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

Zabdiel Brito-Brito [(1)], José E. Rayas-Sánchez [(1)],
Juan C. Cervantes-González [(2)], and Carlos A. López [(2)]

[(1)] Department of Electronics, Systems and Informatics
Instituto Tecnológico y de Estudios Superiores de Occidente (ITESO)
Guadalajara, Mexico, 45604
[(2)] Intel-Guadalajara Design Center, Tlaquepaque, Jalisco, 45600 Mexico

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Outline

- Introduction
- Structure under study
- Formulation of the optimization problem
- Optimization results
- The proposed methodology
- Conclusions

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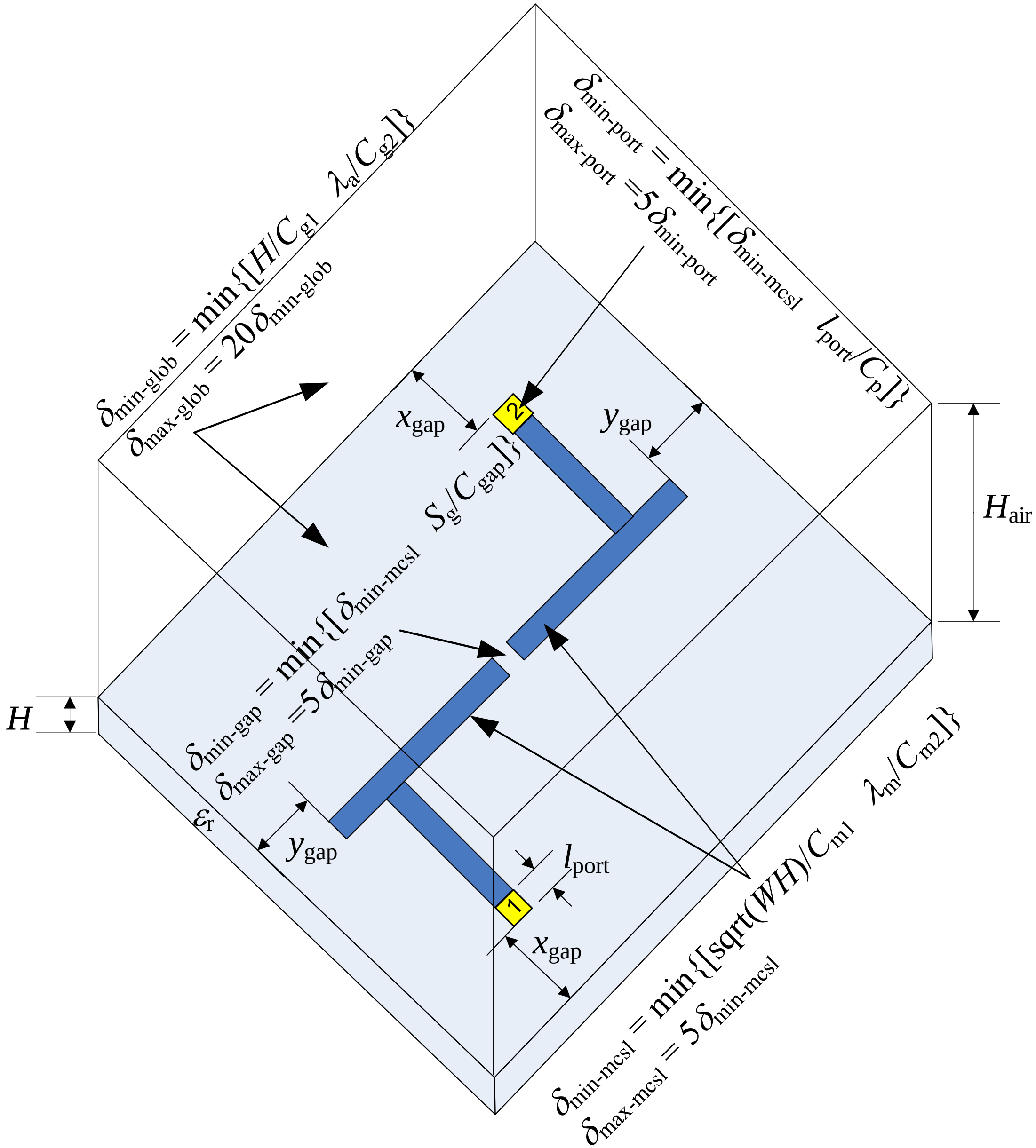
Introduction

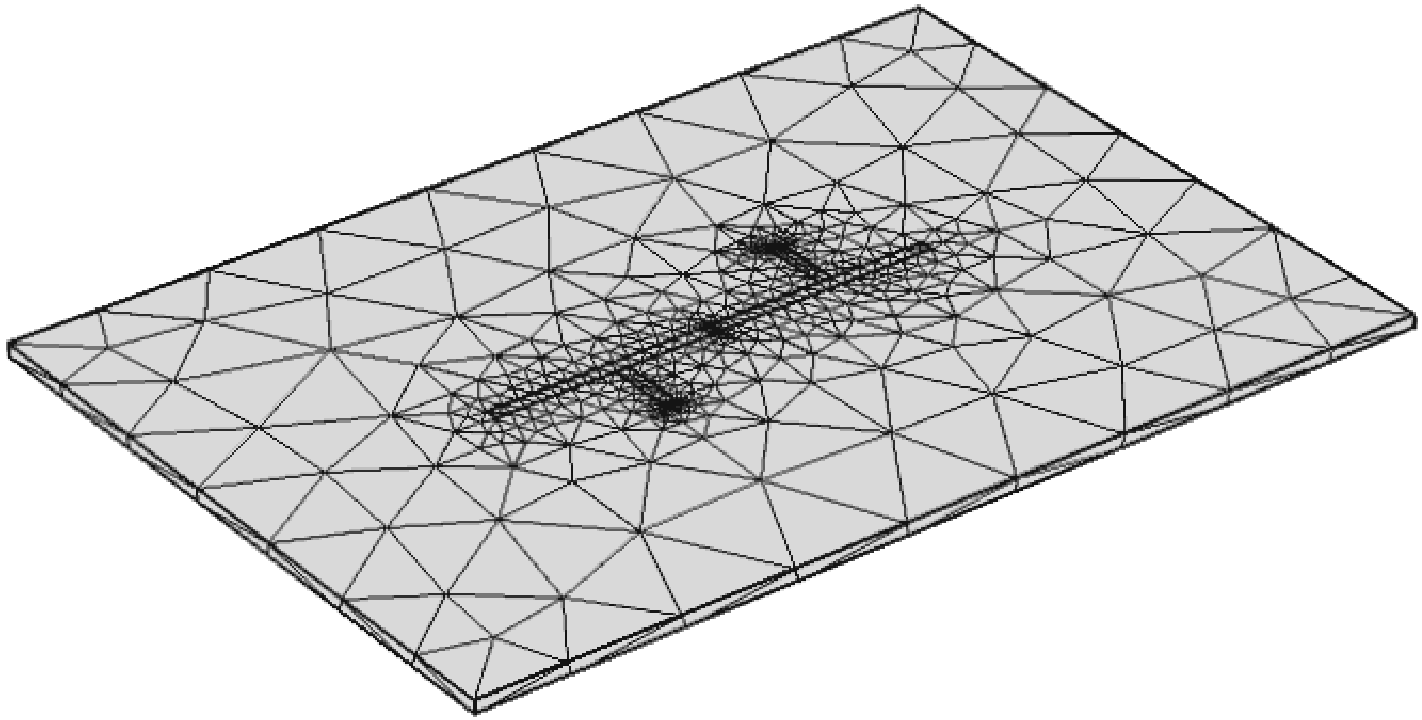
- Accurate simulation of planar structures at high frequencies requires EM solvers
- Low-resolution discretization in 3D solvers is necessary for direct EM optimization
- Coarsely discretized EM models are vulnerable to the selection of 3D EM model configuration
- We propose a procedure to find an appropriate 3D EM model configuration

Structure Under Study



δ_{min}, δ_{max}: minimum and maximum element size for each region

Selecting a 3D EM Model Configuration



$H_{\mathrm{air}} = 20H, y_{\mathrm{gap}} = 20H, x_{\mathrm{gap}} = 20H$

$\boldsymbol{C}_{\mathrm{g}} = [1 \;\; 10]^{\mathrm{T}}, \boldsymbol{C}_{\mathrm{m}} = [4 \;\; 10]^{\mathrm{T}}, C_{\mathrm{p}} = 3$ and $C_{\mathrm{gap}} = 3$

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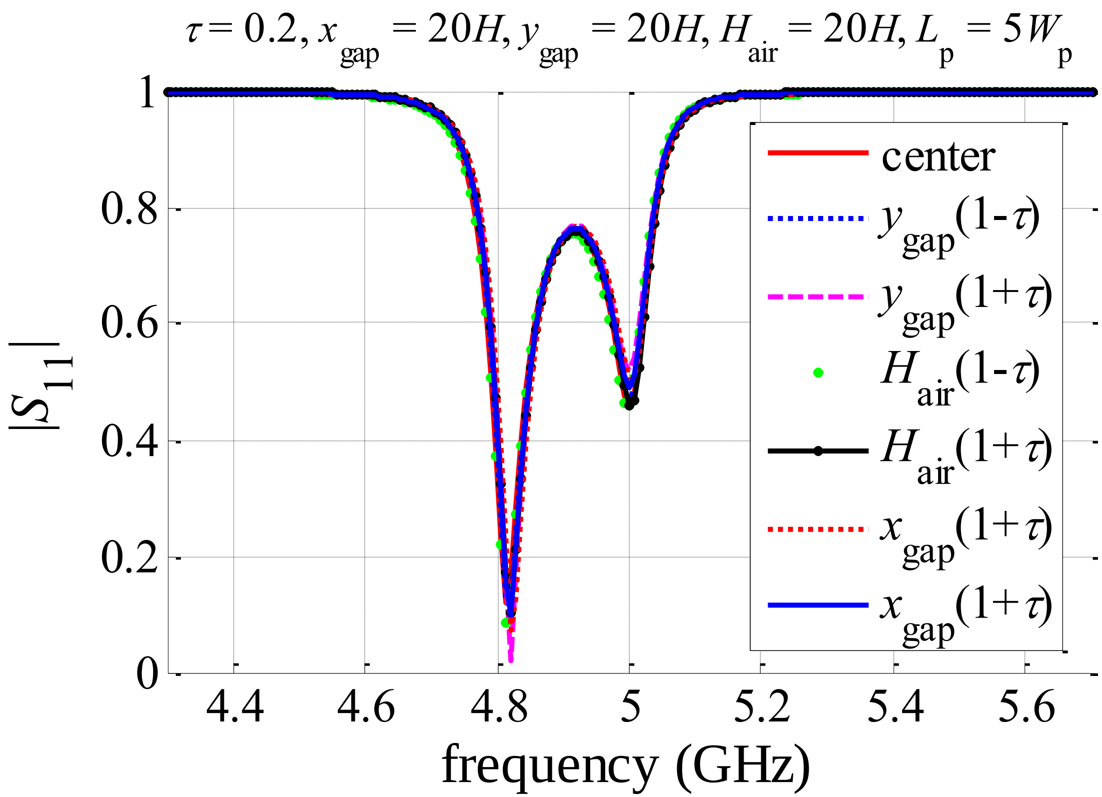
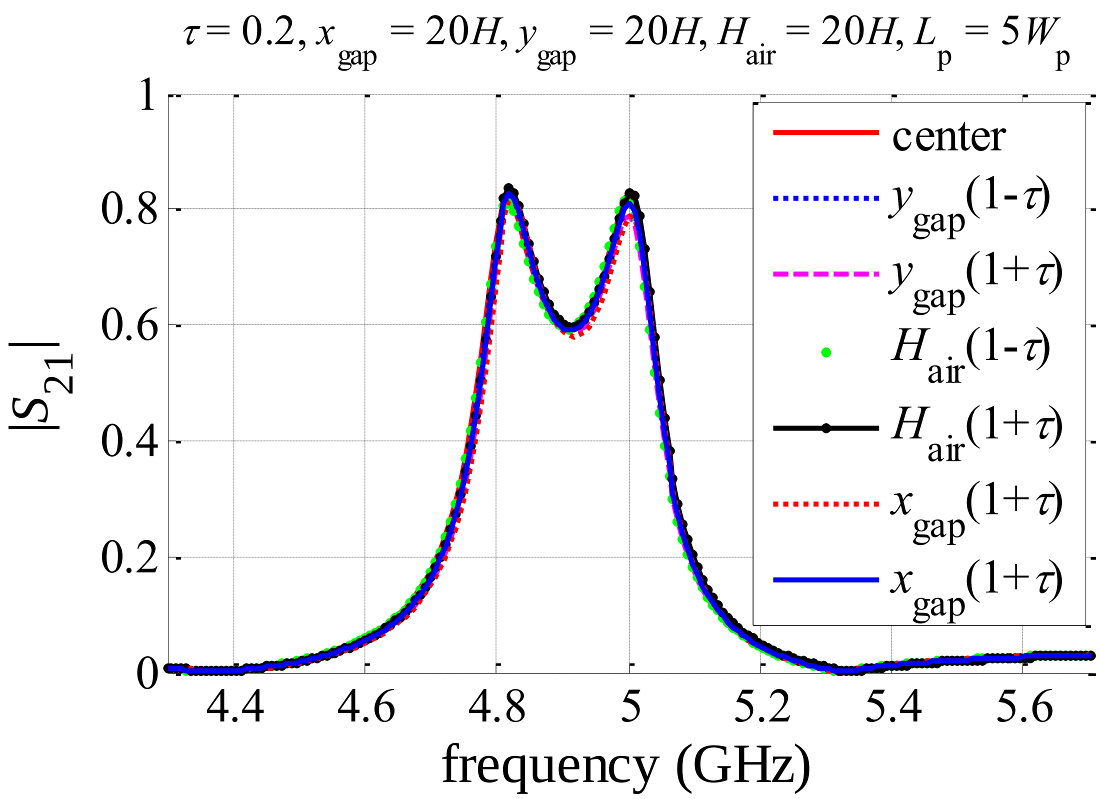
Validating the 3D EM Model Configuration



Validating the 3D EM Model Configuration (cont)



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Formulation of the Optimization Problem

$$\boldsymbol{x}^* = \arg\min_{\boldsymbol{x}\in X} U(\boldsymbol{R}(\boldsymbol{x}))$$

where U is the objective function

$$U(\boldsymbol{R}(\boldsymbol{x})) = \max\{\ldots e_k(\boldsymbol{x})\ldots\}$$

where $e_k(\boldsymbol{x})$ is the k-th error function

Design specifications:

$|S_{21}| > 0.8$ for $4.9 \text{ GHz} \leq f \leq 5.1 \text{ GHz}$

$|S_{21}| < 0.1$ for $5.5 \text{ GHz} \leq f \leq 4.5 \text{ GHz}$

$|S_{11}| < 0.2$ for $4.92 \text{ GHz} \leq f \leq 5.08 \text{ GHz}$

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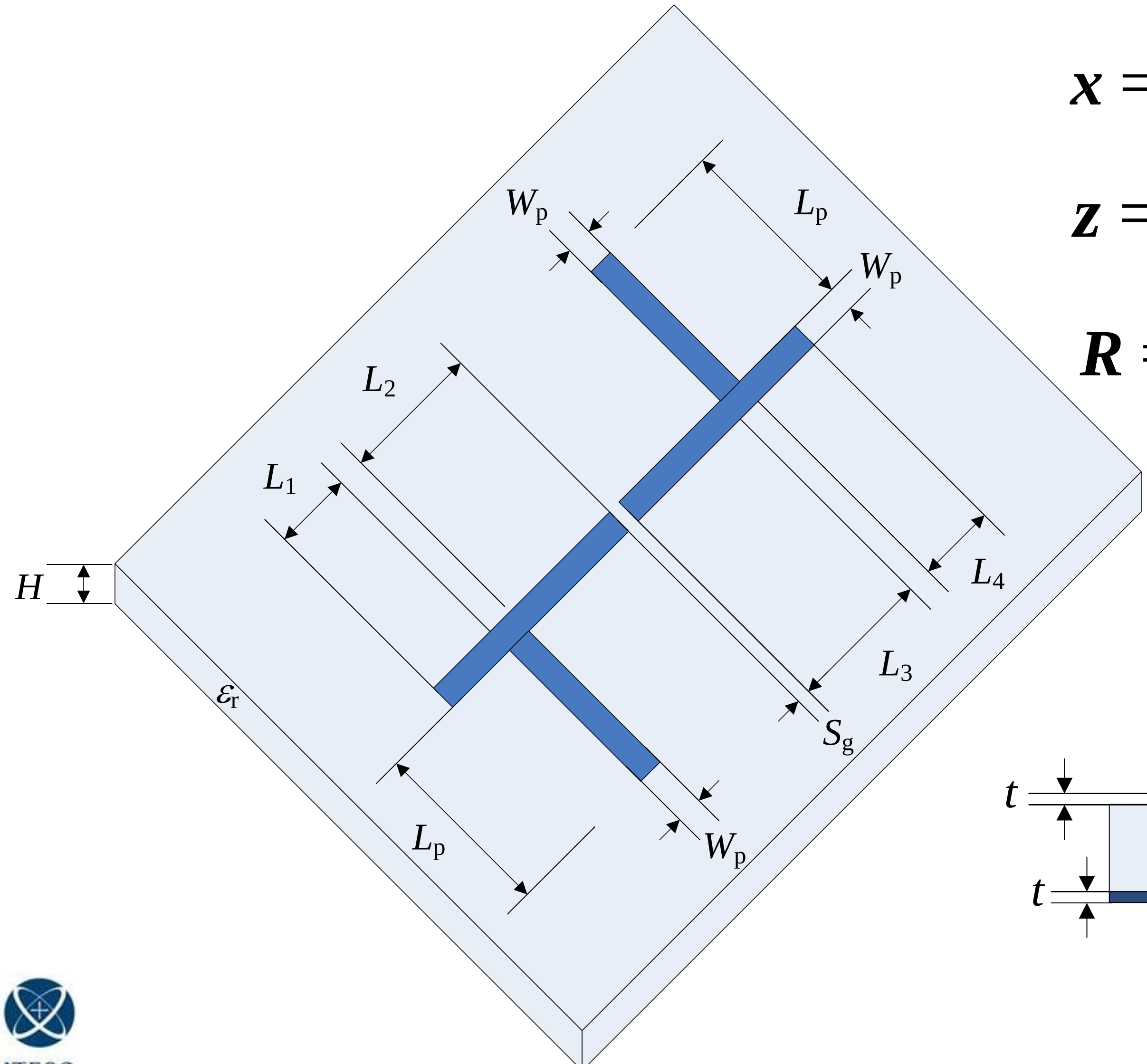
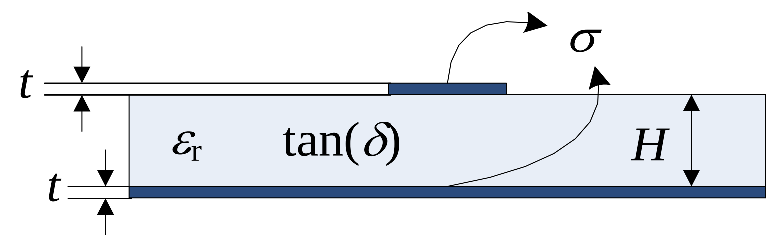
Band-pass Filter Dimensions



$$\boldsymbol{x} = [L_1 \quad L_2 \quad L_3 \quad L_4 \quad S_g]^T$$

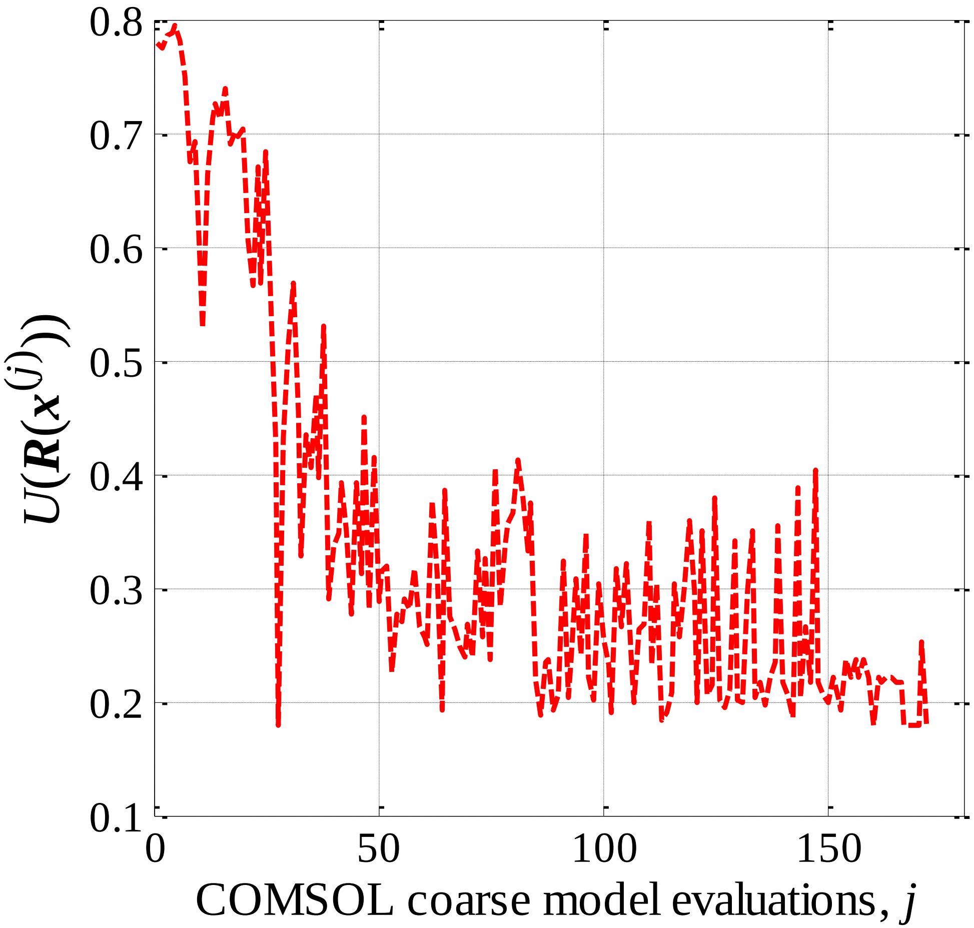
$$\boldsymbol{z} = [H \quad \varepsilon_r \quad W_p \quad L_p]^T$$

$$\boldsymbol{R} = [|S_{11}| \quad |S_{21}|]^T$$



Optimization Results

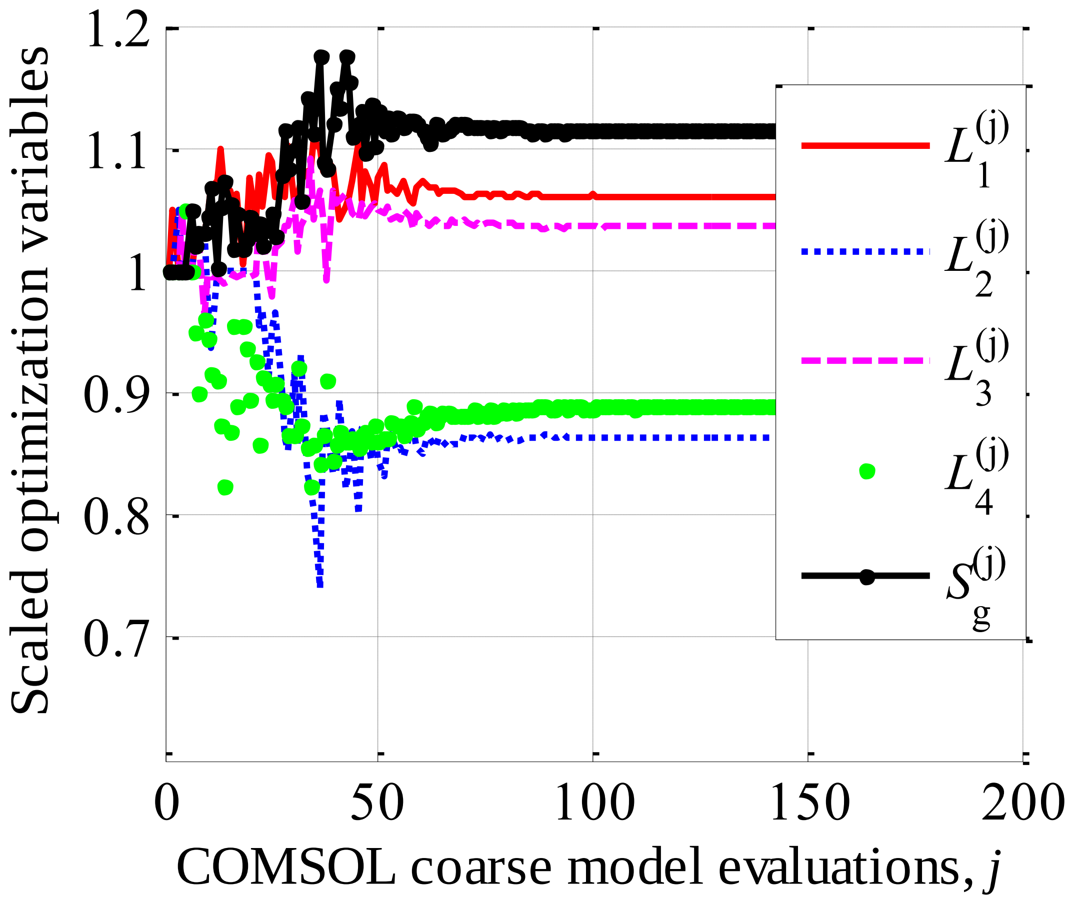
$$\boldsymbol{x}^{(0)} = [6.275 \quad 4.75 \quad 5.9 \quad 5 \quad 0.15]^{\mathrm{T}} \text{ (mm)}$$



Using Nelder-Mead optimization method

Scaled Optimization Variables

$$\boldsymbol{x}^{(0)} = [6.275 \quad 4.75 \quad 5.9 \quad 5 \quad 0.15]^{T} \text{ (mm)}$$



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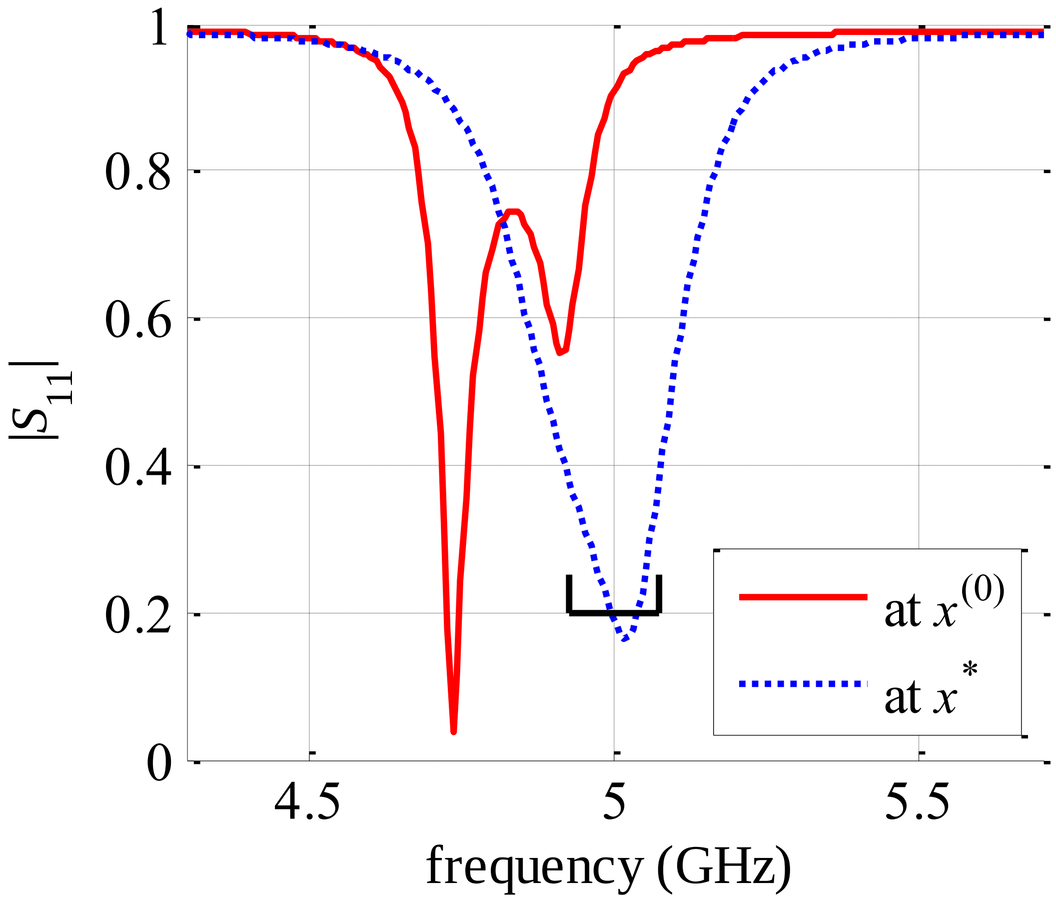
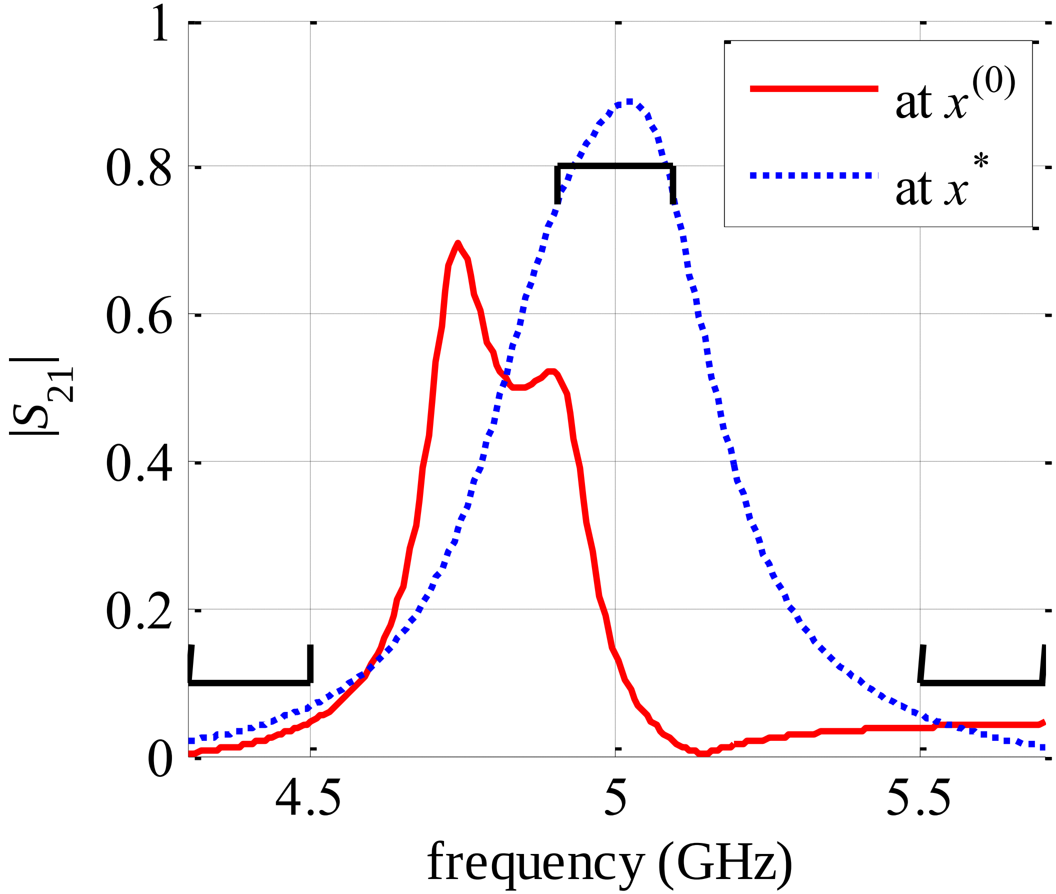
Reflection at Initial and Optimal Designs

$$\boldsymbol{x}^{(0)} = [6.275 \quad 4.75 \quad 5.9 \quad 5 \quad 0.15]^T \text{ (mm)}$$



Transmission at Initial and Optimal Designs

$$\boldsymbol{x}^{(0)} = [6.275 \quad 4.75 \quad 5.9 \quad 5 \quad 0.15]^T \text{ (mm)}$$



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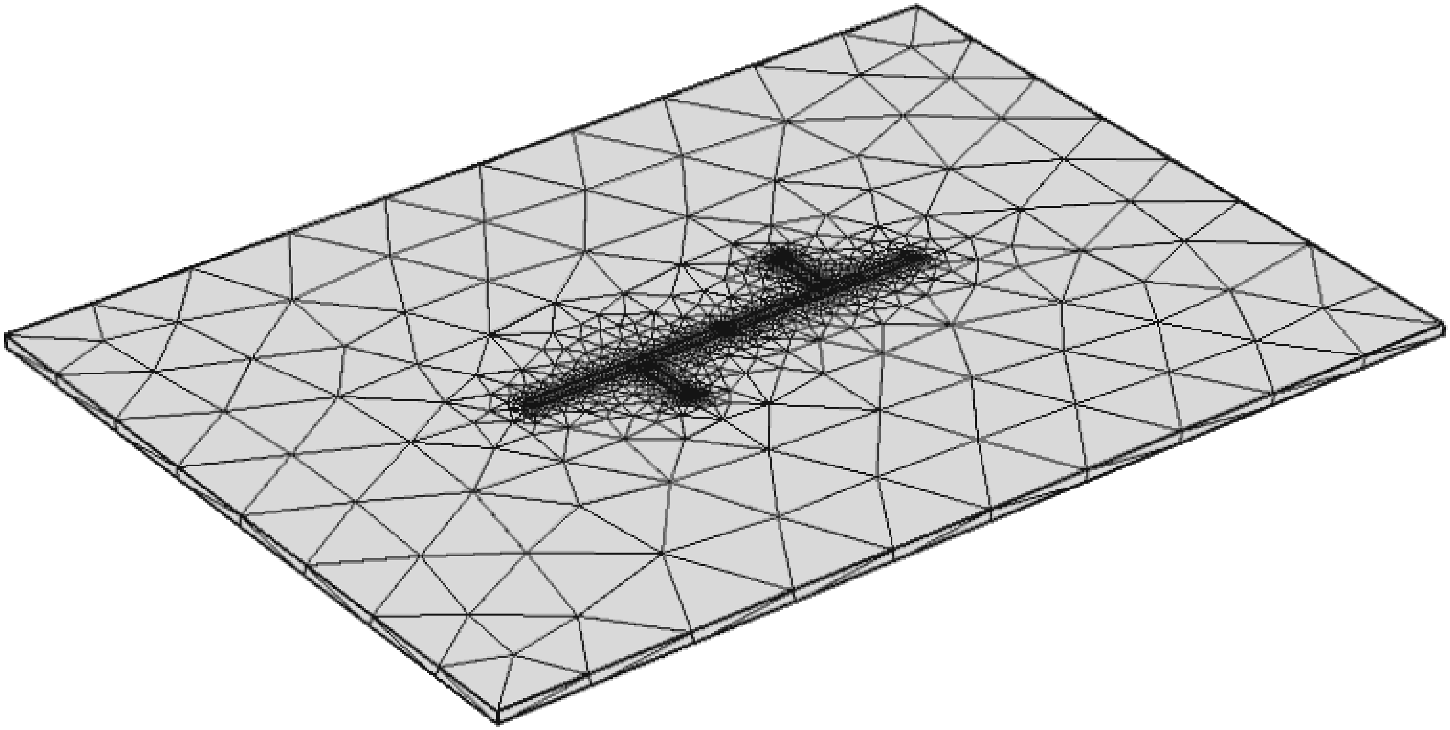
Improving Resolution Mesh and Bounding Box

We repeat the same optimization procedure



$H_{\mathrm{air}} = 25H$, $y_{\mathrm{gap}} = 25H$, $x_{\mathrm{gap}} = 25H$

$\boldsymbol{C}_{\mathrm{g}} = [1\ \ 10]^{\mathrm{T}}$, $\boldsymbol{C}_{\mathrm{m}} = [8\ \ 10]^{\mathrm{T}}$, $C_{\mathrm{p}} = 4$ and $C_{\mathrm{gap}} = 4$

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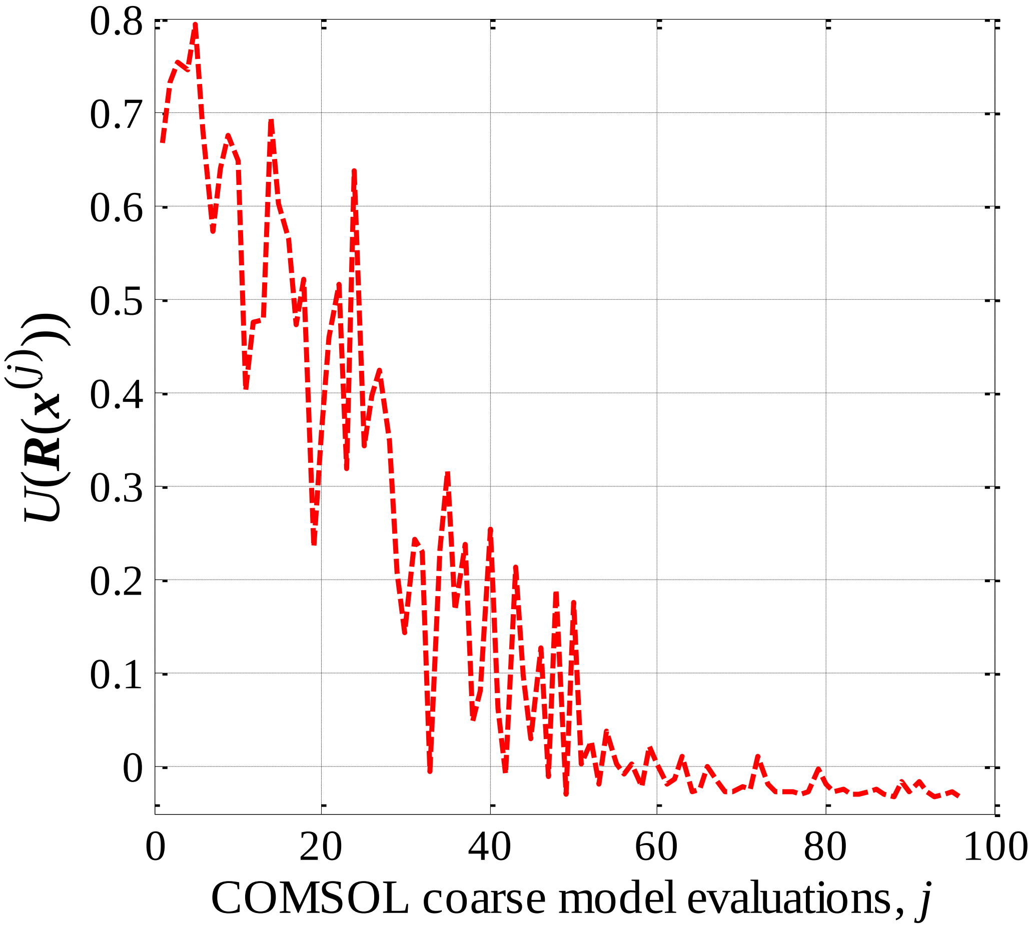
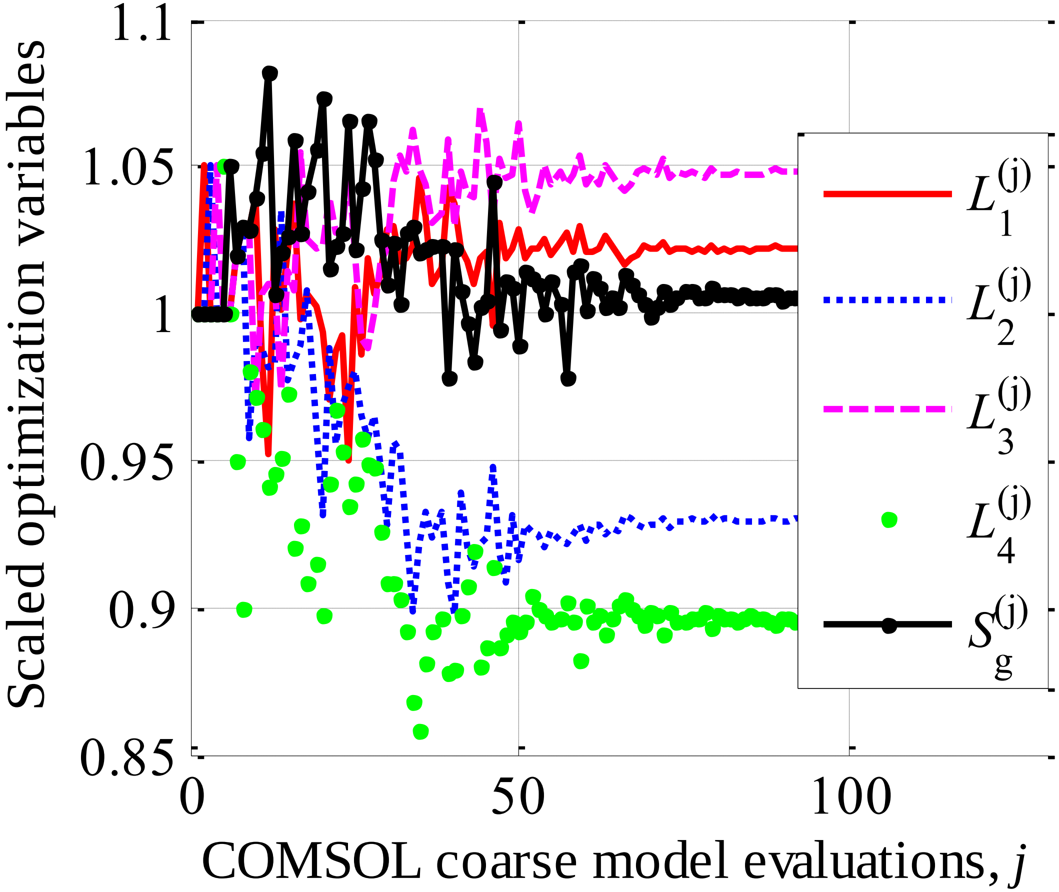
Optimization Results

$$\boldsymbol{x}^{(0)} = [6.275 \quad 4.75 \quad 5.9 \quad 5 \quad 0.15]^T \text{ (mm)}$$



Scaled Optimization Variables

$$\boldsymbol{x}^* = [6.4123 \quad 4.4192 \quad 6.1825 \quad 4.4776 \quad 0.15101]^T \text{ (mm)}$$



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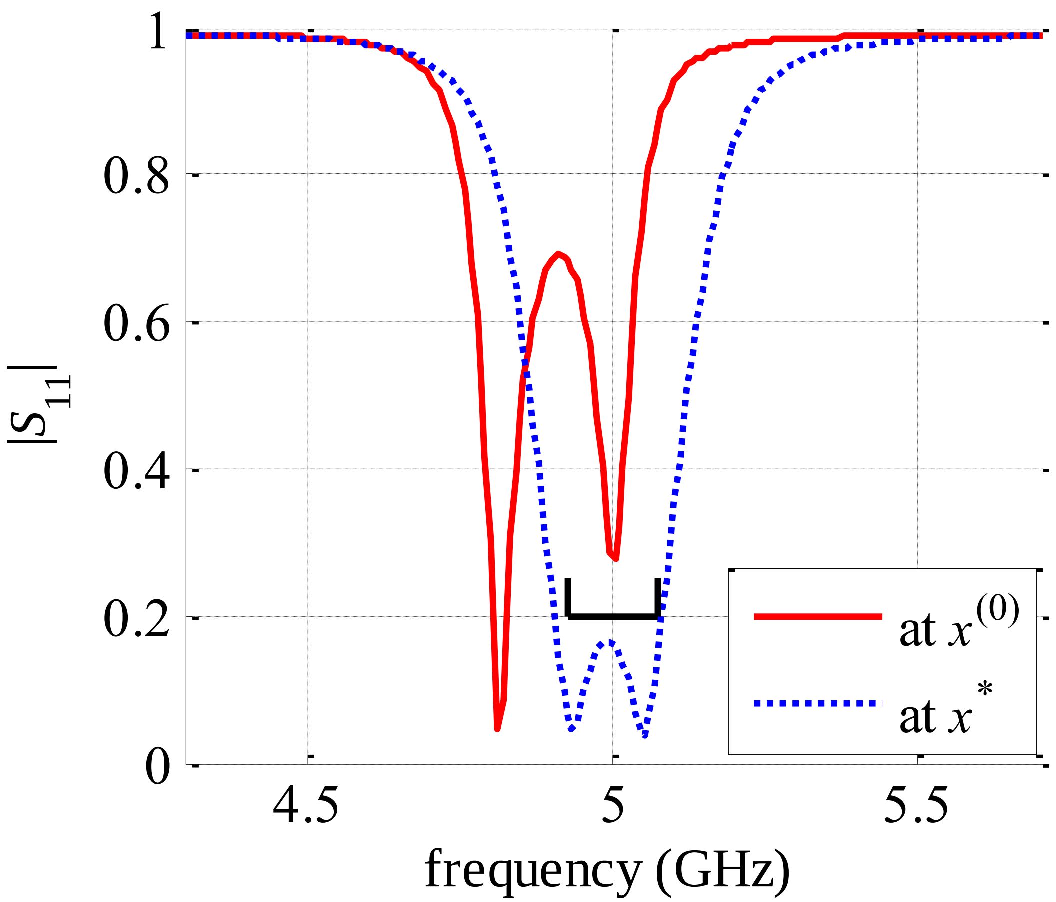
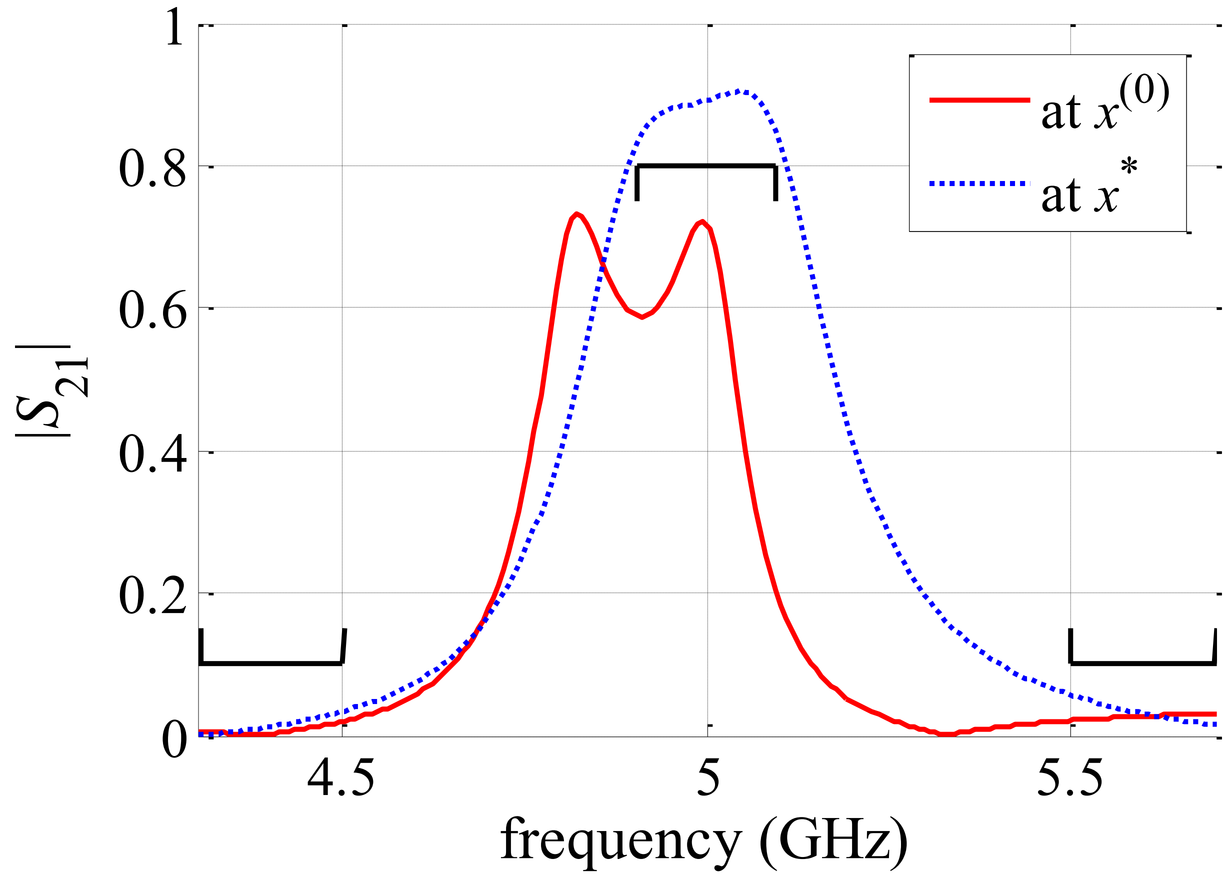
Reflection at Initial and Optimal Designs

$$\boldsymbol{x}^* = [6.4123 \quad 4.4192 \quad 6.1825 \quad 4.4776 \quad 0.15101]^T \text{ (mm)}$$



Transmission at Initial and Optimal Designs

$$\boldsymbol{x}^* = [6.4123 \quad 4.4192 \quad 6.1825 \quad 4.4776 \quad 0.15101]^T \text{ (mm)}$$



The Proposed Methodology

- Select a reasonably small length for the lumped port, using a low-resolution mesh with a large simulation box size
- Validate simulation box by perturbations
- Optimize the structure
- If the optimization process fails, it is necessary to change the model configuration
- Launch the same optimization procedure
- Repeat steps until the objective function becomes negative

Conclusions

- The EM optimization of a coarsely discretized model was realized using two different model configurations
- It was confirmed that the direct EM optimization of coarse models in COMSOL could be enhanced by an appropriate bounding box size as well as by a suitable meshing scheme
- We presented a systematic methodology to find an appropriate 3D model configuration on a direct EM optimization

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