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Wideband Performance Analysis of C-FDTD Based Algorithms in the Discretization Impoverishment of a Curved Surface

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Abstract : In this work, it is analyzed the wideband performance with the mesh discretization impoverishment of the Conformal Finite Difference Time-Domain (C-FDTD) approaches developed by Raj Mittra, Supriyo Dey and Wenhua Yu for the Finite Difference Time-Domain (FDTD) method. These approaches are a simple and efficient way to optimize the scattering simulation of curved surfaces for Dielectric and Perfect Electric Conducting (PEC) structures in the FDTD method, since curved surfaces require dense meshes to reduce the error introduced due to the surface staircasing. Defined, on this work, as D-FDTD-Diel and D-FDTD-PEC, these approaches are well-known in the literature, but the improvement upon their application is not quantified broadly regarding wide frequency bands and poorly discretized meshes. Both approaches bring improvement of the accuracy of the simulation without requiring dense meshes, also making it possible to explore poorly discretized meshes which bring a reduction in simulation time and the computational expense while retaining a desired accuracy. However, their applications present limitations regarding the mesh impoverishment and the frequency range desired. Therefore, the goal of this work is to explore the approaches regarding both the wideband and mesh impoverishment performance to bring a wider insight over these aspects in FDTD applications. The D-FDTD-Diel approach consists in modifying the electric field update in the cells intersected by the dielectric surface, taking into account the amount of dielectric material within the mesh cells edges. By taking into account the intersections, the D-FDTD-Diel provides accuracy improvement at the cost of computational preprocessing, which is a fair trade-off, since the update modification is quite simple. Likewise, the D-FDTD-PEC approach consists in modifying the magnetic field update, taking into account the PEC curved surface intersections within the mesh cells and, considering a PEC structure in vacuum, the air portion that fills the intersected cells when updating the magnetic fields values. Also likewise to D-FDTD-Diel, the D-FDTD-PEC provides a better accuracy at the cost of computational preprocessing, although with a drawback of having to meet stability criterion requirements. The algorithms are formulated and applied to a PEC and a dielectric spherical scattering surface with meshes presenting different levels of discretization, with Polytetrafluoroethylene (PTFE) as the dielectric, being a very common material in coaxial cables and connectors for radiofrequency (RF) and wideband application. The accuracy of the algorithms is quantified, showing the approaches wideband performance drop along with the mesh impoverishment. The benefits in computational efficiency, simulation time and accuracy are also shown and discussed, according to the frequency range desired, showing that poorly discretized mesh FDTD simulations can be exploited more efficiently, retaining the desired accuracy. The results obtained provided a broader insight over the limitations in the application of the C-FDTD approaches in poorly discretized and wide frequency band simulations for Dielectric and PEC curved surfaces, which are not clearly defined or detailed in the literature and are, therefore, a novelty. These approaches are also expected to be applied in the modeling of curved RF components for wideband and high-speed communication devices in future works.

Keywords : accuracy, computational efficiency, finite difference time-domain, mesh impoverishment
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