URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Software defined metasurfaces for future wireless communications

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In response to industry demands, a significant technical challenge is the development of autonomous and reconfigurable systems that integrate communication, sensing, and computing functionalities in contested domains. Addressing this challenge, the Large Reflecting Surface (LIS) has emerged as a promising technology within the realm of software-defined metasurfaces. The LIS is a planar surface composed of passive reflecting elements, each capable of independently imposing the required phase shift on incoming signals. By carefully controlling the phase shifts of these elements, the reflected signals can be reconfigured to propagate in desired directions. In this presentation, we will delve into the key challenges associated with LIS hardware design, particularly focusing on antenna performance and limitations.

At QMUL, we have been exploring the potential of LIS and its applications in wireless communications. Our work has involved the development of a prototype LIS using PIN diodes and varactors. A novel aspect of our design is the implementation of a wireless network with a star or multi-hop topology, eliminating the need for complex biasing lines. This network performs predefined functions to activate tunable materials. Our approach combines active and passive elements, enabling highly directional antennas and steerable antenna beams to compensate for high propagation losses. This is crucial for communication systems and other applications such as mmWave radar sensors.

A critical factor in software-defined metasurface design is the utilization of tunable materials. To discover novel tunable materials, we have employed Machine Learning techniques for materials property prediction. Our developed universal ML model, Finder (Formula graph self-attention network for materials discovery), can predict material properties using either the chemical formula alone or by considering the crystal structure. Finder utilizes a message passing Graph Neural Network (GNN) that incorporates a variant of self-attention mechanism from the transformer architecture. Compared to other models, our approach demonstrates faster convergence and achieves lower errors across all training set sizes examined.

Lastly, the current design strategy for software-defined metasurfaces and large antenna arrays has been limited to periodic, aperiodic, and random distributions. In this presentation, we will introduce software-defined metasurfaces with hyperuniform disorder, showcasing their extraordinary directive emission and scanning capabilities. These metasurfaces offer scalability without requiring additional computational efforts.

Acknowledgements

This work is partially funded by IET AF Harvey Research Prize, UK's Engineering Physical Science Research Council (EPSRC) with projects including EP/R035393/1, EP/W026732/1. EP/X02542X/1) and the Royal Academy of Engineering.

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