Staying Grounded in the Real World

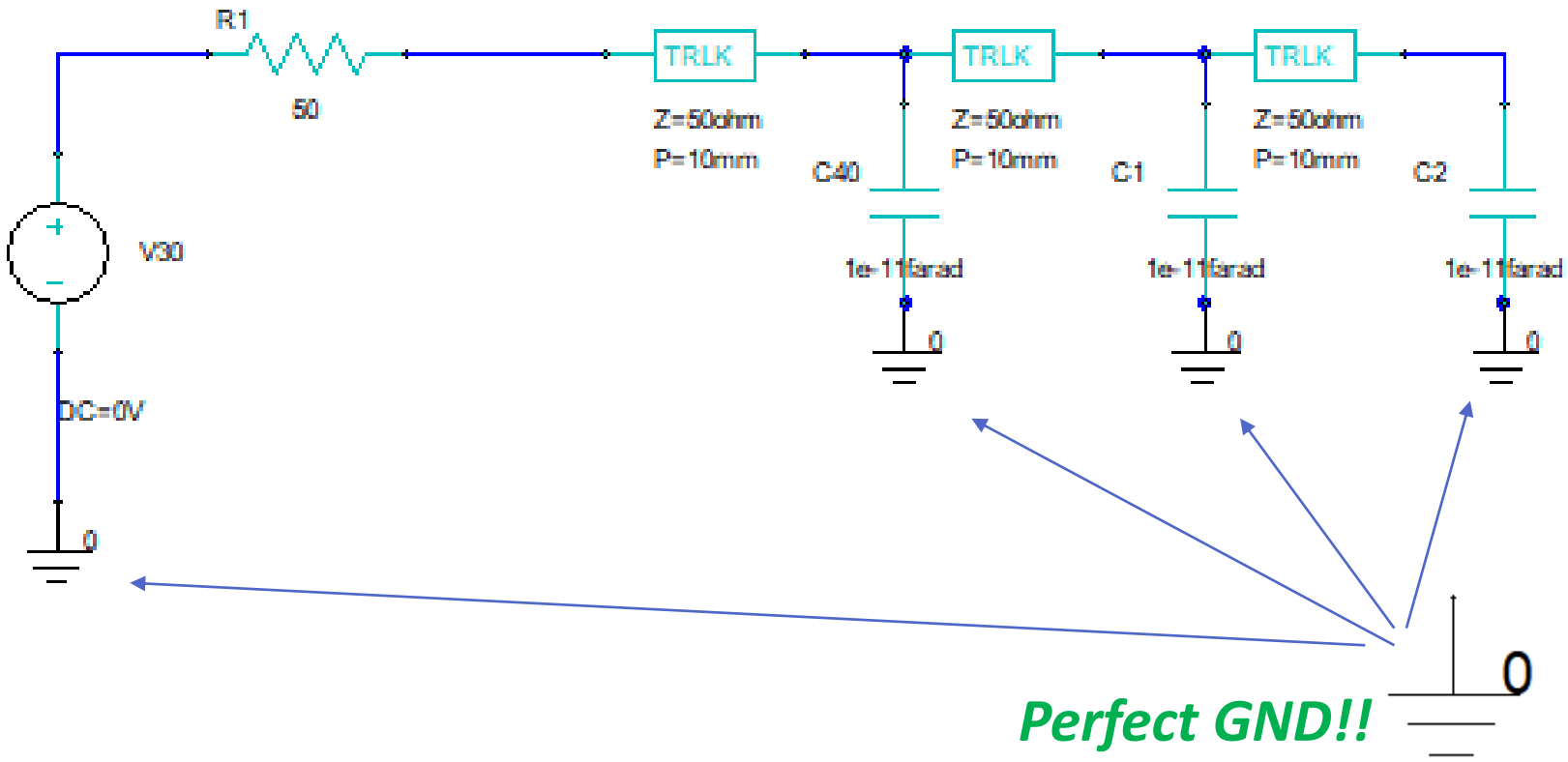
Don’t let return path imperfections trip you up

Sandeep | Samtec, Inc.

Spoiler:

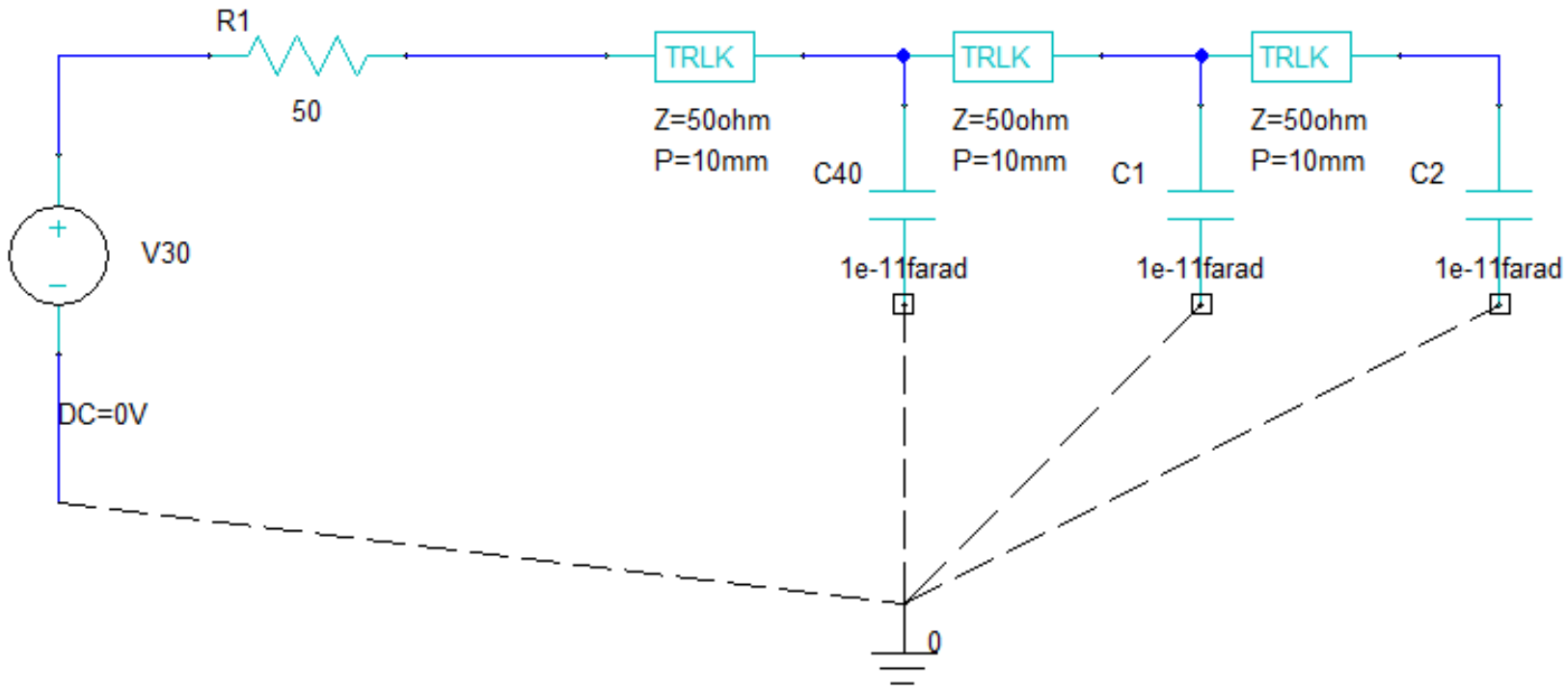
- The return path is just as important as the signal path.
- Expect and account for imperfections and problems in the return path.

Return Path Definition



Key takeaway: Return path ≠ Perfect GND

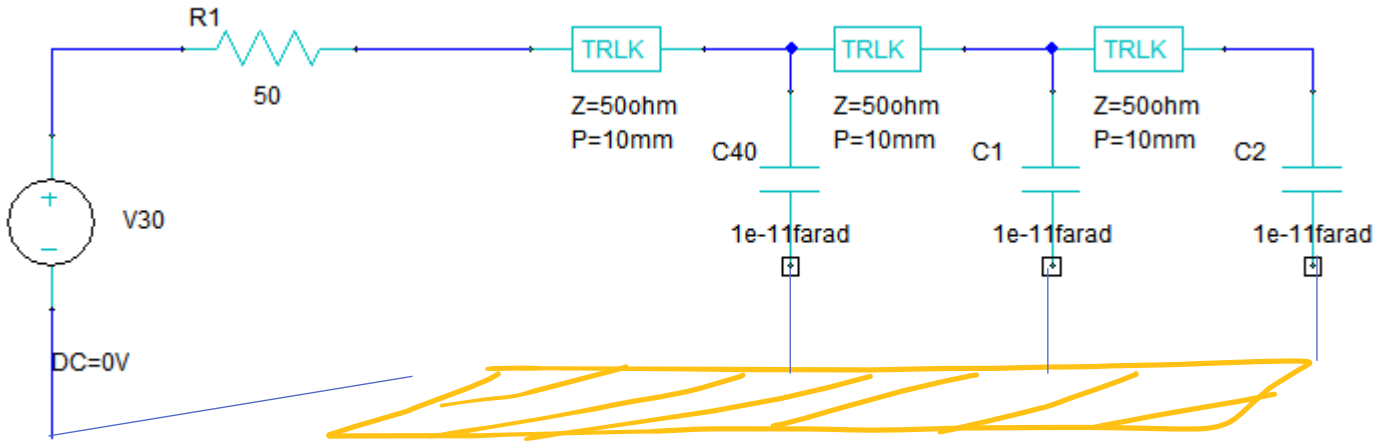
Return Path Definition



Perfect GND!!

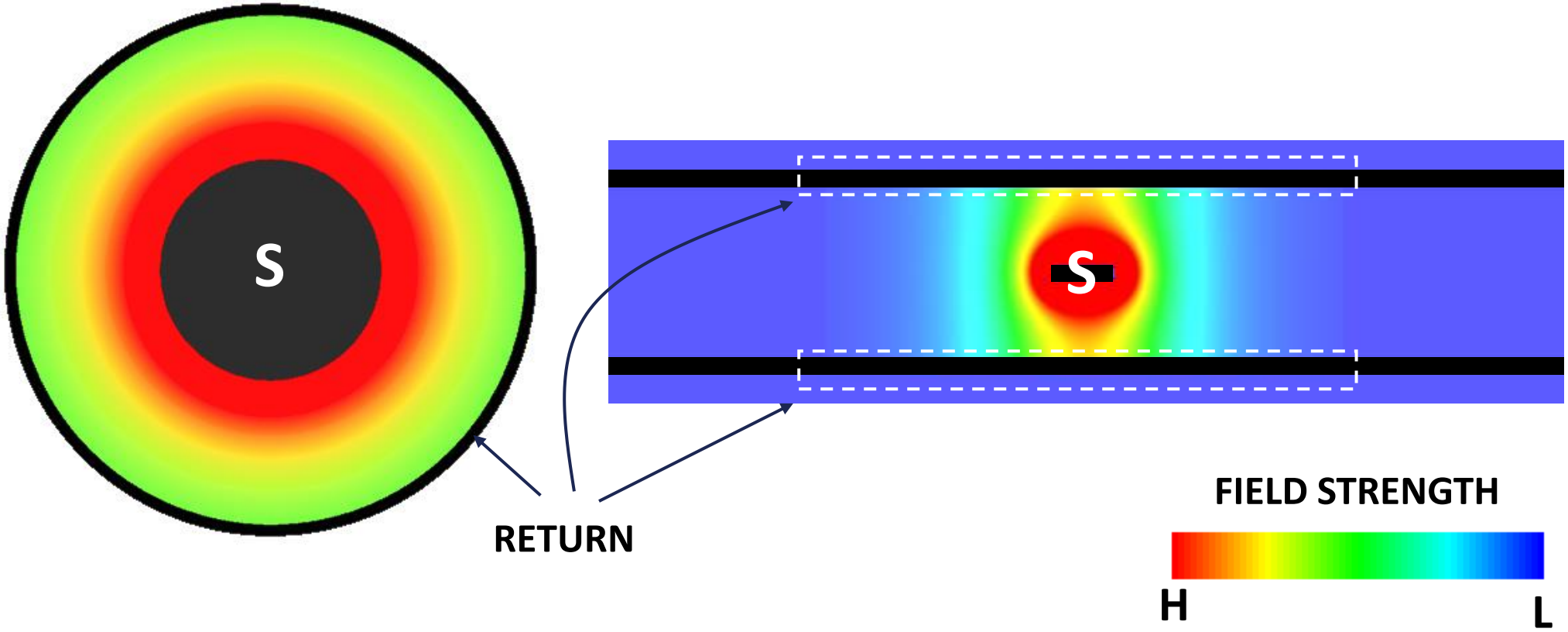
Key takeaway: Return path ≠ Perfect GND

Return Path Definition



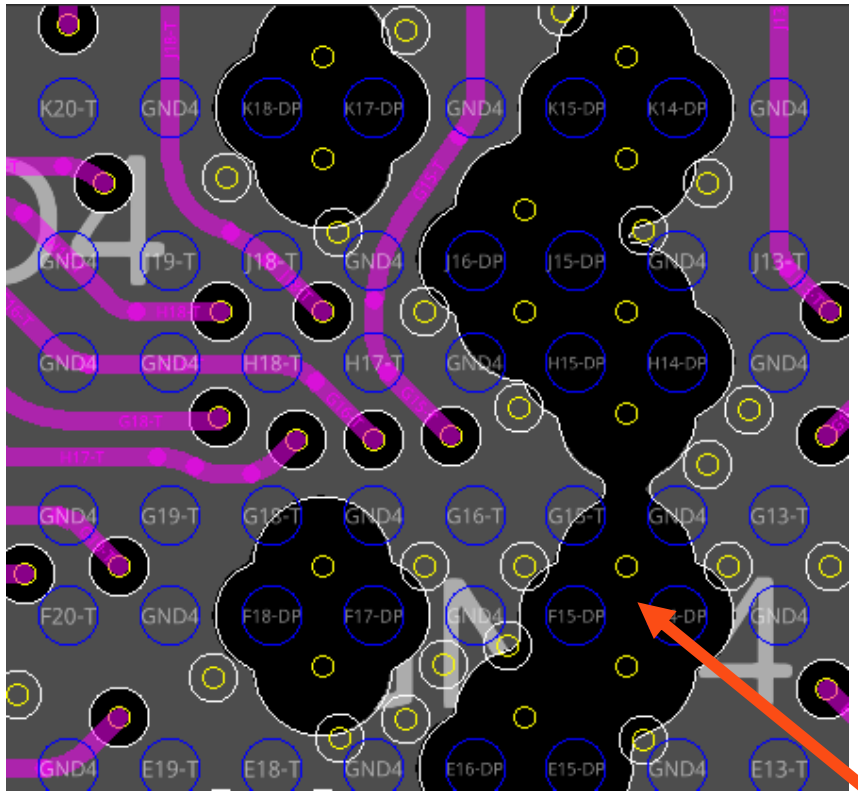
Key takeaway: Return path physical shape and surroundings matter

Return Path Definition



Key takeaway: Energy flows between conductors → Return path shape dependent on where field strength becomes negligible

Return Path in Reality

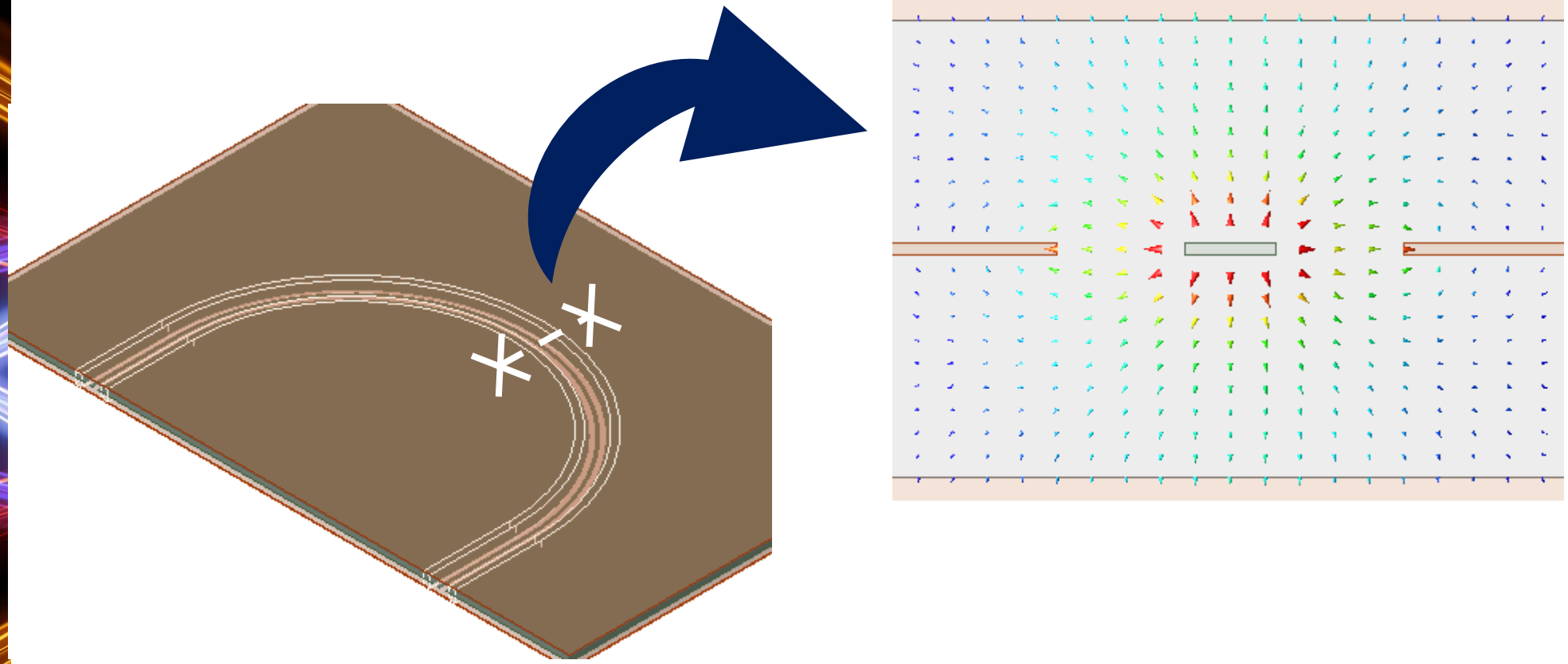


Cutouts, voids and imperfections galore!

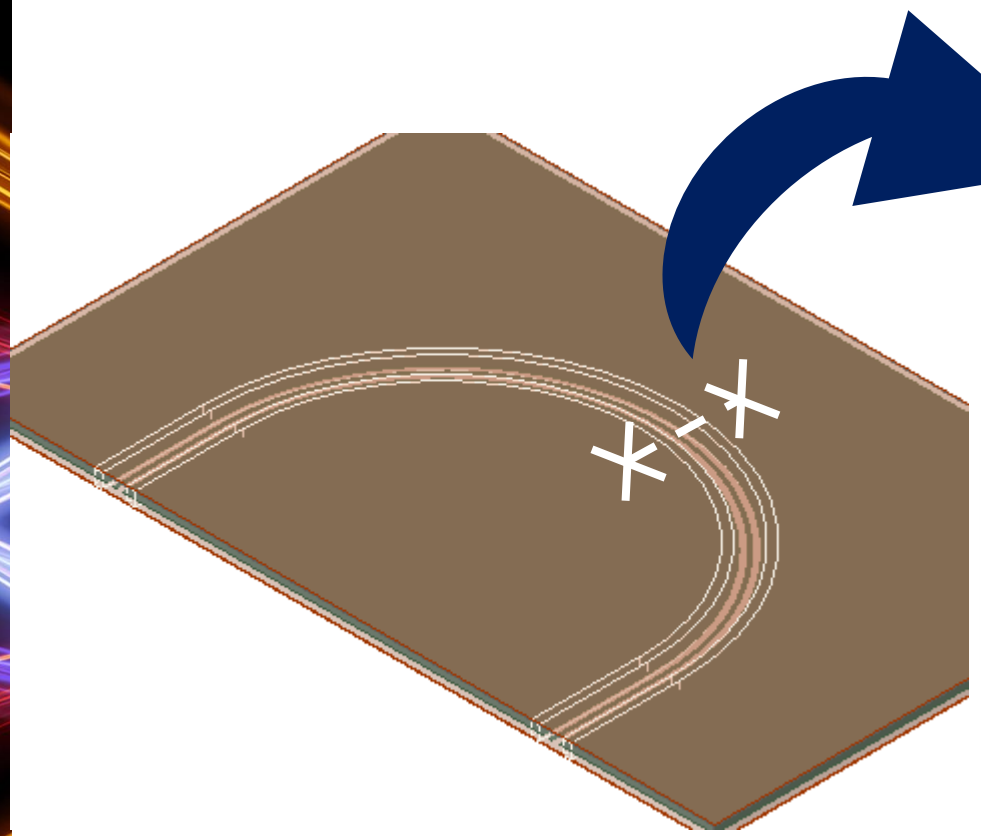
Caution Area 1

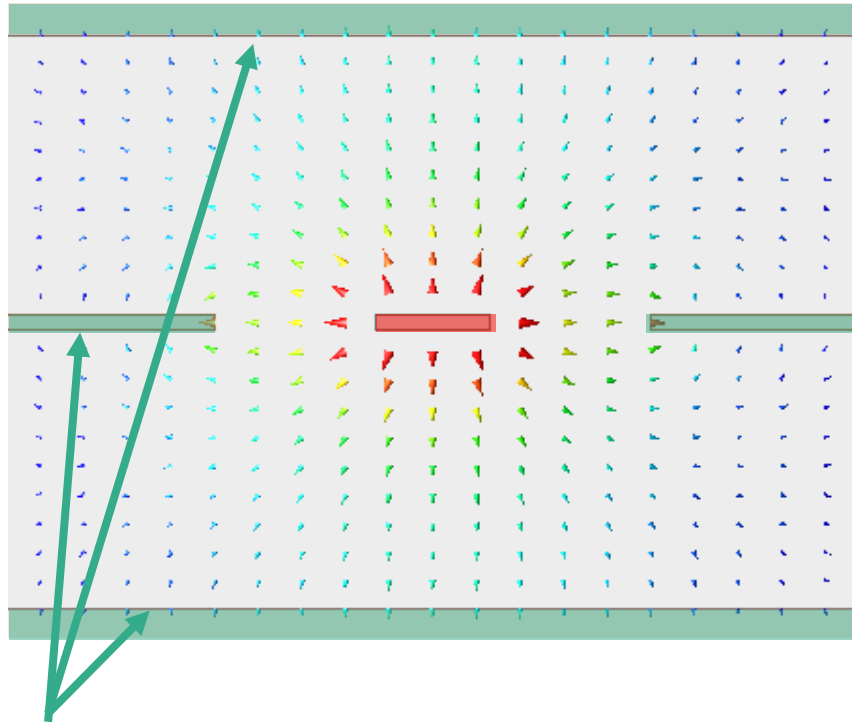
Tying together return path conductors

Tying Return Path Conductors



Tying Return Path Conductors





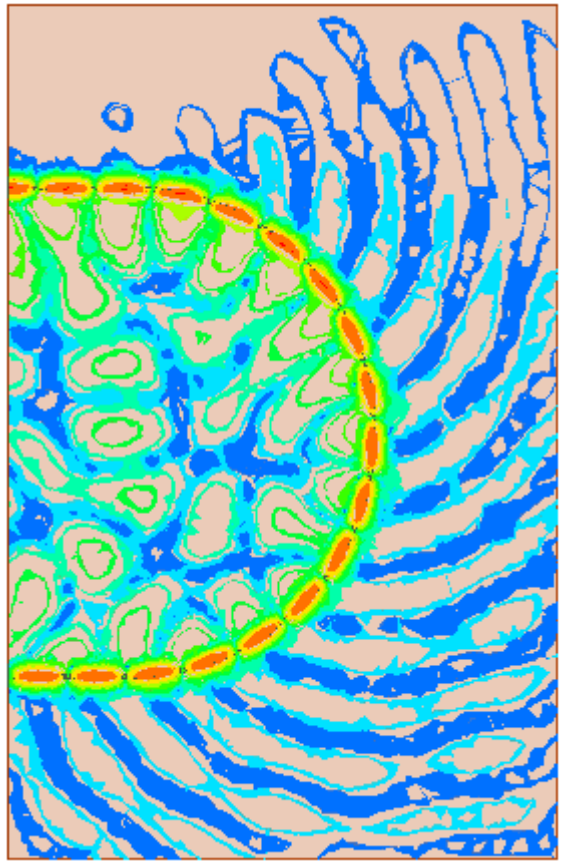
Return

Key takeaway: Multiple return paths → Can behave weirdly if not properly managed

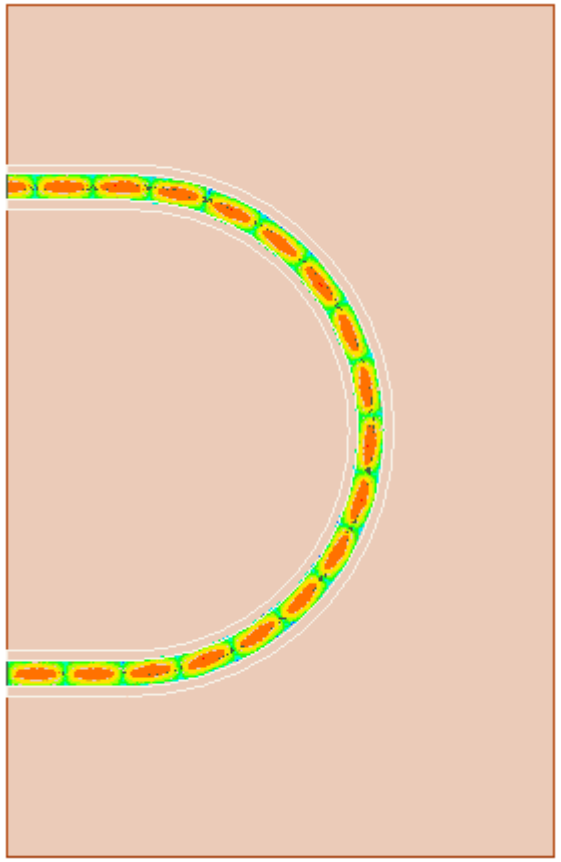
Tying Return Path Conductors

|E| plotted at 20.6 GHz

Source

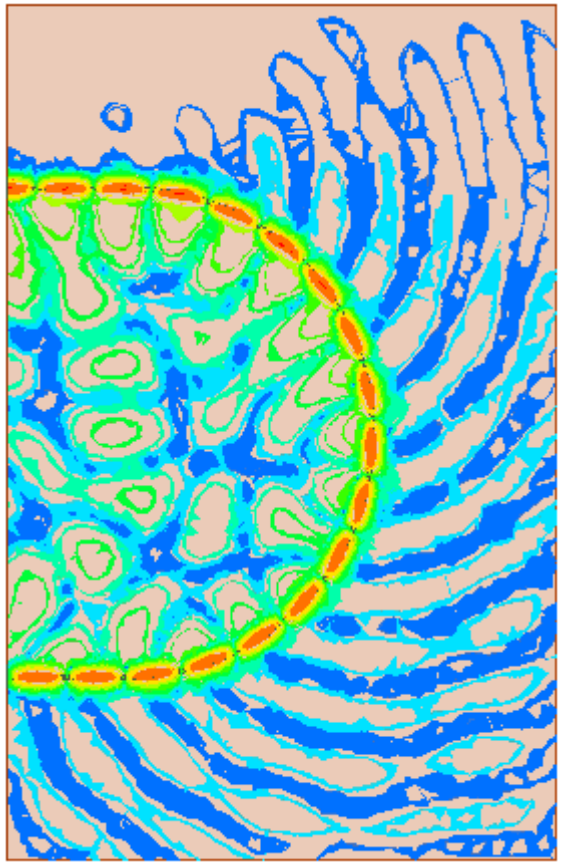


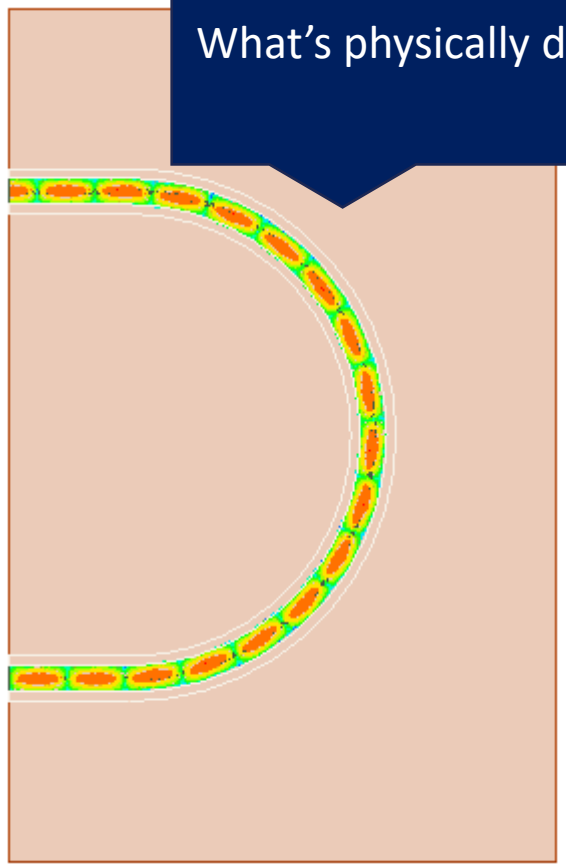
Source



Tying Return Path Conductors

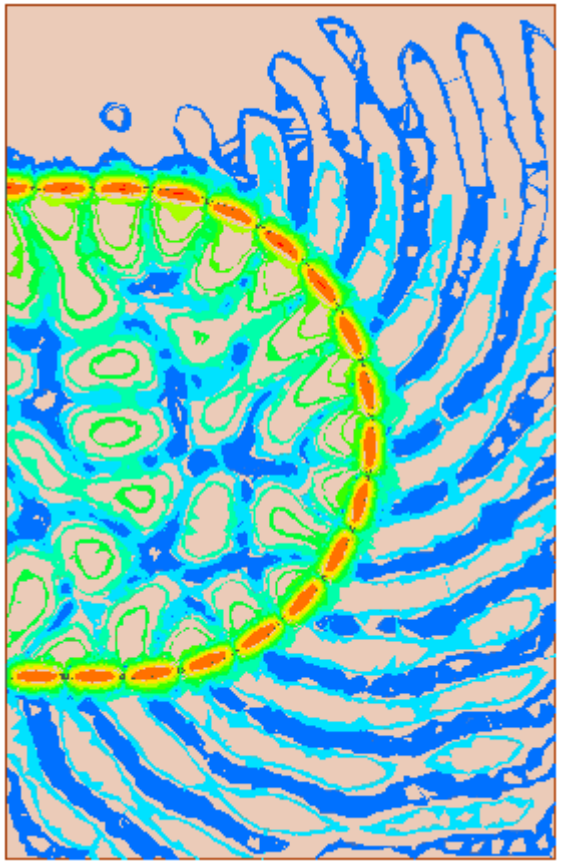
|E| plotted at 20.6 GHz

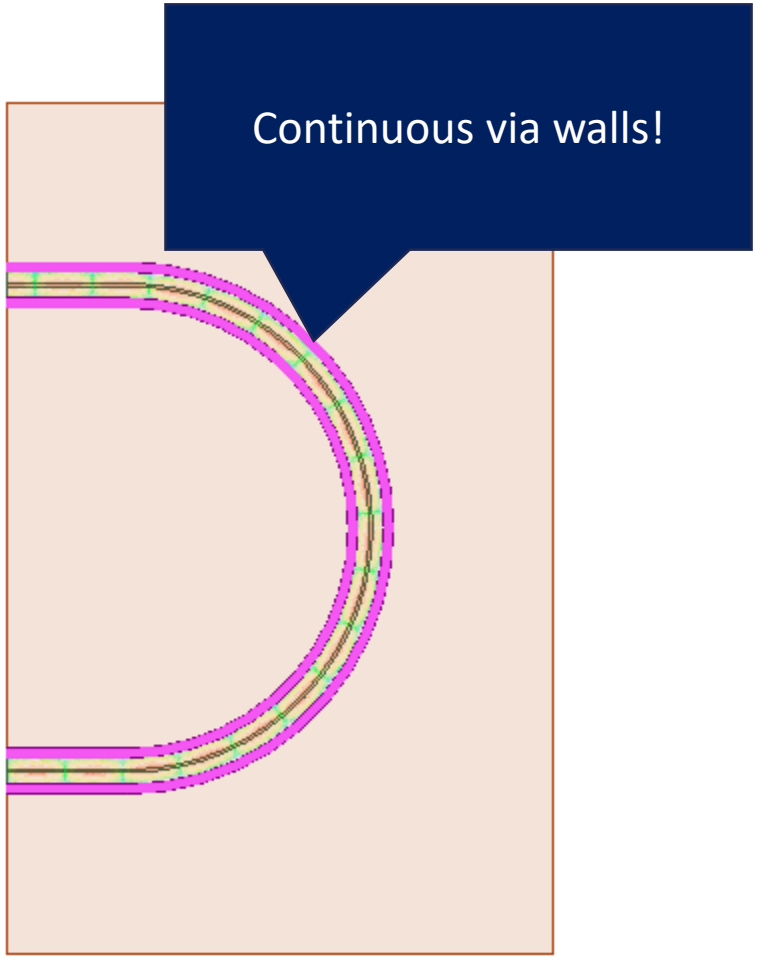




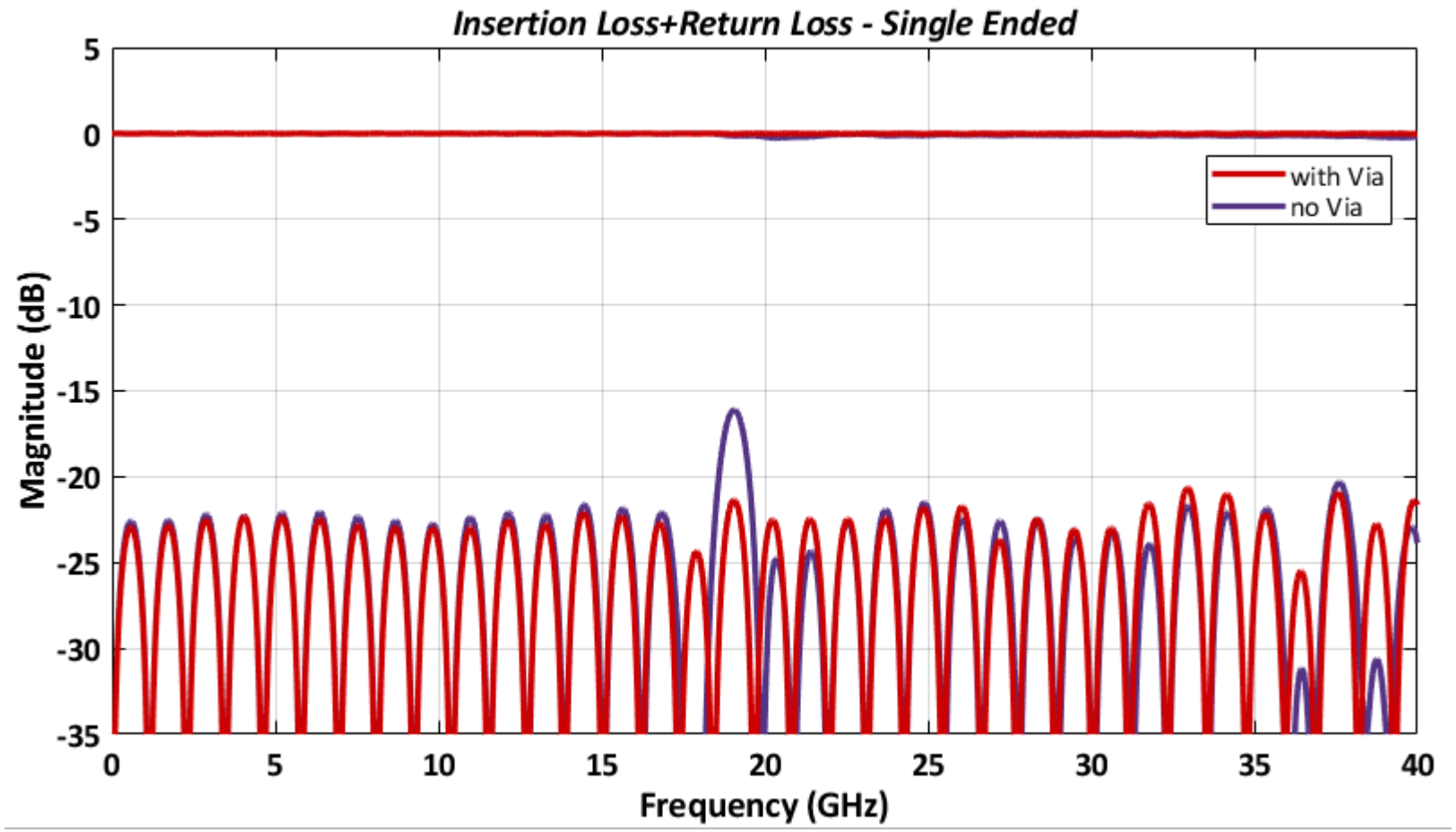
Tying Return Path Conductors

|E| plotted at 20.6 GHz



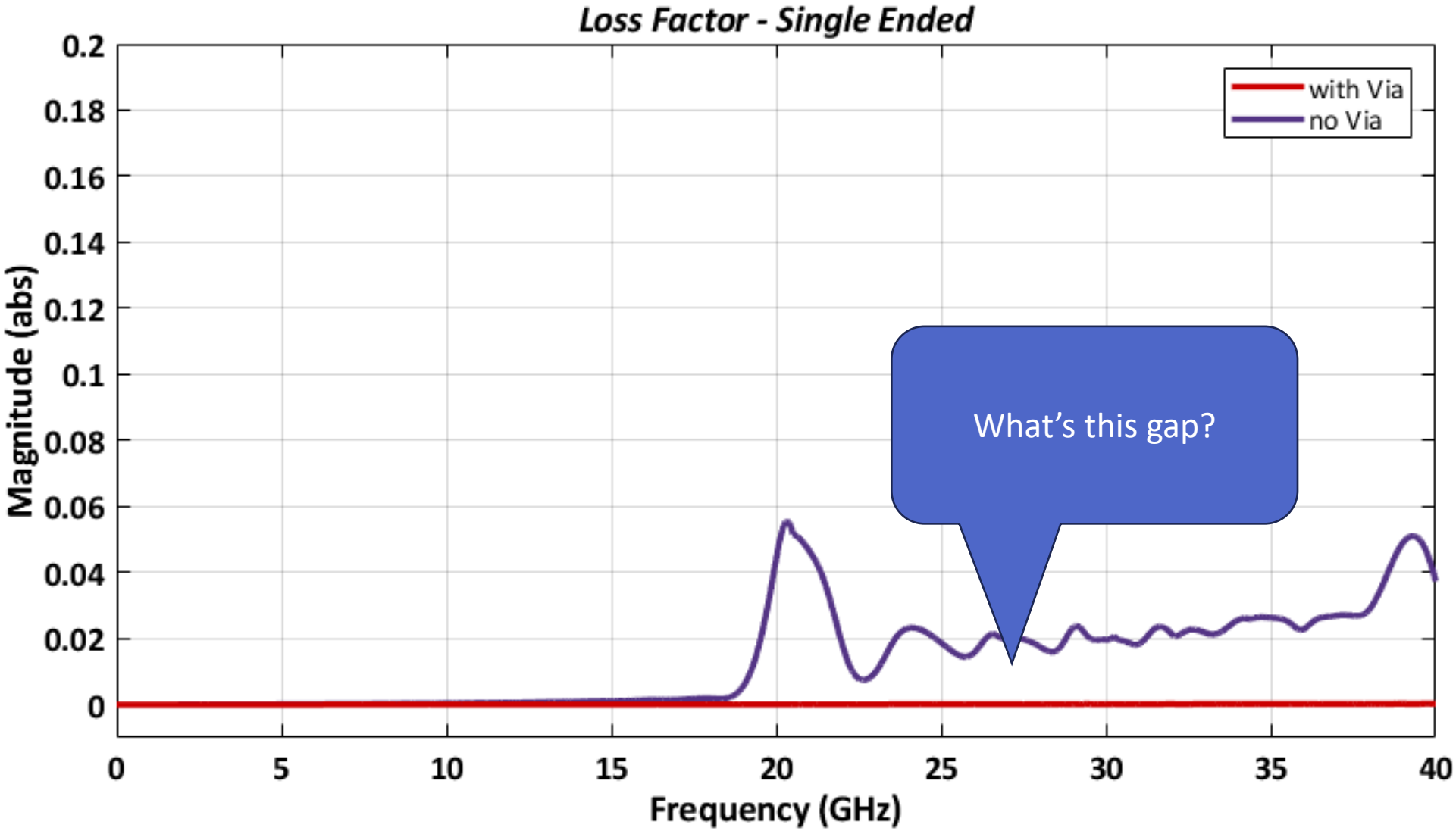


Tying Return Path Conductors: IL, RL View



Performance not drastically different in these plots

Tying Return Path Conductors: Loss Factor View



What is Loss Factor?

gEEk spEEk

FOR 2 PORTS

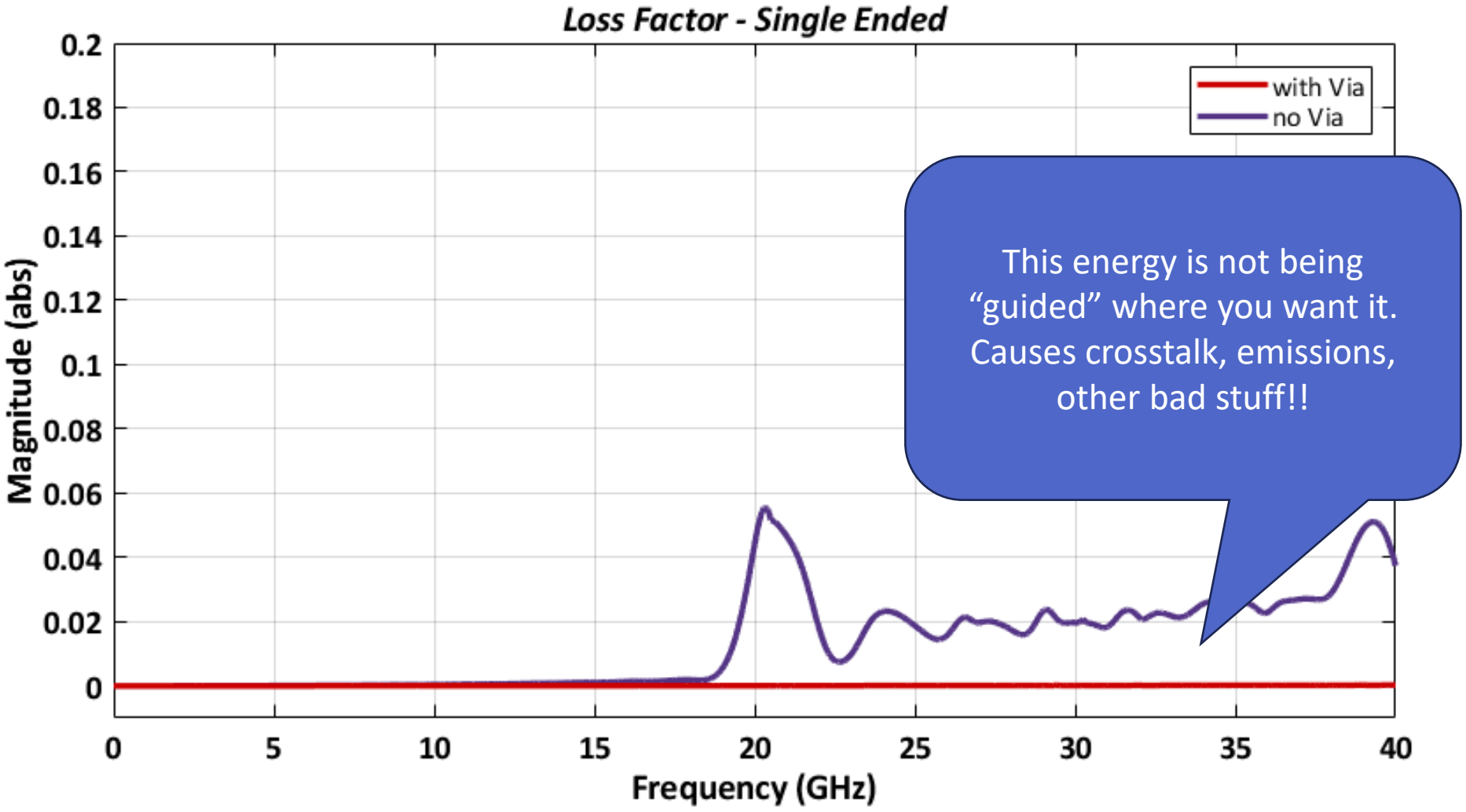
$$|\text{Loss Factor}| = 1 - |S_{21}|^2 - |S_{11}|^2$$

Power that flows along unwanted paths

Transmitted power

Reflected Power

Tying Return Path Conductors: Loss Factor View

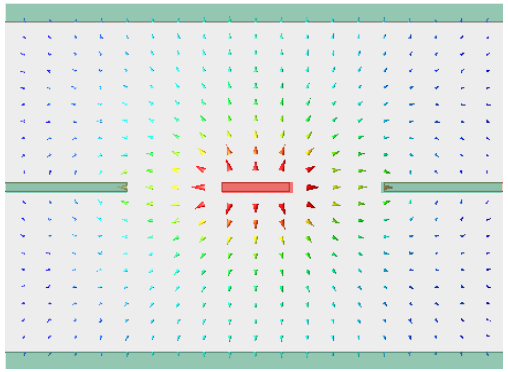


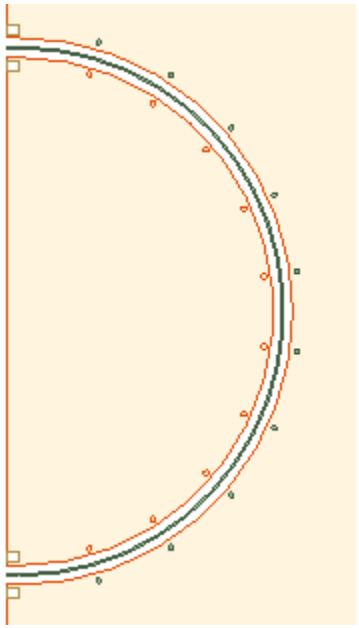
Key takeaway: Ensure return path guides signal energy to desired destination

Caution Area 2

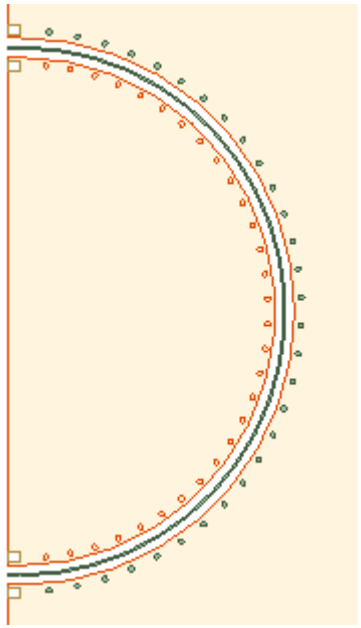
Having sufficient stitching vias

Via Fence Density Impact

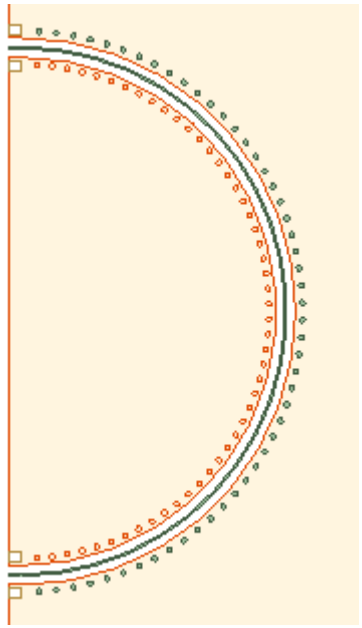




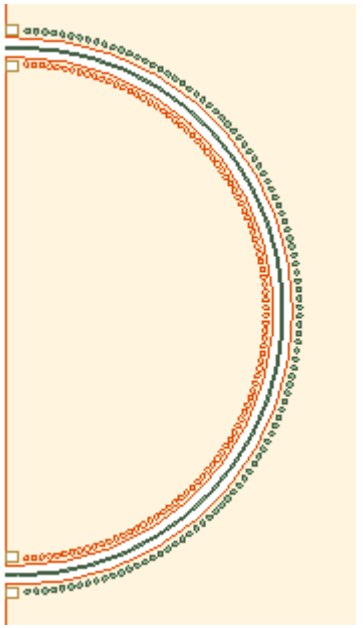
Via count = 10



Via count = 30



Via count = 50

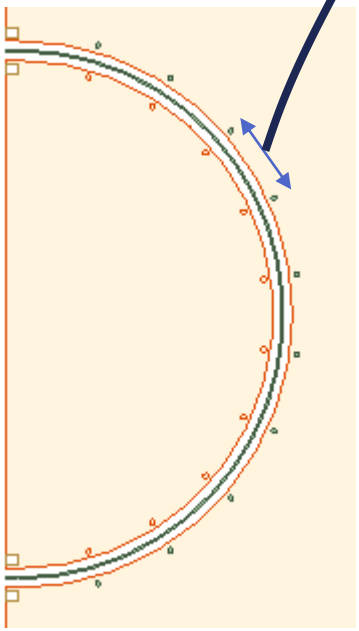


Via count = 100

Via Fence Density Impact

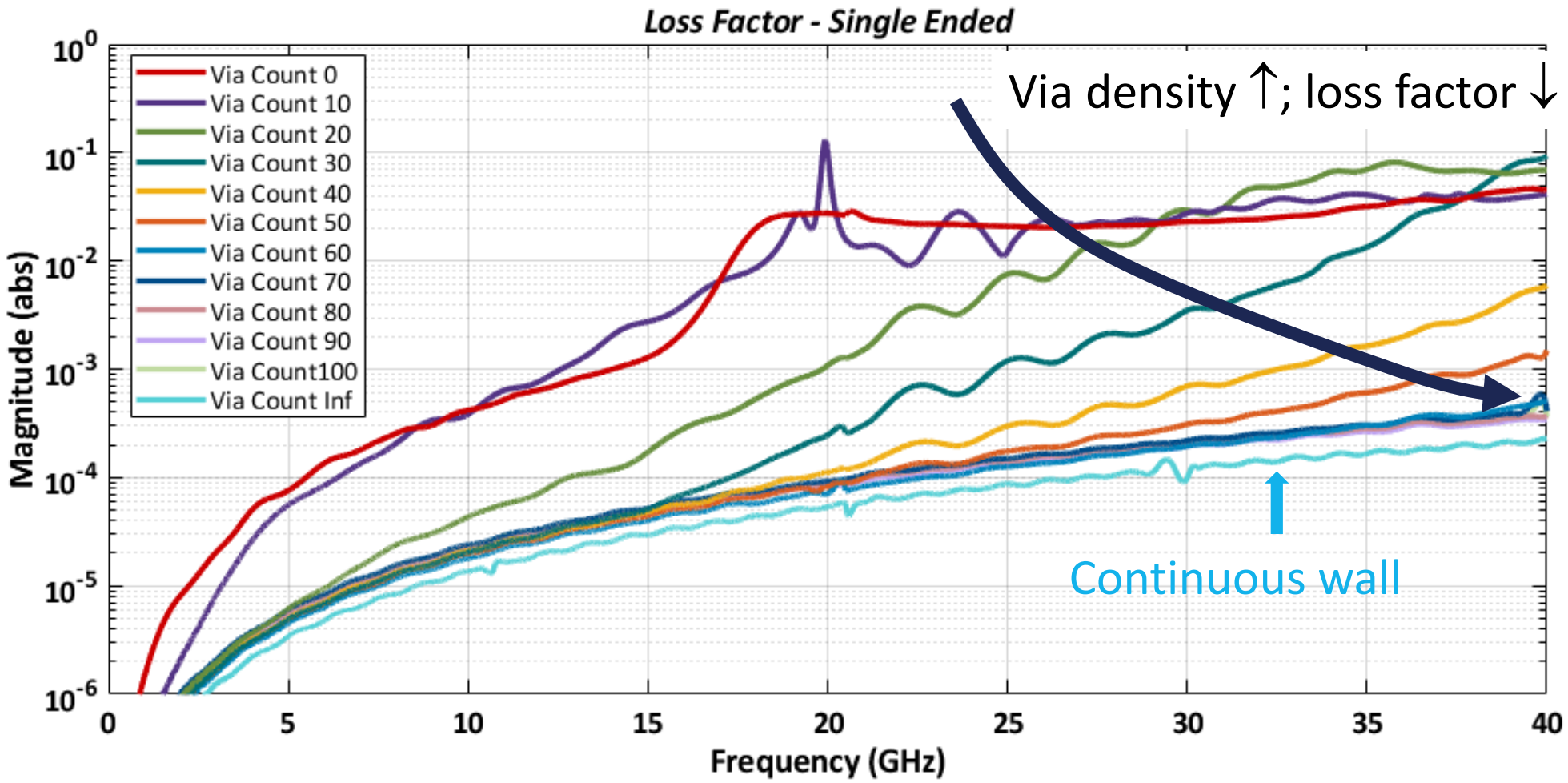
λ / Factor

Factor ↑ via fence → solid wall

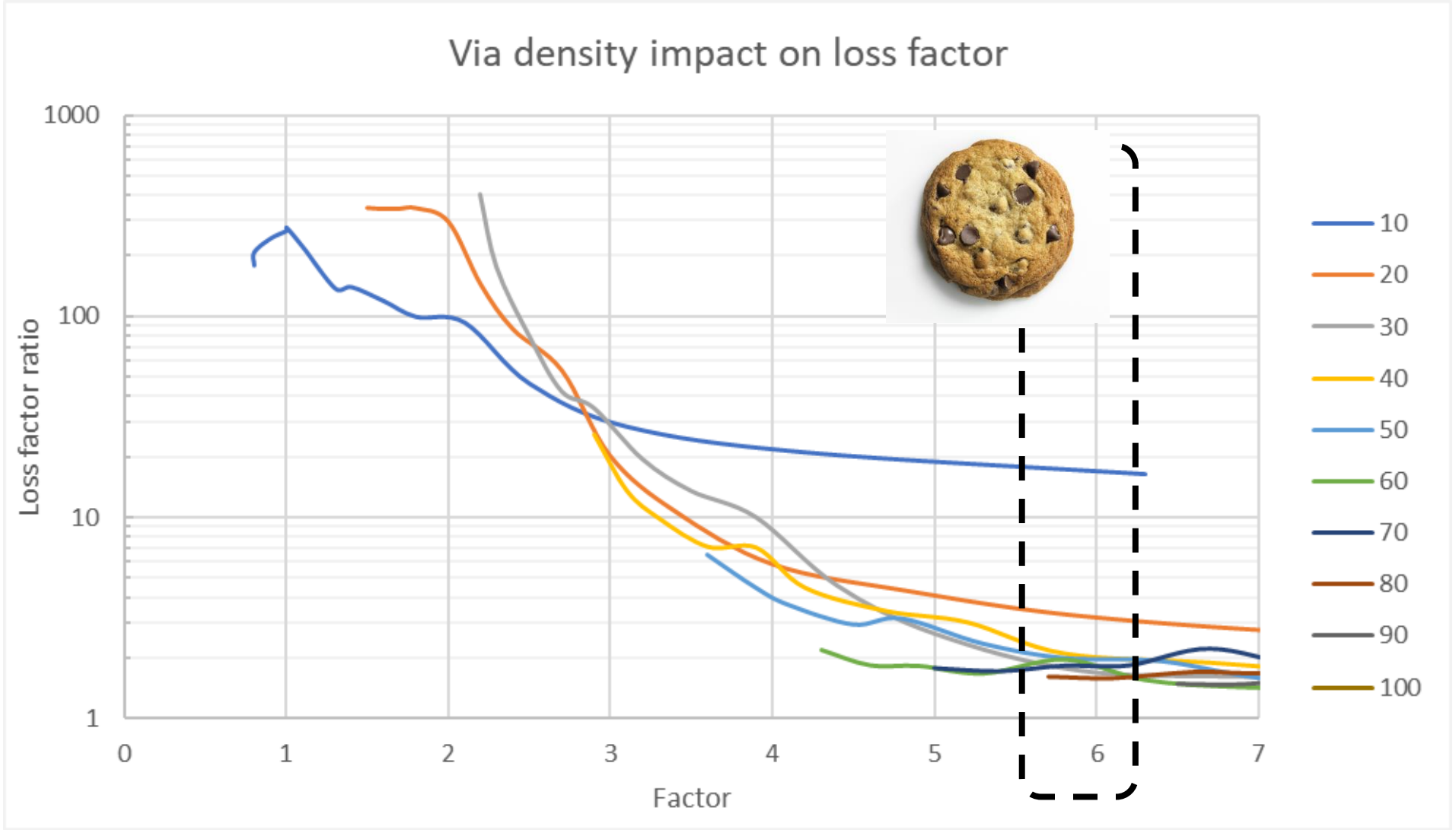


Number of vias \ Frequency [GHz]	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
10	13	6	4	3	3	2	2	2	1	1	1	1	1	1	1	1
20	24	12	8	6	5	4	3	3	3	2	2	2	2	2	2	1
30	35	18	12	9	7	6	5	4	4	4	3	3	3	3	2	2
40	47	23	16	12	9	8	7	6	5	5	4	4	4	3	3	3
50	58	29	19	14	12	10	8	7	6	6	5	5	4	4	4	4
60	69	35	23	17	14	12	10	9	8	7	6	6	5	5	5	4
70	81	40	27	20	16	13	12	10	9	8	7	7	6	6	5	5
80	92	46	31	23	18	15	13	11	10	9	8	8	7	7	6	6
90	103	52	34	26	21	17	15	13	11	10	9	9	8	7	7	6
100	115	57	38	29	23	19	16	14	13	11	10	10	9	8	8	7

Via fence density impact

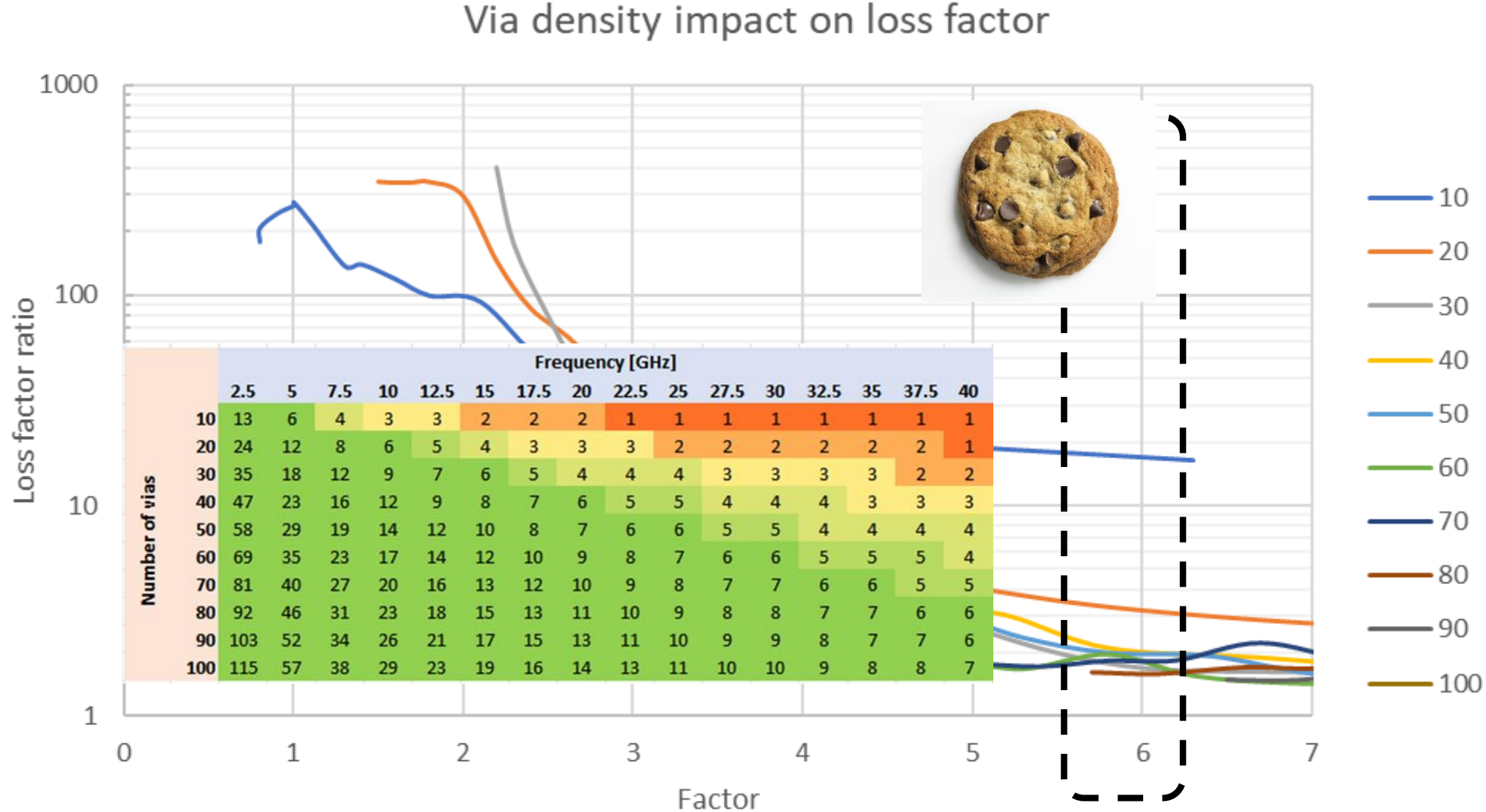


Via Fence Density Impact | the "Sweet Spot"



Key takeaway: Stitching vias required at least every λmin/6

Via Fence Density Impact | the "Sweet Spot"



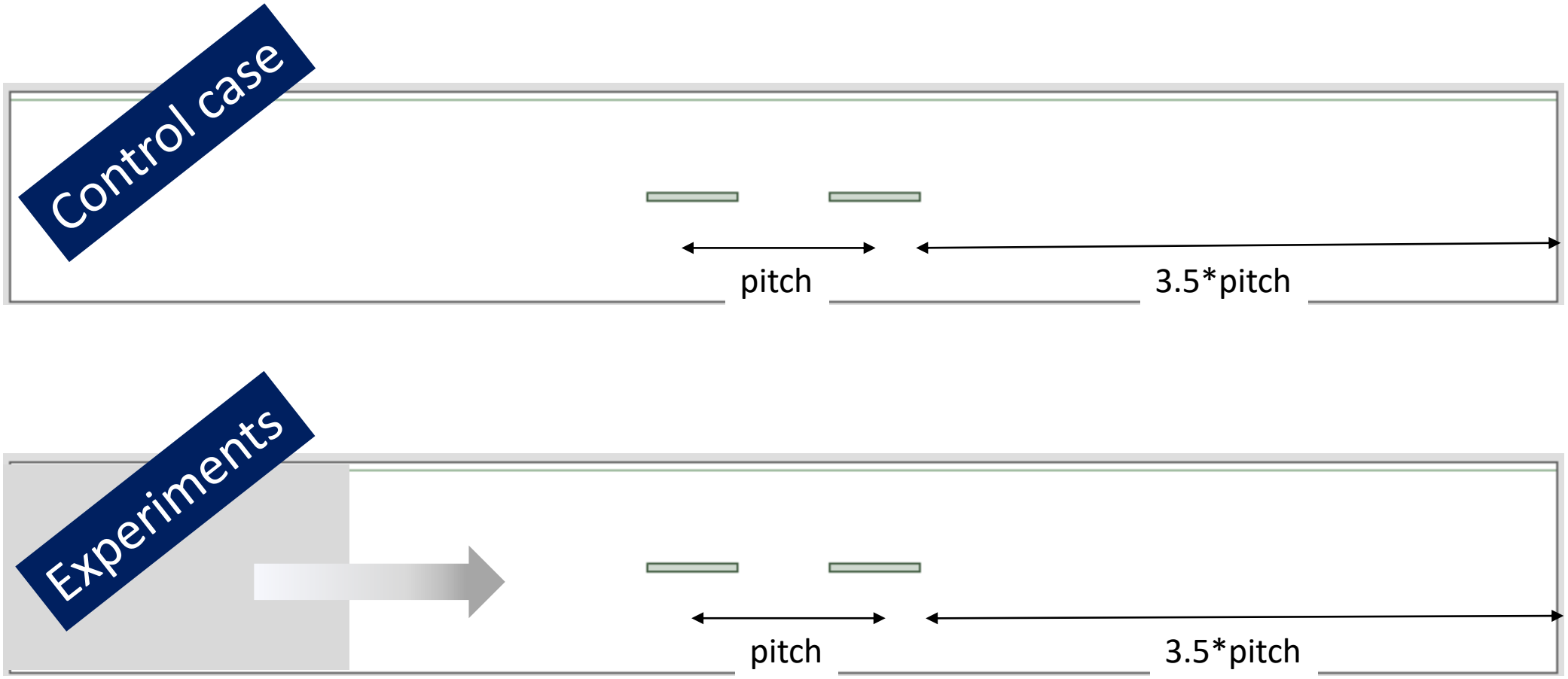
Number of vias \ Frequency [GHz]	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
10	13	6	4	3	3	2	2	2	1	1	1	1	1	1	1	1
20	24	12	8	6	5	4	3	3	3	2	2	2	2	2	2	1
30	35	18	12	9	7	6	5	4	4	4	3	3	3	3	2	2
40	47	23	16	12	9	8	7	6	5	5	4	4	4	3	3	3
50	58	29	19	14	12	10	8	7	6	6	5	5	4	4	4	4
60	69	35	23	17	14	12	10	9	8	7	6	6	5	5	5	4
70	81	40	27	20	16	13	12	10	9	8	7	7	6	6	5	5
80	92	46	31	23	18	15	13	11	10	9	8	8	7	7	6	6
90	103	52	34	26	21	17	15	13	11	10	9	9	8	7	7	6
100	115	57	38	29	23	19	16	14	13	11	10	10	9	8	8	7

Key takeaway: Stitching vias required at least every λmin/6

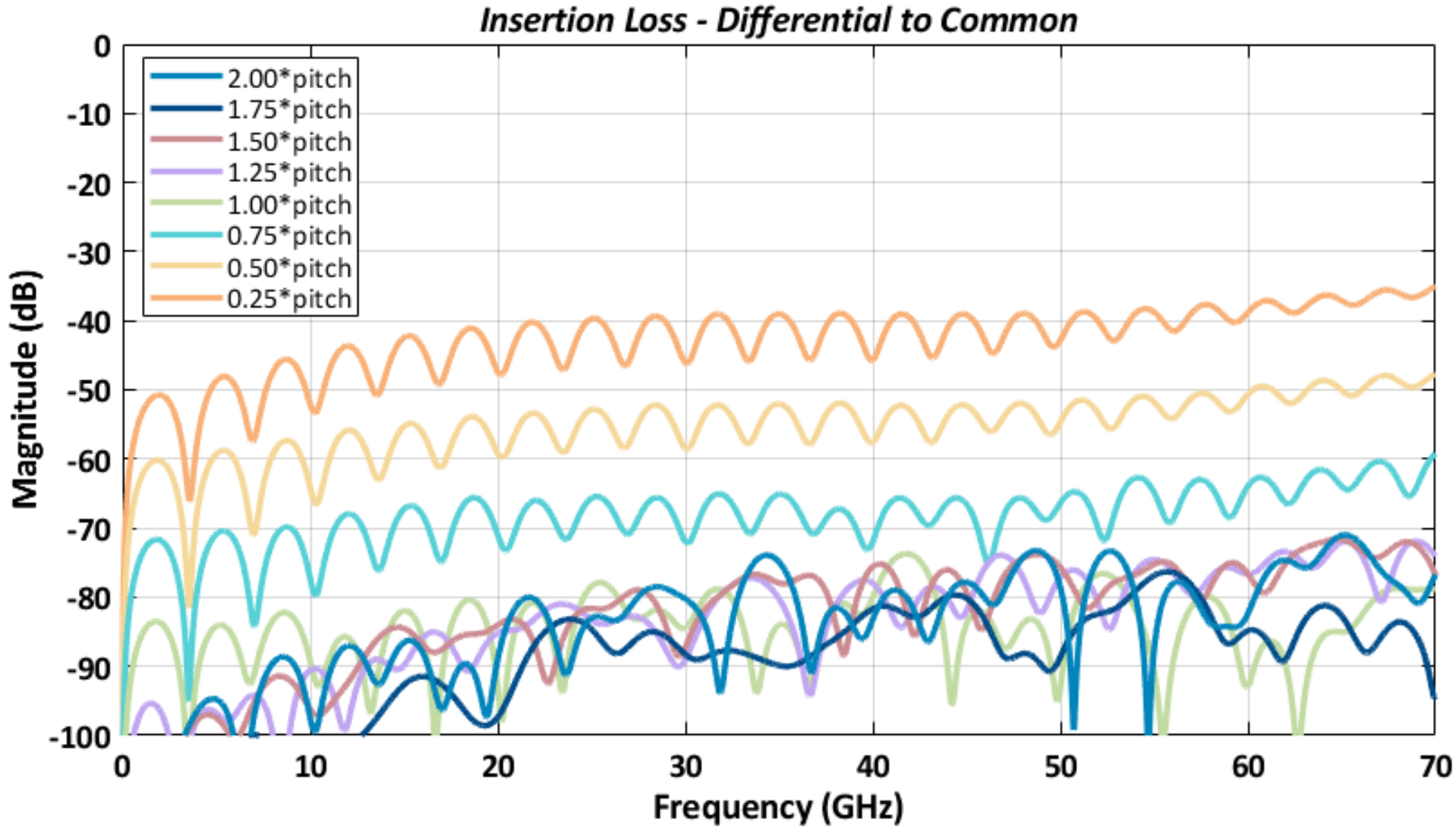
Caution Area 3

Symmetry and Balance

Via Fence Asymmetry

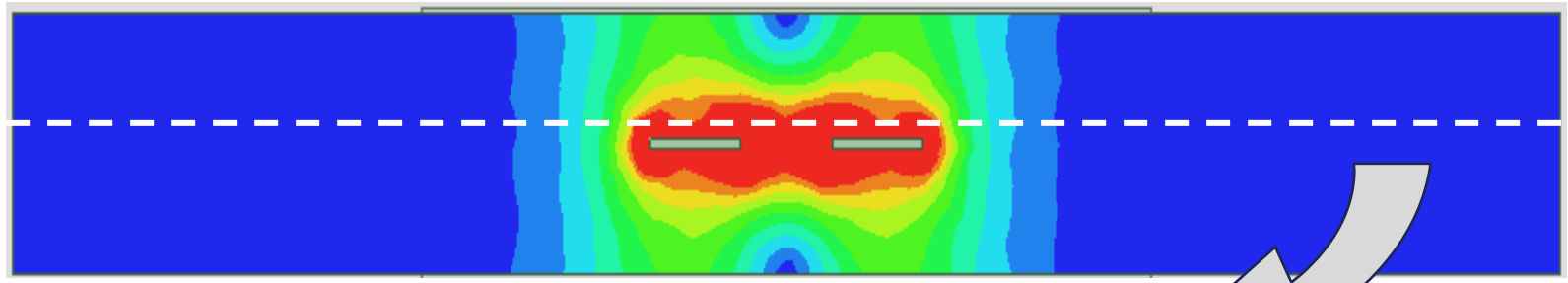


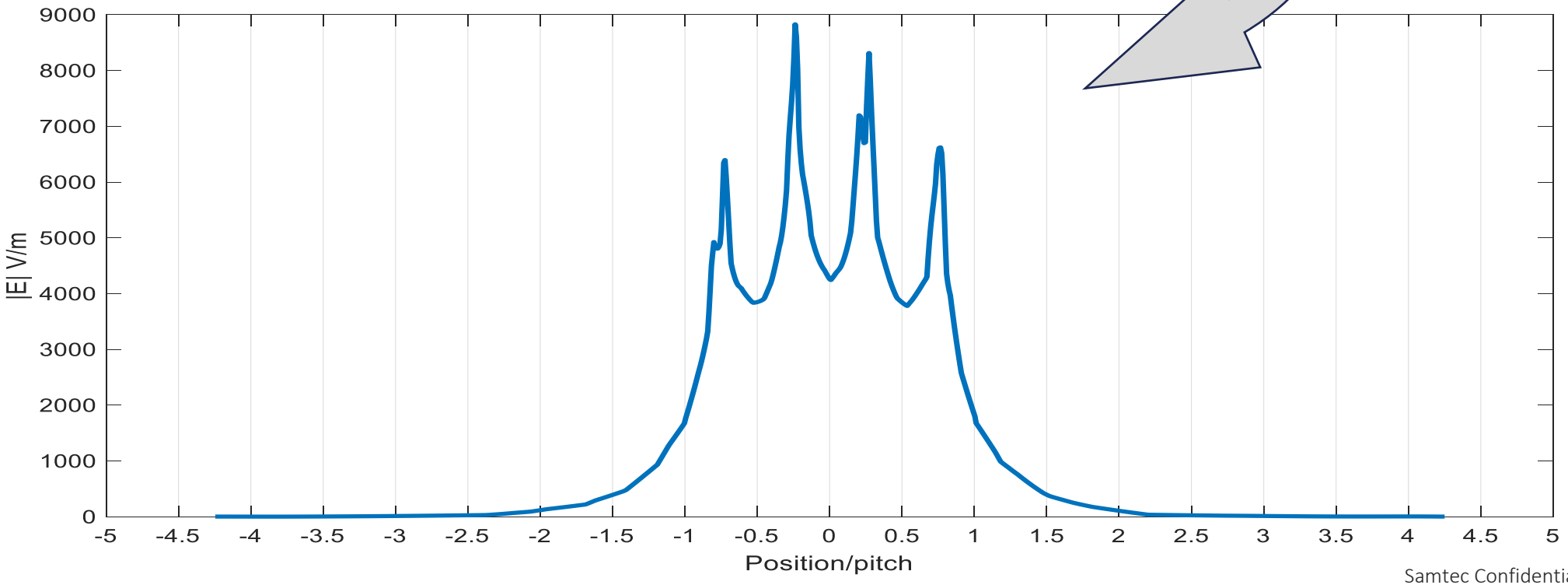
Via Fence Asymmetry



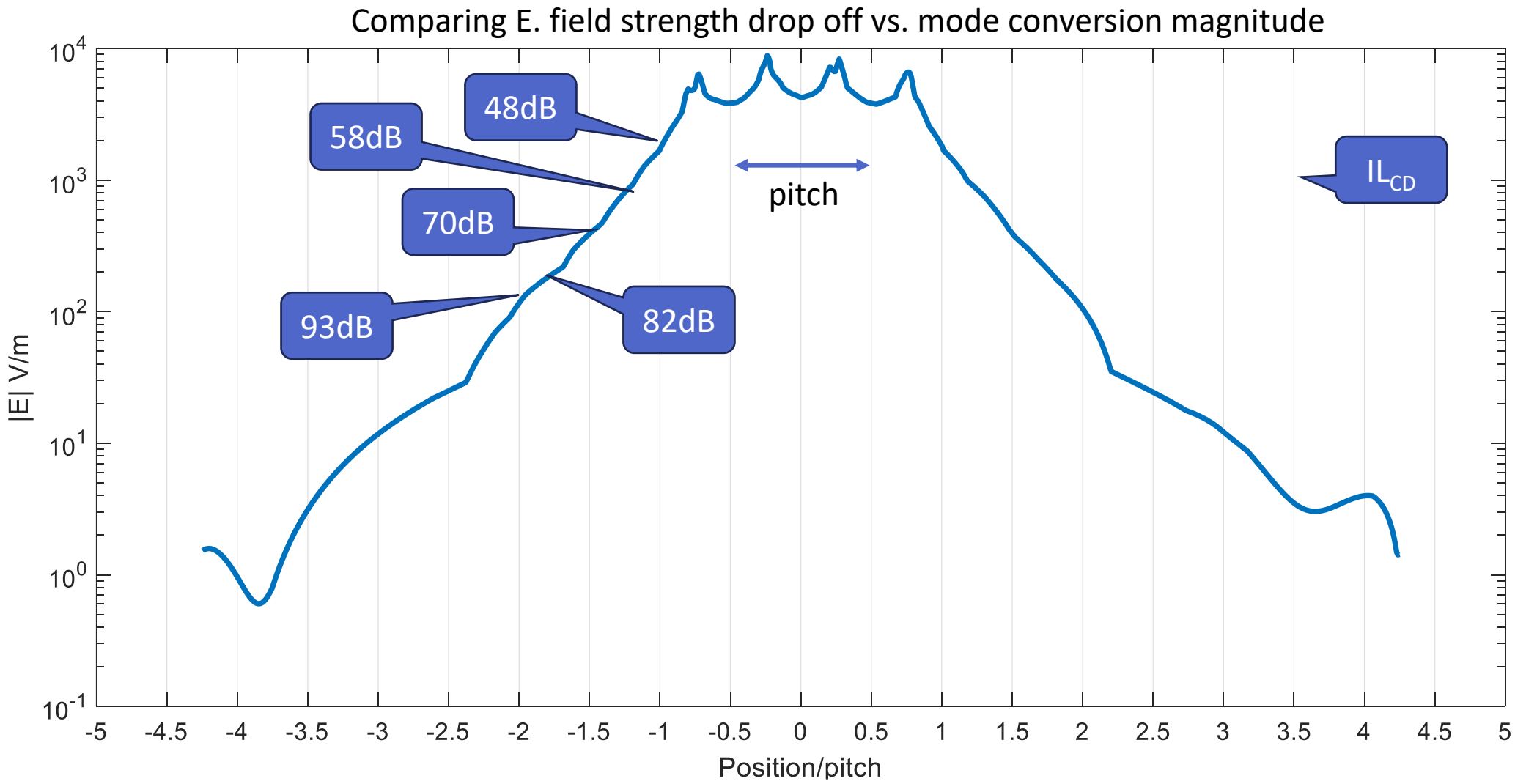
Via Fence Asymmetry

|E| at 5 GHz





Via Fence Asymmetry

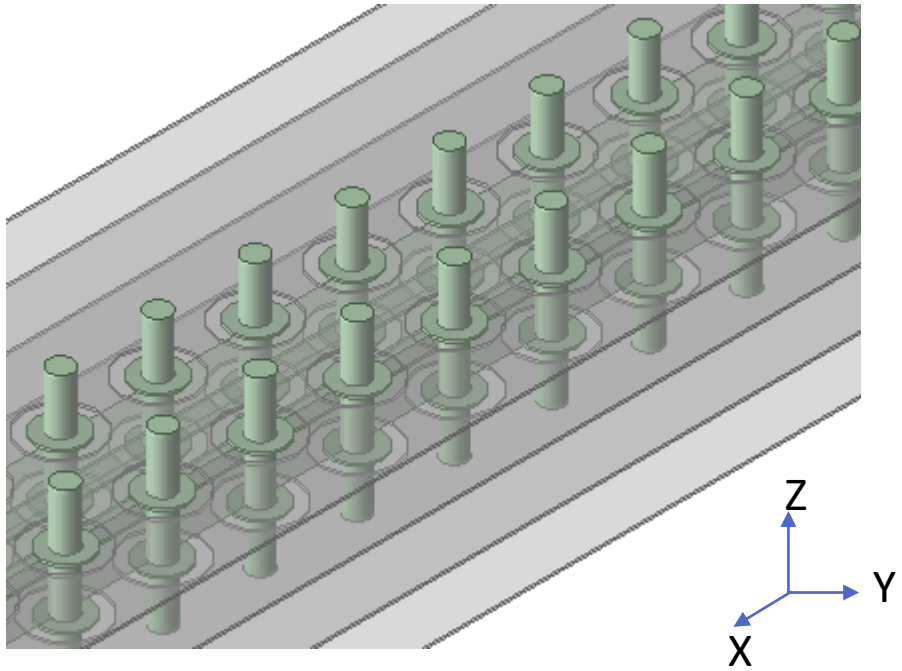


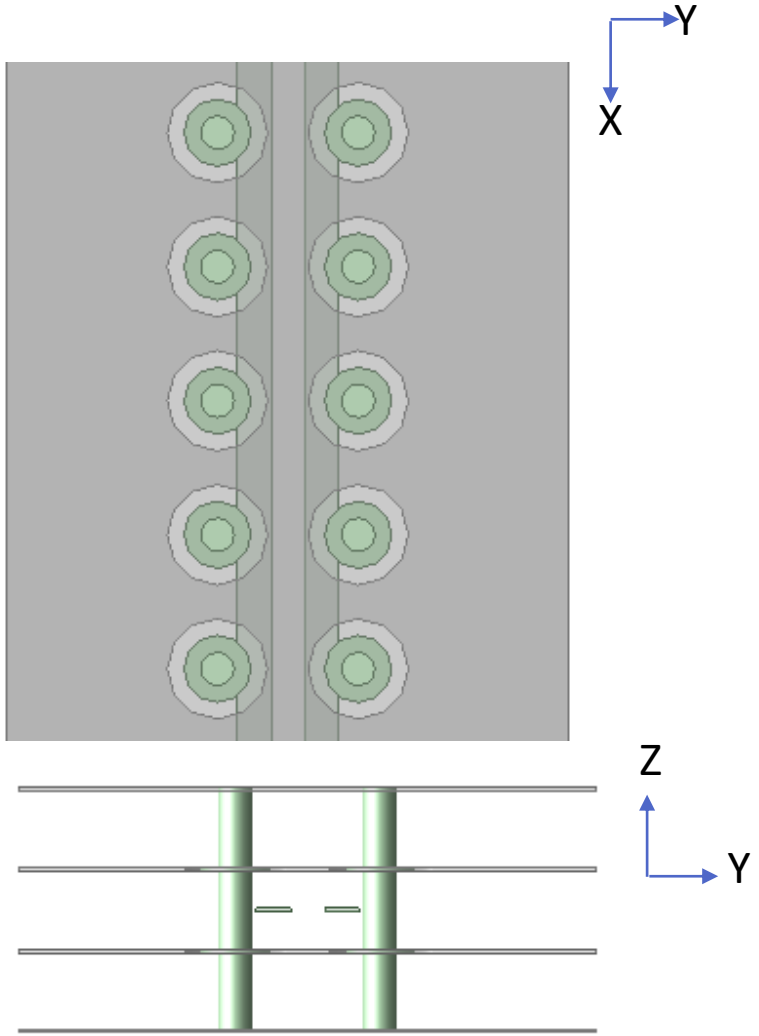
Key takeaway: Imbalance in return path within 1 pitch of signal strongly impacts mode conversion

Caution Area 4

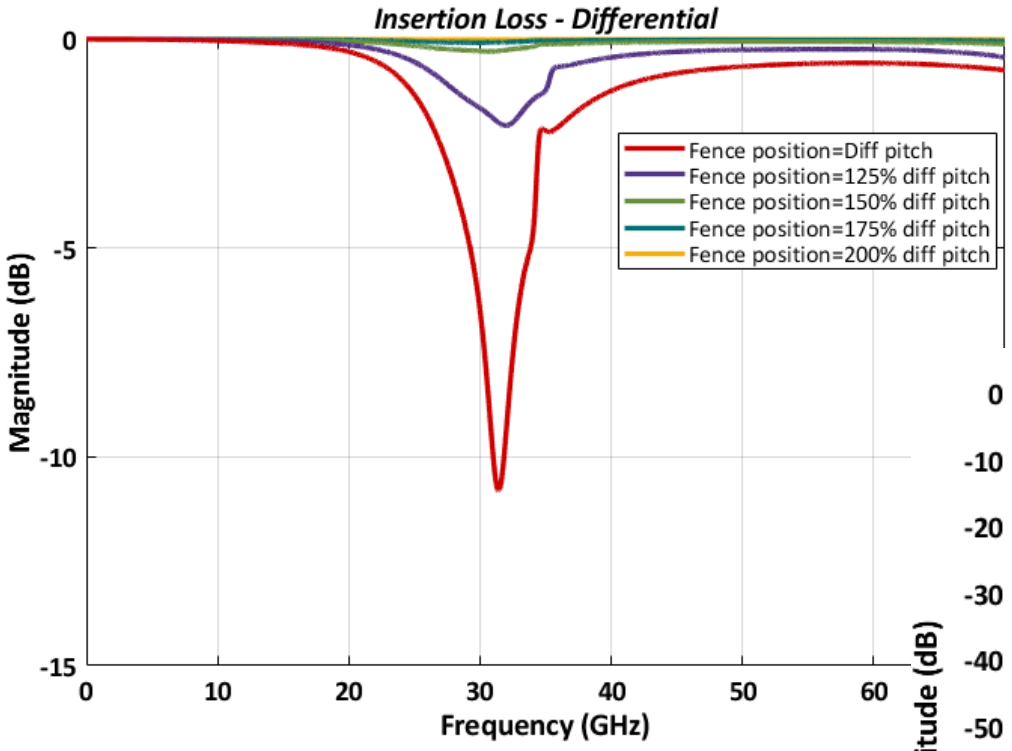
Periodic Discontinuities

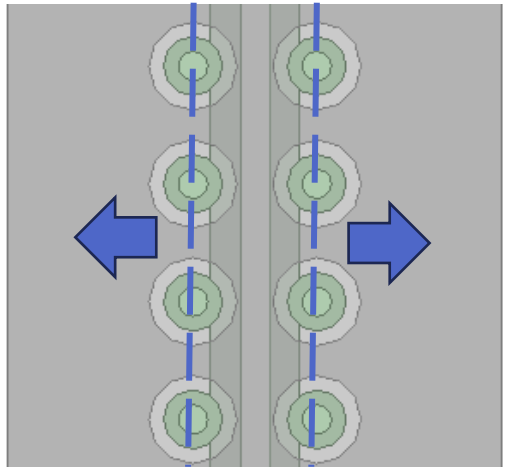
Periodic Albeit Balanced Discontinuities

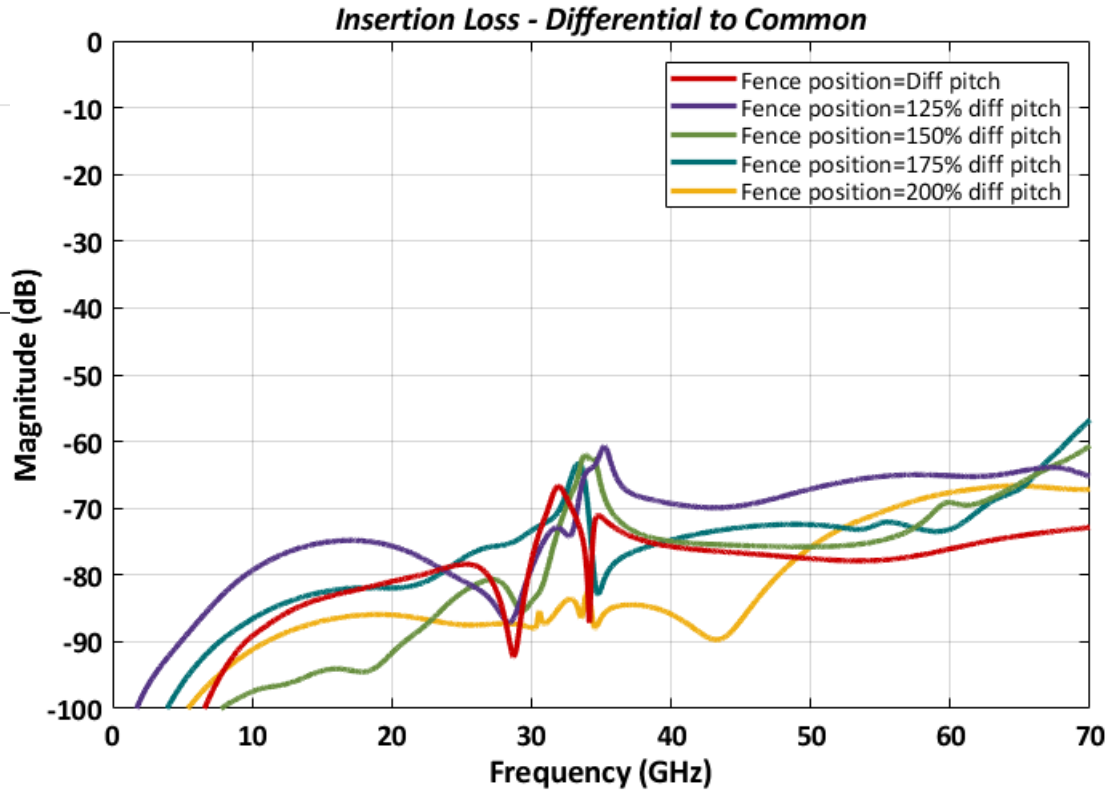




Periodic Discontinuities



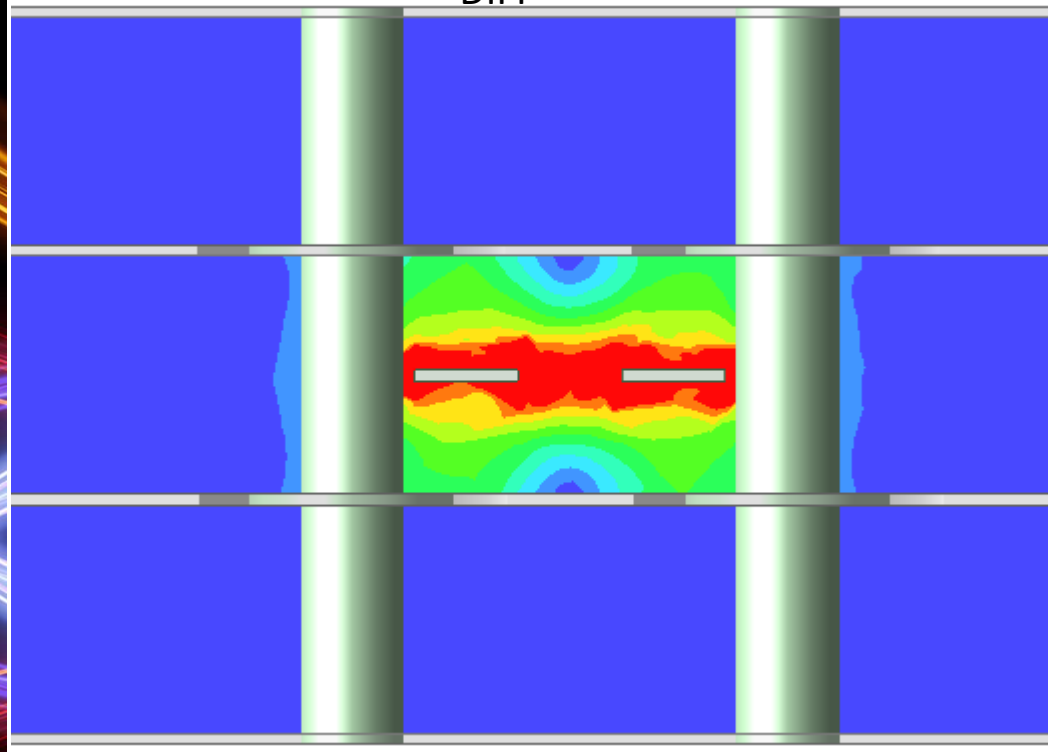




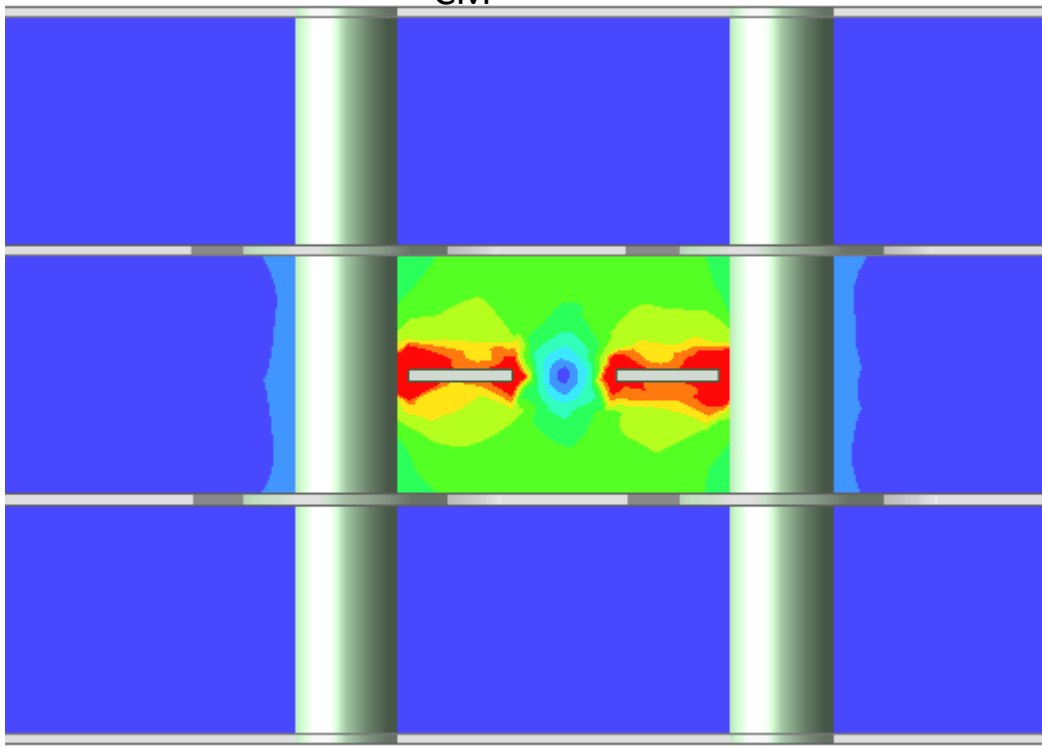
Key takeaway: With balanced discontinuities, diff mode more impacted than mode conversion

Periodic Discontinuities

$|E|_{DIFF}$ at 5 GHz



$|E|_{CM}$ at 5 GHz



3X diff pitch

Key takeaway: Keeping return path balanced and uniform with 1.5*pitch on either side of diff. pair helps SI.

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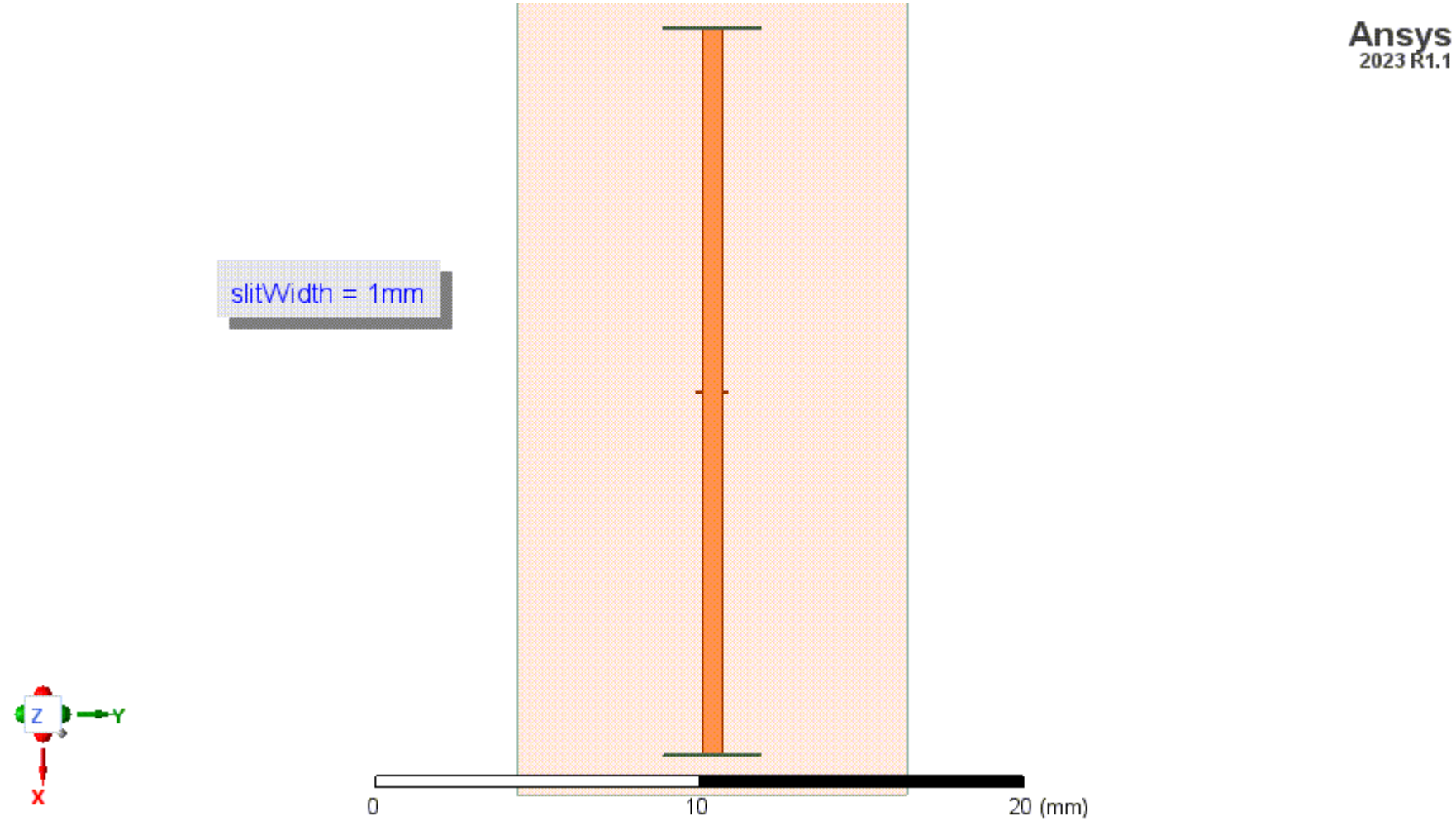
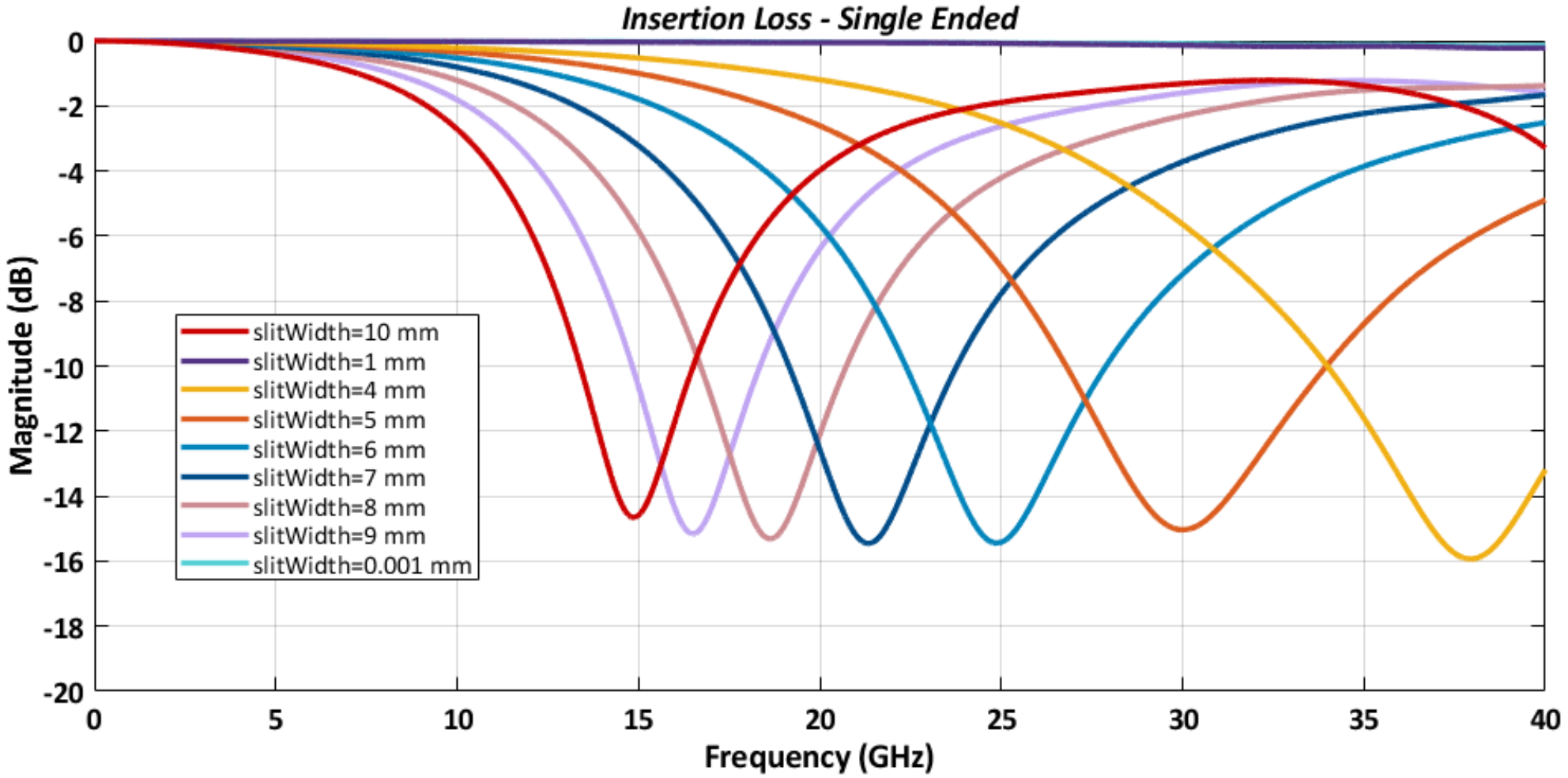
Understanding Behavior of Periodic Discontinuities

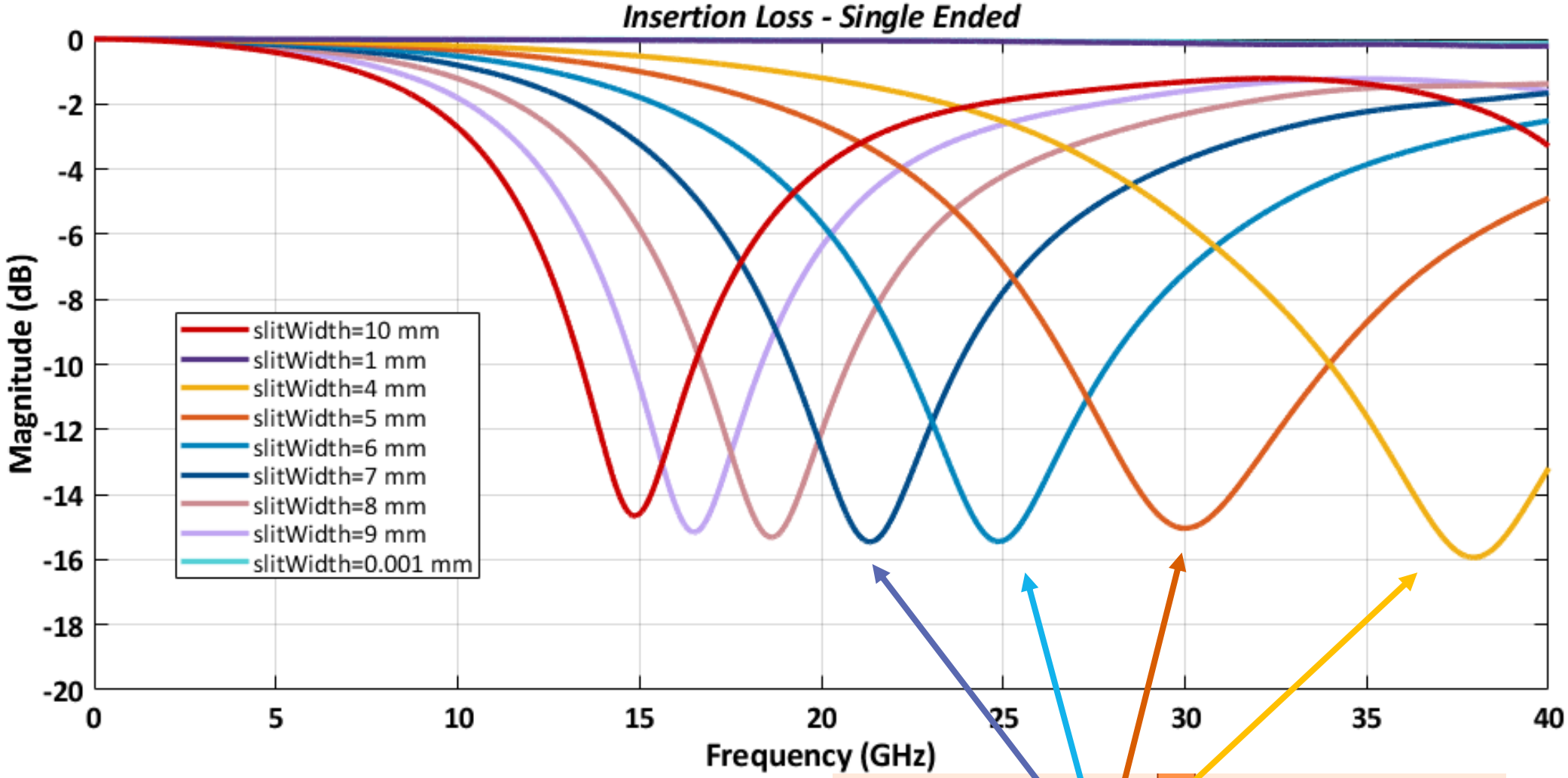
Small Cut in the Reference Plane



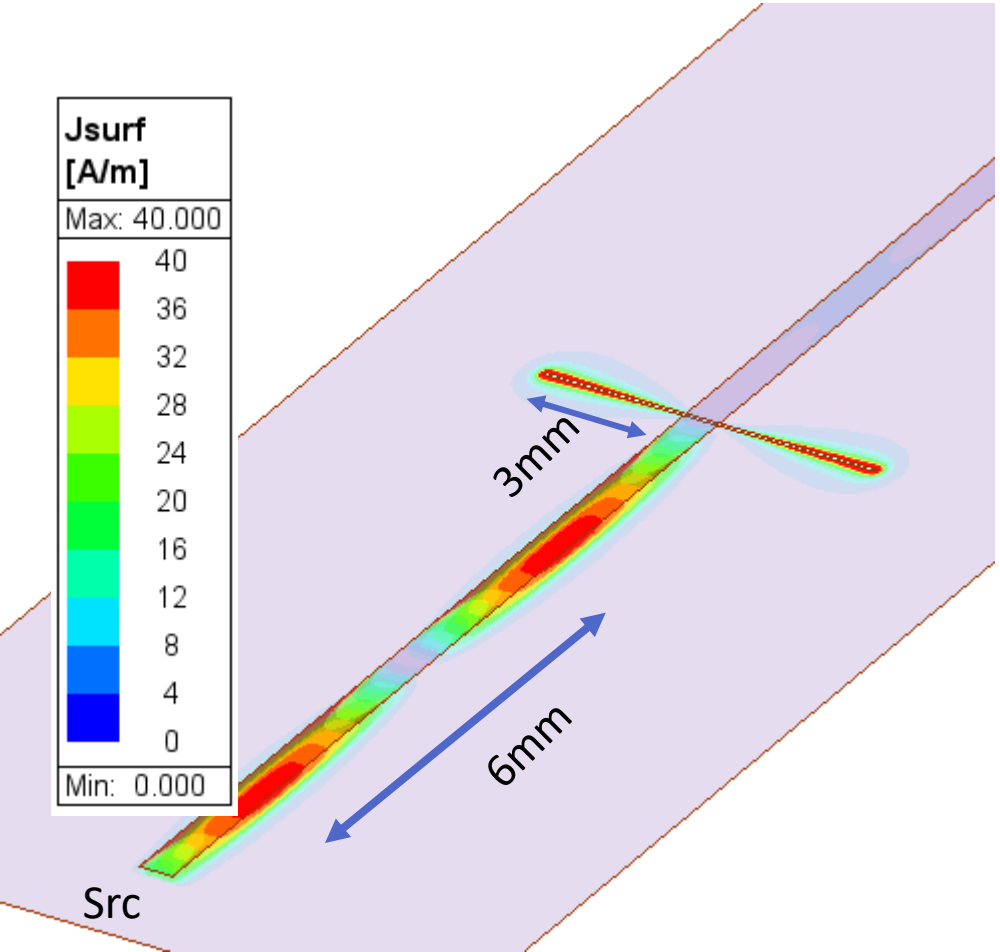
Insertion Loss Behavior

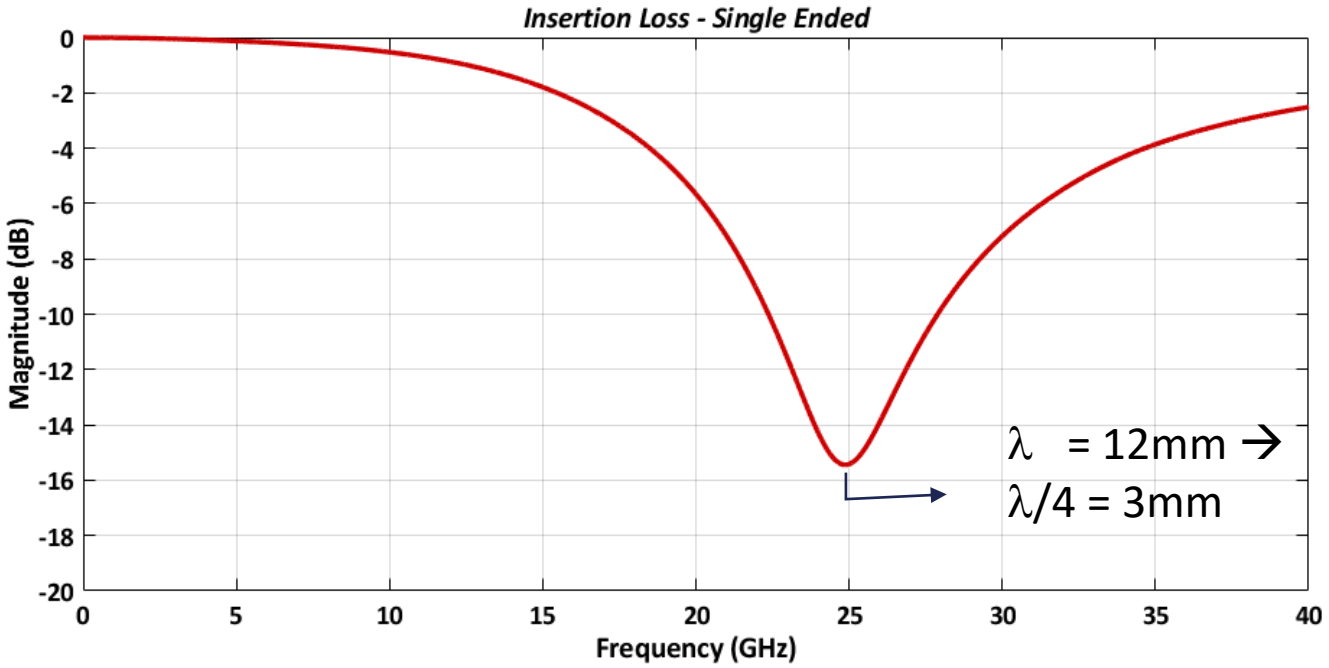


Why These Frequencies?

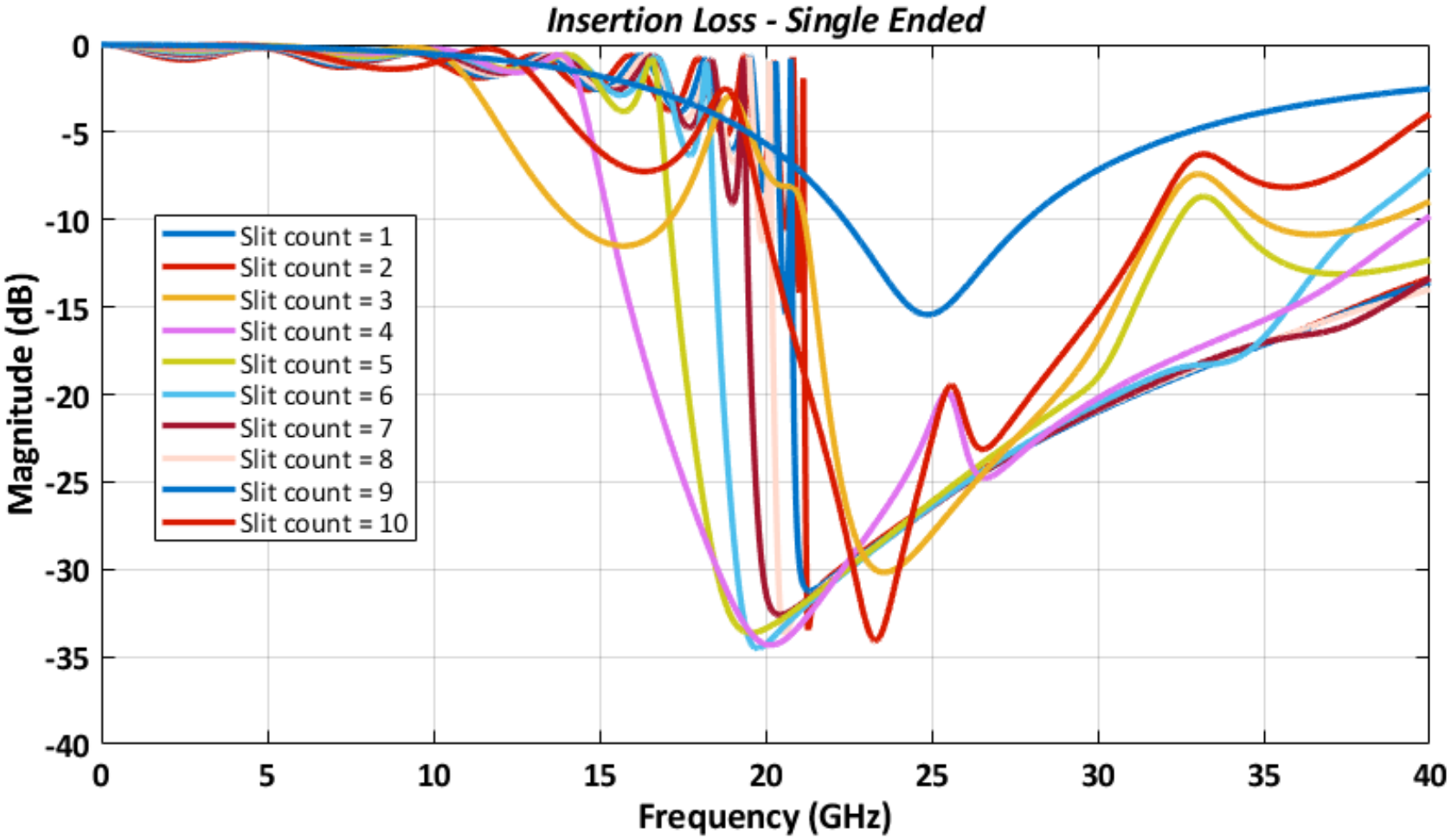


What Does the Current Flow Look Like?





What if there are Multiple Slots?

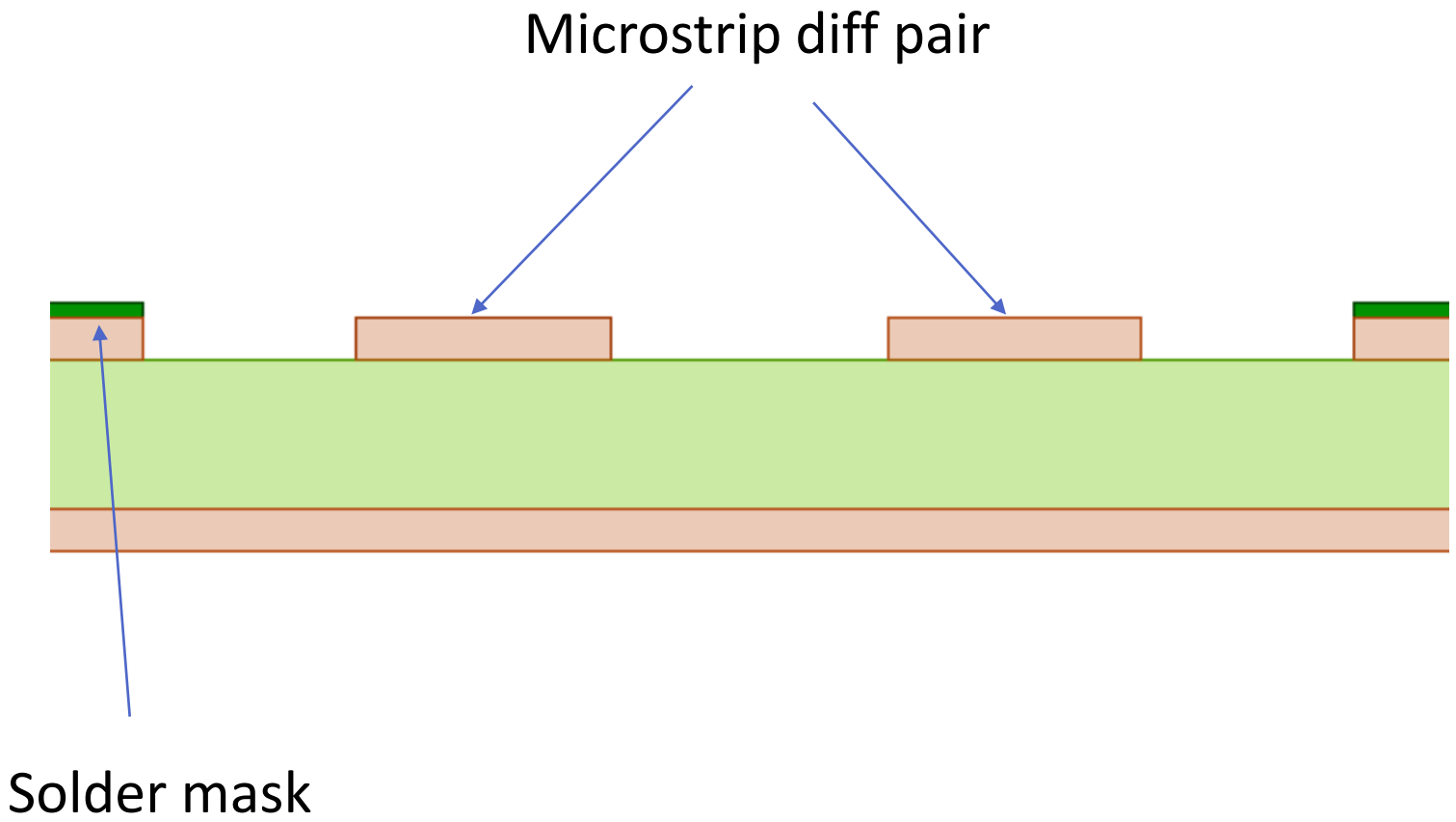


Key takeaway: The discontinuities act like repeating cells. Concept is known as Bloch's theorem: https://en.wikipedia.org/wiki/Bloch%27s_theorem

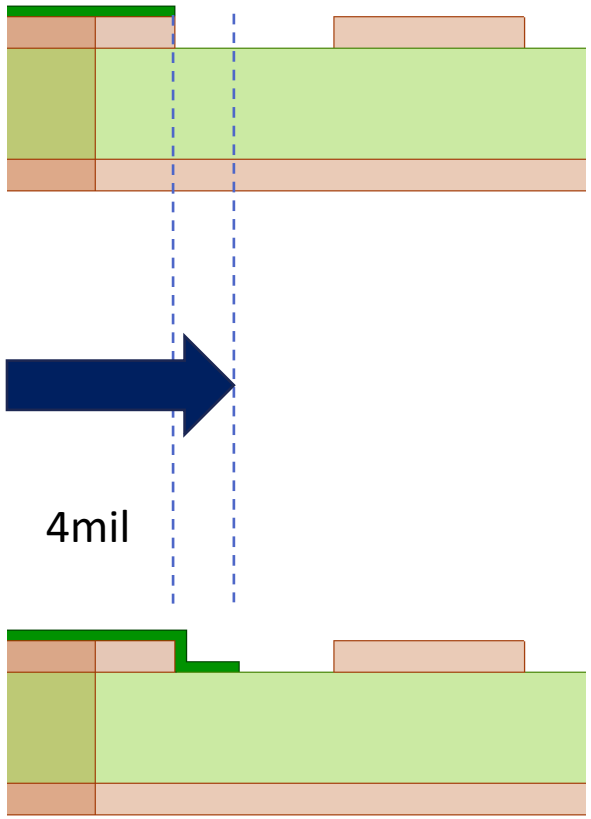
Caution Area 5

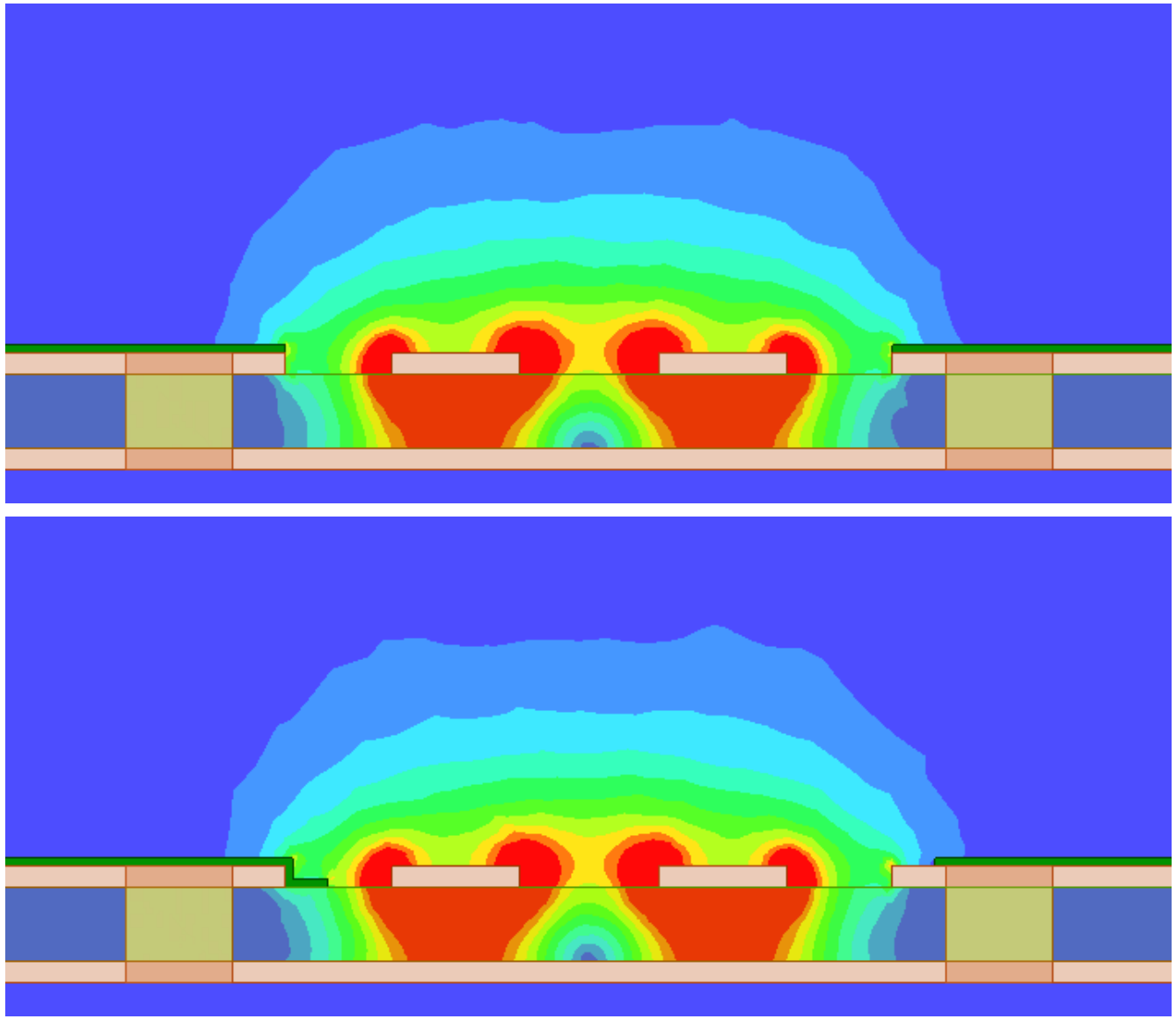
Soldermask Imbalance

Soldermask Imbalance Impact

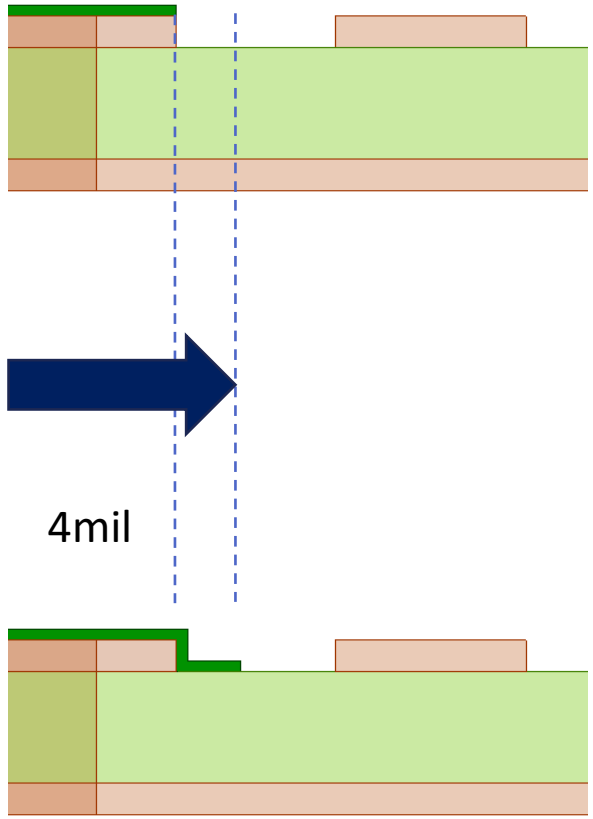


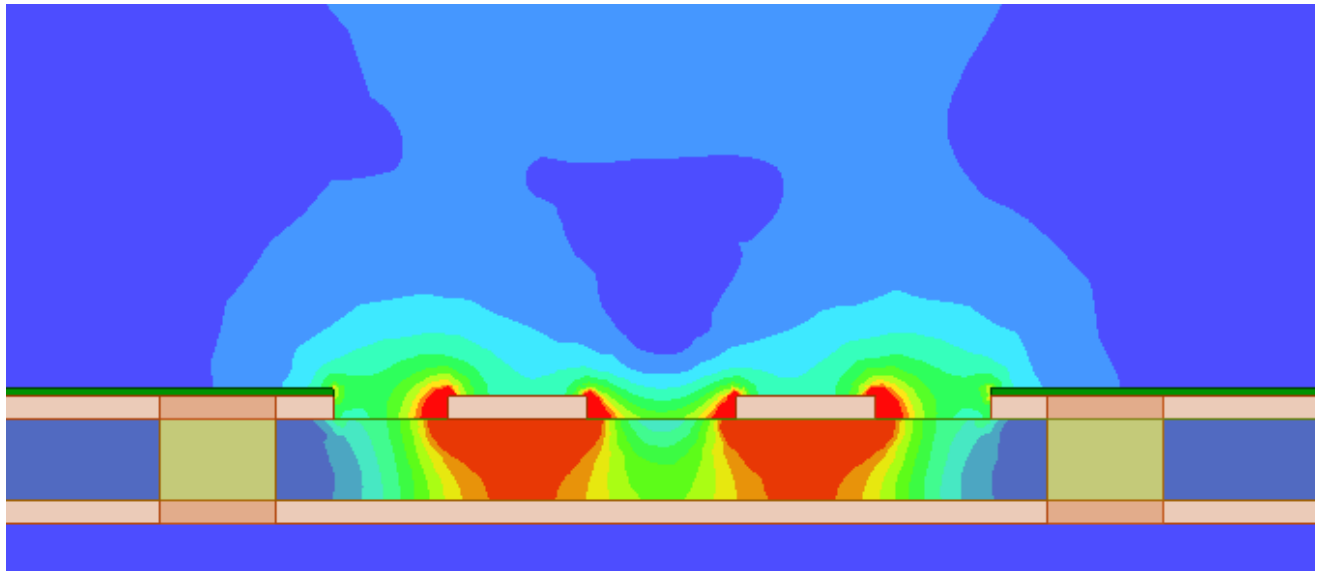
Soldermask Imbalance: |E| Diff excitation

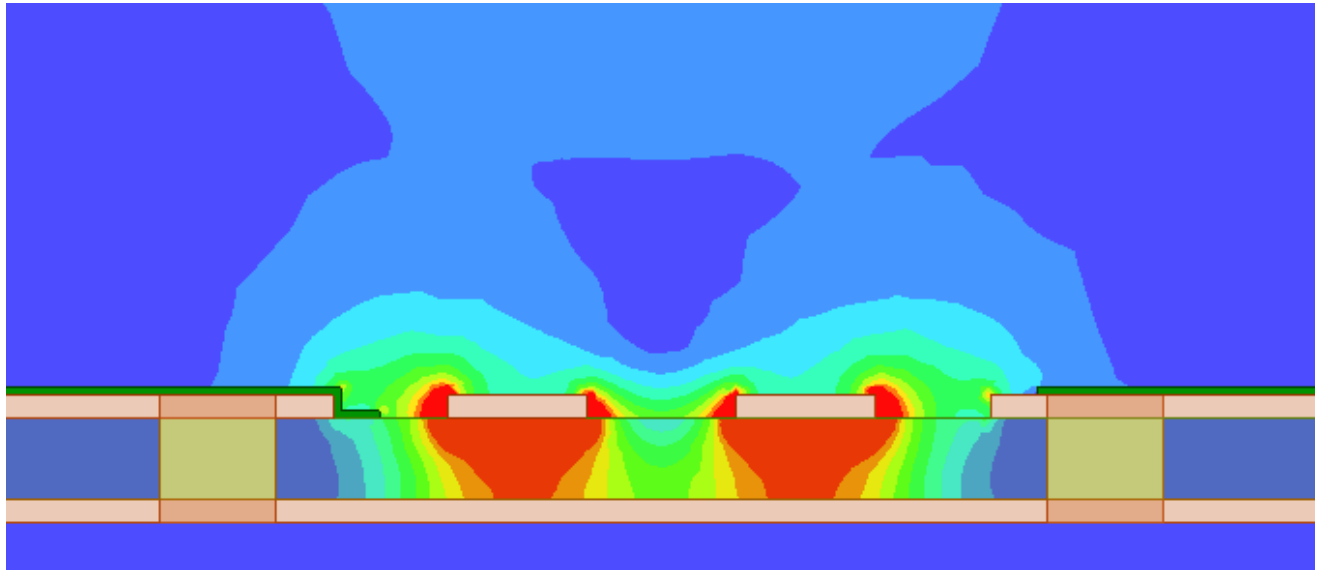




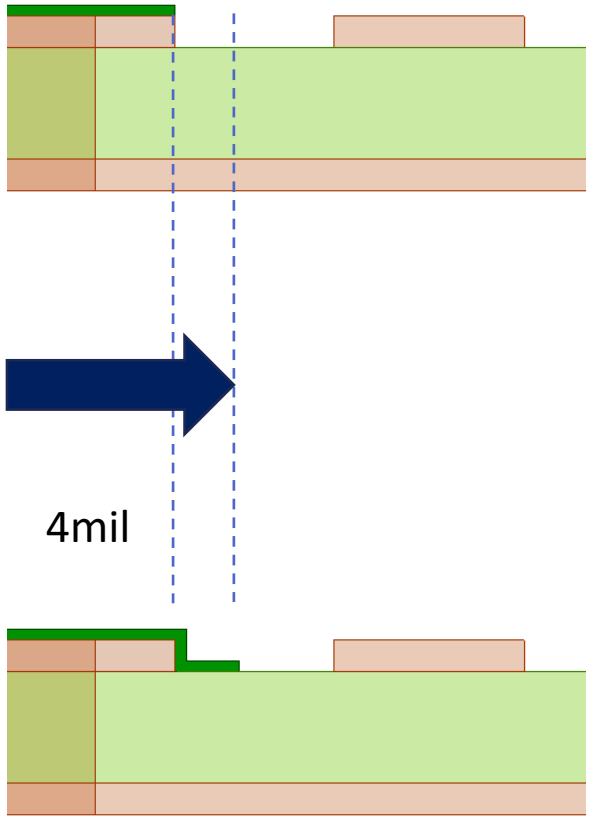
Soldermask Imbalance: |E| Comm. Excitation

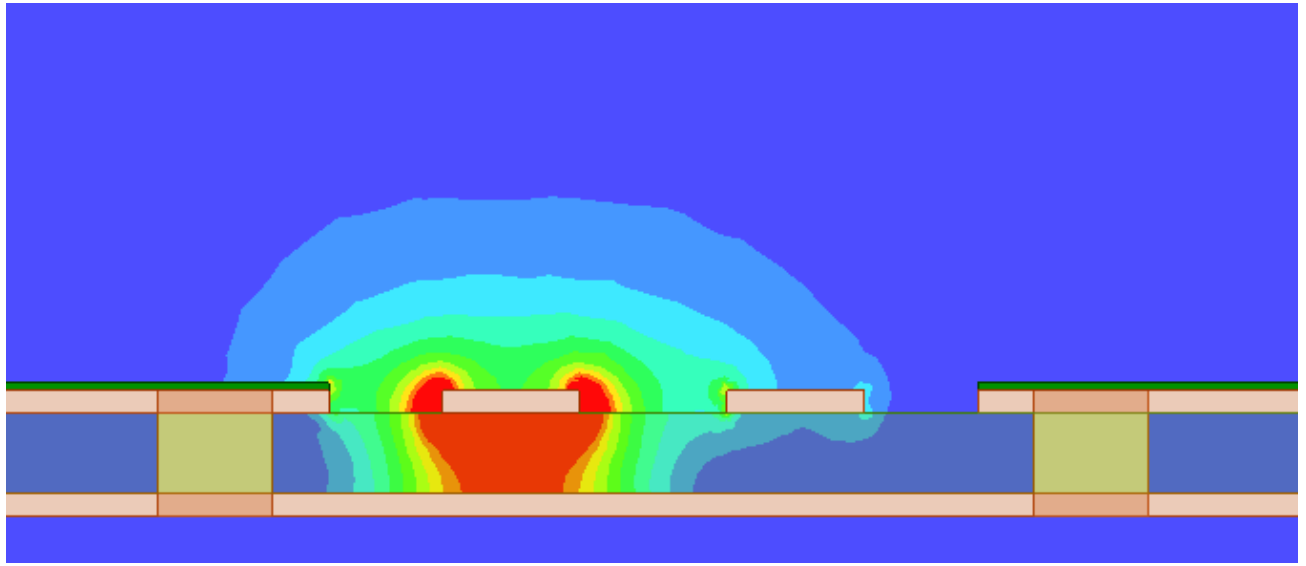


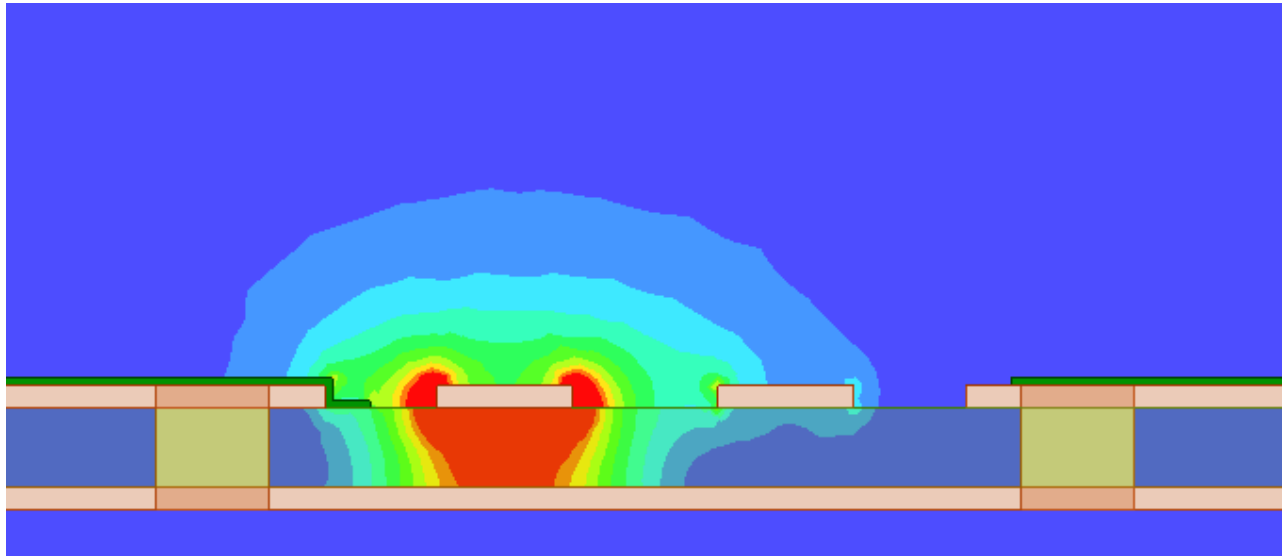




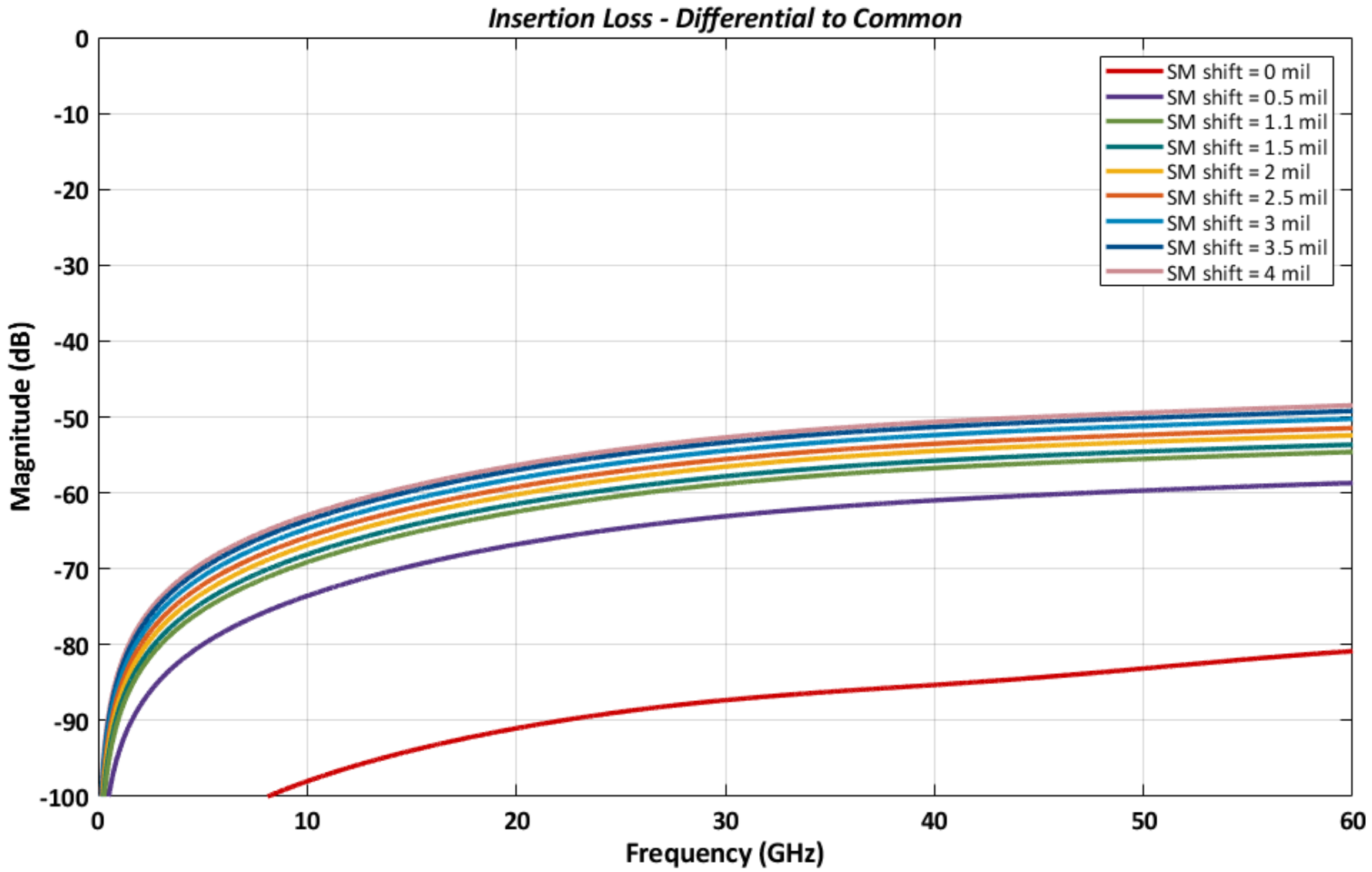
Soldermask Imbalance: |E|SE Excitation



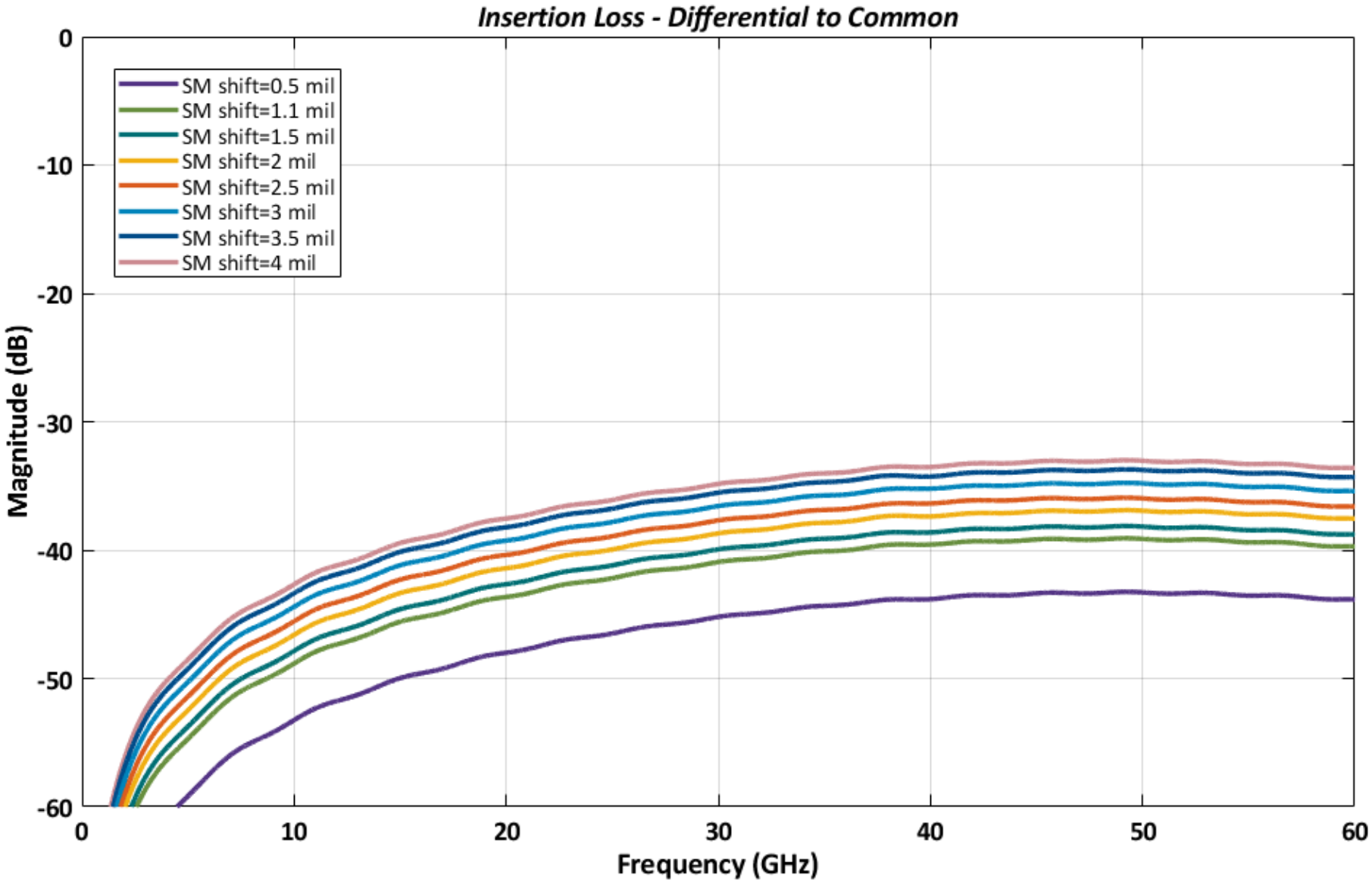




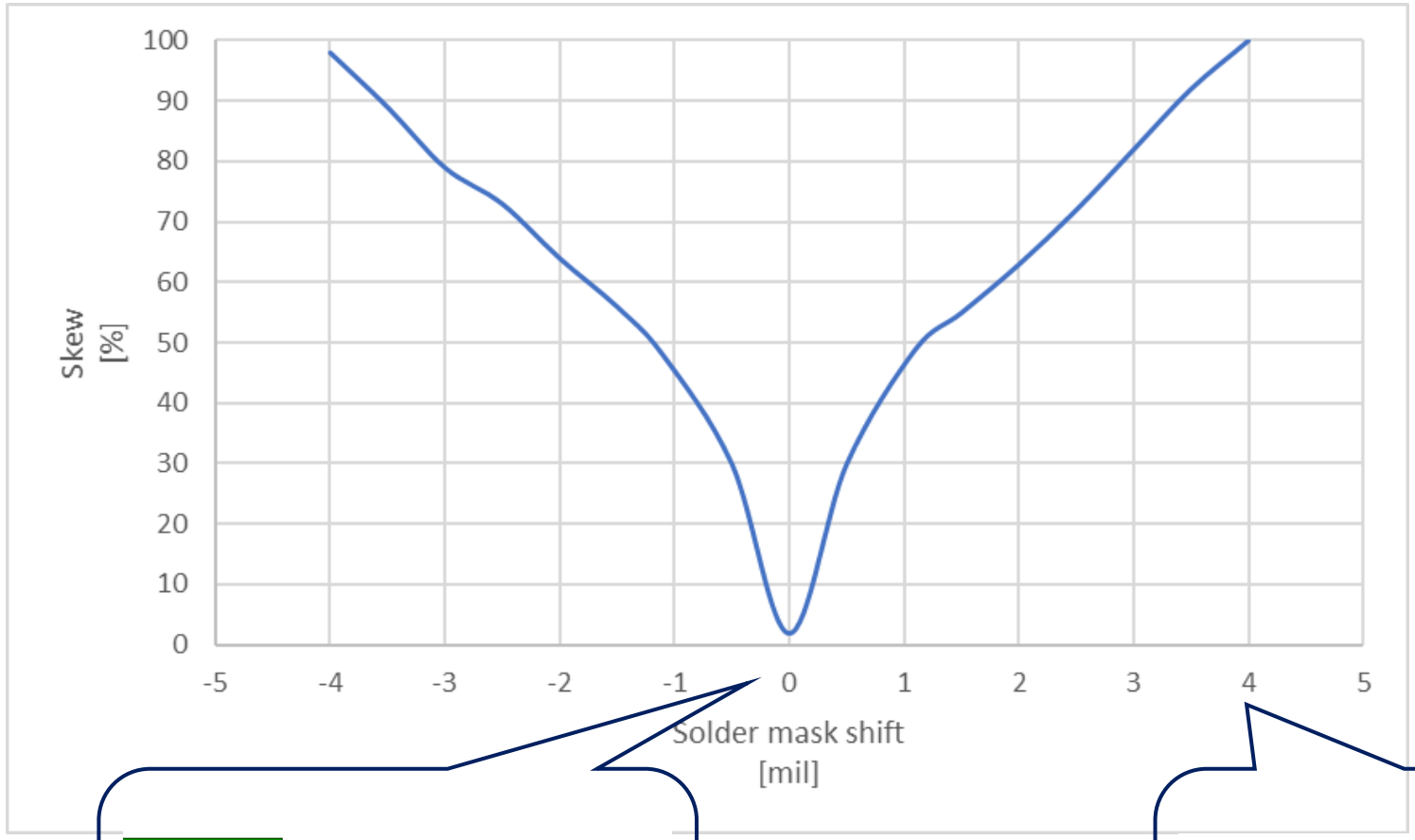
Soldermask Imbalance: Mode Conversion 0.1”

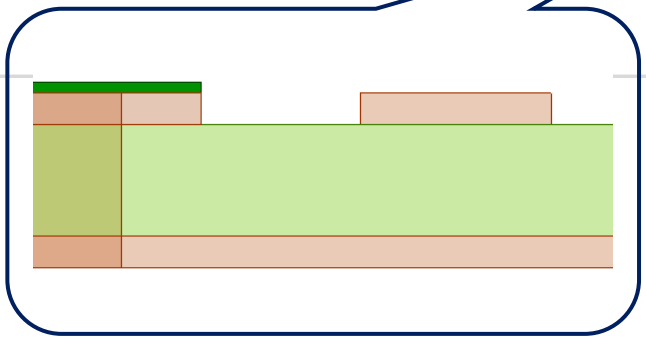


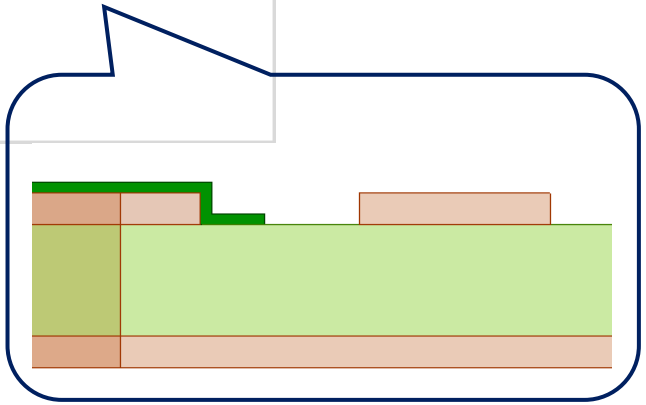
Soldermask Imbalance: Mode Conversion 1”



Soldermask Imbalance: Skew Impact







Wrap Up

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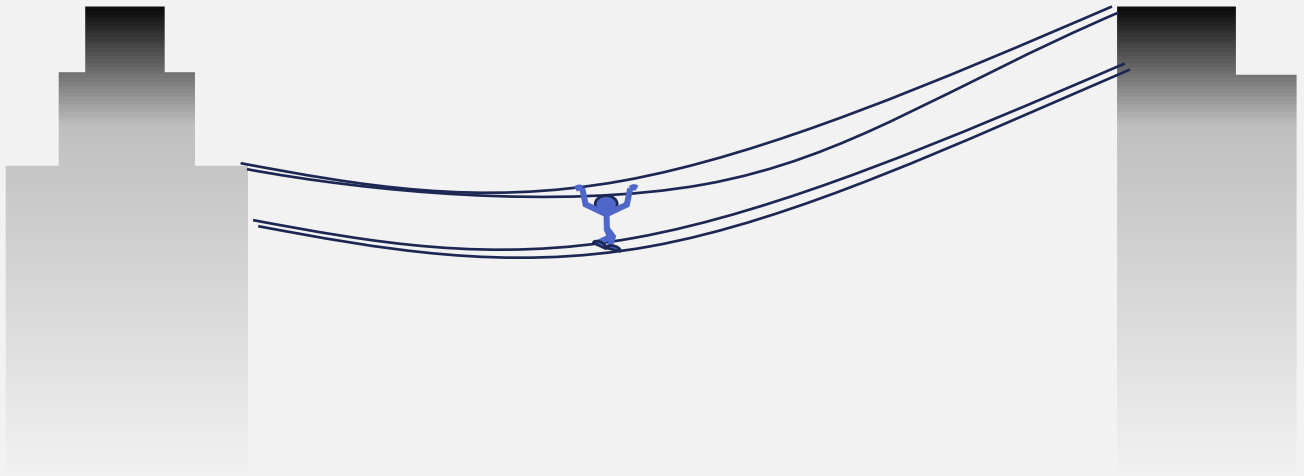
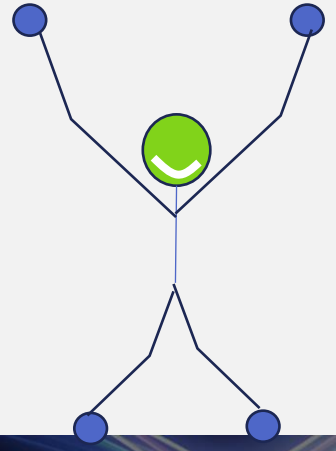
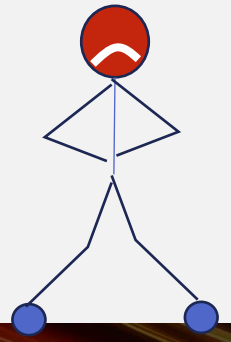
A Useful Analogy



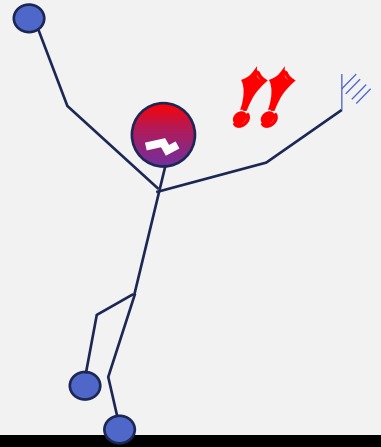
4 wires: ***Stable***



2 wires: ***Unstable***



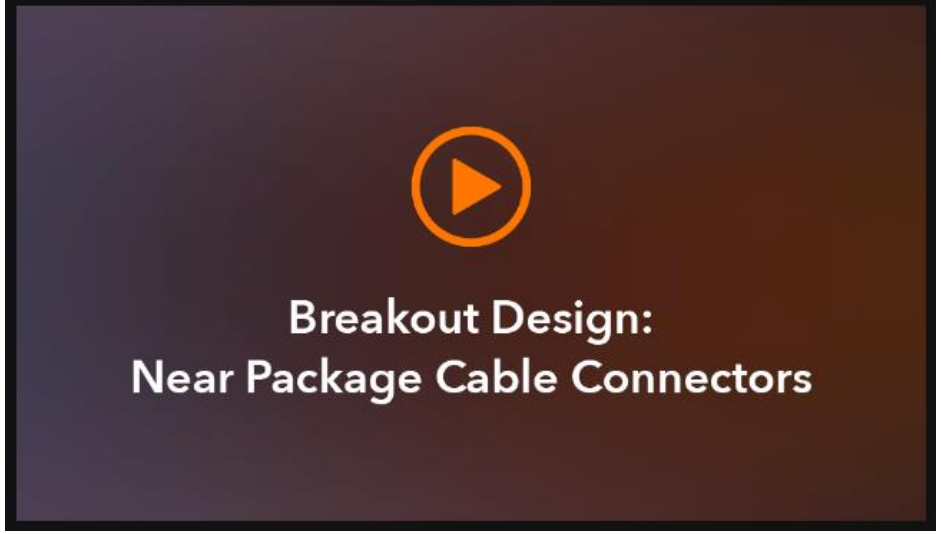
3 wires: ***Unbalanced***



gEEk spEEk

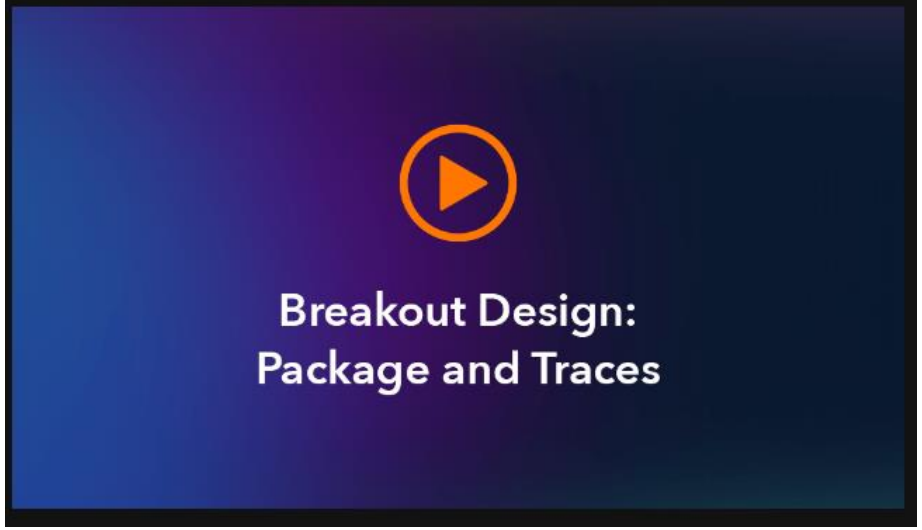
July 20, 2023

Breakout Design: Cable Connectors



June 15, 2023

Breakout Design: Package and Traces

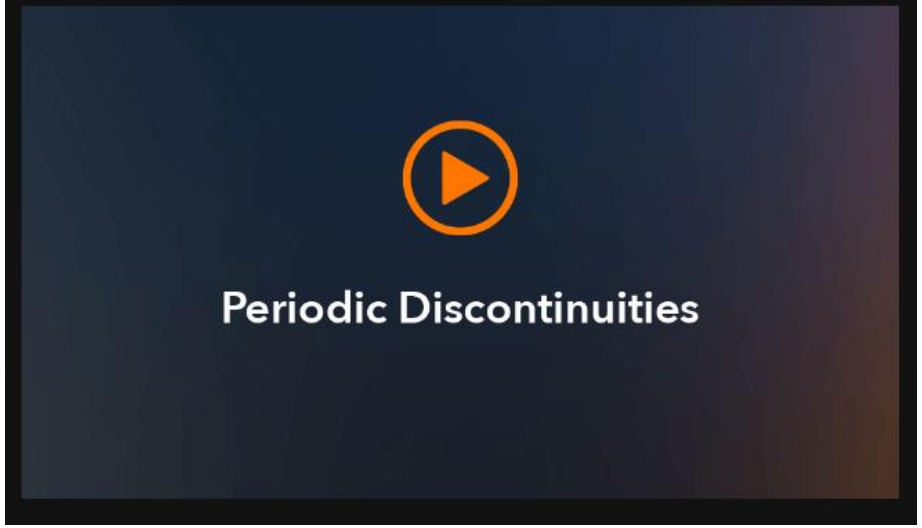


May 18, 2023

SerDes Common Mode Noise - How Much to Too Much?

September 24, 2020

Periodic Discontinuities



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