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Modal Ring Method for the Scattering of Electromagnetic Waves

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MODAL RING METHOD FOR THE SCATTERING OF ELECTROMAGNETIC WAVES

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Abstract **– The modal ring method for electromagnetic scattering from PEC (perfectly electric conducting) symmetrical bodies is presented. The scattering body is represented by a line of finite elements (triangular) on its outer surface. The infinite computational region surrounding the body is represented analytically by an eigenfunction expansion. The modal ring method effectively reduces the two-dimensional scattering problem to a one-dimensional problem similar to the method of moments. The modal element method is capable of handling very high frequency scattering because it has a highly banded solution matrix.**

INTRODUCTION

The modal element method, which couples finite element algorithms to eigenfunction expansions, has been employed in electromagnetic and acoustic scattering problems. The primary reasons for employing this technique are to accurately describe the radiation boundary condition at the computational boundary and to reduce the size of the numerical grid. This hybrid steady state method has been given various titles, such as the unimoment method, the transfinite element method or the modal element method. In electromagnetics, Chang & Mei [1] and Lee & Cendes [2] applied the method to scattering from dielectric cylinders while Baumeister and Kreider [3] have applied the method to acoustic scattering problems.

The goal of this study is to minimize the domain in which finite elements are employed in scattering problems from PEC bodies. In this approach, called the modal ring method, a single line of elements circumscribing the body is used, as shown in Fig. 1.

METHOD OF ANALYSIS

The present study is concerned with computing the magnetic scattering by a symmetrical two-dimensional PEC body of an impinging plane wave traveling in the +x direction. The spatial domain is divided into two subdomains, the homogeneous domain and the finite element ring domain, as shown in Fig. 1 for the case of a circular geometry. In the finite element domain, an approximate solution for the total (incident + scattered) magnetic intensity at the element nodes is calculated by the Galerkin method. In the homogeneous domain, which extends to infinity, an analytic solution (an eigenfunction expansion [2]) for the total magnetic intensity is employed.

The finite element aspects of converting the wave equation, the eigenfunction expansion, interface conditions and the boundary conditions into an appropriate set of global difference equations can be found in [3]. The resulting set of global difference equations is solved by a frontal solver for magnetic intensity at the nodes and the amplitudes of the modal coefficients in the eigenfunction expansion.

RESULTS AND COMPARISONS

Many numerical experiments were performed for the problem of scattering from a PEC cylinder where the exact solution is known. In these experiments, the dimensionless frequency range (ka, wave number * cylinder radius) extends from 1 to 100. There was excellent agreement between all the numerical solutions and the exact analytical results. Figure 2 illustrates typical results. In this example, a unit plane wave ka = 100, incident from the left, strikes a PEC cylinder of dimensionless radius r = 1 oriented with its axis normal to the propagation direction. The excellent agreement between the numerical solutions (hollow squares) and the exact solutions (solid lines) clearly indicates that the modal ring method is suitable for high frequency scattering applications.

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1. S.K. Chang and K.K. Mei, "Application of the unimoment method to electromagnetic scattering of dielectric cylinders," IEEE Trans., Anten. Propag., vol. AP-24, pp. 35-42, 1976.

2. J.-F. Lee and Z.J. Cendes, "The transfinite element method for computing electromagnetic scattering from arbitrary lossy cylinders," in Antennas and Propagation: 1987 International Symposium Digest, Paper AP03-5 (IEEE, New York), 1987.

3. K.J. Baumeister and K.L. Kreider, "Modal element method for scattering of sound by absorbing bodies," NASA TM-105722, Nov. 1992.

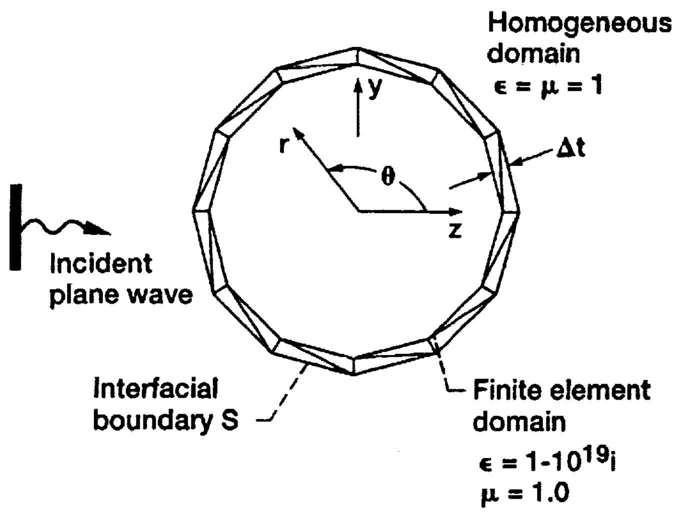

Figure 1.—Finite element ring grid system for PEC bodies.

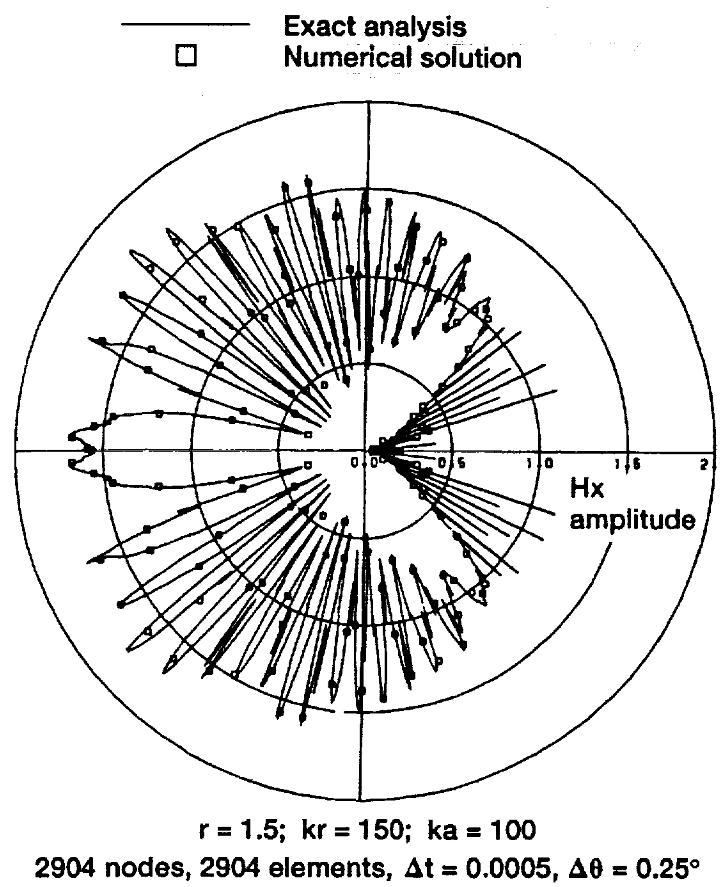

Figure 2.—Polar plot of the magnetic field around a PEC cylinder subjected to a plane wave impingement constructed from modal coefficients determined by modal-ring method.

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The modal ring method for electromagnetic scattering from PEC (perfectly electric conducting) symmetrical bodies is presented. The scattering body is represented by a line of finite elements (triangular) on its outer surface. The infinite computational region surrounding the body is represented analytically by an eigenfunction expansion. The modal ring method effectively reduces the two dimensional scattering problem to a one-dimensional problem similar to the method of moments. The modal element method is capable of handling very high frequency scattering because it has a highly banded solution matrix.

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