Long-term Inconsistency between TWSTFT and GPS Time Transfer Results in PTB-TL and NICT-TL Time Links

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ABSTRACT

In this paper, we compared the TWSTFT and GPSPPP data for the PTB-TL, PTB-NICT, and NICT-TL time transfer links. We investigated the double difference between the time transfer data of TWSTFT and GPSPPP from 2005 to 2010. The results show two time transfer techniques had a conspicuously inconsistency and the patterns of double difference results were similar in PTB-TL and PTB-NICT links. The double difference results of all direct links exhibited the annual varying patterns, whose peak-to-peak phase difference in 1-day moving average are 4.5 ns both for the PTB-TL and PTB-NICT links, and 2 ns for NICT-TL link.

INTRODUCTION

The two-way satellite time and frequency transfer (TWSTFT) and GPS time transfer (GPSTT), such as GPS P3 All-in-View (GPSP3 AV) and GPS precise point position (GPSPPP), are the most accurate techniques in long baseline time transfer. In order to take both of their advantages by combining the TWSTFT and GPSTT data especially for their data alignment [1] or for using one result to calibrate the other one [2], it is necessary to clarify their long-term difference between each other at first. Many articles have compared the difference between GPSTT and TWSTFT. Some studies showed the time transfer results by GPSP3 AV and GPS common view (GPSCV) agreed well with TWSTFT in the level of 5 ns [3][4][5][6]. However, in recent studies, the double difference of GPSPPP and TWSTFT showed inconsistency with an obvious slope [7][8].

The aim of this paper is to verify the long-term consistency between TWSTFT and GPSTT data. The PTB-TL and NICT-TL links are investigated as the typical Euro-Asia and Asia-Pacific time links. The link PTB-NICT is also used for comparison.

DATA

The TWSTFT and TAIPPP data from 2009 to 2010 are examined in this study. The TW PTB-TL and PTB-NICT links are choosen as the long baseline example, and the NICT-TL as the regional example. The basic facilities for these links are listed in table I and table II. Since the indirect NICT-TL TW result can be obtained from the relay calculation via PTB, we also compared the results between NICT and TL for different geo-satellites and TW modems (IS-4 for Satre modem, IS-8 for NICT modem). For conducting the continuely long-term comparison, the NICT-TL link via JCSAT-1B were also examined from 2005 to 2009 as 4-year-longterm reference. The related position of each ground stations and satellites are showed in Figre 1.

TABLE 1. Information for TWSTFT Links

TW LINK	PTB/TL	PTB/NICT	NICT/TL	
Modem	SATRE	SATRE	NICT	
Reference	UTC(PTB)	UTC(NICT)	UTC(TL)	
Baseline	8376 Km	8321 Km	2113 Km	
Satellite	IS-4@72 E	IS-4@72 E	IS-8@166 E	JCSAT-1B@166 E
Period (MJD)	54544-55228	53669-55228	≧ 54958	53553-54921

TABLE 2. Information for GPS sites

GPS site	PTB	NICT	TL
Receiver	Ashtech Z-XII3T	Septentrio PolaRX2 TR	Ashtech Z-XII3T
Reference	UTC(PTB)	UTC(NICT)	UTC(TL)
TAIPPP site	ptbb	nict	twtf

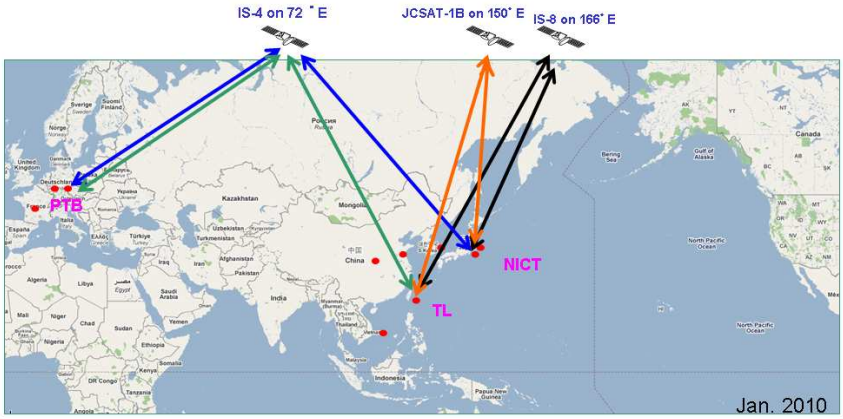

Figure 1. Position of ground station of PTB, NICT, and TL

DOUBLE DIFFERENCE RESULT

At first, two Euro-Asia links, PTB-TL and PTB-NICT, were examined. Figure 2 shows the difference between time transfer results of TWSTFT and GPSPPP, for PTB-NICT link with red dots and PTB-TL link with blue dots. The plots for both links show similar annual varying patterns. The local maxima appear at the beginning of the year (red vertical line) and the local minima appear at the middle of the year. After the 1-day moving average calculation, the peak-to-peak phase differences of the two patterns are about 4.5 ns.

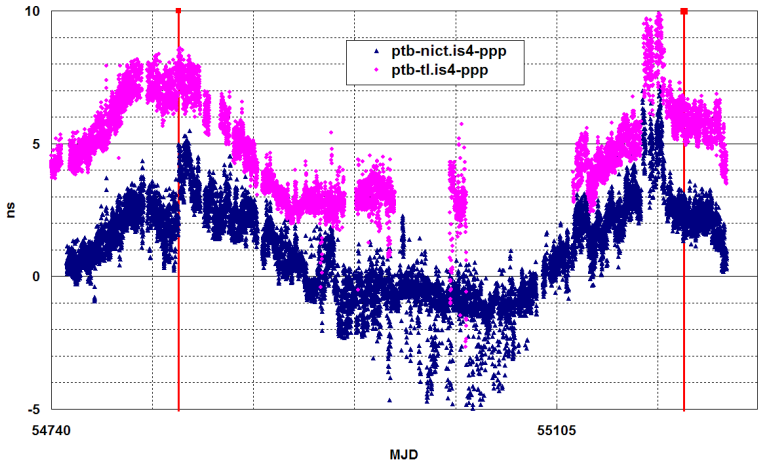

Figure 2. Difference between TWSTFT and TAIPPP, PTB-NICT (red dots) and PTB-TL (blue dots) links

Secondly, we examined the Asia local link. Figure 3 shows the double difference between three kinds of time transfer results for NICT-TL link. They are the NICT-TL direct TW link, the NICT-TL relay TW link via PTB, and NICT-TL GPSPPP link. The difference between the direct link and GPSPPP has a slope about 3 ns/270 days (blue dots). The relay link via PTB agrees well with the GPSPPP result, around ±1 ns range in 400 days (green dots). The direct and indirect TW links were also compared here. Their difference shows an observable slope about 3 ns/270 days, which is the same as the difference between GPSPPP and direct TW link.

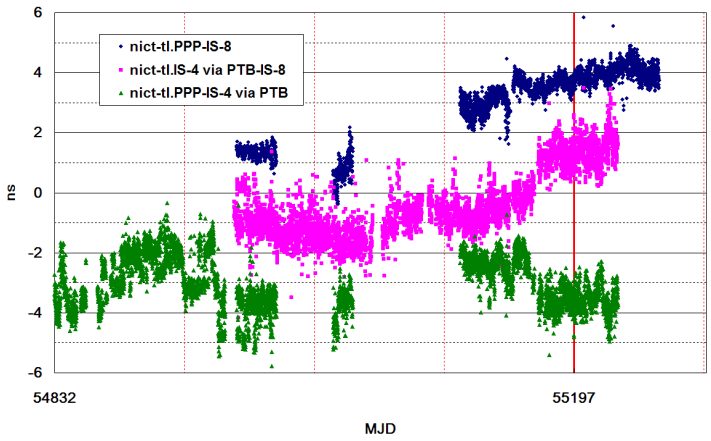

Figure 3. Double difference between 3 kinds of time transfer results of NICT-TL link, GPSPPP-direct TW link (IS-8 link, blue dots), GPSPPP-relay TW link (IS-4 via PTB, green dots), and relay TW - direct TW link (red dots)

The inconsistencies between TWSTFT and GPSPPP have been shown above. In order to verify whether the annual cycle exists in the time transfer data or not, we checked the NICT-TL link from 2005 to 2009. Because the GPSPPP data for NICT-TL link were not available before 2009, we employed the GPS P3 all in view data here. Figure 4 shows that the double difference result between TWSTFT and GPSP3 AV for NICT-TL link appears the similar annual pattern. The local maxima appeared in the beginning of one year except 2006 (red vertical line), and its peak-to-peak phase difference of 1-day moving average is about 2 ns.

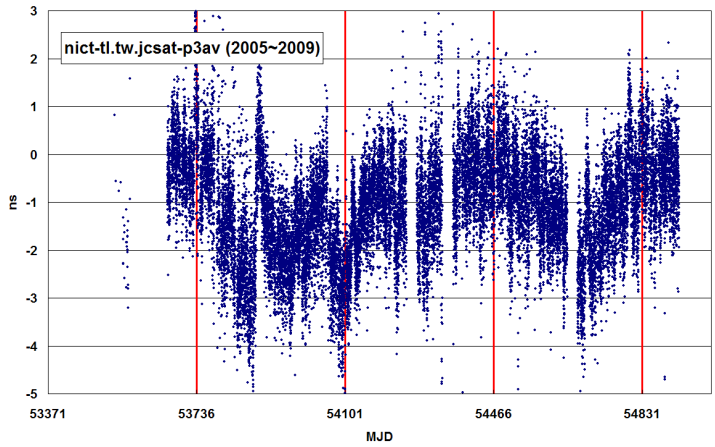

Figure 4. Double difference between TWSTFT and GPSP3 AV for NICT-TL link.

SUMMARY AND DISCUSSION

The analysis of the long-term data shows the difference between TWSTFT and GPSTT results has an annual pattern and their peak-to-peak phase difference would be up to 4.5 ns in long baseline Euro-Asia link and to 2 ns in local area. We suspect the cause of difference might partly come from the TWSTFT, for the reason that the NICT-TL GPSPPP and TWSTFT relay link are consistent within ±1 ns. We guess some effects come from the satellite may vanish in relay calculation, but appear in the direct link.

We noticed that the source of the annual pattern should be global and anniversary. For TWSTFT, the time error may come from satellite movement, ionosphere delay, troposphere delay, station delay instability, and measurement noise [9][10]. The difference of 4.5 ns means about 1 meter path delay in cable; however, the station delay instability would not cause such amount of delay. The troposphere delay and measurement noise should not be a global effect. Therefore, the possible suspect for the annual pattern may be the satellite movement or ionosphere effect. It suggests that it is necessary to employ the real ephemeris of the TWSTFT geo-stationary satellite for investigating the TWSTFT path non-reciprocity.

Excluding the annual pattern, we found the difference between GPSPPP and TWSTFT was around 1 ns; mainly coming from the diurnal effect. It implies if the pattern can be modified, the inconsistency of TWSTFT and GPSPPP would be reduced into 1 ns. Furthermore, if the diurnal could be corrected, the inconsistency of TWSTFT and GPSPPP would be reduced into hundreds of ps, and it would be a great improvement of the systematic uncertainty of both TWSTFT and GPSPPP.

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