K-Band Circularly Polarized Beam Steerable Reflectarray Enabling CubeSat Internet of Space: Conceptualization and Validation

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Internet of space (IoS) envisages establishing a constellation of satellites in low earth orbit (LEO) to provide seamless network coverage across the globe. This vision of IoS, once realized, is going to largely benefit regions that currently lack Internet access, particularly remote areas where the construction and maintenance of ground-based network infrastructures are precluded due to harsh environmental conditions and excessive cost. Since establishment of IoS requires the deployment of vast amount of satellites in space, CubeSats are deemed suitable candidate platforms for their advantages of low-cost and lightweight. However, realization of IoS with CubeSats also accompanies numerous engineering challenges, one of which falls on the development of an antenna system that can sustain a high data-rate link while being amenable to integration with the small CubeSat form factor. This challenge is further magnified by the requirement that the antenna must dynamically reconfigure its radiation pattern to maintain the data link while traveling in orbit. In particular, the antenna for IoS CubeSat is currently anticipated to sustain broadband circular polarization (CP) in K/Ka-band and be capable of beam scan up to 60° in elevation and 360° in azimuth. Achieving a combination of these metrics necessitates innovative antenna design. While considerable amount of publications have recently emerged in the domain of beam steerable antenna, none of the reported works can fully satisfy the technical requirements posed by CubeSat IoS, nor have these antennas been tailored for CubeSat platform.

The aim of this work is to develop a low-profile and lightweight CubeSat antenna that can meet the stringent RF specifications of IoS. We demonstrate the conceptualization and validation of a CP beam steerable reflectarray antenna designed for the band of 17.8-20.2 GHz. The major novelties and contributions of this work includes the following: (a) A "rotation-phase" property is exploited in reflectarray element design to achieve broadband CP performance in the range of 17.8-20.2 GHz. (b) A novel reflectarray unit cell containing multiple Archimedean spiral arms is designed to provide 4 states of phase shift. The phase response of each unit cell can be electronically switched to synthesize the reflectarray aperture phase required for wide-angle beam scan. (c) Proof-of-concept reflectarrays are prototyped and measured. The measurements of reflectarray prototypes have demonstrated RHCP beam scan up to 60° across the targeted frequency band of 17.8-20.2 GHz. These results have validated our concept and highlight the potential of this reflectarray design to meet the technical requirements by IoS CubeSats.