Near Real-Time GPS PPP Time Transfer for Business Continuity in Singapore

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***Abstract*— Driven by the smart nation initiatives, the role of precise time source becomes more significant in highly demanded seamless and efficient municipal services in Singapore. One of the critical requirements is the time continuity which promotes us to build up a Business Continuity (BC) site for continuous time services. Global Positioning System (GPS) based Precise Point Positioning (PPP) technique is one of solutions for precise time transfer from our main laboratory to the BC site for the local realization of Coordinated Universal Time (UTC). In this paper, some preliminary results and observations will be discussed.**

Keywords—GPS time transfer; precise point positioning (PPP); precise time source

I. Introduction

Precise time transfer has many important applications such as financial time stamping, data encryption and security, and thus becomes important in highly demanded seamless and efficient municipal services in Singapore. Driven by these smart nation initiatives, precise time transfer is very critical in building up a Business Continuity (BC) site to provide a continuous time service. Nanosecond (ns) and near real-time time transfer from our main laboratory to the BC site is under a heavy expectation now.

Several different techniques [1-4] have been implemented over the past few decades for time transfer. Global Positioning System (GPS) based Precise Point Positioning (PPP) solution [1, 3-4] shows a high potential for a small but dense urban country like Singapore. It is chosen over other techniques like two-way satellite time and frequency transfer (TWSTFT) and optical two-way time-frequency transfer (OTWTFT) [2], which are both precise but expensive solutions. GPS PPP based technique has been widely used by time laboratories for remote calibration of the atomic clocks and for time transfer applications [3-4].

In this paper, some of our recent effort of adopting this technique to build up our BC site will be presented. This GPS PPP based method is used to compute GPS receiver clock bias for a ground station '*k*', with reference to local UTC(*k*). Relevant information reported in *Circular T* and rapid solution of UTC (UTCr) which are published at the Bureau International des Poids et Mesures (BIPM) website [5] are used as the benchmark to check the accuracy and evaluate its performance for achieving the targeted accuracy at the BC site.

Table 1: Details of the GPS station used in the study

GPS Station	Location [Lat, Lon, H]	Receiver Clock	Date Range (MJD)
SG (Singapore)	1.32°, 103.67°, 21.73 m	External H-maser, UTC(SG)	59185-59215

II. Methodology

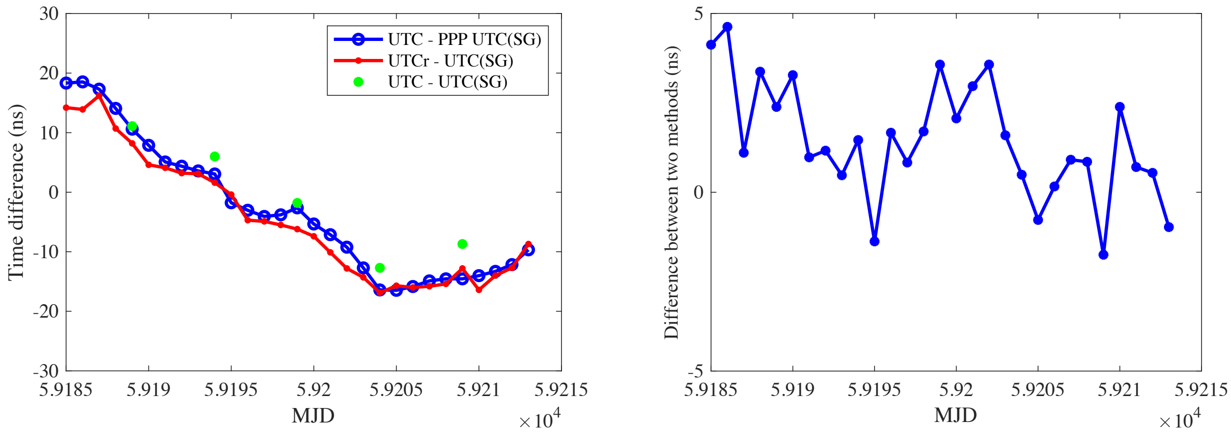
Receiver Independent Exchange (RINEX) observation files recorded at a GPS ground station (Table 1) maintained by the National Metrology Centre of Singapore are processed. The GPS Inferred Positioning System (GIPSY-X) software is run in PPP mode to determine the receiver clock bias. International GNSS System (IGS) based final satellite orbit/clock solution, second order ionospheric model, receiver dependent parameters (antenna parameters), and an elevation mask of 7° are considered for the run.

The receiver clock bias is determined with respect to the GPS time (GPST), i.e., [PPP UTC - GPST]. The difference between UTC and PPP UTC(*k*) for a station '*k*', is then calculated by taking {[UTC - GPST] - [PPP UTC(*k*) - GPST]}, where GPS receiver clock is referenced to the local physical realization of UTC, UTC(*k*). Here, [UTC - GPST] is obtained from the database available at the BIPM website [5]. The processed difference, [UTC - PPP UTC(SG)] (for Singapore station, $k \rightarrow$SG) is then compared to the results published by BIPM.

III. Results & Discussion

Receiver clock bias for SG station is processed using GIPSY-X software, and [UTC - PPP UTC(SG)] is calculated for Modified Julian Date (MJD) ranging from 59185 to 59215. Relevant information from BIPM website is extracted for the same MJD period. Fig. 1 shows the comparative analysis of [UTC - PPP UTC(SG)] with both the BIPM published results; *Circular T* and rapid solution UTCr, in green and red respectively. The *Circular T* is reported every 5 days, whereas the rapid solution is reported every Julian day.

Fig. 1(a) shows that the processed results follow both the BIPM reported results with reasonable agreements. The differences between the calculated PPP results and the rapid solution UTCr are shown in Fig. 1(b). The range of differences is within 5 ns and the average difference is 1.45 ns. Such deviations could be caused by the difference in PPP processing



(a) (b)

Fig 1: (a) Comparison among GIPSY-X PPP technique [UTC - PPP UTC(SG)], rapid solution of UTC [UTCr - UTC(SG)] and *Circular T* [UTC - UTC(SG)] (b) Difference between [UTC - PPP UTC(SG)] and [UTCr - UTC(SG)]

software (BIPM uses NRCan for PPP processing) and also the differences between UTC and UTCr. Similarly, Fig. 2 shows the Allan deviation results to compare their stabilities. Both the curves for processed PPP result and for rapid solution from BIPM follow very well and a stability of 1.29×10^{-13} can be achieved for [UTC - PPP UTC(SG)] for an averaging window of a day. From this study, it is observed that the calculated time differences follow the benchmark well.

The time differences could be locally predicted, which could help us monitor and steer the backup local realization of UTC in Singapore with desired accuracy and stabilities. In addition, the time difference solutions can be made available with a low latency by using IGS rapid or ultra-rapid satellite orbit and clock solutions. This could help us to achieve a near real-time time transfer, and clock steering at our BC site with the desired accuracy and stabilities.

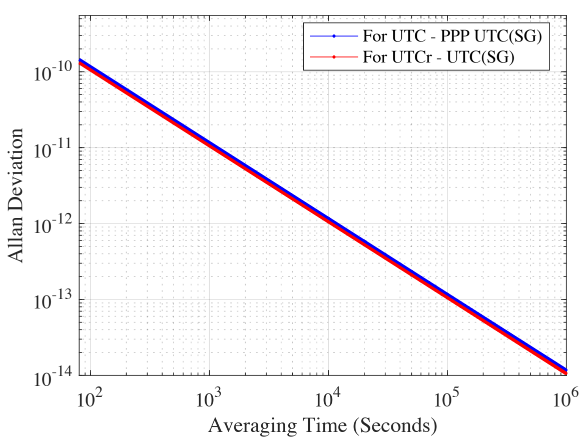


Fig 2: Allan Deviation for [UTC - PPP UTC(SG)] and [UTCr - UTC(SG)]

IV. Conclusions

Precise time transfer techniques are desired for many applications and are important to deliver continuous and accurate time services with good stability. GPS PPP time transfer technique which has been widely accepted was studied. In this paper, some of our recent effort of adopting this technique to build up our BC site was reported.

The time transfer accuracy was compared and analyzed with the BIPM published reports. It is observed that this technique shows promising results and have the potential to predict the time difference in a near-real time fashion with desired accuracy. As an extended work, the time difference will be predicted and then used to steer the backup of local realization of UTC time scale at our BC site.

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