Real-time PPP for time transfer and oscillator disciplining

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We present performance evaluations of a commercial real-time PPP ('RTPPP') timing service (Fugro AtomiChron) for two use-cases: (1) Time transfer and remote clock monitoring and (2) direct oscillator disciplining. Time transfer performance (Fig. 1 a,b) was evaluated by a direct comparison against the UTC(PTB) – TimeTech TWSTFT link[1]. RTPPP time transfer was computed in real time from streams of GNSS observation data[2]. The short-term stability, low latency and scalability of RTPPP compared to TWSTFT opens new opportunities for improved remote clock comparisons and steering, including short time constant disciplining. A prototype disciplined oscillator ('PPPDO') was evaluated against UTC(JV) (Fig.1 c,d). The PPPDO is a self-contained unit steering an OCXO using clock bias estimates (relative to the Fugro time scale) computed by a PPP engine in the embedded receiver (Septentrio Mosaic-T) with corrections received through the GNSS antenna. The prototype's excessive PPS output phase noise masks the short-term stability of the PPPDO evident from the 10 MHz output. High stability, low latency RTPPP clock bias estimates enable short time constant clock steering with the potential for (sub-) nanosecond level time dissemination. Improvements in GNSS receiver chain calibrations and time scale generation are needed to fully realize this potential.

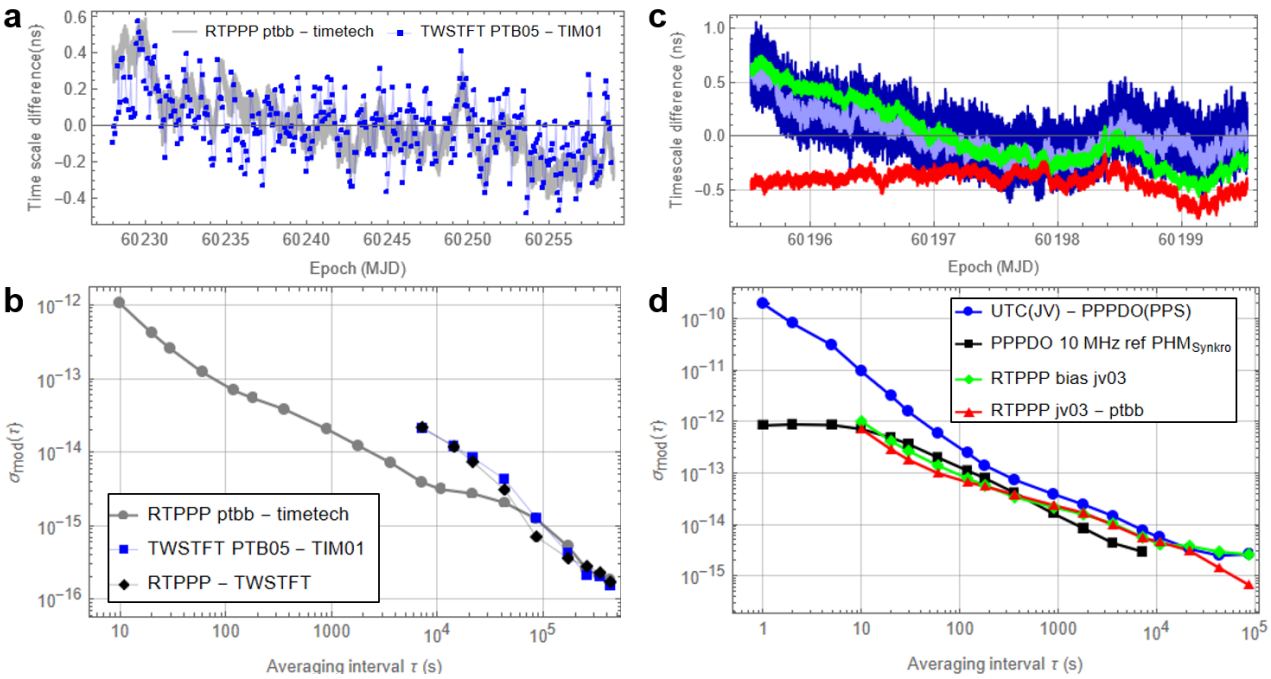

Fig. 1: Performance of a real-time PPP timing service for time transfer (**a** and **b**) and for direct oscillator disciplining (**c** and **d**). Panels **a** and **c:** Data are aligned to zero mean value, except RTPPP jv03 – ptbb (red curve, panel **c**), which is aligned to UTC(JV)-UTC(PTB) values for MJD 60199 published by BIPM. Panel **c**: Measured PPS time differences shown as full series (dark blue) and smoothed 50 pt moving average (light blue).

[1] These are in-loop data since the TimeTech time scale is steered daily to UTC(PTB).

[2] H. Hauglin, O. P. Rønningen and T. Melgård, "Performance of Real-Time PPP for UTC(k) Time Transfer," proc. EFTF/IFCS 2023, pp. 1-3, doi: 10.1109/EFTF/IFCS57587.2023.10272070.