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Calculating Static Field and Charge Distributions Using Full-Wave Boundary Element Methods

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Abstract—In order to model configurations driven by broadband sources (e.g. digital signals), it is desirable to employ a full-wave modeling technique that works well at both high and low frequencies. This paper describes a method for improving the low-frequency performance of existing full-wave boundary element techniques and demonstrates how this method can be used to calculate static electric fields and charge distributions. The new approach involves performing a linear transformation on the moment matrix utilizing an LU decomposition and matrix reconstruction. It does not require special basis functions and is relatively easy to implement in existing boundary element codes. Examples presented demonstrate how modified full-wave software accurately calculates static field and charge distributions for a variety of configurations using the same algorithms and the same input used to do high-frequency calculations.

I. Brief Overview

Most full-wave numerical electromagnetic modeling techniques lose accuracy and become unstable at very low frequencies. These instabilities can be explained in terms of the natural Helmholtz decomposition of Maxwell's equations [1]. Various methods have been developed to overcome these instabilities, but these generally involve the use of special basis functions or employ techniques that are incompatible with high-frequency analysis.

Recently, the authors developed a technique for extending the frequency range of full-wave boundary element codes by performing linear matrix transformations on the vector and scalar components of the impedance matrix [2]. This technique allows accurate field calculations to be made at frequencies where the geometries being analyzed are many orders of magnitude smaller than a wavelength. At these frequencies, it is relatively easy to obtain quasi-static charge distributions and calculate static electric fields with a high degree of accuracy without relying on a separate static field solver. Existing boundary element codes can be modified to obtain both high-frequency and quasi-static solutions. This paper reviews the procedure for extending the frequency range of boundary element codes, presents a technique for calculating static field and charge distributions, and introduces a simple method to correct for the charge singularities that occur at plate edges or corners.

II. Example

Several geometries were analyzed to validate the accuracy of this approach. One of these is illustrated in Fig. 1. A full-wave boundary element code employing triangular (RWG) basis functions was used to calculate the charge distribution and evaluate the mutual capacitance between two metal plates that were far enough apart to have a significant fringing field. The size of the plates was 200 x 200 mm. The initial distance between them was 10 mm.
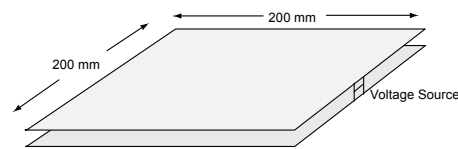

Fig. 1: Thick Parallel-Plate Geometry

Using a static field solver, a value of 42.0 pF was obtained for the mutual capacitance. The full-wave code calculated a value of 41.6 pF (within 1% of the static solver value). Increasing the distance between the metal planes to 40 mm, the static solver calculated a value of 14.3 pF. The full-wave code value was 14.9 pF (within 1.4%). Other configurations evaluated as part of this study included microstrip traces and electric dipoles. High-frequency results obtained using the full-wave code were not affected by the modifications required to do the static charge calculations, so one code was capable of analyzing all frequencies from DC to several GHz .

III. Conclusion

The modified LU recombination and charge singularity correction techniques presented here enable high-frequency and static field modeling to be done with the same boundary element code employing the same mesh and basis functions. Although the technique described is slightly less efficient for calculating static charge distributions than a dedicated static field solver, it allows broadband configurations to be analyzed without switching software. It also allows accurate calculations to be performed at frequencies that are too low for most full-wave approaches and too high for static field solvers.

IV. References

[1] S. Y. Chen, W. C. Chew, J. M. Song, and J. S. Zhao, "Analysis of low frequency scattering from penetrable scatterers," *IEEE Trans. Geoscience and Remote sensing*, vol. 39, no. 4, pp. 726-735, Apr. 2001.

[2] H. Ke and T. Hubing, "A modified LU recombination method for improving the performance of boundary element methods at low frequencies," *Journal of the Applied Computational Electromagnetics Society*, vol. 20, no. 3, pp. 178-185, Nov. 2005.