Digital Metamaterials for Single Pixel Imaging in the Far Infrared

Willie J. Padilla*[(1)], Claire M. Watts[(2)], and Christian C. Nadell[(1)]
(1) Department of Electrical and Computer Engineering, Duke University, Durham, NC, USA
(2) Department of Physics, Boston College, Chestnut Hill, MA, USA

Single pixel cameras are useful imaging devices where it is difficult or infeasible to fashion focal plan arrays. For example in the Far Infrared (FIR) – and longer wavelength ranges – it is difficult to perform imaging by conventional detector arrays, owing to the cost and size of such an array. The typical single pixel camera uses an optical arrangement that forms a conjugate image plane. A spatial light modulator (SLM) is placed in the conjugate image plane and used to sample various portions of the image. The spatially modulated light emerging from the SLM is then sent to a single detector where the light is condensed with suitable optics for detection.

Conventional SLMs are either based on liquid crystals (LCs) or micro-electromechanical system (MEMS) based flipping mirrors – also known as digital mirror devices (DMDs). As such these devices are limited in modulation speeds of order 30 kHz. Further there is little control over the type of light that is modulated. For example, both LC and DMD based spatial light modulators are not capable of modulating only a particular polarization of light, or a specific color (frequency). Instead they are relatively frequency independent and modulate both polarizations identically.

We present metamaterial based spatial light modulators which provide the ability to digitally encode images – with various measurement matrix coefficients – thus permitting high speed and fidelity imaging capability. In particular we use the Hadamard matrix and related S-matrix to encode images for single pixel imaging. Metamaterials thus permit imaging in regimes of the electromagnetic spectrum where conventional SLMs are not available. Additionally, metamaterials offer several salient features that are not available with commercial SLMs. For example, metamaterials may be used to enable hyperspectral, polarimetric, and phase sensitive imaging. We present the theory and experimental results of single pixel imaging with digital metamaterials in the far infrared and highlight the future of this exciting field.