Monotone 3D Microwave Imaging using Aperture Synthesis and Dynamic Metasurfaces

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Microwave imaging systems have widespread use in applications ranging from remote sensing to security screening. In order to realize high resolution, microwave imaging systems frequently use a large spectral bandwidth. A large spectral bandwidth, however, incurs costly radio frequency (RF) components and can be a limiting factor in many applications with strict economic constraints. Recent demonstrations have shown that operating in the radiative near field of an aperture can enable 2D imaging without requiring bandwidth by leveraging structured illumination strategies from a large transmitting and receiving aperture.

In this work, we demonstrate a single-frequency synthetic aperture imaging system which uses dynamic metasurface antennas to conduct 3D microwave imaging. In this system, two dynamic metasurfaces, one as the transmitter and the other as the receiver, are oriented along the azimuth direction. The dynamic metasurfaces used in this work are waveguide-fed devices with metamaterial elements embedded in the upper conductor of a microstrip transmission line. Each element can be biased independently to turn its radiation on or off, leading to an electronically-switchable aperture which can generate a multitude of spatially distinct radiation patterns.

The electrically-large size of the dynamic metasurfaces and their ability to multiplex information from different look-angles into few measurements enables the extraction of scene information in range and cross range from backscattered measurements. By translating these apertures in height, height information can be probed, leading to a system which can reconstruct 3D images from single-frequency measurements. Reconstructions here are conducted with the range migration algorithm (RMA), an efficient method for large data sets. In this work, we outline how the range migration algorithm has been modified to accommodate both the single-frequency measurements and the nontraditional illumination strategies associated with metasurface apertures. In summary, this imaging system represents a high-performance, cost-effective solution for 3D microwave imaging, and can find applications in through-wall imaging, biomedical imaging, and security screening.