EM Scattering from Cylindrical Structures Coated by Materials with Inhomogeneity in both Radial and Azimuthal Directions

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***Abstract*— consider a cylindrical structure with an arbitrary core coated by layers with inhomogeneity in both radial and azimuthal directions in the most general case. The core of the structure may be PEC, PMC, PEMC, impedance surface, dielectric or metamaterial and an EM wave with arbitrary polarization is obliquely incident on the structure. In this paper, EM scattering from such a structure is analyzed, for the first time, through a general method in the frequency domain on the basis of the Taylor series concept. The validity of the proposed method is verified through some comprehensive examples. It is confirmed that the method is simple, fast and highly reliable. Moreover, it is capable of analyzing the scattering of obliquely incident plane waves for all types of cylindrical cores and lossy inhomogeneous layers with continuous dielectric and magnetic profiles. In the last example, to show the applicability of the proposed method in inverse problems, the method is employed in an optimization procedure to reduce the radar cross section of a PEC cylinder.**

***Index Terms*— Cylindrical Structure, Echo Width, Radial and Azimuthal Inhomogeneous Coating, Scattering**

I. Introduction

Cylindrical structures are among the most common structures in engineering electromagnetics. Finding a proper coating for these structures is always desirable for researchers in order to optimize radar cross section [1-2], shielding effectiveness [3], and achieve an arbitrary radiation pattern [4]. Among all coating materials, inhomogeneous media are of great importance because of their extensive use in designing radar absorbers, shields, radomes, filters and so forth [5-7]. Multilayered media are often mistaken for inhomogeneous media by many researchers. While in multilayered homogeneous structures the analysis is based on wave impedance and wave number, inhomogeneous media deal with differential equations; therefore, the aforementioned concepts are not usable in their case. Moreover, contrary to the scattering problems of homogeneous media, the ones dealing with inhomogeneous media do not have exact solutions except for special cases of inhomogeneous profiles.

Scattering from cylindrical structures with inhomogeneous coatings have been studied in literature [8]-[13]. However, these studies were restricted to special cases of single layer coatings [8]-[13], coatings with only radial inhomogeneity [8]-[12], and normal incidence [12].

This paper, considers the most general case in analyzing the scattering of electromagnetic waves from cylindrical structures with multilayered inhomogeneous coating. 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 direction. An EM wave with an arbitrary linear combination of TE and TM polarizations is obliquely incident on the structure. A general method is proposed to analyze scattering from such structures in the frequency domain on the basis of the Taylor series concept. First, the differential equations system describing the propagation of electromagnetic waves in the cylindrical media with two-dimensional inhomogeneity is obtained. Then by substituting the Taylor series expansion of the fields and the electromagnetic parameters in the differential equations system and using Maxwell's equations and boundary conditions, a system of linear equations is achieved. Solving this system of equations, the unknown coefficients in the series of the fields are calculated, from which the fields in the whole space and the scattering parameters can be obtained. The proposed method is used to analyze electromagnetic scattering from cylindrical structures with multilayered inhomogeneous coatings in several comprehensive examples. In order to verify the validity of the method, in the first two examples, two bi-layer coatings, one with radial inhomogeneity and the other with two-dimensional inhomogeneity, are considered, in which differential equations of wave propagation have exact solutions. The scattering echo width of these structures are obtained using exact solutions, the proposed method and other commonly used methods in the field. According to the

Manuscript received May xx, 2013.

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