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Lebedev FDTD Method for Electromagnetic Simulations of Anisotropic Materials

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Extended Abstract

The Finite-Difference Time-Domain [1] method has been around for many decades, and has been a part of many research codes and commercial electromagnetic solvers. It is attractive due to its simplicity and its preservation of important physics of electromagnetic problems. However, the simplicity is lost when simulating anisotropic materials with off-diagonal elements. In anisotropic media, the constitutive relationships necessitate knowledge of spatial derivatives in all three directions of space at the same location. This is usually dealt with by using interpolations because of the staggered nature of field components in the standard Yee method. Interpolation introduces additional error and, as pointed out in [2], the combined operation of interpolation and multiplication with the inverse of permittivity must be symmetric and positive definite; otherwise, late-time instabilities will arise.

To overcome these difficulties, recently we introduced the concept of discretizing Maxwell's equations on a Lebedev grid [3]. The Lebedev grid is a cubic tessellation of the space similar to Yee grid. It is a collocated scheme, meaning that all three components of the fields exist at one location. It is also staggered in space in a sense that magnetic and electric fields are shifted half unitcells in two of the three x,y and z with respect to each other. Because of the collocated nature of the Lebedev grid, the interpolation step is omitted, and boundaries between materials become nearly as simple to handle as in the original FDTD method. For these reasons it becomes very well suited to modelling anisotropic materials. The main drawback is that effectively the Lebedev grid is four staggered Yee grids, resulting in more computational overhead.

Since the original paper [3], which included a perfectly matched layer implementation, we have pursued improvements to the method. These include (i) improvements to the modelling of interfaces and corners for perfect electric conductors where the normal field component must be accounted for [4]; and (ii) a subgridding method to couple the standard Yee grid to the Lebedev grid so that the latter only needs to be used in regions of anisotropy, thereby reducing the computational overhead [5]. Future work includes dealing with inhomogeneous anisotropic dispersive materials.

Our intention with this submission is to provide an overview of the Lebedev FDTD method for electromagnetic simulations, its benefits and drawbacks, and the improvements to the method as well as examples of applications.

References

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