Analytical and Numerical Behavior of a Penetrable Sphere Containing a Concentric Metallic Disk

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Abstract

The electromagnetic scattering of a plane wave by a penetrable sphere made of isotropic material and containing a concentric thin metallic disk is studied by separation of variables and matrix truncation. The analytic-numerical results are compared to high-frequency approximations in the case of backscattering.

1. Description of Research

The scattering of a plane electromagnetic wave with an arbitrary direction of incidence and arbitrary polarization by a spherical structure is considered, in the frequency domain. The structure consists of a penetrable sphere made of a linear, homogeneous and isotropic material characterized by a scalar permittivity ε and a scalar permeability μ. A thin metallic disk whose radius may be less, equal or greater than the radius of the sphere is located in the equatorial plane of the sphere. Preliminary results for the case of sphere and disk having the same radius were presented in [1]. The case of a metallic sphere intersected by a metallic disk was studied in [2-4]. This problem is important as a validation tool for computer codes developed for the remote detection of hidden mines.

The boundary-value problem is analyzed by separation of variables. The space is divided into several regions. If the disk radius is smaller than the sphere radius, there are four such regions: two hemispheres with radius equal to the disk radius and separated by the disk, a concentric spherical region with inner radius equal to the disk radius and outer radius equal to the sphere radius, and the infinite region surrounding the penetrable sphere. In a similar manner, five regions are identified when the disk radius is larger than the sphere radius, whereas only three regions are necessary when disk and sphere radii are equal. The electromagnetic fields inside each homogeneous region are expanded in spherical harmonics with the aid of Debye potentials. Imposition of the boundary conditions leads to an infinite set of algebraic equations for the modal expansion coefficients of the infinite series representing the field components. A first approach consists in solving the algebraic system computationally by matrix truncation, leading to numerical results that are accurate through the resonance region. An alternate and more sophisticated procedure consists in employing a regularization method, following a technique explained e. g. in [5].

For the particular case of backscattering, high-frequency results are obtained and compared to those obtained via the analytical-numerical approach described above.

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2. References

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