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DEMONSTRATION OF COHERENT OPTICAL COMMUNICATIONS AND RANGING FOR SMALL SATELLITES

Abstract

Laser, or optical, communications offer numerous advantages over traditional radio frequency (RF) communication systems. This is particularly true for small satellites, whose capabilities can be constrained by their limited size, weight, and power (SWaP). Due to the high directionality of the laser beam that serves as the carrier, very high data rates can be achieved with smaller, lighter, and less power-intensive terminals. Laser communications also benefit from a less crowded spectrum (in the visible and near-infrared) with little-to-no regulation; no licensing or frequency allocations are necessary as with RF systems. The narrow beamwidth of the laser carrier is also more difficult to intercept, enhancing the security of a laser communications channel as compared to an RF channel.

These advantages have been widely recognized and driven the development of a variety of laser communication terminals intended for micro- and nano-satellites at both companies and research institutes. However, these terminals have predominantly utilized intensity modulation/direct detection (IM/DD) schemes and have yet to incorporate ranging over the communications link. Coherent optical communications links can achieve significantly higher data rates, and high precision range and range-rate measurements can be easily obtained, even simultaneously, as a byproduct of the optical communications link. These measurements can then be used to improve orbit determination and the positioning and coordination of satellites in a constellation.

In this work, we describe an effort to model and experimentally demonstrate the phase-based ranging performance of a coherent optical communication system with simultaneous ranging. While such models and validation have previously been demonstrated, particularly in support of space-based laser interferometry instruments, these neglect to consider the impact of the communications capability, including components for modulation or data decoding, and the constraints of small satellite platforms. We leverage recent advances in terrestrial telecommunications components, such as high performance digital signal processors (DSPs), which have been integral in the development of laser communication terminals for micro- and nano-satellites. The experimental validation includes a laboratory-based testbed and characterization of key components in the communications and ranging terminal.