Characteristic Mode Analysis of the Interaction of Hermite-Gaussian Beams with Wires

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Classical radar systems typically emit fields with uniform planar phase fronts, overlooking the additional degrees of freedom available through the spatio-temporal characteristics of electromagnetic fields. Recently, a variety of spatio-temporally variable beams developed at optical frequencies have been translated to microwave frequencies for use in communication and sensing applications. In this work, we investigate the interaction of Hermite-Gaussian beams with conducting wires. Hermite-Gaussian beams represent a class of solutions to Maxwell's equations under the paraxial approximation, characterized by a Cartesian representation of the amplitude profile. We demonstrate that the power scattered by a perfectly conducting wire can be enhanced, under specific wire orientations and receiver angles, when excited by Hermite-Gaussian beams compared to conventional plane waves. Moreover, we explain this enhancement using the Characteristic Mode Analysis (CMA) of the wire showing strong overlap between the field profile of the Hermite-Gaussian beams and the fundamental current modes of the wire. The definition of the Radar Cross Section (RCS) in the context of these special beams is redefined, allowing for the direct comparison with the RCS achieved using plane wave excitation. Hence, we identify the beam waists, wire lengths, and transmitter/receiver angles of incidences where the Hermite-Gaussian beams will show enhancement compared to a plane wave excitation. In conclusion, this work shows that for targets with certain geometries, the use of spatio-temporally variable waveforms may lead to a better coupling mechanism enhancing the RCS. We also demonstrate that CMA is an effective tool for understanding and predicting scattering behavior from spatio-temporally varying excitations.

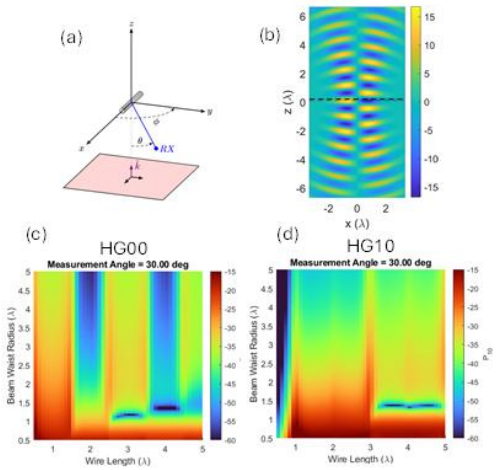

Figure 1. (a) The wire configuration showing the incident (transmitter) and receiver angle. (b) The field profile of the HG_{10} beam, the RCS of the wire in dB due to an (c) HG_{00} mode and (d) HG_{10} mode.

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