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Novel Single Source Integral Equation for Solution of Scattering Problems on 3D Imperfectly Conducting Objects

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1 Introduction

Recently proposed single source integral equation for solution of scattering problems on general 3D homogeneous dielectric objects has been extended to the problems of scattering on imperfect conductors. The new formulation termed Surface-Volume-Surface Electric Field Integral Equation was tested against analytic Mie series solution for the scattering problem on copper sphere in the regimes of weak, intermediate, and strong skin effects. The numerical solution was observed to be robust and error controllable. The proposed formulation offers a new rigorous full-wave boundary element framework for accurate modelling of current flow in 3D conductors ranging from on-chip and in-package high-speed electronic interconnects to power systems installations.

2 Abstract

The boundary element method (BEM) based on Method of Moments (MoM) discretization of the integral equations in electromagnetics provides an economical alternative to the computational frameworks based on the direct discretization of the Maxwell Equations such as Finite Element Method (FEM) and Finite-Difference-Time-Domain (FDTD) method. We recently proposed a new single source integral equation (SSIE) of electromagnetics [1] for solution of the scattering problems on general 3D homogeneous dielectric objects. The new SSIE is derived through constraining of the classical single source field representation with the Volume Electric Field Integral Equations (V-EFIE). While thus obtained SSIE features a single unknown function on the surface of the object, it translates the fields from the surface of the scatterer to its volume and, subsequently, back to its surface, in addition to the field translations from the surface to surface featured in classical SSIEs. The new SSIE is termed the Surface-Volume-Surface EFIE (SVS-EFIE) due to such field translations.

In this work we extend the SVS-EFIE to the scattering problems on 3D imperfectly conducting objects. Such extension brings additional sparsity to the matrices of the MoM discretized SVS-EFIE when the skin-effect is well developed. Under the conditions of the strong skin-effect the volumetric current density is localized near the surface turning SVS-EFIE into a surface-like SSIE but with a fewer integral operator products.

We tested the new SVS-EFIE formulation through comparison of its solutions to the analytical Mie series field representation inside 10μm radius copper sphere at 1GHz and 10GHz. In these two cases the radius of the sphere is about 5 and 15 skin-depths making field attenuation in the order of 0.008 and 0.0000002, respectively. In both scenarios low-order MoM solution of the SVS-EFIE produced accurate results with average error in the range of 1-5% depending on the density of the used surface and volume meshes.

Robustness of the SVS-EFIE solution for the full-wave scattering problem on realistic metal objects serves as a proof of concept for its use in such important practical applications as electromagnetic modelling of high-speed digital interconnects, passives of the radio-frequency integrated circuits, complex power system installations, and various others.

References

[1] V. Okhmatovski, A. Menshov, F. L. S. Hosseini, and S. Zheng, “Novel single-source integral equation in electromagnetics," in *URSI Intl. Symp. Electromagnetic Theory (EMTS)*, pp. 484-487, Espoo, Finland, Aug. 2016.