Impact of a 3D EM Model Configuration on the Direct Optimization of Microstrip Structures

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Abstract

Setup of 3D electromagnetic (EM) models, specifically the selection of proper boundary conditions, size of the simulation box, kind and size of port excitations, and meshing scheme for a given structure are especially important for reliable EM simulations. Examples of particularly sensitive cases are microstrip circuits and other planar structures, since a too small simulation box might alter the results due to unintended EM interaction between the simulated structure and the box walls [1].

Although this problem is empirically solved by selecting a sufficiently large simulation box, we demonstrate that the effective size of the box is dependent upon the mesh size. We calibrate a simulation box by finding the box size at which the structure responses are practically unchanged when small perturbations to the box dimensions are applied for a particular mesh size and then modify the mesh size. We present two different results obtained when performing direct EM optimization of a classical microstrip band-pass filter [2] for two different mesh and box sizes. The simulation was done in COMSOL Multiphysics®.

The filter model under study is illustrated in Figure 1. We keep separations ygap, xgap, and Hair from the filter to the walls (see Figure 1). The horizontal lumped ports length is lport. All walls of the enclosing box are scattering boundary conditions, excepting the bottom cover, which is defined as an impedance boundary condition to account for the ground plane losses. Infinitesimally thin metals, using a transition boundary condition, are employed for the conductors. We include metallic and dielectric losses and the model uses "free-tetrahedral" meshing for all domains. The meshing scheme considers not only the wavelength on different domains, but also the physical size of the different model regions. Different meshing resolutions are assigned for microstrip trace regions, ports, gap, and the global structure, by defining minimum and maximum element sizes (deltamin, deltamax), as illustrated in Figure 1.

The length of the lumped port lport was selected reasonably small to achieve a good quasi-static approximation. Using a low-resolution mesh, we select a large simulation box size such that small perturbations on box dimensions do not change filter responses. The filter is then optimized using the Nelder-Mead optimization method. Figure 2 shows that the objective function U(R(x)) never becomes negative, indicating that the optimization process fails to fulfill the design

specifications. We repeat the same optimization procedure, but now using a larger bounding box and a better resolution. It is seen in Figure 3 that the objective function U(R(x)) becomes negative, requiring a much smaller number of simulations to fulfill the design specifications. These results confirm that selecting an appropriate 3D EM model configuration is critical to achieving optimization goals.

Reference

[1] J. E. Rayas-Sánchez, Z. Brito-Brito, J. C. Cervantez-González and C. A. López "Systematic configuration of coarsely discretized 3D EM solvers for reliable and fast simulation of high-frequency planar structure" IEEE Latin American Symposium on Circuits and Systems, Cusco, Peru, Feb. 2013, 4 pp.

[2] V. Gutiérrez-Ayala and J. E. Rayas-Sánchez, "Neural input space mapping optimization based on nonlinear two-layer perceptrons with optimized nonlinearity," Int. J. RF and Microwave CAE, vol. 20, pp. 512-526, Sep. 2010.

Figures used in the abstract

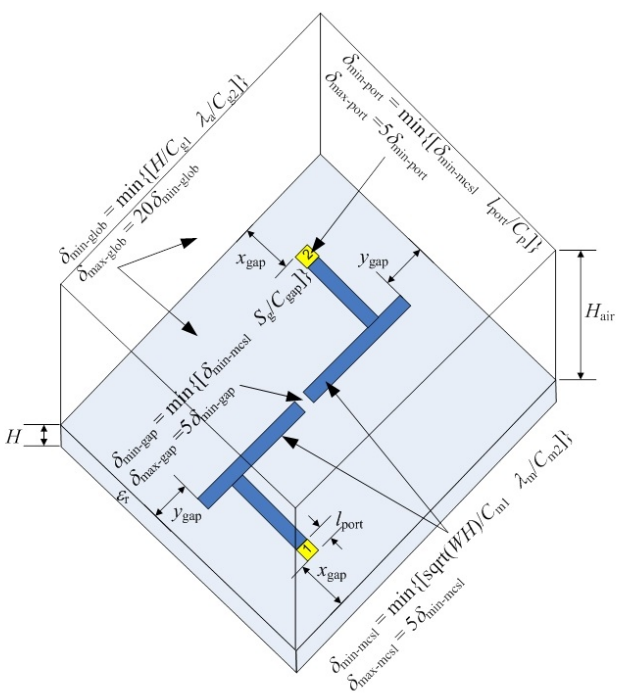

Figure 1: Bounding box dimensions and minimum/maximum element sizes of meshing scheme for a microstrip band-pass filter in COMSOL.

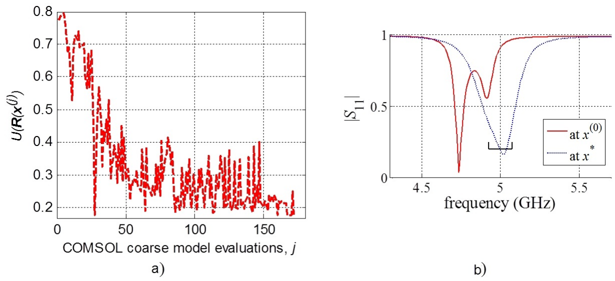

Figure 2: Optimization results using an improper model configuration in COMSOL: a) objective function U(R(x)), b) reflection parameter at initial and optimal designs.

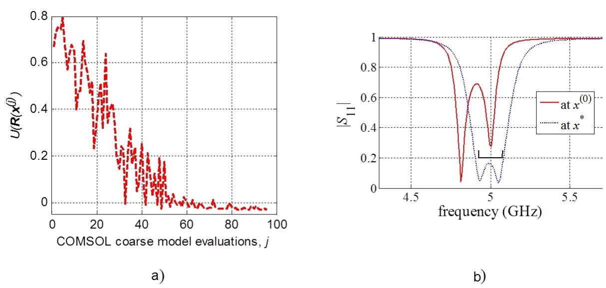

Figure 3: Optimization results using a suitable model configuration in COMSOL: a) objective function U(R(x)), b) reflection parameter at initial and optimal designs.