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# Component Crosstalk Characterization by ICN

Presenter: Steve Krooswyk

# INTRODUCTION

- We characterize components so that we may compare performances, improve designs, make product selections, and more…
- Almost always, this is done by Frequency Domain.
- However, interpretation has many traps.
  Let us consider crosstalk, where we may ask…
  - Is the value at Nyquist most important?
  - When is the ground mode resonance too large?
  - Is it OK to go slightly above -40dB?
  - If NEXT is most critical, does FEXT even matter?
- We will propose a holistic approach to component crosstalk evaluation, for use by the individual or standards groups.

# Mini Case Study: **Assumption**

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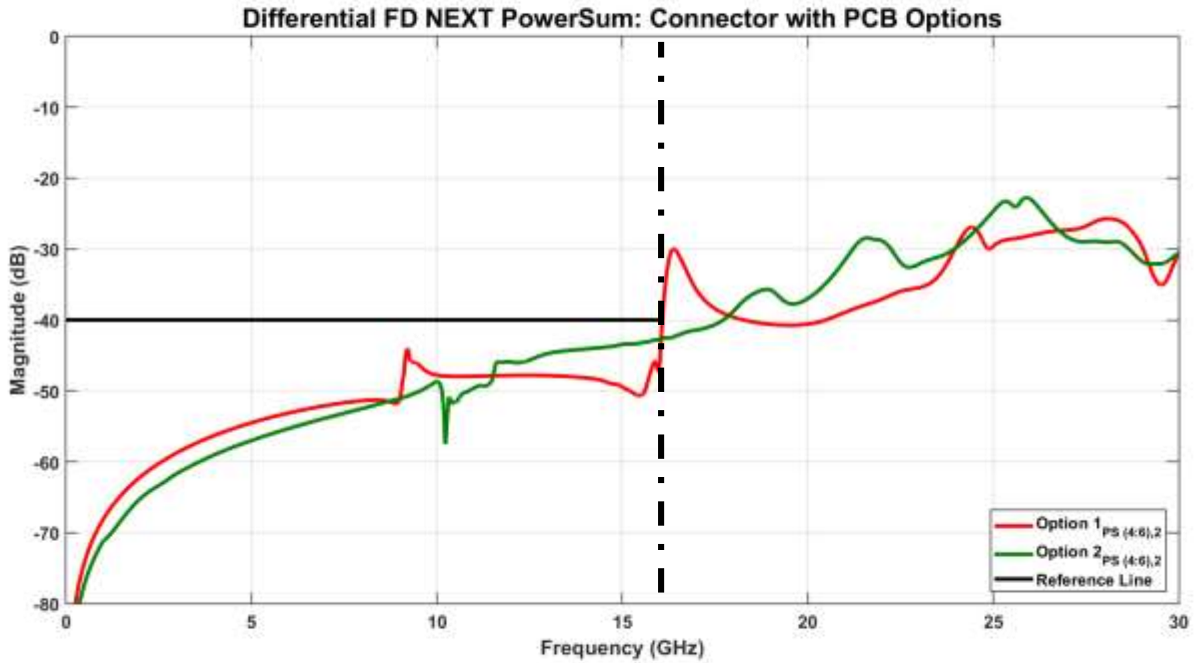
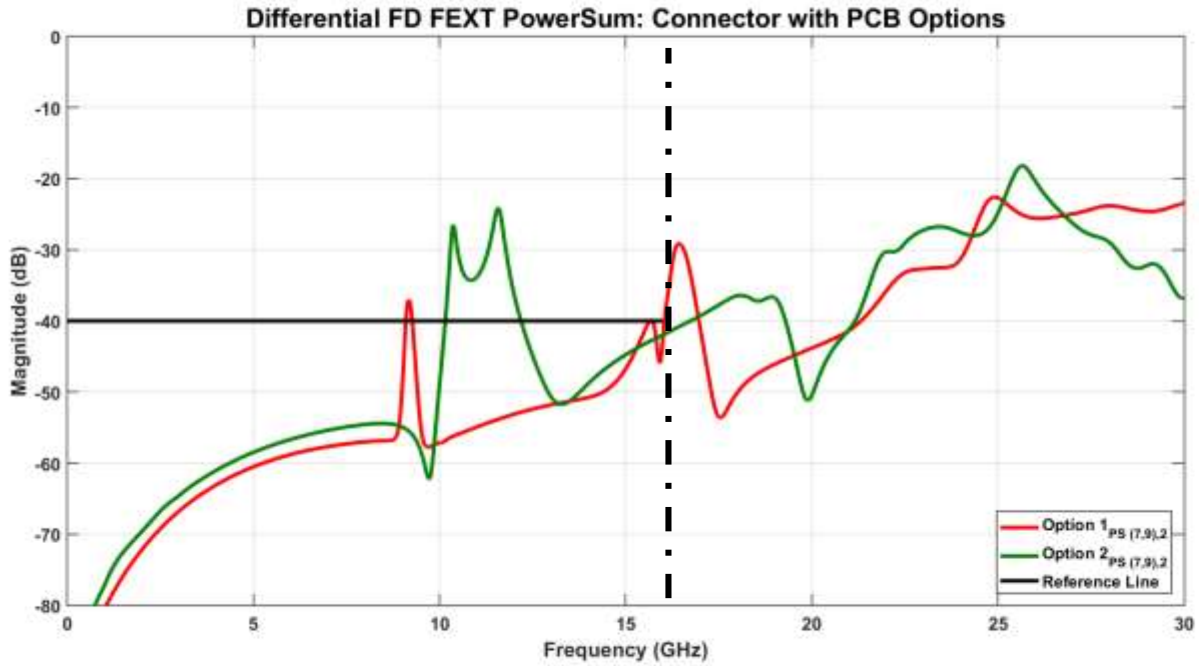
- **Component:** Edge Card connector model with especially high resonance as an interesting study case – not a model of actual Samtec product.
- Test data rate is 32 Gbps
- Desire to compare two different PCB styles
  - **Option 1:** Baseline
  - **Option 2:** Add vias to ground pads

# Mini Case Study: **Connector Response**



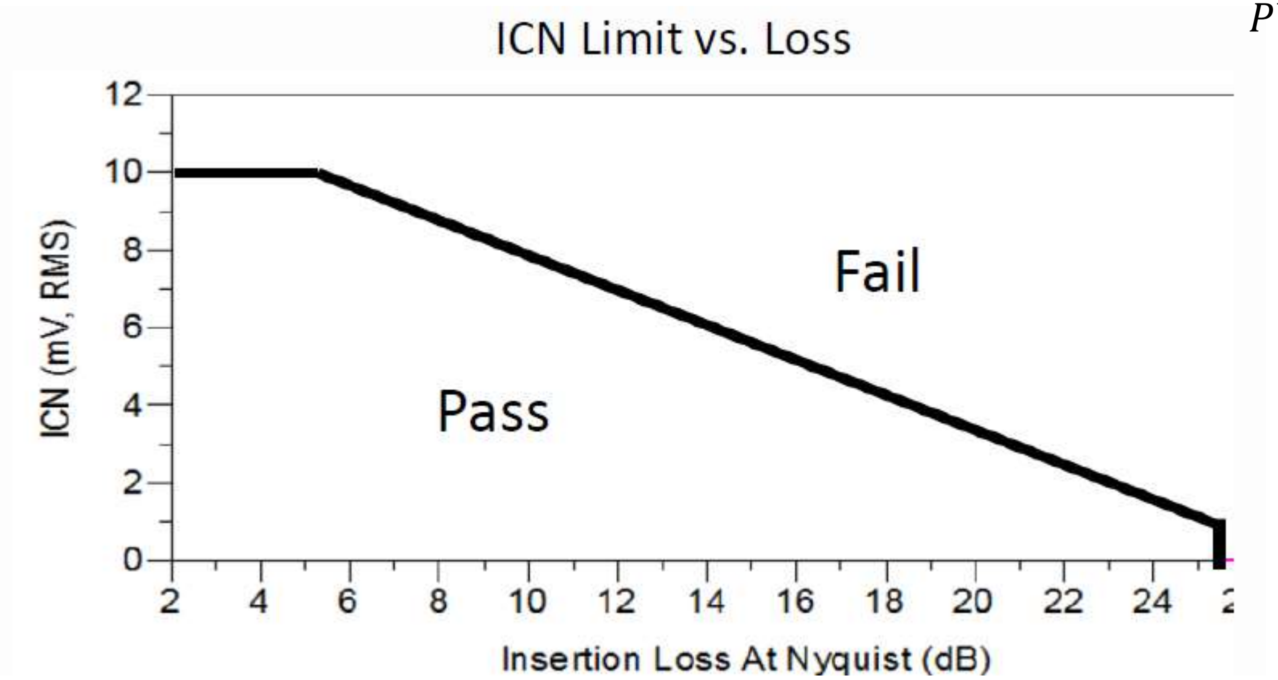




**Option 1** improves low frequency NEXT, but is worse above 12GHz. Which is better?

**Option 2** has higher FEXT, but resonance occurs at higher frequency (albeit much wider). Which is better?

# Integrated Crosstalk Noise

- Applied to channel and cable specifications and single component analysis in various papers
- Many uses trade loss with permitted crosstalk




IEEE 802.3bj; USB; PCIe External Cable; SAS-4

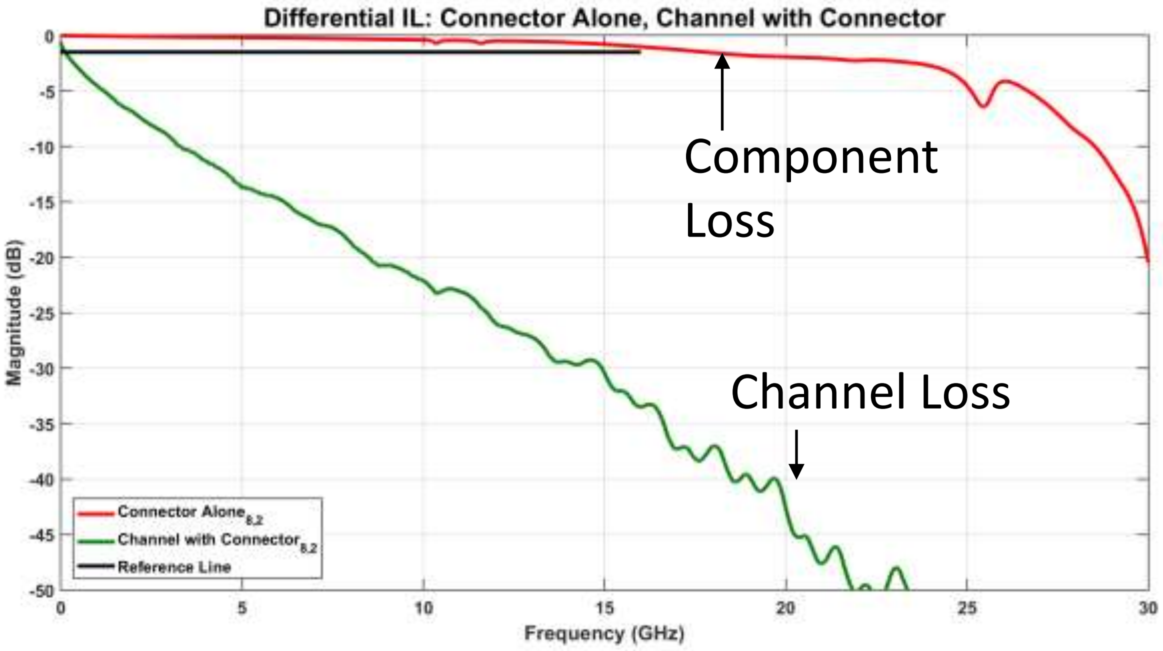
$$\sigma_{ICN} = \sqrt{2 \cdot \Delta f \cdot \sum_{f_{min}}^{f_{max}} \frac{A^2}{f_b} \cdot PWF(f) \cdot 10^{\left(\frac{PwrSumXt}{10}\right)}}$$

$$PWF(f) = UI \cdot sinc(UI \cdot f)^2 \cdot \left(\frac{1}{1+\left(f\frac{T_r}{0.2365}\right)^4}\right) \cdot \left(\frac{1}{1+\left(\frac{f}{F_{RX}}\right)^8}\right)$$

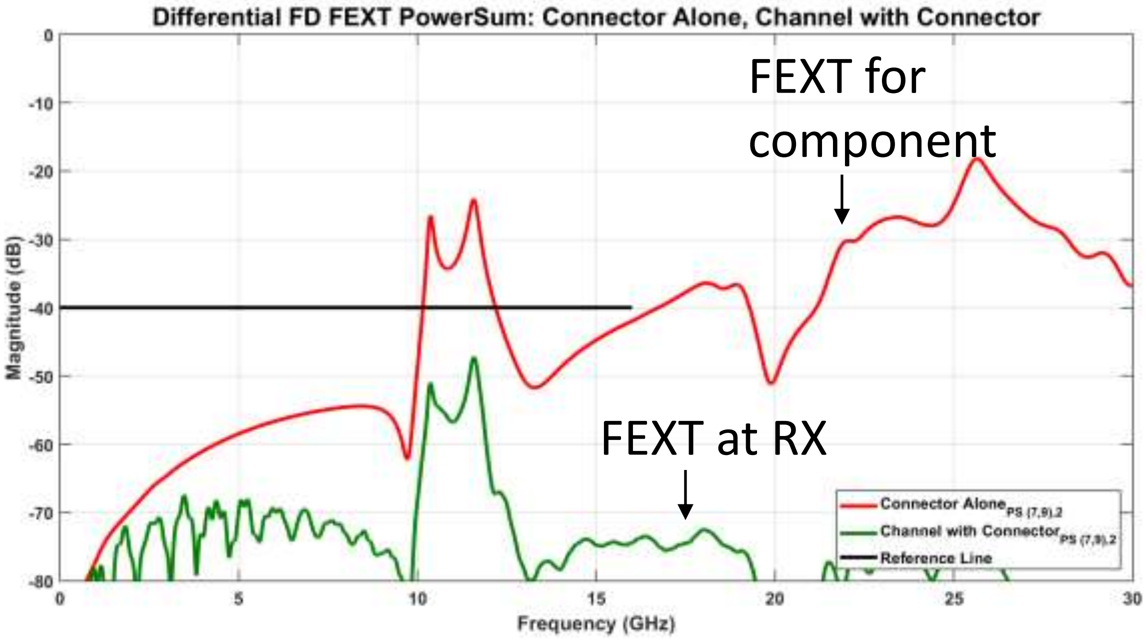
- Operation on crosstalk power sum
- Filter by spectral density and receiver filter
- Integration of remaining energy
- Adds irrespective of phase – a power noise

# ICN for Components: **The Problem & Solution**

- Little to no loss contained within small components
  - Packages, connectors, PCB vias and breakouts
- If ICN is calculated on component, higher frequencies are integrated that were otherwise attenuated by the channel




**Through a lossy channel, this connector crosstalk is near -70dB**



# ICN for Components: **The Problem & Solution**

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- Include system loss into ICN calculation
- Cascade channel is ideal but burdensome
- A scalable loss term is flexible, calling component contribution ICN (ccICN)
- Monotonic loss slope
- Customize for channel application
- Different for NEXT, FEXT

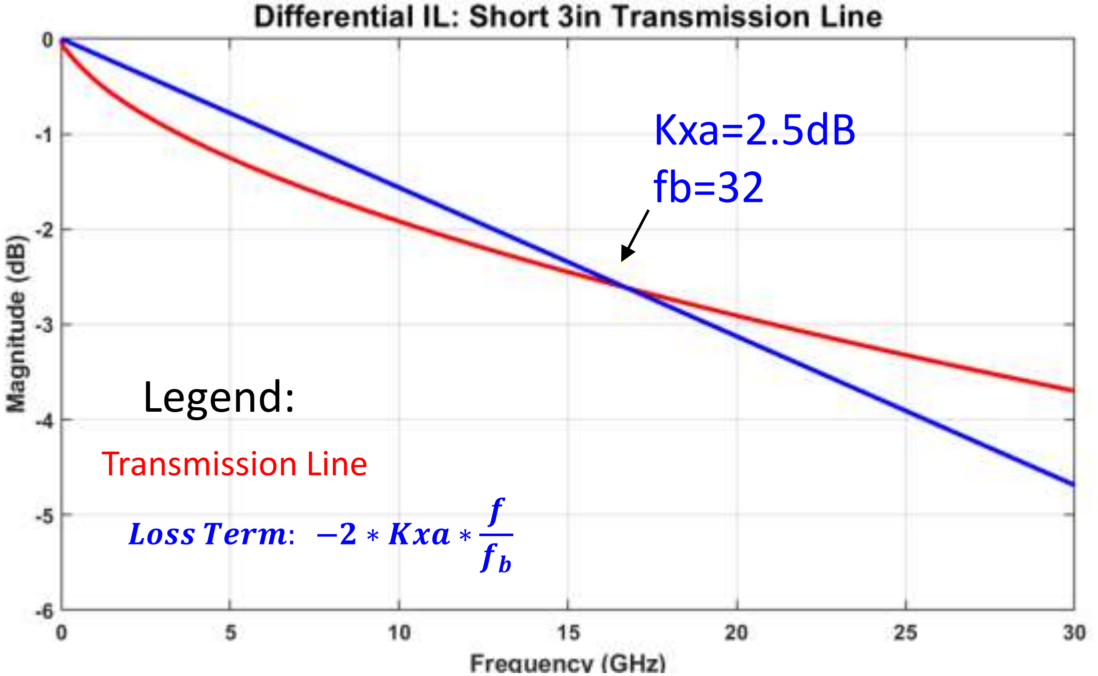
$$10^{\left(\frac{-2*k_{xa}*\frac{f}{f_b}}{10}\right)}$$

*A Method for Calculating Component-Level Crosstalk Contributions to Channel Crosstalk (Kao, Rothemel, Stephens), DesignCon 2018*

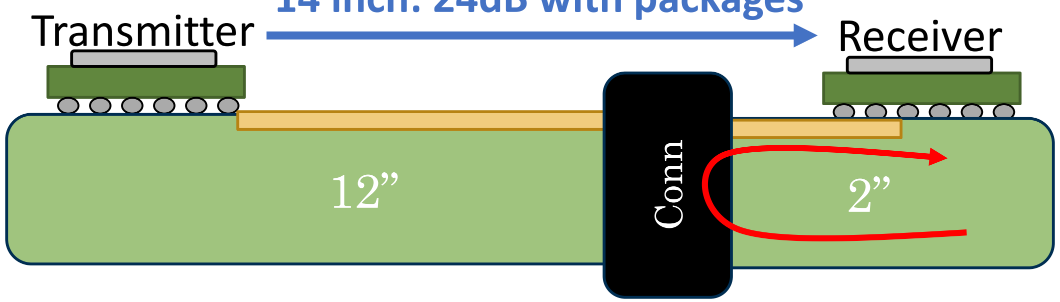
$$\sigma_{ICN} = \sqrt{2 \cdot \Delta f \cdot \sum_{f_{min}}^{f_{max}} \frac{A^2}{f_b} \cdot PWF(f) \cdot 10^{\left(\frac{PwrSumXt}{10}\right)} \cdot 10^{\left(\frac{-2*Kxa*\frac{f}{f_b}}{10}\right)}}$$

Kxa term defines desired insertion loss at fb/2

**Compare Transmission line to ccICN loss term: Same Loss at fb/2**



# ICN w\ Loss is a Position-Sensitive Metric




$$\sigma_{Fext} = \sqrt{2 \cdot \Delta f \cdot \sum_{f_{min}}^{f_{max}} \frac{Af^2}{f_b} \cdot PWF(f) \cdot 10^{\left(\frac{FextPwrSum}{10}\right)} \cdot 10^{\left(\frac{-2 * kxa\_fext * \frac{f}{f_b}}{10}\right)}}$$

$$\sigma_{Next} = \sqrt{2 \cdot \Delta f \cdot \sum_{f_{min}}^{f_{max}} \frac{An^2}{f_b} \cdot PWF(f) \cdot 10^{\left(\frac{NextPwrSum}{10}\right)} \cdot 10^{\left(\frac{-2 * kxa\_next * \frac{f}{f_b}}{10}\right)}}$$

Separate ICN FEXT and NEXT may be Root-Sum-Square together as a Total ICN:

$$\sigma_{Total} = \sqrt{\sigma_{Fext}^2 + \sigma_{Next}^2}$$

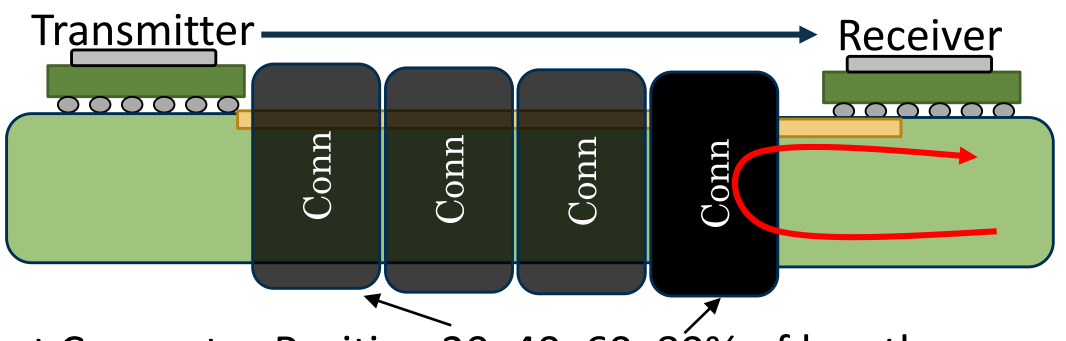
Does position matter?
**Absolutely**

The input for ccICN is the loss experienced by the coupling-path and is position dependent.

**NEXT:** loss changes with channel position.
**FEXT:** loss does not change with position.

# ICN w\ Loss is a Position-Sensitive Metric






| Channel Position | Kxa_next | ICN Next | | Kxa_fext | ICN Fext | | Eye Height |
|---|---|---|---|---|---|---|---|
| 20% | 21.2 dB | 0.092 mV | | 24 dB | 0.099 mV | | 33.56 mV |
| 40% | 18.4 dB | 0.131 mV | | 24 dB | 0.099 mV | | 32.04 mV |
| 60% | 15.6 dB | 0.202 mV | | 24 dB | 0.099 mV | | 31.60 mV |
| 80% | 12.8 dB | 0.339 mV | | 24 dB | 0.099 mV | | 30.15 mV |

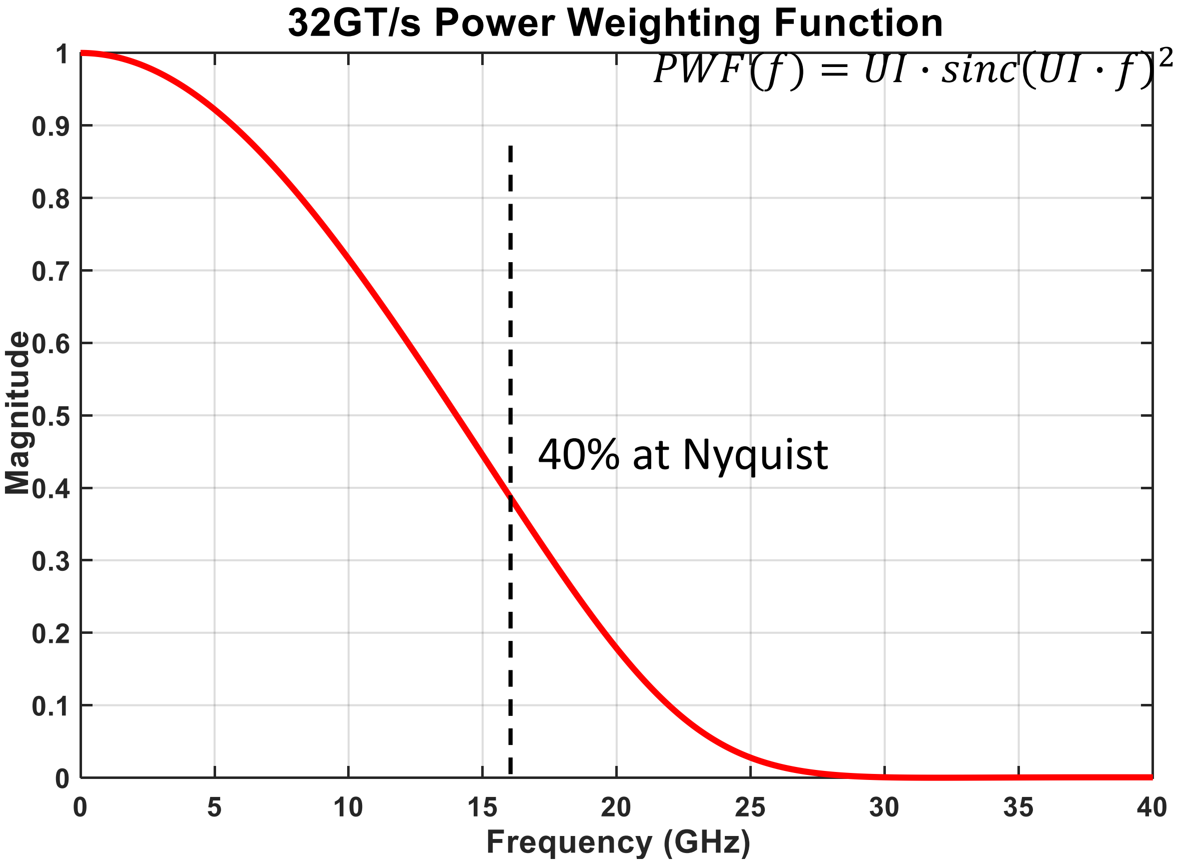
FEXT path is constant, and low crosstalk compared to NEXT.

Nearest Receiver = Lowest loss NEXT path = largest ICN value = Smallest Eye Height

# ICN Components

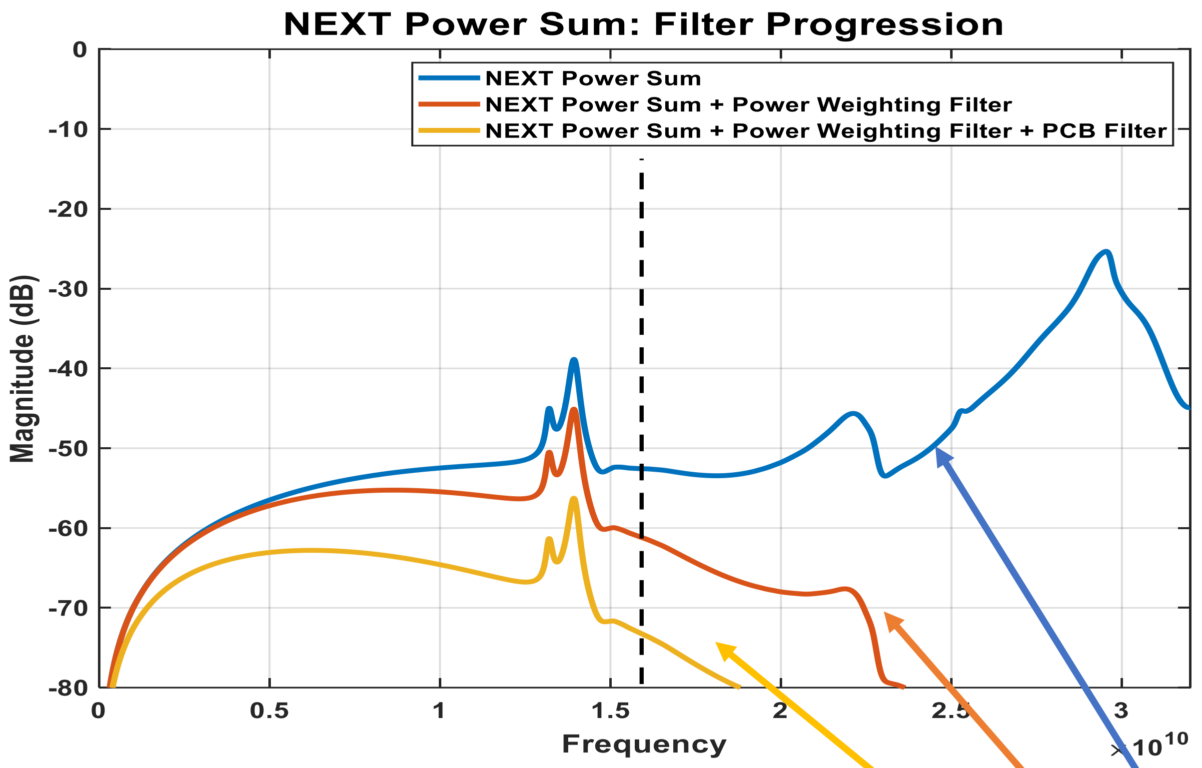
$$\sigma_{ICN} = \sqrt{2 \cdot \Delta f \cdot \sum_{f_{min}}^{f_{max}} \frac{A^2}{f_b} \cdot PWF(f) \cdot 10^{\left(\frac{PwrSumXt}{10}\right)} \cdot 10^{\left(\frac{-2*Kxa*\frac{f}{f_b}}{10}\right)}}$$

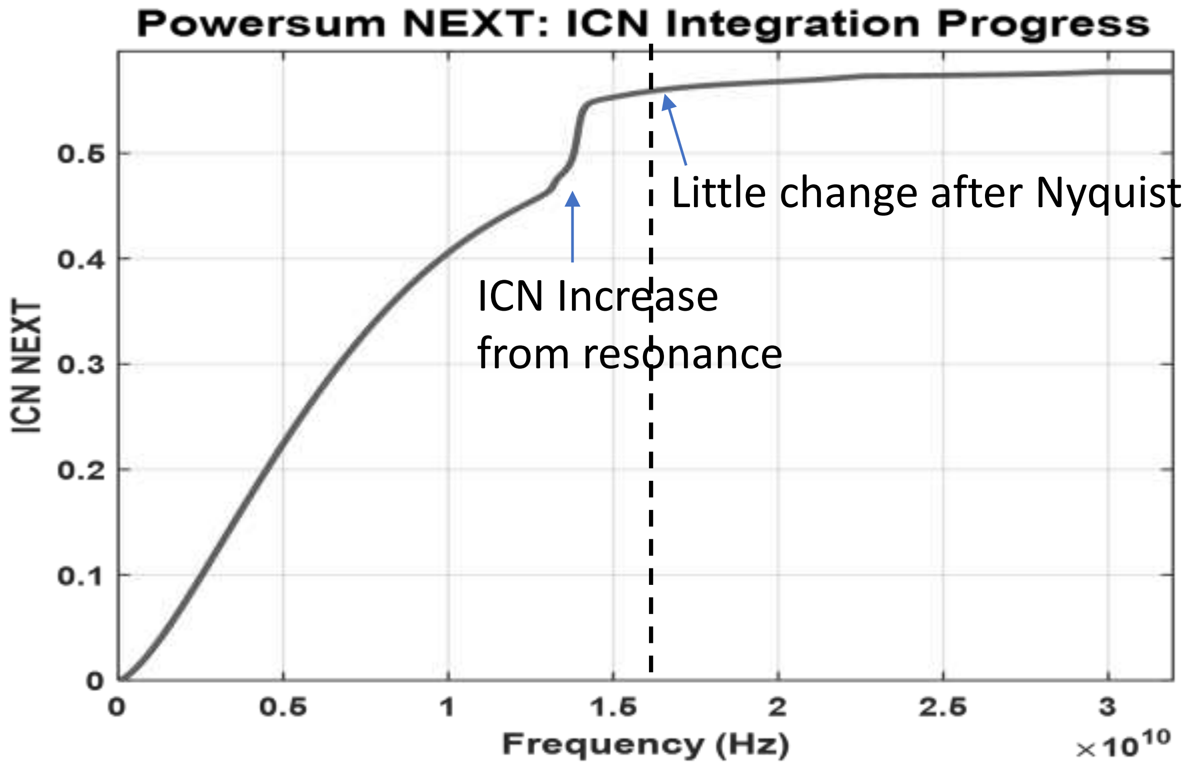
$$PWF(f) = UI \cdot sinc(UI \cdot f)^2 \cdot \left(\frac{1}{1+\left(f\,\frac{T_r}{0.2365}\right)^4}\right) \cdot \left(\frac{1}{1+\left(\frac{f}{F_{RX}}\right)^8}\right)$$



# ICN Components





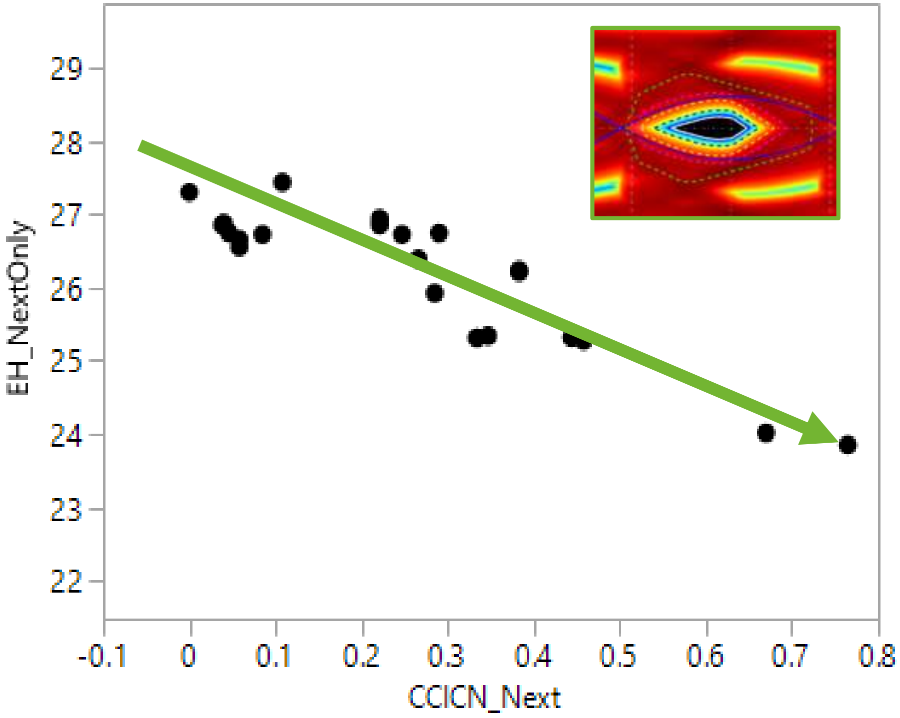




$$\sigma_{ICN} = \sqrt{2 \cdot \Delta f \cdot \sum_{f_{min}}^{f_{max}} \frac{A^2}{f_b} \cdot PWF(f) \cdot 10^{\left(\frac{PwrSumXt}{10}\right)} \cdot 10^{\left(\frac{-2*Kxa*\frac{f}{f_b}}{10}\right)}}$$

# Correlation, and Other Data Rates

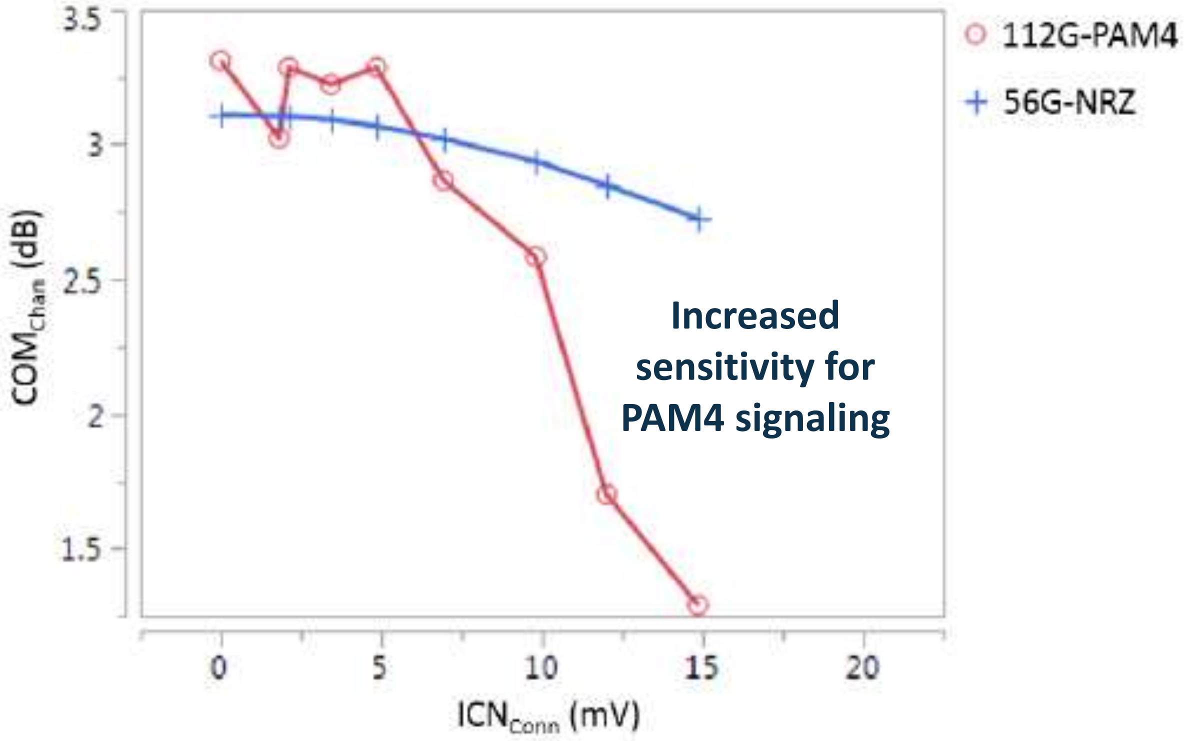


32G Eye Height by ICN:
**Connector Models**




Original ICN R-square 84.2
ccICN R-square 92.2

112G, 56G, COM by ICN:
**Connector Models**

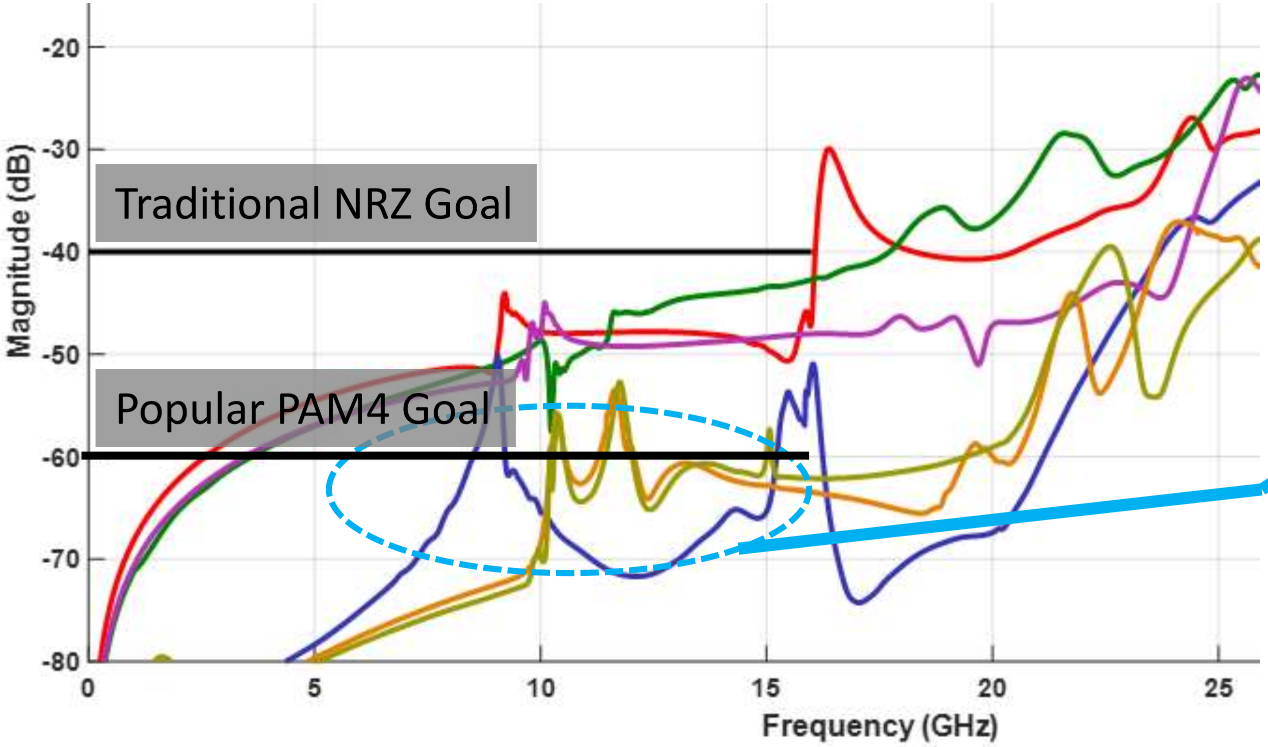



***DesignCon 2019:*** *Don't Judge a Bit Just by Its Fourier: 112 Gbps PAM4 Component Optimization and Selection*
*Steve Krooswyk, Madhumitha Rengarajan*

# Correlation, and Other Data Rates: **64G-PAM4**

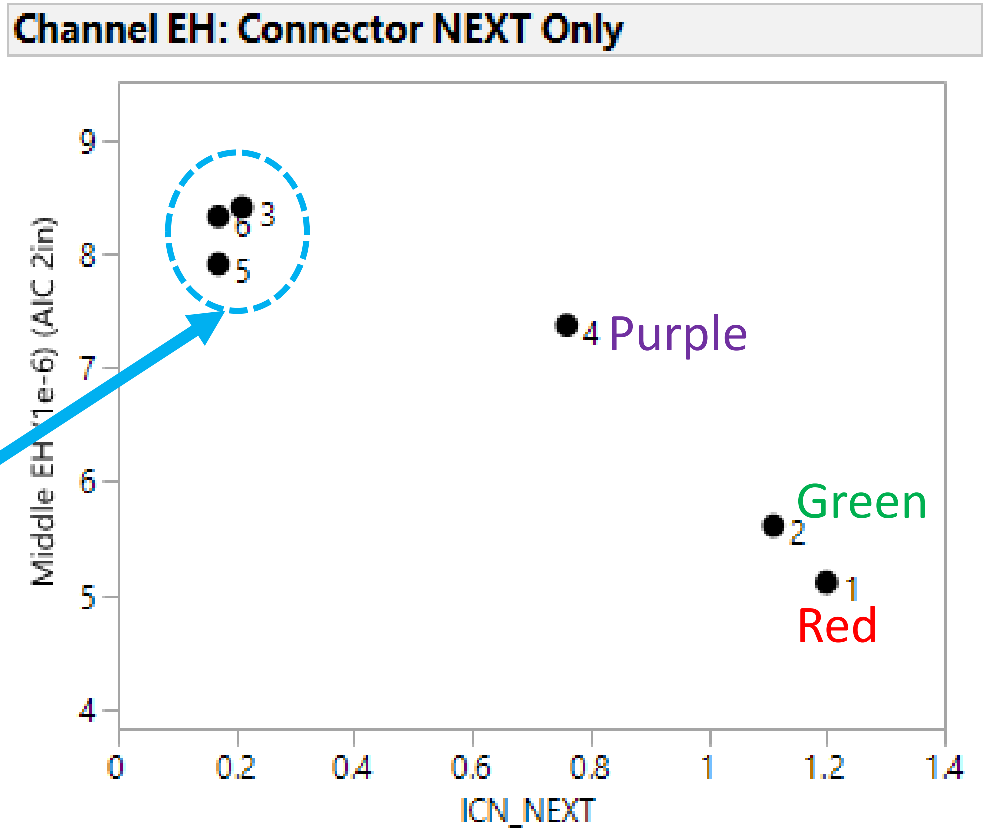


## Components: **NEXT Power Sum**



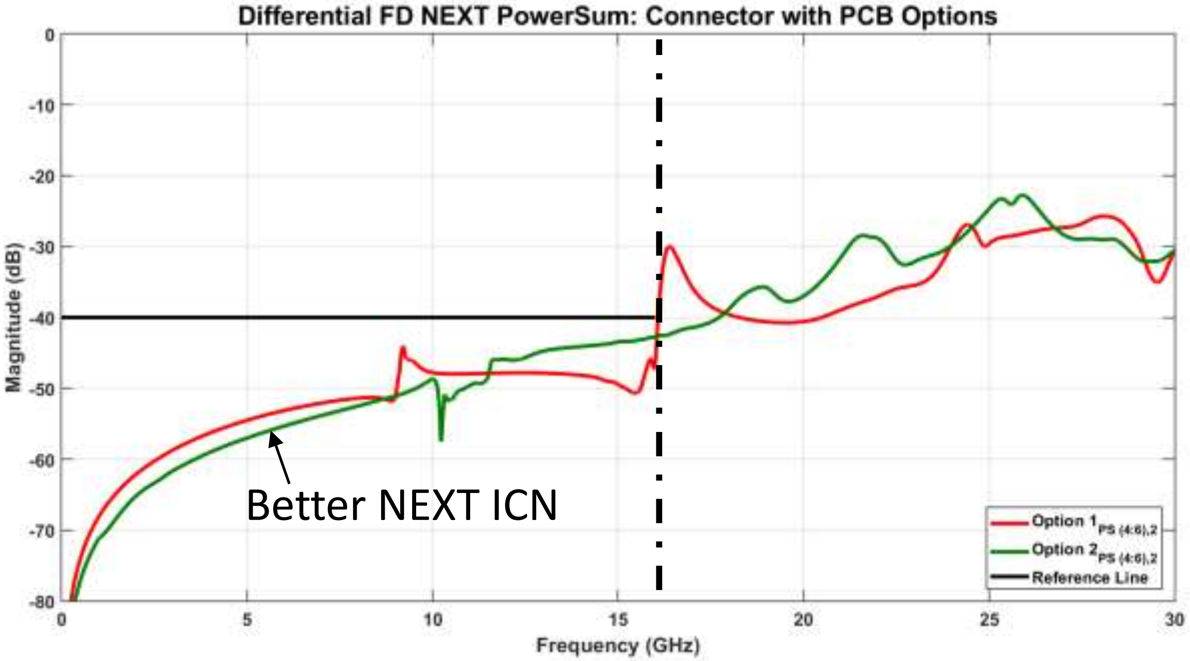

**While -60dB is popular goal, evidence is some exceptions are okay**

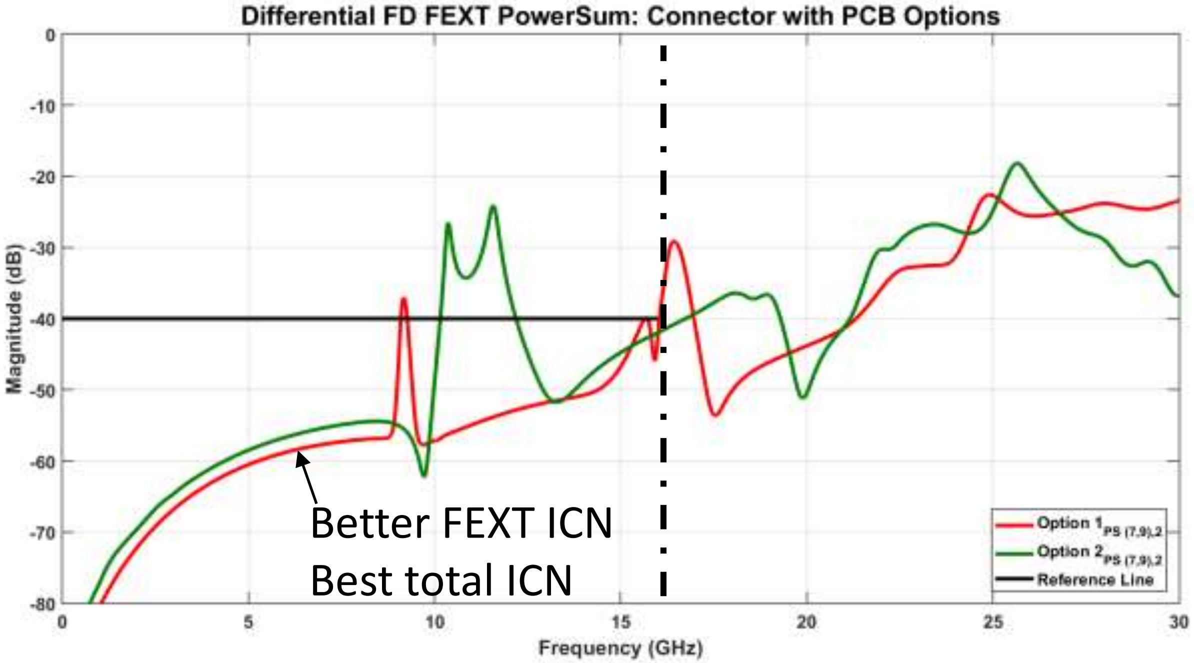
## System: **Eye Height by ICN**




**Performance correlated to ccICN**

# Mini Case Study: **Conclusion**




| | ccICN NEXT |
|---|---|
| Red | 0.202 mV |
| Green | 0.128 mV |

| | ccICN FEXT |
|---|---|
| Red | 0.099 mV |
| Green | 0.252 mV |

| | ccICN Total (RSS) | EH | EW |
|---|---|---|---|
| Red | 0.225 mV | 31.6 | 0.33 |
| Green | 0.283 mV | 30.6 | 0.32 |

# SUMMARY

- Component characterization with ICN provides a tool to better select or improve components
- Full link channel simulation is not necessary to evaluate comparisons
- Clarity for fuzzy differences between performances, where most important frequencies matter the most
- Inclusion of loss (ccICN) improves system prediction, and makes a viable tool for industry standards

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