Optimized Metasurface Apertures for Human-Scale Millimeter Wave Computational Imaging System

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We discuss design considerations for a millimeter wave imaging system based on frequency-diverse, metasurface panels. The desired system consists of nearly 100 (72 Rx and 24 Tx) cavity-backed, Mills-Cross metasurface aperture antennas. Designed to operate at K-band frequencies (18 – 26.5 GHz)—a useful frequency band for security screening applications—each panel provides a number of distinct field patterns related to its effective quality (Q-) factor.

Frequency-diverse antennas are defined by their ability to generate spatially-distinct radiation patterns as a function of frequency. These complex waveforms can be used to illuminate an imaging domain and encode its spatial content into simple backscatter frequency measurements. The resulting signals are post-processed through computational techniques to obtain high-quality images of the scene. In this manner, frequency-diverse apertures can replace cumbersome and cost-prohibitive systems, such as mechanical raster scanning and electronic beamforming, while obtaining comparable image quality within a fraction of the acquisition time.

In this work, we review the outcome of our research efforts on frequency-diverse metasurfaces and their optimization for a human scale millimeter-wave computational imaging system. A complete imaging system, consisting of an array of Mills-Cross metasurface antennas as transmitters and receivers, intended to image human-size objects is also presented. To make the entire system feasible, the metasurface antennas must be carefully optimized to maximize the amount of information that can be obtained from the scene. Optimizing for information content places restrictions on the size of the sub-panels, the number of radiating irises, and other geometrical and physical properties that must be satisfied. The final metasurface design shown (Fig. 1) provides both high radiation efficiency (~50%) with excellent mode diversity, and can be used as the basis for a full imaging system.

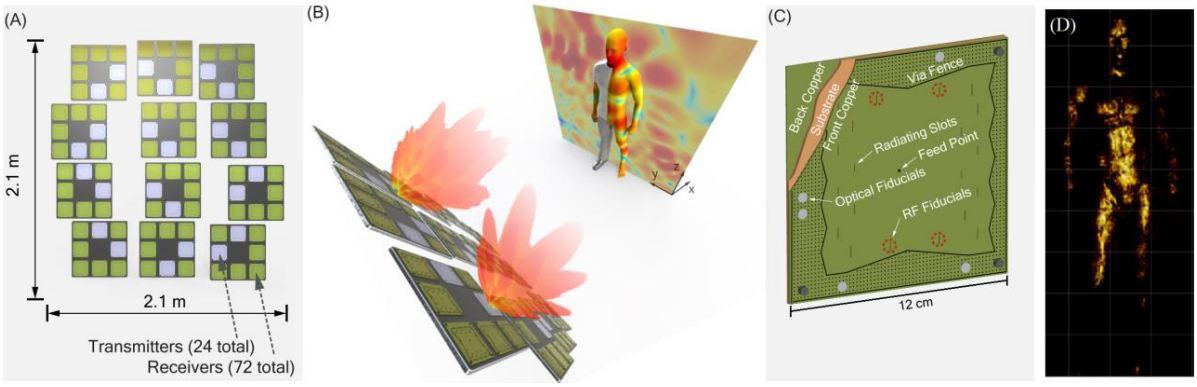

Figure 1. (A) Layout of the system. (B) Illustration of a metasurface-based millimeter wave imager. (C) Detail of a characteristic metasurface panel (receiver). (D) Reconstructed image of a human-size mannequin target.