3D FDTD Modeling of Multi-Scale Structures at Low Frequencies

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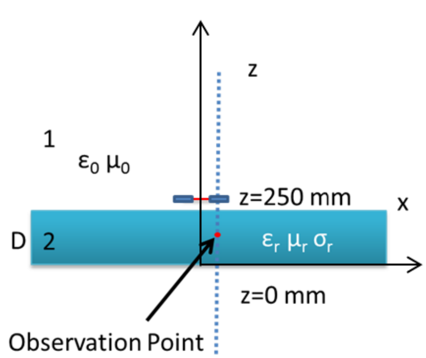
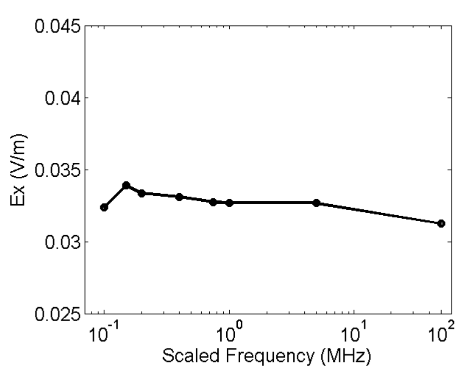
Full Wave 3D electromagnetic modeling at low frequencies is an issue which still remains unresolved for a number of multi-scale problems, such as logging while drilling (LWD), modeling of brain waves, and EMI/EMC in electronic packages. All of the traditional computational methods, including the method of moments (MoM), finite element method (FEM), and the finite difference time domain method (FDTD) breakdown at such low frequencies. In this paper we present an approach for low frequency FDTD modeling, which is useful for the applications mentioned above. The FDTD suffers from two issues at low frequencies. First, we must use a fine mesh, and hence a small time step, to accurately capture the nuances of the geometries of objects with fine features that are present in a multi-scale problem. One consequence of this is that the time duration of a low frequency excitation (say a Gaussian pulse) would have to be very long, making it necessary to run the simulation for an inordinately long time (millions or billions of time steps) in order for the solution to converge. Second, the absorbing boundary conditions become less effective at low frequencies, and we must increase the size of the computational domain to generate accurate solutions. To overcome both of these problems, we have developed a technique in which we solve the problem at a higher frequency (f_s), instead of the actual problem frequency (f), but using scaled material parameters, e.g., $\varepsilon_{rs} = \varepsilon_r(f/f_s)$. As an illustrative example, we consider a lossy, infinite, dielectric slab with a thickness D=250 mm, and with material parameters of ε_r=100, μ_r=1 and σ=.01 S/m at 100 KHz. We assume that an x-polarized dipole source is placed 10 mm above the slab to excite it, and we observe the electric field at a point located at the center of the slab, as shown in Fig 1(a). Fig. 1(b) shows that the electric field inside the slab remains essentially unchanged as we scale the ε_r by using the relationship given above. As for the time advantage, we find that to solve this problem directly at f=100 KHz, we need to run the FDTD simulation for several million time steps before it reaches a convergent solution. But we can achieve the same value of the electric fields in less than 50,000 time steps by scaling the ε_r of the slab, and using a frequency of f_s = 50 MHz to run the actual simulation.



(a)



(b)

Fig. 1 (a) Dielectric Slab excited using a dipole and (b) Electric Field as function of scaled frequency (f_s)