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# Use of Reconfigurable Intelligent Surfaces to Manipulate Fields in Complex Enclosed Scattering Environments*

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Modern electronic systems operate in complex electromagnetic environments and must handle noise, electromagnetic interference, and unwanted coupling. The ability to isolate or reject unwanted signals for mitigating vulnerabilities is critical in any practical application. We describe the use of a binary reconfigurable intelligent surface (RIS) to (i) control the spatial degrees of freedom for waves propagating inside an electromagnetic cavity and demonstrate the ability to create nulls in the transmission coefficient between selected ports, and (ii) create the conditions for coherent perfect absorption. Both objectives are performed at arbitrary frequencies. In the first case, an effective RIS settings optimization algorithm is presented that selectively generates cold spots over a single-frequency band or simultaneously over multiple-frequency bands. We show that this algorithm is successful with multiple input port configurations and varying optimization bandwidths. In the second case, we establish how this technique can be used to establish a multiport coherent perfect absorption state for the cavity in which all injected energy is absorbed in the cavity, with no reflection or transmission.

The RIS has 240 individual pixels, each approximately $\lambda/6$ in size, and they can be digitally toggled between settings that provide either a 0 or $\pi$ phase shift upon normal-incidence reflection between 3 and 4 GHz [1]. The RIS is located on one wall of a 0.76 $m^3$ complex scattering volume, and takes up approximately 1.5% of the area of the enclosure. The pixel states are controlled by a computer, and the S-parameters of the enclosure are measured by a network analyzer. Several algorithms have been developed to program the RIS to achieve a variety of tasks [1]. In particular, we developed a unique and effective stochastic algorithm to create desired outcomes despite the enormous space of possible metasurface commands.

We have demonstrated the ability of a programmable metasurface to generate microwave cold spots in a wave-chaotic cavity at arbitrary frequencies and showed this capability exists even when applied over multiple-frequency bands simultaneously. The cold spots can be generated for different bandwidths and multiple input port configurations. We have also utilized the programmable RIS to control the eigenvalues of the scattering matrix of the enclosure and direct them towards the origin to realize a coherent perfect absorption (CPA) state for the cavity. CPA is a situation in which all energy injected into a system is absorbed, no matter how small the losses are in the system [2]. Creating CPA requires coherent excitation of all the ports in an eigenvector whose corresponding S-matrix eigenvalue is zero. Such conditions can be used to enhance the performance of wireless communications systems, or wireless power transfer, in complex scattering environments. Recent work utilizes multiple nonlinear tunable metasurfaces to achieve near-perfect absorption over a broad range of frequencies.

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## References

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