Initial results from the MIKES-Metsähovi time and frequency link

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Very-Long-Baseline Interferometry (VLBI) uses radio telescopes located around the globe in order to observe simultaneously very distant and weak sources. In order to correlate data the arrivaltime of the radio signals at each radio telescope must be known precisely. Traditionally VLBI stations have relied on local clocks based on hydrogen masers. We are developing a "remote maser" concept for VLBI that will synchronize participant stations to the same reference clock, distributed via optical fibers [1]. We report on the first results from a 50 km optical fiber time and frequency link between VTT MIKES (Otaniemi) and the Metsähovi Radio Observatory. Initial experiments use the White Rabbit (WR) extensions to the Precision Time Protocol (PTP). An evaluation of the systematic and statistical uncertainties is ongoing, with an initial target uncertainty of 100 ps for time-transfer, and $<10^{-15}$ relative uncertainty for frequency transfer at one day averaging time.

An active hydrogen-maser at VTT MIKES, whose frequency-drift is compensated using a high resolution frequency offset generator to produce the Finnish realization of coordinated universal time (UTC(MIKE)), is used as the frequency source of the link. Time and frequency signals are fed to a WR Grand-Master node connected by a single-fiber bidirectional optical link to an identical WR Slave switch at Metsähovi [2]. Time and frequency signals at Metsähovi are compared against local active hydrogen masers. Long-term drift is continuously measured using a time-interval-counter; however, for evaluation of short-term stability the instrument noise-floor of the counter at $2 \cdot 10^{-11}/\tau(s)$ is limiting, and a software-defined-radio-based phase meter [3] with an instrument noise-floor below typical active hydrogen maser performance is being developed.

The round-trip-time (~500 μs) of the optical signal as reported by the PTP-WR hardware was monitored over 20 days, and was observed to show ~7 ns diurnal as well as seasonal changes. These changes do not feed through to the transferred time signal as long as they are symmetric, i.e. the change in uplink delay equals the change in downlink delay. Initial results indicate an asymmetry of the link contributes less than 500 ps to the uncertainty of time-transfer.

We intend to independently verify the time transfer accuracy of the link using a transportable global navigation satellite systems (GNSS) receiver and using Precise Point Positioning post-processing, as well as potentially by transporting a continuously running atomic clock between the two sites.

The time transfer supports geodetic and astronomical measurements at Metsähovi Radio Observatory and Metsähovi Geodetic Research Station. A new geodetic VLBI-station is currently under construction. The new link, together with the atomic clocks of the Metsähovi Radio Observatory, also improves the time and frequency precision for all other measurements undertaken at Metsähovi. Furthermore, the link opens new opportunities for connecting the UTC(MIKE) atomic time scale to other international geodetic observation networks, such as GNSS. Finally, the Metsähovi Radio Observatory's local atomic clocks can be used to support maintenance and robustness of the national time scale UTC(MIKE).

[1] Clivati et al., A coherent fiber link for very long baseline interferometry IEEE Trans. Ultrason., Ferroelect., Freq. Contr., 2015, 62, 1907-1912

[2] Dierikx et al., White Rabbit Precision Time Protocol on Long-Distance Fiber Links, IEEE Trans. Ultrason., Ferroelect., Freq. Contr., 2016, 63, 945-952

[3] Sherman & Jordens, Oscillator metrology with software defined radio Rev. Sci. Instrum., 2016, 87, 054711

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