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Hybrid Cartesian/unstructured numerical method for efficient resolution of Maxwell's equations in time domain: Application to buried object detection from airborne remote sensing platforms

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The growing concern in the study of system electromagnetic environment is frequently dealt with simulation tools. Due to the increasing complexity of structures, more and more efficient simulation methods are required. Currently, the most widely used basic method for solving unsteady Maxwell's equations is the finite-difference time-domain (FDTD) technique based on Yee's scheme [1] which is computationally very efficient. This is partly due to the fact that it is based on a Cartesian mesh requiring little storage and few operations at each time iteration. However, this requirement for Cartesian meshes brings difficulties when dealing with curved geometries and leads to an inaccuracy in field computation in their vicinities. Other methods, such as finite-volume time-domain (FVTD) techniques, have thus been studied using unstructured meshes composed of tetrahedral cells [2]. The disadvantage of these methods is their rather high computational and memory cost compared to Yee's approach. A natural idea is then to use a hybrid Cartesian/unstructured mesh with a limited area of tetrahedral cells around the object. Previous studies have proposed different hybridization methods between FVTD and FDTD schemes but without necessarily ensuring stability [3].

Current paper aims to present a new stable hybrid method for solving unsteady Maxwell's equations, in order to deal with remote sensing problems. We consider two hybrid approaches; the first one is based on FVTD techniques. We present and use a $\beta\gamma$ finite volume scheme [4] adapted to the Cartesian part of the mesh and, in the unstructured part, a MUSCL type scheme with a variable approximation order according to the size of cells in relation to the pulse spectrum with a local time step strategy. The second hybrid approach is based on an FDTD scheme in the Cartesian part and FVTD in the unstructured part. To ensure stability, we give a solution by adding a flux on the finite differences. The first hybrid method is then applied to a remote sensing problem staging airborne source and sensor. The source is considered as a plane wave in the presence of a bi-medium (air/lossy ground) and the far field radiated by the target buried in the lossy ground is evaluated to be consistent with radar measurements. Examples of validations are proposed to show the interest of our hybrid approach compared to pure FDTD or FVTD solutions.

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