Comments and Replies

Comments on “A New Conformal FDTD for Lossy Thin Panels”

M. R. Cabello, S. G. Garcia, L. D. Angulo, A. M. Valverde, S. Bourke, I. D. Flintoft, and J. F. Dawson

***Abstract*—In the article titled “A new conformal FDTD for lossy thin panels” by M. R. Cabello *et al.*, the appearance of spiky antiresonances in the simulation of the shielding properties of lossy thin-shell spherical cavities by FDTD was categorized as spurious solutions. In this article, we briefly clarify this topic and show that these solutions are not really spurious in the common interpretation of the term. Actually, they correspond to physical solutions appearing due to lack of symmetry, inherent to the staggered colocation nature of field components in FDTD.**

***Index Terms*—Finite-difference methods, electromagnetic shielding, resonance, spurious solutions.**

I. Introduction

Flintoft *et al.* [1], Ruiz Cabello *et al.* [2], and Cabello *et al.* [3] employed a spherical cavity with a conductive thin wall to validate novel lossy thin-panel treatments in the FDTD method. A set of spiky solutions, categorized as “spurious,” appeared at frequencies between the “physical” ones. They were present for all the methods employed, either based on network impedance boundary conditions (face centered, leapfrog, and conformal) or on subgridding boundary conditions. Fig. 1 shows an example of results taken from [1], where a reasonably good agreement with analytical data exists at the resonant frequencies of the cavity, together with spiky antiresonances at frequencies in between.

The phenomenon of spurious resonances is actually present in several numerical methods in electromagnetics [4], [5]. They are typically related to the violation of the numerical counterpart of the analytical condition of null divergence of the curl ($\mathrm{div}(\mathrm{curl}(\vec{f})) \neq 0$). In resonant systems, spurious solutions translate into artificial resonances at nonphysical frequencies. Some FDTD-like methods, employing alternative time integration schemes such as the ADI-FDTD, do not fulfill the divergence condition [6], and spurious solutions appear [7]. Even boundary conditions may introduce spurious resonances in FDTD schemes if not handled in a proper manner [8]. However, this is not the case with the usual FDTD method [9], which employs the usual leapfrog second-order time-domain FDTD in a uniform mesh, and does not exhibit spurious solutions for being a numerically divergence-free scheme.

In [1], we misleadingly attributed such a spurious origin to the numerical antiresonances not appearing at the analytical frequencies of resonance. In this article, we show that these antiresonances are actually physical and predictable (as also pointed out in [10] and [11]), and their origin is simply the lack of symmetry in the observation point with respect to the geometry, inherent to the noncollocated nature of FDTD field components in Yee’s grid.

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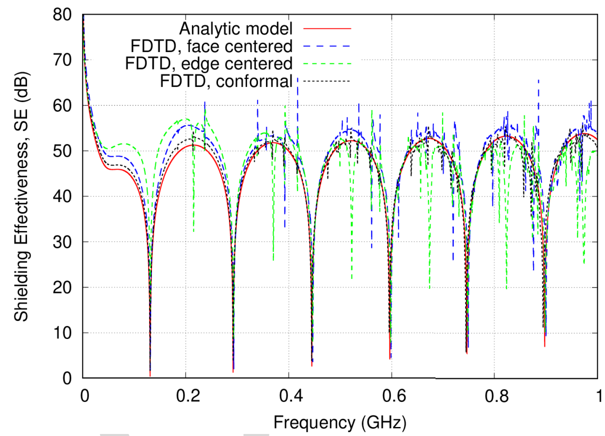

Fig. 1. Shielding effectiveness at the center of the hollow spherical shell with $\sigma = 1$ kS/m and thickness h = 1 mm comparing the analytic solution to the different FDTD methods (taken from [1]).

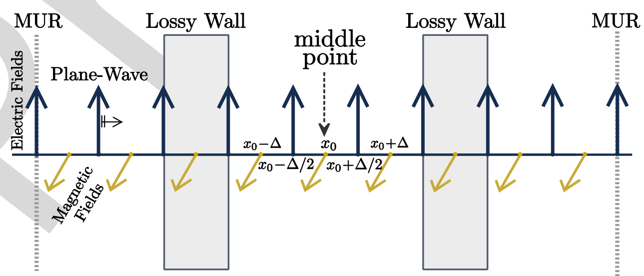

Fig. 2. Discrete test setup for the computation of the electric and magnetic fields inside of a 1-D cavity with lossy walls.

II. Numerical Experiment

For the sake of clarity, we have employed a simple experiment consisting of a 1-D cavity with lossy walls, to allow us to get the field position under control. The results are compared with the analytical values at the same points where the FDTD fields are placed. The aim is to show that these antiresonances occur because of the offset in the position of the observed field with respect to the center of the cavity, and that they do not appear in the field component (either E or H) that is exactly at the center, which can be perfectly controlled in the 1-D case.

The 1-D cavity in Fig. 2 is illuminated with an external plane wave with a Gaussian profile that decays 3 dB at 2 GHz. The cavity walls consist of two lossy slabs with a conductivity of 1000 S/m, a thickness of 1 mm, and separated by 1 m. The space step is $\Delta = 0.25$ mm, the time step is 20 ns, and the computational volume is truncated by Mur’s conditions [13].

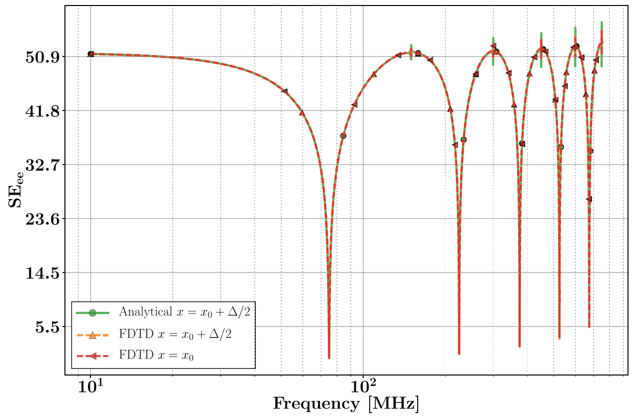

Fig. 3. Shielding effectiveness in the E-field half a step away from the center.

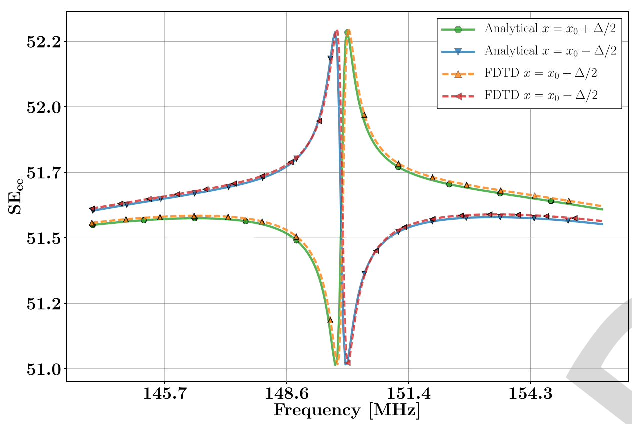

Fig. 4. Zoomed-in view of Fig. 3 around the first spike in the E-field.

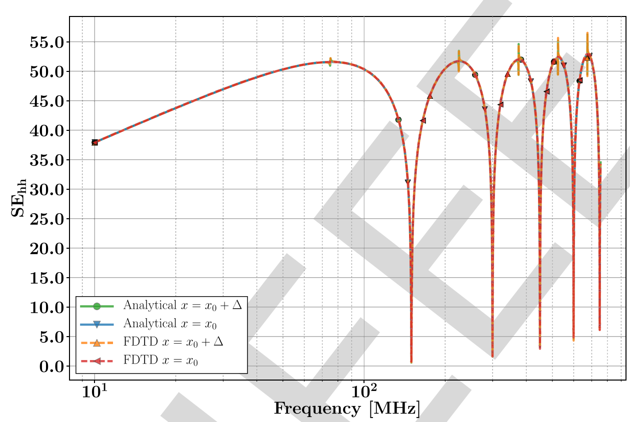

Fig. 5. Shielding effectiveness in the H-field at the center and a step above it.

Figs. 3 and 5 show the shielding effectiveness (transmission coefficient) in E and H exactly at the center the of cavity and one cell away from it. Figs. 4 and 6 show a zoomed-in view around the first antiresonant "spike." We have arranged this setup such that there is a magnetic field exactly placed at the middle position of the cavity x_0. Hence, the simulation does not present any antiresonance (see Fig. 6) in H at that location, whereas they appear in H at the neighboring location. On the other hand, since the electric field E is not at the center because of Yee's staggering (it is displaced by half a space increment), it exhibits the antiresonant spikes (see Fig. 4) in positions $x_0 \pm \Delta/2$. Analytical solutions have been found with the usual expressions of the normal incidence with a multilayered planar structure [12].

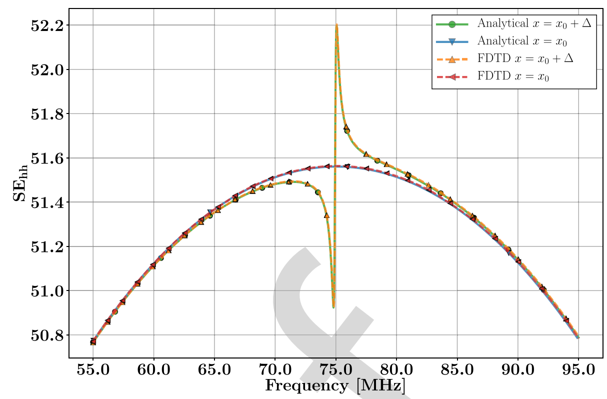

Fig. 6. Zoomed-in view of Fig. 5 around the first spike in the H-field.

III. Conclusion

In this article, we have intended to clarify and correct the claim made in [1], attributing the spikes appearing in lossy wall cavities to nonphysical spurious solutions. We have shown with a simple test case that they actually correspond to physical solutions naturally appearing at observation points, which do not correspond to an exactly symmetry point of the structure under test. While, in 1-D, it is easy to keep this effect under control, in 3-D, the geometrical discretization is not so well controlled; in general, they involve staircasing asymmetries, which lead to an ambiguity of the position of the symmetric observation points, leading to the "corruption" of the results with antiresonances.

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