C2M TP1a test specs proposal

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IEEE 802.3ck Task Force

Supporters

- Your name here!

Outline

- Background – EVEC spec motivation
- Channels and COM settings for analysis
- Modified VEC mask & TP1a to whole link correlation
- Proposed changes to D1p0 for EVEC
- TP1a test methodology – filter for DFE
- Proposed changes to D1p0 for TP1a spec
- Summary

TP1a EVEC Spec – Background

- The followings proposed the ideas of combining VEC & VEO specs, which is EVEC (Effective Vertical Eye Closure)
  - ghiasi_3ck_02a_0919, sun_3ck_01b_1119, wu_3ck_01a_1119
- However, the parameters for EVEC calculation & EVEC thresholds are different among contributions

Contribution		ghiasi_3ck_02a_0919 [1]	sun_3ck_01b_1119 [2]	wu_3ck_01a_1119 [3]	wu_3ck_02_0120 [4]
Parameter (min/max), Unit	Symbol	Value	Value	Value	Value
ESMW (Eye symmetry mask width), UI	ESMW	N/A	TBD	N/A	TBD
Eye height, differential (min), mV	EH	N/A	15	N/A	**15**
Vertical eye closure (max), dB	VEC	***N/A***	N/A	N/A	N/A
EVEC parameters					
- VEC0 (dB) = EVEC_th, max (dB)		9.5	8.5	6.5	**7**
- VEC1 (dB)		12.5	11	11.5	**10.5**
- VEO0 (dB)		10	15	10	**12.5**
- VEO1 (dB)		20	30	25	**25**

- The purpose of this contribution
  - To propose parameters used for EVEC calculation & the EVEC threshold accordingly

Channel and Analysis

- Channel and reference receiver
  - Whole-link & TP1a analysis for 66 IEEE C2M host-to-module channels
    - Sweep host package trace length, z_p1(TX)
      - z_p1(TX) = [7:0.5:10 11:14 15:5:40], from 7 to 40 mm covering wide range
    - total 66 * 17 = 4686 CH+PKG test cases
  - Ref RX = 4-tap DFE as 802.3ck D1p0
- COM parameter settings [details in appendix]
  - COM 2.76
  - Whole link: TX PKG + H2M Channels + RX PKG
    - Table 1
    - g_DC = [-14:1:-3] dB
    - g_DC_HP = [-3:1:0] dB
    - b_max(1) = 0.5, b_max(2..N_b) = 0.2
  - TP1a: TX PKG + H2M Channels
    - Set 'zero' to related RX PKG & on-die settings

Table 1

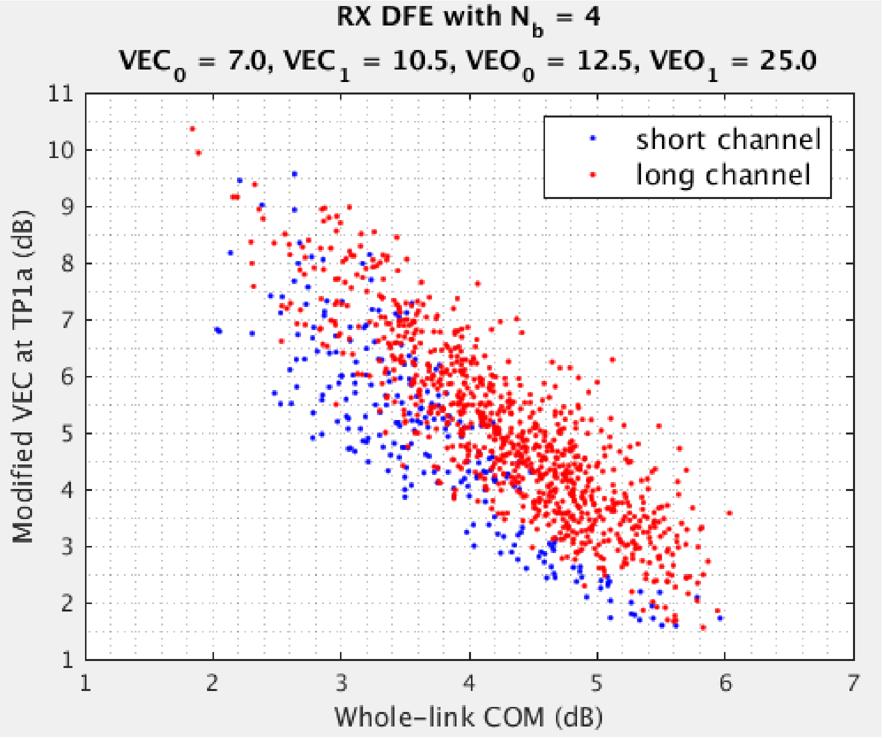
Spec	[Host, Module]	Unit
C_d	[1.2e-4 0.85e-4]	nF
L_s	[0.12 0.12]	nH
C_b	[0.3e-4 0.3e-4]	nF
R_d	[50 50]	Ohm
C_p	[0.87 0.65]	nF
z_p(RX)	[5 0]	Ohm

EVEC Parameters

- $$EVEC(i) = \begin{cases} VEC(i), & if\ VEO(i) < VEO_0 \\ VEC(i) - (VEC_1 - VEC_0)/(VEO_1 - VEO_0) \times (VEO(i) - VEO_0), & if VEO_0 \le VEO(i) < VEO_1 \\ VEC(i) - (VEC_1 - VEC_0), & otherwise \end{cases}$$

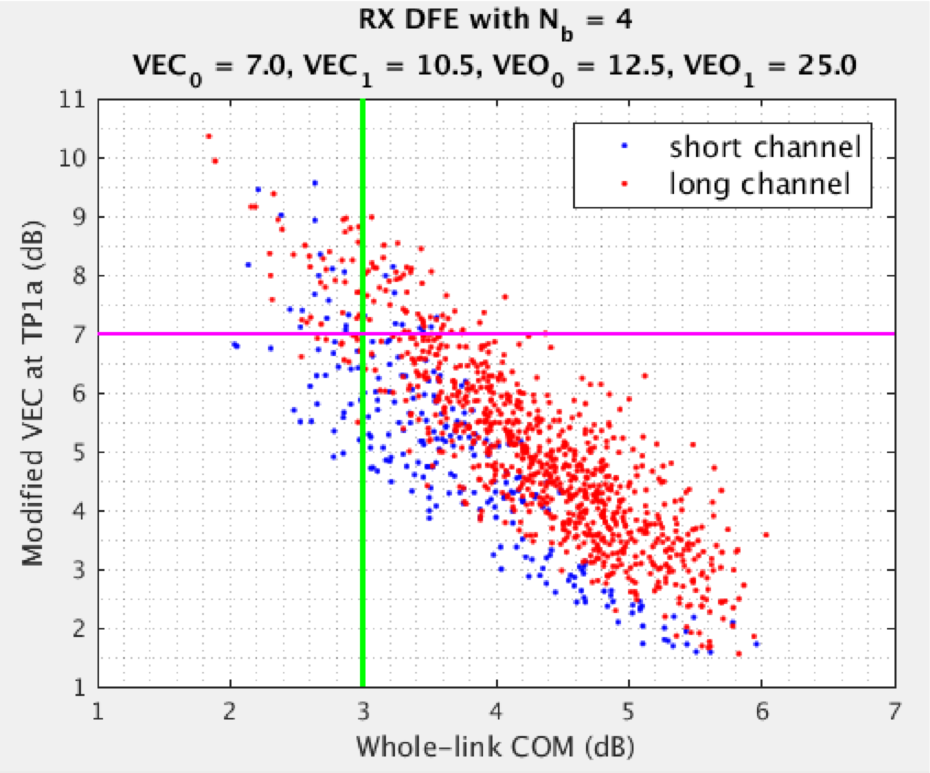
- We swept all the possible values of VEC_0, VEC_1, VEO_0 and VEO_1
  - Set the following optimal values by searching maximum of the correlation coefficients between the whole-link COM and EVEC
  - The EVEC parameters achieving best correlation are

Parameters	Values
VEC_0	7.0
VEC_1	10.5
VEO_0	12.5
VEO_1	25.0

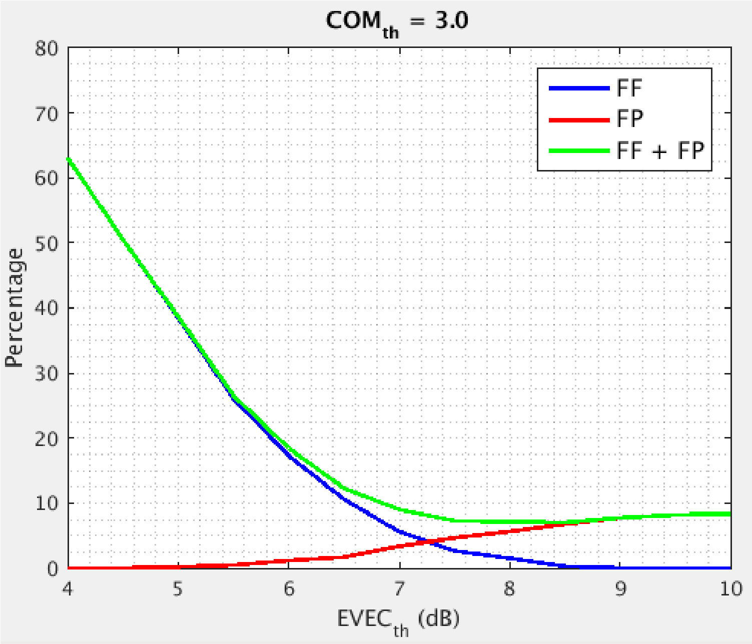


EVEC Mask Threshold

1. Fix TX EQ by TP1a
2. N_b=4
3. Set Eta_0 = 8.2e-9 (SysNs + 0.0mV RxNs)

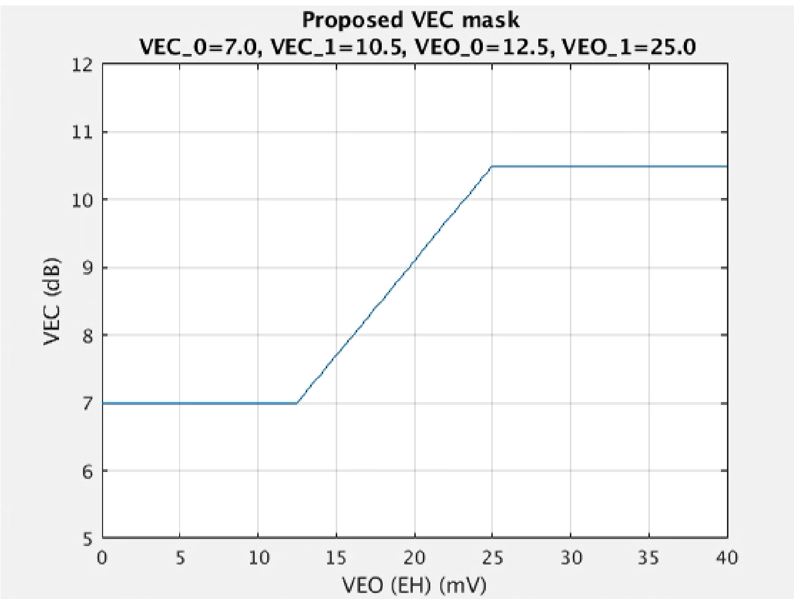


- EVEC Threshold = 7
- % of false fail = 5.6%
- % of false pass = 3.4%
- % of false cases = 9.0%
- Correlation coefficient = -0.822



Proposed EVEC Mask

- $$EVEC = \begin{cases} VEC, & if\ VEO < 12.5\ mV \\ VEC - \ 3.5/12.5 \times (VEO - 12.5), & if\ 12.5\ mV \le VEO < 25\ mV \\ VEC - 3.5, & otherwise \end{cases} \qquad (120G-4)$$



- Insert the following paragraph in 120G.4.2 after Line 31 at Page 226
- h) Compute the effective vertical eye closure (EVEC) by Equation (120G-4)
- Change the parameter of "Vertical eye closure (max)" in Table 120G-1 at page 213 as below

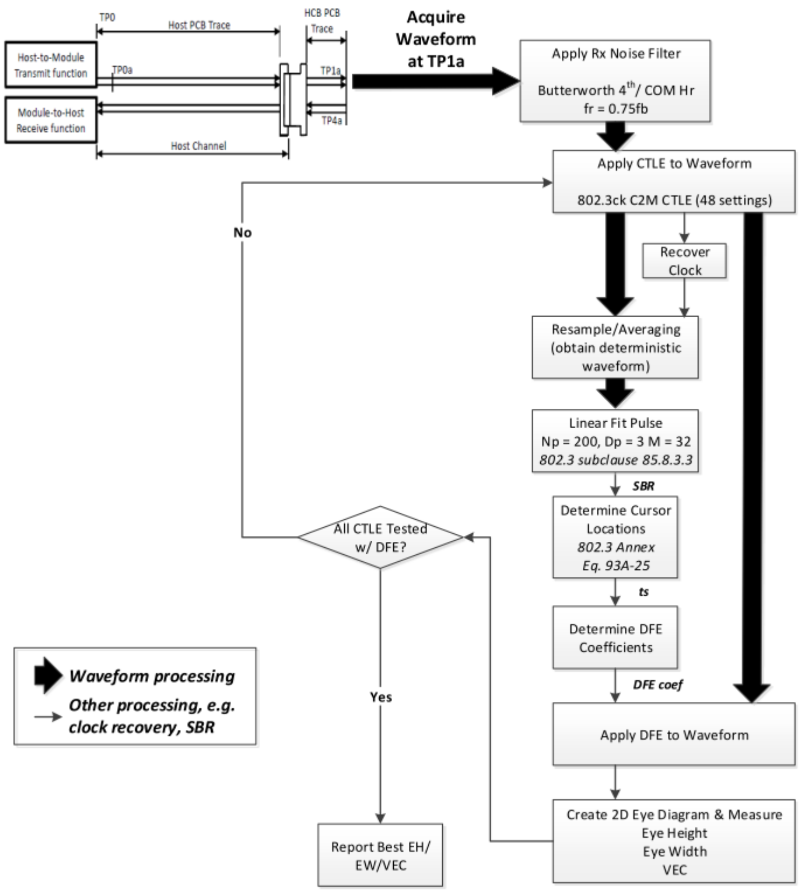
Parameter	Reference	Value	Units
Effective vertical eye closure (max)	120G.4.2	7.0	dB

C2M TP1a specs change proposal

- Criterion: EVEC <= 7.0
- Propose to change D1p0 as below
- Original: 120G.4.2, Line 33 @ Page 226
  - Within the set of combinations of *g*DC and *g*DC2 with eye height meeting the target requirement, for the com-bination resulting in the smallest vertical eye closure, the eye height, eye width, and vertical eye closure are used as the measured values.
- Proposal
  - Within the set of combinations of *g*DC and *g*DC2, the eye height, eye width, and **effective vertical eye closure**, resulting in the smallest **effective vertical eye closure**, are used as the measured values.

TP1a test methodology in D1p0

- TP1a test methodologies had been proposed & adopted in sun_3ck_01b_1119 & sun_3ck_02_1119
  - Detailed implementation can be found in li_3ck_02_1119
- One question remained
  - By “Applying DFE to Waveform”, shall we apply any kind of filters to DFE coefficient?
  - Filter for DFE coefficient matters → have impacts to measured Eye Width, VEC, …
  - We need to make it clear in 802.3ck



Recap – Feedback decision in D1p0

Perform the following five steps for each valid combination of g_{DC} and g_{DC2} as specified in Table 120G–9:

c) Compute the response $y_2(k)$ by applying the effect of the continuous time filter to $y_1(k)$ using the associated parameters in Table 120G–9.

d) Compute the linear fit pulse response of $p_2(k)$ using the method defined in 136.9.3.1.1 with parameter M the same as for step a), D_p equal to 3, and N_p equal to 200.

e) Compute the DFE sampling phase t_s and tap weights $b(n)$ for $p_2(k)$ according to the methodology in 93A.1.6 using the associated parameters in Table 120G–9.

f) Compute receiver input signal $y_{rx}(k)$ by applying the effect of the DFE using the sampling phase t_s and tap weights $b(n)$ determined in the previous step.

g) Compute an eye diagram from $y_{rx}(k)$ and compute the eye height, eye width, and vertical eye closure from the eye diagram using the methodologies in 120E.4.2 and 120E.4.3.

Copied from 93A.1.6

f) ~~e)~~ Compute $h_{ISI}(n)$ per Equation (93A–27). This represents the residual intersymbol interference (ISI) after decision feedback equalization. The c
puted per Equation (93A–31) and Equation (93A

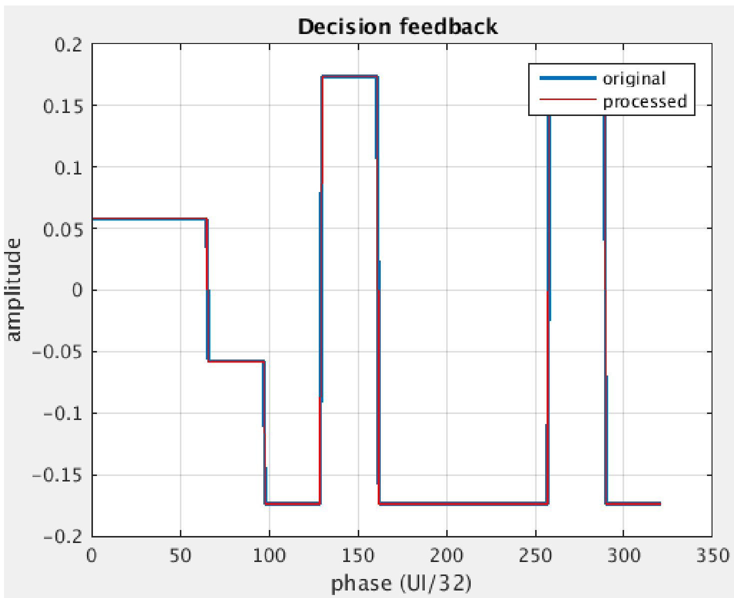
$$h_{ISI}(n) = \begin{cases} 0 & n = 0 \\ h^{(0)}(t_s + nT_b) - h^{(0)}(t_s)b(n) & 1 \le n \le N_f \\ h^{(0)}(t_s + nT_b) & \text{otherwise} \end{cases}$$

- Based on the above description in 93A.1.6
  - It seems 'Constant DFE coefficient' in single UI is adopted → is that true?
  - What if 'Gaussian filter' is applied for DFE coefficient?

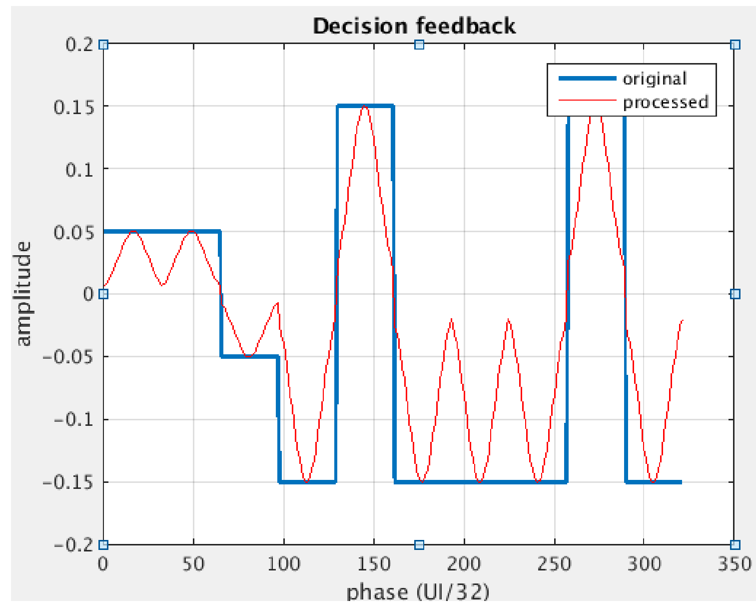
Filter for DFE – Constant vs. Gaussian

- We analyzed two cases of filter to DFE coefficients
  - Constant – DFE values keeps the same for the entire UI
  - Gaussian – Smooth the waveform of DFE values

Constant – no filters at all

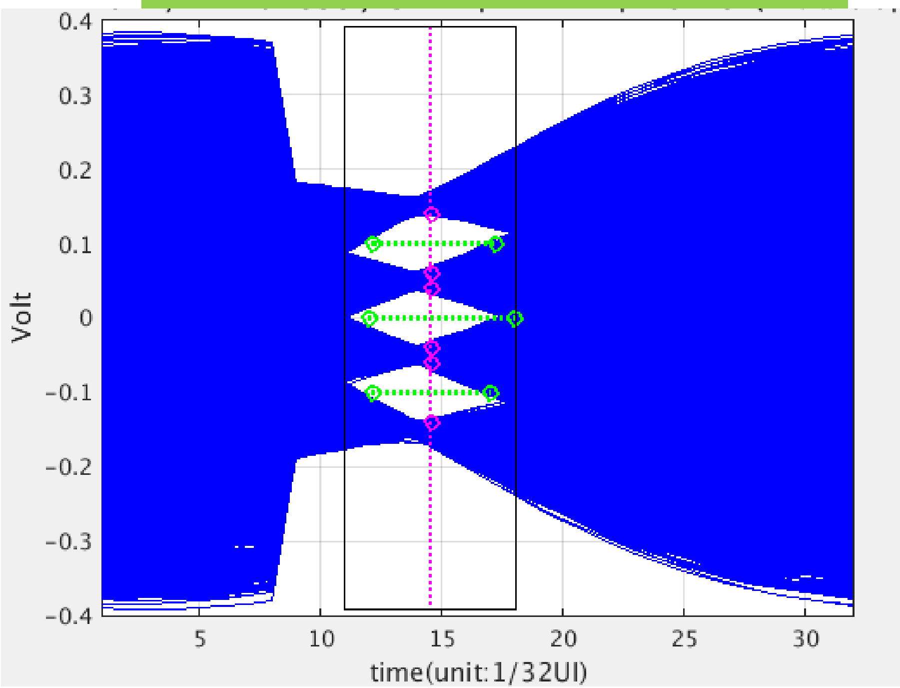


Gaussian filter

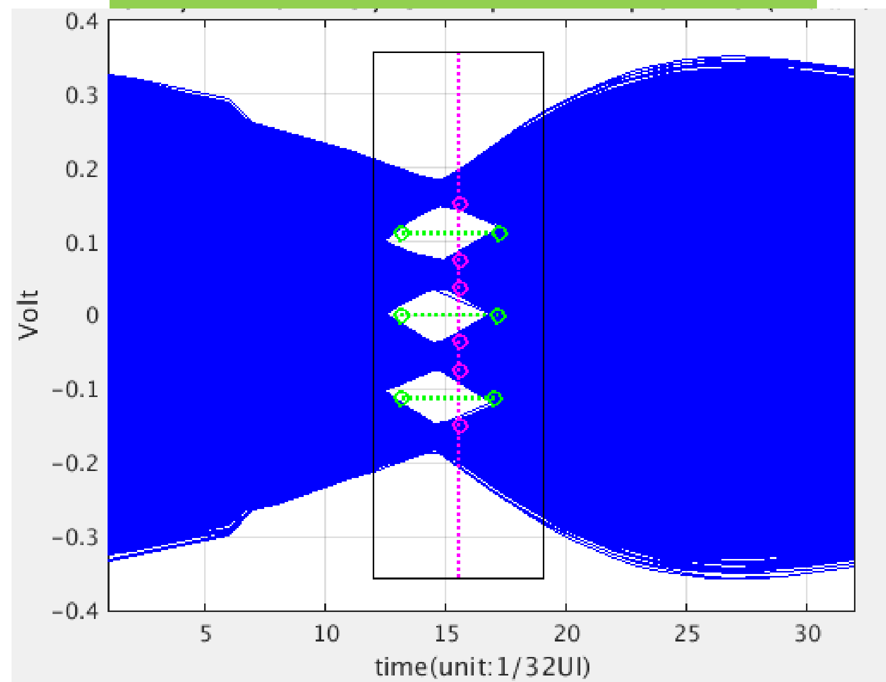


Filter for DFE – Constant vs. Gaussian

Constant – no filters at all



Gaussian filter



- Channel
  - Jane Lim's ch5b_3" with TX 16+1.8mm
- Filter applies to DFE matters
- In order to avoid defining detailed specs of Gaussian filter, we propose to adopt 'Constant'

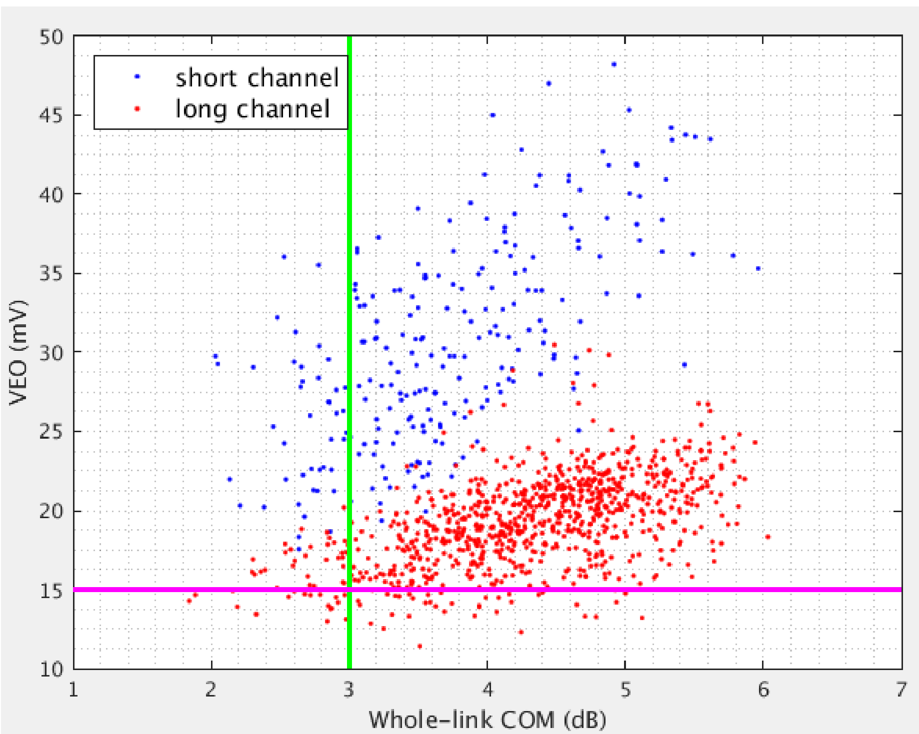
	Constant	Gaussian
TC_{mid}	14.5	15.5
EH5 (mV)	[69.7 **59.0** 69.8]	[50.6 **50.5** 67.5]
EW5 (mUI)	[51 103 **36**]	[**21 23 4**]
VEC5 (dB)	[3.2 **4.6** 3.2]	[6.9 **6.9** 4.4]

Proposed Change to D1p0 –test methodology

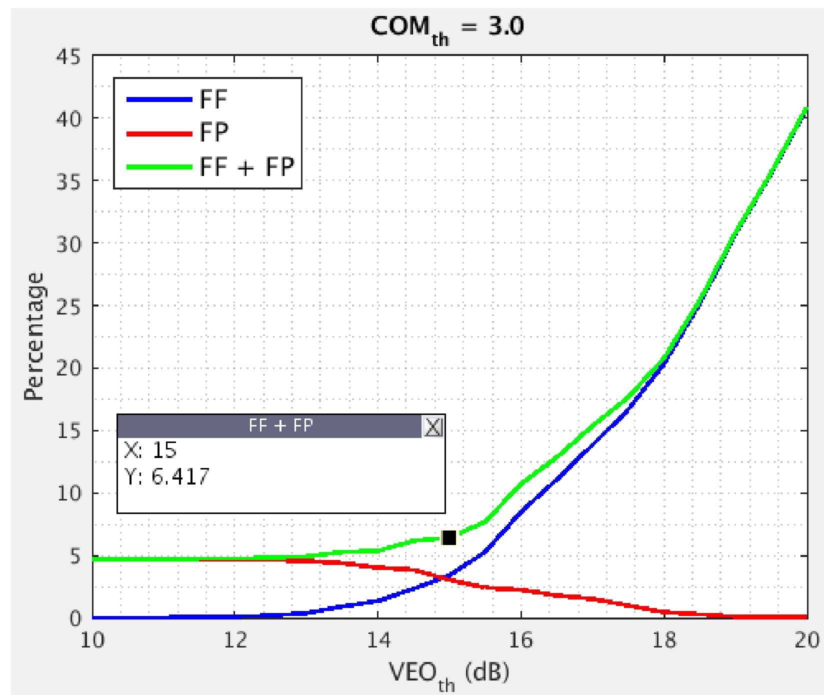
- Original – 120G.4.2 Eye opening measurement method, step f) [Page 226, L28]
  - Compute receiver input signal $y_{rx}(k)$ by applying the effect of the DFE using the sampling phase t_s and tap weights $b(n)$ determined in the previous step.
- Proposal – Insert the following sentence after the original sentence
  - The effect of DFE changes value to $b(n)$ at the time of t_s + half UI and keeps the same value for the following entire UI.

Analysis of 66 C2M Channels – VEO_{min}

1. Fix TX EQ by TP1a
2. N_b=4
3. Set Eta_0 = 8.2e-9 (SysNs + 0.0mV RxNs)



- VEO (EH) Threshold = **15 mV**
- % of false cases = 6.4%



Proposed TP1a Spec

- Spec in D1p0 [Page 213]

Table 120G–1—Host output characteristics at TP1a

Parameter	Reference	Value	Units
ESMW (eye symmetry mask width)	120E.4.2	TBD	UI
Eye height, differential (min)	120E.4.2	TBD	mV
Vertical eye closure (max)	120E.4.2	TBD	dB

- Propose to **change** to

Parameter	Reference	Value	Units
ESMW (eye symmetry mask width)	120E.4.2	TBD	UI
Eye height, differential (min)	120E.4.2	**15**	mV
Effective vertical eye closure (max)	**120G.4.2**	**7.0**	dB

Summary

- Based on nearly 5000 analysis case, we set optimal EVEC parameters & threshold to achieve
  - High correlation coefficient: -0.82
  - Low total false ratio: 9%
- Propose to "no filters" for DFE & make it clear
- Came out EH spec by nearly 5000 analysis case
  - Propose EH_{min} = 15mV
- Propose to adopt the following slides to change D1p0
  - Slide 8, 9, 14, & 16

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COM Settings – Whole Link

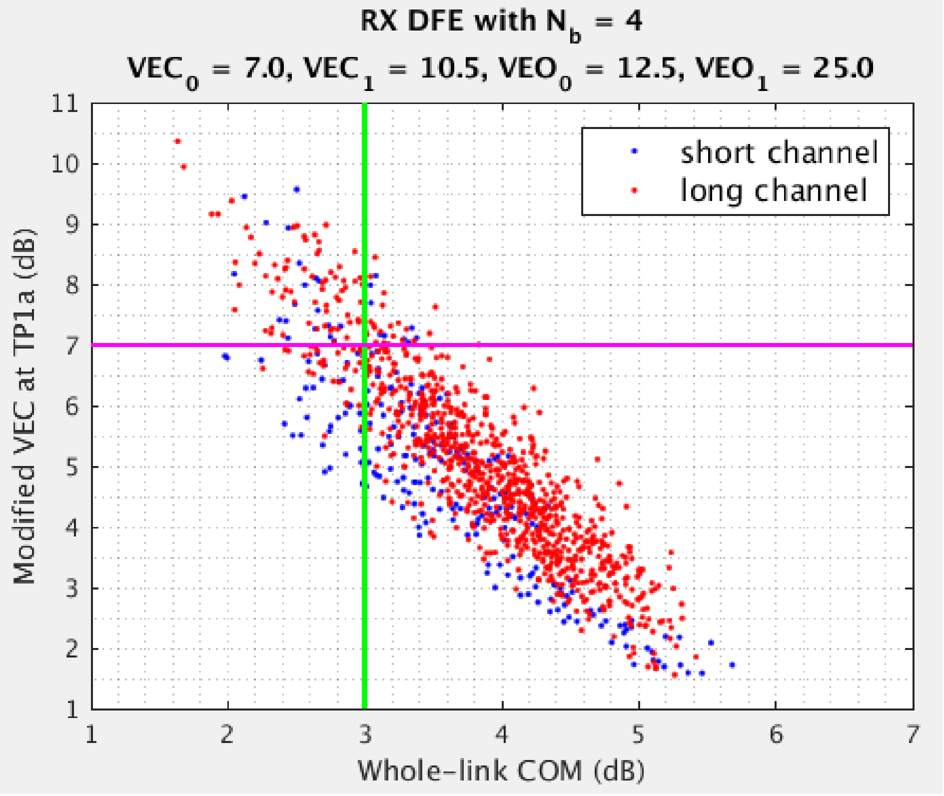
Table 93A-1 parameters				I/O control			Table 93A~~3~~ parameters		
Parameter	Setting	Units	Information	DIAGNOSTICS	1	logical	Parameter	Setting	Units
f_b	53.125	GBd		DISPLAY_WINDOW	0	logical	package_tl_gamma0_a1_a2	[0 0.001734 0.0001455]	
f_min	0.05	GHz		CSV_REPORT	1	logical	package_tl_tau	6.141E-03	ns/mm
Delta_f	0.01	GHz		RESULT_DIR	.\results\100GEL_KR_{date}\		package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
C_d	[1.2e-4 0.85e-4]	nF	[TX RX]	SAVE_FIGURES	0	logical			
L_s	[0.12, 0.12]	nH	[TX RX]	Port Order	[1 3 2 4]		Table 92~~1~~2 parameters		
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]	RUNTAG	KR_eval_		Parameter	Setting	
z_p select	[1 2]		[test cases to run]	COM_CONTRIBUTION	0	logical	board_tl_gamma0_a1_a2	[0 3.8206e-04 9.5909e-05]	
z_p (TX)	[12 16; 1.8 1.8]	mm	[test cases]	Operational			board_tl_tau	5.790E-03	ns/mm
z_p (NEXT)	[2 5; 0 0]	mm	[test cases]	COM Pass threshold	3	dB	board_Z_c	100	Ohm
z_p (FEXT)	[12 16; 1.8 1.8]	mm	[test cases]	ERL Pass threshold	12	dB	z_bp (TX)	110.3	mm
z_p (RX)	[2 5; 0 0]	mm	[test cases]	DER_0	1.00E-04		z_bp (NEXT)	110.3	mm
C_p	[0.87e-4 0.65e-4]	nF	[TX RX]	T_r	6.16E-03	ns	z_bp (FEXT)	110.3	mm
R_0	50	Ohm		FORCE_TR	1	logical	z_bp (RX)	110.3	mm
R_d	[50 50]	Ohm	[TX RX]				C_0	[0.29e-4]	nF
A_v	0.39	V		TDR and ERL options			C_1	[0.19e-4]	nF
A_fe	0.39	V		TDR	1	logical	Include PCB	0	logical
A_ne	0.578	V		ERL	1	logical	Floating Tap Control		
L	4			ERL_ONLY	0	logical	N_bg	0	0 1 2 or 3 groups
M	32			TR_TDR	0.01	ns	N_bf	0	taps per group
filter and Eq				N	600		N_f	40	UI span for floating taps
f_r	0.75	*fb		beta_x	1.7000E+09		bmaxg	0.05	max DFE value for floating taps
c(0)	0.54		min	rho_x	0.3		B_float_RSS_MAX	0.03	rss tail tap limit
c(-1)	[-0.26:0.02:0]		[min:step:max]	fixture delay time	[0 0]	[port1 port2]	N_tail_start	25	(UI) start of tail taps limit
c(-2)	[0:0.02:0.10]		[min:step:max]	TDR_W_TXPKG	0		ICN parameters		
c(-3)	[-0.04:0.02: 0]		[min:step:max]	N_bx	4	UI	f_v	0.723	*Fb
c(1)	[-0.2:0.05:0]		[min:step:max]	Receiver testing			f_f	0.723	*Fb
N_b	4	UI		RX_CALIBRATION	0	logical	f_n	0.723	*Fb
b_max(1)	0.5			Sigma BBN step	5.00E-03	V	f_2	39.844	GHz
b_max(2..N_b)	0.2			Noise, jitter			A_ft	0.600	V
g_DC	[-14:1:-3]	dB	[min:step:max]	sigma_RJ	0.01	UI	A_nt	0.600	V
f_z	12.58	GHz		A_DD	0.02	UI	TBD in D1p0	To be confirmed	Needs COM modification
f_p1	20	GHz		eta_0	8.2E-09	V^2/GHz	Consider to modify	Not check D1p0 yet	
f_p2	28	GHz		SNR_TX	33	dB			
g_DC_HP	[-3:1:0]		[min:step:max]	R_LM	0.95				
f_HP_PZ	1.328125	GHz							

COM Settings – TP1a

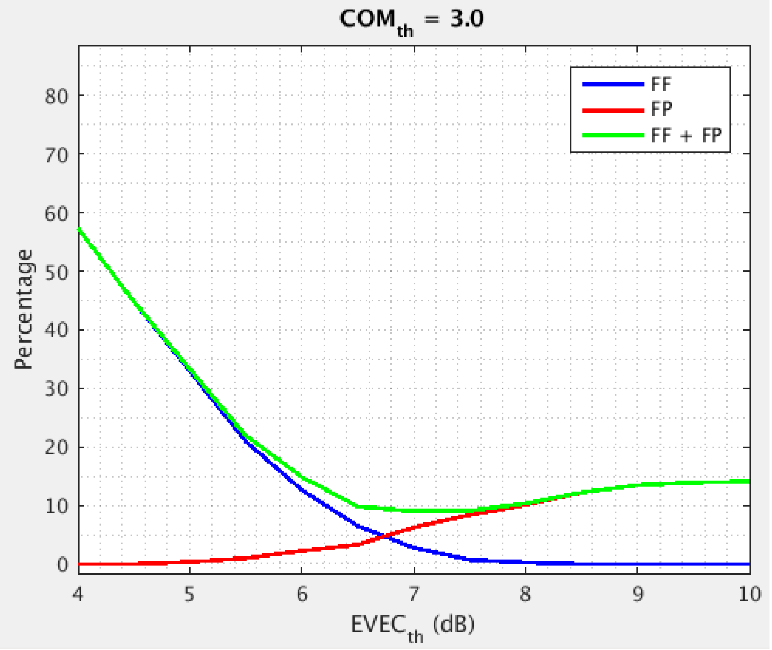
Table 93A-1 parameters				I/O control			Table 93A-3 parameters		
Parameter	Setting	Units	Information	DIAGNOSTICS	1	logical	Parameter	Setting	Units
f_b	53.125	GBd		DISPLAY_WINDOW	0	logical	package_tl_gamma0_a1_a2	[0 0.001734 0.0001455]	
f_min	0.05	GHz		CSV_REPORT	1	logical	package_tl_tau	6.141E-03	ns/mm
Delta_f	0.01	GHz		RESULT_DIR	.\results\100GEL_KR_{date}\		package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
C_d	[1.2e-4 0]	nF	[TX RX]	SAVE_FIGURES	0	logical			
L_s	[0.12, 0]	nH	[TX RX]	Port Order	[1 3 2 4]		Table 92-12 parameters		
C_b	[0.3e-4 0]	nF	[TX RX]	RUNTAG	KR_eval_		Parameter	Setting	
z_p select	[1 2]		[test cases to run]	COM_CONTRIBUTION	0	logical	board_tl_gamma0_a1_a2	[0 3.8206e-04 9.5909e-05]	
z_p (TX)	[12 16; 1.8 1.8]	mm	[test cases]	Operational			board_tl_tau	5.790E-03	ns/mm
z_p (NEXT)	[0 0; 0 0]	mm	[test cases]	COM Pass threshold	3	dB	board_Z_c	100	Ohm
z_p (FEXT)	[12 16; 1.8 1.8]	mm	[test cases]	ERL Pass threshold	12	dB	z_bp (TX)	110.3	mm
z_p (RX)	[0 0; 0 0]	mm	[test cases]	DER_0	1.00E-04		z_bp (NEXT)	110.3	mm
C_p	[0.87e-4 0]	nF	[TX RX]	T_r	6.16E-03	ns	z_bp (FEXT)	110.3	mm
R_0	50	Ohm		FORCE_TR	1	logical	z_bp (RX)	110.3	mm
R_d	[50 50]	Ohm	[TX RX]				C_0	[0.29e-4]	nF
A_v	0.39	V		TDR and ERL options			C_1	[0.19e-4]	nF
A_fe	0.39	V		TDR	1	logical	Include PCB	0	logical
A_ne	0.578	V		ERL	1	logical	Floating Tap Control		
L	4			ERL_ONLY	0	logical	N_bg	0	0 1 2 or 3 groups
M	32			TR_TDR	0.01	ns	N_bf	0	taps per group
filter and Eq				N	600		N_f	40	UI span for floating taps
f_r	0.75	*fb		beta_x	1.7000E+09		bmaxg	0.05	max DFE value for floating taps
c(0)	0.54		min	rho_x	0.3		B_float_RSS_MAX	0.03	rss tail tap limit
c(-1)	[-0.26:0.02:0]		[min:step:max]	fixture delay time	[0 0]	[port1 port2]	N_tail_start	25	(UI) start of tail taps limit
c(-2)	[0:0.02:0.10]		[min:step:max]	TDR_W_TXPKG	0		ICN parameters		
c(-3)	[-0.04:0.02: 0]		[min:step:max]	N_bx	4	UI	f_v	0.723	*Fb
c(1)	[-0.2:0.05:0]		[min:step:max]	Receiver testing			f_f	0.723	*Fb
N_b	4	UI		RX_CALIBRATION	0	logical	f_n	0.723	*Fb
b_max(1)	0.5			Sigma BBN step	5.00E-03	V	f_2	39.844	GHz
b_max(2..N_b)	0.2			Noise, jitter			A_ft	0.600	V
g_DC	[-14:1:-3]	dB	[min:step:max]	sigma_RJ	0.01	UI	A_nt	0.600	V
f_z	12.58	GHz		A_DD	0.02	UI	TBD in D1p0	To be confirmed	Needs COM modification
f_p1	20	GHz		eta_0	8.2E-09	V^2/GHz	Consider to modify	Not check D1p0 yet	
f_p2	28	GHz		SNR_TX	33	dB			
g_DC_HP	[-3:1:0]		[min:step:max]	R_LM	0.95				
f_HP_PZ	1.328125	GHz							

EVEC Mask Threshold

1. Fix TX EQ by TP1a
2. N_b=4
3. **Set Eta_0 = 3.33e-8 (SysNs + 1.0mV RxNs)**

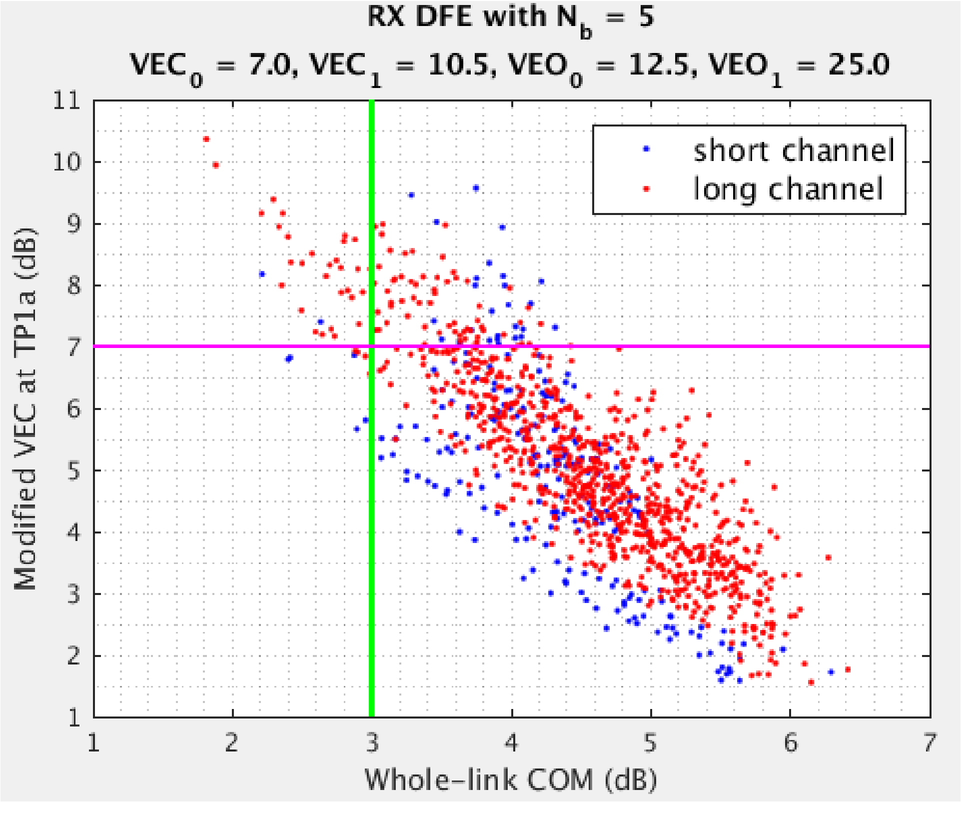


- EVEC Threshold = 7
- % of false fail = 2.8%
- % of false pass = 6.2%
- % of false cases = 9.0%
- Correlation coefficient = -0.89

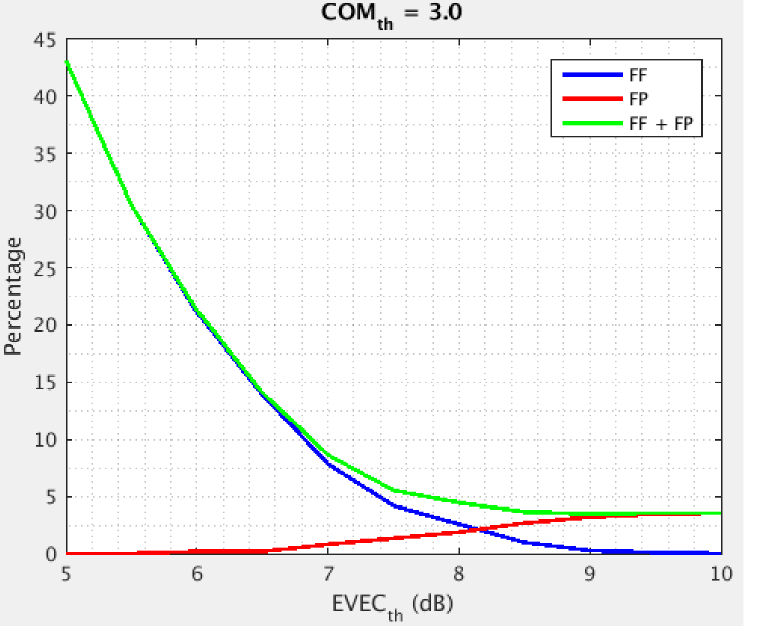


EVEC Mask Threshold

1. Fix TX EQ by TP1a
2. **N_b=5**
3. Set Eta_0 = 8.2e-9 (SysNs + 0.0mV RxNs)

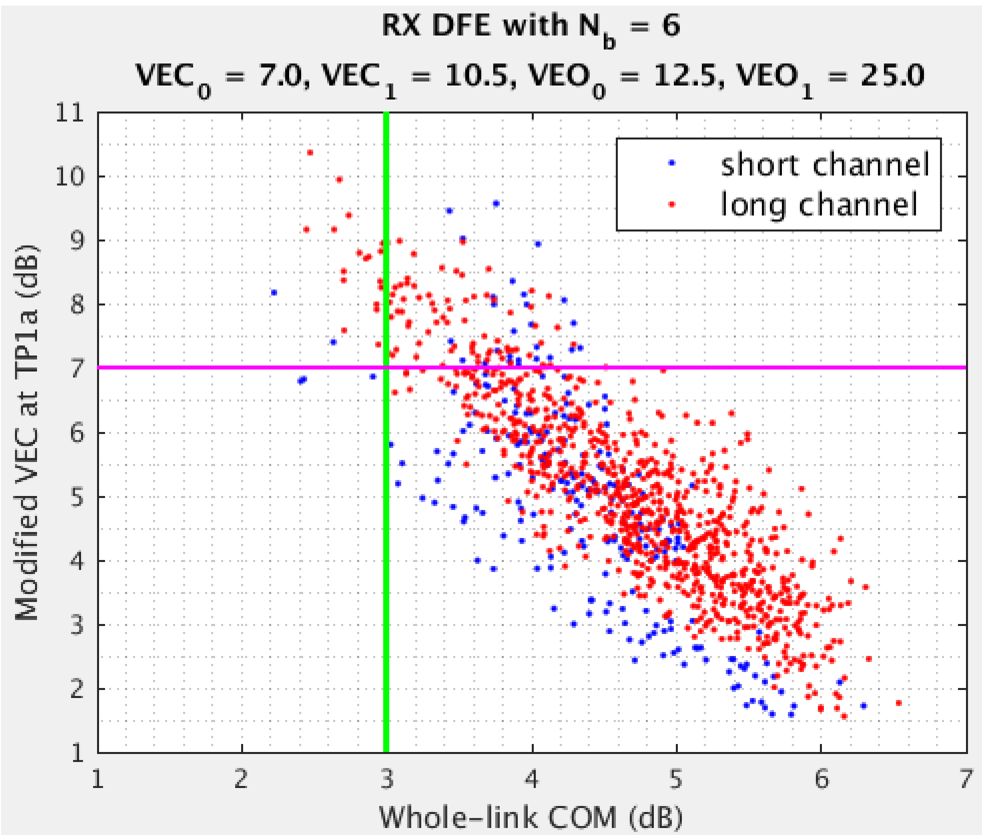


- EVEC Threshold = 7
- % of false fail = 7.8%
- % of false pass = 0.8%
- % of false cases = 8.6%
- Correlation coefficient = -0.827

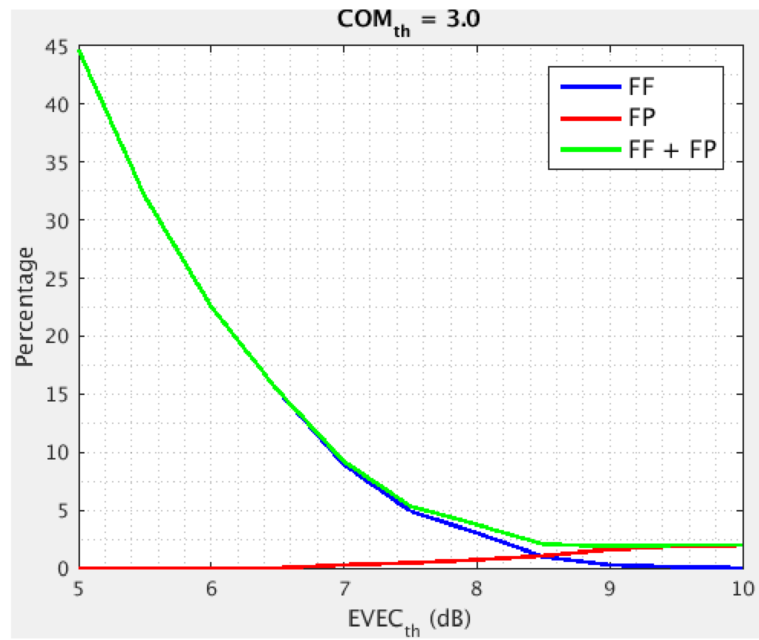


EVEC Mask Threshold

1. Fix TX EQ by TP1a
2. **N_b=6**
3. Set Eta_0 = 8.2e-9 (SysNs + 0.0mV RxNs)

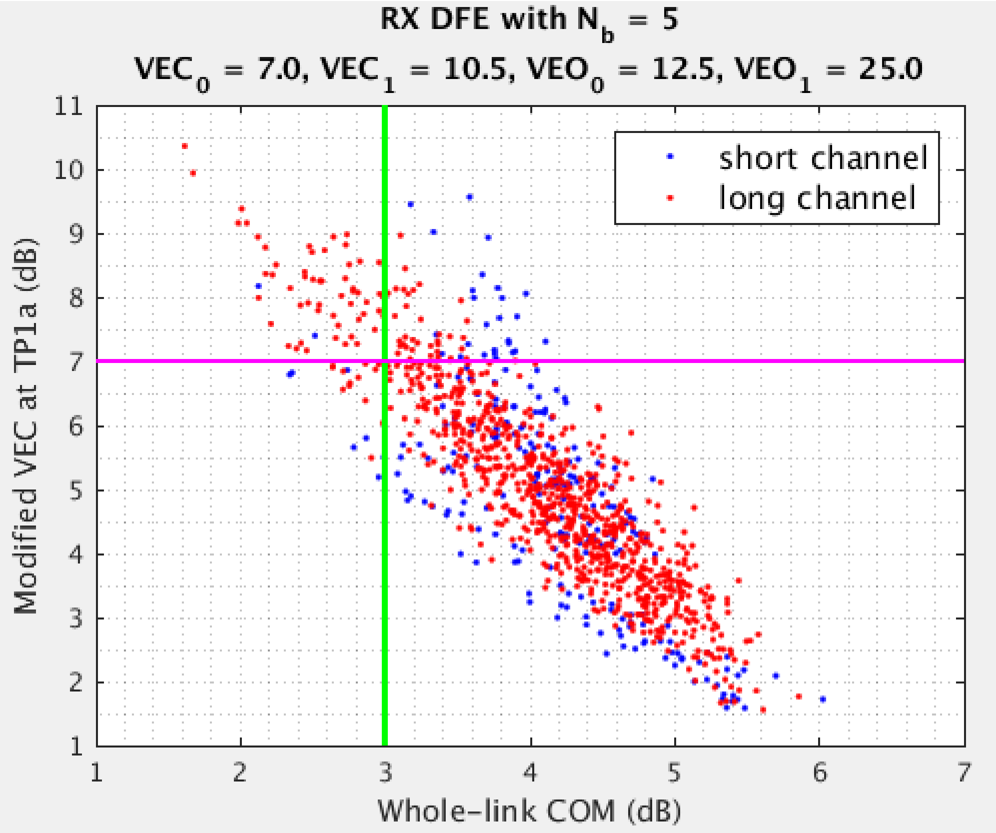


- EVEC Threshold = 7
- % of false fail = 8.9%
- % of false pass = 2.7%
- % of false cases = 9.2%
- Correlation coefficient = -0.826

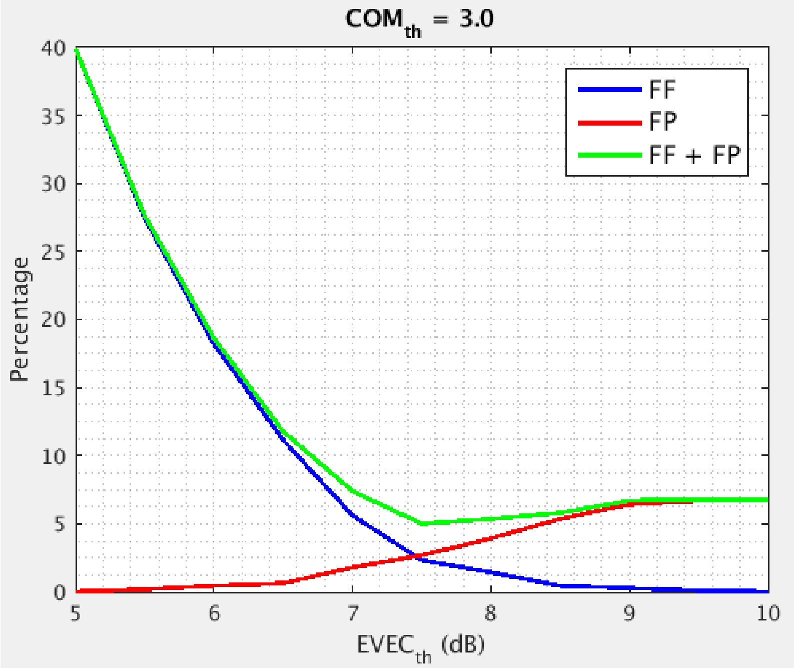


EVEC Mask Threshold

1. Fix TX EQ by TP1a
2. **N_b=5**
3. **Set Eta_0 = 3.33e-8 (SysNs + 1.0mV RxNs)**

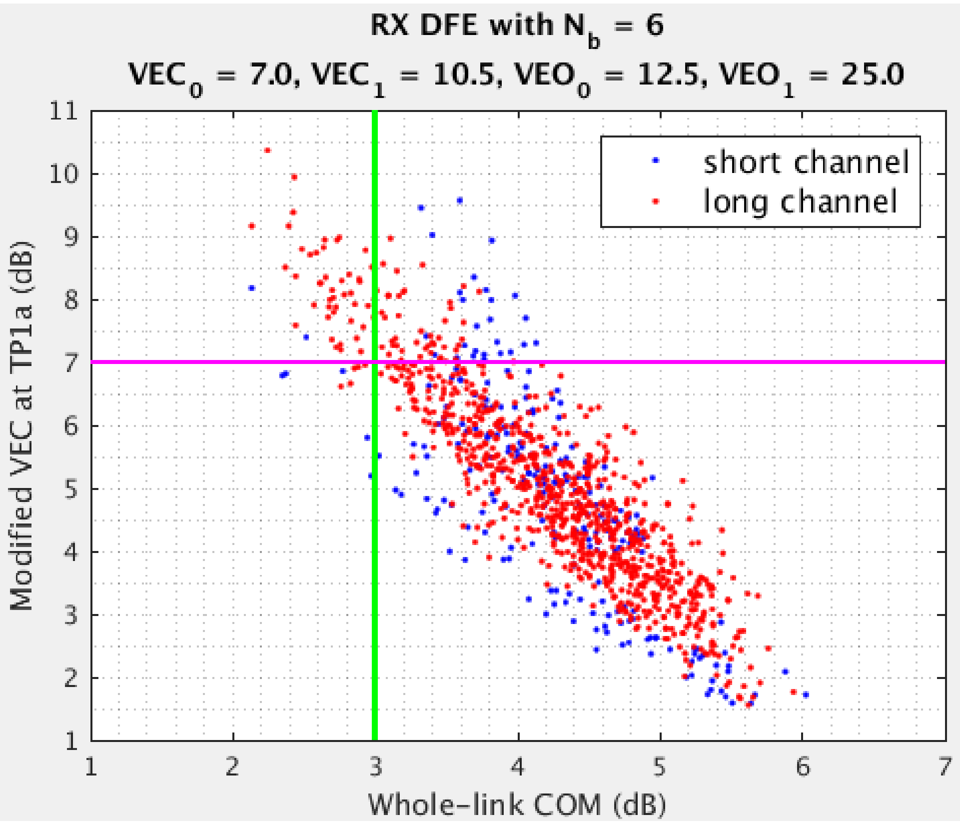


- EVEC Threshold = 7
- % of false fail = 5.6%
- % of false pass = 1.8%
- % of false cases = 7.4%
- Correlation coefficient = -0.871



EVEC Mask Threshold

1. Fix TX EQ by TP1a
2. **N_b=6**
3. **Set Eta_0 = 3.33e-8 (SysNs + 1.0mV RxNs)**



- EVEC Threshold = 7
- % of false fail = 6.4%
- % of false pass = 0.9%
- % of false cases = 7.3%
- Correlation coefficient = -0.872