Wavefront shaping of microwaves using tunable reflectarrays for radar, imaging and wireless communications

Philipp del Hougne, Matthieu Dupré, Mathias Fink, Fabrice Lemoult and Geoffroy Lerosey

Institut Langevin, ESPCI ParisTech and CNRS

1 rue Cuvier, 75005 Paris, France

In this talk we will propose the concept of wavefront shaping of microwaves in complex media using tunable reflectarray or metasurfaces that are used as spatial microwave modulators.

To do so we will first introduce the idea through a review of the state of the art in optics, where wavefront shaping has gathered an enormous interest, due to its ability to control the propagation of light through complex and highly scattering media, for focusing or imaging purposes, thanks to widely available spatial light modulators [1].

Then we will show how a binary tunable reflectarray [2] can be used as a spatial microwave modulator in random, reverberating and scattering media, to shape microwave fields, in order to focus electromagnetic energy or on the contrary to cancel wave fields locally. An application will be proposed in indoor environments with applications in wireless communications [3].

In order to quantify the impact of wavefront shaping of microwave in reverberating media, we will then show how its properties can be inferred from simple analogies with optical wavefront shaping though complex media. This will allow us to quantify how waves can be controlled using this concept [4]. In particular we will show that, depending on the quality factor of the reverberating media, our approach permits to focus waves, to turn a cavity of given geometry into a radically different one, or to create eigenmodes at desired frequencies [4]. Further pushing the idea, we will demonstrate that such a simple spatial control over waves permits, thanks to the coupling between the spatial and temporal degrees of freedom offered by complex media, not only to shape microwaves in the spatial domain but also in the temporal domain, leading to spatio-temporal focusing of microwaves [5].

We will finally underline potential applications of the idea for wireless communications, radar, or imaging purposes, notably through the concept of electronically reconfigurable leaky wave cavities [6].

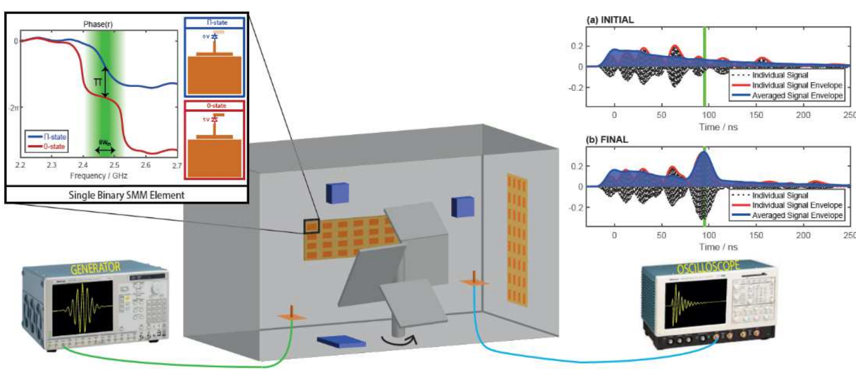

Figure 1: Experimental setup for wavefront shaping in a reverberant cavity. An emitted pulse is spread in time due to multiple reverberations of the microwaves, in the cavity. The binary tunable microwave metasurface allows to compress in time this wave field at any time and any position in the cavity, resulting in a spatio-temporal focusing of the waves

[1] Mosk, A., Lagendijk, A., Lerosey, G., and Fink, M. "Controlling waves in space and time for imaging and focusing in complex media". (Review article), *Nature Photonics* **6**, 283-292 (2012).
[2] Kaina, N., Dupré, M., Fink, M. and Lerosey, G. "Hybridized resonances to design tunable binary phase metasurface unit cells". *Optics Express* **22** (16), 18881-18888 (2014).
[3] Kaina, N., Dupré, M., Lerosey, G., and Fink, M. "Shaping complex microwave fields in reverberating media with binary tunable metasurfaces". *Scientific Reports* **4**, 6693 (2014).
[4] Dupré, M., del Hougne, P., Fink, M., Lemoult, F. and Lerosey, G. "Wave-Field Shaping in Cavities: Waves Trapped in a Box with Controllable Boundaries". *Physical Review Letters* **115**, 017701 (2015).
[5] del Hougne, P., Lemoult, F., Fink, M. and Lerosey, G. "Spatiotemporal Wave Front Shaping in a Microwave Cavity". *Physical Review Letters* **117**, 134302 (2016).
[6] Sleasman, T., Imani, M.F., Gollub, J.N. and Smith D.R. "Microwave Imaging Using a Disordered Cavity with a Dynamically Tunable Impedance Surface". *Physical Review Applied* **6**, 054019 (2016).