The demands of GGOS are a high for a modern system for the distribution of time and frequency on a geodetic fundamental station...

We have designed an all optical time and frequency system based on the “Einstein Synchronization Procedure” that allows a synchronization accuracy of 1 ps for all the distributed systems across the campus. Therefore it will be possible to reference all measurements to the same time scale at every measurement system and more importantly to control the system delays to the same level of accuracy. This opens the door to accurate closure measurements of system delays within each measurement technique and from one technique to the next (e.g. from SLR to VLBI). Furthermore this also means that optical time transfer to satellites is no longer limited by the system delays on the ground. This talk outlines the physical properties of the new time and frequency distribution system and emphasizes its importance for inter- and intra- technique co-location measurements.
Clock and measured delay $\tau$ (orbit) are highly correlated for the 1-way techniques

+ variable and unrecognized system delays are causing biases

Consequence: Time is not an observable in space geodesy
Closure measurements are powerful tools

Observation: Clocks accumulate all sorts of systematics (Delays) of the various techniques.

Therefore clock parameters are showing technique specific delays. This applies for inter- and intra- technique comparisons.

Goal: It would be desirable to operate a “Common (super) Clock” for all techniques within an observatory and link the instrumentation with a “super-conductor for time” and tie all techniques to a single point regardless of their nature.
- Time (broadband) and Frequency (narrowband) are two distinct flavors of clocks.
- In order to monitor (variable) delays we need to watch the phase of a clock.

**Wish list**

- Control of local System - Delays on Campus
- Common Clock for all Techniques
- Spacetime definition for entire Observatory
Clock Comparison between buildings 100 m apart

Variation of cable delay ($\Delta t \approx 60$ ps) over 16 hours

Variation between timescales ($\Delta t \approx 320$ ps) over 16 hours
Generation of Time in Wettzell

Cesium

Cesium

Comp

GPS

Offsets (delay of 1 pps edges)

RG58 time distribution (PPS)

UTC_{IFAG} + Cable Delay
≈ UTC_{GPS} ± 100 ns

Master Clock
H-Maser

Cs-Master

Offset

f -> pps

Time Laboratory

VLBI-/SLR- System

5 MHz

Offset

f -> pps

Δt_{off}

numerical corr. value

± 10 ns

good enough for SLR

nowhere near acceptable for
time transfer
Trend over 5 years

UTC - UTC [IFAG]
practical Realisation of the Einstein Synchronisation...

This diagram is only showing the basic concept. In the real world we have to control all internal delays.

\[ t_B = \frac{t'_A - t_A}{2} + \tau_1 \]

... unter Berücksichtigung der System-Delays
General Idea

100 MHz

H-Maser → OFC

optical fiber

2-way

Splitter

robust: wave group - not phase

pps

Fiber stretcher

$\Delta t = \text{const.}$
• 2-Way compensation technique only possible in the optical domain

• required broadband signal available from fs-pulse lasers only

• Uncertainty < 100 fs: ≈ 5 orders of magnitude gain over current systems

• Consequences for Surveying: 1 mm = 3 ps

Example: FEL in Trieste

\[ \Delta t \approx 10 \text{ fs over 8h} \]
OFC pulse train and 100 fs pulse width and marker laser

\[ \text{OFC pulse train and 100 fs pulse width and marker laser} \]

\[ \text{APD} \rightarrow 100 \text{ MHz (frequency)} \]

\[ \text{APD} \rightarrow 1 \text{ pps per threshold detection} \]

\[ \text{optical} \quad \text{electrical} \]

\[ \rightarrow \text{per 2-way comparison space time definition} \]
- all Delays actively held constant
- Interpolator can be substituted by next generation oscillator at any time
- First Links to be installed in 4/2016
Scenarios for the Future of Time and Frequency in Geodesy

- Campus Distribution: active Delay-compensated T & F
- Stabilisation of Interpolator (Maser) by Composite Clock Approach
- Extreme Low Noise Frequency Source: optical Resonator
- Frequency Stabilisation by fiber Link and optical clock (PTB - Syrte)

Vision: Make Time an Observable