Detecting motion in occluded areas using dynamic metasurface apertures

P. del Hougne*[(1)(2)], M. F. Imani[(2)], T. Sleasman[(2)], J. N. Gollub[(2)], M. Fink[(1)], G. Lerosey[(1)], and D. R. Smith[(2)]
(1) Institut Langevin, CNRS UMR 7587, ESPCI Paris, PSL Research University, 1 rue Jussieu, 75005 Paris, France
(2) Center for Metamaterials and Integrated Plasmonics, Duke University, Durham, North Carolina 27708, USA
* email: philipp.delhougne@gmail.com

Detecting motion and discerning relevant information about it are key abilities of futuristic context-aware environments such as *Smart Homes*. Accurate human presence detection is the cornerstone of any intruder alarm. Moreover, it is expected to substantially reduce the energy consumption of residential homes (up to one third). Intelligent motion detectors could also monitor vital signs, such as respiration rate, of infants or elderly. Yet, all these applications take place in indoor environments, whose complexity presents a tremendous hurdle to traditional motion detectors, for instance in the case of motion outside the line-of-sight (in occluded areas).

Here, we propose a motion detector that ideally matches the physics of the problem: we leverage the medium's complexity and propose a concept that enjoys a co-design of hardware and software for the task at hand, simplifying both infrastructure and analysis. We exploit the fundamental sensitivity of the electromagnetic modes supported by any residential or office room (constituting essentially a large disordered cavity with low quality factor) to perturbations, here originating from moving objects (dynamic scatterers). In particular, we explain theoretically and demonstrate experimentally the benefit of using dynamic metasurface apertures (DMAs), as a novel sensor for detecting dynamic scatterers (thus motion) in an indoor setting. DMAs can generate a multitude of spatially distinct radiation patterns using simple electronic circuitry. These patterns probe all corners of an indoor environment and multiplex scattering events before arriving at a receiver. By monitoring the received signal, or more specifically, the fluctuation of the received signal, we can detect the presence of any moving scatterer, even in occluded areas. Given the ability of DMAs to generate patterns at MHz rates, much faster than any motion in an indoor setting, we can also discern temporal variations of the moving object. Such a capability, along with learning algorithms, has the potential to be used to distinguish between different types of motion (using their distinctive temporal variations).

In this presentation, starting with a description of the underlying physics of the problem, we motivate our proposed system and shed light on the DMA's role. Then, we present a series of experiments with microwaves in the K-band to thoroughly study our system. We establish three key features of the proposed system: (i) single-frequency operation, (ii) non line-of-sight ("around-the-corner") motion detection, and (iii) ability to capture temporal variations of the motion such as periodicity. We examine the perspective of using DMAs as efficient, accurate and yet affordable active microwave occupancy sensors.