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Continuous IPPP links for UTC

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GNSS Precise Point Positioning with integer ambiguity resolution (IPPP) has been shown in recent years to provide time stability and frequency accuracy of order $1x10^{-16}$ typically within 10-day averaging and reaching the low 10^{-17} range at one month [1,2]. It could therefore provide significant improvement with respect to the currently used UTC links if the IPPP links can be generated in time for the UTC computation. We have performed IPPP computations in deferred time each month over 22 months for selected UTC links and we present results aiming at characterizing the ability to generate continuous links and the achieved stability.

We used GPS dual frequency phase and code data from a dozen laboratories participating to UTC to generate IPPP links. Monthly computations were carried out following the methods in [2] using the integer products from the GRG analysis center [3] when they are published, in general with a delay of about two weeks. Results for month n have thus been available close to the middle of month n+1 and have been published in the monthly directories of link comparisons at [4].

The generation of continuous links started in January 2020 for 8 links and eventually was expanded to some 12 links end 2021. It is shown that the phase continuity of the reference chosen for all IPPP links (PTB) could be maintained over the whole duration of the experiment by continuous comparison of two receivers at PTB. When using a single master receiver at a given station, the median duration of phase continuity of the IPPP link to PTB is observed to be about one year. We present a detailed analysis of our operational results.
Most of these links also provide Two-way satellite time transfer results, either using SATRE modems only (TWSTFT) or with SATRE emitters and Software-Defined Radio receivers (TWSDRR). We present results of time links comparisons between IPPP, PPP, TWSTFT and TWSDRR and discuss the inferred stabilities of the techniques.

We show that the IPPP technique could readily provide continuous links for UTC as soon as the satellite products allowing Integer ambiguity resolution become available with a delay sufficiently short for the computation of a given month to be performed as required for the publication of Circular T. We estimate that the instability of frequency transfer is of order $1x10^{-15}/T$ where T is the total duration in days of the interval of comparison, over which the phase continuity of the two receivers must be ensured. Although all comparisons to optical links [2, 5] have so far shown no significant drift in the IPPP solutions, a conservative approach would call for considering a systematic frequency uncertainty similar to the instability. The total standard frequency uncertainty would then fall below $1x10^{-16}$ for typical intervals of operation of primary and secondary frequency standards used for evaluating TAI frequency, providing a significant gain with respect to presently used techniques and improving the accuracy of TAI.

1. G. Petit, A. Kanj, S. Loyer, J. Delporte, F. Mercier and F. Perosanz, "$1x10^{-16}$ frequency transfer by GPS PPP with integer ambiguity resolution," Metrologia 52, pp. 301-309, 2015.

2. G. Petit "Sub-10^{-16} accuracy GNSS frequency transfer with IPPP" GPS Solutions 2021. https://doi.org/10.1007/s10291-020-01062-2.

3. https://igsac-cnes.cls.fr/

4. https://webtai.bipm.org/ftp/pub/tai/timelinks/lkc/

5. J. Leute, G. Petit, P. Exertier, E. Samain, D. Rovera, P. Uhrich, "High accuracy continuous time transfer with GPS IPPP and T2L2", EFTF 2018, 249-252.