Overview of Convergence and Accuracy Properties of Iterative Physical Optics

Santi C. Pavone\(^{(1)}\), Luca Pandolfo\(^{(2)}\), Mirko Bercigli\(^{(2)}\), and Matteo Albani\(^{(1)}\)

\(^{(1)}\) Department of Information Engineering and Mathematics (DIISM), University of Siena, 53100 Siena, Italy.
\(^{(2)}\) Ingegneria dei Sistemi S.p.A., 56121 Pisa, Italy.

1 Extended Abstract

Iterative Physical Optics (IPO) is a high-frequency technique introduced by Burkholder \([1, 2]\) used for the approximate but computationally very efficient electromagnetic (EM) analysis of structures large in terms of wavelength.

An important issue of the IPO algorithm is the singular behavior of the updating current rule for a pair of closely spaced sample points. Indeed, in the IPO algorithm the current induced on the scatterers is modeled by sampling it in a set of points on the scatter surface. At each iteration, the current refinement requires the calculation of the magnetic field radiated by any current sample at the position of all the other samples. Since each current sample is assumed to be a spatially impulsive dipole, its radiated field is singular when observed at the current sample point, and unlimitedly grows in strength when the observation point is close to such sample point position. Therefore, when two current samples are taken very close each other, an overestimation of their interaction effect occurs.

Such a result is due to the infinite reactive energy stored around an elementary dipole, hence such a huge amount of spurious reactive energy is detrimental for both the algorithm accuracy and convergence. This hypothesis is confirmed by the fact that such a problem can be easily alleviated by heuristically approximating the dipole field by its far-field approximation. Although this approximation becomes less accurate to estimate the interaction of two closely spaced points, it reduces the singularity order to \(1/R\), and avoids fictitious reactive energy storage, which eventually implies convergence and accuracy surprising improvements.

It has been shown \([3]\) that the IPO scheme is deeply connected to the Magnetic Field Integral Equation (MFIE) solved by the Method of Moments (MoM), hence one can revisit the IPO in terms of MoM concepts. Indeed, the current sampling assumed in the IPO algorithm can be thought as a delta-Dirac basis function in the MoM assumption. Similarly, the IPO current updating rule at the same sample points can be interpreted as a MoM Point Matching. Accordingly, the calculation of the field radiated by a current sample at the position of another current sample within the IPO current updating rule, can be interpreted as a MoM mutual coupling, i.e. an extra-diagonal entry in the MoM matrix.

Therefore, by using a standard MoM terminology, the IPO singularity problem here addressed can be regarded as a rough choice of basis and testing functions, which entails slow convergence and inaccurate results. In particular, such bad results can be interpreted by thinking that the normal four-folded coupling integral describing the MoM testing procedure in the IPO scheme is estimated by using an inaccurate one-point quadrature rule, whose error dramatically increases when two interacting elements are closely spaced.

In this work, we assess the above mentioned problems and try to propose a modified version of the traditional IPO scheme to solve them, based on a more efficient calculation of element coupling. Moreover, we will show that a Gaussian basis/testing function can be considered as a good candidate for the replacement of more traditional impulsive dipoles.

References

