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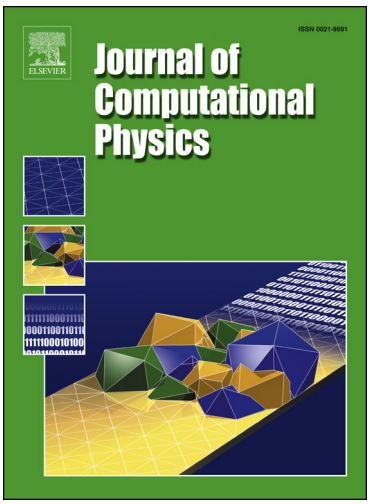

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A Hierarchical Preconditioner for the Electric Field Integral Equation on Unstructured Meshes Based on Primal and Dual Haar Bases

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Abstract

A new hierarchical basis preconditioner for the electric field integral equation (EFIE) operator is introduced. In contrast to existing hierarchical basis preconditioners, it works on arbitrary meshes and preconditions both the vector and the scalar potential within the EFIE operator. This is obtained by taking into account that the vector and the scalar potential discretized with loop-star basis functions are related to the hypersingular and the single layer operator (i.e., the well known integral operators from acoustics). For the single layer operator discretized with piecewise constant functions, a hierarchical preconditioner can easily be constructed. Thus the strategy we propose in this work for preconditioning the EFIE is the transformation of the scalar and the vector potential into operators equivalent to the single layer operator and to its inverse. More specifically, when the scalar potential is discretized with star functions as source and testing functions, the resulting matrix is a single layer operator discretized with piecewise constant functions and multiplied left and right with two additional graph Laplacian matrices. By inverting these graph Laplacian matrices, the discretized single layer operator is obtained, which can be preconditioned with the hierarchical basis. Dually, when the vector potential is discretized with loop functions, the resulting matrix can be interpreted as a hypersingular operator discretized with piecewise linear functions. By leveraging on a scalar Calderón identity, we can interpret this operator as spectrally equivalent to the inverse single layer operator. Then we use a linear-in-complexity, closed-form inverse of the dual hierarchical basis to precondition the hypersingular operator. The numerical results show the effectiveness of the proposed preconditioner and the practical impact of theoretical developments in real case scenarios.

Keywords: Electric field integral equation (EFIE), hierarchical basis, integral equations, numerical methods, preconditioning, multiresolution, multilevel

1. Introduction

The boundary element method applied to the electric field integral equation (EFIE) solves scattering and radiation problems in electromagnetics. The system matrix stemming from the discretization of the EFIE is ill-conditioned

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