WLRS tracking experience on GNSS

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Abstract

The laser ranging of GNSS satellites during daytime is one of the most demanding tasks in the ILRS. Since the satellites are in orbits more than 19 000 km above the Earth, the link budget is not favorable. On top of that we find that sparse laser returns are often masked by noise events caused by background radiation. This paper summarizes the experiences and applied practices from the Wettzell Laser Ranging System (WLRS).

1 Introduction

GNSS satellites are difficult to track. In particular during daytime when the signal to noise ratio is low. It is hard to identify valid returns even in the presence of moderate background noise level. Applying the laser link equation [1] to the system parameters of the WLRS according to table 1 yields that we have to expect a number of less than 10 photo-electrons from the existing variety of GNSS satellites, except for some GLONASS satellites with laser cross sections of the order of 240 million square meter, where the return signal level is slightly above 20 photo-electrons.

Table 1: WLRS parameters for signal strength and noise reduction

	MCP (Photec PMT210)	APD (laser components SAP500)
Detector quantum efficiency	11%	>90%
Laser energy	15mJ@20Hz (avg. 0,3W), 120ps+	
Receive aperture	0,42m²	
Transmit/receive efficiency	0,2/0,5	
Beam divergency (full a.)	24arcsec (8arcsec Lageos)	8arcsec
Field of view (full angle)	30 arcsec	18arcsec
Range gate	600ns (40ns resolution)	200ns (40ns resolution)
Spectral filtering	0.35nm	0.15nm

The WLRS was constructed to be capable of ranging to the moon. Hence it has a single aperture of 0.75 m, which is used both for transmit and receive functions. There are 2 distinctly different detectors attached to the system. For LEO tracking we usually use the MCP detector, while an Avalanche Photodiode (APD) is used for the GNSS satellites. The latter sensor has a much higher quantum efficiency, but at the same time also suffers from intrinsic detector noise. Ranging to the GNSS satellites therefore requires good and stable telescope pointing, a narrow field of view (spatial filtering) and sharp spectral filtering. Last but not least the transmit laser beam has to be aligned to the pointing axis of the telescope with high accuracy. For the WLRS we find these parameters to be approximately ±25 µrad for the telescope pointing accuracy including laser alignment. The field of view is adjustable between 10 and 75 µrad half angle with 50 µrad a rather typical value. The spectral filters are specified to have a bandwidth of 0.15 nm and 0.35 nm respectively. Since the laser of the WLRS is more than 15 years old, the beam energy rarely exceeded 15 mJ over the last 12 month.

2 GNSS observation

In order to evaluate the system performance with respect to GNSS tracking, we have looked at HEO satellites, which were continuously available during the last decade. These are the Etalons, GLONASS and GPS satellites. Although Etalon is not a GNSS satellite, it shows almost the same characteristics with respect to the link budget and is therefore included in this analysis. The WLRS was continuously tracking HEOs, with an almost constant number of passes from 2004 to 2007. In 2008 the system degraded slowly, as the telescope slowly developed a small optical misalignment, which affected both system transmission and pointing. This trend was exacerbated by some detector issues and resulted in a major overhaul in 2010 including the refurbishment of the telescopes motors and encoders. This was followed by an realignment of the optical path of the telescope in 2011 and resulted in returning to the previous performance of 2004 to 2007. At the end of 2011 the repetition rate of the WLRS was doubled to 20 Hz and the high efficient APD was installed. From then on, especially the GPS observations were going up by more than a factor of 2. Comparing day- to nighttime measurements of Etalon showed that HEO satellites also became much more unpopular with the observers as it was hard to obtain measurements during the period where the telescope degraded. An increasing number of HEO satellites with better cube corner arrays in recent times caused a swing towards these targets. It is easier to track Galileo than Etalon. Figure 1 shows the ratio between daylight and nighttime normal points from the Etalon satellites for illustration purposes. The WLRS always had the capability to track remote targets during daytime, although this was more difficult and required a lot more operator patience.

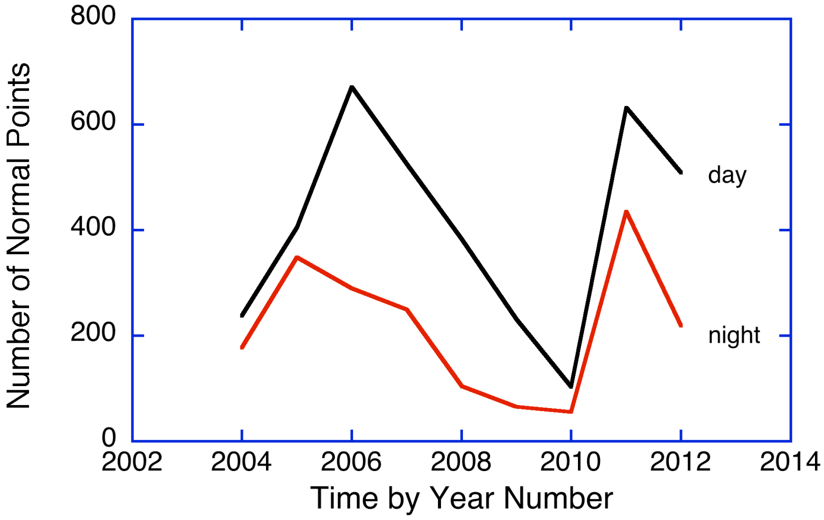

Fig. 1: Ratio of daylight and nighttime normal points from the Etalon satellites observed by the WLRS system in Wettell.

3 Improvements

Several improvements were applied to the WLRS recently. The semi-automated verification of the optical system alignment is an important step. For the WLRS there are three optical axes, which have to coincide. A quick verification of these settings can now be made with software assistance. There is no need to change some mechanical settings by hand any longer. The level of reliability was improved by installing industry qualified opto-mechanical components. The central component for the system automation is our modular control software package SLR 2.0, which is now operational and was introduced in 2012 for routine tracking. It is designed to support automated tracking and remote control and also introduces satellite interleaving to the WLRS tracking schema. The implementation of the SAP500 APD from Laser Components GmbH was highly improving the system efficiency and noise performance. Therefore it is now easier for the observer to find the high earth orbiter satellites.

5 Conclusion

At the moment the WLRS is a highly efficient SLR system, spanning almost the entire range of available targets. We are currently in the process of aiming to track even more demanding targets like RadioAstron and the lunar reflectors. As we are increasing the level of automation, we expect to improve the performance of the system by developing a good interleaving strategy and by balancing the observation load more in favor of unpopular targets.

[1] J. Degnan, “Millimeter Accuracy Satellite Laser Ranging: A Review,” Geodynamics Series, **25**, p. 133 - 162, (1993)