Dynamic Metasurface Antennas for Computational Microwave Imaging

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Computational imaging at microwave frequencies has shown promise as a well-rounded strategy for obtaining high-quality images with fast acquisition rates. In this method, the imaging process relies on using few spatially-diverse patterns to multiplex the spatial content of a region of interest. Computational power is then leveraged to retrieve the scene information through computational techniques. In this setting, a simple radiating aperture would be used to illuminate a scene with random, uncorrelated radiation patterns which are then backscattered and collected to obtain the scene spatial content. For this purpose, metasurface antennas and cavity-backed apertures have especially gained traction as the hardware of choice to generate the required radiation patterns. These apertures are able to generate spatially-distinct radiation patterns as a function of the driving frequency, allowing for the scene information to be retrieved with simple and fast frequency measurements. This method, which has recently shown the possibility for real-time imaging of human-scaled objects, requires a wide bandwidth of operation. This requirement increases the complexity of the RF circuitry and may not be readily achievable due to regulations.

To combat these limitations, we present dynamic metasurface antennas as an ideal means for computational microwave imaging. These antennas consist of a waveguide loaded with numerous subwavelength metamaterial radiators, each leaking a portion of the guided mode into free space. The overall radiation pattern is then the superposition of the individual elements' contribution. By introducing a switchable component into each metamaterial element, and independently addressing each of them, we can alter the radiation pattern without using any complex RF circuitry or moving parts. In addition, the control over the phase and amplitude of each radiator, though not independent, opens the way to sculpting the radiation patterns and optimizing their characteristics to fit the requirement of the intended applications.

In this presentation, we present recent advances in dynamic metasurfaces and discuss their applications in microwave imaging. We describe the primary design considerations, illustrate the physics behind dynamic metasurface operation, and expound upon the practical tradeoffs. The distinction between dynamic metasurfaces and leaky-wave antennas are clarified. We will also demonstrate computational imaging using dynamic metasurfaces in a series of experiments. Interesting new avenues possible with dynamic metasurfaces, including quasi-real time imaging and three-dimensional monochromatic imaging, are also presented. The proposed dynamic metamaterial antenna is well-suited to a variety of applications including security screening, through-wall imaging, synthetic aperture radar (SAR), and MIMO communications, among others.