CAUI-4 C2C Simulations and Compliance

IEEE 802.3 bm

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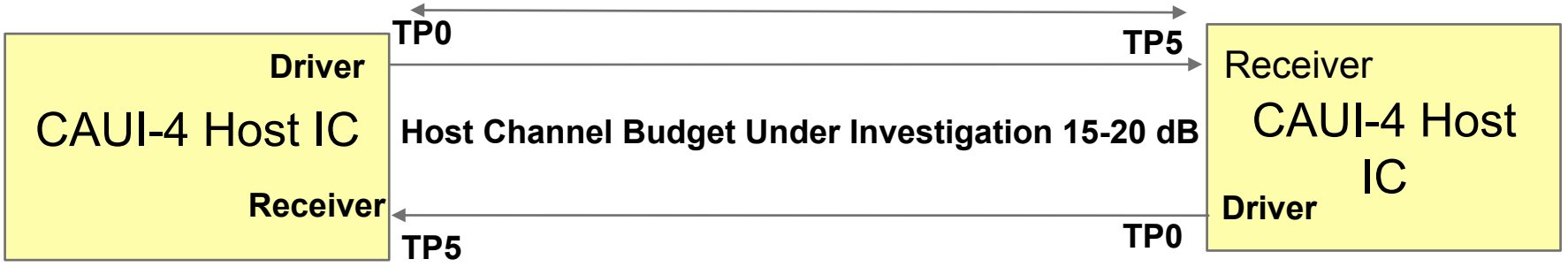
CAUI-Adhoc

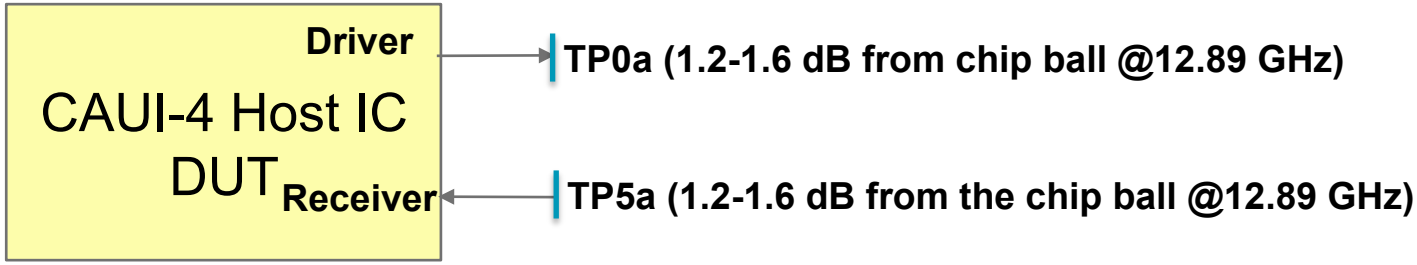
Overview

- With a BJ like package a fast/low jitter driver and a KR like driver were implemented to investigate eye diagram at TP0 and TP0a
  - Fast driver has amplitude of 600 mV
  - KR/ hot driver has amplitude of 800 mV
  - The hot driver deliver greater eye opening up to ~10 dB channel but fast driver start performing better on channel >10 dB loss
  - An eye mask complicate at TP0a allow transmitter tradeoffs and improve far end signal correlation
- A CAUI-4 chip to chip adhoc has been investigating channel with loss of 15-20 dB assuming 3 tap TX FIR with RX CTLE
  - There is strong preference on the user side to push the channel loss to 20 dB but need to be balanced with what is feasible and practical
  - With BJ like package model and 19-20 dB channels delivered a signal of only ~20 mV without crosstalk and just 10 mV with crosstalk at TP5
  - Above signal will be further degraded by ~30% due to receiver package and DC blocks
  - CAUI-4 C2C channel compliance either commercial tools such as ADS, SiSoft, or a customized version of BJ COM for this application.

CAUI-4 Architecture and Reference Points

- There is strong user preference to push the channel loss to 20 dB something that require end to end simulation or BJ like COM code
  - We need to consider the user preference but ultimately we need to deliver a robust specification that can be built and meets the BER objective

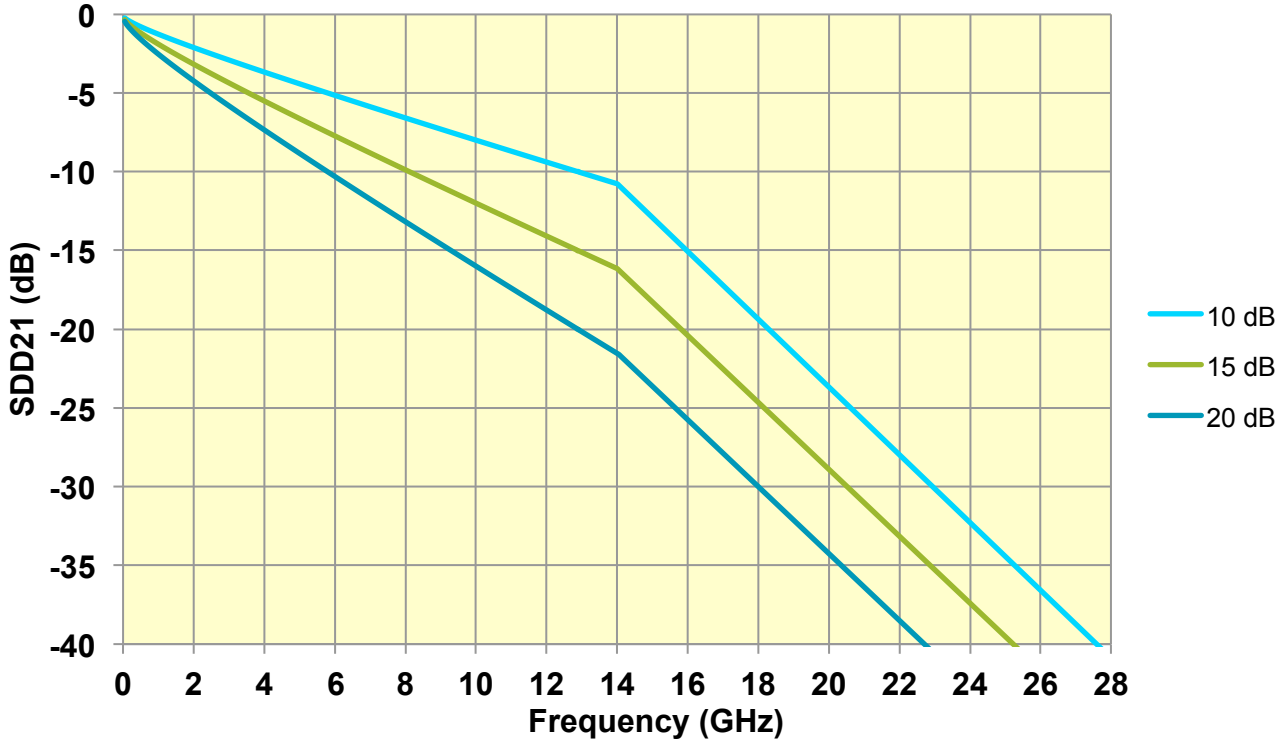




CAUI-4 Chip to Chip Informative Channel

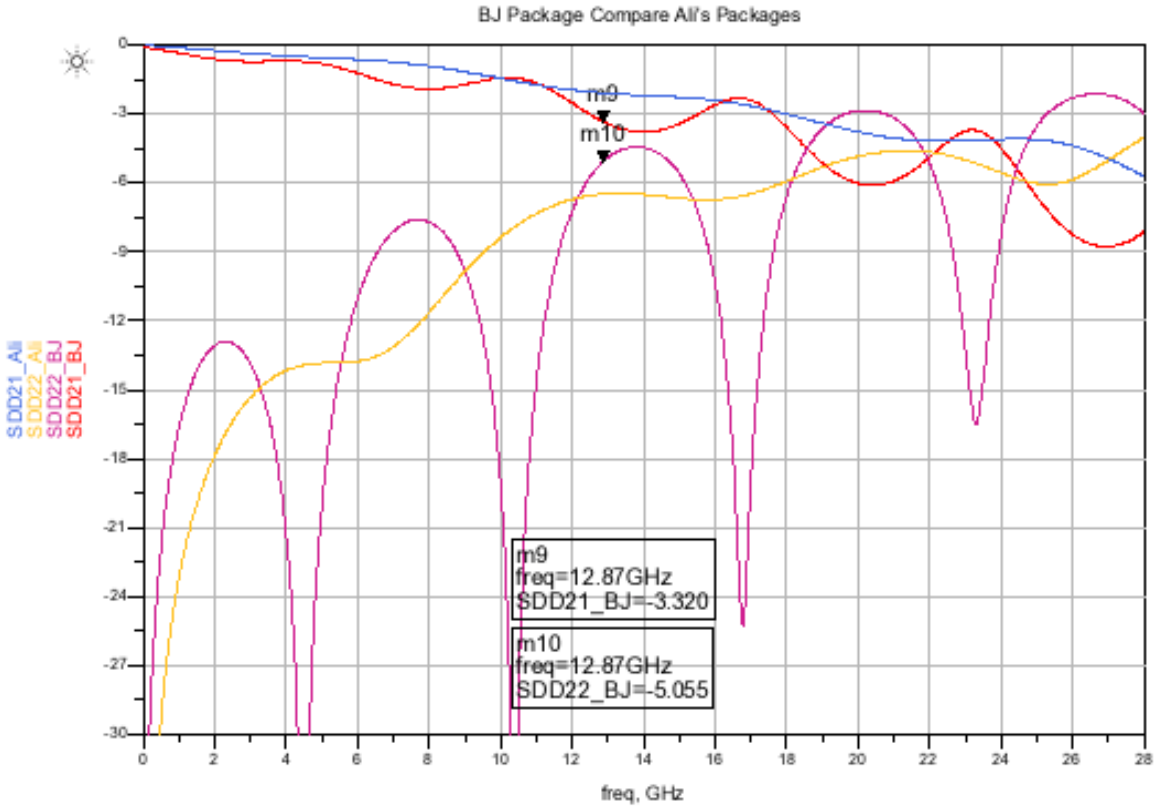
- We could define an informative lower / upper bound for the channel loss but use COM for normative compliance

$$SDD21(15dB) = -0.121 - 0.867 * \sqrt{f} - 0.914 * f \quad from\ 0.05 - 14\ GHz$$
$$= 19.368 - 2.152 * f \quad from\ 14 - 25\ GHz$$
$$SDD21(20dB) = -0.161 - 1.156 * \sqrt{f} - 1.218 * f \quad from\ 0.05 - 14\ GHz$$
$$= 13.368 - 2.152 * f \quad from\ 14 - 25\ GHz$$



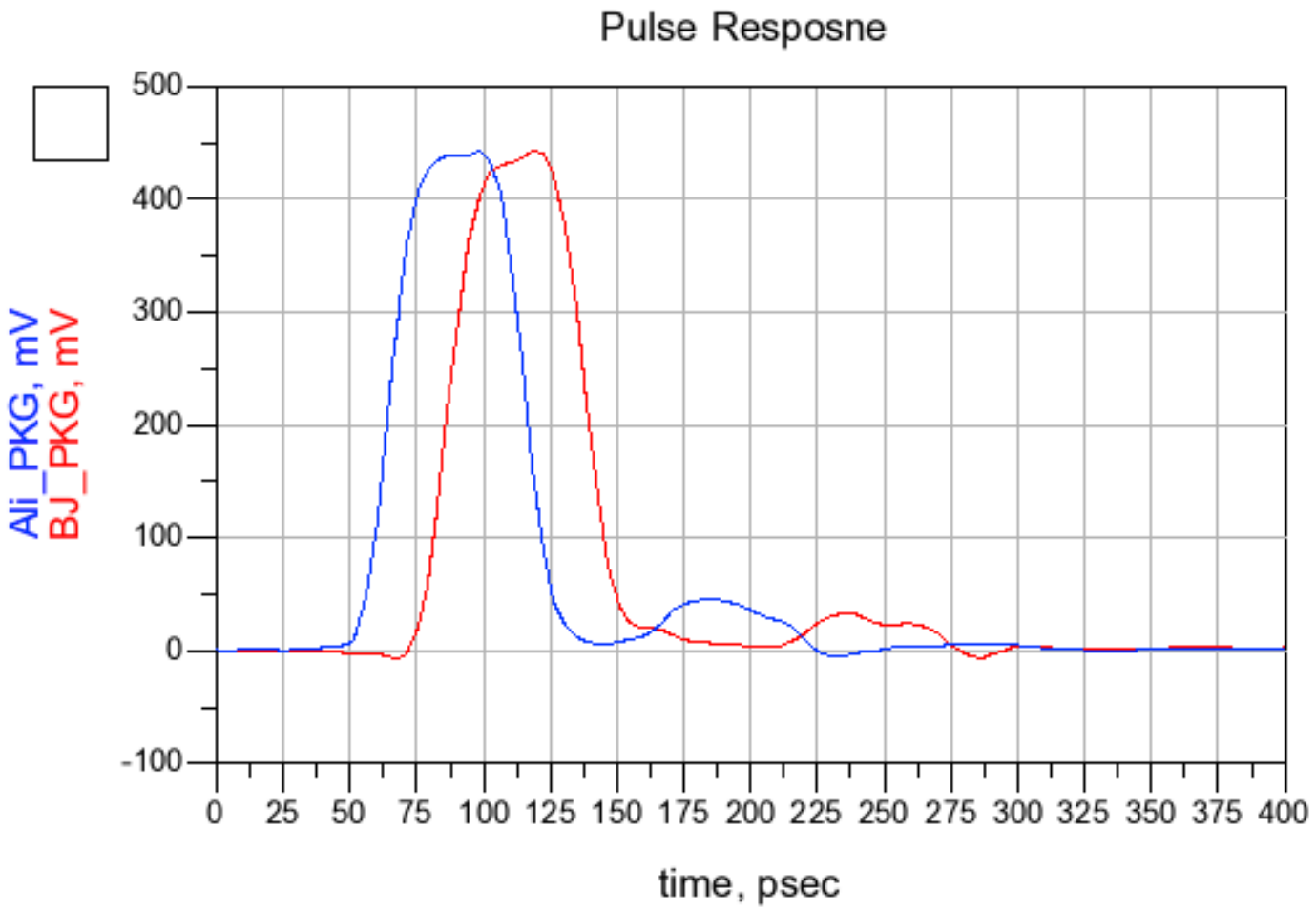
Comparison HFSS Extracted Package vs BJ Package

- HFSS extracted Ali's package is a moderate size
  - ESD is identical to the BJ package
  - Package is slightly better than BJ package
  - As expected the HFSS extracted package does not have the resonance structures and ILD visible in BJ package



Pulse Response

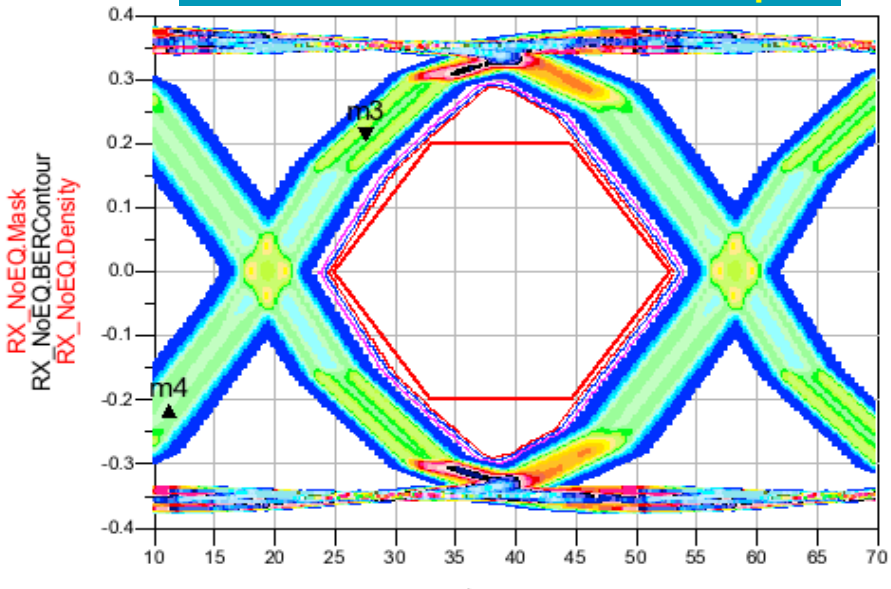
- BJ D2.1 does exhibit slight amount non passivity



Example of Big and Little Chip CAUI-4 Transmitter

- Define Hot driver with standard jitter but 800 mV output
  - Tr ~ 17 ps TJ=0.28 UI@1E-15 (de-emphasis 1 dB)
- Define Fast-low jitter with 600 mV output
  - Tr ~ 12 ps TJ=0.18 UI@1E-15 (de-emphasis 0.5 dB)
- Eye mask at TP0a provide flexibility to trade off Tr/Tf, amplitude, and jitter
  - Mask coordinates (0.14,0), (0.35,±0.2), (0.65,±0.2), (0.86,0)

CAUI-4 Hot Transmitter Tr=17 ps



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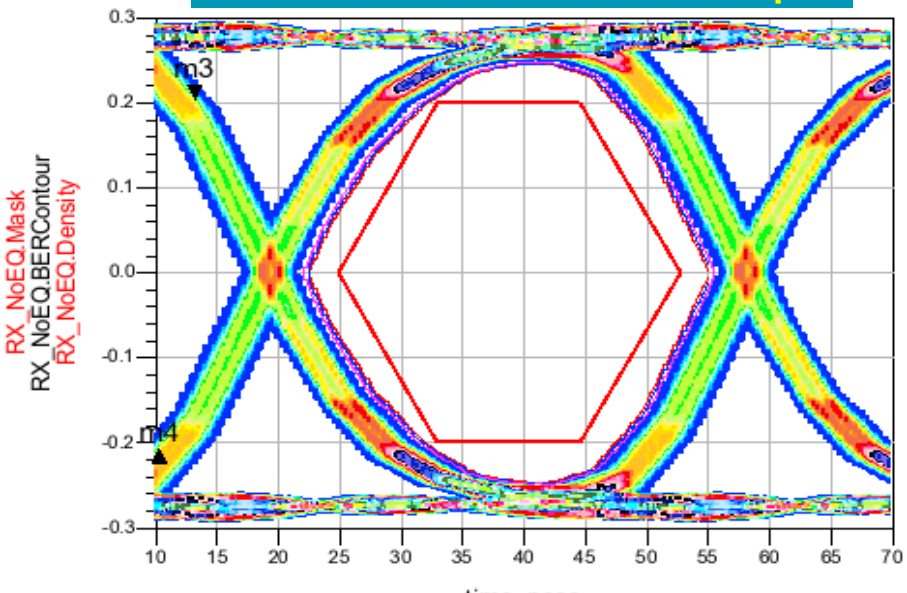
CAUI-4 Fast Transmitter Tr=12 ps



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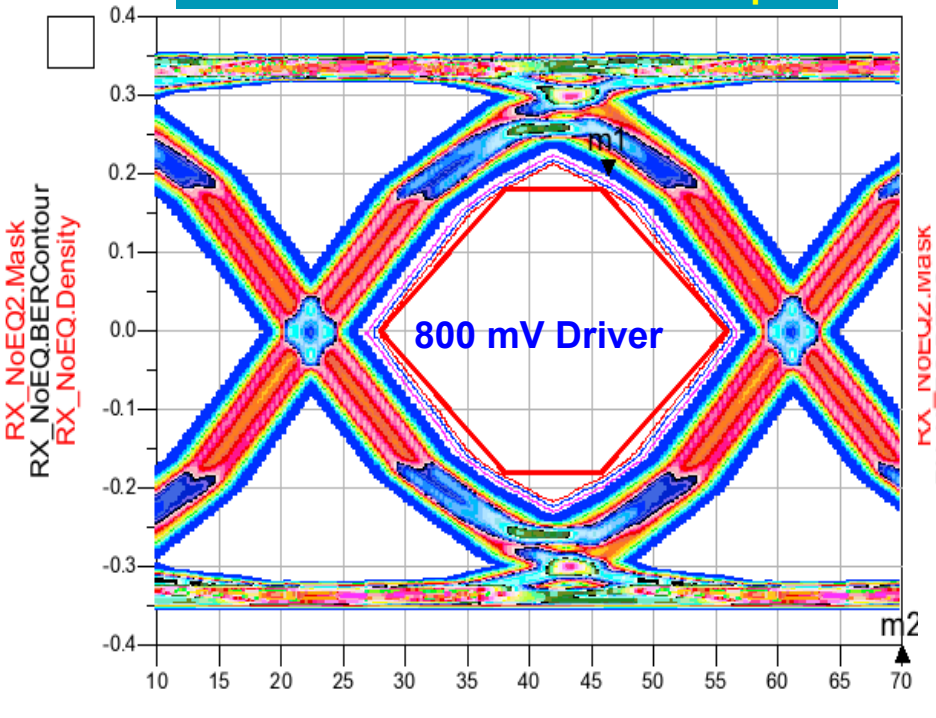
Shifting Eye Mask Compliance to TP1a (option I)

- A channel with loss of 1.4 dB @ 12.89 GHz was added to the package to shift the reference point from TP0 to TP0a
- Eye Mask coordinates at TP0a are (0.14,0), (0.4,±0.18), (0.5,±0.18), (0.86,0)

CAUI-4 Hot Transmitter Tr=17 ps



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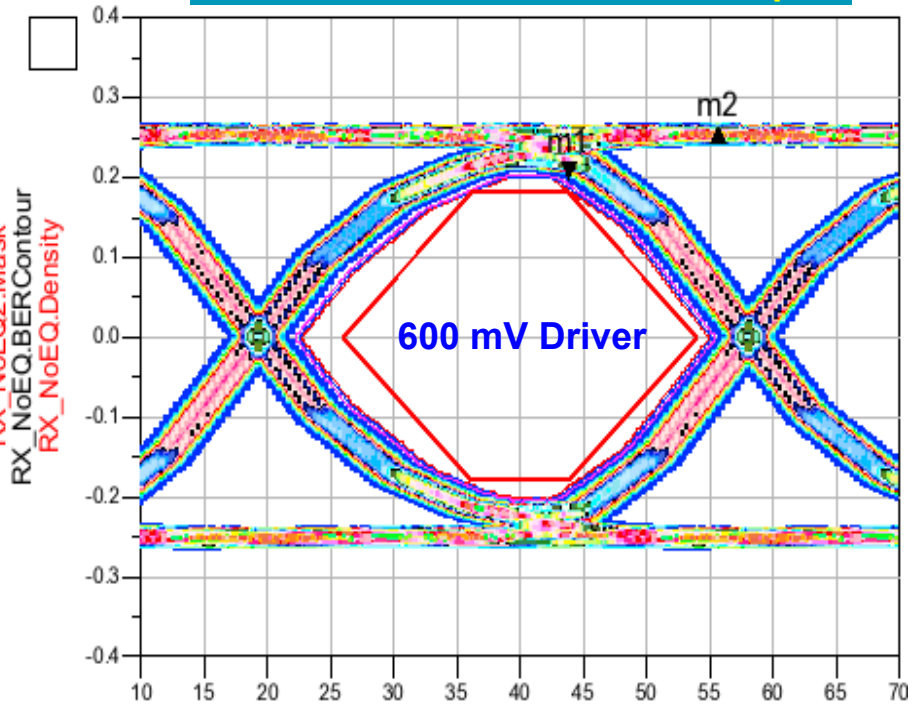
m3 m4 0.000	3.142E-11	0.400

CAUI-4 Fast Transmitter Tr=12 ps



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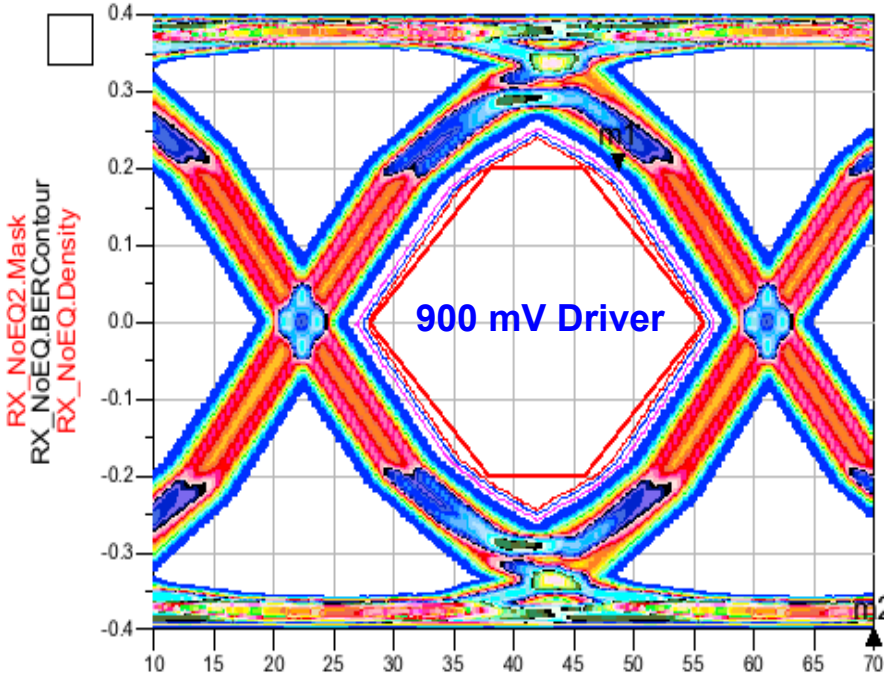
m3 m4 0.000	3.413E-11	0.369

Shifting Eye Mask Compliance to TP0a and Increasing Driver Amplitude by 12.5% (option II)

- A channel with loss of 1.4 dB @ 12.89 GHz was added to the package to shift the reference point from TP0 to TP0a
- Eye Mask coordinates at TP0a are (0.14,0), (0.4,±0.2), (0.6,±0.2), (0.86,0)
  - All the TP5 results presented here would scale by +12.5%

CAUI-4 Hot Transmitter Tr=17 ps



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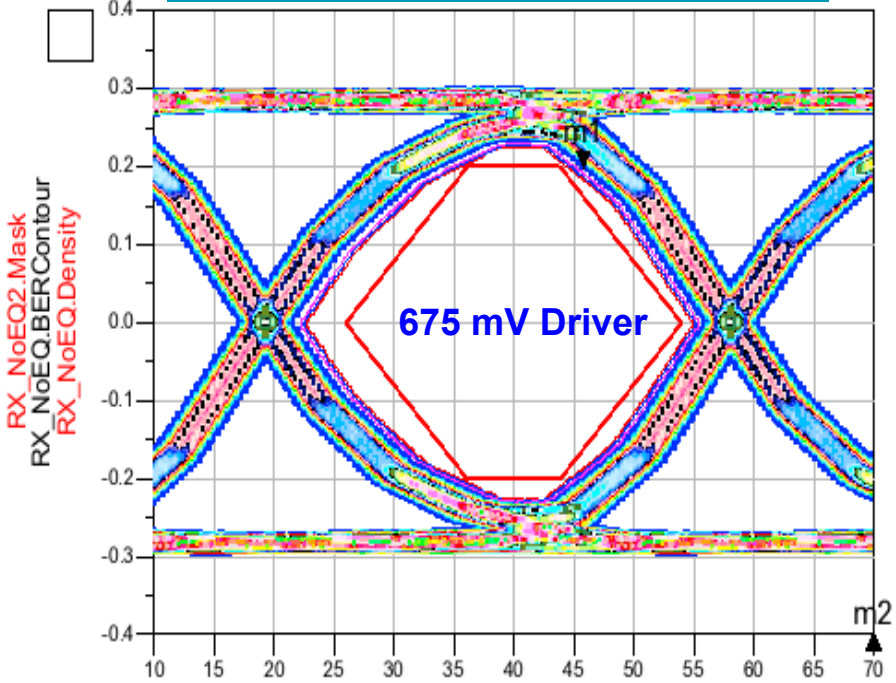
m3 0.000	3.142E-11	0.452

CAUI-4 Fast Transmitter Tr=12 ps



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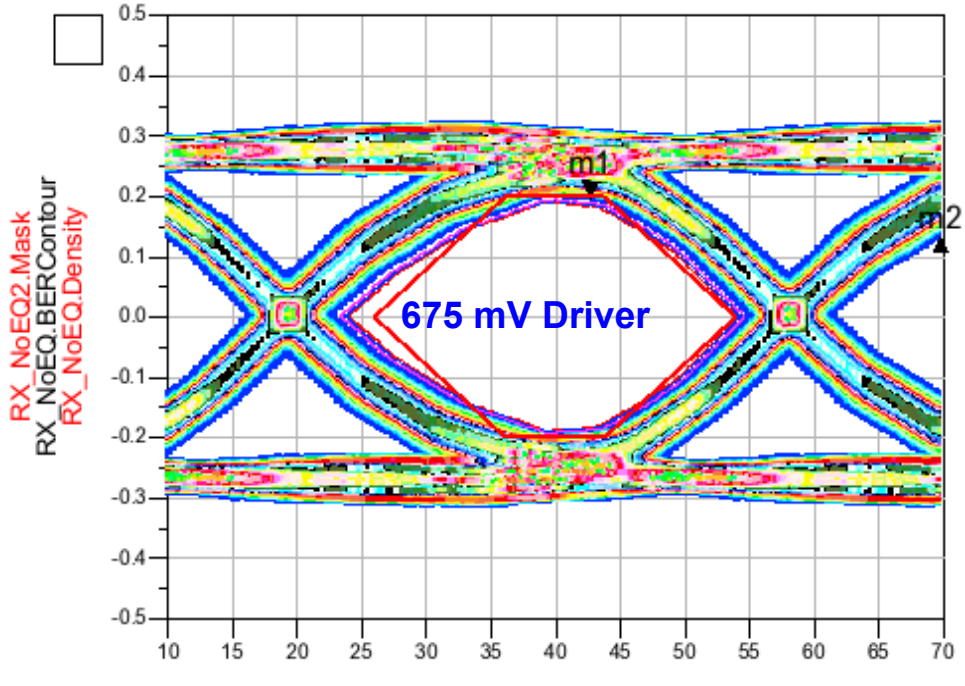
m3 0.000	3.413E-11	0.416

Eye Mask Compliance at TP0a with BJ Package

- BJ package due to ILD and resonances even with ideal input has more penalty than Ali's HFSS package with added PJ and RJ
  - BJ COM code assume ideal source drives the BJ package due to inherent degradation
  - Compare to fast driver there is 1.5 ps of jitter hit and 52 mV of amplitude hit
  - Even with ideal driver and just with RJ (σ=0.006 ps) the BJ package has more degradation

CAUI-4 Fast Transmitter Tr=12 ps



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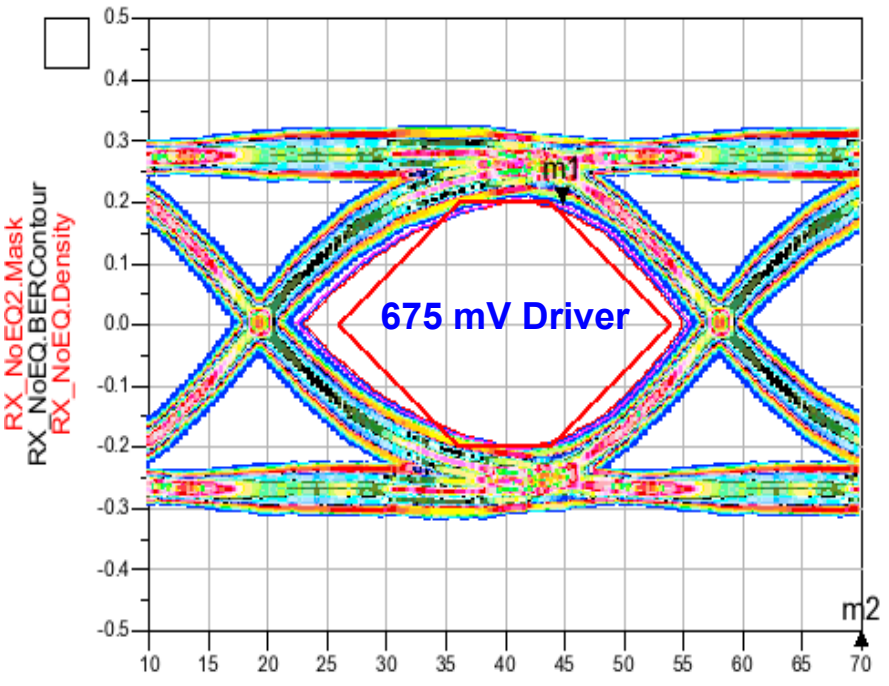
0.000	3.258E-11	0.348

CAUI-4 Ideal Transmitter with RJ



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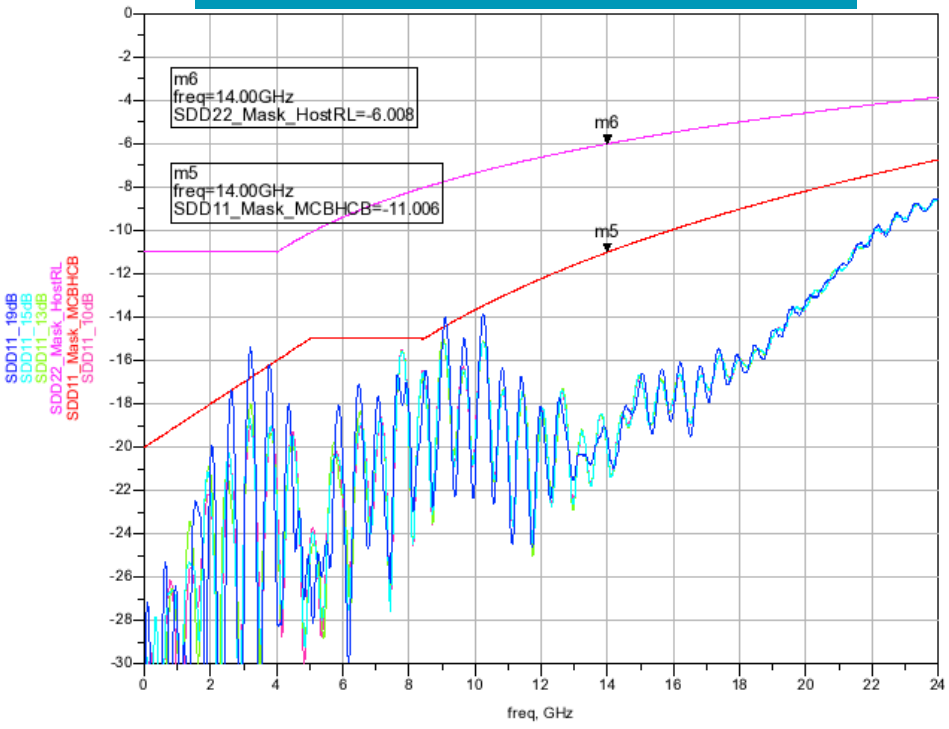
0.000	3.452E-11	0.364

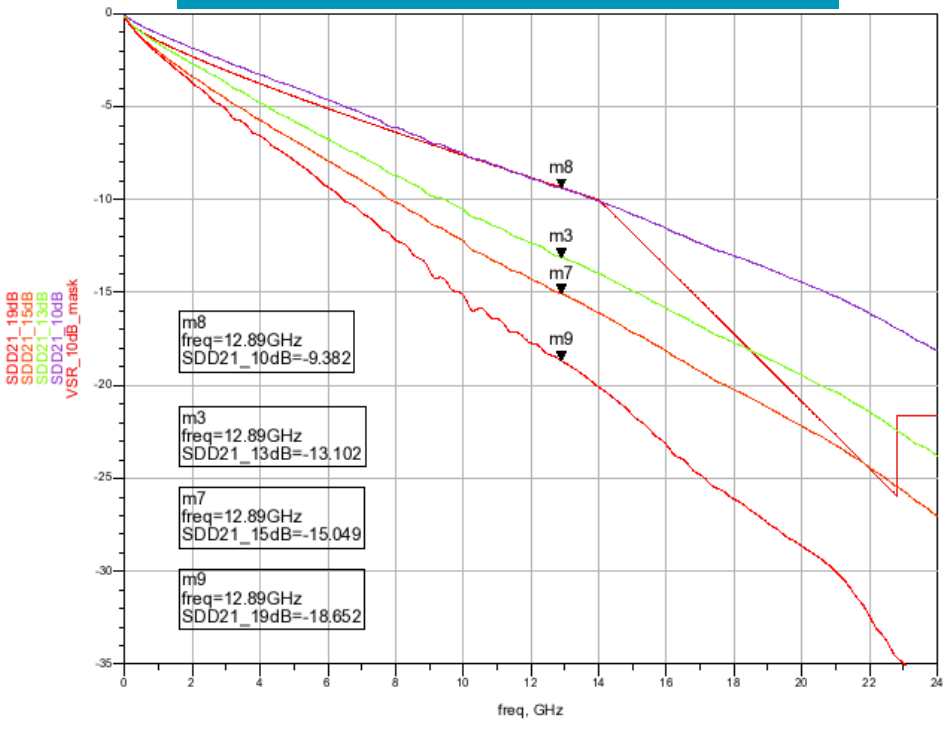
FR4 Channel Response

- Channels are
  - 5” FR4 Channel with two long (80 mils) vias and 2 12 mils stub
  - 5” FR4 + 3” Megtron 6 Channel
  - 5” FR4 + 5” Megtron 6 Channel
  - 10” FR4 2x of 5” FR4 channel

FR4 Host Channel



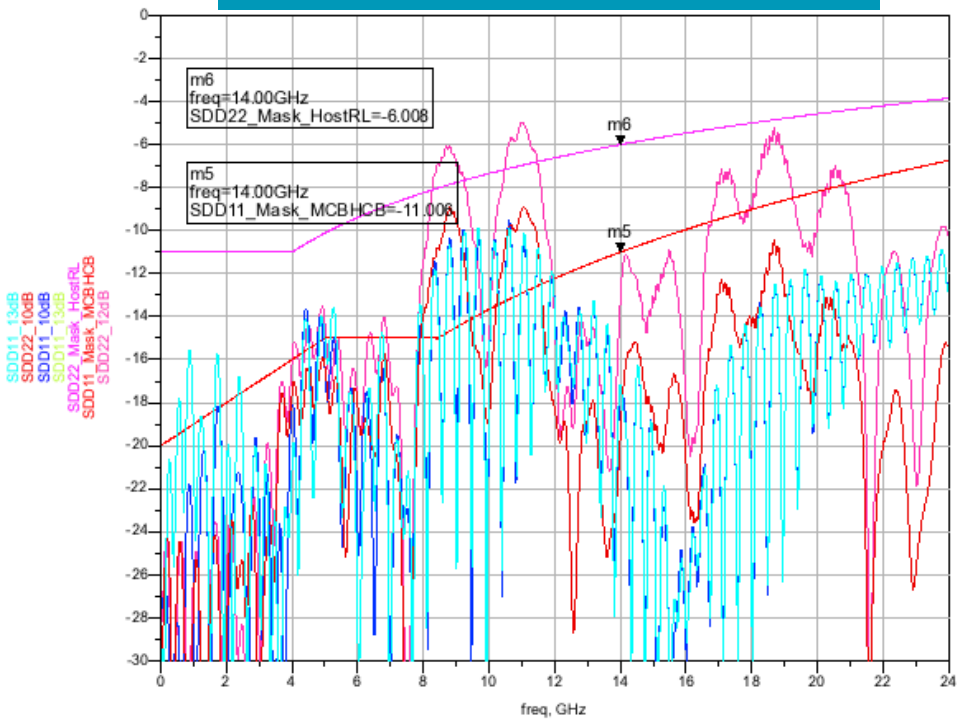
FR4 Host Channel



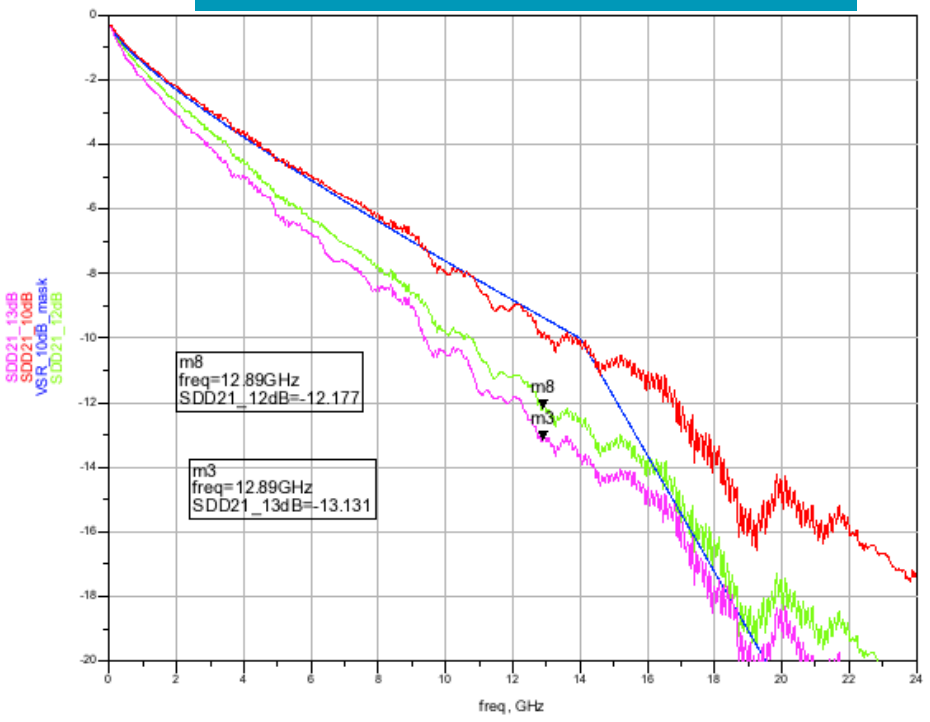
TE 7” Quadra Channel Response

- Channels are
  - TE Quadra channel with 10 dB loss
  - TE 7” Quadra + 1.25” plug board+ 2” Meg6 Channel
  - TE 7” Quadra + 1.25” plug board + 2” FR4 Channel

TE Host Channel

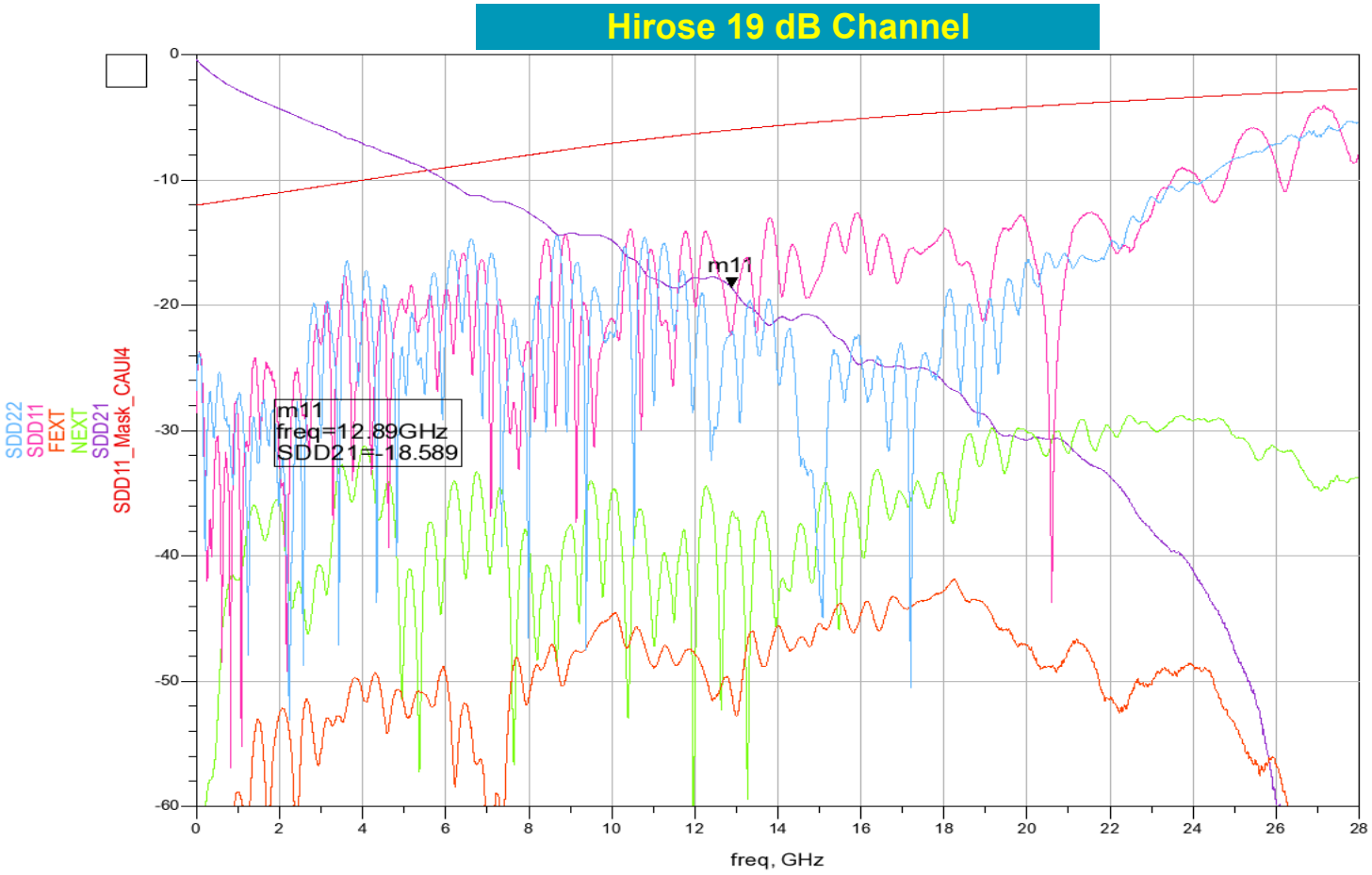


TE Host Channel



Hirose Mezzanine Channel

- Megtron 6 channel 6” + connector + 6” construction
  - Crosstalk was dominated by 1 FEXT/NEXT shown below and simulated with
  - Data courtesy of Jeremy Buan of Hirose

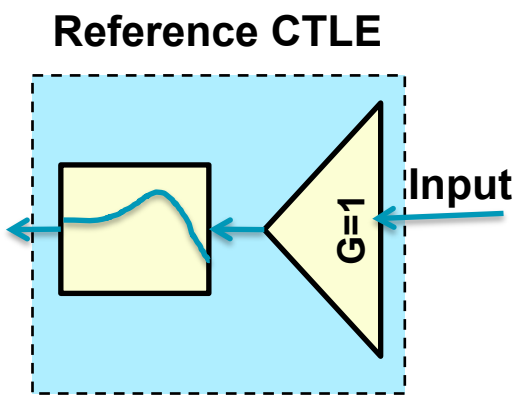


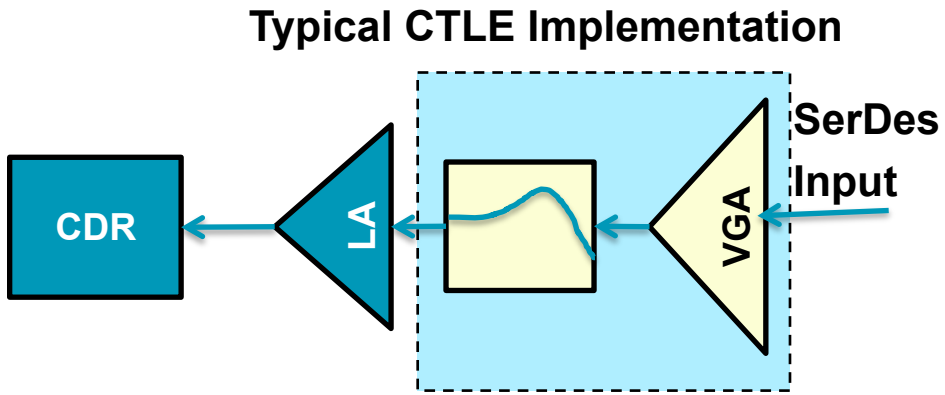
OIF 28G VSR/CAUI-4 Chip to Module CTLE Definition

- Based on most common implementation of CTLE with single pole with 2 zeros

$$Gain = G\frac{P1 \bullet P2}{Z}\frac{(Z - j*\omega)}{(P1 - j*\omega)(P2 - j*\omega)}$$

  - For reference comparison the CTLE should have no AC gain
  - Actual implementation will have VGA as well as limiting AMP with AC gain
  - Scopes software CTLE implementation is based on the reference CTLE for TP5 compliance

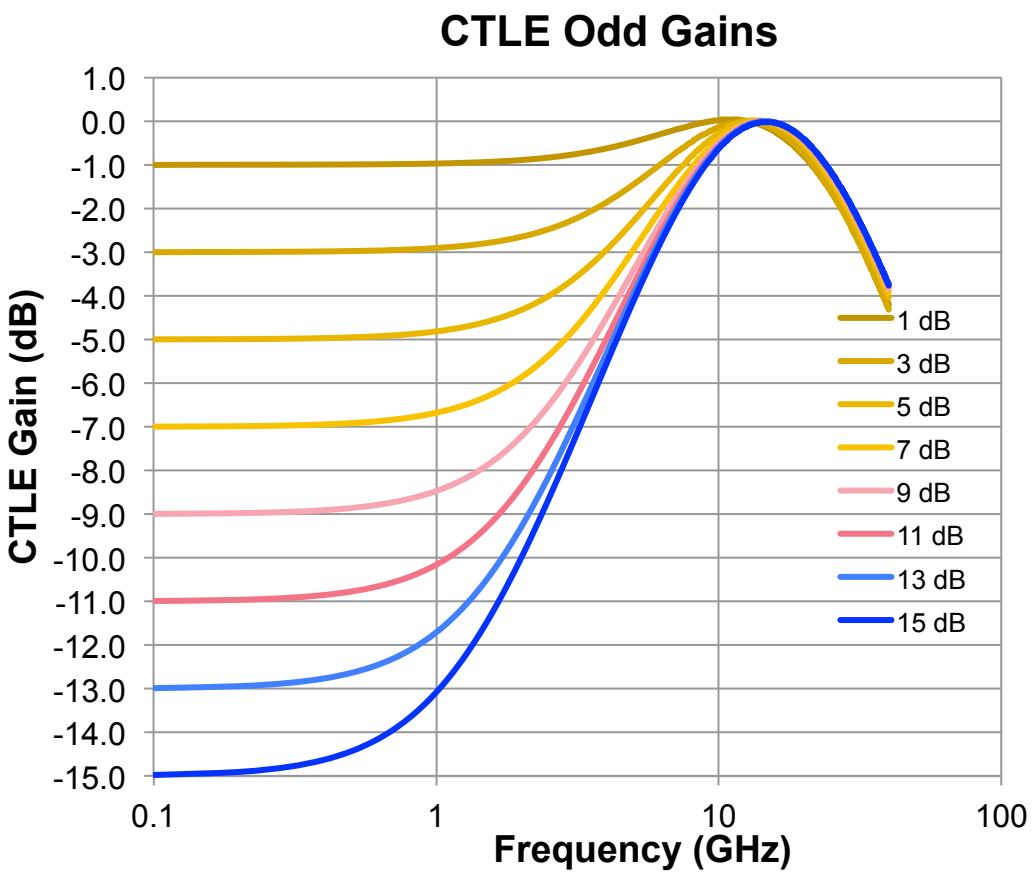




Expanded CTLE Response

- OIF 28G-VSR and CAUI-4 chip to module define CTLE response from 1-9 dB
  - Additional CTLE filter 10-15 are provided for purpose of CAUI-4 C2C study

http://www.ieee802.org/3/bm/public/tools/index.html

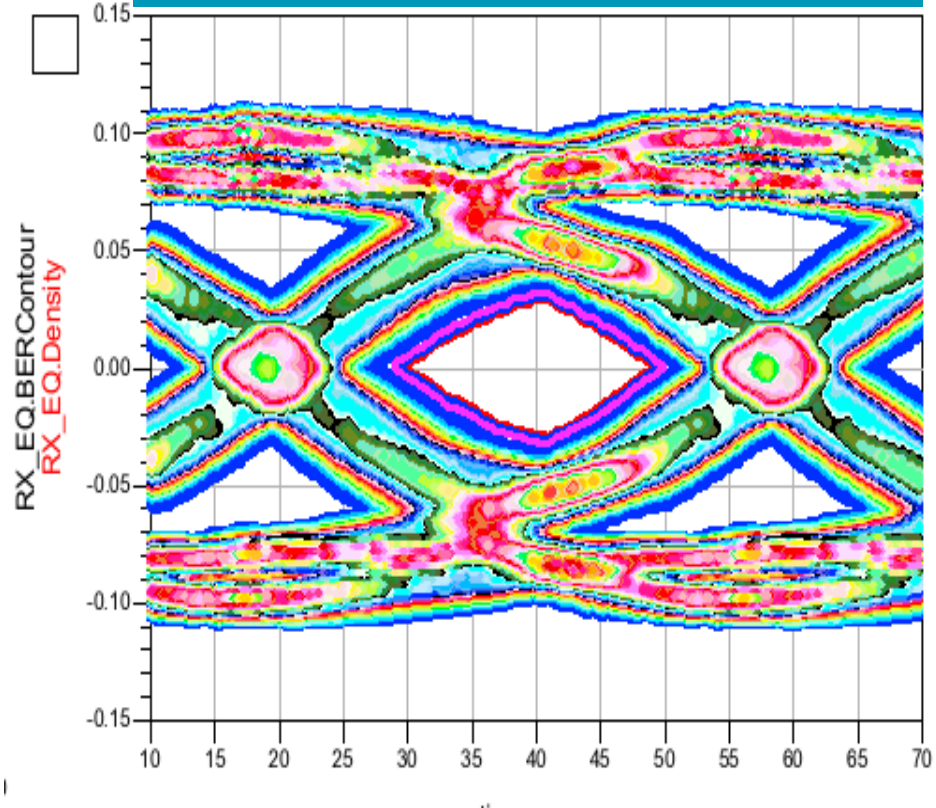


Gain (dB)	G (Linear)	Z (GHz)	P1 (GHz)	P2 (GHz)
1	0.89	7.1e9	1.86e10	1.41e10
2	0.795	7.1e9	1.86e10	1.41e10
3	0.795	7.1e9	1.56e10	1.41e10
4	0.633	4.98e9	1.56e10	1.41e10
5	0.563	4.35e9	1.56e10	1.41e10
6	0.5	3.82e9	1.56e10	1.41e10
7	0.446	3.4e9	1.56e10	1.41e10
8	0.398	3e9	1.56e10	1.41e10
9	0.3548	2.672e9	1.56e10	1.41e10
10	0.316	2.372e9	1.56e10	1.41e10
11	0.2818	2.11e9	1.56e10	1.41e10
12	0.2512	1.874e9	1.56e10	1.41e10
13	0.2239	1.67e9	1.56e10	1.41e10
14	0.1995	1.484e9	1.56e10	1.41e10
15	0.1778	1.325e9	1.56e10	1.41e10

Far end eye for 15 dB FR4 Channel

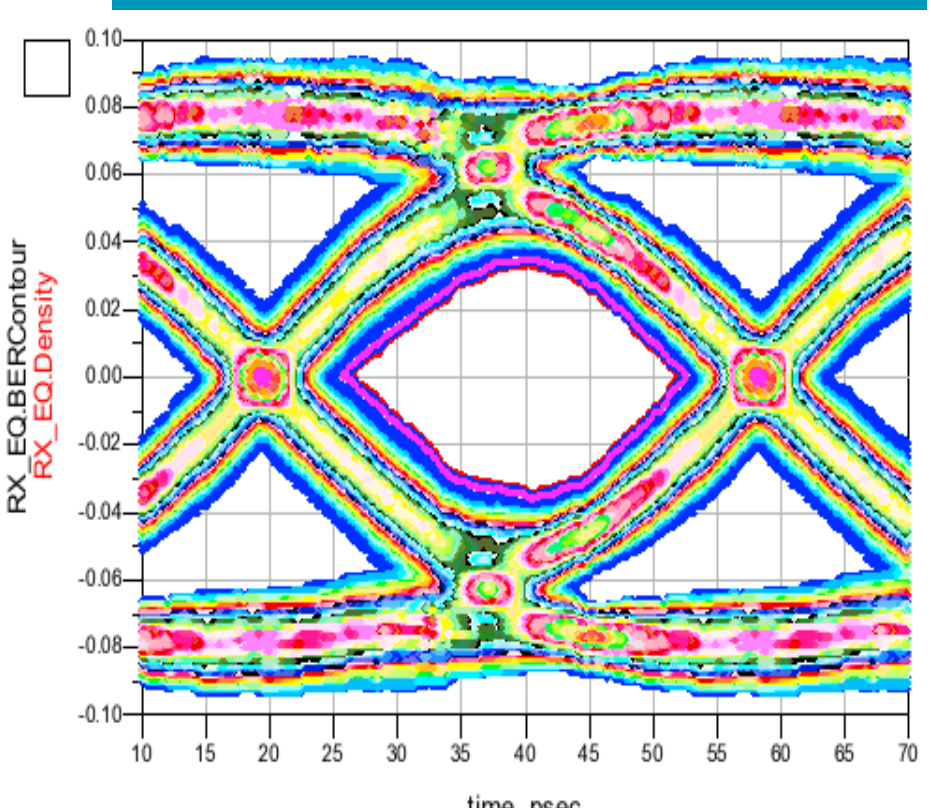
- For the hot and fast transmitter

Hot Transmitter 800 mV Post 6 dB CTE=9dB dB



index	..._EQ.WidthAtBER)	...EQ.HeightAtBER)
0.000	1.939E-11	0.058

Fast Transmitter 600 mV Post 4 dB CTE=9 dB



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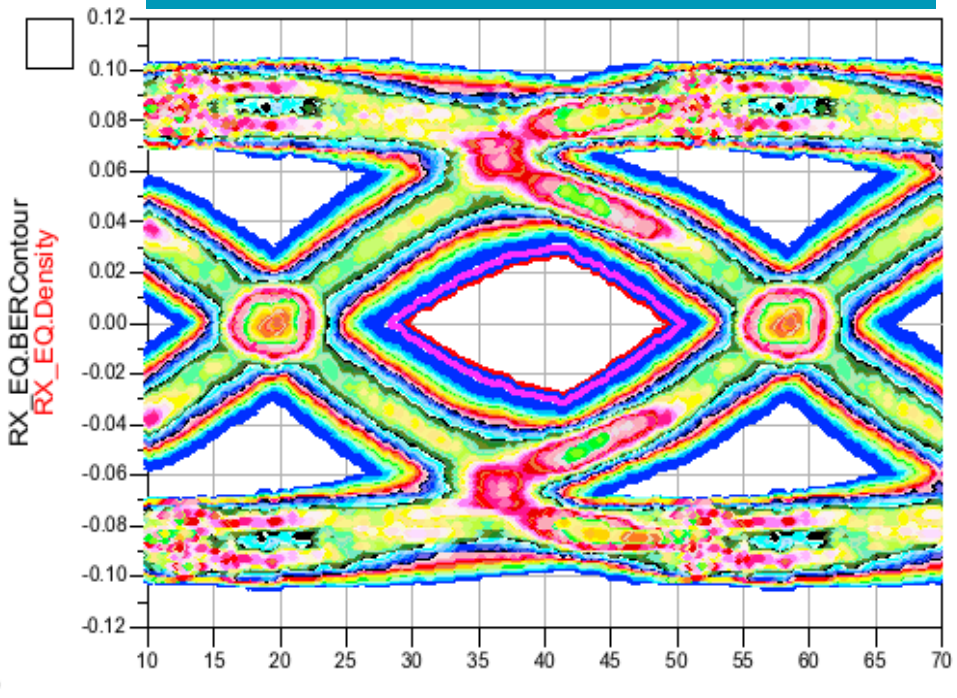
0.000	2.599E-11	0.068

Far end eye for 15 dB FR4 Channel with BJ Package

- For the hot and fast transmitter

Hot Transmitter 800 mV Post 6 dB CTE=9dB dB



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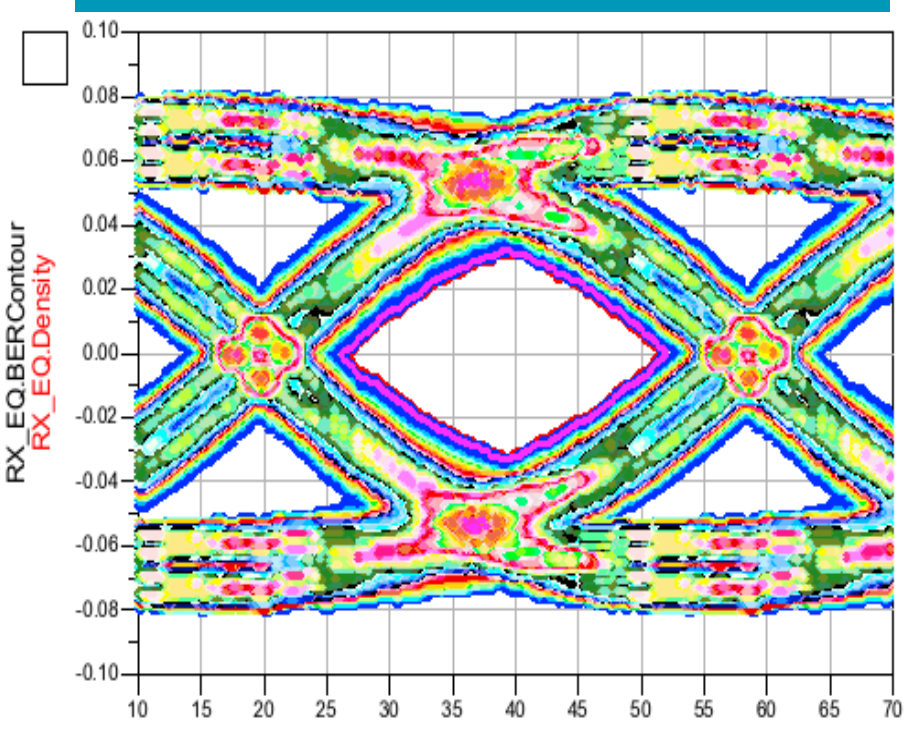
0.000	1.998E-11	0.055

Fast Transmitter 600 mV Post 6 dB CTE=9 dB

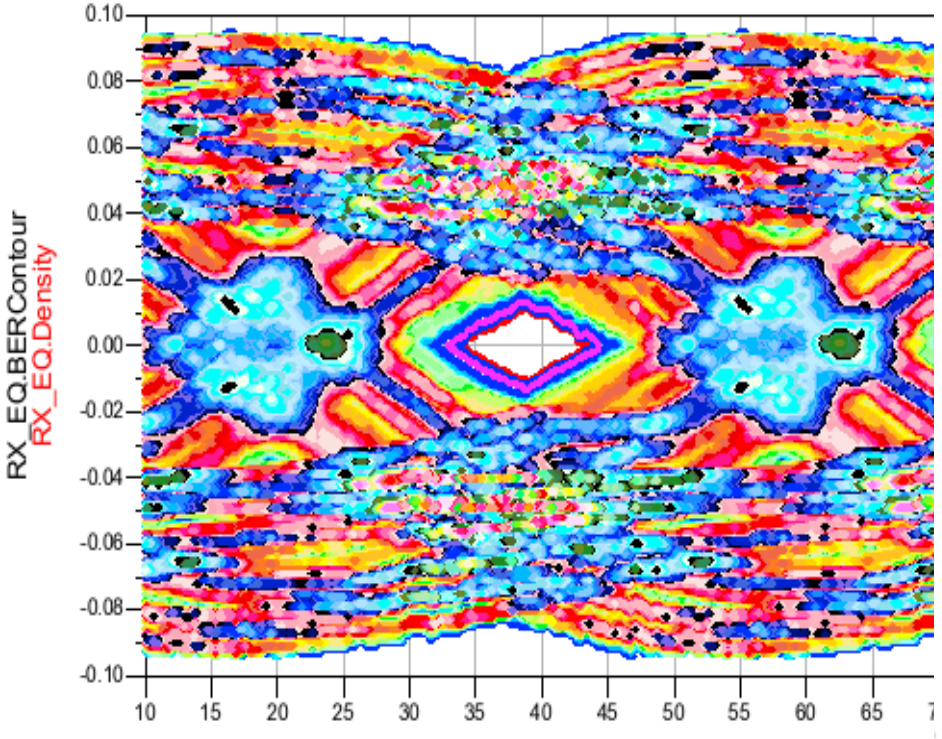


index	..._EQ.WidthAtBER)	...EQ.HeightAtBER)
0.000	2.502E-11	0.063

Far end eye for 19 dB FR4 Channel

- For the hot and fast transmitter

Hot Transmitter 800 mV Post 4 dB CTE=14 dB



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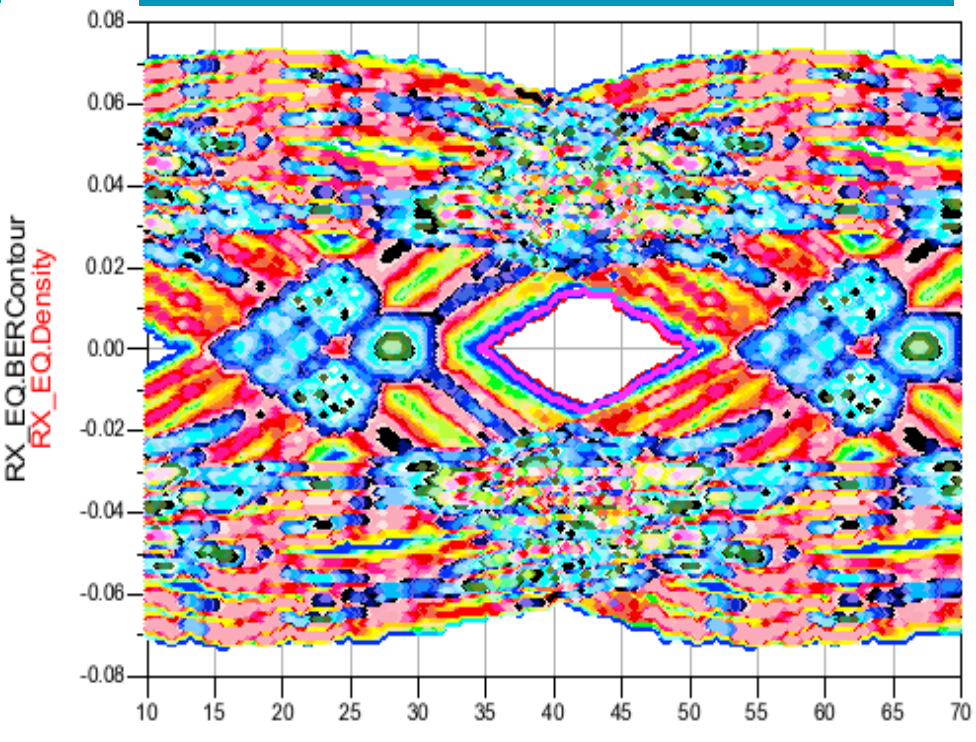
0.000	1.009E-11	0.022

Fast Transmitter 600 mV Post 4 dB CTE=14 dB



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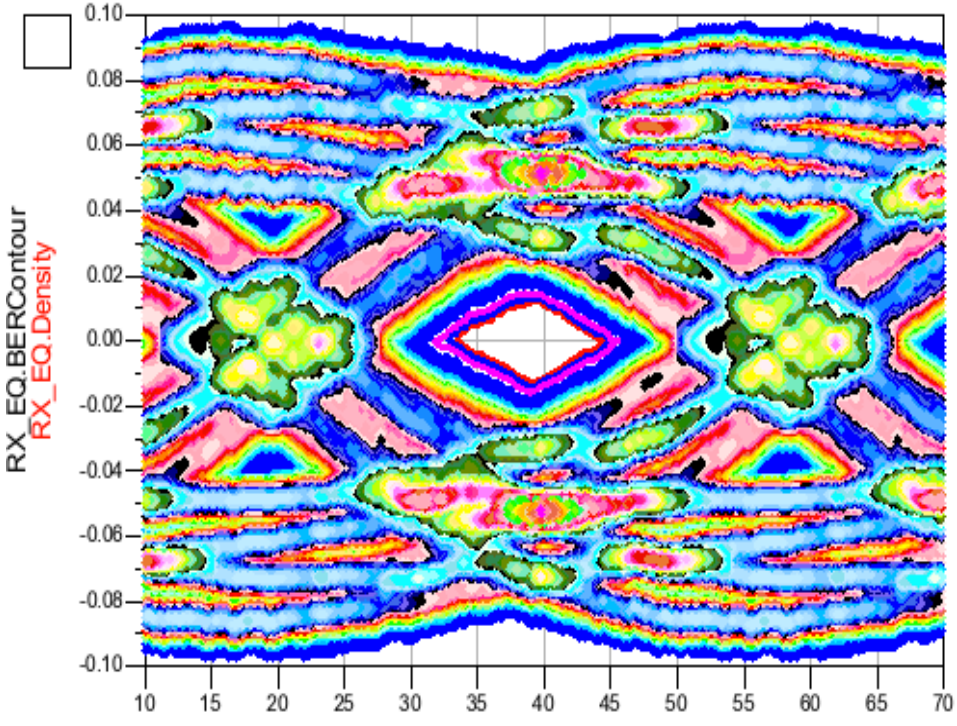
0.000	1.532E-11	0.028

Far end eye for 19 dB Hirose Channel

- For the hot and fast transmitter

Hot Transmitter 800 mV Post 2 dB CTE=14dB



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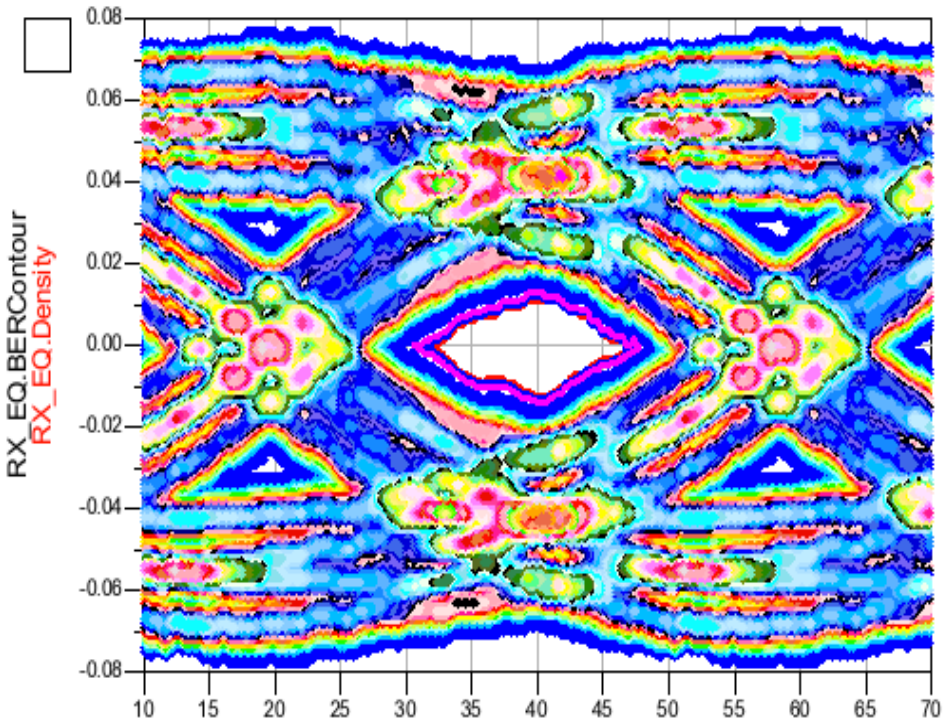
0.000	1.513E-11	0.021

Fast Transmitter 600 mV Post 3 dB CTE=14 dB



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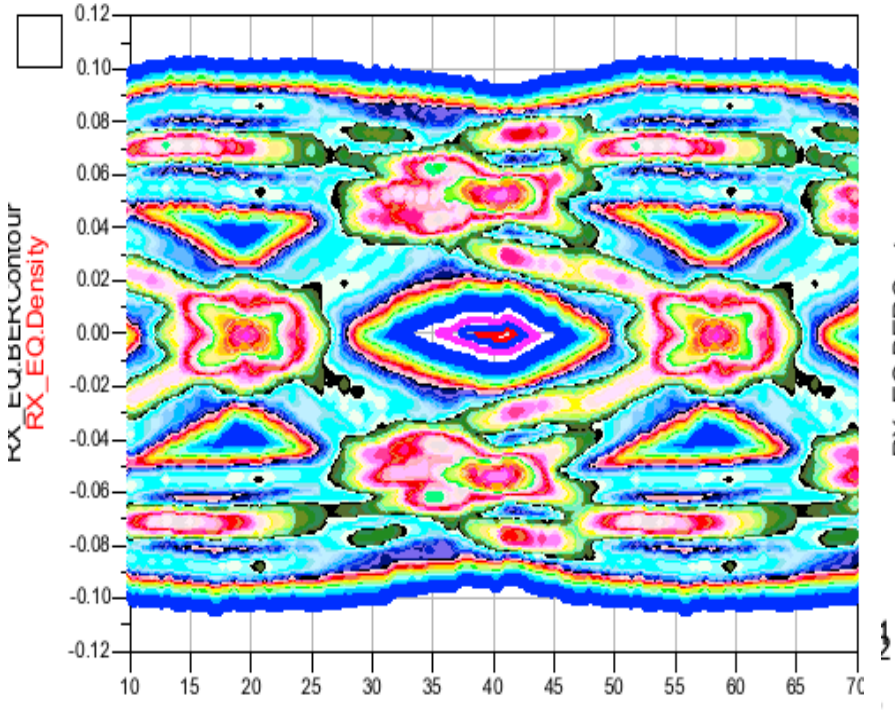
0.000	1.862E-11	0.022

Far end eye for 19 dB Hirose Channel With Xtalk

- Worst case FEXT and NEXT included

Hot Transmitter 800 mV Post 2 dB CTE=14dB



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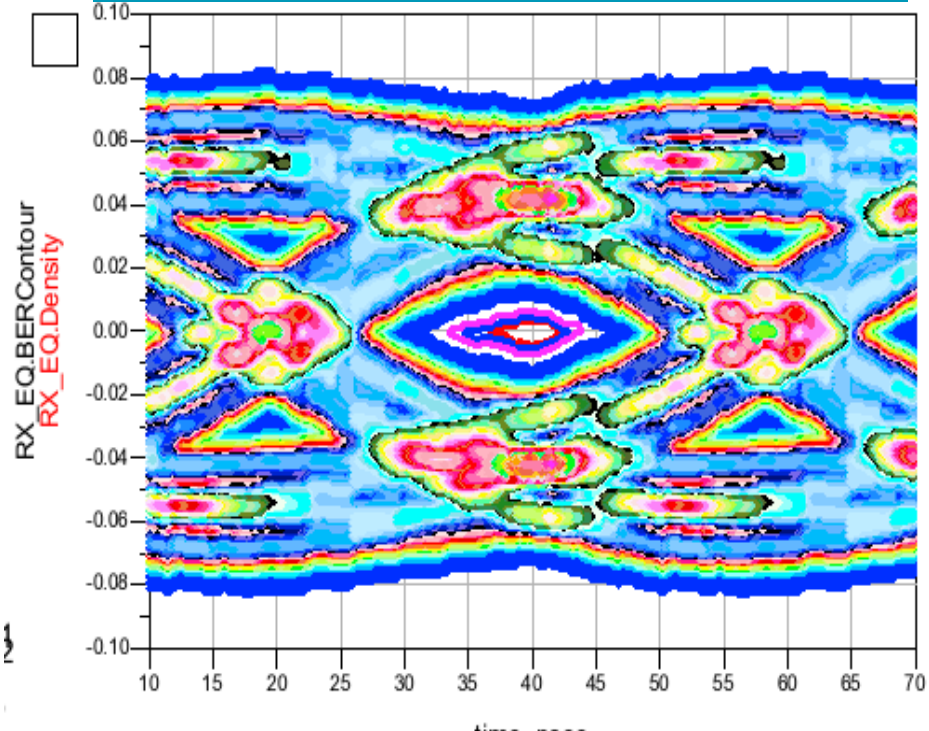
0.000	1.222E-11	0.009

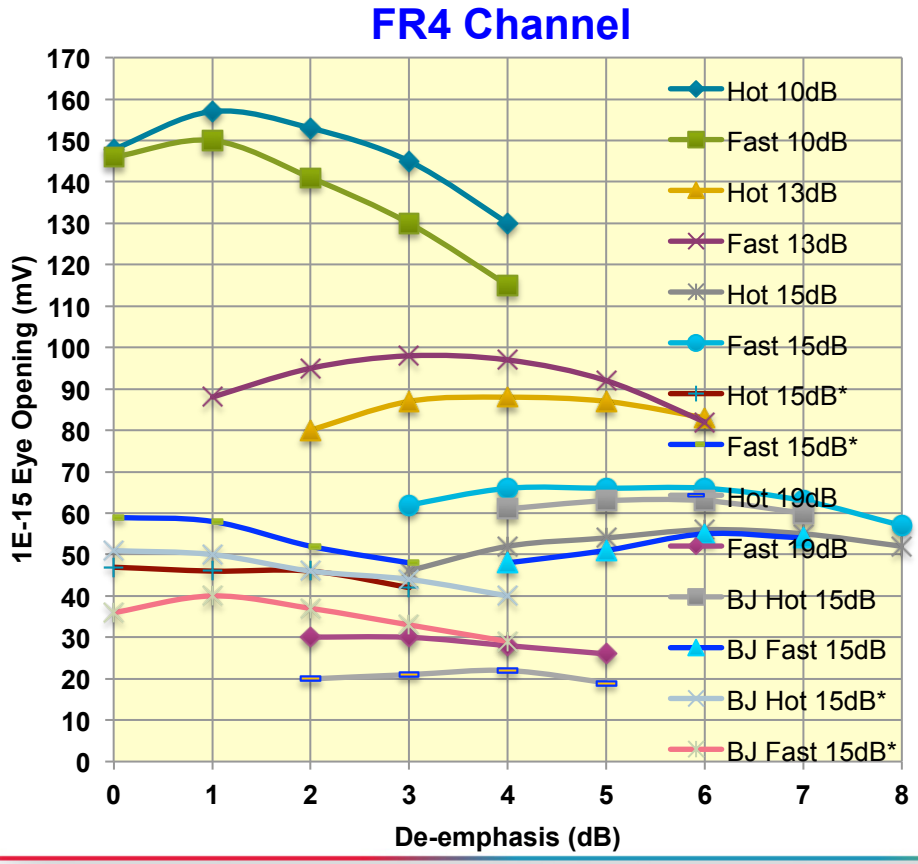
Fast Transmitter 600 mV Post 2 dB CTE=14 dB

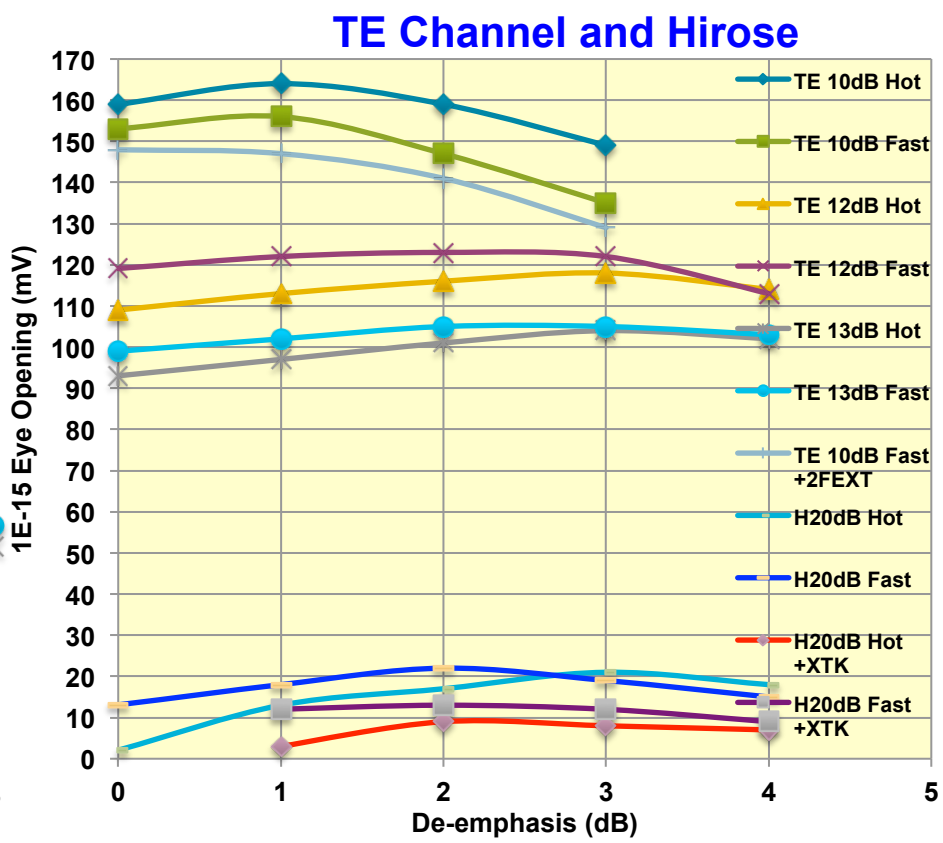


index	...te(RX_EQ.Width)	...te(RX_EQ.Height)
0.000	1.358E-11	0.013

Summary of Eye Opening

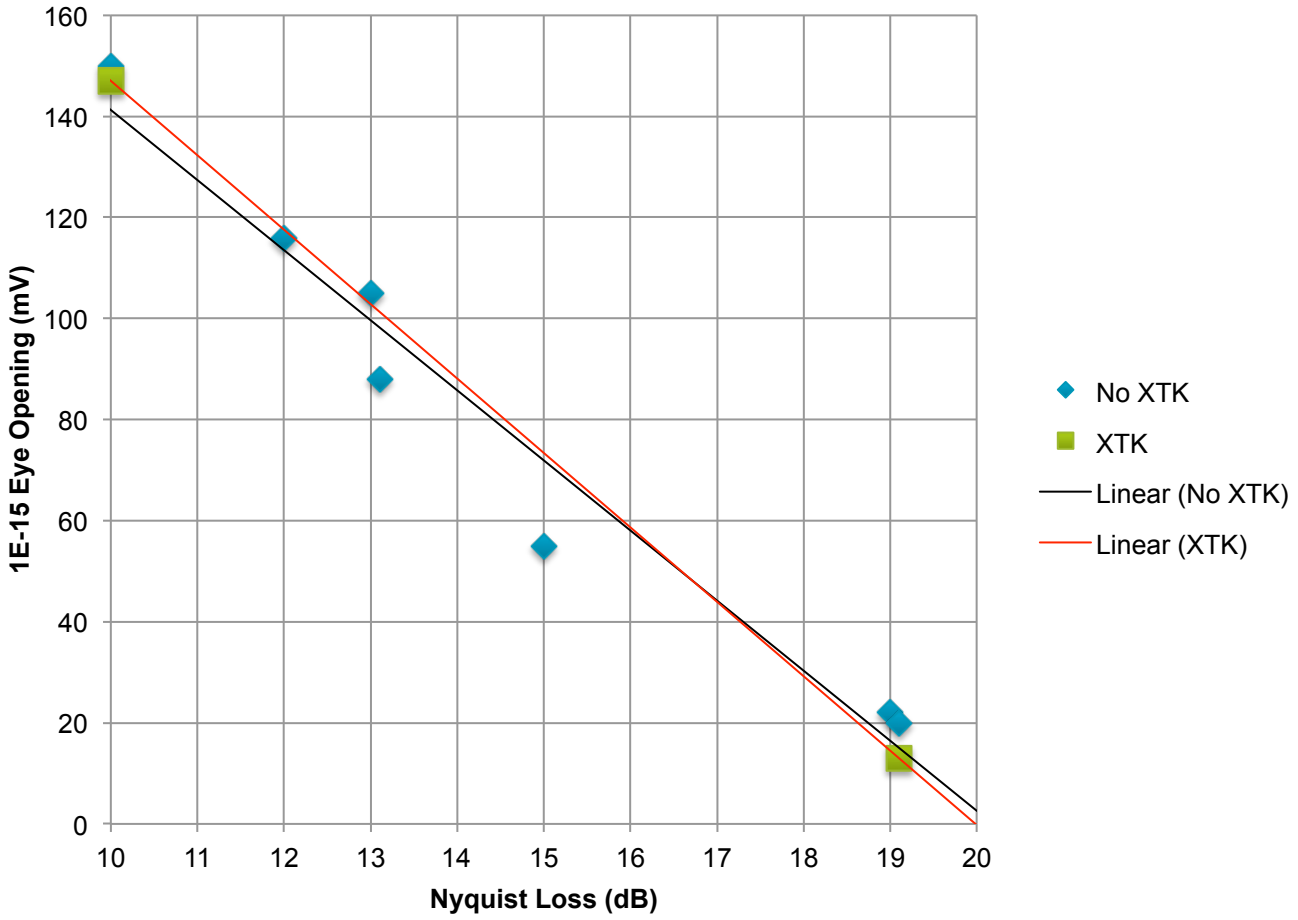
- Fast driver performs better for higher loss channel
  - For full simulation details see http://www.ieee802.org/3/bm/public/mar13/ghiasi_01_0313_optx.pdf
  - Increasing CTLE filter peaking did not improve far end eye opening just reduced TX FFE setting
  - Optimizing TX FFE pre-cursor improves results below by ~10%
  - 19-20 dB channel results in only ~10 mV signal at TP5





Summary of Eye Opening at TP5

- For worst case transmitter configuration hot vs fast
  - Result with BJ package not included



Summary

- A channel with loss of 1.4 dB @12.89 GHz was used to move the statistical eye mask reference TP0a
  - The eye mask allow flexibility in the transmitter and improve the correlation to TP5 receive eye
- There is strong user preference to increase channel loss budget to 20 dB but our 1st responsibility is to define robust specification that can be built and meet the BER objective
  - Pushing channel loss to 19-20 dB results in ~ 10 mV eye opening at at TP5 for BER 1E-15 and even less at the slicer
  - As the channel loss budget is increased tool such as ADS, SiSoft, or IEEE BJ COM would be required to qualify the channel compliance
- Based on study of reasonable package and channels, pushing channel loss budget beyond 15 dB is very challenging with just TXFF and CTLE receiver
  - TP5 1E-15 eye opening should not <40 mV
  - COM or commercial tool can qualify certain channels with >15 dB loss that will deliver more than 40 mV at TP5.

Thank You !