

SOLVING LARGE ELECTROMAGNETIC PROBLEMS IN SMALL COMPUTERS: A REVIEW OF OUR WORK AT UPC

Juan M. Rius, Alex Heldring, Eduard Úbeda

*Dept. of Signal Theory and Communications (TSC), Universitat Politècnica de Catalunya (UPC)
Jordi Girona 1-3, mòdul D3, Campus Nord UPC, 08034 Barcelona, Spain*

Josep Parrón

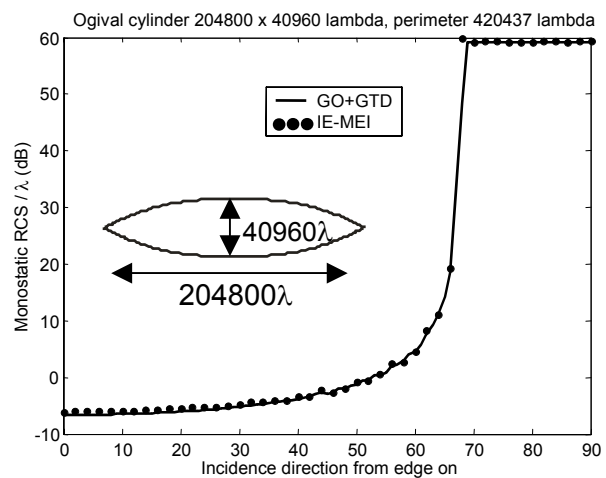
*Dept. of Telecommunications and System Engineering, Universitat Autònoma de Barcelona (UAB)
Edifici Q, Campus de la UAB, 08193 Bellaterra, Barcelona, Spain.*

Abstract: The aim of this paper is to review our activity in the last years in order to develop and/or implement accelerated techniques for the solution of large electromagnetic problems. We will restrict our attention to 3D integral equations formulation discretized by Method of Moments (MoM) Harrington [1], Rao, Wilton and Glisson (RWG) basis functions Rao et al. [2].

1. THE INTEGRAL EQUATION MEI (IE-MEI)

A sparse matrix integral equation formulation was developed. The results for TM and TE 2D problems Rius et al. [3][4] are excellent (Fig. 1), but the object must be of convex shape to avoid full sub-matrices Rius et al. [5]. The implementation in 3D with RWG is neither accurate nor efficient Rius et al. [6].

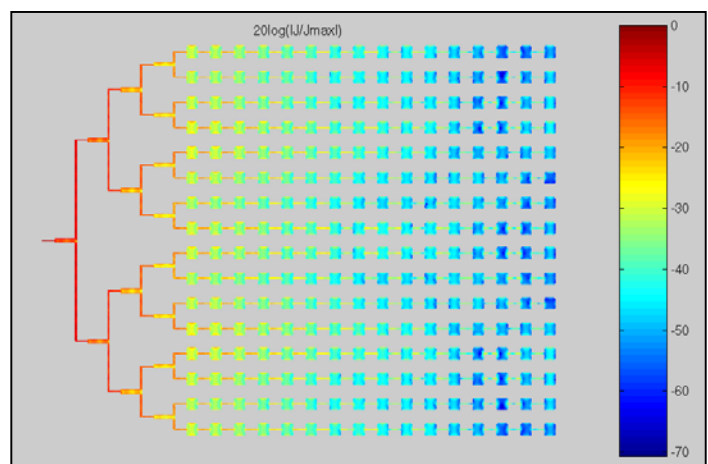
Fig. 1: Monostatic RCS of a 2D $204800\lambda \times 40960\lambda$ ogival cylinder, TM polarization, IE-MEI compared with Geometrical Optics (GO) and Geometrical Theory of Diffraction (GTD) high frequency approximation. The number of pulse basis functions (and unknowns) is 4,096,000. Induced current computation time is 19.5sec. per incidence direction with AMD Athlon CPU at 1.66 GHz and 4GB of RAM.



2. MULTILEVEL MATRIX DECOMPOSITION ALGORITHM (MLMDA)

The 2D MLMDA Michielsen et al. [7] was extended to 3D problems Rius et al. [8]. MLMDA in 3D is very efficient to analyze planar or piece-wise planar objects with any Green's function. For example, the results for microstrip antennas are excellent Parrón et al. [9] (Fig. 2) and the computation time is comparable to free-space implementation of MLFMA for the same accuracy.

Fig. 2: Induced current in a 16×16 microstrip array, of size $14\lambda \times 11.5\lambda$. A coarse discretization of multilayer MPIE with 27,720 RWG basis functions was analyzed by MLMDA and ILU preconditioning in 13 min., and a fine mesh discretization with 58,884 unknowns in 56 min., without using symmetries or redundancies, in a PC computer with AMD Athlon CPU at 1.33 GHz and 1.5 GB of RAM.



3. MULTILEVEL FAST MULTIPOLE ALGORITHM (MLFMA)

The MLMFA Song et al. [10] is possibly the most efficient algorithm for accelerating the MoM solution of general 3D electromagnetic problems with arbitrary surfaces. Previous research in MLFMA, ref. [10], addresses scattering computations with the well-conditioned CFIE. We have concentrated our efforts in the computation of antenna radiation with EFIE, which is ill-conditioned for very large numbers of unknowns and requires the use of large preconditioners. Fig 3. shows an example of educational interest for our Antenna Theory courses.

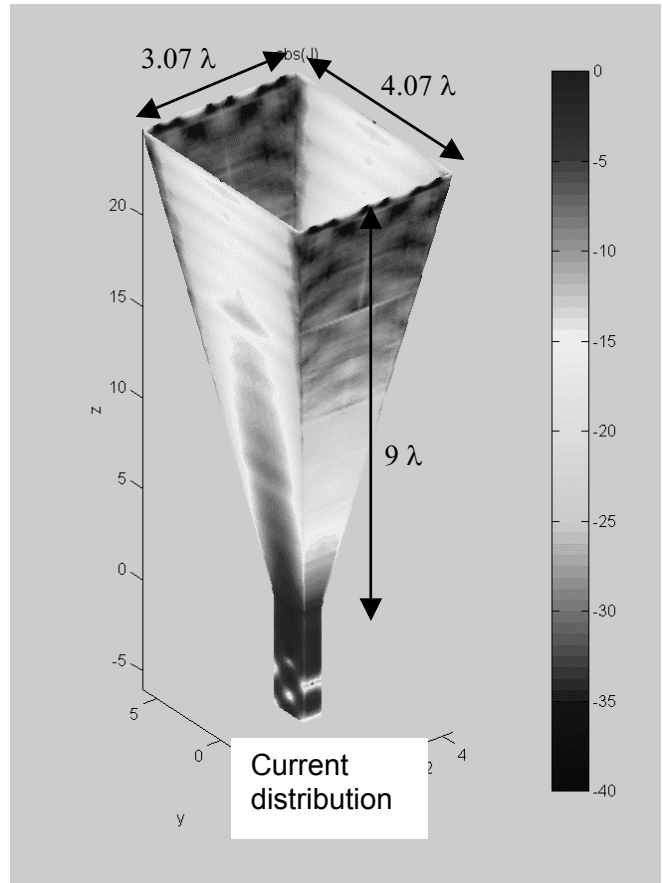
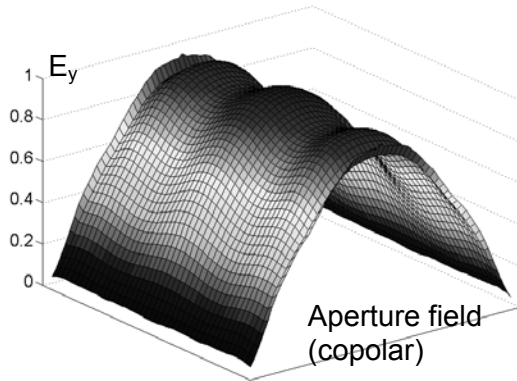


Fig. 3: Aperture field and current distribution in a X-band horn. The discretization of EFIE with 69,000 RWG basis functions was solved by the MLFMA with ILU preconditioning in 55 min. in a PC computer with AMD Athlon CPU at 1.0 GHz and 1.5 MB of RAM.

4. BLOCK-ILU PRECONDITIONER

When the preconditioner required for the iterative solution of EFIE with MLMFA and GMRES is too large to fit in-core RAM memory of the computer, one cannot efficiently do the conventional ILU decomposition of the preconditioner. In order to remove this bottleneck, we have developed a block-ILU algorithm Heldring et al. [11] that allows the use of huge preconditioners (Fig. 4).

ACKNOWLEDGEMENTS

This work was supported by the “Departament d'Universitats Recerca i Societat de la Informació (DURSI)” under “Distinció de la Generalitat de Catalunya per a la Promoció de la Recerca Universitaria”, the Spanish “Comisión Interministerial de Ciencia y Tecnología (CICYT)” through grant TIC 2001-2364-C01-01 and the European Commission through FET project IST-2001-33055.

REFERENCES

- [1] R. F. Harrington, *Field Computation by Moment Methods*, MacMillan, 1968.
- [2] S. M. Rao, D. R. Wilton and A. W. Glisson, “Electromagnetic scattering by surfaces of arbitrary shape”, *IEEE Transactions on Antennas and Propagation*, vol.30, n° 3, pp. 409-418, May 1982.

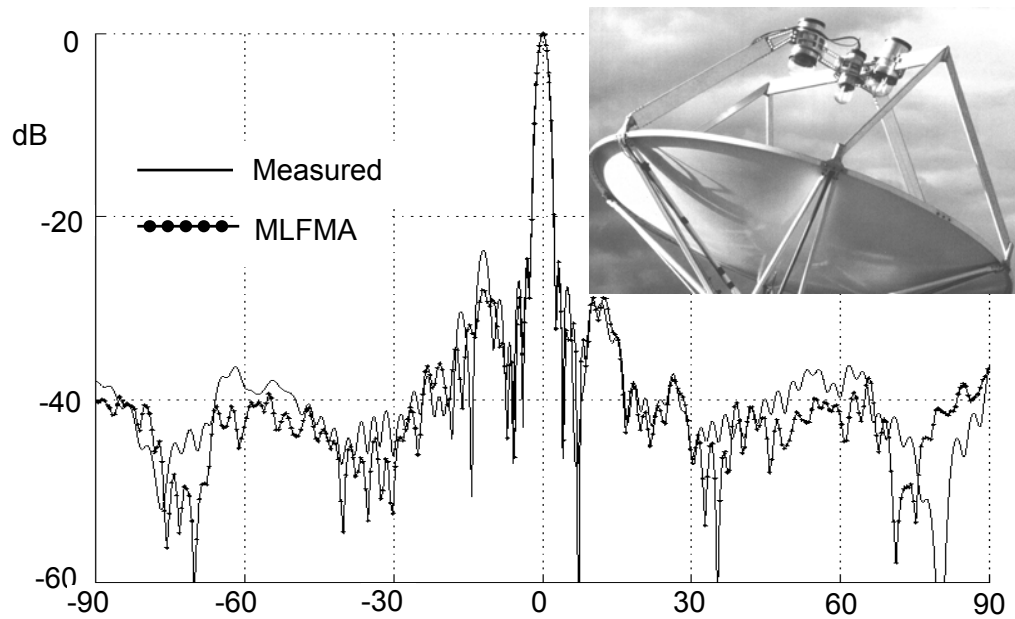


Fig. 4: Radiation pattern of the unshielded TARA antenna. The diameter is 33λ and the reflector, feeder, and supporting struts have been modeled with 479,200 RWG basis functions. The EFIE was solved with a 40-block ILU preconditioner and MLFMA in 65 hours in a PC computer with AMD Athlon CPU at 1.0 GHz and 1.5 MB of RAM.

- [3] J.M.Rius, R.Pous, A.Cardama, "Integral Formulation of the Measured Equation of Invariance: A Novel Sparse Matrix Integral Equation Method", *IEEE Trans. on Magn.*, Vol. 32, No. 3, pp. 962-967, May 1996.
- [4] J.M.Rius, C.Pérez Carpintero, A.Cardama, J.R.Mosig, "Frequency Extrapolation in the Integral Equation MEI", *IEE Electronics Letters*, Vol. 32, No. 25, pp. 2324-2326, 5th December 1996.
- [5] J.M.Rius, C.Pérez Carpintero, A.Cardama, K.A.Michalski, "Analysis of Electrically Large Concave Scatterers with the Integral Equation MEI", *Microwave and Optical Technology Letters*, Vol. 14, No. 5, pp. 287-289, 5/4/1997
- [6] J.M.Rius, J.Parrón, E.Úbeda, J.R.Mosig, "The Integral Equation MEI applied to three-dimensional arbitrary surfaces", *IEE Electronics Letters*, Vol. 33, No. 24, pp. 2029-2031, November 1997.
- [7] E. Michelsen and A. Boag, "A multilevel matrix decomposition algorithm for analyzing scattering from large structures", *IEEE Trans. Antennas Propag.*, 44, 1086-1093, (1996).
- [8] J.M. Rius, J. Parrón, E. Úbeda, J.R. Mosig, "Multilevel Matrix Decomposition Algorithm for Analysis of Electrically Large Electromagnetic Problems in 3-D", *Microwave and Optical Technology Letters*, Vol. 22, No. 3, pp. 177-182, 5th August 1999.
- [9] J. Parrón, J. M. Rius, J. R. Mosig, "Application of the Multilevel Matrix Decomposition Algorithm to the Frequency Analysis of Large Microstrip Antenna Arrays" *IEEE Transactions on Magnetics*, scheduled for March 2002.
- [10] J. Song, C.C. Lu and W.C. Chew, "Multilevel Fast Multipole Algorithm for Electromagnetic Scattering by Large Complex Objects", *IEEE Trans. Antennas Propag.*, Vol. 45, No. 10, pp. 1488-1493, October 1997.
- [11] A. Heldring, J.M. Rius, L. Ligthart, "New block ILU preconditioner scheme for numerical analysis of very large electromagnetic problems", *IEEE Trans. on Magnetics*, accepted and scheduled for March 2002.
- [12] J. Parrón, J. Romeu, J.M. Rius, J. Mosig, "Method of Moments enhancement technique for the analysis of Sierpinski pre-fractal antennas", submitted to *IEEE Antennas and Propagation*, submission number AP0201-0018.