Accounting for Mode Conversion

Addressing
unsatisfied D2.1 modal ERL comments: 253, 254, 256, 257, 258, 259, 261, 262, 264, 265, 266, 267, 268
unsatisfied D2.2 modal ERL comments :121, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134,135
D2.3 comments 40, 41

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January 2026, Austin, TX, IEEE P802.3dj Interim

Supporters

- ❑ Jason Chan, Arista
- ❑ Howard Heck, TE Connectivity
- ❑ Xu Jiang, LUXSHARE-ICT
- ❑ Upen Reddy Kareti, Cisco Systems Inc.
- ❑ Rohan Phadke, Arista
- ❑ Rick Rabinovich, Keysight
- ❑ Jeremy Stephens, AMD
- ❑ Scott Sommers, Molex
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- ❑ Geoff Zhang, AMD

Agenda

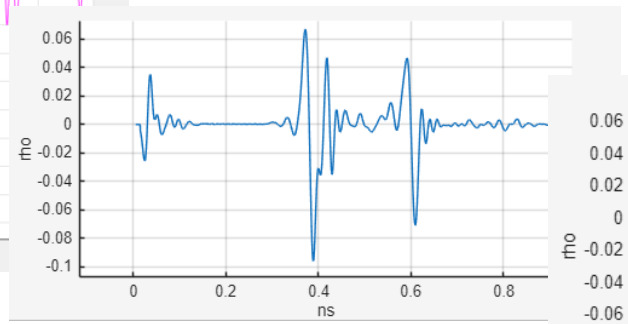
- ❑ Background
- ❑ ERL Fundamentals and Modal Approach
- ❑ Broadened Coverage and Correlation Studies
- ❑ C2M Experiment Results
- ❑ Specification Alternatives
- ❑ Options Summary

Background

- Unclear impact: How modal 200 Gb/s specifications affect performance is not well understood.
- Limited evidence: Few studies link CM reflection mask excursions to receiver voltage impairments for 200 Gb/s 802.3dj context.
- Current parameters: SCMR and VCM expected to bound CM noise
  - Covering: C2D, D2C, and CM-to-CM conversions.
- Gap in COM: DD2DD modal conversion at TX/RX is not included in COM calculations.
- Prior work: “Moving toward ERL CC/DC/CD specification” mellitz_3dj_adhoc_01a_251030
- Expanded scope: Includes CA and C2M host channels (beyond KR).
- Goal: Define best path for accounting CM in the standard.

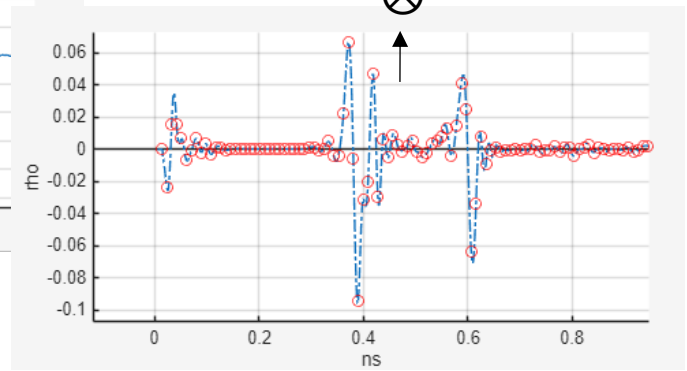
ERL Review

RL vs. frequency

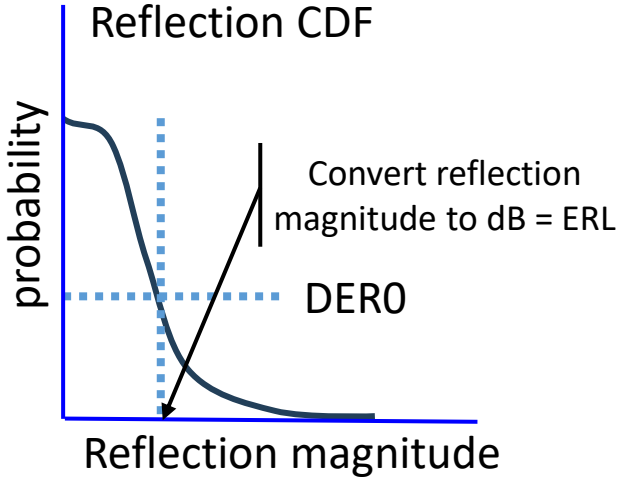


Reflection Pulse Response

Data pattern



Sampled



"Convolve the UI sampled reflection response with the symbol sequence to estimate the probability distribution of effective reflection magnitude.

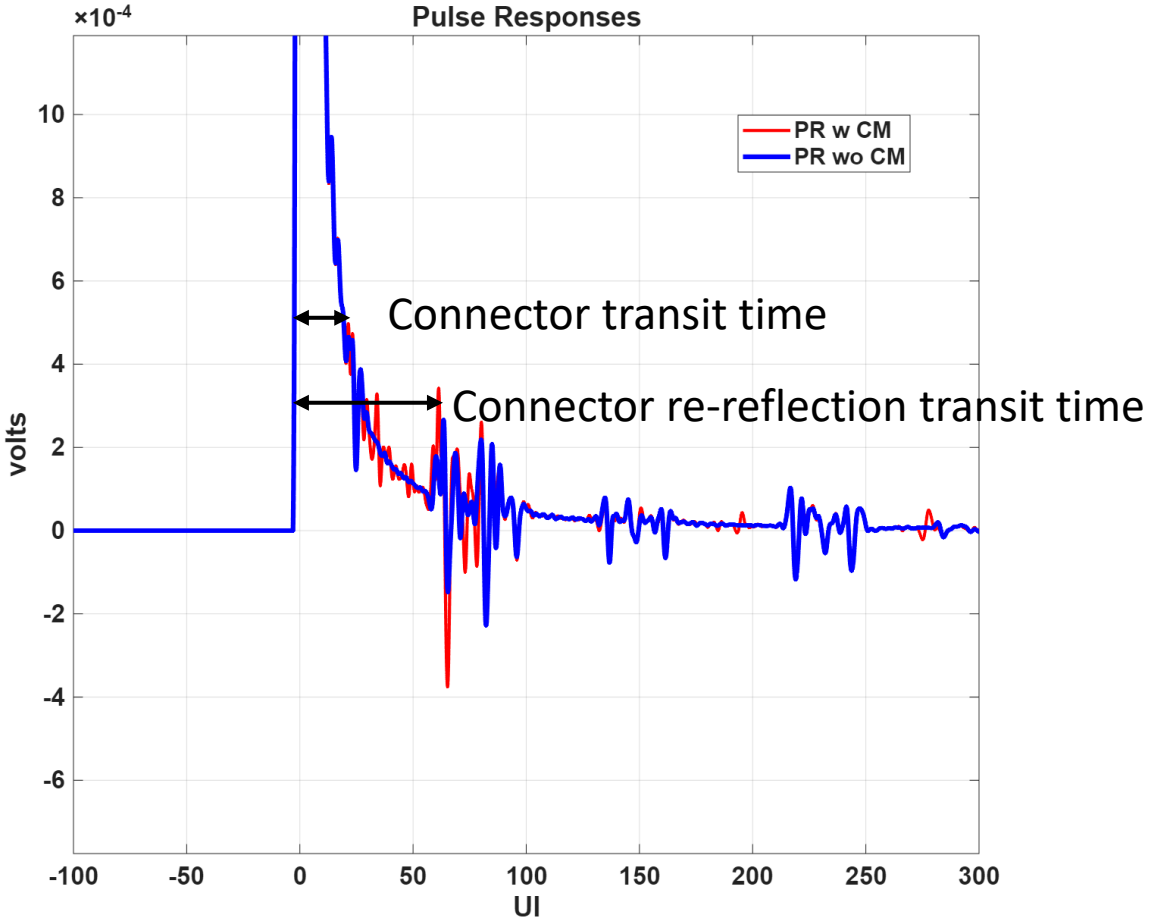
- Return Loss (RL): A frequency-domain metric indicating the magnitude of signal reflections at a port.
- Limitation: RL masks only describe reflections versus frequency and ignore timing effects.
- **Effective Return Loss (ERL): A statistical metric that accounts for timing and cumulative impact of reflections on the sampled signal, providing a more realistic performance measure.**
- Modal ERL: Applies ERL methodology to RL_{cc}, RL_{cd}, and RL_{dc} instead of RL_{dd}.

Next slide shows how modal ERL impacts a pulse response—with and without common-mode reflections.

Common Mode Reflections: Effect on a Pulse Response

Review from mellitz_3dj_01a_elect_250828

- COM ignores mode-conversion reflections at TP0 and TP5 (e.g., RL_{cc}, RL_{cd}, RL_{dc}).
- A modal-aware COM variant was used to estimate worst-case impact of common-mode reflections on performance.
- Purpose: Sensitivity analysis only; not a proposal to replace COM in the standard.
- Common-mode effects are strongest within the channel, particularly at connectors near the port, and are typically much smaller than reflections between transmitter (Tx) and receiver (Rx) terminations



Coordination with Prior Work and Broadened Coverage

KR (backplane) and Modal ΔCOM

- ❑ Modal ERL and SCMR_CH data reported
- ❑ Correlations observed between modal ERL, SCMR_CH, and Modal-aware COM (Modal ΔCOM)
- ❑ *Channels data in:* *mellitz_3dj_adhoc_01a_251030*

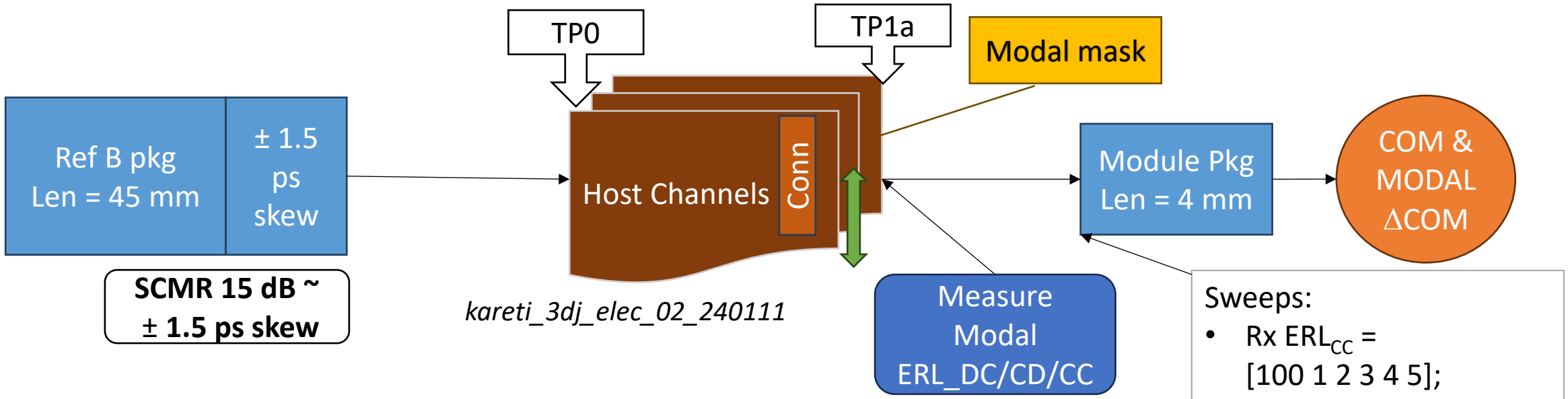
Expanded Scope (CA & C2M)

- ❑ Cable Assemblies (CA):
  - *Early* indications *and from ellison_3dj_01a_2511 suggest SCMR_CH ranges*
  - *More complete CA data is forthcomong*
- ❑ C2M Host Channels:
  - Extensive dataset across skew and CM impairments
  - Channels are ideal for correlation between modal ERL, SCMR, and modal-aware COM
  - *Channel data:* *kareti_3dj_elec_01a_240111*

C2M Modal ERL Study Objectives

- Correlate modal ERL, modal masks, and modal ΔCOM to assess spec effectiveness.
- Tx skew cases as Tx common-mode stress proxy
- Compute Modal ΔCOM = Modal-aware COM minus Reference COM
- Dataset: Host channels consistent with 2RU, 64-port, 512-radix system design.
- Goal: Understand COM impact for no skew, max tolerable skew, and excessive skew.

C2M Host Experiment Setup



Apportioned skew impaired channels
- kareti_3dj_elec_02_240111
- No Skew, Max Tolerable, Excessive

Sweeps:
- Modal ERL as proxy for Rx package CM RL (TP1a)
- Tx CM reflection emulated with Tx package skew

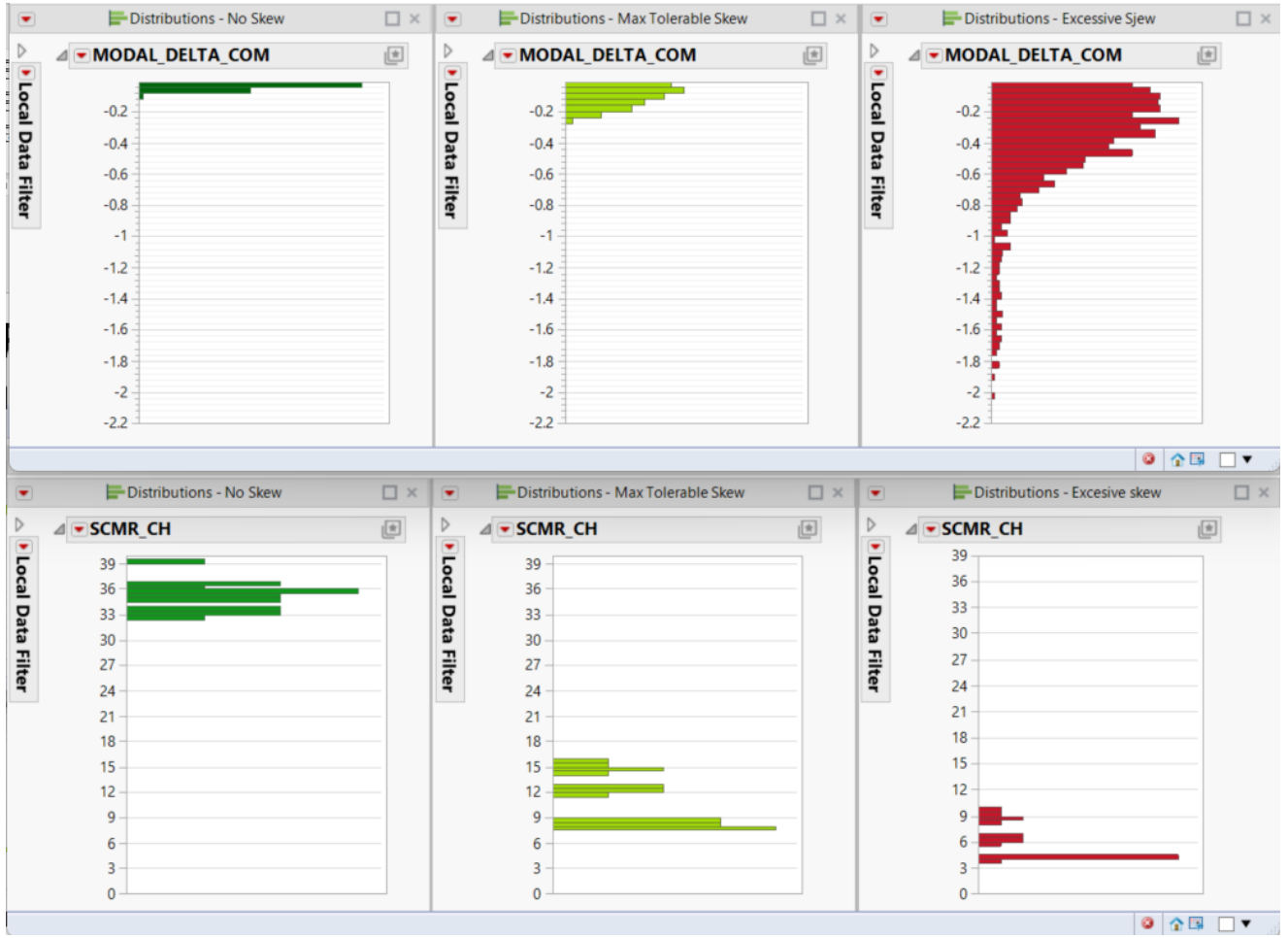
Other Parameters in C2M COM spreadsheet (in backup)

Report:
- ❑ Modal ΔCOM = Modal-aware COM minus Reference COM
- ❑ Modal ERL into host at TP1a
- ❑ SCMR_CH between TP0 and TP1a
- ❑ Modal mask failures

Modal ΔCOM and SCMR_CH* Track Channel Skew Impairments

CHANNELS PASSING REFERENCE COM

*P_{peak}=DER0



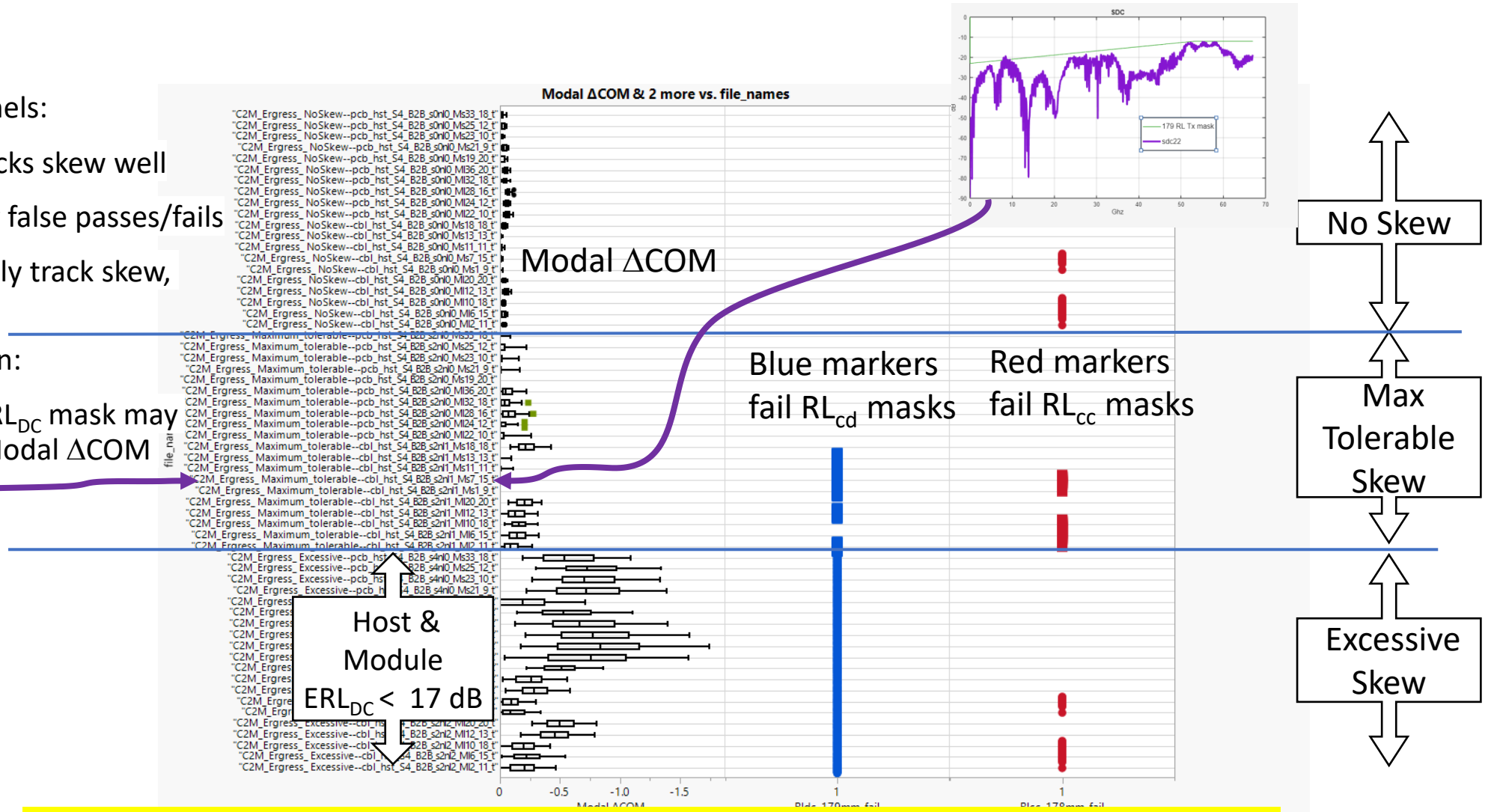
Comparative Results for Skew-Impaired Channels

Skew-Impaired Channels:

- ❑ Modal ΔCOM tracks skew well
- ❑ RL_{cc} masks: Many false passes/fails
- ❑ R_{Lcd} masks: Loosely track skew, false negatives

Threshold Comparison:

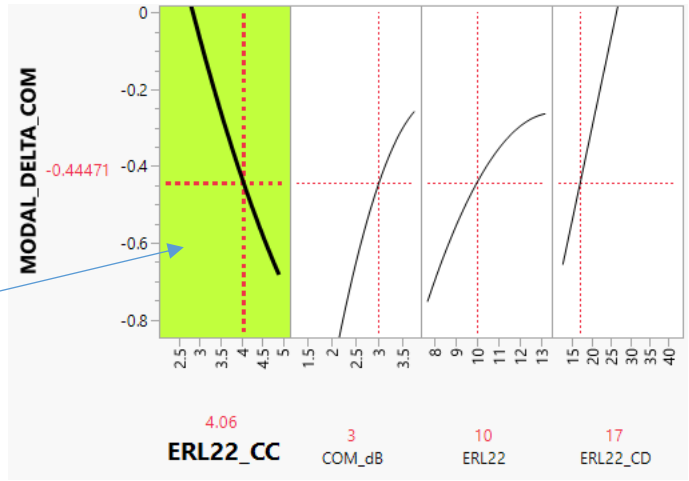
- ❑ Channels failing RL_{DC} mask may have negligible Modal ΔCOM impact



Takeaway: Modal ΔCOM is a more reliable indicator than RL masks for interoperability.

Masks vs Modal ERL: Efficacy & Recommendation

- RL_{cc}:
  - Many false passes/fails.
  - Does not correlate with performance.
  - Good design tool, not for interoperability.
- For these COM 3 dB hosts, modal ΔCOM decreases with more CC reflection (ERL_{cc})
- RL_{dc} & RL_{cd}:
  - Masks often fail channels by small excursions → pessimistic.
  - RL_{dc} and RL_{cd} interplay and take together are good indicators common mode non-linearity.
  - Together = better indicators.



Recommendation:

- remove common-to-common mode reflections specifications
- Let SCMR handle common-mode issues.
- Specify both RL_{cd} and RL_{dc}.
- Consider Modal ERL for better coverage.

Results Summary

FOR ALL CHANNELS REVIEWED SO FAR (THOUSANDS), NOT ONLY C2M HOSTS

- ERL_{cc} ranged between 2 dB and 5 dB
  - CC reflections are **always** high
  - This occurs because destructive coupling is used to significantly improve DD performance.
- ERL_{cd} and ERL_{dc} is 12.5 dB and 50 dB
- SCMR ranged between 3.4 dB and 40 dB
- Modal ΔCOM was minimized (< 0.1 dB) by
  - KR: ERL_{cd} and ERL_{dc} min = 17 dB and SCMR min = 15 dB
  - C2M: ERL_{cd} and ERL_{dc} min = 17 dB and SCMR min = 12 dB

Option 1 – Full Modal ERL Implementation

Modal Mask References in d2.3

	tx			rx			channel tx or rx		
	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd
178.9.2 Transmitter characteristics	remove	17 db	17 db						
178.9.3 Receiver characteristics					17 dB	17 dB			
178.10 Channel characteristics								17 db	17 db
179.9.4 Transmitter characteristics	remove	17 db	17 db						
179.9.5 Receiver characteristics					17 dB	17 dB			
179.11 Cable assembly characteristics							remove	17 db	17 db
176C.6.3 Transmitter characteristics	remove	17 db	17 db						
176C.6.4 Receiver characteristics					17 dB	17 dB			
176C.7 Channel characteristics								17 db	17 db
176D.6.4 Host output characteristics	remove	17 db	17 db						
176D.6.5 Module output characteristics	remove	17 db	17 db						
176D.6.6 Host input characteristics					17 db	17 db			
176D.6.7 Module input characteristics					17 db	17 db			

key
replace with new row
add new row

- ❑ Remove all CM masks
- ❑ Add section describing modal ERL
- ❑ Add ERL_{CD} and ERL_{DC} respective tables
  - Note: use ERL setting for Modal ERL

Option 2 - Channel Only ERL implementation

Modal Mask References in d2.3	tx			rx			channel tx or rx		
	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd
178.9.2 Transmitter characteristics	remove								
178.9.3 Receiver characteristics						keep mask			
178.10 Channel characteristics								17 db	17 db
179.9.4 Transmitter characteristics	remove	keep mask							
179.9.5 Receiver characteristics						keep mask			
179.11 Cable assembly characteristics							remove	17 db	17 db
176C.6.3 Transmitter characteristics	remove	keep mask							
176C.6.4 Receiver characteristics						keep mask			
176C.7 Channel characteristics								17 db	17 db
176D.6.4 Host output characteristics	remove	keep mask							
176D.6.5 Module output characteristics	remove	keep mask							
176D.6.6 Host input characteristics						keep mask			
176D.6.7 Module input characteristics						keep mask			

key
replace with new row
add new row

- Remove all RL_{CC} masks
- Remove **Channel** RL_{CD} Masks
- Add ERL_{CD} and ERL_{DC} to respective channel tables
- Keep Tx RL_{dc} and Rx RL_{cd} ,masks

Option 3- Remove All CM Masks

Modal Mask References in d2.3

	tx			rx			channel tx or rx		
	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd
178.9.2 Transmitter characteristics	remove								
178.9.3 Receiver characteristics						remove			
178.10 Channel characteristics									remove
179.9.4 Transmitter characteristics	remove	remove							
179.9.5 Receiver characteristics						remove			
179.11 Cable assembly characteristics							remove		remove
176C.6.3 Transmitter characteristics	remove	remove							
176C.6.4 Receiver characteristics						remove			
176C.7 Channel characteristics									remove
176D.6.4 Host output characteristics	remove	remove							
176D.6.5 Module output characteristics	remove	remove							
176D.6.6 Host input characteristics						remove			
176D.6.7 Module input characteristics						remove			

- Remove All CM Masks sections and respective table entries

Option 4 – Compromise: Remove Channel CM Masks

Modal Mask References in d2.3

	tx			rx			channel tx or rx		
	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd	ERLcc	ERLdc	ERLcd
178.9.2 Transmitter characteristics	remove								
178.9.3 Receiver characteristics						keep mask			
178.10 Channel characteristics									remove
179.9.4 Transmitter characteristics	remove	keep mask							
179.9.5 Receiver characteristics						keep mask			
179.11 Cable assembly characteristics							remove		remove
176C.6.3 Transmitter characteristics	remove	keep mask							
176C.6.4 Receiver characteristics						keep mask			
176C.7 Channel characteristics									remove
176D.6.4 Host output characteristics	remove	keep mask							
176D.6.5 Module output characteristics	remove	keep mask							
176D.6.6 Host input characteristics						keep mask			
176D.6.7 Module input characteristics						keep mask			

- Remove all RL_{CC} masks
- Remove Channel RL_{CD} Masks
- Keep Tx RL_{dc} and Rx RL_{cd} ,masks

Options Summary

- Option 1 – Full Modal ERL Implementation
  - Most coverage
  - Biggest .3dj schedule impact
- Option 2: Channel Only ERL implementation
  - Better coverage than just all masks
  - Still big .3dj schedule impact because adding modal ERL
- Option 3: Remove all CM Masks
  - Simplest, least schedule impact
  - No Rx CM reflection control.
- Option 4: Compromise: : Remove Channel CM Masks
  - Minimal impact schedule
  - Rely on SCMR_CHs
  - Mask efficacy still undetermined and remains a risk
- Postpone Option 1 or 2 for SA revisions with more complete CA data

Thank You!

Backup

Host COM spreadsheet

config_com-4p12p0_802p3dj_d2p3_200G_C2M_TP0_TP2_Egress_25_11_14.xlsx Values and settings in the spread sheet may not be align with a standard. Please check before using

data rate, die load, ref impedance			
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]
R_0	46.25	Ohm	changed for 2.1
PKG_NAME	**PKG_HiR_CLASSB PKG_Module**		TX RX
z_p select	[4 4]		
L	4		
M	32		
filter and Eq			
f_r	0.55	*fb	
c(0)	0.54		min
c(-1)	0	[-0.34:.02:0]	[min:step:max]
c(-2)	0	[0.14:.02:0]	[min:step:max]
c(-3)	0		[min:step:max]
c(-4)	0		[min:step:max]
c(1)	0	[-0.2:.02:0]	[min:step:max]
N_b	1	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	0		not used
b_min(1)	0		As/dffe1
b_min(2..N_b)	0	S	not used
g_DC	[-20:1:0]	dB	[-20:1:0]
f_z	42.50	GHz	
f_p1	42.50	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	1.328125	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
WRITE_CSV_TRANSPOSED	0	logical
RESULT_DIR	.\results**C**2M_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2M_Ergress_	
COM_CONTRIBUTION	0	logical
DO_NOT_COMPUTE_COM	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	ns
TR_TDR	0.005	
N	1600	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	1	UI
N_bx	16	??
fixture delay time	[0 0]	
Tukey_Window	1	
Z_t	46.25	
P_peak	1.00E-07	
Noise, jitter, and quantization		UI
sigma_RJ	0.01	UI
A_DD	0.02	V^2/GHz
eta_0	7.90E-09	dB
SNR_TX	33.5	
R_LM	0.95	
N_qb	6	bits
P_qc	1.00E-07	changed for 2.2

Operational			
ERL Pass threshold	7.3	dB	
COM Pass threshold	3	db	
DER_0	0.00002		
T_r	0.00400	ns	
FORCE_TR	1	logical	for legacy but required
PMD_type	C2C	for MMSE use C2C only	
EW	0		
MLSE	0	logical	
ts_anchor	1		
sample_adjustment	[-24 24]		
Local Search	0		
TS_SRCH_MODE	middle	full-sweep, middle	only of local_search=2
Filter: Rx FFE			
ffe_pre_tap_len	**5**	UI	d_w
ffe_post_tap_len	8	UI	N_fix-d_w+1
ffe_pre_tap1_max	0.7	(normalized)	w_max(d_w) and -w_min(d_w)
ffe_post_tap1_max	0.7	(normalized)	w_max(d_w+2) and -w_min(d_w+2)
ffe_tapn_max	0.7	(normalized)	all other fixed w_max and w_min
num_ui_RXFF_noise	4096		
Floating Tap Control			
N_bg	**2**	0 1 2 or 3 groups	N_wg
N_bf	4	taps per group	N_wf
N_f	50	UI span for floating taps	Nmax-d_w-1
bmaxg	0.05	max FFE value for floating taps	all floating w_max and w_min
N_tail_start	9	(UI) start of tail taps limit	not supposed to be used but untested
s-parameters processing			
ZERO_PAD	1	logical	
zero_pad_tukey_window_in_fb	0.2	fb	
flim	6.70E+10	Hz	

ERL parameters

Host COM spreadsheet: Package section

.START	PKG_HiR_CLASSB		
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[0.0005 0.00065 0.000293]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[87.5 87.5 ; 95 95 ; 100 100; 78 78]	Ohm	
R_d	[46.25 46.25]	Ohm	[TX RX]
z_p (TX)	[8 24 45 45 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (NEXT)	[8 24 44 44 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (FEXT)	[8 24 45 45 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
z_p (RX)	[8 24 44 44 ; 2 2 2 2; 1.3 1.3 1.3 1.3 ; 1.5 1.5 1.5 1.5]	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[TX RX]
A_v	0.385	V	Vf=0.400
A_fe	0.385	V	Vf=0.399
A_ne	0.481	V	Vf=0.400
.END			

.START	PKG_Module		
Parameter	**Setting**	**Units**	Information
package_tl_gamma0_a1_a2	[0.0005 0.00089 0.0002]		
package_tl_tau	0.006141	ns/mm	
package_Z_c	[87.5 87.5 ; 95 95 ; 100 100; 100 100]	Ohm	
R_d	[46.25 46.25]	Ohm	[TX RX]
z_p (TX)	[0 0 4 10 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
z_p (NEXT)	[0 0 4 10 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
z_p (FEXT)	[0 0 4 10 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
z_p (RX)	[0 0 4 10 ; 1.8 1.8 1.8 1.8 ; 0 0 0 0 ; 0 0 0 0]	mm	[test cases]
C_p	[0.4e-4 0.4e-4]	nF	[TX RX]
A_v	0.385	V	Vf=0.400
A_fe	0.385	V	Vf=0.399
A_ne	0.481	V	Vf=0.400
.END			

COM command modifying parameters

```
% Build ERL modal string
ERL_modal.str = ['[ ' mat2str(ERL_CMC(j)) ' ' mat2str(ERL_CMC(j)) ' ' mat2str(ERL_CC(i)) ' ]'];
%% Call function and get base struct **************
% tempStruct = com_ieee8023_4p12p0_Modal_VTF( ...
tempStruct = com_ieee8023_( ...
        config_file, 0, 0, channel_file(ifile).str, ...
        'OP.DEBUG', WINDOWS, ...
        'OP.DISPLAY_WINDOW', WINDOWS, ...
        'OP.DO_NOT_COMPUTE_COM', NO_COM, ...
        'param.P_peak', '1e-7', ...
        'param.Z_t','46.25','param.Z0','46.25',...
        'OP.pkg_len_select','3',...
        ' param.num_ui_RXFF_noise','1024',...
        'param.Txnskew','1.5e-12',...
        'param.TX_modal_ERL_spec', '[ 100 100 100 ]', ...
        'param.RX_modal_ERL_spec', ERL_modal.str ...
        );
```