FDTD Subgridding Based Upon the Finite Element "Hanging Variable" Concept

Ryan A. Chilton[*(1)], and Robert Lee [(1)]
(1) Electroscience Lab, Columbus, OH, 43212, http://esl.eng.ohio-state.edu

Yee's FDTD scheme has proven a robust and versatile method for time domain simulation of transient electromagnetic behavior. However it remains troubled with staircasing errors when approximating curved surfaces. Furthermore, it is penalized when attempting to model high contrast materials because the spatial discretization step must be uniform – with uniform grids either the low contrast media is oversampled or the high contrast media is undersampled in terms of wavelength resolution.

Subgridding the Yee scheme via interpolation/cloning, or attempting to coax it into an unstructured boundary conforming method has been investigated by numerous members of the CEM community. In general, these schemes can impart additional problems including reduction of accuracy, numerical impedance mismatch and most seriously, unconditional late-time instability. Such instabilities are often associated with non-reciprocal "field borrowing" operations.

Though it is a concept originally developed for the finite element regime, the "hanging variables" approach can be applied readily once the Yee FDTD is recast as a special kind of time domain finite elements (FETD) formulation. Via the "restriction operator", fine field variables in a subgridded Yee element are constrained such that they span the same FE space as the coarse field variables in adjacent non-subgridded Yee elements. Such a restriction results in an implicit update of field variables located near the coarse-fine interface, but away from this interface the traditional Yee scheme can be recovered.

The proposed scheme will be demonstrated by first investigating closed body non-rectangular cavity problems, so that the effect of the method on controlling staircasing error can be evaluated. Additionally, subgridding will be applied to problems containing high contrast dielectrics. The late time stability properties of the algorithm will be investigated, as well as the reciprocity properties of the new restricted, implicit stencil.