of equipment including the receiver, the splitter(s), the frequency distributor(s), the amplifier(s), the phase micro stepper(s) … plus the cables/connectors between the antenna and the receiver as well as the cables between all the laboratory equipments, including the Δ (see the left plot in Figure 1). As shown in plot, the delay on the path of the satellite signal from the antenna to the $UTCP_k$. If the calibration point $CLBP_i$ and $UTCP_i$ are not the same, the delay between them is the Δ which should be measured by the Lab(*k*).

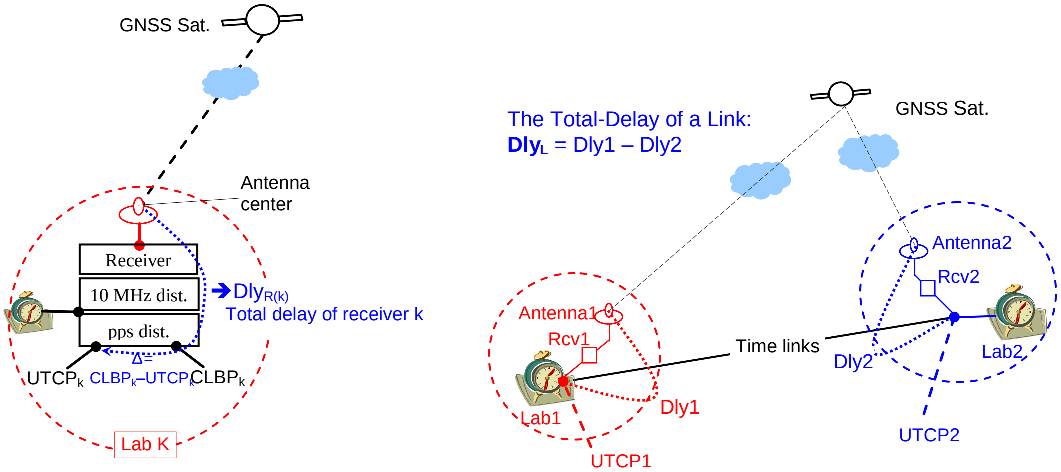


Figure 1. *Left*: "Total Delay" of a "Receiver" at Lab(*k*); *Right*: "Total Delay" of a "Link" between Lab1 and Lab2. The calibration result is then the Total-Delay of a Link: Dly_L = Dly1 – Dly2.

B. *The total delay of a GNSS time link: Dly_L*

The total delay of a receiver (Dly_R) as defined above is not measurable only with the BIPM link calibration scheme. The Dly_R serves here only to define the Dly_L, the total delay of a time link between Lab(*i*) and Lab(*j*). The Dly_L can be determined by the BIPM scheme:

$$Dly_L(i - j) = Dly_R(i) - Dly_R(j)$$

For a UTC link with *j*=PTB, it becomes:

$$Dly_L(k - PTB) = Dly_R(k) - Dly_R(PTB).$$

The total delay of a link Dly_L is the CALR in the case of a TW link. However, the methods to obtain them are quite different. The "Time link" in the right plot in Figure 1 is an arbitrary link of either GPS or GLONASS or TWSTFT. It illustrates the configuration of the geometry of the Dly_L which is directly measurable in the BIPM scheme; cf. [4] for details.

III. THE SETUP

Figure 2 illustrates the general set-up up of the BIPM calibration scheme at the Lab(*k*). Here the "time transfer equipment" represents one or all the time transfer techniques: TW, GLONASS and GPS C/A, P3 and PPP, etc. The configuration between the pulse distributor driven by the master clock and the receivers of Lab(*k*) as well as the BIPM traveling standard is demonstrated. The traveling receivers and related equipment is installed in the BIPM standard calibration station Std_B (Figure 2), composed of two GPS geodesic receivers driven by the same master clock as the receiver(s) at Lab(*k*). The pulse passes first through the $CLBP_k$ of the distributor, then goes through the BIPM receiver cables, and goes to the splitter in the station where it is separated into two signals going to the two BIPM individual standard receivers, Std(1) and Std(2). The delay of the ensemble of the BIPM Std from the antennas to the $CLBP_k$ is fixed and therefore the same at all the Labs and will be canceled in the time links. The difference of the links of the Std_B-PTB and that of the Lab(*k*)-PTB is what we look for, the *link* calibration correction.

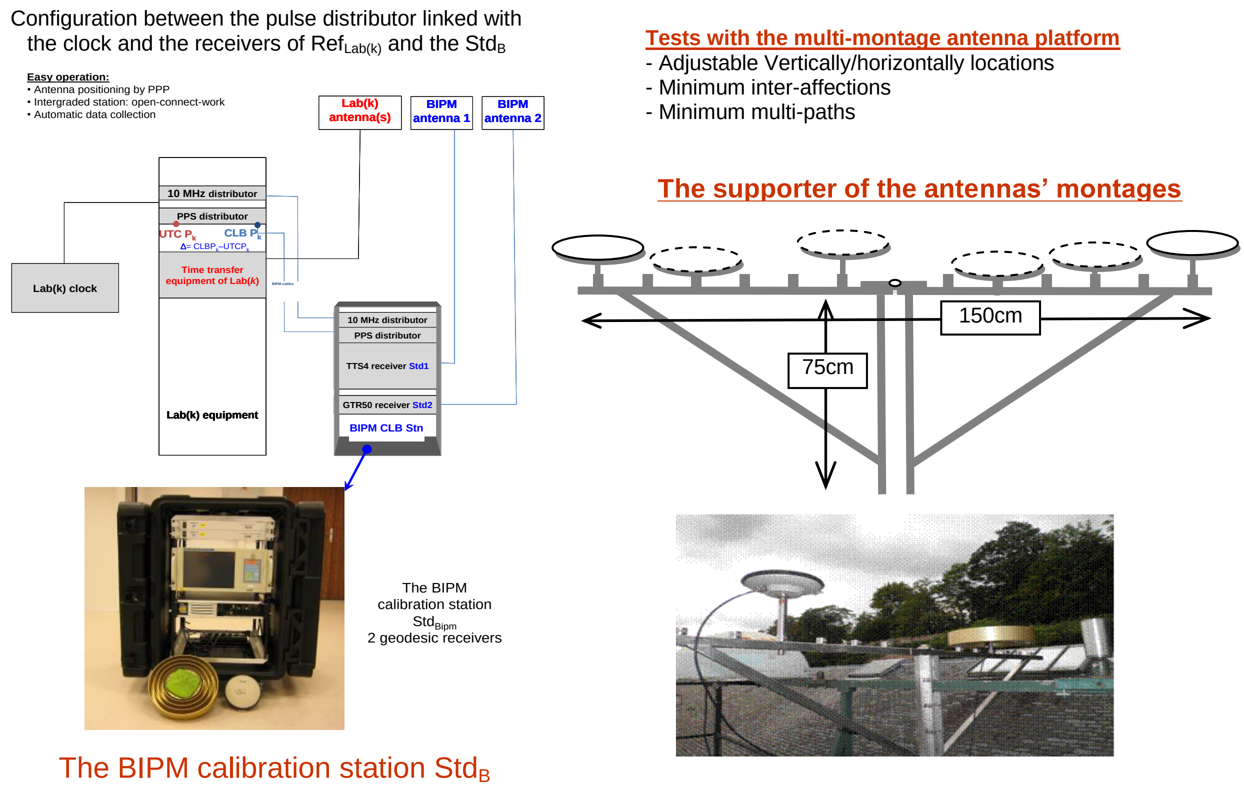


Figure 2. The BIPM calibration station and experiment setup inside of the laboratory and on the roof of the Observatoire building

IV. EXPERIMENTS

A. Cable delay measuring on a common-Clock Baselines

A first experiment is to add and remove one or several delay-known cables and then we measure the cable delays by using the METODE. We then compare the delays obtained by the two methods: the direct measured delay and that of the METODE. We tested different configurations of the add/remove cables with different receivers using different frequency/PPS inputs. One of them is as illustrated in Figures 3 and 4, where we added and then removed a cable between the output 2 of the 1 PPS distributor installed in the BIPM calibration station and that of the input of the receiver GTR50, as shown in the Figure 3. A delay of 15.1 ns for the 3.0 m cable was measured by both methods: the direct measurement with a TIC and the effect on the CGGTTS data of the METODE. See Figure 4 for the 15.1 ns offset due to the change of the cables on the common-clock short baseline. In this example, only the result of the receiver GTR50 vs. the Z12T is presented.

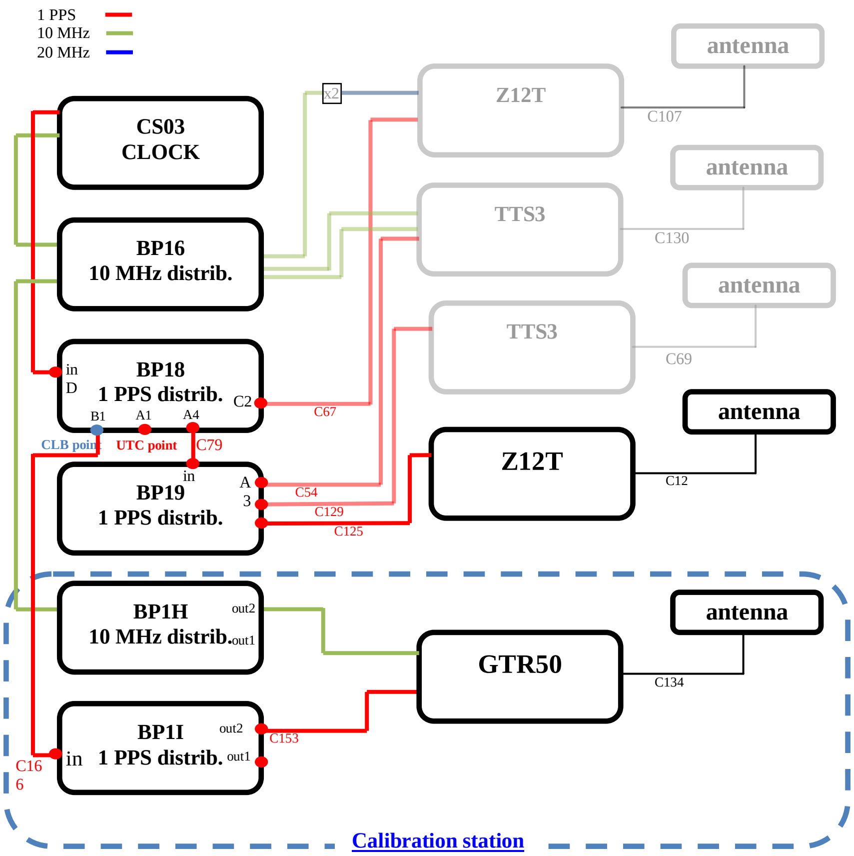


Figure 3. Configuration of the clock, CLBP, UTCP and the calibration station.

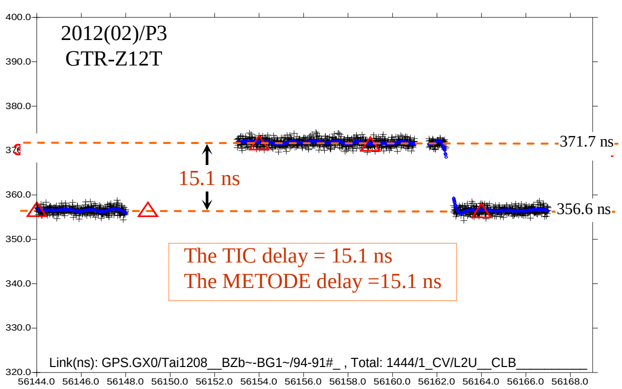
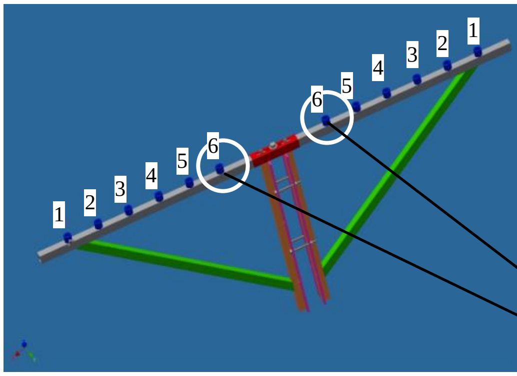


Figure 4. The common-clock experiment between the METODE GTR50 and a Z12T reference receiver is used to measure the delay changes caused by inserting/removing a cable .

B. Distance measurement on a common-Clock very short baseline

The second experiment is designed to test the accuracy and the precision through the distance measurements. As can be seen in Figure 5 and the associated table, the antenna supporter is 1.5 m long with a fixing point every 10 cm, on which two antennas can be installed. By changing the positions of the two antennas, we can determine the relative distances between them. The METODE data are processed with Precise Point Positioning and the PPP distances are compared with the distances measured between the fixing points. The results are given in the associated table in Figure 5, the differences for distances varying from 0.33 m to 1.33 m are typically a few mm with a maximum -0.0123 m in length or 41 ps in time. This reflects the uncertainty in the PPP solutions, and must also include the impacts of the multi-passes and the possible inter-influences between the two antennas.



Uncertainty in measuring the distances

Baseline	Known Distance /m	Re-found distance by PPP	Difference /m	Difference /ps
1-1	1,3338	1,3306	-0,0032	-11
2-2	1,1338	1,1252	-0,0086	-29
3-3	0,9338	0,9215	-0,0123	-41
4-4	0,8338	0,7231	-0,0107	-36
5-5	0,5338	0,5323	-0,0015	-5
6-6	0,3338	0,335	0,0012	4

Figure 5. The distances measured on the common-clock short baselines.

V. SUMMARY

More attention should be given to the link calibration for the application in UTC time/frequency transfers. Some successful experiences have demonstrated that type B uncertainty can be of the 2 ns. This could be possible for the use in the UTC time transfers. To do this, we do not really need the traveling receivers to be calibrated. The BIPM has undertaken studies and developed hardware in the aim of developing the link calibration:

- Theoretical works: convert link calibrations to receiver calibrations and uncertainty estimates;
- Software development: installed in the UTC/TAI software package Tsoft;
- Hardware preparation: BIPM portable calibration station METODE.

A pilot experiment over Asia-Europe is planned.

The final goal is to achieve uncertainties $u_B < 2$ ns (degrading with time) and $u_A \leq 0.3$ ns for all major *UTC* time links.

ACKNOWLEDGMENT

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