Analysis of electromagnetic scattering from metallic and penetrable cylinders with edges using a multifilament current model

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Abstract: A method of moments solution is presented for the problem of electromagnetic scattering from homogeneous cylinders with edges. Transverse magnetic (TM) and transverse electric (TE) cases for metallic and penetrable cylinders are also treated. The moment solution uses a recently suggested multifilament current model to simulate fields, special attention being paid to the accommodation of edges when using this model. An alternative hybrid method that uses a combination of a few on-surface pulse functions to simulate the field behavior near the edges together with a filamentary current model whose field can represent the smooth field constituent on the boundary very well is also presented. Results of both methods are given and compared with available known solutions based on a standard moment method solution that employs surface pulse functions.

1 Introduction

The problem of electromagnetic scattering by cylinders with edges has been treated extensively in the literature. In many cases the method of moments with pulse, or other subsectional type basis functions has been used [1–6]. Hybrid methods that combine the geometrical theory of diffraction (GTD) or the uniform theory of diffraction (UTD) with a moment method procedure have also been attempted [7–8]. Recently, even a pure UTD approach has been pursued [9].

Recently, a method has been presented for solving the problem of electromagnetic scattering by homogeneous cylinders of arbitrary smooth shape [10–11]. This method employs sets of fictitious filamentary sources that take the place of equivalent electric and magnetic currents in the commonly used surface integral equation. A brief outline of this previous formulation, which we intend to extend to handle cylinders with edges, is presented below. For the penetrable case, two simulated equivalent situations are set up that are related to the outside and inside of the cylinder in the original situation, respectively. Each situation has a corresponding set of filamentary sources, of yet to be determined complex amplitudes, which are used to simulate the fields in that situation. The field scattered by the cylinder is simulated by a set of filamentary currents located inside the cylinder, while the field inside the cylinder is simulated by filamental currents placed outside it. Only the scattered field need be simulated in the metallic case, so one set of sources, located inside the cylinder, is employed. Forcing the boundary conditions in some sense at a finite number of points on the surface of the cylinder, a matrix equation is obtained for the unknown complex amplitudes of the filamentary sources. Once these amplitudes are determined, the fields and related parameters of interest can be evaluated in a straightforward manner.

In this paper we follow the same technique, but take special care to treat the edges. This is effected by locating extra filamentary sources in the vicinity of the edges. The fields of these sources can bear the required singular edge behavior very well and thereby enhance the accuracy of the numerical solution. An alternative approach using a standard pulse surface distribution near the edges, together with filamentary sources, is also presented. We refer to this latter method as the hybrid one. Both techniques are compared with an independent standard moment method solution that uses only surface pulses. The production which employs only filamentary sources is the most rapid and easy to use since no integrations are performed for the various field calculations. The hybrid procedure is only a little slower but, employing two types of sources, is less simple. Both techniques, of course, are superior by far to the standard surface formulation approach.

2 Problem specification

Consider an infinite cylinder of arbitrary cross-section, uniform along the z axis of a Cartesian co-ordinate system. Fig. 1 shows the pertinent co-ordinate system together with the cross-section of a square cylinder and the vectors which appear in the equations. We have drawn a square cylinder because this is the specific problem for which numerical results will be presented. The formulation is, of course, general. The cylinder is immersed in free space with permeability \( \mu_0 \) and permittivity \( \varepsilon_0 \). In the penetrable case the cylinder is composed of homogeneous material with permeability \( \mu \) and permittivity \( \varepsilon \). In the metallic case the cylinder is formed from a perfectly conducting shell. We will refer to the region external to the cylinder as region I, to the cylinder region as region II, and to the cylindrical boundary between these regions as C. For the transverse magnetic