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A scattering matrix based approach to design anomalous reflection from a PEC plane

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"Anomalous reflection" refers to the deviation from traditional or expected behavior in the reflection of waves, such as light, sound, or electromagnetic waves, at interfaces between different media. While standard reflection follows predictable rules governed by the well-known Snell's law (i.e., the angle of incidence equals the angle of reflection), anomalous reflection occurs under specific conditions where this basic law is modified.
The possibility of realizing such an anomalous reflection has been studied extensively in optics, acoustics and electromagnetics, where materials with unusual properties or unconventional devices can lead to novel and counterintuitive behaviors [1]. By focusing on devices, metasurfaces, particularly gradient metasurfaces [2], have been widely exploited so far. Recently, metagratings (i.e., periodic array of metallic/dielectric nanostructures) start to gain considerable attention due to their ability to manipulate waves with very high efficiencies, enhancing performance achievable with metasurfaces [3].
The initial approach for designing metagratings focused on manipulating Floquet-Bloch modes, which allows for the propagation of the first-order (anomalous reflection) mode while suppressing the fundamental (specular reflection) mode [4]. More recently, other analytical models have been proposed for this purpose [5].
In contrast, we explore the potential of realizing metagratings-like devices using the inverse scattering framework. An inverse scattering problem aims at retrieving the electromagnetic properties of unknown targets (e.g., shape, permittivity) starting from the knowledge of the field scattered from them when illuminated by given incident fields. However, by replacing measurements of scattered field with assigned field specifications, the imaging problem is turned into a synthesis/design one. Notably, such an interesting possibility has been explored for the design of lens antennas [6],[7]. In particular, in [7] we took profit from the scattering matrix method [8] to directly realize discrete devices.
Recently, we developed a new tool based on the scattering matrix concept for the evaluation of scattering from a set of cylindrical targets in presence of perfect electric conductive (PEC) plane [9]. Actually, a linear arrangement of scatterers above the PEC plane resembles the structure of a metagratings.
In this contribution, we investigate the possibility of turning the recent approach in [9] for the inverse design of metagratings-inspired devices. Specifically, our goal is to determine the optimal arrangement of scatterers to achieve anomalous reflection. In detail, after selecting the number and positions of each cylindrical scatterer, we aim to implement normal reflection when a plane wave is incident at a specified angle. The optimal configuration is determined using a combined optimization approach, which includes global optimization via Very Fast Annealing and local optimization through the Nonlinear Programming Solver.

Further details of the proposed inverse design methodology, along with the results and comparisons to commercial software, will be presented at the conference.

References

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