SLR and GNSS co-location and delay control for the application of laser time transfer

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Abstract. *Recent progress in the optical time transfer using SLR stations is increasing the demands for the stability and accuracy of the local ties measurement of the stations. The main aim of projects like the European Laser Timing (ELT) is the time synchronization with a precision of better than 40 ps rms and an absolute error well below 100 ps. Synchronization in time requires a good control over all system delays involved in the measurement process. We have put a lot of effort in improving the Wettzell Laser Ranging System (WLRS) to cover these requirements. Furthermore we have developed a two-way measurement technique allowing the collocation of the GNSS receivers at Geodetic Observatory Wettzell with respect to time. We are continuously working on improving the additional external target calibration techniques with the goal of including the external target measurements daily and automatically. Our next activity is focused in development of the new GNSS station, which is connected to the same clock as the WLRS. The GNSS antenna contains corner cube retro-reflectors allowing the two SLR stations WLRS and Satellite Observing System Wettzell (SOSW) on site to jointly use this external target and to increase the consistency between them. Last but not least, we have added a new reference target to the local ties network, which will be used for ELT calibration. The paper discusses the obtained results and proposes how to properly deal with the system calibration in applications of the optical time transfer.*

Introduction

The precise and accurate time transfer is a prerequisite of a number of experiments in fundamental physics, Earth science, global navigation and many other disciplines. One of the most challenging disciplines is the time transfer ground to space. The standard techniques used recently are based on radio frequencies. They do provide nanosecond accuracies (Defraigne2008). A significant improvement in time transfer accuracy between ground and space is expected to be achieved by using optical frequencies (Pearlman2002). The contributors of systematic errors to the overall error budget in the optical domain may be reduced to the level of 10 picoseconds.
In the past years, at the geodetic observatory (GO) Wettzell Intra-technique co-locations have been intensively studied. Comparing local GNSS baselines with the local ties, differences of a few cm were found to be induced by deficiencies in antenna phase center calibration, (temperature-induced) local deformations and other time-dependent variations. A global multi-year analysis of all stations with two or more receivers within the IGS network would help to correctly judge the frequency and size of local effects. For SLR and VLBI no short baselines exist (apart from a few short-term operations of mobile systems. Therefore, intra-technique comparisons for these techniques were only possible by analyzing different solution types (e.g., Rothacher2011). The two radio telescopes

and the two laser stations at the GO Wettzell will open up completely new possibilities for intra-technique co-location.

The principal simplified schematic of how the different geodetic techniques are related is in Figure 1. The local ties measurements at GO Wettzell are carried out at regular basis during the last 25 years, (Klügel2011). The results are showing no significant displacement of the space reference points. The new TWIN radio-telescopes have been added to the local ties network in 2012 (Lösler2013).

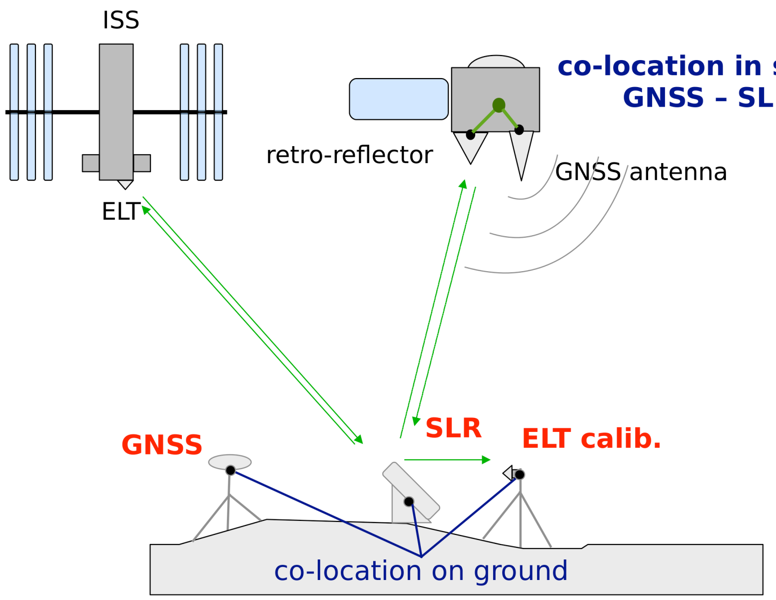

Figure 1 Principal schematic of co-location on the ground.

ELT and GNSS time transfer

The laser time transfer (LTT) ground to satellite is an extension of the standard measurement technique of satellite laser ranging (SLR). A ground SLR station fires laser pulses toward the satellite and records the local times epochs of the laser firings. On board of a satellite the laser pulses are detected and time tagged to the satellite time scale. At the same time the laser pulses are reflected by a system of retro-reflectors back toward the ground station, which, again, detects the return pulses and time tags them to the ground time scale. The recorded data on board of the satellite is then sent to the ground using a standard telemetry channel. Combining the laser firings times, propagation and instrumental delays and satellite arrival times, the space and the station clocks may be compared.

Challenging objective of the T2L2 and ELT projects are comparison of systematic errors of the optical time transfer with microwaves techniques. Such experiments require deep understanding of timing systems at sites. At GO Wettzell we are running UTC(IFAG) and the station is equipped with several atomic clocks, which are distributed all around the station, the schematic distribution of the atomic clocks is in Figure 2.

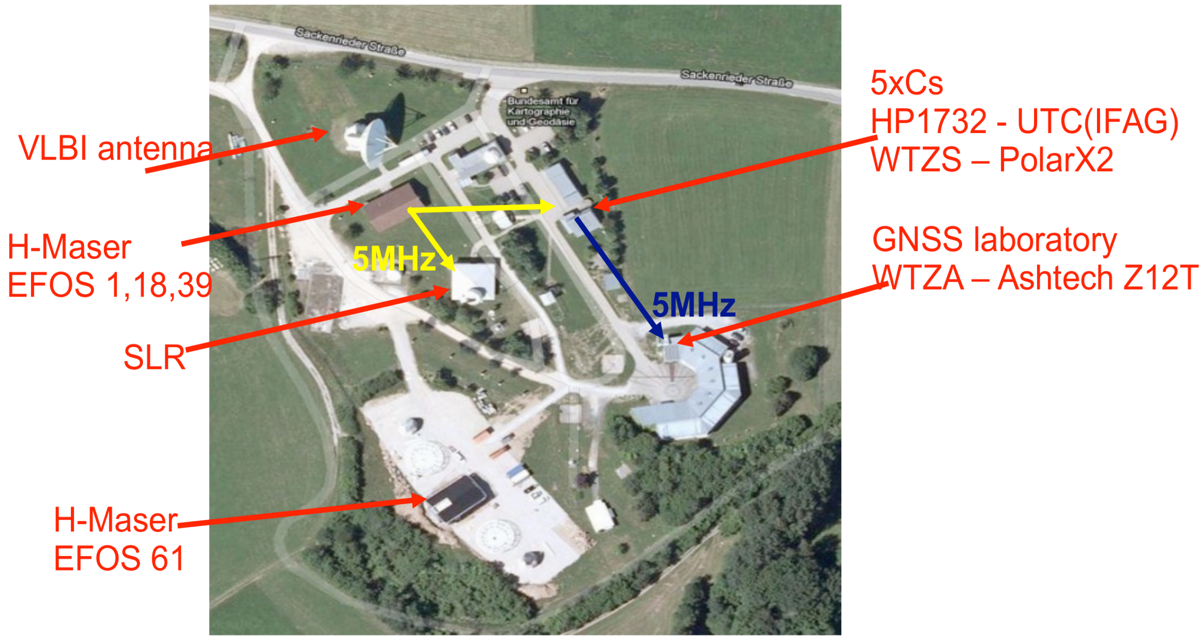

Figure 2 Stable Time and Frequency Standard for all Space Techniques at Wettzell.

For the ELT project the location of H-Maser EFOS 18 from which SLR station is supplied is essential. Generally the entire time distribution at the station is done by distributing the reference frequency of 5 MHz and generating the time scale (represented by PPS) at each building. In the past we have developed the TWTT technique (Panek2012), which was used for monitoring of the time scales between different geodetic techniques. We have focused mainly on the timing bias between SLR and our master clock. An example of the timing instabilities is in Figure 3, which is showing the time scale comparison of the time scales between SLR and master clock located in a different building 60 m away.

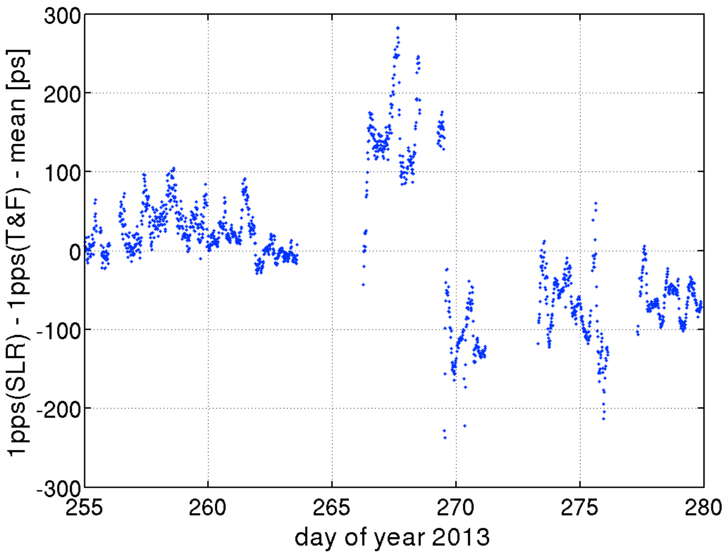

Figure 3 Time scale comparison between WTZS and SLR time scale.

Along with UTC(IFAG) there is a GNSS receiver indented to being used for time transfer in the master clock building. From Figure 3 one can conclude that comparing SLR and GNSS time transfer will be highly effected by such instabilities.

Very poor timing distribution of time scales at GO Wettzell is the main reason for us to build up a new timing infrastructure in the future, which will be based on the optical frequency comb time transfer technique (Pape2010).

In addition to the new timing system we are building a new GNSS station located at the WLRS. The antenna will be installed in front of the WLRS station and involve a retro reflector installed close to the reference point of the antenna such way that it can be used as an external calibration target.

Another activity is focused on the WLRS station calibration in the ELT project. Beside others, (Prochazka2014) we are building up the infrastructure for installation of the ELT detector. The entire ELT calibration is based on an estimation of the length between the reference point of the telescope and the ELT detector, as indicated in Figure 4. Therefore, we are planning to add the ELT calibration reference point to the local tie survey. We have prepared an ELT installation platform next to the SLR external target. It is possible to take the ELT detector off and put a small retro-reflector at the position of its reference point, which can be used for measuring the distance L (Figure 4).

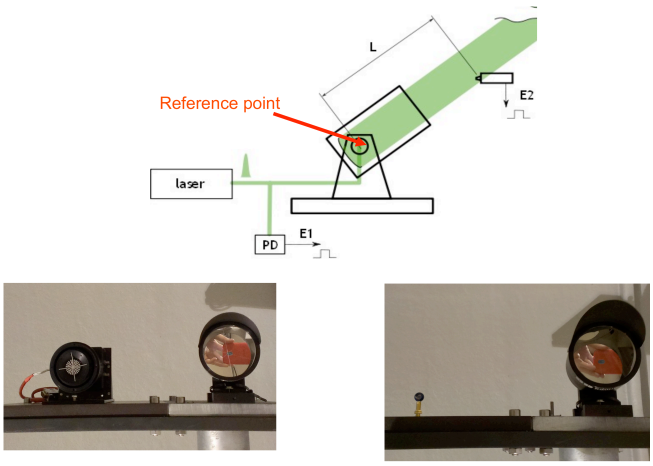

Figure 4 The Elt calibration mission is based on correct estimation of distance L as it is displayed in the block diagram. The photographs are showing instalation of the ELT detector in front of the WLRS telescope.

The ELT calibration can be considered as a special case of the external target calibration. During the last year we have added the external target measurement routine to our every week schedule. As the time, the measurement is not completely automated. However, we are working on it at the software and hardware level. The timeline of the external target calibration constant is plotted in Figure 5.

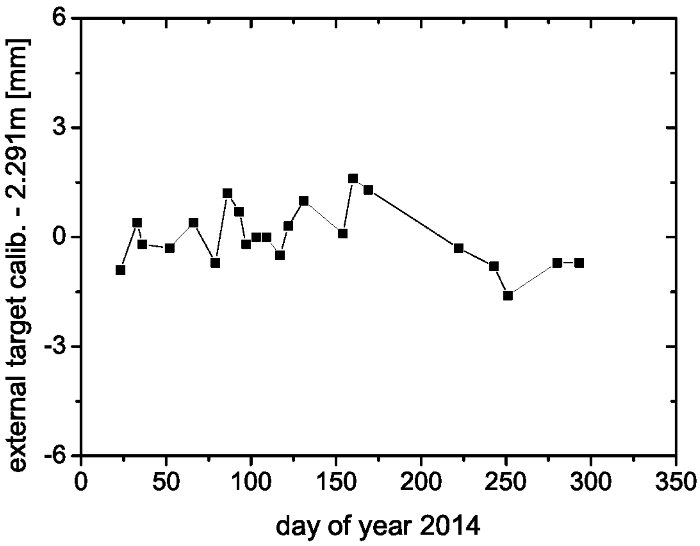

Figure 5 WLRS External Target Calibration.

Conclusion

We are systematicly working on improving the local ties at the GO Wettzell. Long-term measurements of geodetic points at the station (spanning more than 25years) do not show significant displacement. Therefor, we are focusing on the co-location of different geodetic instruments. We are planning to install a new GNSS station located in the SLR station with its antenna located near, by such a way, that it will be possible to put a retroreflector close to the reference point of the antenna. This retroreflector will be used as an external target in the future. With the external target is closely connected with ELT calibration. In the last year we have build up an important infrastructure for doing this calibration in the WLRS.
Another activity is focused on the GO Wettzell timing system. We have implemented the Two Way Time Transfer method for comparing the locally generated system time scales with our timing reference point UTC(IFAG). Primarily we have concentrated on time scales between the WLRS and our master clock.

ACKNOWLEDGMENT

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