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Cabello, M. R., Garcia, S. G., Angulo, L. D. et al. (2020) Comments on ”A new conformal FDTD for lossy thin panels”. Ieee transactions on antennas and propagation. pp. 7234-7235. ISSN: 1558-2221

https://doi.org/10.1109/TAP.2020.2976582

Comments on ”A new conformal FDTD for lossy thin panels”

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***Abstract*—In the paper ”A new conformal FDTD for lossy thin panels” by M. R. Cabello *et al.*, the appearance of spiky anti-resonances in the simulation of the shielding properties of lossy thin-shell spherical cavities by FDTD, was categorised as spurious solutions. In this document, 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 co-location nature of field components in FDTD.**

***Index Terms*—Finite-Difference methods, Electromagnetic shielding, Resonance, Spurious solutions**

I. INTRODUCTION

In previous papers [1]–[3], the authors 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 in network impedance boundary conditions (face-centered, leap-frog and conformal), or in 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 anti-resonances at frequencies in between.

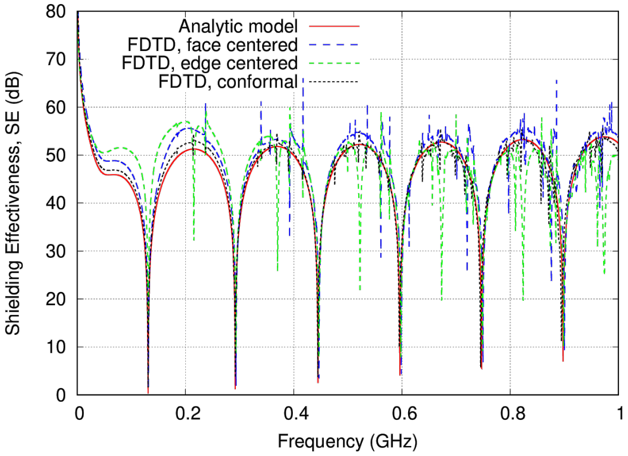

Fig. 1. Shielding effectiveness at the center of the hollow spherical shell with σ = 1 kS/m and thickness h = 1 mm comparing the analytic solution to the different FDTD methods (taken from [1]).

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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 non-physical frequencies. Some FDTD-like methods, employing alternative time integration schemes like 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 of the usual FDTD method [9], which employs the usual leap-frog 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 anti-resonances not appearing at the analytical frequencies of resonance. In this manuscript, we show that these anti-resonances are actually physical and predictable (as also pointed out in [10], [11]), and their origin is simply the lack of symmetry in the observation point with respect to the geometry, inherent to the non-collocated nature of FDTD field components in Yee’s grid.

II. NUMERICAL EXPERIMENT

For sake of clarity, we have employed a simple experiment consisting on a 1D 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 purpose is to show that these anti-resonances occur because of the offset in the position of the observed field with respect to the center of the cavity, and they do not appear in the field component (either E or H) which is exactly at the center, which can be perfectly controlled in the 1D case.

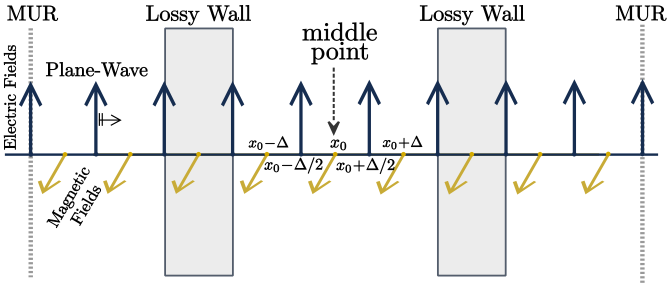

Fig. 2. Discrete test setup for the computation the electric and magnetic fields inside of a 1D cavity with lossy walls.

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

Fig. 3 and 5 show the shielding effectiveness (transmission coefficient) in E and H exactly at the center the cavity, and one cell away from it. Figs. 4 and 6 is a zoom around the first anti-resonant "spike". We have arranged this setup so that there is a magnetic field exactly placed at middle position of the cavity x_0. Hence, the simulation does not present any anti-resonance (Fig. 6) in H at that location, whereas they appear in H at the neighbor 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 anti-resonant spikes 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].

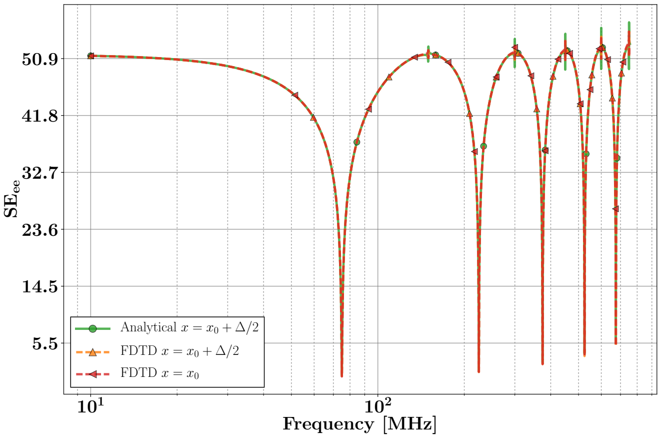

Fig. 3. Shielding effectiveness in the E-field half a step away from the center.

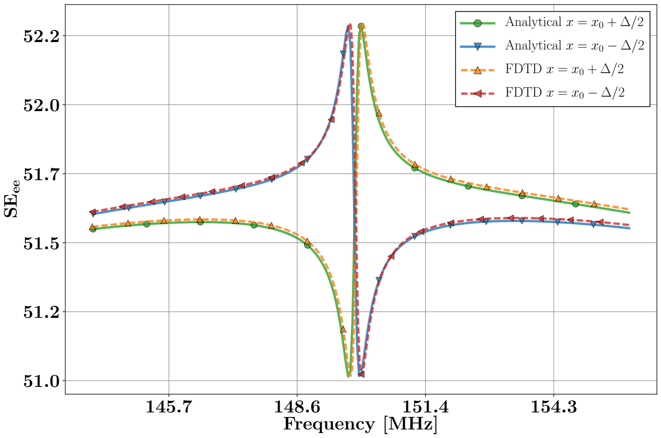

Fig. 4. Zoom of Fig. 3 around the first spike in the E-field.

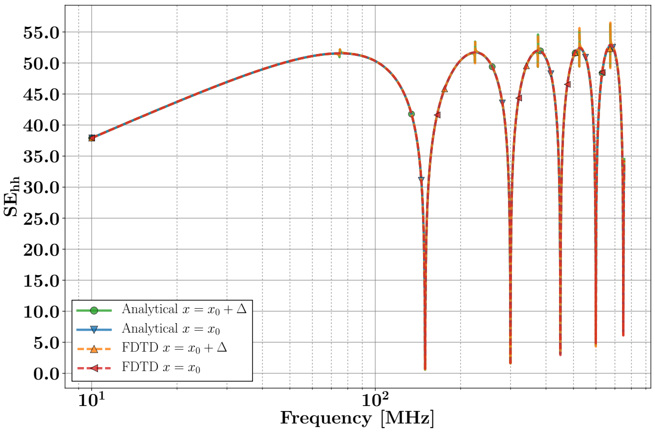

Fig. 5. Shielding effectiveness in the H-field at the center and a step above it.

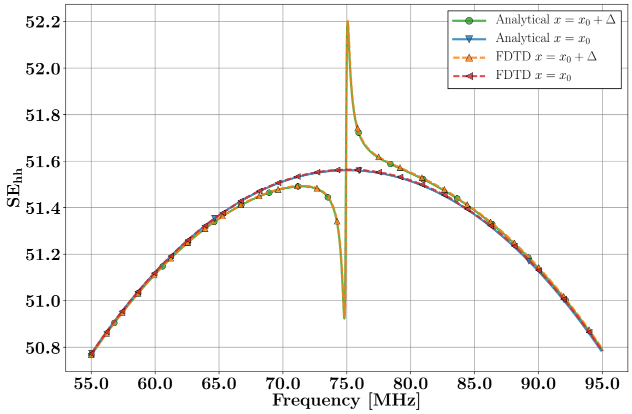

Fig. 6. Zoom of Fig. 5 around the first spike in the H-field.

III. CONCLUSIONS

In this communication, we have intended to clarify and correct the claim made in [1] attributing the spikes appearing in lossy-wall cavities, to non-physical 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 1D it is easy to keep this effect under control, in 3D the geometrical discretization is not so well controlled, and, 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 anti-resonances.

ACKNOWLEDGEMENTS

The work described in this paper and the research leading to these results have been supported by the Spanish MINECO and EU FEDER under Project TEC2016-79214-C3-3-R (MINECO, Spain), COST Action IC1407 (ACCREDIT) and EPSRC Studentship 1642594.

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