Closing CR Baseline Specifications with Signal to Noise Distortion Ratio (SNDR)

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Cable Assembly (CA) COM Background: The Story

- healey_3ck_01_0319:
  - Host "PCB escape routing and vias are not included" in COM CA computations

  "The TP0 to TP5 channel estimate calculated for cable assembly COM should be compared to TP0 to TP5 channels based on the same cable assembly and realistic host implementations "
- lim_3ck_01_0519
  - This is the comparison suggested by healey_3ck_01_0319 comparing end to end vs. CA with concatenated IL

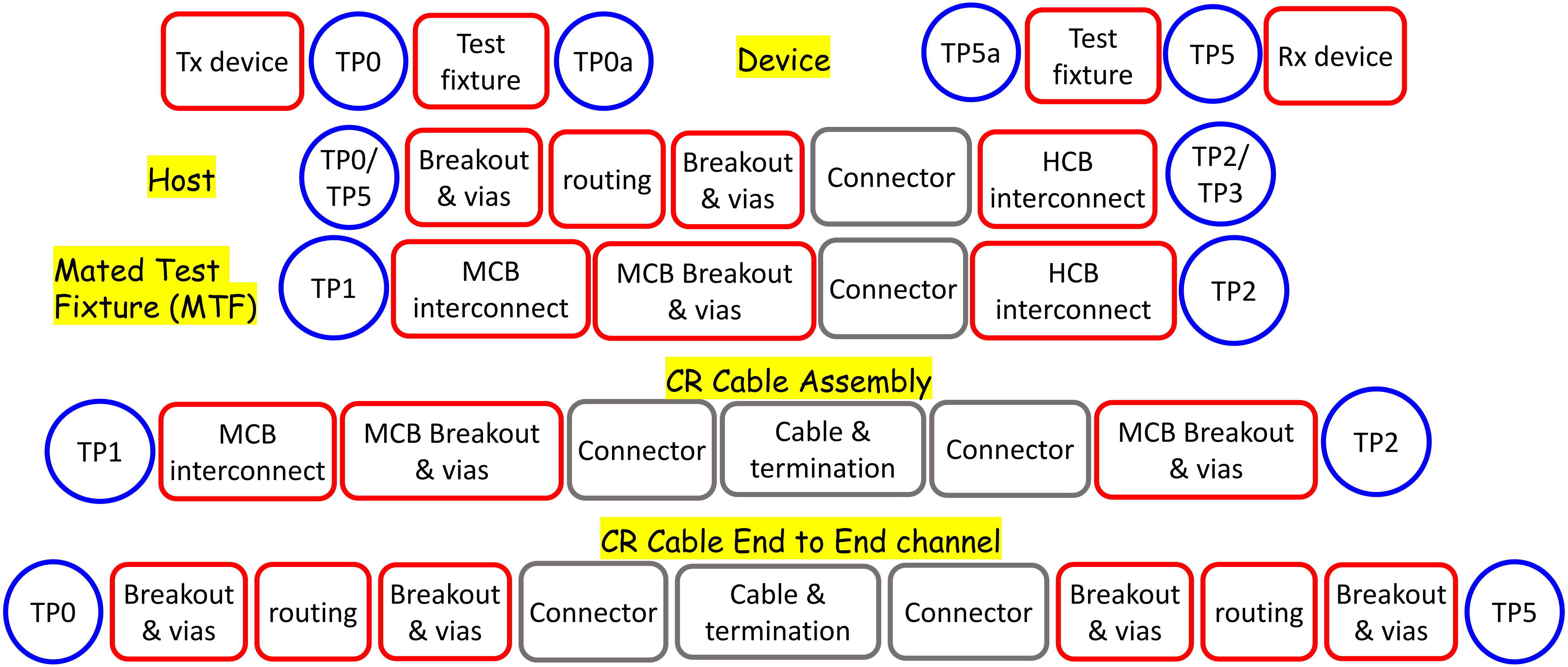
  "Algebraic method of concatenating IL doesn't paint the whole picture"
- benartsi_3ck_adhoc_01_062619
  - Suggest adding capacitors around the "concatenated IL" to emulate reflection in the host
- This work
  - Suggest comprehending host crosstalk, by using a lower SNR_{Tx} for COM computations

Agenda

- ❑ CR maze of test points and specs
- ❑ SNDR Premise
- ❑ Review of SNDR
- ❑ Review of ICN* as reported by the COM code
- ❑ Estimate Host SNDR measured at TP2
- ❑ Call for Action

*ICN – Integrated Crosstalk Noise

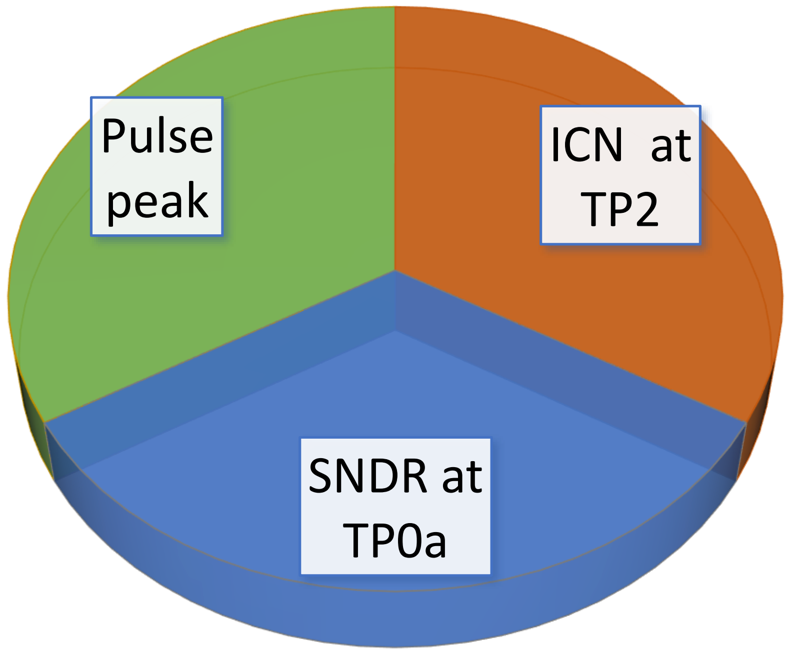
Challenge: Tightly Meshed Spec's for All of These



The SNDR Premise

- SNDR first proposed in ran_3bj_01_0912
- SNDR measured at TP2 is related to other specifications such as
  - SNDR measured at TP0a
  - Crosstalk and other added noise associated with the host
- SNR_{Tx} is used in the COM computation to model transmitter noise and distortion.
  - This is controlled in the transmitter with the transmitter signal to noise distortion ratio (SNDR) specification
- SNDR at TP2 may be estimated from
  - ICN
  - Pulse response measurements
  - SNR_{Tx}
- SNDR at TP2 can be a control for the host noise

SNDR @ TP2 CONTRIBUTIONS FOR A HOST (NOT TO SCALE)



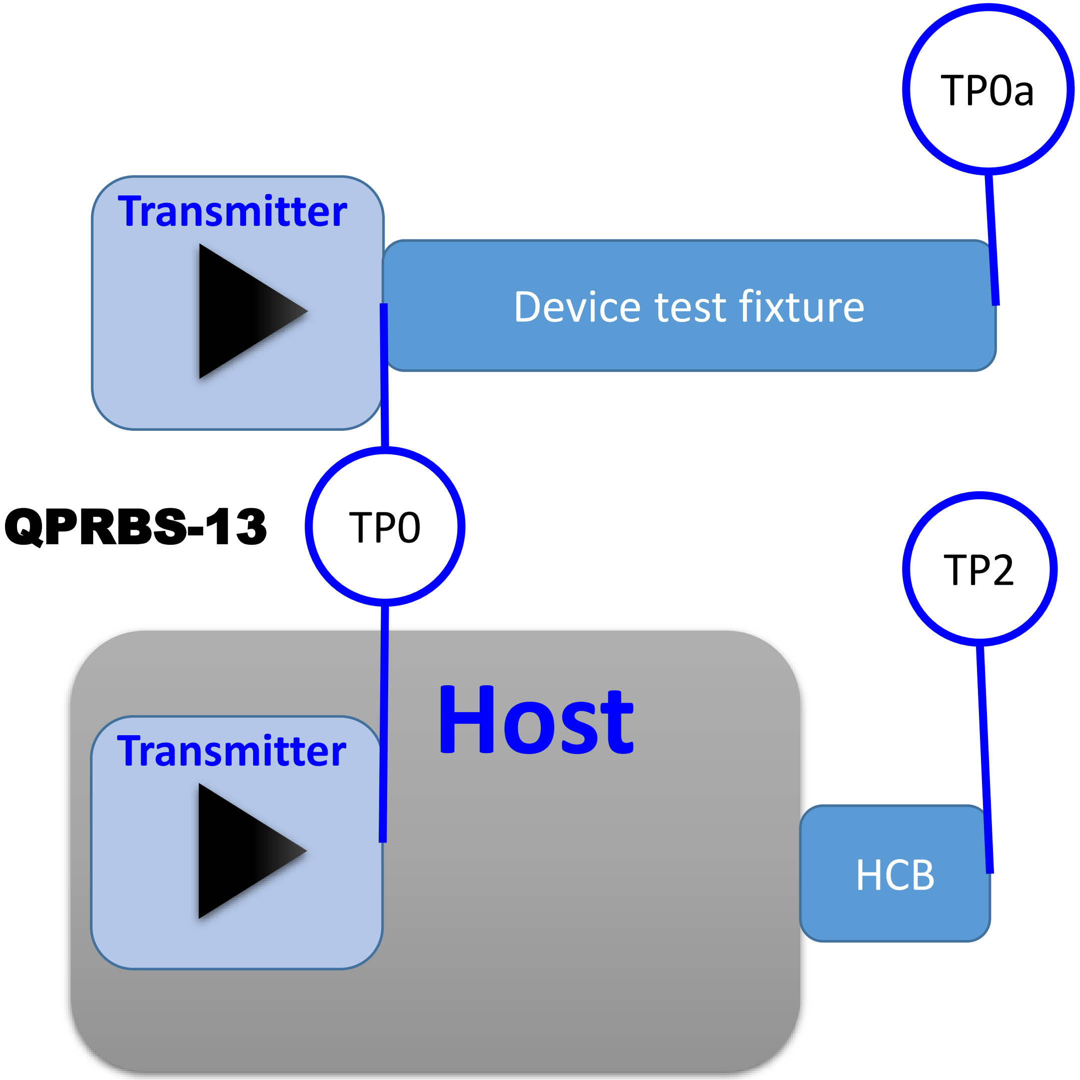
*Relative contributions not to scale

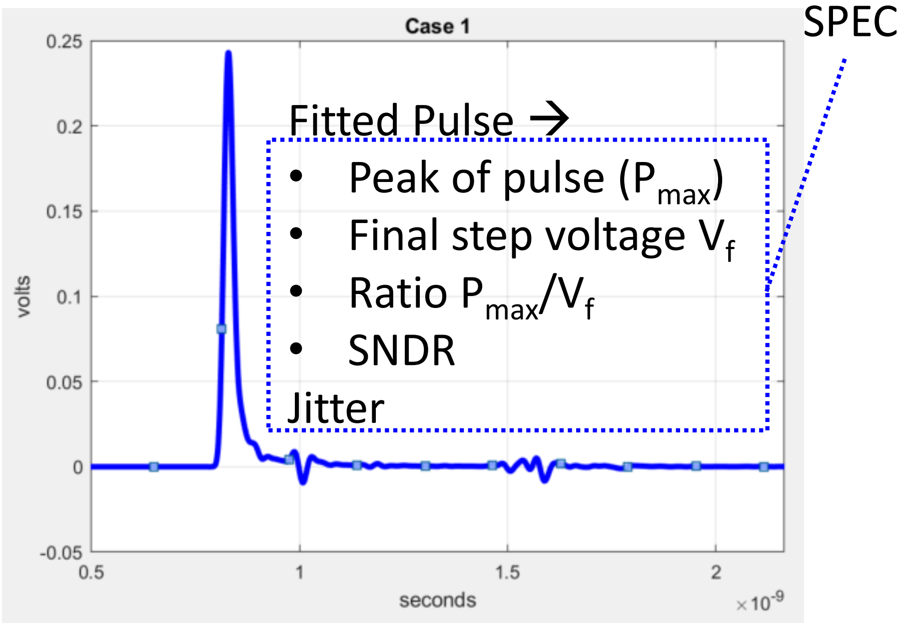
SNDR is Defined in Equation 120D-7

$$\mathrm{SNDR} = 10log10\left({P_{max}}^2 / ({\sigma_e}^2 + {\sigma_n}^2) \right)$$

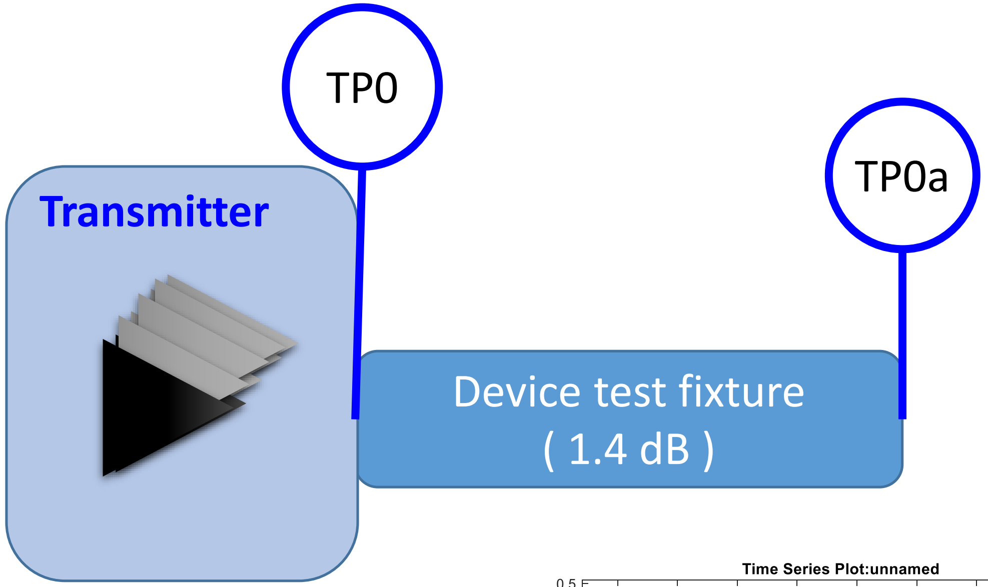
- ❑ SNR_{Tx} is used in the COM computation to model transmitter noise and distortion. This is controlled in the transmitter with the transmitter signal to noise distortion ratio (SNDR) specification
- ❑ It's acquire from a fitted pulse response at tp0a
  - P_{max} is the peak of the pulse response
  - σ_e is essentially the distortion from a linear response
  - σ_n is essentially the crosstalk and all other external noise
- ❑ $\sigma_{0a} = \sqrt{({\sigma_e}^2 + {\sigma_n}^2)}$ is the voltage RMS of an AWGN source

Transmitter Testing Utilizes a Fitted Pulse Response

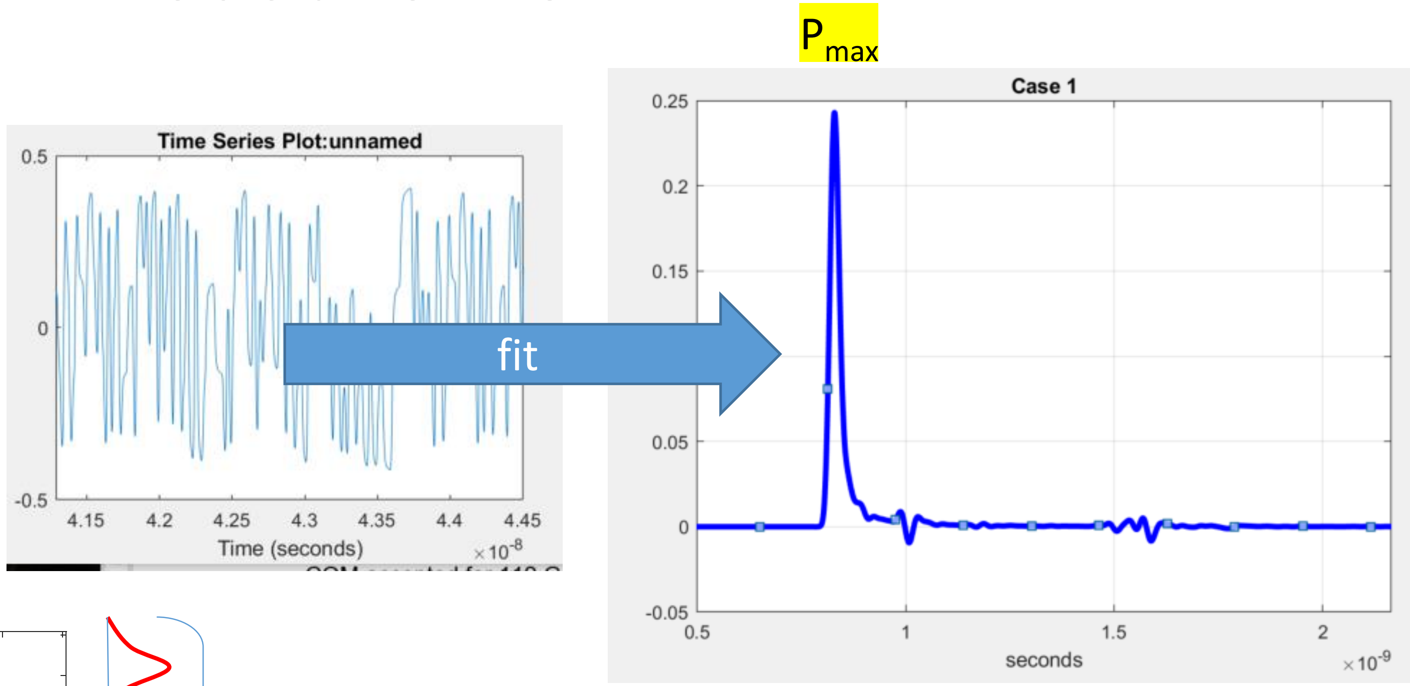


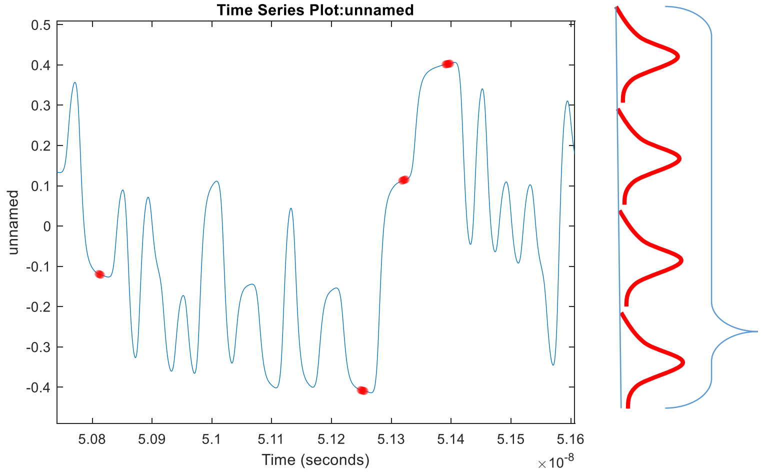


Review of how crosstalk and device noise are considered in an SNDR measurement



All transmitting QPRBS13





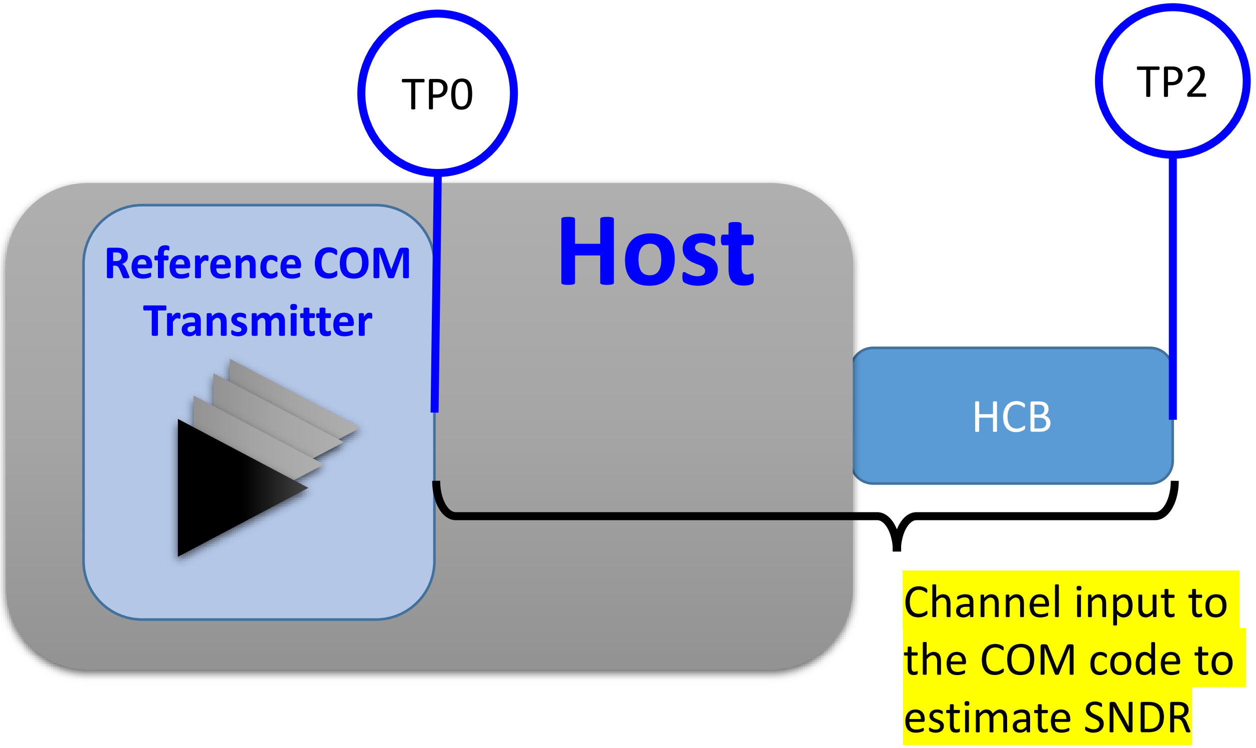
Voltage distributions

Root sum square of RMS noise (σ) at all 4 levels determines σ_n

How to Estimate SNDR at TP2 for a CR Host

- ICN is related to SNDR
- Problem: Getting the noise concepts on the same page
  - ICN would need to be adjusted to RMS (σ) assumptions used for SNR_{Tx}
- COM code reports ICN
- It would be useful to use this to estimate SNDR

Review of ICN Reported from the COM code



- NEXT is included in the ICN calculation
- ICN calculation emulates all lanes functionally active
- Driving back into TP2 should be included for SNDR calculations
  - But it may be a stretch to interpret it this way in the standard

ICN is **only** specified for a MTF (mated test fixture)

- The ICN for the MTF specification has very specific parameters
- The σ_x reported here is for NRZ
- We can re-use this, but adjustments need to be made

$$W_{nt}(f_n) = (A_{nt}^2/f_b)\text{sinc}^2(f_n/f_b)\left[\frac{1}{1+(f_n/f_{nt})^4}\right]\left[\frac{1}{1+(f_n/f_r)^8}\right] \quad (92\text{–}44)$$

$$W_{ft}(f_n) = (A_{ft}^2/f_b)\text{sinc}^2(f_n/f_b)\left[\frac{1}{1+(f_n/f_{ft})^4}\right]\left[\frac{1}{1+(f_n/f_r)^8}\right] \quad (92\text{–}45)$$

where the equation parameters are given in Table 92–14.

Note that the 3 dB transmit filter bandwidths f_{nt} and f_{ft} are inversely proportional to the 20% to 80% rise and fall times T_{nt} and T_{ft} respectively. The constant of proportionality is 0.2365 (e.g., $T_{nt}f_{nt}$ = 0.2365; with f_{nt} in hertz and T_{nt} in seconds). In addition, f_r is the 3 dB reference receiver bandwidth, which is set to 18.75 GHz.

The near-end integrated crosstalk noise σ_{nx} is calculated using Equation (92–46).

$$\sigma_{nx} = \left[2\Delta f\sum_n W_{nt}(f_n)10^{-MDNEXT_{loss}(f_n)/10}\right]^{1/2} \quad (92\text{–}46)$$

The far-end integrated crosstalk noise σ_{fx} is calculated using Equation (92–47).

$$\sigma_{fx} = \left[2\Delta f\sum_n W_{ft}(f_n)10^{-MDFEXT_{loss}(f_n)/10}\right]^{1/2} \quad (92\text{–}47)$$

where Δf is the uniform frequency step of f_n.

The total integrated crosstalk noise σ_x is calculated using Equation (92–48).

$$\sigma_x = \sqrt{\sigma_{nx}^2 + \sigma_{fx}^2} \quad (92\text{–}48)$$

The total integrated crosstalk noise for the mated test fixture is computed using the parameters shown in Table 92–14.

Table 92–14—Mated test fixture integrated crosstalk noise parameters

Description	Symbol	Value	Units
Symbol rate	f_b	25.78125	GBd
Near-end disturber peak differential output amplitude	A_{nt}	600	mV
Far-end disturber peak differential output amplitude	A_{ft}	600	mV
Near-end disturber 20% to 80% rise and fall times	T_{nt}	9.6	ps
Far-end disturber 20% to 80% rise and fall times	T_{ft}	9.6	ps

COMPUTING ICN 6x

COM Spreadsheet to Test a Host Tp0-Tp2

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	53.125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.2e-4 0]	nF	[TX RX]
L_s	[0.12 0]	nH	[TX RX]
C_b	[0.3e-4 0]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[0 0 ; 0 0]	mm	[test cases]
z_p (FEXT)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (RX)	[0 0 ; 0 0]	mm	[test cases]
C_p	[0.87e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[45 50]	Ohm	[TX RX]
A_v	0.39	V	vp/vf=.694
A_fe	0.39	V	vp/vf=.694
A_ne	0.578	V	
L	2		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.5		min
c(-1)	[0]		[min:step:max]
c(-2)	[0]		[min:step:max]
c(-3)	[0]		[min:step:max]
c(1)	[0]		[min:step:max]
N_b	0	UI	
b_max(1)	0.85		
b_max(2..N_b)	0.3		
g_DC	[0]	dB	[min:step:max]
f_z	100	GHz	
f_p1	100	GHz	
f_p2	200	GHz	
g_DC_HP	[0]		[min:step:max]
f_HP_PZ	0.01	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_KR_{date}\	
SAVE_FIGURES	1	logical
Port Order	[1 3 2 4]	
RUNTAG	CR_eval_	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	1	dB
ERL Pass threshold	10	dB
DER_0	1.00E-04	
T_r	6.16E-03	ns
FORCE_TR	1	logical
Include PCB	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	3000	
beta_x	2.53E+09	
rho_x	**0.25**	
fixture delay time	0	s
TDR_W_TXPKG	1	
N_bx	24	UI
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0	UI
A_DD	0	UI
eta_0	1.00E-20	V^2/GHz
SNR_TX	500	dB
R_LM	0.95	

Table 93A–3 parameters		
Parameter	**Setting**	**Units**
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Table 92–12 parameters 5.2dB at

$$W_{nt}(f_n) = (A_{nt}^2/f_b)\mathrm{sinc}^2(f_n/f_b)\left[\frac{1}{1+(f_n/f_{nt})^4}\right]\left[\frac{1}{1+(f_n/f_r)^8}\right]$$

$$W_{ft}(f_n) = (A_{ft}^2/f_b)\mathrm{sinc}^2(f_n/f_b)\left[\frac{1}{1+(f_n/f_{ft})^4}\right]\left[\frac{1}{1+(f_n/f_r)^8}\right]$$

N_bg	**0**	**0 1 2 or 3 groups**
N_bf	*4*	taps per group
N_f	40	UI span for floating taps
bmaxg	0.1	max DFE value for floating taps

f_v	1.1631	*fb
f_n	1.1631	*fb
f_f	1.1631	*fb
yellow indicates WIP		

Run with specified N_b to get a better estimate for V_f

Relevant COM Outputs

peak_uneq_pulse_mV:	P_{max}	384.5226	
steady_state_voltage_mV:	V_f	580.1311	Rerun with specified N_b for a better estimate
ICN_mV:	σ_x	4.8175	
MDNEXT_ICN_92_46_mV:		1.2614	
MDFEXT_ICN_92_47_mV:		4.6494	
Pmax_by_Vf_est:		0.6628	Rerun with specified N_b for a better estimate
IL_dB_channel_only_at_Fnq:		6.6014	

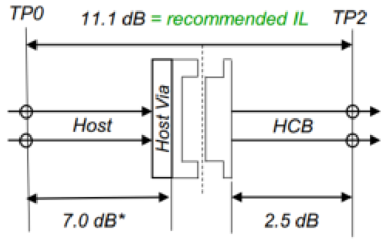
Estimate Noise at TP2 from ICN and SNR_{Tx}

- Given ICN reported at TP2
- Use σ_x (eq 93A-29) to adjust for PAM-4 , $\sqrt{\frac{L^2-1}{3(L-1)^2}}$ = 0.7453
  - "L" is the number of PAM levels
- $\sigma_{icn} = \sigma_x ICN$
- The RMS noise from TP0a, $\sigma_{0a@2}$, is
  - P_{max_tp2} is acquired from the COM code
  - $\sigma_{0a@2} = P_{\max\_tp2} 10^{-SNDR_{tp0a}/20}$

SNDR estimate at TP2

- Estimate noise at TP2 com using COM code reported ICN and SNR_{tx}
  - $\sigma_{host\_tp2}{}^2 = \sigma_{icn}{}^2 + \sigma_{0a@2}{}^2$
- The SNDR for the host under test may be computed using the P_{max} reported at tp2 using the aforementioned COM configuration sheet
  - $SNDR_{\ tp2} = 10log10\left({P_{\max\_tp2}}^2 / {\sigma_{host\_tp2}}^2\right)$

Results



set	name	IL dB	ERL22 dB	Pmax mV	ICN mV	SNDR dB	SNR_ISI dB	Pmax/Vf	Vf mV
mellitz_3ck_01_0518_C2M	C2M__Z100_IL9_BC-BOR_N_N_N	8.95	17.18	171.67	2.12	32.32	34.58	0.45	378.95
mellitz_3ck_01_0518_C2M	C2M__Z100_IL10_WC-BOR_H_L_H	9.96	10.78	181.09	4.20	30.97	29.24	0.48	380.06
lim_3ck_01_0718	100GEL_C2M_10dB	10.03	12.36	163.52	3.03	31.60	33.47	0.43	379.54
mellitz_3ck_01_0518_C2M	C2M__Z100_IL11p2_BC-BOR_N_N_N	11.16	18.71	149.24	1.80	32.35	33.09	0.40	370.73
lim_3ck_01_0718	100GEL_C2M_12dB	12.12	13.04	147.10	2.71	31.61	32.52	0.39	374.72
mellitz_3ck_01_0518_C2M	C2M__Z100_IL12_WC-BOR_H_L_H	12.18	12.40	160.73	3.71	30.99	29.75	0.43	373.25
lim_3ck_01_0918_QDD_new_pairs	100GEL_C2M_12dB	12.19	13.97	146.60	3.17	31.18	32.74	0.39	374.89
mellitz_3ck_01_0518_C2M	C2M__Z100_IL13_BC-BOR_N_N_N	13.12	20.26	130.07	1.57	32.35	30.81	0.36	362.57
mellitz_3ck_01_0518_C2M	C2M__Z100_IL14_WC-BOR_H_L_H	13.87	13.88	143.06	2.98	31.30	29.17	0.39	366.47
tracy_100GEL_02_0118	Host_Tx7_Mod_Tx7_OIF_Long_Barrel	13.93	17.54	131.43	1.50	32.42	31.58	0.36	369.36
lim_3ck_01_0718	100GEL_C2M_14dB	13.96	13.60	133.67	2.49	31.59	31.31	0.36	370.13
lim_3ck_01_0918_QDD_legacy_pairs	100GEL_C2M_14dB	14.02	14.04	132.25	2.36	31.69	31.79	0.36	370.52
tracy_100GEL_06_0118	Host_Rx7_Mod_Rx7_OIF_microvia	14.36	18.10	136.19	1.43	32.50	33.19	0.37	371.74
tracy_100GEL_06_0118	Host_Rx8_Mod_Rx8_OIF_microvia	14.41	17.35	133.65	1.43	32.48	32.51	0.36	370.81
tracy_100GEL_06_0118	Host_Rx3_Mod_Rx3_OIF_microvia	14.48	17.61	134.87	1.43	32.49	32.82	0.36	371.35
tracy_100GEL_06_0118	Host_Rx4_Mod_Rx4_OIF_microvia	14.51	17.37	134.02	1.43	32.48	32.59	0.36	371.02
tracy_100GEL_06_0118	Host_Rx5_Mod_Rx5_OIF_microvia	14.57	18.14	135.71	1.43	32.49	32.93	0.37	371.47
tracy_100GEL_06_0118	Host_Rx6_Mod_Rx6_OIF_microvia	14.59	17.32	134.42	1.43	32.48	32.57	0.36	370.88
tracy_100GEL_02_0118	Host_Tx8_Mod_Tx8_OIF_Long_Barrel	15.32	17.91	132.41	1.50	32.42	32.22	0.36	370.41
tracy_100GEL_02_0118	Host_Tx3_Mod_Tx3_OIF_Long_Barrel	15.36	17.47	130.74	1.50	32.41	31.92	0.35	369.58
tracy_100GEL_02_0118	Host_Tx4_Mod_Tx4_OIF_Long_Barrel	15.54	18.30	132.39	1.50	32.42	32.36	0.36	370.24
lim_3ck_01_0918_QDD_legacy_pairs	100GEL_C2M_16dB	15.83	14.39	119.21	2.02	31.80	30.27	0.33	366.19
lim_3ck_01_0718	100GEL_C2M_16dB	15.90	14.14	121.02	2.31	31.52	29.95	0.33	364.53
lim_3ck_01_0918_QDD_new_pairs	100GEL_C2M_16dB	15.96	14.78	118.72	2.51	31.25	30.20	0.32	365.33
tracy_100GEL_02_0118	Host_Tx6_Mod_Tx6_OIF_Long_Barrel	16.08	17.88	130.97	1.50	32.41	32.28	0.35	370.41
tracy_100GEL_02_0118	Host_Tx5_Mod_Tx5_OIF_Long_Barrel	16.48	17.60	129.25	1.50	32.40	31.79	0.35	369.65

Highlighted are candidates for spec limit

Need to check with more CR host channels

What to do with the SNR_{Tx}

- Find COM_1 end to end
  - With embedded cable assembly and host
- Find COM_2 for the CA with added transmission line and capacitors as in benartsi_ck_01_0719
- Adjust SNR_{Tx} in COM_2 to produce in the same value as COM_1
- Determine SNDR at TP2 for hosts used for COM_1
  - Formulate specification for SNDR based on this collection
  - SNDR may be used to limit the amount of host crosstalk

Call for Action Moving Toward Baseline

- ❑ Lock down MTF specifications such as ICN
  - Review ICN parameters for MTF utilizing MTF s-parameters
- ❑ Lock down equalization
  - So that ERL, $V_{f,}$ and P_{max} may be determined
- ❑ Identify Host Tp0-Tp2 channels to be considered
  - We need more CR host channels which include the BGA foot print.
  - The posted C2M channel are not sufficient
- ❑ Determine SNR_{Tx} to be used in COM for cable assemblies
  - Uses noise differences from end to end KR COM and a fabricated host with a HCB.
- ❑ Recommend for SNDR at TP2 baseline needs more CR host channel data
  - SNDR at TP2 needs to be less than SNR_{Tx}
  - In .3cd, they were the same
  - Evaluate using "equivalent_ICN_assuming_Gaussian_PDF_mV" reported in COM for a better SNDR estimate

Thank You!