Microwave Imaging with a Dynamic Metasurface Antenna

Timothy Sleasman[(1)], Mohammadreza F. Imani[(1)], Michael Boyarsky[(1)], Laura Pulido-Mancera[(1)], Thomas Fromenteze[(1)], Jonah N. Gollub[(1)], Matthew Reynolds[(2)], and David R. Smith[(1)]
(1) Duke University, Department of Electrical Engineering, Durham, NC
(2) University of Washington, Department of Electrical Engineering, Seattle, WA

Computational imaging at microwave frequencies has recently emerged as a well-rounded strategy for obtaining high-quality images with fast acquisition rates. In this method, the imaging process relies on using spatially-diverse waveforms to multiplex the content of a scene into a set of backscatter measurements. By post-processing these measurements, scene information can be extracted by leveraging computational techniques. The crux of this approach lies in creating a series of uncorrelated radiation patterns. In initial realizations, passive metasurface apertures were used which relied on sweeping the excitation frequency to create diverse patterns, but this provides performance that is strictly limited by the available bandwidth. An alternate strategy has recently been investigated where dynamically-tunable components are directly embedded within the aperture layer. A dynamic metasurface aperture is thus created which can alter its radiated waveforms with a simple control stimulus, providing great potential in computational microwave imaging settings.

We present an experimental one-dimensional dynamic metasurface aperture to demonstrate the utility of this device in different microwave imaging scenarios. This aperture consists of complementary metamaterial elements etched into a microstrip line. Semiconductor components have been introduced to each element and can be biased individually to modulate each element between a radiating and a nonradiating state. By applying different voltage patterns to the constituent elements, a plethora of waveforms can be generated to multiplex a 2D scene's information with a narrow bandwidth. The low-correlation among waveforms means that fewer measurements can be used, thus enabling fast imaging, on the order of real-time framerates, without using any moving part or expensive phase shifters. We discuss the design and performance of this dynamic aperture prototype and demonstrate its experimental imaging capabilities.

The versatility of the presented dynamic metasurface aperture can also open new avenues in microwave imaging. For example, this aperture is able to resolve objects in the cross range using only a single frequency—an ability that can significantly simplify RF source design and lower the overall cost. In addition to generating uncorrelated waveforms for computational imaging, beamsteering capabilities have been successfully applied in stripmap and spotlight SAR imaging. The prospect of scaling to a 2D prototype are discussed along with other future research directions. In addition to SAR, the proposed dynamic metasurface aperture is well-suited to a variety of other applications including security screening, through-wall imaging, and MIMO communications.