Local ties control in application of laser
time transfer

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Motivation – optical time transfer ground to space

- Based on existing SLR network
- Several projects in space or in development
  - T2L2 – France
  - LTT – China
  - ELT – ESA
  - Glonass
- Space to ground comparison of clocks 4 ps @ pass, 7 ps @ 10^6 s, **accuracy 50 ps**
- Used to calibrate MWL
- Time transfer is actually realized between space scale and scale kept inside event timer => requires deep understanding of timing systems of SLR stations
**Geodetic Observatory Wettzell**

- 5x Cs clocks, HP1732 – UTC(IFAG) reference point
- 4x H Maser clocks, SLR and VLBI are running from EFOS 18
- Building separations (50 – 100m long interconnecting cables)
Timing system in Geodetic Observatory Wettzell

GNSS building

Master CLK building

VLBI building

SLR building

~100m RG214

distrib 5MHz

PPS gen. & distrib.

UTC(IFAG)

~150m RG214

distrib 5MHz

~80m RG58

distrib 5MHz

~80m RG214

distrib 5MHz

SLR

Start/Stop

goal: optical time transfer

SLR Event Timer

SLR

Start/Stop

goal: optical time transfer

SLR Event Timer

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Temperature dependency of cables

- Cables frequently used in Wettzell are RG214, RG58, RG223
- Interconnecting cables are 90 cm underground => annual variation $+3/16^\circ C$
- Temperature stability $>1000$ppm
- => expected annual changes $>0.5$ns/year
- Instrumentation temp. dependency $\sim 20$ ps
Two Way Time Transfer principal

- Single coaxial cable is used for interconnection of two ET
- TWTT modules activated alternately
- Resulting time scale diff.: $DS = \frac{(EB1 - EA1) + (EB2 - EA2))}{2}$
- TWTT ~1ps rms; < 10ps systematic error for distances > 100m
- Systematic error depends on quality of the interconnecting cable
- LDF4, 100m => 3ps

Calibration of the TWTT method for comparing 1pps time scales

- TWTT method is used to set “0” between Event timers
- 1pps are connected to 2\textsuperscript{nd} input => additional calibration
- Measuring difference of 1pps and TWTT input (using spitted pulses); \( \Delta ET = 3.6 \) ps
- Connecting to ref. points with cables \( \tau_{C1} \) and \( \tau_{C2} \) and exchanging them => \( \Delta \tau_{C} = \tau_{C2} - \tau_{C1} = 10.183 \) ns

\[ SLR_{ref.} - UTC(IFAG) = ppsDiff - \Delta \tau_{C} - \Delta ET \]
TWTT UTC(IFAG) ↔ SLR

1) UTC(IFAG)  SLR ref. point

2) GNSS WTZS  SLR ref. point; comparing H masers

TWTT 93 m long cable

HP1732 - UTC(IFAG) and WTZS

5MHz EFOS18
TWTT UTC(IFAG) ↔ SLR

two different clocks

UTC(IFAG) time scale is derived from Cesium
SLR time scale is derived from H maser EFOS 18
TWTT time scale comparison < 1ps rms
T2L2 and ELT requires picoseconds control of local time scales
TWTT GNSS WTZS ↔ SLR
same clock, different passes

- Implementing TWTT method to support T2L2 and ELT time transfers
- Comparing T2L2 and GNSS time transfer
- TWTT was calibrated several times; consistency < 50 ps (BNC connectors)
- During the T2L2 campaign Wettzell was calibrated
- Comparing T2L2 calibration and TWTT results:
  - biggest difference 252 ps
TWTT implementation in to the observation

Comparing Cs vs. H maser during the pass

- Comparing Cs vs. H maser during 20 min pass
  - Observation must be corrected piecewise with linear fit

- Comparing H maser vs. H maser during 20 min pass
  - Observation can be corrected with linear interpolation

- *.NPT and *.FRD (rate data) unchanged

- *.FRF - changed - including TWTT measurements and calibration T2L2/ELT
TWTT UTC(IFAG) ↔ SLR, problems

- Jumps in clocks in SLR; during storms
- The time bias is not corrected to the same value
- Problems when T2L2 calibrate us, the calibrations are not valid after the jump
- Mission calibration should be related only to SLR
- Time difference between SLR and another techniques (GNSS, MWL, …) must be reported
- Time setting in SLR Event timer works with uncertainty > 1 ns

Conclusion

- The possible implementation of Two Way Time Transfer method using two event timing systems was investigated in Geodetic Observatory Wettzell.
- The absolute calibration for comparing time scales of TWTT was done (reproducibility < 50 ps).
- In the frame of T2L2 campaign Wettzell was calibrated. Calibration is within 250 ps compared to TWTT.
- In future it is planned to apply TWTT measurements in to *.FRF.
Event timing system - New Pico-Event Timing

Temperature dependence ~170 fs/K

TDEV < 4 fs (τ= 300 s up to 2 h)

Timing jitter:

Synchronous pulse ~ 490 fs rms

Asynchronous pulse ~ 700 fs/ch rms

TWTT systematic error < 10ps

> 4 kHz measurement rates, depends on quality of interconnecting cable