A Clock Performance Analysis of GNSS Receivers with CORS

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Key words: Allan variance, Atomic clock, CSRS-PPP, Clock offset

SUMMARY

Timing is an essential part of GNSS. While high end atomic clocks are implemented on GNSS satellites, quartz clocks are frequently utilized for receivers. For the CORS application, there are high end receivers equipped with external atomic clock, and also those receivers with lower cost. In this study, the clock performance of receivers belonging to different categories are analyzed with daily solutions from Precise Point Positioning. The setups include Trimble NetR9, Septentrio mosaic-X, and a Septentrio POLARX5TR with an external H-maser clock. The analysis found that the clock performances in terms of Allan variance are not significantly different. And, the existence of low frequency noises are not observed with 10 days accumulated clock offset series.

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1. INTRODUCTION

The GNSS receiver clock is acknowledged for its lower accuracy and stability compared to the atomic clock installed on satellites. Typically, the clock offset of the receiver is treated as an unknown parameter to be determined alongside the three-dimensional coordinates of the station. Despite the existence of minimum requirements for receiver clocks, variations in clock quality persist across different receiver models. In this study, clock corrections derived from the post-processed Precise Point Positioning (PPP) procedure were employed to assess the performance of clocks installed on three distinct receivers.

2. THE DATA AND ANALYSIS

For this study, data were sourced from three Continuously Operating Reference Stations (CORS) operated by National Yang Ming Chiao Tung University (NYCU), National Taiwan Ocean University (NTOU), and Geoscience Australia, respectively. The NYCU-owned receiver is a Trimble NetR9 (serial number 5118K75486, version 5.03), featuring a Zephyr Geodetic 2 RoHS antenna (TRM57971.00 NONE). This station, situated on the roof of Engineering Building II at Kwang-Fu campus, Hsinchu, enjoys a full open sky.

The NTOU receiver is equipped with a Septentrio Mosaic X5. The selected Australian station is PARK, an International GNSS Service (IGS) station located in Parkes, NSW, Australia. The PARK station employs a Septentrio PolaRx5TR receiver (serial number 3055081, version 5.5.0) paired with a Leica AR-25 antenna (LEIAR25 NONE). A noteworthy and distinctive feature of station PARK is the presence of an external H-Maser, manufactured by Vremya CH, providing a frequency at 10 Hz. In essence, an atomic clock is utilized for this station.

2.1 Clock offsets

Ten-day observations from each station in 2023 were collected for processing. CSRS-PPP (https://webapp.csrs-scrs.nrcan-rncan.gc.ca/geod/tools-outils/ppp.php), an online service renowned for its reliability (Bulbul, et al., 2021), was employed for GNSS data processing. The ITRF reference frame was chosen, and the data were processed in static mode, with the sampling interval automatically set to 30 seconds by CSRS-PPP.

The sigma (95%) values pertaining to the three-dimensional coordinates for a daily file solution, as presented in the CSRS-PPP PDF report, consistently exhibit uniformity across the

10 days for each station, as detailed in Table 2. Notably, the relatively larger value observed for the NTOU station in the height dimension is attributed to the specified antenna model. It is noteworthy that in the CSRS-PPP submission, no antenna model was included in the RINEX file for station NTOU.

CORS	DOY	Sampling interval
PARK	271-280	30 sec
NTOU	336-338; 340-346	1 sec
NYCU	294-296; 298-304	1 sec

Table 1: The data used

CORS	DOY	n	e	h
PARK	271	0.002	0.002	0.008
NTOU	336	0.002	0.002	0.010
NYCU	294	0.002	0.002	0.008

Table 2: The Sigma (95%) from a daily solution (in m)

The CSRS-PPP PDF report includes a representation of the clock offset time series, featuring a sample for each station in Figures 1-3. Upon scrutinizing the clock offset values, it is evident that the PARK station exhibits the smallest magnitude among the three, followed by NTOU, and then NYCU.

Regarding instrumentation, the Septentrio PolaRx5TR with an external H-Maser typically produces offsets in the order of 10^{-9}. Over the course of 24 hours on DOY list in Table 2, most offsets are negative, but positive offsets are also observed. However, there may be intervals of significant fluctuation, likely stemming from H-Maser malfunctions. Figure 1 illustrates a roughly 120-minute period, occurring around 18:00 and concluding around 20:00, during which substantial fluctuations are apparent. This malfunctioning behavior manifested on Days of Year (DOY) 272, 277, 279, and 280. Although the duration and timing of this behavior vary each day, the magnitudes remain consistent. Together with DOY 271, these fluctuations occurred on 50% of the 10 days, suggesting a recurring pattern. On 'normal' days without such large fluctuations, the range of clock offsets typically remains around 12 ns.

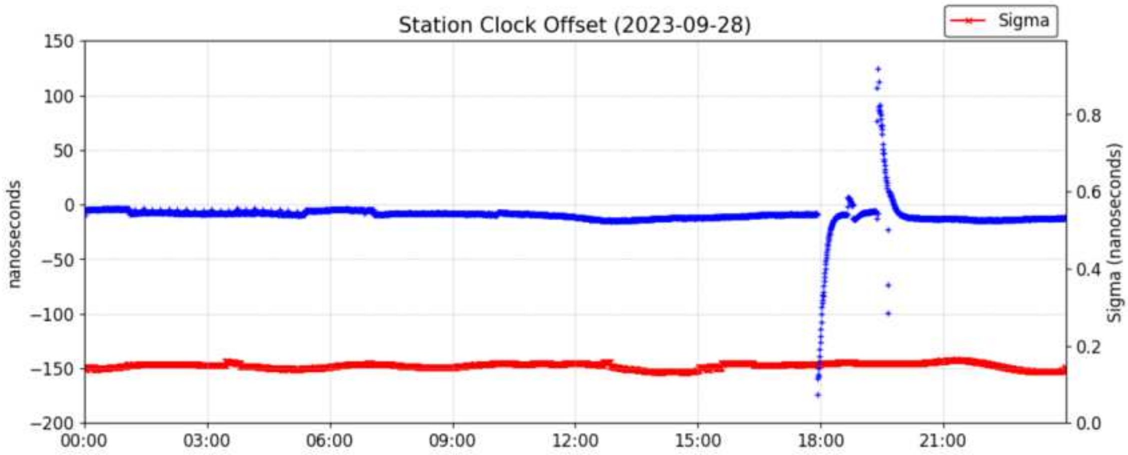

Figure 1: Station Clock Offset, PARK, DOY:271

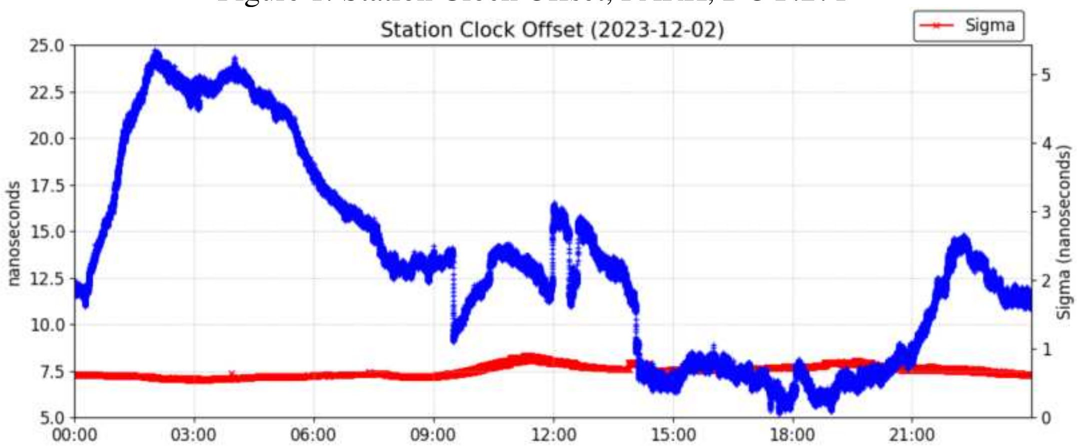

Figure 2: Station Clock Offsets, NTOU, DOY:336

At Station NTOU, equipped with a Septentrio Mosaic X5, the clock offsets are generally on the order of 10^{-8}. On Day of Year (DOY) 336, all offsets are consistently positive. Similarly, Station NYCU, utilizing a Trimble NetR9 without an external clock, exhibits offsets typically in the range of 10^{-8}, with all offsets on DOY 294 displaying a negative sign. Figures 2 and 3 illustrate the range of clock offsets, with Figure 2 displaying a 20 ns range and Figure 3 showing a 30 ns range.

Examining the clock offset behaviors from Figure 1-3, the clock steering algorithms utilized are similar for these three receivers.

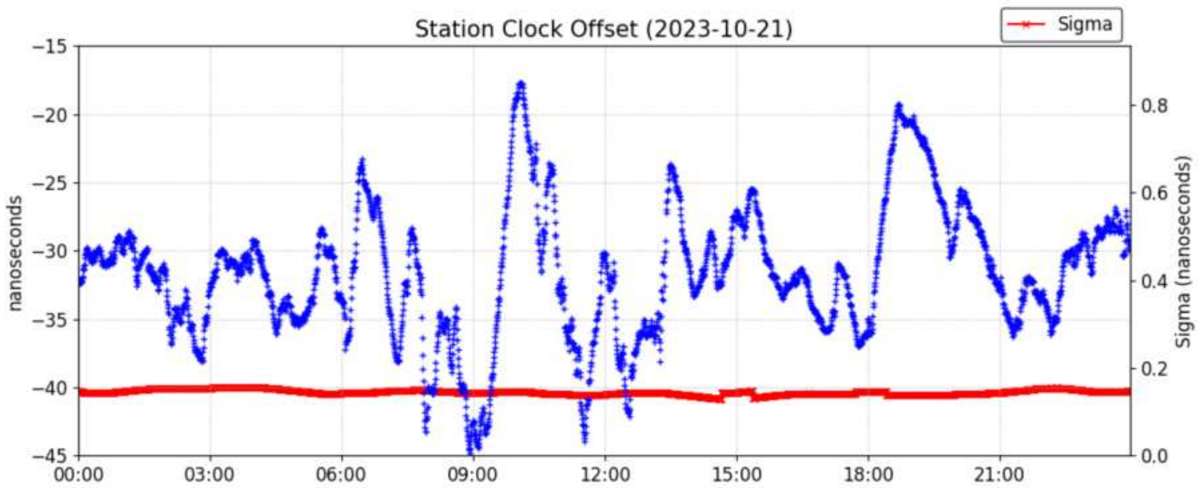

Figure 3: Station Clock Offset, NYCU, DOY:294

2.2 Allan deviations

Within the output files generated by CSRS-PPP, there exists a .clk file formatted in RINEX_CLOCK. This file contains information on the receiver clock offset and the clock offset sigma (95%) for each processed epoch. In this study, the clock offset data extracted from the .clk file is subjected to evaluation using Allan variance, facilitated by the application of Stable32 (http://www.stable32.com/). Allan variance and deviation, are well developed indices for frequency stability analysis (Howe, 2008; Yeh et al., 2013).

Given the 30-second sampling interval of the RINEX observation file, there are 2,880 epochs each day, resulting in a total of 28,800 epochs over 10 days for the PARK station. The frequency stability plots generated using Stable32 are depicted in Figures 4-6 for PARK, NTOU, and NYCU, respectively.

For the NTOU station, the sampling interval is 1 second, but missing epochs are observed daily. Over the 10-day period, there are a total of 863,544 epochs. Unexpectedly, clock offset values are present for each epoch submitted to CSRS-PPP, which contrasts with the anticipated outcome since the 1 Hz sampled observation files were submitted.

For the NYCU station, a 1-second sampling interval was utilized, but the dataset contains missing epochs. For the CSRS-PPP submission, the data were down-sampled to 30 seconds using the gfzrnx tools developed by GFZ (Nischan, 2022) [https://gnss.gfz-potsdam.de/services/gfzrnx]. The resulting dataset consists of 28,761 samples with clock offsets. The corresponding Allan deviation plot is presented in Figure 6.

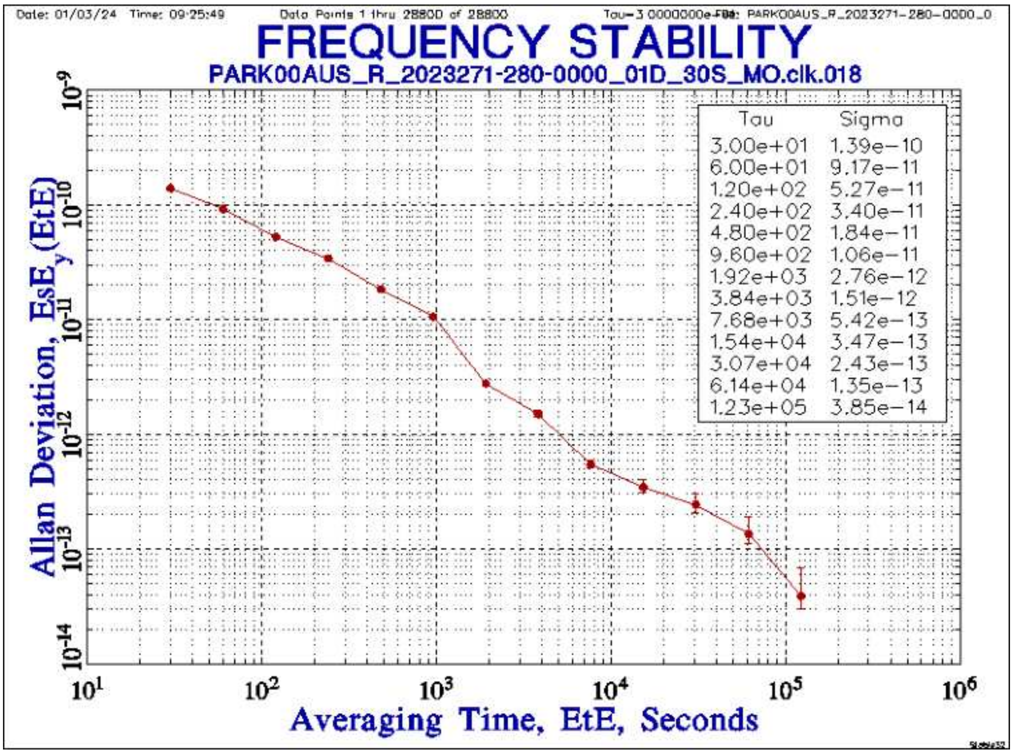

Figure 4: PARK, 10 days, Allan deviation

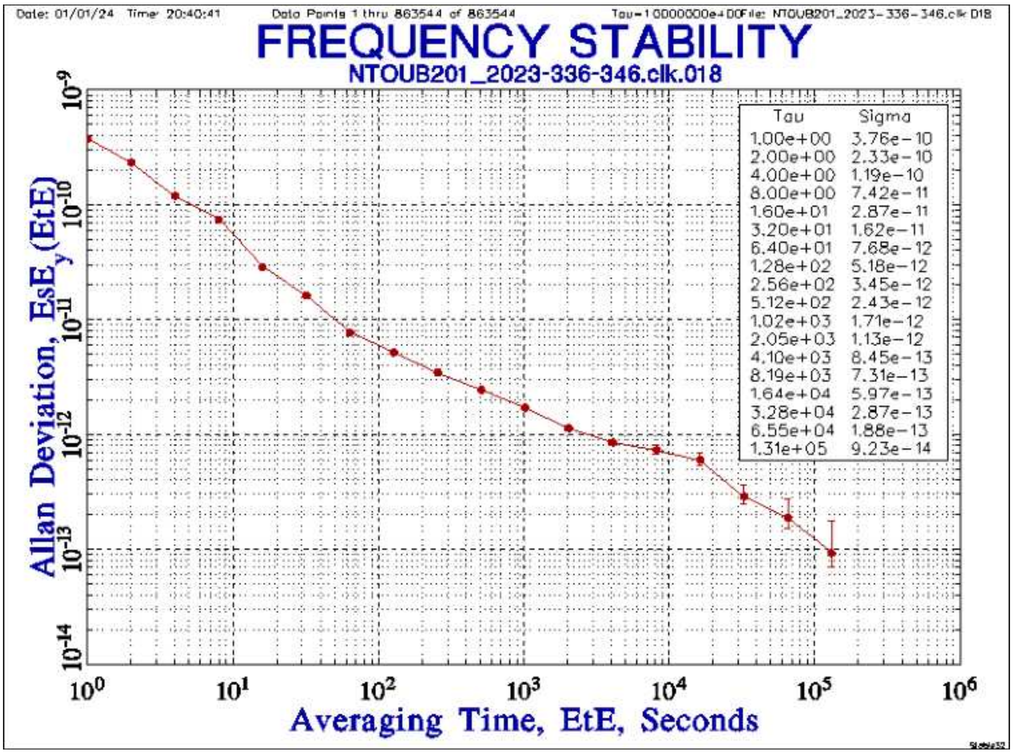

Figure 5: NTOU, 10 days, Allan deviation

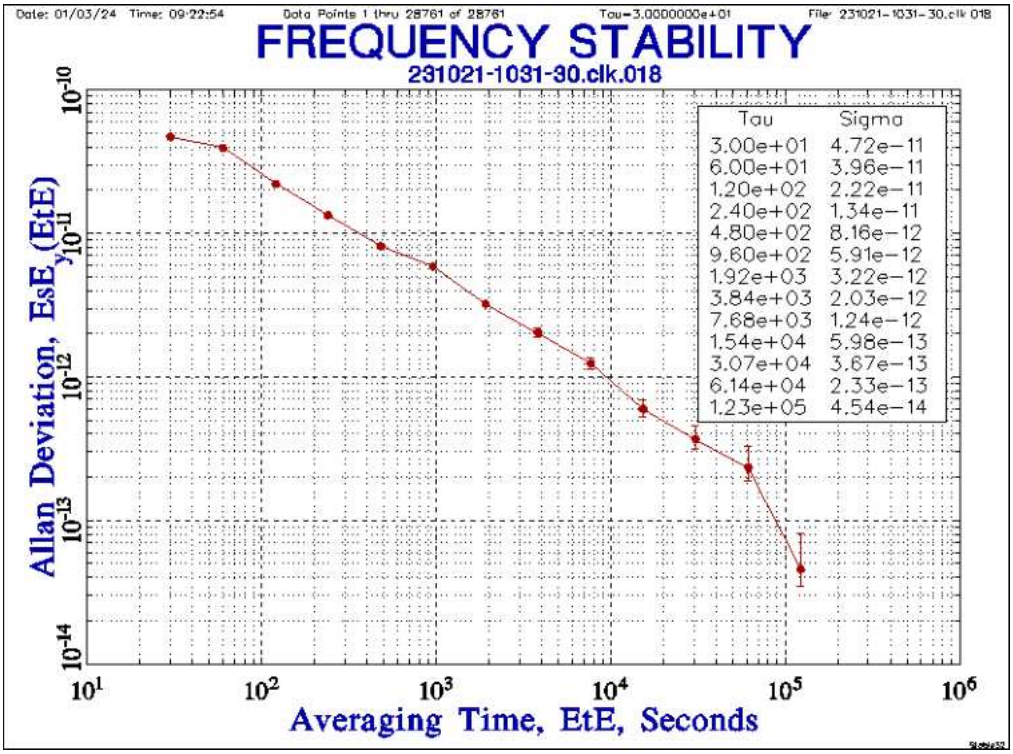

Figure 6: NYCU, 10 days, Allan deviation

3. CONCLUDING REMARKS

In the conducted experiments, all three stations exhibited no reverse point in their Allan deviation plots with 10 days clock offsets derived from CRSR-PPP. From the perspective of Allan deviation, the behaviors of the three distinct receiver models and settings appeared similar. Further evaluation is necessary to determine if an external H-Maser clock could enhance performance.

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BIOGRAPHICAL NOTES

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