# Evaluation Of A New Low-Cost Receiver for GNSS Time-Transfer

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***Abstract*—We have evaluated the performance of the Septentrio mosaic-T GNSS receiver for both code and carrier-phase time transfer. The receiver's performance has been compared on short baselines with several other receivers. The data indicate satisfactory performance for all but the most demanding applications.**

***Keywords—GNSS receiver; time transfer***

## I. INTRODUCTION

We use GNSS time-transfer systems to provide traceable time and frequency signals to remote customers in Australia [1,2]. These time-transfer systems are custom built and use a single-frequency receiver and a time-interval counter to make the measurements needed to produce CGGTTS time-transfer files. In-house software is used to log and process the receiver pseudo-range measurements and combine them with the counter measurements.

Recently, the Septentrio mosaic-T has become available, providing the capabilities of high-end timing receivers at a price that is low enough to be attractive for use in our time-transfer systems. In particular, this receiver has inputs for 10 MHz and 1 pps signals. This greatly simplifies our software, eliminates the need for a counter and enables higher precision time-transfer.

We present here a preliminary evaluation of the performance of the Septentrio mosaic-T GNSS receiver for both code and carrier-phase time-transfer. Its operation with two inexpensive dual frequency, multi-GNSS antennas is also evaluated.

## II. CODE MEASUREMENT NOISE

Noise in the code measurements sets the baseline for performance of code-based time transfer. This noise was estimated by operating the mosaic-T (MOS1) on the same antenna (the IGS station SYDN) as a Septentrio PolaRx4TR (SEP3) via a splitter. Code measurements in the RINEX observation files are then matched between the two receivers, satellite by satellite, and the differences averaged at each observation time. No weighting or filtering was applied. Fig. 1 shows these differences for the GPS C2W signal. Typically, 6 to 10 satellites were visible at each observation time.

Figures 2, 3 and 4 show the time deviation (TDEV) of the differences for selected GPS, Galileo and BeiDou signals. GLONASS measurements were available, but were not analysed. SEP1 is a Septentrio PolaRx2TR receiver operating on SYDN. SEP1 does not track Galileo and BeiDou, so comparison data are not available for those GNSS.

For GPS, the mosaic-T offers comparable performance to SEP1. Generally, TDEV is better than 0.1 ns for all GNSS and signals at averaging times of more than 1000 s.

## III. TIME TRANSFER NOISE

Time-transfer noise was characterized by common clock comparisons using some of the GNSS receivers available at NMIA. SEP1, SEP3 and MOS1 were connected to the SYDN IGS station antenna (Ashtech choke ring). SEP5 is a Septentrio PolaRx5TR receiver connected to an antenna (Septentrio choke ring) on a rooftop about 200 m from SYDN. All receivers were located in our main timing laboratory.

GPS P3 CGGTTS files were generated using r2cggtts and compared using an unweighted average of satellites in common view at each observation time (Fig. 5). As expected from the code noise measurements, the mosaic-T has very similar performance to the other receivers (Fig. 6).

PPP clock solutions were generated using the online NRCAN PPP service (Fig. 7). The much older receiver SEP1 shows distinctly poorer PPP performance than the mosaic-T. The mosaic-T compares well with the other Septentrio receivers (Fig. 8).

## IV. OPERATION WITH INEXPENSIVE ANTENNAS

The recent availability of inexpensive multi-frequency receivers has meant that similarly priced multi-band antennas have also become available. Two antennas were tested: the TOPGNSS TOP106 and ublox ANN-MB-00. The reference system was a Septentrio PolaRx5 receiver (SEP5) and Septentrio choke ring antenna, located about 2 m from the test antenna. Tests were performed sequentially on the same pole.

PPP clock solutions (GPS only) generated using the NRCAN PPP service were used to compare performance of the antennas (Fig. 9). While both of the inexpensive antennas did not perform as well as the Ashtech, the maximum increase in noise, 20 ps, is still well below what might be considered acceptable (Fig. 10).

## V. CONCLUSIONS

The mosaic-T offers only slightly reduced GPS time-transfer performance at a modest price. It may be attractive for use in travelling systems used for receiver delay calibration.

We have now purchased another mosaic-T and will be conducting longer term testing, including characterizing Galileo, BeiDou and GLONASS time-transfer and assessing the stability of the receiver's internal delay.

## REFERENCES

[1] M. J. Wouters and E. L. Marais, "GPS-based time transfer using low-cost receivers," MAPAN, vol. 34, pp. 521–528, 2019.

[2] M. J. Wouters, E. L. Marais, A. Sen Gupta, A. S. bin Omar, and P. Phoonthong, "The Open Traceable Time Platform and its application in finance and telecommunications," Int. J. Electrictrical Engineering, vol. 26, pp. 175–183, 2019.

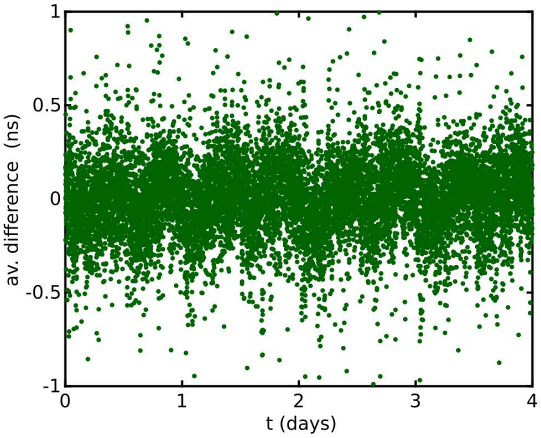


Fig. 1. [MOS1-SEP3] GPS C2W pseudorange differences.

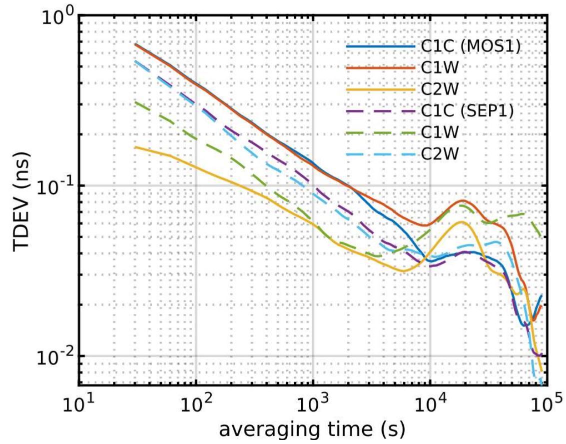


Fig. 2. Time deviation of [MOS1/SEP1 – SEP3] GPS code measurements.

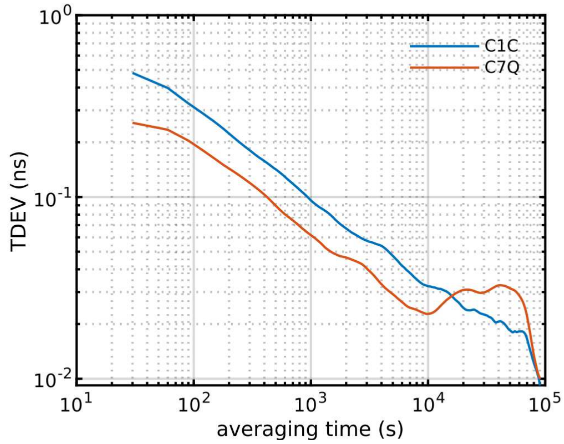


Fig. 3. Time deviation of [MOS1-SEP3] Galileo code measurements.

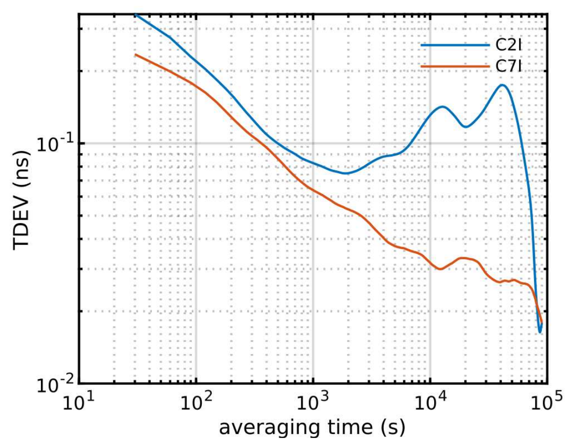


Fig. 4. Time deviation of [MOS1-SEP3] BeiDou code measurements.

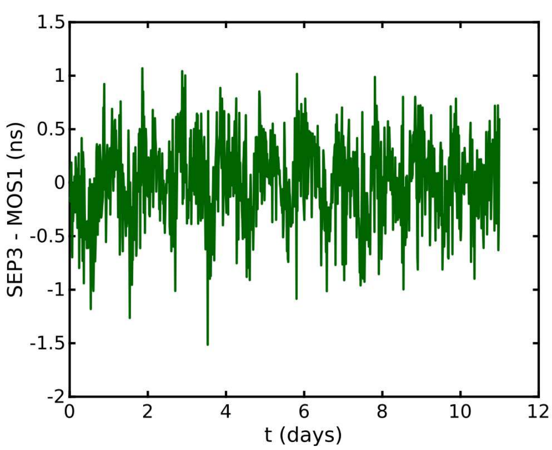


Fig. 5. [SEP3-MOS1] GPS P3 CGGTTS time transfer.

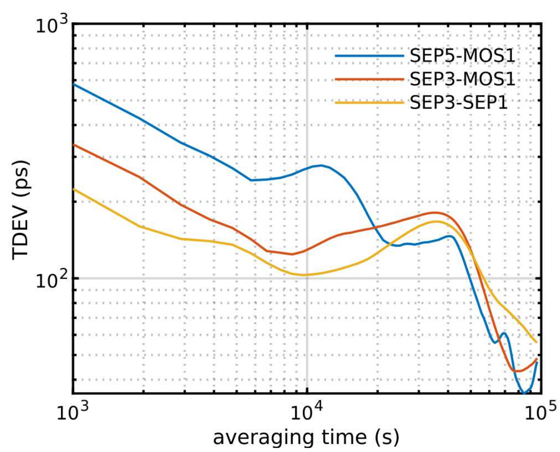


Fig. 6. Time deviation of GPS P3 CGGTTS time transfer.

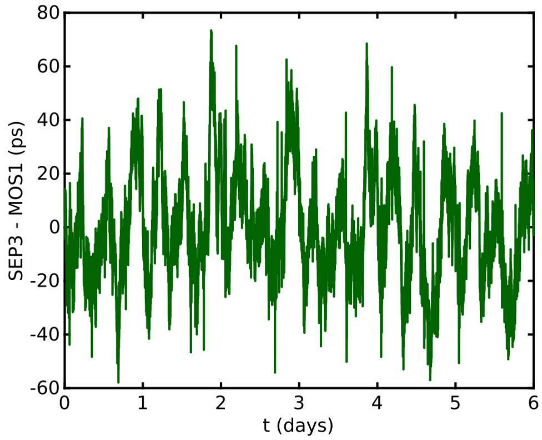

Fig. 7. [SEP3-MOS1] GPS PPP time transfer using NRCAN.

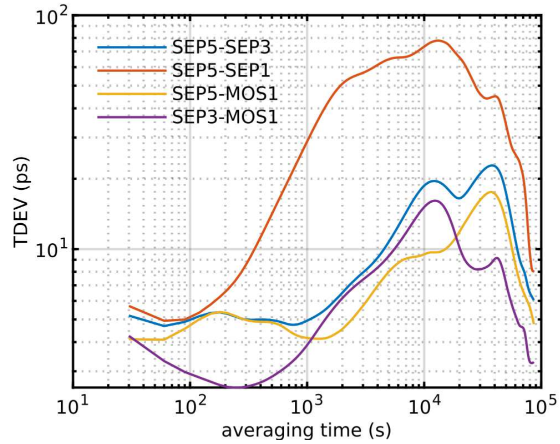

Fig. 8. Time deviation of GPS PPP time transfer using NRCAN.

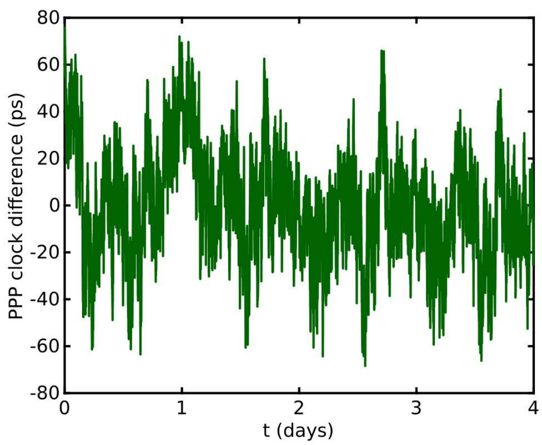

Fig. 9. PPP time transfer with TOPGNSS antenna.

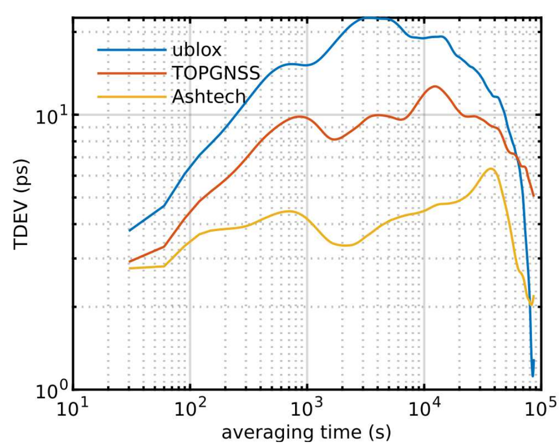

Fig. 10. Time deviation of PPP time transfer with various antennas.