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PERFORMANCE ANALYSIS OF IN-ORBIT SPACE DEBRIS TRACKING USING LOW-COST PASSIVE BISTATIC RADAR

Abstract

The growing threat of space debris in Low Earth Orbit (LEO) presents significant challenges to satellite operations and sustainability. STRATHcube, a student-led 2U CubeSat mission developed at the University of Strathclyde, seeks to address this issue by deploying a novel Passive Bistatic Radar (PBR) payload capable of in-orbit tracking of space debris. By leveraging illuminators of opportunity, the PBR system detects variations in received signal energy during target passes, allowing for post-processing analysis to estimate debris size and velocity vectors. This research aims to enhance the mission's Technology Readiness Level (TRL) by developing a comprehensive performance assessment framework for the PBR system, ensuring its effective operation in orbit.

Through four structured work packages (WP), this paper focuses on modelling key radar performance parameters, including Forward Scatter (FS) Radar Cross Section (RCS), Doppler effects, and Signal-to-Noise Ratio (SNR) variations. WP1 develops an FS RCS model to refine radar link budget calculations, while WP2 simulates Doppler frequency shifts for improved target motion analysis. WP3 integrates these models to assess PBR performance under varying transmission power and SNR conditions, and WP4 establishes a flexible framework for future refinements. This iterative methodology enables rapid assessment of critical design interdependencies, supporting STRATHcube's custom L-band front-end development. To support these, a simulation of key satellite orbits, including the Iridium constellation and targets such as the International Space Station, is conducted to assess observation windows for the PBR.

Outcomes of this study include a validated performance model that informs system optimisation, ensuring the PBR payload meets mission requirements. The research findings play a crucial role in advancing the TRL classification of the demonstrator, contributing to global efforts towards improved Space Surveillance and Tracking. Future research will refine the FS RCS and Doppler models to enhance debris tracking accuracy. Additionally, simulations of variable transmission power and SNR will support planned investigations into SNR sweeps of the PBR post-processing algorithm, antenna gain patterns, bit depth analysis, and link margins, all essential for ensuring robust mission performance.