Antenna Arrays Optimization for Generating Structured Beams

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Spatial structure in electromagnetic radiation – that is, propagating non-planar/non-spherical waves – can provide a useful additional degree of freedom in communications, imaging, and radar, improving performance metrics and offering additional trade-offs in design. In this work, we design and optimize 8 element patch antenna arrays to generate a wide range of structured and unstructured beams. The designed array is used to generate beams with unstructured phase profiles: (*i*) a linearly polarized Gaussian beam (approximating a plane or spherical wave) and (*ii*) a circularly polarized Gaussian beam. By varying the input phase of each antenna, the array is also used to generate structured beams such as Laguerre-Gaussian beams, Hermite-Gaussian beams, each in linear and circular polarization, along with radially-polarized vector beams. The Ettus USRP X440 Software Defined Radio (SDR) is used to excite the antenna array and process the received signal. The relationship between the divergence of the beam and the diameter of the antenna array is quantified and used to guide target placement. In a simple, quasi-monostatic, S-band radar experiment, operating at 2.92 GHz, we show that illuminations with structured beams can increase the reflected power from a target. Specifically, the reflected power from a 10 cm copper wire is measured due to a linear polarized Gaussian beam and a structured radially-polarized vector beam. The fundamental modes of the wire are quantified using Characteristic Mode Analysis (CMA). The radially-polarized vector beam couples more efficiently to the higher-order modes of the wire showing significant enhancement compared to an unstructured Gaussian beam. The generality of the results, across distance, power, frequency, and other dimensions, is discussed from both theoretical and practical perspectives.

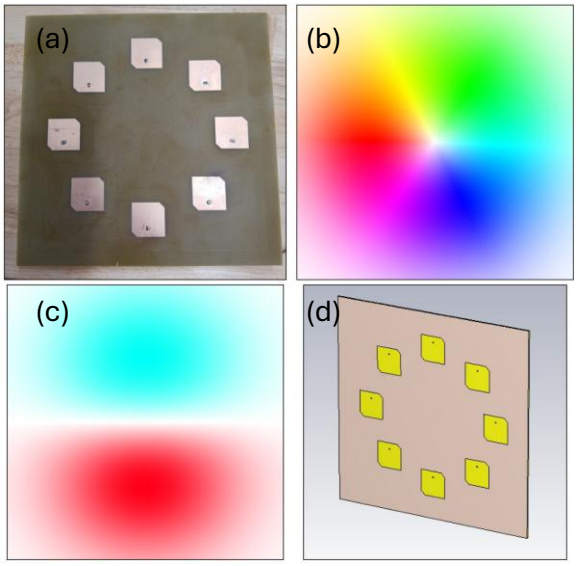

Figure 1. (a) Fabricated eight-element circularly polarized uniform circular array; (b) typical transverse phase profile for a Laguerre-Gaussian beam of orders 0 and 1, with opacity weighted by amplitude; (c) typical transverse phase profile for a Hermite-Gaussian beam of orders 0 and 1, with opacity weighted by amplitude; (d) model of eight-element circularly polarized uniform circular array

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