Passive TWSTFT for UTC(k) dissemination

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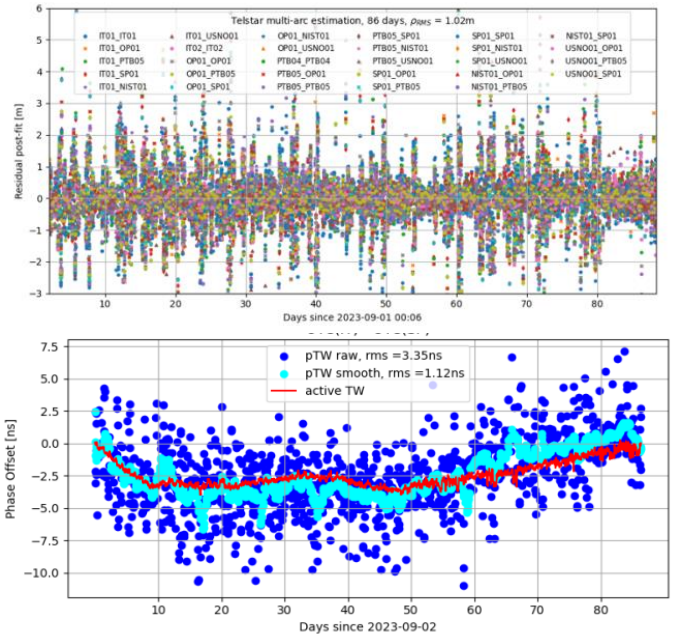
Two-Way Satellite Time and Frequency Transfer (TWSTFT) is the most accurate long distance time transfer method to date, enabling ns-level clock comparisons at intercontinental scales. By relying on differenced pseudoranging observables reflected via a geostationary satellite, *active* (Tx & Rx) TWSTFT cancels common sources of systematic error, notably atmospheric delays and uncertainties in the satellite position. Nonetheless, the complexity of operations and the high costs of equipment and transponder access limits its use to a few UTC(k) laboratories.

This study aims to broaden the access to UTC(k) signals to *passive* (Rx-only) users equipped with non-specialized instruments, such as Software Defined Radio (SDR) receivers. Similarly to Ref [1], ranging measurements collected at the active TWSTFT network are processed in an Orbit Determination (OD) filter to determine the satellite ephemeris and station hardware delays, yielding residuals of ~1m over a 3-month timeline. Subsequently, pseudoranging measurements to passive users are corrected for the dynamic path and atmospheric delays to enable a direct comparison of the user clock with one of the UTC(k) of the active TWSTF network. Preliminary results show passive TWSTFT data, smoothed over 1 day, are in agreement with active TWSTFT results with a residual noise of ~1 ns.

The current limitations of the proposed method concern the tropospheric calibration model, whose fidelity tapers off when mapped to low elevation angles, and the uncertainties on the station positions, inducing daily modulations on the estimated hardware delays. Orbit-keeping maneuvers, occurring twice per day, interrupt the coherency of the OD solution and thus the continuity of service. Ongoing efforts are focused at estimating the ΔV of such maneuvers for real-time implementation, and foresee an in-field experimentation with a mobile (SDR-equipped) passive TWSTFT user station. The end goal is the development of passive TWSTFT synchronization to UTC(k) for timing users, as an alternative to GNSS for enhanced timing resiliency, resistance to jamming and multipath.



Top: Post-fit ranging residuals of TWSTFT satellite. Bottom: Active vs passive TWSTFT UTC(IT)-UTC(SP), with respective rms difference.

[1] Rieck, C., Jarlemark, P., & Jaldehag, K. (2018, April). Passive utilization of the TWSTFT technique. In 2018 European Frequency and Time Forum (EFTF) (pp. 263-269). IEEE.