Modeling Di-Electric Interfaces in the FDTD-Method

C.H. Teng

Abstract

Using the classical finite-difference time-domain (FDTD) method for the simulation of the interaction of electromagnetic waves with geometrically complex objects, one very often encounters that the simple Cartesian grid fails to properly describe the boundaries of the object, e.g., material interfaces and metallic boundaries. The classic approach to overcome this problem is found in the introduction of a staircase approximation of the boundaries. Hence, the problem of forced to conform to the simple grid structures. It is well known, however, that this approach has a severe impact of the overall scheme, reducing the scheme to first order accuracy at best and with the possibility of localized non-convergent behavior.

Several techniques have been proposed in the past to improve on this unfortunate situation. The straightforward approach is the use irregular nonorthogonal grids or curvilinear coordinate instead of the simple Cartesian Yee cell for either the whole domain or close to the object. Clearly, this is much more complicated as compared to the simple FDTD approach. Emphasizing simplicity, an alternative approach, centered around the idea of defining averaged material properties at the staircased material interfaces, has been used extensively in the past, clearly yielding superior results as compared to not doing anything.

However, as we shall discuss in the first part of this presentation, these averaging techniques do little in improving the convergence rate for general two- and three-dimensional problems with discontinuous solutions. We shall present a detailed comparison between a number of known techniques for defining the averaged material properties. The main conclusion of our study is that using the averaging techniques do present a significant improvement for problems where the spatial derivatives are computed of smooth components only, e.g., for problems where the material axes are aligned with the Cartesian grid. In such situations, 2nd order accuracy appears to be restored. However, for the much more general problem with spatial derivatives being computed of discontinuous field components, e.g., all problems where the material interfaces do not align with the Cartesian grid or has curvature, the averaging techniques do little to improve the convergence. Generally, the accuracy of the scheme is significantly less than first, and the scheme becomes non-convergent in points where material interface intersects with a grid-point.

With this in mind, we present in the second half of the presentation a new general second order scheme for the solution of Maxwells equations. The new algorithm relies on special schemes constructed for different kind of boundary conditions at the grids near the boundary. Uniform areas of the objects are treated using the FDTD scheme and the majority of the extra work lies in a preprocessing stage in which the special schemes near the boundaries and interfaces are constructed. The new scheme treats general curved material interfaces as which the correct jump conditions of the field components are enforced. The performance of this new method is illustrated through a number of examples, confirming the expected 2nd order accuracy for very general problems with field components being continuous or discontinuous at a general curvilinear material interface.

Topic : Computational techniques: Finite difference time domain.

This is a joint work with A. Ditkowski and J.S. Hesthaven