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MEMBRANE REFLECTARRAY ANTENNA DESIGN DEPLOYED ON SMALL SATELLITES USING COMPOSITE BOOMS

Abstract

Some small satellites require large antennas for high-frequency Earth observation or large-capacity high-speed communication. This paper shows an innovative deployable reflectarray antenna design, enabling a 50cm-by-50cm two-layer square antenna to be stowed into 1U. The mass is only 300g, including deployment mechanisms. A one-layer deployable membrane structure was already demonstrated by 3U CubeSat OrigamiSat-1 in 2019. The design has been updated to a two-layer membrane structure; one layer is for antenna patches, and another is for electrical ground. Two layers are 5mm apart to be used as a dielectric layer. This deployable reflectarray antenna technology will be demonstrated on 3U CubeSat OrigamiSat-2, launched in 2025 by JAXA's Epsilon rocket. This paper describes mechanical and electrical design details, manufacturing processes, verification methods, and verification results for the flight model.

One significant feature of the proposed membrane reflectarray is its unique mechanical design. A 50cm-by-50cm deployable structure is made of two layers of flexible substrates. It can be stowed in 1U CubeSat volume using a flasher origami pattern and deployed only using the elastic energy stored in four diagonal cylindrical composite booms. These features are enabled by (i) pop-up picture book mechanisms of flexible substrates, (ii) the use of textile material as a base membrane to accommodate the non-negligible thickness of the substrates, (iii) new hybrid cylindrical booms that combine the carbon composite cylinder and steels convex tapes; and (iv) a simple hold-and-release mechanism activated by cutting polymer wires by a nichrome heater.

The reflectarray's electrical performance is first predicted by numerical electromagnetic field analysis and later verified by measurement in an anechoic chamber. The structural performance is first estimated by prototyping and later verified by deployment test on the ground, long-term stowage test, and vibration and shock test. OrigamiSat-2 will demonstrate 5.8GHz communication between the satellite at 500km altitude and a ground station. The proposed technology will enable large deployable antennas, even on small satellites, for the frequency from L-band up to X-band.