Exploring The Requirements for 224 Gbps Channel

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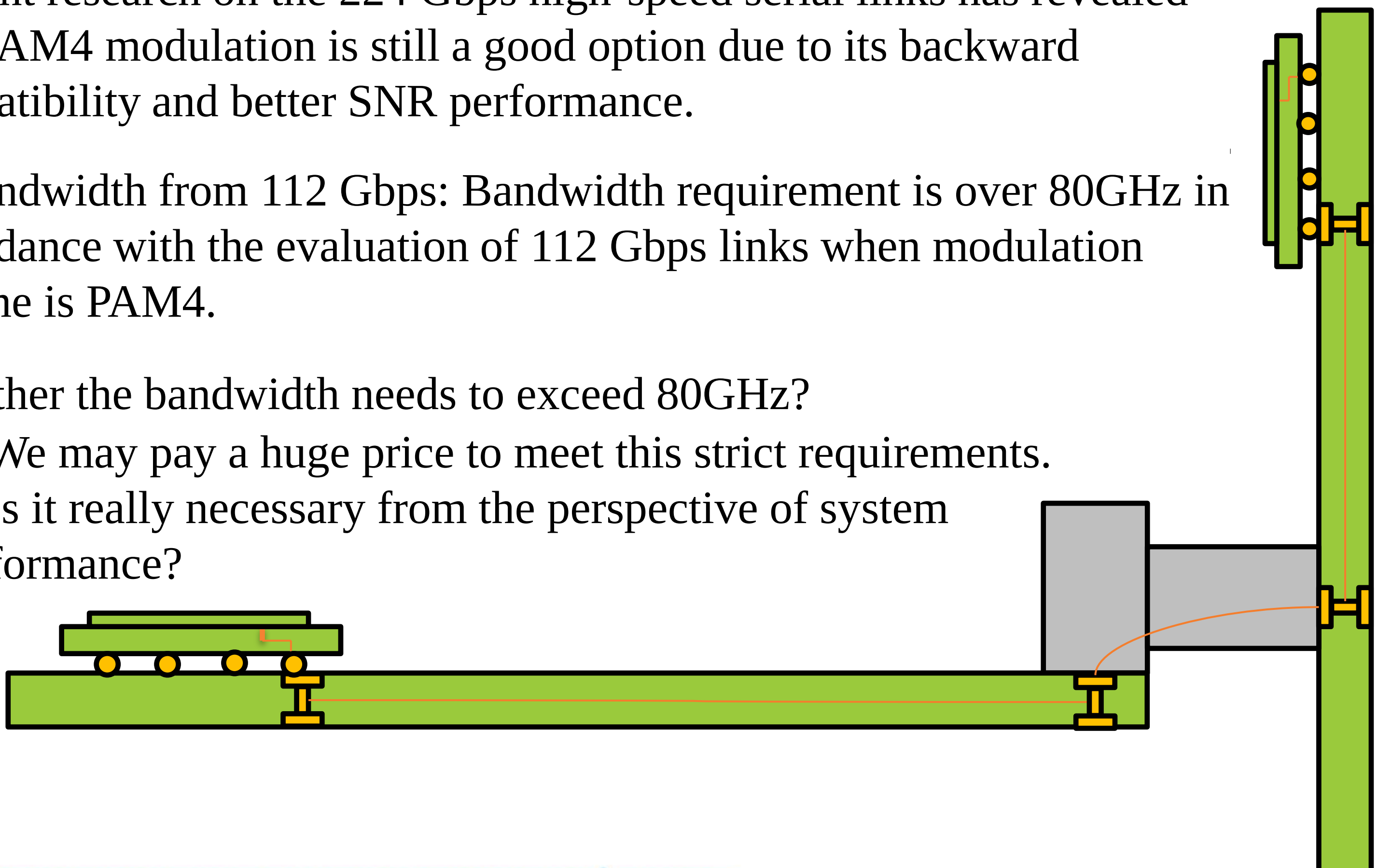
Outline

- Overview
- System Modeling
- Simulation Results
- Summary&Conclusion

Increasing Bandwidth is Challenging

- Bandwidth of system components increases with data rate, keeping increasing bandwidth is very challenging in next generation high-speed serial interconnection.
- Current research on the 224 Gbps high-speed serial links has revealed that PAM4 modulation is still a good option due to its backward compatibility and better SNR performance.
- 2x bandwidth from 112 Gbps: Bandwidth requirement is over 80GHz in accordance with the evaluation of 112 Gbps links when modulation scheme is PAM4.
- Whether the bandwidth needs to exceed 80GHz?
  - We may pay a huge price to meet this strict requirements.
  - Is it really necessary from the perspective of system performance?

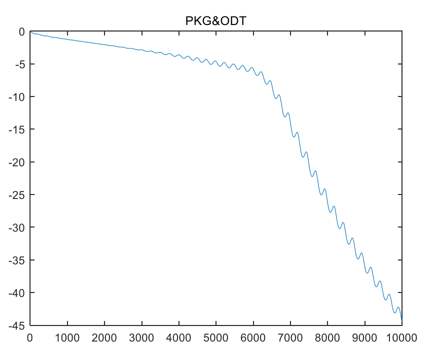


Whole Analog Channel Matters

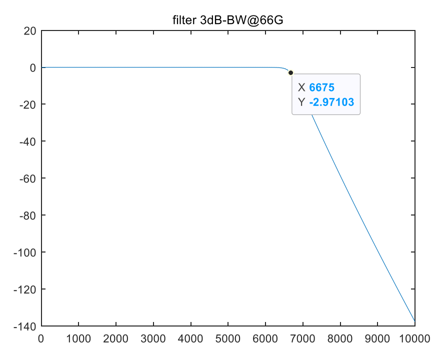
- The bandwidth of the system not only refers to the bandwidth of the system components , but also includes the bandwidth of analog front end at transceiver.

- When we design 224G system, it's not just about silicon performance, but also components, such as package, PCB, connector and cable, all of them have to improve dramatically.

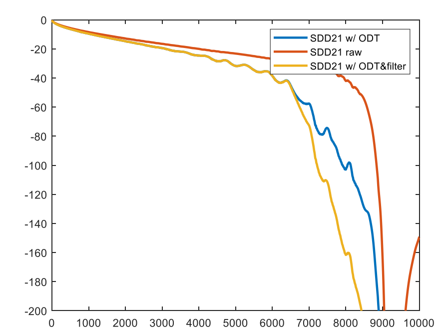
- We define channel “bandwidth” as : At the specific frequency, signal amplitude is rapidly decreased at a roll-off rate higher than the normal loss (conductor loss or dielectric loss).



SDD21 of PKG&ODT



Receiver filter ~67 GHz



SDD21 of whole system

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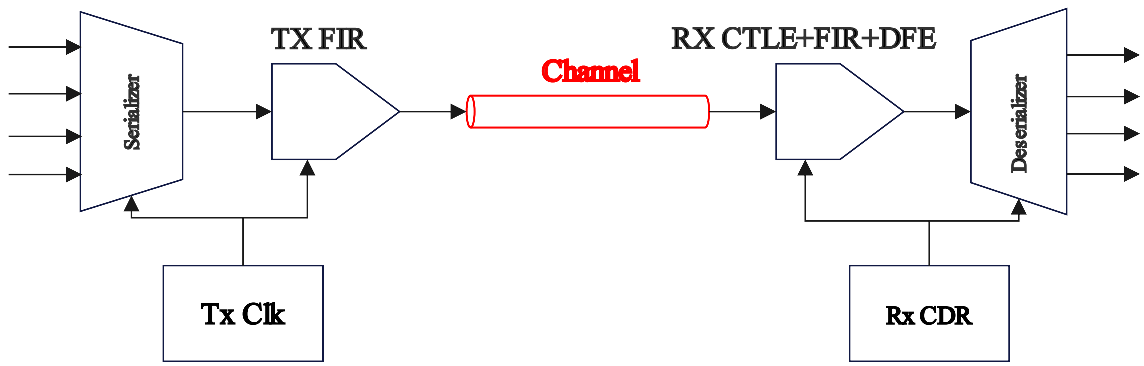
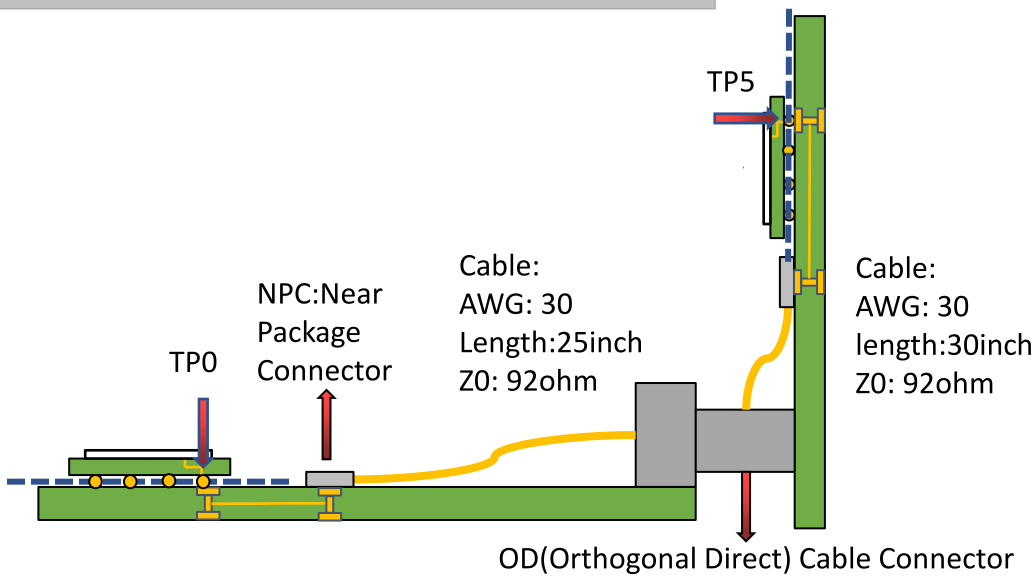
Channel description

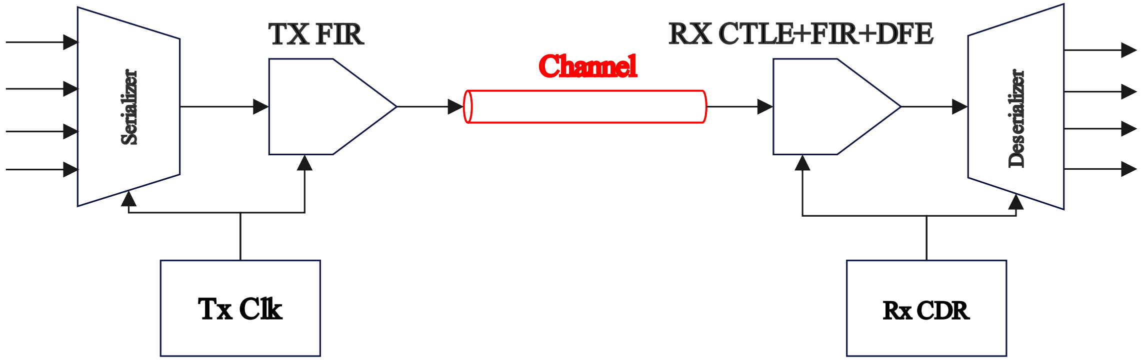


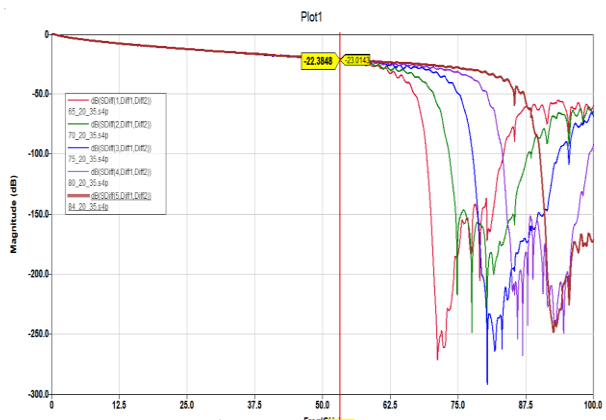
TX TP0 → BGA footprint + PCB trace +NPC footprint + NPC connector + CABLE +OD cable connector +CABLE + NPC connector + NPC footprint + PCB trace+BGA footprint → RX TP5

- Not include package
- BGA/NPC Connector Via:
  Length: ~3.6mm; Stub: ~4mil
- PCB Trace/Cable:
  Stripline: width:6.4mil
  PCB length: 2in; PCB trace loss: ~0.85dB/in@56GHz
  Cable loss: ~0.27dB/in@56GHz
- 224G NPC/OD Cable Connector

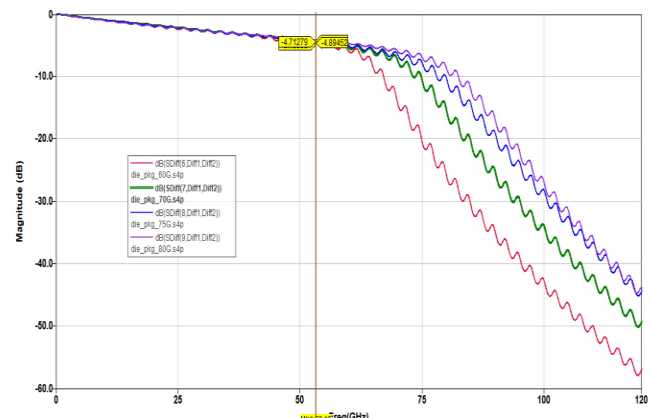


Channel Characteristics Analysis





SDD21 of channel Tp0-Tp5

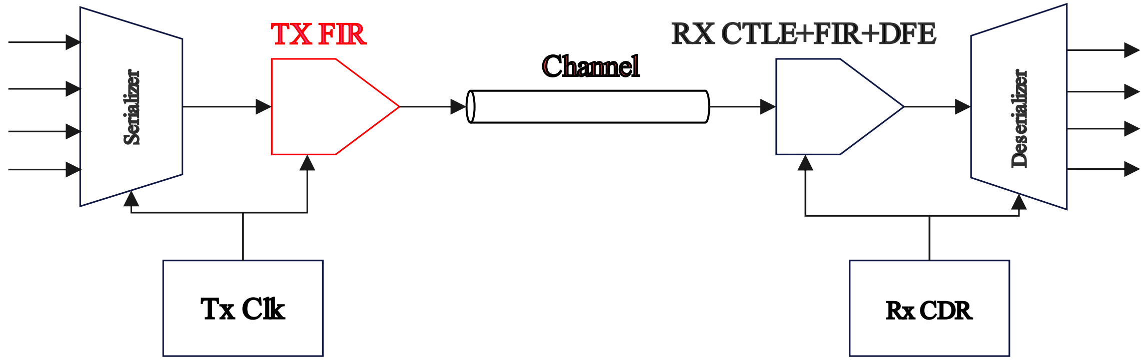


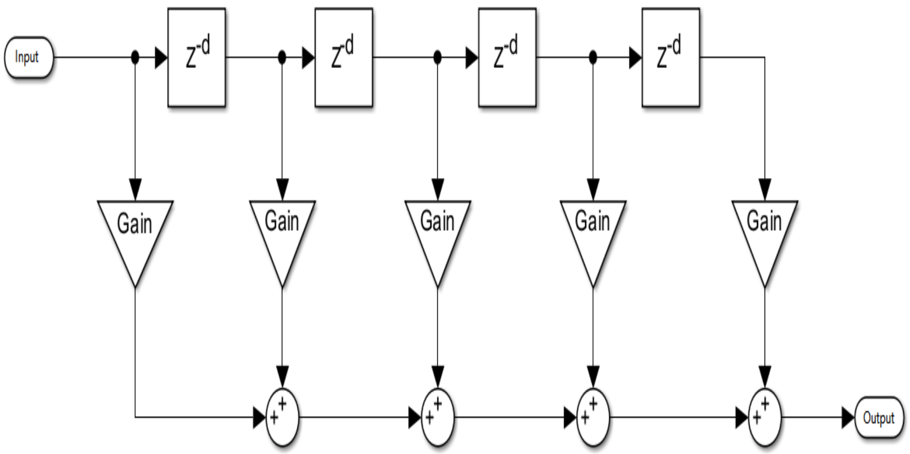
SDD21 of die&pkg

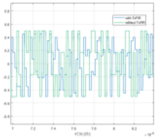
Tp0-Tp5 IL: ~23dB @ 53.125GHz
pkg&die IL:~5dB @30mm
~2dB @12mm
Roll-off Frequency@ x GHz, marked as 60, 65, 70, 73, 80 GHz.

Reference Die and Package Models refer to IEEE802.3df mli_3df_02a_220316.pdf
Roll-off Frequency@ x GHz, marked as 60, 70, 75, 80 GHz.

Tx Equalizer



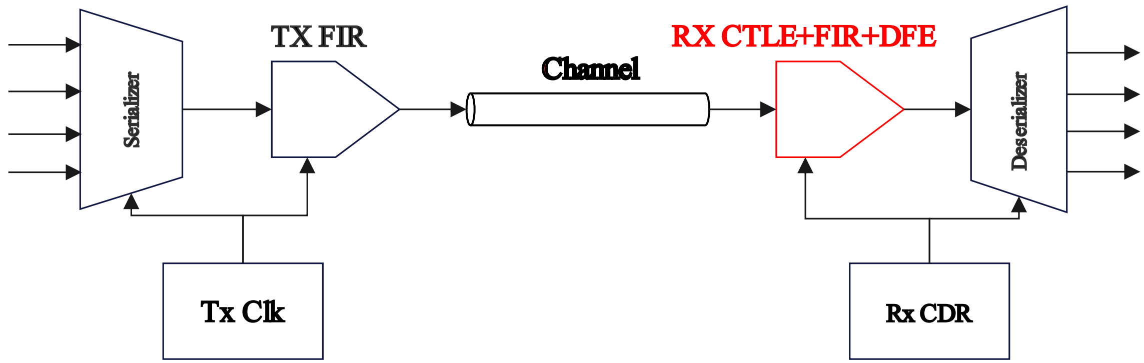


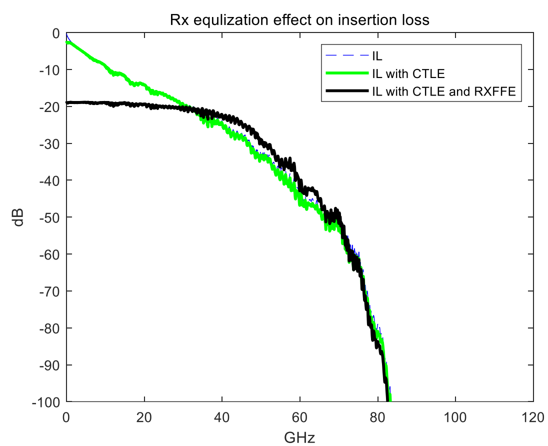


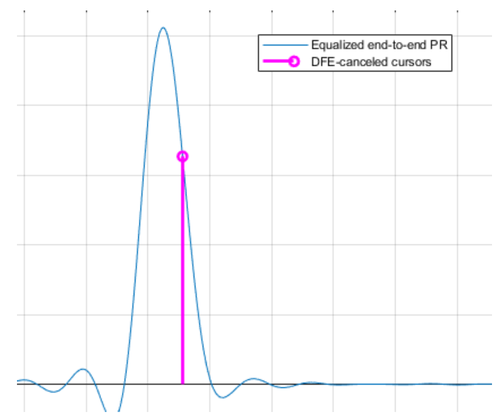
- Tx FIR has 3 pre, 1 post.

Tx FIR effects in time domain

Rx Equalizer







CTLE and RX FIR effect in frequency domain

DFE effect in time domain

- CTLE is modeled by Poles and Zeros, Receiver bandwidth ranges from 60 GHz to 80 GHz, marked as 60, 70, 75, 80 GHz.
- Rx FIR has 5-pre and 24-post.
- DFE has 1 tap.

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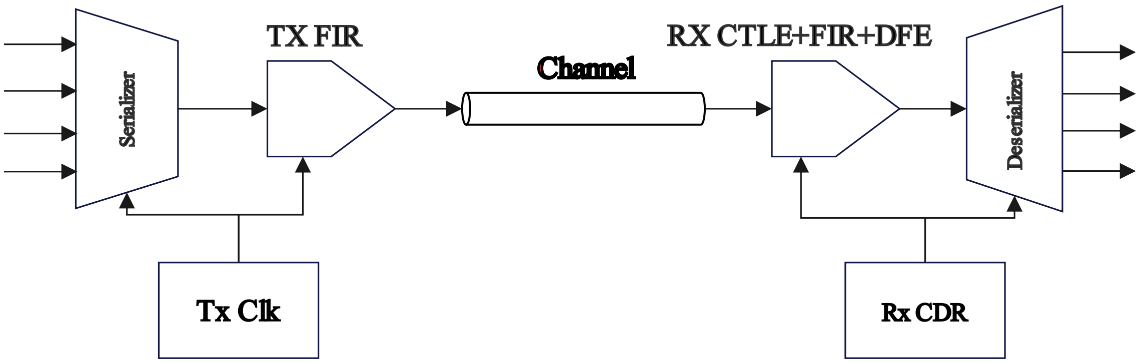
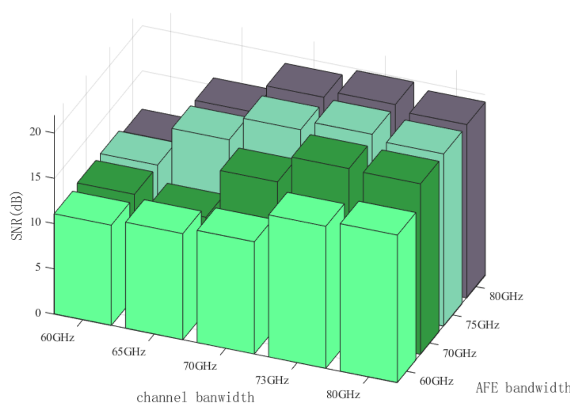
Simulation Results



- Based on the previous slides, now we have:
  - Different channel models: they have basically the same loss, but different roll-off frequency, marked as 60, 65, 70, 73, 80 GHz.
  - AFE models: they have different roll-off frequency, marked as 60, 70, 75, 80 GHz.
- There are 20 combinations of different AFE models and channel models, we can get SNR through simulation.

Simulation Results

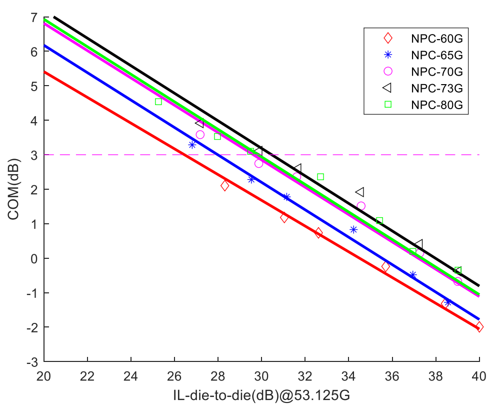
SNR（dB）	AFE Bandwidth				
		60GHz	70GHz	75GHz	80GHz
ChannelBand width	60GHz	11.08	11.37	11.49	10.8
	65GHz	11.72	10.42	15.85	15.83
	70GHz	12.39	15.89	18.54	19.01
	73GHz	15.68	18.94	19.61	19.78
	80GHz	16.28	18.83	19.02	19.14



- Both AFE Bandwidth and channel bandwidth seriously affect channel performance.
- When the bandwidth continues to increase, the improvement of SNR is not obvious.

Simulation Results

- Based on COM 4.0.
- COM configuration in appendix
- The fit curves of 70 GHz,73 GHz and 80 GHz are nearly overlap.



Channel name	IL(dB)	IL_die_to_die(dB)（case1/case）	ERL /dB	FOM_ILD /dB	COM
60G_15IN_30IN	18.97	28.31/35.69	19.53	3.00	2.08/0.25
65G_15IN_30IN	18.66	26.81/34.23	22.03	1.43	3.45/1.22
70G_15IN_30IN	18.23	27.18/34.57	21.08	0.72	3.73/1.89
73G_15IN_30IN	18.16	27.19/34.55	20.40	0.10	4.02/2.21
80G_15IN_30IN	17.99	25.26/32.69	22.06	0.04	4.65/2.82
60G_15IN_35IN	21.68	31.04/38.43	19.53	3.02	1.53/-1.06
65G_15IN_35IN	21.38	29.53/36.95	22.05	1.44	2.69/0.043
70G_15IN_35IN	20.94	29.87/37.26	21.08	0.72	3.12/0.54
73G_15IN_35IN	20.87	29.89/37.26	20.42	0.10	3.40/0.88
80G_15IN_35IN	20.72	27.97/35.42	22.07	0.04	3.76/1.52
60G_20IN_30IN	20.57	29.91/37.29	19.45	3.01	1.90/-0.57
65G_20IN_30IN	20.26	28.41/35.83	21.92	1.43	3.12/0.63
70G_20IN_30IN	19.86	28.87/36.26	21.06	0.72	3.45/1.17
73G_20IN_30IN	19.79	28.95/36.30	20.35	0.10	3.65/1.54
80G_20IN_30IN	19.60	26.74/34.20	22.00	0.04	4.15/2.11
60G_20IN_35IN	23.29	32.61/40.00	19.45	3.01	0.84/-1.58
65G_20IN_35IN	23.01	31.15/38.56	21.95	1.44	2.06/-0.84
70G_20IN_35IN	22.57	31.61/39.01	21.07	0.72	2.54/-0.16
73G_20IN_35IN	22.53	31.68/39.04	20.34	0.10	2.85/0.17
80G_20IN_35IN	22.38	29.50/36.94	21.98	0.04	3.34/0.77

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Summary&Conclusion

- Both passive channels and analog front end of transceivers have a strong impact on system performance.
- We conduct passive channels with different bandwidth based on simulation models of all components in the system under next-generation technical conditions. We also build various models of analog front end in time-domain simulation.
- We use the time-domain simulation tool and COM to investigate the impact of bandwidth on performance.
- The bandwidth of the transceiver and channel should be higher than the Nyquist frequency for PAM4. However, it does not need to be 1.5 times Nyquist frequency. Based on simulation results, a bandwidth higher than 70 GHz would be a good option.

Appendix

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	[0.4e-4 0.9e-4 1.1e-4 ;0.4e-4 0.9e-4 1.1e-4]	nF	[TX RX]
L_s	[0.13 0.15 0.14; 0.13 0.15 0.14]	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)	[12 31 45; 1 1 1 ; 0.1 0.1 0.1 ; 0.58 0.58 0.58]	mm	[test cases]
z_p (NEXT)	[12 29 45; 1 1 1 ; 0.1 0.1 0.1 ; 0.58 0.58 0.58]	mm	[test cases]
z_p (FEXT)	[12 31 45; 1 1 1 ; 0.1 0.1 0.1 ; 0.58 0.58 0.58]	mm	[test cases]
z_p (RX)	[12 29 45; 1 1 1 ; 0.1 0.1 0.1 ; 0.58 0.58 0.58]	mm	[test cases]
PKG_Tx_FFE_preset	0		
C_p	[0.5e-4 0.5e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 45]	Ohm	[TX RX]
A_v	0.4	V	vp/vf=
A_fe	0.4	V	vp/vf=
A_ne	0.6	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.5		min
c(-1)	[-0.4:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.2]		[min:step:max]
c(-3)	[-0.1:0.02:0]		[min:step:max]
c(1)	[-0.2:0.02:0]		[min:step:max]
N_b	24	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	[0.5 0.3*ones(1,5) 0.2*ones(1,17)]		As/dfe2..N_b
b_min(1)	0.3		As/dffe1
b_min(2..N_b)	-0.3		As/dfe2..N_b
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	42.5	GHz	
f_p1	42.5	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	
Butterworth	1	logical	include in fr
Raised_Cosine	0	logical	include in fr
RC_Start	6.70E+10	Hz	start freq for RCos
RC_end	7.97E+10	Hz	end freq for RCos

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
MLSE	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\CAKR_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	CAKR_RCos_eval_	
COM_CONTRIBUTION	0	logical
Operational		
ERL Pass threshold	10	dB
COM Pass threshold	3	db
DER_0	1.00E-04	
T_r	4.71E-03	ns
FORCE_TR	1	logical
PMD_type	C2C	
EW	1	
TDR and ERL options		logical
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	ns
TR_TDR	0.01	
N	1000	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	UI
N_bx	24	
fixture delay time	[0 0]	
Tukey_Window	1	
Noise, jitter		UI
sigma_RJ	0.01	UI
A_DD	0.02	V^2/GHz
eta_0	4.10E-09	dB
SNR_TX	33	
R_LM	0.95	
11-2022 BenArtsi pkg	oif2022.065.02	
highlighted are under re-consideration		

Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0008455 0.000340225]	
package_tl_tau	0.00644805	ns/mm
package_Z_c	[92 92 ; 70 70; 80 80; 100 100]	Ohm

Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 6.44084e-4 3.6036e-05]*	1.5 db/in @ 56G
board_tl_tau	*5.790E-03*	ns/mm
board_Z_c	100	Ohm
z_bp (TX)	*125*	mm
z_bp (NEXT)	*0*	mm
z_bp (FEXT)	*125*	mm
z_bp (RX)	*0*	mm
C_0	[0.2e-4 0]	nF
C_1	[0.2e-4 0]	nF
Include PCB	**0**	**logical**

Seletions (rectangle, gaussian,dual_rayleigh,triangle		
Histogram_Window_Weight	gaussian	selection
Qr	*0.02*	UI

ICN parameters		
f_v	0.278	Fb
f_f	0.278	Fb
f_n	0.278	Fb
f_2	79.688	GHz
A_ft	0.450	V
A_nt	0.450	V

Floating Tap Control		
N_bg	6	0 1 2 or 3 groups
N_bf	3	taps per group
N_f	120	UI span for floating taps
bmaxg	0.2	max DFE value for floating taps
B_float_RSS_MAX	0.1	rss tail tap limit
N_tail_start	25	(UI) start of tail taps limit

Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V

- Thank you !