Precise Time Transfer Activities in Singapore

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***Abstract*— Precise time transfer is one of the essential works for time-keeping laboratories in maintaining the standards of time and frequency. At the National Metrology Centre (NMC) in Singapore, we have been seeking to improve the time scale performance and time transfer capability by employing different time transfer techniques. Currently, three different time transfer systems are used in the laboratory, namely, GPS code observation by a single frequency multi channel receiver and a dual frequency multi channel receiver; GPS carrier phase observation by geodetic receiver; Two Way Satellite Time and Frequency Transfer (TWSTFT). In this paper, the results of time links between NMC and other Asian and European laboratories are presented, using GPS C/A and TWSTFT techniques.**

I. INTRODUCTION

NMC is the national time authority of Singapore. Its acronym in BIPM Circular T is SG [1]. There are four cesium clocks and one hydrogen maser in the laboratory. Currently, UTC(SG), the official real time realization of UTC, is generated by the master clock – one of the high performance cesium clocks. A phase micro stepper is used to steer the clock aligning with UTC. The performance of UTC(SG) is monitored by UTC-UTC(SG) which is computed and issued by BIPM monthly using the global time transfer network.

In NMC, we have three different types of GPS receivers. They are: a Motorola VP Oncore single frequency code receiver with an ordinary antenna installed in year 2001; a TTS-3[2] multi-channel GPS/GLONASS receiver with Javad Legacy card and Javad choke ring antenna, implemented in 2007; a new carrier phase Septentrio PolaRx2eTR geodetic receiver with a Leica three dimension choke ring antenna, set up in January 2009. The VP Oncore and TTS-3 are dedicated timing receivers. They both generate observation results in CGGTTS data format and have been used alternatively for the UTC time transfer. The Septentrio PolaRx2eTR receiver has already been used to take part in a BIPM TAIPPP pilot study, but the data collected are not discussed in this paper.

Besides, NMC has been participating TWSTFT time link network in Asia Pacific Rim region for years. This gives independent accurate and precise time transfer results. The whole system is provided by NICT. It is a multi channel modem made by NICT [3]. It allows us to carry on a simultaneous time transfer with other national laboratories in Ku-band through commercial satellite JCSAT-1B.

TABLE I. ASSOCIATED INFORMATION FOR THE TIMING LABORATORIES

Lab. Acronym in TAI / Country	GPS Receivers	Time Source / Clock Type	Time Links Involved	Baseline between SG and Lab/ km
SG Singapore	Motorola VP Oncore AOS TTS-3	UTC(SG) industrial Cs	GPS C/A TWSTFT	-
NICT Japan	PolaRx2 TR	UTC(NICT) H-maser	GPS P3 TWSTFT	5310
KRIS Korea	Ashtech Z-12T	UTC(KRIS) H-maser	GPS P3 TWSTFT	4450
TL Chinese Taipei	Ashtech Z-XII3T	UTC(TL) H-maser	GPS P3 TWSTFT	3060
NTSC China	Motorola VP Oncore	UTC(NTSC) industrial Cs	GPS C/A TWSTFT	3700
PTB Germany	AOS TTS-3	UTC(PTB) laboratory Cs	GPS C/A	10120

In this paper, we will present time transfer results between NMC (hereafter SG) and other timing laboratories, obtained using above mentioned time transfer techniques. A brief summary on all laboratories involved and their equipment [4] is given in Table I. All the selected laboratories have a local time scale realized by an ensemble of H-maser and Cs atomic clocks except SG.

II. Observational Data

In order to conduct time transfer, all the GPS receivers and TWSTFT system are connected to the 1 PPS signal disseminated from UTC(SG). The required reference frequency is also from the master clock. The frequency of the master clock is always steered at a constant of 1.45×10^{-13} using an HROG-5 phase stepper during the observation period. Here, we report the time link results using GPS C/A and TWSTFT observations.

A. Time Transfer between SG and Asian Timing laboratories Through GPS C/A Code

At present, the GPS all in view (AV) method is used for UTC generation because it gives better precision than common view method especially for long baseline time links as described in the paper by Jiang[5]. All the GPS time transfer data used in this study are computed using the GPS AV technique and the raw data have been processed with the IGS (International GPS Service) products to determine the geometric distances between satellite and the laboratories. Each point indicates the observation result from a standard 13 minutes tracking.

The time link comparison is first made by using data from VP Oncore GPS receiver between SG and four Asian laboratories for the period of MJD 54827 to MJD 54861. The equipment in SG is a single frequency 8 channels receiver. The results are presented in Figure 1. The distribution of data points shows that the measurement from this receiver is rather noisy.

Then, a similar comparison is made for data acquired from another receiver TTS-3 between MJD 54864 and MJD 54891. TTS-3 has 12 channels and gives quieter result, as depicted in Figure 2. For ease of comparison, arbitrary offsets are introduced in both figures.

B. Time Transfer Between SG and PTB Through GPS C/A Code

The time link between SG and PTB is also presented. This is because the long baseline between the two timing laboratories is about ten thousand kilometers and both are using TTS-3 receiver as one of the actual UTC links. The use of identical receiver produces less noisy time transfer result. The SG and PTB time difference from MJD 54827 to 54861 is described in Figure 2. In order to make comparison, a similar link result but using VP Oncore receiver at SG for the same observational period is also given in Figure 1.

C. Time Transfer Through TWSTFT

For TWSTFT comparison, all laboratories involved are located in Pacific Rim region and equipped with the NICT modems. The time transfer is performed regularly, through 5 minutes continuous observation every hour. The collected data used in this study by this method is between MJD 54832 and MJD 54898. Unfortunately, only a few data points are available from MJD 54844 to MJD 54856 due to link disruption. The results are shown in Figure 3.

III. Analysis and Discussion

In Figures 1, 2 and 3, we show the direct time comparison results between SG and other laboratories by VP Oncore GPS receiver, TTS-3 receiver and TWSTFT system respectively. From Figure 1 and 2, we see that TTS-3 receiver performs much better than VP Oncore receiver. This could be due to reasons like different GPS engine and different types of GPS antennae. Compared to GPS C/A, even though TWSTFT has less observational data per day, the time transfer results it provides definitely have higher precision.

To evaluate the time transfer performances, the modified Allan deviations are calculated and plotted in Figures 4, 5 and 6 between SG and other Asian timing laboratories and PTB for different transfer techniques. To make comparison more meaningful, time link results calculated from BIPM Circular T are also presented in Figures 5 and 6. Figure 4 displays the stability results calculated from TTS-3 observational data. It is noticed that for SG and PTB link, which has the longest baseline distance, the time transfer stability result is about the same as those for other shorter baseline links. A separate chart for SG and PTB link only is given in Figure 5. Clearly, by deploying same TTS-3 receiver, the time transfer stability is considerably improved.

Additionally, from Figures 6a to 6d, we give the time link results between SG and other four Asian timing laboratories. The four charts confirm the above findings: for GPS C/A AV time link, TTS-3 receiver produces much better result than VP Oncore receiver; TWSTFT, on the other hand, shows best performance at averaging time shorter than 4×10^{4} s, and the corresponding stability is about a factor of 2 lower than those from GPS C/A AV observation; at averaging time longer than 4×10^{4} s, both methods give quite close results if taking into account the increased uncertainties and it is difficult to give a conclusion.

IV. Conclusions

We have reported time link comparisons between SG and other timing laboratories through GPS C/A AV and TWSTFT techniques by using different equipment with about one month observational data. The measurement and analysis show that the performance of TTS-3 receiver is better than VP Oncore receiver; by using same type receiver, the results between two stations with long baseline show the same level of time transfer stability as the short baseline time links;

compared with GPS C/A AV method, TWSTFT can significantly improve time transfer stability for averaging time shorter than 4×10^4 s; longer than that, both methods agree well within the error bars and further investigation is underway to interpret this clearly.

At present we are studying the time transfer performance using GPS P3 and TAIPPP methods for the time link between UTC and UTC(SG). A hydrogen maser is to be used as the time source of UTC(SG).

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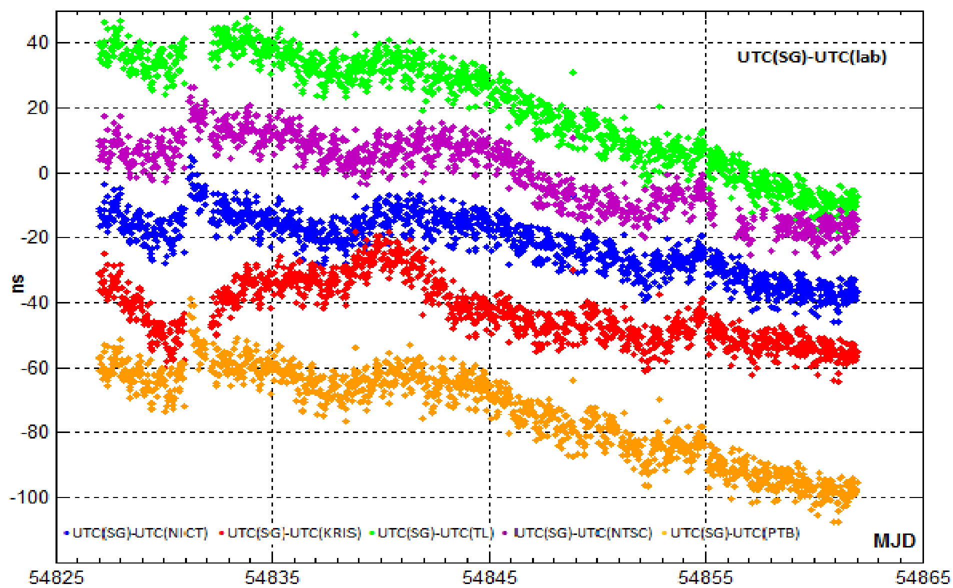

Figure 1. GPS time links between UTC(SG) and UTC(lab) using VP OnCore receiver. Some arbittrary offsets have been introduced.

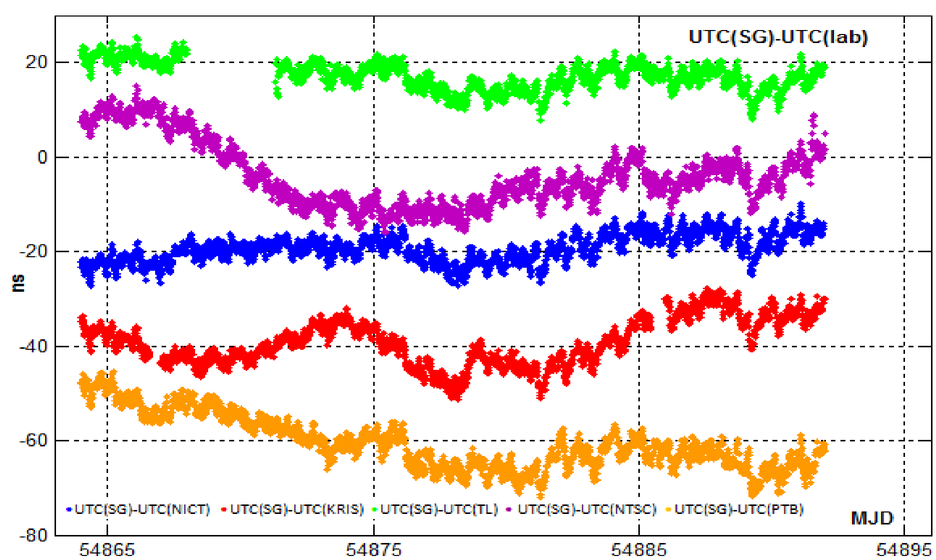

Figure 2. GPS time links between UTC(SG) and UTC(lab) using TTS-3 receiver. Some arbittrary offsets have been introduced.

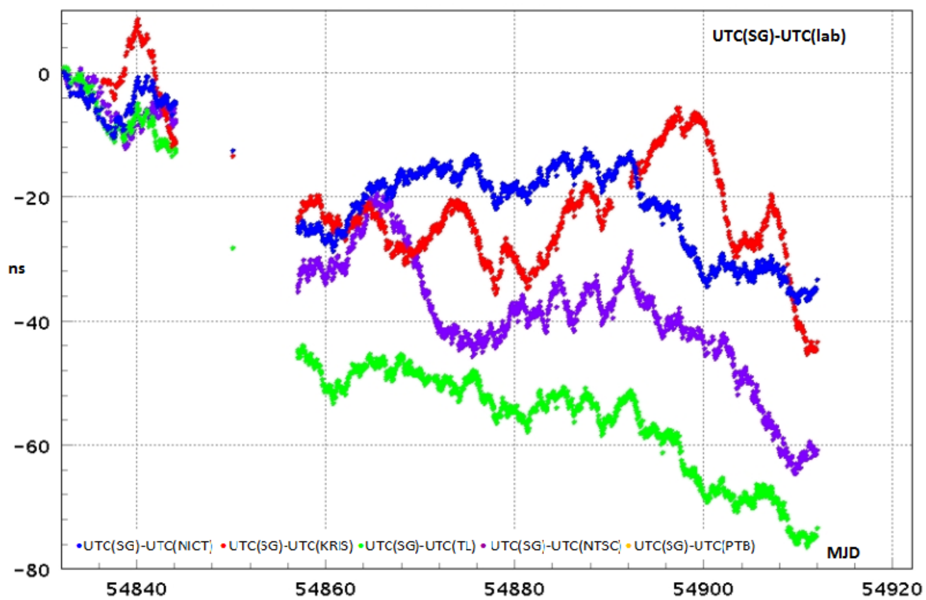

Figure 3. TWSTFT links between UTC(SG) and UTC(lab).

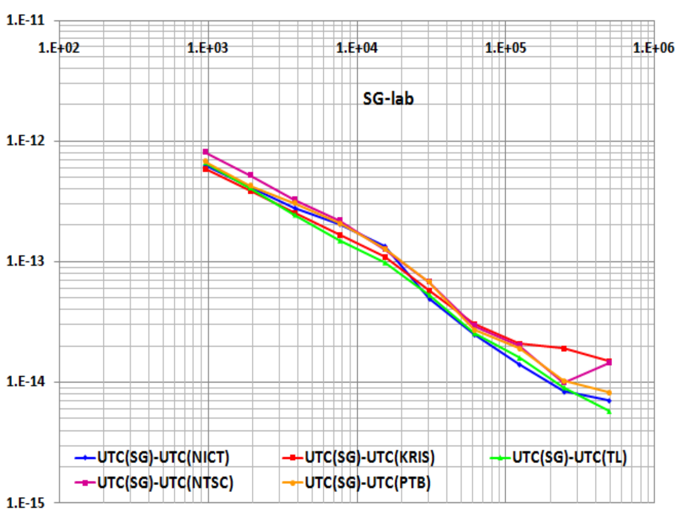

Figure 4. Modified Allan Deviations for links between SG and other labs using TTS-3 receiver. Five colors are used to indicate different links: blue for SG-NICT, red for SG-KRISS, green for SG-TL, purple for SG-NTSC and orange for SG-PTB. The x axis is averaging time in second.

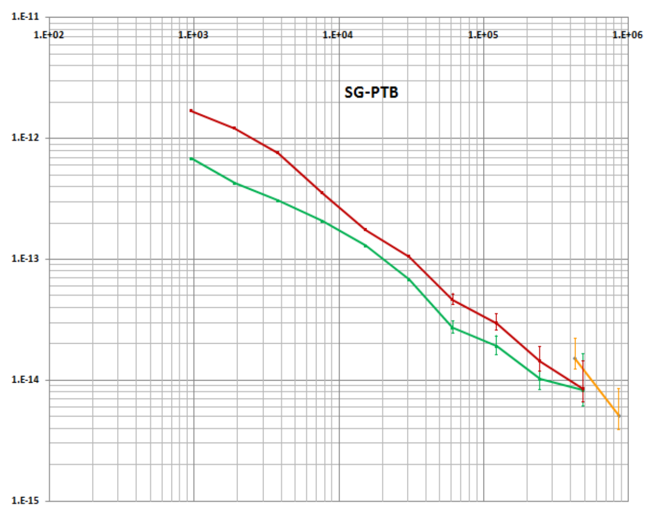

Figure 5. Modified Allan deviations between SG and PTB. Green and dark red lines indicate data obtained using TTS-3 and VP Oncore receivers respectively. Orange line is the link result calculated from data of Circular T. The x axis is averaging time in second.

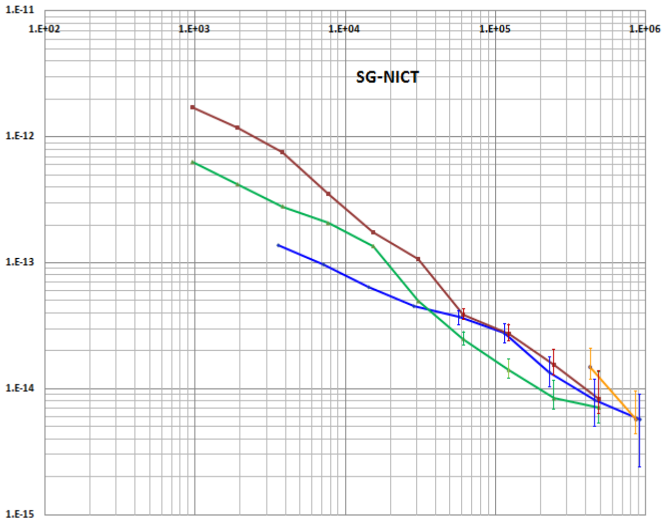

Figure 6a.

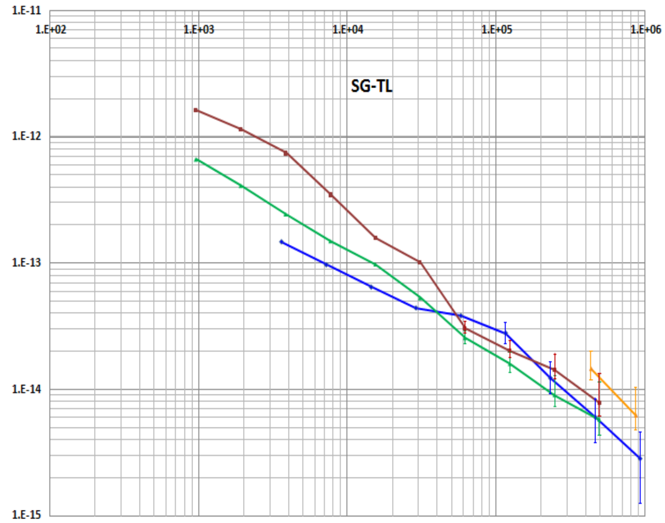

Figure 6c

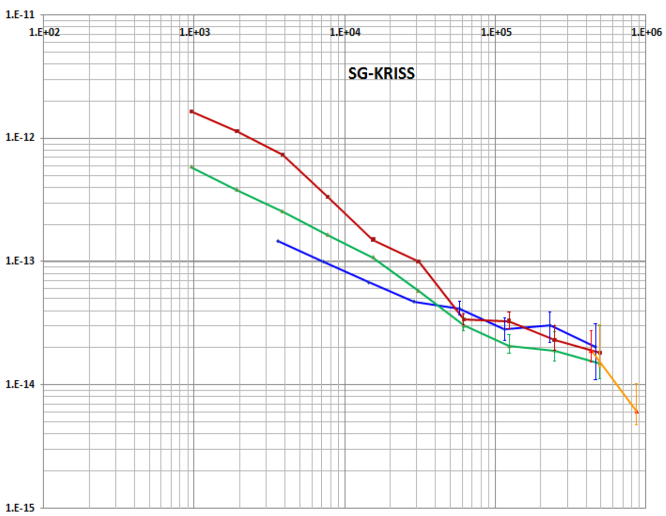

Figure 6b.

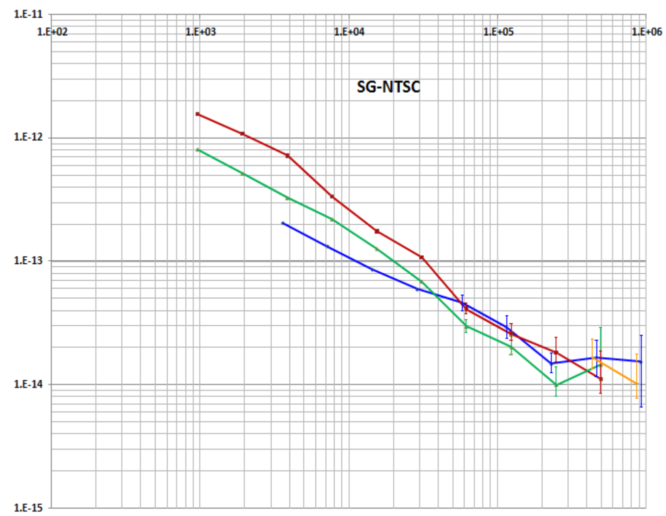

Figure 6d.

Figure 6. 6a-6d are comparisons of modified Allan deviation between SG and other laboratories. Four different colors are used to represent time links obtained from different ways: dark red for VP Oncore receiver; green for TTS-3 receiver; blue for TWSTFT; orange for BIPM Circular T. The x axis is averaging time in second.