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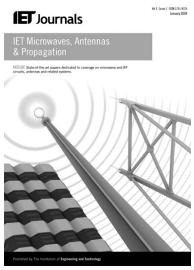

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Numerical analysis of scattering from cylindrical structures coated by layers having inhomogeneity in both radial and azimuthal directions

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Abstract: In this study, the problem of electromagnetic scattering from cylindrical structures with multi-layered coating having inhomogeneity in both radial and azimuthal directions is investigated. The core of the structure may be PEC, PMC, PEMC, impedance surface, dielectric or metamaterial. The previous investigations have been restricted to a special case, for example, coatings with only radial inhomogeneity, normal incidence etc. Moreover, in these investigations only single layer coatings are considered and the analysis is based on modelling inhomogeneous coating by homogeneous layers. However, in this study, for the first time, electromagnetic scattering from cylindrical structures coated by multilayered inhomogeneous coating is considered in the most general case for any arbitrary number of layers, incident angle and polarisation. The analysis is based on finite difference method which is a common method in solving engineering electromagnetic problems and the inhomogeneous coating is not approximated by homogeneous layers. The validity of the proposed method is verified through some comprehensive examples. Comparing the results of the proposed method with exact solutions and the results obtained from other commonly used methods in the literature, it is confirmed that the method is simple, fast, accurate and valid for all inhomogeneous layers with continuous electromagnetic profiles.

1 Introduction

Cylindrical structures are of the most applicable structures in engineering electromagnetics. Finding a proper coating for these structures is always a favourite of researchers to optimise radar cross section, shielding effectiveness and to achieve an arbitrary radiation pattern [1–5]. Among all coating materials, inhomogeneous media is of great importance because of the extensive use of these materials in designing radar absorbers, shields, radomes, filters and etc. [6–10]. Multi-layered homogeneous media are often mistaken for inhomogeneous media by many researchers. Although in multi-layered homogeneous structures the analysis is upon the wave impedance and wave number, inhomogeneous structures deal with differential equations and mentioned concepts are not usable anymore.

Thus far, various studies have been carried out to analyse scattering from cylindrical structures with inhomogeneous coatings. However, these studies have been restricted to a special case, for example, single layer coatings [11–16], coatings with only radial inhomogeneity [11–15], normal incidence [15] etc. Moreover, the approach of analysis in these investigations is based on modelling of inhomogeneous coating by homogeneous layers which is an approximation of the exact problem [12, 14].

However, in this paper, for the first time, scattering of electromagnetic waves from cylindrical structures with multilayered inhomogeneous coating is considered. The core of the structure may be PEC, PMC, PEMC, Impedance surface, dielectric or metamaterial. The coating layers may have inhomogeneous dielectric and magnetic profiles in both radial and azimuthal directions. An EM wave with an arbitrary linear combination of TE and TM polarisations is incident on the structure, obliquely.

According to the references cited above and the structure discussed in the paper, unlike the previous investigations, in this contribution no limit is set on the conditions of the problem and the most general case is considered. Moreover, the approach of the analysis is not based on approximating inhomogeneous coating by homogeneous layers and the exact problem is studied.

A general method is proposed to analyse electromagnetic scattering from such structures in the frequency domain based on the finite difference concept which is a common method in solving electromagnetic problems dealing with partial differential equations [17, 18]. First, the differential equations system describing propagation of electromagnetic waves in each inhomogeneous coating layer is obtained. Then, each inhomogeneous layer is subdivided into several thin layers and the electromagnetic fields in the coating layers and the scattering parameters of the structure are calculated by using the finite difference concept in the system of differential equations and boundary conditions. In the last section, the proposed method is employed to analyse electromagnetic scattering from cylindrical structures with multi-layered two-dimensional inhomogeneous coatings in