SCHEME OF IMPROVING ACCURACY OF MOM SOLUTIONS BASED ON ANALYSING BOUNDARY CONDITIONS PERFORMANCE

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Abstract. An effective scheme is suggested for improving accuracy of MoM solutions to EM problems on arbitrary surfaces. This scheme is based on analyzing boundary conditions performance (BCP) on scatterer surface and allows treating both close and open geometries. Validation of scheme on benchmark solutions is shown, and its application to realistic car geometry is demonstrated.

1. Introduction

EMC simulations have become nowadays an essential part of automobile, aircraft and other vehicle design. The modern vehicles consist of a number of large-scale surfaces, cables (harness), antennas and electronic devices resulted in a vast complexity of arisen EM problems. Since these problems cannot be truly analyzed by any existing numerical technique, a variety of techniques, both full-wave and hybridized, are used for treating separate parts and interactions to be incorporated in desired solution to the stated problem. The method of moments (MoM) [1] continues to be the most powerful and popular numerical technique for electromagnetic modeling of complicated surfaces. However, this method is computationally intensive in modeling of large-scale geometries. Therefore, although much effort was done to enhance MoM scheme [2-4], it remains to be of little use for obtaining reliable solutions for large-scale geometries. Moreover, the problems arise to estimate accuracy of these solutions.

In this paper, we suggest a proper error metrics to estimate accuracy of MoM solutions, and present an effective scheme of improving this accuracy based on analyzing boundary conditions performance (BCP) on scatterer surface. Further, we validate our approach on benchmark closed and open geometries, and show its effectiveness in time for matrix inversion being of order of 10-1000. Finally, we demonstrate an application of the suggested scheme to analyzing realistic car geometry.

2. BCP Error Metrics

The usually applied method to estimate accuracy of MoM solutions is based on analyzing convergence of solutions by comparison of near-field characteristics with those obtained for refined discretization of geometry. Recently [5], we have found a proper BCP error metric for estimating accuracy of MoM solutions for EFIE formulation on arbitrary surfaces, including open ones. This error metric for electric field (hereinafter, BCP-E) is of the form

$$\varepsilon_E[\%] = 100\frac{\int_S |\vec{n}\times(\vec{E}^{sc}+\vec{E}^{inc})|\,dS}{\int_S |\vec{n}\times\vec{E}^{inc}|\,dS} \qquad (1)$$

and directly indicates, how well the obtained solution satisfies formulated problem. Hereinafter, S is the scatterer surface, and $\vec{n}$ is a normal to this surface,

However, we have found, that error metric (1) is not sufficient enough to totally characterize near-field errors. Really, additional error for magnetic field (hereinafter, BCP-H) should be also introduced to be of the form

$$\varepsilon_H[\%] \equiv 100\frac{\int_S |\vec{n}\cdot(\vec{H}^{sc}+\vec{H}^{inc})|\,dS}{\int_S |\vec{n}\times\vec{H}^{inc}|\,dS} \qquad (2)$$

Both sophisticated and numerical analysis show that BCP errors (1)-(2) are sufficiently enough to totally characterize accuracy of the obtained MoM solution. And, what is more, the values of these errors are in total accordance with those obtained for near-field characteristics (currents and charges). The convincing examples of such accordance will be demonstrated.

3. Improving Accuracy Scheme

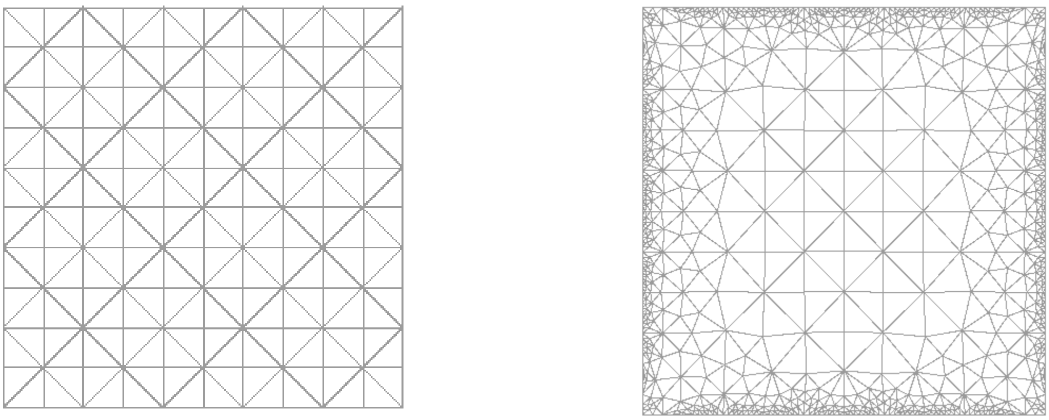
An analysis of a standard solution shows that uniformly fine discretization of geometry is not optimum enough to obtain reasonably accurate solution. Therefore, EMC-engineer usually designs geometry discretization in such a way to refine it separate parts. This manual process involves a mixture of experience, intuition, and guesswork of designer and does not automatically guarantee the progress in improving accuracy. Therefore, this way may be applied only for simple cases [6].

Our scheme of improving accuracy of MoM solutions is based on analyzing partial BCP errors on scatterer surface, picking out the geometry elements, which are mostly contributed in the total error on the structure. Then, the chosen elements should be re-discretized (re-meshed) using appropriate geometrical tools. The improving accuracy scheme should be used, until the total BCP errors will be within the reasonable limits. EMC parameters of interest, such as shielding effectiveness, gain patterns, S-parameters, antenna parameters, radiation losses and others are then derived from refined current distributions.

4. Realization of the Suggested Scheme

Realization of the suggested scheme needs applying advanced EM and geometric tools, allowing proper near-field calculations on scatterer surface and extending remeshing capabilities. For this purpose, we use advanced EM solver TriD [7] and specialized geometric tool Remesh, designed in EMCoS (ElectroMagnetic Consulting and Software group).

Fig. 1 shows an initial and improved mesh for the benchmark square plate subject to plane wave excitation incident from above [8]. Initial mesh (a) is characterized by BCP errors ε_E=22.0%, ε_H =21.5%, whereas current error is obtained by comparison with benchmark solution of [8] to be ε_J =20.6%. Improved mesh (b), obtained after 3 steps, is characterized by BCP errors ε_E=11.3%, ε_H =10.4%, whereas ε_J =11.2%. The BCP errors above are in truly correspondence with current errors and validate reliability of the suggested scheme for open geometries. The Gain obtained for the considered geometry is in time for matrix inversion (compared to uniform mesh) is of: G_E =8.4, G_H =7.0.

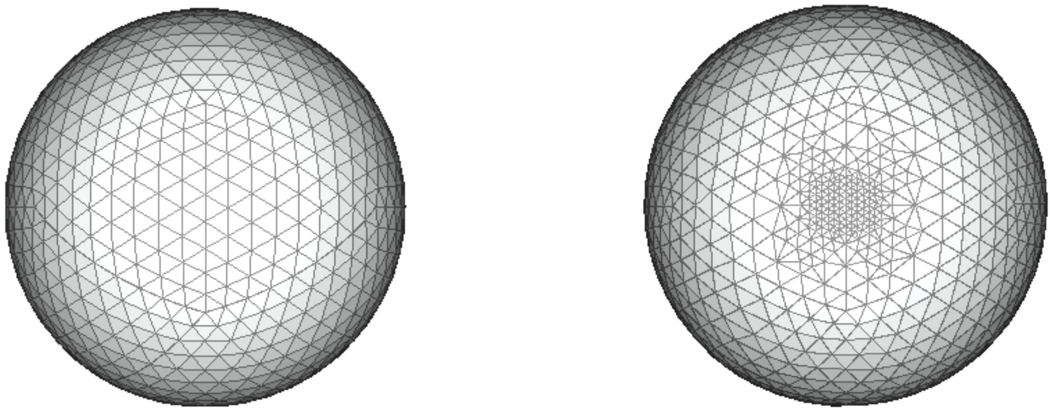


a - Initial mesh (200 triangles) b - Adaptive mesh (1456 triangles)

Fig. 1. Improving mesh of square plate geometry (L=1m, λ =1m)

Fig. 2 shows an initial and improved mesh for the sphere excited by electric dipole located nearby the top (at distance d=0.02m). Initial mesh (a) is characterized by BCP errors ε_E=55.4%, ε_H =21.8%, whereas current and charge errors calculated by comparison with MAS [9] solution, are: ε_q=42.1%, ε_J =30.0%. Improved mesh obtained after 2nd refinement is characterized by BCP errors ε_E =17.40%, ε_H =11.1%, whereas ε_q =20.9%, ε_J =14.3%. Gain obtained here in time for matrix inversion (compared to uniform mesh) is of: G_E =1175, G_H =1277, G_q =221, G_J =1197. These results validate our scheme for closed geometries.

Finally, we demonstrate application of the suggested iterative scheme for improving accuracy of MoM solutions for realistic car geometry. Fig. 2 presents the distribution of BCP errors on car surface. The scroll bars on the left and on the right show the values of contributions of separate triangles to the total BCP errors. The results of application of iterative scheme will be demonstrated.



a - Initial mesh (1620 triangles)   b - Adaptive mesh (1920 triangles)

Fig. 2. Improving mesh of sphere geometry (D=1m, λ =1m)

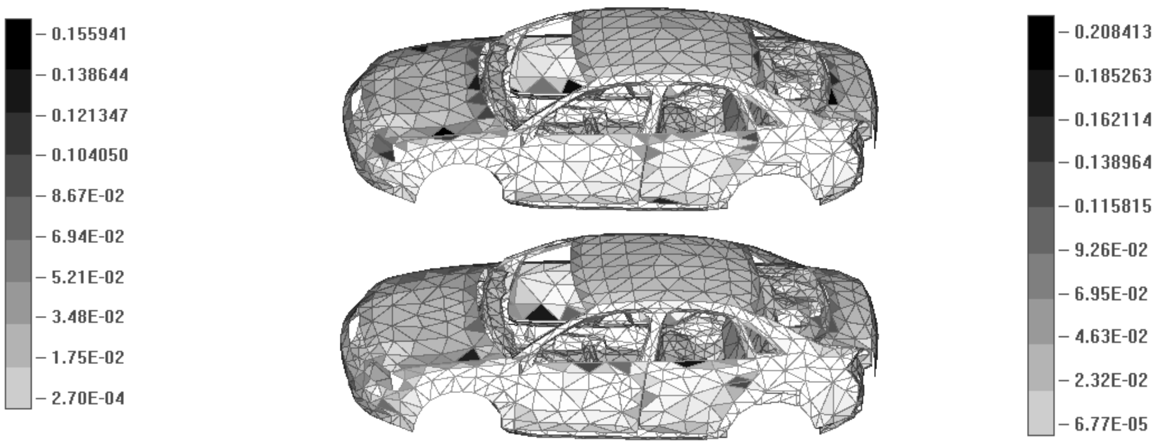


Fig.3. Black-and-white map of partial error distribution on car surface (4449 triangles):
top – partial BCP-E error with scroll bar on the left, bottom – partial BCP-H error with scroll bar on the right

5. Conclusions

An effective scheme for improving accuracy of MoM solutions has been developed and validated on benchmark geometries. Realization of this scheme for realistic car geometry has been demonstrated. Applicability of scheme for improving accuracy of large-scale EM/EMC problems has been shown.

References

1. R.F. Harrington,. Field Computation by Moment Methods, IEEE Press, New York, 1993.
2. S.D. Rao, D. Wilton, A.Glisson, Electromagnetic scattering by surfaces of arbitrary shape, IEEE Trans. & Antennas Propagat., Vol. AP-30, 409-418, 1982.
3. S.U. Hwu, D.R. Wilton, Electromagnetic scattering and Radiation by Arbitrary Configurations of Conducting Bodies and Wires, San Diego State University, Technical Report No. 87-17, May 1998.
4. M. Bücker., Enhanced numerical integration technique, IEEE 1999 International EMC Symposium, Seattle, Washington, 328-333, 1999.
5. F.G. Bogdanov and R.G. Jobava, Examination of boundary conditions performance for estimating accuracy of MoM solutions on square plate benchmark geometry using triangle doublet basis functions, Microwave and Optical Technology Letters, 5, November 2003.
6. J.M. Taboada, J.L.Rodrigues, and F.Obelleiro, Comparison of moment-method solutions for wire antennas attached to arbitrarily shaped bodies, Microwave & Opt. Techn. Letters, Vol. 26, 413-419, 2000.
7. B.M Kolundžija, Accurate solution of square scatterer as benchmark for validation of electromagnetic modeling of plate structures, IEEE Trans. & Antennas Propagat., Vol. AP-46, 1009-1014, 1998.
8. F.G. Bogdanov, R.G. Jobava, P. Tsereteli, TriD: Tri-Dimensional code for electromagnetic modeling of arbitrary surface and wire configurations. User's Guide, version 2.14, EM Consulting and Software, Report No. D-0018, Tbilisi, October 2003.
9. F.G. Bogdanov D.D. Karkashadze, R.S. Zaridze. The method of auxiliary sources in electromagnetic scattering problems, chapter 7 in a book: Generalized multipole techniques for electromagnetic and light scattering, edited by Th.Wriedt, Elsevier Science B.V., 1999, pp. 143-172.