COM Simulation and Analysis for 200Gbps/Lane Chip-to-Module

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2022/03/16

Outline

- Overview
  - Motivation and methodology
  - Objectives
- COM simulation for 200Gbps/Lane PAM4 C2M
- Channel feasibility: key challenges
- SerDes feasibility: COM sensitivity to key parameters
- Conclusion

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Motivation and Methodology

- **Straw poll #4 (Feb. 24, '22) – PAM4 for 200G/L optical PMDs (500m & 2km)**
  - Q: Will be PAM4 feasible for 200G/L C2M?
- **Exploration of the feasibility of 200G/L chip-to-module AUI PAM4**
  - Channel & SerDes requirements?
- **Channel requirements analysis – by COM v3.7 simulation**
  - All available 200G C2M channels from IEEE & OSFP (total 38x)
  - Based on baseline SerDes
- **SerDes feasibility – starting from COM sensitivity by sweeping key SerDes parameters**
  - Provide the directions to make good trade-off between performance & power/cost of SerDes

Objectives

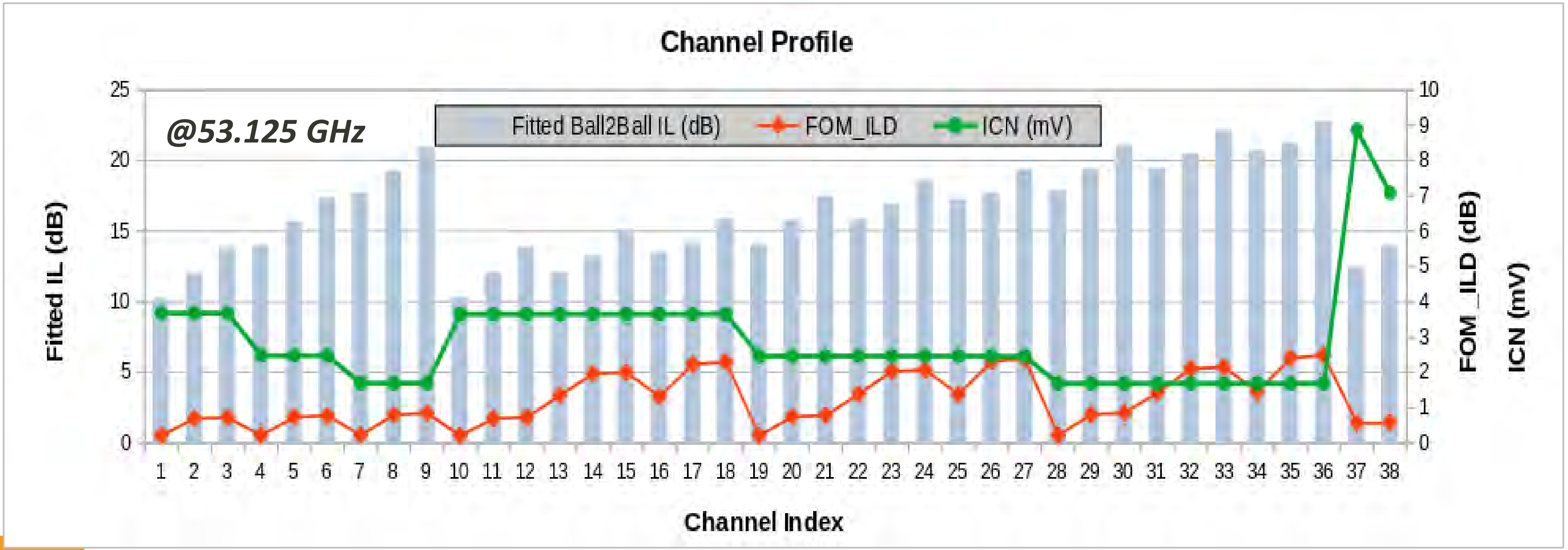
- Do
  - Leverage published channel materials to represent potential 200Gbase channel characteristics and evaluate their corresponding performance
  - Analyze 200G/L PAM4 C2M feasibility from the system's point of view
  - Point out key challenges of channel – reflection (roll-off) & crosstalk
  - Direction of SerDes – COM sensitivity of key parameters
- Don't
  - Offer the SerDes or channel solutions

C2M Channel Profile

CH Index	S-Parameter File	Crosstalk	Contributor	Source
1 ~ 36		1 FEXT, 1 NEXT	C2M model from Amphenol BGA model from Keysight	OSFP200GEL
37	KEY_C2M_200G_120G_2p5HCB_022422_Thru	1 FEXT, 1 NEXT	Rick Rabinovich	IEEE 802.3df: rabinovich_3df_022422
38	KEY_C2M_200G_120G_4p0HCB_022422_Thru	1 FEXT, 1 NEXT		

- **Channel variations mainly come from**
  - Host/Module trace length & impedance
  - BGA breakout topology
  - Connector transition finger connectivity
  - Crosstalk

The objective is to explore diverse channels to assess C2M technology feasibility
- **Channel ball2ball IL: 10~23 dB**
- **FOM_ILD: 0~3 dB**



COM Simulation Consideration: 200G Baseline

Table 93A-1 parameters				
Parameter	Setting	Units	Information	
f_b	106.25	GBd		
f_min	0.05	GHz		
Delta_f	0.01	GHz		
C_d	[0.7e-4 0.7e-4]	nF	[TX RX]	
L_s	[0.12 0.12]	nH	[TX RX]	
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]	
z_p select	[1 2]		[test cases to run]	
z_p (TX)	[15 31; 1.8 1.8]	mm	[test cases]	
z_p (NEXT)	[8 15 ; 0 0]	mm	[test cases]	
z_p (FEXT)	[15 31; 1.8 1.8]	mm	[test cases]	
z_p (RX)	[8 15 ; 0 0]	mm	[test cases]	
C_p	[0 0.65e-4]	nF	[TX RX]	
R_0	50	Ohm		
R_d	[50 50]	Ohm	[TX RX]	
A_v	0.413	V		
A_fe	0.413	V		
A_ne	0.45	V		
L	4			
M	32	Samp/UI		
samples_for_C2M	32	Samp/UI		
T_O	0	mUI		
AC_CM_RMS	0	V	[test cases]	0.0235 0.0256
filter and Eq				
f_r	0.75	*fb		
c(0)	0.54		min	
c(-1)	[-0.34:0.02:0.1]		[min:step:max]	
c(-2)	[-0.1:0.02:0.1]		[min:step:max]	
c(-3)	[-0.1:0.02:0.1]		[min:step:max]	
c(-4)	[-0.04:0.02:0.04]			
c(1)	[-0.1:0.02:0.2]		[min:step:max]	
N_b	8	UI		
b_max(1)	0.85		As/dffe1	
b_max(2..N_b)	[0.3 0.3 0.2*ones(1,5)]		As/dfe2..N_b	
b_min(1)	0.3		As/dffe1	
b_min(2..N_b)	[0.05 0.05 -0.03*ones(1,5)]		As/dfe2..N_b	
g_DC	[-13:1:-2]	dB	[min:step:max]	
f_z	42.5	GHz		
f_p1	42.5	GHz		
f_p2	106.25	GHz		
g_DC_HP	[-3:0.5:0]		[min:step:max]	
f_HP_PZ	2.65625	GHz		
G_Qual	[-2 -13 ;-3 -12; -4 -11;-5 -10]	dB	ranges	
G2_Qual	[0 -1 -2 -3]	dB	ranges	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	0	logical
CSV_REPORT	0	logical
RESULT_DIR	.\results\100GEL_C2M_host_{date	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2M_eval_	
COM_CONTRIBUTION	0	logical
Local Search	2	
Operational		
VEC Pass threshold	12	db
EH_min	10	mV
ERL Pass threshold	7.3	dB
Min_VEO_Test	0	mV
DER_0	1E-05	
T_r	0.00375	ns
FORCE_TR	1	logical
PMD_type	C2M	
BREA		
SAVE_		
F		
E		
fixtu		
TDR		
Tuk		
RX_C		
Sign		
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	2.05E-08	V^2/GHz
SNR_TX	32.5	dB
R_LM	0.95	

Table 93A-3 parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 0.000644085 0.00018018]	
package_tl_tau	5.700E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
ICN & FOM_ILD parameters		
f_v	0.594	*Fb
f_f	0.594	GHz f_r specified in first column
f_n	0.594	GHz
f_2	80	GHz
A_ft	0.600	V
A_nt	0.600	V
Histogram_Window_Weight	gaussian	Seletions (rectangle, gaussian,du
COM Pass threshold	3	

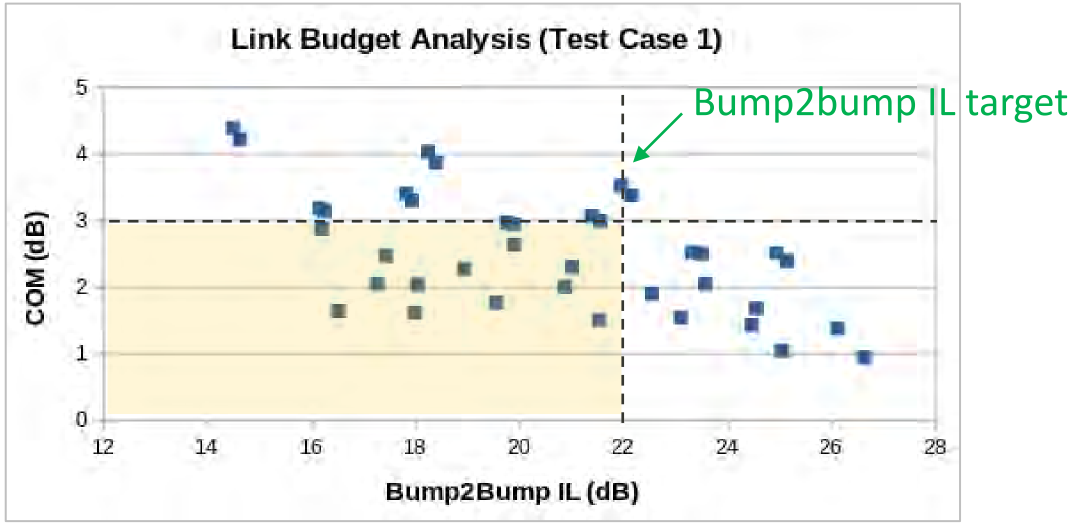
- **Die model** : keep the similar IL as 100G (parameters need further investigation)
- **PKG model**: 25% trace loss improvement from 100G, follows the values proposed in oif2021.596.01 (parameters need further investigation)
- **Equalization length & frequency/Rise time/Jitter/Noise** scaled with 2x baud rate
- **DER/TX swing/TX SNR/Nonlinearity** kept the same as 100G
- COM version: 3.7
- Test case 1 (short package): [z_p (TX) z_p (RX)] = [15 8] mm
- Test case 2 (long package) : [z_p (TX) z_p (RX)] = [31 15] mm

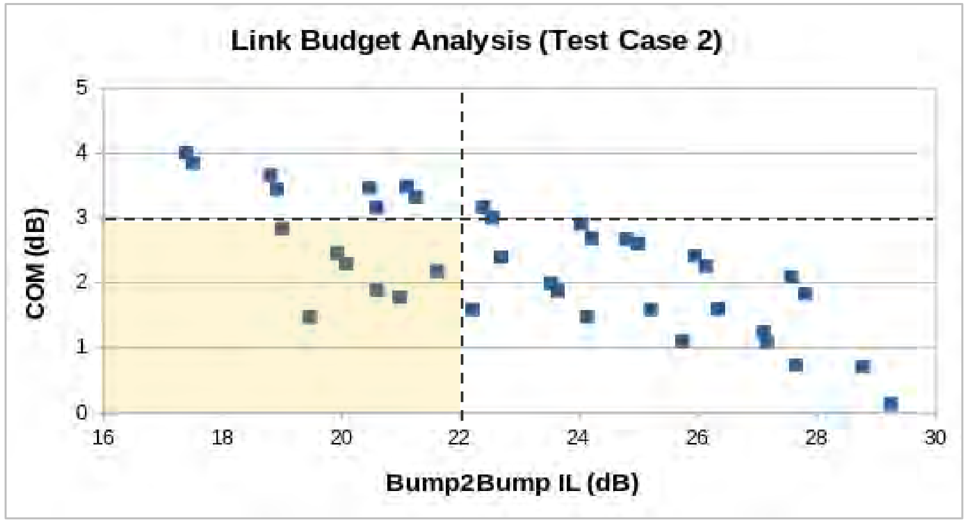
** TX C_p = 0 fF as it is included in the channel model*

COM Simulation for 200G/L PAM4 C2M

- **Whole link budget analysis**
  - To allow the interoperability among channel components
  - Analyze performance from the system's point of view
  - Evaluate COM instead of VEC & VEO
- **Whether 200G/L PAM4 C2M works?**
  - If keep the same bump2bump IL target from 100G to 200G
    - IL target in 100G/L PAM4 C2M: 16 dB ball2ball + PKG loss = ~22 dB bump2bump
  - If make SerDes capability aligned from 100G to 200G

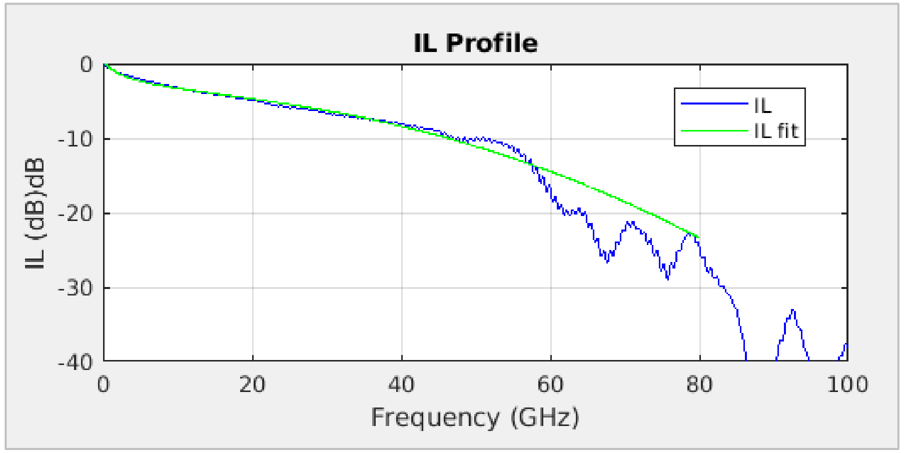
22dB bump2bump still reasonable for 200G/L C2M?



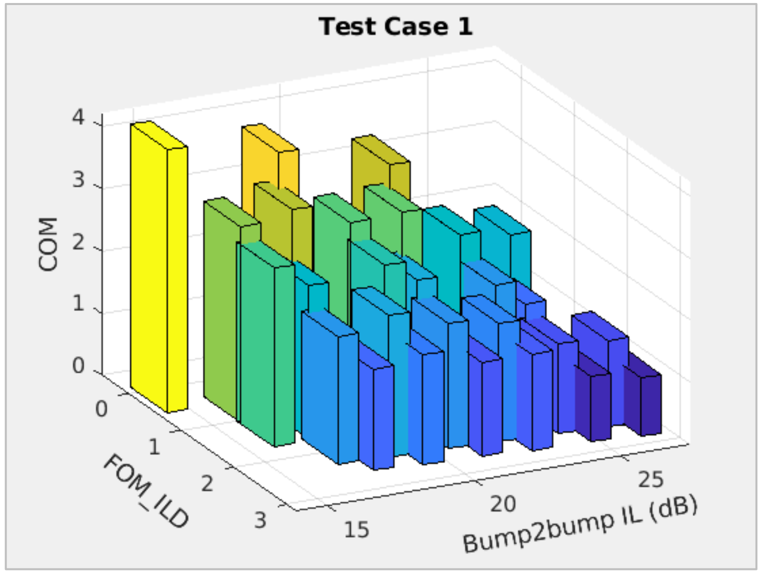


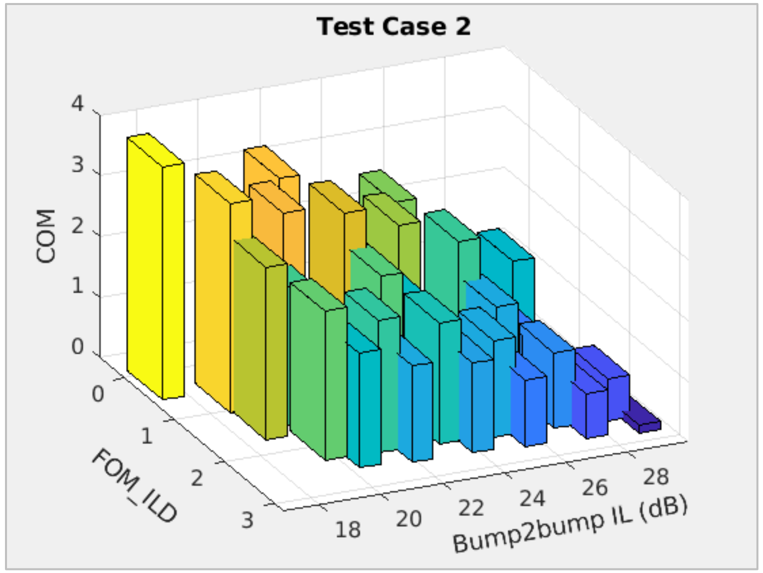
Channel Feasibility: FOM_ILD

- **FOM_ILD represents reflection severity**
  - **Banks of floating taps (FLTs) are needed with increasing FOM_ILD**
  - **Roll-off in IL profile**
    - Can cause severe IL degradation at Nyquist frequency
    - Can cause multiple reflections



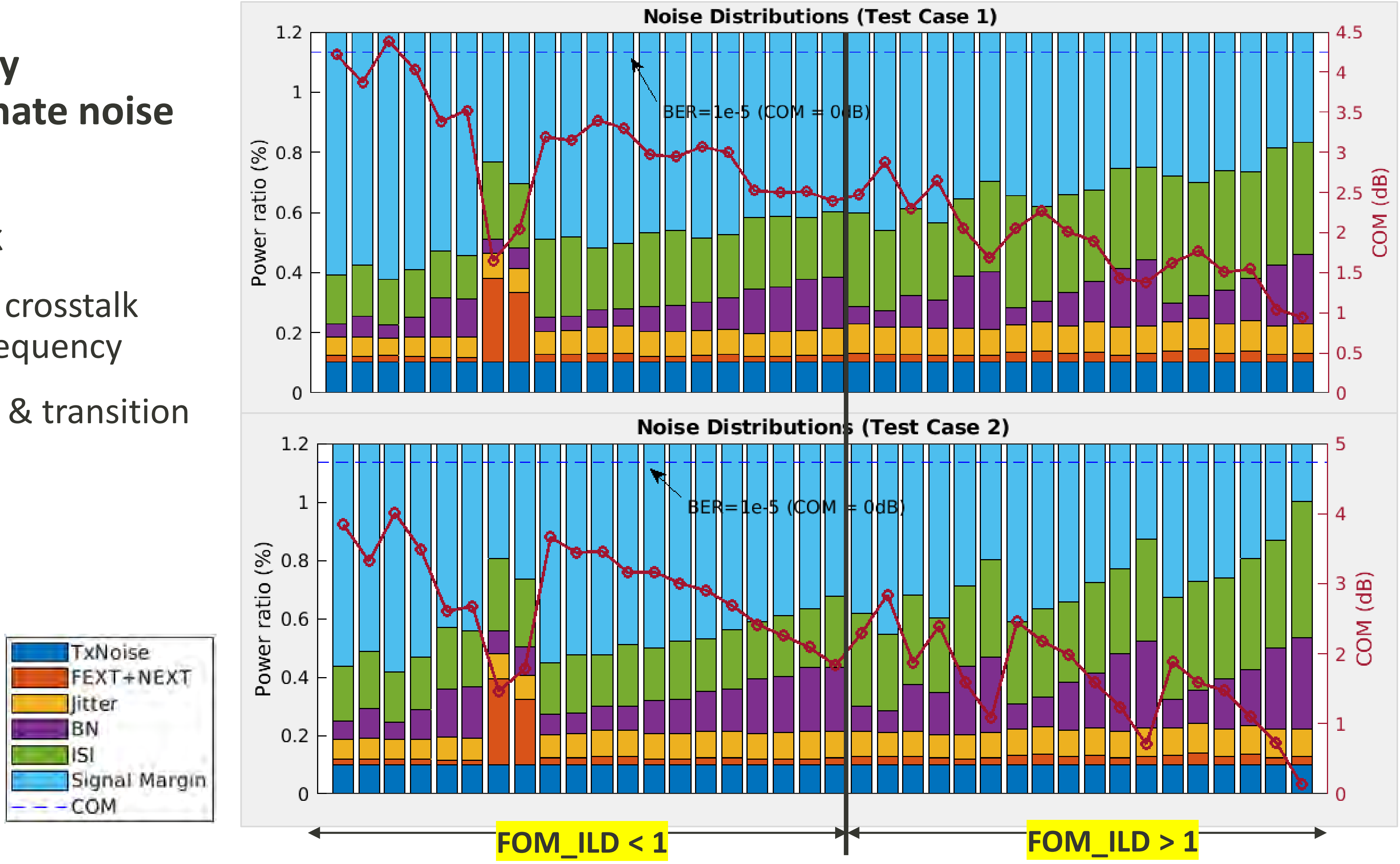
- **FOM_ILD < 1 feasible?**





Channel Feasibility: FOM_ILD & Crosstalk

- **Residual ISI caused by reflection may dominate noise budget**
- **Concerns in crosstalk**
  - PAM4 feasibility: crosstalk increases with frequency
  - Particular in BGA & transition via region



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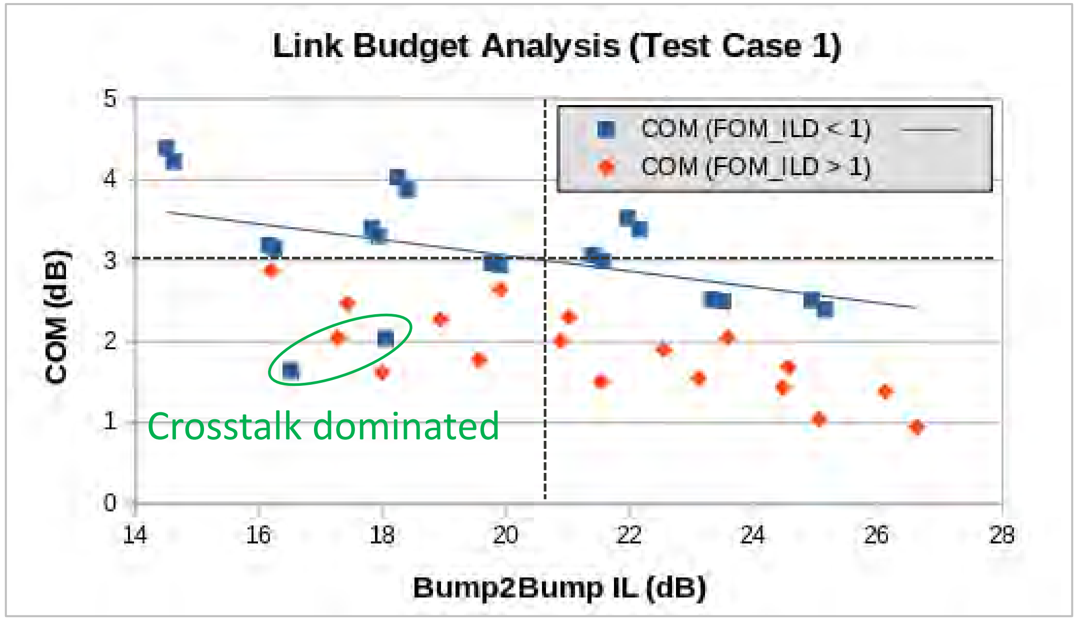
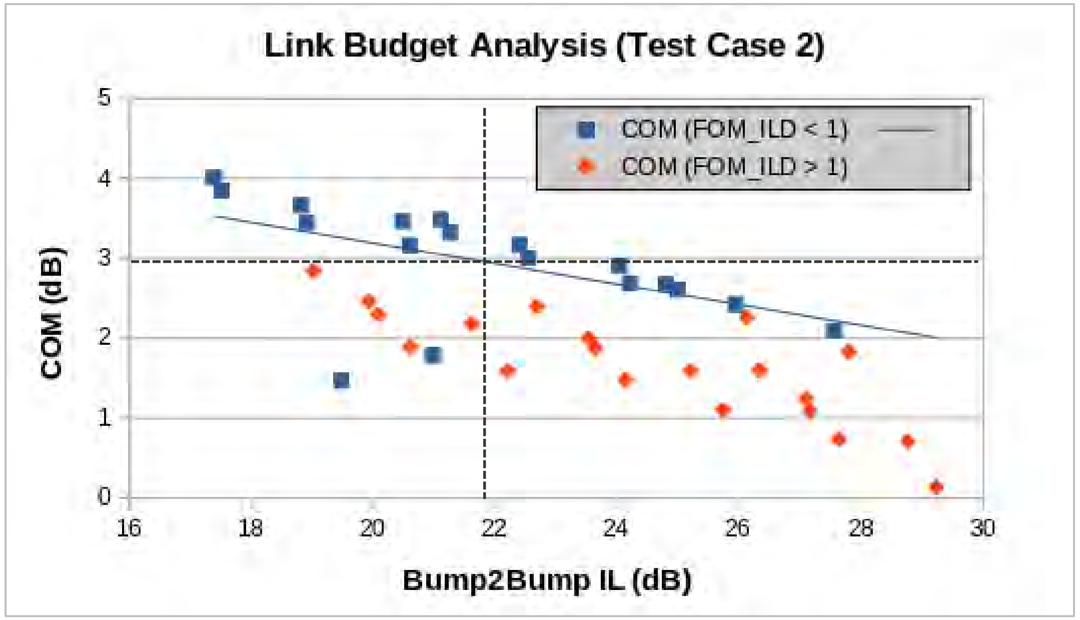
200G/L PAM4 C2M Feasibility: Reach

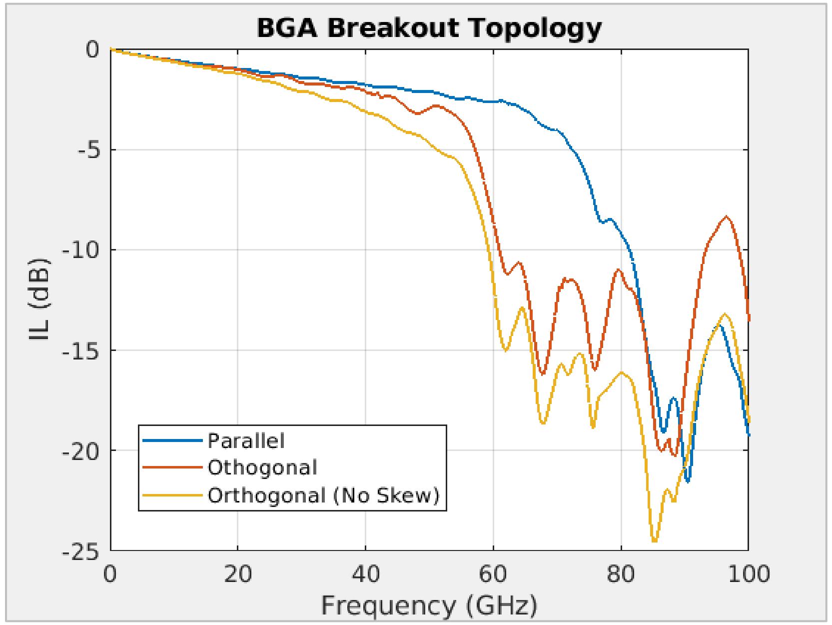




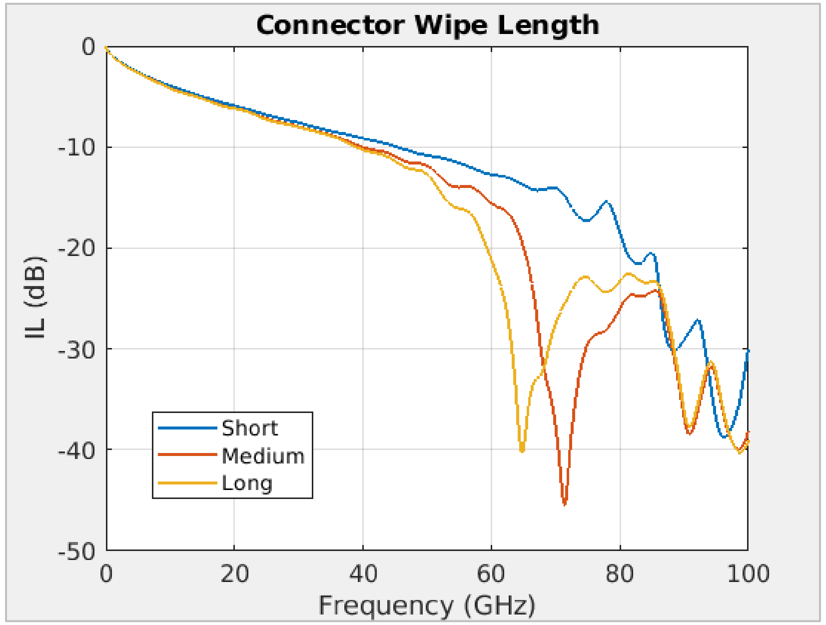
- **Support 22dB bump2bump IL seems possible**
  - If can keep IL at frequency of interest at the close vicinity of that for 100Gb/L
  - If SerDes capability can align with increased baud rate
- **Short channel effect in test case 1 needs further investigation**
  - Will be accentuated by higher Nyquist frequency

Roll-Off in IL Profile

- **Impairments in next generation have been discussed in noujeim_3df_01_220224**
  - Including BGA dimensions, connector transition connectivity, and other structures
- **Frequency of resonances characterizing impairments affects roll-off characteristics**
  - Can cause multiple reflections, especially challenging for short channels



BGA breakout model from *Keysight via OSFP200GEL*



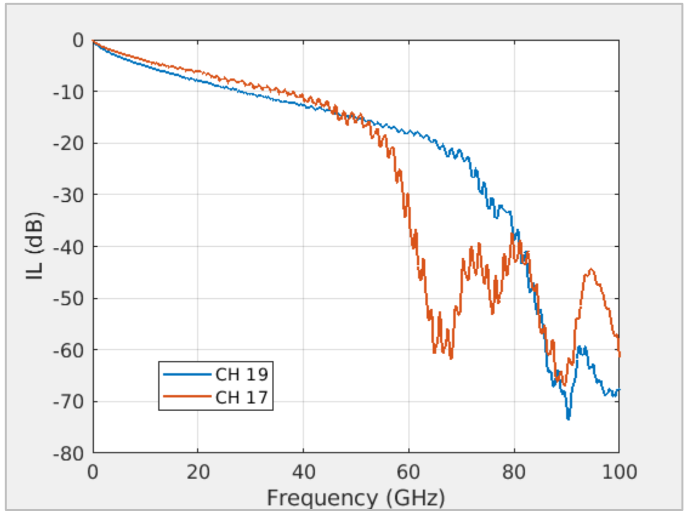
C2M channel with effective wipe sweep from *Amphenol via OSFP200GEL*

Impact from Roll-Off

- **COM results of two channels with different resonance frequencies**

	CH IL (dB)	FOM_ILD	COM (w/o FLT)	COM (wi 3*3 FLT)
CH 19	14.04	0.21	3.32	4.88
CH 17	14.17	2.23	1.89	3.43

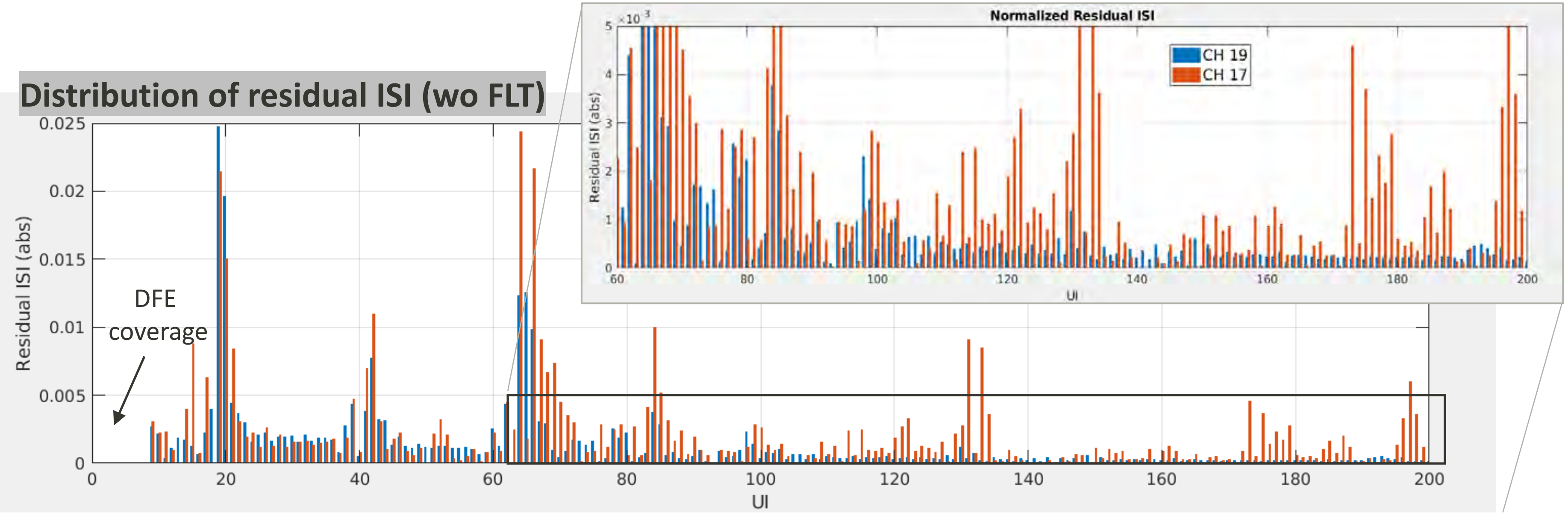
**Max. UI span for floating taps: 80*



- **Roll-off in proximity of Nyquist frequency will cause multiple reflections**
  - More DFE taps or banks of floating taps (FLTs) are required

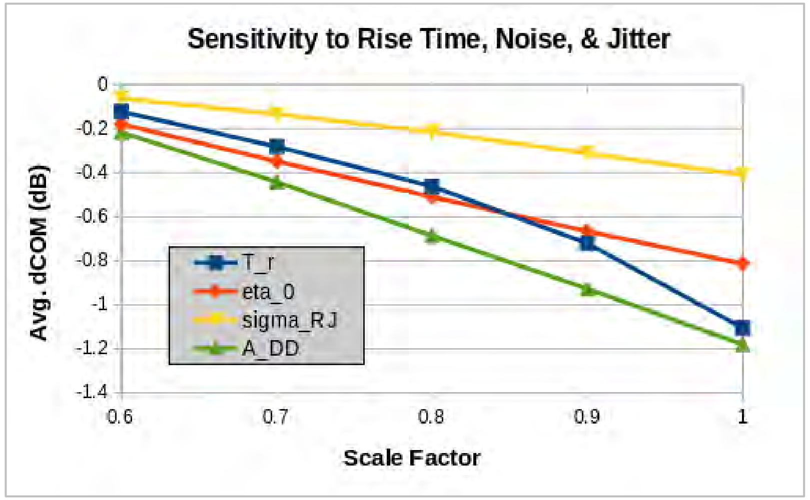
- **Resonances just beyond Nyquist seems not good enough**

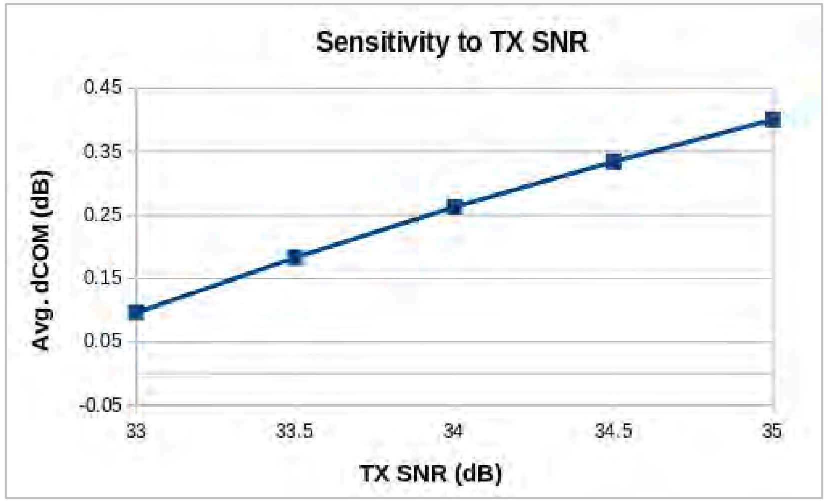
→ ***Required bandwidth?***

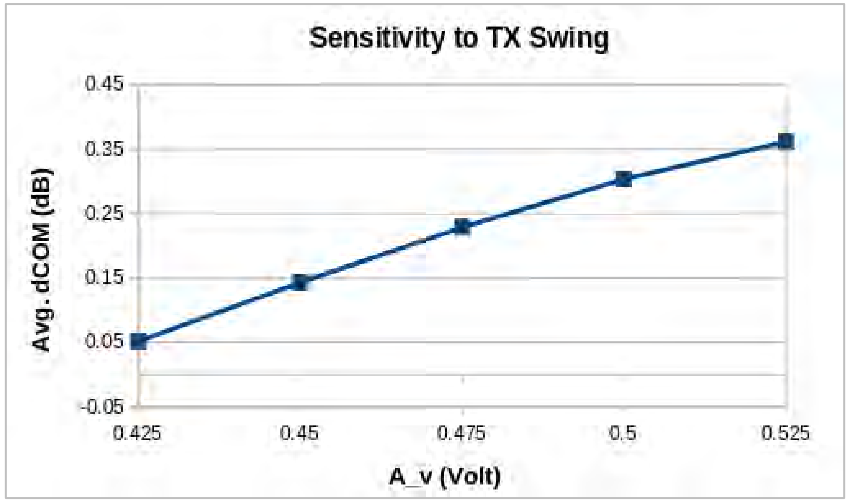


Sensitivity to Transceiver Capability

- **Necessity of delicate balance among performance, power, and area in SerDes design**
  - Possibility of increased SerDes performance and functionality (200G baseline shown in P.6)?
- **COM sensitivity check of key SerDes parameters**
  - SerDes alternatives can be observed from the results of sensitivity analysis
  - For jitter, a stricter A_DD may be a complementary solution for sigma_RJ without sacrificing performance







** Scale factor = 1 → 100G values*
** Scale factor = 0.5 → 200G expected values (Baseline)*

- *Choose critical channels with 2 < COM < 4 for analysis*

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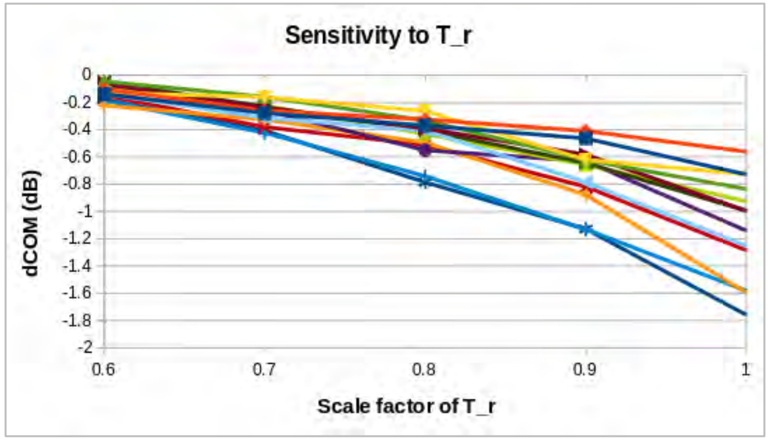
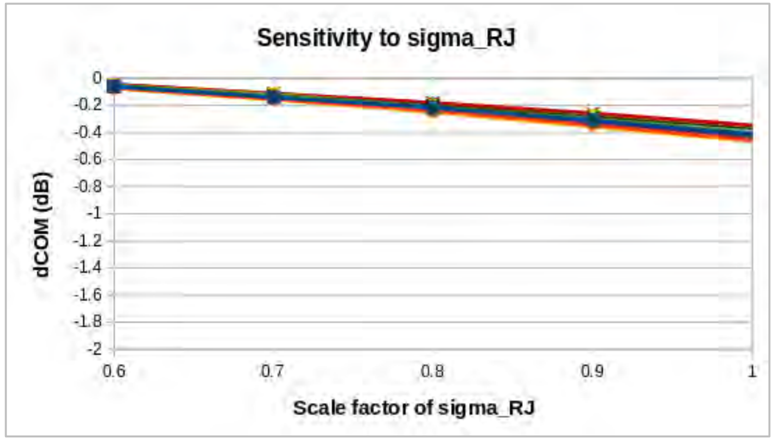
Conclusions of 200G/L PAM4 C2M

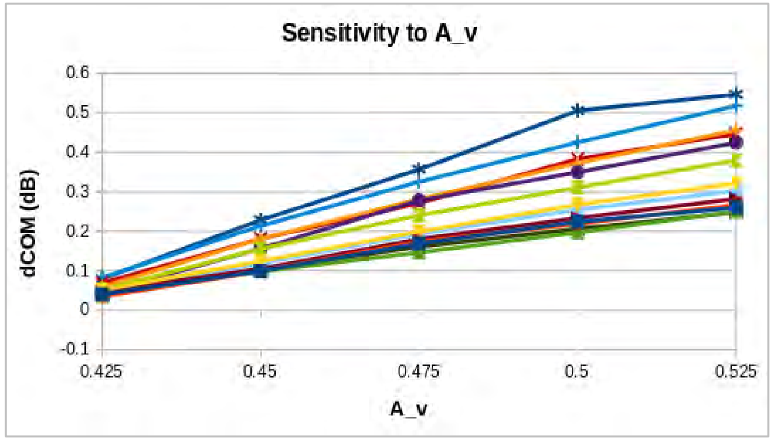
- **Feasibility of 200G/L PAM4 C2M requires both channel and SerDes technology enablement**
  - Keep IL profile at frequency of interest at the close vicinity of that for 100G/L
  - SerDes capability should be enhanced as higher Nyquist frequency
- **Channel feasibility is analyzed with**
  - Potential reach: bump2bump IL ~22 dB
    - Ball2ball (TP0 to TP1a) IL target for 200G C2M could be derived from 22 dB once the consensus of package model have been reached
  - Resonances characterizing impairments & crosstalk are observed
  - Short channel effects need further investigation
- **SerDes feasibility starts with the sensitivity check of key parameters, further investigation will be conducted with the trade-off among performance, power, & area**

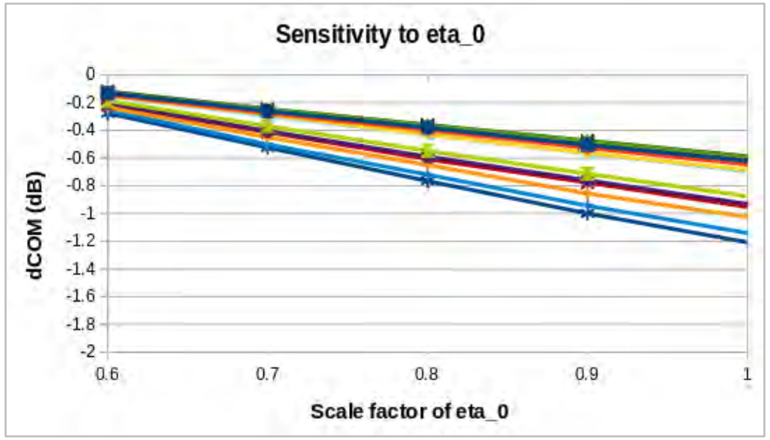
APPENDIX

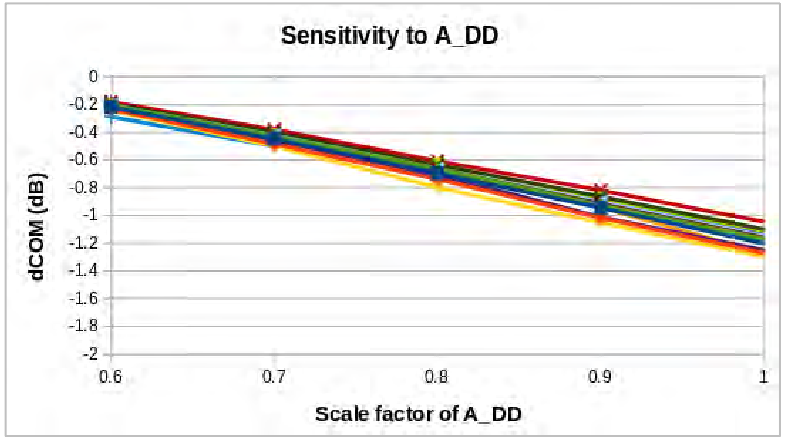
Sensitivity to Transceiver Capability

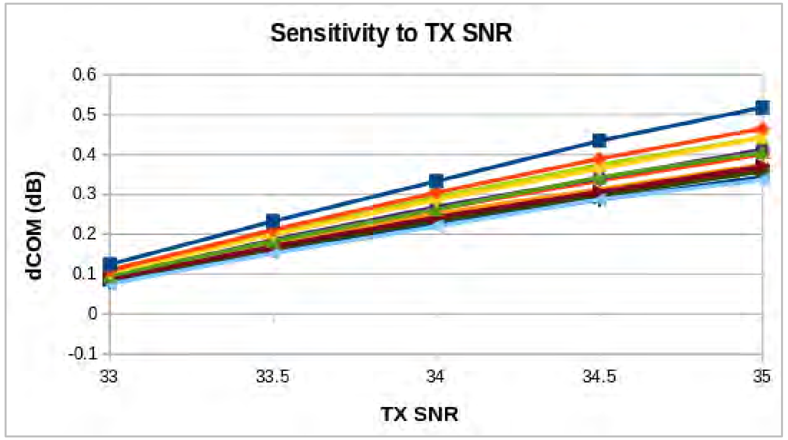












**Each curve represents one channel*