Innovation Launchpad Network+

CASE STUDY

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The Challenge

The rapid expansion of Low Earth Orbit (LEO) satellite systems and CubeSat platforms has created significant challenges for reliable satellite communication infrastructure. One of the primary difficulties arises from the strict physical constraints of CubeSats, including limited mass, volume, and power availability, which restrict the implementation of conventional high-gain antenna technologies. Traditional solutions such as parabolic reflectors and phased-array antennas are often unsuitable because they require bulky mechanical deployment systems or high-power consumption, making them impractical for small satellite missions.

Another challenge is achieving stable beam control and high data-rate communication within compact satellite platforms. Communication links operating in the Ka-band require precise phase control, high antenna gain, and efficient radiation characteristics to maintain reliable uplink and downlink connectivity between satellites and ground stations. However, maintaining broadband phase stability and consistent beam performance across the operational band remains technically demanding, particularly under dynamic orbital conditions. In addition, many existing antenna architectures rely on complex feed networks or mechanical beam-steering mechanisms, which increase system complexity, cost, and potential failure risks in space environments. ecognising these limitations, researcher Dr Uddin highlights the need to investigate alternative antenna architectures capable of meeting CubeSat constraints while maintaining high communication performance. Addressing these challenges requires exploring innovative antenna concepts that can provide stable beam control, high gain, and broadband phase response without relying on mechanically deployable structures. To validate such concepts, researchers must redesign and develop prototype antenna structures suitable for small satellite platforms such as CubeSats. Experimental verification is essential to determine whether the proposed architectures can satisfy practical communication requirements.

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Innovation

This project introduces an innovative reflectarray antenna architecture designed to address the performance limitations of conventional CubeSat communication antennas. The novelty of the research lies in the development of a metamaterial-inspired reflectarray structure that enables compact size, stable beam performance, and broadband phase response while maintaining compatibility with the strict size and mass constraints of CubeSat platforms. Unlike traditional reflector or phased-array systems that require either bulky mechanical deployment or complex feed networks, the proposed design employs engineered unit-cell geometries to manipulate electromagnetic wavefronts across the antenna aperture.

The reflectarray design incorporates metamaterial-based unit-cell structures that enable controlled phase compensation and improved radiation efficiency. These unit-cells combine multi-resonant geometrical features to achieve smooth phase variation and stable reflection magnitude across the operational Ka-band frequency range. This approach allows the antenna to maintain high gain and controlled beam characteristics while preserving a low-profile and structurally simple architecture suitable for small satellite platforms.

To validate the innovative design, a physical prototype of the reflectarray antenna was fabricated and experimentally characterised. The experiment was conducted within an anechoic chamber facility provided by the Satellite Applications Catapult. Measurements were performed in a near-field testing configuration across multiple azimuth and elevation incidence angles to investigate the beam patterns and radiation characteristics of the antenna. The experimental results confirm that the proposed reflectarray exhibits stable radiation behaviour, controlled beam formation, and suitable efficiency for high-frequency satellite communication. These findings demonstrate the feasibility of integrating the compact reflectarray antenna into CubeSat platforms, supporting the development of resilient non-terrestrial satellite communication systems.

Result

The project successfully demonstrated the development and validation of a compact reflectarray antenna architecture operating within the Ka-band for CubeSat communication applications. The system-level results confirm that the proposed design approach enables controlled electromagnetic wavefront manipulation through a planar, low-profile structure suitable for space-constrained platforms.

Unit-cell evaluation under electromagnetic excitation showed stable reflective behaviour with a continuous and sufficiently wide phase response, enabling effective phase compensation across the aperture. The multi-resonant characteristics observed in the design contributed to smooth phase variation and improved operational bandwidth, supporting consistent reflectarray functionality without disclosing specific structural parameters.

Numerical simulations verified that the antenna produces a directive radiation pattern with a well-defined main beam and stable performance across the intended frequency range. The results indicate efficient aperture utilisation and coherent field combination, demonstrating reliable beam formation and maintaining performance consistency under different excitation conditions.

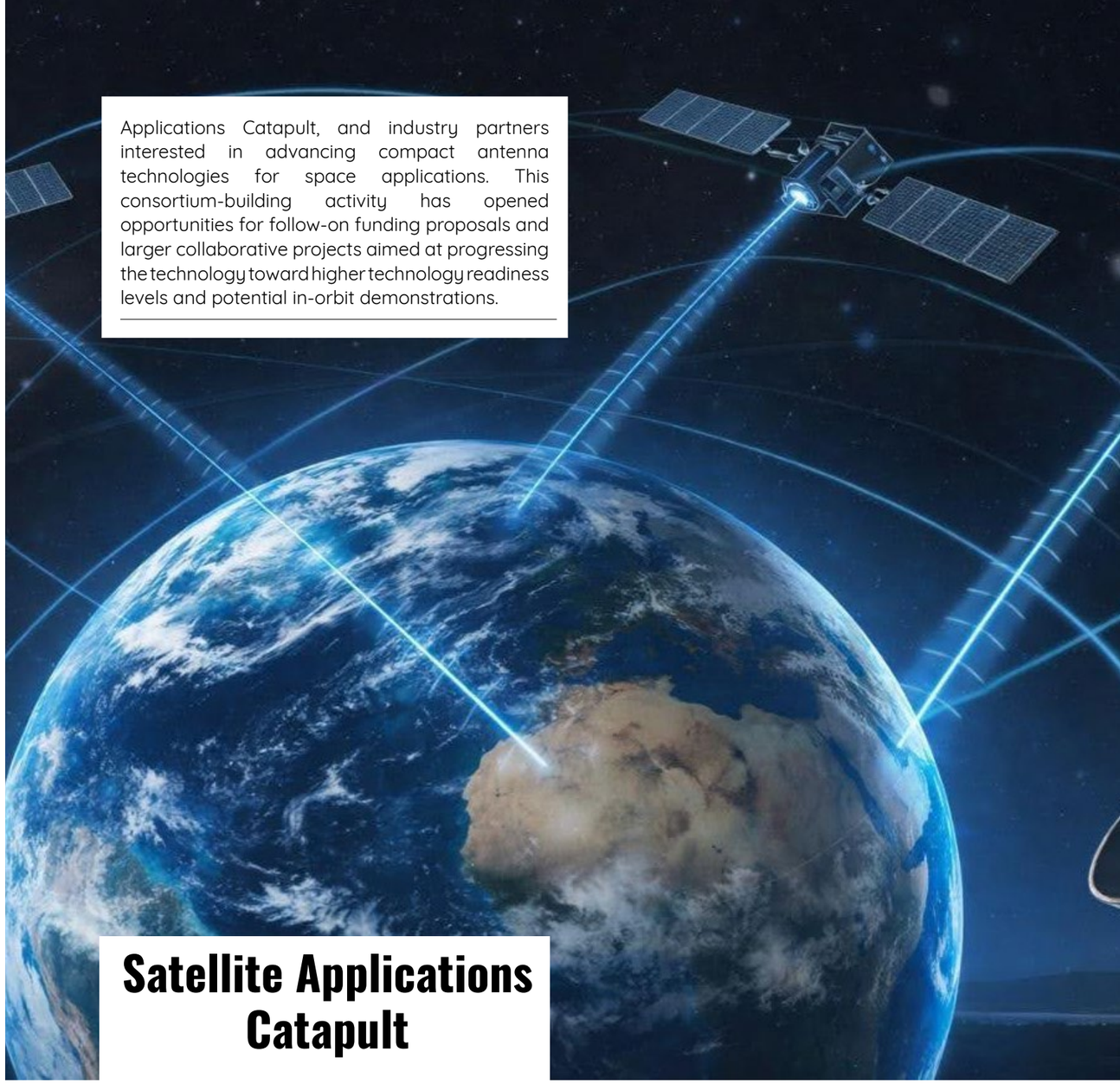
Experimental measurements conducted in an anechoic chamber confirmed the simulated behaviour, validating the formation of a stable beam with controlled sidelobe characteristics and preserved polarization performance. The agreement between simulated and measured results demonstrates the robustness of the design methodology.

Impact

The project generated several academic, industrial, and community impacts that extend beyond the immediate technical outcomes of the research. One important outcome was the dissemination of knowledge through a peer-reviewed article published in IEEE Access, provided a comprehensive overview of reflectarray antenna technologies, including different design architectures, structural configurations, radiation characteristics, and integration approaches for small satellite systems. By synthesising recent developments in reflectarray design and highlighting their relevance for CubeSat applications, the article contributes to the broader research community by clarifying design challenges and identifying future research directions in high-frequency satellite communication systems.

Another significant impact was to organise a Space Satellite Challenge Workshop, which brought together approximately 40 participants from academia, industry, and the wider space technology community. The workshop created a platform for discussing current challenges in small-satellite communication systems and exploring innovative antenna solutions. This event helped translate the technical outcomes of the project into accessible insights for a broader audience, including SMEs, researchers, and early-career engineers, thereby strengthening knowledge exchange within the UK space ecosystem.

The project also facilitated the development of a collaborative research consortium involving academic researchers, the Satellite →



Applications Catapult, and industry partners interested in advancing compact antenna technologies for space applications. This consortium-building activity has opened opportunities for follow-on funding proposals and larger collaborative projects aimed at progressing the technology toward higher technology readiness levels and potential in-orbit demonstrations.

Satellite Applications Catapult

"Dr Jasim Uddin's Researcher in Residence programme demonstrated how close collaboration between academia and the Satellite Applications Catapult can translate advanced research into experimentally validated technology. He successfully designed, fabricated, and tested a Ka-band reflect-array, making effective use of the Catapult's specialist facilities and system-level expertise. His proactive delivery and strong engagement with academia and industry helped de-risk the technology and establish a credible pathway towards future satellite communications applications." **Harvinder Nagi, Senior System Architect, Satellite Applications Catapult.**

CATAPULT Satellite Applications

Jasim Uddin

"Through this project, we developed and validated a compact reflectarray antenna for resilient CubeSat communication. In collaboration with the Satellite Applications Catapult, this work bridges research and industry application, delivering a scalable, high-performance solution and advancing the technology toward real-world deployment and future commercialisation."

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