XLAUI/CAUI Electrical Specifications

IEEE 802.3ba
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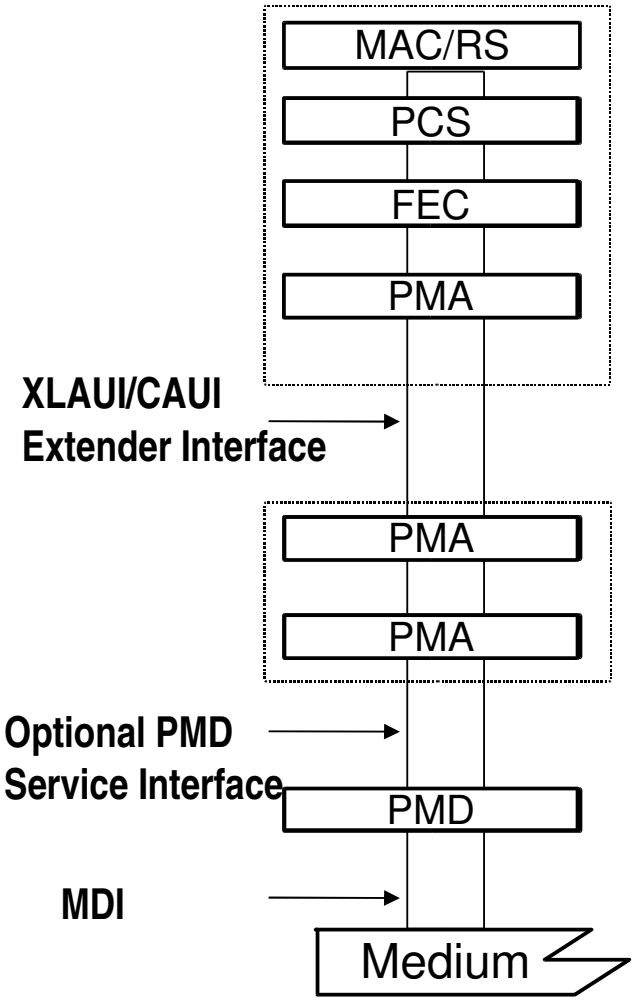
Overview

- XLAUI/CAUI interface
- Optimized electrical interface for XLAUI/CAUI
- Channel simulation
- Channel measurement
- Jitter transfer

The proposed XLAUI/CAUI are not final and are subject to the IEEE review process.

XLAUI/CAUI Interface

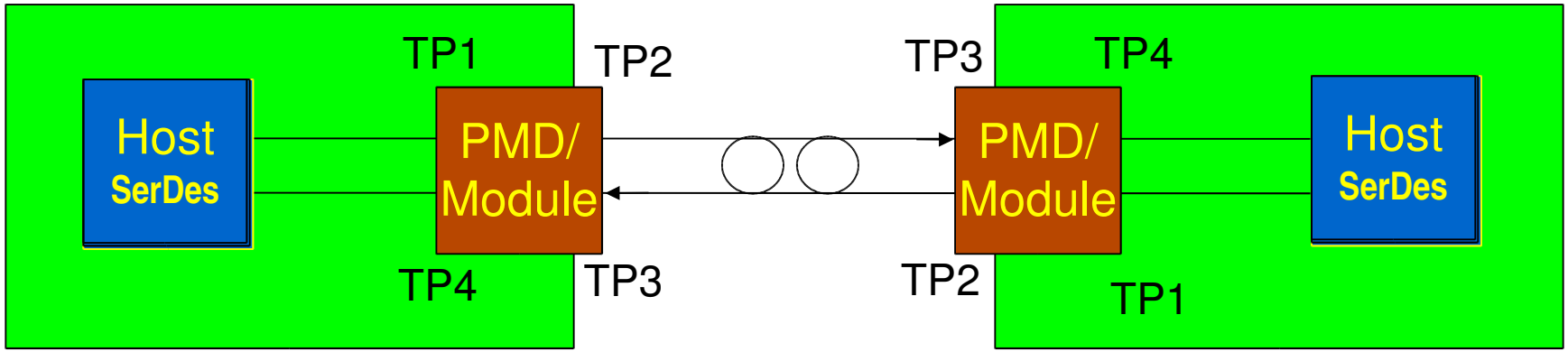
- Simple, low power chip to chip or chip to module interface.
  - Simplifies ASIC SerDes by not requiring to support TP1/TP4 requirements for all PMD's.
- Retimed interface with relax jitter budget and ASIC friendly.
- Take advantage of pre-emphasis to increase PCB loss with simple CDR receiver.
- Operate over ~250 mm FR4-8 stripline or ~375 mm FR4-13 stripline.
- XLAUI/CAUI will be the bolting point for future electrical interface based on 25 GBd/lane.



see ganga_01_0508.pdf for XLAUI and CAUI layer definition

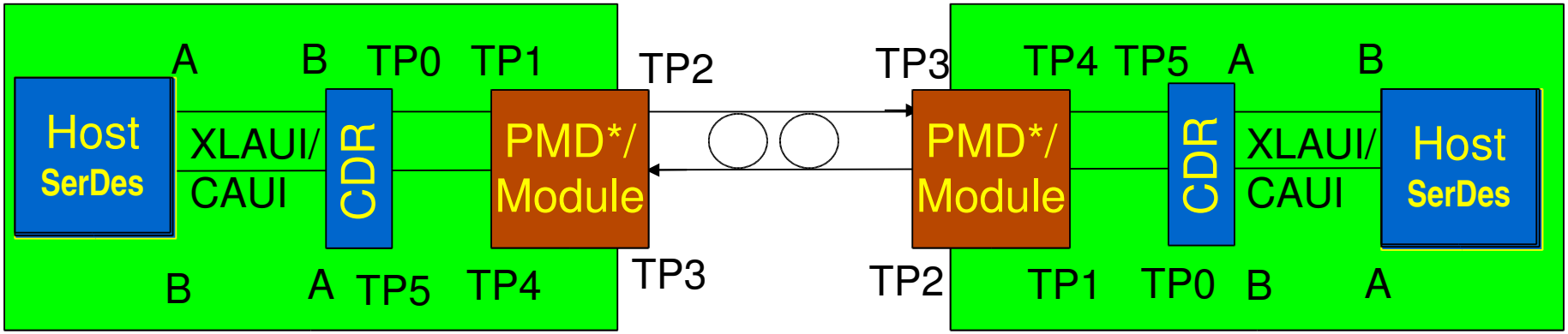
Application Not Using XLAUI/CAUI

- **ASIC capable of interfacing with the PMD are not required to use the XLAUI/CAUI retimer, see petrilla_01_0508.pdf.**
- **Likely scenarios are:**
  - **A simplified ASIC supporting single PMD type**
  - **ASIC SerDes support all PMDs when the technology is mature and there is little power penalty (i.e. SFP+ now).**

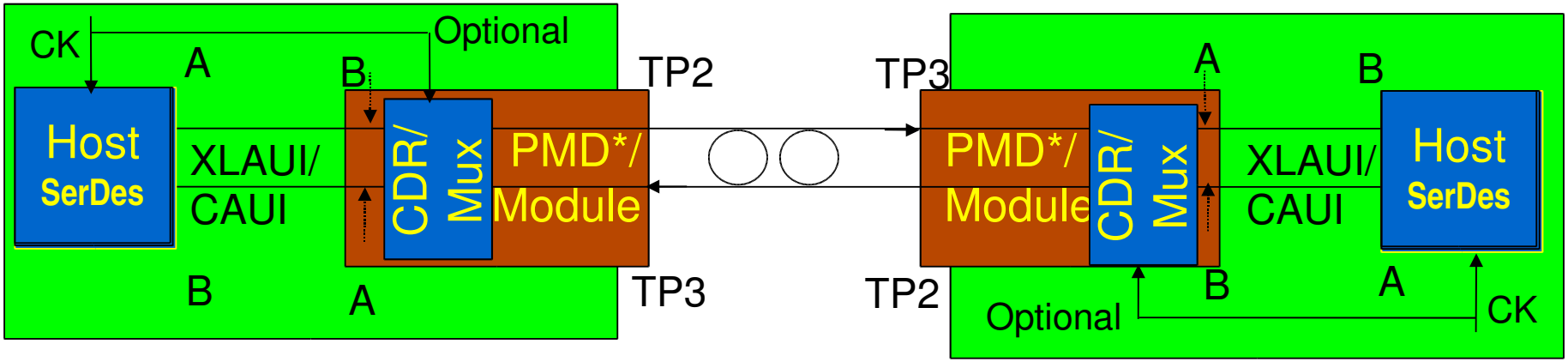


Application XLAUI/CAUI Extender for Front Ports (PMD nx10Gbaud)

- **Application with CDR on the host PCB (QSFP/CSFP)**

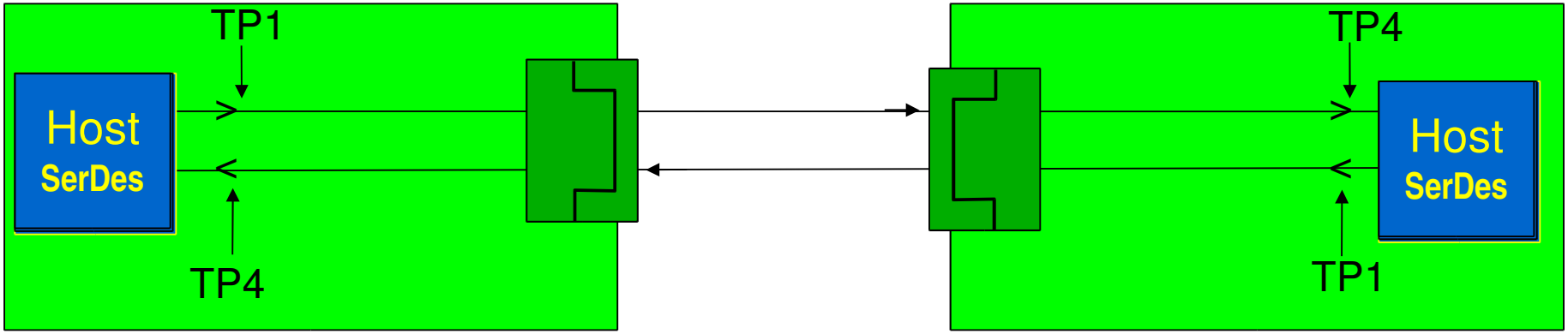


- **Application with CDR or Mux/De-mux in the module (QFP/CFP) with optional XLAUI/CAUI clock**

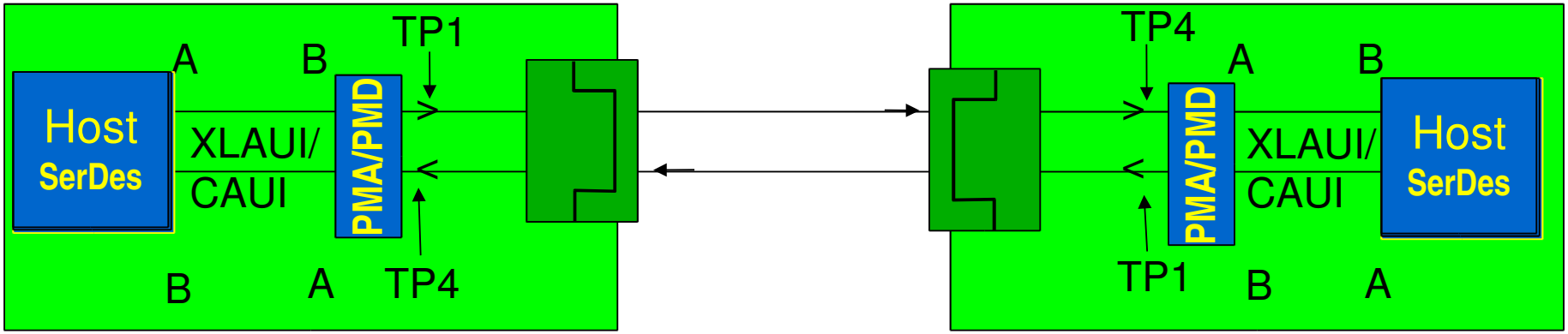


XLAUI/CAUI Extender for KR Application Ports

- **KR application without XLAUI/CAUI Retimer**

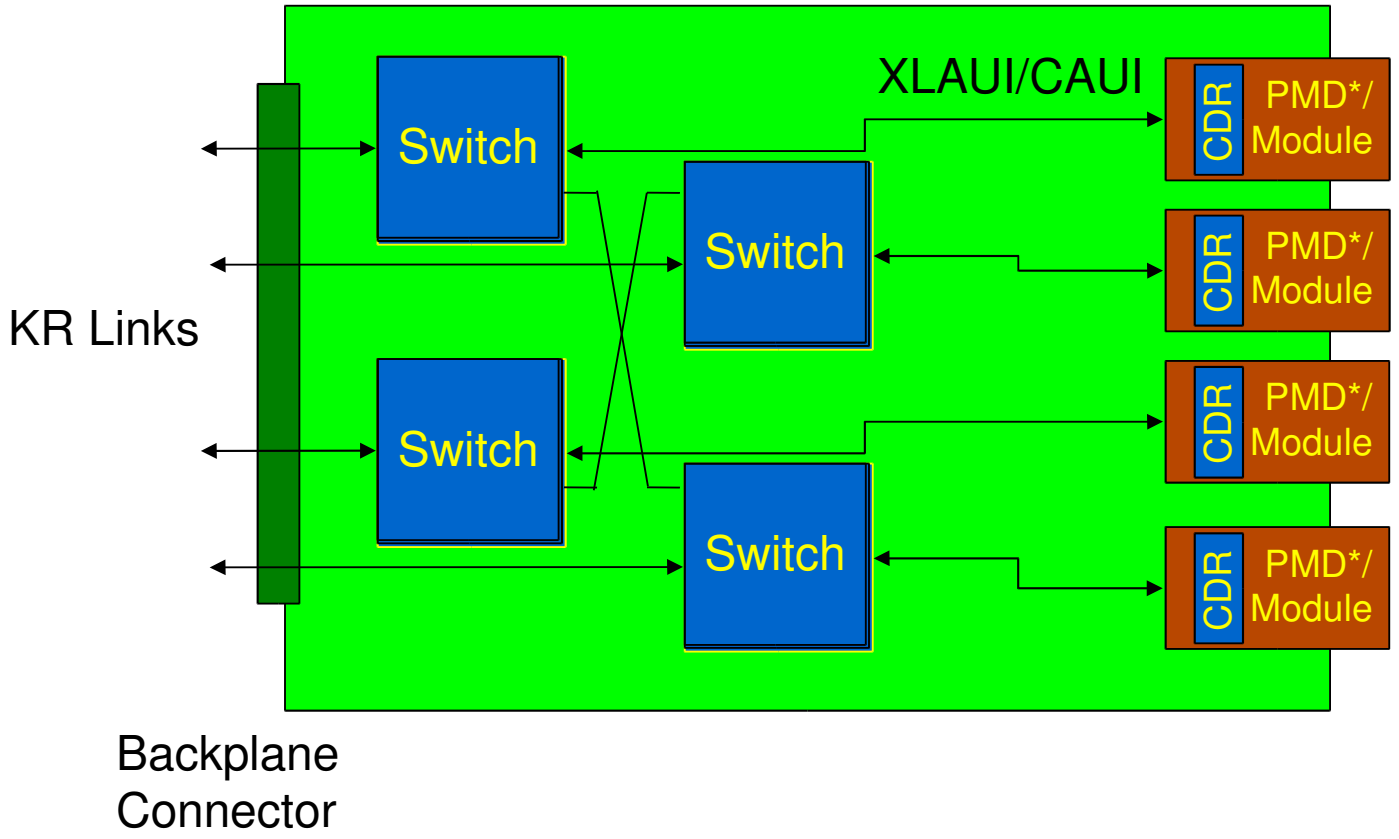


- **KR application with XLAUI/CAUI Retimer**



Linecard Application of XLAUI/CAUI

- **Typical CAUI implementation can be supported with 250 mm on FR4.**
- **In the implementation shown below 375 mm on improved FR4 may be required.**

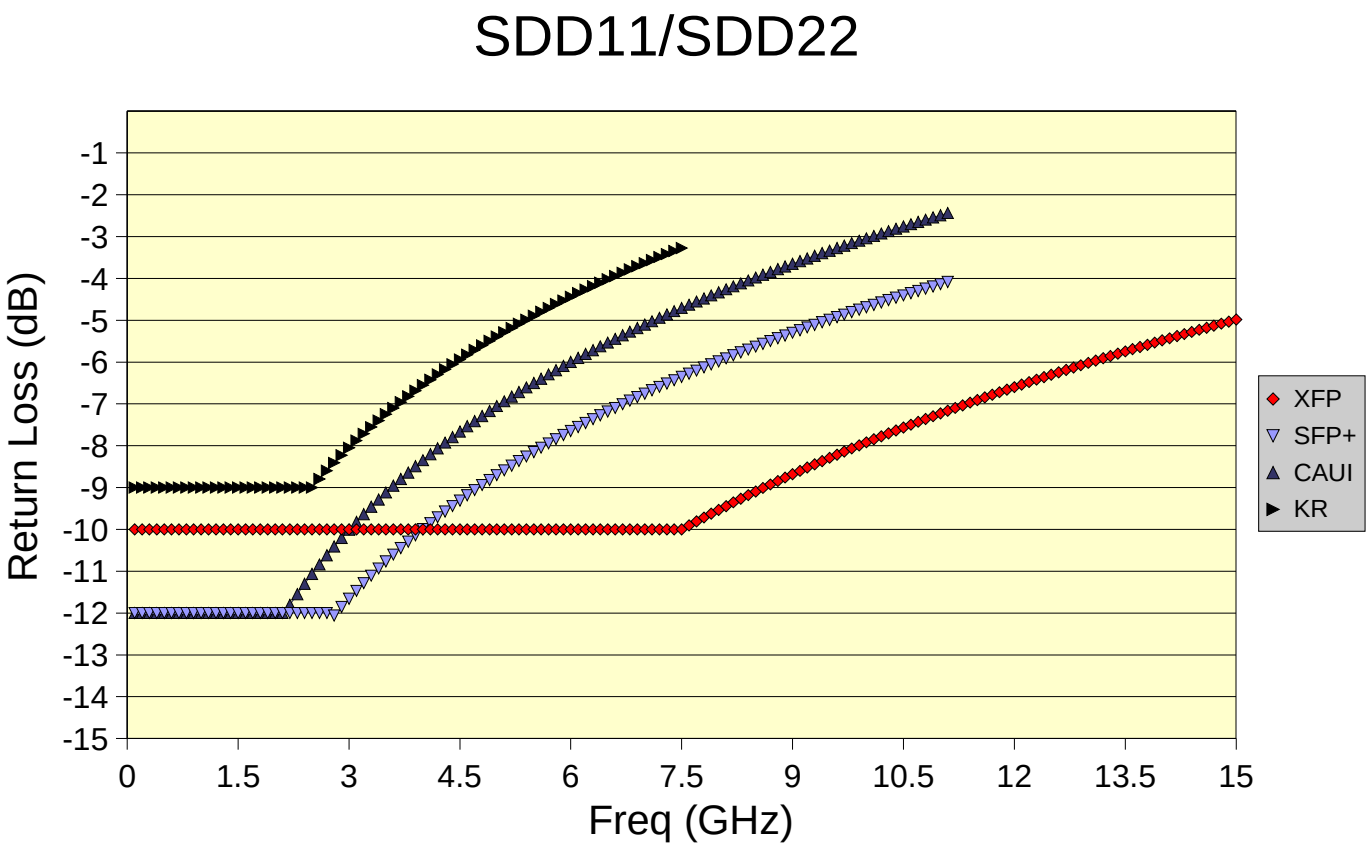


XLAUI/CAUI Electrical Interface

- **XFI has very stringent SDD return loss -10 dB up to 7.5 GHz.**
  - **Flat return loss up to 7.5 GHz is not realistic, too tight at high frequency, but too loose at the low frequency!**
  - **The proposed XLAUI/CAUI specifications is based on SFF-8431 with corner frequency pulled back to 2.125 GHz from 7.5 GHz but with improved return loss up to 2.125 GHz.**
- **XFI has very stringent common mode return loss -6 dB up to 15 GHz.**
  - **The proposal here is for SCC to follow SDDxx – 3 dB.**
  - **SCC for the receiver is not required as it limits the implementation.**
- **XFI and SFI allocate only 6 dB of channel loss at ½ the baudrate which has either limited the host PCB and/or require improved FR4**
  - **The proposed channel increases the loss at ½ the Baudrate to 10 dB for more flexible PCB design supporting ~250 mm on FR4 (Isola FR4-8) or ~375 mm on improved FR4 (Nelco N4000-13).**

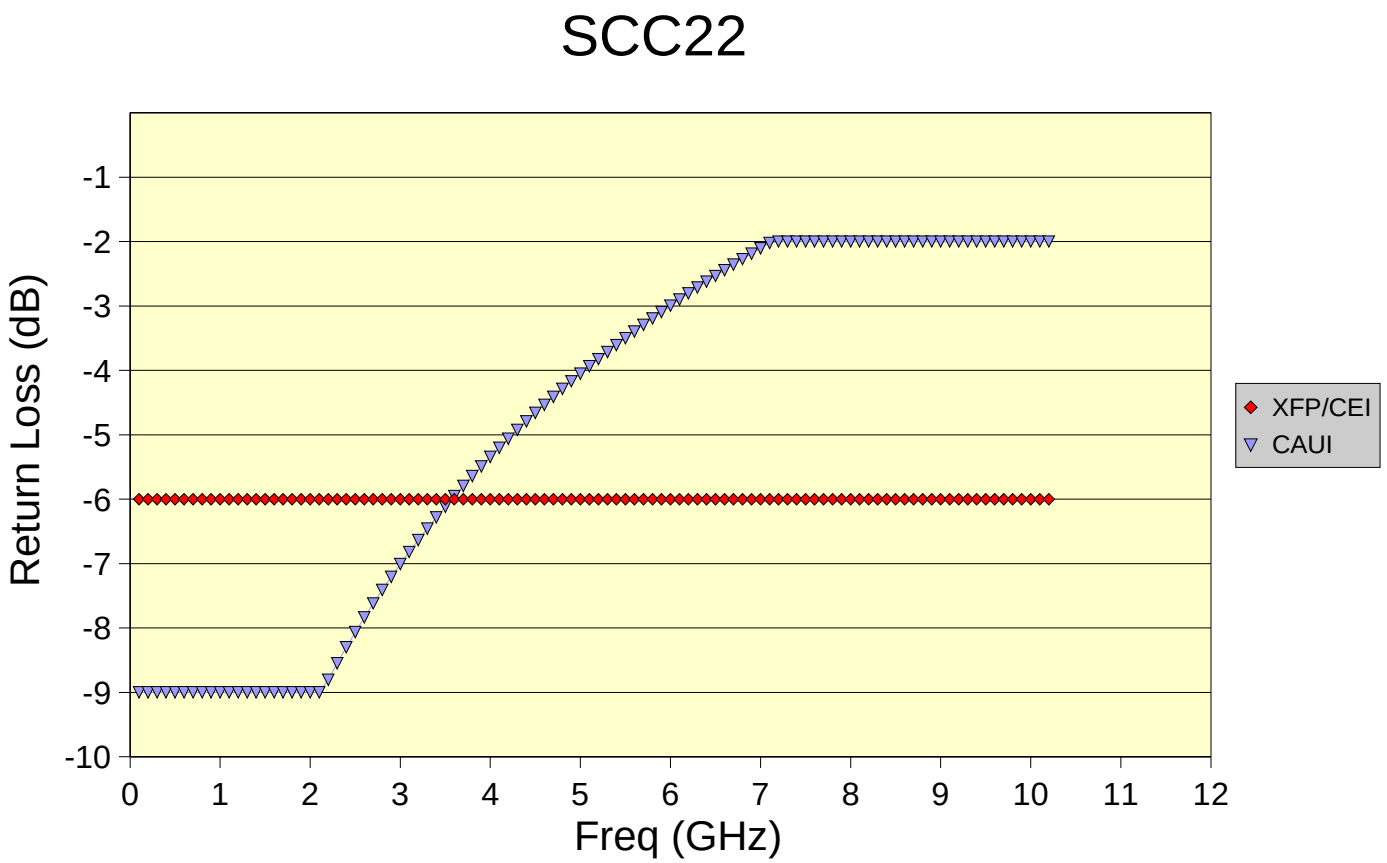
XFI, CEI, SFP+, CAUI Return Losses

- **Physical limitation of the IC parasitics makes it difficult to meet XFI return loss at high frequency but low frequency too relaxed.**
  - **This proposal uses 8.5 SFP+ Host return loss s4p available asT11-838v0.**
    - **-12 dB up to 2.125 GHz. -6.5 + 13.33LOG10(f/5.5) from 2.125 GHz to 11.1 GHz.**



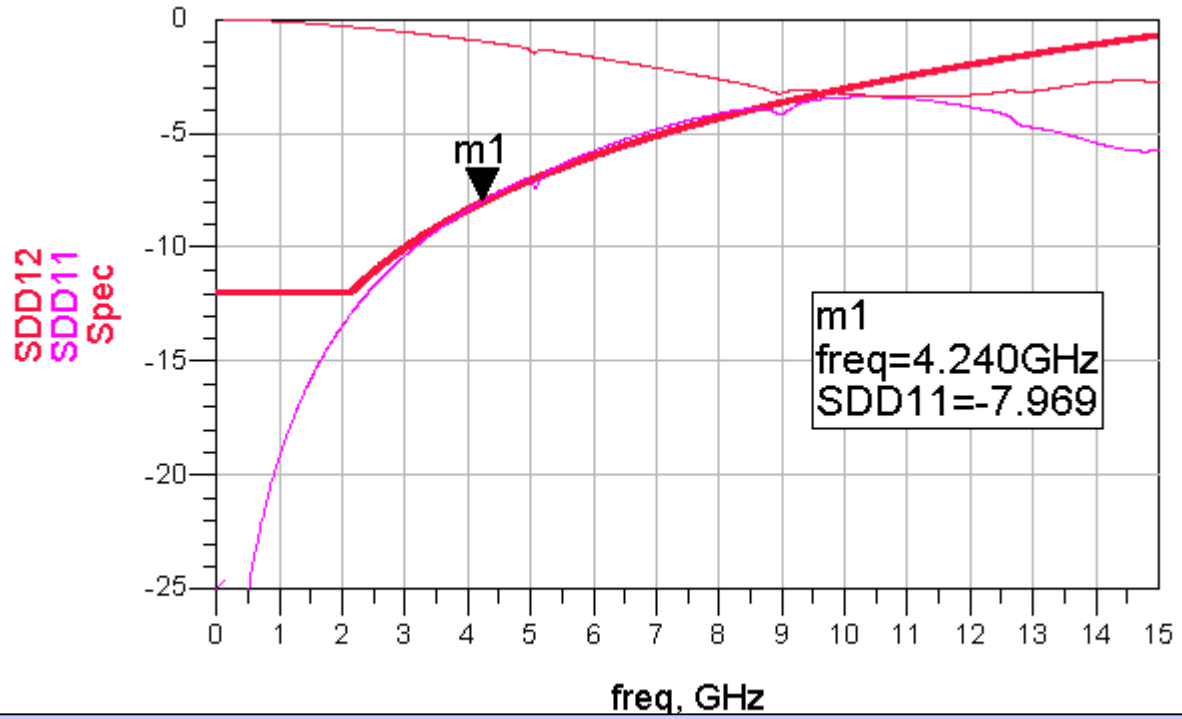
XFI, CEI, and CAUI/XLAUI RL

- **XFP/CEI common mode more difficult than SDD and not practical!**
- **SFP+ defines SCC to follow the SDD mask but 3 dB worse:**
  - **-9 dB from 0.1 to 2.125 Ghz, (-3.5 + 13.333LOG10(f/5.5)) from 2.125 to 7.1 Ghz, -2 from 7 to 11.1 GHz.**



RX/TX Chip Return Loss

- **CAUI SDDxx mask overlayed on top of the 8.5Gig SFP+ Host return loss, s4p file is available from T11 website as T11-838v0.**



SDD Mask=-12 if <2.125 GHz else -6.5 + 13.33*LOG10(f/5.5), where f is in GHz

XLAUI/CAUI Channel Loss Budget

- XFI, SFP+, and CEI 11G-SR operate only over ~150 mm of FR4-8 (Isola Fr4-8) stripline
- The proposed channel loss for XLAUI/CAUI is 10 dB at Nyquist, with following estimated PCB trace reach:
  - About 250 mm on FR4 (Isola FR4-8)
  - About 375 mm on improved FR4 (N4000-13)

Parameter	Channel Loss @ 5.15 GHz
Channel Loss (SDD21) Including one Connector	10 dB *
Reflection and other penalties	2.5 dB
Total Loss	12.5 dB
* SDD21 = -0.144 – 1.323*SQRT(f) – 1.333*(f/1e9), where f is given in GHz.	

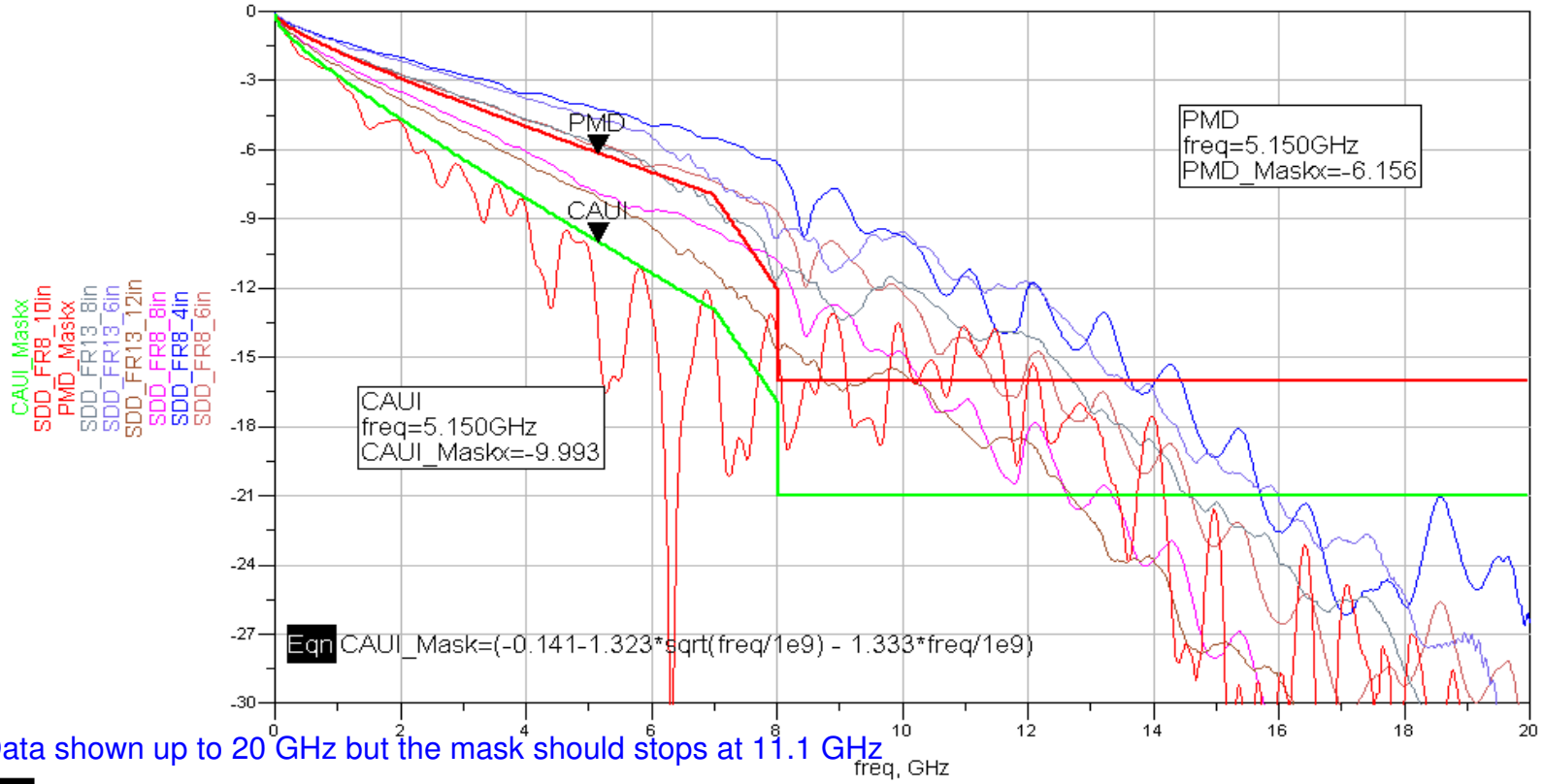
PCB Trace Reach

- **Current proposal allows for 250 mm of Isola FR4-8 or 375 mm of Nelco N4000-13 stripline traces with one connector.**
  - **Use of transmit pre-emphasis and relaxed far end jitter allows increasing the channel loss budget compare to SFI or petrilla_02_0508.**
  - **All channels are routed on lower stripline with two short stubs ~ 13 mils.**

Interface	Isola FR4-8 *	N4000-13 **	Loss at Nyquist	Host PCB Loss at Nyquist 2	Relative to XFI
XFP/SFI	150 mm	200 mm	6 dB	4.500	0.00%
petrilla_02_0508	150 mm	200 mm	6 dB	4.500	0.00%
XALUI/CAUI Proposal	250 mm	375 mm	10 dB	8.500	189.00%
*. Assumes 5 mils moderately coupled ~ 7% wide 0.5 oz striplines					
**. Connector loss and HCB loss subtracted					

XLAUI/CAUI Channel SDD21 (Informative)

- **XLAUI/CAUI supports about 250 mm of FR4-8 or about 375 mm of 5.5 mils FR4-13 striplines**
  - **The 10 dB channel was created by cascading 2nd PCB with 2 dB loss at Nyquist with the 8" Fr4-8 channel which is adding some ripple.**



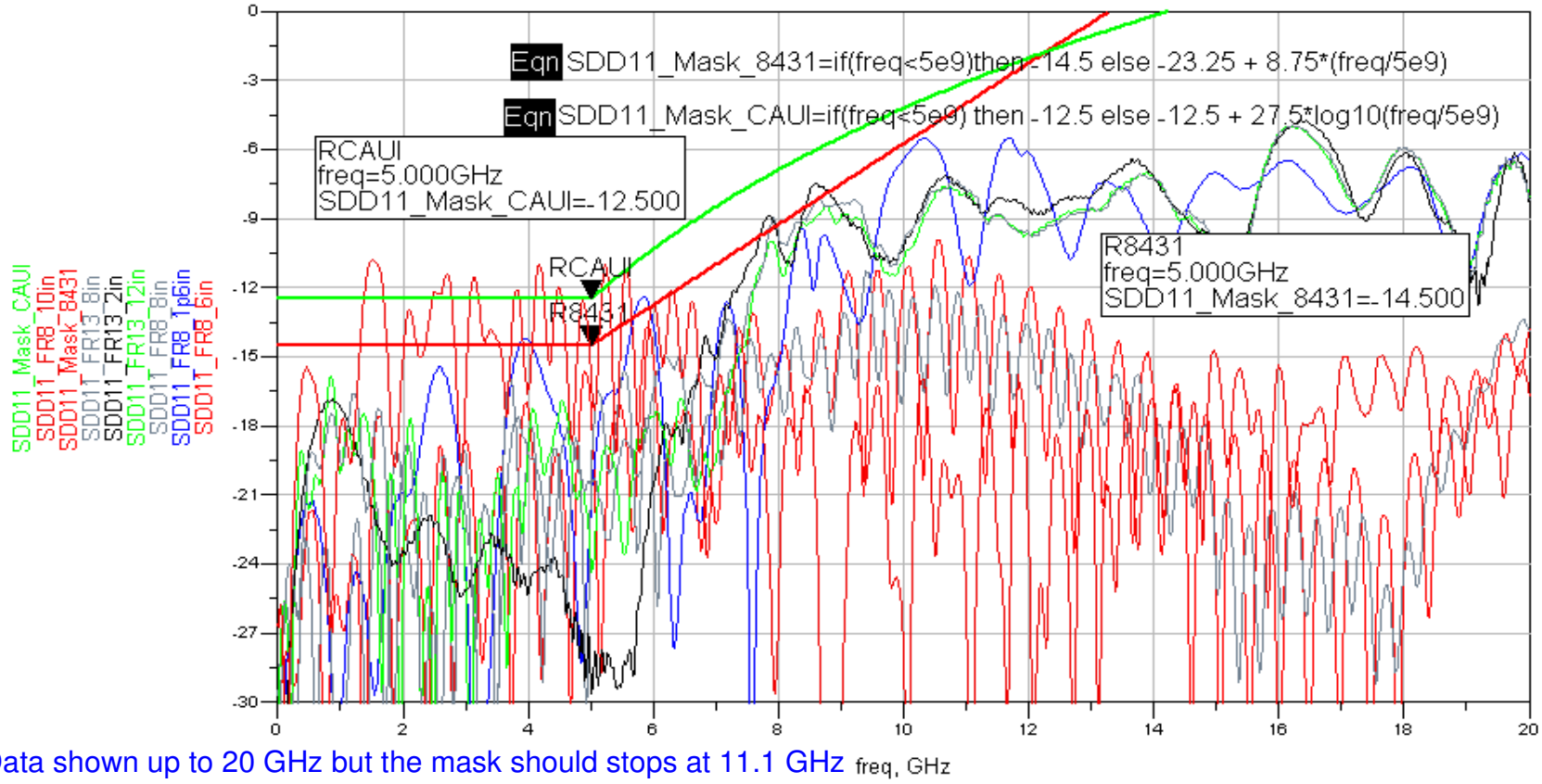
Data shown up to 20 GHz but the mask should stops at 11.1 GHz

Eqn CAUI_Maskx=if(freq<7e9) then (-0.141-1.323*sqrt(freq/1e9) - 1.33*freq/1e9) elseif (freq<=8e9) then 15.1-4.*freq/1e9 else -21 endif

Eqn PMD_Maskx=if(freq<7e9) then (-0.108-0.845*sqrt(freq/1e9) - 0.802*freq/1e9) elseif (freq<=8e9) then 20-4*freq/1e9 else -16 endif

XLAUI/CAUI Channel SDD11(Informative)

- **The CAUI informative channel SDD11/SDD22 is ~ 2 dB more relaxed than SFF-8431.**
  - **The cascaded channel with 10 dB loss at Nyquist its SDD11 is degrades about 3 dB.**



Data shown up to 20 GHz but the mask should stops at 11.1 GHz

XLAUI/CAUI Transmitter Electrical Specifications (Point A)

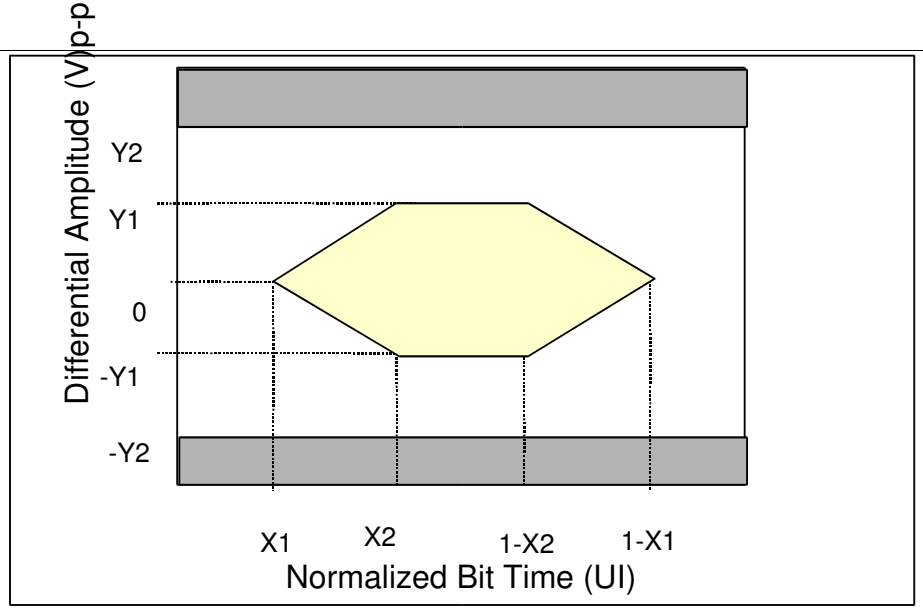
- **Starting with SFF-8431 specification at A**

Parameter	*Symbol*	*Conditions*	*Min*	*Typ*	*Max*	*Units*
Differential Output Voltage, p-p	Vdiff				see [1]	mV
Termination Mismatch		at 1 MHz			5	%
Output AC Common Mode Voltage (RMS)	Vcm				15	mV
Output Rise and Fall time (20% to 80%)	t_{RH}, t_{FH}		24			ps
Differential Output S-parameters	SDD22	0.01 to 2.125 GHz			-12	dB
		2.125-11.1 GHz			*[2]	dB
Common Mode Output S-parameters	SCC22	.01-2.125 GHz			-9	dB
		2.125-7.1 GHz			* [3]	dB
		7.1-11.1 GHz			-2	dB

1. **Must meet eye mask parameter Y1 and Y2.**
2. **SDD22(dB) = -6.5 + 13.33*LOG10(f/5.5), f is given in GHz**
3. **SCC22(dB)= -3.5 + 13.33*LOG10(f/5.5), f is given in GHz**

XLAUI/CAUI Transmit Eye Mask (Point A)

Parameter	*Symbol*	*Conditions*	*Min*	*Typ*	*Max*	*Units*
Determinstic Jitter					0.17	UI
Total Jitter	TJ				0.32	UI
Eye Mask	X1				0.16	UI
Eye Mask	X2				0.38	UI
Eye Mask	Y1				190	mV
Eye Mask	Y2				380	mV



XLAUI/CAUI Receiver Electrical Specifications (Point B)

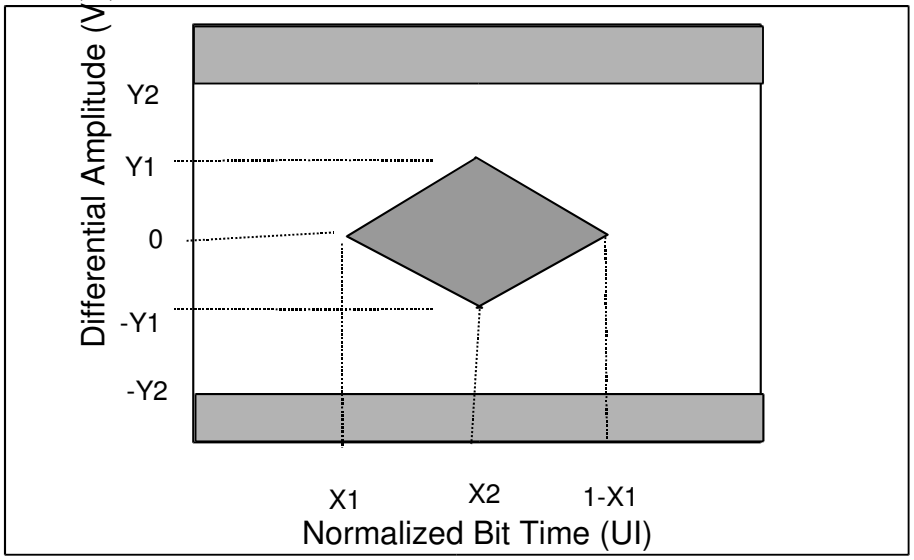
- **Starting with SFF-8431 Receiver specification**

Parameter	*Symbol*	*Conditions*	*Min*	*Typ*	*Max*	*Units*
Differential Input Voltage , Differential p-p	Vdiff	see 1	90		850	mV
Input AC Common Mode Voltage (RMS)	Vcm		20			mV
Input Rise and Fall time (20% to 80%)	t_{RH}, t_{FH}		24			ps
Differential Input S-parameters	SDD11	0.05 to 2.125 GHz			-12	dB
		2.125-11.1 GHz			*[2]	dB
Differential to Common Mdoe Input Conversion S-parameters	SCD11	0.01-11.1 GHz			-15	

1. **Max value is 850 mV for compatibility with TP4 see petrila_01_0508.pdf**
2. **SDD22(dB) = -6.5 + 13.33*LOG10(f/5.5), f is given in GHz.**

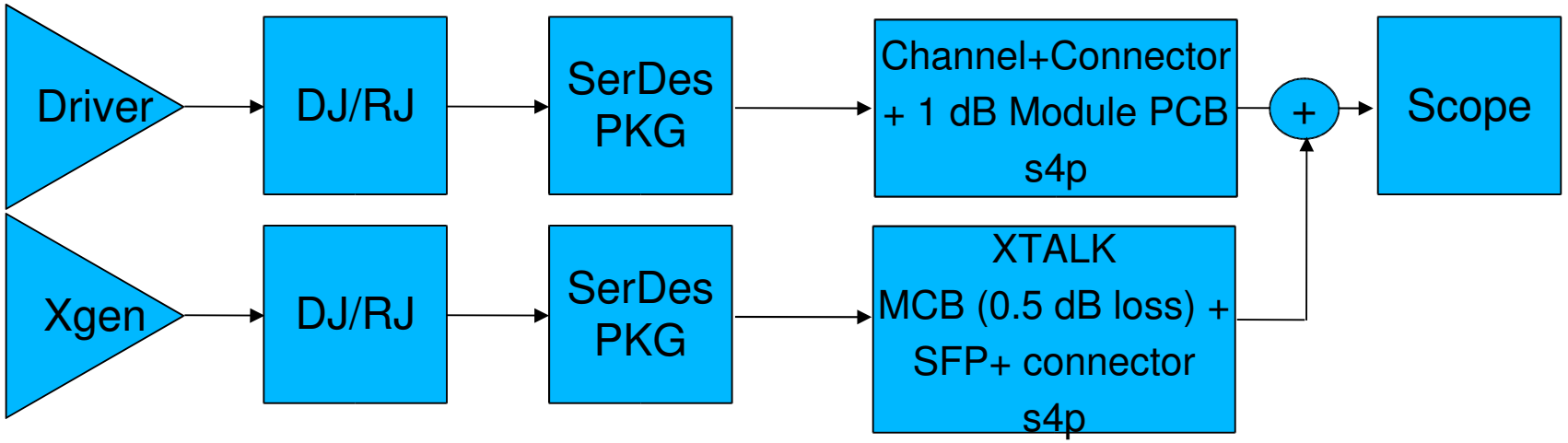
XLAUI/CAUI Receive Eye Mask Specifications

Parameter	*Symbol*	*Conditions*	*Min*	*Value*	*Max*	*Units*
non-EOI Jitter (TJ – ISI)	DJ	Corner Frequncy>4 MHz			0.42	UI
Total Jitter	TJ	Corner Frequncy>4 MHz			0.62	UI
Eye Mask	X1				0.31	UI
Eye Mask	X2			0.5		UI
Eye Mask	Y1		45			mV
Eye Mask	Y2				425*	mV
*same as SFP+						

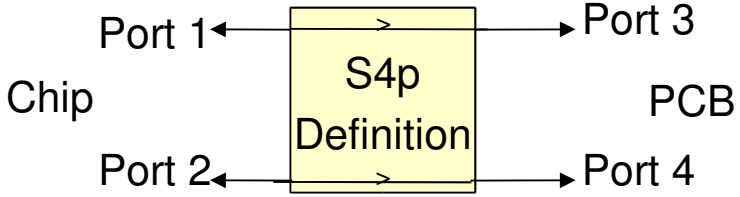


Link Simulation Set-up

- **Host SerDes package model was cascaded with the channel**
  - **The crosstalk source Xgen amplitude was set to 3x the driver to account for additional XTALK due to multi-aggressor and/or connectors possibly worse than SFP+.**

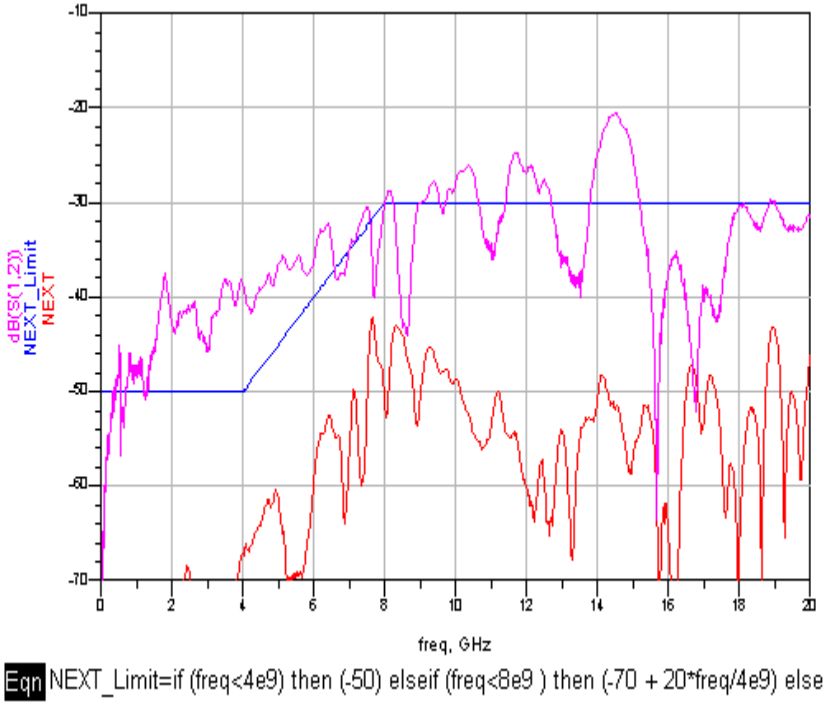


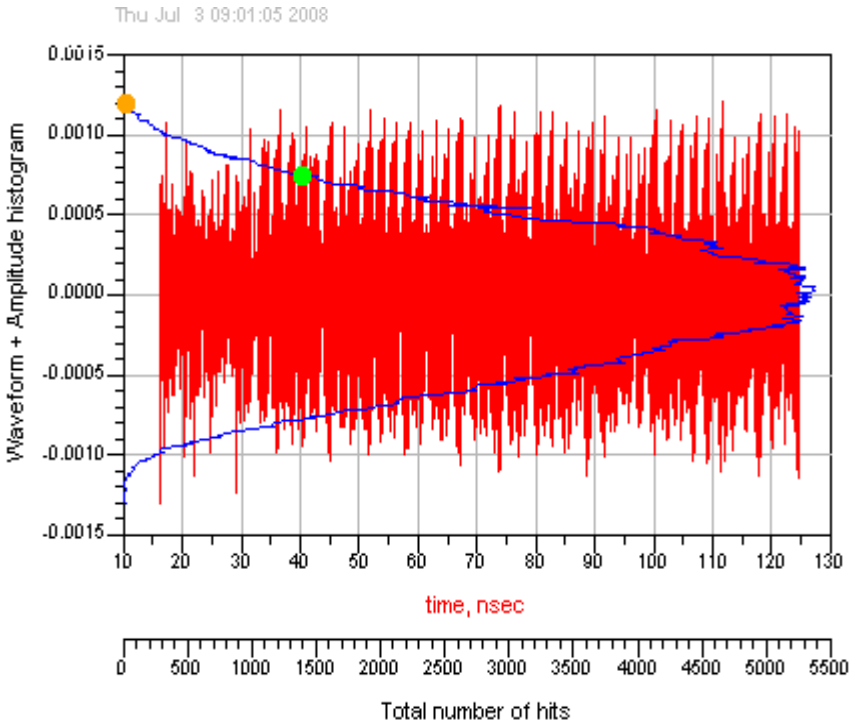
S4P File Definition for Through Channel



Connector XTALK

- **Simulation here uses 3x the amplitude with SFF-8083 (SFP+) connector till more suitable Xtalk data available.**

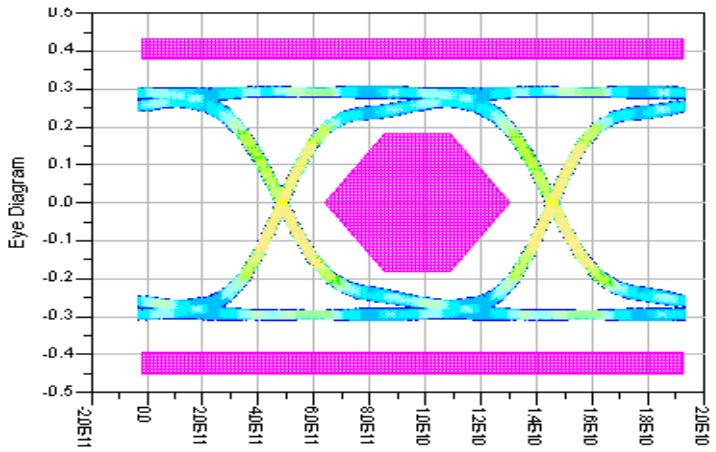




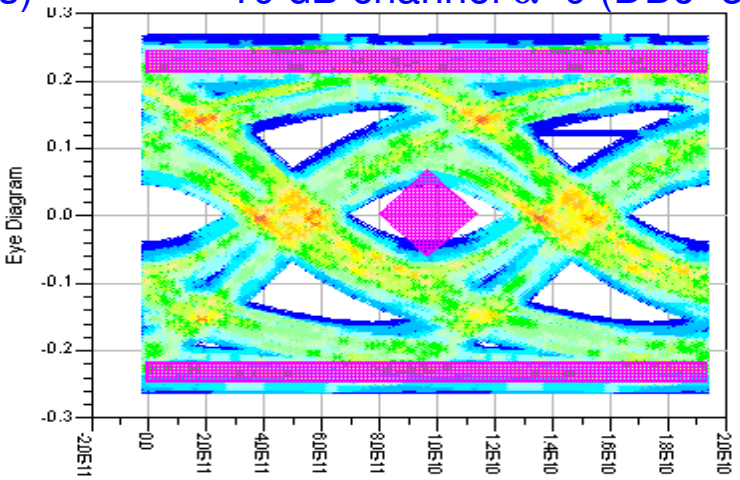
Meeting Far End CAUI/XLAUI Mask with Single Pre-emphasis Setting

- **TX launch was 600 mV pk-pk differential**

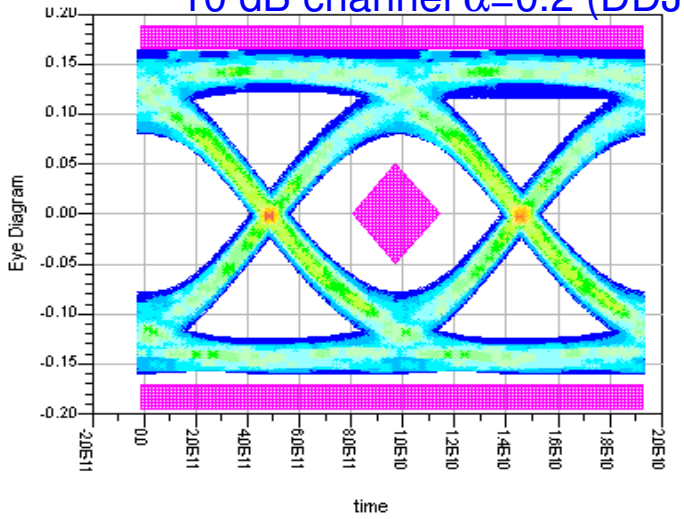
Near End Eye α=0 (DDJ=0.8 ps)



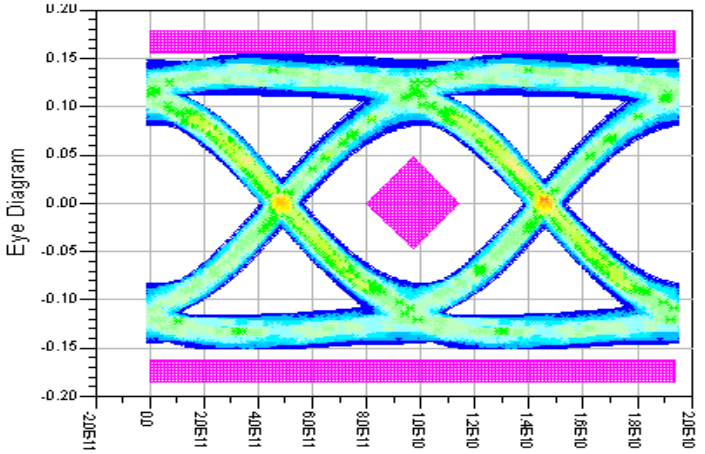
10 dB channel α=0 (DDJ=39.6 ps)



10 dB channel α=0.2 (DDJ=12.7 ps)



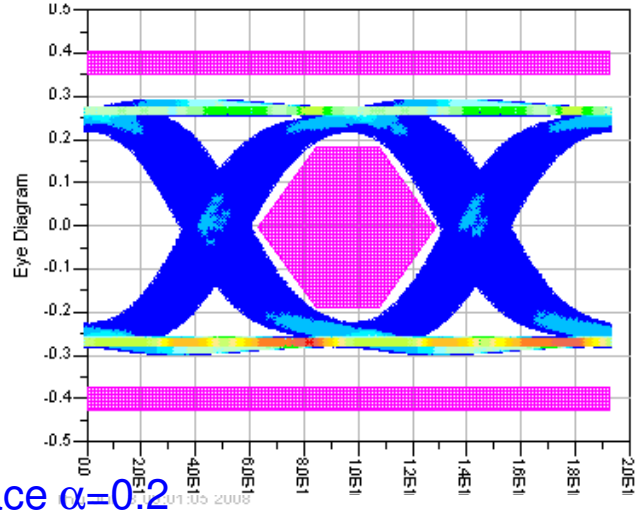
10 dB channel α=0.24 (DDJ=12.5 ps)



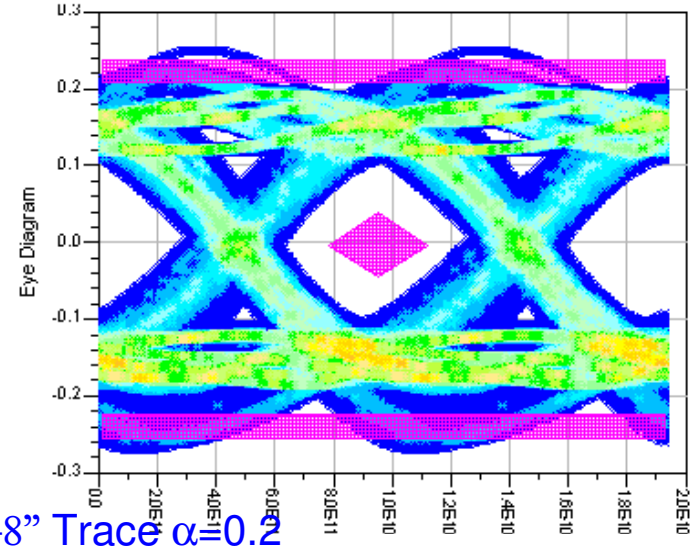
Meeting Eye Mask with Maximum Transmitter DJ and RJ

- **TX launch was 550 mV pk-pk differential**

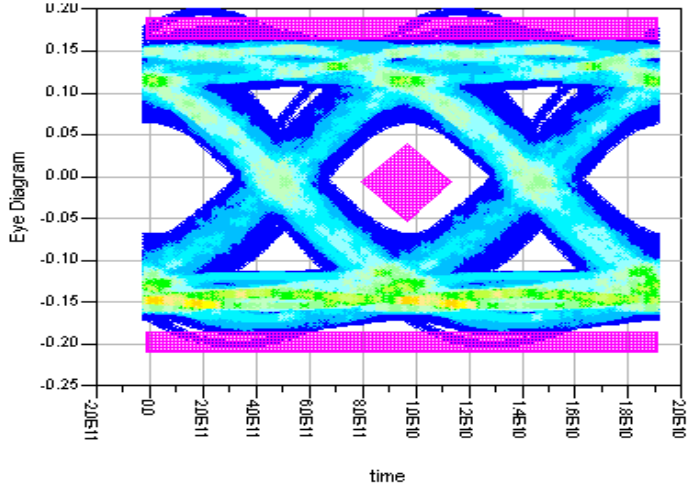
Near End Eye α=0



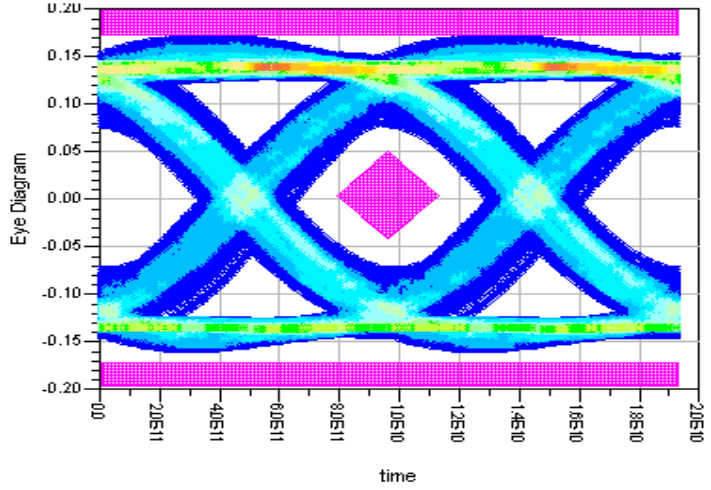
2” Trace α=0.2



6” Trace α=0.2



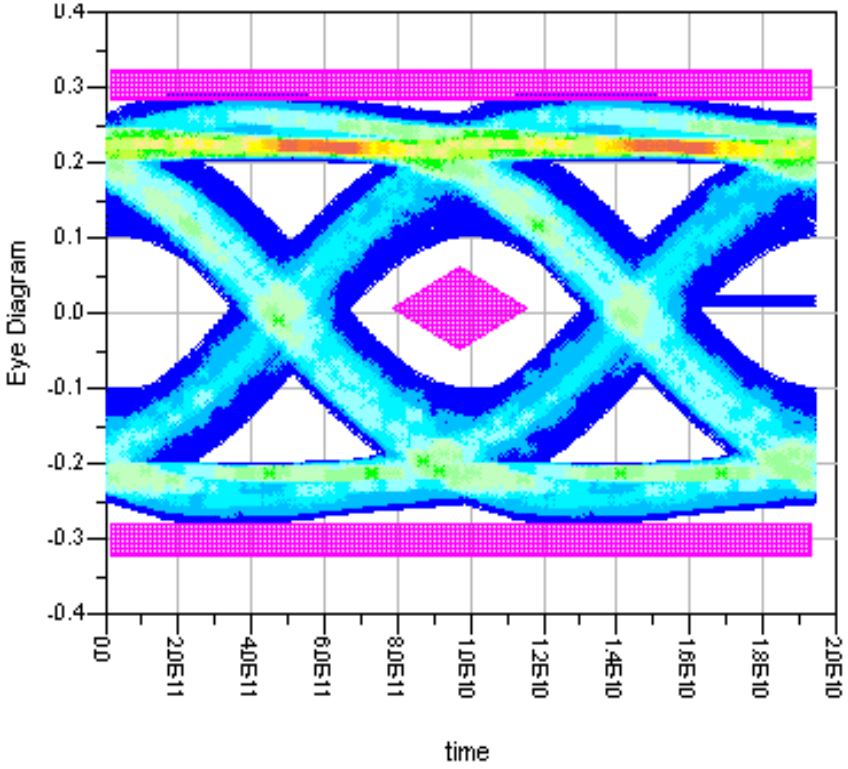
2”+8” Trace α=0.2



Meeting Eye Mask with Maximum Transmitter DJ and RJ

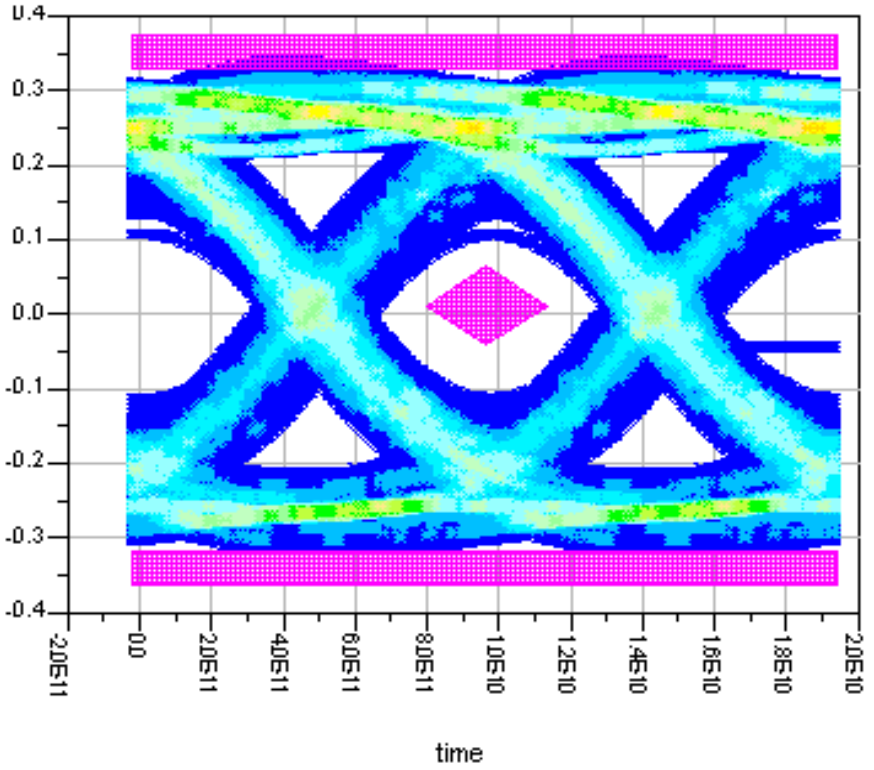
- **TX launch was 550 mV pk-pk differential**

2"+8" Channel XTALK off α=0.2



TJ ~ 0.45 UI

2"+8" Channel XTALK on α=0.2



TJ ~ 0.52 UI

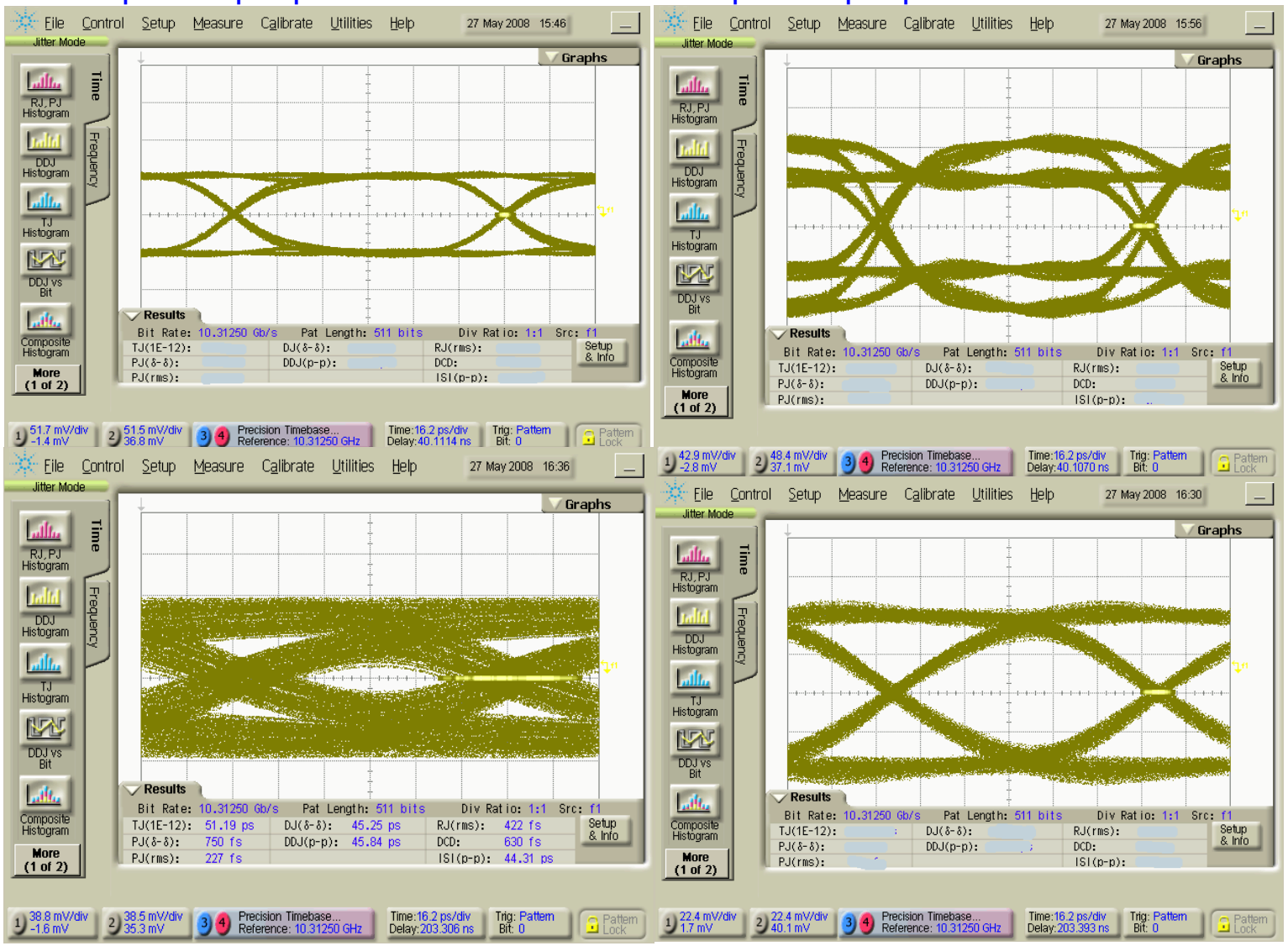
Output Eye Digram for Near and Far End

pre-emp Optimum for Near End

pre-emp Optimum for Far End

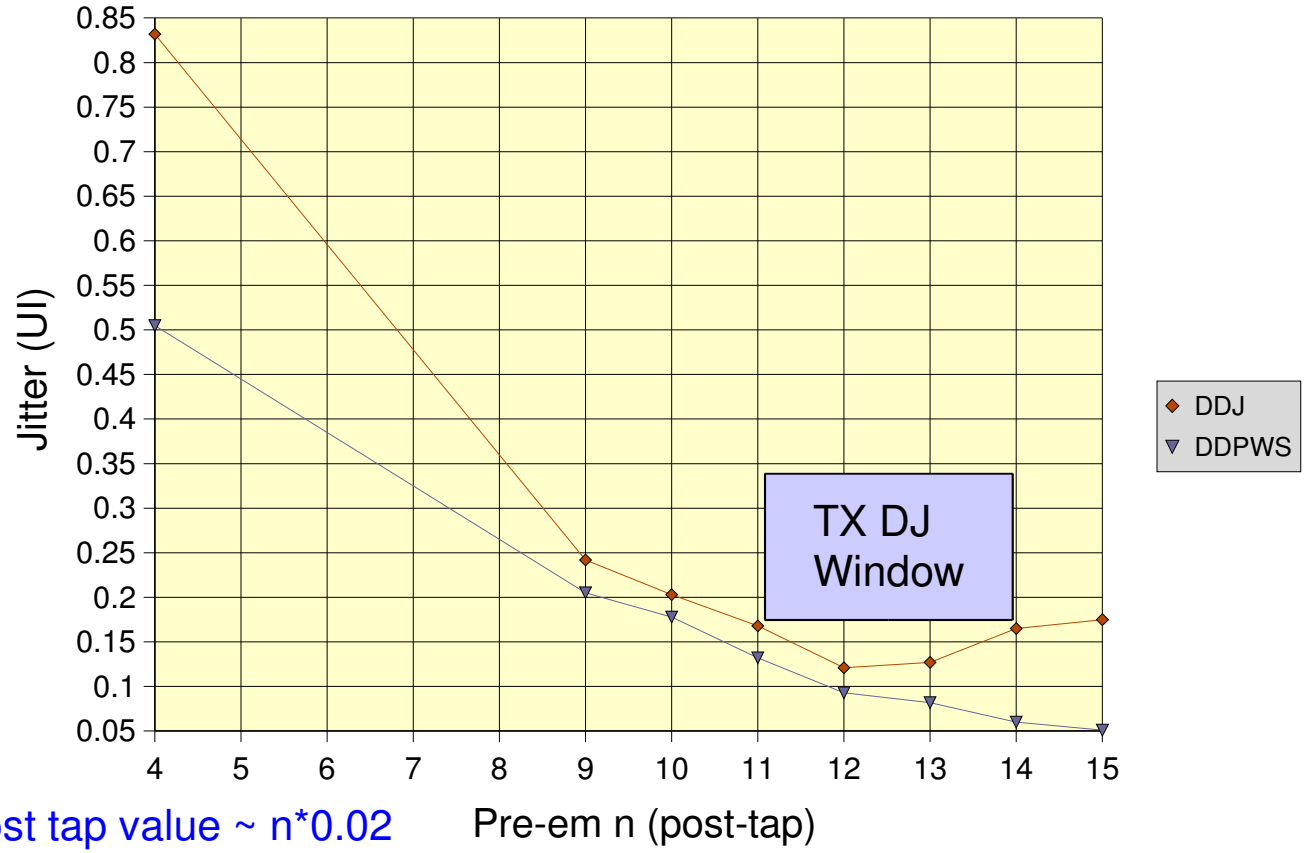
Chip Out

8” FR4-8



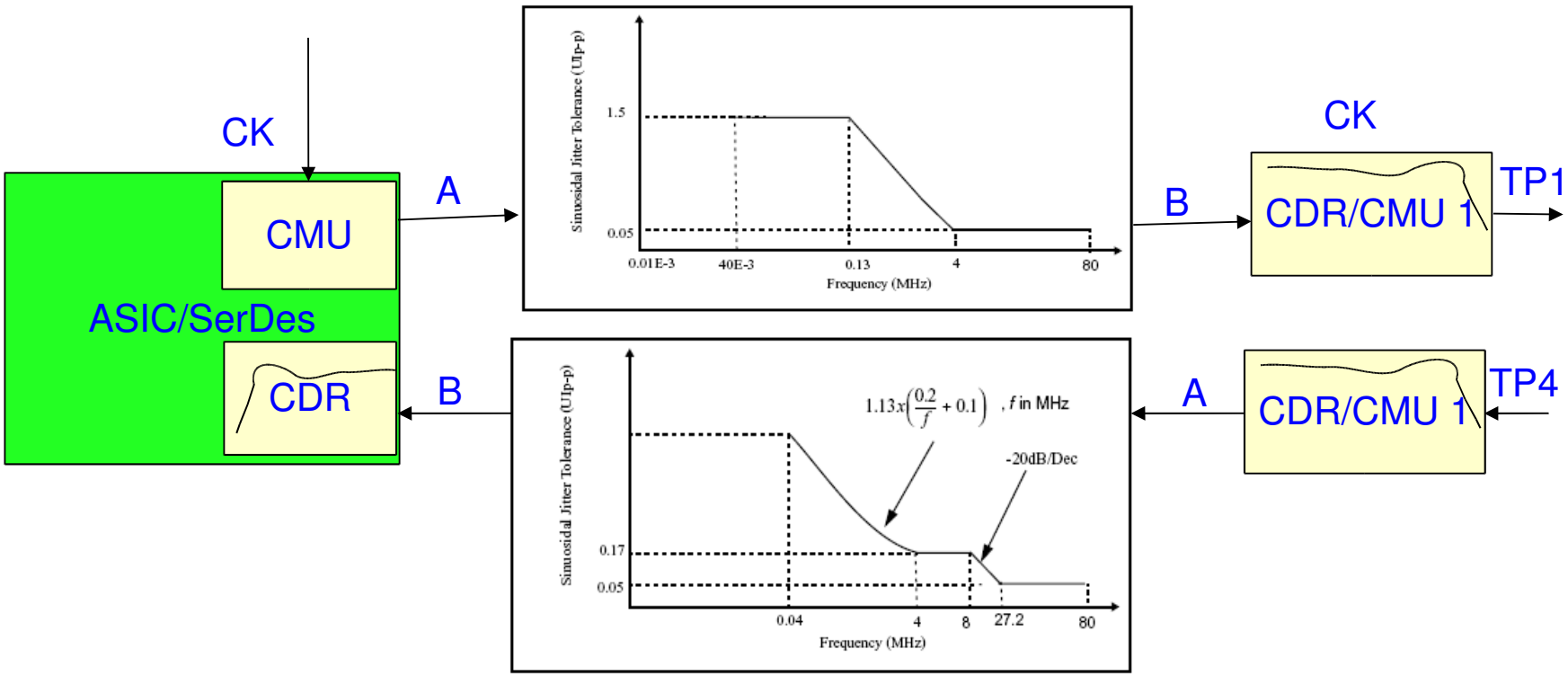
8” Fr4-8 Jitter

- **DDJ and DDPWS for PRBS9 as function of pre-emphasis**
  - **SerDes near end DDJ and DDPWS subtracted from the results.**



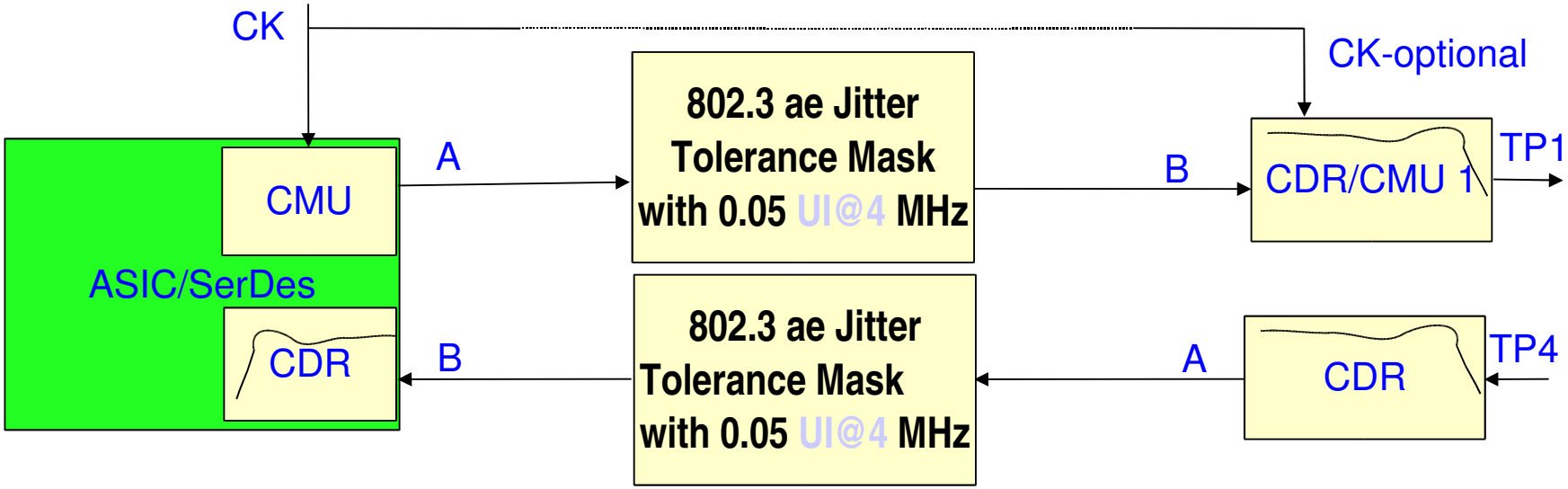
XFI Jitter Transfer Concept

- **XFP assumes CDR has BW of 4-8 Mhz with 1 dB peaking**
- **As the diagram below illustrates this creates additional jitter tolerance penalty on the receiving host.**



CAUI/XALUI Jitter Transfer Concept

- To not penalize the host ASIC the CAUI/XALUI retimer will be based on one of the following implementations:
  - CMU mode (can only be done on the TX path)
  - CDR several implementation are possible low BW with high peaking or high BW with low peaking. No need to define an implementation, just meeting A, B, TP1, and TP4 is sufficient
  - E-FIFO (latency and complexity)



Conclusion

- XALUI/CAUI electrical interface leverage XFI and SFI work, but with several key improvements:
  - Channel length increased to 250 mm of Isola FR4-8 or 375 mm of Nelco N4000-13 by levering pre-emphasis
  - More ASIC friendly return loss than SFI or XFI.
- Simulation shows with XTALK 3x the SFP+ and as transmitter with maximum DJ/TJ the far end eye mask is met with margin.
  - Measurement shown here as well as in latchman_01_0708 confirms the budget.
- Based on simulation and measurement shown here single pre-emphasis setting is adequate for channels with 10 dB loss at Nyquist.
  - Optionally pre-emphasis may be adjusted for each trace for more margin.
- Propose to use 802.3ae jitter tolerance mask with 0.05 UI amplitude at 4 Mhz for jitter tolerance.