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Advance Higher Throughput Communications and Networks for GEO and LEO satellites (3)

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DEVELOPMENT OF A LOW-COST, COMPACT AND PORTABLE OPTICAL GROUND STATION FOR HIGH BANDWIDTH LEO DOWNLINKS

Abstract

The growth of satellite constellations has created an unprecedented demand for high-bandwidth communication capabilities such as Free Space Optical (FSO) communications, which offers a revolutionary alternative, providing throughput improvements of 10-100 times over RF technology. There have been considerable developments globally on satellite laser communication terminals, but the full benefits of high-speed downlinks can only be realized by the development of low cost, portable, commercial optical ground stations. To this end, this paper introduces 'AstroBeam'—a low-cost, compact, and portable Optical Ground Station (OGS) designed specifically for LEO satellite optical downlinks. The system features a 16-inch Ritchey-Chrétien telescope integrated with an optical backend that houses Fine Tracking components and specialized opto-electronics. An 888 nm guide beacon emitted from the OGS enables rapid acquisition by LEO optical downlink terminals. The telescope's Az-El drive system achieves open-loop pointing accuracy of ¡80 microradians; post that the system tracks in closed loop with the acquisition camera. For receiving the 1550 nm intensity-modulated data beam, AstroBeam employs a two-stage tracking system: a coarse stage using an acquisition camera and a fine tracking stage utilizing a quadrant detector coupled with a Fast-Steering Mirror (FSM). This configuration delivers arc-second level pointing precision and efficient coupling into single-mode fibers. The paper presents the details of the OGS design, including system trade-offs, optical and mechanical considerations, electronics architecture, FPGA implementation, software design, and the Pointing, Acquisition, and Tracking (PAT) system. Performance validation through both star tracking and actual LEO satellite observations demonstrates the system's capabilities, while field testing with 'AstroLink' 0.8U optical terminal under various conditions validates AstroBeam's ability to support high-bandwidth optical communications between LEO satellites and ground stations.