Reliable Full-Wave EM Simulation of a Single-Layer SIW Interconnect with Transitions to Microstrip Lines

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Outline

- Introduction
- SIW design and implementation in COMSOL
- Configuration settings: meshing scheme and simulation bounding box
- Final results
- Conclusions

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Introduction

- Procedure to obtain reliable EM responses
- Procedure focuses on meshing scheme and simulation bounding box
- SIW interconnect with transitions to microstrip lines

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SIW Design

- Single-layer substrate integrated waveguide (SIW) interconnect with transitions to microstrip lines

H = 16mil

W = 341.91mil

W_p = 34.14mil

W_tap = 211.36mil

d = 18.9mil

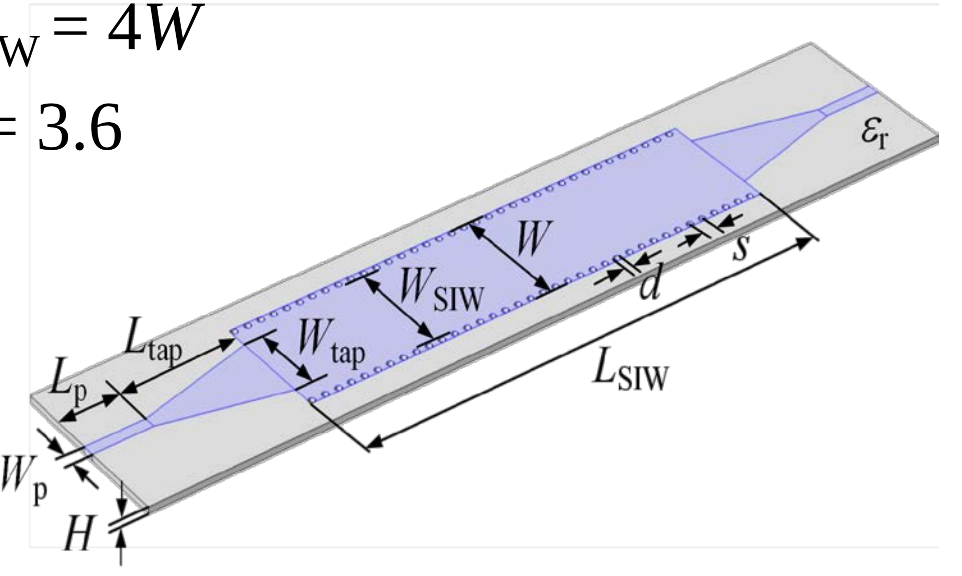
$s = 2d$

$L_\mathrm{p} = 1.5W$

$L_\mathrm{tap} = 3W$

$L_\mathrm{SIW} = 4W$

$\varepsilon_\mathrm{r} = 3.6$



(*Rayas-Sanchez et. al. 2009*)

SIW COMSOL Configuration

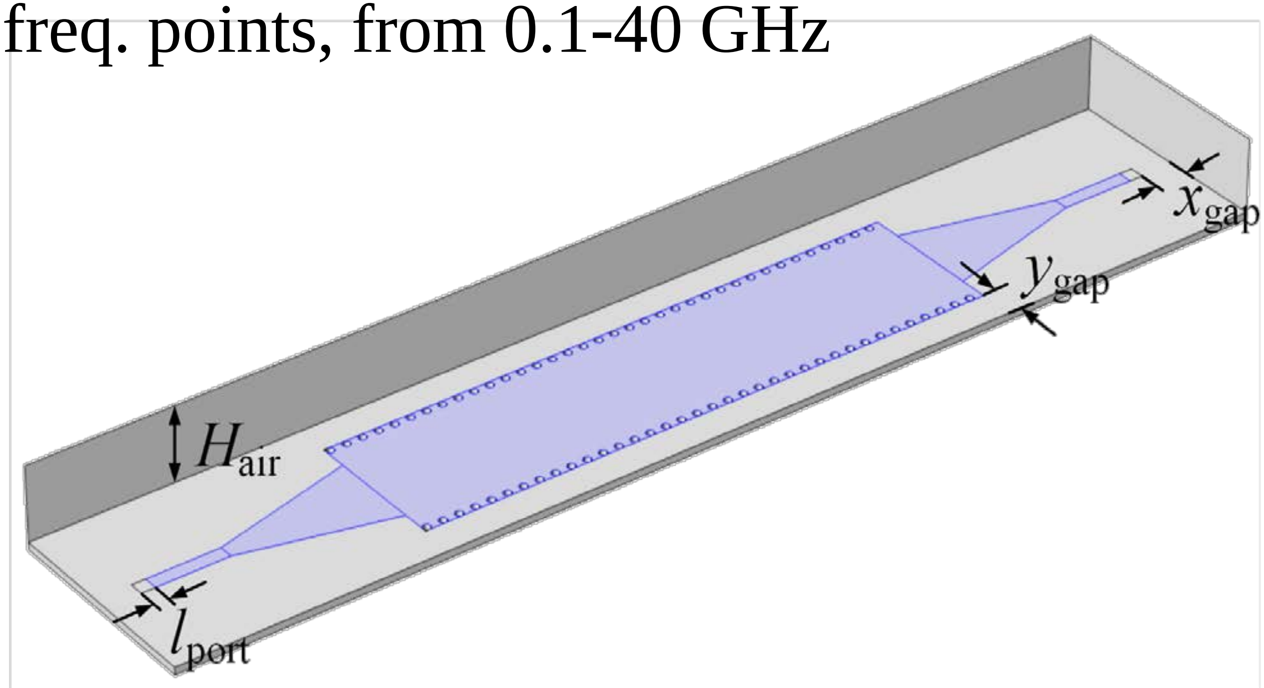
Horizontal lumped ports ($l_{\mathrm{port}} = 1H$)

PEC for the trace metals and the bottom box layer

Dielectric losses $\tan\delta = 0$

Scattering boundary condition for the rest of the box

AWE using100 freq. points, from 0.1-40 GHz



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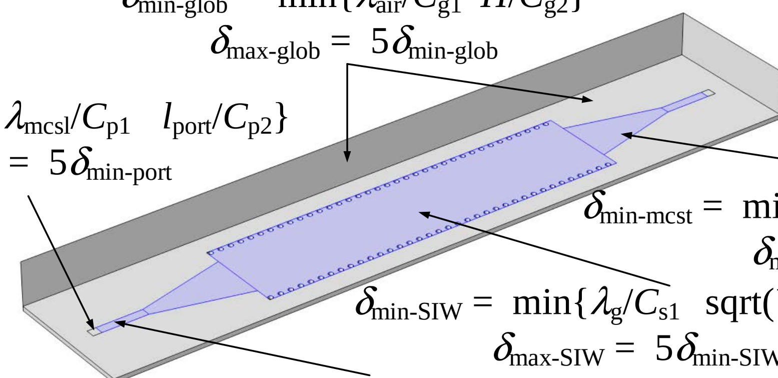
COMSOL Configuration

- Reliable EM responses:
  - Meshing scheme
  - Simulation bounding box dimensions

$$\delta_{\text{min-glob}} = \min\{\lambda_{\text{air}}/C_{g1} \quad H/C_{g2}\}$$
$$\delta_{\text{max-glob}} = 5\delta_{\text{min-glob}}$$

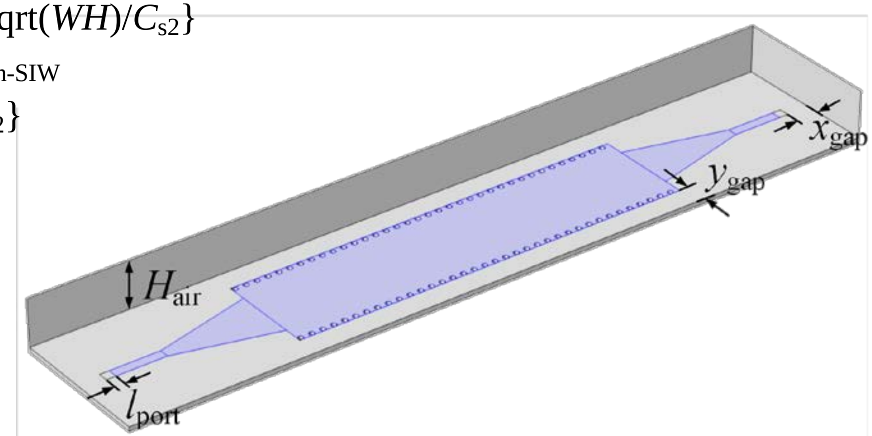
$$\delta_{\text{min-port}} = \min\{\lambda_{\text{mcsl}}/C_{p1} \quad l_{\text{port}}/C_{p2}\}$$
$$\delta_{\text{max-port}} = 5\delta_{\text{min-port}}$$



$$\delta_{\text{min-mcst}} = \min\{\lambda_{\text{mcst}}/C_{t1} \quad \text{sqrt}(W_{\text{avg}}H)/C_{t2}\}$$
$$\delta_{\text{max-mcst}} = 5\delta_{\text{min-mcst}}$$

$$\delta_{\text{min-SIW}} = \min\{\lambda_{g}/C_{s1} \quad \text{sqrt}(WH)/C_{s2}\}$$
$$\delta_{\text{max-SIW}} = 5\delta_{\text{min-SIW}}$$

$$\delta_{\text{min-mcsl}} = \min\{\lambda_{\text{mcsl}}/C_{m1} \quad \text{sqrt}(W_{p}H)/C_{m2}\}$$
$$\delta_{\text{max-mcsl}} = 5\delta_{\text{min-mcsl}}$$



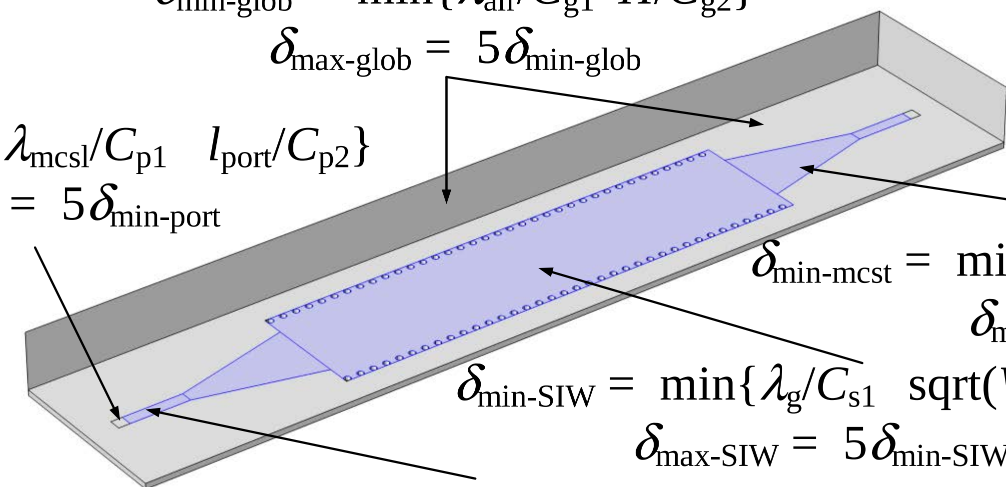
(*Brito-Brito et. al. 2013*)

Meshing Scheme

- Minimum element size, δ_{min} = Minimum between a fraction of the wavelength and a fraction of the minimum geometrical size in the region

$$\delta_{\text{min-glob}} = \min\{\lambda_{\text{air}}/C_{g1} \quad H/C_{g2}\}$$
$$\delta_{\text{max-glob}} = 5\delta_{\text{min-glob}}$$

$$\delta_{\text{min-port}} = \min\{\lambda_{\text{mcsl}}/C_{p1} \quad l_{\text{port}}/C_{p2}\}$$
$$\delta_{\text{max-port}} = 5\delta_{\text{min-port}}$$



$$\delta_{\text{min-mcst}} = \min\{\lambda_{\text{mcst}}/C_{t1} \quad \mathrm{sqrt}(W_{\text{avg}}H)/C_{t2}\}$$
$$\delta_{\text{max-mcst}} = 5\delta_{\text{min-mcst}}$$

$$\delta_{\text{min-SIW}} = \min\{\lambda_{g}/C_{s1} \quad \mathrm{sqrt}(WH)/C_{s2}\}$$
$$\delta_{\text{max-SIW}} = 5\delta_{\text{min-SIW}}$$

$$\delta_{\text{min-mcsl}} = \min\{\lambda_{\text{mcsl}}/C_{m1} \quad \mathrm{sqrt}(W_{p}H)/C_{m2}\}$$
$$\delta_{\text{max-mcsl}} = 5\delta_{\text{min-mcsl}}$$

Meshing Scheme

Resol 0 = [C_{g2}=1, C_{p2}=1, C_{m2}=1, C_{t2}=1, C_{s2} =1]

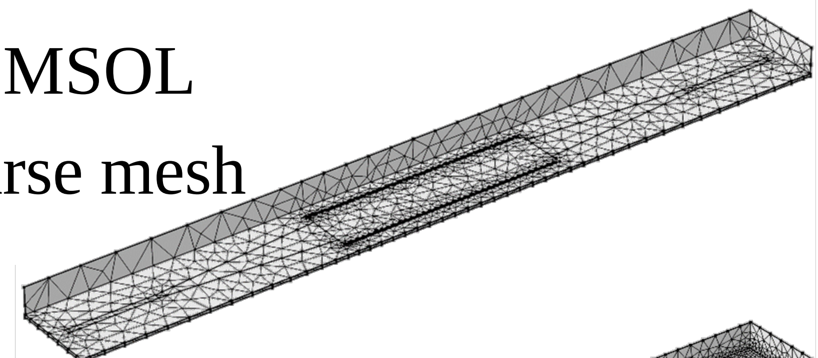
Resol 1 = [C_{g2}=1, C_{p2}=1, C_{m2}=3, C_{t2}=7, C_{s2} =10]

Resol 2 = [C_{g2}=1, C_{p2}=1, C_{m2}=7, C_{t2}=14, C_{s2} =20]

For all = [C_{g1}=20, C_{p1}=20, C_{m1}=20, C_{t1}=20, C_{s1} =20]

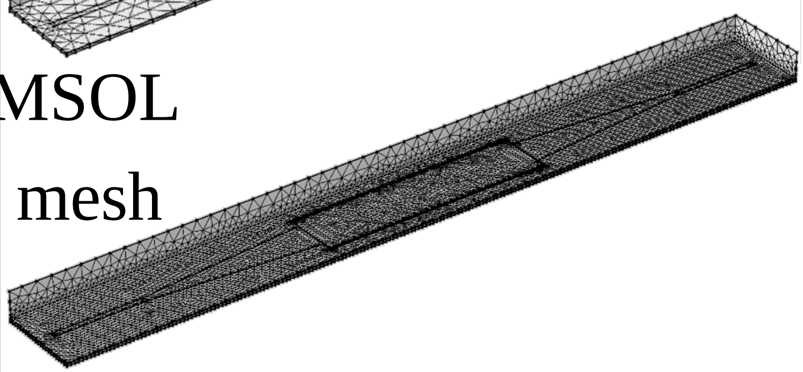
COMSOL

coarse mesh

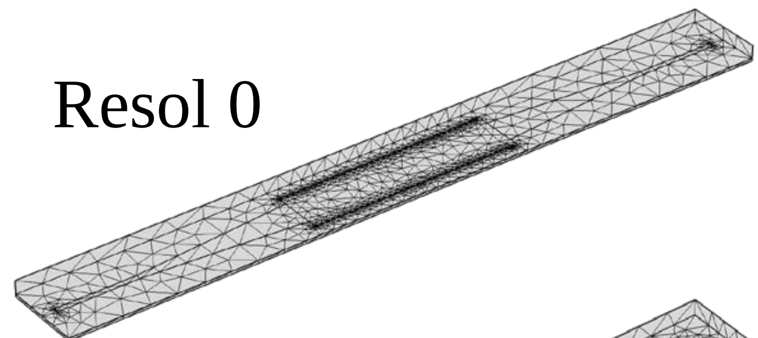


COMSOL

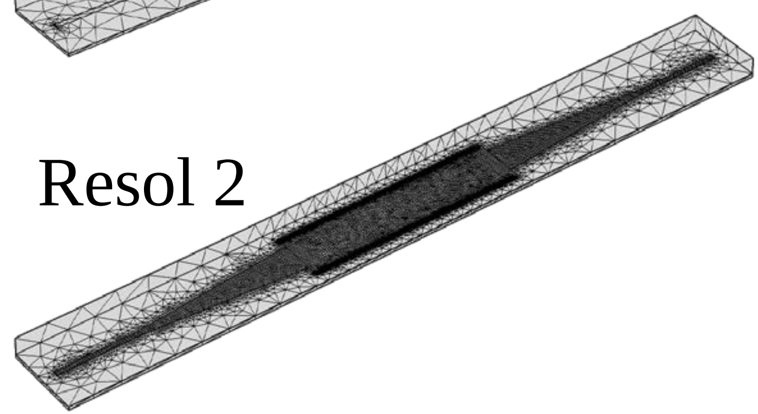
fine mesh



Resol 0



Resol 2



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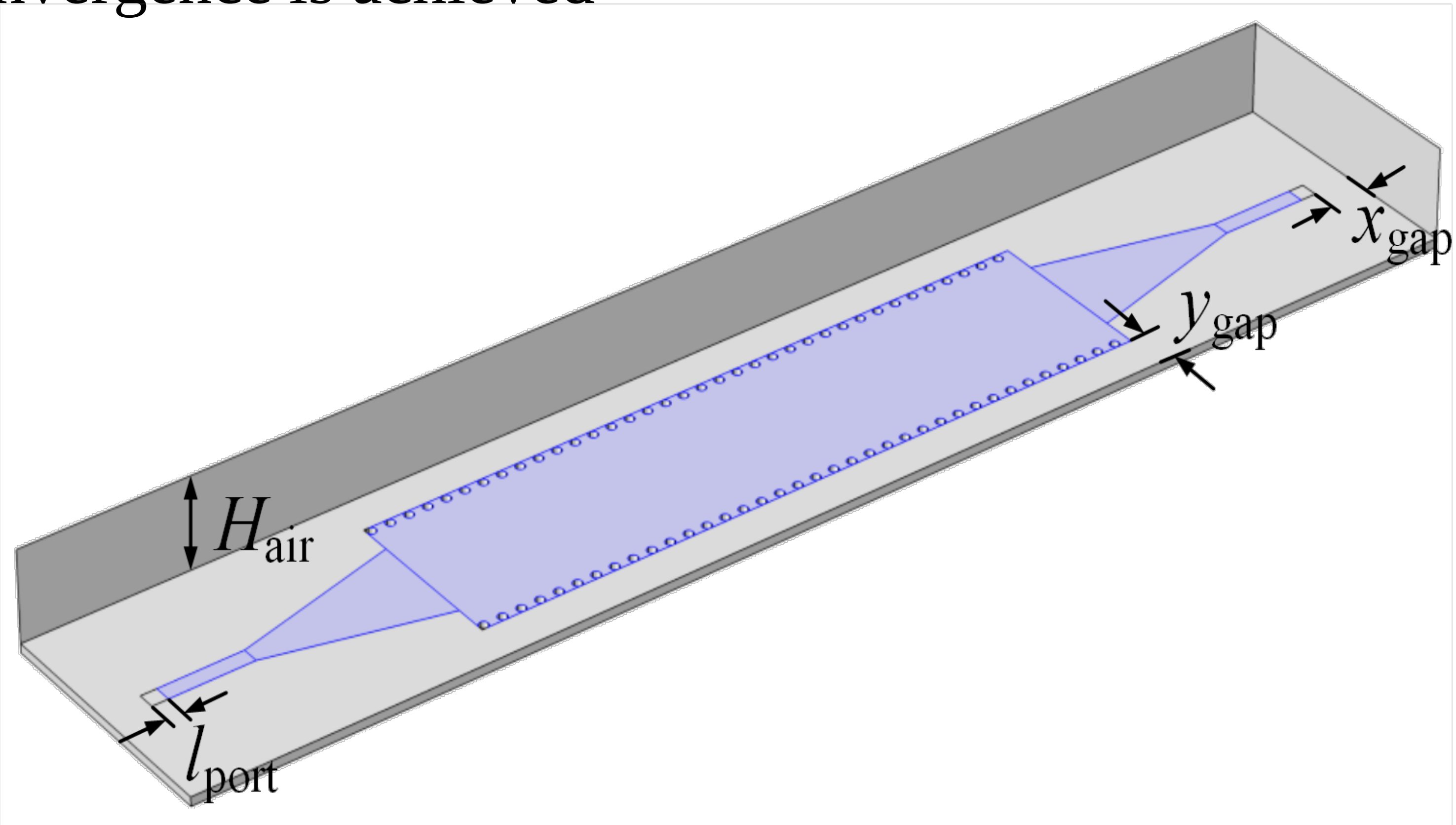
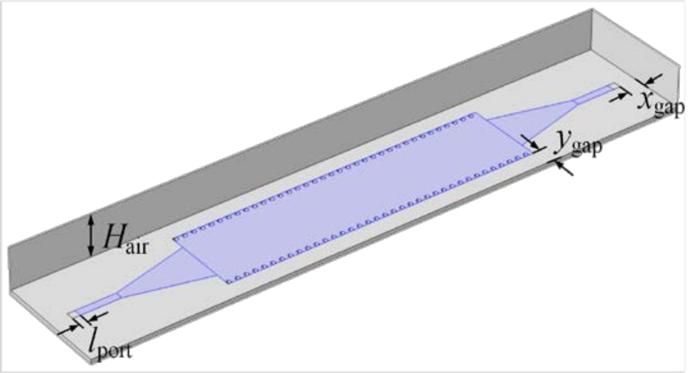
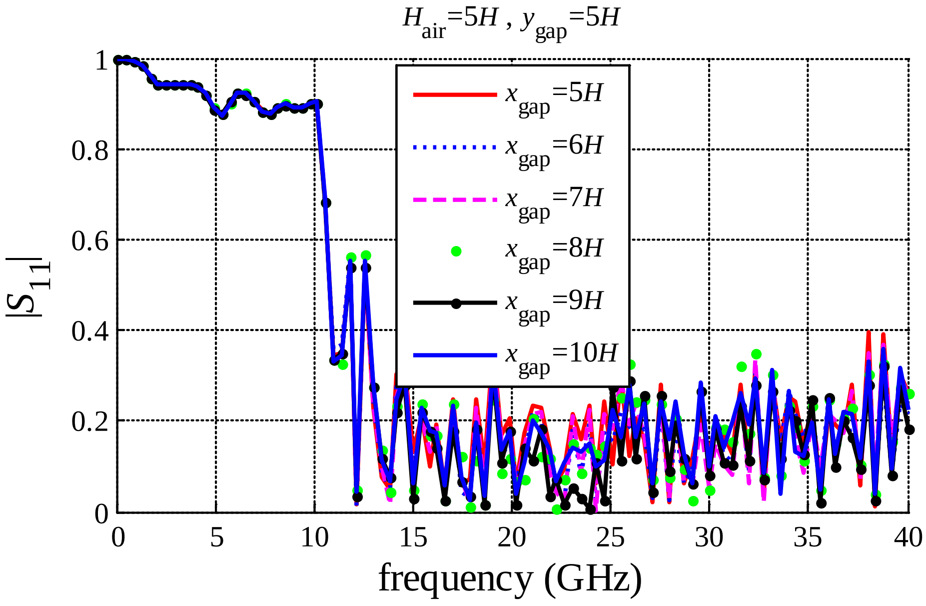
Simulation Bounding Box

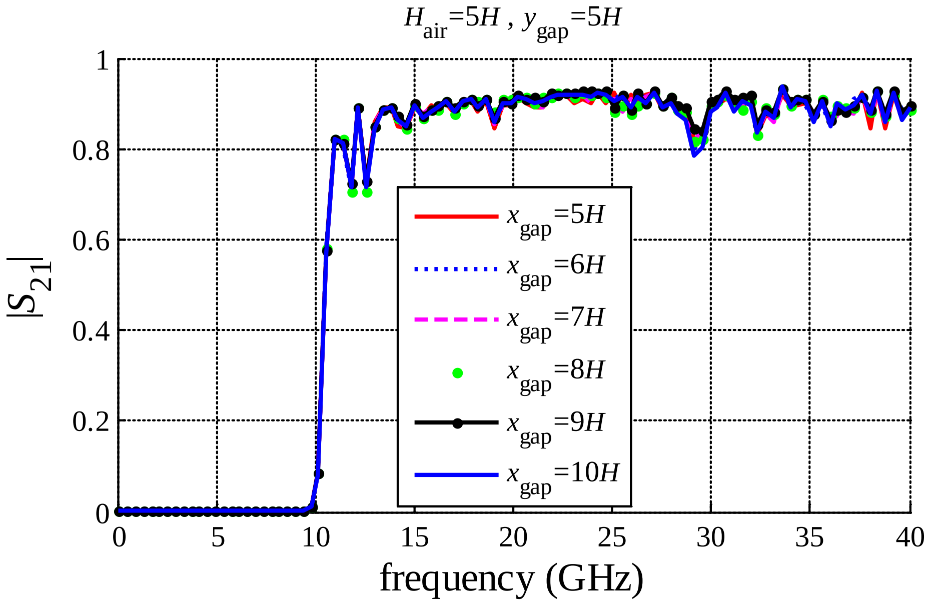
- Initial dimensions: $H_{\text{air}} = y_{\text{gap}} = x_{\text{gap}} = 5H$
- Procedure: Gradually increase each side until EM convergence is achieved



Simulation Bounding Box – x_{gap} Sweep







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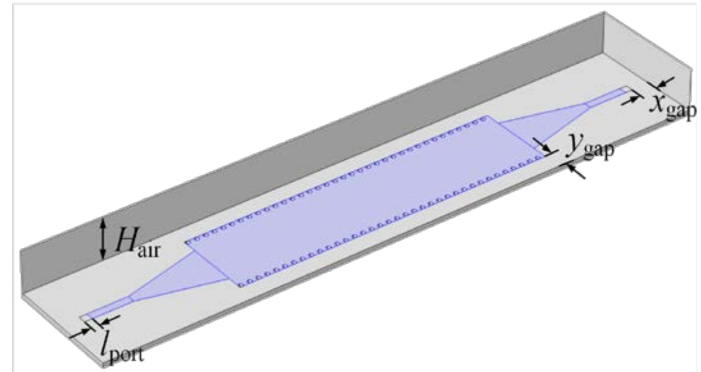
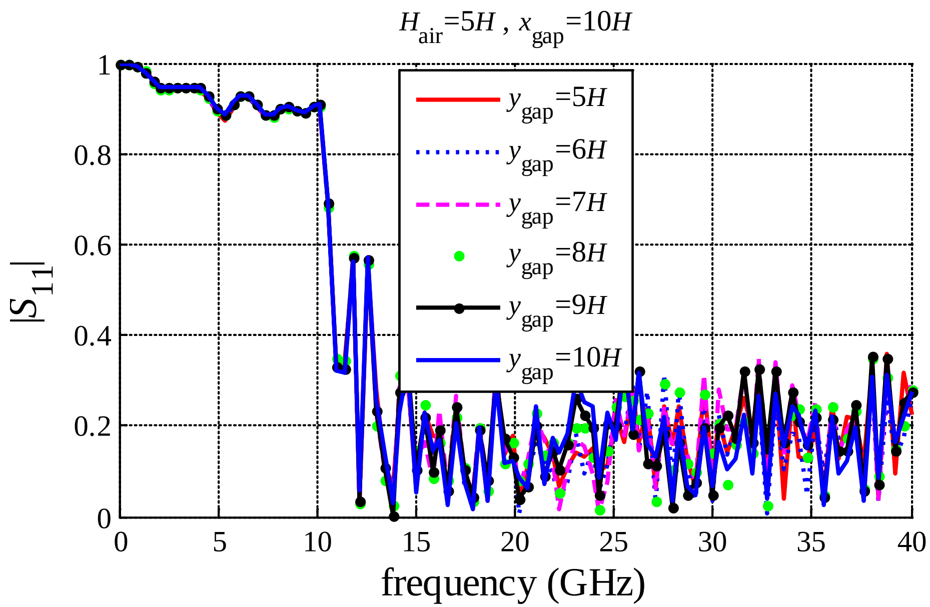
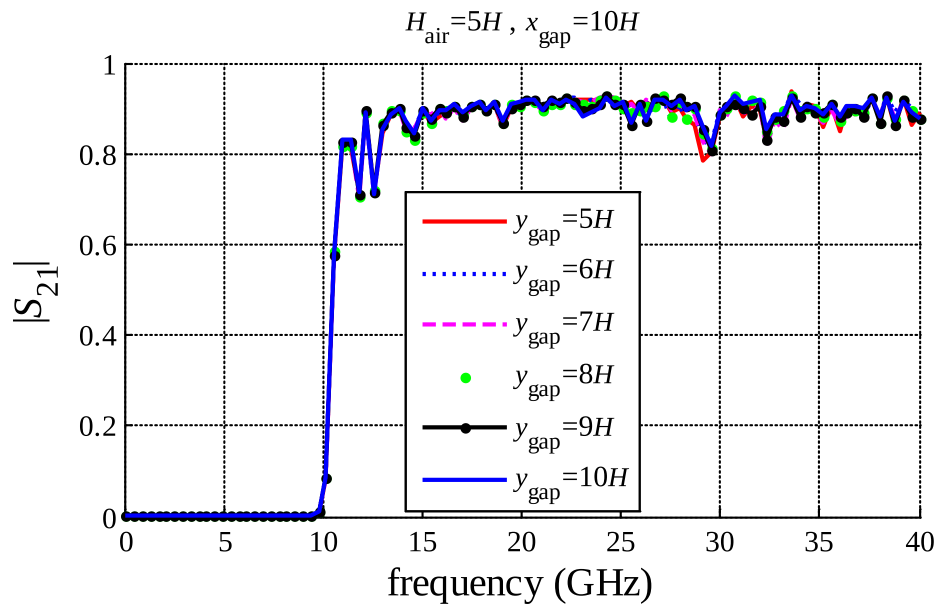
Simulation Bounding Box – y_{gap} Sweep







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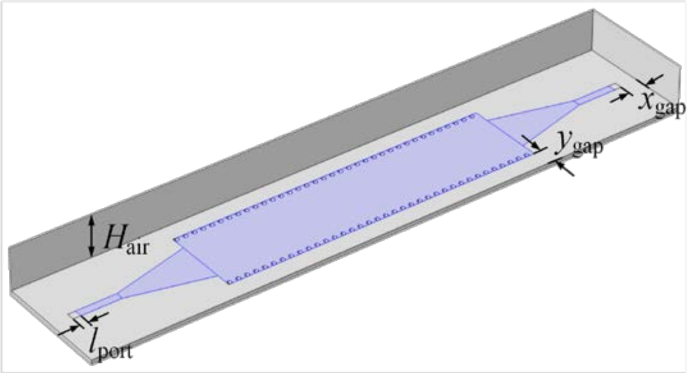
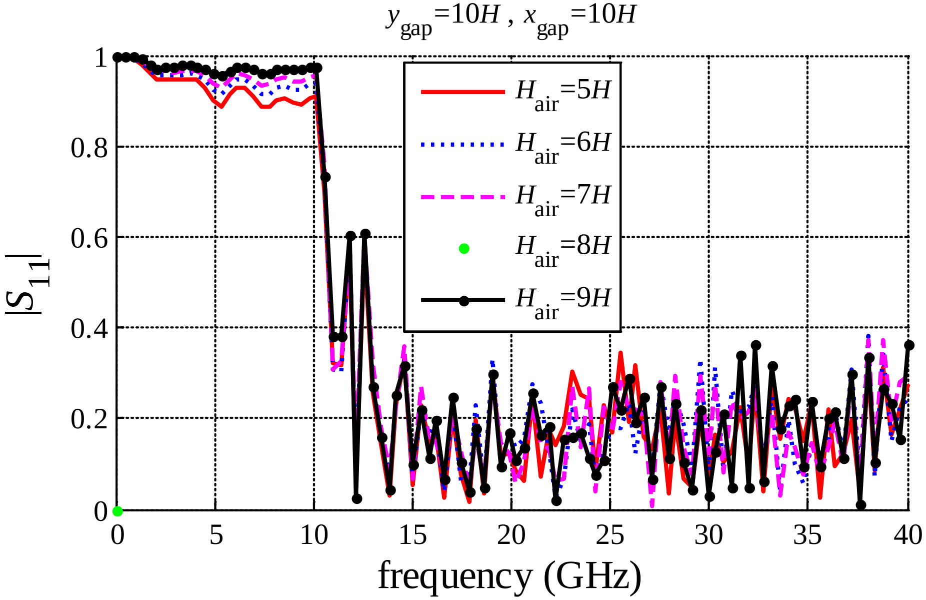
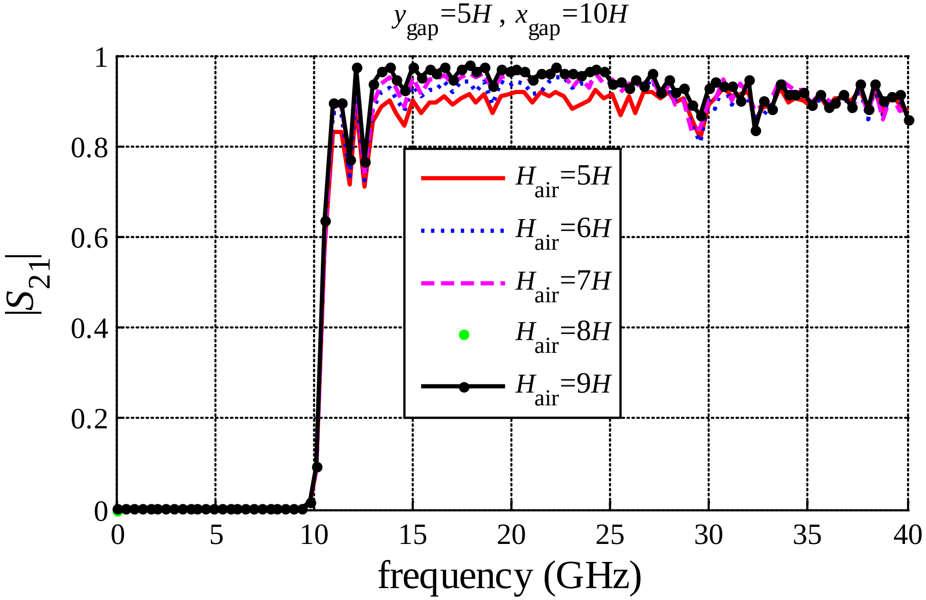
Simulation Bounding Box – H_{air} Sweep







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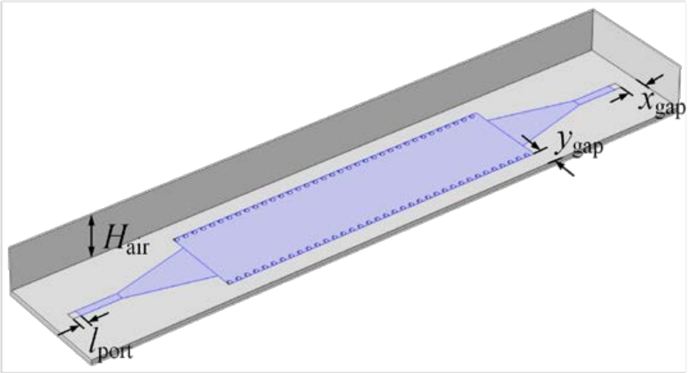
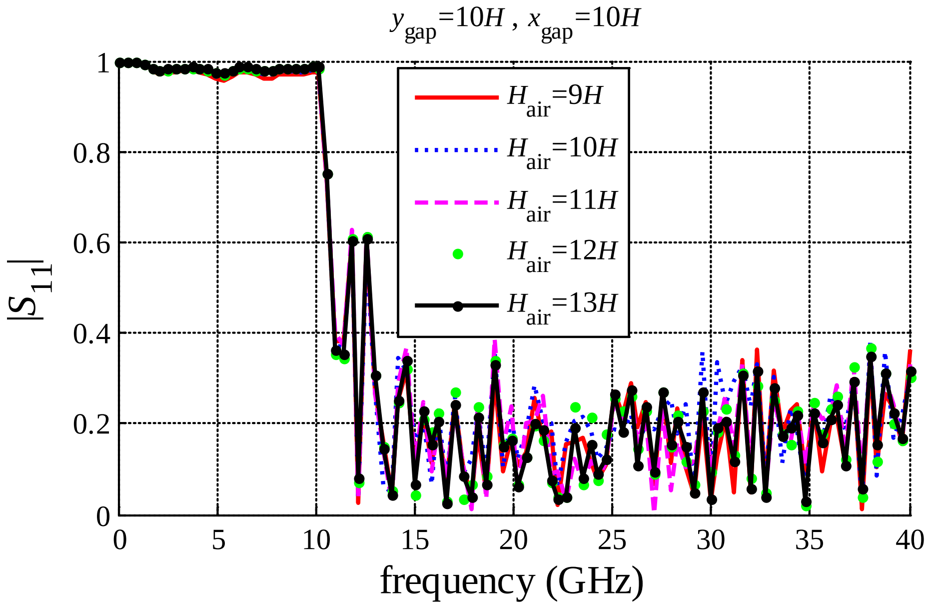
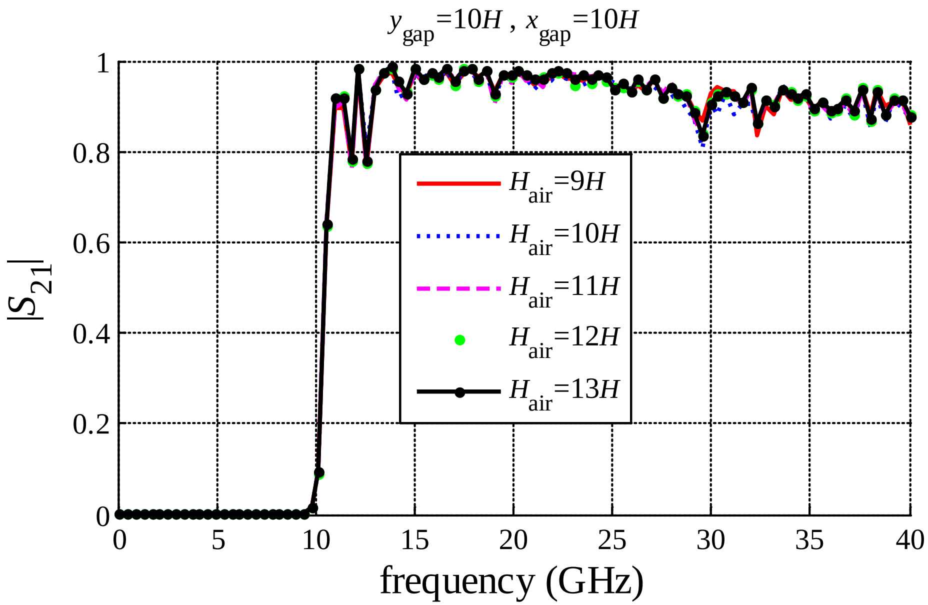
Simulation Bounding Box – H_{air} Sweep (cont.)







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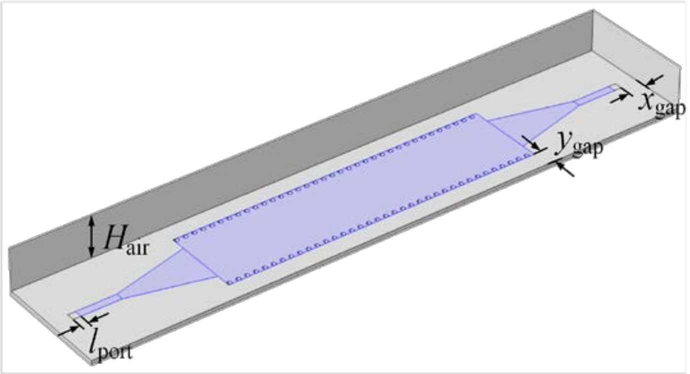
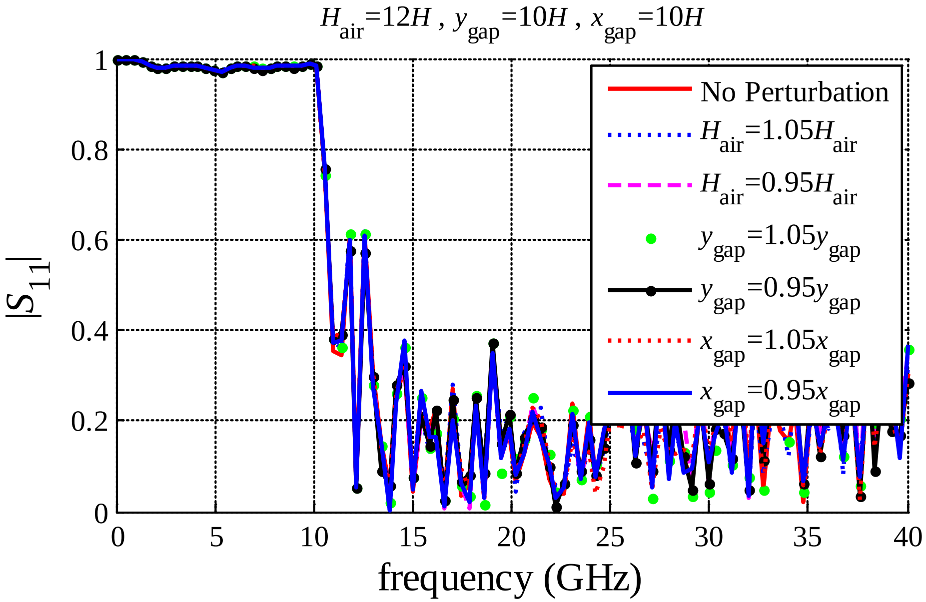
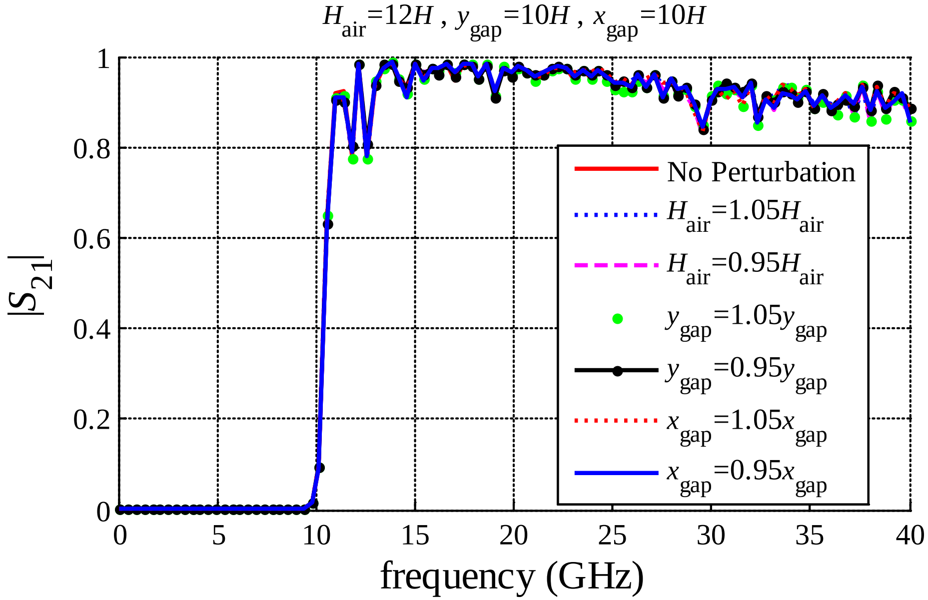
Box Perturbation Test

- $H_{\text{air}} = 12H, y_{\text{gap}} = x_{\text{gap}} = 10H$
- Final box ± 5%



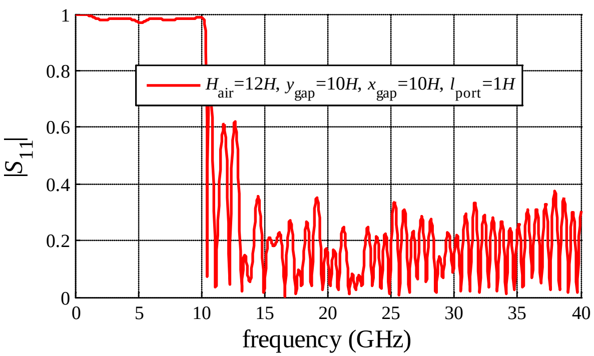


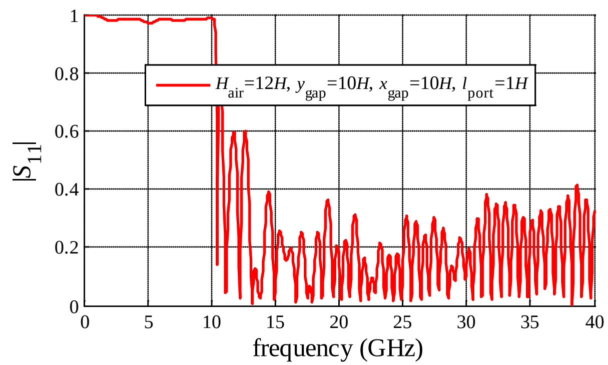


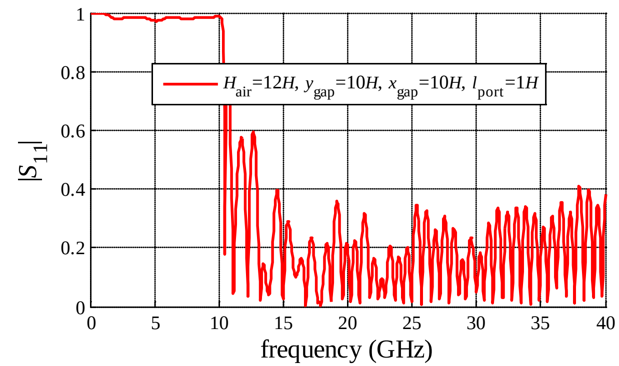
Final EM responses

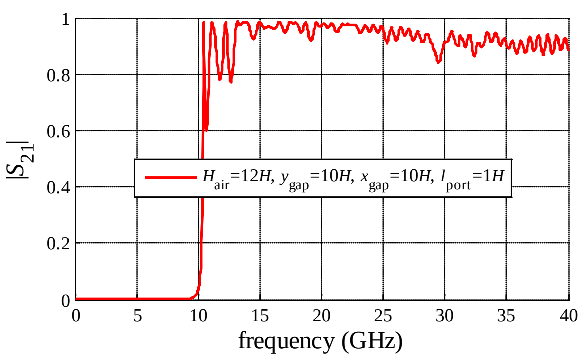
- $H_{air} = 12H$, $y_{gap} = x_{gap} = 10H$ with 1000 freq. points

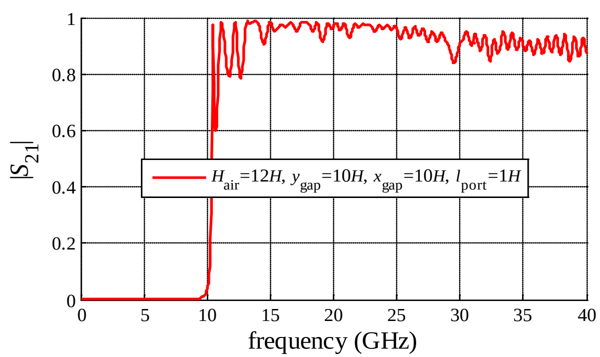
Resol 0	Resol 1	Resol 2

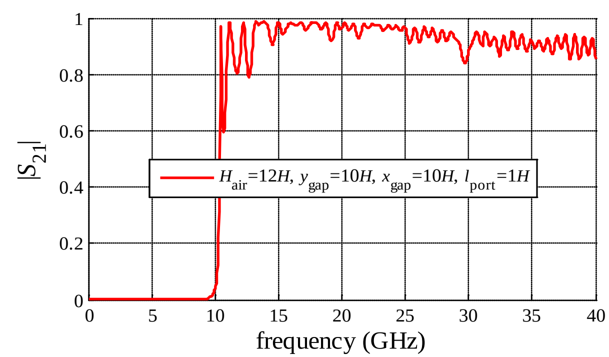












2h 23m	3h 40m	5h 22m

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Conclusions

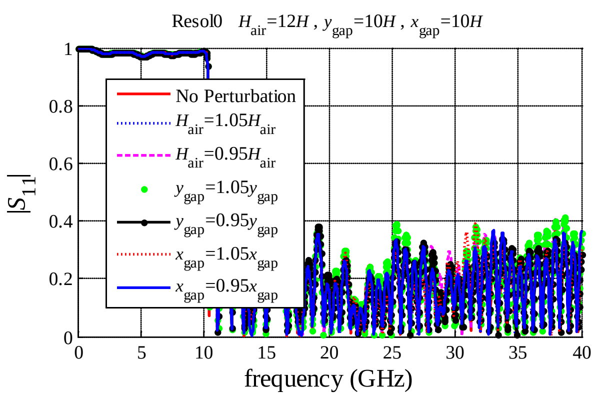
- We presented a procedure to configure COMSOL to achieve reliable EM responses for a SIW interconnect
- We focused on the meshing scheme and the simulation bounding box
- For the meshing scheme we divided the structure into five regions and we proposed three different resolution schemes
- For the simulation bounding box we increased each bounding box dimension until visually achieve EM convergence
- We perturbed the final simulation box and applied the same box to the three resolution schemes

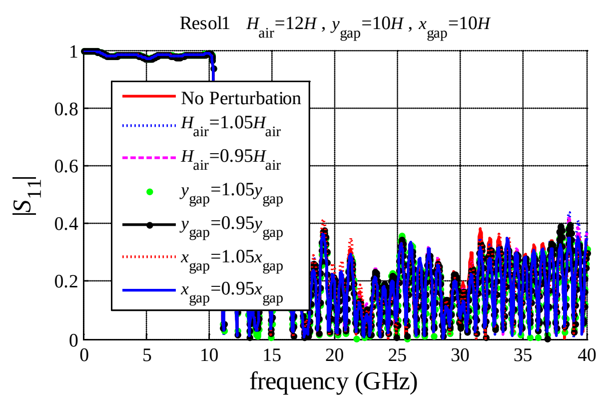
Backup Slides

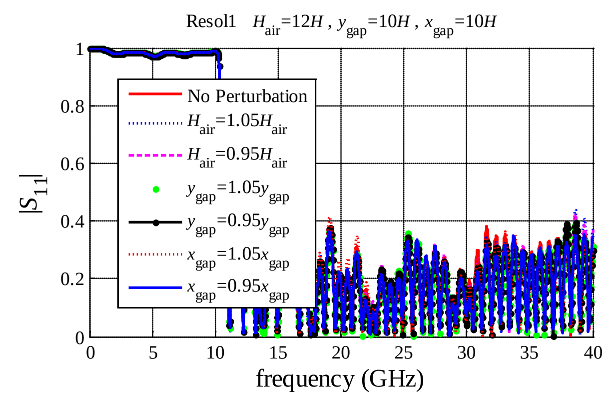
Perturbation Test

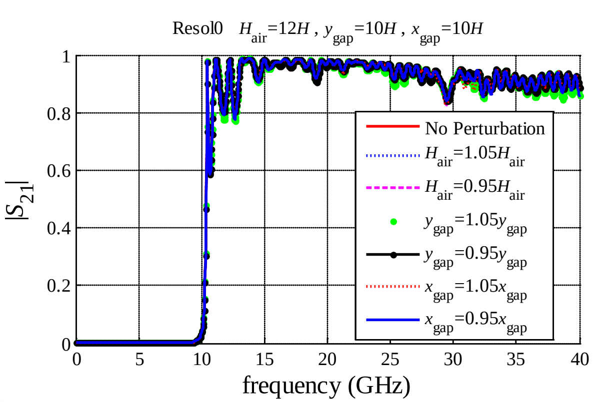
- $H_{\text{air}} = 12H$, $y_{\text{gap}} = x_{\text{gap}} = 10H$ with 1000 freq. points

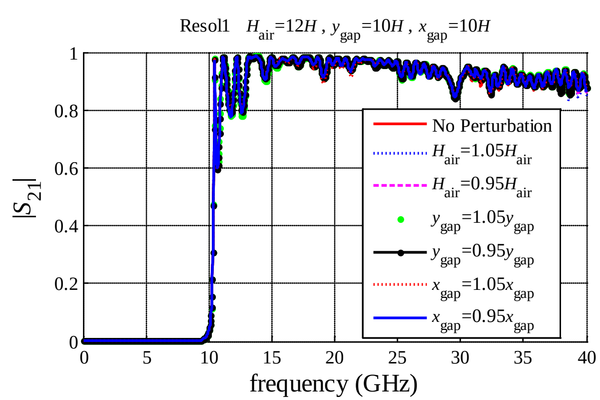
Resol 0 | Resol 1 | Resol 2

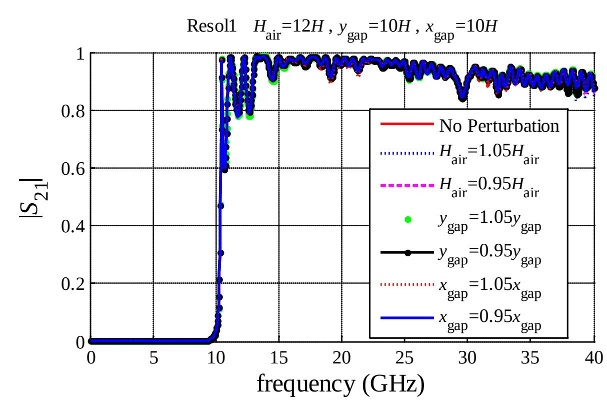












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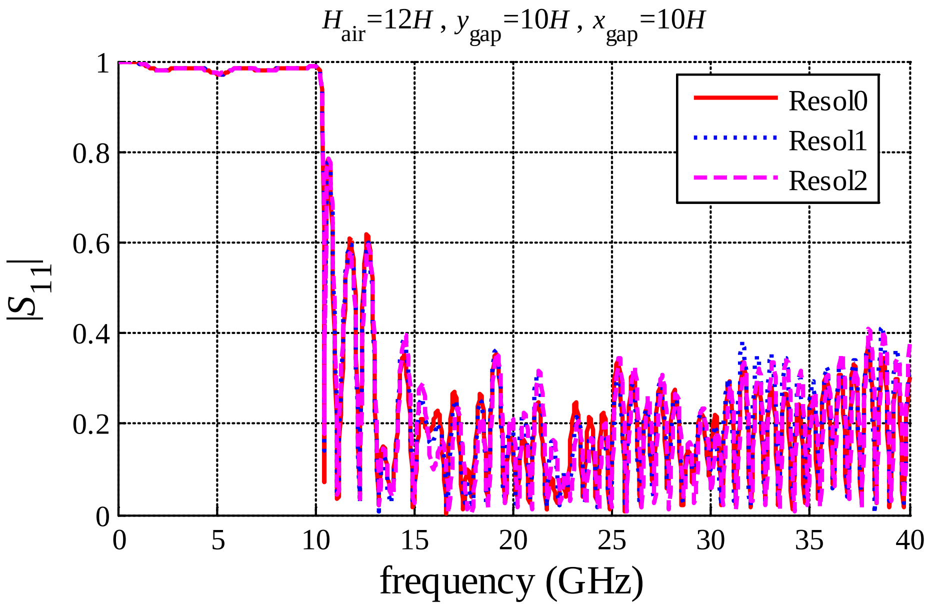
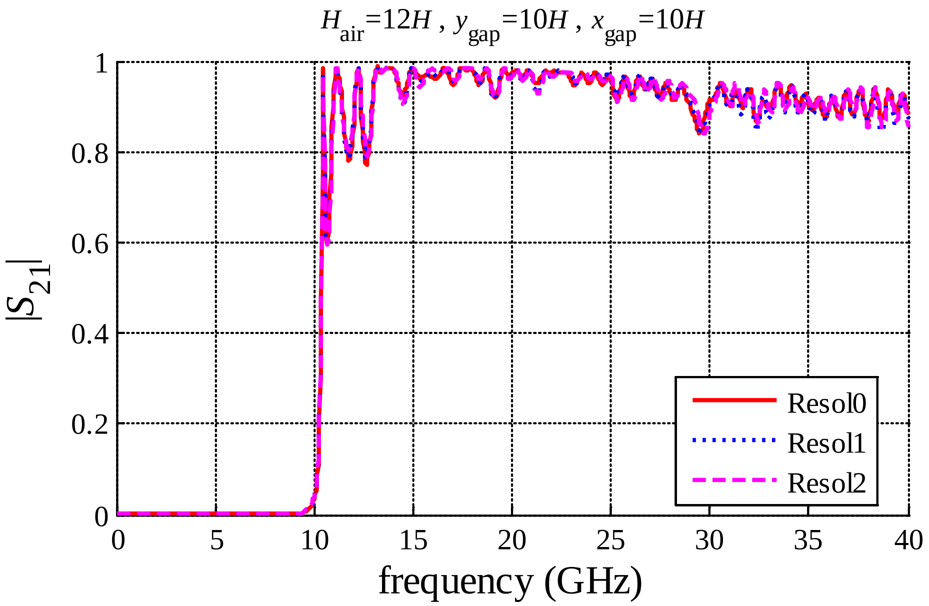
Final EM Responses Comparison





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