

EXACT SCATTERING BY METALLIC BODIES AT THE INTERFACE BETWEEN ISOREFRACTIVE HALF-SPACES

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ABSTRACT

Metallic scatterers with a plane of symmetry are considered. The symmetry plane separates the space surrounding the scatterer into two half spaces, that are filled with linear and isotropic materials isorefractive to each other. The primary field is an electromagnetic plane wave propagating in a direction parallel to the symmetry plane. The analysis is performed in the frequency domain, with time-dependence factor $\exp(j\omega t)$ omitted throughout. A fundamental theorem is given, which states that if a solution to the boundary-value problem is known for the given metal scatterer and the given direction of incidence in free space, then the solution is also known in the presence of the two isorefractive half-spaces. The theorem is applied to several configurations, yielding solutions to boundary-value problems that were previously unavailable.

INTRODUCTION

Two isotropic media are called isorefractive if they have the same index of refraction (and therefore the same propagation constant and phase velocity), but different intrinsic impedances. Isorefractive media enjoy several properties, among them the fact that at a planar interface separating two isorefractive half-spaces, the angle of refraction equals the angle of incidence, and the reflection and transmission coefficients are independent of both polarization and angle of incidence of the primary wave. As a consequence, the interface between isorefractive media supports lateral waves, but not evanescent waves. If a plane wave propagates in a direction parallel to the planar interface between the two media, it appears as two lateral waves whose components of the electric and magnetic fields parallel to the interface are the same in both media, whereas the field components perpendicular to the interface are scaled by a factor equal to the ratio of the intrinsic impedances of the media. An arbitrarily polarized plane wave propagating parallel to the interface can always be decomposed into the sum of two linearly polarized waves, with their electric field parallel (E-polarization) and perpendicular (H-polarization) to the interface, respectively.

Consider a metallic scatterer with a plane of symmetry, surrounded by free space. If a plane wave is incident on the scatterer in a direction parallel to the symmetry plane with its electric (magnetic) field parallel to the symmetry plane, then by simple symmetry considerations it follows that the electric (magnetic) field scattered by the metallic object is, in the symmetry plane, also parallel to the symmetry plane itself. If the symmetry plane now becomes the interface between two isorefractive half-spaces, then the electric (magnetic) scattered field still remains parallel to the interface, at the symmetry plane. It follows that if a solution to the scattering problem is known when the metallic object is in free space, it is also known when it is immersed in the two isorefractive half-spaces. Several boundary-value problems based on this conclusion are solved, in two and three dimensions.

TWO-DIMENSIONAL SCATTERING

We first consider a parabolic cylinder with its symmetry plane containing the focal line as the plane that separates the isorefractive half-spaces, and assume that the plane primary wave is incident on the convex side of the cylinder. The solution by Lamb [1] is extended to this case. In particular, the scattered field is obtained in closed form for both polarizations. Then the particular case of the half-plane at the interface between isorefractive half-spaces is analyzed, and the closed-form scattered field is transformed into an infinite series of eigenfunctions of MacDonald's type [2], thereby allowing for the consideration of a cylindrically capped half-plane at the planar interface. Next we examine a metallic elliptic cylinder with its interfocal strip either parallel or perpendicular to the plane separating the isorefractive half-spaces; this is a special case of a previously solved boundary-value problem [3]. The cases of a

metal strip either in the interface plane or perpendicular to it follow as particular cases of the elliptic cylinder. We then consider a metallic wedge with its bisector plane as the interface between isorefractive half-spaces, possibly with a cylindrical cap on its edge. The above nine new canonical solutions are all two-dimensional.

THREE-DIMENSIONAL SCATTERING

The metallic paraboloid of revolution with its axis on the interface between the isorefractive half-spaces and axial incidence on its convex side yields a three-dimensional, closed-form canonical solution that coincides with geometrical optics. This is an extension of the exact geometrical optics solution of Schensted [4] for the metallic paraboloid in free space. Three other three-dimensional configurations are solved exactly: a sphere and a cone (possibly capped by a sphere) located half above and half below the isorefractive interface. All these new canonical solutions are of interest not only per se, but also because they provide challenging validation test-beds for general-purpose frequency-domain computer codes.

REFERENCES

- [1] Lamb, H., "On Sommerfeld's diffraction problem; and on reflection by a parabolic mirror", *Proc. London Math. Soc.*, vol. 4, pp. 190-203 (1906).
- [2] MacDonald, H. M., *Electric Waves*. Cambridge, England: University Press (1902).
- [3] Erricolo, D., and Uslenghi, P. L. E., "Exact radiation and scattering for an elliptic metal cylinder at the interface between isorefractive half-spaces", *IEEE Trans. Antennas Propagat.*, vol. 52, pp. 2214-2225 (Sept. 2004).
- [4] Schensted, C. E., "Electromagnetic and acoustic scattering by a semi-infinite body of revolution", *J. Appl. Phys.*, vol. 26, pp. 306-308 (1955).