Mode Conversion Due To Residual Via Stubs in Differential Signaling

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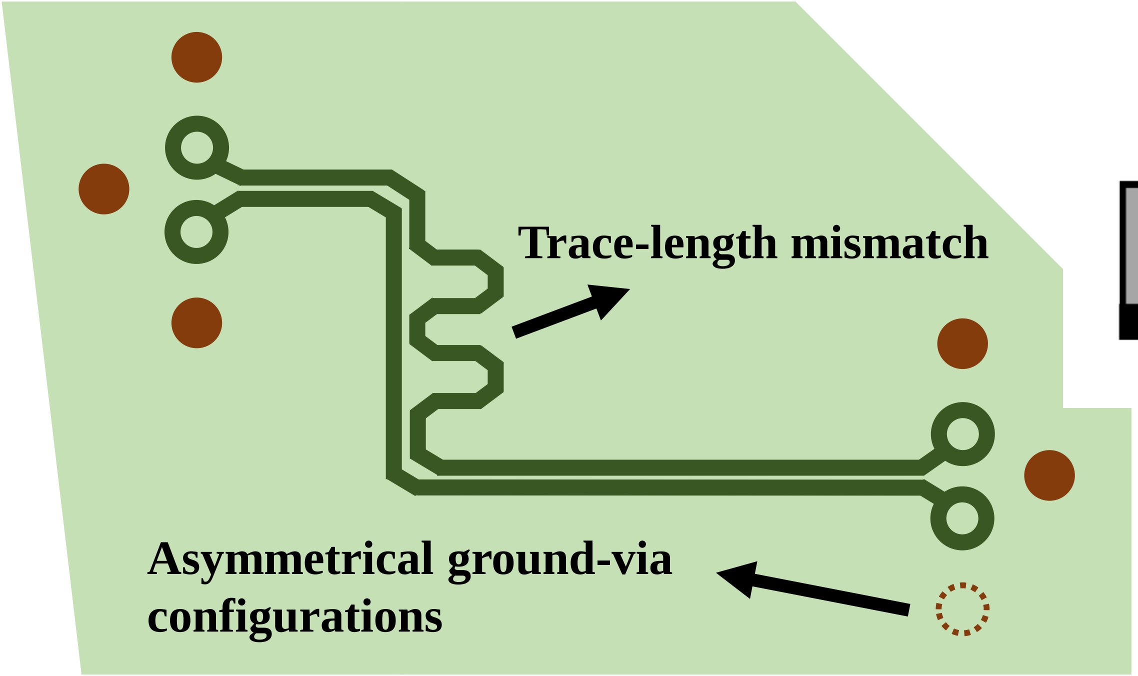
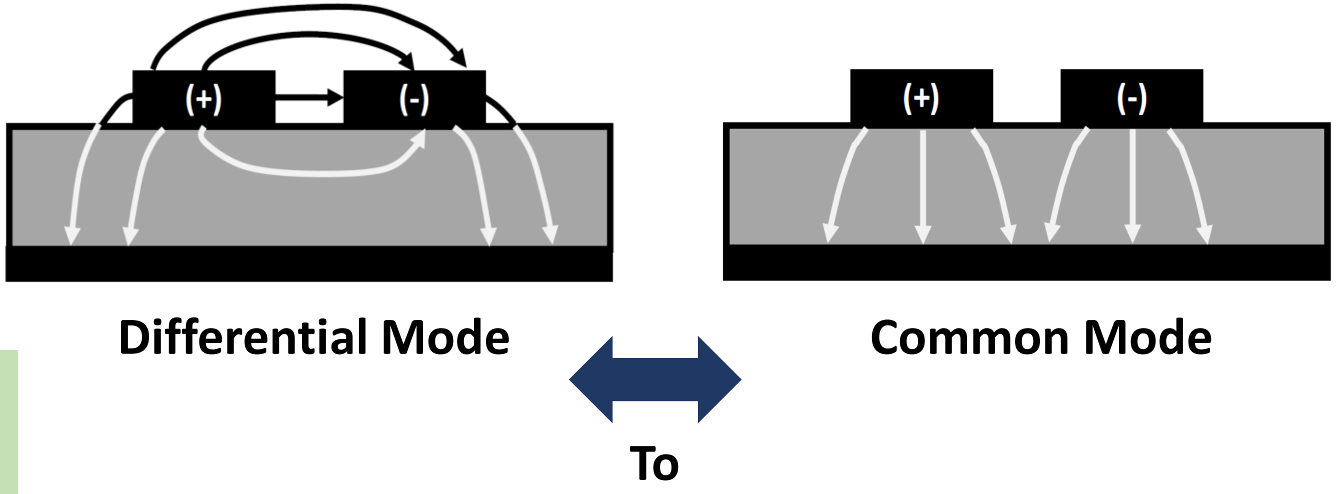
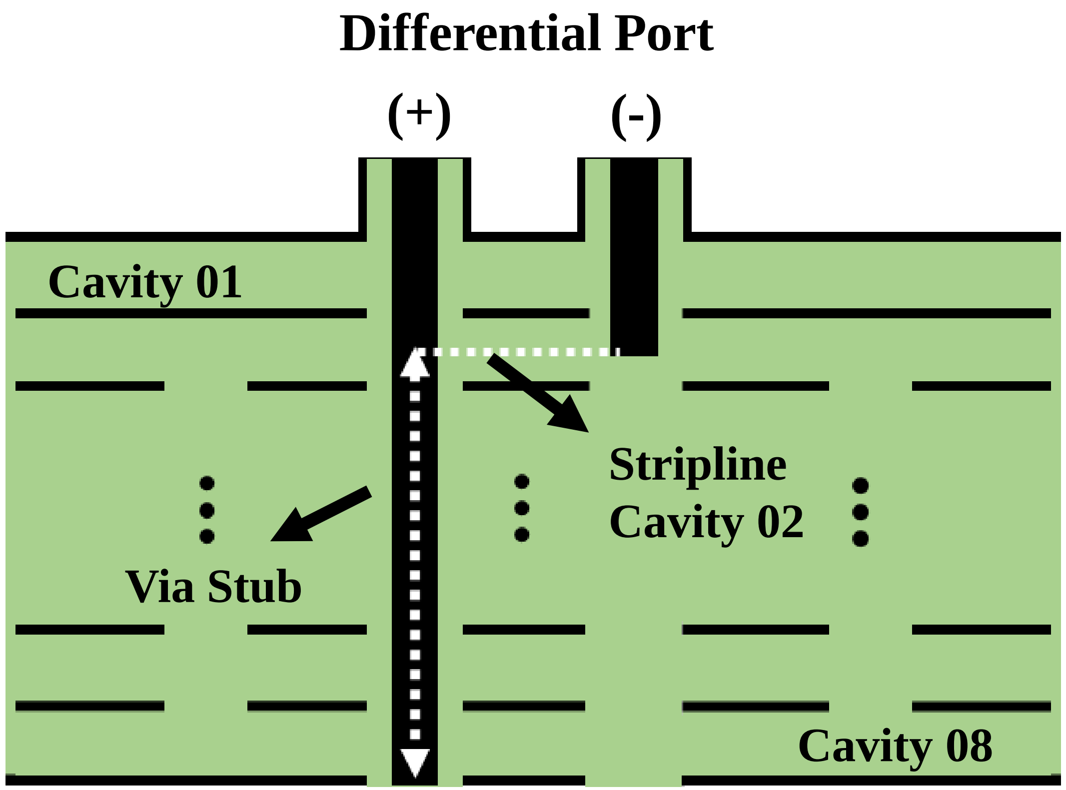
Motivation

- 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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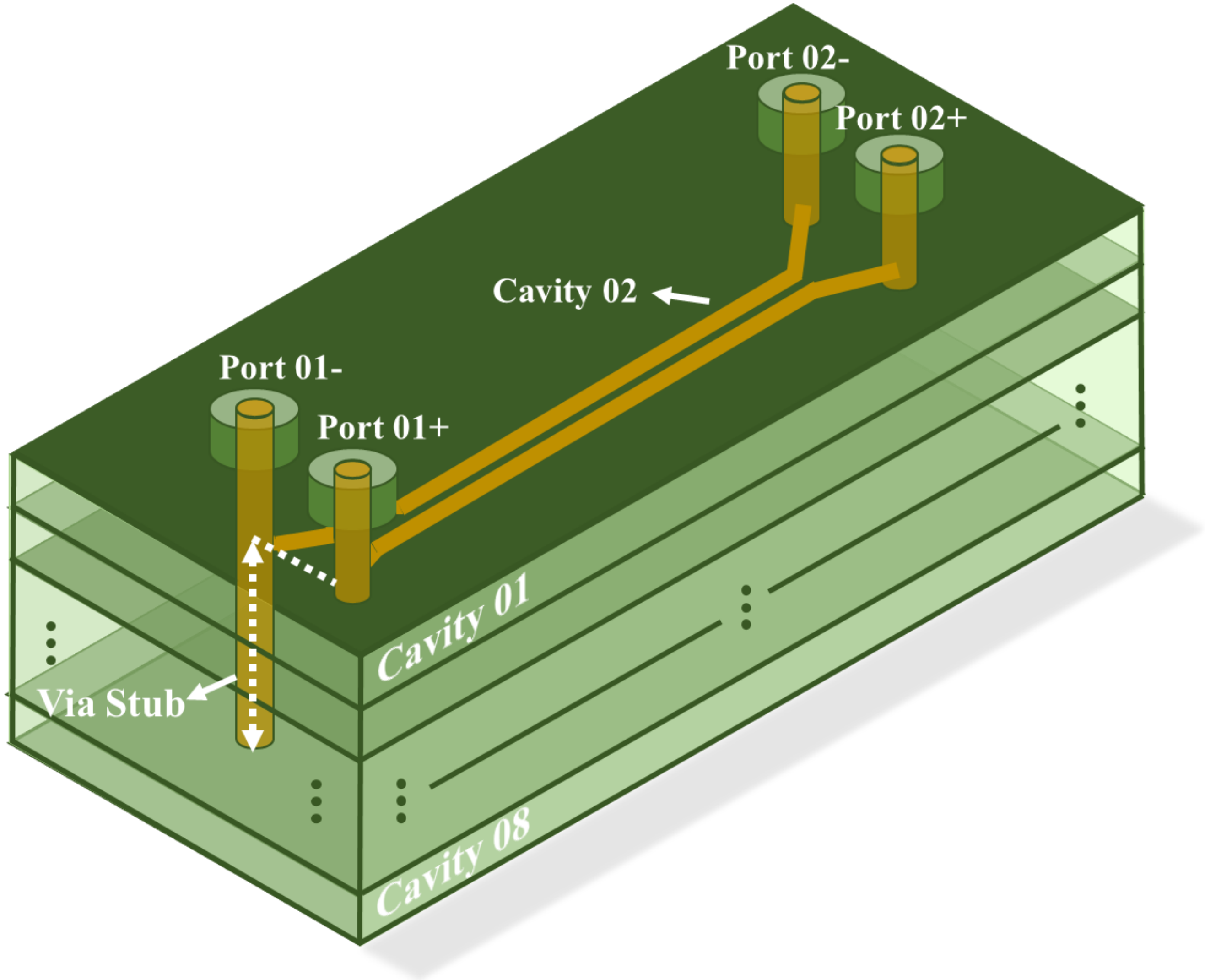
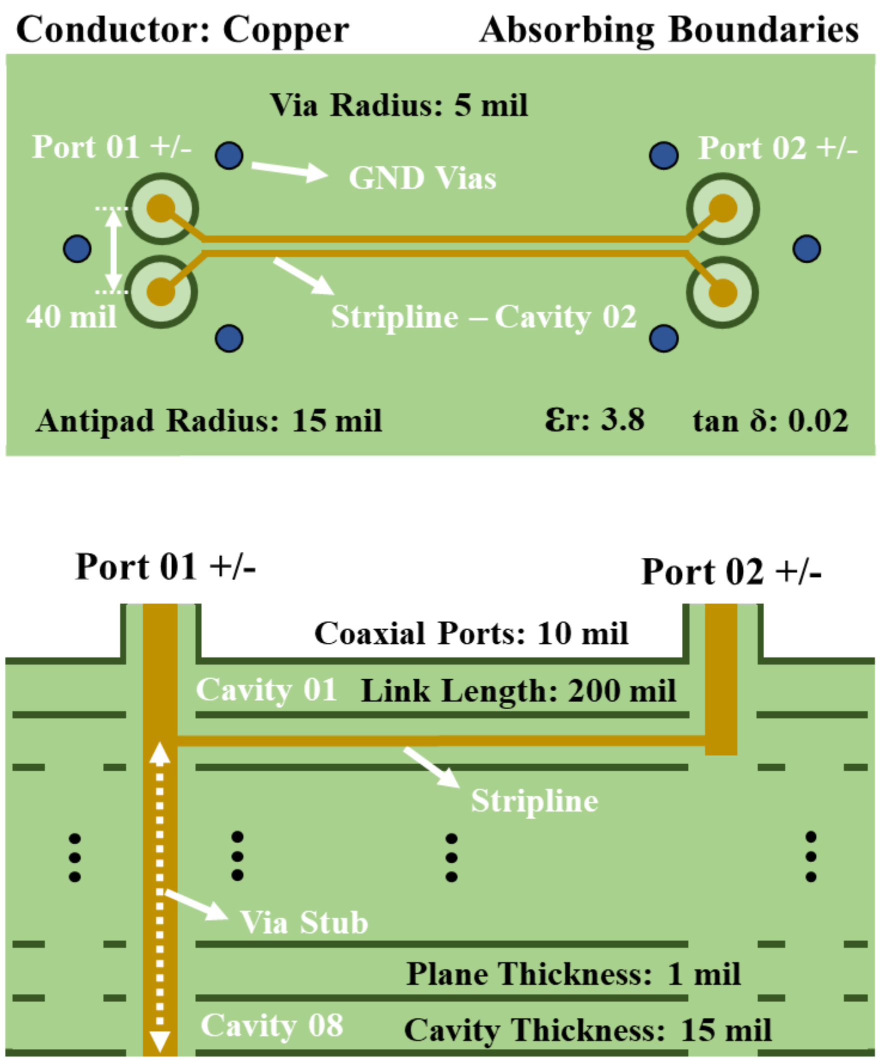
Case of Study



- Asymmetrical via stubs are present at the differential Port 01. This can lead to mode conversion!
- Full-wave simulation model.

Case of Study



- 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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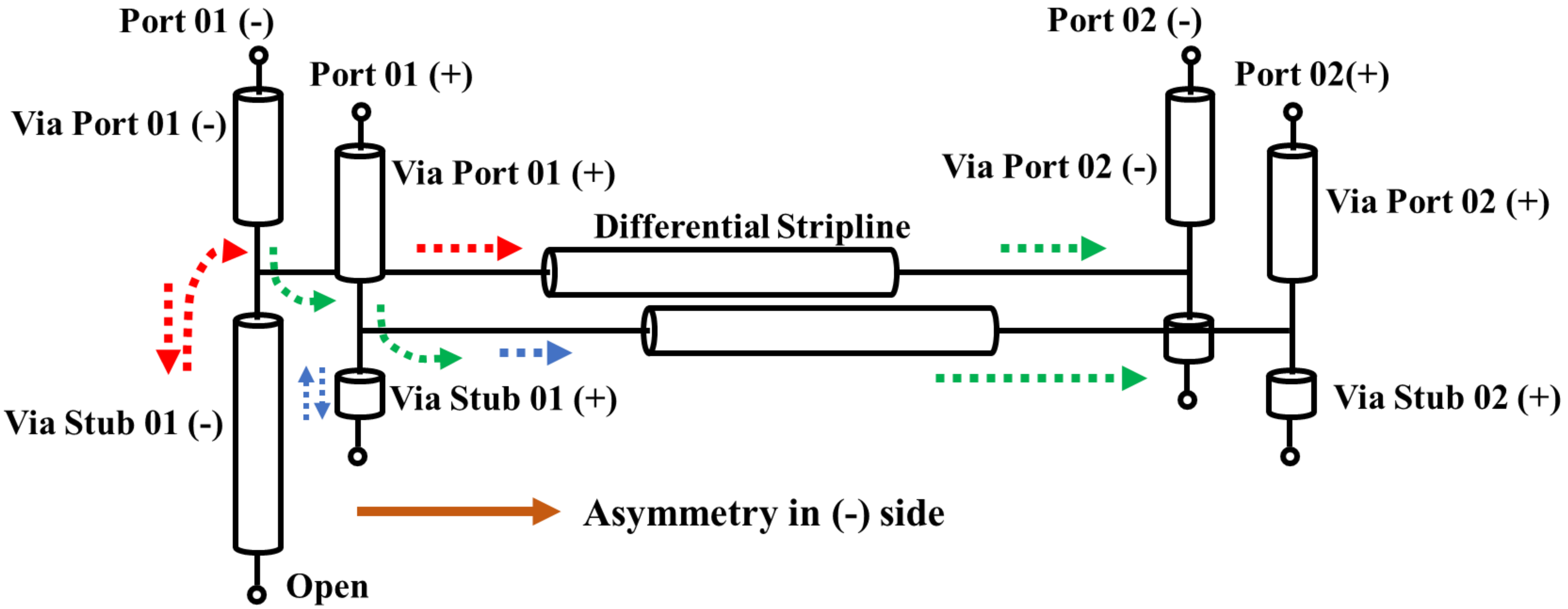
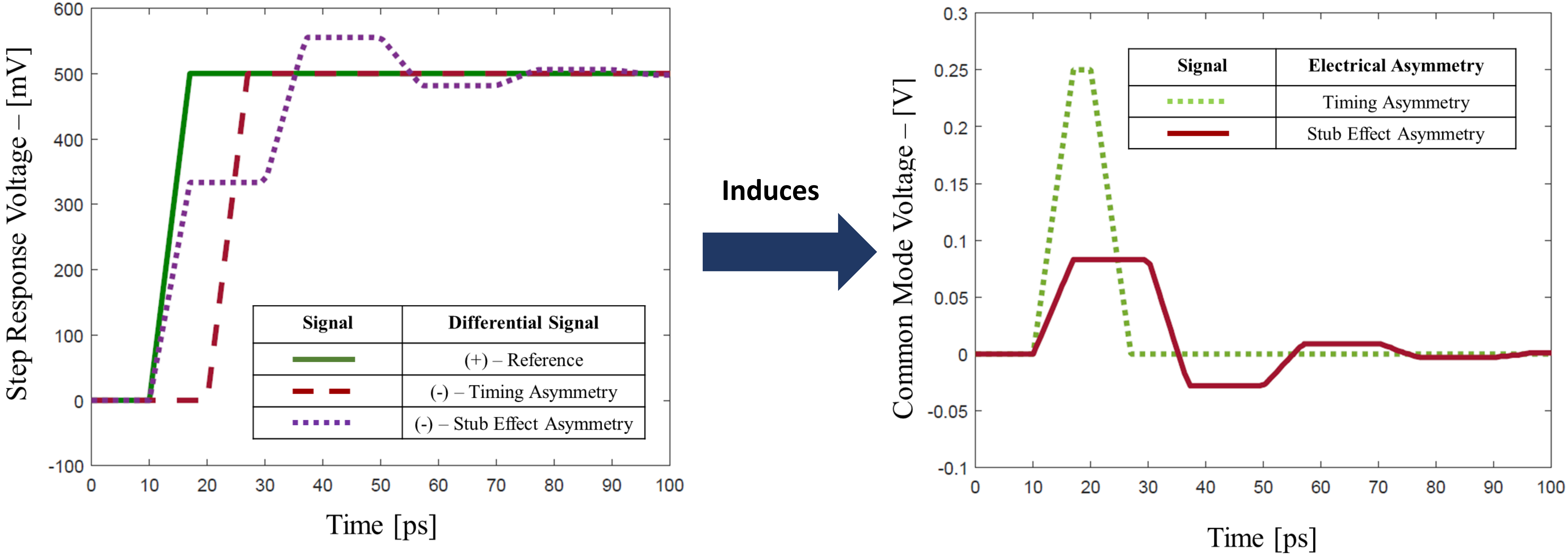
Mode Conversion Due to Asymmetrical Via Stubs



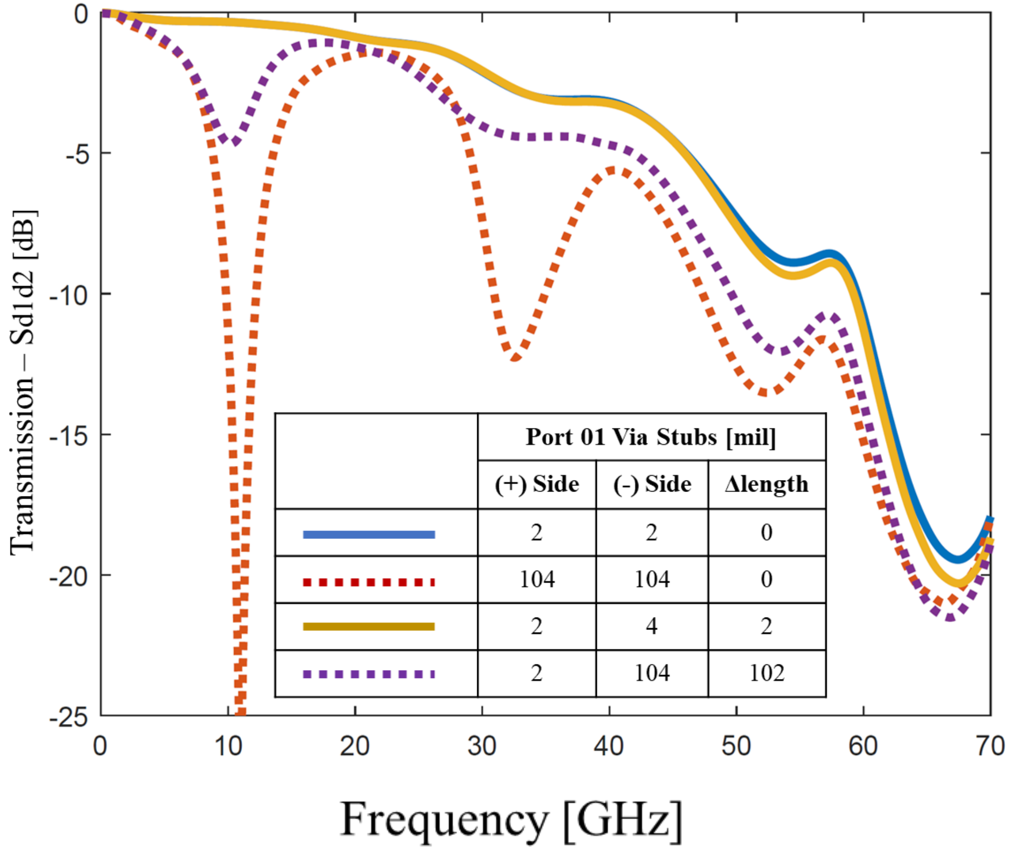
Stub effect at the Port 01 (-) results in a timing asymmetry in the differential pair – skew converted into common-mode signals.

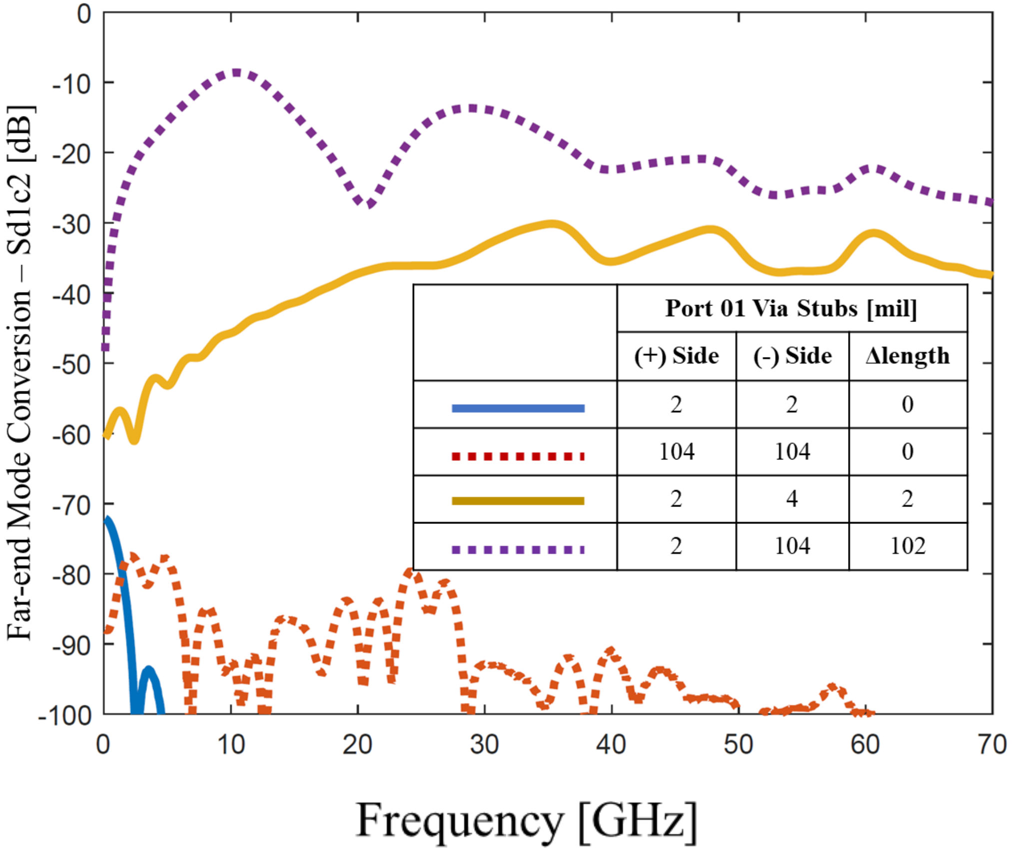
Mode Conversion Due to Asymmetrical Via Stubs



- Important magnitude (~100 mV) of common-mode signals are induced by a stub effect asymmetry!

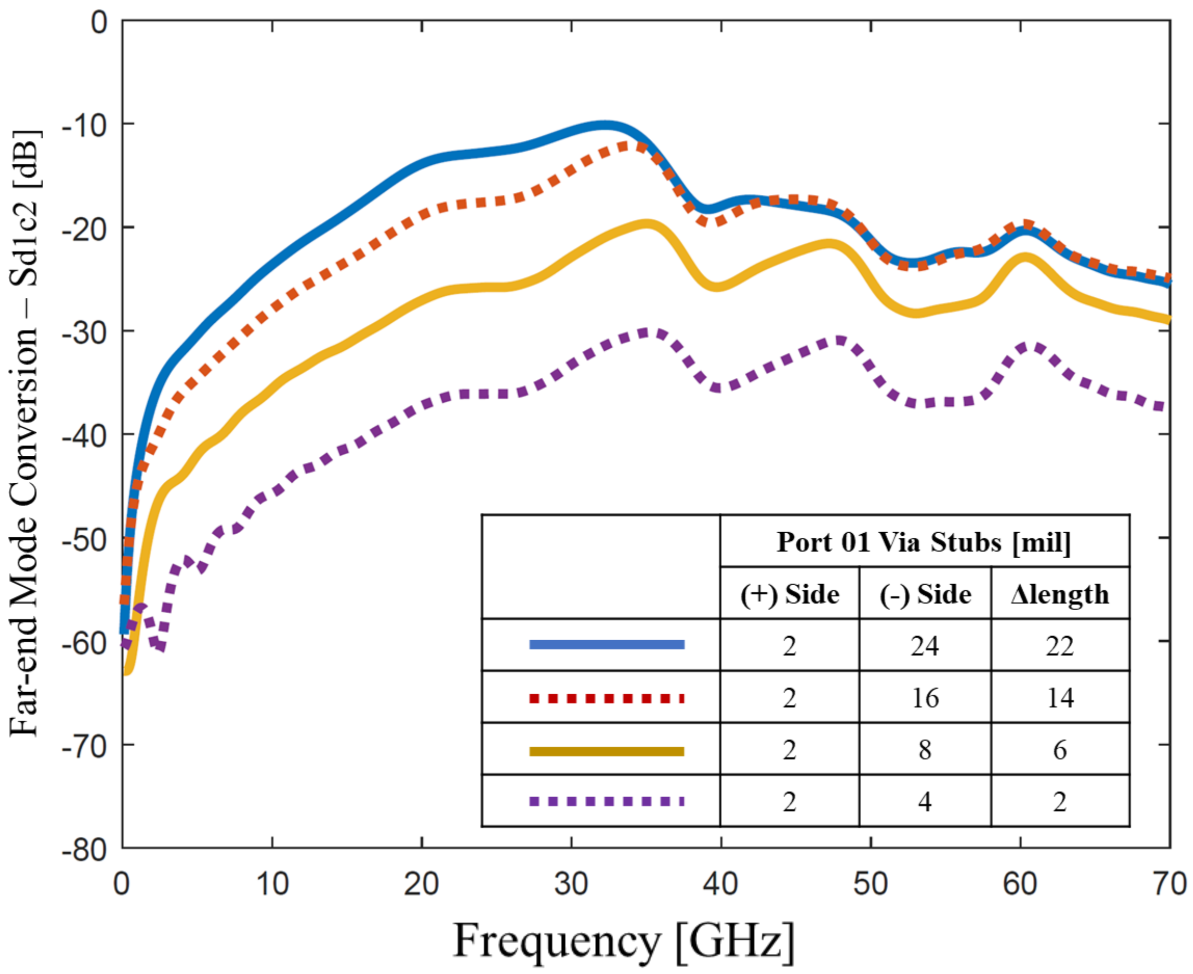
Mode Conversion Due to Asymmetrical Via Stubs





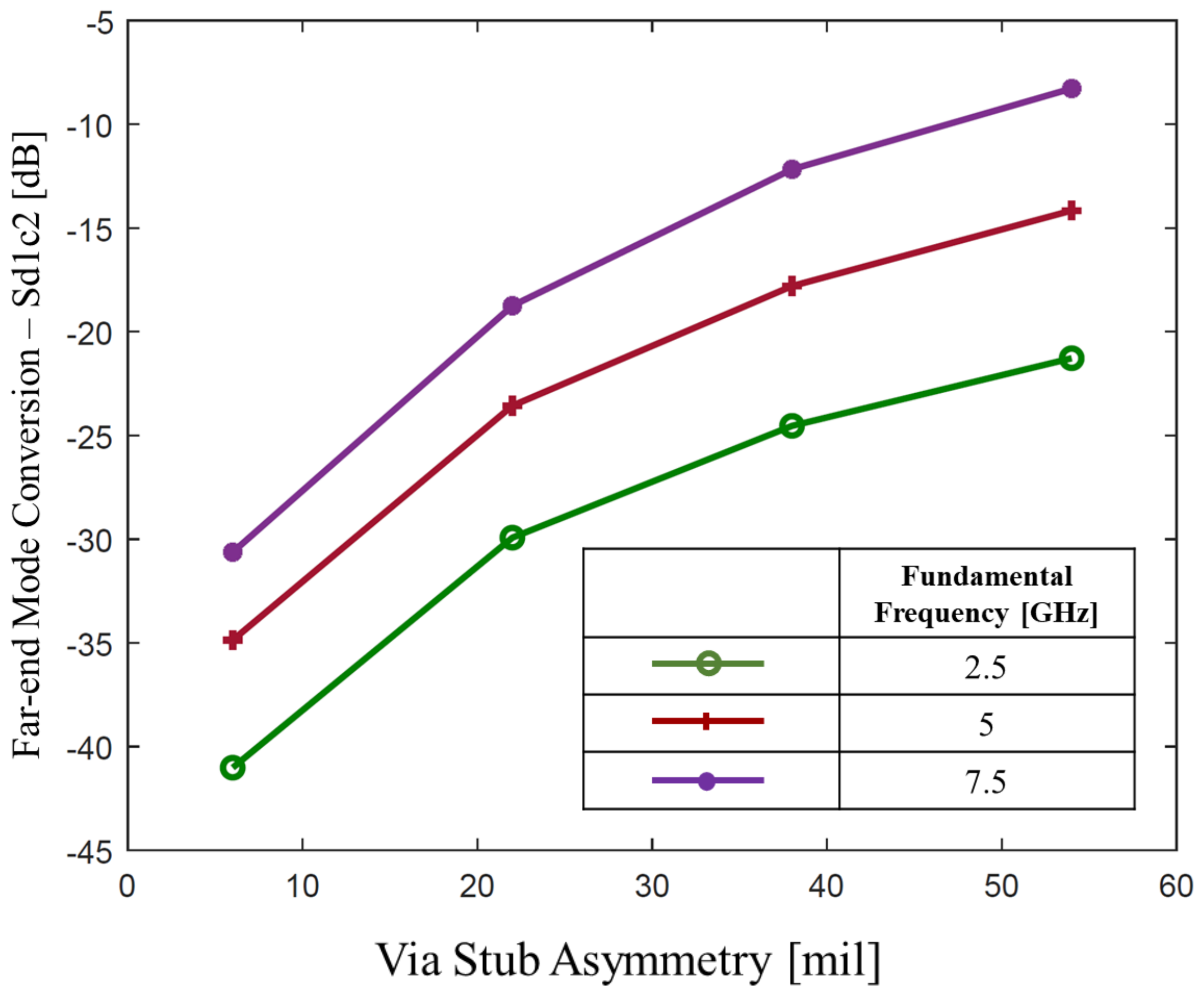
- Mode conversion magnitude has a direct relation with the differential via asymmetry.
- Symmetrical cases (regardless via stub length) present very low mode conversion levels (noise floor)

Mode Conversion Due to Asymmetrical Via Stubs



- 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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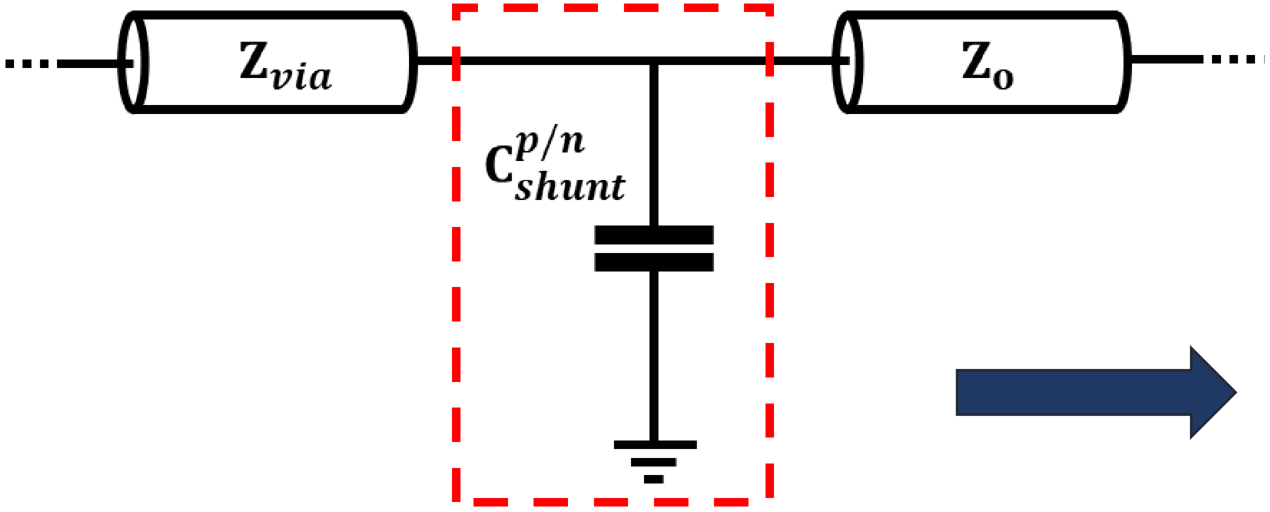
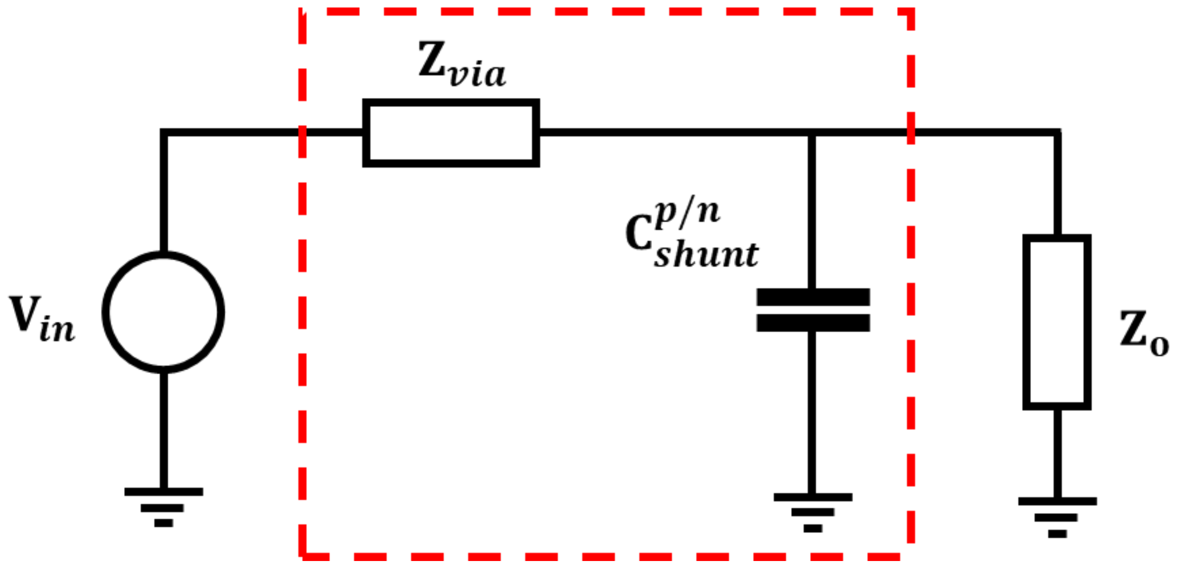
Estimation of Mode Conversion for Residual Via Stubs

- A low-frequency estimation can be applied, considering the via stub as a shunt capacitor.

Via Stub Representation

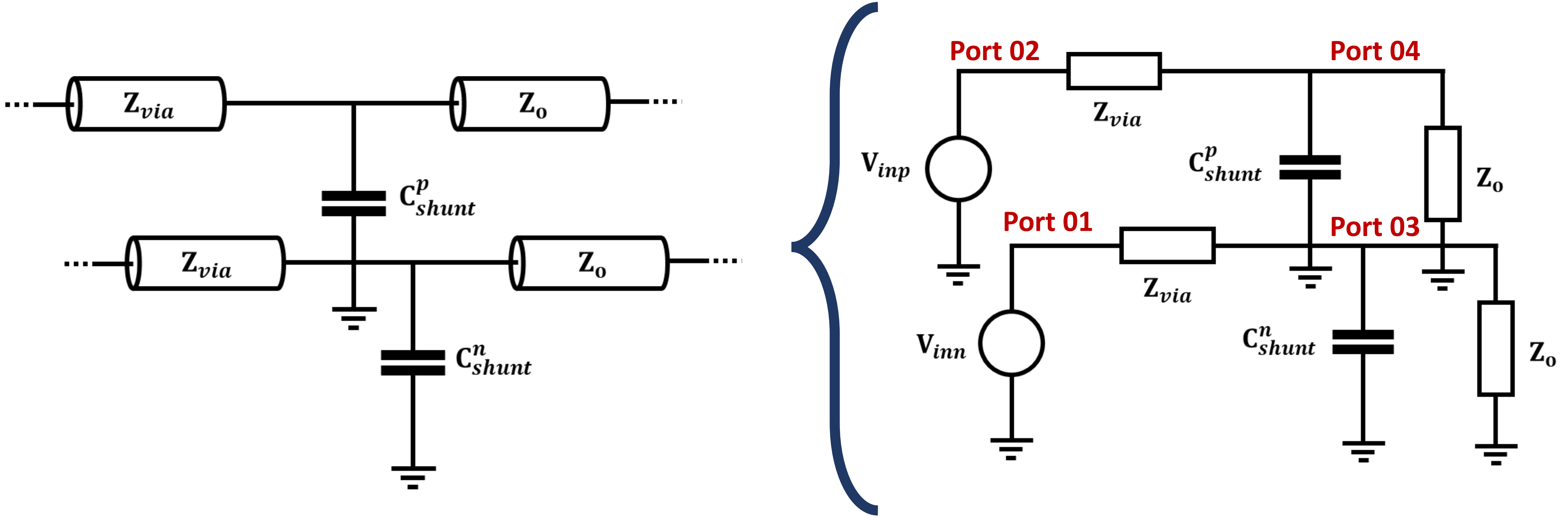




Electrical Representation

Estimation of Mode Conversion for Residual Via Stubs

- For both sides of the link, there exits residual via stubs:



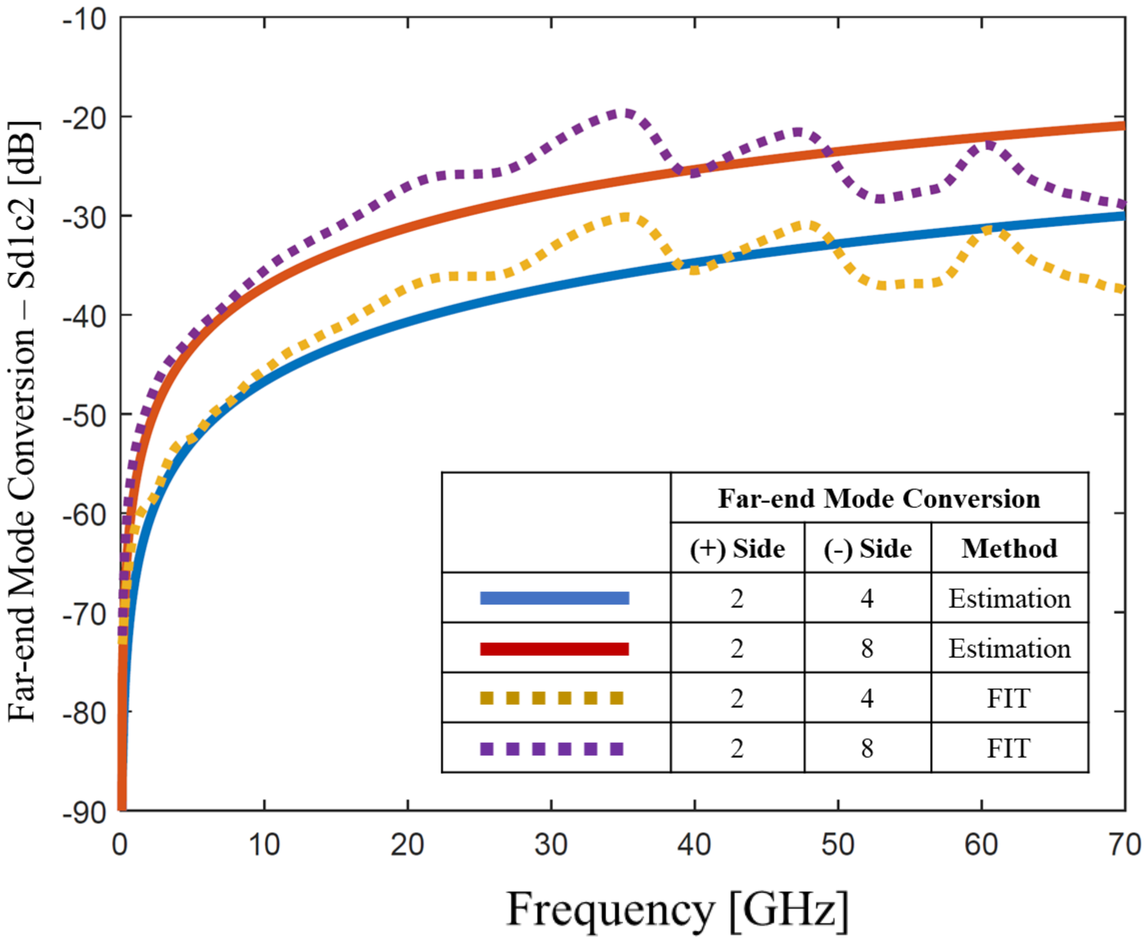
Estimation of Mode Conversion for Residual Via Stubs

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

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

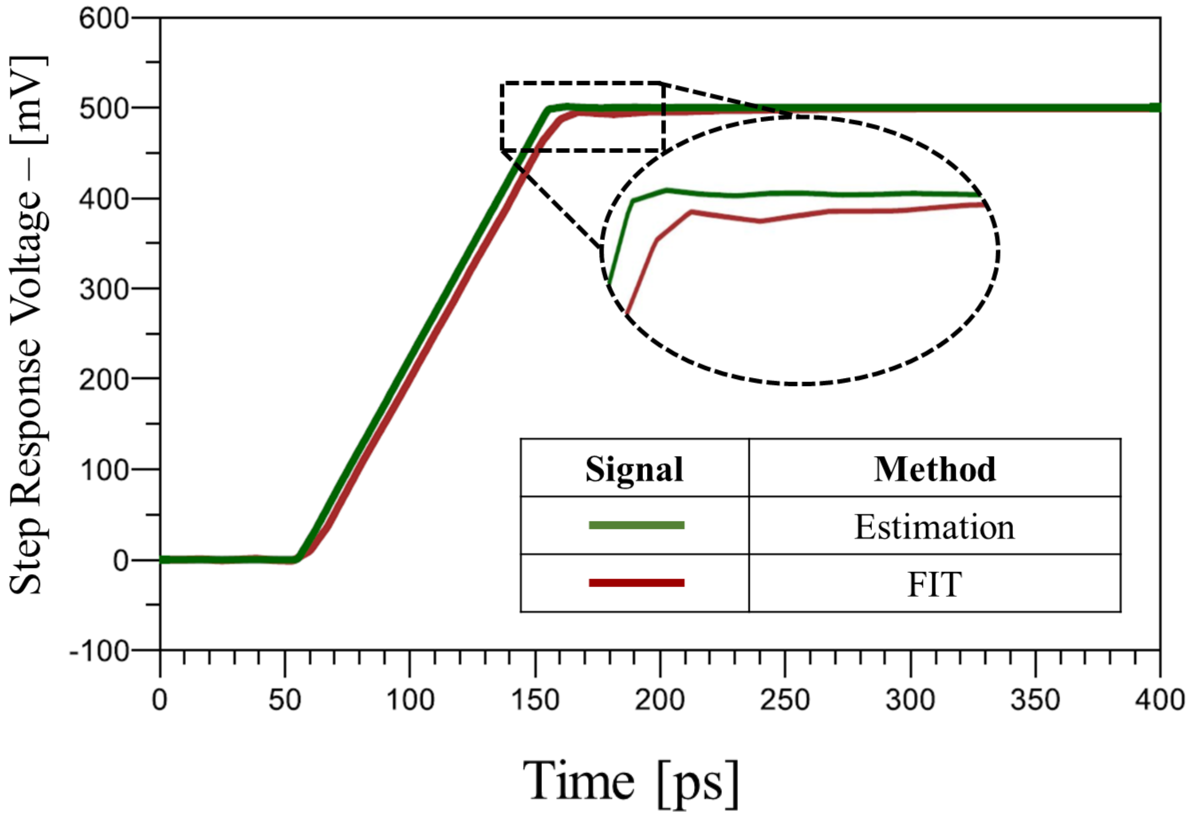
$$C \approx \frac{l_{stub}}{v_{ph} \cdot Z_{via}}$$

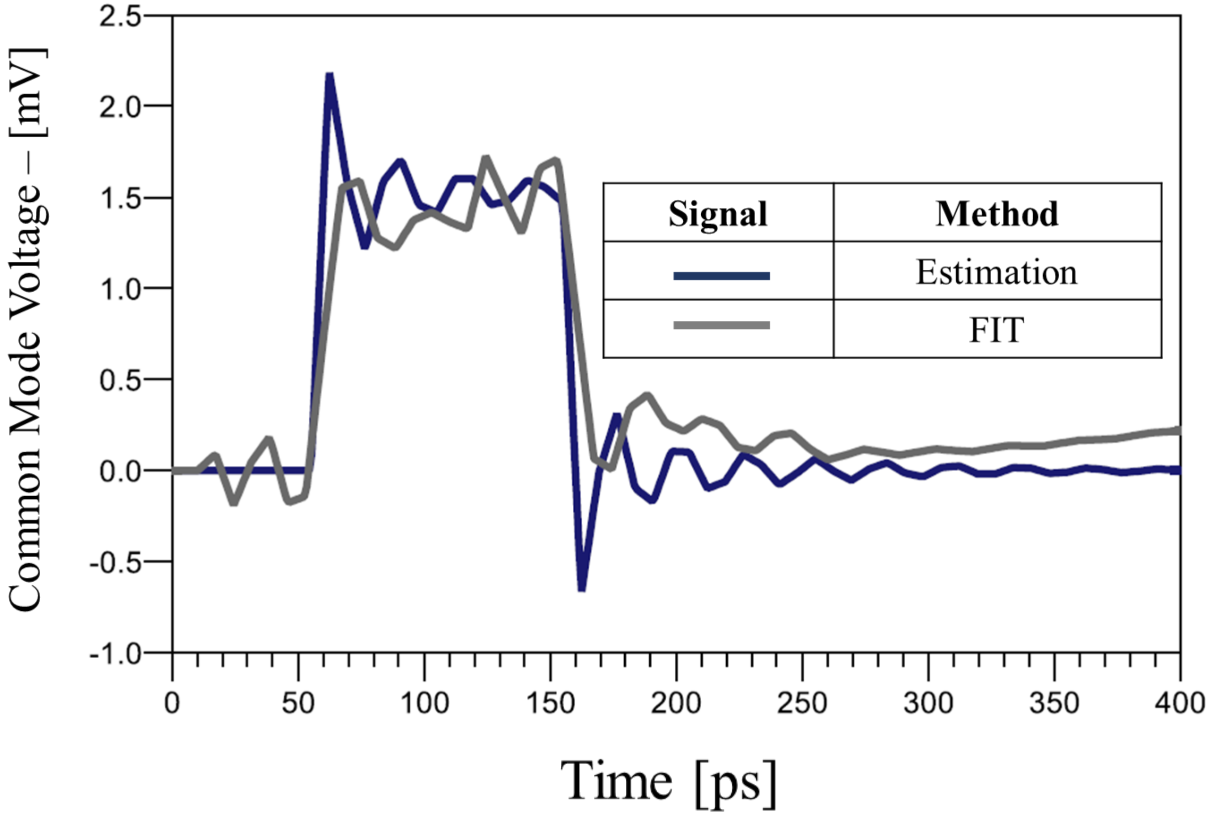
Reference Case [mil]	Fundamental Frequency - @2.5 GHz	
	FIT [dB]	Estimation [dB]
$\Delta l_{stub} = 22$	-30.33	-31.95
$\Delta l_{stub} = 14$	-34.51	-35.86
$\Delta l_{stub} = 6$	-42.11	-43.21
$\Delta l_{stub} = 2$	-52.44	-52.75



Estimation of Mode Conversion for Residual Via Stubs

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





$$f_{max} = 5\ GHz, t_r = 100\ ps$$

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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.

Contents

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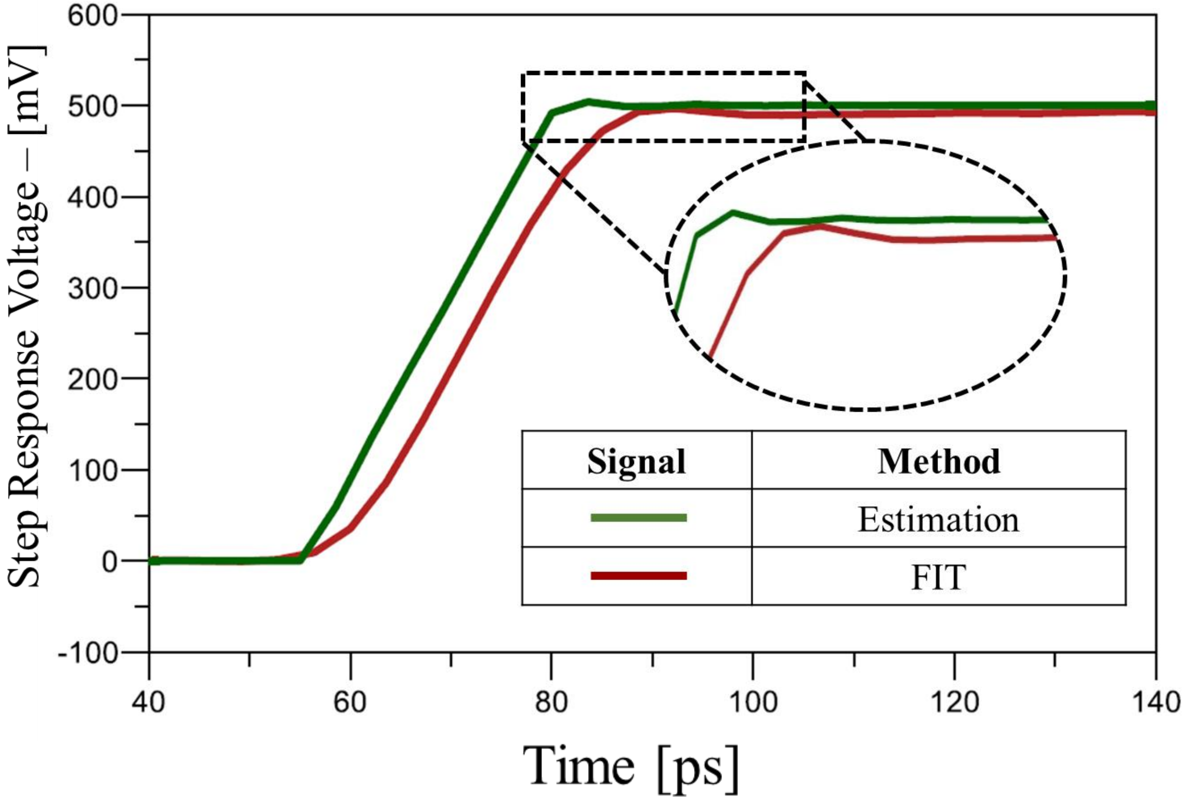
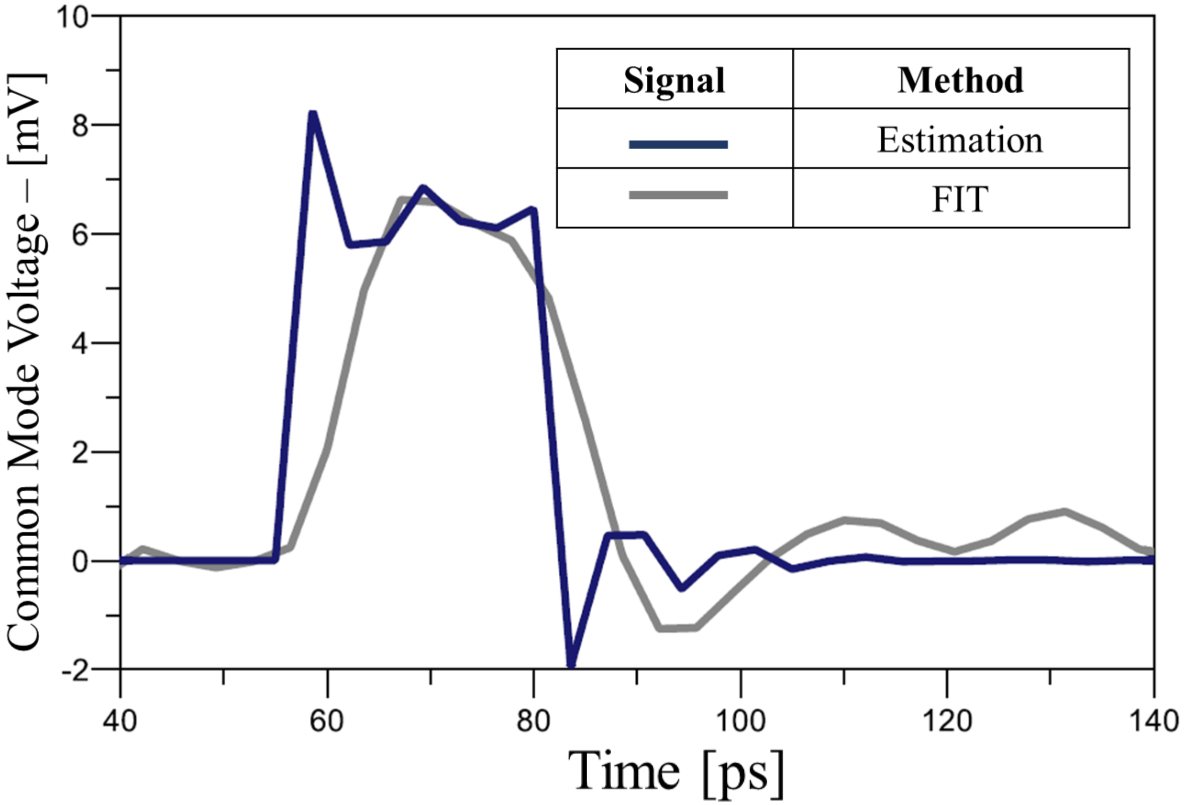
Backup

Estimation of Mode Conversion for Residual Via Stubs

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





$$f_{max} = 20\ GHz, t_r = 25\ ps$$