Assessment of Time Transfer Performance between TWSTFT and GPS Carrier Phase at KRISS

Sung Hoon Yang, Chang Bok Lee, Seung Woo Lee, Young Kyu Lee
Division of Physical Metrology
KRISS
Daejeon, Republic of Korea
shyang@kriss.re.kr

Youn Jeong Heo
Dept. of Astronomy and Space Science
Chungbuk University
Cheongju, Republic of Korea

***Abstract*— By the use of Global Position System (GPS) carrier phase and Two-way Satellite Time and Frequency Transfer (TWSTFT) measurements, a set of time comparisons has recently been conducted world-wide. Those time transfer methods have been conducted between Korea Research Institute of Standards and Science (KRISS) and other National Metrology Institutes (NMIs). The GPS time transfer can be routinely conducted at KRISS and the TWSTFTs are utilized as well. The GPS all-in-view time transfer method is currently officially utilized by BIPM for the computation of International Atomic Time (TAI), while time transfer by carrier phase method still needs more researches. Since the precision that carrier phase measurements can provide is much higher than that of P code, some effects that could be safely ignored in P-code time transfer should be accounted for in order to fully utilize the precision of the carrier phase measurements. We present the comparison results between TWSTFT and GPS time transfer using carrier phase and P3 code for several months.**

I. INTRODUCTION

According to the development of atomic clocks and of industry, more precise time transfer is necessary for time comparison and synchronization. For these reasons, the methods of the GPS time transfer and TWSTFT have been studied continuously in order to develop and increase the accuracy and precision of comparison. GPS in the time transfer has been dominated by the technique of common view C/A code since 1980s. But GPS carrier phase time transfer is more than an order of magnitude more precise than the code time transfer for 1 day [1]. Therefore recently many institutes devote themselves to utilization of this technique for time transfer.

KRISS has constructed three TWSTFT stations since 2002: one is for Asian link, another is for Oceania link and the other is for Europe link as shown in Fig. 1. In addition to, we have also equipped GPS time transfer receivers for P3-code and carrier phase methods. Now we have been operating several types of GPS receivers such as TTR6s, Euro-80, R100-40T, and Ashtech Z12Ts [2].

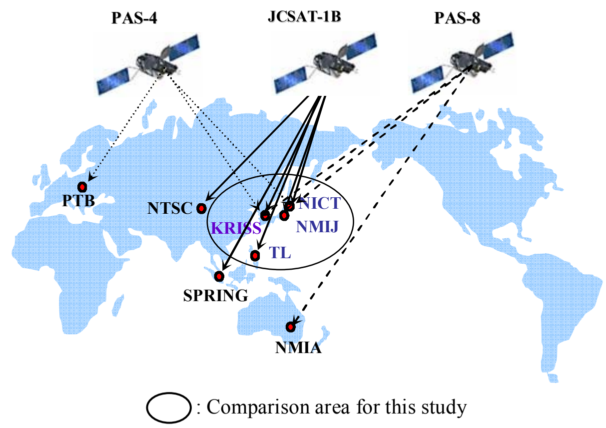


Figure 1. TWSTFT Links with KRISS

This assessment of comparisons performance of P3-code, GPS carrier phase time transfer and TWSTFT were conducted for three links which are KRISS/NICT, KRISS/NMIJ and KIRSS/TL. Time comparisons have been carried out using a GPS Ashtech Z12T receiver and a two-way satellite time transfer system using a multi-channel modem via JCSAT-1B satellite. For evaluating P3-code measurement, we used the data from BIPM file server. We are also developing a software, named GV4, for processing carrier phase time comparison. In this pare we processed the carrier phase data using the software. We present the comparison results between TWSTFT and GPS time transfers by carrier phase and P3 code data set collected for seven months (Aug. 31, 2006 ~ Mar. 31, 2007) .

II. TIME TRANSFER METHODS

Fig. 2 represents the participant time transfer institutes and methods for these comparisons, and Table 1 shows the distance between KRISS and each institute.

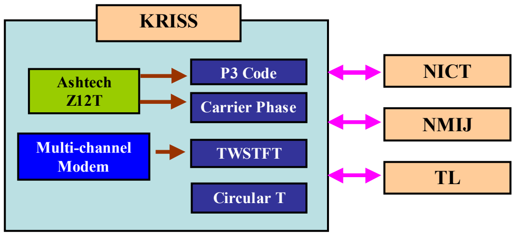


Figure 2. Participant institutes and methods for this time comparion with KRISS, and the used equipment used for this comparison.

TABLE I. DISTANCE BETWEEN KRISS AND EACH INSTITUTE.

NICT (Japan)	1093 km
NMIJ (Japan)	1146 km
TL (Taiwan)	1397 km

As shown in Fig. 2, we have conducted the evaluation and comparison with the four method types: 1) all-in-view P3-code, 2) common-view carrier phase, 3) TWSTFT, 4) Circular T issued by BIPM. . Here all compared UTC(k)s have been maintained by Hydrogen Maser.

The modem used for TWSTFT via JCSAT-1B is a multi-channel model based on the code division multiple access (CDMA) technique. Simultaneous time transfer among 7 institutes can be conducted by employing a modem. It is observed that one extra channel in the modem is dedicated to measure the signal path delay in order to account for the temperature variations and unexpected events occurred during signal travel [3]. At this comparison, we processed data of four institutes as mentioned above, by generating Receiver INdependent Exchange (RINEX) format files.

For the GPS time comparison, geodetic receivers are generally used to measure pseudo-range and collect carrier phase measurements [4]. Two geodetic receivers are now in operation at KRISS and are continuously retrieving code and phase measurements from all observable satellites at both L1 and L2 frequencies. The receivers are referred to 20 MHz and 1 pulse per second (PPS) signals from a hydrogen maser generating UTC(KRIS). The code and phase measurements recorded by the receivers are stored at every 30 seconds in RINEX format files. It is well known that some corrections to the time transfer measurements should be made in order to achieve a higher precision: for example, applying precise orbit data and eliminating ionospheric and tropospheric delays. A software GV4 is used to analyze the GPS carrier phase data. The input data to the software for the GPS time comparison are obtained from the RINEX files, and the GPS carrier phase and pseudo-range data are processed together with the precise GPS orbit information provided by the International Global Navigation Satellite System (GNSS) Service. The effect of ionosphere delays is removed by applying the ionosphere-free combination of L1 and L2 carrier phase data, while tropospheric delay is removed by using Saastamoinen's model with the given standard atmosphere values of temperature, atmospheric pressure and vapor pressure coefficients. We used

TABLE II. GENERATION OF DATA SET

	TWSTFT	GPS CP	GPS P3
Sample period	1 hour	5 min.	16 min.
Sample interval	1 s	30 s	30 s
Averaging No.	300	10	26
Comparison Method	Two-way	Common-view	All-in-view
Period of data	MJD 53978 ~ MJD 54190 (Aug. 31, 2006 ~ Mar.31, 2007)		

the estimation strategy for receiver clock offset as follows; weighted least square estimation, IGS final orbit, Neill's mapping function, Zenith wet delay and ambiguity estimated, Satellite antenna offsets and phase wind-up, etc. For generating the each data set, we employed the rules as shown in Table 2.

III. TIME COMPARISON RESULTS

With the use of above methods, we got the results that P3 code, carrier phase and TWSTFT. We plotted all comparison results in a figure in order to discriminate the correspondences and to find the discrepancy among them. As shown in Fig. 3, the all comparison results of UTC(KRIS)-UTC(NICT) agree with well, however as shown in Fig. 6 and 9, UTC(KRIS)-UTC(NMIJ) and UTC(KRIS)-UTC(TL) have less than ten nanoseconds offset between TWSTFT and other methods which are the results of P3-code, carrier phase and Circular T. This is caused by the reason why the calibration between KIRSS and NICT was performed in October, 2006 using portable station, while the other institutes have not done yet. We calculated the Allan deviations of each result and evaluated the residuals of difference between each time transfer data and its own smoothed curve in Fig. 4, 5, 7, and 8. We can hereby observe that the all time transfer results between KRISS and NICT are slightly better than those of other institutes.

A. *Comparison Results between UTC(KRIS) and UTC(NICT)*

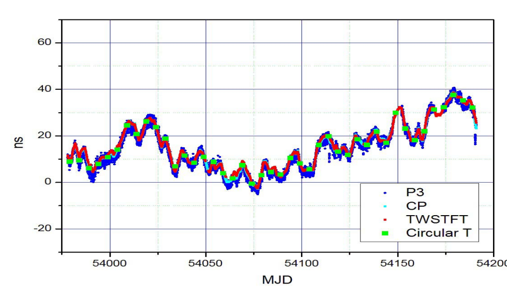


Figure 3. Comparison results between UTC(KRIS)-UTC(NICT) by P3-code, carrier phase, TWSTFT and Circular T.

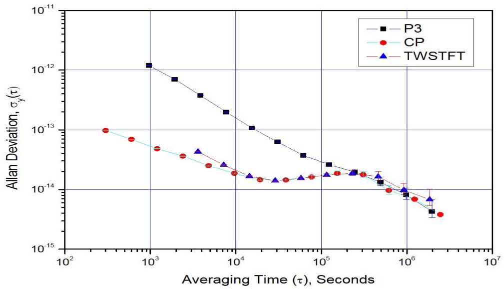
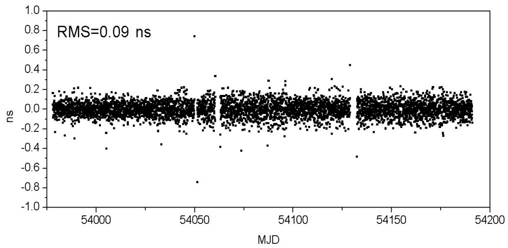
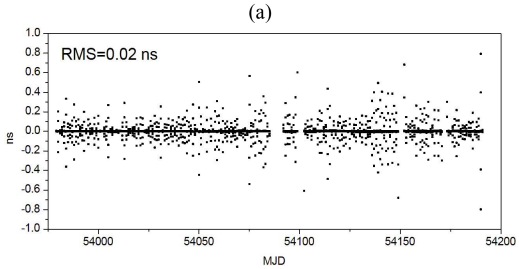


Figure 4. Allan deviations by means of P3-code, carrier phase, TWSTFT.



(a)



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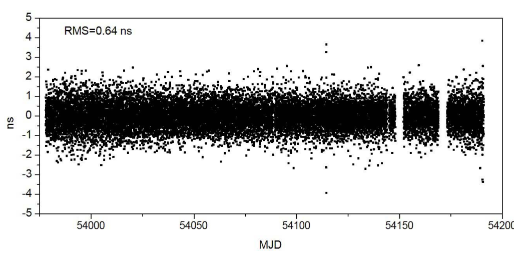


(c)

Figure 5. Residuals of difference between each time transfer data and its own smoothed curve: (a) TWSTFT, (b) carrier phase, (c) P3-code.

B. Comparison Results between UTC(KRIS) and UTC(NMIJ)

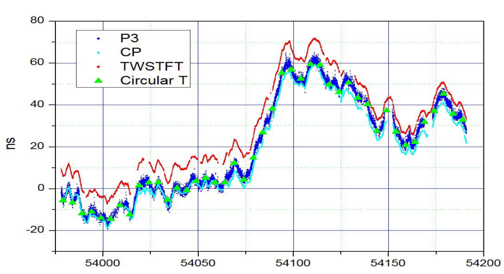


Figure 6. Comparison results between UTC(KRIS)-UTC(NICT) by P3-code, carrier phase, TWSTFT and Circular T.

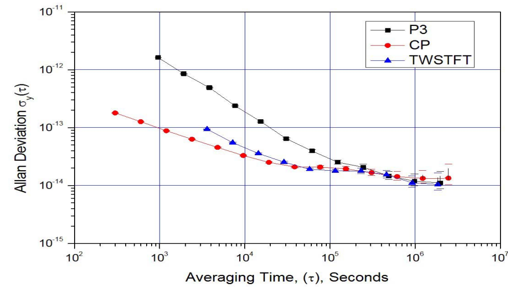
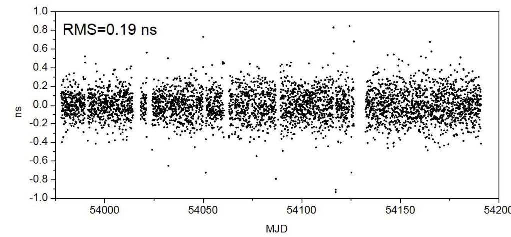
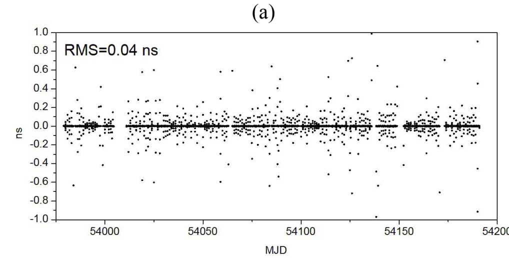


Figure 7. Allan deviations by means of P3-code, carrier phase, TWSTFT .



(a)



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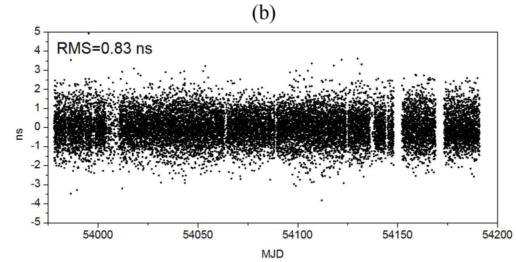


(c)

Figure 8. Residuals of difference between each time transfer data and its own smoothed curve: (a) TWSTFT, (b) carrier phase, (c) P3-code.

C. Comparison Results between UTC(KRIS) and UTC(TL)

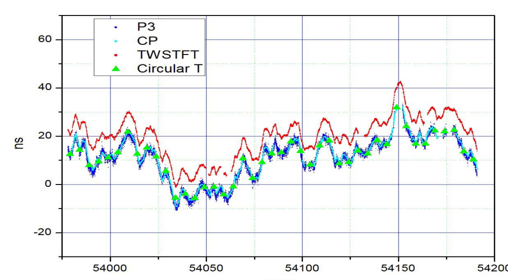


Figure 9. Comparison results between UTC(KRIS)-UTC(NICT) by P3-code, carrier phase, TWSTFT and Circular T.

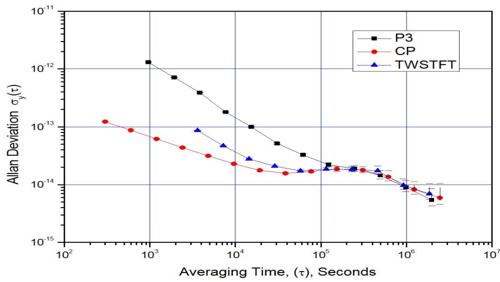
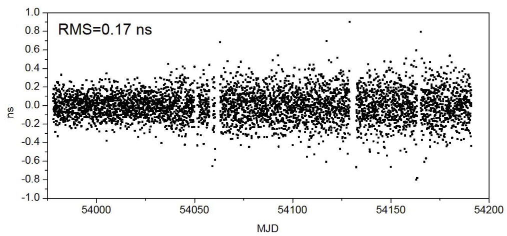
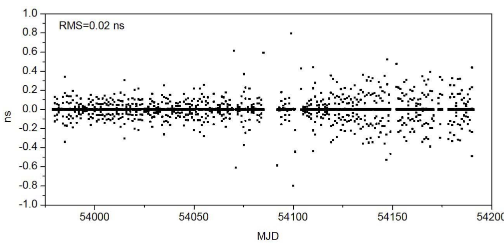


Figure 10. Allan deviations by means of P3-code, carrier phase, TWSTFT.



(a)



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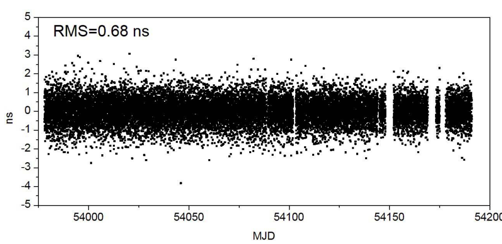

(c)

Figure 11. Residuals of difference between each time transfer data and its own smoothed curve: (a) TWSTFT, (b) carrier phase, (c) P3-code.

IV. CONCLUSION

We assessed the time transfer performance between KRISS and NICT, NMIJ and TL using TWSTFT, GPS carrier phase and P3-code techniques for over 210 days (MJD 53978 ~ MJD 54190). In comparison with NICT, the results agree well with not only each other but also Circular T issued by BIPM. But the other institutes show around 10 nanosecond time difference between CP and TWSTFT, we think that it is caused by not carrying out the TWSTFT calibration with KRISS yet. The carrier phase time transfer was compared with the two-way time transfer, hereby we observed that the performance of GPS carrier phase is slightly better than that of TWSTFT. To conduct the GPS carrier phase time transfer, we used a home-made software, named GV4, by KRISS. Throughout the data span of carrier phase measurements, we found a few jumps and outliers at data set in NMIJ and TL, even though getting automatically rid of day boundary jumps by a program, we could however not see any jump in NICT.

For further work, we will conduct to eliminate the day-boundary discontinuity entirely, and to compare with long base-line stations using GPS all-in-view carrier phase measurement.

ACKNOWLEDGMENT

We appreciate the cooperation of participant institutes: NICT, NMIJ and TL.

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