Staircasing errors due to orthogonal meshing of electromagnetic cavities in FDTD

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The Finite-Difference Time-Domain method is a popular numerical technique for modelling electrodynamics. The method involves creating models of physical systems on an orthogonal grid. Staircasing is the name used to describe the representation of non-aligned or curved surfaces on an orthogonal grid. Staircasing is a known and documented source of error in FDTD models; however, little work focuses on the errors in simulations of electromagnetic cavities.

This work examines the different errors that arise as a direct result of using an orthogonal approximation of a hollow spherical shell. The spherical shell used has a radius of 1 m and is constructed of a simple material with a conductivity σ = 1000 S/m and a thickness h = 1 mm. This material was represented using a thin boundary surface impedance boundary (SIBC) model allowing a mesh size much larger than the thickness of the material. The orthogonally meshed sphere was illuminated using a plane-wave and the electric field measured at the centre allowing the shielding effectiveness (SE) to be calculated.

There are some prominent errors in the simulated SE in Figure 1. The resonant frequencies of the cavity are shifted slightly due to the imprecise representation of the geometry. The resonances are consistently at higher frequencies corresponding to a smaller effective radius, this can be attributed to the inner edges of the orthogonal mesh that dominate the resonant behaviour since they are closer to the centre than the actual smooth surface of the unmeshed sphere.

There are a number of spurious resonances that are not apparent in the analytical results. These extra resonances are in fact expected spherical resonances that should have a node at the centre of the shell. Due to difficulties in observing exact positions in a Yee cell grid, further exacerbated by the geometric inaccuracies of an orthogonally meshed structure, the observation point at the centre does not lie exactly on the node of these secondary resonances.

The magnitude of SE of the FDTD model is consistently higher than the analytical result. This error can be related to the fact that an orthogonal approximation of a curved surface has a greater surface area than the surface being modelled. In the case of a sphere this error is around 50%. The simulation was repeated using different mesh sizes (dx). The results shown in Figure 2 show a strong correlation between the error in surface area and the error in SE.

A common alternative to orthogonal meshing is to use a conformal method. There is a large amount of literature surrounding this topic; however, it is important to note that orthogonal meshing has its advantages. Resource consumption of conformal techniques can become very high for advanced structures.. Ultimately it becomes a trade-off between accuracy and performance, with neither method being the definitively best solution.

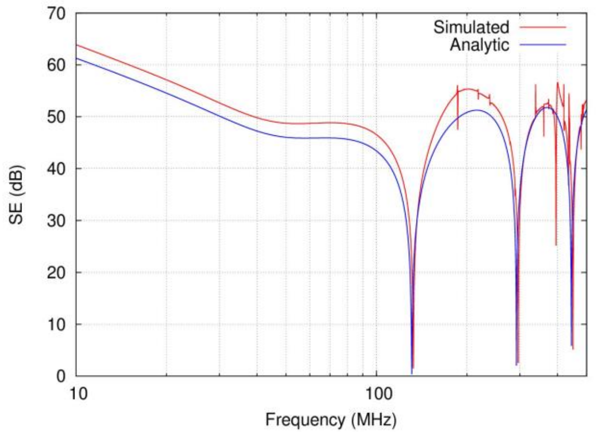

Figure 1: Analytic v FDTD SE

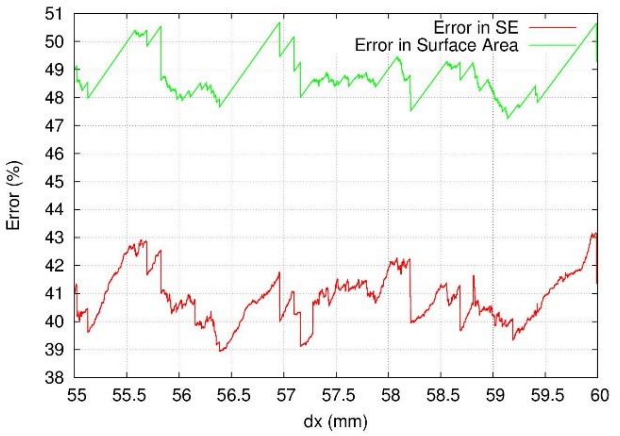

Figure 2: Error in SE v mesh size