Contributions to Stability and Accuracy of a General-Purpose 3D FDTD Subgridding Algorithm

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1 Extended Abstract

This work is placed within the field of computational electromagnetism (CEM) and specifically within the subgridding techniques of FDTD (Finite Differences Time Domain). FDTD consists in a simple leap-frog scheme that solves Maxwell's equations numerically by discretizing the space into a uniform lattice. Subgridding methods allow to locally refine these cells into subgridded regions (namely subgridding levels), sometimes applying a different time-stepping in each level, which is known as Local Time Stepping (LTS). These methods allow to efficiently address multiscale problems, however they encounter issues related to stability and precision. This work is focused on studying these phenomena in a specific subgridding algorithm: the Orthogonalized Integral-based Subgridding (OI-SG) [1] The main challenge in subgridding schemes is devising a connection algorithm between the different subgridding levels. The OI-SG solves this issue by deriving a simple explicit expression by using finite integrations that preserves recirprocity and causality between the field components, and can be viewed as a generlized FDTD update equation. The obtained grid can be orthogonalized by fixing a certain deformation parameter δ_r, which plays a critical role into the stability. In the first part of this work, we show how this parameter impacts in the stability by three different methodologies: an analytical method, a spectral analysis by studying the eigenvalues of the update operator, and finally a heuritic method. We also design a Locally Enlarged Cell Technique (LECT) to improve the stability. For the second part of the work, we study the accuracy of the method in a variety of simulation cases, which include the transmission coefficient of a Frequency Selective Surface (FSS), the near-field of an All-Angle Negative Refraction (AANR) metasurface, the bistatic Radar Cross Section (RCS) of a NASA almond, and the monostatic RCS of a Perfect Electric Conductor (PEC) sphere.

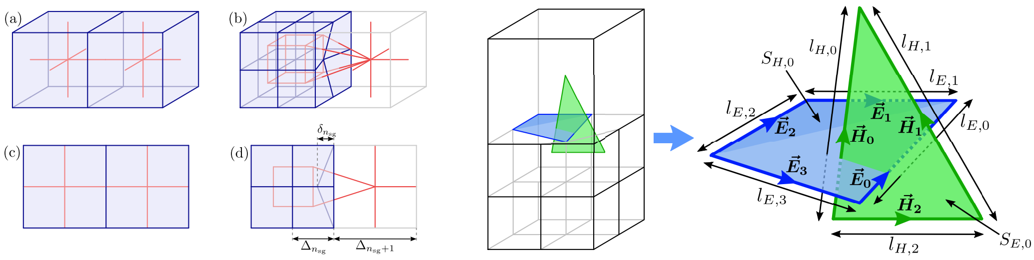

Figure 1. Left: Representation of Yee cells without subgridding (a), with subgridding (b), and their respective 2D projections (c,d). Right: An example of the finite integration scheme applied to the OI-SG field components.

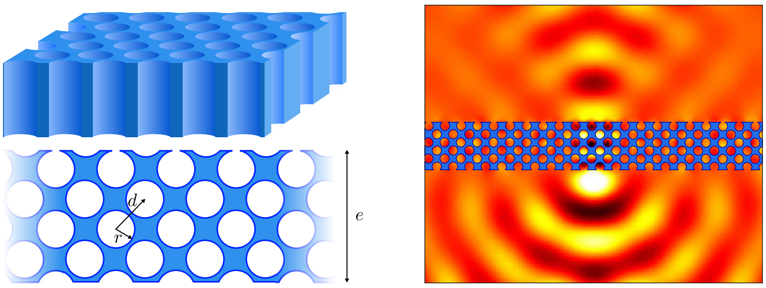

Figure 2. Left: Scheme of the AANR metasurface simulated with the OI-SG. Right: Screenshot of the AANR simulation where the negative refraction effect may be seen.

References

[1] A. M. Valverde, M. R. Cabello, C. C. Sánchez, A. R. Bretones, and S. G. Garcia, "On the effect of grid orthogonalization in stability and accuracy of an fdtd subgridding method," IEEE Transactions on Antennas and Propagation, vol. 70, no. 11, pp. 10 769–10 776, 2022.