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Transponder Testbed for Optical Ranging at Lunar Distances and beyond

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Abstract

Ranging to lunar retro reflector targets is the most demanding task for any laser ranging facility, because the link-margin for the existing Apollo- and Lunakhod- targets is very marginal. Although the time-series of lunar laser ranging is the longest of all space geodetic techniques, the overall data yield is very sparse. Furthermore there are wide data gaps near full and new moon because of the high background noise level. This inhomogeneous data distribution limits the resolution for the analysis with respect to fundamental physics quantities such as the equivalence principle. Future lunar landing missions, equipped with active transponders may provide a much enhanced link budget and hence denser data with much fewer gaps. We have set up a transponder test-bed experiment to investigate the properties of such future instrumentation. This paper outlines the experiment and reports some results.

1. Introduction

For a given laser ranging station and retro reflector panel at distance r, the receive signal intensity falls off with r^{-4}. At lunar distances at around 380000 km, the signal level quickly approaches the single photon regime, which makes the moon a hard target to range to. For one-way optical ranging transponders in comparison, the link budget drops off at a much lower rate corresponding to r^{-2}. However, an active optical receiver and timer in space require much higher system complexity on top of an electric power supply, although the overall mass balance is in favor of the optical transponder, since current corner cube arrays are very heavy. Another important aspect of one-way ranging is the requirement of a highly stable and clock, synchronized to the ground station. This latter demand may be provided by a microwave link in the context of a variety of different payloads on a lunar lander. In order to investigate the properties of optical transponders experimentally, we have built a small instrument package for the detection and transmission of a pulsed laser beam and mounted and mounted it on top of the Wettzell Laser Ranging System (WLRS) on the Geodetic Observatory Wettzell. Using passive satellites equipped with corner cube reflectors we have folded the beam pass of each sub-station back to the respective partner instrument [1]. Figure 1 shows the experimental setup.

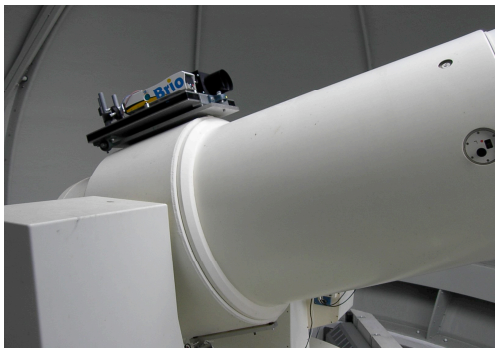

Figure 1: The transponder test-bed package on top of the laser ranging telescope of the WLRS.

2. Observations

A number of measurements have been carried out to various satellite targets in different configurations in order to evaluate the test assembly and to gain experience with optical transponders in general. In a reduced form the link budget turned out to be dependent on the instantaneous distance to the

satellite (d) and the radar cross-section of the reflector array (σ_s) as eq. 1 shows.

$$r_t = d^2 \sqrt{\frac{4\pi}{\sigma_s}} \quad (1)$$

Figure 2 shows an example of a daylight Ajisai pass with the transponder unit operated as a single ranging device.

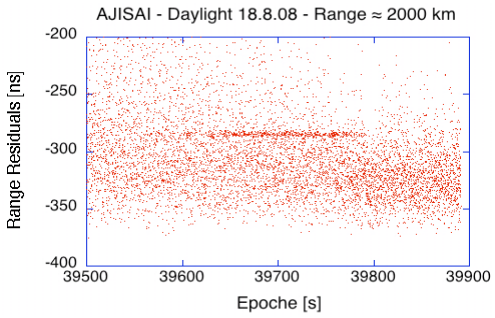

Figure 2: A residual plot of a satellite ranging measurement taken with the transponder test module.

The telescope receive aperture in this experiment was only 10 cm wide and the transmit aperture did not exceed 3 cm.

Real one-way ranging transponder measurements to the Lunar Reconnaissance Orbiter were also carried out, verifying the results from the test facility.

3. Summary and Conclusions

In order to work towards a new approach for lunar laser ranging, we have evaluated transponder and one-way ranging techniques at the WLRS system using a test-bed system and the Lunar Reconnaissance orbiter as targets. Apart from one-way ranging to the moon also asynchronous transponder measurements were obtained successfully.

Acknowledgements

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References

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