The Comparison Between TWSTFT and GPS Time Transfer Result of PTB-TL LINK

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***Abstract*—In this paper we compare the PTB-TL time transfer link data of TWSTFT and GPS carrier phase solutions. We investigated in detail the double difference between the time transfer data of TWSTFT and GPS IGSC/TAIPPP. Our results show the PTB-TL link has a conspicuously diurnal effect. The periodicity is almost exact 1 day and the peak-to-peak amplitude is about 1~1.5 ns. We also found a phase drift which is about 5 ns between TWSTFT and GPS data during a period of 130 days.**

I. INTRODUCTION

TL has devoted to the establishment of intercontinental Two-Way Satellite Time and Frequency Transfer (TWSTFT) links in recent years. After the first Europe-Asia (TL-VSL) link has been set up in 2003 [1], [2], we successfully established the PTB-TL TWSTFT link in early 2008. It's an important link because the international UTC time transfer network is a one-pivot system, in which PTB currently is the pivot point and all UTC time laboratories are directly linked to PTB through either GPS or TWSTFT. The provided data of the PTB-TL TWSTFT link hopefully contribute to the TAI and UTC calculations in near future.

Since the GPS carrier phase shows the best time transfer ability in short term and the TWSTFT perform the best long term time transfer accuracy, a comparison between those two methods is to clarify the details of TWSTFT results in short term stage.

The aim of this paper is to compare the results of GPS carrier phase time transfer and TWSTFT of the PTB-TL link, and then characterize their difference especially for the diurnal effect. The TWSTFT ground stations' instruments of PTB and TL are listed in Table I. Here we note that the SSPA and UP/Down converter at TL02 station is located outdoors, so that these two devices may be influenced by local environment conditions such as temperature. For the data of GPSCP, we use the final time scale of IGS [3] (International GNSS Service) product in all cases; the IGSC (final time scale of the IGS result) data are also the results of the BIPM TAIPPP [4] (BIPM TAI links in the Precise Point Positioning pilot experiment) solutions. Here we choose IGSC as our short term reference. Some details of the GPSCP link between PTB-TL are listed in Table II.

We investigate the double difference between the time transfer data of TWSTFT and IGSC of the link PTB-TL and we fit in a second step the diurnal of TWSTFT data using a sinusoidal function. The fit parameters we get the period and amplitude of the diurnal variations. We will discuss its possible sources, but we do not develop a detailed model of the diurnal variation in this paper.

TABLE I. INSTRUMENTS DETAILS OF PTB/TL LINK

Ground station	***PTB03 (NICT-design)***	***TL02***
Antenna	Vertex 2.4 m	Andrew 2.4 m
Modem	SATRE (280)	SATRE (066)
SSPA	Advantech (Outdoor)	Codan 5908 **(Outdoor)**
UP/Down Converter	Radyne ComStream (lab)	Codan 5900 **(Outdoor)**
IF Cable	Only short connections (3-4 m)	Andrew SFJ1-50A
Counter	internal	External (SR-620)
OP and Analyzing SW	continuously controlling modem and switches	Automatically hourly operating by TL
Others	70 MHz BP filter 1km optical fiber RF-connection between lab and antenna	70 MHz BP filter

TABLE II. GPS CARRIER PHASE DETAILS OF PTB/TL LINK

	PTB	***TL***
Receiver	Ashtech Z-XII3T	Ashtech Z-XII3T
Reference	UTC(PTB)	UTC(TL)
IGS and BIPM TAIPPP site	ptbb	twtf

II. TIME TRANSFER RESULTS AND THE DIURNAL

We examined the TWSTFT and GPSCP data from MJD 54770 to 54900, about 130 days. First, we compared TWSTFT and 3 different GPS solutions, namely IGSC, TAIPPP, and UTC(PTB)-UTC(TL) as published in the BIPM Circular T. Figure 1 shows these 4 kinds of time transfer results. From Figure 1, we find the TAIPPP (blue) and IGSC (green) are almost the same and match the result of Circular T (red). It's reasonable because the BIPM uses for the TAI link of PTB-TL the GPS P3 all in view computation.

The TWSTFT result shows a slight offset of about 5 ns to the GPS solutions. We also identify a diurnal variation in the TWSTFT results in the entire examined period.

To emphasize the diurnal effect, we calculate the double difference between TWSTFT and IGSC results of PTB-TL link. Figure 2 shows the diurnal is become clearly apparent

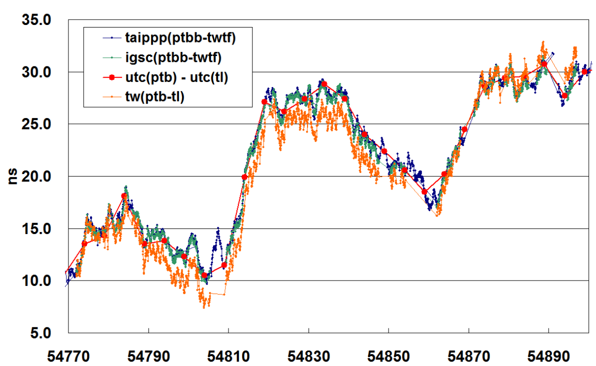

Figure 1. The result of TW, IGSC, TAIPPP, and Circular T of PTB-TL

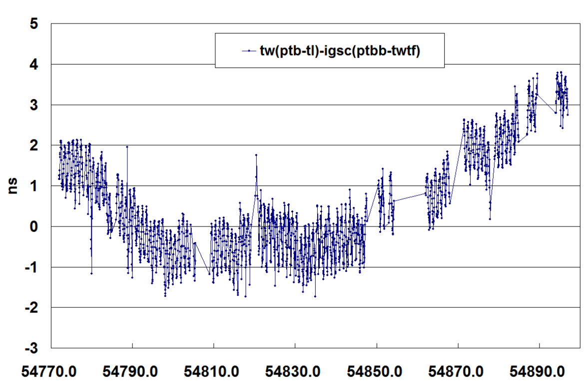

Figure 2. Double difference between TWSTFT and IGSC results

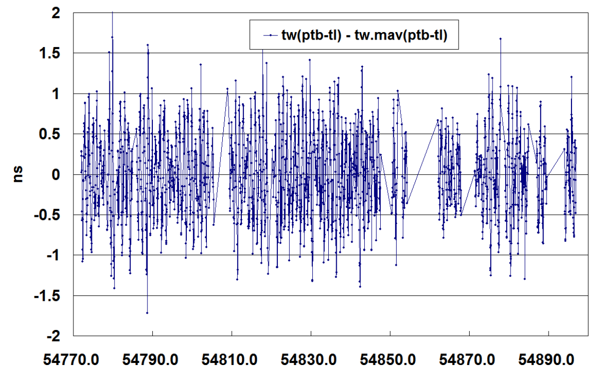

Figure 3. Difference between TWSTFT and its moving average result

when compared with Figure 1, but we also find there is a phase drift between both completely independent solutions, so that it is not easy to determine the amplitude of the diurnal directly from this data. To estimate the amplitude, we exchange the data of GPS carrier phase solution by a 24 hours moving average of TWSTFT results. We assume that the daily fluctuation will vanish when we average over a whole period (about 24 hours) of the diurnal. The result is showed in Figure 3, the average peak-to-peak amplitude of diurnal is about 1 ns, and as large as 1.5 ns in some periods.

III. SINOUAL FIT OF DIURNAL

To take a closer look to the diurnal variations, we fit the difference between the TWSTFT data and its moving average by using a sinusoidal function. We hope the precise parameters of amplitude and period will help us to model the diurnal in future.

We use a simple fitting function: 3 parameters for amplitude, period, and the shift of period are determined by minima the standard deviation of {(TWSTFT results) – (24 hours moving average of TWSTFT results) – (fitting sinusoidal function)}. The final fitted sinuous function is illustrated below:

$$\text{Diurnal} \cong 0.51\text{ns} \cdot \mathit{sin}\,(\text{MJD}-0.67). \qquad (1)$$

From (1) we see that the peak-to-peak amplitude of is about 1.02 ns, it is consistent with the observation from Figure 3. The period of (1) is exactly 24 hours and the period shift is about 2/3 day. To verify this simple approach, we remove the phase of (1) from the TWSTFT results, and than form the double difference between the residuals and IGSC results (Figure 4). Obviously, the main diurnal effect vanishes in all 130 days examined time that means (1) can be used for describing the diurnal variations.

In frequency domain, Figure 5 shows the Allan deviation of the double differences between TWSTFT and IGSC result before remove of the diurnals (1) (blue line) and thereafter (1) (red line). The blue line exhibits clearly periodic bulges when the average time equals to 0.5 day and its odd-numbered harmonics. After removing the phase of (1), all bulges vanished. If the period of diurnal would slightly changes with time, some bulges and its harmonic would remain. Figure 5 also proofs the period of diurnal is exact 24 hours.

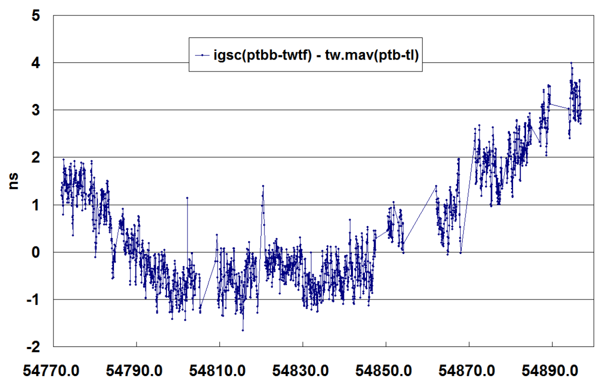

Figure 4. Double difference between TWSTFT and IGSC results, sinuous fit removed

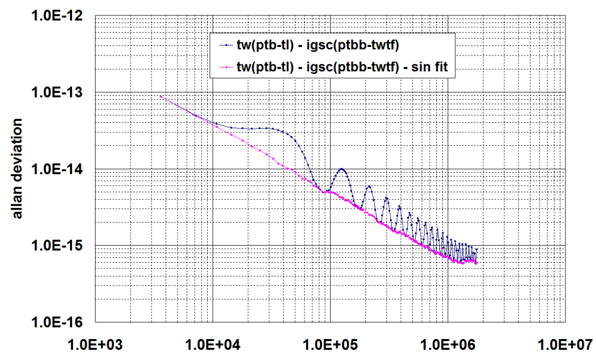

Figure 5. Double difference between TWSTFT and GPSCP, frequency domain

IV. SUMMARY AND DISCUSSION

Through the analysis, we find the peak-to-peak amplitude of the diurnal of the PTB-TL link is about 1~1.5 ns, and its period is exact 24 hours during the period of observation of 130 days. Here we don't discuss the source of the amplitude of the diurnal variations, which is not understood at present. Because we found that the period of the diurnal is exactly 24 hours, we identify internal delay variation of the communication satellite we use for the PTB-TL TWSTFT link as a possible candidate. The exposure of the satellite by sun radiation may cause internal temperature variations and change the propagation path delay of the transmitted signal.

In Figure 4, one can see that even if we remove the fitting function (1) from the TWSTFT results, there is still a several hundred pico-second level periodical effect remaining from MJD 54820 to 54850. Another possible candidates are environmental effects at the ground stations [5]; the daily cycle of temperature also generally cause a change of the internal propagation delay, but its period could not be exact 24 hours. In future we want to check the other existing Europe-Asia TWSTFT links i.e. the ones between OP-TL and PTB-NICT to find out the source of diurnal variations.

We also note there is a phase drift in the time transfer solutions between TWSTFT and GPS in the PTB-TL link, which is about 5 ns in 130 day. This matches to the type B uncertainty of the PTB-TL TAI link (4.8 ns in BIPM Circular T report). We hope we will to find out the source of it because this PTB-TL TWSTFT link will hopefully contribute to the TAI and UTC calculations in near future.

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