200 Gbps/lane AUI C2M Channel Selection Criteria

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Introduction

- There are complex relationships between the AUI C2M channel characteristics, the AUI C2M BER target, AUI C2M TX/RX complexity, the optical PMD BER target, etc.
- Many AUI C2M channels are available for study via the 3dj TF website as well as through other industry groups
  - Over 100 channels with various assumptions and differing levels of maturity and complexity

Goals

- The goals of this contribution are to:
  - Form several “classes” of reference equalizers for comparison purposes
  - Selectively reduce the number of AUI C2M channels for analysis in order to focus baseline proposal development efforts
  - Provide a relative comparison using COM with these reduced channels
  - Start discussions in the Task Force on which contributed AUI C2M channels should pass versus which should fail
    - Discuss the ones that fall in the middle
- Not debating the C2M specification parameters at this time, including the reference receiver model, package parameters and COM, etc.
  - Please look for the high-level trends, not at the minutiae

Classes of Reference Equalizers

- Various contributions look at different reference equalizers
- Propose different classes for the relative comparison of performance for *direction finding* purposes
  - Taken from https://www.ieee802.org/3/dj/public/23_03/li_3dj_01a_2303.pdf
  - (Mild) Class I: 802.3ck C2M-like
  - Class II: 802.3ck C2M-like + Floating Taps
  - Class III: 802.3ck CR-like
  - (Spicy!) Class IV: 802.3ck CR-like + MLSE
- Note: these classes are starting points, not specific recommendations. We had to start with *something* ☺

Reference EQ Highlights – By Class

- Class I/II/III/VI

Parameter	802.3ck C2M	802.3ck CR	802.3ck KR	802.3ck C2M-like	802.3ck C2M-like + FLT	802.3ck CR-like	802.3ck CR-like + MLSE
				Exploratory of 802.3dj Medium Loss AUI C2M		Exploratory of 802.3dj High Loss AUI C2M	
DER_0	1E-5	1E-4	1E-4	1E-5/5E-5/1E-4	1E-5/5E-5/1E-4	1E-5/5E-5/1E-4	1E-5/5E-5/1E-4
SNR_TX	32.5	32.5	33	32.5	32.5	33	33
R_LM	0.95	0.95	0.95	0.95	0.95	0.95	0.95
TxFIR Length	4 (2 pre)	5 (3 pre)	5 (3 pre)	5 (3 pre)	5 (3 pre)	6 (4 pre)	6 (4 pre)
eta_0	4.10E-08	9E-09	8.2E-09	2.05E-08	2.05E-08	4.1E-09	4.1E-09
N_b	4	12	12	8	8	24	24
N_bg	0	3	3	0	**3**	6	6
N_bf	-	3	3	3	3	3	3
N_f	-	40	40	80	80	80	80
MLSE	0	0	0	0	0	0	**1**
Ref TX/RX Class				**I**	**II**	**III**	**VI**

(Mild) (Spicy!)

Note: these classes are starting points, not specific recommendations.

https://www.ieee802.org/3/dj/public/23_03/li_3dj_01a_2303.pdf

Reducing the # of Channels

- Across the inventory of AUI C2M channels available, we attempted to reduce the total number of channels down to ~10-15 unique, representative channels
  - Decrease analysis time
  - Assess the outliers
  - Eliminate obviously bad channels
- Channel parameters that we used include: Fit IL, ERL, ICN, ICR

802.3dj C2M Channel Contributions

Contribution	Channel List	Host Type
akinwale_3df_01_2209 (21x)	C2M_PCB_85ohms_10~30dB_202208016_v2_thru1	CONV PCB
akinwale_3df_02_2209 (21x)	C2M_PCB_93ohms_10~30dB_202208016_v2_thru1	CONV PCB
akinwale_3df_03_2209 (21x)	C2M_PCB_100ohms_10~30dB_202208016_v2_thru1	CONV PCB
rabinovich_3df_01_2209 (3x) rabinovich_3dj_02_230116 (1x)	Rabinovich_C2M_200G_Ortho_[19, 67, 93]mil_092122_Thru.s4p Rabinovich_C2M_200G_Ortho_135mil_011723_Thru.s4p	CONV PCB
rabinovich_3df_02_2209 (3x) rabinovich_3dj_03_230116 (1x)	Rabinovich_C2M_200G_Paral_[19, 67, 93]mil_092122_Thru.s4p Rabinovich_C2M_200G_Paral_135mil_011723_Thru.s4p	CONV PCB
tracy_3df_02_2211	TE_224G_C2M_Conventional_[5,7,13]inHst_100622_THRU.s4p	CONV PCB
	TE_224G_C2M_NCC_100622_THRU.s4p	NCC
	TE_224G_C2M_CPC_CPB_091622_THRU_mod.s4p	CPC

Extreme impedance corners
(not included at this time)

Technology still stabilizing
(not included at this time)

https://www.ieee802.org/3/df/public/tools/index.html

Expanded List of Channels

Fit IL (dB)	<= 16	16 < X <= 28	> 28

	Max	Q3	Med	Q1	MIN
ERL	19.19	13.46	12.79	12.02	10.29

Challenge	Channel	IL (dB)	Fit IL (dB)	FOM_ILD (dB)	ERL (DER_0 = 1E-5)	ICN (mV)	ICR (dB)
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_10dB	8.77	10.35	0.53	11.33	2.55	26.96
Reflection	ak Saved to U: Drive 2209/C2M_PCB_93ohms_11dB	9.61	11.22	0.52	11.56	2.32	27.72
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_12dB	10.45	12.07	0.52	11.80	2.11	27.11
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_13dB	11.31	12.92	0.52	12.02	1.93	27.58
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_14dB	12.17	13.83	0.55	11.48	1.91	26.96
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_15dB	13.03	14.67	0.56	11.68	1.76	27.07
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_16dB	14.73	16.33	0.57	12.03	1.50	26.75
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_17dB	15.55	17.16	0.58	12.18	1.40	26.63
	akinwale_3df_02_2209/C2M_PCB_93ohms_18dB	16.42	17.98	0.59	12.33	1.30	26.28
	akinwale_3df_02_2209/C2M_PCB_93ohms_19dB	17.24	18.80	0.60	12.46	1.22	26.20
	akinwale_3df_02_2209/C2M_PCB_93ohms_20dB	18.11	19.62	0.61	12.59	1.15	25.65
	akinwale_3df_02_2209/C2M_PCB_93ohms_21dB	19.80	21.25	0.64	12.80	1.04	24.85
	akinwale_3df_02_2209/C2M_PCB_93ohms_22dB	20.63	22.06	0.65	12.89	0.99	24.66
	akinwale_3df_02_2209/C2M_PCB_93ohms_23dB	21.49	22.87	0.66	12.98	0.95	23.87
	akinwale_3df_02_2209/C2M_PCB_93ohms_24dB	22.33	23.68	0.68	13.06	0.92	23.57
	akinwale_3df_02_2209/C2M_PCB_93ohms_25dB	24.02	25.29	0.70	13.21	0.86	22.29
	akinwale_3df_02_2209/C2M_PCB_93ohms_26dB	24.87	26.09	0.72	13.27	0.84	21.46
	akinwale_3df_02_2209/C2M_PCB_93ohms_27dB	25.71	26.89	0.73	13.33	0.83	20.89
	akinwale_3df_02_2209/C2M_PCB_93ohms_28dB	26.56	27.70	0.74	13.38	0.81	20.06
IL, Xtalk	akinwale_3df_02_2209/C2M_PCB_93ohms_29dB	28.25	29.30	0.76	13.49	0.79	18.57
IL, Xtalk	akinwale_3df_02_2209/C2M_PCB_93ohms_30dB	29.10	30.11	0.78	13.53	0.78	17.83
	Rabinovich_C2M_200G_Ortho_19mil_092122	12.38	13.57	0.70	18.06	1.79	28.68
	Rabinovich_C2M_200G_Ortho_67mil_092122	14.70	14.87	0.69	17.50	2.71	27.00
	Rabinovich_C2M_200G_Ortho_93mil_092122	14.17	14.81	0.95	15.36	2.83	24.90
Xtalk	Rabinovich_C2M_200G_Ortho_135mil_011723	13.35	14.99	0.96	15.20	3.39	22.24
	Rabinovich_C2M_200G_Paral_19mil_092122	12.27	13.16	0.47	18.30	2.35	26.93
	Rabinovich_C2M_200G_Paral_67mil_092122	13.32	13.91	0.50	17.90	2.87	26.79
Xtalk	Rabinovich_C2M_200G_Paral_93mil_092122	13.44	14.12	0.67	14.98	3.17	24.32
Xtalk	Rabinovich_C2M_200G_Paral_135mil_011723	12.93	14.44	0.49	15.51	3.78	22.23
	tracy_3df_02_2211_C2M_CONV_5p4dB_HOST	10.26	10.64	0.55	18.76	1.58	45.15
	tracy_3df_02_2211_C2M_CONV_7p6dB_HOST	12.36	12.79	0.56	18.94	1.24	46.47
	tracy_3df_02_2211_C2M_CONV_14dB_HOST	18.78	19.18	0.62	19.19	0.64	49.12
	tracy_3df_02_2211_C2M_NCC_HOST	10.43	11.09	0.41	15.27	2.28	28.52

- **This presentation does not intend to propose any channel specifications**
- **The relative ERL, ICN, and ICR are compared under largely channel commonality:**
  - **OSFP connector (possibly from the same contributor)**
  - **Host type: CONV PCB (except one is NCC)**

Package loss is ~7dB per 30mm, ~9dB total for 30mm+8mm.
Source: https://www.ieee802.org/3/df/public/22_11/benartsi_3df_01a_2211.pdf

Relative COM Comparison with Proposed Channels

- The assumed AUI C2M BER targets were 1E-5, 2E-5, 5E-5, 8E-5
  - Much less interest in 1E-4
- Of course, the reported COM results will change depending on the channel, Cd, Cp, host and module package trace lengths, reference receiver model architecture & settings, etc.
- One package scenario: 30mm + 8mm (~9 dB IL)

Straw Poll #1 and 2 -- directional

At this time, I prefer the 200 Gbps/lane AUI BER target option per brown_3dj_elec_01_230420 slide 18:

a. Option A: C2M and C2C AUI BER 1E-5

b. Option B: C2M and C2C AUI BER 2E-5

c. Option C: C2M and C2C AUI BER 5E-5

d. Option D: C2M and C2C AUI BER 1E-4

e. Option E: C2M AUI BER 8E-5 and C2C AUI BER 2E-5

SP#1 Results (Chicago rules): A: 29 B: 19 C: 25 D: 8 E: 24

SP#2 Results (Choose one): A: 12 B: 4 C: 17 D: 0 E: 12 NMI: 11

https://www.ieee802.org/3/dj/public/adhoc/electrical/23_0420/straw_polls_3df_elec_adhoc_230420.pdf

A Relative Comparison

Fit IL (dB)	<= 16	16 < X <= 28	> 28
COM (dB)	>= 3.5	2.5 <= X < 3.5	< 2.5

	Max	Q3	Med	Q1	MIN
ERL	19.19	13.46	12.79	12.02	10.29

Challenge	Channel	IL (dB)	Fit IL (dB)	FOM_ILD (dB)	ERL (DER_0 = 1E-5)	ICN (mV)	ICR (dB)	COM (DER_0 = 1E-5, 30mm/8mm)				COM (DER_0 = 5E-5, 30mm/8mm)				COM (DER_0 = 1E-4, 30mm/8mm)			
								I	II	III	IV	I	II	III	IV	I	II	III	IV
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_10dB	8.77	10.35	0.53	11.33	2.55	26.96												
Reflection	ak[illegible]2209/C2M_PCB_93ohms_11dB	9.61	11.22	0.52	11.56	2.32	27.72												
Reflection	akinwale_3df_02_2209/C2M_PCB_93ohms_12dB	10.45	12.07	0.52	11.80	2.11	27.11												
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	akinwale_3df_02_2209/C2M_PCB_93ohms_26dB	24.87	26.09	0.72	13.27	0.84	21.46												
	akinwale_3df_02_2209/C2M_PCB_93ohms_27dB	25.71	26.89	0.73	13.33	0.83	20.89												
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	Rabinovich_C2M_200G_Ortho_67mil_092122	14.70	14.87	0.69	17.50	2.71	27.00												
	Rabinovich_C2M_200G_Ortho_93mil_092122	14.17	14.81	0.95	15.36	2.83	24.90												
Xtalk	Rabinovich_C2M_200G_Ortho_135mil_011723	13.35	14.99	0.96	15.20	3.39	22.24												
	Rabinovich_C2M_200G_Paral_19mil_092122	12.27	13.16	0.47	18.30	2.35	26.93												
	Rabinovich_C2M_200G_Paral_67mil_092122	13.32	13.91	0.50	17.90	2.87	26.79												
Xtalk	Rabinovich_C2M_200G_Paral_93mil_092122	13.44	14.12	0.67	14.98	3.17	24.32												
Xtalk	Rabinovich_C2M_200G_Paral_135mil_011723	12.93	14.44	0.49	15.51	3.78	22.23												
	tracy_3df_02_2211_C2M_CONV_5p4dB_HOST	10.26	10.64	0.55	18.76	1.58	45.15												
	tracy_3df_02_2211_C2M_CONV_7p6dB_HOST	12.36	12.79	0.56	18.94	1.24	46.47												
	tracy_3df_02_2211_C2M_CONV_14dB_HOST	18.78	19.18	0.62	19.19	0.64	49.12												
	tracy_3df_02_2211_C2M_NCC_HOST	10.43	11.09	0.41	15.27	2.28	28.52												

Saved to U: Drive

Medium Loss AUI C2M Candidates

These channels need more equalization (class III or better) than the others

High Loss AUI C2M Candidates

These channels could work with a Medium complexity Equalizer (class I-II)

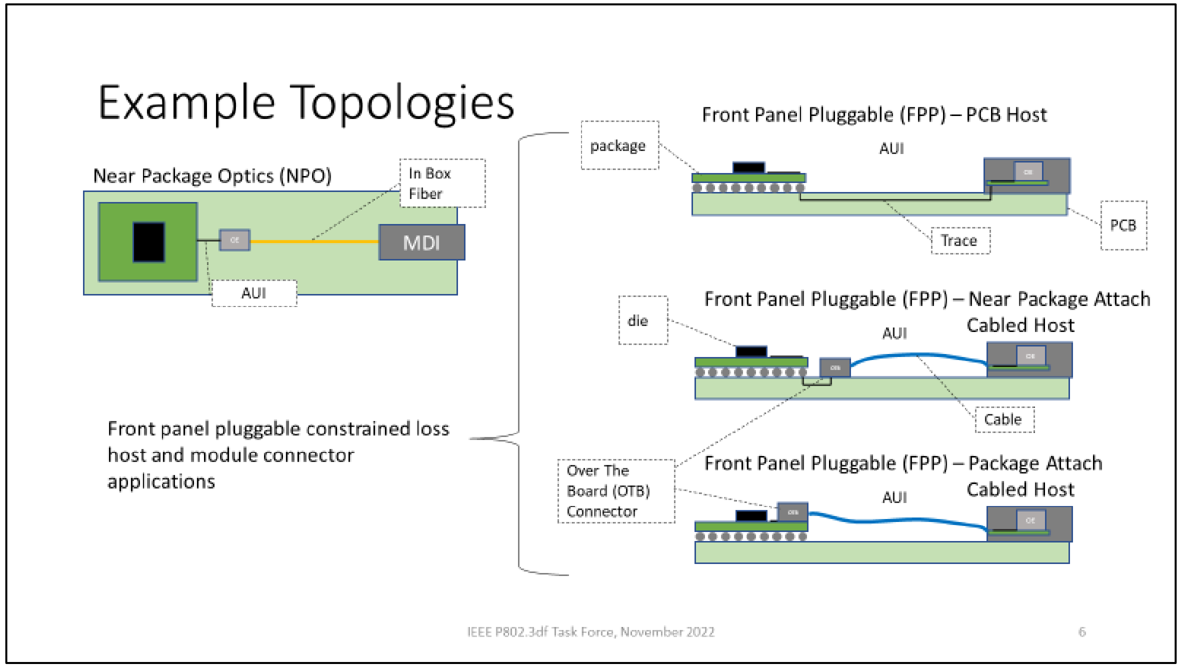
Medium Loss AUI C2M Candidates

- **This presentation does not intend to propose any channel specifications**
- **The relative ERL, ICN, and ICR are compared under largely channel commonality:**
  - **OSFP connector (possibly from the same contributor)**
  - **Host type: CONV PCB (except one is NCC)**

Package loss is ~7dB per 30mm, ~9dB total for 30mm+8mm.
Source: https://www.ieee802.org/3/df/public/22_11/benartsi_3df_01a_2211.pdf

AUI C2M Loss Reminder

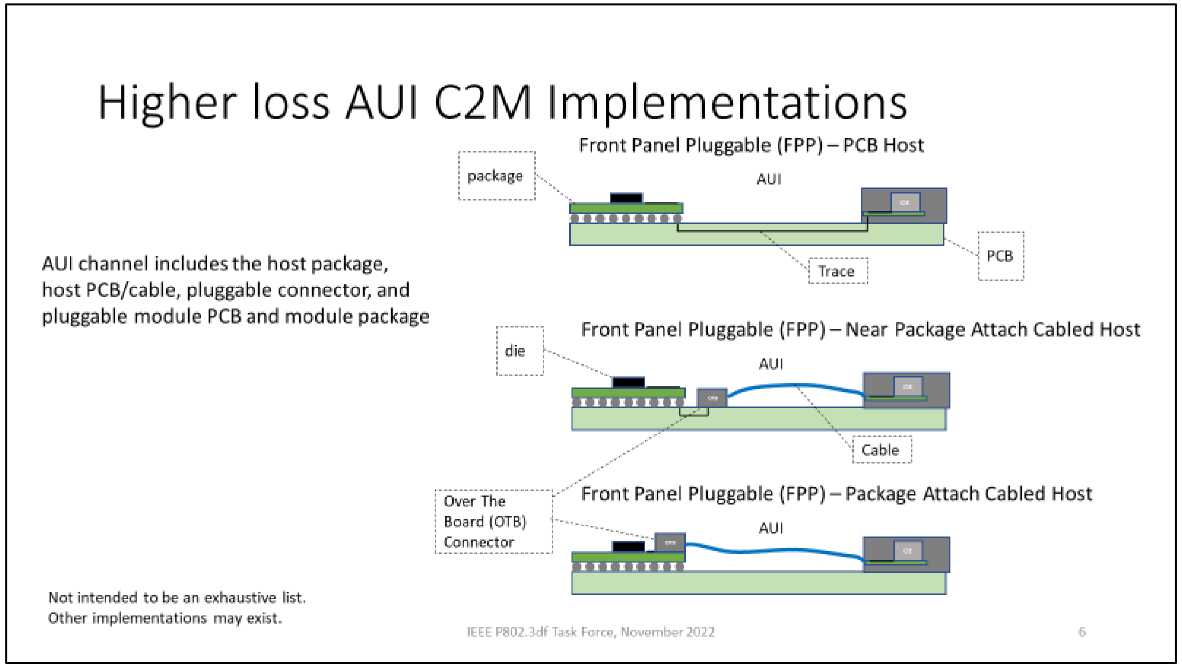
Medium Loss AUI C2M



- Targets ~22 dB IL die-die
- NPO and constrained loss FPP
- The COM reference transmitter and receiver models and parameters are an evolution from 3ck, scaled to the higher signaling rate

https://www.ieee802.org/3/df/public/22_11/lusted_3df_03a_2211.pdf

High Loss AUI C2M



- Targets ~36 dB IL die-die
- Primarily FPP
- Reference receiver and transmitter models leveraged from 3ck backplane and copper cable, scaled appropriately

https://www.ieee802.org/3/df/public/22_11/lusted_3df_02_2211.pdf

Summary

- Established several “classes” of reference equalizers for relative comparison purposes
  - “Mild” (Class I) to “spicy” (Class IV)
- Selectively reduced the number of AUI C2M channels for analysis in order to focus baseline proposal development efforts
- Provided a relative comparison using COM with these reduced channels
  - Some channels work with medium complexity equalization assumed for medium loss AUI C2M
  - Almost all channels work with higher complexity equalization assumed for high loss AUI C2M
- Next step is to recommend a pass/fail grading for the reduced channels, by AUI C2M loss category
  - Plan to have initial grading for the May 2023 interim meeting
  - Please reach out to us to get involved in the proposed grading

Thanks!

BACKUP

COM Reference Sheets for Class I/II/III/VI

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)	[15 30; 1 1 ; 1 1 ; 0.5 0.5]	mm	[test cases]
z_p (NEXT)	[8 8; 0 0 ; 0 0 ; 0 0]	mm	[test cases]
z_p (FEXT)	[15 30; 1 1 ; 1 1 ; 0.5 0.5]	mm	[test cases]
z_p (RX)	[8 8; 0 0 ; 0 0 ; 0 0]	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	[50 50]	Ohm	[TX RX]
A_v	0.413	V	vp/vf=
A_fe	0.413	V	vp/vf=
A_ne	0.45	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.54		min
c(-1)	[-0.34:0.02:0]		[min:step:max]
c(-2)	[0:.02:0.12]		[min:step:max]
c(-3)	[-0.06:.02:0]		[min:step:max]
c(-4)	[0:.02:0.04]		[min:step:max]
c(1)	[-0.12:0.02:0.1]		[min:step:max]
N_b	24	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	[0.5 0.3 0.3 0.2*ones(1,20)]		As/dfe2..N_b
b_min(1)	0.3		As/dffe1
b_min(2..N_b)	[0.2 0.05 0.05 -0.05*ones(1,20)]		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	1.328125	GHz	
Butterworth	1	logical	include in fr
Raised_Cosine	0	logical	include in fr

I/O control		
DIAGNOSTICS	0	logical
DISPLAY_WINDOW	0	logical
CSV_REPORT	0	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	3.75E-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	800	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	UI
N_bx	8	
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	
Enforce Causality	1	
S-parameter magnitude extrap	trend_to_DC	
MLSE	1	logical

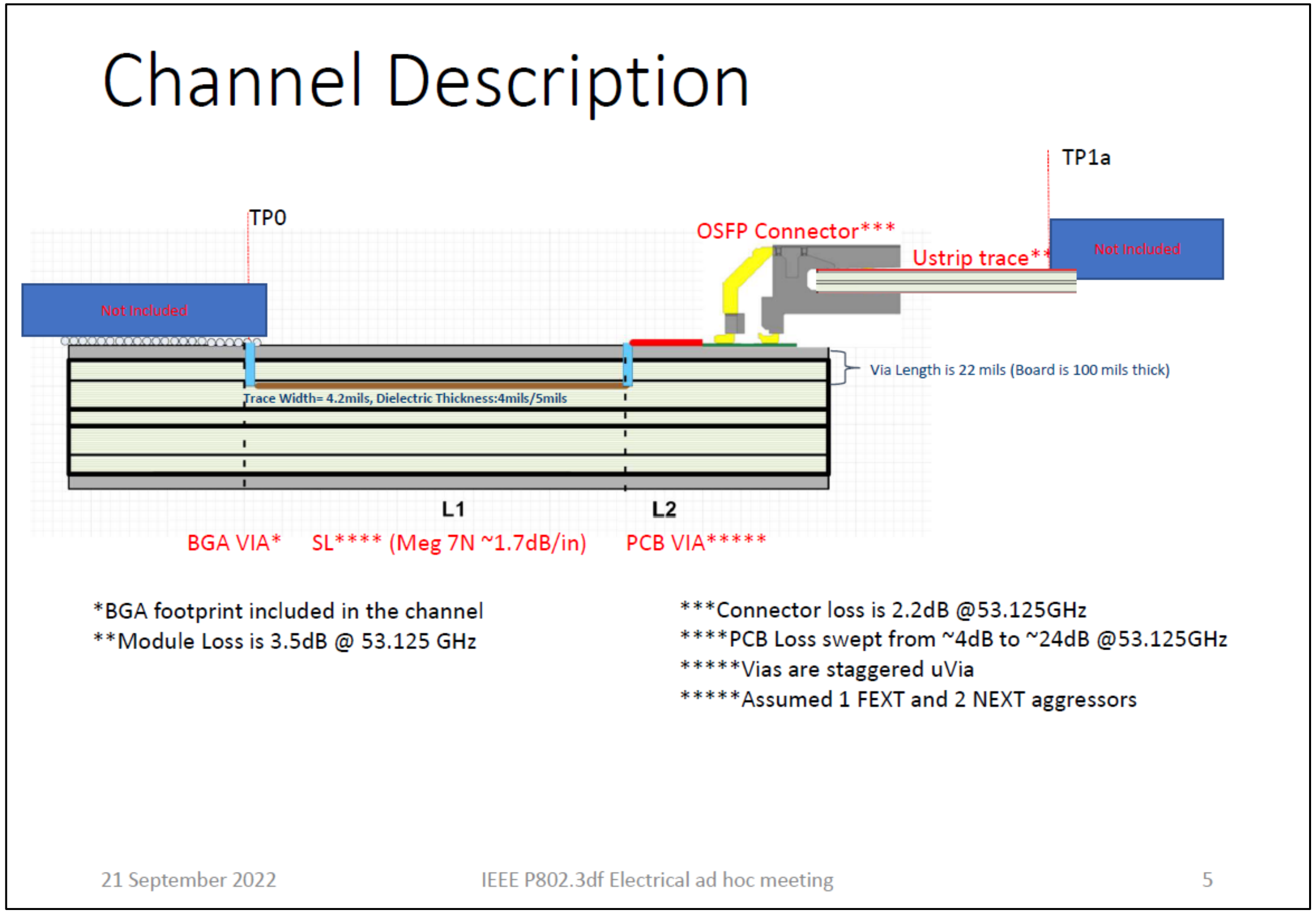
Table 93A-3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0008455 0.000340225]	
package_tl_tau	0.00644805	ns/mm
package_Z_c	[92 92 ; 70 70; 80 80; 100 100]	Ohm
Parameter	**Setting**	
board_tl_gamma0_a1_a2	[0 6.44084e-4 3.6036e-05]	1.5 db/in @ 56G
board_tl_tau	5.790E-03	ns/mm
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	0.594	Fb
f_f	0.594	Fb
f_n	0.594	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	80	UI span for floating taps
bmaxg	0.2	max DFE value for floati
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V

**ERL and ICN parameters*

*** Make changes of Class I/II/III/VI based on parameters listed in slide 6*

C2M Channel Summaries (1/3)

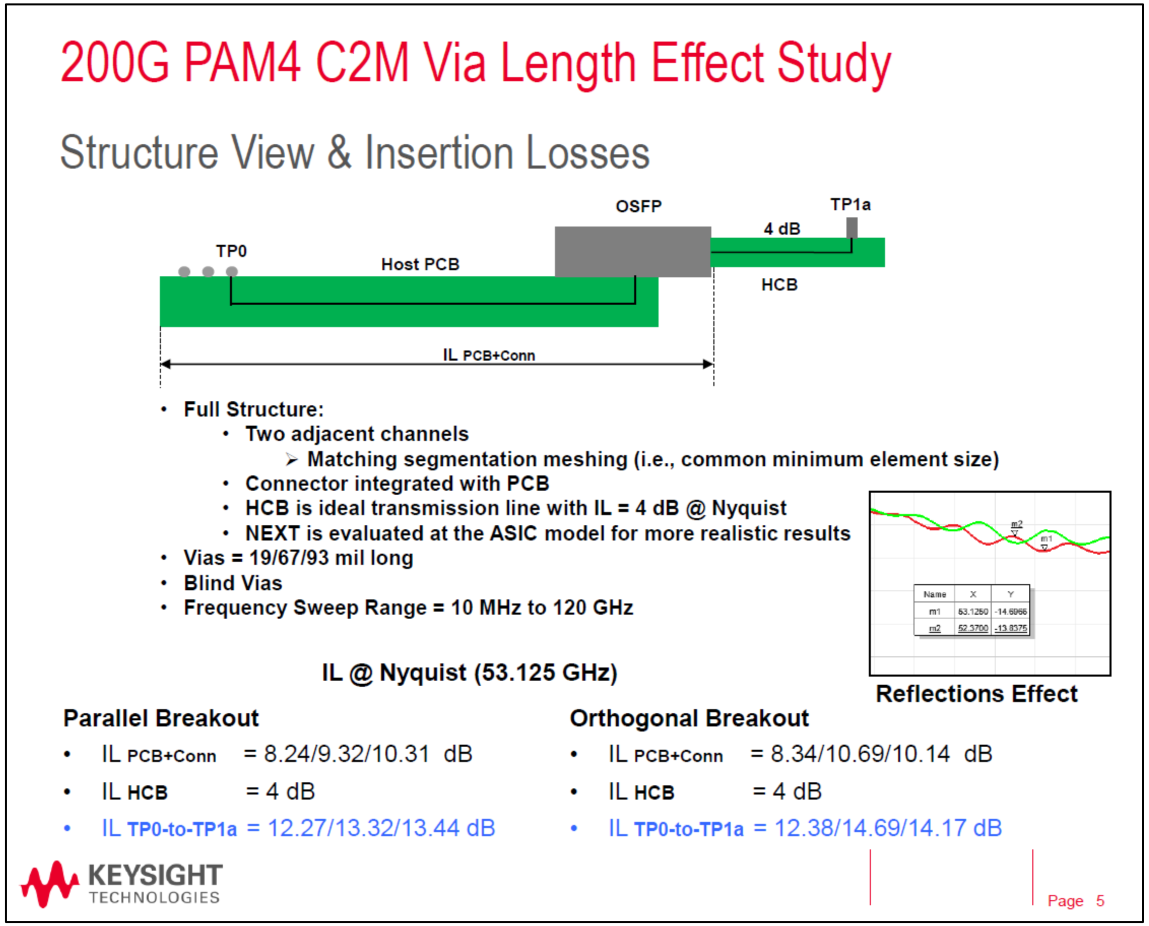
- TP0 to TP1a IL range from 10.35dB to 29.56dB in two different model variants
  - Host PCB length
  - Host PCB impedance



Contribution: akinwale_3df_elec_01_220921
Channel: akinwale_3df_01_2209, akinwale_3df_02_2209, akinwale_3df_03_2209

C2M Channel Summaries (2/3)

- TP0 to TP1a IL range from 10.64dB to 14.99dB in two different model variants
  - ASIC breakout topology
  - Via length



Contribution: rabinovich_3df_elec_01b_220921, rabinovich_3dj_01_230116
Channel: rabinovich_3df_01_2209, rabinovich_3df_02_2209, rabinovich_3dj_02_230116, rabinovich_3dj_03_230116

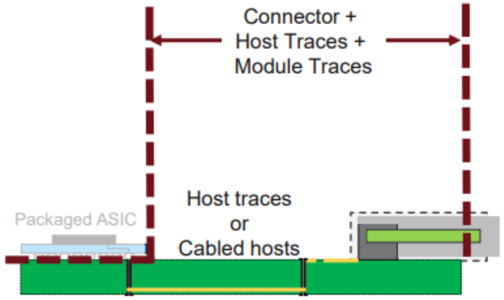
C2M Channel Summaries (3/3)

- TP0 to TP1a IL range from 7.54dB to 19.18dB in two different model variants
  - Host type
  - Host PCB length

Contribution: tracy_3df_02_2211
Channel: tracy_3df_02_2211_sparameters

Description

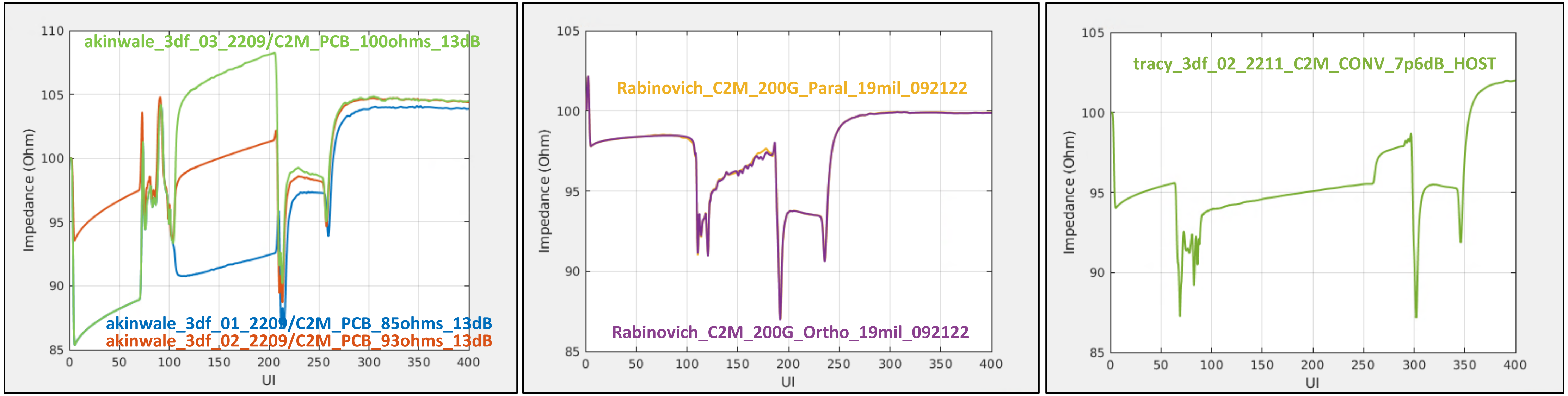
- Simulation for 200G chip to module channels using concept connector with various host architecture options
- Includes BGA escape model provided by Regee Petaja of Broadcom
- Does NOT include silicon package
- Current view of Chip to Module performance in various host implementations
- What this presentation is NOT:
  - Modulation proposal
  - Channel or host loss proposal
  - Compliance board proposal
  - A specific host architecture proposal;
    - comparative performance options are presented, i.e., traces vs. cabled host to “near ASIC” vs. co-package copper
  - Asymmetric architectures (managed deployment)



5

Coarse Selection via Impedance Corner

- TP1a-die (host) TDR
  - Impedance mismatch among MCB-Conn-HCB in **akinwale_3df_01_2209 (85Ohm)** and **akinwale_3df_03_2209 (100Ohm)** are greater than **10%**



Two AUI C2M Host Losses

Straw Poll #1

For the front panel pluggable use case, I am interested in 200 Gbps/lane AUI C2M specifications for:

A. medium loss only (e.g. up to ~22 dB IL die-die per lusted_3df_01_220927)
B. higher loss only (e.g. up to ~36 dB IL die-die per lusted_3df_01_220927)
C. both medium and higher loss
D. need more information

pick one

Results: A: 17, B: 11, C: 49, D: 12

https://www.ieee802.org/3/df/public/22_10/motions_3df_221004.pdf