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DESIGN, VERIFICATION, AND VALIDATION OF THE COMMUNICATION SYSTEM OF AN UNDERGRADUATE CUBESAT MISSION

Abstract

This paper outlines the design, verification, and validation of the communications system of the Carleton University CubeSat project. The CubeSat project is an opportunity for final-year undergraduate students to partake in the design, verification, and validation of systems on a 3U CubeSat. As an undergraduate capstone project, there is an increased emphasis on implementing as many in-house solutions as possible. The communications system is comprised of ground and spacecraft-based elements, in order to deliver spacecraft telemetry and payload data consisting of locations of detected ongoing forest fires in Canada. In addition, the satellite operator uses the system to transmit telecommands to the spacecraft.

The ground station is designed, built, and tested in house and consists of four subsystems: Structure, Tracking, Radio Frequency (RF), and Digital Processing. The ground station consists of commercial-off-the-shelf, in-house manufactured and additive manufactured parts. Ground station software is a combination of open-source software, in-house written firmware, and GNU Radio flowgraphs. The spacecraft element is categorized in three main subsystems: Antenna, Antenna Feed Network (AFN), and Transceiver. The antenna and antenna feed network are designed in-house using ANSYS High Frequency Structure Simulator (HFSS), and Keysight Advanced Design System (ADS). The communications system uses a single antenna on the spacecraft, operating in half-duplex, transmitting a circularly polarized signal at Ultra High Frequency (UHF) while the ground station supports two redundant UHF antennas. Software on a space-proven transceiver is configured through testing to satisfy link budget requirements.

Verification and validation can vary based on the subsystem of interest. The system link budget is verified through analysis, and subsystems are tested individually to ensure they can deliver the required operational performance. The AFN and antennas undergo Vector Network Analyzer (VNA) testing at the component and subsystem level to quantify gain, losses, and other performance parameters of the subsystem. The transceiver is configured through testing to select the optimal settings such as modulation and coding. Ground station subsystems are validated by communicating with on-orbit satellites that have similar communications architectures. Spacecraft validation involves end-to-end tests in a simulated environment to accurately test the functionality using predicted losses from the link budget and empirical data from subsystem tests.