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Numerical method for analysis of one- and two-dimensional electromagnetic scattering based on using linear Fredholm integral equation models

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ABSTRACT

Since many problems in one- and two-dimensional electromagnetic scattering can be modeled by linear Fredholm integral equations of the first or the second kind, the main focus of this paper is to present an effective numerical method for solving them. This method is based on vector forms of block-pulse functions. By using this approach, solving the linear Fredholm integral equation reduces to solve a linear system of algebraic equations. The advantages of the proposed method are low cost of setting up the equations without applying any projection method such as collocation, Galerkin, etc., setting up a linear system of algebraic equations of appropriate condition number, and good accuracy. Test problems are provided to illustrate its accuracy and computational efficiency, and some practical one- and two-dimensional scatterers are analyzed by it.

1. Introduction

Many problems in one- and two-dimensional scattering from perfectly conducting bodies can be modeled by linear Fredholm integral equations of the first kind [1–4]. These equations are in general ill-posed. That is, small changes to the problem's data can make very large changes to the answers obtained [5,6]. So, obtaining the numerical solutions is very difficult.

Several regularization methods have been proposed to overcome the ill-posedness [7,8]. In recent years, some numerical methods based on different basis functions have been illustrated. These methods often use a projection method and transform a first kind integral equation to a linear system of algebraic equations. This system usually has a large condition number, therefore a suitable approach such as Conjugate Gradient (CG) method should be considered [9,10].

Integral equation technique is a well-known approach for modeling of scattering problems. Traditionally, most of the numerical methods for the solution of these models use basis functions including, for example, characteristic basis functions [11], Rao, Wilton, and Glisson (see references of [12]), radial basis functions [13], Fourier series [14], wavelets [15, 16], etc. Some methods solve the integral equation model using entire domain basis functions [17] and some of them use the singular integral equation approach [18,19]. Some researchers have proposed modified or hybrid methods to increase the computational efficiency of the traditional approaches. A regularized combined field integral equation (CFIE) pertinent to the analysis of scattering from two-dimensional perfect electrically conducting objects is presented in [20], in which the regularization is achieved via analytical inversion of the hypersingular part of the CFIE. An alternate form of the CFIE

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