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Method-of-Moments (MoM) Based Approach for Characterizing Intelligent Reflecting Surface Aided Communication Systems

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The concept of deploying IRS (intelligent reflecting surfaces) in the environment (eg. the walls of buildings) is becoming extremely popular, for its potential in leading to enhanced data rate, extended coverage, minimized power consumption, and more secure transmission [1]. Generally in an IRS, a frequency selective surface (FSS) or "meta-surface", i.e. large two-dimensional array of software-controlled passive scattering elements, are used to make a joint phase control of all scattering elements or unit cells [1]. By arbitrarily tuning the reflecting phase and angles of the incident RF signals, while the received signal power can boosted by coherent addition for some UEs, as well as inter-user interference can also be mitigated by destructive interference [1]-[2].

Performance evaluation of IRS-based communication systems have motivated wireless engineers to explore quasi-analytical tools and Ray-tracing methods, but mostly they are based on simplistic assumptions, ignoring the effects of dispersive FSS properties, spherical wave-front illumination, or mutual coupling in the IRS unit-cells. Therefore, it has become important to apply computational electromagnetic (CEM) tools like PO (Physical Optics) [2] or FDTD (Finite-Difference Time-Domain Method) [3] to properly characterize IRS behaviour in a wireless network. In this work, we will demonstrate the use MoM (Method of Moments) based MATLAB Antenna Toolbox to analyze SISO (single-input single-output) and MIMO (multiple-input multiple-output) communication links, by modelling the IRS as $M \times N$ rectangular array of thin-wire dipole-type scatterers (see Fig. 1, $M = 2, N = 8$). It is possible to alter the switching states of the IRS unit-cells by varying the load impedance terminations for the dipoles, thereby paving the way for optimization of the sum-rate capacity response and down-link beam-forming direction (see Fig. 1 for variation in transmitter radiation patterns caused by IRS).

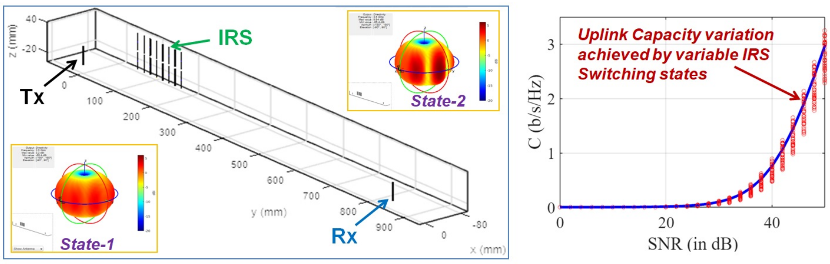

Figure 1. Schematic diagram of a SISO link with IRS near the Transmitter (Tx), along with demonstration of Tx-beamforming and link capacity control based on IRS switching states.

Being a full-wave simulation scheme, MoM-based approach allows us to properly account any mutual coupling effect, unlike the asymptotic PO methodology adopted in [2]. At the same time, the computation time and memory requirement in MoM is much less compared to FDTD adopted in [3]. In the extended work, we will explore the challenges of fast computation of path-loss models and angular power distributions, along with possibility of incorporating dielectric structures or metal-plate scatterers in the MoM-based paradigm.

References

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