

Exact Geometrical Optics Scattering by Some Penetrable Structures Made of Double-Negative Material

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The scattering of a plane electromagnetic wave by some two-dimensional (2D) and three-dimensional (3D) penetrable structures that are made of double-negative (DNG) lossless material whose intrinsic impedance equals the intrinsic impedance of the surrounding medium is considered. For all the structures analyzed herein, geometrical optics provides the exact solution to the scattering problem.

The first problem consists of the 2D scattering of a plane wave incident perpendicularly to the edge of a right-angle wedge. The direction of incidence may vary within a $\pi/2$ radian angular range, so that both faces of the wedge are illuminated. The DNG material inside the wedge has permittivity and permeability that are the opposites of the permittivity and permeability of the surrounding medium, respectively. As a consequence, the refractive index inside the wedge is the opposite of the refractive index outside the wedge, whereas the intrinsic impedances inside and outside the wedge are the same. Under these conditions, the incident wave is totally transmitted across both faces of the wedge and an exact solution that is also the geometrical optics solution is obtained. The wedge behaves in a peculiar way: it is as though the incident plane wave were reflected at a plane perpendicular to the direction of incidence and containing the edge of the wedge, but the plane acts as either a perfect electric or a perfect magnetic conductor depending on polarization. This is the only known exact geometrical optics solution for scattering by a wedge. Some other penetrable structures that utilize this exact solution are illustrated.

The second problem examines the 3D scattering of a plane wave axially incident from the concave side of a paraboloid of revolution. The DNG medium on the convex side of the paraboloid has the same impedance but the opposite permittivity and permeability of the medium on the concave side. The incident plane wave is totally transmitted across the paraboloidal interface. On the convex side of the interface, it looks like the electromagnetic field emanates from a source at the focus of the paraboloid. The geometrical optics solution to this problem is also the exact solution.

A related problem, also exactly solvable by geometrical optics, is that of a DNG material radome whose surfaces are two confocal paraboloids of revolution. Under the same previous assumptions (DNG radome with same intrinsic impedance but opposite refractive index than the surrounding medium), a plane wave axially incident from either the convex or concave side is totally transmitted across the radome.