Staggered Upwind Embedded Boundary Method for 3D Maxwell's Equations

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The Yee's finite-difference time-domain (FDTD) algorithm has enjoyed widespread applications in computational electromagnetics. However, in spite of its flexibility and 2nd-order accuracy in a homogeneous medium, the FDTD method suffers from a serious degradation when treating material interfaces, greatly reducing its accuracy in the presence of inhomogeneous media and perfect conductors. Indeed, such a so-called staircasing approximation may lead to local divergence and loss of global convergence. In this work, an embedded FDTD scheme, the staggered upwind embedded boundary (SUEB) method, is developed for the solution of 3D Maxwell's equations. This simple embedded technique uses upwind flux to penalize the numerical jumps of the tangential field components that do not satisfy the boundary conditions. This process makes the location and physical conditions of material and metallic interfaces asymptotically correct, thus eliminating problems caused by the staircasing approximation in the FDTD method. Accuracy analysis has been made to show that the SUEB method maintains a 2nd-order accuracy globally. Since the entire problem has been embedded into the simple staggered grid similar to that employed by the Yee method, an extra effort is only needed when treating the grid points close to the interfaces. Therefore, little additional computational cost is needed over the Yee method. The embedded FDTD scheme has been validated by the analytical solutions for some typical benchmark cases. Numerical examples show that this method is much more efficient than the FDTD method.