CAUI-4 C2C Simulations in Support D1.0 Comments

IEEE 802.3 bm

Ali Ghiasi

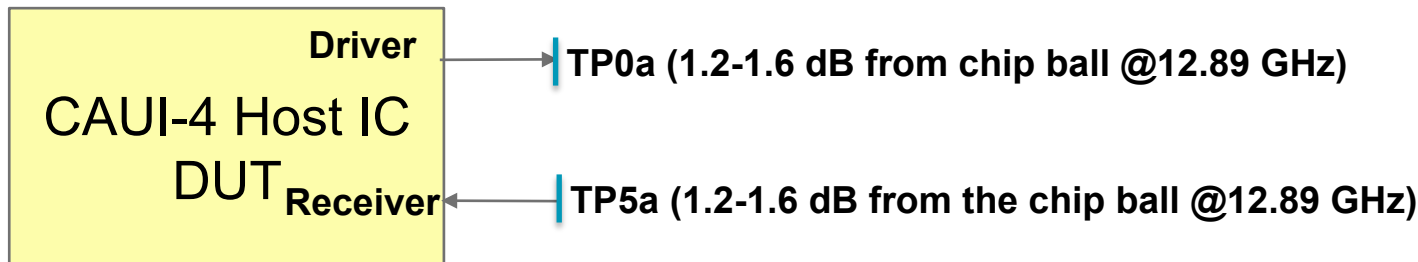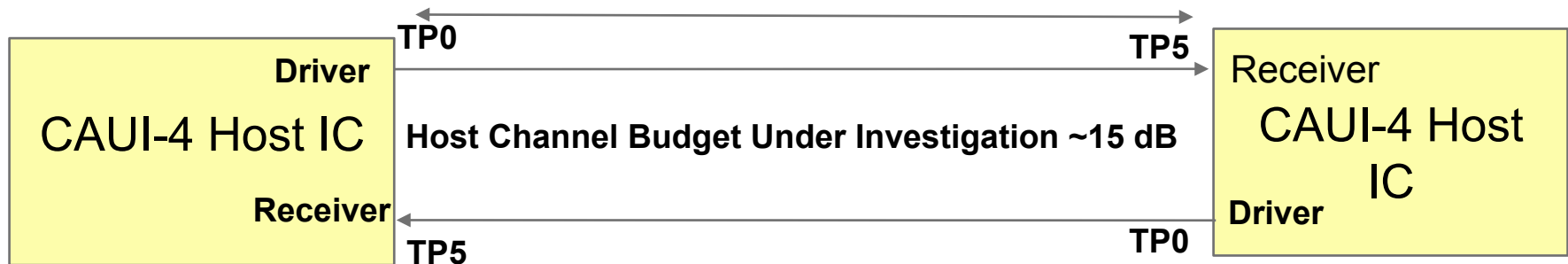Broadcom Corporation

July 16 , 2013

Geneva

- 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 /lower jitter driver has amplitude of 600 mV
  - KR/ hot /higher jitter driver has amplitude of 800 mV
  - Current BJ package require jitter driver with ~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 (comment 162, 164)

- There is strong user preference to push the channel loss to 20 dB
  - 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
  - Based on these simulation as well as other independent COM simulation CAUI adhoc need to focus on 15 dB C2C
    http://www.ieee802.org/3/bm/public/cuadhoc/meetings/jun28_13/CAUI-4_July13.pdf

Host Channel Budget Under Investigation ~15 dB

TP0a (1.2-1.6 dB from chip ball @12.89 GHz)

TP5a (1.2-1.6 dB from the chip ball @12.89 GHz)

Does 15 dB C2C have Broad Market Potential?

- PCB loss estimate assumptions and tools for calculation
  - IEEE 803.bj spreadsheet http://www.ieee802.org/3/bj/public/tools/DkDf_AlgebraicModel_v2.02a.xlsm for N4000-13SI and Megtron-6 calculation
  - Rogers Corp impedance calculator (free download but require registration) https://www.rogerscorp.com/acm/technology/index.aspx for FR4-6 and N4000-13
  - Stripline ~ 50 Ω, trace width is 5 mils, and with ½ oz Cu
  - Surface roughness med per IEEE spreadsheet or 2.8 um RMS
  - FR4-6 DK=4.2 and DF=0.02, N4000-13 DK=3.6 and DF=0.014, N4000-13SI and Meg-6 per IEEE spreadsheet

Host Trace Length (in)	Total Loss (dB)	Host Loss(dB)	FR4-6	N4000-13	N4000-13SI	Megtron 6
Nominal PCB Loss/in at 5.15 GHz	N/A	N/A	1.00	0.79	0.56	0.43
Nominal PCB Loss/in at 12.89 GHz	N/A	N/A	2.00	1.60	1.25	0.92
CAUI Classic	10.5	6.81	6.8	8.6	12.2	15.8
PPI CL85A/86A with one connector & HCB#	6.5	4.37	4.4	5.5	7.8	10.2
CAUI-4 with one connector & HCB*	10.5	6.81	3.4	4.3	5.4	7.4
802.3bj CL92A with one connector & HCB *	10.5	6.81	3.4	4.3	5.4	7.4
CAUI-4 Chip to Module	10	10	5.0	6.3	8.0	10.9
CAUI-4 Chip to Chip	13	13	6.5	8.1	10.4	14.1
CAUI-4 Chip to Chip	15	15	7.5	9.4	12.0	16.3
OIF 28G-MR	20	20	10.0	12.5	16.0	21.7

\# Assumes connector loss is 0.87 dB and HCB loss is 1.26 dB at 5.5 GHz.

* Assumes connector loss is 1.69 dB and HCB loss is 2.0 dB at 12.89 GHz.

- Now that 20 dB CAUI4 C2C does not look feasible propose to adopt 15 dB Channel

$$SDD21(15dB) = -0.121 - 0.867 * \sqrt{f} - 0.914 * f \quad from \; 0.05 - 14 \, GHz$$
$$= 19.368 - 2.152 * f \quad from \; 14 - 25 \, GHz$$
$$SDD21(20dB) = -0.161 - 1.156 * \sqrt{f} - 1.218 * f \quad from \; 0.05 - 14 \, GHz$$
$$= 13.368 - 2.152 * f \quad from \; 14 - 25 \, GHz$$
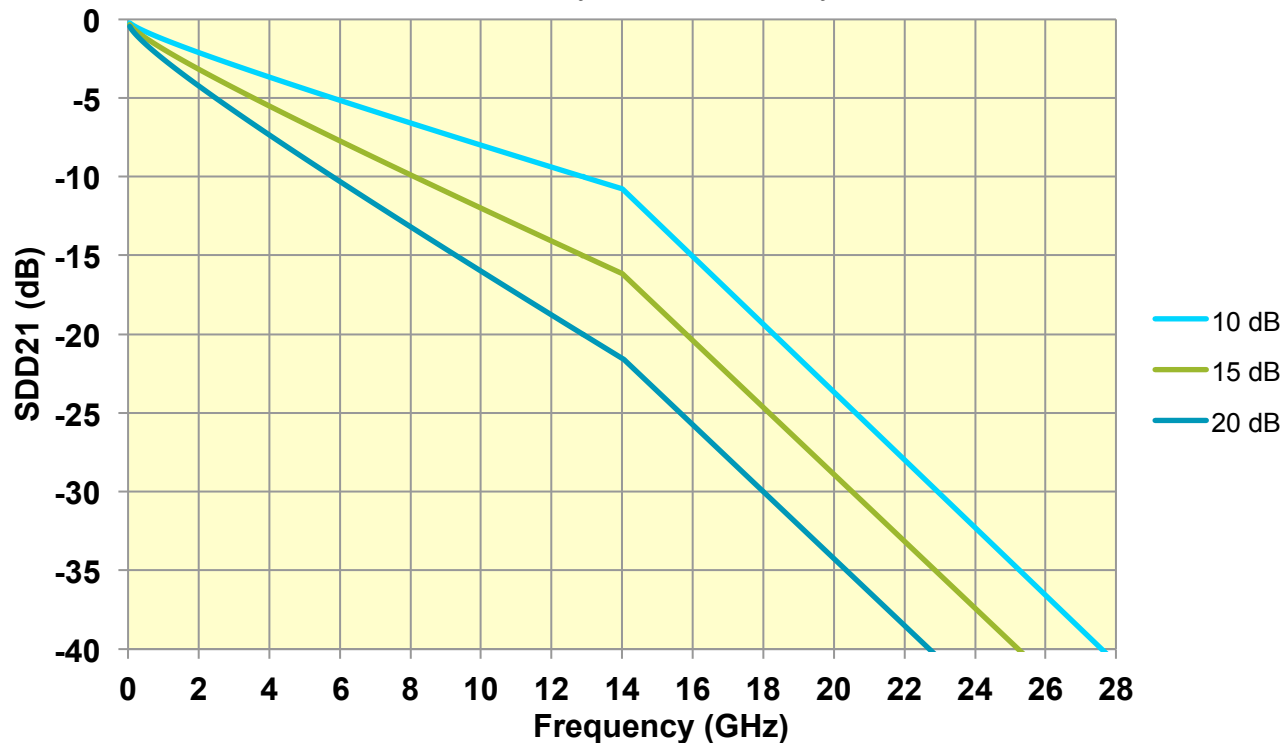
- ## HFSS extracted Ali's package is a moderate size
  - ESD is identical to the BJ package
  - Package is slightly better than BJ package
  - As expected the HFSS extracted package does not have the resonance structures and ILD visible in BJ package


BJ Package Compare Ali's Packages

m9
freq=12.87GHz
SDD21_BJ=-3.320

m10
freq=12.87GHz
SDD22_BJ=-5.055
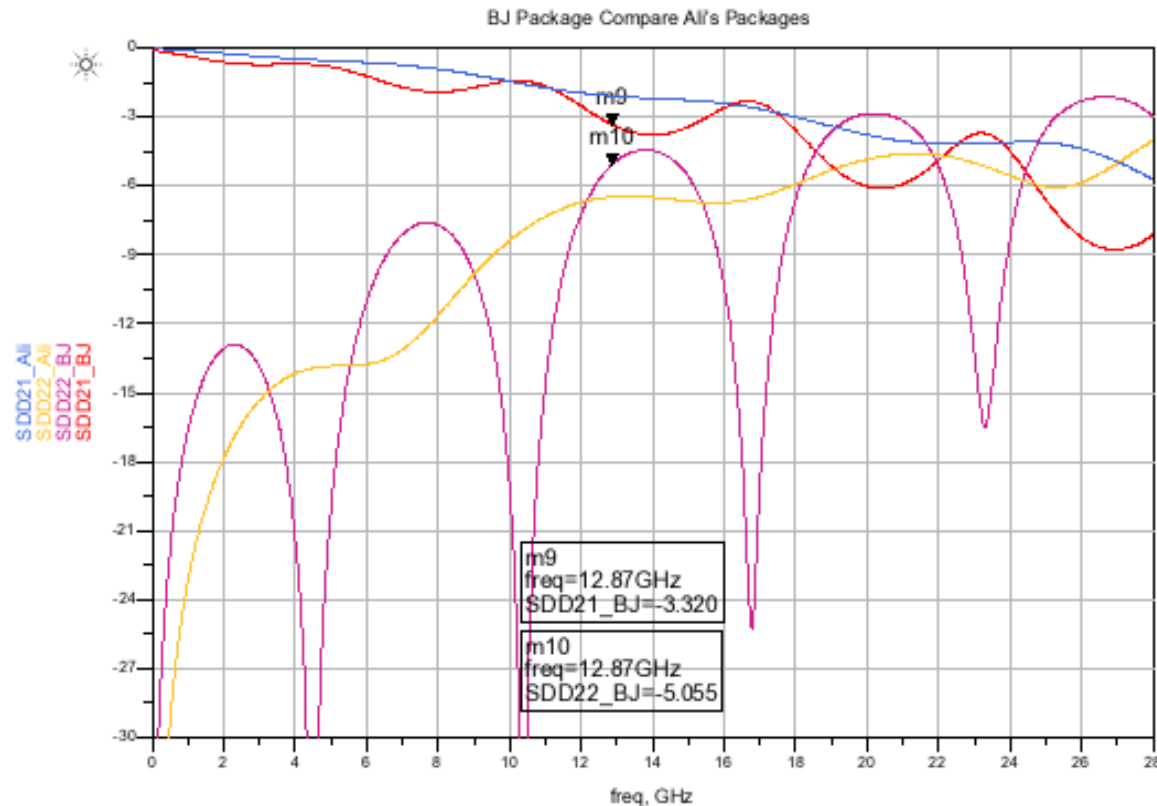
- Ali and BJ D2.1 package looks similar
  - But BJ package exhibit slight amount non passivity and more DJ

Pulse Resposne
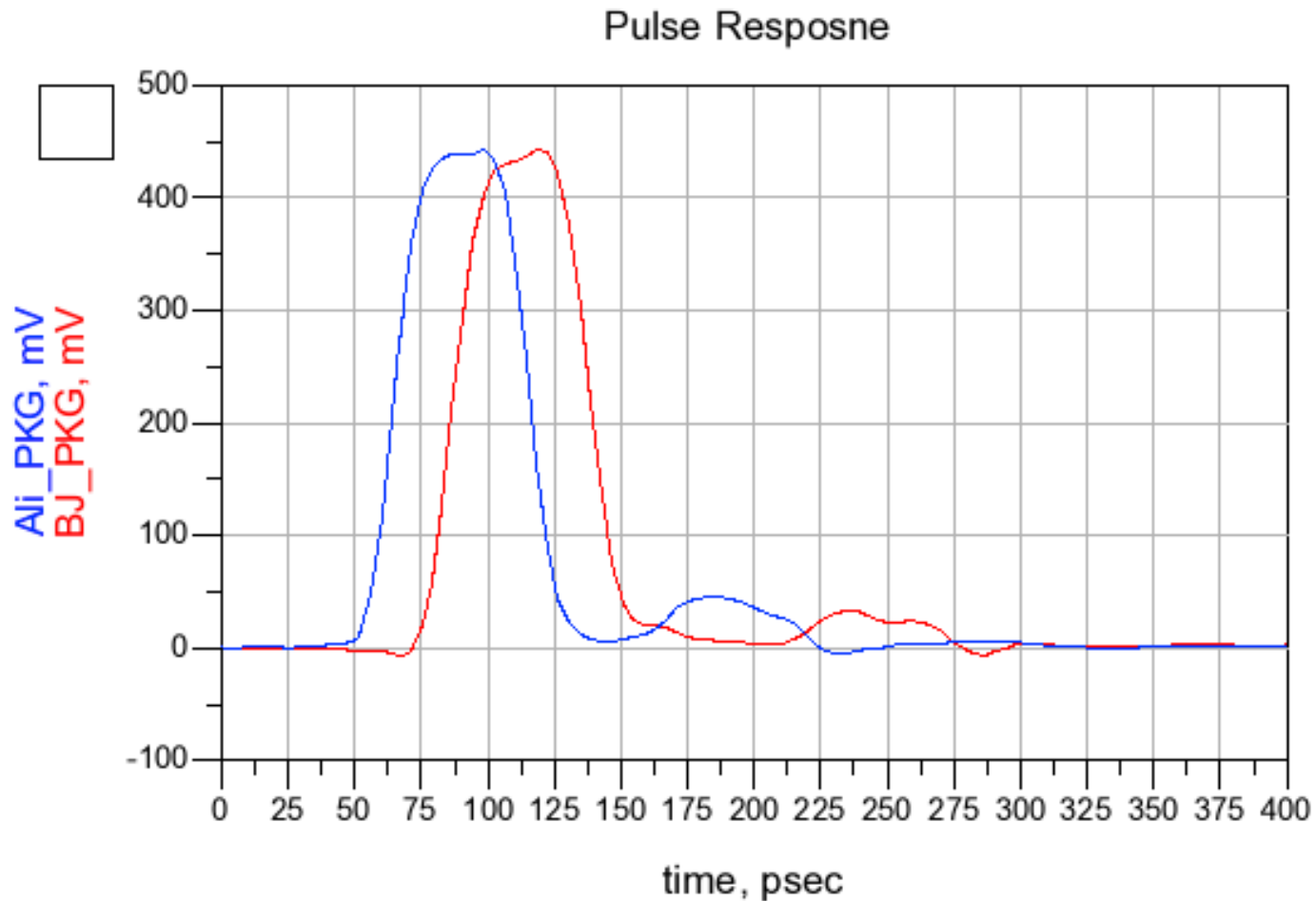
Example of Big and Little Chip CAUI-4 Transmitter at TP0

- 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)
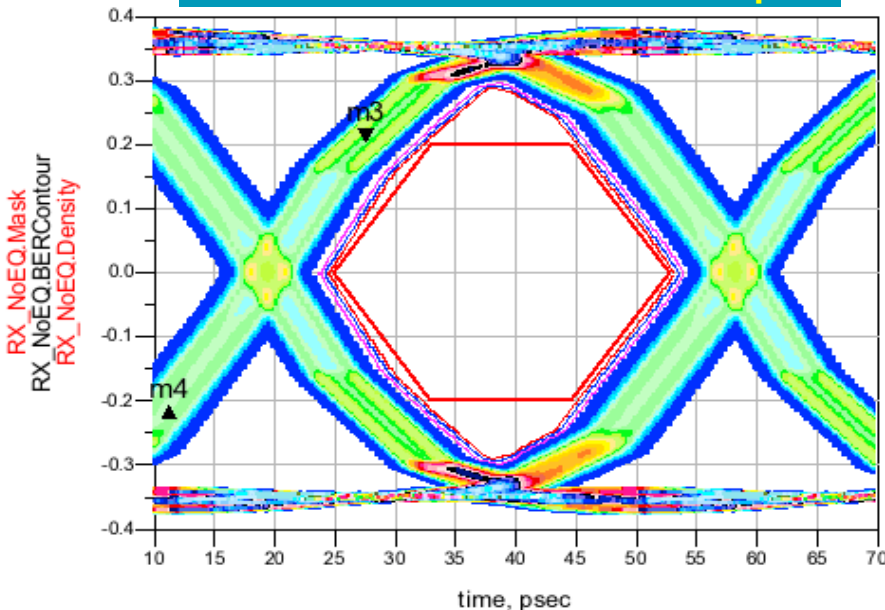
index	..._NoEQ.WidthAtBER)	...NoEQ.HeightAtBER)
0.000	2.890E-11	0.579
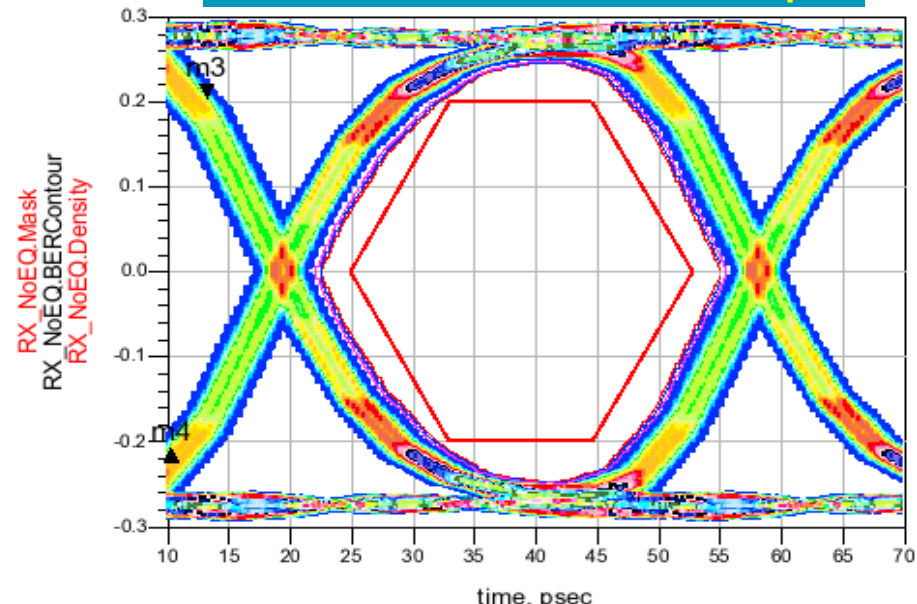
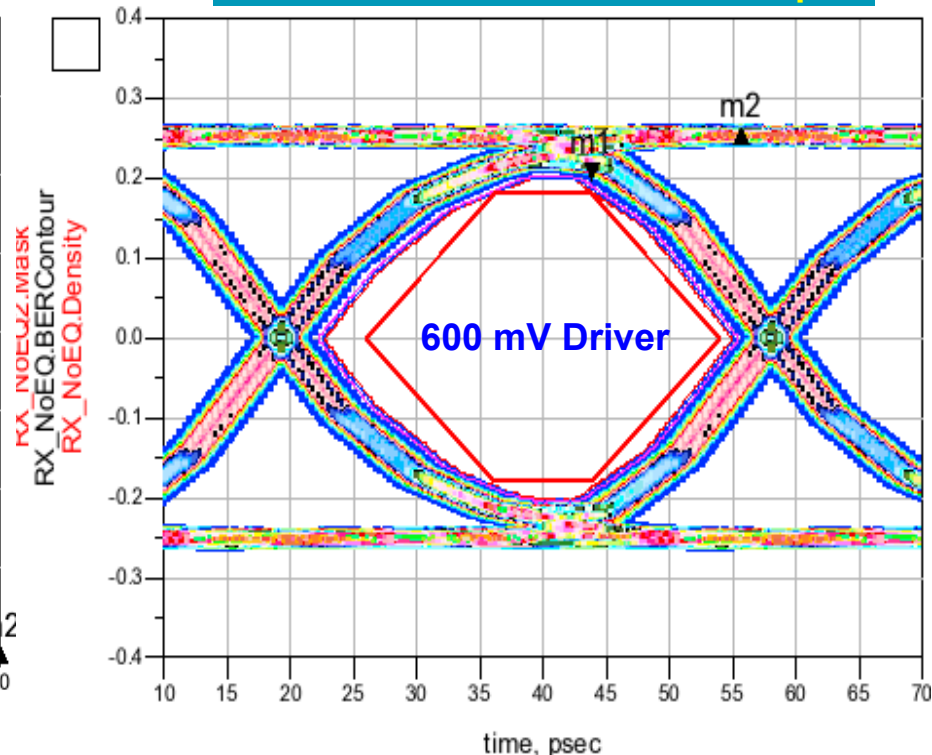| index	..._NoEQ.WidthAtBER)	...NoEQ.HeightAtBER)
0.000	3.278E-11	0.493

Shifting Eye Mask Compliance to TP1a (option I - keeping driver amplitude)

- 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

CAUI-4 Fast Transmitter Tr=12 ps

	index	...te(RX_NoEQ.Width)	...te(RX_NoEQ.Height)
m3	0.000	3.142E-11	0.400

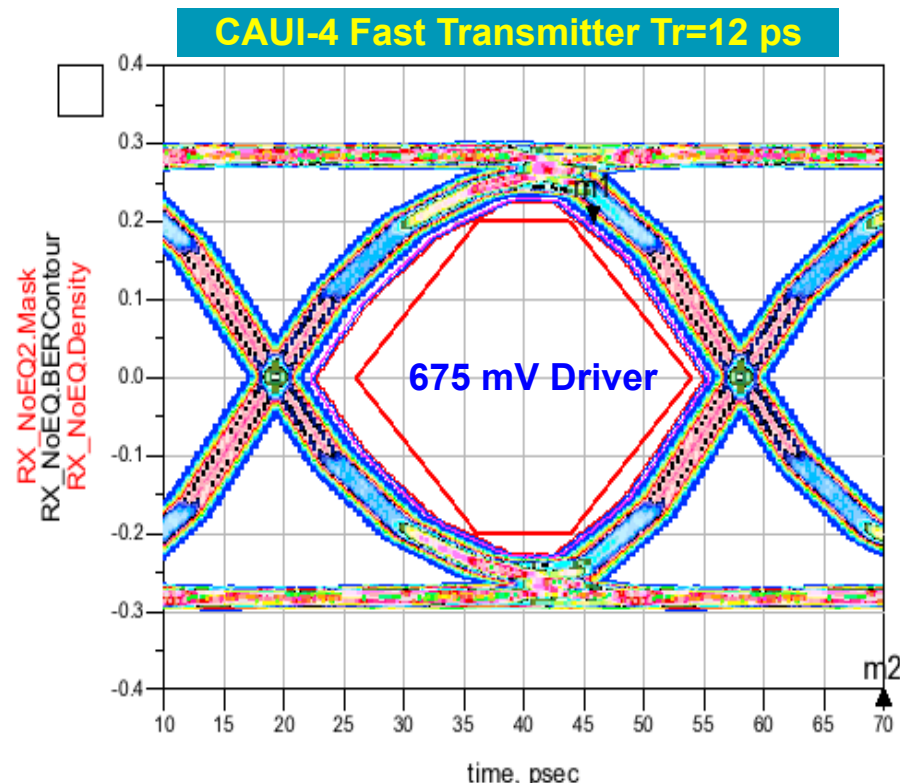|	index	...te(RX_NoEQ.Width)	...te(RX_NoEQ.Height)
m3	0.000	3.413E-11	0.369
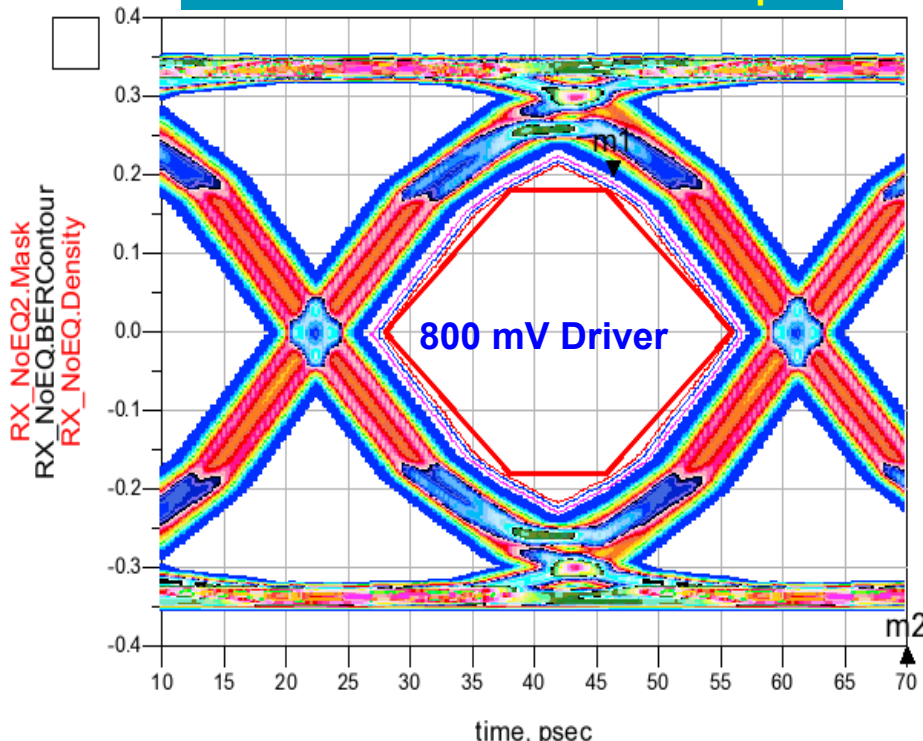
Shifting Eye Mask Compliance to TP0a (option II-increase Amplitude by 12.5%, comment 151 & 154)

- 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

900 mV Driver
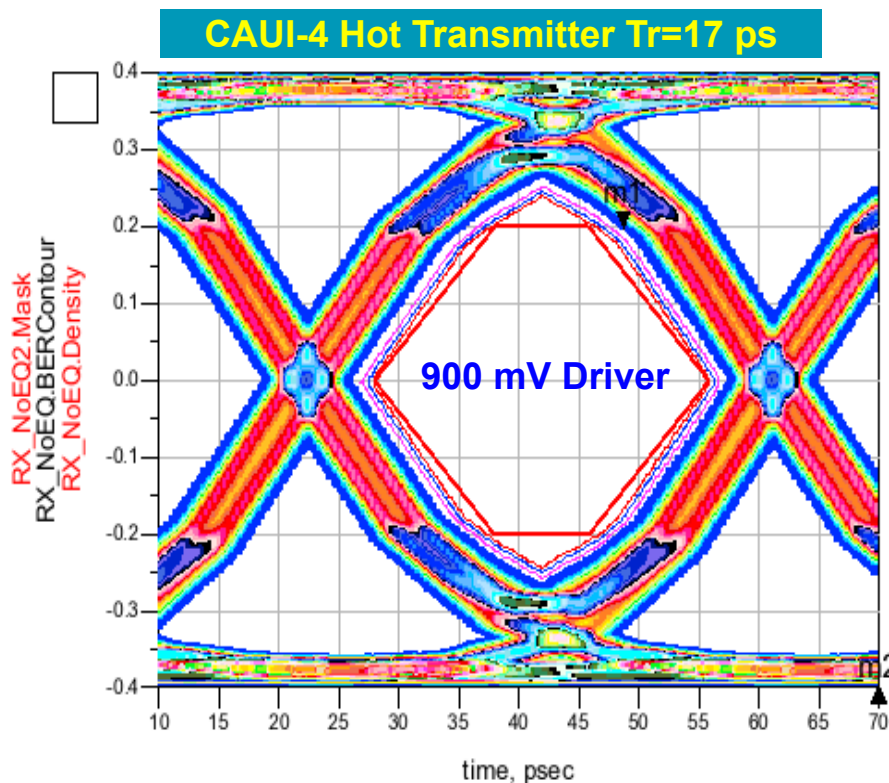
index	...te(RX_NoEQ.Width)	...te(RX_NoEQ.Height)
0.000	3.142E-11	0.452

CAUI-4 Fast Transmitter Tr=12 ps

675 mV Driver

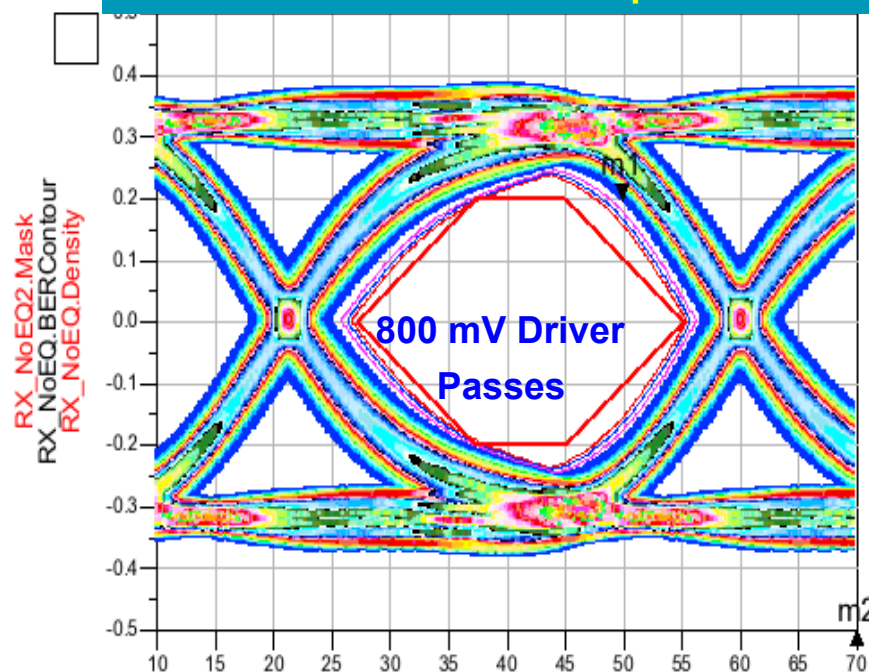| index	...te(RX_NoEQ.Width)	...te(RX_NoEQ.Height)
0.000	3.413E-11	0.416

- BJ COM code driver Tr is band limited by the package, RJ = 0.38 ps (RMS), and DJ=5.4 ps

- The left eye mask fails to deliver 0.28 UI TJ with BJ driver setting and package
  - Not sure why inherent driver DJ is so high given the package inherent DJ!

- The right eye mask meets 0.28 UI TJ if driver inherent DJ is reduced to 2.7 ps
  - To meet TP0a with BJ package 800 mV low DJ jitter is required (similar to fast driver but with 800 mV amplitude)

CAUI-4 with BJ PKG and 5.4 ps Driver DJ
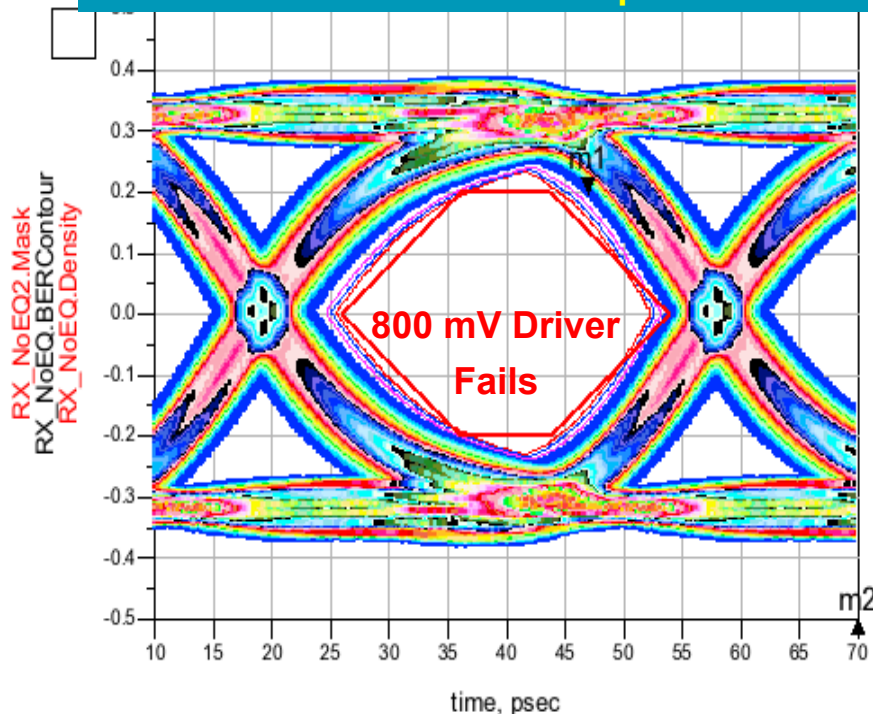
	index	...te(RX_NoEQ.Width)	...te(RX_NoEQ.Height)
m3	0.000	3.026E-11	0.437

CAUI-4 with BJ PKG and 2.7 ps driver DJ

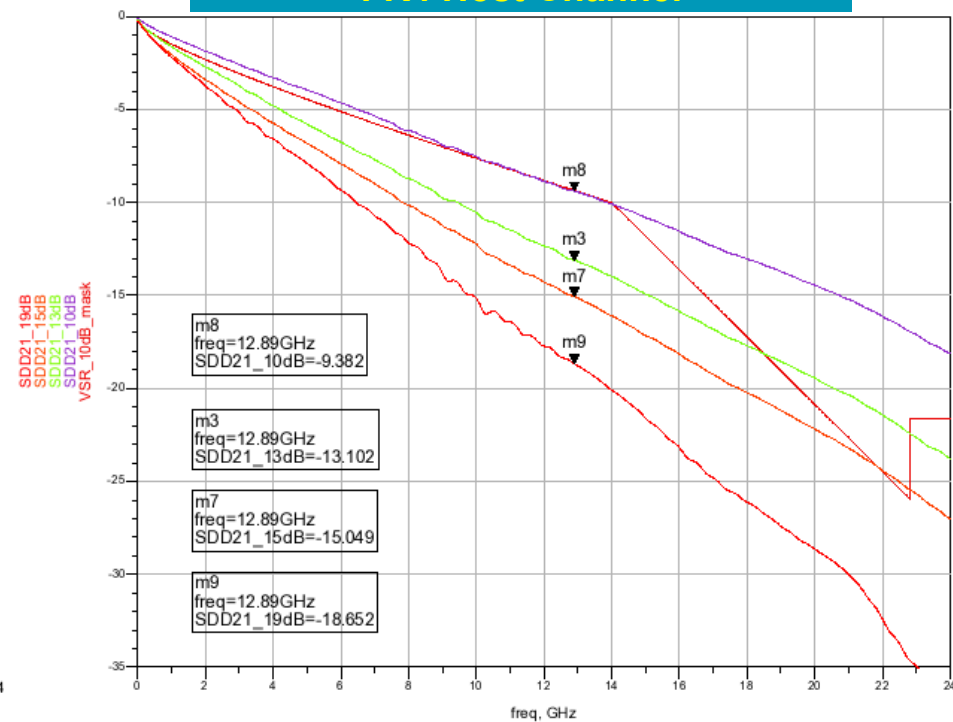|	index	...te(RX_NoEQ.Width)	...te(RX_NoEQ.Height)
m3	0.000	3.297E-11	0.439

- 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
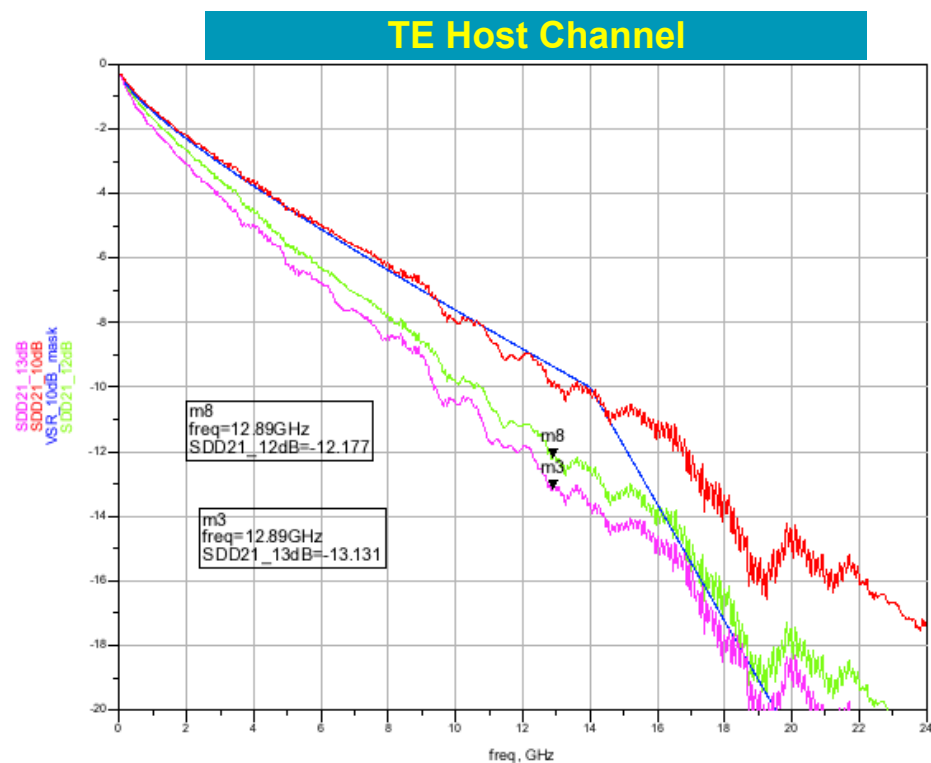 - 10" FR4 2x of 5" FR4 channel
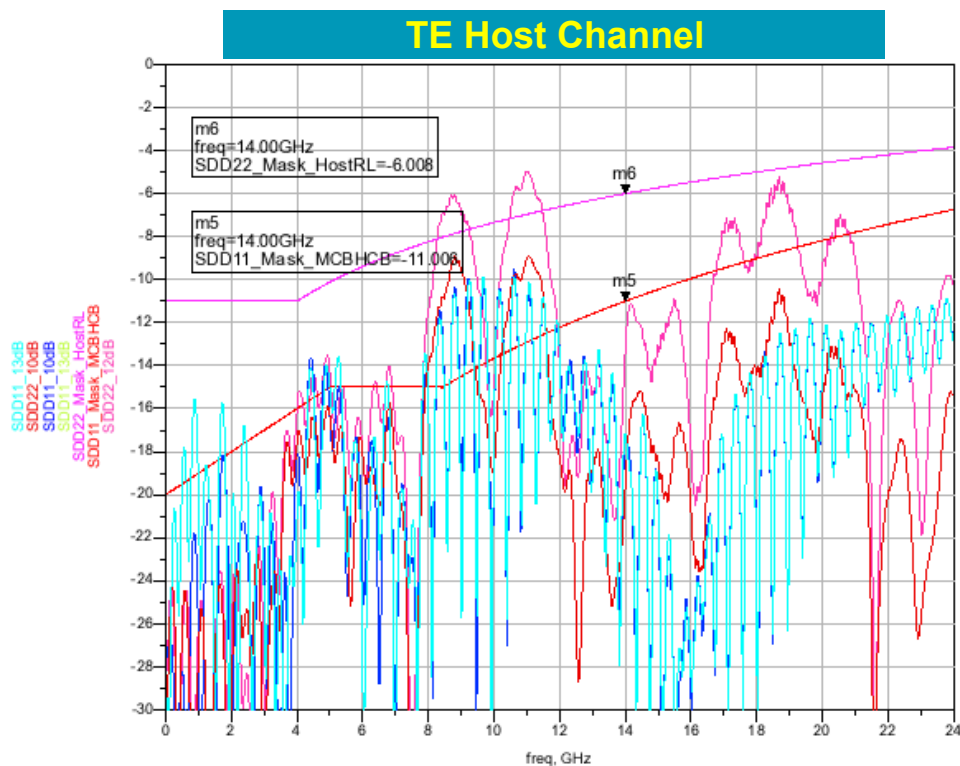

FR4 Host Channel

m6
freq=14.00GHz
SDD22_Mask_HostRL=-6.008

m5
freq=14.00GHz
SDD11_Mask_MCBHCB=-11.006

FR4 Host Channel

m8
freq=12.89GHz
SDD21_10dB=-9.382

m3
freq=12.89GHz
SDD21_13dB=-13.102

m7
freq=12.89GHz
SDD21_15dB=-15.049

m9
freq=12.89GHz
SDD21_19dB=-18.652
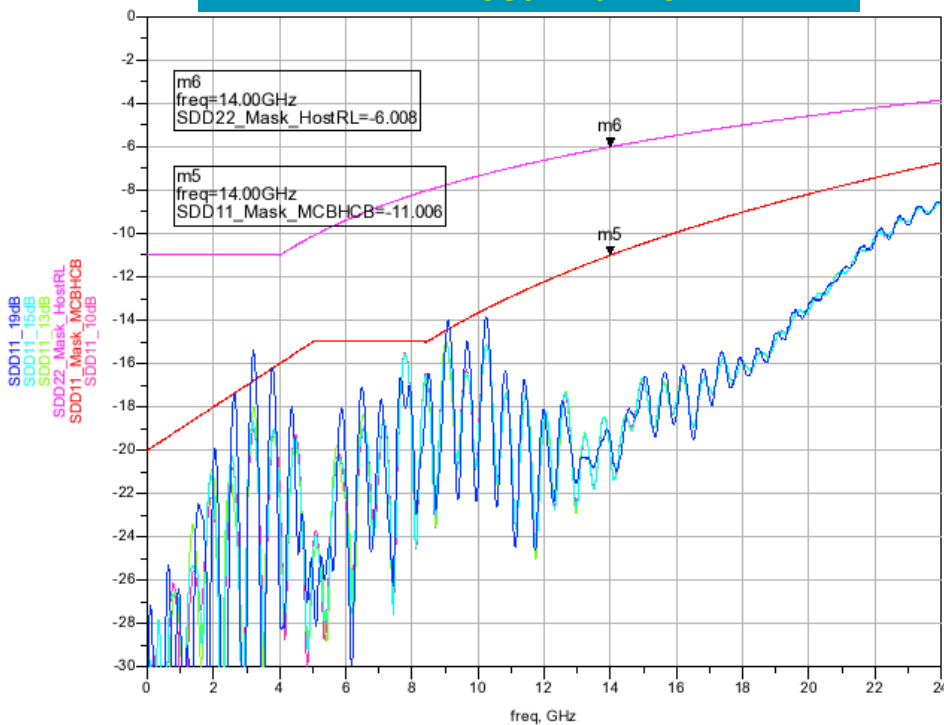
- Channels are
  - TE Quadra channel with 10 dB loss
  - TE 7" Quadra + 1.25" plug board+ 2" Meg6 Channel
  - TE 7" Quadra + 1.25" plug board + 2" FR4 Channel

- 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

Hirose 19 dB Channel

m11
freq=12.89GHz
SDD21=-18.589
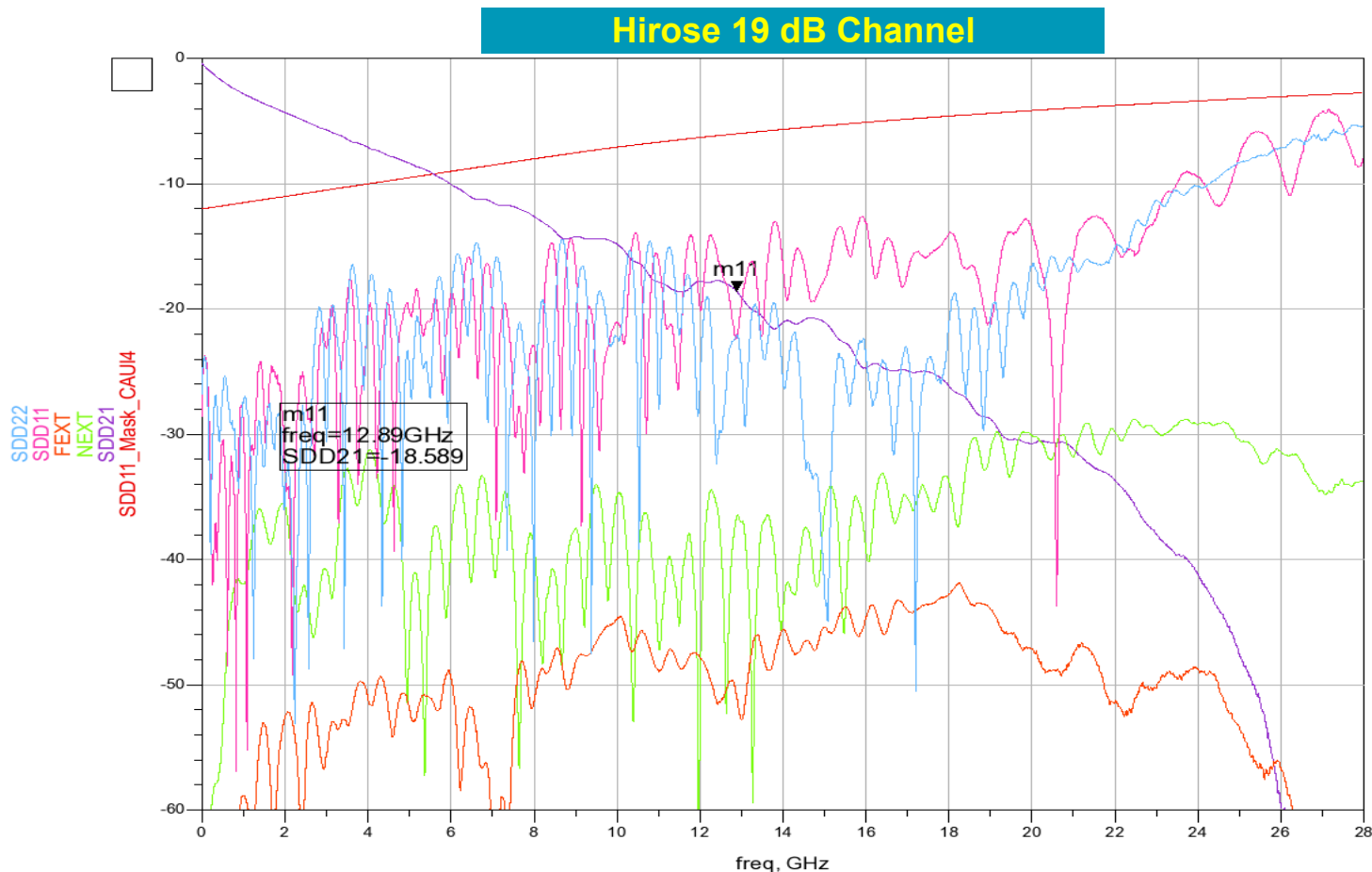
- Based on most common implementation of CTLE with single pole with 2 zeros

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

- 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

Reference CTLE

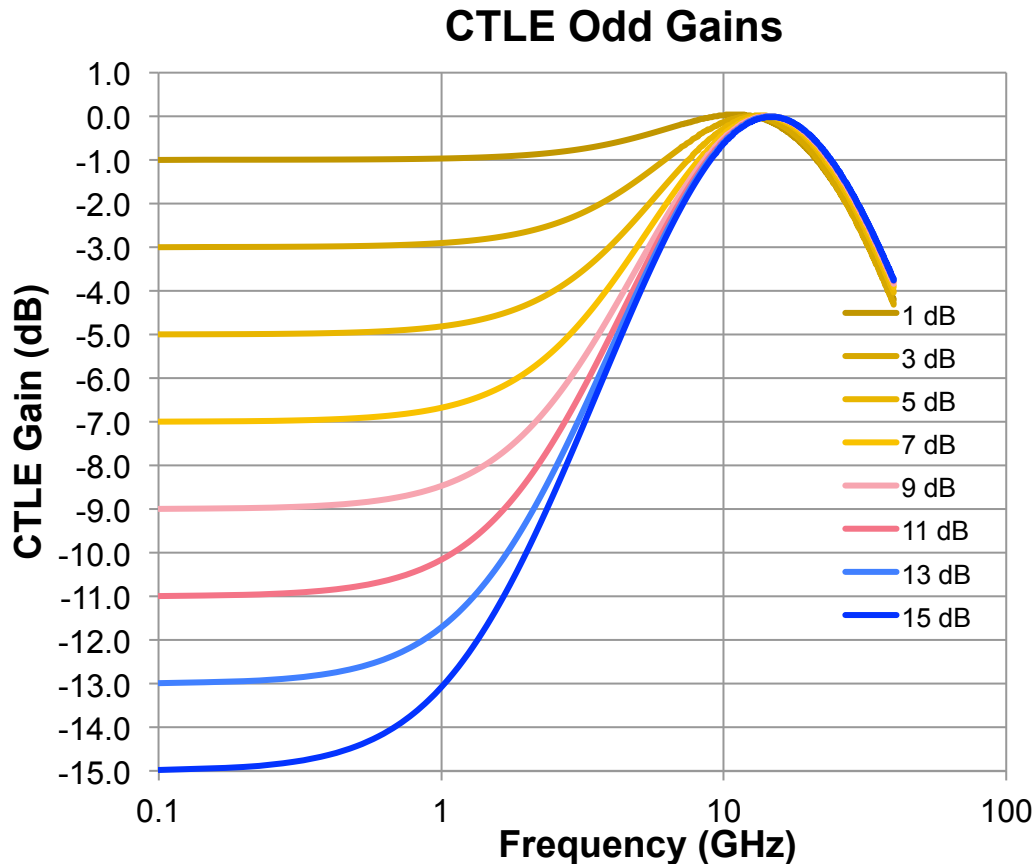**Typical CTLE Implementation**
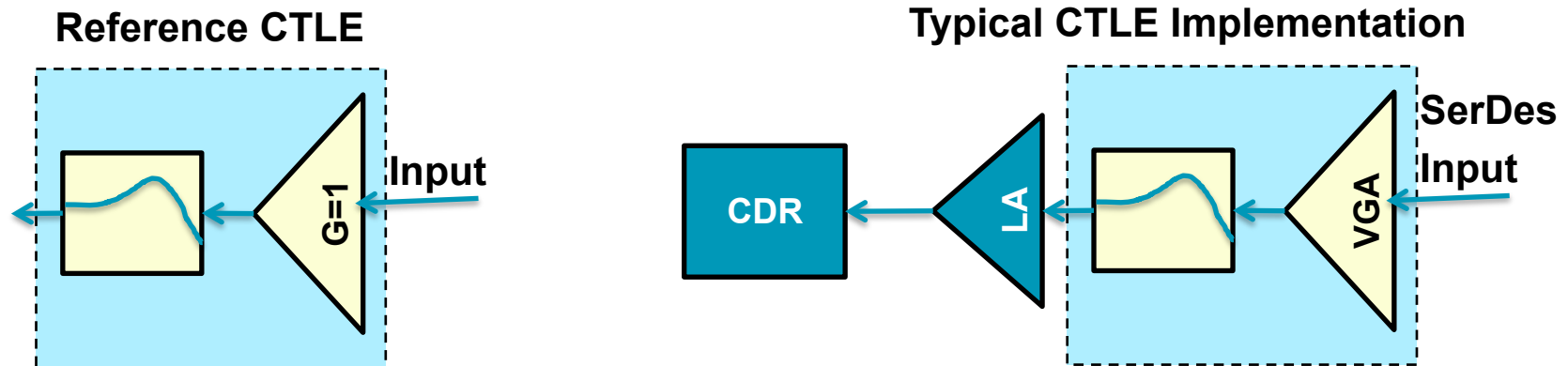
Expanded CTLE Response (comment 134, 138 and 163)

- 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
  - Assume we go with 15 dB then there is no reason to require more than 12 dB CTLE

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

CTLE Odd Gains

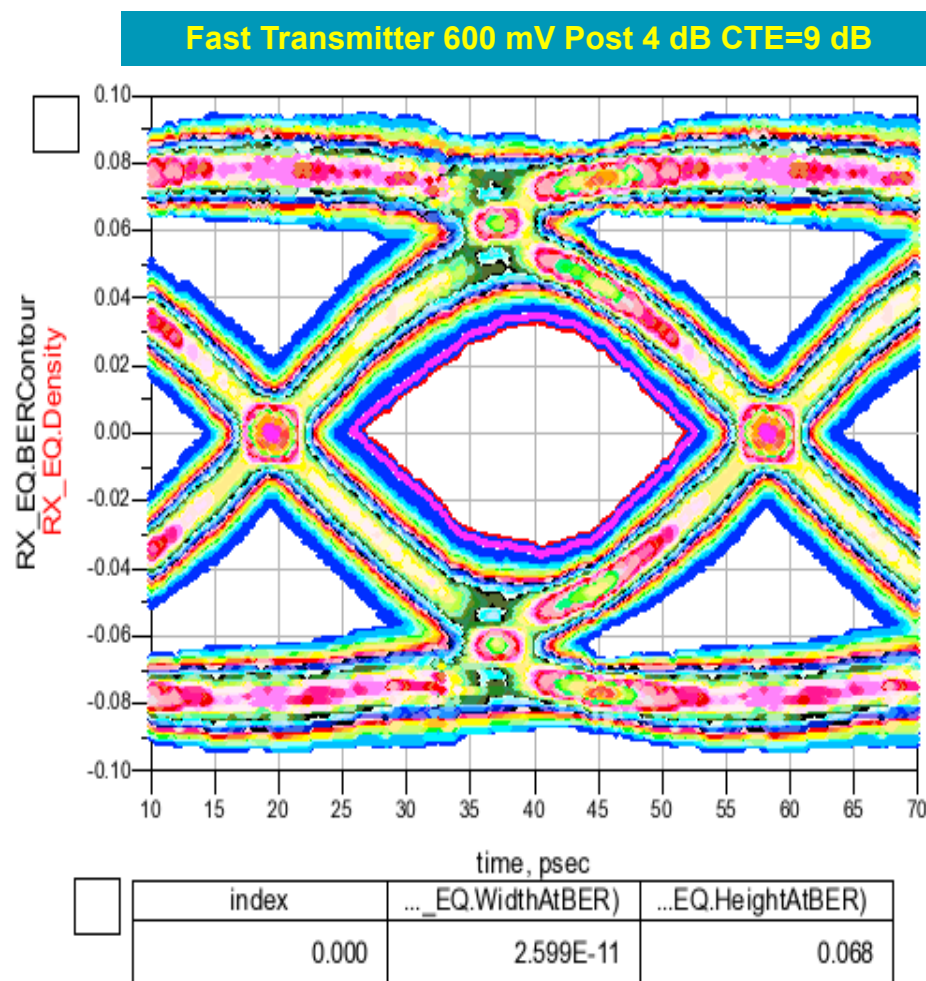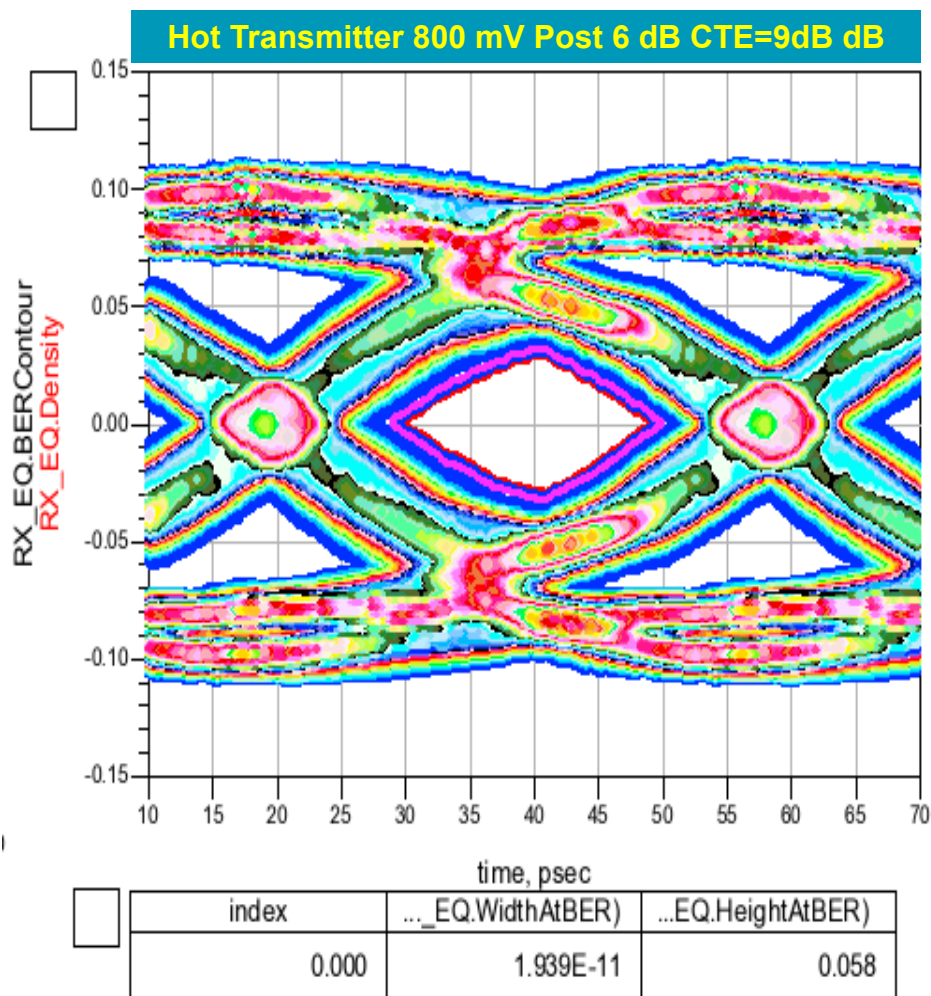| Gain (dB)	G (Linear)	Z (GHz)	P1 (GHz)	P2 (GHz)
1	0.89	7.1e9	1.86e10	1.41e10
2	0.795	7.1e9	1.86e10	1.41e10
3	0.795	7.1e9	1.56e10	1.41e10
4	0.633	4.98e9	1.56e10	1.41e10
5	0.563	4.35e9	1.56e10	1.41e10
6	0.5	3.82e9	1.56e10	1.41e10
7	0.446	3.4e9	1.56e10	1.41e10
8	0.398	3e9	1.56e10	1.41e10
9	0.3548	2.672e9	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

Transmitter FFE Requirements (comment 137, 152, 159)

- Assuming we go with 15 dB for CAUI4 C2C

- No need to define more than 12 dB CTLE with 1 dB steps

- No need need to define more than 6 dB post with step of 0.5 dB

- Pre can open the eye by ~10% and would be nice to have 3 dB with 0.5 dB steps

- C2C TX FFE can be much similar than 100G-KR4

- The above C2C still is subset of 100G-KR4 but one could implement much similar transmit FFE for CAUI-4 applications compare to 100G-KR4.
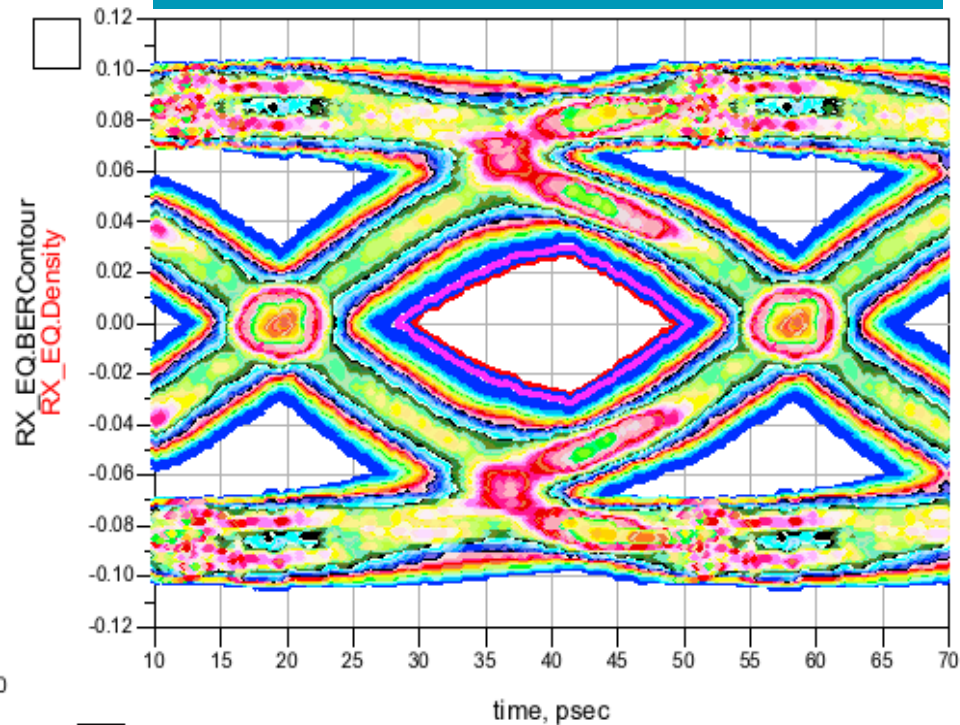
BROADCOM.
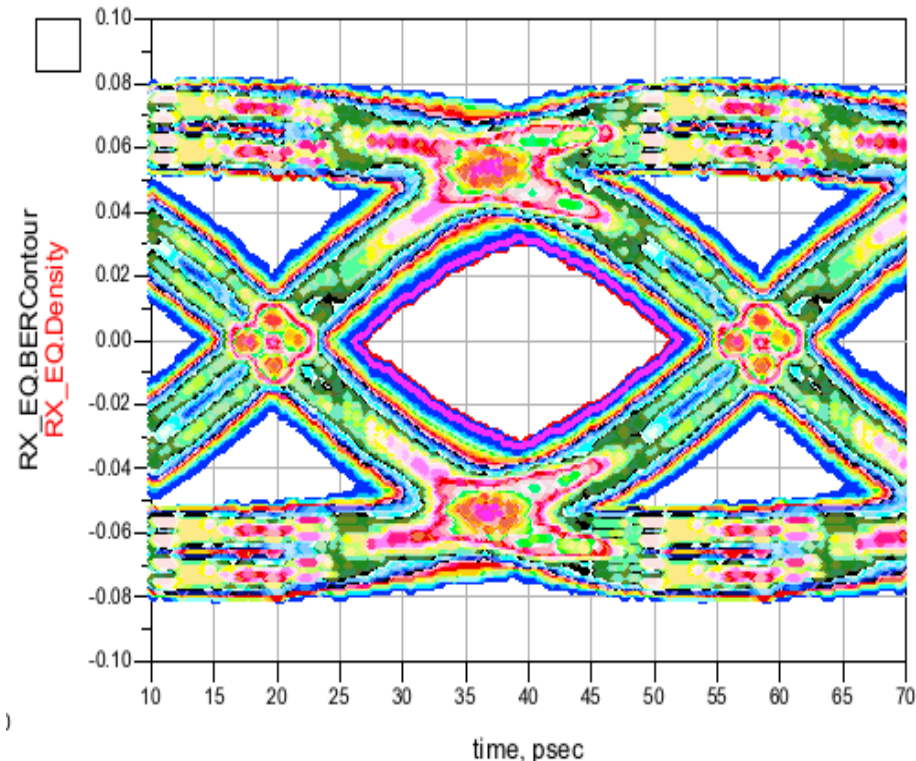
- For the hot and fast transmitter

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

index	..._EQ.WidthAtBER)	...EQ.HeightAtBER)
0.000	2.599E-11	0.068

- For the hot and fast transmitter

Hot Transmitter 800 mV Post 6 dB CTE=9dB dB
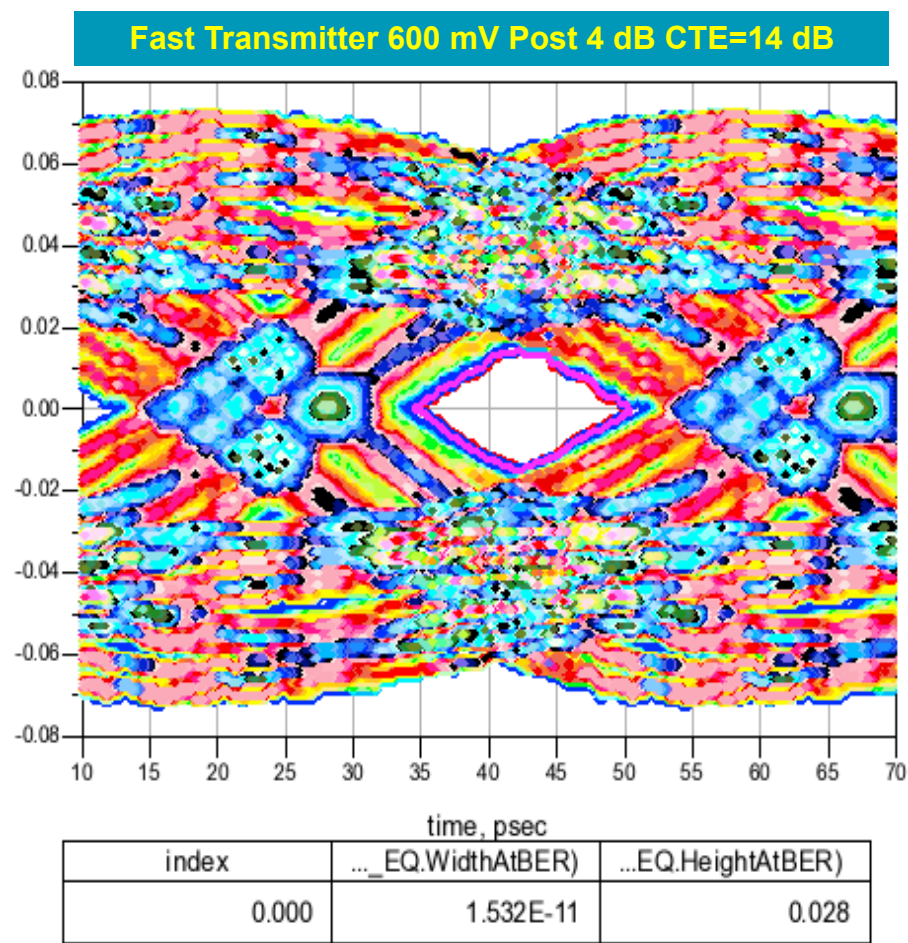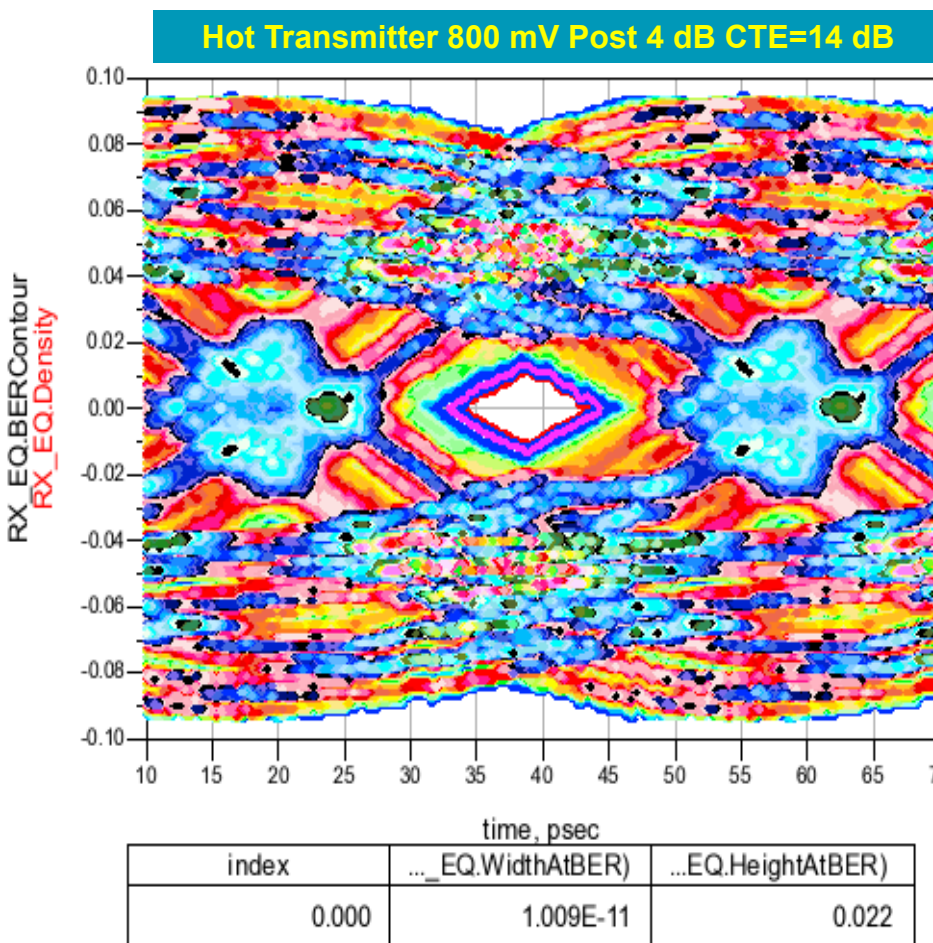
index	..._EQ.WidthAtBER)	...EQ.HeightAtBER)
0.000	1.998E-11	0.055

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
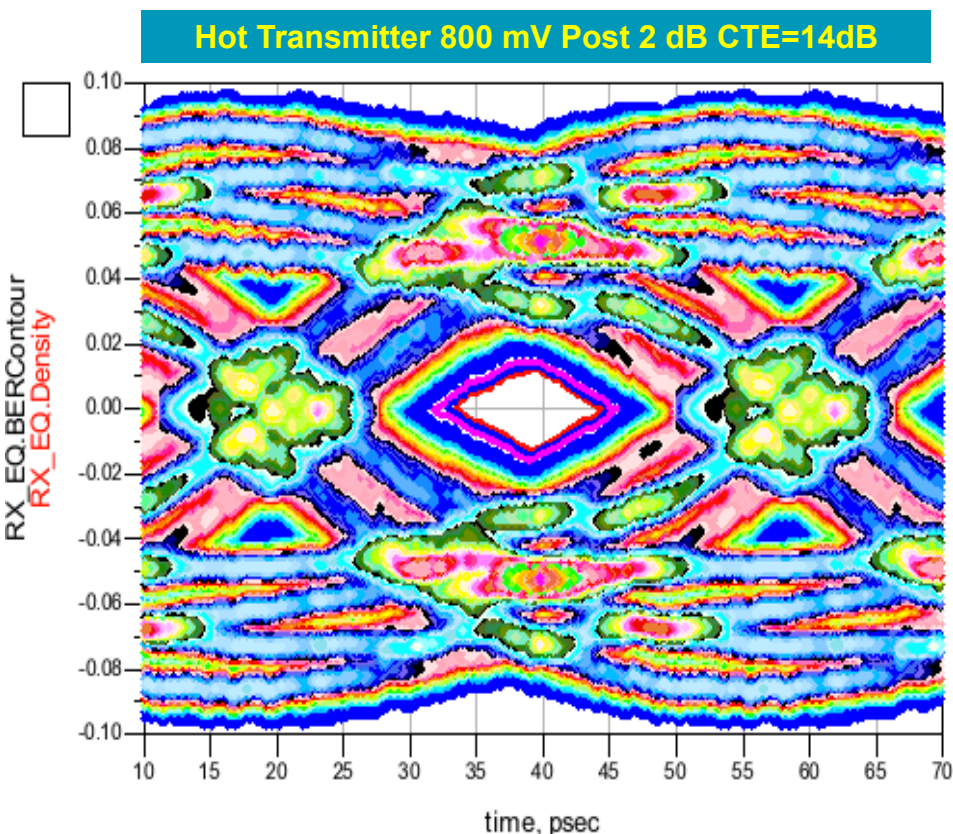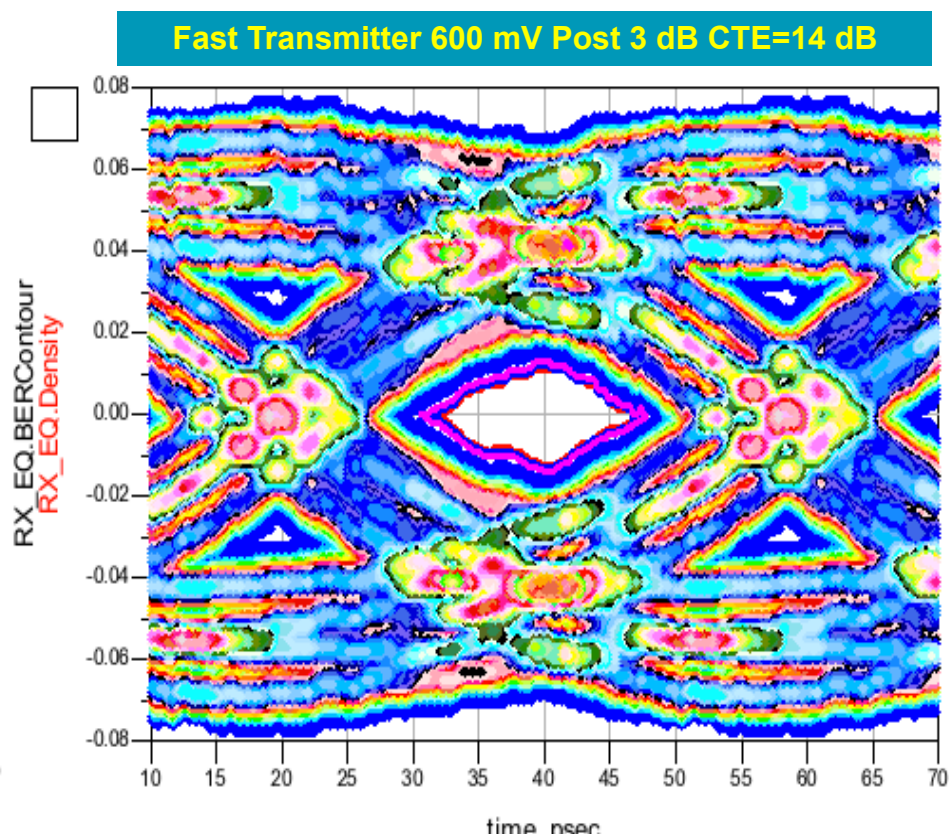
Hot Transmitter 800 mV Post 4 dB CTE=14 dB

index	..._EQ.WidthAtBER)	...EQ.HeightAtBER)
0.000	1.009E-11	0.022

Fast Transmitter 600 mV Post 4 dB CTE=14 dB

index	..._EQ.WidthAtBER)	...EQ.HeightAtBER)
0.000	1.532E-11	0.028

- For the hot and fast transmitter

- Worst case FEXT and NEXT included

Hot Transmitter 800 mV Post 2 dB CTE=14dB

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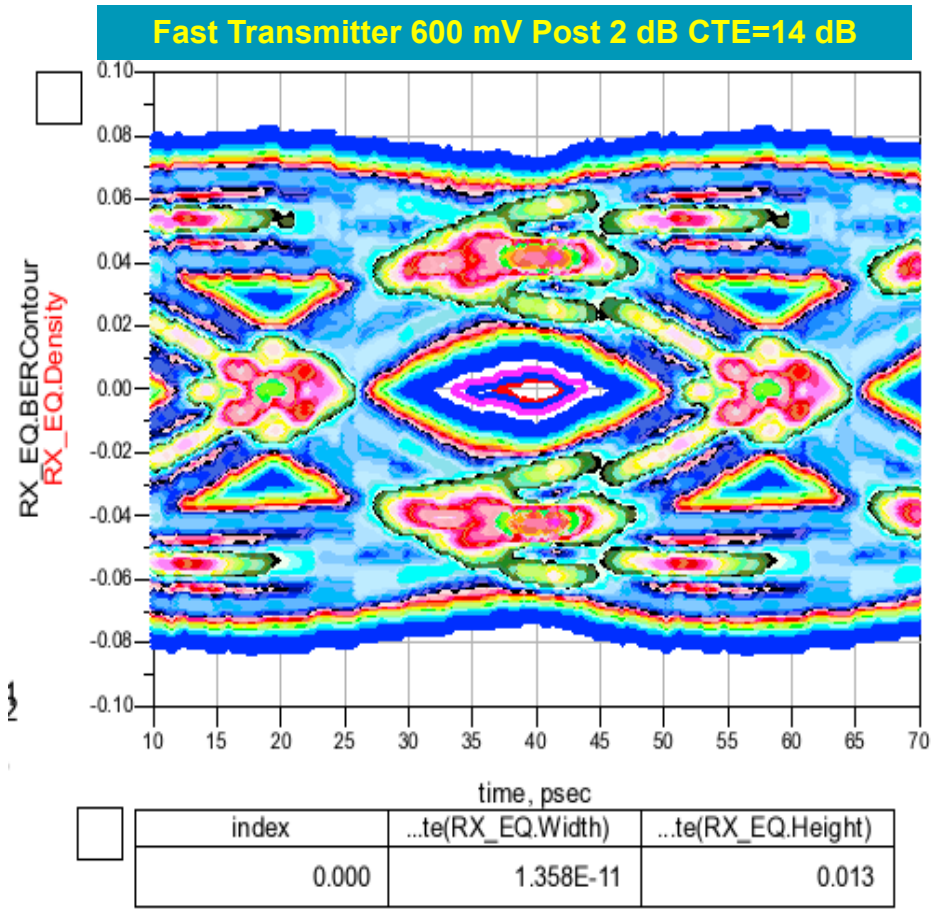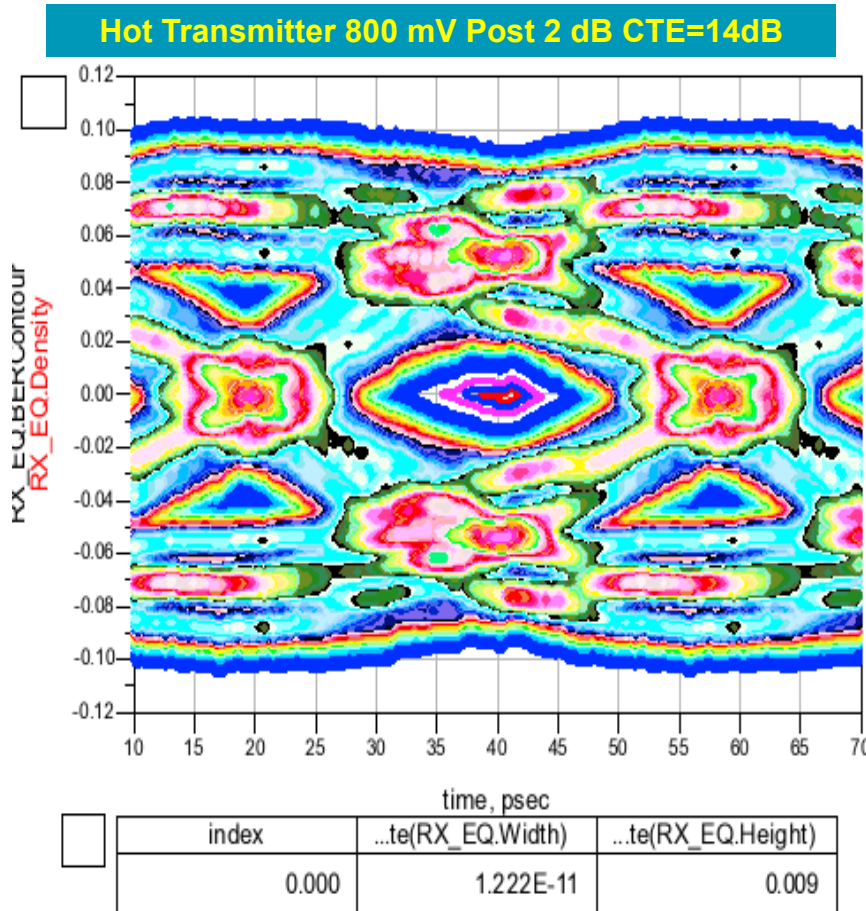
- Fast driver performs better for higher loss channel
  - For full simulation details see http://www.ieee802.org/3/bm/public/mar13/ghiasi_01_0313_optx.pdf
  - Increasing CTLE filter peaking did not improve far end eye opening just reduced TX FFE setting
  - Optimizing TX FFE pre-cursor improves results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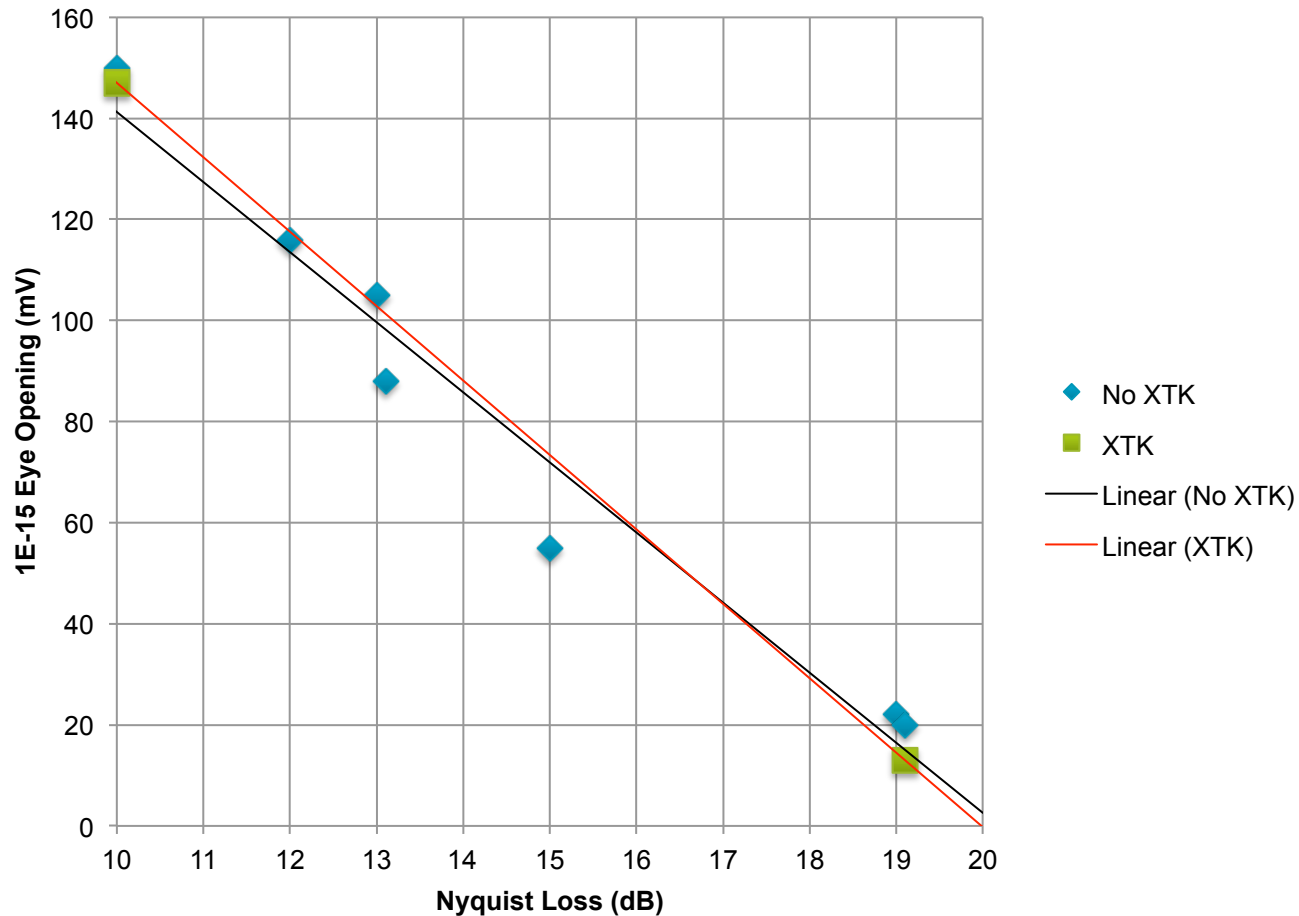

FR4 Channel
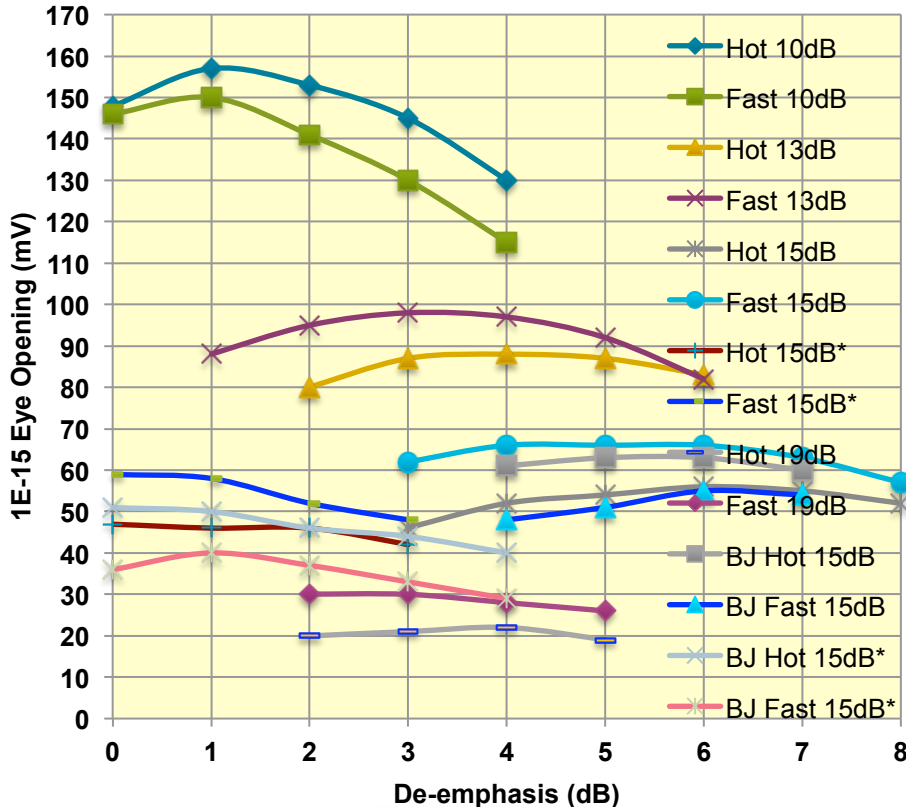
TE Channel and Hirose
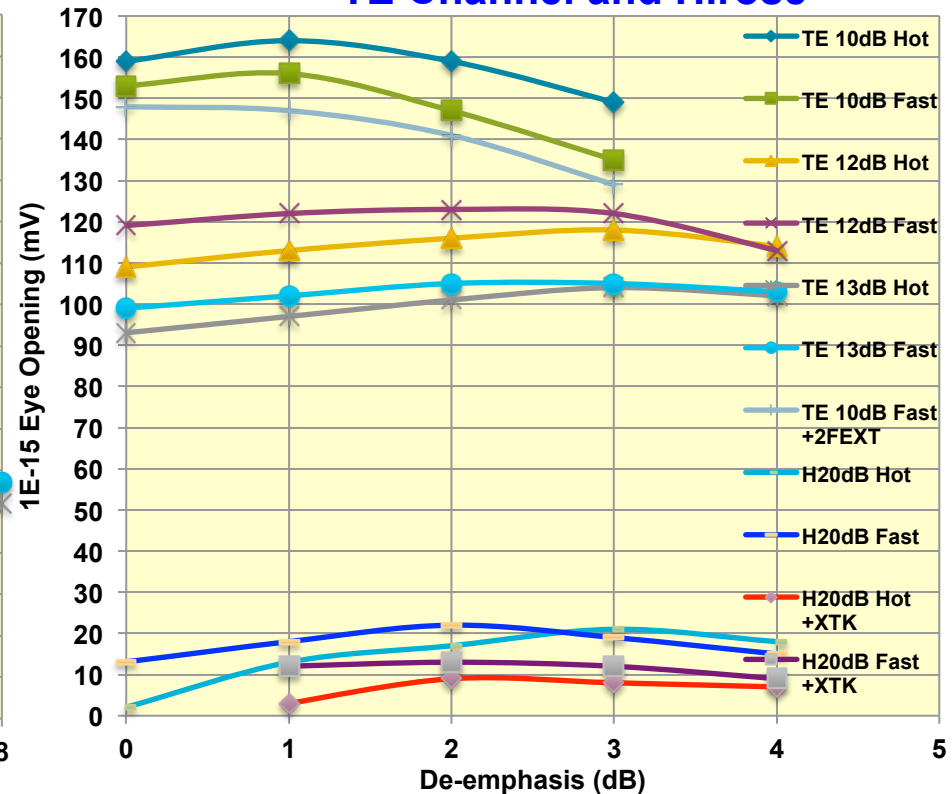
- For worst case transmitter configuration hot vs fast
  - Result with BJ package not included

- A channel with loss of 1.4 dB @12.89 GHz was added to move the statistical eye mask reference to TP0a from TP0
  - The eye mask allow flexibility in the driver-package combination allowed and improve the correlation to TP5 receive eye
  - A BJ like package having inherent DJ can still meet TP0a if the driver inherent jitter is reduced and with driver amplitude of 800 mV

- This analysis as well as independent COM analysis have now shown 19-20 dB is not feasible with just TX FFE and CTLE receiver
  - Hirose 19 dB channel resulted in an eye opening of just ~ 10 mV TP5

- Based on this study the CAUI-4 adhoc should focus on defining 15 dB C2C
  - Need to leverage TP0a eye mask
  - 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

- Need to qualify if 15 dB C2C has sufficient broad market potential.

Thank You !