Acquiring the inter-satellite laser link in the GRACE Follow-On Laser Ranging Interferometer

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1 Abstract

The laser ranging interferometer (LRI) on GRACE Follow-On [1] acquired a laser link between two satellites, separated by 200 km and with relative spacecraft velocities of 5 m/s. *Initial acquisition*, a key step in the commissioning of any space-based laser interferometer, minimizes pointing uncertainties between satellites following launch and tunes the laser frequency offsets between lasers on all satellites until trackable, heterodyne beatnotes are available on all photodetectors. This was the first time optical link acquisition has been demonstrated between satellites and, despite differences between the planned LISA acquisition strategy and the LRI's, the results of the LRI acquisition could inform the development and testing of LISA acquisition. In this talk we present the results of the LRI link acquisition, describe the testing and development of the acquisition algorithm, and discuss implications for LISA acquisition.

The LRI's initial link acquisition involved a 9-hour scan that resolved 5 degrees-of-freedom: two pointing degrees of freedom per satellite and a laser frequency detuning between the frequency stabilized laser on the *master* satellite and the free-running laser on the *transponder* satellite. Unlike in LISA, the initial acquisition scan was performed without a dedicated acquisition sensor. Instead, it used the measurement hardware: while both satellites performed spatial scans, and the transponder satellite swept its laser frequency, the output of the measurement photodiodes onboard each satellite were monitored for heterodyne signals appearing in band. Each satellite recorded the scan position, laser frequency and amplitude of any heterodyne signals that were measured. At the end of the scan, the recorded measurements from both spacecraft were analyzed on the ground, and the pointing corrections for each satellite, as well as the frequency detuning were determined. Once these corrections were applied, the two satellites were commanded into *reacquisition* mode. An automated procedure, reacquisition is used to optimize the pointing and frequency detuning of the two satellites by performing a reduced scan, ending when both spacecraft acquire a beat note in band. Reacquisition needs to be autonomous since it is also used if the links are lost or disabled at any point. It is possible that LISA could use a similar reacquisition strategy as the goal – acquiring heterodyne beatnotes simultaneously on all satellites while competing with MHz laser frequency doppler shifts and long optical delays – are common to the two missions.

A novel technique used in testing the LRI acquisition algorithms, that could find application in the testing of LISA reacquisition algorithms, is the system on a chip (SoC), a full simulation of the GRACE Follow-On LRI that runs on an FPGA. A single SOC runs a copy of the LRI flight software and includes models of the laser frequency noise and sensitivity to misalignment of the optical link. Connecting two SoCs with ethernet allows a two satellite LRI simulation to be performed, providing a way to test optical link acquisition. This talk will discuss how the SOC was used to evaluate the acquisition algorithms, comparing the results with results from the initial acquisition scan performed in orbit. We will also present on how a similar SOC model is planned to be used in the development and testing of reacquisition algorithms for LISA.

2 References

[1] B. S. Sheard, et al., J. Geodesy **86** (12), pp 1083-1095 (2012).