SCMR (signal to common mode ratio) for Channels d2.0 Comments 49, 50

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June 26, 2025

IEEE P802.3dj Ad Hoc

Abstract

❑ Proposal

- Introduce SCMR_CH (signal to common mode ratio for channels) and interconnect.

❑ Rational

- The current COM model emphasizes Sdd21 but may overlook common-mode conversion effects, potentially allowing marginal channels to pass simulation while failing in real-world applications.
- SCMR_CH is intended to
  - Limit channel inter pair skew
  - Limit skew based signal asymmetric distortion
  - Limit other channel comment mode impairments

Table of Contents

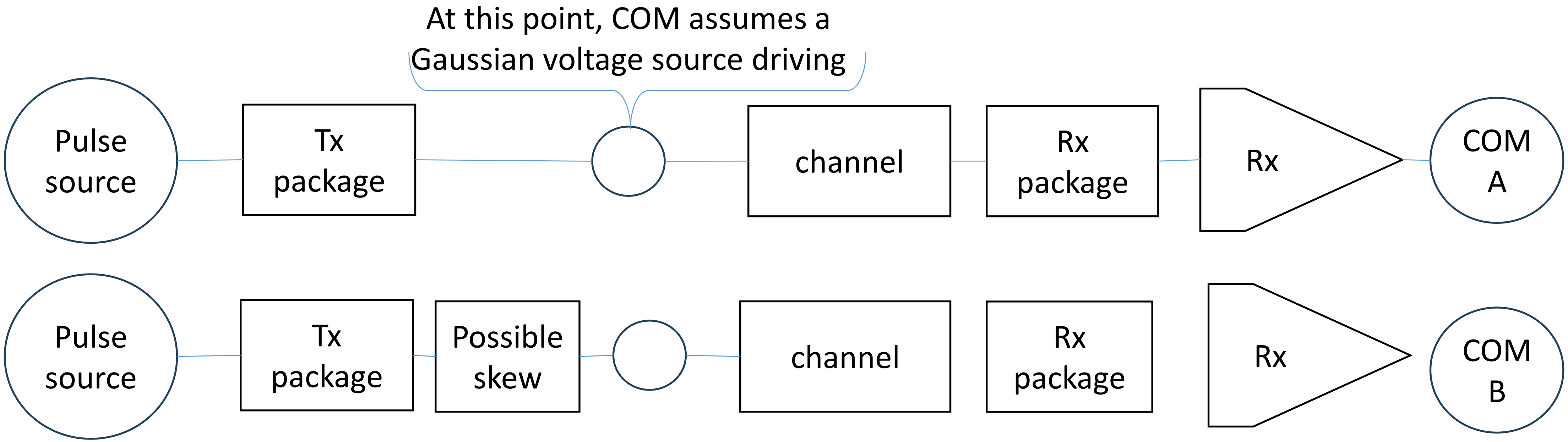
- Interoperability
- SCMR computation for interconnect channel using time domain (TD) and frequency domain (FD)
- Context: Estimate maximum reference device skew
- COM and SCMR experiments
- Introducing skew in COM example code

Interoperability

Parts pass COM which fail in a real-world system.

- Skew contributes to common-mode conversion, alongside other imbalances.
- COM specifies a minimum differential performance
- S-parameters passed to COM can include the skew and other common mode effects. So, the effect of skew for a given channel is included in COM.
- The effects of skew or common mode entering a channel is weakly controlled with the following
  - Signal to AC common-mode noise ratio, SCMR (min)
  - Common-mode to common-mode return loss, RL_{cc} (min)
- The next slide diagrams a skew impact scenario

Skew Impact on Interoperability

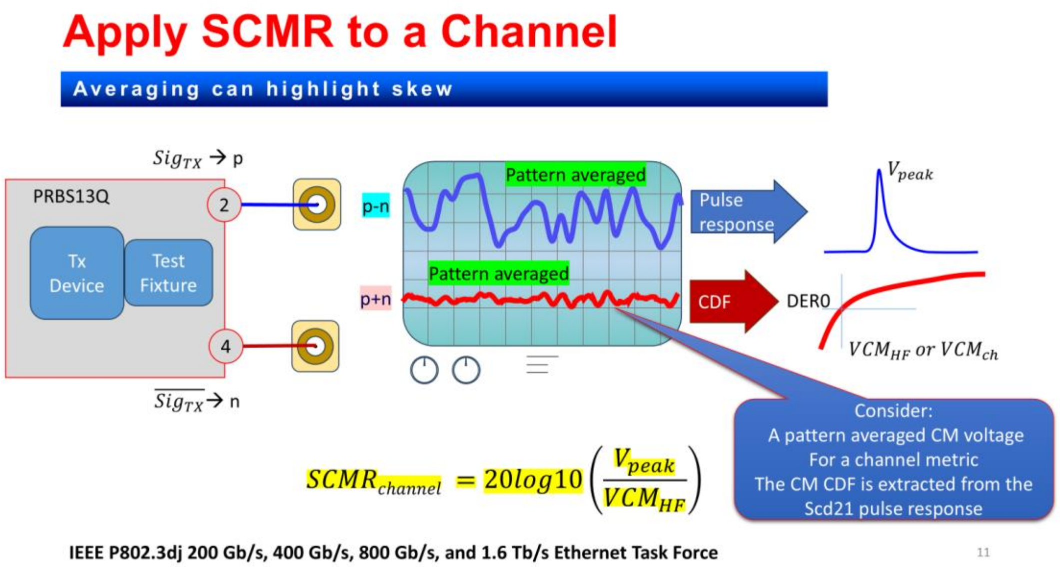


- An upper limit for skew for the reference packages may be determined from Signal to AC common-mode noise ratio, SCMR (min)
- If skew is included in COM, how significantly does it alter the computed COM between configurations A and B?
- Another question is how does the channel interact with the skew and can that be controlled with SCMR for the channels (ref: mellitz_3dj_02_elec_231207)

2023 Presentation on Skew and SCMR

mellitz_3dj_02_elec_231207

- Consider the channel is LTI an usually passive.
- The pulse response from a pattern averaged signal on an LTI network approaches the computed pulse response of the network.
- Signal and noise power is computed from the pulse responses.
- Compute SCMR by combining pulse response metrics from SNDR and noise variance like for ERL



$SCMR_{ch}$ Quantifies Signal Integrity Degradation Due to CM conversion

- It starts by evaluating pulse DD and CD pulse responses and determines the ratio of signal power to common-mode power
- CM noise power is handledd similarly to refection noise power in ERL.
- Diagram on next slides

SCMR Step 1: Pulse Responses

Determine signal and CM sampled pulse responses

Edge rate filter

$H_t(f)$

scd21

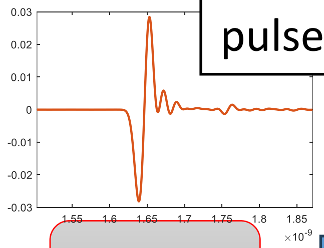
Receive filter

$H_r(f)$

Pulse (f)

sinc

iFFT



Common mode pulse response

$h_{cd21}(t)$

Sampled

UI Subsample set 1

UI Subsample set 2

• • •

UI Subsample set M

Similar sampling of PTDR for ERL

No_package|PCB added

Edge rate filter

$H_t(f)$

sdd21

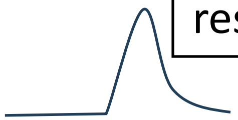
Receive filter

$H_r(f)$

Pulse (f)

sinc

iFFT



Differential pulse response

$h_{dd21}(t)$

Peak referenced Sampling

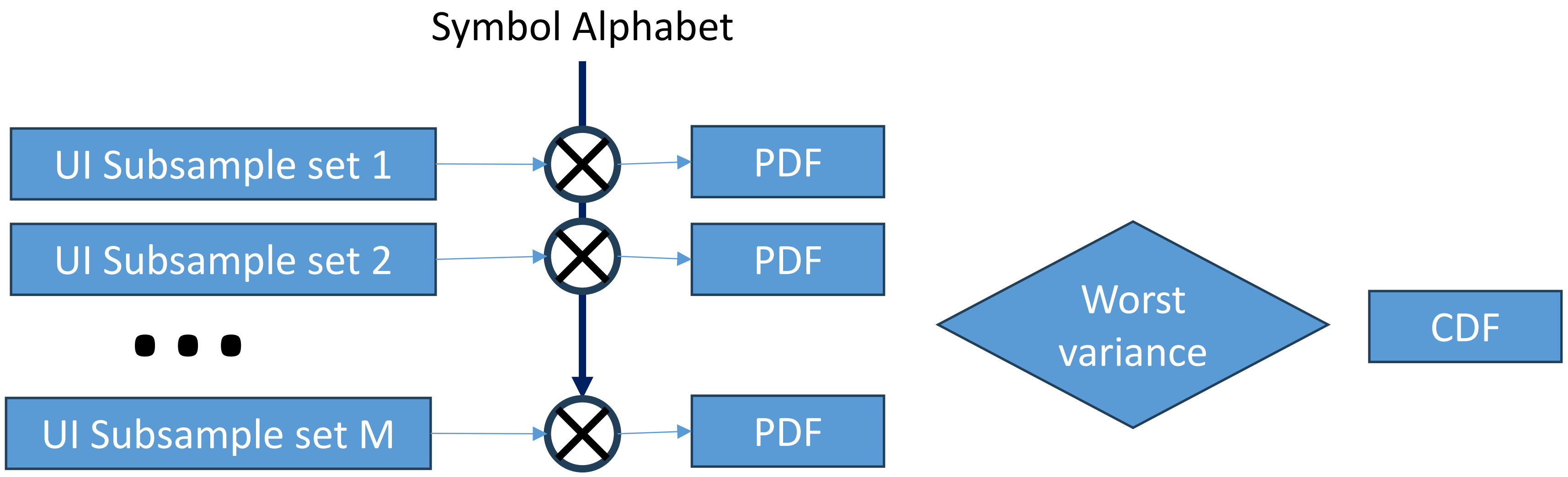
using σ_{ts} instead of V_{peak}

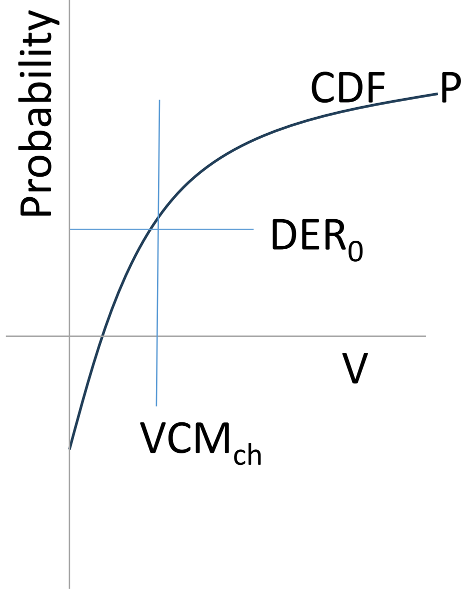
σ_{ts}

Eq (179–13)

Step 2: Compute $SCMR_{ch}$

Determining VCM_{ch} voltage with method like when computing ERL





$$SCMR_{ch} = 10 * log10\left(\frac{\sigma_{ts}{}^2}{VCM_{ch}{}^2}\right) \quad \text{(Recommended)}$$

$$SCMR_{ch\_pk} = 10 * log10\left(\frac{V_{peak}^2}{VCM_{ch}{}^2}\right) \quad \text{(like for d2.0 Rx measurements)}$$

Also, consider $\mathrm{SCMR}_{\mathrm{CH\_FQ}}$ computed in the frequency domain

- ❑ Like $\mathrm{SNR}_{\mathrm{MDFEXT}}$
- ❑ $SCMR_{CH\_FQ} = 10log_{10}\left(\frac{\hat{P}_{signal}}{\hat{\sigma}^2_{scd21}\sigma_x^2\ \mathrm{Q}^{-1}(DER_0)^2}\right)$
  - $\hat{P}_{signal} = 2\Delta f \sum w(f) 10^{-IL(f)/10}$,Normalized signal power
  - $\hat{\sigma}^2_{scd21} = 2\Delta f \sum w(f)\ S_{cd21}{}^2$,Normalized common mode power

$w(f) = \frac{1}{f_b} sinc\left(\frac{f}{f_b}\right)^2 \left[\frac{1}{1+\left(f/f_{ft}\right)^4}\right]\left[\frac{1}{1+\left(f/f_r\right)^8}\right]$ …from eq. (93A–57) note: f_{tf} , f_t , f_1, and f_2 are assumed to be the same

$IL(f) = -20log_{10}(|sdd21(f)|)$

$\sigma_x^2 = {(L^2-1)}/{3(L-1)^2}$ …note: L is number of PAM levels

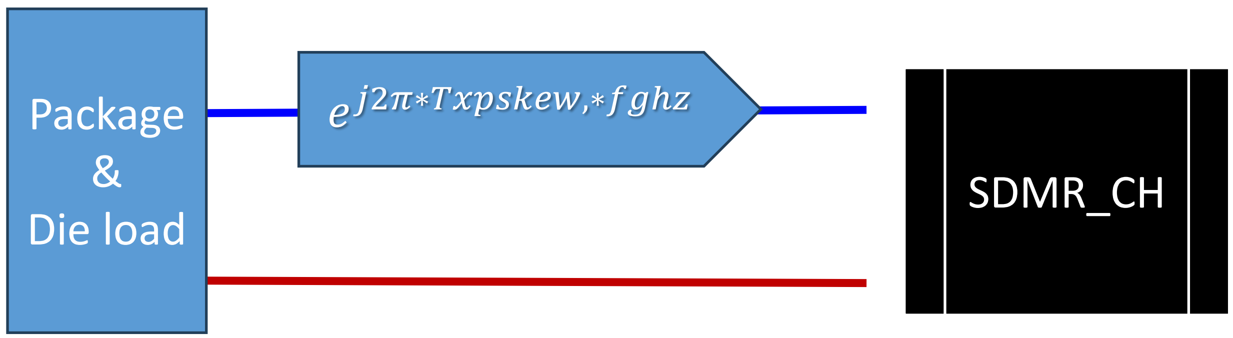
$1/Q^{-1}(DER_0)$ aligns RMS to DER_0

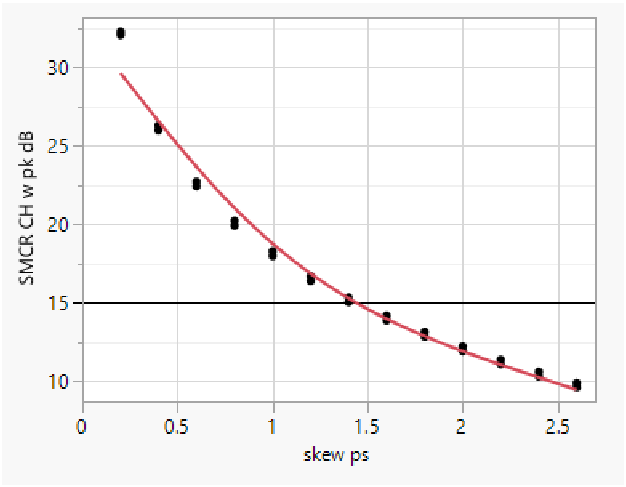
SCMR is computed COM from branch Called SCMR

In Richard Mellitz Git Fork

- SCMR_ch_dB and SCMR_ch_fq_dB are output in COM branch SCMR
- Pointer to a single COM code file
  - https://opensource.ieee.org/richard.mellitz/com_code/-/raw/SCMR/release/com_ieee8023_4p9p1_SCMR.m?ref_type=heads&inline=false
- Pointer to spread sheets templates used
  - https://opensource.ieee.org/richard.mellitz/com_code/-/tree/SCMR/config_templates/testing_SCMR?ref_type=heads

Context: Estimate Maximum Device Skew



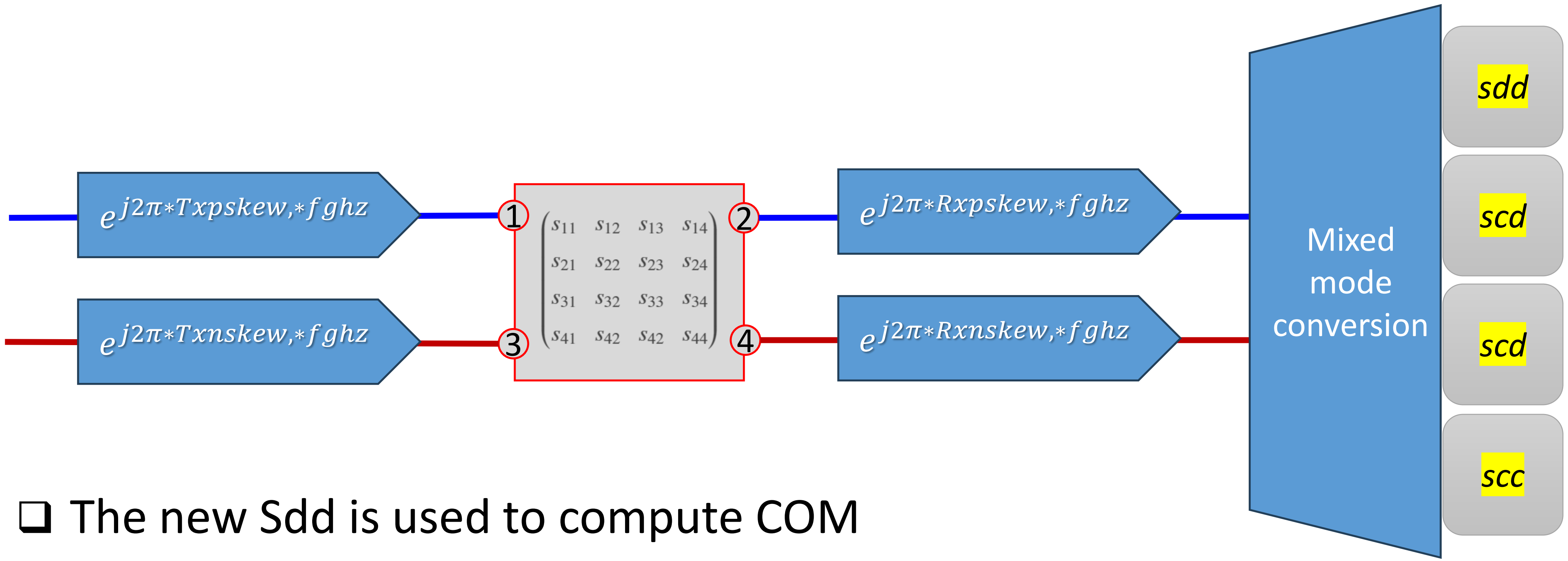


- ❑ Signal to AC common-mode noise ratio, SCMR (min) is 15 dB
  - Based of using Vpeak
- ❑ Not all contributions to SCMR (min) are from skew
- ❑ For the reference package, skew it would be limited to a about 1.5 ps
  - No other CM impairments are considered
- ❑ Skew (delay) is highly correlated to SCMR
- ❑ This sets the bounds for the next step of experiments

COM and SCMR experiments

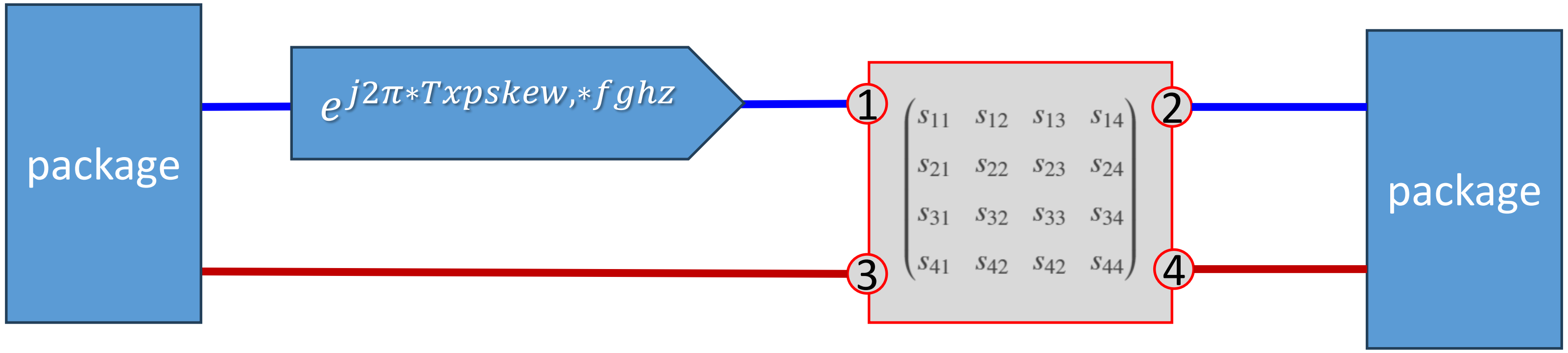
- For collection of channels (see backup for list)
  - These files have varying amount of common mode
  - 30 mm package
  - Includes crosstalk
- Add varying amounts of skew (ideal delay) to the s4p files (ref: mellitz_3dj_02_elec_231207)
  - This can be done in COM with the keywords Txpskew, Txnskew, Rxpskew, and Rxnskew
  - For this experiment only Txpskew is used.
- Determine COM, SCMR_ch_dB, SCMR_ch_fq_dB, and delta COM for each skew
  - Define delta COM(delay) = COM(delay=0)- COM(delay)
- Evaluate delta COM to SCMR_CH, SCMR_CH_FD, COM, and skew

Skew (delay) is added before COM example code computations



- ❑ The new Sdd is used to compute COM
- ❑ The new Sdd and Scd are used to compute SCMR_ch
- ❑ The new Sdd is used to compute all the FD parameter too

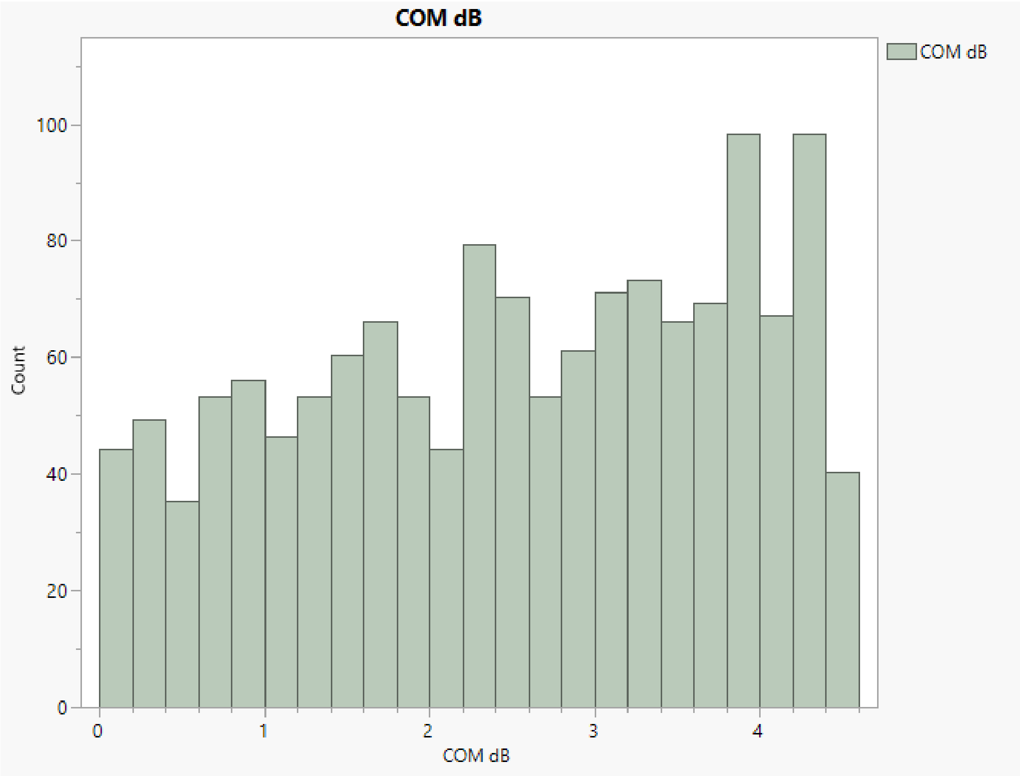
Skew is added in COM as an ideal s-parameter delay.



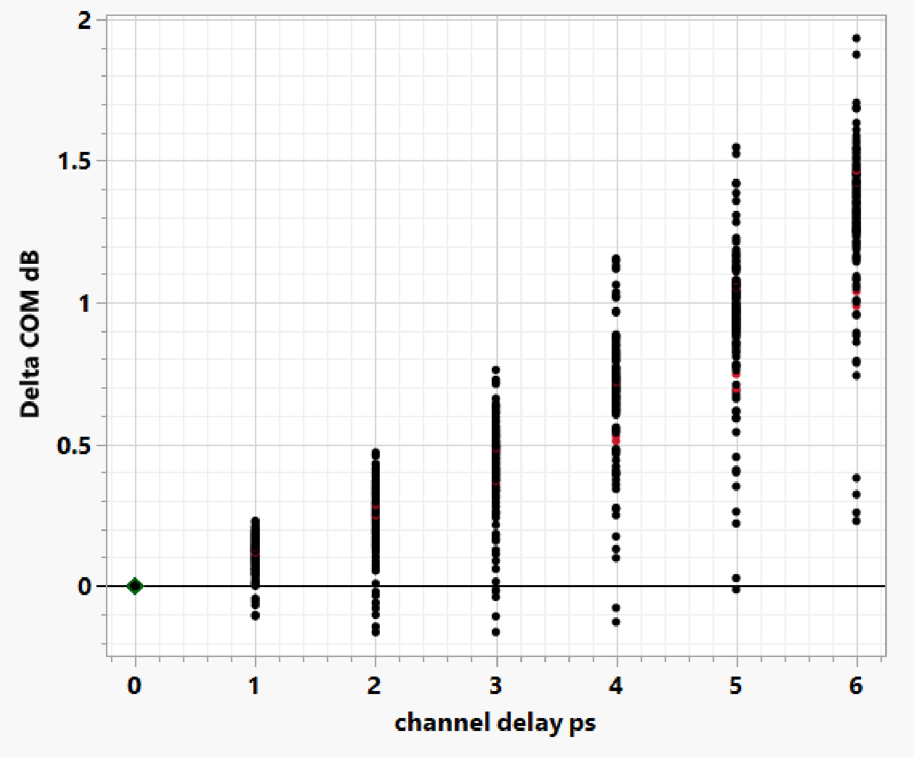
- ❑ In this experiment skew is added to one side of the Tx channels
- ❑ The COM zero-delay case is COM of the channel.
- ❑ SCMR and COM change drastically when delay introduced

Large Skew Greatly Affects Delta COM

Relatively flat distribution of COM



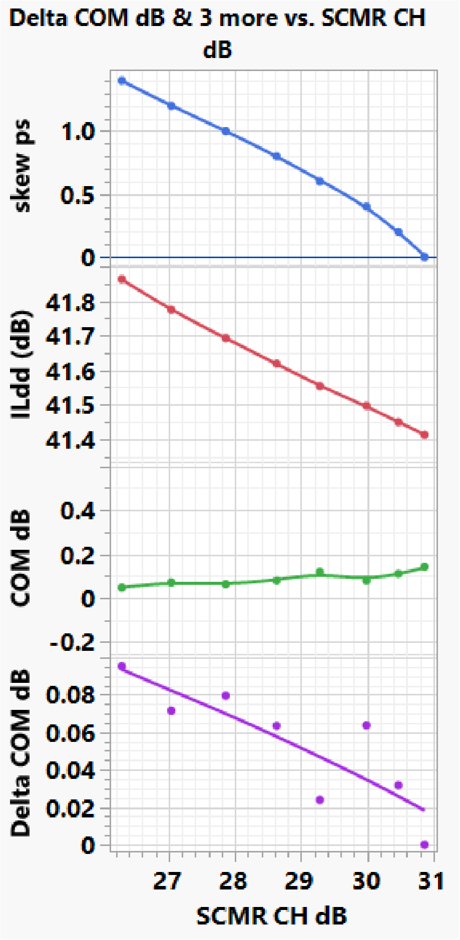
Delta COM increases with skew.



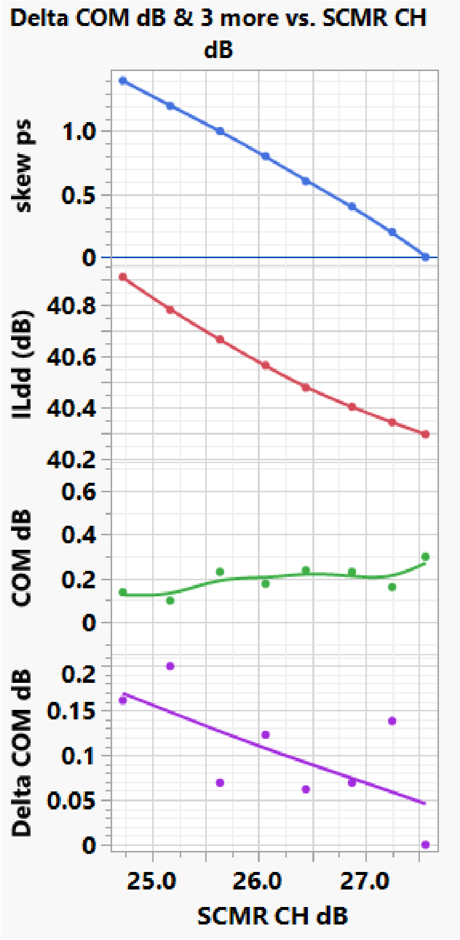
This amount of skew is not likely

Reconsider with skew below 2.6 ps

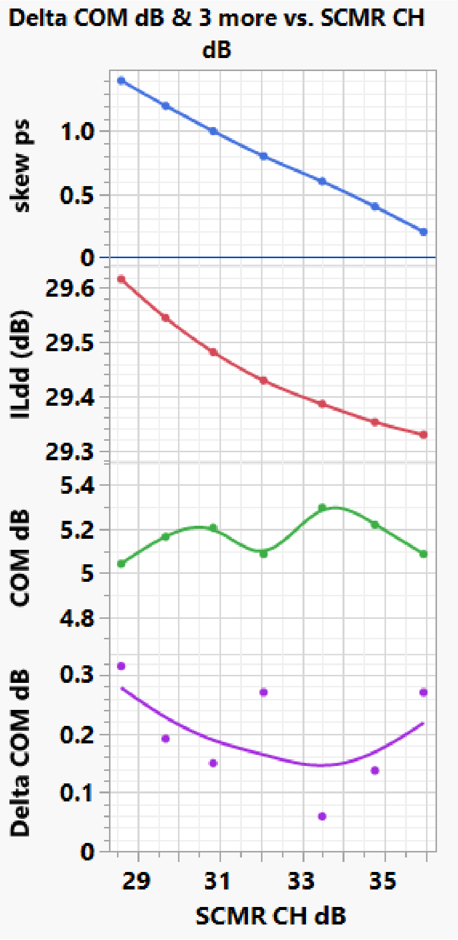
The effect of skew is different for different channels



akinwale_3dj_01_2311_

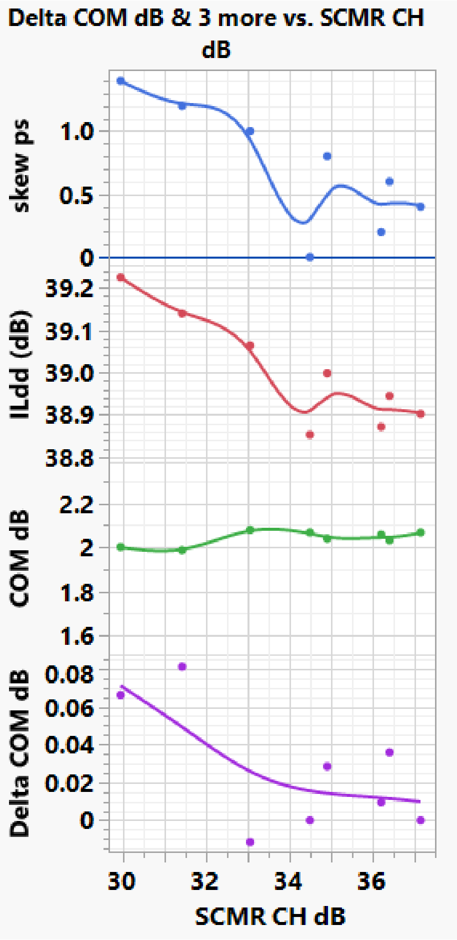


lim_3dj_03n04_2306205

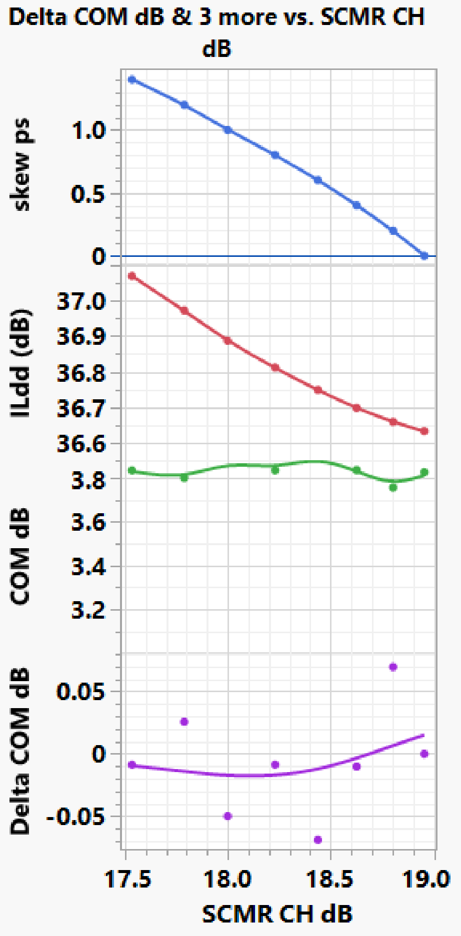


mellitz_3dj_02_elec_230504_

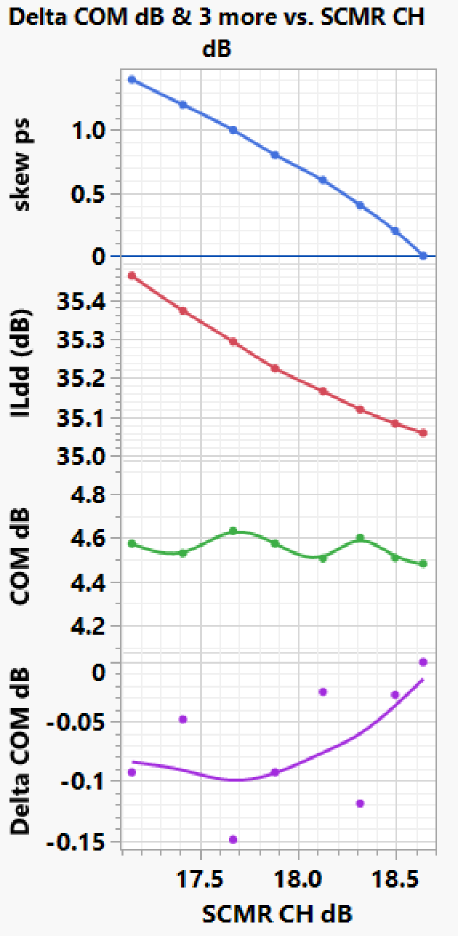
The effect of skew is different for different channels (cont’d)



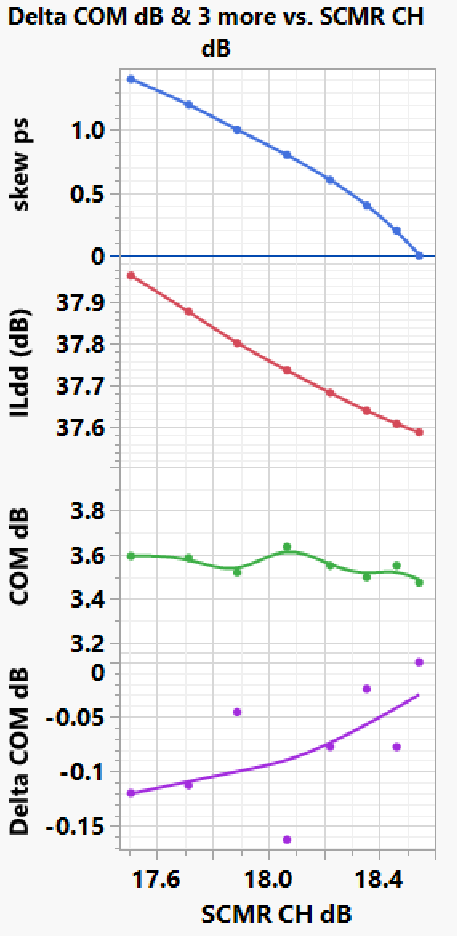
weaver_3dj_02_2311_



weaver_3dj_02_2303_



weaver_3dj_02_2305_



weaver_3dj_elec_01_230622a_

Initial recommendation: Set SCMR_ch_dB (min) = 18.5 dB based on observed delta COM stabilization below 0.3 dB for skew < 1.5 ps

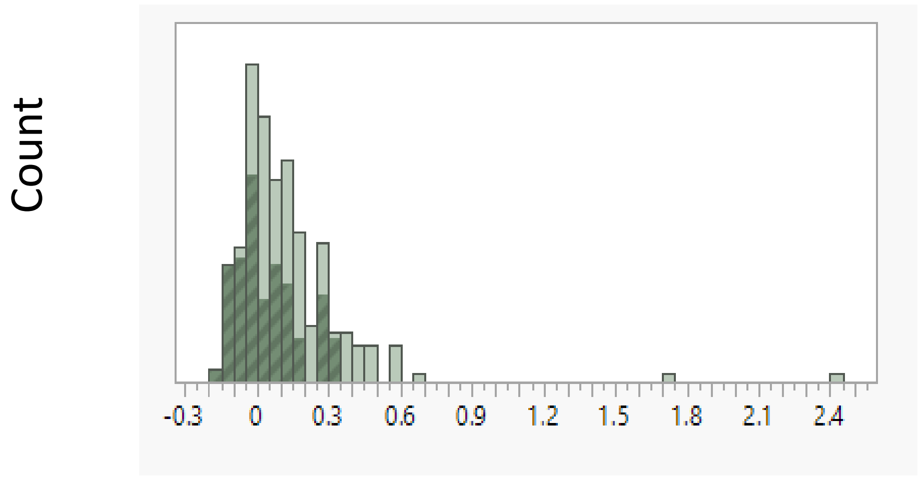
Dark color is Delta COM with < 1.5 ps skew

Control delta com to +/- 0.3 dB relative to SCMR_ch_dB with zero skew

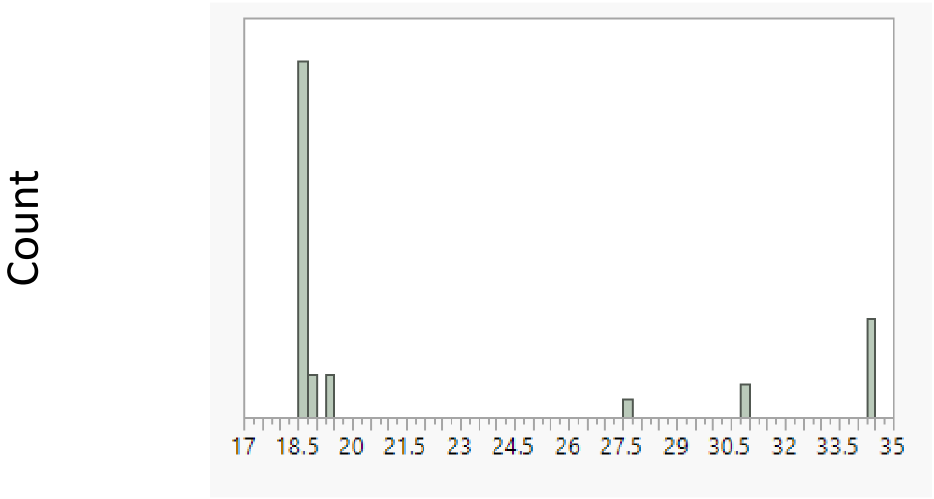
Previous data indicated larger delta COM was associated with > 5 dB COM

SCMR_ch_dB with corresponding <u>zero skew</u>

i.e. Actual SCMR of channel (from ~ 100 Channels)



Delta COM dB



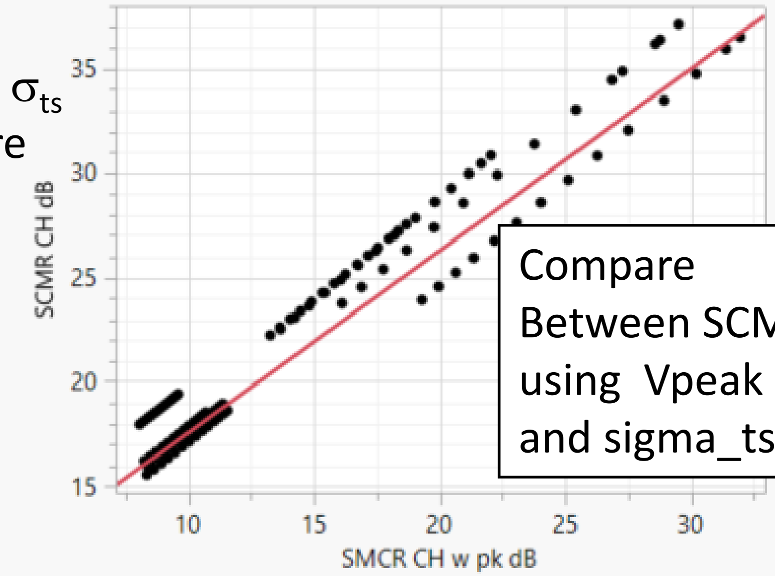
SCMR ch dB

More data

Allowing for 0.7 dB guard band SCMR_CH_fq would be 12 dB

Peak to σ_{ts} compare

Bivariate Fit of SCMR CH dB By SMCR CH w pk dB



Compare Between SCMR using Vpeak and sigma_ts

Linear Fit

Linear Fit

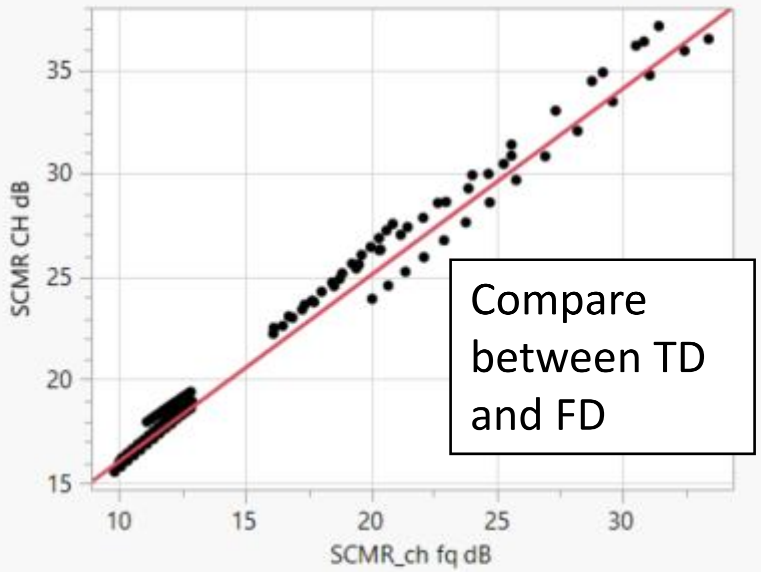
SCMR CH dB = 8.9066322 + 0.8694842*SMCR CH w pk dB

Summary of Fit

RSquare	0.967772
RSquare Adj	0.967746
Root Mean Square Error	1.215261
Mean of Response	23.25255
Observations (or Sum Wgts)	1274

FD to TD compare

Bivariate Fit of SCMR CH dB By SCMR_ch fq dB



Compare between TD and FD

Linear Fit

Linear Fit

SCMR CH dB = 7.0597691 + 0.901995*SCMR_ch fq dB

Summary of Fit

RSquare	0.989262
RSquare Adj	0.989253
Root Mean Square Error	0.701479
Mean of Response	23.25255
Observations (or Sum Wgts)	1274

Summary

- ❑ Add section for $SCMR_{ch}$ computation in COM as a channel metric
- ❑ Recommend:
  $SCMR_{ch}$ (min) =18.5 dB (TD) or $SCMR_{ch\_fq}$ (min) =12 dB (FD)
- ❑ $SCMR_{ch}$ enhances COM by bounding skew-induced CM conversion effects
- ❑ Future work: Investigate $SCMR_{ch}$ post-equalization

Thank You!

Back up

Channels Sets

- ❑ akinwale_3dj_01_2311
- ❑ kocsis_3dj_02_2305
- ❑ lim_3dj_03n04_2306205
- ❑ mellitz_3dj_02_elec_230504
- ❑ weaver_3dj_02_2303
- ❑ weaver_3dj_02_2305
- ❑ weaver_3dj_02_2311
- ❑ weaver_3dj_elec_01_230622a

COM template sheet (see GITLAB)

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	50	Ohm	
PKG_NAME	**PKG_HiR_CLASSB PKG_HiR_CLASSB**		TX RX
z_p select	[3 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	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	0	logical
RESULT_DIR	.\results\CAKR_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	KR_pkgA_	
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	7000	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	UI
N_bx	16	??
fixture delay time	[0 0]	
Tukey_Window	1	
Z_t	42.5	
Noise, jitter		UI
sigma_RJ	0.01	UI
A_DD	0.02	V^2/GHz
eta_0	1.00E-08	dB
SNR_TX	33.5	
R_LM	0.95	

Operational			
ERL Pass threshold	11	dB	
COM Pass threshold	3	db	
DER_0	2.00E-04		
T_r	0.00400	ns	
FORCE_TR	1	logical	for legacy but required
PMD_type	C2C	for MMSE use C2C only	
EW	1		
MLSE	1	logical	
ts_anchor	1		
sample_adjustment	[-16 16]		
Local Search	0		
TS_SRCH_MODE	middle	full-sweep, middle	only of local_search=2
Filter: Rx FFE			
ffe_pre_tap_len	**6**	UI	d_w
ffe_post_tap_len	8	UI	N_fix-d_w
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	80	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
added skew			
Txpskew	0	ps	
Txnskew	0	ps	
Rxpskew	0	ps	
Rxnskew	0	ps	

SAVE_CONFIG2MAT	0	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
ICN parameters		
T_t	6.000	ps
f_v	0.371	39.42
T_ft	4.250	ps
T_nt	4.250	ps
f_f	0.524	55.65
f_n	0.524	55.65
f_1	0.010	GHz
f_2	67.000	GHz
A_ft	0.600	V
A_nt	0.600	V

Parameter	**Setting**	
board_tl_gamma0_a1_a2	*[0 5.95e-4 2.6e-05]*	1.4 db/in @ 53.125G
board_tl_tau	*5.790E-03*	ns/mm
board_Z_c	92.5	Ohm
z_bp (TX)	*9*	mm
z_bp (NEXT)	*9*	mm
z_bp (FEXT)	*9*	mm
z_bp (RX)	*9*	mm
C_0	[0 0]	nF
C_1	[0 0]	nF
Include PCB	**0**	**logical**

.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 30 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 29 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 30 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 29 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			