Disordered Cavity-Fed Dynamic Metasurface Antennas for Microwave Imaging

Timothy Sleasman*[1], Mohammadreza F. Imani[1], Michael Boyarsky[1], and David R. Smith[1]
(1) Duke University, Department of Electrical and Computer Engineering, Durham, NC 27708

Conventional microwave imaging strategies employ a mechanically-translated antenna or an array of antennas to create a large aperture that illuminates a scene and collects backscattered signals. These approaches have delivered adequate performance but are not easily scalable to large apertures, on the order of tens or hundreds of wavelengths (λ). An alternative approach uses electrically-large antennas (≈10λ), each covering a sizable portion of the total aperture (≈50λ), so as to reduce the overall number of antennas needed and minimize the associated hardware costs. To leverage this hardware simplification, a mechanism must exist in each antenna to access the independent spatial information that is being measured across that antenna—in essence, this is done by creating a collection of spatially-distinct radiation patterns in the scene. One way to do this is through steering a beam with an electrically-scanned antenna which sequentially sweeps across the entire scene to obtain information. Computational imaging is an alternative paradigm, where a collection of pseudo-random patterns is used in lieu of a scanned beam and images are reconstructed in post processing.

In this presentation we will introduce a dynamic metasurface antenna which is fed by a planar disordered cavity and is suitable for computational imaging. This planar structure consists of a parallel plate waveguide cavity which supports a collection of irregular spatial modes. These cavity modes couple with metamaterial radiators etched into one of the cavity's walls to create radiation patterns useful for computational microwave imaging. Furthermore, the radiating elements include tunable components so that the patterns may be actuated as a function of the elements' external voltage biases or the cavity's excitation frequency—providing the opportunity to create modular radiation patterns in either a narrow or wide bandwidth setting. Design studies are presented for the dynamic metasurface antennas from the cavity layer up to the full imaging and reconstruction process. A K-band system's imaging performance is assessed and future prospects for cavity-fed dynamic metasurface antennas are discussed. Such dynamic apertures can be used in microwave imaging applications ranging from biomedical diagnostics to security screening.