Crosstalk - the other PAM4 constraint

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TestConX™
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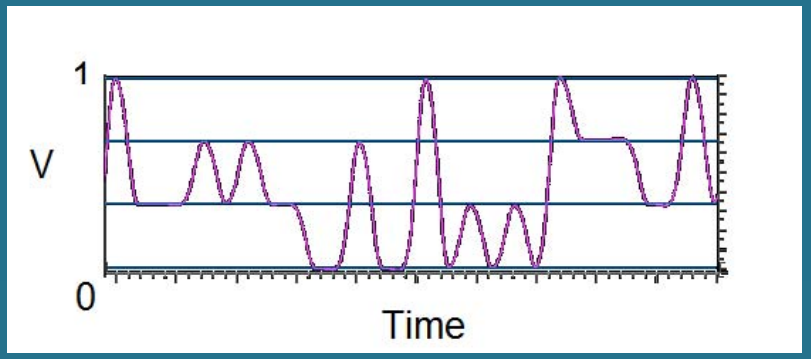
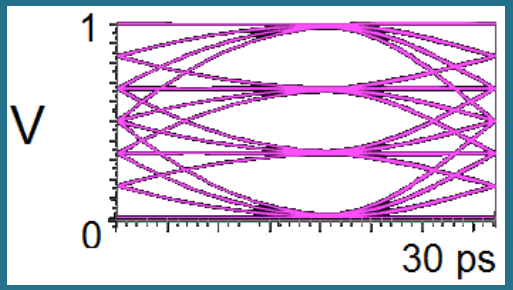
Problem

- Crosstalk -> Signal appears on adjacent lines
- Why has crosstalk become more important ?
  - 4-level signaling leads to reduced margins:





  - Increase in operating frequencies often worsens crosstalk

Crosstalk

- *Forward crosstalk* aka FEXT (far-end XT)
  - In direction of signal travel
  - Generally this is the one to worry about
- *Backward crosstalk* aka NEXT (near-end XT)
  - Against direction of signal travel
  - Less significant if source well terminated and not an active receiver input

Objective

- Define relevant crosstalk
- Identify contributors
- Examine impact of design and design parameters
- Foster better understanding of constraints
- High frequency operation

Approach

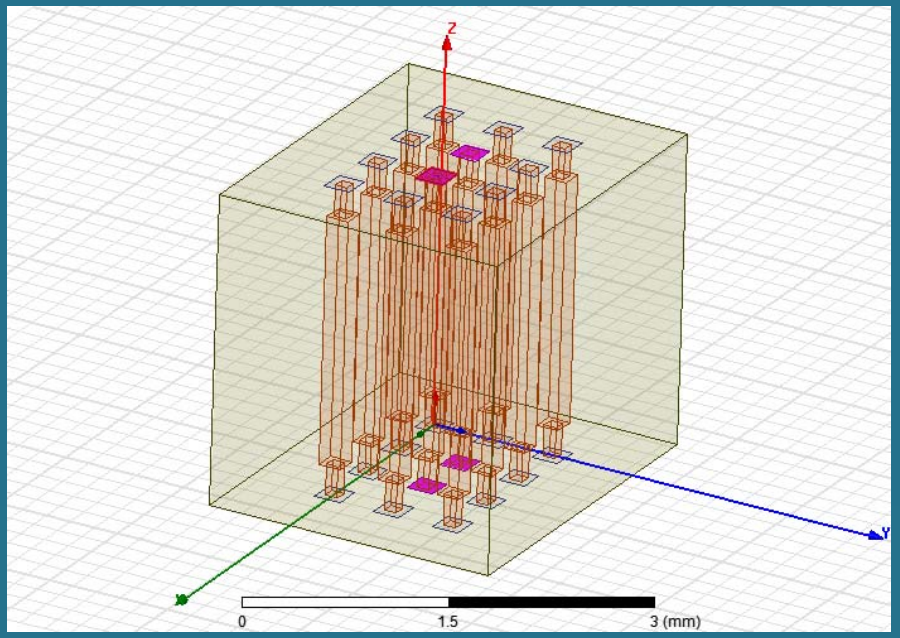
- Set up example socket model
- Examine performance via 3D field analysis
  - begin with single ended configurations
    - Develop basic understanding of contributors
    - Vary parameters to find sensitivity
  - expand to high speed differential configurations
    - Evaluate options for crosstalk reduction
- Identify PCB contributions

Relevant Socket Parameters

- Ground locations
- Pitch
- Contact length
- Contact lateral dimensions
- Housing construction (metal vs. dielectric)
- Housing material, e.g. dielectric constant

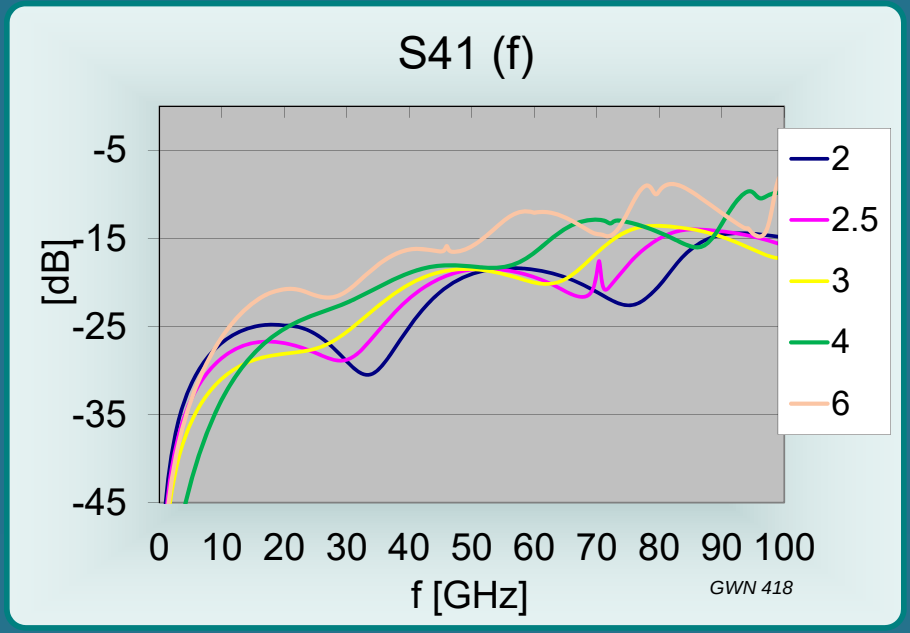
Only parameter examples that affect crosstalk are listed

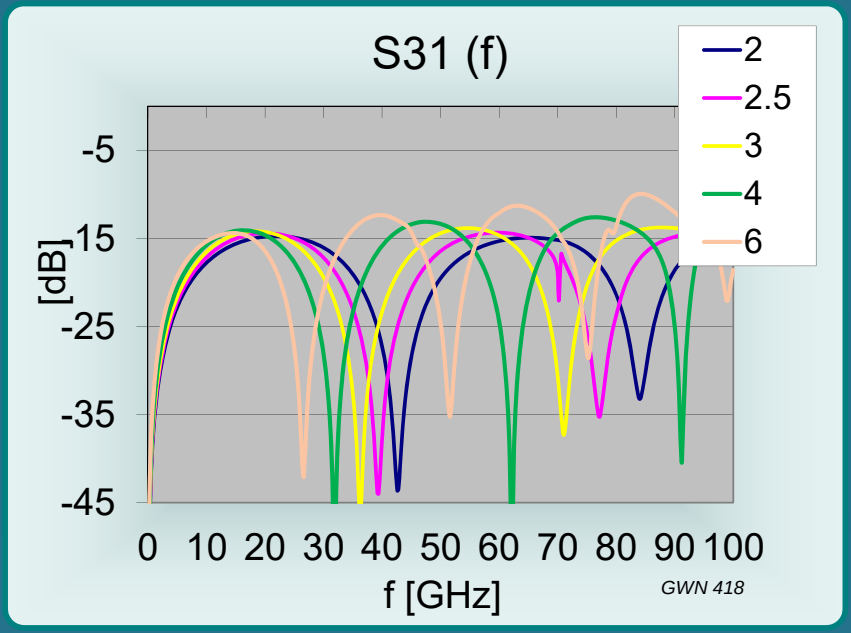
Single-ended line crosstalk model



Coupling between two adjacent pins carrying individual unrelated signals

FEXT and NEXT as a function of dielectric constant



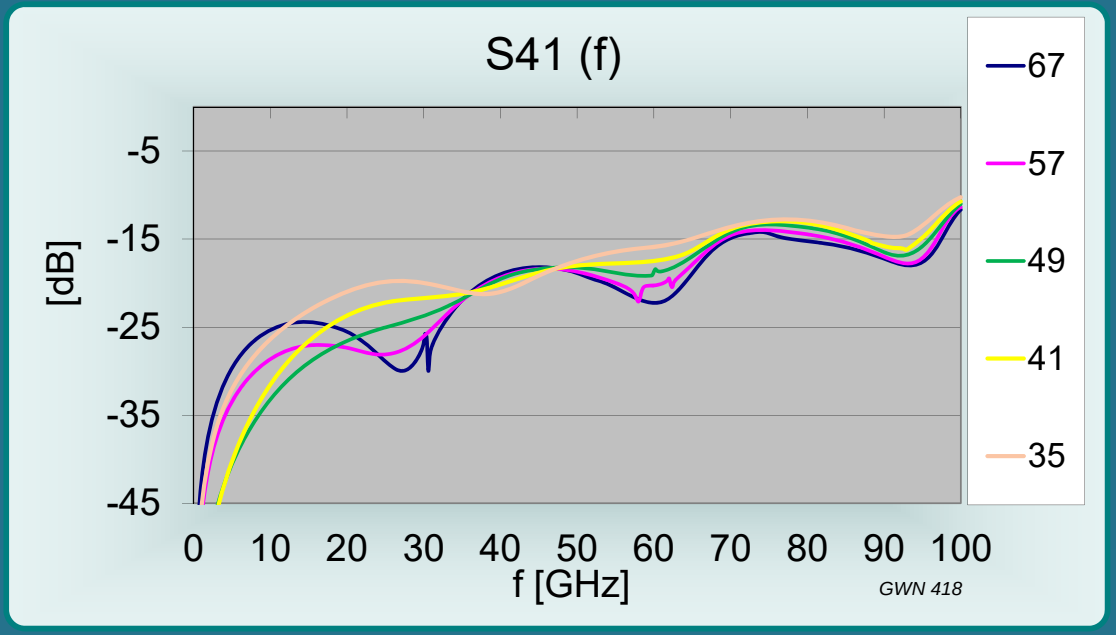


FEXT -> noticeable variability (Zo changes)

NEXT -> only small changes below 20 GHz

(Zo will vary depending on dielectric constant)

FEXT as a function of impedance

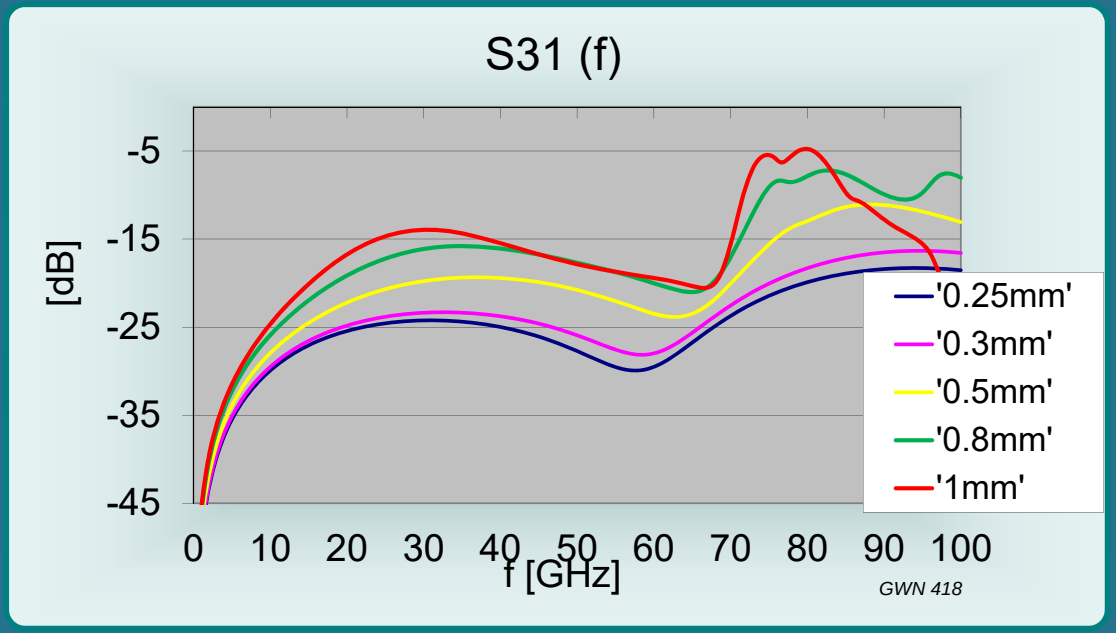


All cases:

- Constant pitch
- Identical height

Smoothest overall performance at Z=49 Ohms

NEXT as a function of length

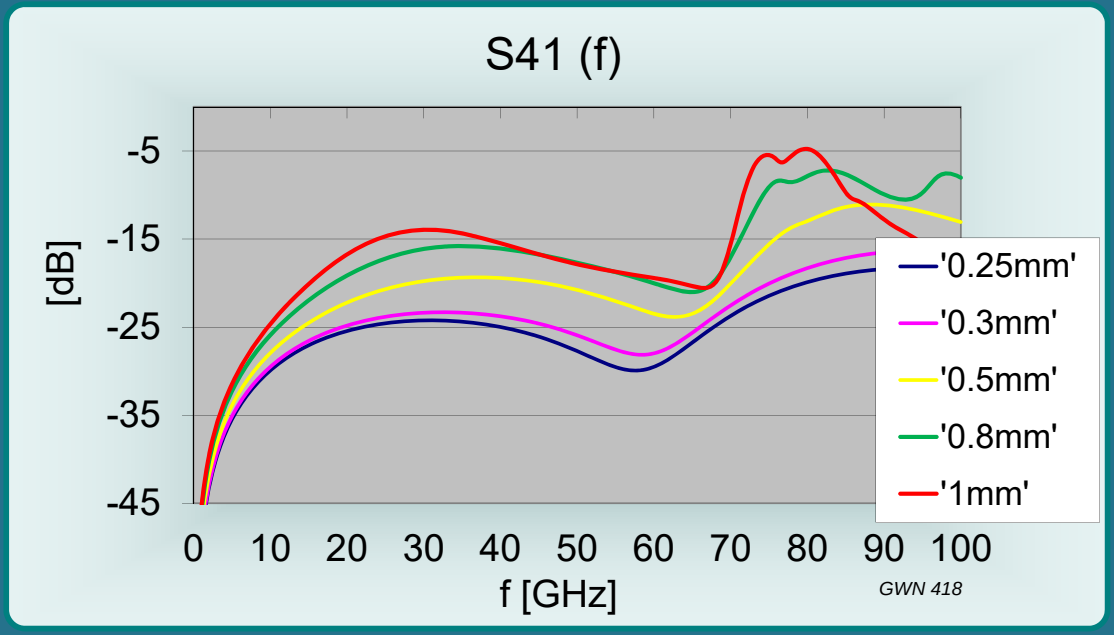


All cases:

- Zo~50 Ohms
- Identical pitch

FEXT does ***not*** change appreciably with length (not shown)

FEXT as a function of pitch



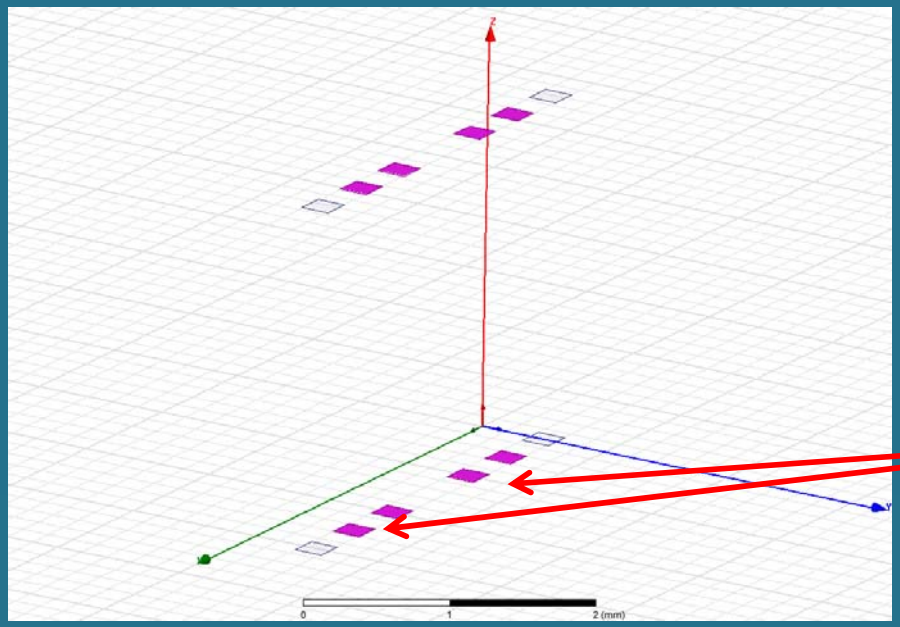
All cases:

- Zo~50 Ohms
- Identical height

Lowest FEXT for smallest pitch

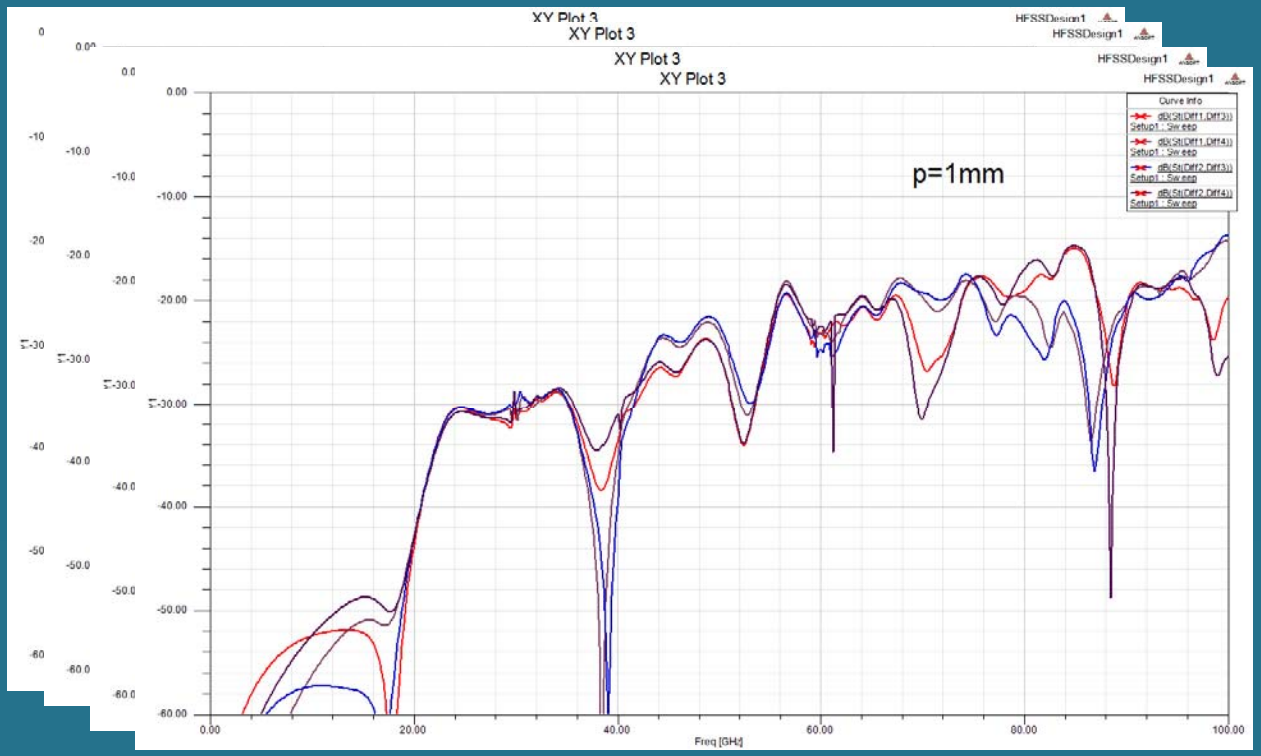
(however, no significant changes for NEXT)

Differential crosstalk as a function of pitch (edge configuration)



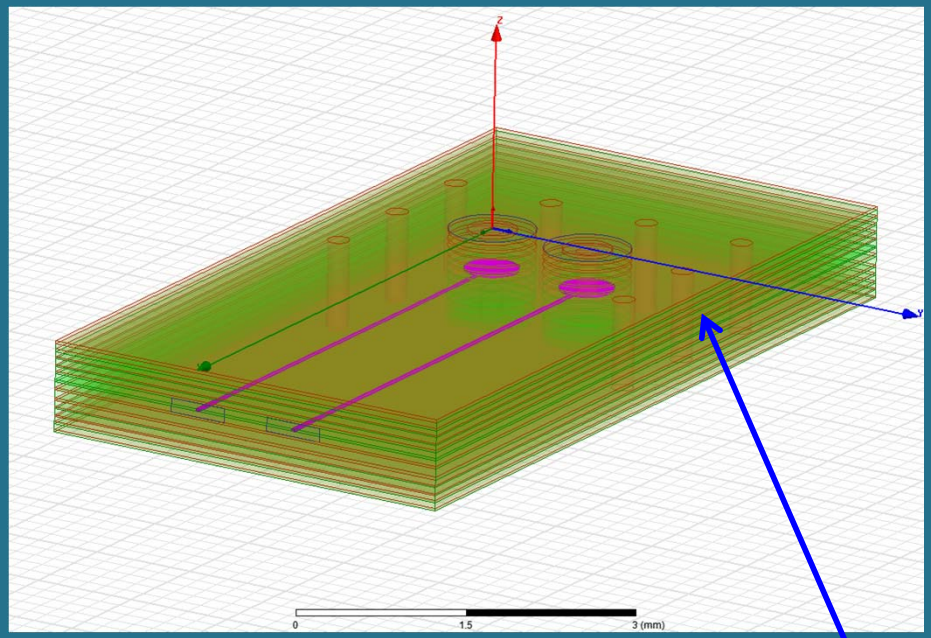
2 edge pairs without ground between signals

Differential crosstalk as a function of pitch



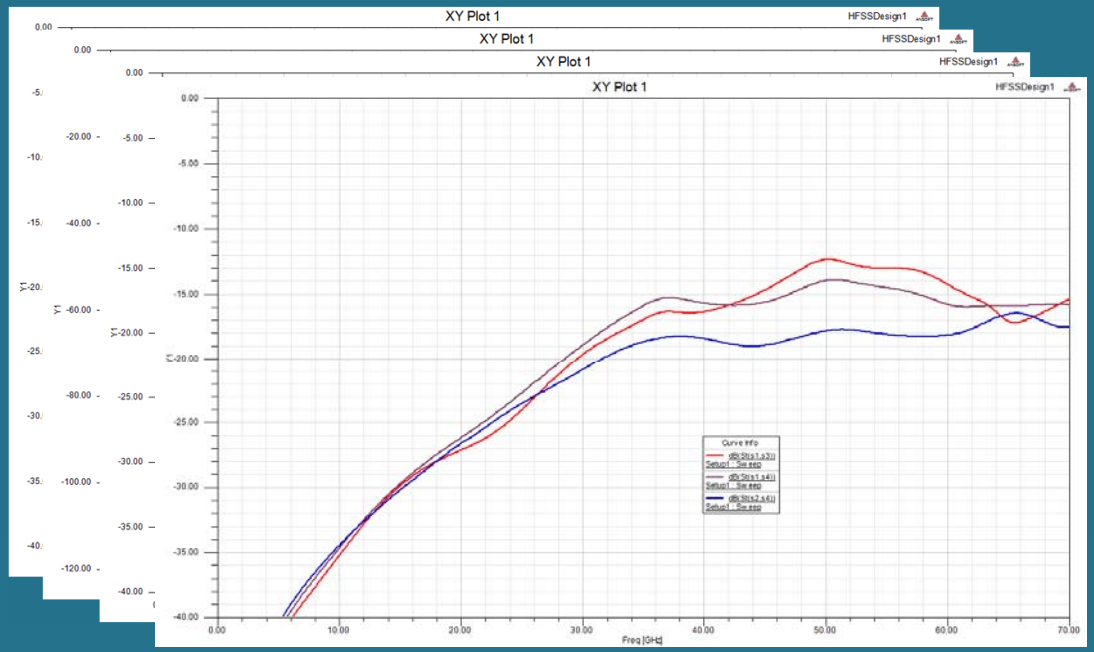
In this case, too, crosstalk increases with increasing pitch

Interactions with PCB routing



Stripline example with optional ground vias

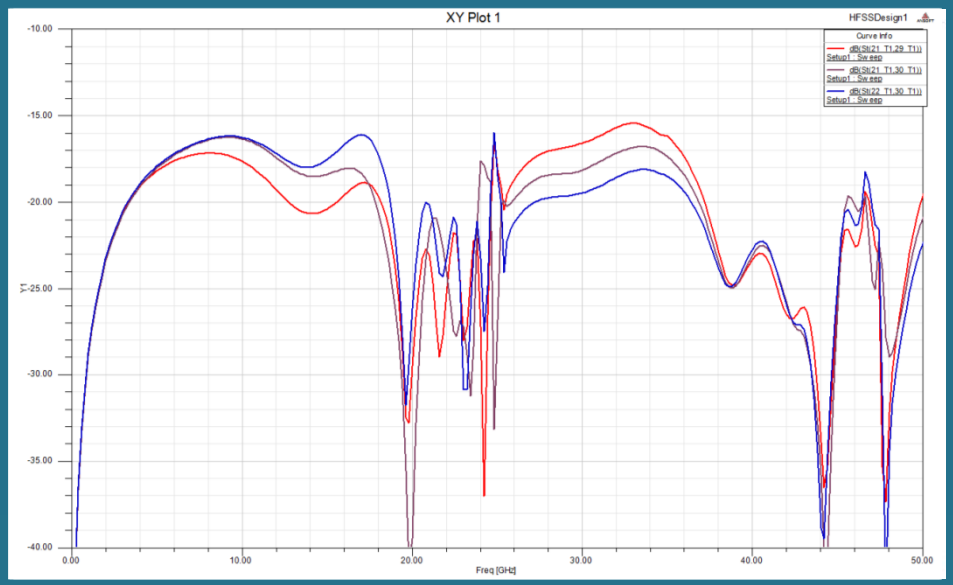
Crosstalk as a function of PCB features

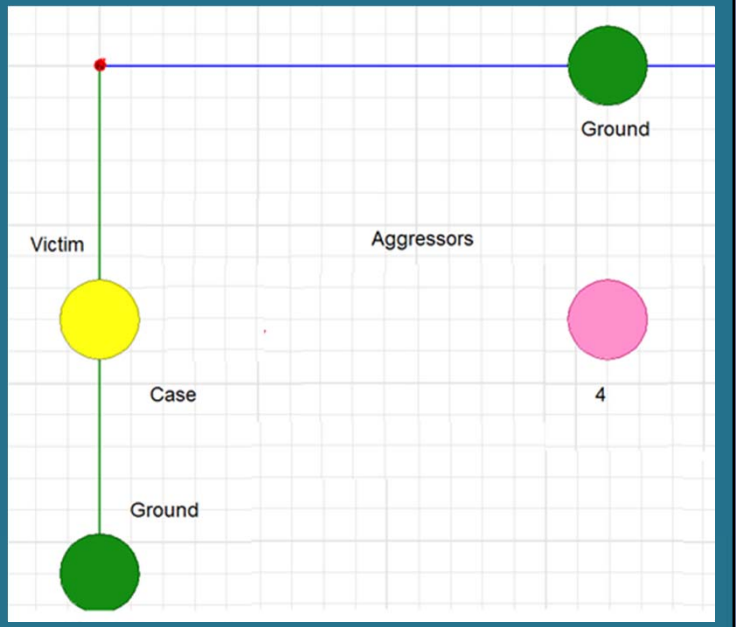


1,2 – traces only
3 – signal vias only
4 – with ground vias

Ground vias, while generally needed, can actually increase crosstalk

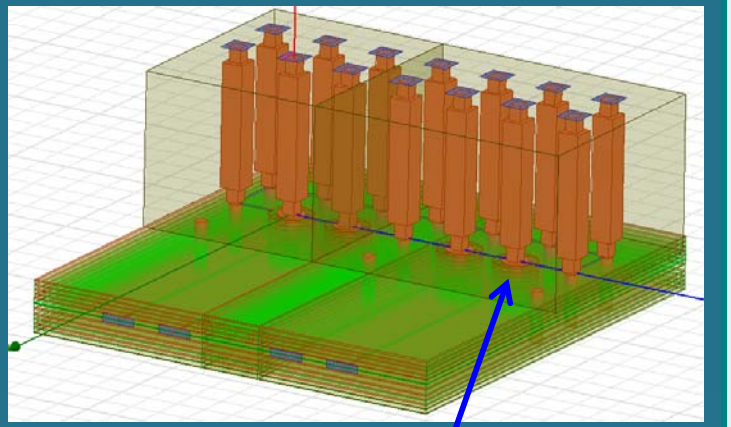
Crosstalk (all) as a function of configuration

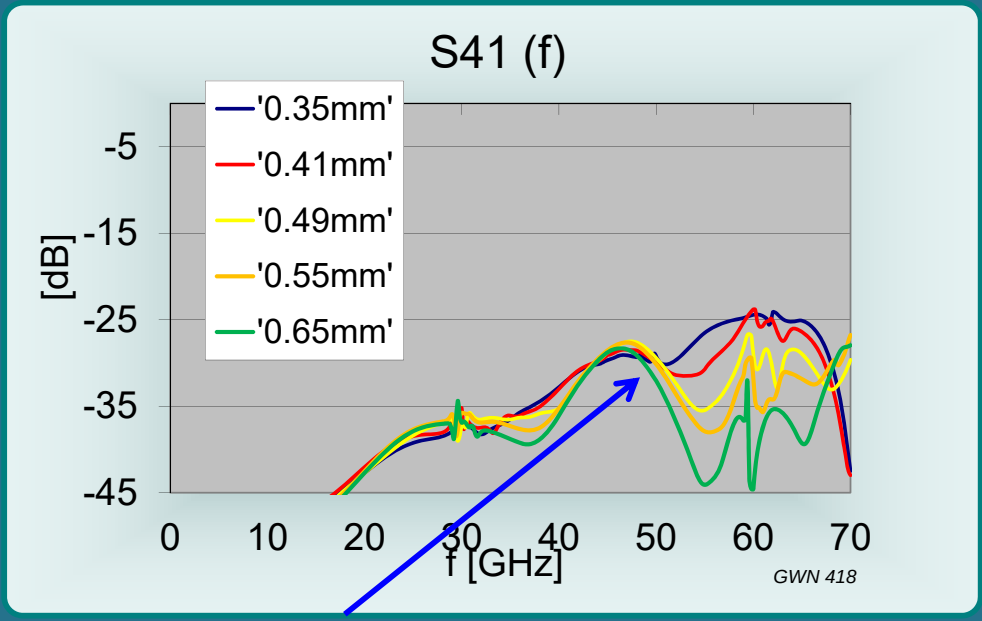




Coupling is reduced for greater spacing between aggressor and victim below 20 GHz
Coupling may increase with increasing spacing at higher frequencies

FEXT as a function of antipad size

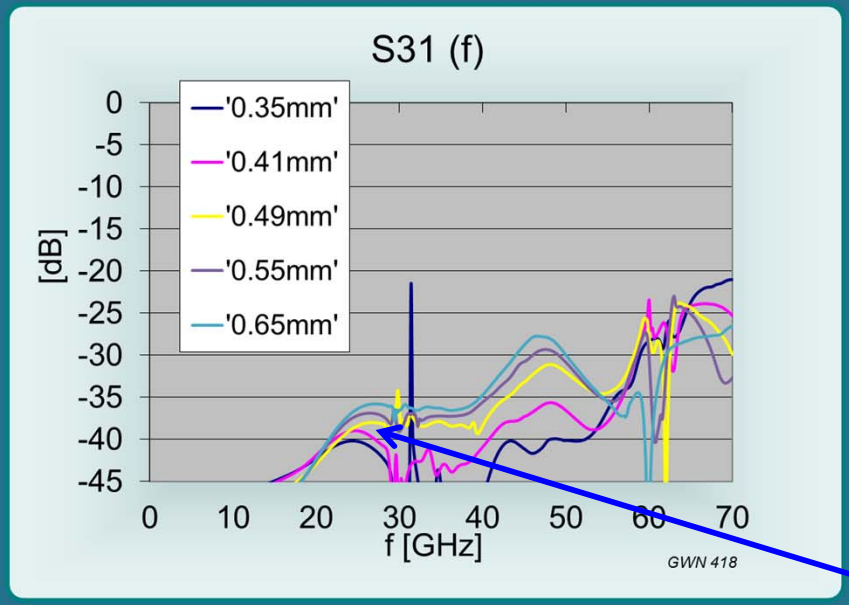


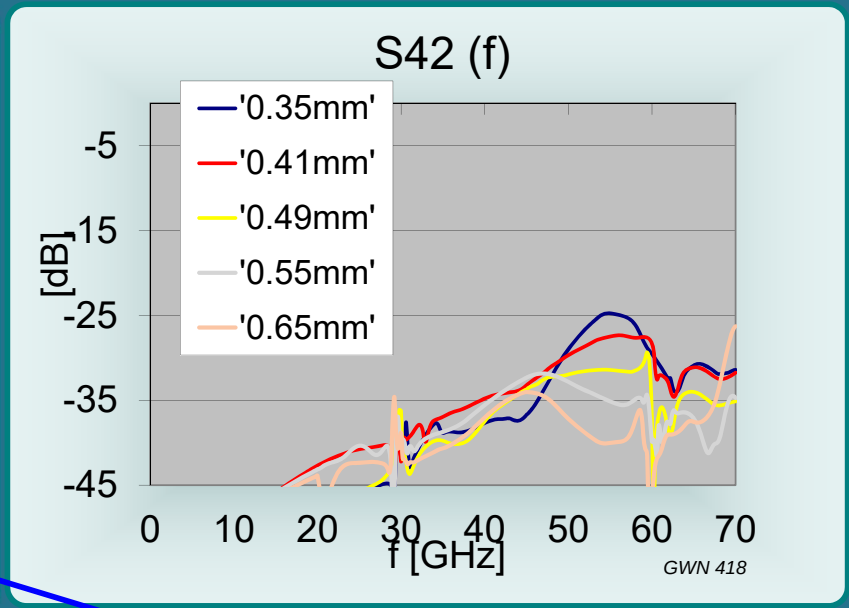


Noticeable impact above 50 GHz

optimal antipad size (0.41mm) for Sdd11 performance is **NOT** the best solution for crosstalk

NEXT as a function of antipad size

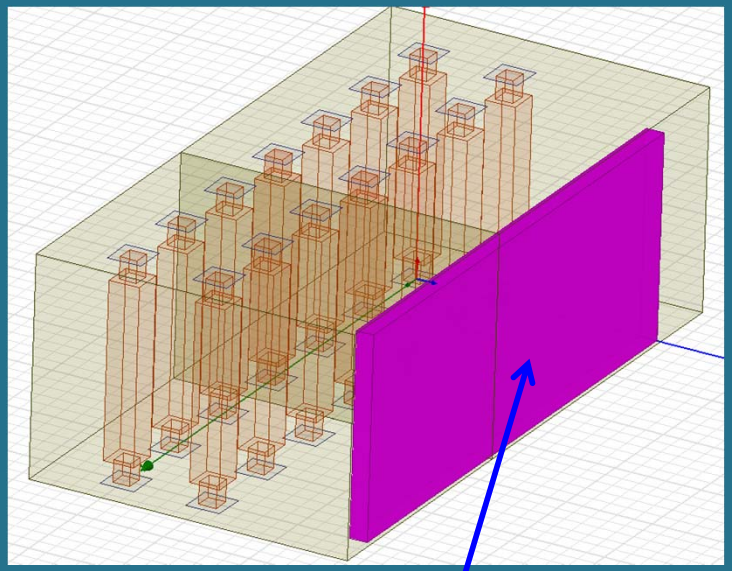


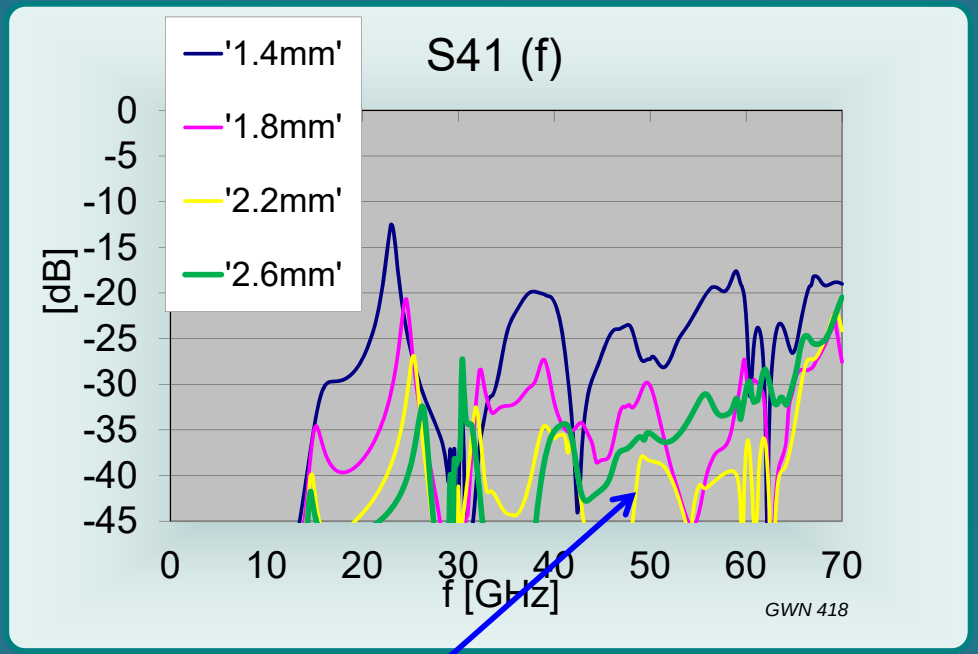


Noticeable impact above **25** GHz

optimal antipad size for Sdd11 performance is **NOT** the best solution for crosstalk

FEXT as a function of shield position

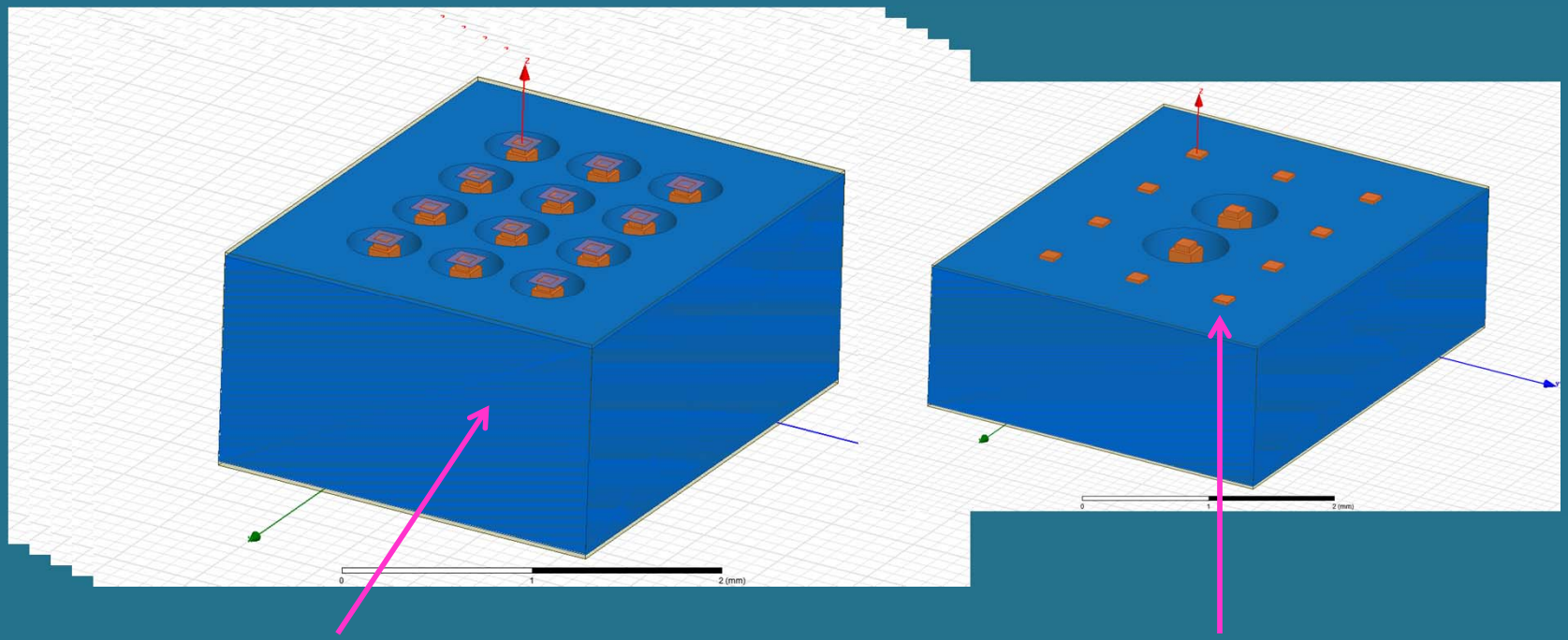




Shield position can reduce crosstalk over a range of frequencies

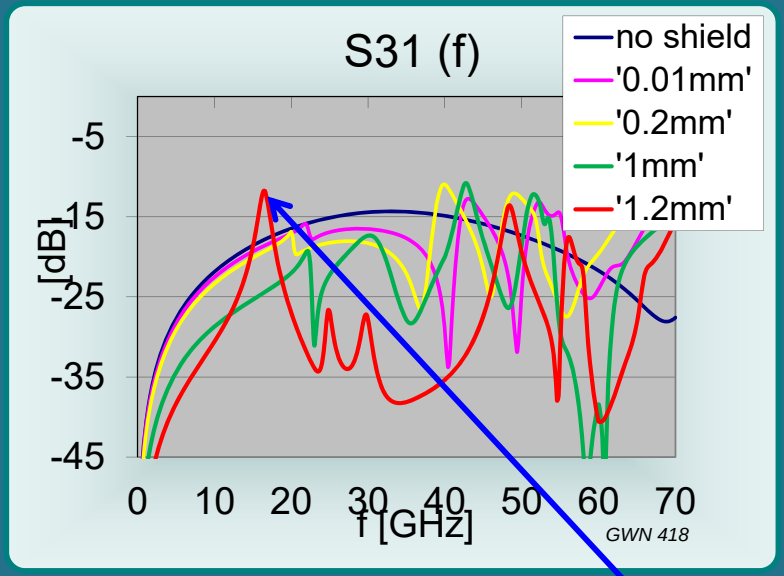
(in this case this is also true for NEXT)

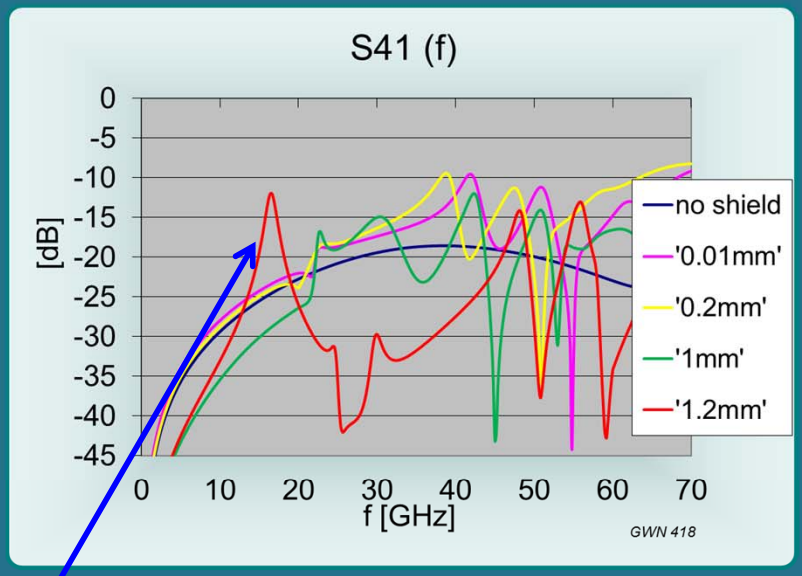
Metal shields



Cases: A) Shield thickness as variable B) ground connection to pins

Case A): NEXT and FEXT as a function of shield thickness

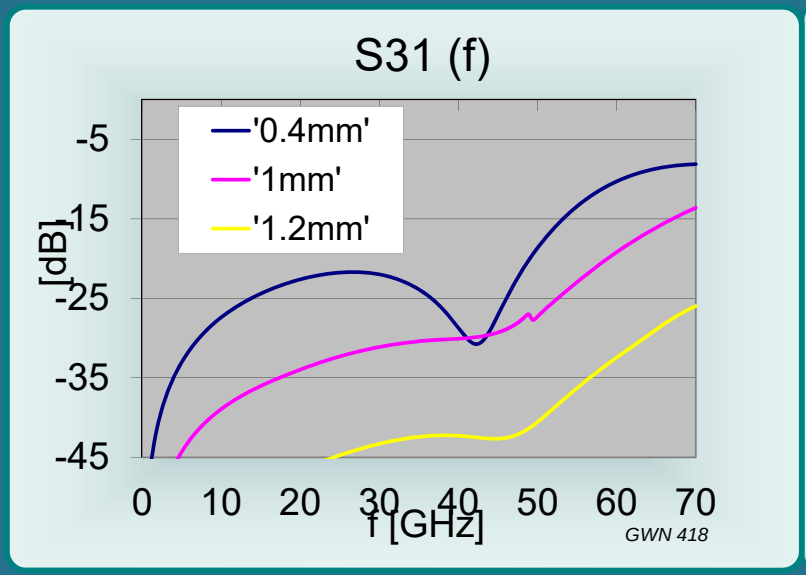


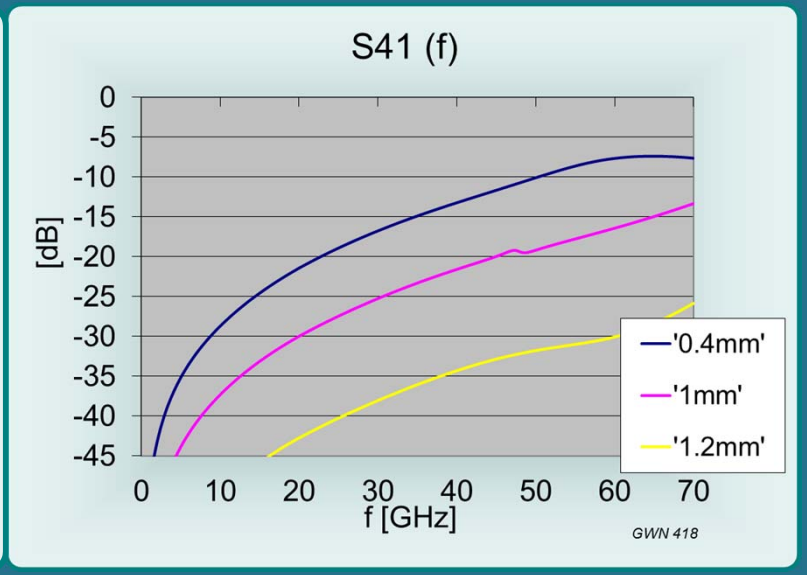


Improvements only possible to ~20 GHz

Noticeable peaks for thickest shield (!)

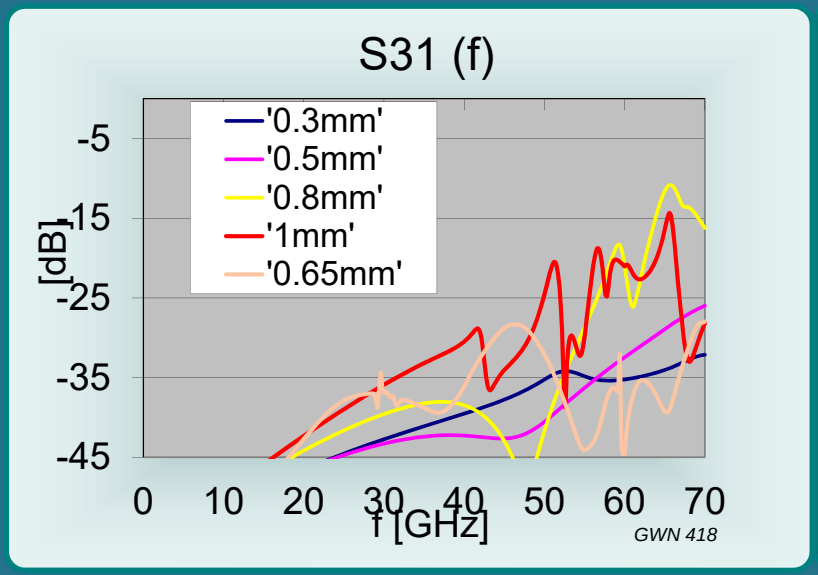
Case B): NEXT and FEXT as a function of grounded shield thickness

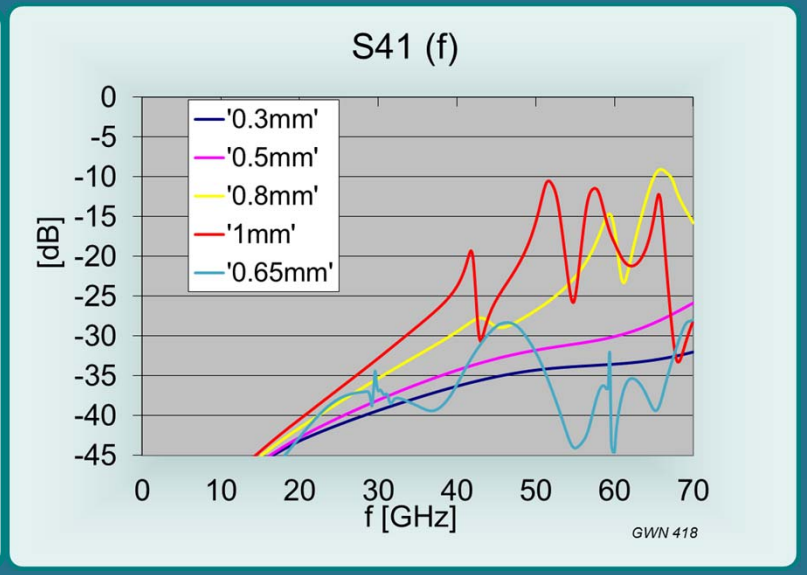




Best performance for thickest shield

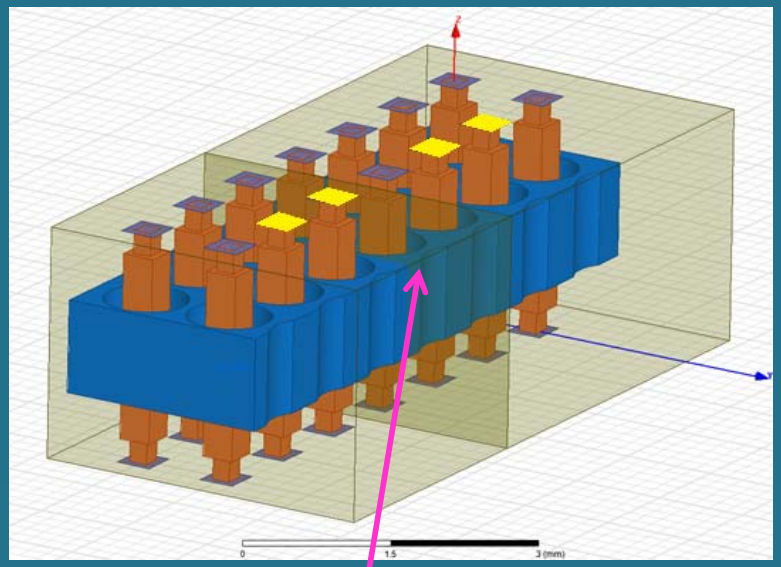
Case B): NEXT and FEXT as a function of pitch (full height shield)

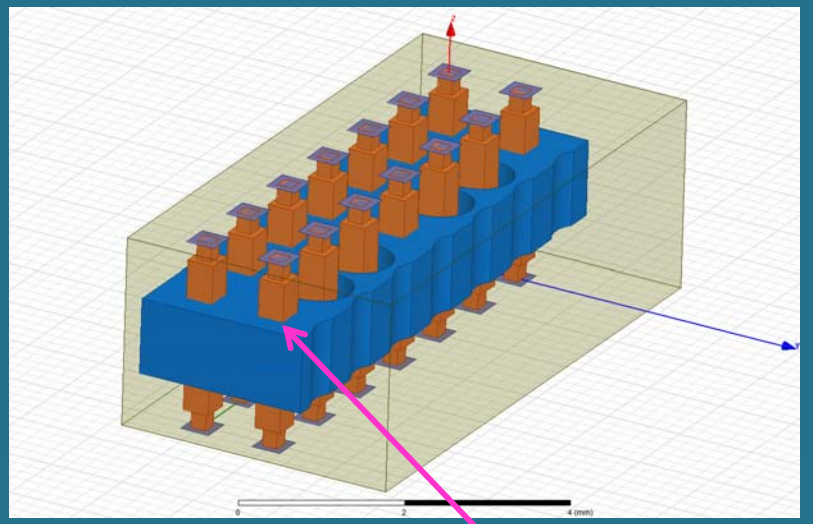




Best performance for 0.3 mm and 0.5 mm pitch

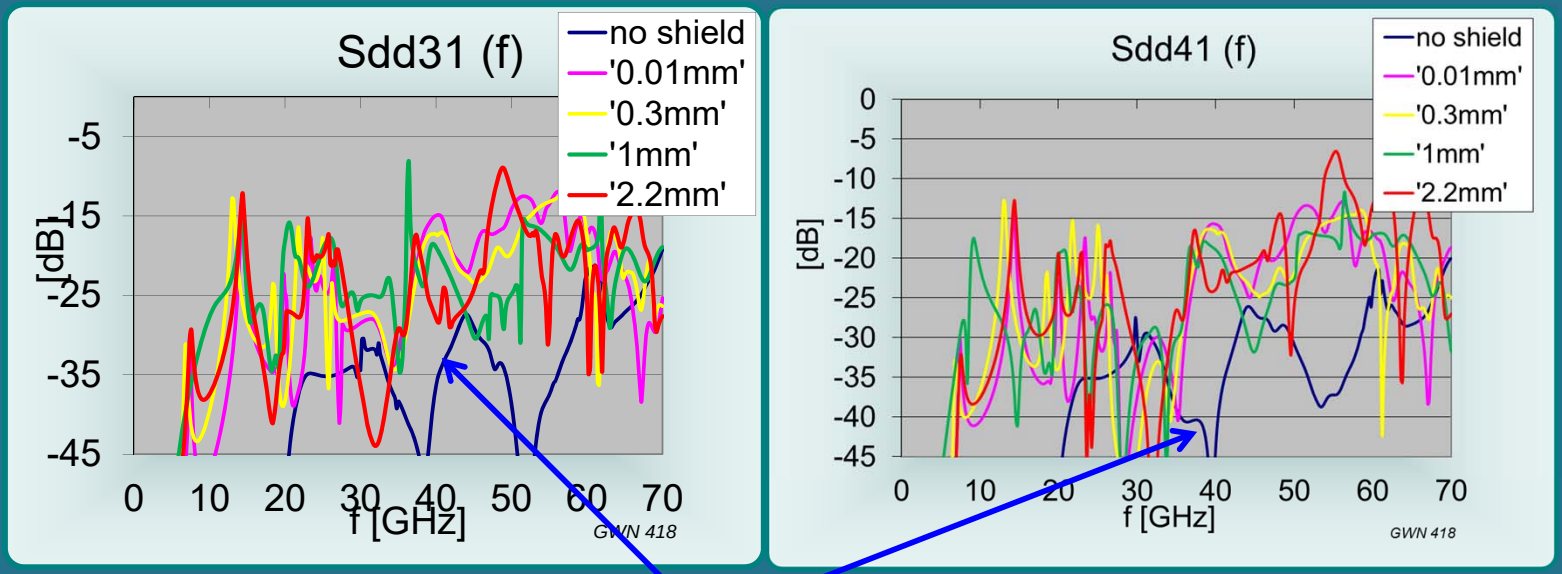
Metal shield, differential configuration





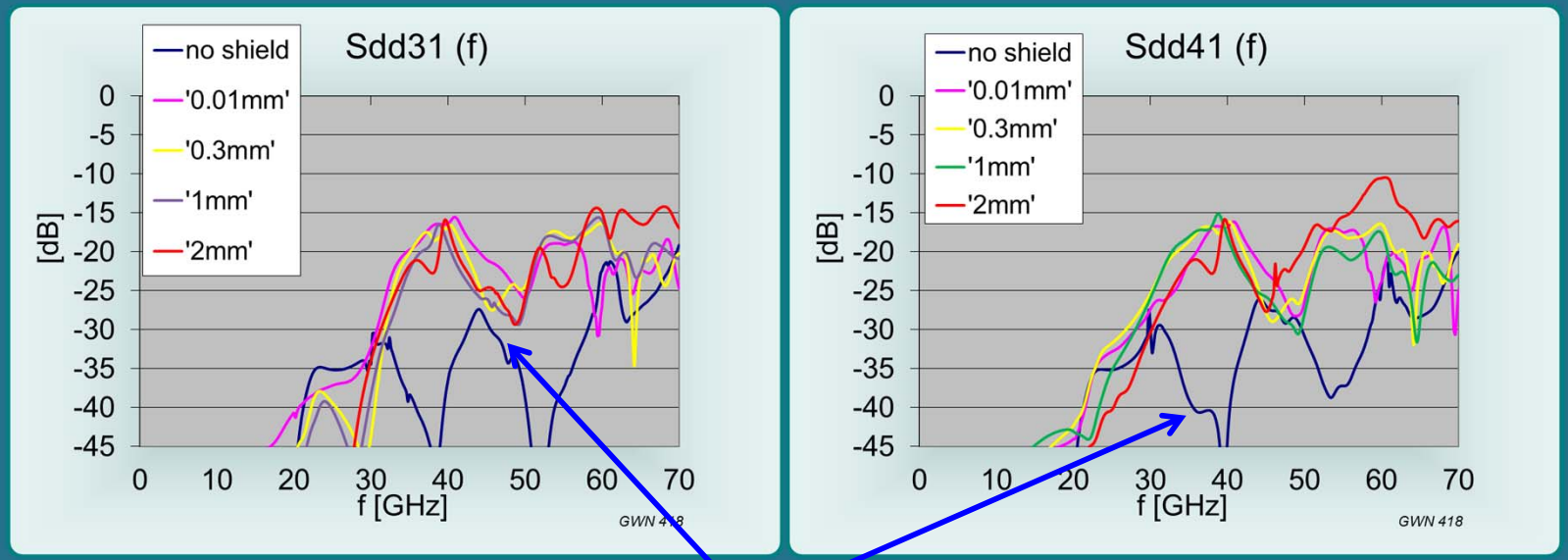
Cases: C) Shield thickness as variable D) ground connection to pins

Case C): NEXT and FEXT as a function of shield thickness



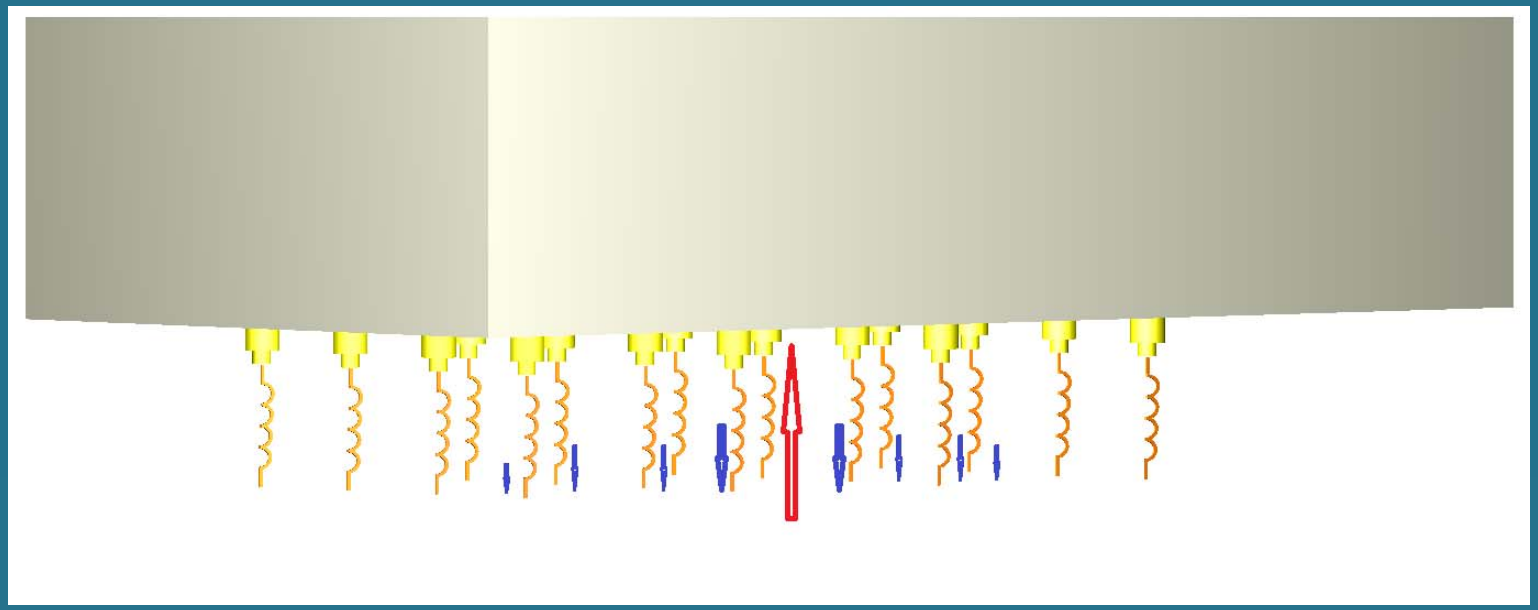
No improvements possible (!) compared to 'no shield' case

Case D): NEXT and FEXT as a function of grounded shield thickness



No improvements possible (!) compared to 'no shield' case

Cause of crosstalk in case of metal body



Ground return current couples into adjacent pins

Observations

- Pitch reduction reduces crosstalk
- Increasing contact length generally increases crosstalk
- Impedance near 50 Ohms yields best results
- Short interconnect can be worse than moderate length (this is likely due to field configuration / parasitics)

Comments

- Single-ended crosstalk is shown to establish trends
- Can (with caution) be applied to differential configurations
- Crosstalk improvements from various shielding efforts were not shown to be conclusive (differential signaling) and must be individually assessed according to frequency range and configuration

Conclusion

- Surprising / unexpected results make careful analysis mandatory.
- Interaction with PCB routing requires inclusion in analysis of initial design for optimal performance.

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