Considerations for the choice of η_0

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September 2023 (r0)

Introduction

- The Channel Operating Margin (COM) calculation includes two terms that allocate margin for practical receiver implementations
  1. Input-referred noise spectral density η_0
  2. Minimum COM value required for channel compliance
- There has been a lack of clarity about what η_0 is intended to represent and this has led to challenges in choosing an appropriate value
- There has been no assessment of the minimum COM value to determine if it is sufficient to account for receiver impairments not addressed by η_0
- This presentation is intended to start a *conversation* about these terms

What should be considered in the value of η_0?

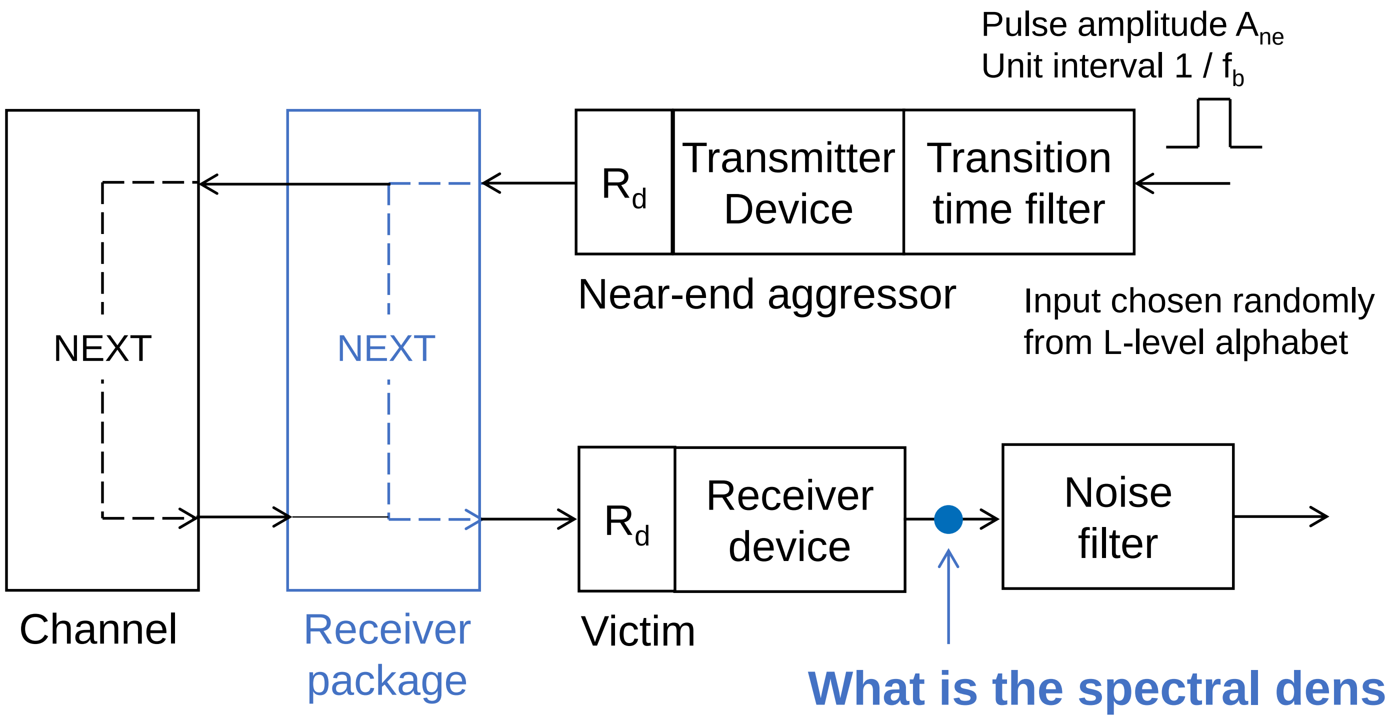
- Known sources of noise at the receiver input e.g., ...
- Thermal noise
- Receiver package near-end crosstalk (NEXT)
- Receiver package far-end crosstalk (FEXT)

- It could also include input-referred equivalents to likely sources of noise internal to the receiver
- More about this later...

Receiver package near-end crosstalk

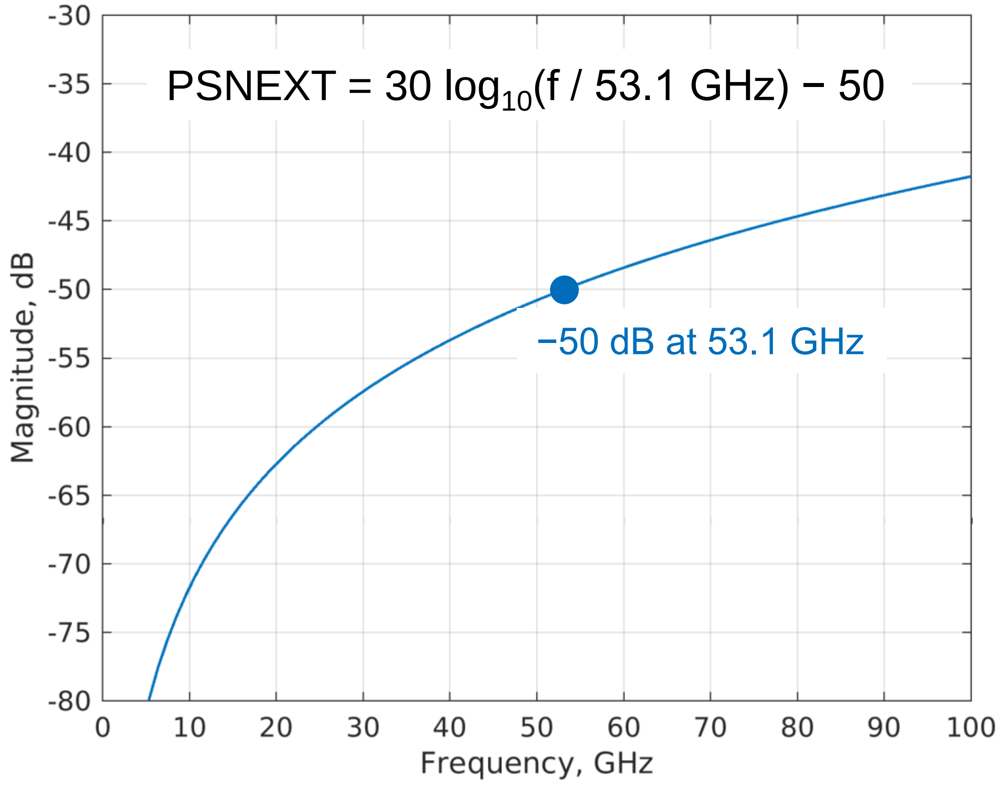
Channel NEXT is included in the channel measurements input to COM.

Receiver package NEXT should be accounted for in the COM reference package model.



What is the spectral density of the near-end aggressor at this point?

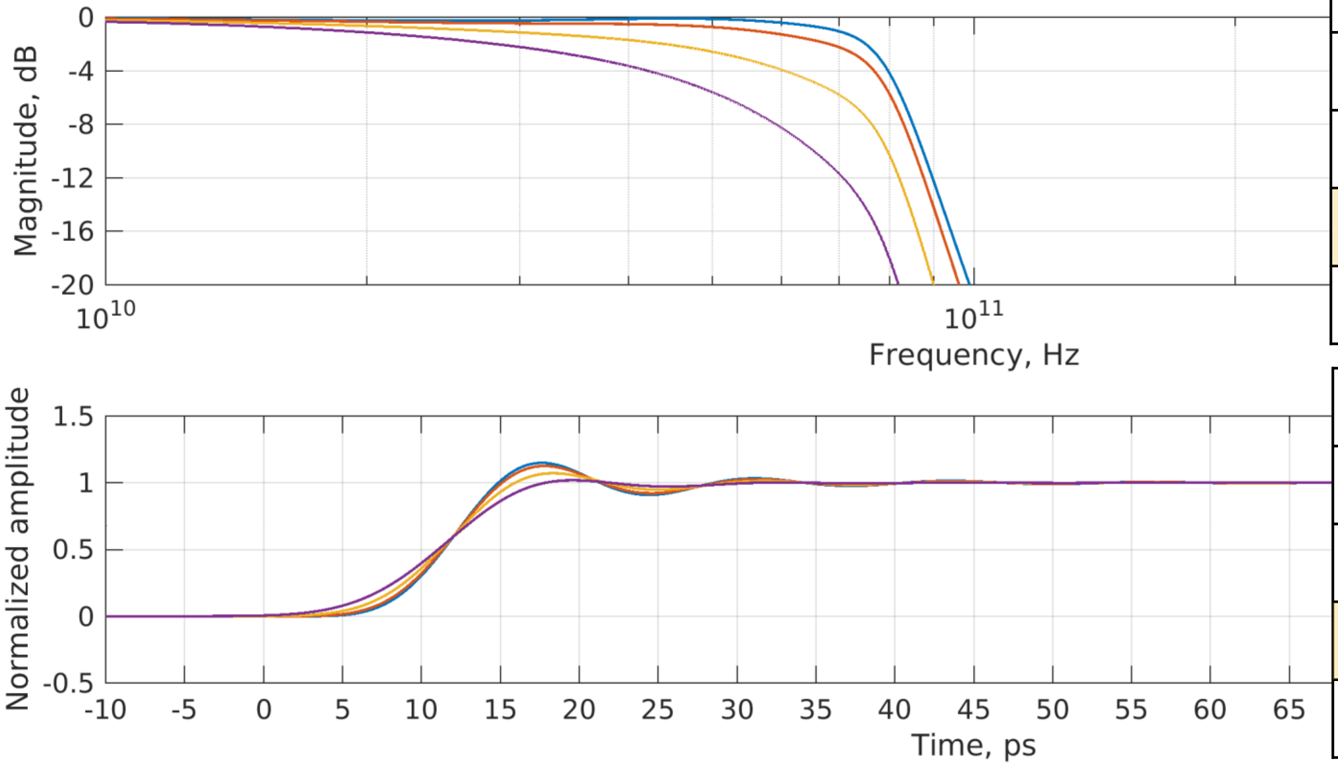
Package PSNEXT model (example)



A side note about transmitter and aggressor rise times

The device model has an s21 characteristic and hence an intrinsic rise time.

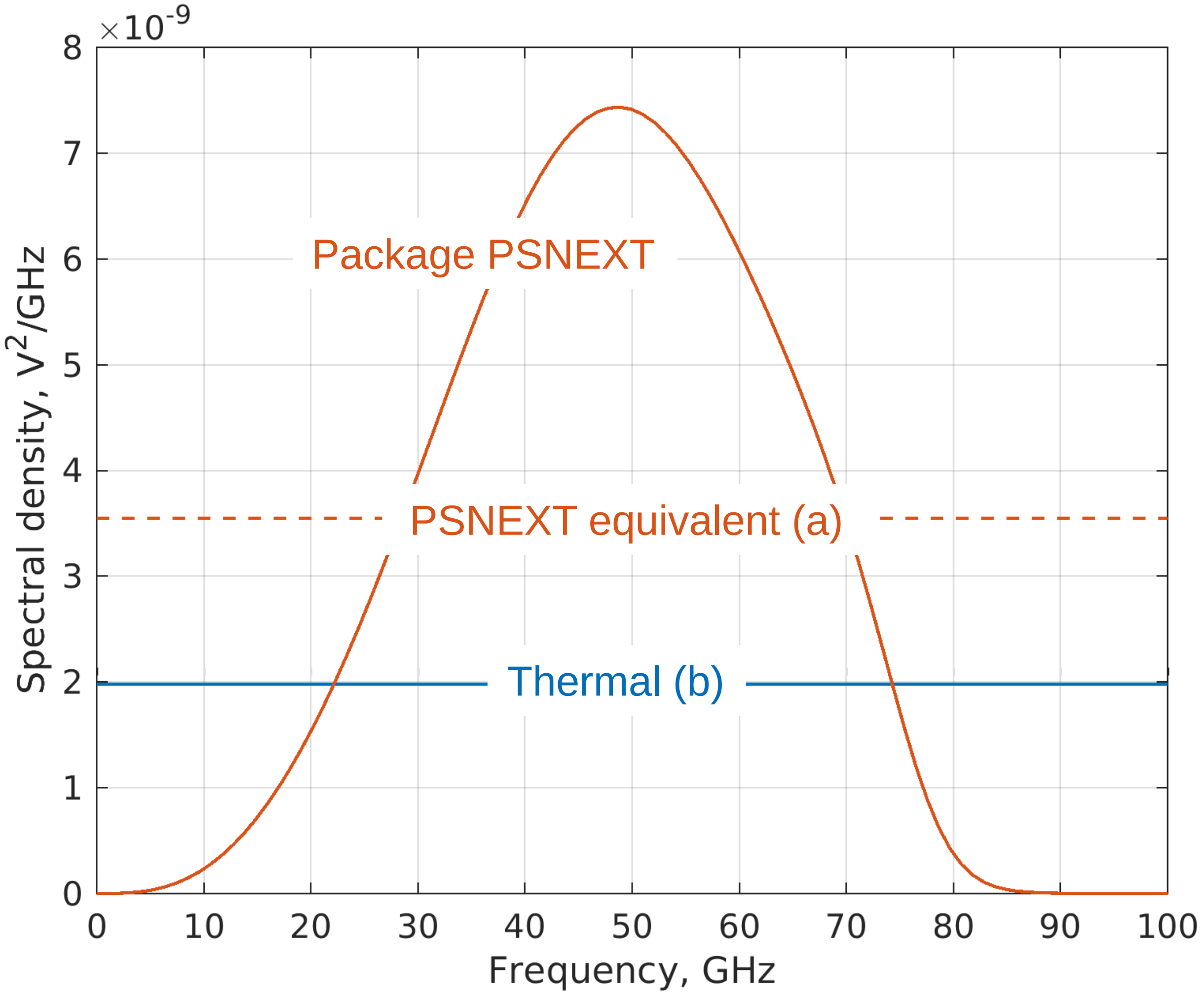
The rise time at the “bump” is the combination of this intrinsic rise time and the impact of the transition time filter.



T_r, ps	IL at 53.1 GHz at “bump”, dB
0	0.2
2	0.9
4	2.9
6	6.3

T_r, ps	Rise time at “bump”, ps
0	4.3
2	4.6
4	5.4
6	6.7

Interim summary of the components of input-referred noise



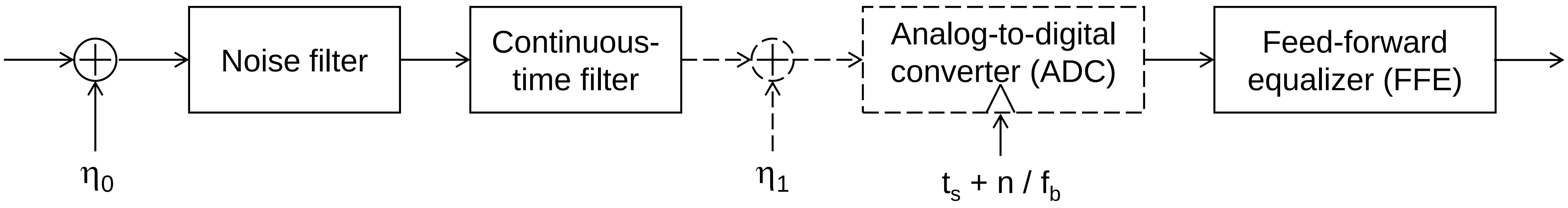
Component	Spectral density, V^2/GHz
Thermal	2e−9
Package NEXT	3.6e−9
Package FEXT	f.f.s.
Other, margin	f.f.s.
Total	> 5.6e−9

An η_0 value of 4e−9 or 5e−9 V^2/GHz is not sufficient to represent all of the input-referred noise sources that practical receivers will need to tolerate.

(a) "PSNEXT equivalent" is the flat input spectral density that produces the same PSNEXT RMS voltage at the receiver noise filter output.

(b) The thermal noise spectral density is $4k_BTR$ where k_B is the Boltzmann constant, T is (125C + 273.15) K, and R is $2R_d$ = 90 Ω (matching the COM configuration spreadsheet).

What impairments can the minimum COM allocation cover?



- Likely sources of noise internal to the receiver e.g., ...
- Amplifier (gain, continuous-time equalization) output-referred noise
- Amplifier distortion
- Analog-to-digital converter (ADC) effective number of bits (ENOB)
- Sampling time jitter

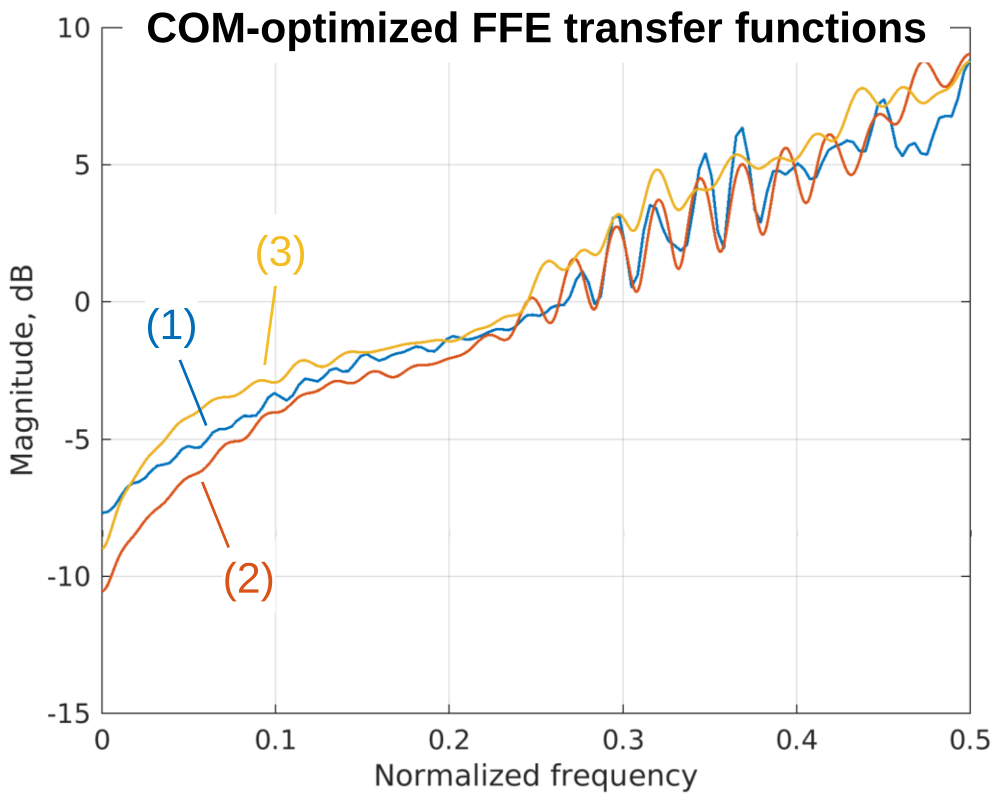
- Certain noise sources may be better modeled by an additional receiver noise term, or referred to the receiver input, due to scaling with loss

Some test cases for a receiver impairment study

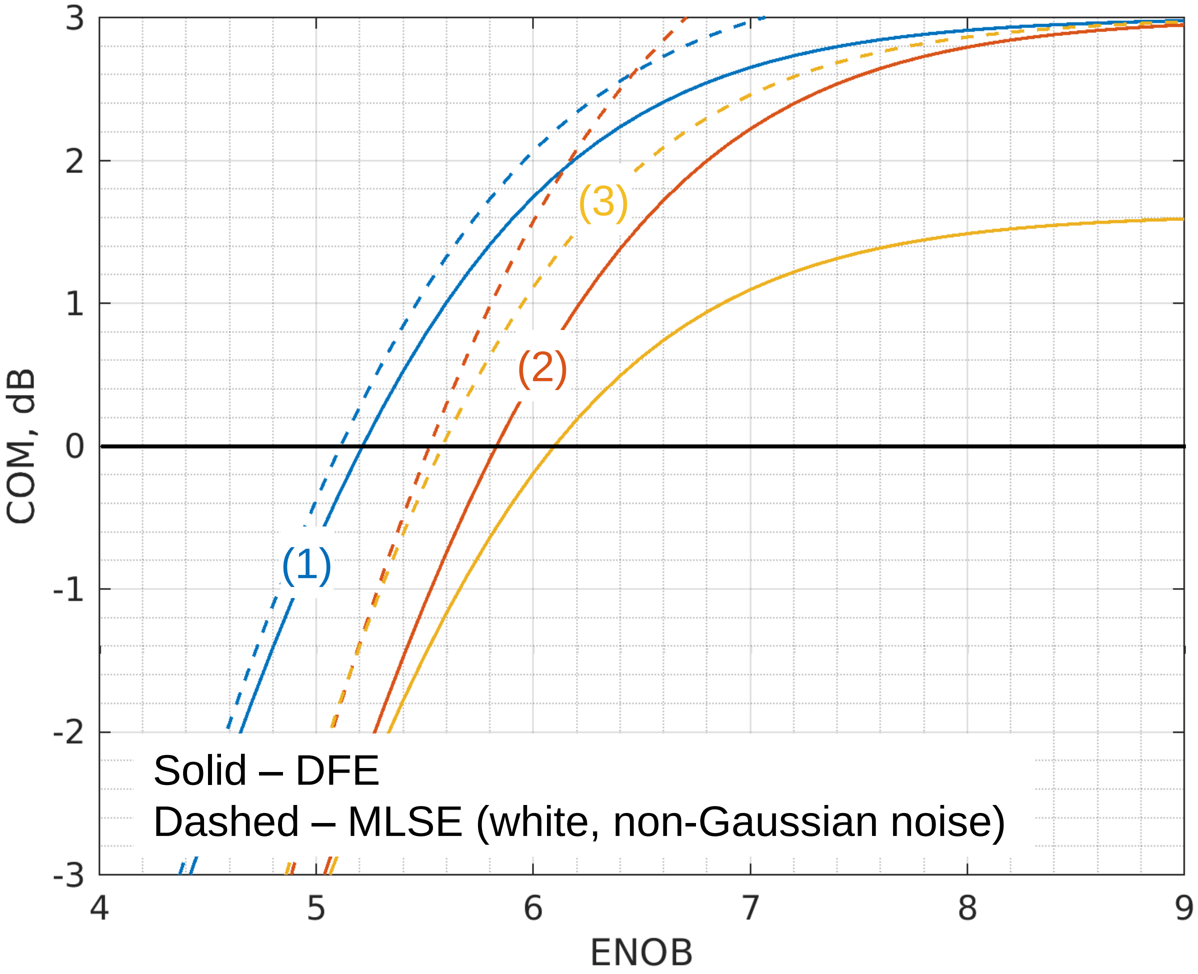
#	Die-die IL, dB	Source
1	23.5	mellitz_3dj_03_elec_230504, C2C_withXtalk_Mezz_1_PCB-25mm_25mm_*
2	32.7	mellitz_3dj_02_elec_230504, KRCA_wXTALK_MX_4_PCB-25-25_mm_FO-200-200_mm_CA-200_mm_*
3	40.5	shanbhag_3dj_01_2305, CR_1mOSFPDAC_TP0TP5_25p9dB_PCBHost_4p9dB_*

Normalize all of the test cases to COM = 3 dB by adding noise at the receiver FFE output.

#	Rx	Added noise for COM = 3 dB, mV RMS
1	DFE	2.7
2	DFE	1
3	MLSE	0.4



COM implementation penalty due to ADC ENOB



#	Rx	Minimum ENOB for COM > 0 dB
1	DFE	5.2
2	DFE	5.8
3	MLSE	5.6

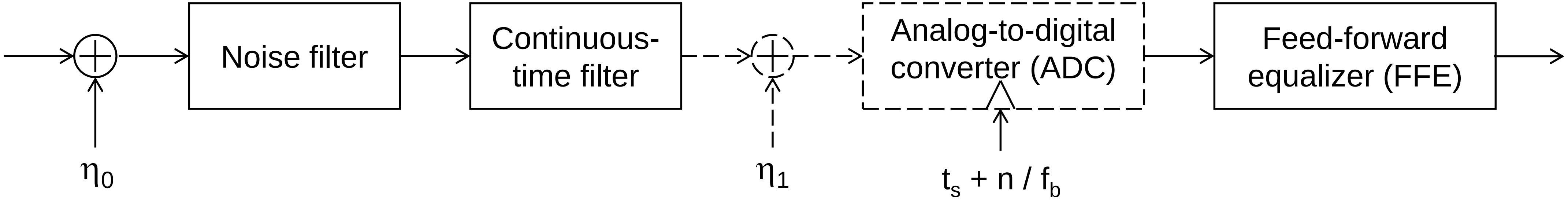
#	Rx	COM penalty for ENOB = 6, dB
1	DFE	1.3
2	DFE	2.5
3	MLSE	1.9

This one receiver impairment consumes the bulk of the 3 dB implementation allowance.

What about the other impairments?

NOTE – ENOB is modeled as a flat spectral density at the input to the receiver FFE. It can be equated to low-frequency ENOB since it does not include degradation at higher frequency due to jitter. This also means that the jitter impairment is not included in this estimate of the COM penalty. COM penalty calculation assumes 90% loading of the ADC input.

Other consideration for the minimum COM allocation



- Differences between reference equalizer and practical implementation e.g., limited number of taps, finite precision arithmetic
- Imprecise performance predictions due to use of approximations
- Optimistic performance predictions due to idealized models

Summary and next steps

- Commonly-used values for η_0 do not appear to be large enough to account for the most likely sources for receiver input-referred noise
- Certain receiver impairments can be expected to scale with channel loss
- A fixed allocation for these impairments e.g., a minimum COM, may be too generous for low-loss channels and insufficient for high-loss channels
- More explicit accounting of these impairments using new or existing noise terms is needed
- This presentation is intended to start a *conversation*
- The desired outcome of that conversation is consensus on what the noise terms represent and values for those noise terms that enable reasonable implementations to comply with the standard
- The minimum COM allocation may then need to be revisited based on the consensus noise definitions

Back-up materials

COM configuration spreadsheet, 1 of 2

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]
R_0	50	Ohm	
R_d	[45 45]	Ohm	[TX RX]
A_v	0.386	V	vp/vf=
A_fe	0.386	V	vp/vf=
A_ne	0.6	V	
L	4		
M	32		
filter and Eq			
f_r	0.58	*fb	
c(0)	0.55		min
c(-1)	[-0.4:0.02:0]		[min:step:max]
c(-2)	[0:.02:0.1]		[min:step:max]
c(-3)	0		[min:step:max]
c(-4)	0		[min:step:max]
c(1)	[-0.2:0.05:0]		[min:step:max]
N_b	1	UI	
b_max(1)	0.75		As/dfe1
b_max(2..N_b)	0.3		As/dfe2..N_b
b_min(1)	0		As/dfe1
b_min(2..N_b)	-0.15	S	As/dfe2..N_b
g_DC	[-15:1:-3]	dB	[min:step:max]
f_z	25.16	GHz	
f_p1	40.00	GHz	
f_p2	56.00	GHz	
g_DC_HP	[-5:1:0]		[min:step:max]
f_HP_PZ	1.328125	GHz	
Butterworth	1	logical	include in fr

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	0	logical
RESULT_DIR	esults\CACR_set1_{date}\	
SAVE_FIGURES	0	logical
Port Order	**[1 3 2 4]**	
RUNTAG	KR_set1_eval_	
COM_CONTRIBUTION	1	logical

TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	ns
TR_TDR	0.01	
N	4000	logical
TDR_Butterworth	1	
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	UI
N_bx	20	
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	4.00E-09	dB
SNR_TX	33	
R_LM	0.95	

Table 93A–3 parameters			
Parameter	**Setting**	**Units**	Information
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	
z_p select	2		[test cases to run]
z_p (TX)	[6 31; 1 1; 1 1; 0.5 0.5]	mm	[test cases]
z_p (NEXT)	[8 29; 1 1; 1 1; 0.5 0.5]	mm	[test cases]
z_p (FEXT)	[6 31; 1 1; 1 1; 0.5 0.5]	mm	[test cases]
z_p (RX)	[8 29; 1 1; 1 1; 0.5 0.5]	mm	[test cases]
C_p	[0.5e-4 0.5e-4]	nF	[TX RX]

Filter: Rx FFE			
ffe_pre_tap_len	6	UI	
ffe_post_tap_len	60	UI	
ffe_tap_step_size	0		
ffe_main_cursor_min	0.7		
ffe_pre_tap1_max	0.7		
ffe_post_tap1_max	0.7		
ffe_tapn_max	0.7		

Operational			
ERL Pass threshold	10	dB	
COM Pass threshold	3	db	
DER_0	1.00E-04		
T_r	0.00400	ns	
FORCE_TR	1	logical	
PMD_type	C2C		
EW	1		
MLSE	0	logical	
ts_anchor	1		
sample_adjustment	[-32 32]		
Local Search	2		

NOTE – This configuration was used exclusively for the purpose of producing the examples shown in this presentation. It is not a proposal for COM parameter values.

COM configuration spreadsheet, 2 of 2

SAVE_CONFIG2MAT	0	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
ICN parameters		
f_v	0.278	Fb
f_f	0.278	Fb
f_n	0.278	Fb
f_2	61.625	GHz
A_ft	0.450	V
A_nt	0.450	V

Parameter	Setting		
board_tl_gamma0_a1_a2	*[0 6.44084e-4 3.6036e-05]*	1.4 db/in @ 53.125G	
board_tl_tau	*5.790E-03*	ns/mm	
board_Z_c	100	Ohm	
z_bp (TX)	*32*	mm	
z_bp (NEXT)	*32*	mm	
z_bp (FEXT)	*32*	mm	
z_bp (RX)	*32*	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	

Floating Tap Control				
N_bg	**0**	0 1 2 or 3 groups		
N_bf	4	taps per group		
N_f	80	UI span for floating taps		benartsi_3df_01a_2211
bmaxg	0.2	max DFE value for floating taps		mli_3df_02_220316
B_float_RSS_MAX	0.1	rss tail tap limit		
N_tail_start	25	(UI) start of tail taps limit		

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