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A novel method to reduce differential crosstalk in a high-speed channel

Kunia Aihara, Jeremy Buan, Adam Nagao, Toshi Takada,
Hirose Electric (USA), Inc.

Ching Chao Huang
AtaiTec Corporation

ataitec

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Outline

- Introduction and motivation
- Theory and simulation result
  - Edge-coupled vias
  - Broadside-coupled vias
  - Broadside-coupled vias with offset
- Measurement
  - Example 1 Broadside-coupled vias with offset
  - Example 2 Broadside via and edge-coupled via transitions
  - Example 3 via-connector-via
- Conclusion

Introduction

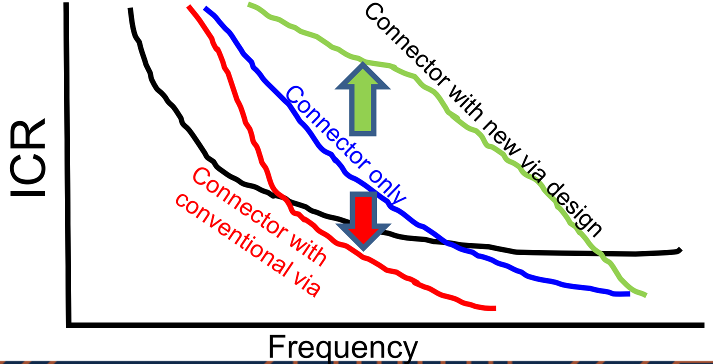
- Highspeed channel
  - Communication channel data rate is exponentially increasing to meet industry and consumer demand
- High density connection, crosstalk an issue
  - Connector and via crosstalk have become big contributors to total channel crosstalk due to their inherent large number of microwave transitions in order to support mechanical spec/tolerance/robustness
  - There exists situations where designing for impedance control degrades crosstalk, and so xtalk becomes even more of an issue

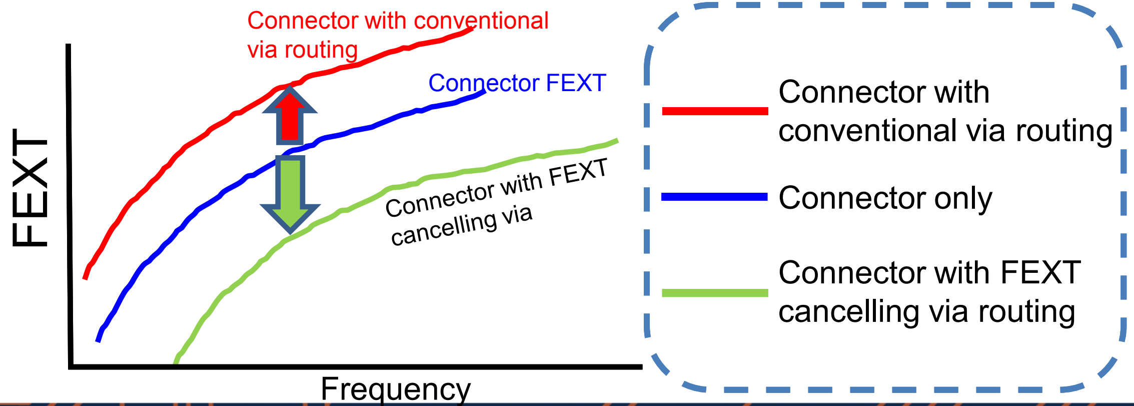
Introduction

- How crosstalk was handled in the past (isolation, cap/inductance control and polarity swapping)
  - Capacitive coupling can be controlled by varying ε_r and inductive coupling by varying the radius of a wire/pin/via
  - Complexity on capacitance and inductance control, especially in PCB material
  - Polarity swapping adds complexity to routing
  - Relying too much on isolation (spacing) will consume valuable real estate on PCB
  - Relying too much on ground vias to contain crosstalk can take up PCB space and populate power planes with antipads

Motivation

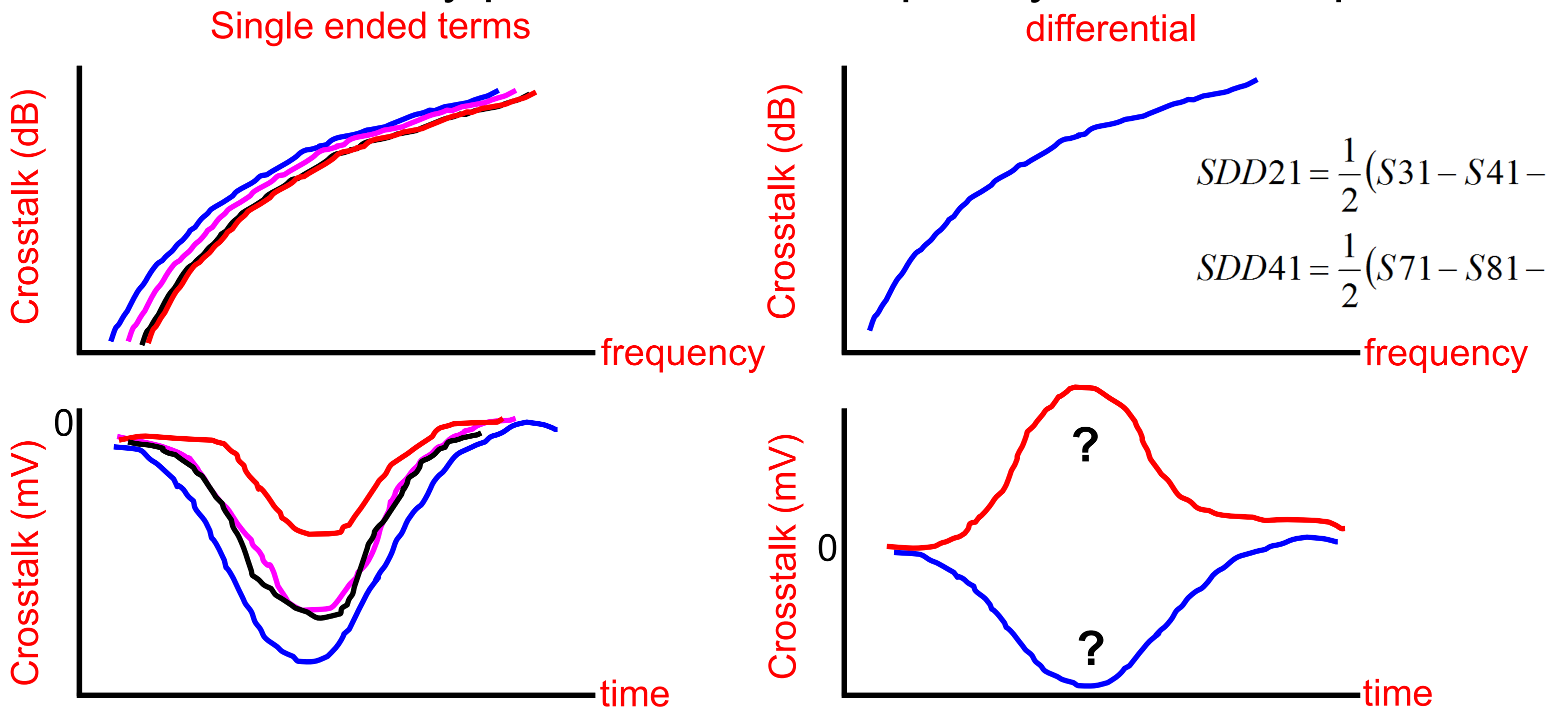
- Adjusting individual single-ended terms to achieve desired differential crosstalk (either minimum within a component or desired magnitude and polarity in each component to have minimum in an entire channel)
  - Reduction in crosstalk NEXT/FEXT at component level
  - Reduction in FEXT by cascading multiple components with adjusted individual single-ended terms of components to provide opposite characteristic of each other





Analyzing crosstalk in time domain

- Viewing crosstalk in time domain gives valuable information that one cannot immediately perceive from frequency domain response

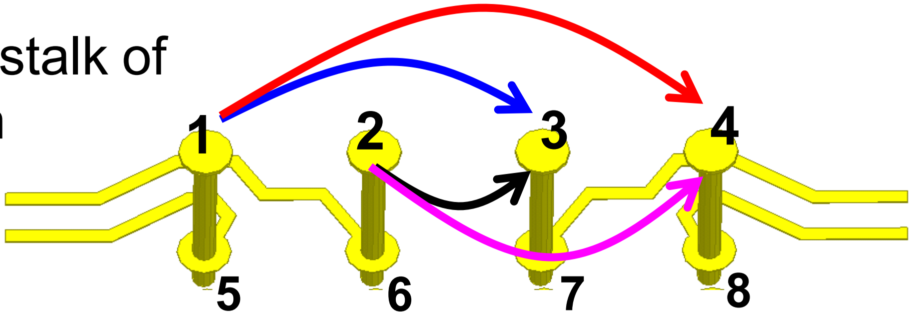


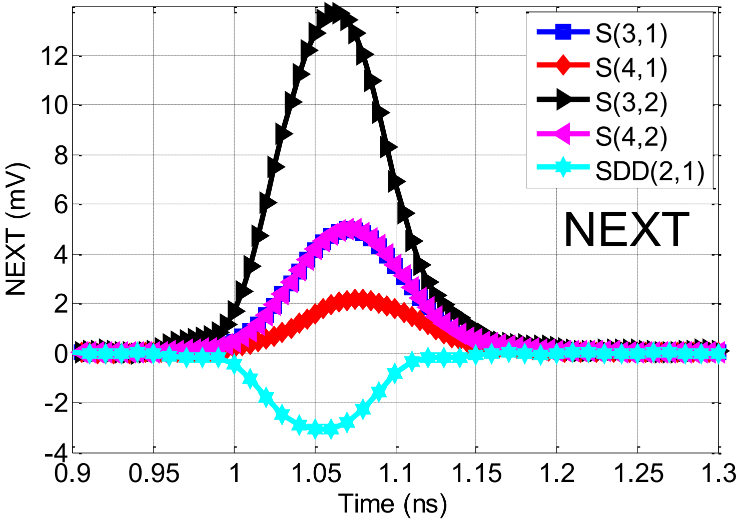
$$SDD21 = \frac{1}{2}(S31 - S41 - S32 + S42)$$

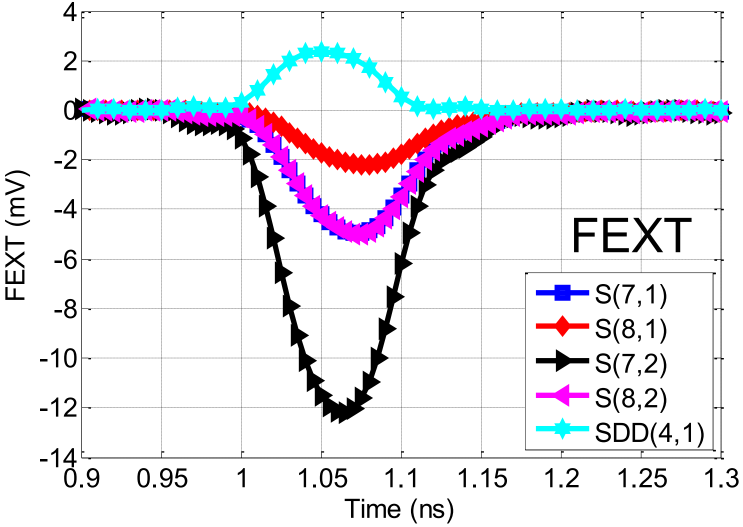
$$SDD41 = \frac{1}{2}(S71 - S81 - S72 + S82)$$

Edge-coupled

- Single ended and differential crosstalk of edge-coupled vias in time-domain
- Applies to connector pins

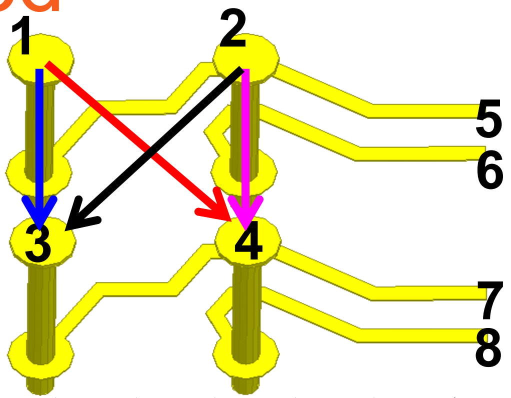


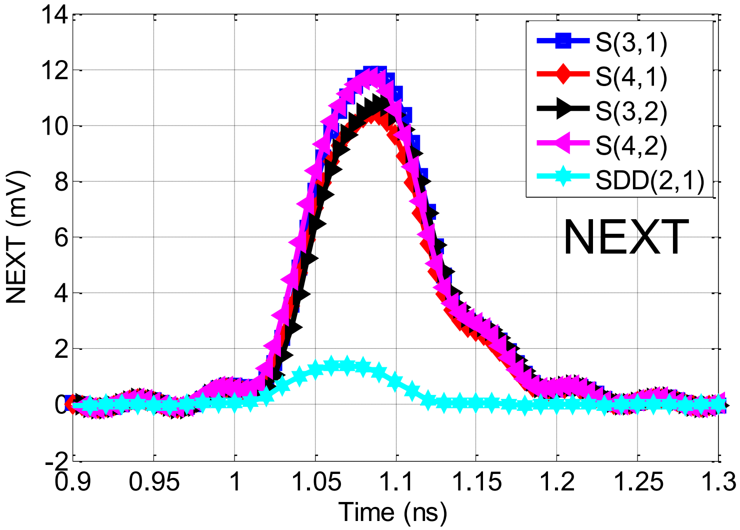


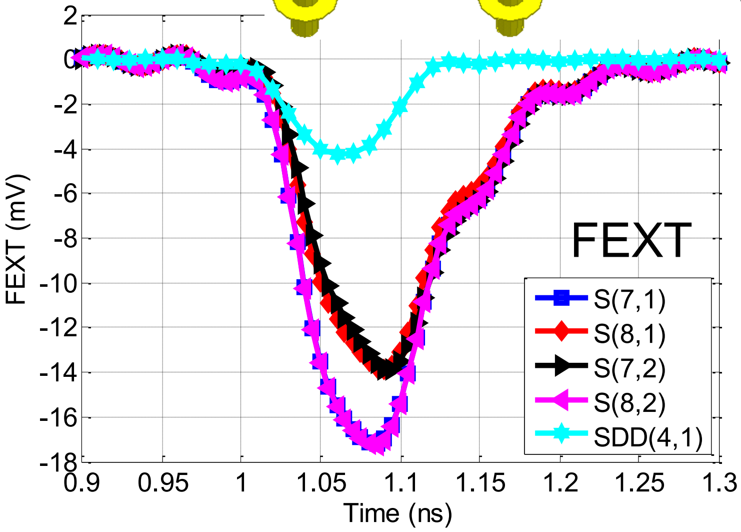


Broadside coupled

- Single ended and differential crosstalk of broadside-coupled vias in time-domain

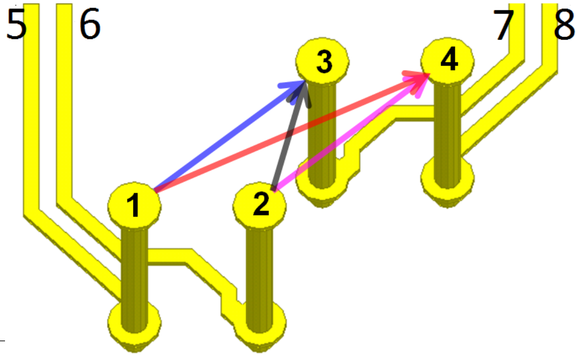


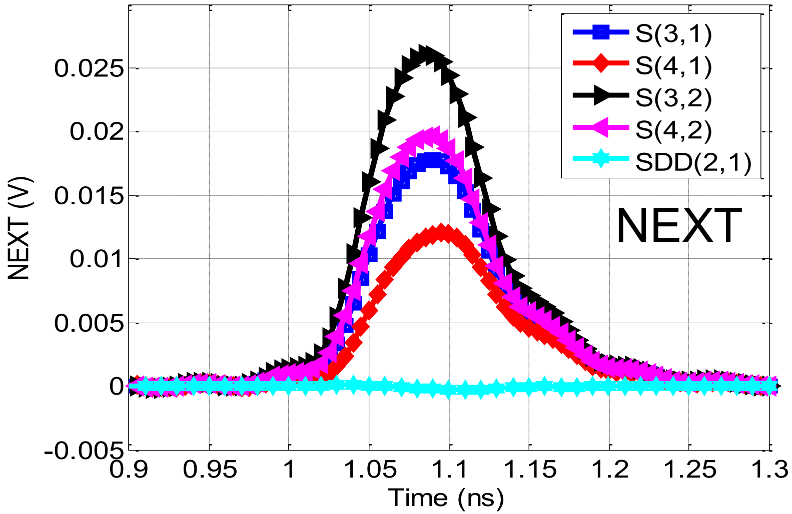


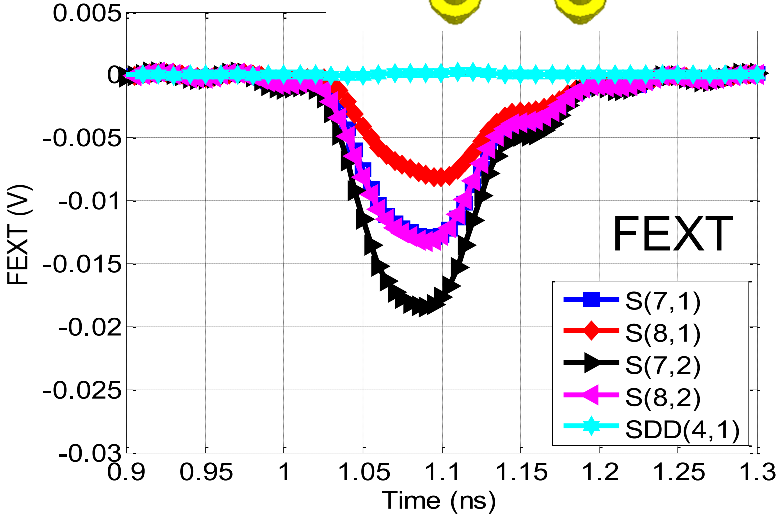


Broadside coupling with offset

- Single ended and differential crosstalk of broadside-coupled vias with an offset
- An optimum offset can significantly reduce differential crosstalk







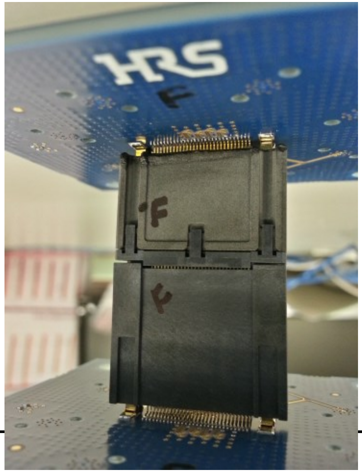
Measurement result

1. Broadside-coupled vias with offset

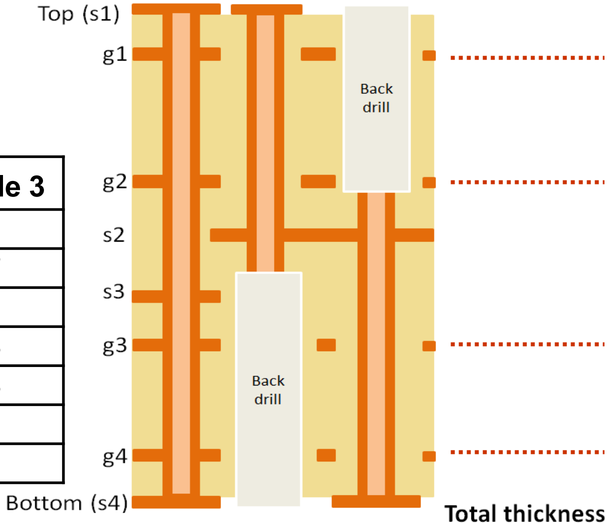
2. Broadside via and edge-coupled via transitions

3. via-connector-via

Test structure PCB stack up



	Ex 1 and 2	Example 3
Via drill Φ	0.2	0.2
Intra differential pair via pitch	0.7	1.27
Inter differential pair pitch	NA	1.5
Sig. layer via pad Φ	0.45	0.45
Via depth	1.5	0.65
Differential antipad Φ	0.6	NA
Antipad Φ	NA	0.91

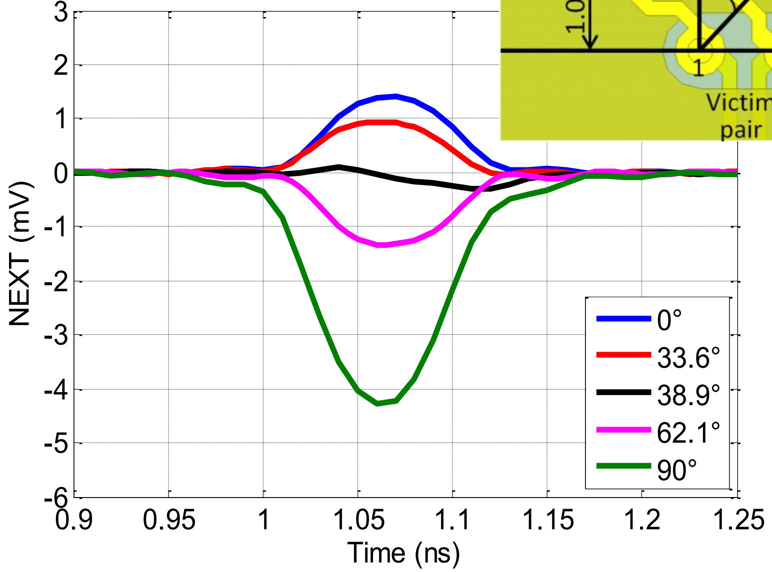


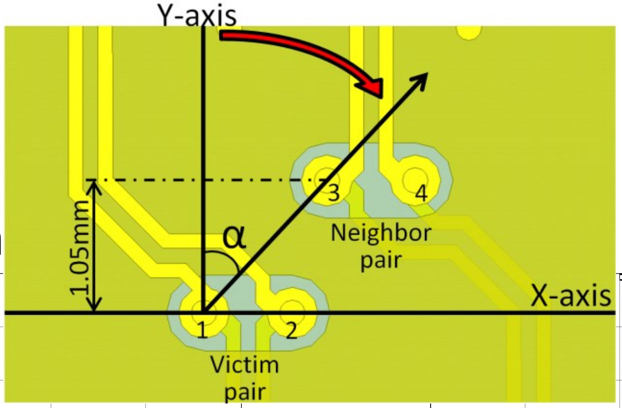
	Design stack up		Actual stack up	
	Laminate	εr	Laminate	εr
	4 mils	3.7	3.2 mils	3.44
	12 mils		4.0 mils	3.66
			4.6 mils	3.28
			4.0 mils	3.66
	6 mils		5.8 mils	3.44
	6 mils		8.0 mils	3.66
	6 mils		5.8 mils	3.44
	12 mils		4.0 mils	3.66
			4.6 mils	3.28
			4.0 mils	3.66
	4 mils		3.2 mils	3.44
Total thickness	50 mils		51.2 mils	

Broadside coupled vias with offset

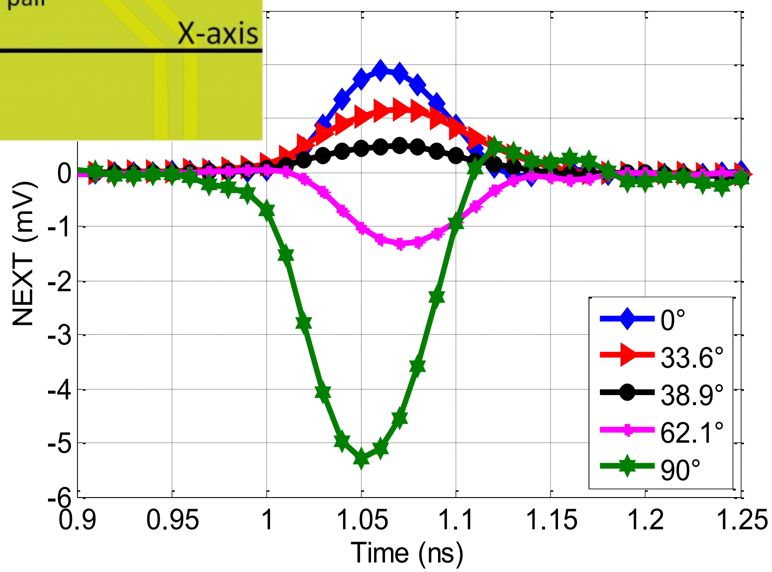
- NEXT time domain

Simulation



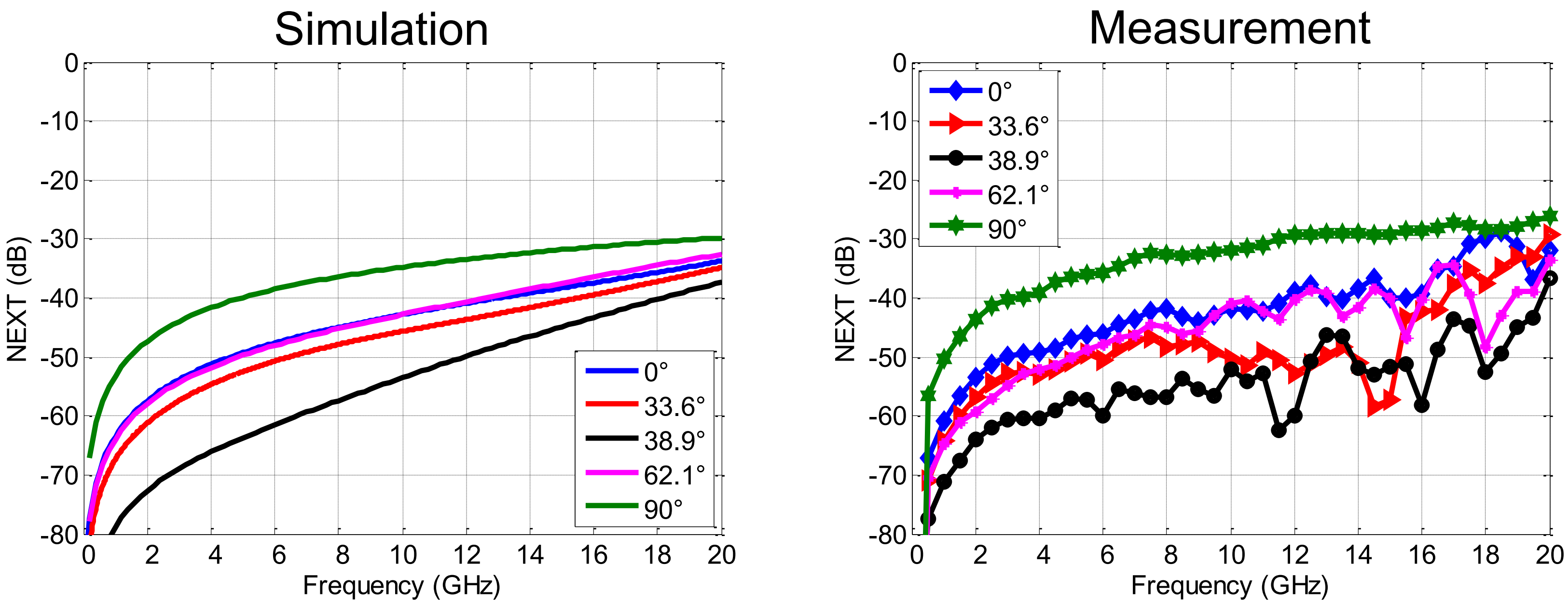


Measurement



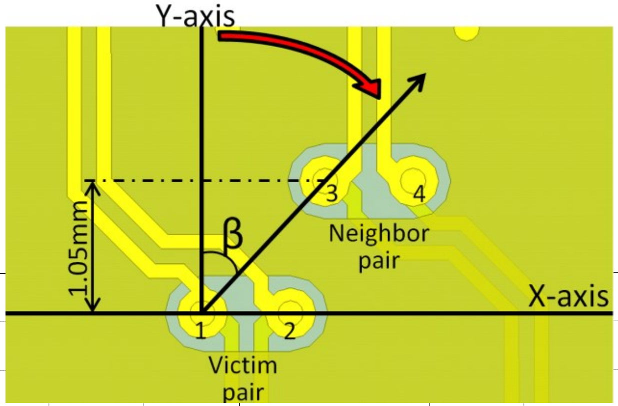
Broadside coupled vias with offset

- NEXT frequency domain

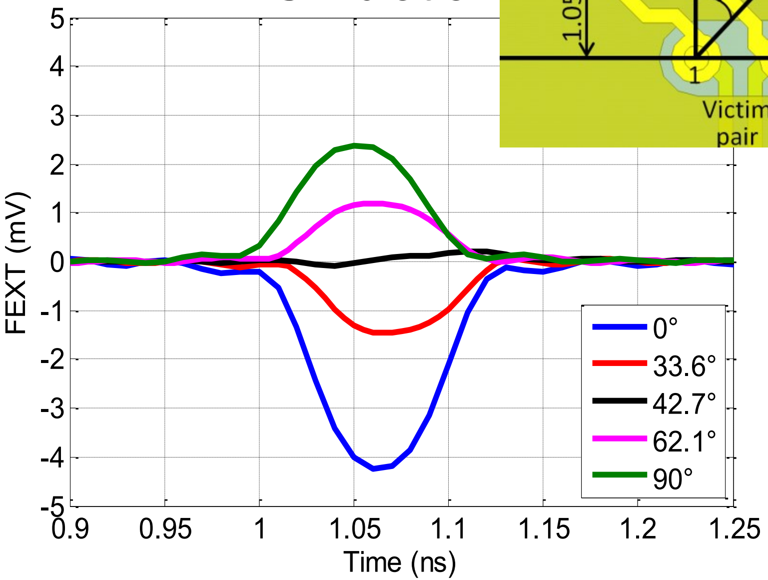


Broadside coupled vias with offset

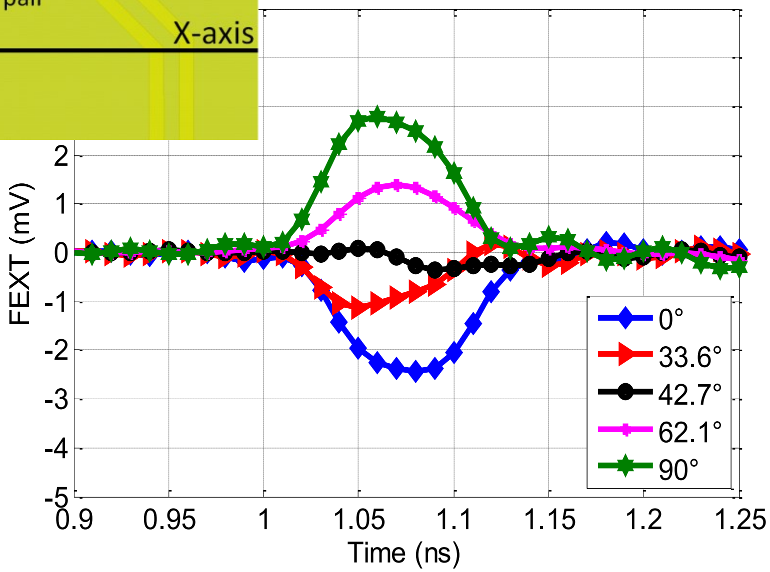
- FEXT time domain



Simulation

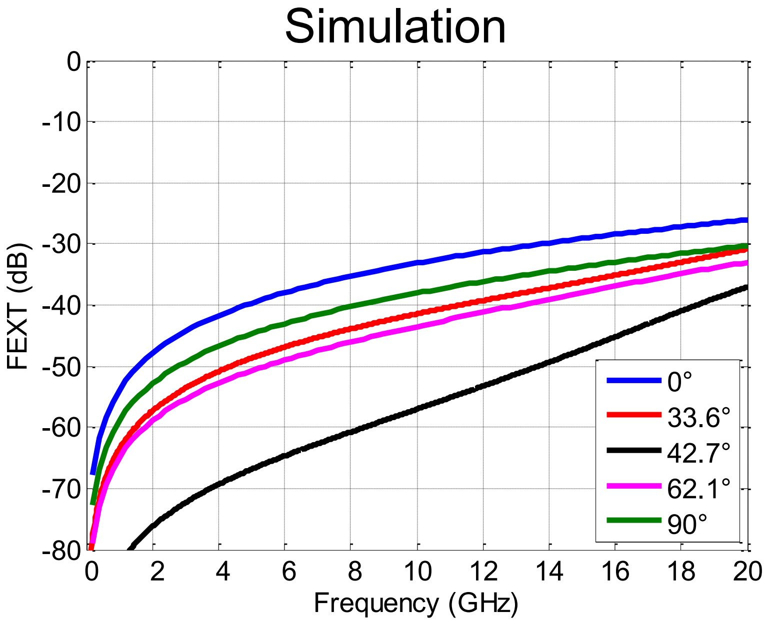


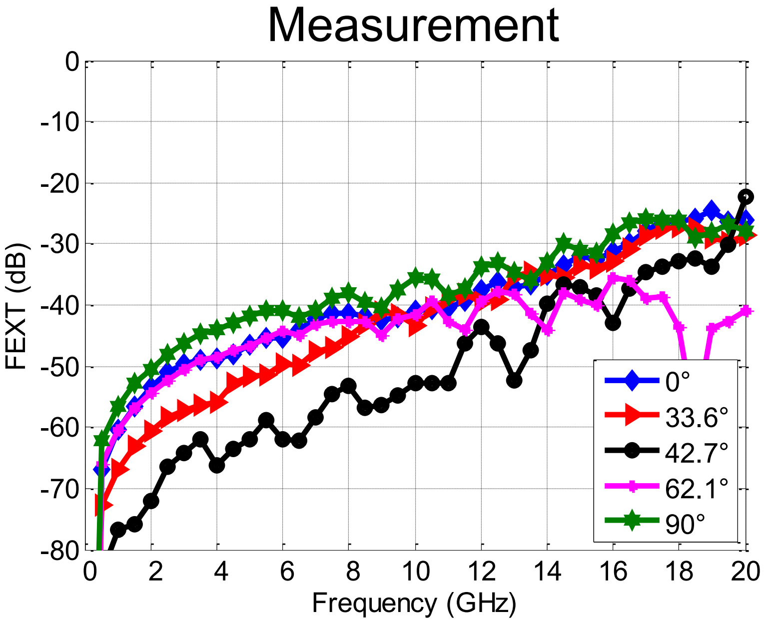
Measurement



Broadside coupled vias with offset

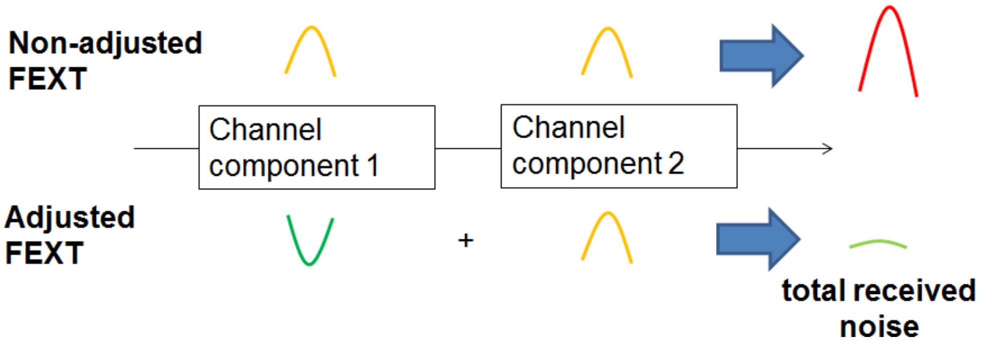
- FEXT frequency domain

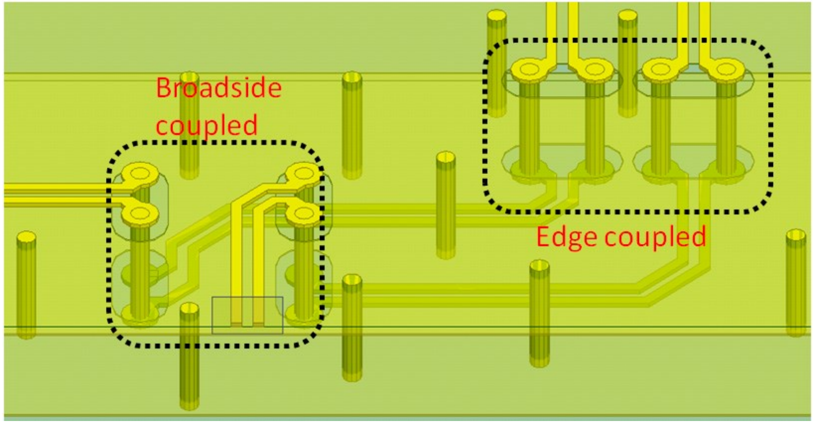




Edge/broadside-coupled vias cascaded

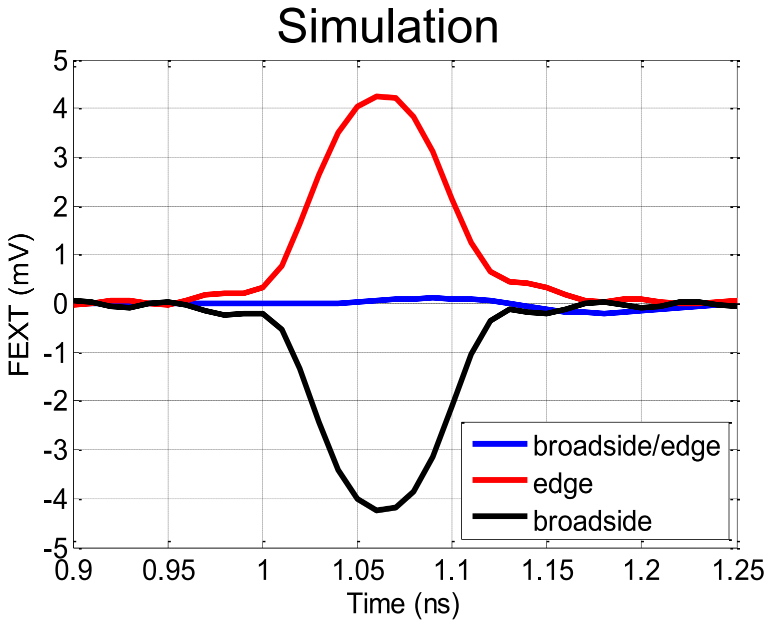
- FEXT reduction through multiple components
- Need to analyze and adjust polarity of FEXT of each component to enable cancellation
- Proof of concept using edge-coupled and broadside-coupled vias in series

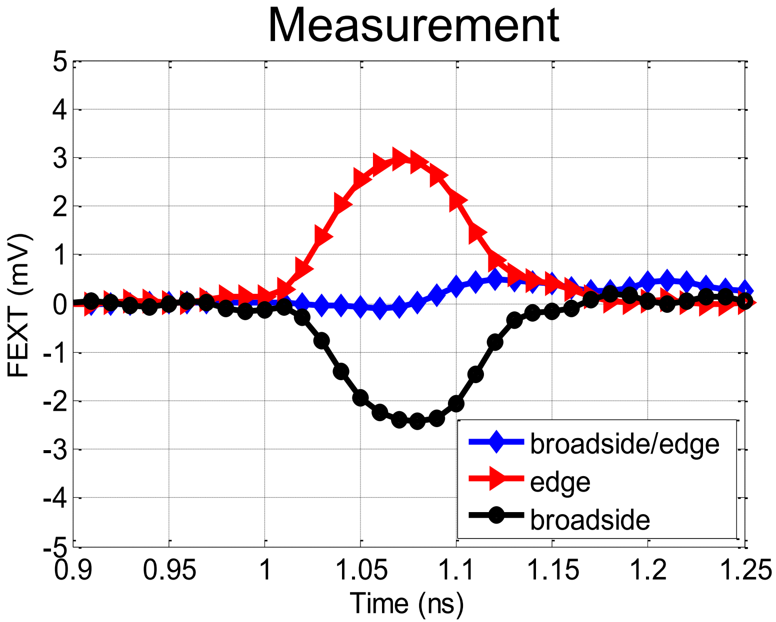




Edge/broadside-coupled vias cascaded

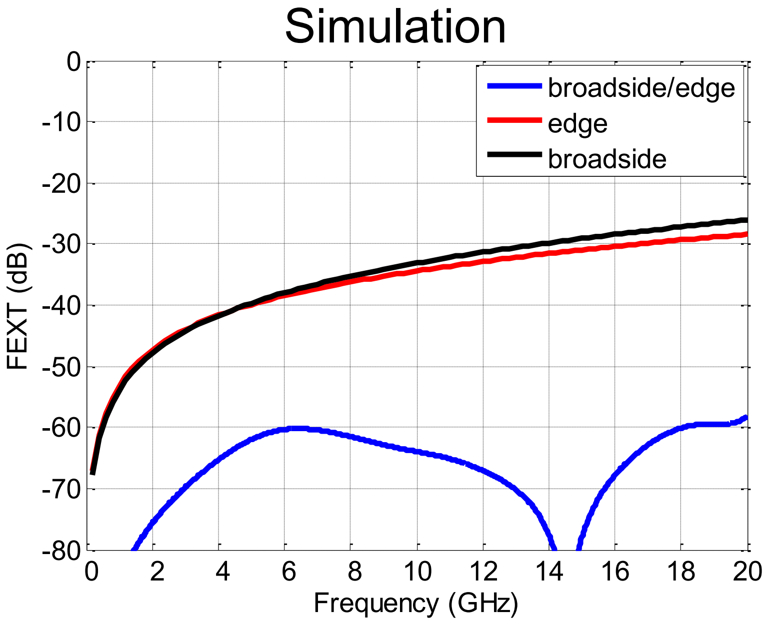
- Time domain response

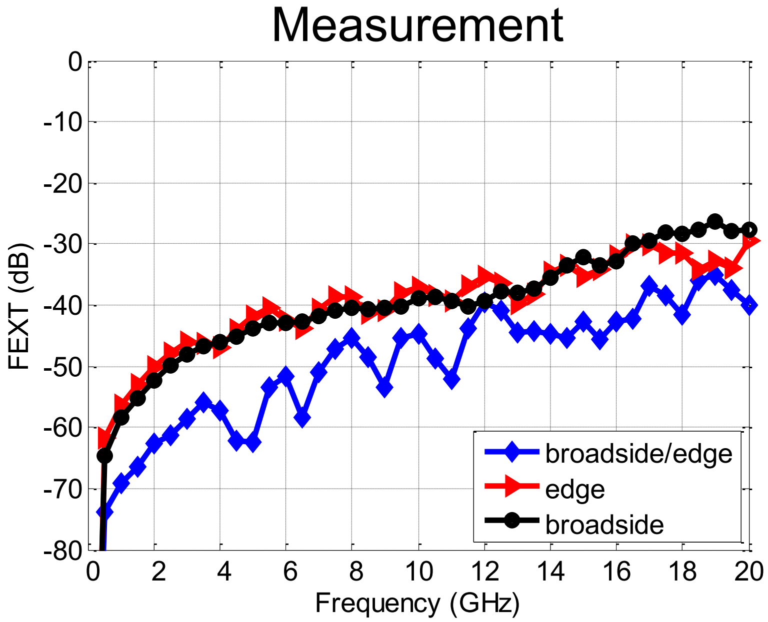




Edge/broadside-coupled vias cascaded

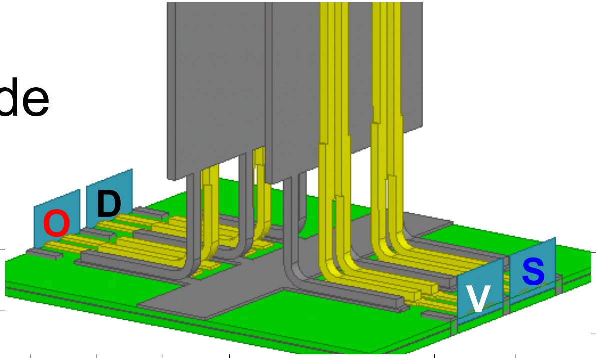
- Frequency domain response

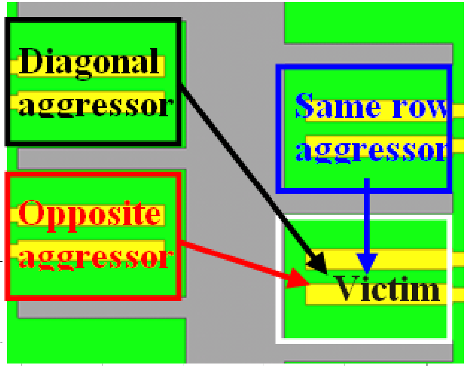


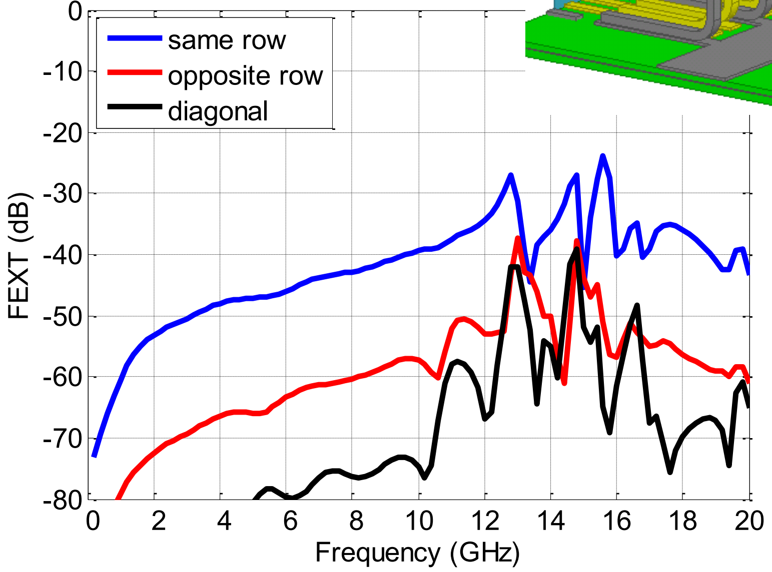


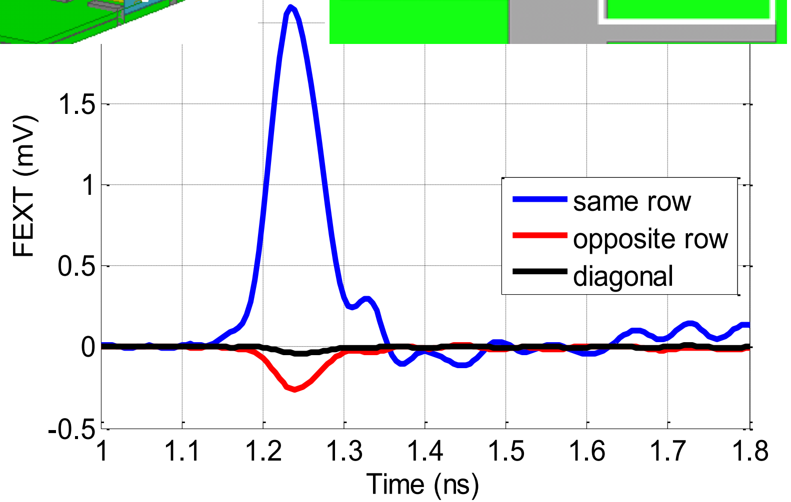
Via-Connector-Via (simulation)

- Connector FEXT polarity and magnitude analyzed



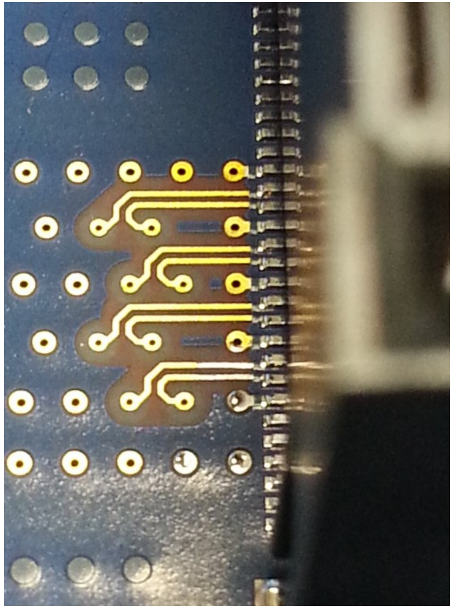


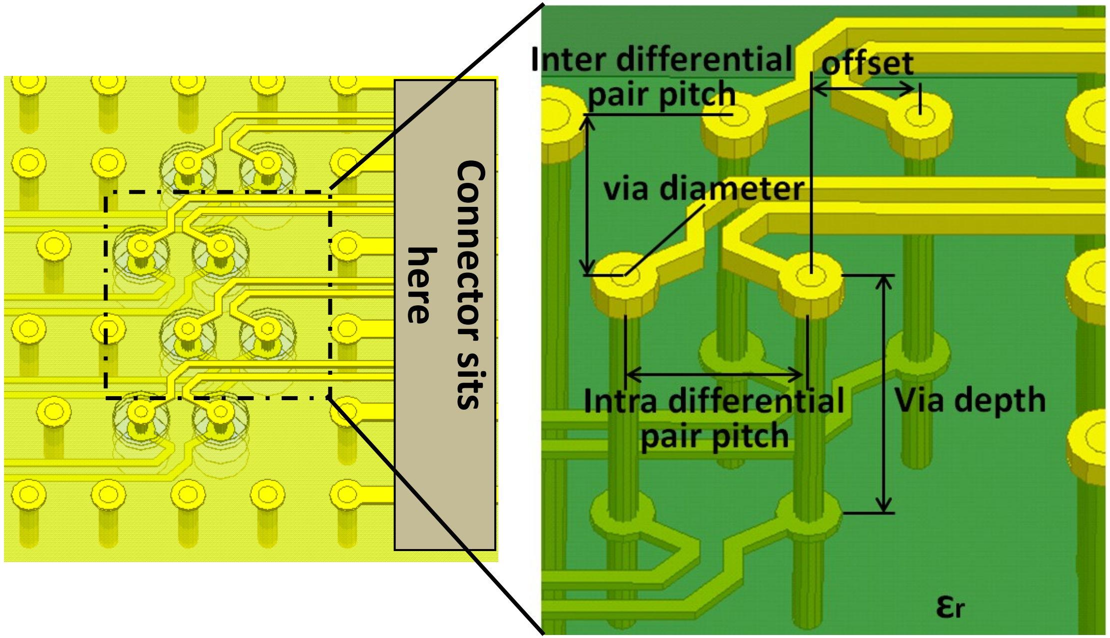




Via-Connector-Via

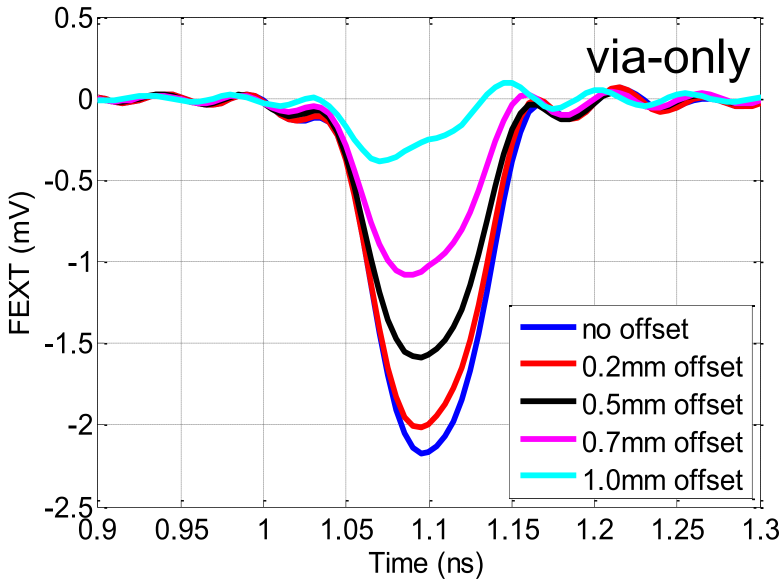
- Several tuning variables are available in designing proper polarity and magnitude of via design to reduce FEXT of the connector



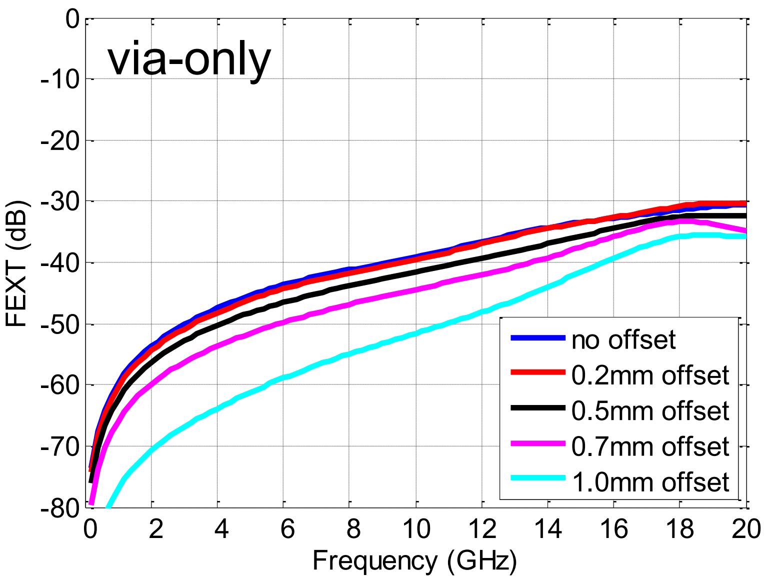


Via-Connector-Via (simulation)

- Offset of inter-differential pair vias varied to determine favorable FEXT cancellation value for the via design



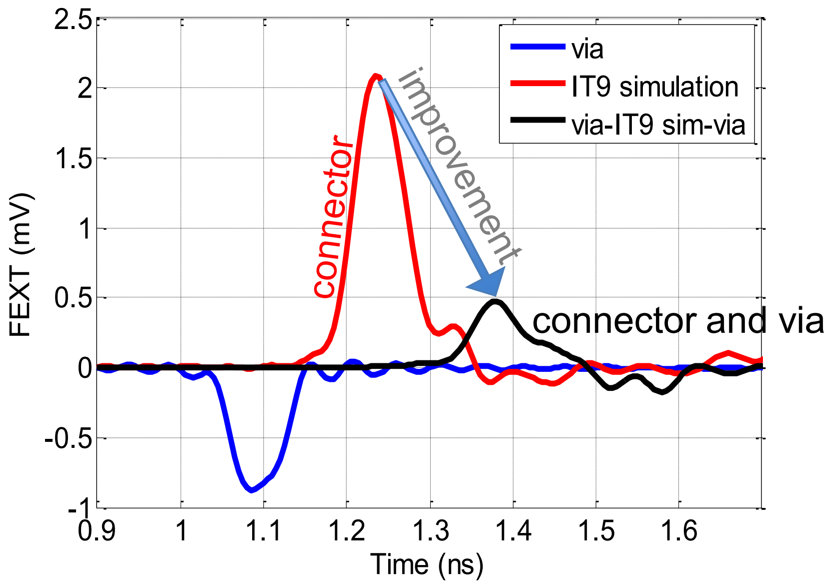
Time domain



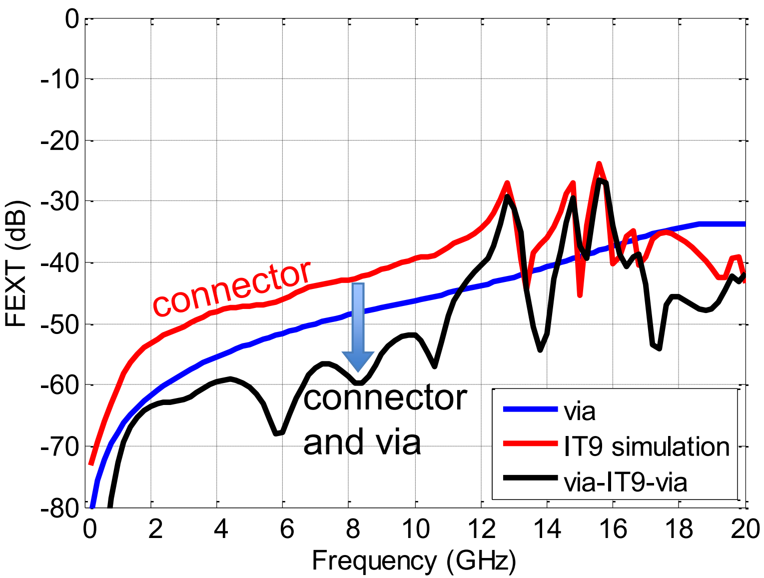
Frequency domain

Via-Connector-Via (simulation)

- Via design cascaded with connector model
- Improvement seen in both time and frequency domain



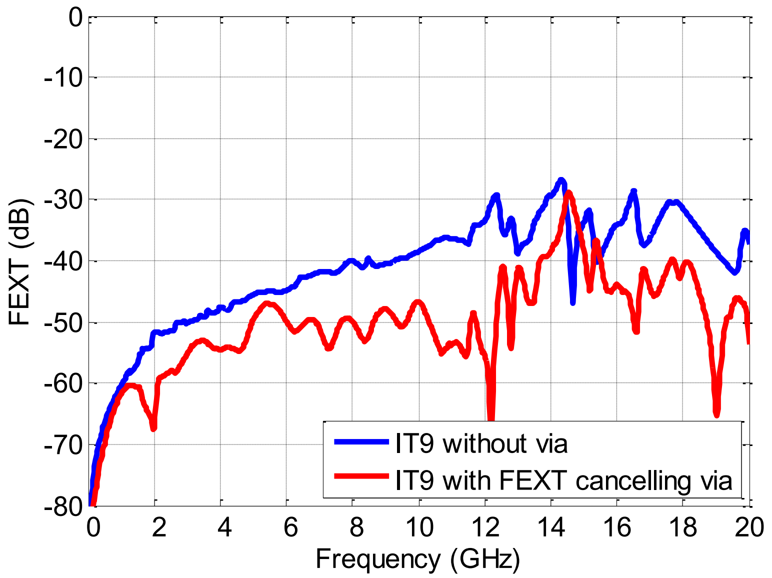
Time domain

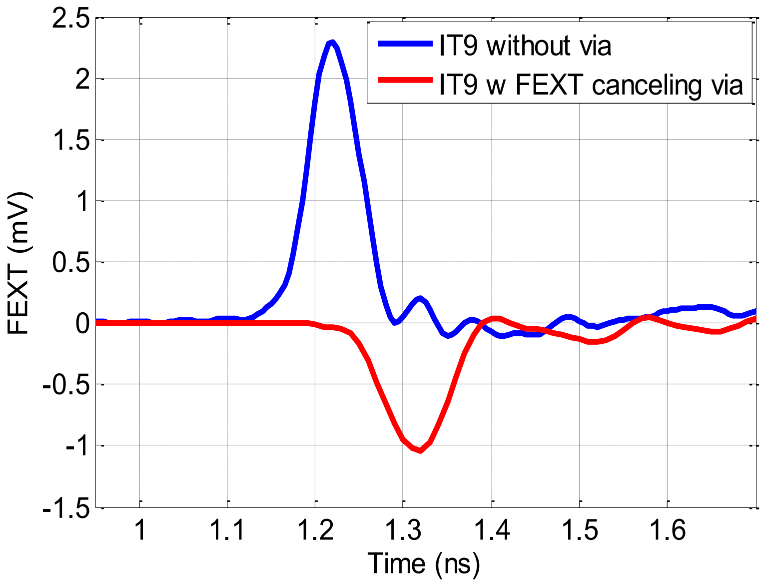


Frequency domain

Via-Connector-Via (measurement)

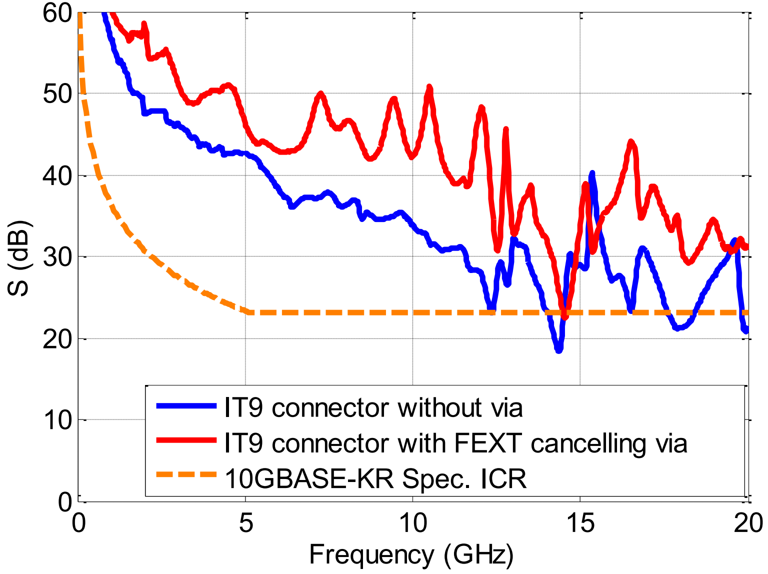
- Measurement shows that cancellation indeed occurs
- Time domain data indicates that connector FEXT was over compensated and there is space for improvement





Via-Connector-Via

- ICR using 5 FEXT aggressors
- Improvement observed over wide frequency range



Conclusion

- Differential crosstalk reduction technique was investigated
- Polarity of crosstalk was explored using edge-coupled and broadside coupled PCB vias
- Crosstalk reduction within a component was demonstrated using vias that are broadside-coupled with an optimum offset
- Crosstalk reduction through multiple components was demonstrated using via-connector-via transitions

Thank you!