Mode Conversion Due To Residual Via Stubs in Differential Signaling

Jonathan Cedeño-Chaves (jcedeno@estudiantec.cr), Katharina Scharff, Allan Carmona-Cruz, Heinz-Dietrich Brüns, Renato Rimolo-Donadio, and Christian Schuster

Costa Rica Institute of Technology :: Department of Electronics Engineering
Hamburg University of Technology :: Institute of Electromagnetic Theory

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Motivation

- Mode conversion is an important degradation cause in differential links.
- Asymmetries on interconnects for differential signaling lead to mode conversion.
Motivation

• Analysis of a different source of mode conversion: via stub mismatch.

• Back-drilling process can get tolerances of around 10 mil.

• Can asymmetrical via stub length lead to a significant amount of mode conversion?

→ How important is to consider the residual via stubs mismatch in differential signaling?
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Case of Study

• Asymmetrical via stubs are present at the differential Port 01. This can lead to mode conversion!

• Full-wave simulation model.
• Model has been implemented in an 8-cavity stackup, routed with differential stripline in cavity 2.

• Simulations were validated with FIT and FEM methods.
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Mode Conversion Due to Asymmetrical Via Stubs

Stub effect at the Port 01 (-) results in a timing asymmetry in the differential pair – skew converted into common-mode signals.
Mode Conversion Due to Asymmetrical Via Stubs

- Important magnitude (~100 mV) of common-mode signals are induced by a stub effect asymmetry!
Mode Conversion Due to Asymmetrical Via Stubs

- Mode conversion magnitude has a direct relation with the differential via asymmetry.
- Symmetrical cases (regardless via stub length) present very low mode conversion levels (noise floor)
Differences on the differential via stubs in the order of back-drilling residual tolerances can lead to important amount of mode conversion.

Around 30 GHz, mode conversion can reach a magnitude of around -10 dB.
Mode Conversion Due to Asymmetrical Via Stubs

- As the frequency increases, magnitude of mode conversion increases as well, reaching high levels for relatively small asymmetries.
- Within the range of typical cavity thicknesses (~10-20 mils), the impact of the stub asymmetry can lead to mode conversion levels up to -25 dB.
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• A low-frequency estimation can be applied, considering the via stub as a shunt capacitor.
Estimation of Mode Conversion for Residual Via Stubs

• For both sides of the link, there exits residual via stubs:
Estimation of Mode Conversion for Residual Via Stubs

• 4-port system can be described in terms of mixed-mode S-parameters.

• $C_{shunt}$ for both sides, can be approximated as:

$$C \approx \frac{l_{stub}}{v_{ph} \cdot Z_{via}}$$

<table>
<thead>
<tr>
<th>Reference Case [mil]</th>
<th>Fundamental Frequency - @2.5 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FIT [dB]</td>
</tr>
<tr>
<td>$\Delta l_{stub} = 22$</td>
<td>-30.33</td>
</tr>
<tr>
<td>$\Delta l_{stub} = 14$</td>
<td>-34.51</td>
</tr>
<tr>
<td>$\Delta l_{stub} = 6$</td>
<td>-42.11</td>
</tr>
<tr>
<td>$\Delta l_{stub} = 2$</td>
<td>-52.44</td>
</tr>
</tbody>
</table>
Estimation of Mode Conversion for Residual Via Stubs

- In time domain, this estimation can be reflected as follows:

\[ f_{\text{max}} = 5 \, \text{GHz}, \quad t_r = 100 \, \text{ps} \]
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Conclusions and Outlook

• Asymmetrical via stubs can be an important source of mode conversion.

• Stub length differences within typical tolerances of back-drilling can induce a maximum mode conversion over -20 dB.

• A low-frequency approximation was used to estimate the amount of mode conversion as a function of the via stub length asymmetry.

• Further investigations can address a comparative analysis against other known sources, e.g. asymmetrical ground via configurations, and the effect of multiple via stub asymmetries.
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Backup
Estimation of Mode Conversion for Residual Via Stubs

- In time domain, this estimation can be reflected as follows:

\[ f_{\text{max}} = 20 \text{ GHz}, t_r = 25 \text{ ps} \]