URSI AP-RASC, Sydney, Australia, 17 – 22 August 2025

Thin-membrane Metasurface Antennas for Small Satellites: Challenges and Opportunities

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Extended Abstract

Small satellites are designed and utilized for increasingly challenging missions, where more versatile and better performing antennas are also needed. While satellite size and available mass budget are shrinking, higher antenna gain and larger apertures are desired for advanced Earth Observation and communication satellites. In navigation and positioning constellations, accurately shaped beams are needed for full ground coverage with minimum constellation size, while missions beyond Earth orbit need very high gain to beam all the data back to home. Multifrequency capabilities of antennas can provide benefits for signal reliability in challenging weather conditions, for signal interference scenarios such as jamming, or simply for the efficient usage of the spectrum available for the mission.

In most use cases, a single satellite antenna with the capability of generating multiple frequency bands and beams would enable significant reduction of satellite mass and cost. Holographic leaky-wave metasurface antennas have been demonstrated to be able to fulfill all these performance requirements while providing many additional desirable features such as simple feeding mechanisms and planar structures [1], which makes them attractive options for satellites. However, such antennas must be large, typically at least 14 wavelengths in diameter, to enable efficient operation [2]. This limits the usability of traditional rigid panel metasurface antennas on small satellites.

To enable the use of highly versatile holographic leaky-wave metasurface antenna technology on small satellites, Project DIAMANT, co-funded by Business Finland and Aalto University, is developing a method to integrate such antennas on thin-membrane substrates. The flexible thin-membrane structures enable stowing the antennas in small volumes and deploying them in orbit, making the antennas also suitable for smaller spacecraft even at lower frequencies where the antenna size would otherwise be too large. The DIAMANT project develops solutions to the design challenges related to the low thickness and relatively low permittivities of flexible substrates. In addition, the project explores suitable deployment mechanism solutions that can provide sufficient deployment accuracy and thin-membrane flatness and smoothness.

This work presents advances in designing large metasurface antennas for small satellites and discusses the challenges which still need to be solved. Our first results show that thin-membrane holographic metasurface antennas can enable a wide range of completely new opportunities for small satellites in the future.

References

[1] Marco Faenzi et al. “Metasurface antennas: New models, applications and realizations”. In: *Scientific reports* 9.1 (2019), p. 10178.

[2] Amrollah Amini and Homayoon Oraizi. “Adiabatic floquet-wave expansion for the analysis of leaky-wave holograms generating polarized vortex beams”. In: *Physical Review Applied* 15.3 (2021), p. 034049.