E-band feeder link and mechanical phased array antennas for very high-throughput LEO satellite ground terminals

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Recent advancements have significantly mitigated connectivity challenges in rural and underserved regions. Low Earth Orbit (LEO) satellite constellations have emerged as a transformative solution, providing low-latency, high-capacity connectivity on a global scale. This remarkable success demonstrates the techno-economic viability of LEO satellite systems as a solution for global connectivity. As the industry moves toward higher throughput and link capacity, the focus shifts to developing next-generation antennas that reduce cost, complexity, and power consumption by leveraging E/V bands and non-traditional beam-steering methods. The following discussion explores advancements in E-band feeder links, innovative Moiré-pattern-based beam steering, and prototype mechanically steerable arrays (MSAs) for future satellite systems.

On the ground station side, E-band and V-band are lightly regulated compared to Ka/Ku bands and it has abundant GHz bandwidth to support the next generation of high capacity. In 2017, we demonstrated E-band long distance air-to-ground backhaul link with a 1.2 meter diameter ground terminal antenna and projected to be able close the link to a LEO satellite (Q. Tang et al., "Demonstration of a 40Gbps Bi-directional Air-to-Ground Millimeter Wave Communication Link," 2019 IEEE MTT-S International Microwave Symposium, Boston, MA, USA, 746-749, 2019). A 40Gbps link can be sustained up to an altitude of 28km at 90° elevation angle (zenith) for a 99.9% availability, while a 10Gbps data rate link can be maintained for altitudes up to 310km in Los Angeles region. We also conducted a test campaign at Quillayute to measure the atmospheric loss at E-band and verified ITU-R P.618-12 rain and cloud attenuation model.

On the user terminal side, before the advent of widely adopted ESAs in user terminals, we introduced an innovative approach to phased-array antenna design, combining mechanical beam-steering techniques with moiré-pattern-based spatial interference (B. H. McGuyer and Q. Tang, "Connection between antennas, beam steering, and the Moiré effect," Physical Review Applied 17, 034008, 2022). By integrating insights from flat-panel mechanically steerable array antennas and the beam-steering–moiré effect connection, our approach elucidates how planar antennas can achieve beam control using only two mechanical degrees of freedom (e.g., rotations or translations). This concept fundamentally pertains to generating and manipulating the aperture distribution, in contrast to conventional ESAs that may require hundreds or thousands of phase shifters.

As next-generation high-throughput fixed-satellite services transition to V-band and new ground terminal stations adopt E-band backhaul feeder links, operating in the millimeter-wave range enhances system link budget gain for given physical size limit of antenna apertures. However, this shift introduces challenges in cost scalability due to the increased number of array elements. We investigate the potential of leveraging moiré patterns to significantly reduce the reliance on numerous phase shifters while maintaining ESA performance standards. We conducted two prototypes validate the concept's viability, achieving wide scanning angles and high aperture efficiency with minimal complexity. Examples to follow use the connection this opportunity for cost and power reduction was the motivation for our prior work (Q. Tang et al., "Flat-Panel Mechanical Beam Steerable Array Antennas With In-Plane Rotations: Theory, Design and Low-Cost Implementation," in IEEE Open Journal of Antennas and Propagation, 2, 679–688, 2021).

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