Simulations and Methodology Addressing CAUI-4 C2C

IEEE 802.3 bm

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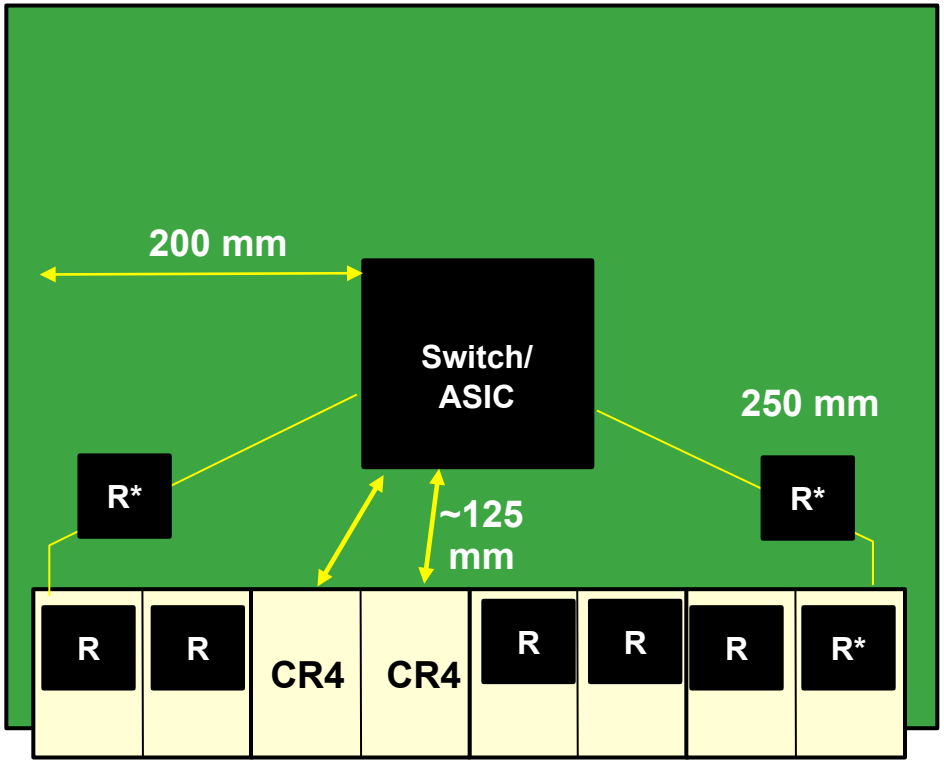
Overview

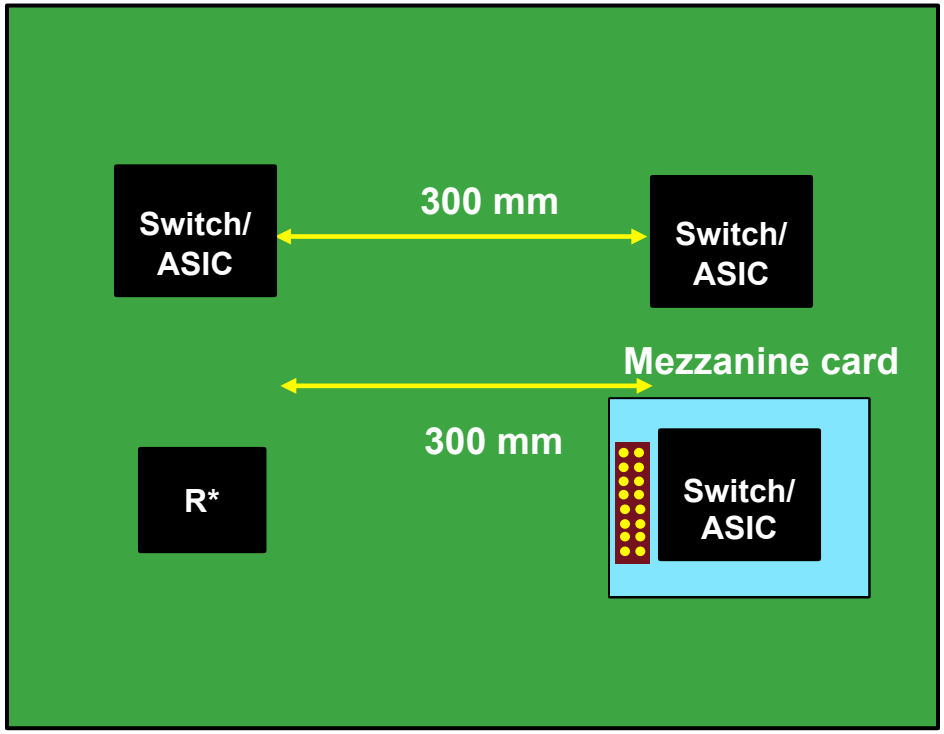
- A CAUI-4 chip to chip adhoc has been investigating channel with13-20 dB assuming TX FIR with RX CTLE
- Results presented in Phoenix showed feasibility of 15 dB channel http://www.ieee802.org/3/bm/public/jan13/ghiasi_01a_0113_optx.pdf
- Results presented in Phoenix also showed far end is function of transmitter amplitude, rise/fall time, and jitter
- Two type of transmitter were defined
  - Hot transmitter with 800 mV diff Amp, TJ=0.28 UI, and Tr/Tf=17 ps
  - Fast transmitter with 600 mV p-p diff Amp, TJ=0.18 UI, Tr/Tf=12 ps
- Hot transmitter delivered greater far end eye opening up to about 11-12 dB channel loss but as the channel loss increases fast transmitter with less amplitude delivered better far end eye
- Transmitter trade offs impact on the far end eye are further investigated as function of rise time and jitter.

CAUI-4 Applications and Background

- http://www.ieee802.org/3/bj/public/jul12/ghiasi_02a_0712.pdf identified CAUI-4 applications as well as limitations
- Most common CAUI-4 C2C application is between big chip and little chip
  - Big chip will have challenging ball map and package loss will in ~ 2 to 3 dB
  - Little chip have easily routable ball map and package loss will be in 0.5 to 1.5 dB



* R – Retimer/CDR



PCB Reach for Various Interfaces

- 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

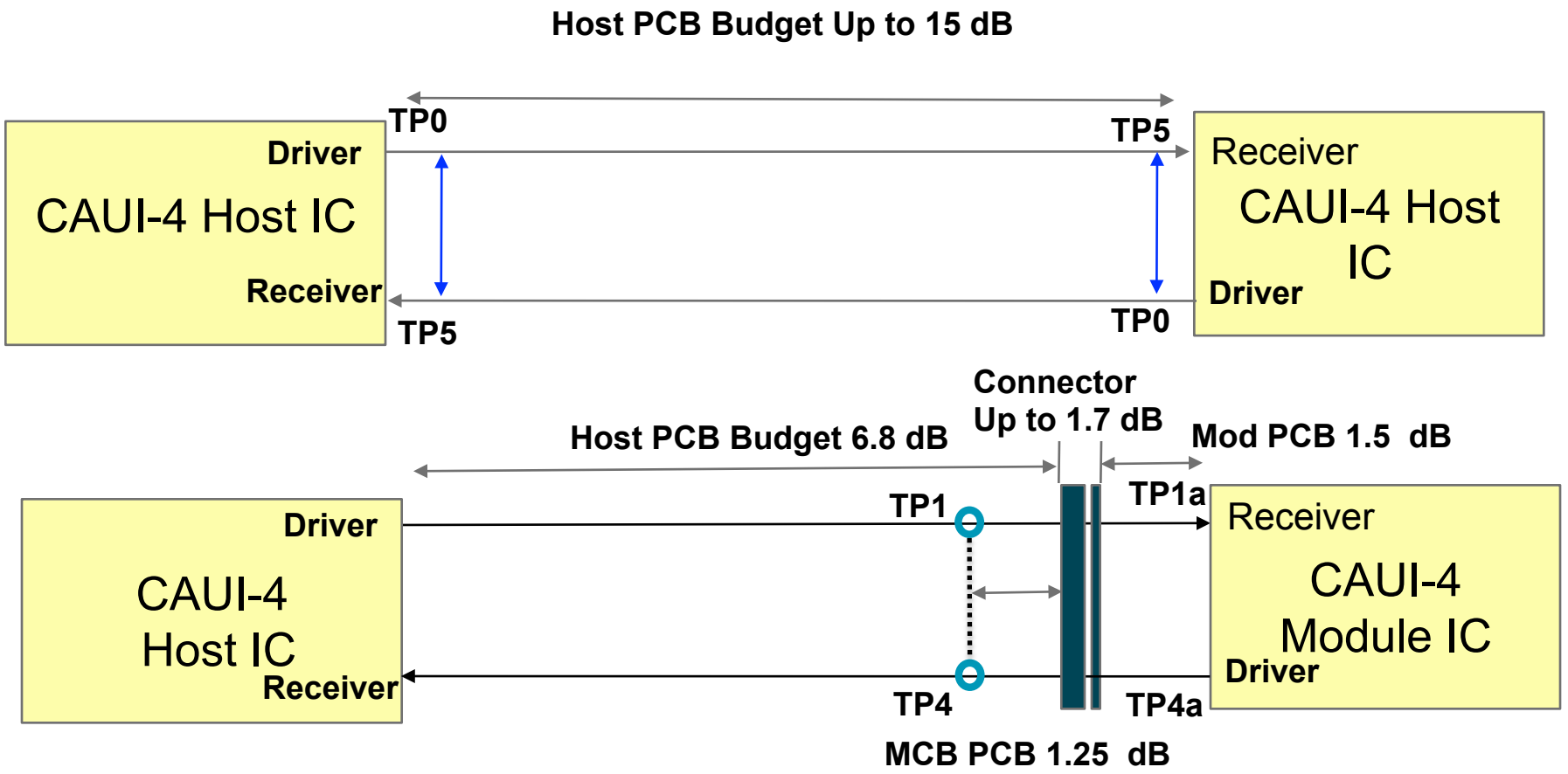
Host Trace Length (in)	Total Loss (dB)	Host Loss(dB)	FR4-6	N4000-13	N4000-13SI	Megtron 6
Nominal PCB Loss/in at 5.15 GHz	N/A	N/A	1.00	0.79	0.56	0.43
Nominal PCB Loss/in at 12.89 GHz	N/A	N/A	2.00	1.60	1.25	0.92
CAUI Classic	10.5	6.81	6.8	8.6	12.2	15.8
PPI CL85A/86A with one connector & HCB#	6.5	4.37	4.4	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.

CAUI-4 Architecture and Reference Points

- The bm group need to further study CAUI-4 chip to chip application

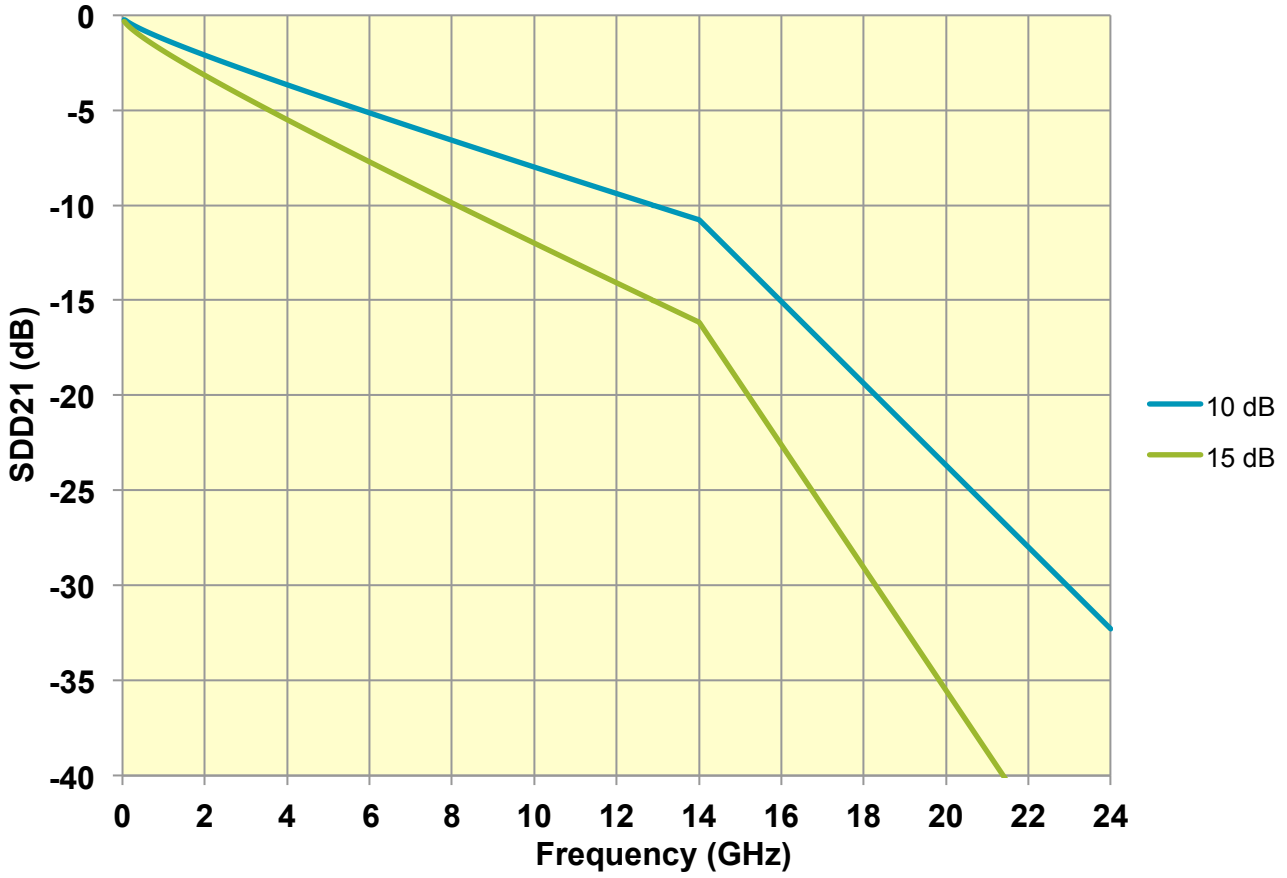


Increasing CAUI-4 Chip to Chip Reach

- Parameters that can increases CAUI-4 chip to chip reach
- Transmitter parameters and exact parameter that can be improved is dependent if this is large ASIC or PHY
  - Rise/fall time, jitter, and amplitude have direct impact on the far end eye a simple eye mask could allow trading off these parameters
    - Results here show faster/lower jitter driver delivers better far end eye than one with larger amplitude
  - Return loss – no change
- Channel parameters
  - ILD, ICN, return loss, SDD21 a1 fit are key parameters that determine far end eye a tool such as COM could be used to trade of various parameters
  - Return loss – no change
- Receiver parameters
  - CTLE gain 1-9 dB – no change
  - Sensitivity – to be studied if it needs to improved from 100 mV
  - Return loss – no change

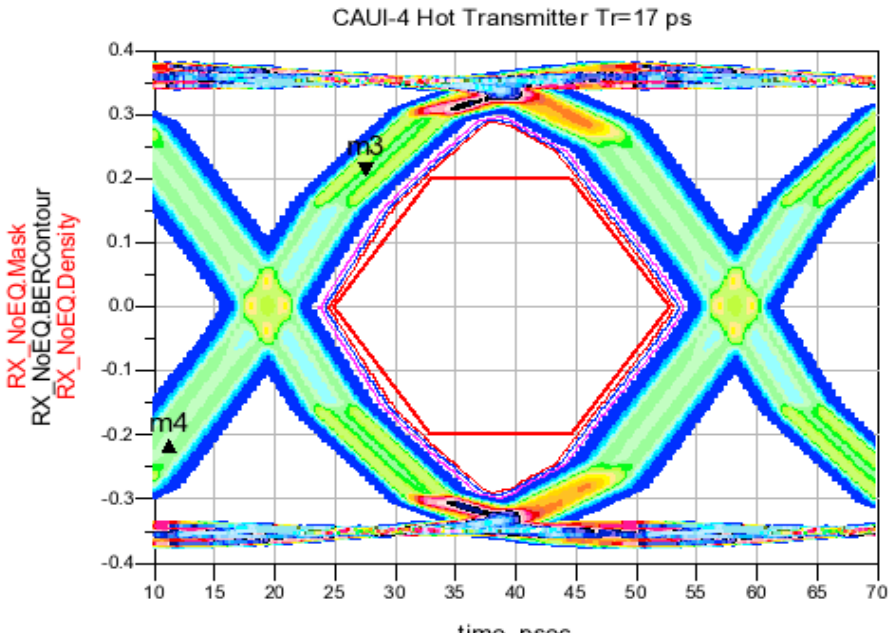
CAUI-4 Chip to Chip Informative Channel

- CAUI-4 chip to chip loss budget
  - By improving some of the transmitter parameters and operating the link where naturally has lower ICN/ILD the loss budget can be 15 dB



Example 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)



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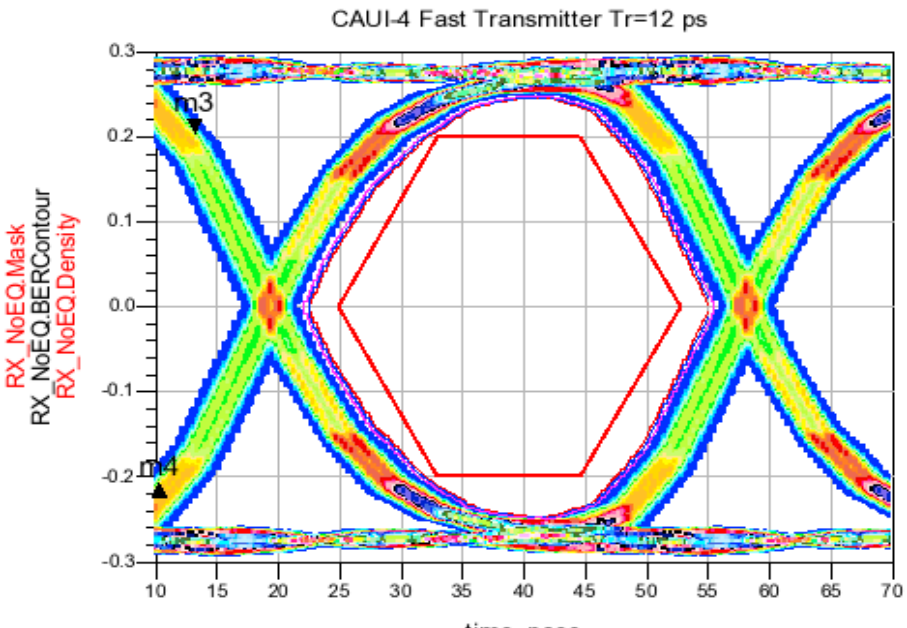

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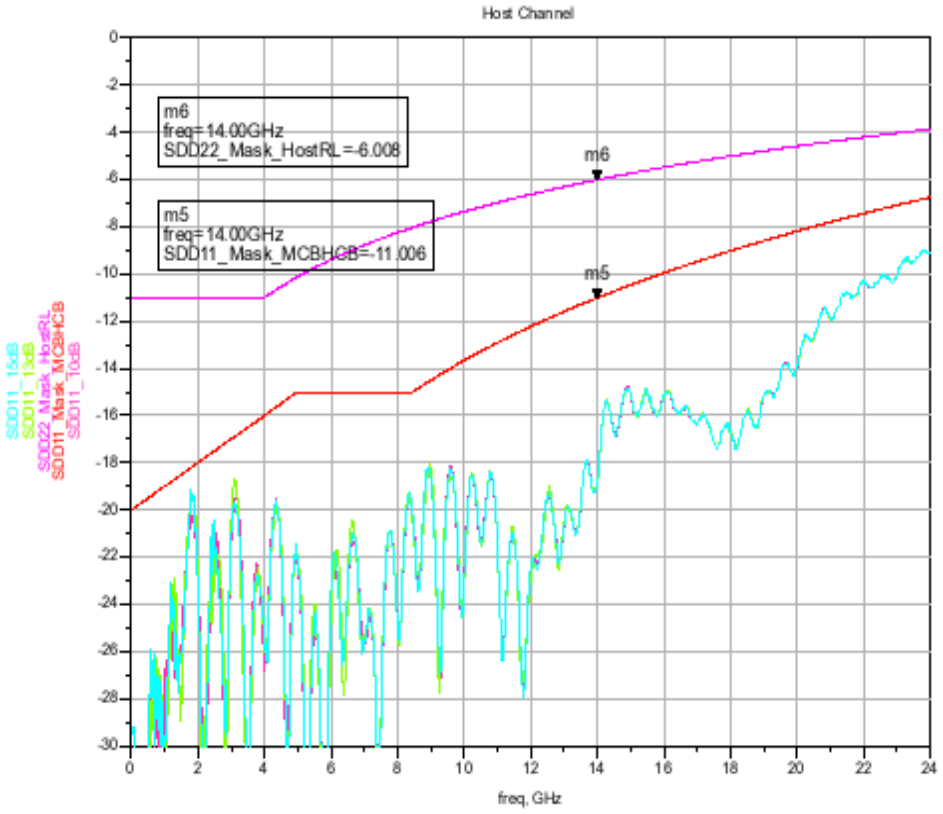
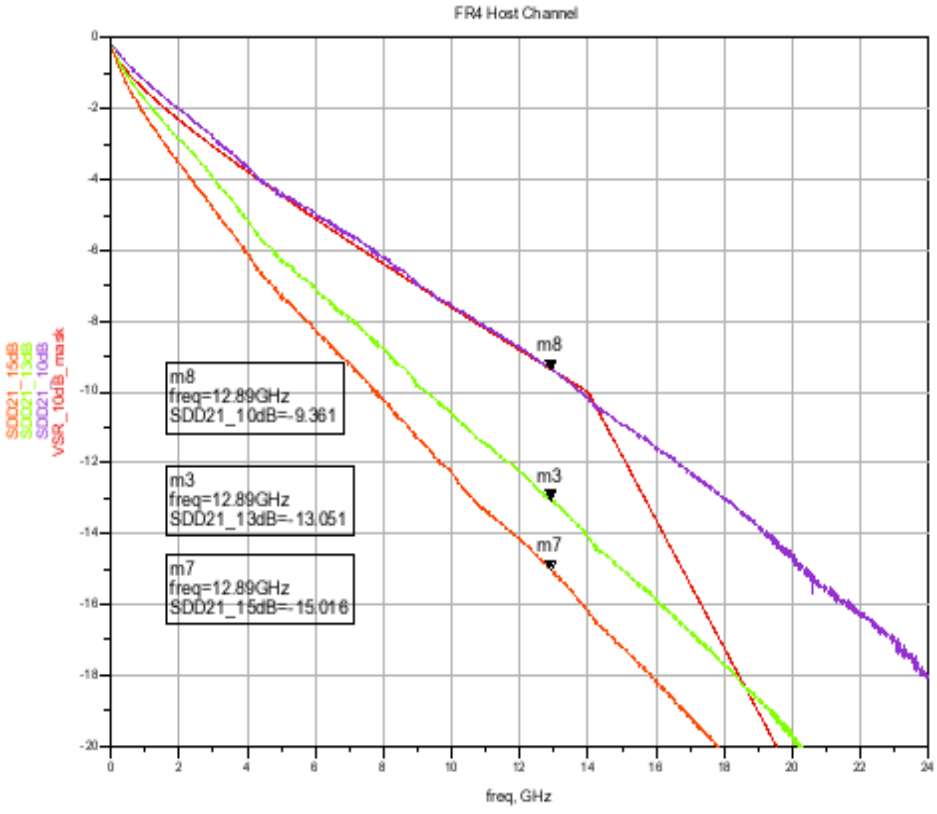
FR4 Channel Response

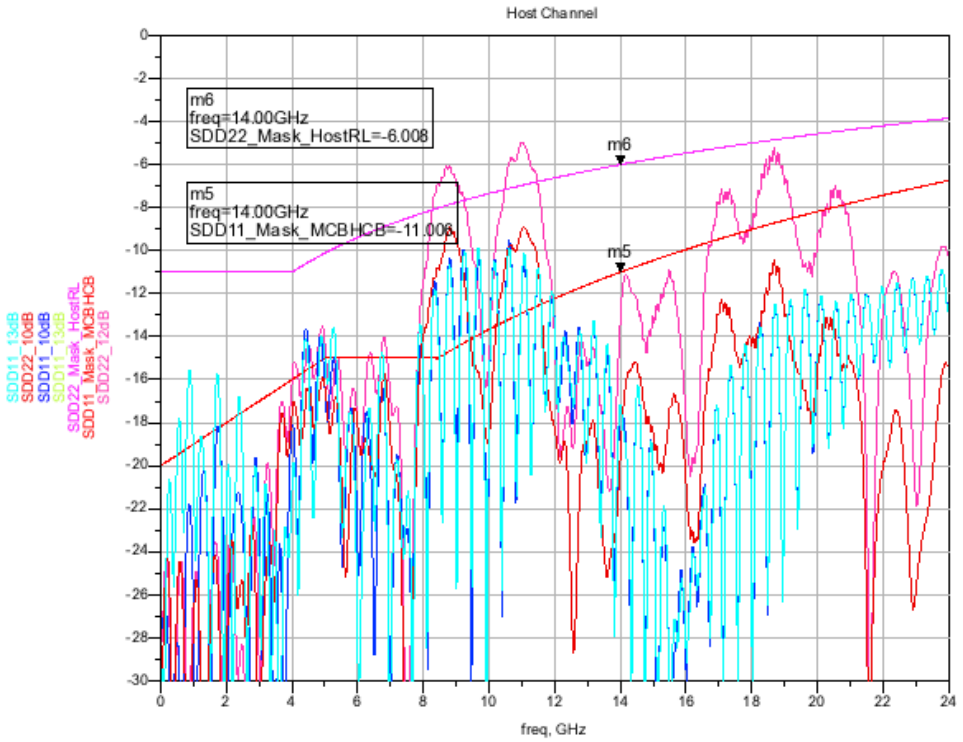
- Channels are
  - 5” FR4 Channel with two long (80 mils) vias and 2 12 mils stub
  - 5” FR4 + 3” Meg6 Channel
  - 5” FR4 + 5” Meg 6 Channel

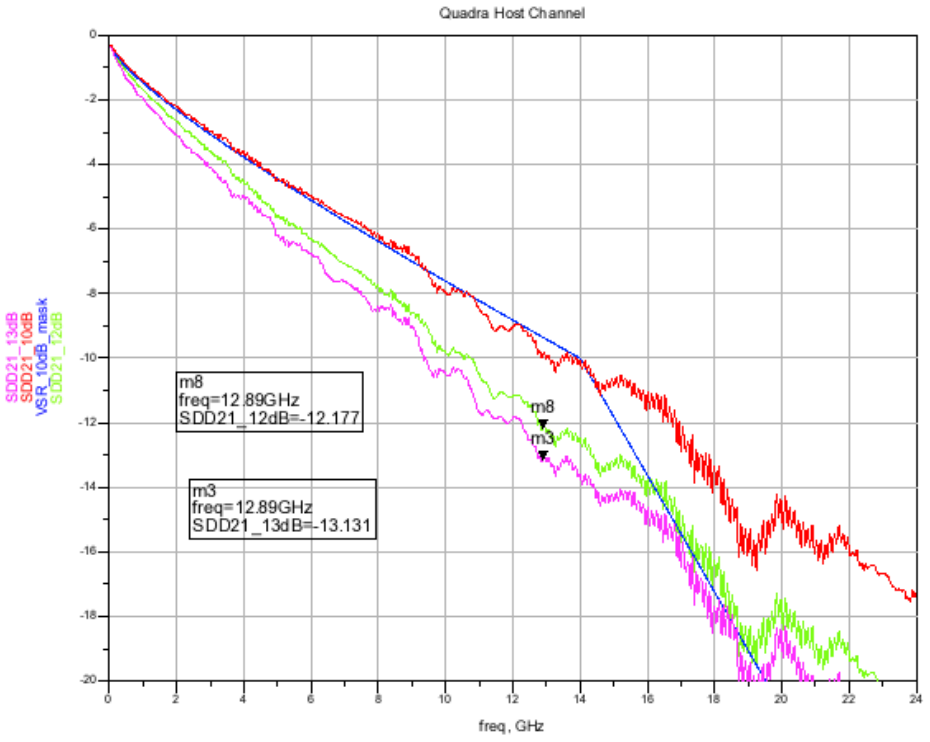




TE 7” Quadra Channel Response

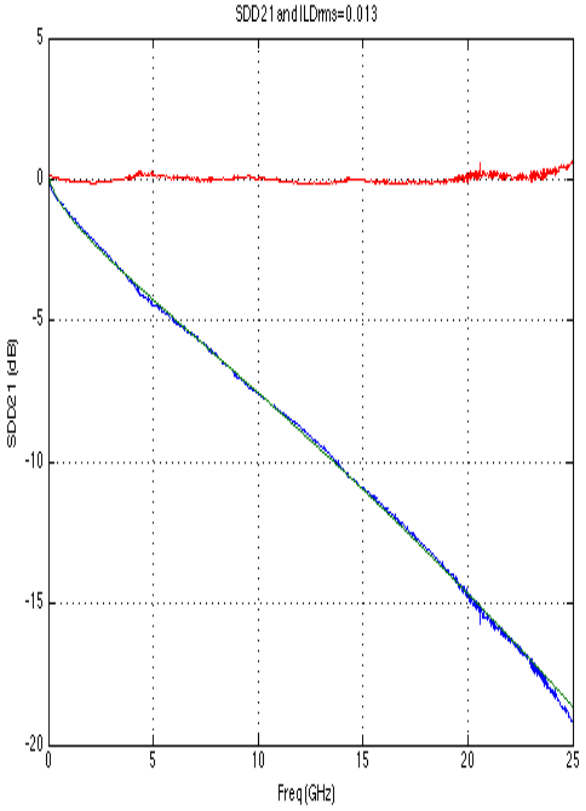
- Channels are
  - TE Quadra channel with 10 dB loss
  - TE 7” Quadra + 1.25” plug board+ 2” Meg6 Channel
  - TE 7” Quadra + 1.25” plug board + 2” FR4 Channel

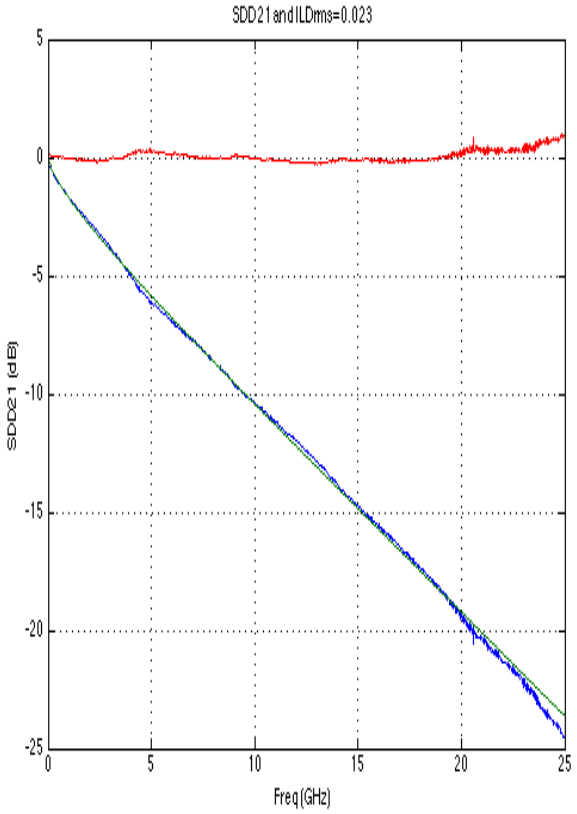


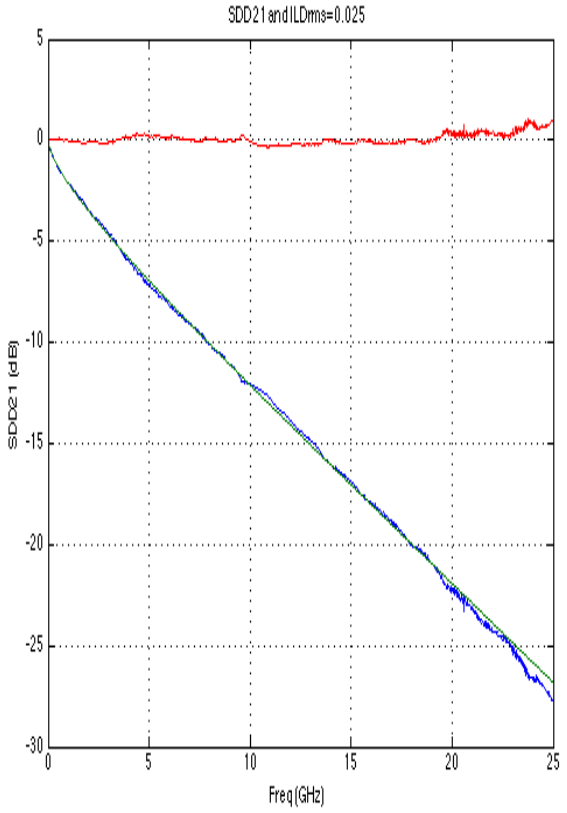


FR4 Channel ILD and Fit

- 10 dB channel has ILDrms=0.013 and a1/a0=0.23
- 13 dB channel has ILDrms=0.023 and a1/a0=0.59
- 15 dB channel has ILDrms=0.025 and a1/a0=0.46

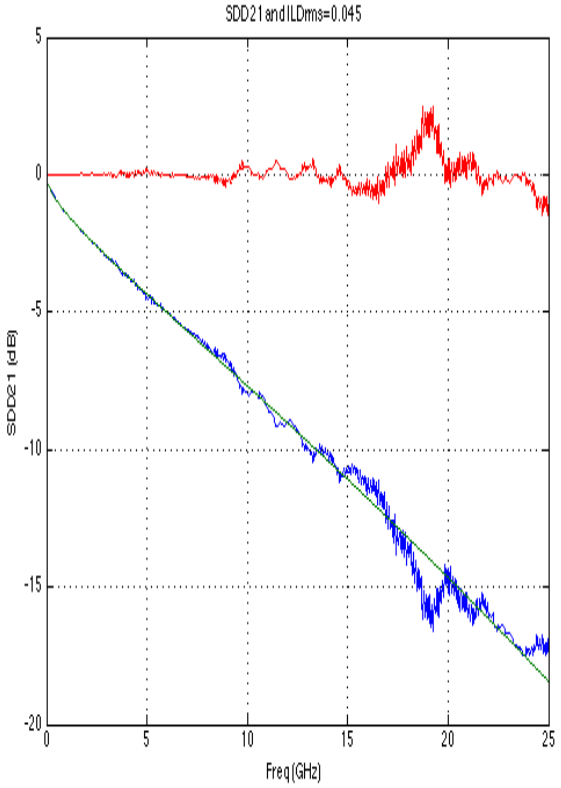


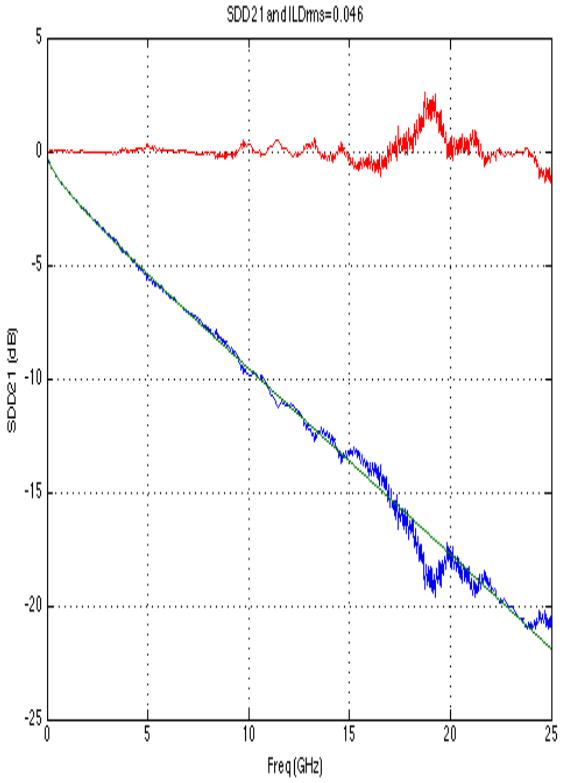


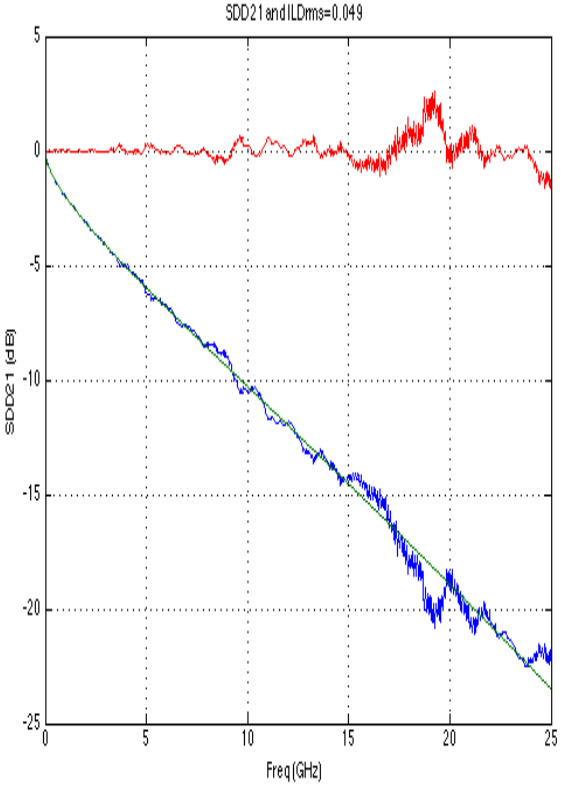


TE Quadra Channel ILD and Fit

- 10 dB channel has ILDrms=0.045 and a1/a0=0.45
- 12 dB channel has ILDrms=0.046 and a1/a0=0.62
- 13 dB channel has ILDrms=0.049 and a1/a0=0.34





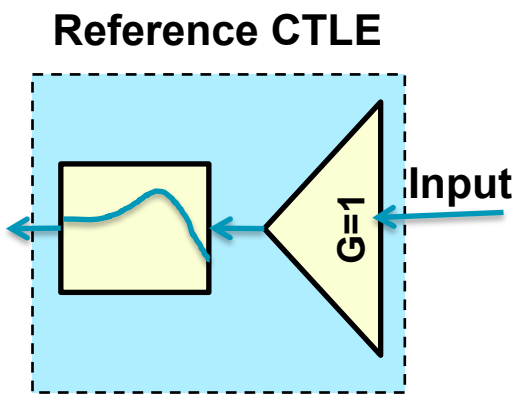


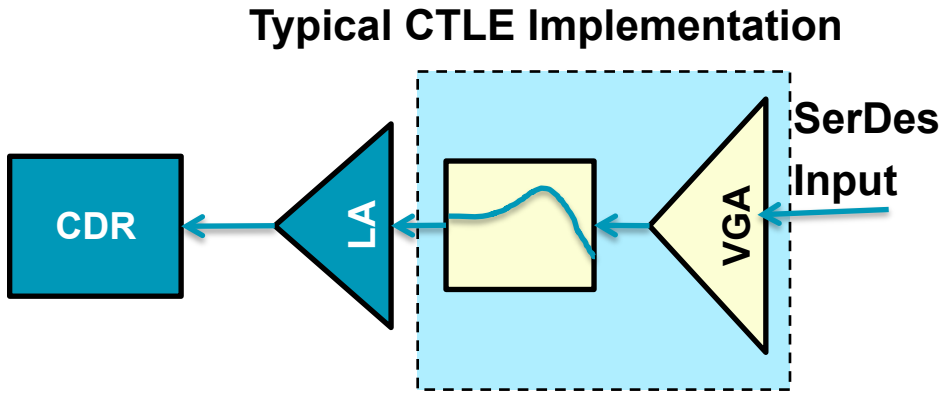
OIF 28G VSR/CAUI-4 Chip to Module CTLE Definition

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

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

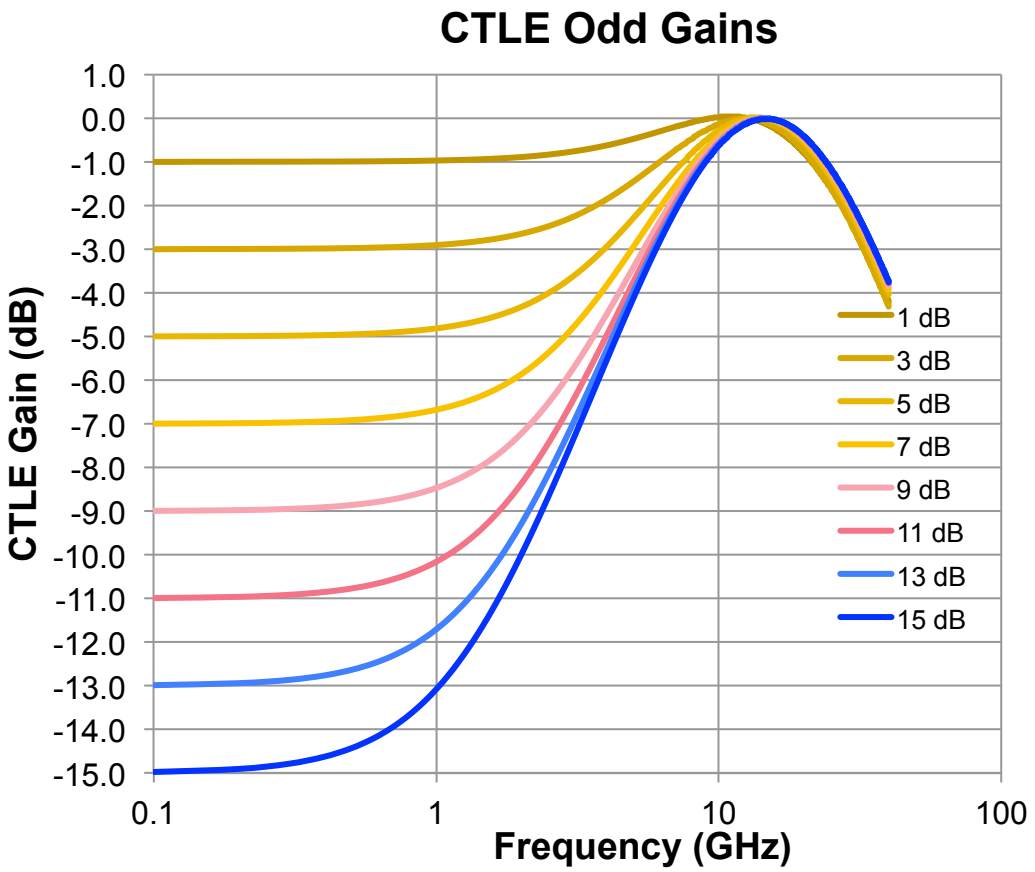
  - For reference comparison the CTLE should have no AC gain
  - Actual implementation will have VGA as well as limiting AMP with AC gain
  - Scopes software CTLE implementation is based on the reference CTLE for TP5 compliance





Expanded CTLE Response

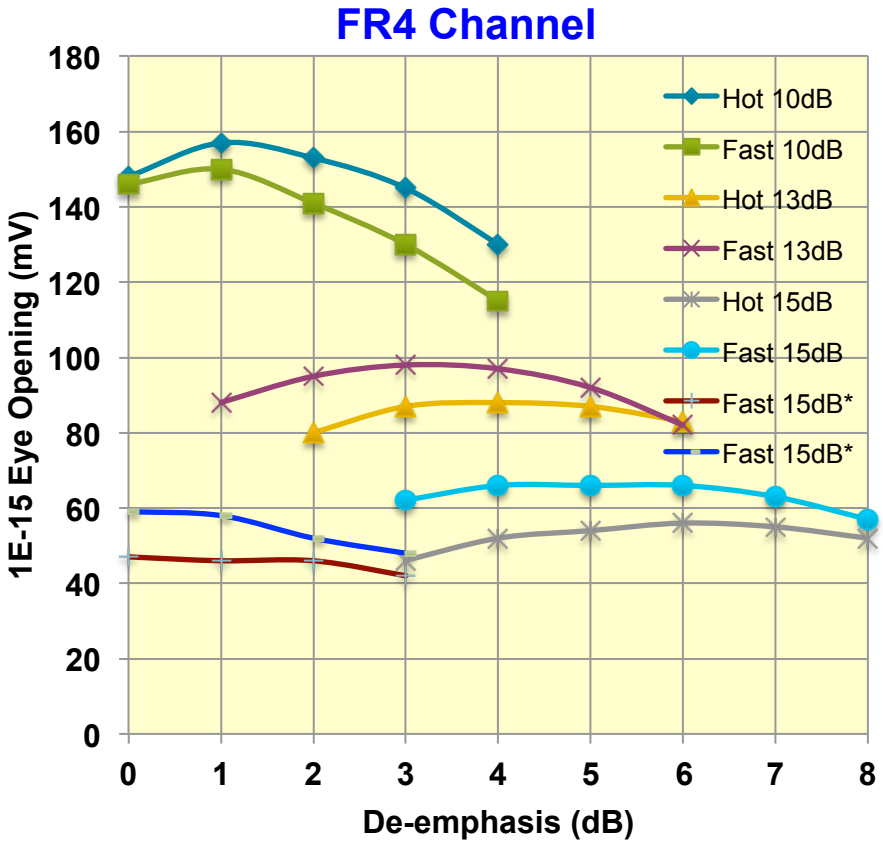
- OIF 28G-VSR and CAUI-4 chip to module define CTLE response from 1-9 dB
  - Additional CTLE filter 10-15 are provided for purpose of CAUI-4 C2C study

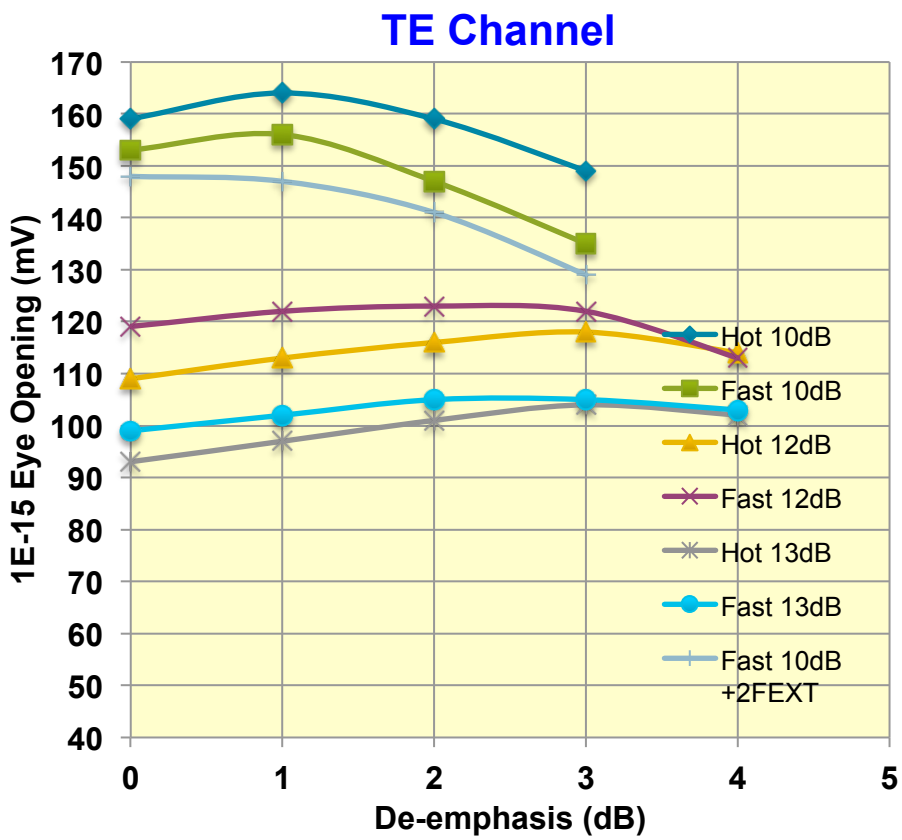


Gain (dB)	G (Linear)	Z (GHz)	P1 (GHz)	P2 (GHz)
1	0.89	7.1e9	1.86e10	1.41e10
2	0.795	7.1e9	1.86e10	1.41e10
3	0.795	7.1e9	1.56e10	1.41e10
4	0.633	4.98e9	1.56e10	1.41e10
5	0.563	4.35e9	1.56e10	1.41e10
6	0.5	3.82e9	1.56e10	1.41e10
7	0.446	3.4e9	1.56e10	1.41e10
8	0.398	3e9	1.56e10	1.41e10
9	0.3548	2.672e9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

Summary of Eye Opening

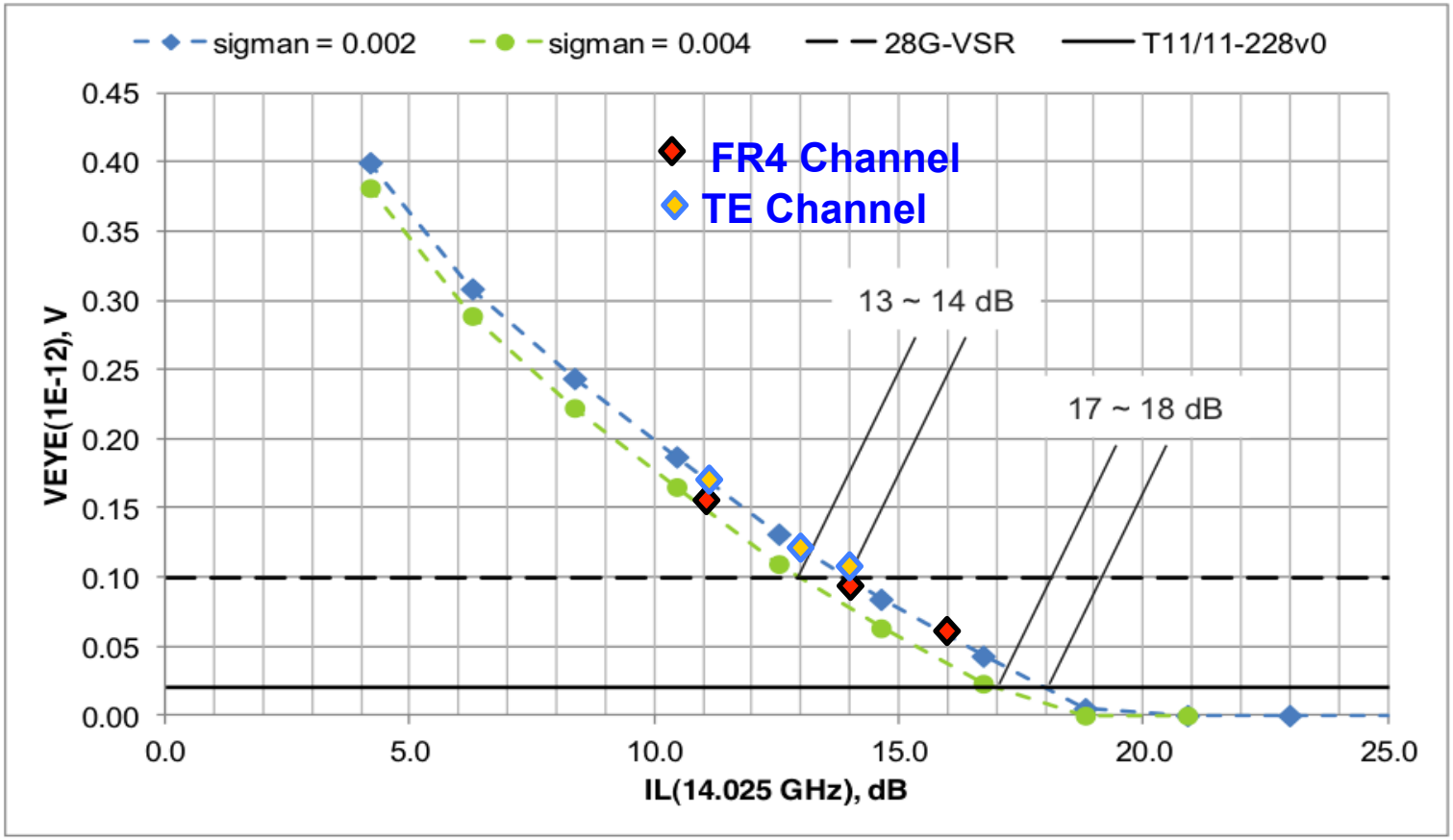
- Fast driver performs better for higher loss channel
  - All results are with 9 dB CTLE with exception of result with * based on 14 dB CTLE
- TE Quadra 10 dB channel has slightly better performance compare to channel with two long vias (~80 mils) and two short stub (~12 mils)
- Considering only 2 FEXT TE 10 dB channel ~ 6% VEC penalty





Results Matches Healey T11 VSR Simulations

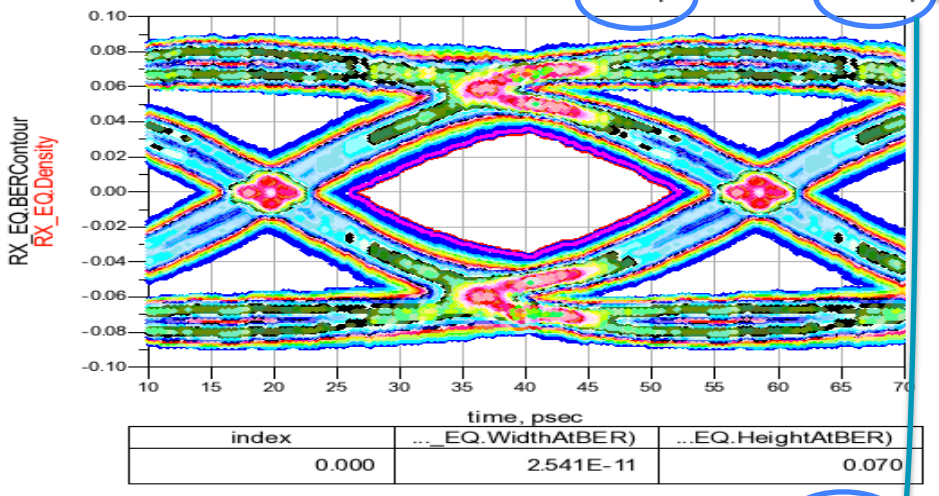
- **Full results available from T11 website** http://www.t11.org/fd/11-448
  - When package loss of ~ 1 dB was included the results matches 2 mV ICN line



NOTE: Insertion loss includes device packages

Effect of Driver DJ and Rise Time on TP5

- Fast driver (600 mV)as function of rise and fall time



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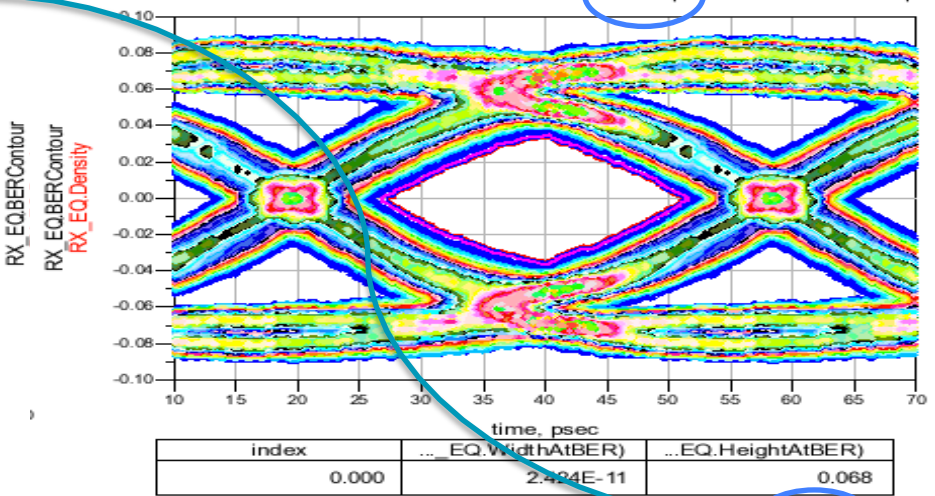

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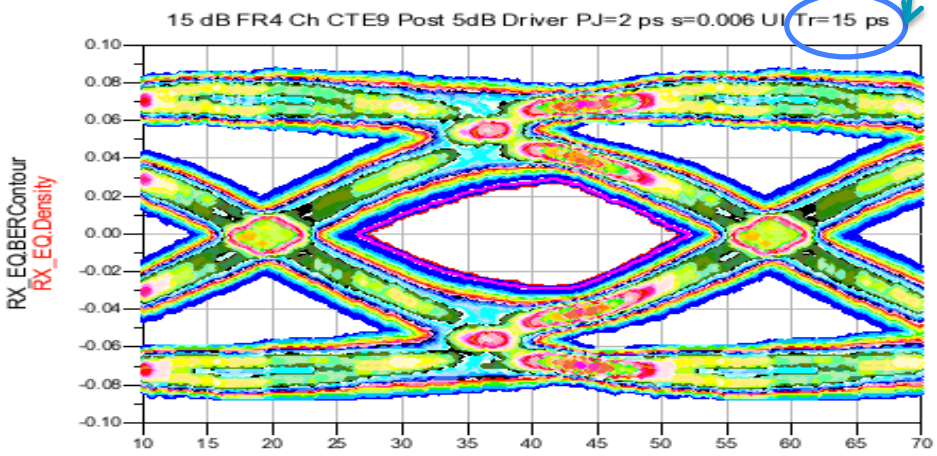

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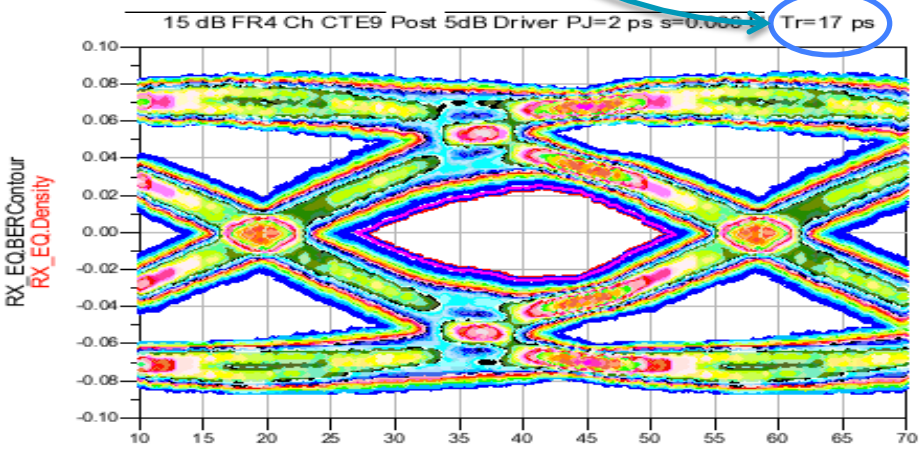

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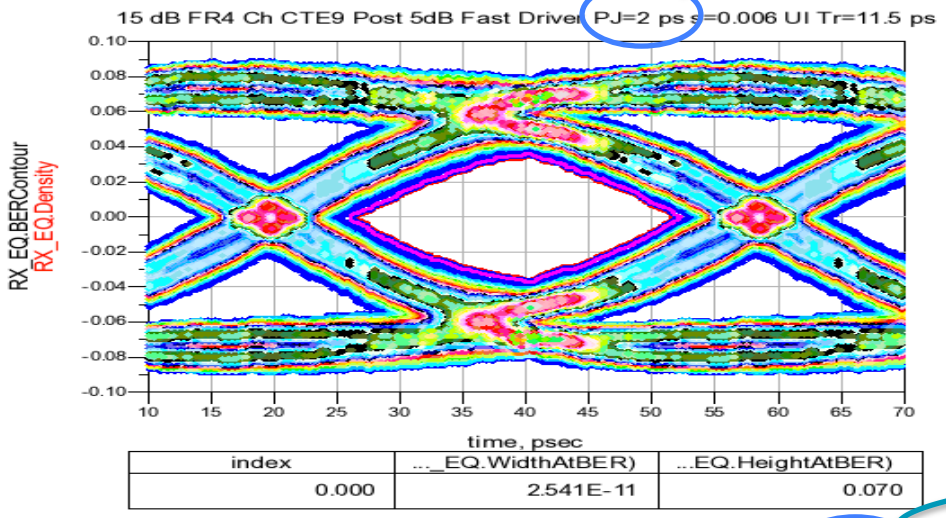
Effect of Driver DJ and Rise Time on TP5

- Driver (600 mV p-p) Rise and fall time has the biggest impact on TP5



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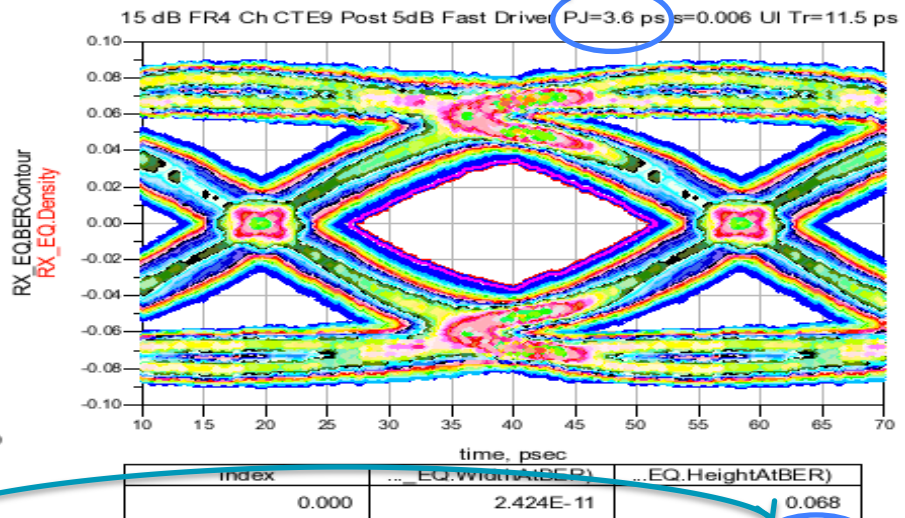

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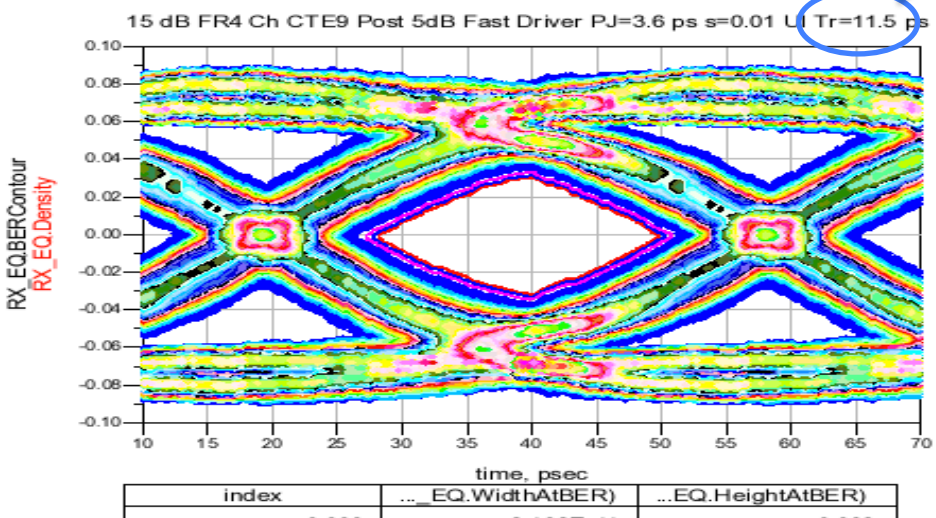

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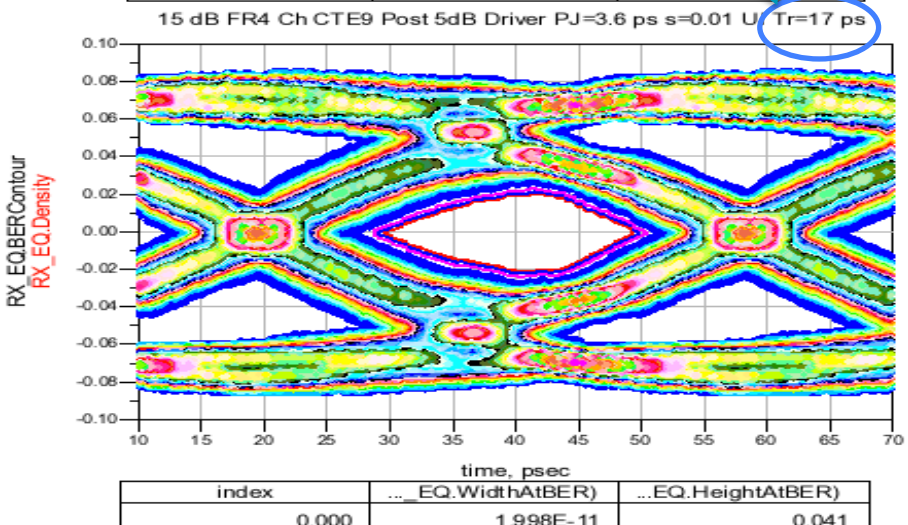

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How to deal with compliance

- Transmitter Normative
  - CAUI-4 test method at TP1a can be applied to TP0a
  - Apply statistical eye mask for compliance either at 1e-12 or 1E-15
  - Eye mask allows to trade off transmitter Tr/Tf, jitter, and amplitude to deliver similar TP5 eye for range of transmitter for given channel
    - COM does not provide trading off transmitter property for equal far end eye
    - BJ output waveform does capture amplitude aspect, indirectly the Tr/Tf, but jitter effect drop off due to average waveform
- Receiver Normative
  - Use CAUI-4 TP1a test method with software CTLE to determine hardware compliance as well as calibration of stress generator for TP5
  - The same CTLE can be used on simulated channel to determine far end eye for compliance with commercial tools ADS, SiSoft based on actual driver AMI model
- Channel Informative
  - Define generic 15 dB loss but actual link performance will vary based on the channel impairment
  - As a group we can retrofit COM with generic transmitter model as a tool to qualify channels

Summary

- For CAUI-4 chip to chip two channels were investigated
  - FR4 channel include deep vias and short stubs
  - TE Quadra based channel
- Result shown here are far end eyes similar to TP1a, which excludes DC block, receiver package and parasitic actual eye opening at the slicer would ~25% smaller
  - Most of the results are observed with 9 dB CTLE and some with 14 dB CTLE having no AC gain
  - Increasing CTLE peaking from 9 dB to 14 dB made the results slightly worse
  - Hot transmitter has comparable performance to fast transmitter having 25% less amplitude
  - As the channel loss increases >12 dB fast TX start performing better
  - Use of statistical eye mask (already established for TP1a testing) at TP0a is an effective way to allow trade-off transmitter Tr/Tf, jitter, and amplitude
- For CAUI-4 C2C to support 15 dB assuming TX FFE and RX CTLE TP5 sensitivity need to be 50 mV from current chip to module limit of 100 mV at TP1a.

Thank You !