Time Comparisons by GPS C/A, GPS P3, GPS L3 and TWSTFT at KRISS

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***Abstract*—We present an overview of time transfer activities at Korea Research Institute of Standards and Science (KRISS). During the last few years, we have equipped the geodetic receivers for P code and carrier phase measurements, and built two-way satellite time and frequency transfer (TWSTFT) system to improve the time comparison accuracy. Now, we are conducting the time comparisons between KRISS and National Institute of Information and Communications (NICT, Japan) including several institutes in Asia using various GPS time transfer methods such as GPS C/A code, P3 code, carrier phase, and TWSTFT techniques. The equipment for time transfers are TTR6, 3S-R100, Euro-80, and a geodetic receiver (Z12-T) for GPS link, and multi-channel TWSTFT via JCSAT-1B satellite for two-way link. From the all data, we have compared and evaluated the differences between the various comparison methods by GPS versus TWTSTF.**

I. INTRODUCTION

In 1981, the first GPS common-view time transfers using single-channel C/A code were introduced [1]. BIPM has been using clock data via GPS since 1983 for establishing the International Atomic Time (TAI). And UTC scale is realized by using the combination of TAI. For the purpose of this, timing laboratories are using navigation satellites and/or geostationary satellites, that is, GPS, GLONASS and communication satellites. Especially, GPS has offered many effective ways to national standard institutes for time comparisons between clocks over the last two decades. But the first common-view method so-called single-channel GPS C/A code common-view time transfer is insufficient for the present-day clock comparison. Accordingly more accurate time transfer method becomes to be essential. The needs of the current of the times have developed the methods of multi-channel GPS C/A code [2], GPS P3 code, GPS carrier phase [3] and TWSTFT [4].

KRISS has begun to report the time transfer data by GPS in the place of LORAN-C to BIPM since 1987. Up to the present we have equipped and maintained various time transfer receivers: AOA TTR6 receivers, a 3S Navigation R100-40T GPS/GLONASS receiver and Ashtech Z12-T geodetic receivers. Moreover recently we have constructed TWSTFT links as shown in Fig. 1. We present the comparison results between UTC(KRIS) and UTC(NICT) by using the several types of time transfer methods mentioned before: multi-channel GPS C/A code, GPS P3 code, GPS L3 and TWSTFT. Besides TWSTFTs are compared with GPS P3 code between UTC(KRIS) and UTC(NMIJ), UTC(NTSC), UTC(TL) based on Circular T.

The intention of this paper is to introduce KRISS time transfer activities and to present how well we can compare time difference between KRISS and other institutes in Asia using GPS satellites and TWSTFT links at the present.

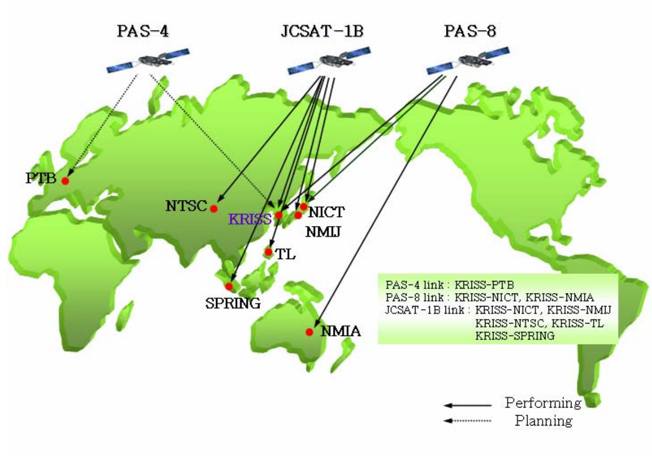

Figure 1. TWSTFT links at KRISS.

II. TIME TRANSFER APPARATUS AT KRISS

A. TTR6

The NBS-type single channel GPS C/A code common view receiver is well known to timing laboratories. We have maintained three TTR6 receivers and these are operating for the redundant transfer system and domestic time synchronization experiments [5].

B. R100-40T

An R100-40T receiver purchased in 1999 can provide highly accurate time transfer capabilities with temperature stabilized antenna. Besides, it combines measurements of GLONASS as well as GPS satellites. But unfortunately it had worked abnormally after being built. Recently this receiver has been working well owing to the upgrade of software and hardware. However the comparison by this receiver is not evaluated in this paper.

C. Euro-80

We have operated a Topcon Euro-80 receiver introduced in 2002, which is developed by NMIA in Australia for the purpose of GPS dual frequency L1/L2 common view time transfer system. So we can get the measured ionosphere delay with modeled results. At present this receiver has been operating as main time transfer equipment at KRISS.

We present the time difference between KRISS and NICT by multi-channel C/A code using these receivers in this paper.

D. Z12-T

Ashtech Z12-T GPS receiver provides highly accurate time transfer through P-code and carrier phase comparison. GPS P-code signal has two main advantages for precise time transfer: (1) GPS P code pseudo-range measurements are more precise than GPS C/A code measurements because of one tenth of chip-length, compared to GPS C/A code; (2) it is possible to measure the ionospheric delays owing to receiving both L1 and L2 frequencies at the same time. In addition, this one offers the capability of conducting the carrier phase measurement of which accuracy is at the level of sub nanosecond [6]. Two Z12-T receivers have been equipped and the comparison results by P3 code will contribute to time scale. Now one of these is participating in calibration trip by BIPM and we will report regularly the comparison results to BIPM as a master link in this year.

E. TWSTFT

TWSTFT earth stations at KRISS have been established since 2002. At present we have constructed two stations, one has linked to Asia region via JCAST-1B satellite and the other has linked to Oceania region via PAS-8 satellite. Besides one more system will be introduced for Europe link in this year. All of modems were developed by NICT and have multi-channel function, therefore we are able to compare simultaneously with several institutes [7]. KRISS, NICT, NMIJ, NTSC, TL and SPRING are participating in these comparisons via JCSAT-1B using this modem. Unfortunately during April, we did not have the comparison data of SPRING because of the system failure at that time. In addition to JCSAT-1B, KRISS has the link to NMIA and NICT via PAS-8 satellite.

NICT calculated and reported the calibration results of Asia-Pacific two-way link using GPS all-in-view, GPS common view and/or previous TWSTFT link using Atlantis modem [8]. We compensated these calibration results for this computation and could verify that they were in consistency with Circular T and calibrated GPS comparison.

III. Time Comparison Results

For measuring the time difference between KRISS and NICT, we used the GPS receivers (TTR6, Euro-80, Z12-T) and TWSTFT for the period of three months. Fig. 2 to Fig. 4 show the time comparison results by various time transfer equipment from April to June 2005. They are coincident well with each other, so the curves are shifted up from Circular-T by 20 ns each for better visibility. The data from TTR6 and Euro-80 receivers are gathered up to 48 each day by BIPM schedule. By the observation schedule, we computed the difference between UTC(KRIS) and UTC(NICT) from [UTC(KRIS) - GPS time] and [UTC(NICT) - GPS time]. But we did not compensate the delays and offsets by Z12-T receiver because it was not calibrated yet. So we drew the inartificial results, and only P3 code data were shifted against L3 by 20 ns for visibility. In order to compare the quality, all the stabilities are computed by transfer methods during the same period for about 4 days (MJD 53475 to 53478). The selected evaluation date was chosen by the period of the consecutive measured time of both TWSTFT and GPS comparison results. Here we calculated the stabilities using one-second sampled two-way data, 16-minute sampled P3 code data and 30-second sampled carrier phase data obtained from RINEX file.

As shown in Fig. 4, we observe a significant improvement in frequency stability of the carrier phase and the TWSTFT measurement for consecutive period for averaging time. Table I shows the rms values in average for the measurement period.

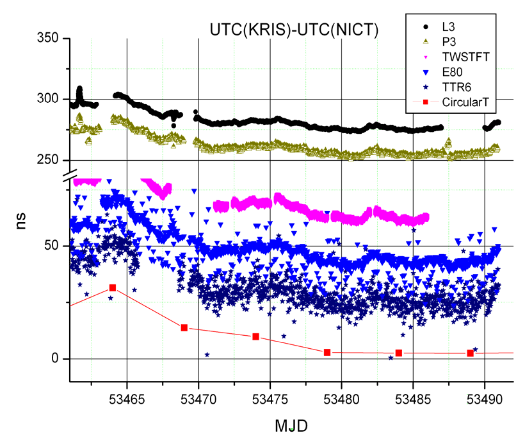

Figure 2. Time differences between UTC(KRIS) and UTC(NICT) computed by L3, P3, TWSTFT, M/C CV, S/C CV and Circular T in order. Curves were intentionally shifted by 20 ns each for visibility. L3 and P3 data were not compensated with calibration offset values. (April 2005).

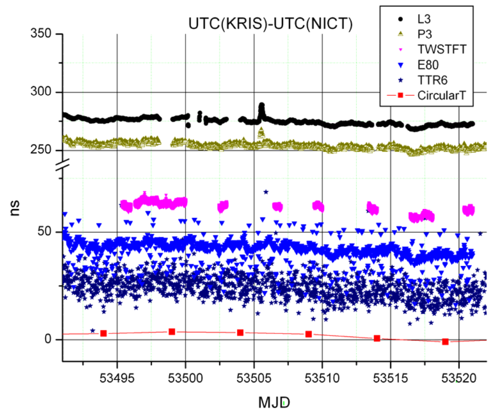

Figure 3. Time differences between UTC(KRIS) and UTC(NICT) computed by L3, P3, TWSTFT, M/C CV, S/C CV and Circular T in order. Curves were intentionally shifted by 20 ns each for visibility. L3 and P3 data were not compensated with calibration offset values. (May 2005).

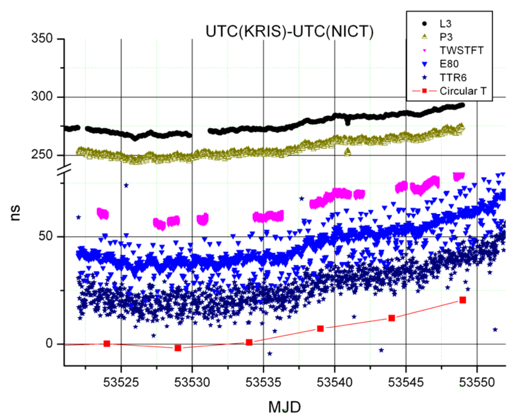

Figure 4. Time differences between UTC(KRIS) and UTC(NICT) computed by L3, P3, TWSTFT, M/C CV, S/C CV and Circular T in order. Curves were intentionally shifted by 20 ns each for visibility. L3 and P3 data were not compensated with calibration offset values. (June 2005).

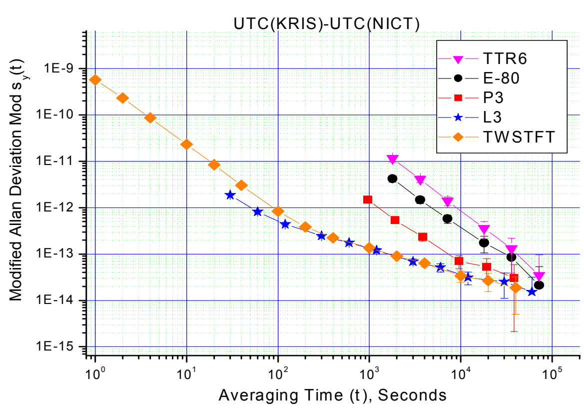

Figure 5. Stabilities between UTC(KIRS) and UTC(NICT) by time transfer methods.

TABLE I. AVERAGE RMS VALUES BETWEEN UTC(KRIS) AND UTC(NICT) BY EACH METHOD

Transfer method	Rms in ns	Equipment
GPS Single channel C/A-code	11.5	TTR6
GPS Multi-channel C/A-code	5.7	Euro-80
GPS P-code	2.7	Z12-T
GPS carrier phase	2.6	Z12-T
TWSTFT	2.8	NICT Multi-channel modem

We compared the time differences between UTC(KRIS) and UTC(NMIJ) by GPS P3-code and TWSTFT during April 2005. The comparison results are shown in Fig. 6. In this figure, the P3 code data moved towards the time difference of TWSTFT and Circular T in order to compare each other easily. As shown in Fig. 7, then we calculated the stabilities during the period from MJD 53461 to 53467 (denoted tm in Fig. 6) and presented their rms values in Table II.

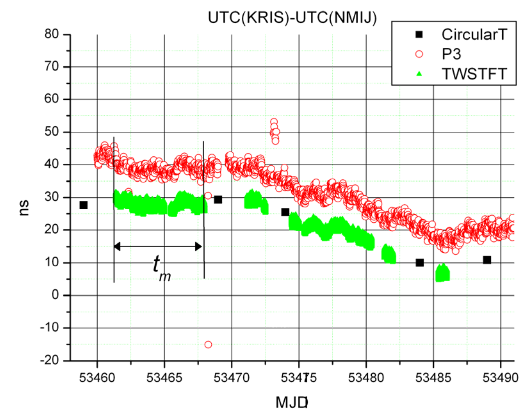

Figure 6. Time differences between UTC(KRIS) and UTC(NMIJ) computed by P3, TWSTFT and Circular T. The P3 code data were not compensated with the calibration offset value and just shifted for visibility. (April 2005).

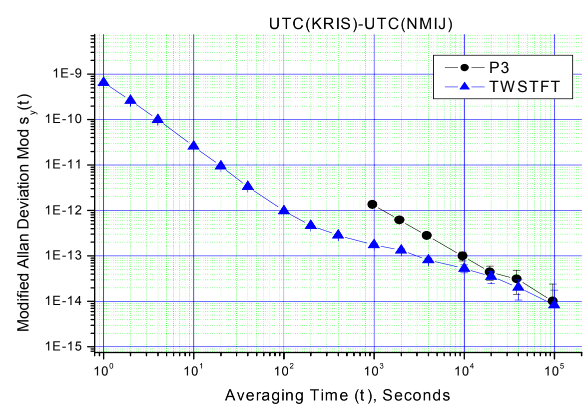

Figure 7. Stabilities between UTC(KIRS) and UTC(NMIJ) by P3 code and TWSTFT.

TABLE II. AVERAGE RMS VALUES BETWEEN UTC(KRIS) AND UTC(NMIJ) BY EACH METHOD

Transfer method	rms in ns	Equipment
GPS P-code	1.4	Z12-T
TWSTFT	1.0	NICT Multi-channel modem

We also show the measured differences between UTC(KRIS) and UTC(NTSC) for a month in Fig. 8, and calculate the stabilities by GPS P3 code and TWSTFT for the period from MJD 53461 to 53467 (denoted tm in Fig. 8) in Fig. 9. We also shift the P3 code data for better visibility.

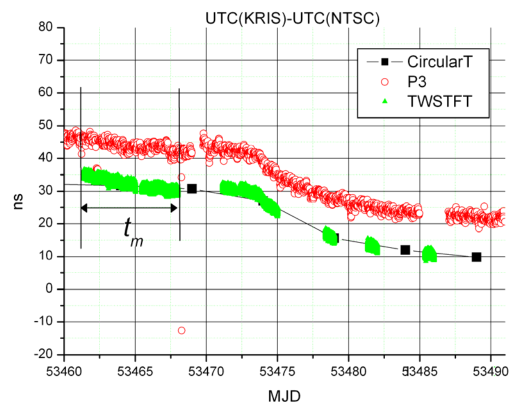

Figure 8. Time differences between UTC(KRIS) and UTC(NTSC) computed by P3, TWSTFT and Circular T. The P3 code data were not compensated with the calibration offset value and just shifted for visibility. (April 2005).

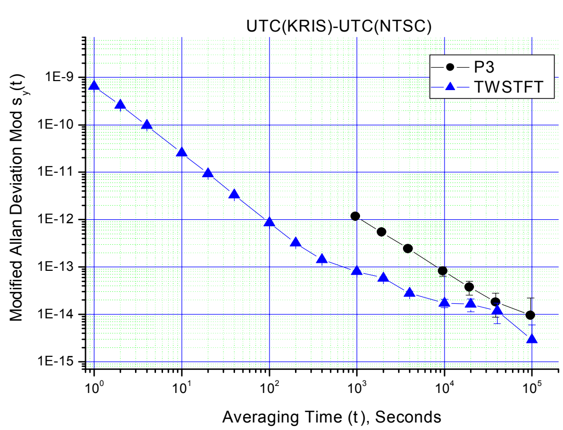

Figure 9. Stabilities between UTC(KIRS) and UTC(NMIJ) by P3 code and TWSTFT.

For comparing UTC(KRIS) with UTC(TL), we calculated the time differences during the period from MJD 53472 to 53481 (denoted tm in Fig. 10) and Fig. 11 represents the stabilities of each time transfer method.

TABLE III. AVERAGE RMS VALUES BETWEEN UTC(KRIS) AND UTC(NTSC) BY EACH METHOD.

Transfer method	rms in ns	Equipment
GPS P-code	1.6	Z12-T
TWSTFT	1.6	NICT Multi-channel modem

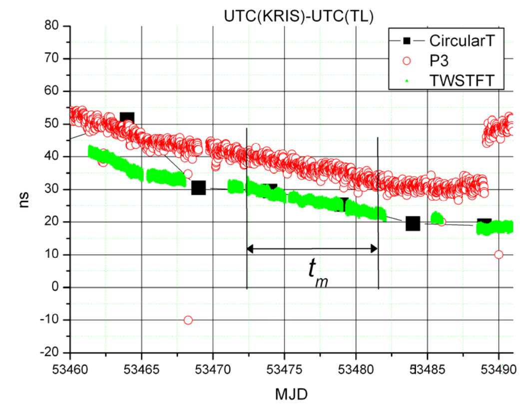

Figure 10. Time differences between UTC(KRIS) and UTC(TL) computed by P3, TWSTFT and Circular T. The P3 code data were not compensated with the calibration offset value and just shifted for visibility. (April 2005).

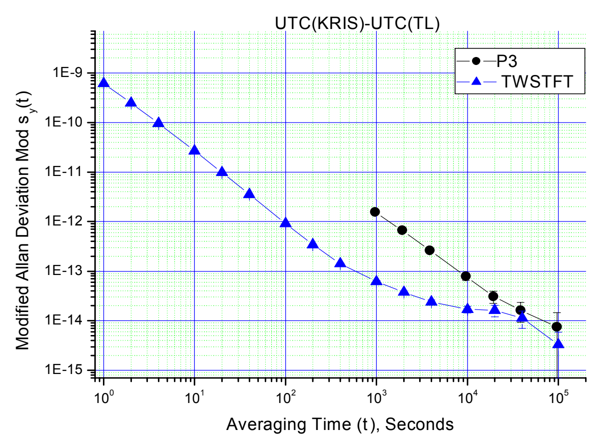

Figure 11. Stabilities between UTC(KIRS) and UTC(TL) by P3 code and TWSTFT.

TABLE IV. AVERAGE RMS VALUES BETWEEN UTC(KRIS) AND UTC(TL) BY EACH METHOD.

Transfer method	rms in ns	Equipment
GPS P-code	2.5	Z12-T
TWSTFT	2.3	NICT Multi-channel modem

IV. CONCLUSIONS

We presented the activities of KRISS time transfer and the comparison results of time differences between several institutes in Asia using various types of methods.

The stability of time transfer is improved when GPS common-view time transfer is carried out in P3 code measurement. Furthermore, we observed a significant improvement in frequency stability, using GPS carrier phase and TWSTFT. Here for carrier phase measurement between KRISS and NICT, we used the self-developed software to process the RINEX file from a Z12-T geodetic receiver [9].

We have performed the manifold time transfer applications to improve the accuracy. At present, we are participating in the Z12-T receiver calibration trip performed by BIPM. Therefore, after compensating the offset value from the calibration result, we will generate the more accurate time transfer data. In the near future, the comparison results by GPS P3 code and TWSTFT link will be reported officially with multi-channel GPS C/A code data. Furthermore, we expect that GPS carrier phase measurement and TWSTFT link to Europe (we plan to link to PTB with NICT via PAS-4 satellite) will contribute to the better TAI computation.

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