Utilizing a Reconfigurable Metasurface Antenna as a Device for Spatial Multiplexing and Modulation

John Hodge* (1), Amir I. Zaghloul(1,2)
(1) Virginia Tech, Baltimore, MD 21230; (2) U.S. Army Research Laboratory, Adelphi, MD 20783
jah70@vt.edu, amir.i.zaghloul.civ@mail.mil

With an increasing global demand for higher data rates in RF wireless communications, new antenna technologies are necessary to make more efficient use of constrained spectrum. The demands for higher data rates within constrained spectrum will increase multi-fold with the onset of fifth-generation (5G) wireless communications systems. Key antenna technologies that have been proposed to enable 5G systems are multi-beam antennas (MBAs), beamforming for multiple-input multiple-output (MIMO) systems, and versatile antenna beam shaping (Hong *et al.*, IEEE AP-S Trans, 2017). Additionally, as demand increases for high-capacity, highly flexible satellite communication systems, there is a need for new types of RF switch matrix multiplexers (Assal *et al.*, U.S. Patent #*5,220,320*, 1992). To achieve the requirements of next-generation wireless communications at reduced cost and form factor, antenna and beamforming technologies can incorporate new ways to spatially modulate and multiplex RF signals.

Previous work by this author introduced an antenna enhancing structure consisting of capacitive-loaded loop (CLL) metamaterial elements arranged radially around a conventional dipole antenna at an electrically small distance to create a directive antenna with high realized gain (Hodge, Anthony, Zaghloul, IEEE AP-S Symp, 2014). This antenna was made to be switchable and tunable using active circuit elements embedded in the CLL-loaded dipole antenna for dynamic frequency tuning and electronic beam scanning (Hodge *et al.*, USNC-URSI Meeting, 2015). This concept was extended to metasurfaces by simulating passive and active variants of a holographic metasurface antenna using both the CLL element and traditional patch elements as a proof of concept of an addressable and reconfigurable metasurface (Hodge *et al.*, USNC-URSI Meeting, 2017).

This presentation proposes the use of a reconfigurable RF metasurface for spatially multiplexing and modulating RF wireless communication signals due to its subwavelength thickness and planar nature. Spatial multiplexing and modulation of multiple RF signals will be demonstrated using what we refer to as an electronically reconfigurable metasurface (ERM). In this concept, multiple data signals are fed into a multiplexing signal matrix which is used to control the phase distribution across the metasurface using addressable varactor diodes embedded within each metasurface unit-cell (referred to as a meta-atom). This multiplexing metasurface device provides the opportunity for both spatial and time modulation. The modulation of the metasurface can be engineered to support carrier waves at multiple frequencies. Additionally, the ERM can double as both a modulating multiplexer and a beamformer. In our proposed concept, the multiplexing metasurface devices can be realized as either a closed RF-switched matrix device or in a direct-radiating metasurface antenna configuration.

This presentation is divided into two parts: A) Methods of performing spatial multiplexing though a metasurface matric device while incorporating temporal, frequency, or code modulation; B) Design and simulation of a meta-atom to implement reconfigurable digital phase change along the metasurface using addressable varactor diode devices. The performance and functionality of the multiplexing metasurface will be demonstrated through HFSS full-wave simulation. Future work will attempt to fabricate a prototype of the multiplexing metasurface demonstrated in this work to achieve measured to modeled comparison. This work is part of the authors' larger effort to design and demonstrate digitally addressable and reconfigurable metasurface antennas as an alternative to traditional active phased arrays.