Generalized Formulations for Electromagnetic Scattering from Perfectly Conducting and Homogeneous Material Bodies—Theory and Numerical Solution

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Abstract—Generalized E-field formulation for three-dimensional scattering from perfectly conducting bodies and generalized coupled operator equations for three-dimensional scattering from material bodies are introduced. The suggested approach is to use a fictitious electric current flowing on a mathematical surface enclosed inside the body to simulate the scattered field and, in the material case, to use in addition a fictitious electric current flowing on a mathematical surface enclosing the body to simulate the field inside the body. Application of the respective boundary conditions leads to operator equations to be solved for the unknown fictitious currents which facilitate the fields in the various regions through the magnetic vector potential integral. The existence and uniqueness of the solution are discussed. These alternative operator equations are solvable via the method of moments. In particular, impulsive expansion functions for the currents in conjunction with a point-matching testing procedure can be used without degrading the capability of the numerical solution to yield accurately near-zone and surface fields. The numerical solution is simple to execute, in most cases rapidly converging, and is general in that bodies of smooth but otherwise arbitrary surface, both lossless and lossy, can be handled effectively. Boundary condition tests to see the degree to which the required boundary conditions are satisfied at any set of points on the body surface are easily made for validating the solution. Finally, results are given and compared with available analytic solutions, which demonstrate the very good accuracy of the moment procedure.

I. INTRODUCTION

THREE-DIMENSIONAL problems of electromagnetic scattering by perfectly conducting and material bodies have been a subject of intense investigation and research to the electromagnetic community for many years. The study of electromagnetic scattering is not solely of academic interest, but of practical importance as well in many application areas. These efforts have led to a development of a large number of analysis tools and modeling techniques for quantitative evaluation of electromagnetic scattering by various objects. Among these methods, surface integral equation formulations are probably the most suitable ones for numerical solutions. The general procedure is to reduce the three-dimensional problem to two dimensions by casting the problem in terms of unknown functions defined on the surface of the body rather than in terms of unknown volume functions. In considering scattering from a conducting body (Fig. 1), the problem is formulated in terms of the yet to be determined surface current \( \mathbf{J}_s \) induced on the conducting body surface \( S \). This can be done in two alternative ways discussed both by Poggio and Miller in [1]. One formulation, known as the \( E \)-field integral equation, is derived by setting the component tangential to \( S \) of the sum of the incident electric field and the electric field due to \( \mathbf{J}_s \), both calculated with the conducting body absent, equal to zero on \( S \). The other formulation, known as the \( H \)-field integral equation, is derived by setting the component tangential to \( S \) of the sum of the incident magnetic field and the magnetic field due to \( \mathbf{J}_s \), both calculated with the conducting body absent, equal to zero just inside \( S \). In considering scattering from a homogeneous material body (Fig. 2), the problem can be formulated in terms of yet to be determined equivalent electric and magnetic currents \( \mathbf{J}_e, \mathbf{M}_e \) over the body surface \( S \). Application of boundary conditions leads to a set of four integral equations to be satisfied. Linear combinations of these four equations leads to a coupled pair of integral equations to be solved. One choice of combination constants gives the formulation described by Poggio and Miller [1]. Another choice of combination constants gives the formulation obtained by Müller [2]. If either the \( E \)-field or the \( H \)-field integral equation for the conducting body case were solved exactly, we would have the true solution. Similarly, if the coupled pair of integral equations for the material body case were solved exactly, we would have the true solution. To obtain approximate solutions, these equations are reduced to matrix equations via the method of moments [3]. The solution of the matrix equations is then

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