Wave-Field Shaping in Cavities: Waves Trapped in a Box with Controllable Boundaries

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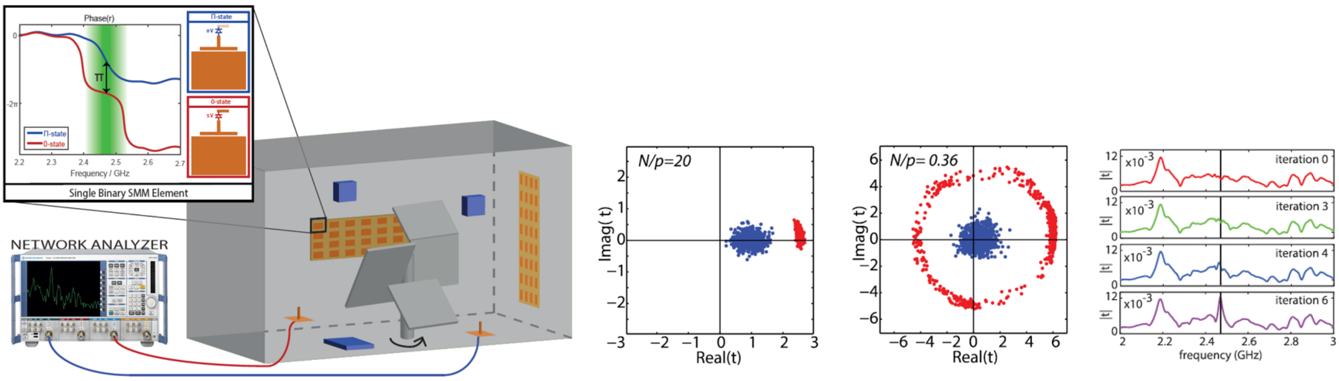
1. Extended Abstract

The trapping of electromagnetic waves in a cavity occurs in many day-to-day situations (e.g. indoor telecommunication, microwave oven), in applied physics (e.g. electromagnetic compatibility) and in fundamental physics (e.g. quantum electrodynamics, quantum chaos [1]). The wave equation defines the eigenmodes of such a system based on the cavity geometry and boundary conditions. Here, we partially cover the walls of a metallic cavity with simple elements of electronically reconfigurable reflection coefficient, a so-called Spatial-Microwave-Modulator (SMM), allowing us to locally switch between Dirichlet and Neumann conditions. We investigate experimentally to what extent this enables us to control the wave-field in different regimes, characterized by the amount of modes N contributing to the spectrum at the working frequency, and model the underlying physical mechanism.

To that end, we probe the transmission between two antennas in a disordered metallic cavity at a given frequency; we control the cavity's quality factor Q with different amounts of electromagnetic absorbers (cf. Figure 1). With an iterative optimization algorithm [2], we identify step by step the ideal configuration of the SMM that maximizes the transmission. Finally, we realize disorder to repeat the experiment with new initial conditions with a mode-stirrer.

In the low-Q limit, N is much larger than the amount of modes p that the SMM can control [3]; this manifests itself in a large, uncontrollable part of the transmission. We develop a model for this regime that predicts the expected enhancement. As N approaches p, the SMM has full control over the transmission and can impose any desired phase. Finally, in the very high-Q limit where resonances become discrete, the SMM manages to create new resonances at wish – it has full control over the cavity wave-field.



(a) Schematic of experimental set-up. (b) $N \gg p$. (c) $N \sim p$. (d) $N \ll p$.

Figure 1. (a) Experimental set-up. (b,c) Clouds in the complex plane of measured transmissions for different realisations, before (blue) and after (red) the iterative optimisation with the SMM, in the indicated regimes. (d) Example of how the SMM iteratively creates a resonance in the very high-Q limit.

In conclusion, we have experimentally studied and modeled dynamically reconfigurable microwave cavities in three different regimes, with many applications in fundamental and applied physics.

2. References

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