

Integrated Additive Manufacturing and Origami Antenna Systems for Autonomous CubeSat Radar and Remote Sensing

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This paper introduces a novel concept that combines origami-inspired deployable antennas, additive manufacturing techniques, and continuous wave radar systems to revolutionize CubeSat capabilities for autonomous remote sensing and Earth observation. By leveraging additive manufacturing for lightweight, multi-material structures and integrating low-power continuous wave radar, the proposed system offers a compact, efficient, and scalable solution for various CubeSat missions. This design emphasizes reduced power consumption, broad frequency operation, and optimized deployment in extreme environments, such as space or oceanic monitoring. The concept also integrates conformal antennas on CubeSat solar panels and incorporates floating receiver networks to enhance communication efficiency and data collection reliability.

CubeSats have gained significant attention due to their compact size, low cost, and versatility in a range of applications, including remote sensing, communication, and Earth observation. However, key challenges such as limited power capacity, constrained antenna space, and difficulties in robust sensing systems persist. This paper proposes a next-generation CubeSat system that combines three cutting-edge technologies: origami-inspired deployable antennas, additive manufacturing for lightweight structures, and continuous wave radar for low-power sensing. In this presentation, we will introduce a novel concept that merges these technologies into a cohesive design, demonstrating how they address critical challenges in CubeSat design. We will also discuss how this integration expands the potential of CubeSats in applications such as space debris tracking, environmental monitoring, and oceanic sensing. The proposed CubeSat system employs origami-inspired antennas for ultra-wideband communication and sensing. These deployable antennas allow for compact storage during launch and autonomous expansion in orbit, offering high gain and broad frequency coverage. Additive manufacturing, using advanced multi-material 3D printing, is employed to fabricate lightweight CubeSat components, including the deployable antennas and housing. This significantly reduces the mass and complexity of the system, while also enhancing thermal and structural resilience. To further augment CubeSat capabilities, continuous wave radar systems are integrated, enabling low-power, multi-mode remote sensing for applications such as space debris monitoring and near-Earth scanning. To maximize available surface area and reduce design constraints, conformal antennas are integrated onto CubeSat solar panels and other surfaces. Additionally, floating receiver networks, incorporating quasi-isotropic antennas, are proposed for seamless communication in remote areas, including oceanic environments. These receivers operate as part of a distributed network that enables real-time data acquisition and relay for CubeSats deployed in low Earth orbit. The combination of these technologies creates a robust, modular system that can adapt to diverse mission requirements.

The CubeSat design process involves several stages. First, origami-inspired deployable dipole arrays are fabricated using multi-material 3D printing techniques. Beam steering, radiation patterns, and deployment reliability are tested through simulations and experimental setups. Second, a compact continuous wave radar system is developed and integrated with CubeSat surfaces. Simulations of electromagnetic performance, impedance matching, and link budgets are performed using CST and MATLAB software. Third, floating receiver networks are designed for seamless data relay. These receivers utilize quasi-isotropic antennas to ensure reliable communication over large areas. Finally, the complete system is subjected to thermal and vibration tests to ensure performance under simulated space conditions. The details of these stages, including technical challenges and experimental results, will be discussed during the conference presentation.

This research was supported by Penn State NASA.