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Analysis and Design of Periodic Metasurfaces for Anomalous Scattering

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The capability to perform anomalous reflection and refraction has recently emerged as an important application of artificial surfaces, or metasurfaces (MTSs). In particular, it represents an enabling technology for the futuristic Smart Radio Environment paradigm [1].

Anomalous scattering is achieved through a proper periodic modulation of the equivalent homogenized boundary conditions offered by the MTS, which can induce a controlled spectral shift into the impinging electromagnetic field. The first designs were based on the generalized laws of reflection and refraction [2], according to which each element of the metasurface is independently designed to provide the local phase compensation required to create the desired reflected/transmitted wavefront. This corresponds to designing reflection or transmission coefficients with a linear phase variation. However, it has been shown that this approach is not rigorous, and, as a consequence, it gives rise to spurious radiation in undesired directions [3].

This contribution illustrates how the interaction between the impinging field and a periodically modulated MTS can be effectively and rigorously described by analyzing the relevant canonical problem through the Floquet Wave (FW) expansion of the fields and currents. In this context, the objective of the metasurface design is conveniently formulated by defining the desired FW coefficients. In particular, perfect anomalous scattering corresponds to the excitation of a single, higher order FW, and the vanishing of all the other terms, including the 0-indexed one (corresponding to specular reflection or direct transmission). The approach can be applied to different homogenized models of the MTS: a first model is based on impenetrable impedance boundary conditions, and it can be used for a generic MTS realization, although it fails to correctly represent the MTS spatial dispersion. A second model, which uses a penetrable impedance sheet over a grounded dielectric slab, provides a more accurate description for MTSs realized in PCB technology.

Through the proposed approach, it is shown that perfect anomalous reflection in general can only be achieved with a passive, lossless and non-dispersive MTS if accompanied by polarization conversion. An exception is represented by the case of retroreflection, which can be realized also without polarization conversion [4]. In practical designs, the requirements can be loosed by allowing for the excitation of FWs falling outside the visible region, since they are not contributing to the scattered field. This approach, which also applies to the case of anomalous refraction, leads to an alternative MTS design.

Numerical results, including MTS implementation and full wave simulations, will be presented at the conference.

References

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