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A Deployable Multi-faceted Reflectarray Antennas for Space Applications

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***Abstract*—**Deployable structures enable reducing mass, stowed volume, and design complexity in space exploration missions requiring efficient, lightweight, and compact designs. Antennas are essential components of satellites and their design directly impacts the performance of wireless communication systems. Reflectarray (RA) antennas are particularly attractive for high-gain applications, combining the benefits of phased array and reflector antennas. However, traditional RA designs often optimize electrical and mechanical aspects separately, leaving a gap in achieving fully integrated solutions.

This work introduces a novel mechanical and Radio-Frequency (RF) co-design methodology for a foldable, multi-faceted RA that expands upon deployment into a shape that improves RF performance. The approach integrates structural integrity and deployability while minimizing the required signal transmission delays. The proposed design offers a cost-effective solution with high stowage efficiency, low RF loss, ease of flat-panel manufacture, and the ability to create shaped beams with efficient beam-pointing. Its compact stowed state and large deployed size eliminate the need for separate backing structures to withstand launch loads, further reducing mass, volume, and complexity.

The design consists of a central panel surrounded by six deployable petals, enabling expansion to four times the stowed area. Rigid foldability ensures the panels rotate about distinct axes without deformation, preserving flatness and preventing phase errors that could impact RF performance. However, a key challenge lies in accommodating material thickness, as self-intersecting panels can hinder deployability. To overcome this, we explore several techniques, including Hinge-Shift, Spatial Linkages, Split-Vertex, and Synchronized-Offset Rolling-Contact Element (SORCE). These methods increase the deployed-to-stowed diameter ratio while preserving structural integrity. We define several quantitative metrics to evaluate overall performance, such as packing efficiency, which measures how compactly the structure can be stowed, and usable deployed area accounting for space lost due to gaps created by the thickness accommodation technique. We also assess the number of hinges to reduce mechanical complexity and potential failure points, while considering limitations like protruding hinges. Since surface area is directly proportional to antenna gain, maximizing surface area enhances RF performance, offering more versatile and efficient solutions for satellite communications.

This co-design approach bridges the gap between RF performance and mechanical deployability, providing scalable solutions for space systems. It lays the foundation for advancing foldable polygonal mechanisms inspired by origami. Moreover, this methodology can inspire designs for terrestrial and airborne applications, adaptable to various frequency bands and platforms, from CubeSats to large satellites. *(Abstract-1)*

***Keywords-component*—Deployable; Reflectarray antenna; Foldable multi-faceted mechanism; Design engineering; Space.**

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