Flux Corrected Transport Algorithm for FDTD Modeling of Shockwaves Generated by Non-Linear Dielectrics

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The finite-difference time-domain (FDTD) method is a simple, robust tool for a variety of electromagnetic modeling scenarios. The particle-in-cell (PIC) method adds charged particle tracking via the Lorentz force law and allows the modeling of low density, non-collisional plasmas. Non-linear dielectrics can also be modeled as the method operates in the time domain. However, strongly non-linear dielectrics can lead to the formation of shockwaves and spurious oscillations, which corrupt the simulation.

The non-linear dielectric and shockwave induced oscillations can be removed by adding diffusion to the method (Greenwood, et al, 28th Annual Review of Progress in Applied Computational Electromagnetics, 2012). However, the artificial diffusion lowers the overall accuracy of the method. Flux corrected transport algorithms (Zalesak, Journal of Computational Physics 31, 1979) seek to add the diffusion only where it is needed, which is near the shock front. A previously published flux corrected transport algorithm (Omick and Castillo, IEEE Transactions on Electromagnetic Compatibility 35, 1993) is extended to the staggered Yee FDTD scheme. The extension of the algorithm to the staggered Yee scheme allows existing FDTD and PIC codes (such as the Air Force Research Laboratory's ICEPIC) to be retrofitted to handle strongly non-linear dielectrics and shockwaves. Numerical examples are presented to show the applicability of the method and the ability to remove spurious oscillatory behavior.

While the flux corrected transport algorithm allows the diffusion to be included only where needed, it adds computational burden to the simulation. Future work in this area involves the investigation of algorithms such as essentially non-oscillatory (ENO) and weighted essentially non-oscillatory (WENO) algorithms used to model shockwaves in the fluid dynamics community.