Session 2: Ground Station Performance from Current Satellite Arrays
Chairs: Georg Kirchner and Matthew Wilkinson

Matthew Wilkinson (matwi@nerc.ac.uk), NERC Space Geodesy Facility, Herstmonceux, UK.

Introduction

The final test of any laser retro-reflector array on-board a satellite supported by the ILRS is how easily it is acquired and tracked by the SLR station network. The best targets are quickly acquired, can be tracked in daytime and through hazy skies, have small satellite signature and give consistent range measurements.

The optical performance of a retro-reflector can be designed and tested before launch. It's response can be computationally modelled and optimised using ray tracing simulations and once it is manufactured its optical properties can be measured in a laboratory, such as the SCF in Frascati. Once the satellite is in orbit, however, can SLR stations make any assessment of the optical performance of a retro-reflector array? To do so a station must be able to accurately determine values for each parameter in the radar link budget to predict the expected return signal strength for comparison with the station measurements. Alternatively, relative comparisons can be made, which should be repeatable between stations if all variables are properly accounted for.

Uncoated corner cubes are used on the latest GNSS satellites and it has been suggested that a polarisation dependent range error is present for this cube type. Is this effect detectable by SLR station and is is a significant error?

Radar Link Equation

The radar link equation (Degnan, 1993) is:

$$n_{pe} = \eta_q \left(E_T \frac{\lambda}{hc} \right) \eta_t G_t \sigma \left(\frac{1}{4\pi R^2} \right)^2 A_r \eta_r T_a^2$$

where η_{pe} is the number of photoelectrons, η_q is the detector quantum efficiency, E_T is the laser pulse energy, λ is the laser wavelength, h is Planck's constant, c is the speed of light, η_r and η_t are the receive and transmission efficiencies, G_t is the transmitter gain, σ is the satellite optical cross section, R is the range to the satellite, A_r is the effective area of the telescope and T_a is the one-way atmospheric transmission. This equation gives the theoretical performance for a station that can be compared to its measurements, provided that all terms are accurately modelled and measured.

Relative Performance Assessment

Without taking the link budget approach, it is still possible for individual SLR stations to make relative in-orbit assessments of satellite retro-reflectors. In the paper by Wilkinson and Appleby, 2011, this was done by averaging return signal measurements over many satellite passes which smoothed atmospheric transmission variability and system polarisation dependence. Careful consideration of station working practices and system upgrades was required. This investigation used full rate data from 2007 to 2010.

Figure 1 shows the final return rates scaled for satellite range, atmospheric attenuation and array area for the Herstmonceux and Yaragadee stations. The Compass-M1 retro-reflectors were shown to perform approximately twice as well as those on Etalon1+2, 3 GLONASS, GIOVEA+B and GPS35+36.

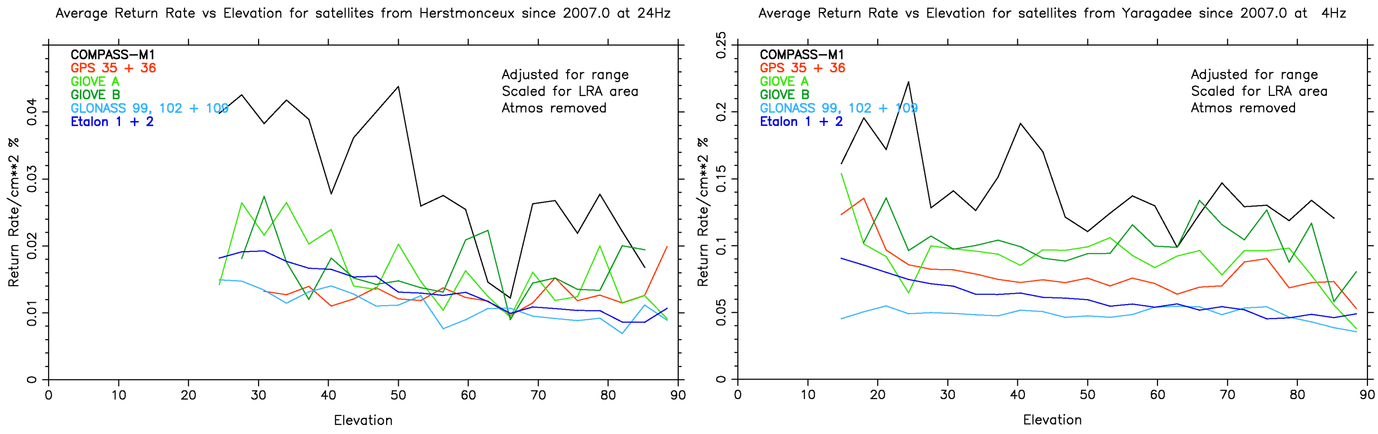

Figure 1. Return rates scaled for range, atmospheric attenuation and array area for the Herstmonceux and Yaragadee SLR stations.

Conclusions

In this session, NGSLR showed they were performing within minimum and maximum link budget calculations and a wide range of return rates were possible. Narrow divergence and pointing errors were identified as a causes for return signal strength to be an order of magnitude or more down from what it could be.

Studies at Herstmonceux used energy densities measured on Jason-2 and at the station. But at present these measurements do not agree with the link budget calculations, which require further refinement.

Mark Davis showed the wide range of cube designs used on MEO targets (QZSS, ETS-8 and COMPASS) and calculated link budgets for some SLR stations. Most observation performances were well below the link budget estimations.

Mark recommended that the link budget calculations are improved by better divergence calculations and Ray Burris described on a poster a new method to calculate the divergence from beam scanning 2 satellites.

The MéO station reported successful tracking of RadioAstron at 20% return rate at 50 000km and at a few % to beyond 250 000km. However they do not always get it when they attempt and would expect. This fits with the unsuccessful attempts by other stations. MéO are also working to improve their link budget, including potentially by a factor of 100 using an adaptive optics unit.

Georg Kirchner demonstrated SLR range errors measured at Graz by controlling the laser linear polarisation on uncoated cube targets. This was as much as 8mm on Glonass 115. It was recommended that stations consider switching to circular polarisation.

References

Degnan, J.J. *Millimeter accuracy satellite laser ranging: a review*, in: Contributions of Space Geodesy to Geodynamics: Technology, Geodynamics Series. Series, vol. 25, pp. 133–162, 1993.

Wilkinson M., Appleby G, *In-orbit assessment of laser retro-reflector efficiency onboard high orbiting satellites*, Advances in Space Research, Volume 48, Issue 3, 3 August 2011, Pages 578-591, ISSN 0273-1177, 10.1016/j.asr.2011.04.008. (http://www.sciencedirect.com/science/article/pii/S0273117711002456)