Optical Two-Way Time and Frequency Distribution for Space Geodesy Applications

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The reference frame is a cornerstone element in all metrological applications related to Earth science. It is based on a combination of measurement systems like Global Navigation Systems, Very Long Baseline Interferometry, and Satellite Laser Ranging. Despite the accuracy of the measurements used to build the reference frame has improved significantly in the last two decades, it still suffers from centimeter-level errors, which can be identified using different combination strategies.

In this contribution, we present a new system for combining space geodetic techniques at the geodetic observatory Wettzell, Germany. Unlike the classical combination approach, where instruments are combined based on geometry, our approach uses a delay drift-free optical time and frequency system to combine the systems based on the origin of the measurement signal and through timing signals. We call this new approach "timing-tie" as an analogy to geometric “local ties”.

The system connects a clock based on a hydrogen maser to a laser that generates ultra-short pulses. These pulses are transmitted through delay-compensated fiber lines to transmit time and frequency coherently. To accurately compensate for all delays, we have developed a new generation of electronic interfaces that generate and distribute Pulse-Per-Second signals with sub-picosecond stability, low-temperature coefficient (0.8 ps/°C), and a constant delay relative to the master reference. To interface with measurement systems, we provide a set of standard RF signals (5, 10, 100 MHz) with low phase noise (-160 dBc/Hz at 10kHz) and high fractional frequency stability. This means that the system preserves the stability of the master clock without significant loss, resulting in a precise copy of the master clock that is perfectly synchronized at each endpoint. Our presentation will detail the fundamental properties of this system and showcase the achieved results, demonstrating its potential to enhance the precision and reliability of geodetic measurements within Earth science applications.

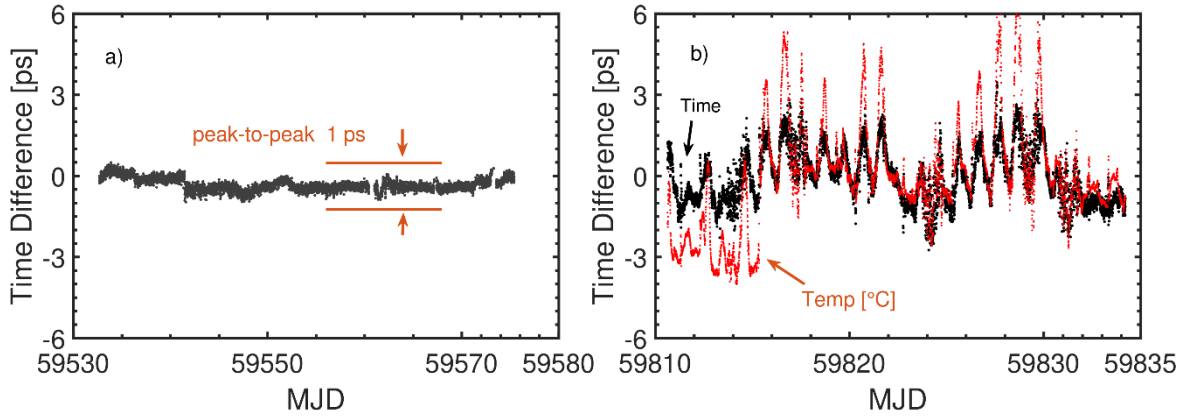

Fig. 1: Two types of timing differences of electrical signals were measured: the first one generated at the end of two stationary links a), and the time difference measured between two radiotelescopes, Radiotelescope Wettzell (Wz) and TWIN Wettzell-North (Wn) b). 59530 corresponds to 11.12.2021.