Comparison of GNSS All-in-View (AV) and Upsampled Common-View (UCV) time transfers

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***Abstract*—This study compares the difference between the GNSS P3 code-based time transfer data of the all-in-view (AV) and the proposed upsampled common-view (UCV) methods. The results show that the modified Allan deviations (MDEVs) of the AV and UCV difference for the TL-PTB link are 1.1×10^{-15} at 1 day averaging time and 9.3×10^{-17} at 1 week averaging time. The difference distribution appears as a bell curve with a mean of -0.128 ns. For the OP-PTB link, the mean of the difference between the AV and UCV data is only 0.02 ns. The MDEVs of the difference are 1.28×10^{-15} at 1 day averaging time and 3.27×10^{-17} at 10-day averaging time.**

Keywords—GNSS; P3 code; time transfer; All-in-view; upsampled common-view

I. Introduction

The GNSS code-based time transfer is important for many synchronization applications. The common-view (CV) technique generally works well if the baseline between the two sites is less than 3000 km. In the case of very long-baseline links, the all-in-view (AV) method, which does not depend on the distance between two stations, has become a key solution since 2007 [1]. Both sites do not need to simultaneously receive signals from the same GPS satellites. Instead, the time difference of the two sites is computed after separately averaging the data from the GPS satellites observed at each site, with respect to a common reference timescale. Thus, the AV solution relies on IGS products. Moreover, a diurnal pattern often appears in the AV data. This is possibly due to the fact that different groups of satellites were used for the average at different epochs and no correction for the solid Earth tides of stations was applied. The upsampled common-view (UCV) method is proposed to reduce the dependence on IGS products and improve the rapid results of P3-code based time transfer in long baselines [2]. By using linear interpolation to estimate the values between two samples separated by the period of 1 sidereal day when the same satellite appears in the same part of the sky, the diurnal pattern can be reduced in the UCV results.

However, the previous study for UCV solution focused on the rapid results computed by using daily observations and the broadcast satellite clock and ephemeris. In this study, we aim to investigate the long-term performance of UCV solution. Thus, we use the IGS products to further reduce the biases of the satellite clock and ephemeris estimates. We also aim to compare the difference between the data of AV and UCV and to proof that the UCV solution is valid for not only long baselines but also short baselines.

II. Results

The observed GPS P3 data in CGGTTS version 2E format [3] were utilized in this study. The data corrected with IGS products were used for computing the results of P3 AV and UCV time links. Both the data were computed with a 300 s interval on the same epoch. The detailed information of data processing is available in the previous work [2].

A. TL-PTB link

Since the distance to the Physikalisch-Technische Bundesanstalt (PTB) from the Telecommunication Laboratories (TL) in Taiwan is approximately 8383 km, only the AV and UCV data are available for the TL-PTB link. The difference between the AV and UCV data for the TL-PTB link is shown in Fig. 1. The data ranging from MJD 58,842 to 58,881 (December 25, 2019–February 2, 2020) are compared. There is a high agreement between them in the long-term trend. The histogram in Fig. 2 shows the range of the AV and UCV difference. The distribution appears as a bell curve with a mean of -0.128 ns and the standard deviation is 0.59 ns. When we enlarge the plot by showing only the 5 days of data in Fig. 3, daily regular pattern can be observed. We think most of the pattern comes from the AV data. Nevertheless, the source of the pattern is still need to be studied.

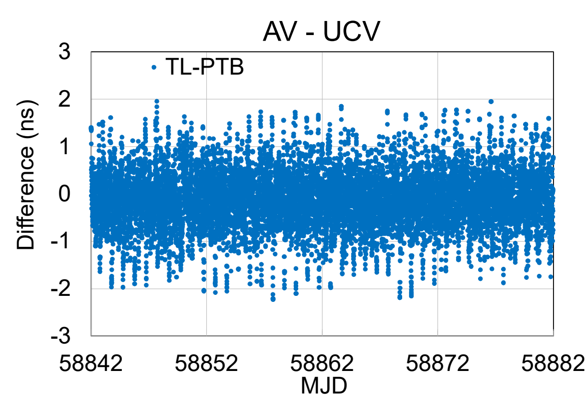

Fig. 1. Difference between the AV and UCV data for the TL-PTB link.

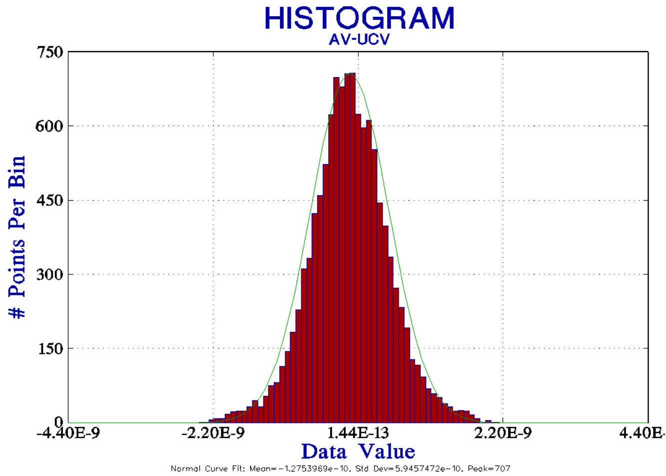

Fig. 2. Histogram showing the range of the AV and UCV difference for the TL-PTB link.

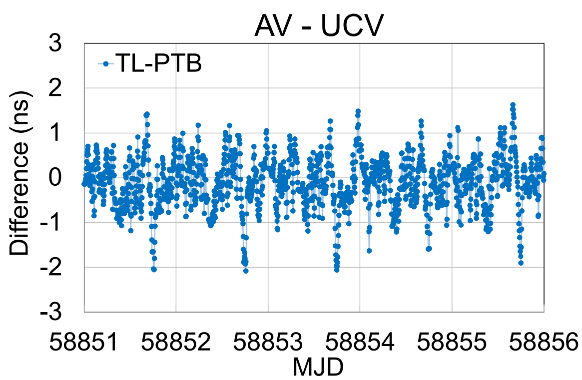

Fig. 3. Difference between the AV and UCV data for the TL-PTB link. Only 5 days of the data are presented.

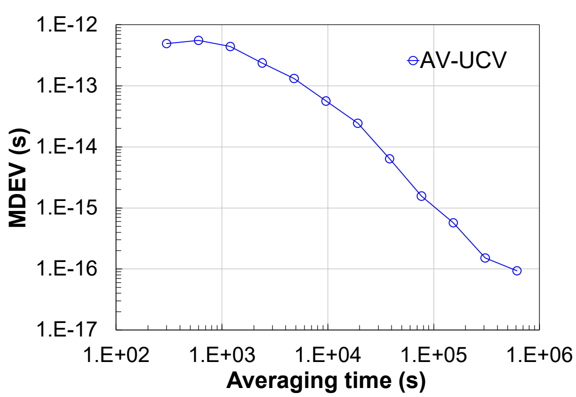

Fig. 4. Modified Allan deviation (MDEV) of the difference between the AV and UCV data for the TL-PTB link.

The modified Allan deviation (MDEV) of the difference is plotted in Fig. 4. A small bump appeared at the averaging times of less than 1 day. The MDEV of the difference at 1 day averaging time is 1.1×10^{-15}, and the MDEV at 1 week averaging time is 9.3×10^{-17}. The results show that the difference between the AV and UCV exists not only for the times within 1 day. The long-term effect between these two methods is not small enough to ignore.

B. OP-PTB link

The distance from the PTB to the LNE-SYRTE/OP (Paris) is approximately 700 km. The difference between the AV and UCV data for the OP-PTB link is shown in Fig. 5. The data ranging from MJD 59,212 to 59,306 (December 29, 2020–April 2, 2021) are compared. The mean of the difference between the AV and UCV data is only 0.02 ns and its standard deviation is 0.57 ns.

The MDEV of the difference is plotted in Fig. 6. The MDEV of their difference at 1 day averaging time is 1.28×10^{-15}, and the MDEV at 10-day averaging time is 3.27×10^{-17}. Compared with the long baseline TL-PTB link, they have similar stabilities at the averaging times of less than 1 day. However, the OP-PTB link shows better long-term stabilities. It may be because the shorter baseline provides a better geometry condition for the both methods.

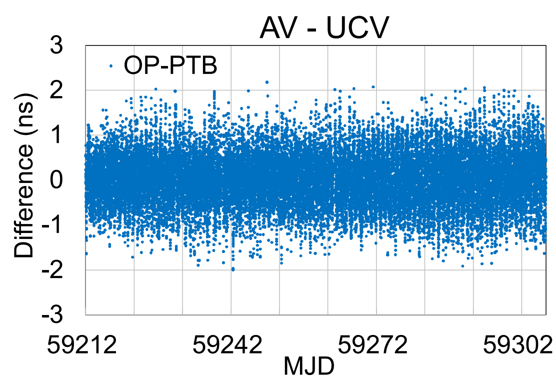

Fig. 5. Difference between the AV and UCV data for the OP-PTB link.

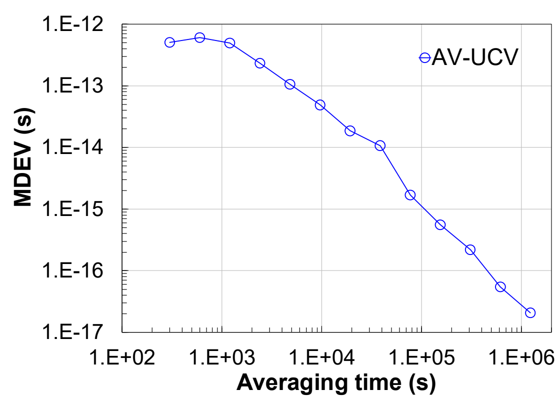

Fig. 6. Modified Allan deviation (MDEV) of the difference between the AV and UCV data for the OP-PTB link.

III. CONCLUSIONS

For investigating the long-term performance of UCV results corrected with IGS products, we compared the difference between the GPS P3 AV and UCV data. There is a high agreement between the AV and UCV solutions in the long-term trend. For both TL-PTB and OP-PTB links, the MDEV at 1 day averaging time can reach 1.3×10^{-15}, and the MDEV at 1 week averaging time can be less than 1×10^{-16}. The mean offset between the two methods is very small for the OP-PTB link, but it reaches -0.128 ns for the TL-PTB link. Moreover, daily regular pattern can be observed in the difference of the two methods. The source of the pattern is worth to be further studied.

ACKNOWLEDGMENT

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