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# Dynamic Metasurface Apertures for Synthetic Aperture Radar Imaging Applications

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## 1. Extended Abstract

Synthetic aperture radar has become an indispensable component across a broad range of applications, including spaceborne and airborne imaging as well as security screening. Based on the application and depending on the desired radiation properties, the hardware that is implemented can range from a horn-fed reflector dish to a phased array. Common techniques, such as stripmap and spotlight SAR, often require a beam which can be steered by means of mechanical motion (in the form of a gimbal-supported dish antenna) or electronic tuning (accomplished by phase shifters and amplifies). While impressive results have been obtained using these systems, the hardware layers tend to be complicated which makes them prohibitive in some applications. In addition, the mechanically-steered solution is slow and bulky while the phased array is expensive, consumes too much power, and requires precise design. Recently, efforts have been focused on obtaining similar performance from a dramatically simplified aperture layer. In particular, metasurface antennas, developed in the context of holographic apertures, have shown great promise for producing the radiation patterns desired for SAR systems.

Metasurface antennas typically consist of a waveguide structure loaded with metamaterial resonators, each leaking a portion of the guided wave. The resulting radiation pattern is the superposition of the fields radiated by the individual elements. In a similar manner to leaky-wave antennas, the phase and amplitude across the aperture is in part determined by the guided wave; but metasurface apertures have added flexibility due to the subwavelength spacing between elements and the resonators' dexterous design principles. More specifically, altering the resonant response of the elements along the waveguide can provide a large variety of phase/amplitude patterns for implementing holograms. Further control can be garnered by adding a tunable component to each individual element, creating a dynamic metasurface aperture. From this platform, a plethora of radiation patterns can be generated, including traditional directive beams as well as diverse, uncorrelated patterns. The latter patterns are ideal for computational imaging, in which a series of uncorrelated patterns sequentially illuminates a scene to multiplex the data acquisition—post-processing subsequently reconstructs the image. Dynamic metasurface antennas have already shown promise across the field of stationary security scanning, but within this presentation we extend these concepts to show the capabilities of a dynamic metasurface in a SAR contexts.

We begin by explaining the physical operation of the dynamic metasurface aperture and contrast the device with comparable technologies. After describing the specific sample of a microstrip-based 1D aperture that operates near 20 GHz, we review the fundamentals of microwave imaging and demonstrate the performance of such an aperture in a SAR system. In addition to the traditional modalities of stripmap and spotlight SAR, which utilize directive beams created from the dynamic aperture, we also introduce an advanced imaging technique termed *diverse pattern stripmap* which utilizes uncorrelated radiation patterns in a manner inspired by computational imaging. The three techniques are contrasted and experimentally compared. Finally, we show experimental results for volumetric imaging based on translating the aperture along one cross-range dimension and multiplexing information with diverse patterns in the other cross-range dimension. Ultimately, it is seen that dynamic metasurface apertures can become a powerful architecture across the field of synthetic aperture radar and can be adapted to a variety of usage scenarios.