# Link and connector requirements for 10 Gb/s interconnects

Stefaan Sercu and Vittal Balasubramanian

# Outline

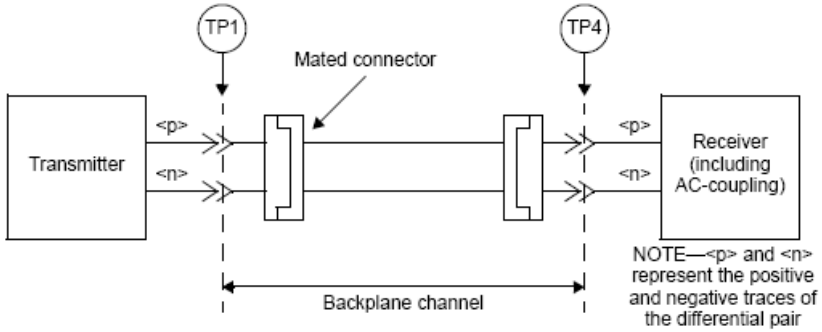
- IEEE 802.3ap provide backplane link performance guideline to meet 10G Ethernet compliant signal channels
- Review of the guideline
- Informative component level design rules
  - Can a connector component specification be derived to ensure IEEE 802.3ap compliancy?
- How confident can designers be following the guideline?
  - An in-depth assessment is made based on BER link simulations
- Summary & conclusions

# Review of Annex 69B of the IEEE 802.3ap guideline

# IEEE 802.3ap - Annex 69B - objective

- Supply informative recommendations to assist backplane designers in identifying backplane channels that are interoperable with “Backplane Ethernet compliant” devices
- Backplane channel specification
  - if you pass, you are quite sure (have a high confidence) that you don’t have to bother your channel performance any more
    - Arbitrary length
    - Independent of board material
    - Don’t mind individual component performance
      - Doesn’t matter if more budget is given to backpanel, component boards or connector as long as complete picture is OK
      - How to define connector compliance?

# IEEE 802.3ap - Annex 69B – Model assumptions




- Model assumptions
  - 100 ohm environment
  - Up to 1m of differential traces
  - Improved FR4
  - 2 connectors
  - AC coupling capacitors not part of the interconnect model
  - BER = 10e-12
  - 3 traps transmitter equalization (1 pre, 1 post cursor)
  - No receive equalization defined
    - Requirements developed under the assumption of a 5-tap DFE
    - Receiver must exhibit an expected level of performance as established via the interference tolerance test
      - Examines the ability of the receiver to equalize a high-loss channel in presence of interference (jitter and noise)

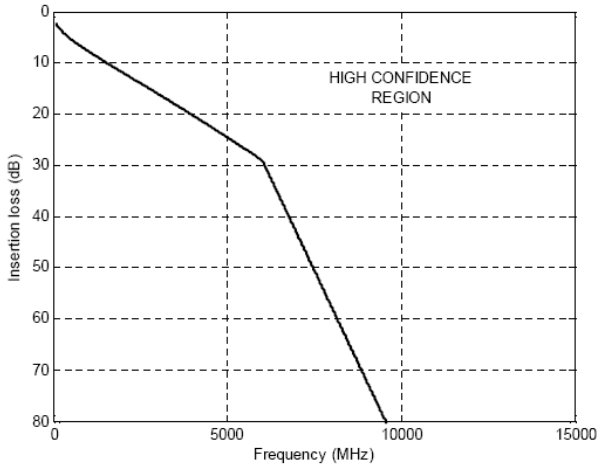
# IEEE 802.3ap - Annex 69B – Performance Parameter

- 5 frequency domain performance parameters defined
  - Maximum fitted attenuation (A)
  - Maximum insertion loss (IL)
  - Maximum deviation of insertion loss from the best-fit attenuation (ILD)
  - The minimum return loss (RL)
  - Limit on crosstalk in relation to insertion loss (ICR)

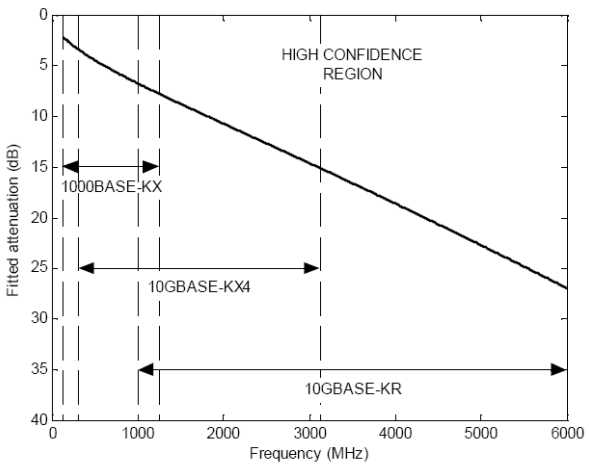
- 3 Speeds
  - Focus on 10GBASE-KR (10 Gb/s serial)

# IEEE 802.3ap - Annex 69B – Performance Parameter

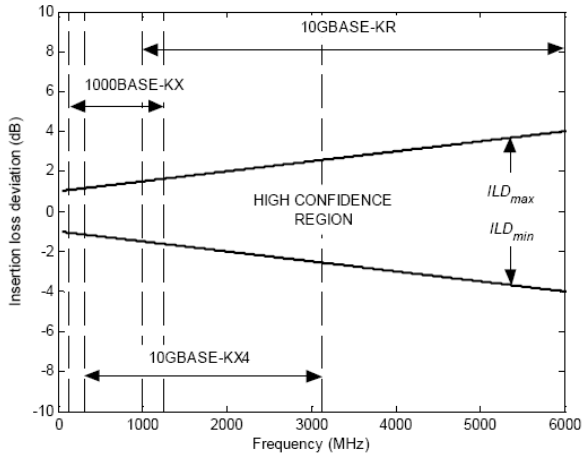
## Insertion loss

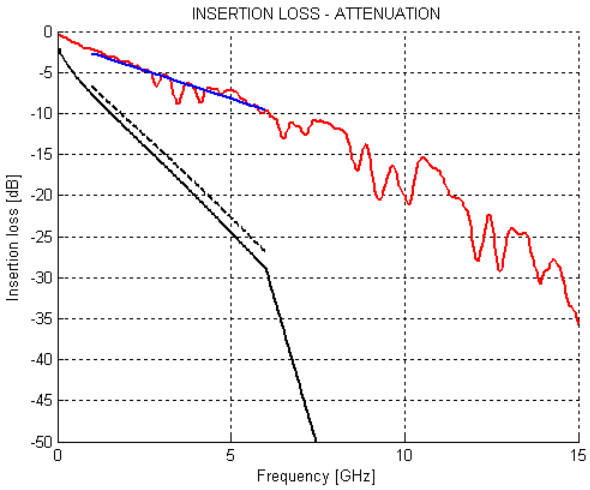


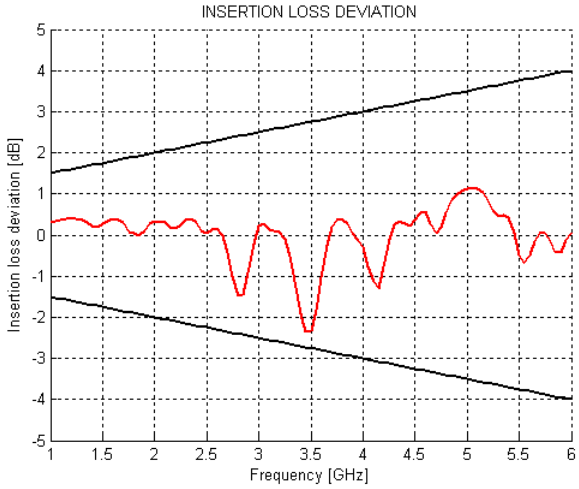

## Fitted attenuation




## Insertion loss deviation



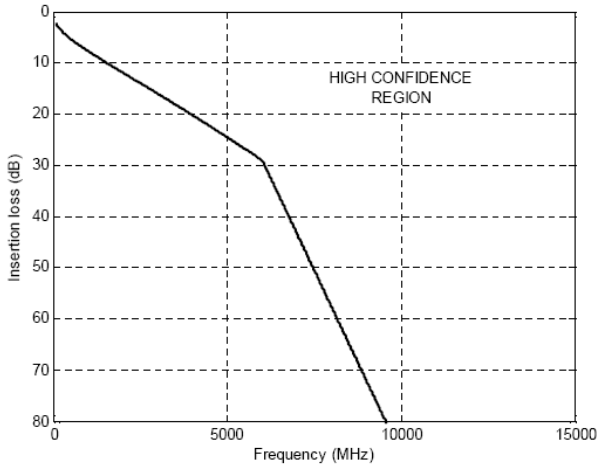



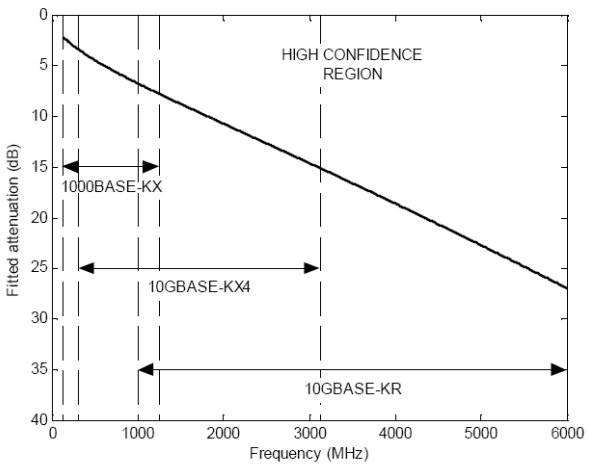

**ILD = IL – A**

# IEEE 802.3ap - Annex 69B – Performance Parameter

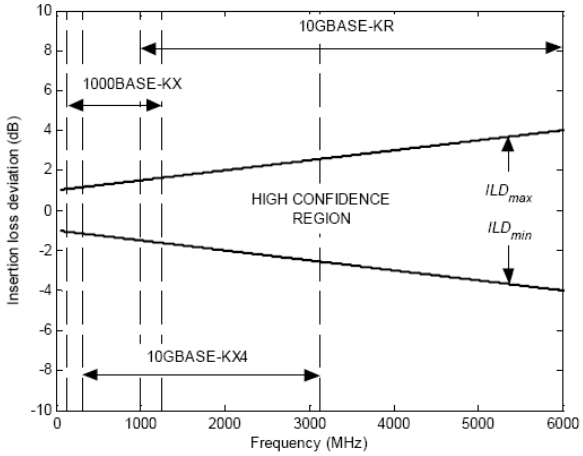
## Insertion loss



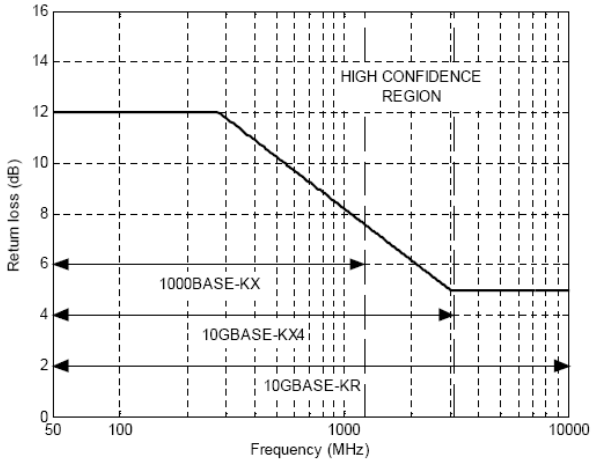

## Fitted attenuation



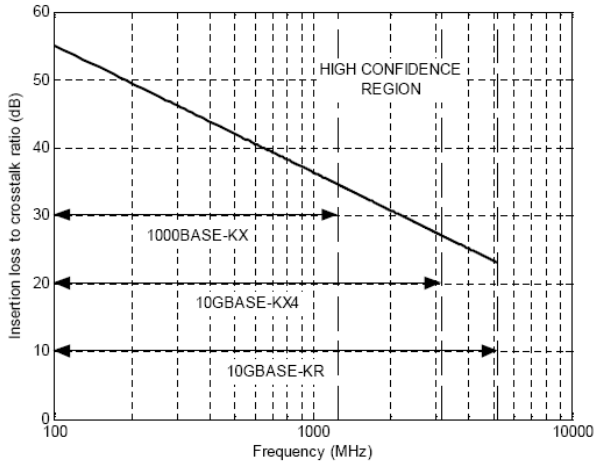

## Insertion loss deviation

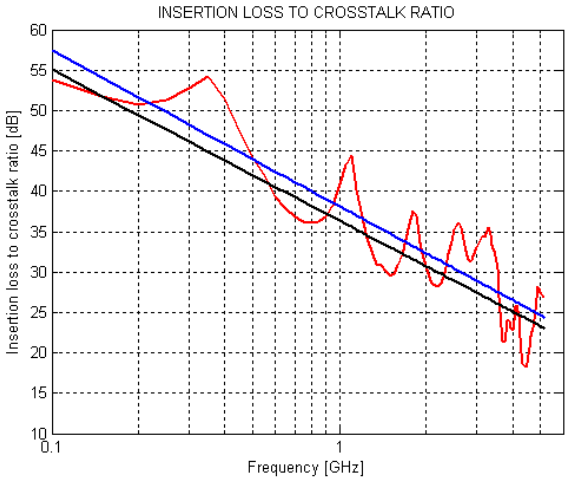



## Return loss




## Insertion loss to crosstalk ratio



# Informative component level design rules

# Informative component level design rules

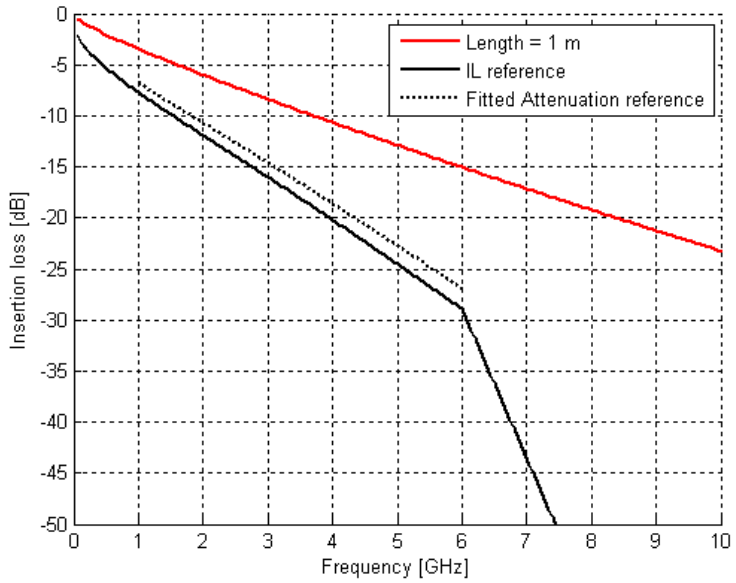
- Insertion loss and Attenuation
  - Backpanel and Component Boards:
- Return loss, Insertion loss deviation and ICR
  - Connector and connector footprint

# Insertion loss and Attenuation

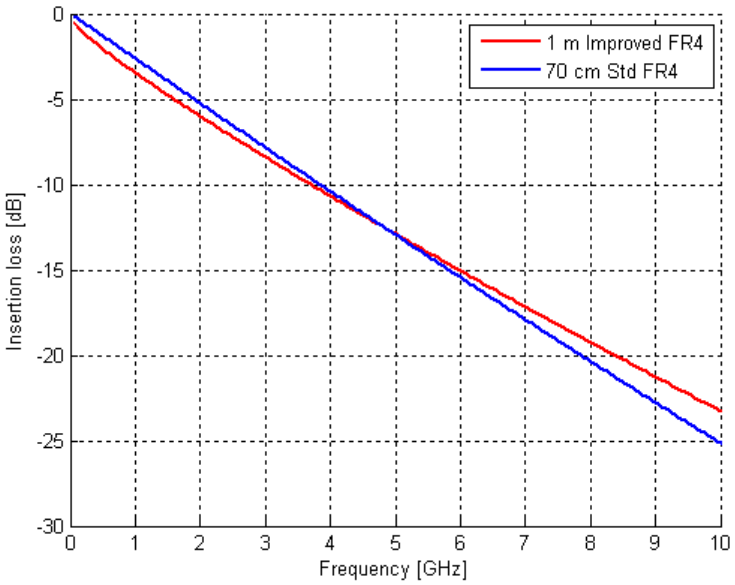
- Backpanel and component board performance determined by
  - Length
  - Trace width, trace to trace isolation
  - Board material, board build-up
  - …

2 x CB + BP

**1m improved FR4**

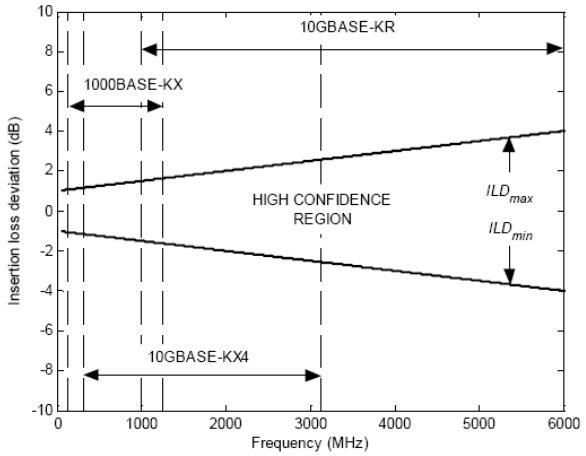



**Improved FR4 vs Std FR4**

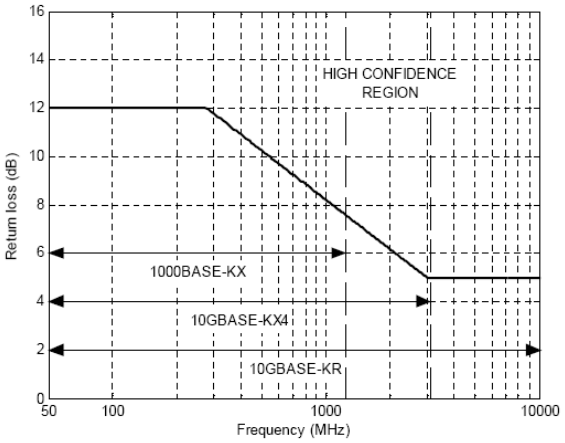


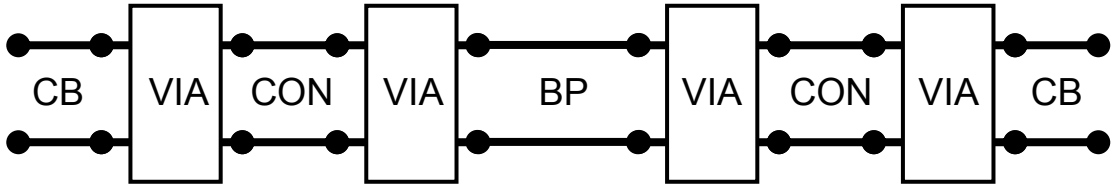
# Insertion loss deviation ILD – Return loss RL

## Insertion loss deviation




## Return loss




## CB - Component board: lossy TL

- Z = 100 ohm,
- Length = 12.5 cm
- Improved FR4

## BP - Backpanel: lossy TL

- Z = 100 ohm,
- Length = 75 cm
- Improved FR4

## CON - Connector: lossy TL

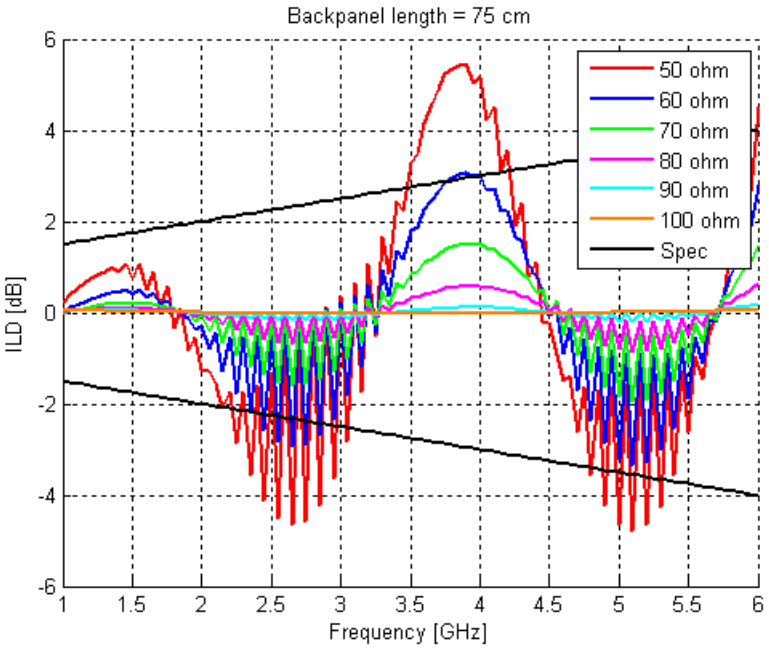
- Z = 100 ohm
- Delay = 150 ps

## VIA - Via holes: lossy TL

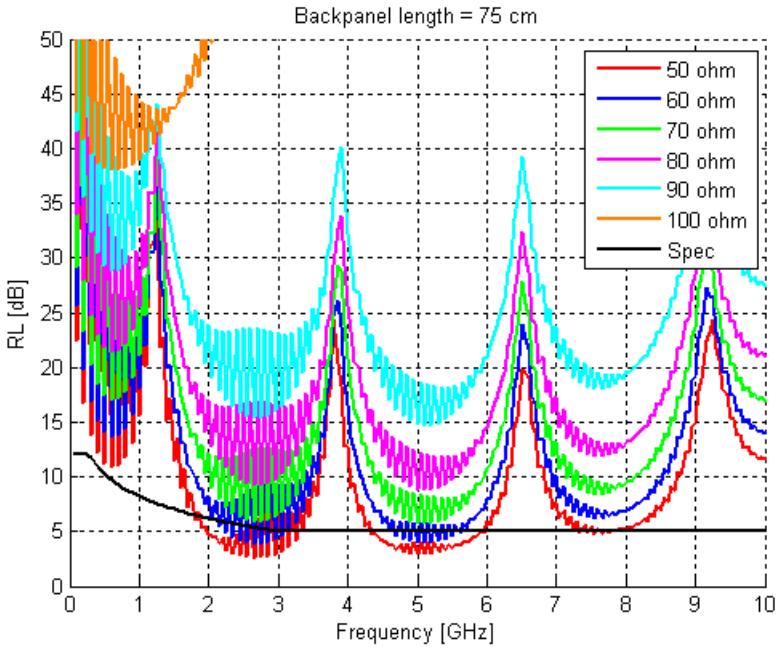
- Z = 50 ohm, …, 100 ohm
- Delay = 50 ps

# Insertion loss deviation ILD – Return loss RL

## Insertion loss deviation



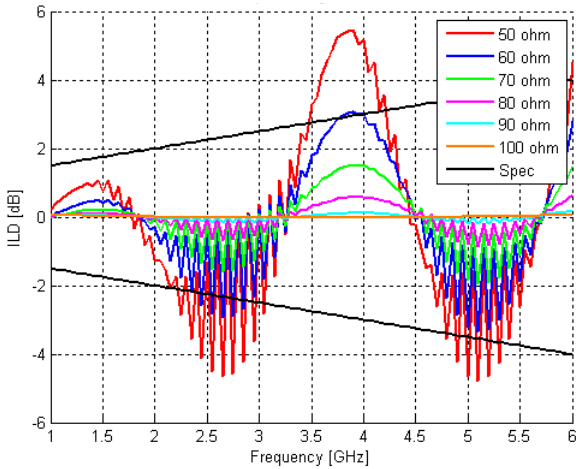

## Return loss



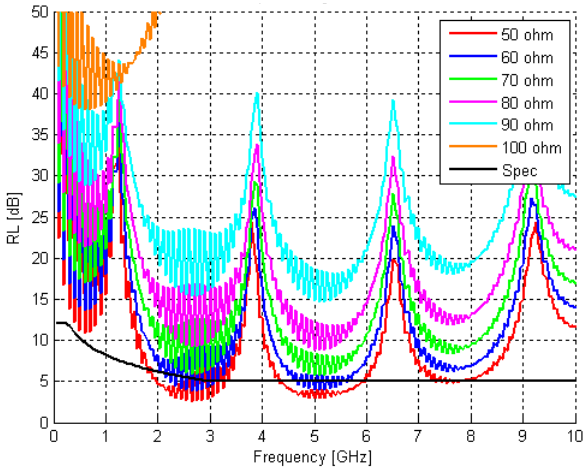
# Insertion loss deviation ILD – Return loss RL

## Backpanel length = 75 cm

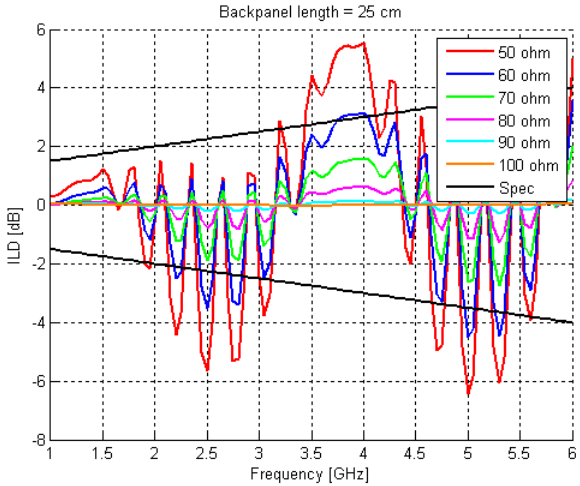
### Insertion loss deviation

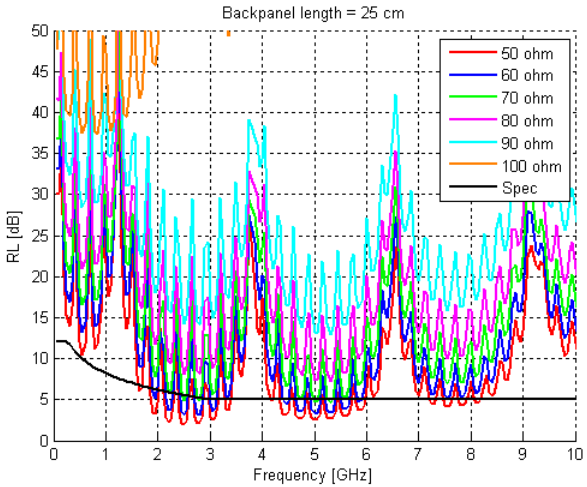



### Return loss

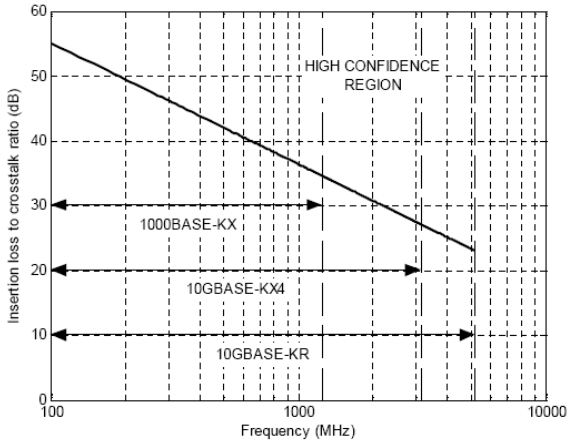


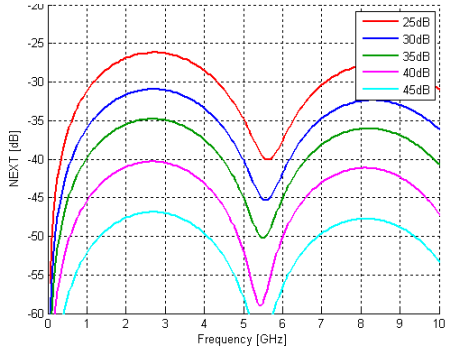

## Backpanel length = 25 cm

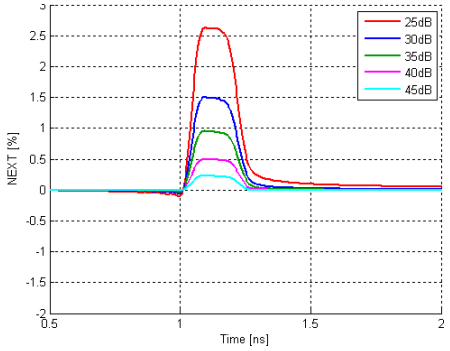


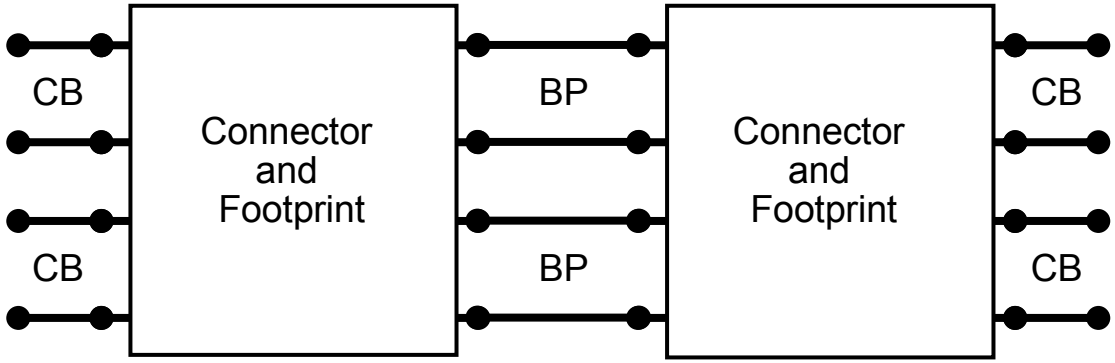



# Insertion loss to crosstalk ratio - ICR




## CB - Component board: TL

- Z = 100 ohm
- Length = 12.5 cm
- Improved FR4

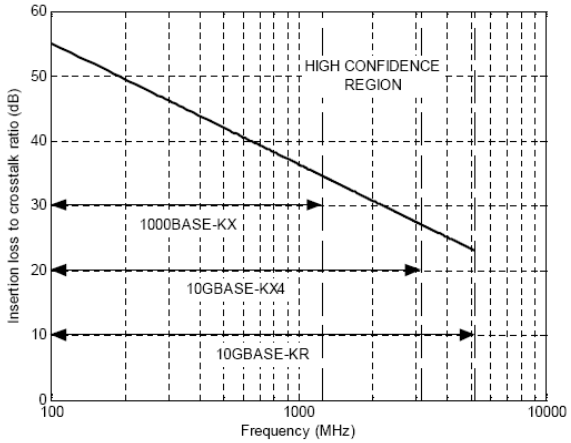
## BP - Backpanel: TL

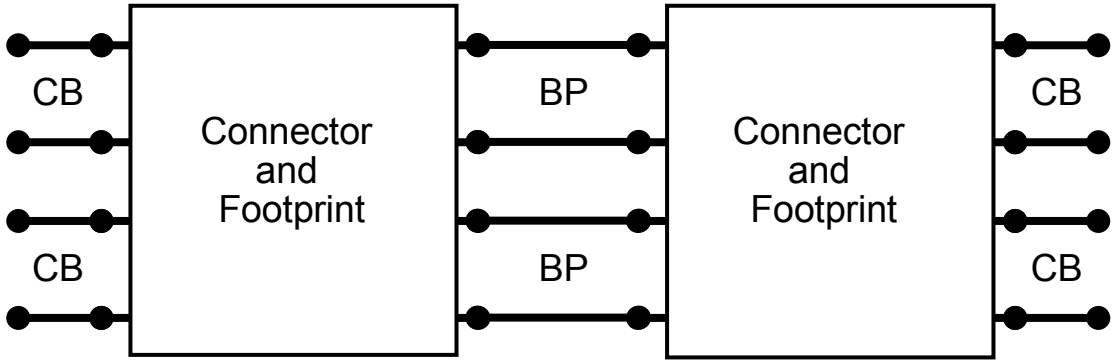
- Z = 100 ohm
- Length = 25, 75 cm
- Improved FR4

## Connector and footprint: coupled TLs

- Z = 100 ohm
- Next crosstalk levels = 25 dB, 30 dB, 35 dB, 40 dB, 45 dB

# Insertion loss to crosstalk ratio - ICR

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## BP - Backpanel: TL

- Z = 100 ohm
- Length = 25, 75 cm
- Improved FR4

## Connector and footprint: coupled TLs

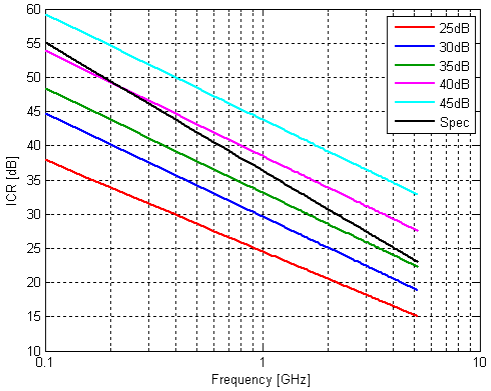
- Z = 100 ohm
- Next crosstalk levels = 25 dB, 30 dB, 35 dB, 40 dB, 45 dB
- Coupling length = 71 ps, 100ps, 167 ps
- Nr of crosstalk channels
- Tx, Rx pin assignment

# Insertion loss to crosstalk ratio - ICR

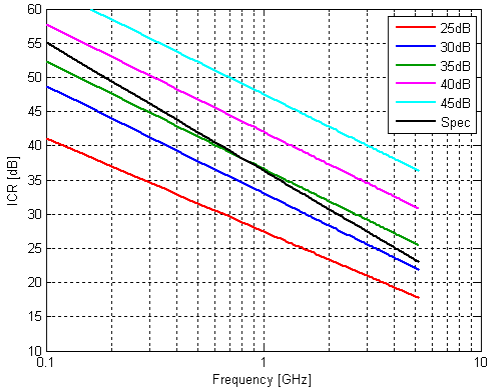
Nr Next channels = 1, Nr Fext channels = 1

## Backpanel length = 25 cm

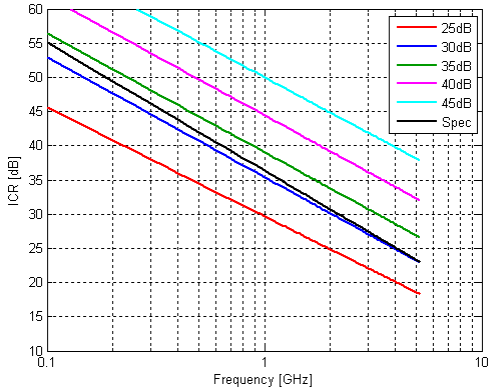
**Coupling length = 167 ps**




**Coupling length = 100 ps**

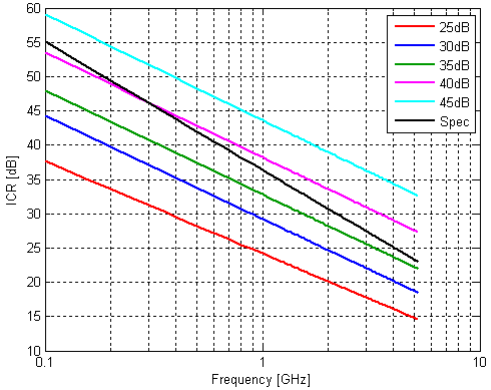



**Coupling length = 71 ps**

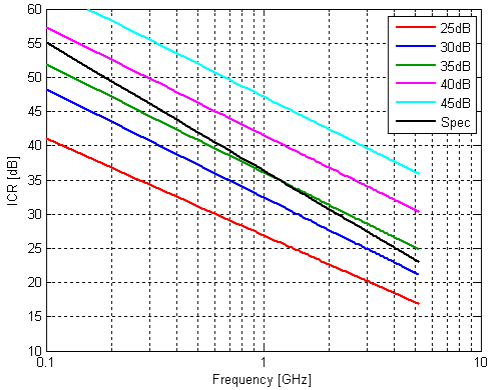



## Backpanel length = 75 cm

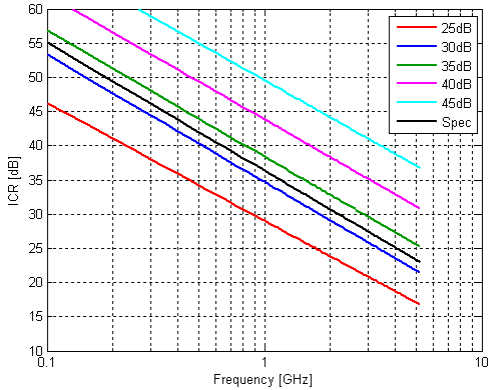
**Coupling length = 167 ps**




**Coupling length = 100 ps**



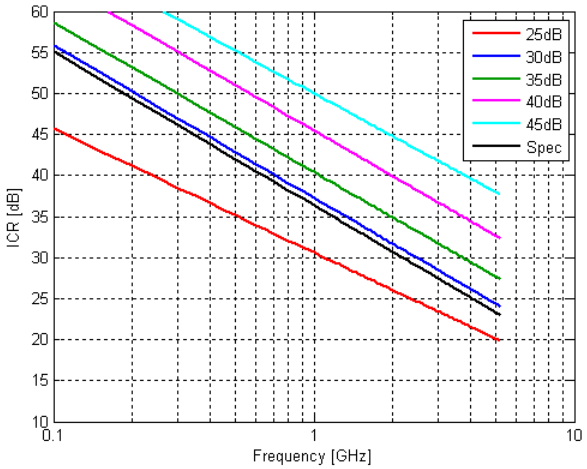

**Coupling length = 71 ps**



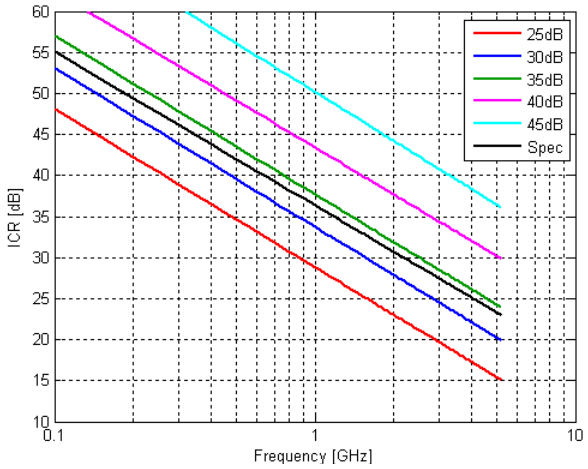
# IEEE 802.3ap informative reference

Backpanel length = 75 cm
Coupling length = 71 ps

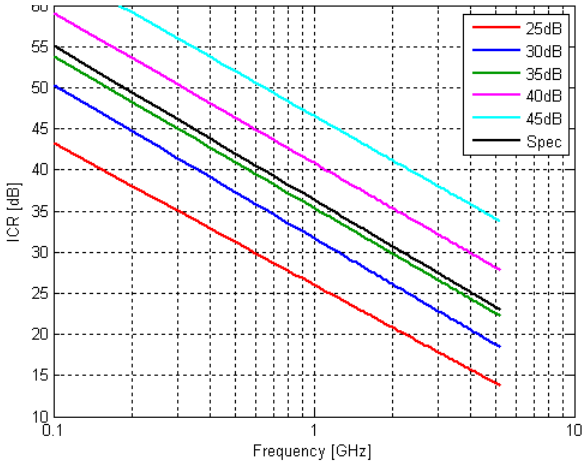
0 Next, 2 Fext channels



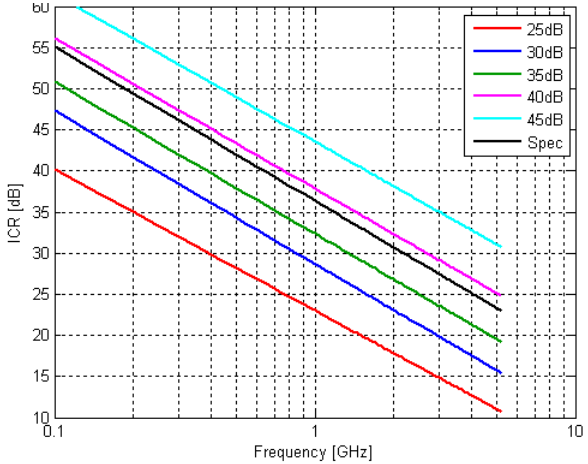

2 Next, 0 Fext channels




2 Next, 2 Fext channels



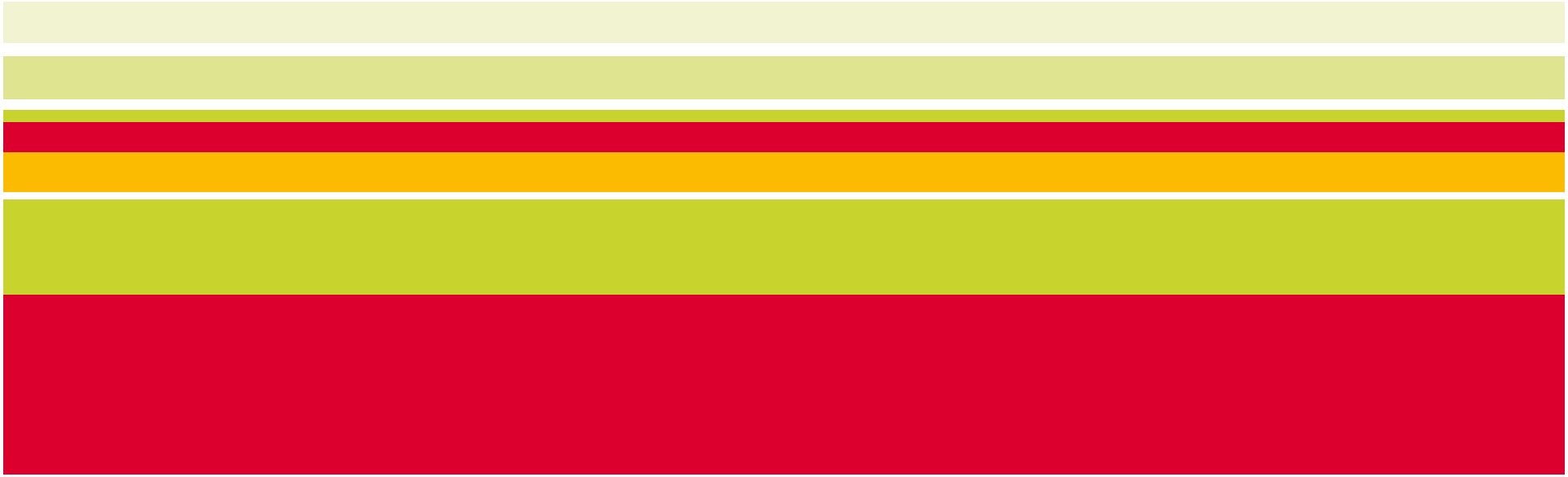

4 Next, 4 Fext channels



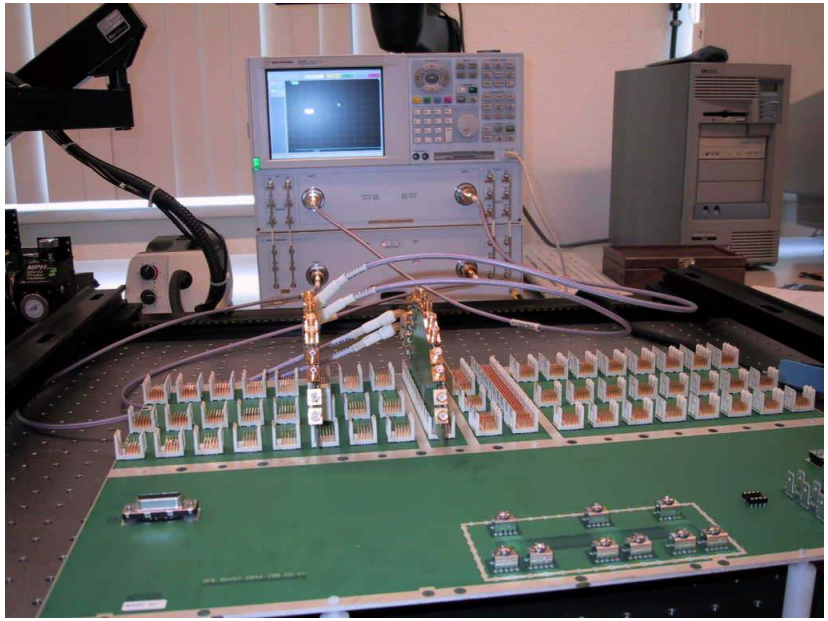
# Summary design rules

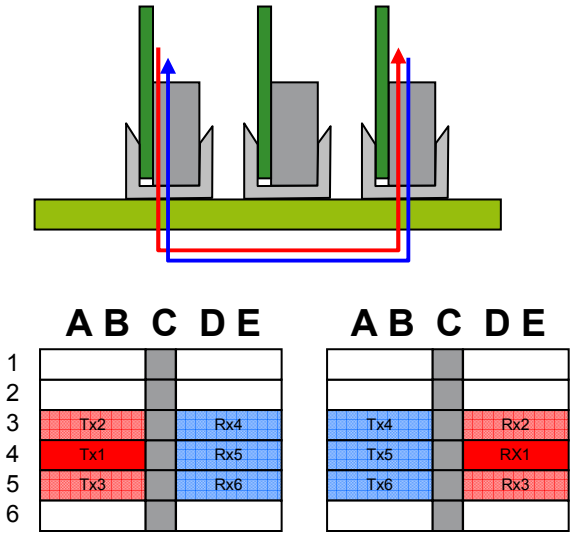
- IL, Attenuation
  - PCB + CB's: performance better than 1m Improved FR4
- ILD, RL
  - Via hole impedance > 70 ohm
- ICR
  - Maximum allowed crosstalk level determined by
    - Crosstalk duration (coupling length),
    - Nr of channels
    - Tx and Rx pin assignment
  - A connector and associated footprint that works for one application will not necessarily work for another application
  - Not possible to put a single crosstalk number

# IEEE 802.3ap - channels meeting/not meeting informative reference and BER link performance: is there a match?



# Example: Metral 4000 backpanel link

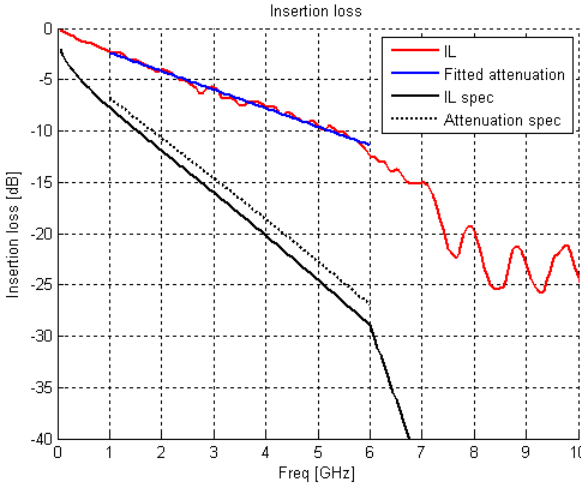


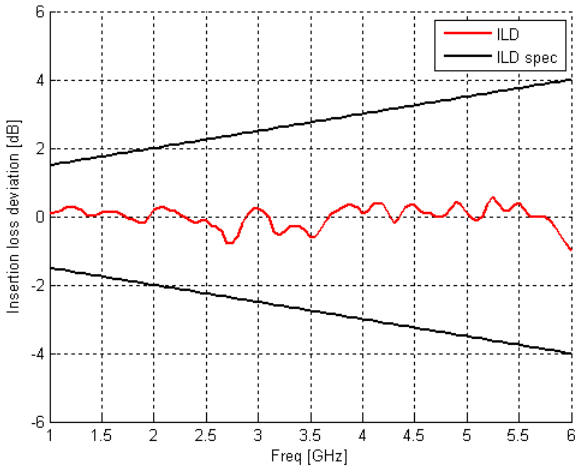


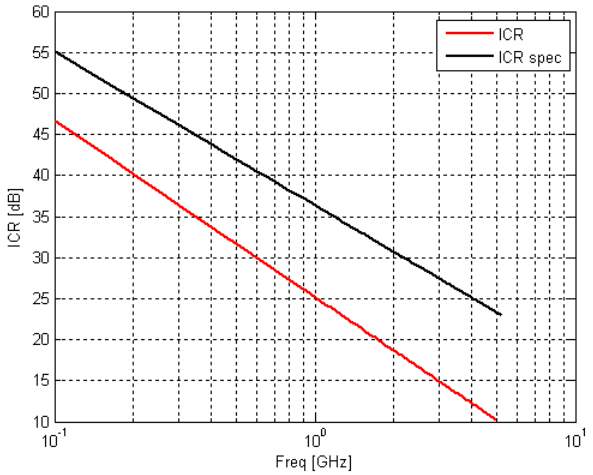

Backpanel link
- 8 cm
- Standard FR4
- 2 Metral 4000 connectors
- designed for 3.125 Gb/s
- 5 crosstalk aggressors (2 Fext, 3 Next)

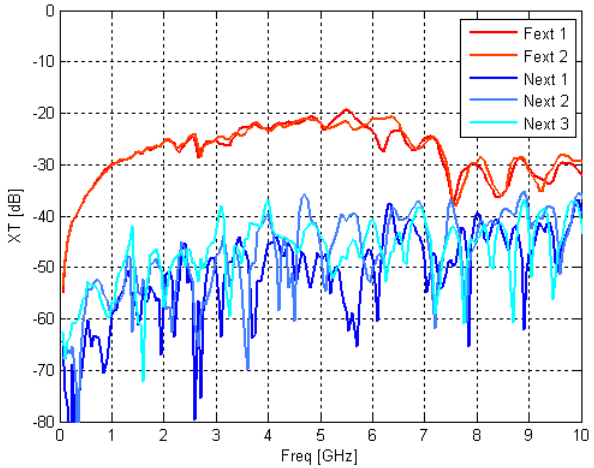
**BER testing: AMCC QEB2025 Evaluation Board**

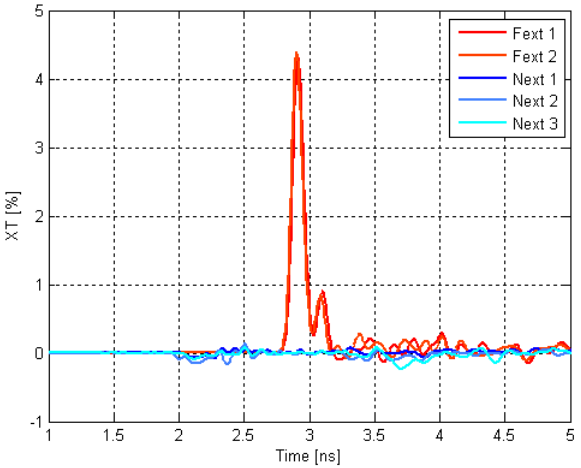
# Example: Metral 4000 backpanel link



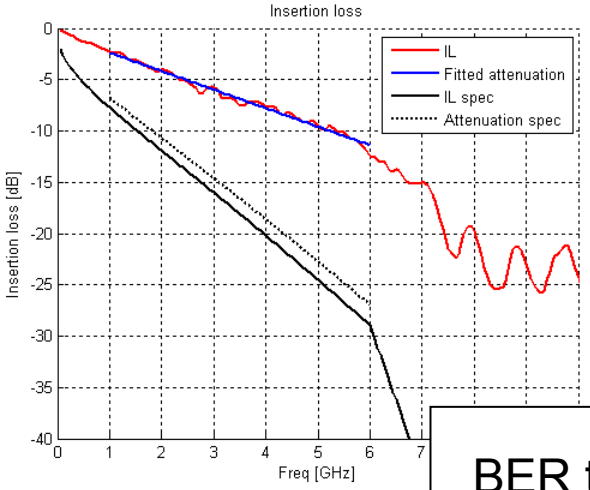



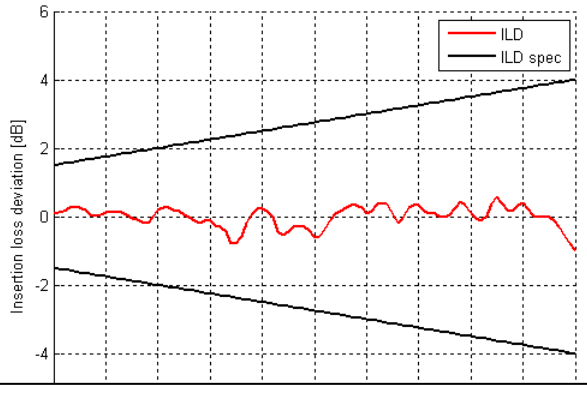



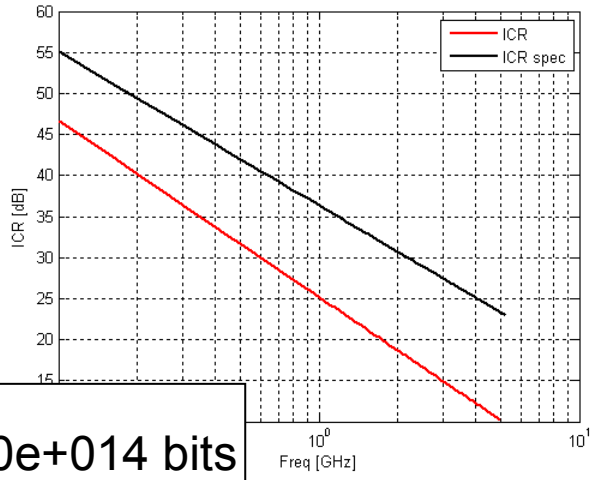



# Example: Metral 4000 backpanel link

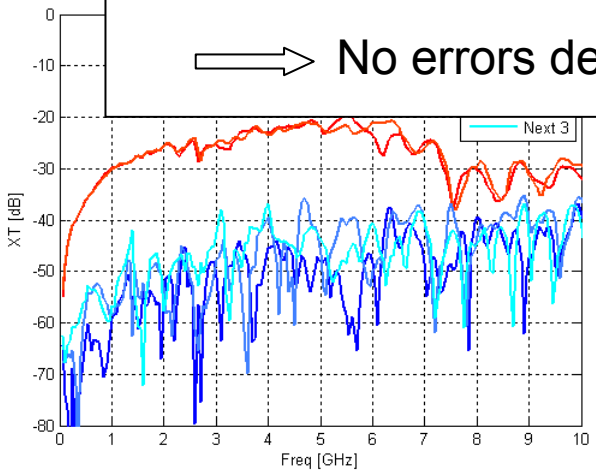


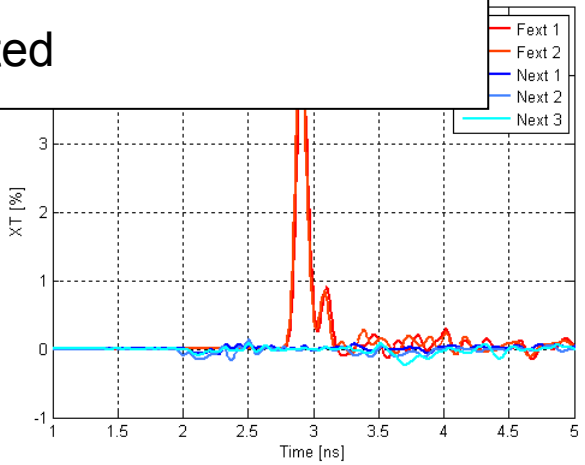



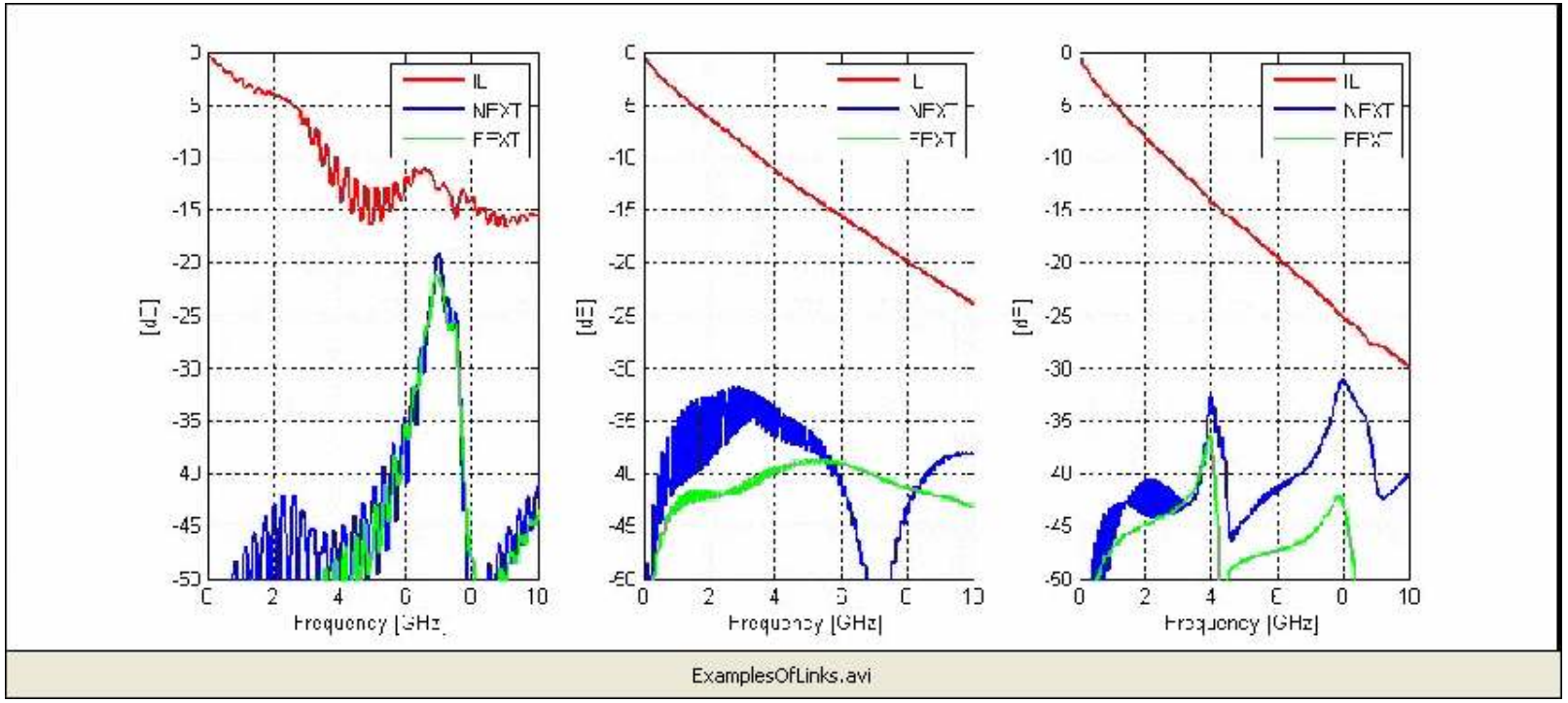

BER testing during 24 hours - 8.6400e+014 bits
(including 2 fext and 1 next crosstalk channel)

⇨ No errors detected

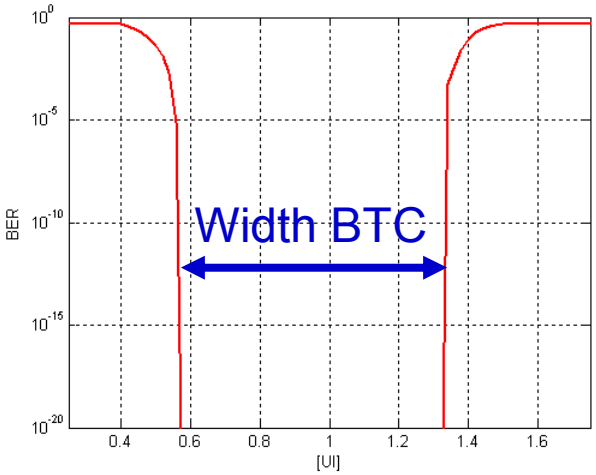


- To have a better feeling about the IEEE informative reference a number of link simulations have been performed
  - Links with varying IL, large small ripple, much crosstalk, no crosstalk, high impedance mismatch, low mismatch

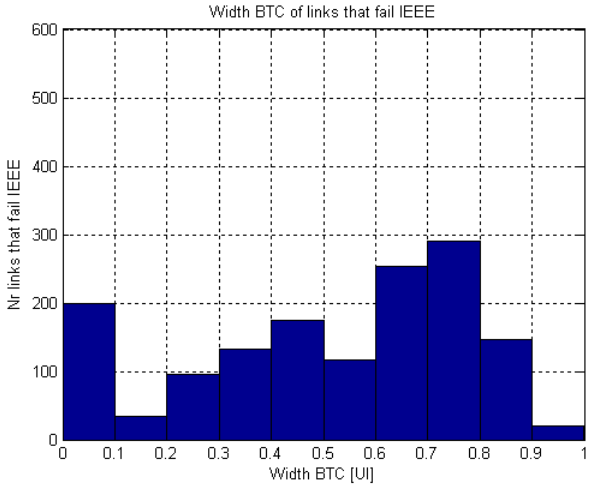


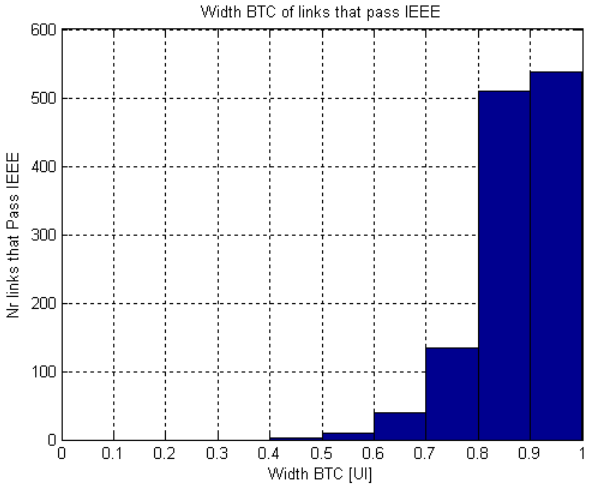
- For each of the links
  - performance is compared to the IEEE 802.3ap informative reference
  - BER simulations performed
    - No Jitter, No noise
    - 3 taps adaptive transmit equalization (1 pre-, 1 post-cursor)
    - 5 taps DFE
    - Performance figure: width BTC for BER = 10e-12

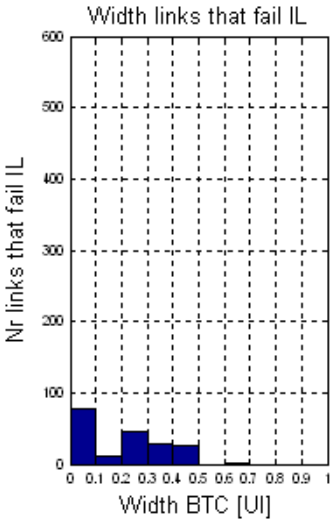


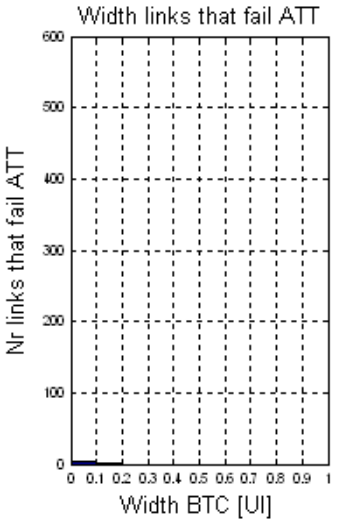
# Backpanel length = 25 cm

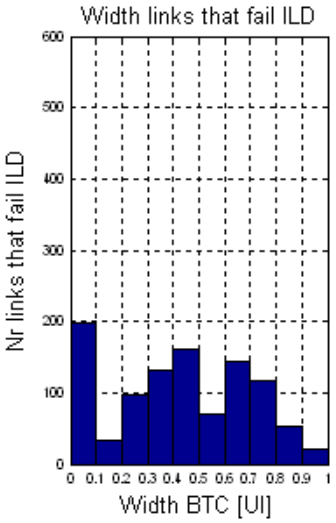
Total link length = 50 cm

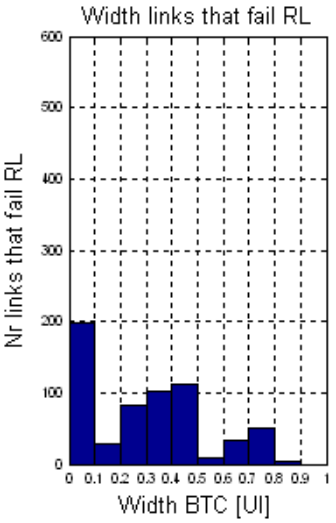


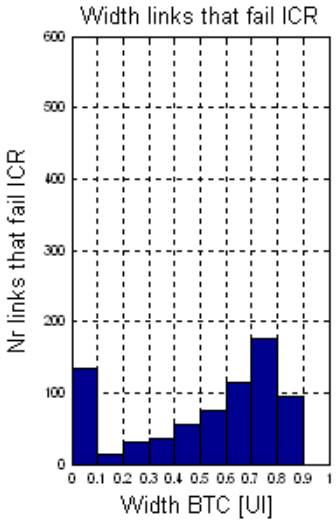



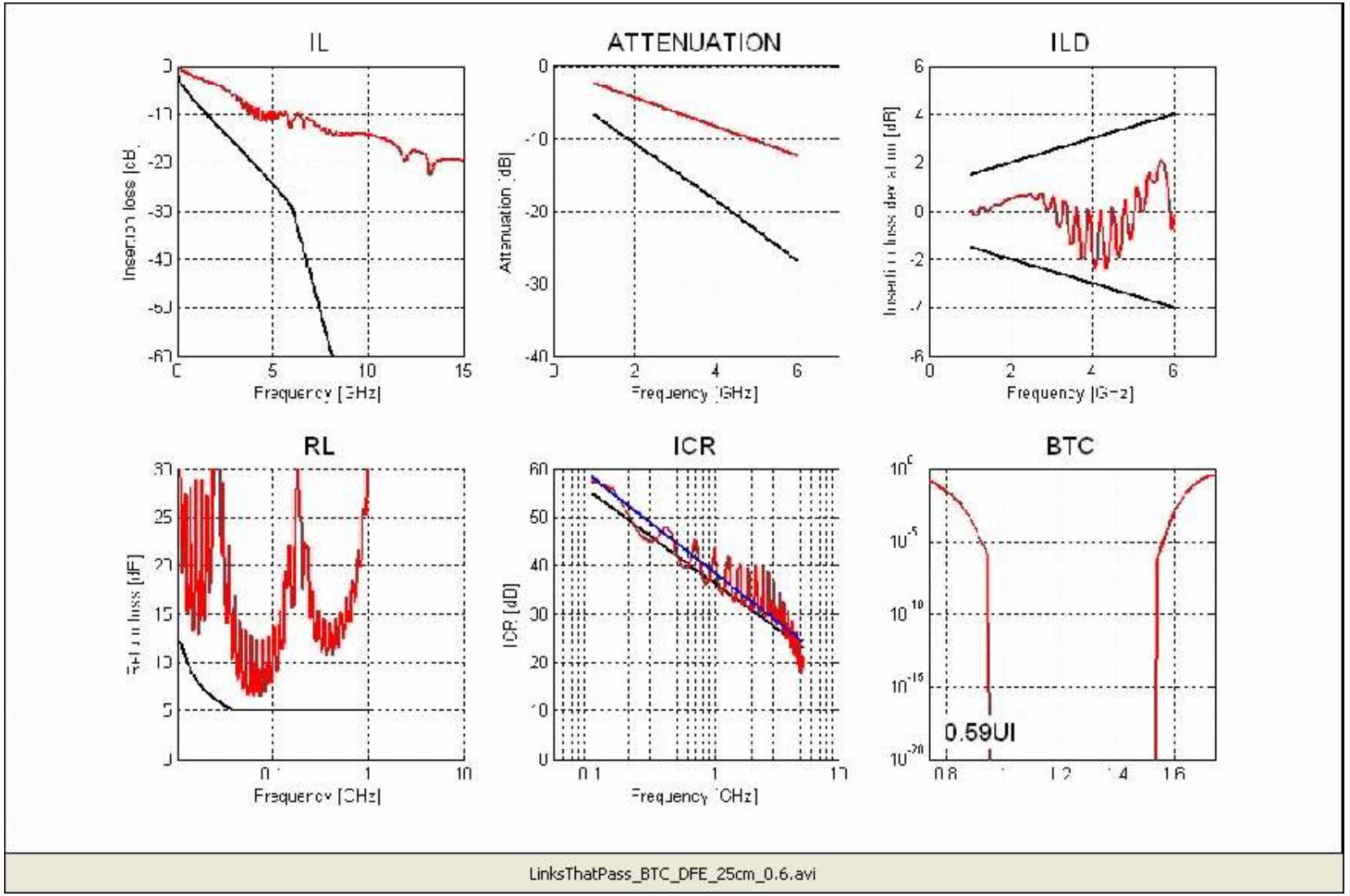



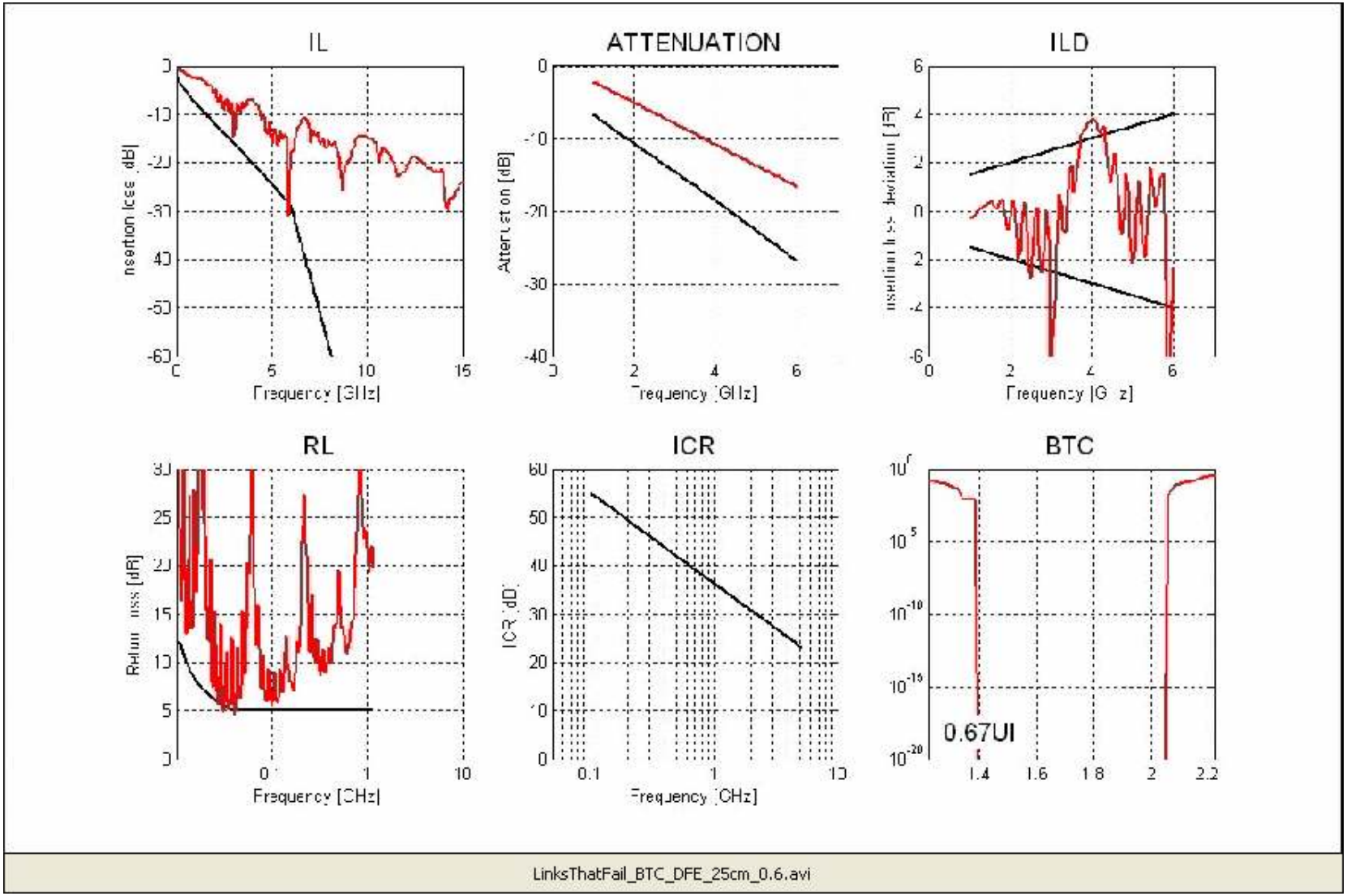
# Links that pass IEEE with BTC<0.6

Backpanel length = 25 cm
Total link length = 50 cm



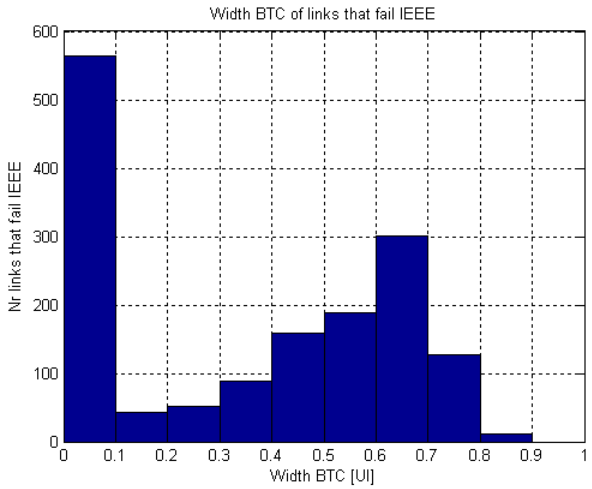
# Examples links that fail IEEE with BTC>0.6

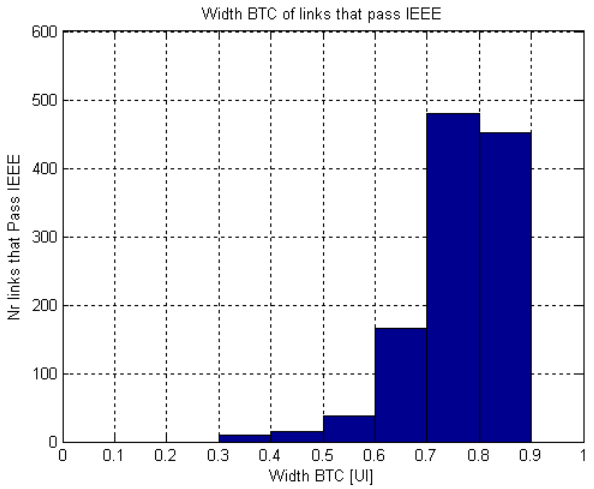
Backpanel length = 25 cm
Total link length = 50 cm

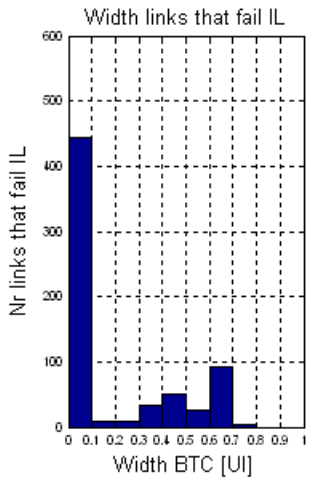


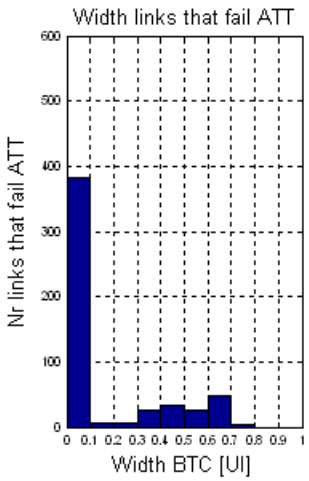
# Backpanel length = 75 cm

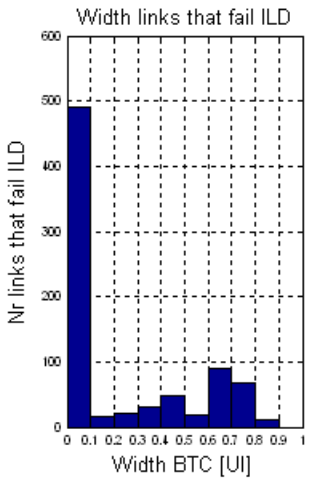
Backpanel length = 75 cm
Total link length = 1 m

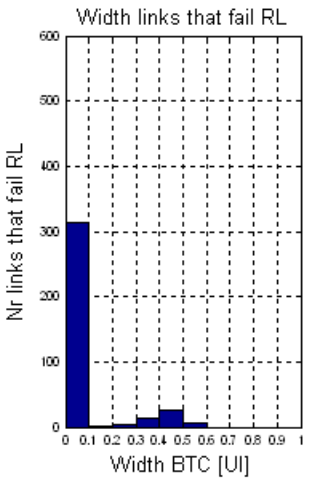


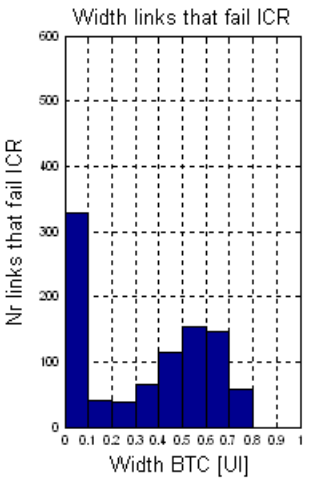



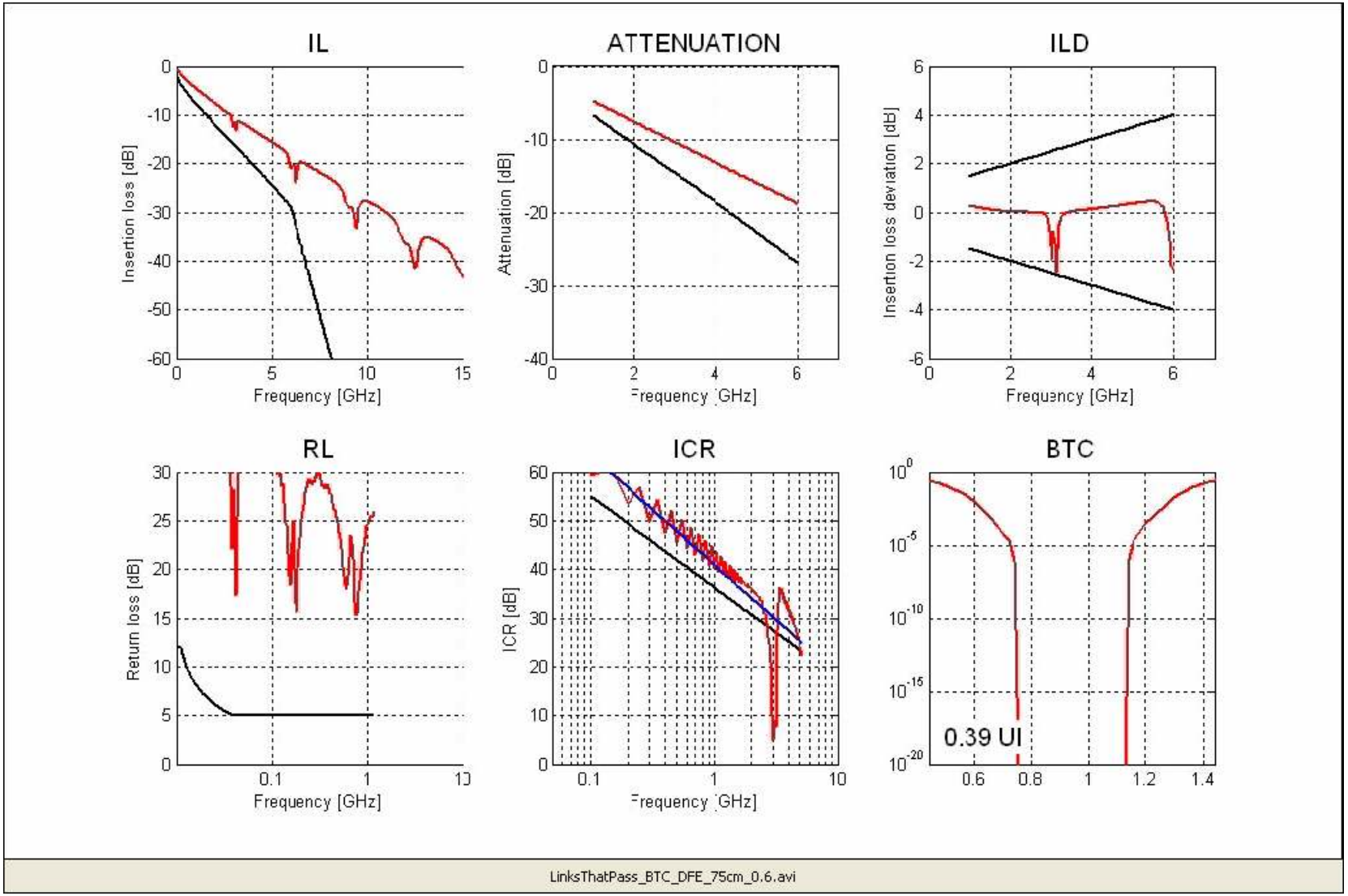



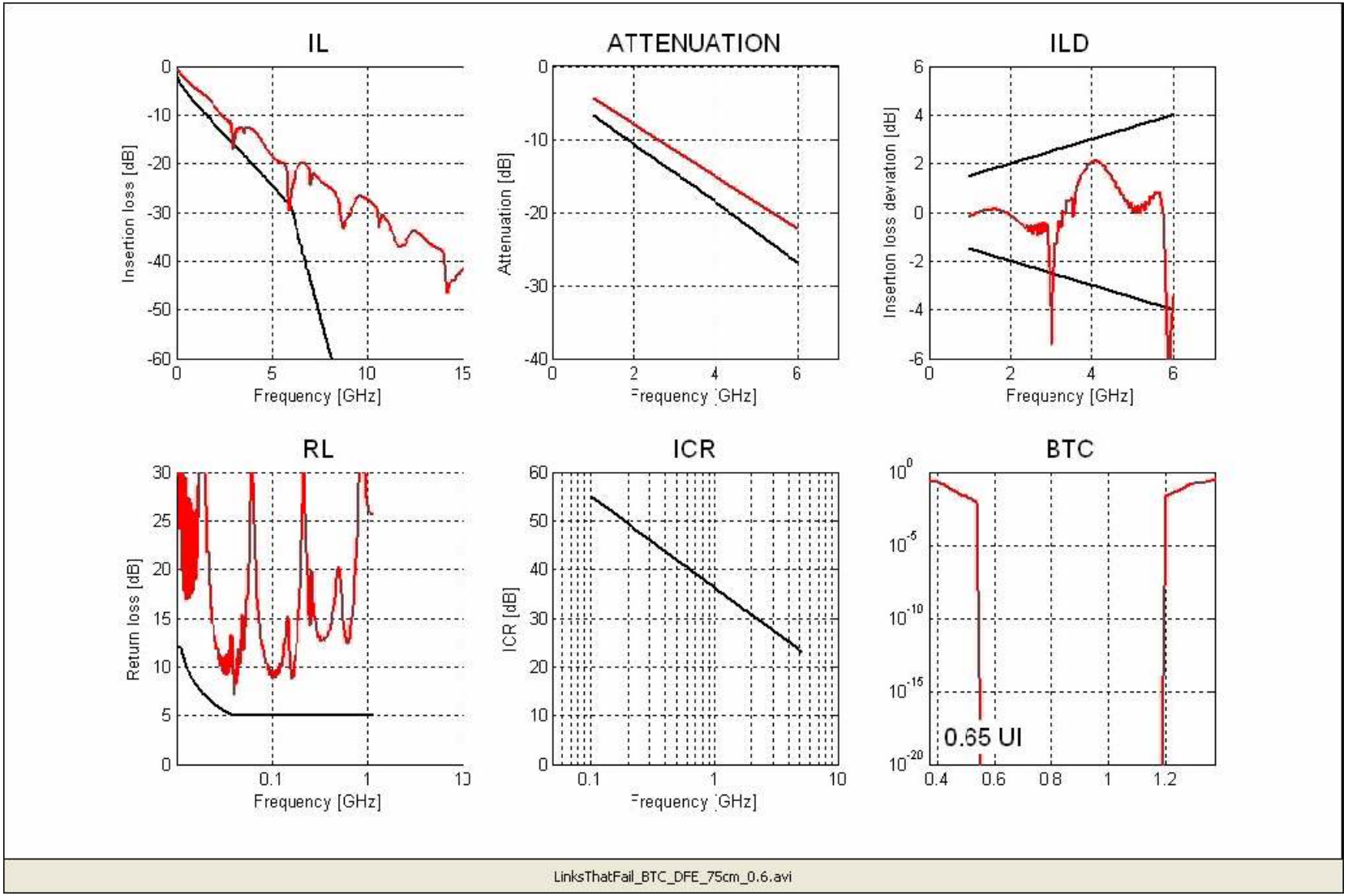
# Links that pass IEEE with BTC<0.6

Backpanel length = 75 cm
Total link length = 1 m



# Examples links that fail IEEE with BTC>0.6

Backpanel length = 75 cm
Total link length = 1 m



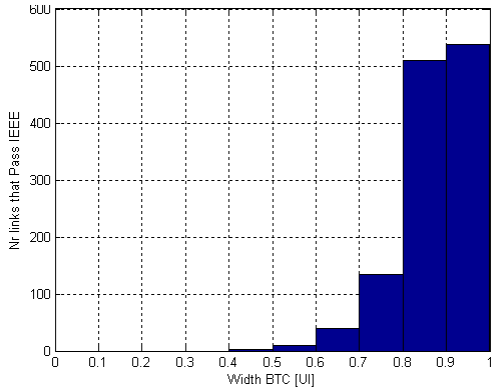
# Conclusions

- Links that pass IEEE and have bad BER
  - Links with high crosstalk resonance in ICR
  - Further analysis required
- Links that have good BER and fail IEEE
  - Links with no/low crosstalk and fail ILD/RL
  - Links with low ILD/RL and fail ICR

# Why fitted crosstalk?

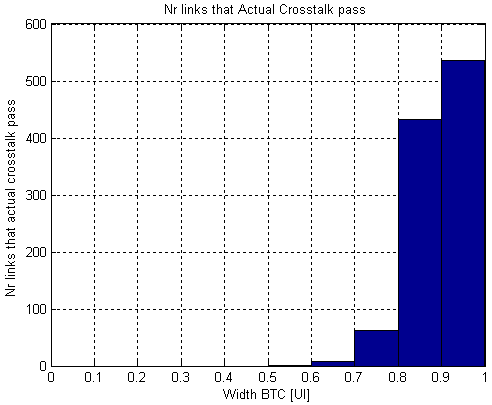
Backpanel length = 25 cm
Total link length = 50 cm

## Links that pass fitted crosstalk requirement

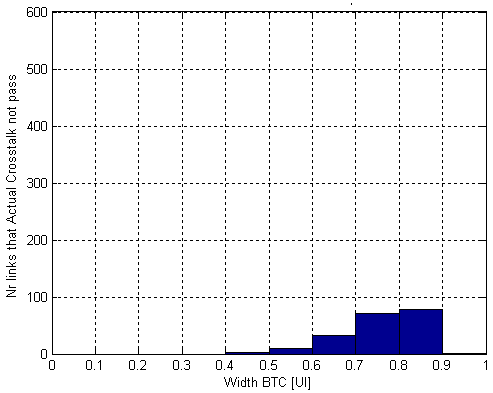



## Fitted crosstalk requirement replaced by actual crosstalk requirement

## Links that pass actual crosstalk requirement




## Links that Fail actual crosstalk requirement, but pass fitted requirement



# Summary/conclusions/ recommendations

- IEEE 802.3 ap – 5 Informative channel requirements for 10 Gb/s data transmission
- Informative component level design rules have been derived
- IEEE very good indication if a link will operate at 10 Gb/s
- But
  - If your system has nearly no crosstalk
    - More ripple allowed and mismatch than defined by IEEE
  - System is well impedance matched, small ripple
    - More crosstalk allowed than what is advised by IEEE
  - System with high crosstalk resonance may pass IEEE but still have a limited BER
- For final System verification BER simulations with actual driver and receiver are recommended

QUESTIONS?