A Multiplicative Calderòn Preconditioner for the Electric Field Integral Equation

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Among all integral equations pertinent to the analysis of scattering from three-dimensional perfect electrically conducting surfaces, the Electric Field Integral Equation (EFIE) remains the most widely used. Unfortunately, the EFIE operator is ill-posed as its eigenvalues accumulate at zero and infinity. For this reason, the linear system matrix that results upon discretization the EFIE using the Method of Moments (MoM) is highly ill-conditioned whenever the surface mesh is dense. The need for dense surface discretizations commonly often arises when analyzing electromagnetic phenomena on structures with sub-wavelength geometric features, e.g. millimeter and microwave integrated circuits, antenna feeds and beam-forming networks, aircraft fuselage details, etc.

The recent literature abounds with techniques to precondition EFIEs by leveraging Calderòn identities (H. Contopanagos et al., IEEE Trans. Antennas Propagat., 50(12), 2002, 1824-1830, R. J. Adams and N. J. Champagne, IEEE Trans. Antennas Propagat., 52(9), 2004, 2262-2266), S. Borel, D. Levadoux, and F. Alouges, IEEE Trans. Antennas Propagat., 83(9), 2005, 2995-3004). These techniques exploit the self-regularizing property of the EFIE, i.e. the fact that the square of the EFIE operator has a bounded spectrum, thus giving rise to MoM matrices that are well-conditioned independent of the surface mesh used. Unfortunately, none of the Calderòn preconditioners introduced to date are easily integrated into existing codes. Invariably, implementation bottlenecks can be traced to the need to properly discretize the spaces in between the two EFIE operators, and the difficulty in constructing well-conditioned Gram matrices linking them.

This paper presents a multiplicative Calderòn EFIE preconditioner that is trivially integrated into existing MoM codes. The preconditioned EFIE is obtained by multiplying two standard EFIE matrices (produced with a Rao-Wilton-Glisson code) weighted by sparse Gram and projection matrices, containing O(N) nonzero elements that are evaluated using closed-form expressions. The proposed multiplicative preconditioner leverages a recently developed set of basis functions that properly discretizes the range of the EFIE operator on a barycentric mesh (A. Buffa and S. Christiansen, Comptes rendus. Mathématique, 340(6), pp. 461-464). The multiplicative preconditioner is obtained by exploiting a simple relationship between ordinary and barycentric Rao-Wilton-Glisson basis functions to analytically map one basis set into the other.

The effectiveness of the new preconditioner in lowering the condition number of the EFIE operator and the number of iterations required for convergence, will be demonstrated.

B-85: Numerical Techniques: IE and FE Methods

Thursday, July 26, 2007 • Ballroom

Co-Chairs: *D. Wilton, University of Houston, USA*
A. Barka, Office National d'Etudes et de Recherches Aérospatiales-Toulouse, France

8:30 AM URSI468: "Interior Green's Function for a Thick and Finite Dielectric Slab"
A. Parsa, R. Paknys, Concordia University, Canada
Presenter: Armin Parsa, Concordia University, Canada

8:50 AM URSI689: "Efficient Computation of the Ewald Representation for Periodic Green's Functions"
F.T. Celepickay[1], F. Capolino[2], D.R. Jackson[1], D.R. Wilton[1],
[1]University of Houston, USA, [2]University of Siena, Italy
Presenter: Ferhat Celepickay, University of Houston, USA

9:10 AM URSI685: "An Investigation of the Ewald Method for Complex Waves"
V.R. Komanduri[1], F. Capolino[2], D.R. Jackson[1], D.R. Wilton[1],
[1]University of Houston, USA, [2]University of Siena, Italy
Presenter: Varada Komanduri, University of Houston, USA

9:30 AM URSI100: "MODELING OF RAM COATED INLETS RCS WITH SUB-DOMAIN METHODS AND HYBRID MODES"
A. Barka, J. Simon, Office National d'Etudes et de Recherches Aérospatiales-Palaiseau, France,
P. Soudais, Dassault Aviation, France
Presenter: Andre Barka, Office National d'Etudes et de Recherches Aérospatiales-Toulouse, France

9:50 AM URSI591: "Hybrid Use of AWE with Spatial Matrix Interpolation in the Analysis of Printed Structures"
G. Ogucu, University of Gaziantep, Turkey
Presenter: Golge Ogucu, University of Gaziantep, Turkey

10:30 AM URSI202: "A Comparison of Several Local Error Estimators for Integral Equation Formulations"
U. Saeed, A.F. Peterson, Georgia Institute of Technology, USA
Presenter: Usman Saeed, Georgia Institute of Technology, USA

10:50 AM URSI357: "Applications of the Generalized Moment Method to Augmented Integral Operators"
N.V. Nair, B.S. Shanker, Michigan State University, USA
Presenter: Naveen Nair, Michigan State University, USA

11:10 AM URSI695: "A Multiplicative Calderon Preconditioner for the Electric Field Integral Equation"
F.P. Andriulli[1], K. Cools[2], F. Olyslager[2], E. Michielssen[1],
[1]University of Michigan at Ann Arbor, USA, [2]Ghent University, Belgium
Presenter: Francesco Andriulli, University of Michigan at Ann Arbor, USA

11:30 AM URSI379: "A Generalized Moment Method Solution to Vector Electromagnetic Integral Equations"
N.V. Nair, B. Shanker, Michigan State University, USA
Presenter: Naveen Nair, Michigan State University, USA

11:50 AM URSI418: "Analysis of complex structures using generalized finite element methods"
C. Lu, B. Shanker, Michigan State University, USA
Presenter: Chuan Lu, Michigan State University, USA

12:10 PM URSI267: "Dispersion Analysis of Vector Generalized Finite Element Method"
O. Tuncer, C. Lu, B. Shanker, L.C. Kempel, Michigan State University, USA
Presenter: Ozgur Tuncer, Michigan State University, USA

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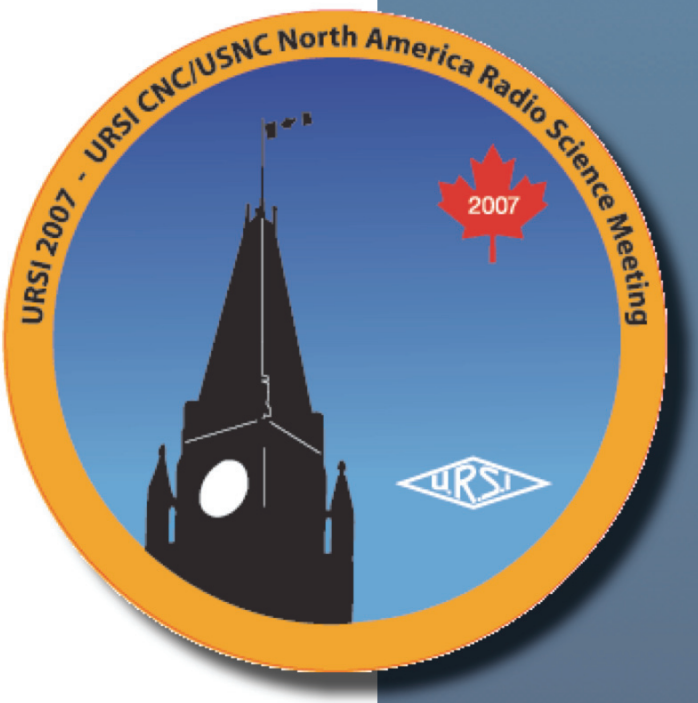

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