URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020

Index-Modulated Metasurface Transceiver Design using Reconfigurable Intelligent Surfaces

John A. Hodge* (1), Kumar Vijay Mishra (2), and Amir I. Zaghloul(1)(2)
(1) Virginia Tech, Falls Church, VA 22043, USA
(2) CCDC Army Research Laboratory (ARL), Adelphi, MD, 20783, USA

Higher spectral and energy efficiencies are the envisioned defining characteristics of next-generation high data-rate sixth-generation (6G) wireless networks. One of the enabling technologies to meet these requirements is index modulation (IM), which transmits information through permutations of indices of spatial, frequency, or temporal media. In this paper, we propose novel electromagnetics (EM)-compliant designs of reconfigurable intelligent surface (RIS) apertures for realizing IM in 6G transceivers. RISs, also known as reconfigurable metasurfaces (R-MTSs), are electrically thin surfaces that comprise an array of spatially-varying sub-wavelength scattering elements (or meta-atoms) that include an embedded tuning mechanism. Through careful engineering of each meta-atom, MTSs can transform an incident EM wave into an arbitrarily tailored transmitted or reflected wavefront. Recent developments in time-modulated metasurfaces have unlocked a new class of nonlinear and nonreciprocal behaviors including direct modulation of carrier waves, programmable frequency conversion, and controllable frequency harmonic generation [1].

In this work, we consider RIS modeling and implementation of spatial and subcarrier IMs, including beam steering, spatial multiplexing, and phase modulation capabilities. We establish the programmable ability of these transceivers to vary the reflection phase and generate frequency harmonics for IM through full-wave electromagnetic analyses of a specific reflect-array metasurface implementation. In particular, we demonstrate the concept of using R-MTSs to simplify communication system architectures and support next-generation IM waveforms including spatial modulation (SM) and orthogonal frequency division multiplexing with IM (OFDM-IM). The MTS-based integrated antenna-transceiver architecture provides compelling advantages of low RF complexity, cost, and power consumption compared to current phased array antennas and heterodyne transceiver architectures. Additionally, complexity and cost advantages of R-MTS antennas over traditional phased arrays scale with increasing aperture size. This makes direct modulation R-MTS arrays a compelling solution for IM, massive MIMO, and shared-aperture multi-beam antennas in 5G and 6G wireless networks.

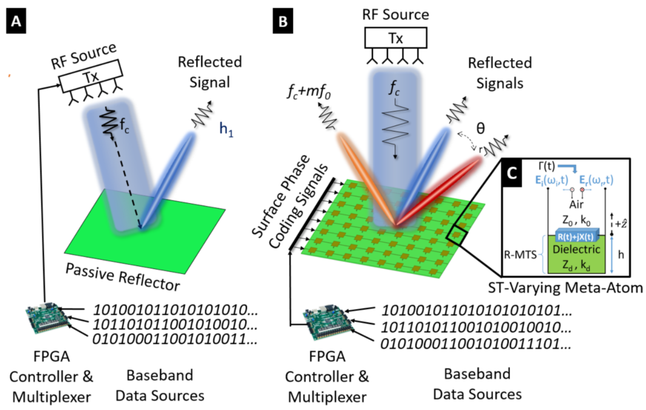

Figure 1. (a) Simplified illustration of a (a) conventional reflect-array transmitter using a passive reflector and (b) our digitally programmable time-varying R-MTS transceiver comprising meta-atoms, each of which is implemented using (c) active element circuit. The reflected radiation pattern scan angle is denoted as θ and the harmonic frequency of the reflected signal is $f_c + mf_0$ where f_c is the carrier frequency, f_0 is the harmonic spacing, and m is an integer value of the harmonic.

References

[1] J. A. Hodge, K. V. Mishra, and A. I. Zaghloul, “Reconfigurable metasurfaces for index modulation in 5G wireless communications,” in IEEE International Applied Computational Electromagnetics Society Symposium, 2019, pp. 1–2.