Beamforming with Dynamic Metasurface Antennas Using Euclidean Modulation

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Many microwave applications, including satellite communication and synthetic aperture radar (SAR), have employed reflector dishes or phased arrays as a means of generating directive beams. These hardware platforms, however, are heavy, expensive, and can require moving parts—characteristics which are particularly difficult to tolerate in spaceborne applications. An alternative platform, dynamic metasurface antennas, stands to match the performance of these systems while drastically improving the hardware platform.

Dynamic metasurface antennas consist of a waveguide structure loaded with radiating metamaterial elements which can be individually addressed by electronic tuning. The elements in a dynamic metasurface antenna do not include phase shifters or amplifiers, which allows them to reduce the hardware and power requirements. While metamaterial elements cannot achieve the same level of modulation as a phased array, they attempt to regain some of the lost control by sampling the guided wave at a finer interval, often deeply subwavelength. The metamaterial elements behave as dipole antennas whose phase and magnitude are jointly determined by the phase of the guided mode and any tuning control over the elements. The subsampling of the aperture allows some of the control lost in this manner to be recovered. While traditional phased array antennas can employ a phase hologram for beamforming, the coupled nature of metamaterial elements results in a more complicated problem. To address this challenge, Euclidean modulation has recently been proposed as a new criterion for selecting the tuning states of the constituent elements of a dynamic metasurface antenna. This technique considers the problem of tuning metasurface elements in the full complex plane, simultaneously optimizing the magnitude and phase of each element, rather than considering the phase or magnitude of the elements independently. By using this method, optimal beamforming performance can be achieved from dynamic metasurface antennas.

In this presentation, a sample dynamic metasurface antenna has been designed and simulated to validate its ability to use Euclidean modulation for beamforming. This dynamic metasurface antenna exhibits the ability to generate steerable, directive beams with minimal side- and grating lobes across a wide bandwidth. Such an antenna represents the opportunity to achieve comparable beamforming performance to traditional microwave hardware from a physical platform which is lightweight, inexpensive, easy-to-fabricate, and planar.