# New Combined Formulations for Broadband Solutions of Electromagnetic Problems Involving Perfect Electric Conductors with Closed Surfaces

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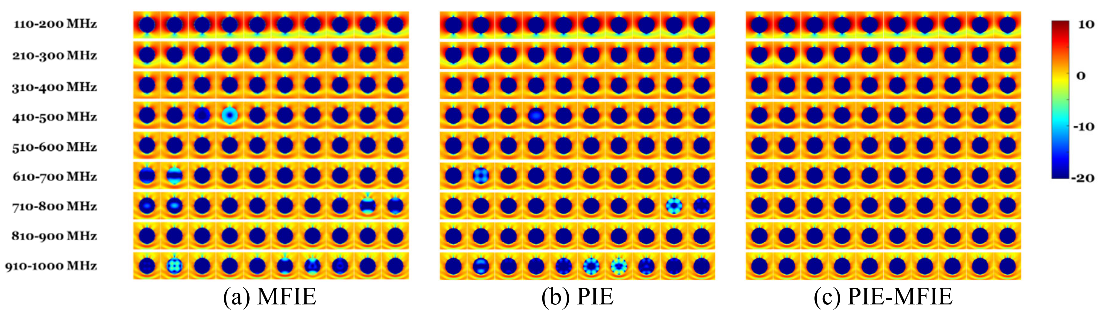
Recently, new potential integral equations (PIEs) have been derived and implemented for stable solutions of low-frequency and dense-discretization problems in electromagnetics [1]-[3]. It has been demonstrated that these integral-equation formulations enable accurate and efficient simulations of perfectly conducting objects for arbitrarily low frequencies and dense discretizations, without needing special discretization schemes. Hence, they have become important alternatives to the conventional electric-field integral equation (EFIE) that is known to possess low-frequency and dense-discretization breakdowns, which limit its applicability to a plethora of problems.

Effectiveness of PIEs have been demonstrated in low-frequency regimes, while their application to high-frequency problems is not covered in the literature. In fact, similar to EFIE and the magnetic-field integral equation (MFIE), PIEs seem to suffer from internal resonances, providing fictitious internal fields at discrete frequencies and in their vicinities. Consequently, the existing implementations of PIEs are not very suitable to be used in wide frequency ranges, without eliminating internal resonances. In this work, we consider alternative combined formulations involving PIEs together with suitable formulations such that internal resonances are eliminated, while the low-frequency stability is preserved.

One relatively straightforward combined formulation involves the integration of MFIE into PIEs. Since a conventional implementation of PIEs involves both electric current density and the normal component of the magnetic vector potential, MFIE can be placed on the upper diagonal block. Despite its simple form, such a combined formulation does not involve internal fields, provided that the integral-equation terms are properly balanced. Fig. 1 presents a set of experiments involving a sphere of diameter 0.6 m from 110 MHz to 1.0 GHz. Using MFIE (RWG functions) and an implementation of PIEs (using RWG and pulse functions), internal resonances are clearly visible at various frequencies. The combined formulation (PIE-MFIE), however, is free of internal fields in the entire frequency range. We note that, since both PIEs and MFIE are stable at low frequencies, the resulting combined formulation does not have any low-frequency and dense-discretization breakdowns.




(a) MFIE (b) PIE (c) PIE-MFIE

Figure 1. Electric field intensity (dBV/m) in the vicinity of a perfectly conducting sphere of diameter 0.6 m.

## References

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