EM Simulation of a Low-Pass Filter Based on a Microstrip Defected Ground Structure Using COMSOL

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presented at
COMSOL Conference 2012, Boston, MA, October 4, 2012
Outline

- Introduction
- Low-pass filter based on defected ground structure (DGS) units
- Fine and coarse model implementations
- EM responses
- Comparisons with measured data
- Fields and radiation losses
- Conclusions
Introduction

- DGS units have been introduced as high-performance bandgap structures
- Enhanced DGS-based filters have been developed with very high attenuation and wide rejection bands
- However, radiation in DGS can be significant
- We implement fine and coarse models of a low-pass filter based on DGS units
Low-Pass Filter Based on DGS Units

\[
Z_0 = 0.107 \text{ pF} \\
3.67 \text{ nH} \\
2.33 \text{ pF} \\
0.107 \text{ pF}
\]

\( (\text{Ahn et. al. 2001}) \)
Fine Model Implementation

- High-mesh resolution
- 48,542 elements in mesh
- 57min (100 frequency points)

- Lossy microstrips and ground plane
- Lossy dielectric
Coarse Model Implementation

- Lossless microstrips and ground plane
- Lossless dielectric
- Low-mesh resolution
- 3,269 elements in mesh
- 53s (50 frequency points)
EM Responses

<table>
<thead>
<tr>
<th>$\text{S}_{21}$ (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
</tr>
<tr>
<td>Coarse</td>
</tr>
<tr>
<td>Fine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\text{S}_{11}$ (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
</tr>
<tr>
<td>Coarse</td>
</tr>
<tr>
<td>Fine</td>
</tr>
</tbody>
</table>
Comparison with Measured Data


(Ahn et. al. 2001)
Electric Field, $E \, (V/m)$

Open stub

Narrow etched aperture
(input port side)

$|S_{21}|$ Fine

$|S_{11}|$ Fine

0 2 4 6 8 10

-40
-30
-20
-10
0

Frequency (GHz)

(dB)

$S_{21}$ Fine

$S_{11}$ Fine

$\nabla \ 0.0109$

$\Delta \ 1.9397 \times 10^4$
Electric Field, $E \, (V/m)$ (cont.)

(5.5 GHz)

- Open stub
- Narrow etched aperture (input port side)

Frequency (GHz)

<table>
<thead>
<tr>
<th>$S_{21}$</th>
<th>Fine</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{11}$</td>
<td>Fine</td>
</tr>
</tbody>
</table>

- 0.0109
- $7.4583 \times 10^4$
Electric Field, $E$ (V/m) (cont.)

(10 GHz)

open stub

narrow etched aperture
(input port side)

$|S_{21}|$ Fine
$|S_{11}|$ Fine

$\nabla 0.0391$

$\Delta 7.4583 \times 10^4$
Power Flow

\[ S = E \times H \quad \text{(W/m}^2\text{)} \]

(0.1 GHz)  
(5.5 GHz)
Power Flow (cont.)

\[ S = E \times H \quad (\text{W/m}^2) \]

(10 GHz)
Radiation Loss

Upper scattering plane

Bottom scattering plane

Normalized radiation losses

1. $L_{\text{total}}$
2. $L_{\text{upper}}$
3. $L_{\text{bottom}}$
Conclusions

- We analyzed a low-pass filter based on DGS units
- Coarse and fine models were implemented
- The coarse model is a good representation of the fine model over certain frequency interval
- Coarse model reduces significantly simulation time (approximately 35 times faster)
- Fine model results are in excellent agreement with measured data
- Large radiation loss is the main disadvantage of the defected ground technique
Backup Slides
Low-Pass Filter (cont.)

\[ g = 0.5 \text{ mm} \]
\[ W = 2.4 \text{ mm} \]
\[ a = 5 \text{ mm} \]
\[ b = 5 \text{ mm} \]
\[ W_c = 5 \text{ mm} \]
\[ P_c = 6 \text{ mm} \]
\[ H = 0.787 \text{ mm} \]

(Ahn et. al. 2001)
Meshing

- Coarse and fine model meshing based on $\lambda_a$ and $\lambda_m$

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fine model</th>
<th>Coarse model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta_{\text{max-air}}, \delta_{\text{max-sub}}$</td>
<td>$\lambda_a/5, \lambda_m/20$</td>
<td>$\lambda_a/2, \lambda_m/4$</td>
</tr>
<tr>
<td>$\delta_{\text{min-air}}, \delta_{\text{min-sub}}$</td>
<td>$\lambda_a/50, \lambda_m/200$</td>
<td>$\lambda_a/20, \lambda_m/40$</td>
</tr>
<tr>
<td>Number of elements in mesh</td>
<td>48,542</td>
<td>3,269</td>
</tr>
<tr>
<td>Number of degrees of freedom</td>
<td>398,890</td>
<td>21,922</td>
</tr>
<tr>
<td>Frequency points</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Simulation time</td>
<td>57min 24s</td>
<td>53s</td>
</tr>
</tbody>
</table>

- FEM COMSOL solver (ver. 4.3)
- Platform Dell XPS8300 Intel Core i7-2600 at 3.4 GHz and 16 GB RAM
Fine Model Implementation

\[ H_{\text{air}1} = 10H \]
\[ H_{\text{air}2} = 10H \]
\[ y_{\text{gap}} = 6W \]
\[ L = W_c + 2a + 8W \]

\[ W_{\text{port}} = 6W \]
\[ H_{\text{port}} = 8H \]

\[ \varepsilon_r = 2.94 \]
\[ \tan(\delta) = 0.0009 \]
\[ \sigma = 5.8 \times 10^7 \text{ S/m} \]
\[ t = 0.65 \text{ mil} \]
Coarse Model Implementation

\[
H_{\text{air1}} = 10H \\
H_{\text{air2}} = 10H \\
y_{\text{gap}} = 6W \\
L = W_c + 2a + 8W
\]

\[
x_{\text{gap}} = 0.9W
\]

\[
\varepsilon_r = 2.94 \\
\tan(\delta) = 0 \\
\sigma = \infty \text{ S/m} \\
t = 0 \text{ mil}
\]
Power Loss Prediction

![Graph showing power loss prediction](image)

- **Coarse 2** (dotted line)
- **Fine** (solid line)

- Frequency (GHz) on the x-axis
- $1 - |S_{11}|^2 - |S_{21}|^2$ on the y-axis