Analysis of two-dimensional electromagnetic scattering from a periodic grating of cylinders using a hybrid current model

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A method of moments solution is presented for the problem of two-dimensional electromagnetic scattering from a periodic grating composed of an infinite set of penetrable cylinders illuminated by a TM (transverse magnetic relative to the cylinder axis) plane wave. The reduction of the general problem to a consideration of the fields over a suitably selected period, referred to as the unit cell, is facilitated by the Floquet theorem. The solution then uses fictitious spatially periodic and properly modulated electric current strips to simulate the scattered field in the exterior region within the unit cell and fictitious filamentary currents to simulate the field penetrated into the cylinder enclosed within this cell. The fields radiated by the current strips are represented in terms of Floquet modes. Finally, the simulated fields are forced to obey the continuity conditions for the tangential components of the electric and magnetic fields at a selected set of points on the cylinder boundary within the unit cell. The procedure is simple to implement, rapidly converging, and is applicable to cylinders of arbitrary smooth cross section. Perfectly conducting cylinders are treated as reduced cases of the general procedure for penetrable cylinders. Results are given and compared with available data. The efficiency of the suggested method is demonstrated.

1. INTRODUCTION

The study of two-dimensional electromagnetic scattering of a plane wave from periodic gratings formed by cylinders is long standing. These studies have been motivated not solely by academic curiosity, but by many engineering applications as well. For example, they are of practical importance in designing reflection and transmission gratings often used as filters, broadband absorbers, and polarizers. A large body of early work analyzed metallic gratings. Most of them dealt exclusively with closely spaced thin wires [Marcuvitz, 1951; Wait, 1954; Astrakhian, 1968]. An analytical multiple-scattering approach which is applicable to a wider range of parameters has been presented in a work by Twersky [1956, 1962]. Calculations based on the analytic formulation of Twersky [1956, 1962] have been carried out by Wasylikowski [1971] for gratings of circular metallic cylinders. Later, Kalhor and Armand [1975] employed an integral equation numerical technique and Moaveni [1979a, b] applied the finite element and finite difference techniques to the analysis of gratings of metallic cylinders of arbitrary cross section. Recent theoretical and numerical works with perfectly conducting wire gratings can be found in Suratteau et al. [1985] and Moaveni [1986]. In the former an integral equation approach is employed for solving the Helmholtz equation rigorously without any physical simplifying assumptions. In the latter a numerical solution based on finite difference is used to analyze metallic gratings of cylinders embedded in an inhomogeneous and lossy dielectric. Periodic gratings of penetrable cylinders of arbitrary elemental cross section, however, have received less attention. Tremain and Mei [1978] applied the unimoment method to an array of rectangular dielectric cylinders. More recently, Lakhtakia et al. [1986] have presented a numerical procedure based on Fourier-Bessel expansions and the T-matrix method for solving dielectric cylindrical gratings embedded in a dielectric slab.

In this paper, we introduce a novel method for analyzing scattering from a periodic grating of penetrable cylinders (Figure 1). The technique is applicable to homogeneous cylinders of smooth, but otherwise arbitrary, cross section. The size of the cylinders is also to a large extent arbitrary. The cylinders might be small as well as on the order of a wavelength or greater. The size will only be limited by the storage capacity of the available computer. Lossy cylinders can be handled with no additional complexity. Perfectly conducting cylinders can be easily treated as a reduced case of the general procedure.

In the suggested approach, we use the method outlined in Leviatan et al. [1987b] for analyzing scattering from homogeneous scatterers of smooth shape. The basic idea in this method is as follows: Instead of employing surface integral equations to solve for conventional electric and magnetic sur-