Rx Filter Redux

The presentation explores replacing the COM Rx filter with a raised cosine filter. Some benefits may be improvements in COM and reduced measurement bandwidth requirements.

Richard Mellitz, Samtec

Acknowledgement: Adam Gregory, Samtec

06-21-2022

Supporters

❑ John Calvin, Keysight

Agenda

❑ Introduction and Background

❑ 200 Gbps KR

❑ 200 Gbps C2M

❑ Summary

Higher Bandwidth Concerns

❑ Measurements
  - How Much Bandwidth is Enough (HMBE) is a re-occurring theme

❑ High frequency ISI and crosstalk
  - Small physical feature imperfections result in high frequency (> 60 GHz) ISI and crosstalk
  - … even after filtering with a Butterworth filter

❑ Consider the normalized spectral density of noise in the context of filtering
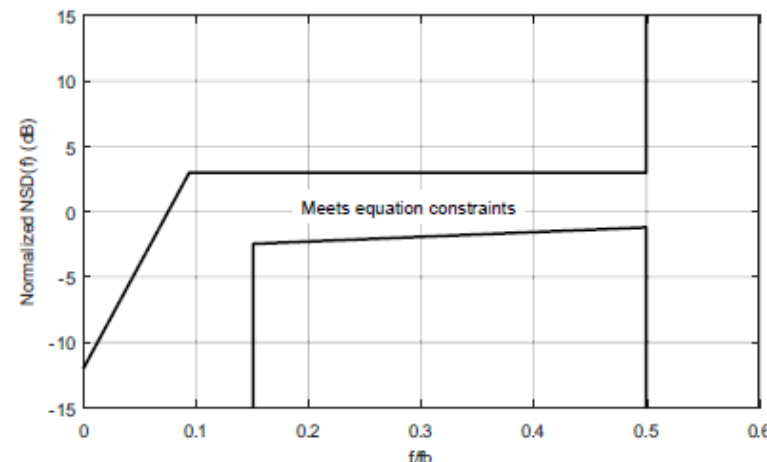 - Example Clause 162.9.4.3.4
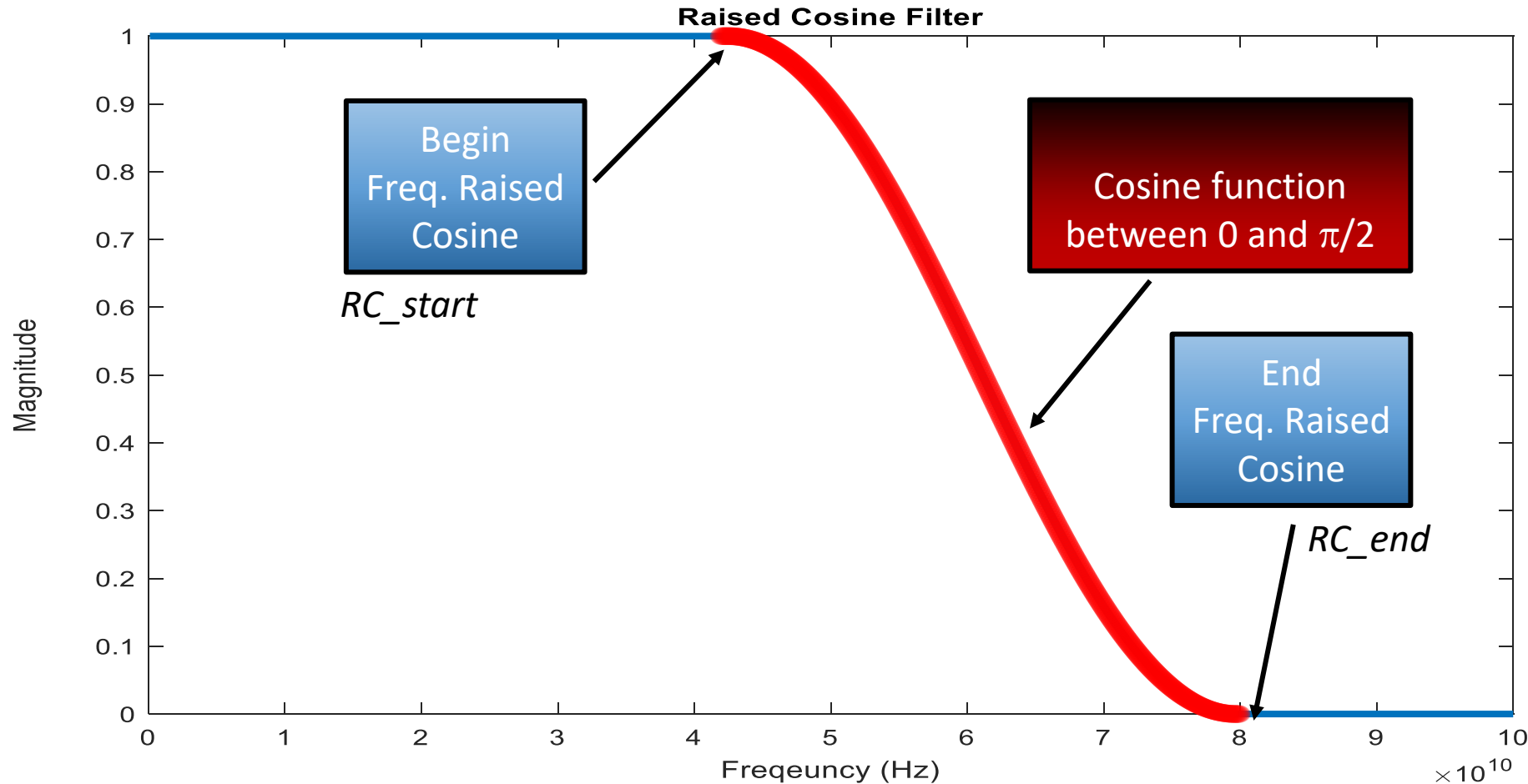

Figure 162–6—NSD(f) constraints
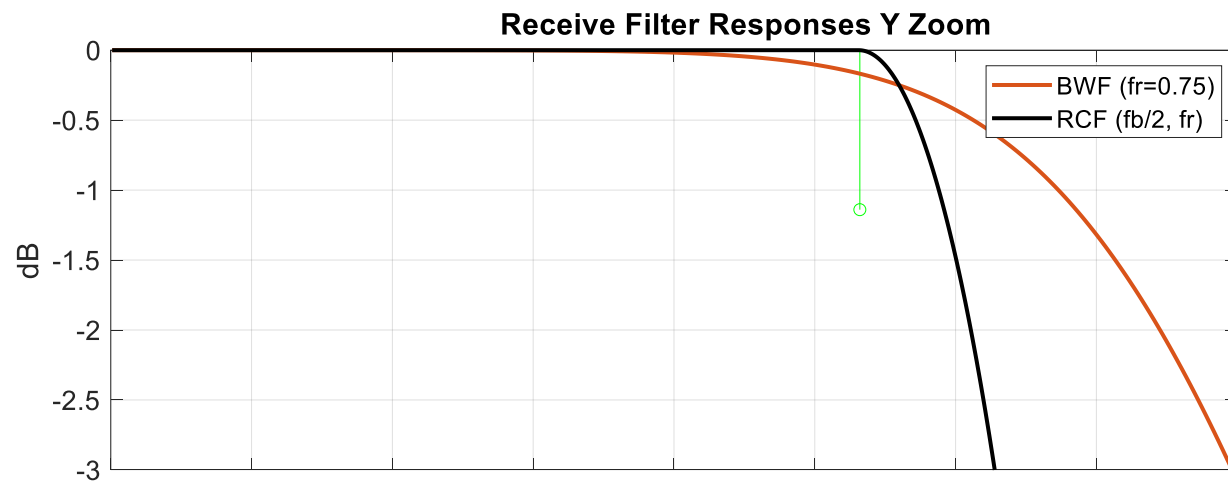
Experiment

❑ Compare COM using KR/CR and C2M channel examples using Butterworth filters (BWF) and raised cosine filters (RCF).

- RC does not denote resistor-capacitor in this presentation.
- The RC filter is like the Turkey filter used for ERL computation

❑ The COM spreadsheets are not proposals per se

- For C2M, aggressive and less aggressive COM configurations are considered.

Raised Cosine (RC) Low Pass Filter

Raised Cosine Filter

Begin
Freq. Raised
Cosine

RC_start

Cosine function
between 0 and $\pi/2$

End
Freq. Raised
Cosine

RC_end

Magnitude

Freqeuncy (Hz)

$\times 10^{10}$

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IL Comparison Between BWF and RCF

Receive Filter Responses

Receive Filter Responses Y Zoom

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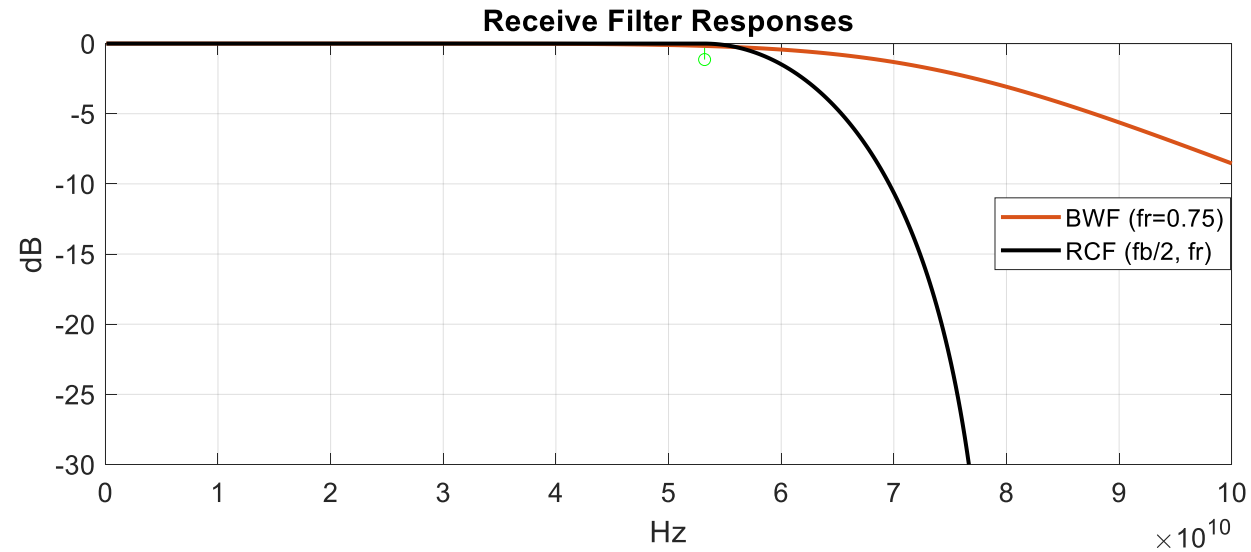
COM 3.8 Syntax Which Invokes the RC filter

Raised_Cosine	0	logical	1 is an enable
Butterworth	1	logical	1 is an enable
RC_end	79.7E+9	Hz	End of Tukey range
RC_start	42.5E+9	Hz	Begin Tukey range

❑ 3 keywords added for the receive filter

❑ "Butterworth" was already implemented, and its default is 1

❑ "Raised_Cosine" is either 0 or 1 with a default as 0 which is not to enable

❑ RC_start and RC_end are illustrated on the prior slide. If Raised_Cosine is 1, RC_start and RC_end are used. The default for RC_start is $f_b/2$ and RC_end is f_b*f_r if not specified.

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Review: Reference Nomenclature Review

$H_{21}^{k}(f)$, Used to compute "*VIP_to_VIM_IL_dB_at_Fnq*" (eq 93A-18)

IL with pkgs

COM ref Package

Back Plane Channel

VIP

Host channel w/ HCB

Host channel w/ HCB

VMP

TP0

TP5

Voltage Injection Point

Voltage Measurement Point

Cable Channel

Rd [s die term]

TP1 TP2 TP3 TP4

[s die term] Rd

[s pkg]

[s pkg]

bump

Mated Connector

AC-coupling

ball

Device Package

Package-to-board-interface

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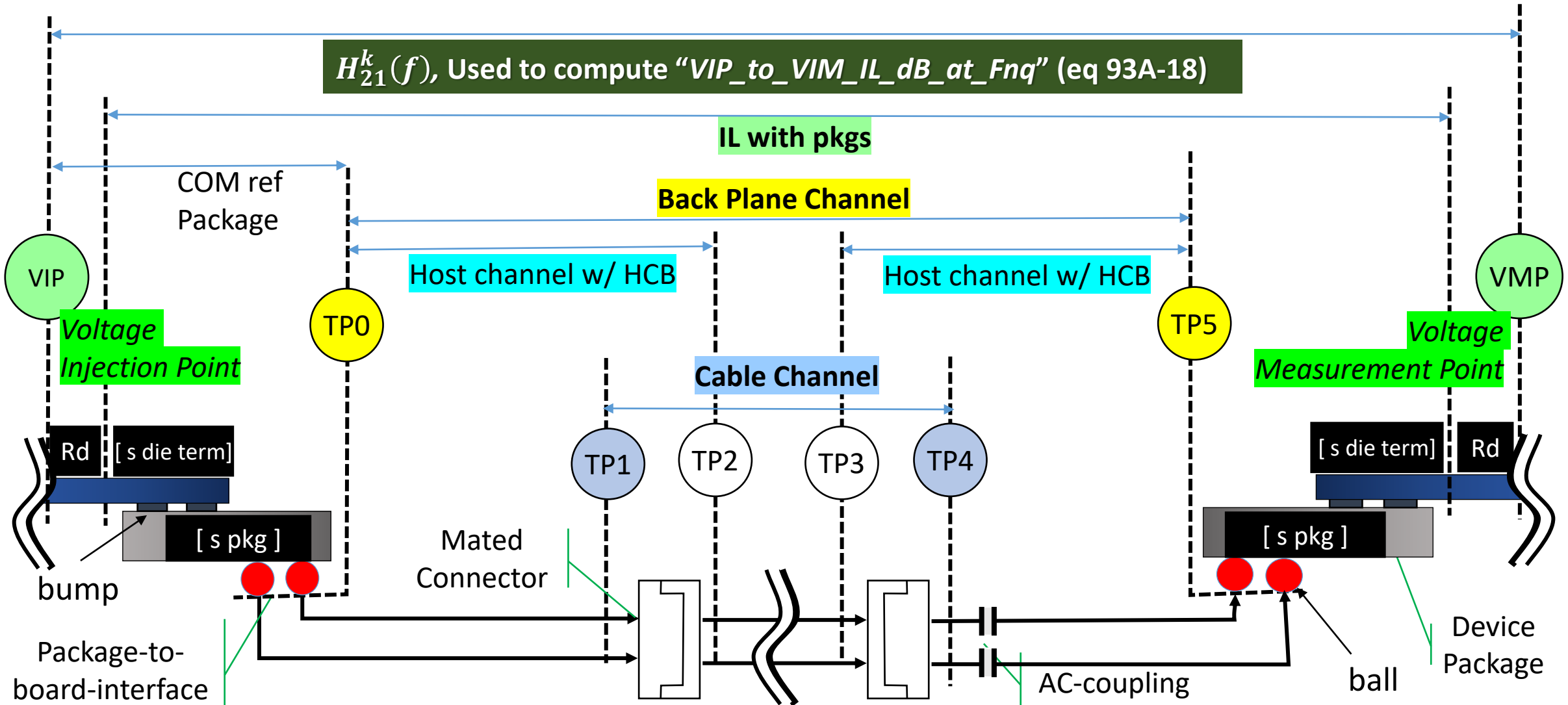
COM 3.8 Frequency Domain Graph

- New addition is the VTF curve (black)
  - VTF is equation 93A-19 but not including Tx or Rx equalization
  - $VFT(f) = H_t(f)H_{21}^0(f)H_r(f)$
- Purpose: Assist in channel and specification evaluation

C2M13 akinwale_3df_01_20220502--C2M_PCB_13dB Losses

- IL w/o pkg or board
- IL with pkgs
- IL fit
- RL11
- RL22
- VTF (no Tx/Rx eq)

C2M6 akinwale_3df_01_2__502--C2M_PCB_13dB Losses

- IL w/o pkg or board
- IL with pkgs
- IL fit
- RL11
- RL22
- VTF (no Tx/Rx eq)

COM 3.8 Figure 301 example

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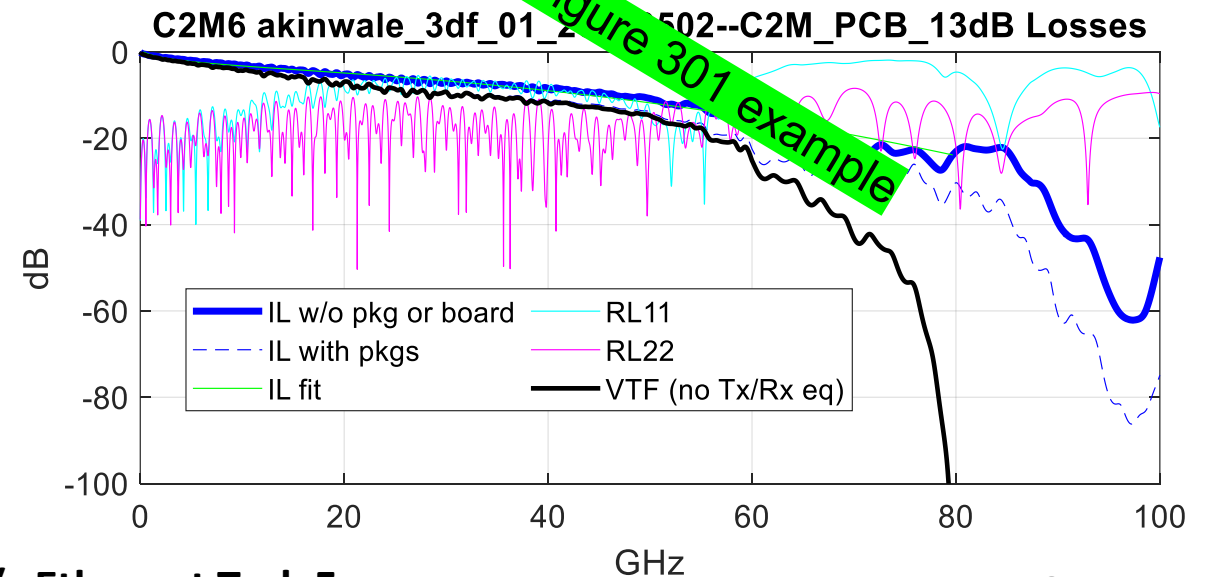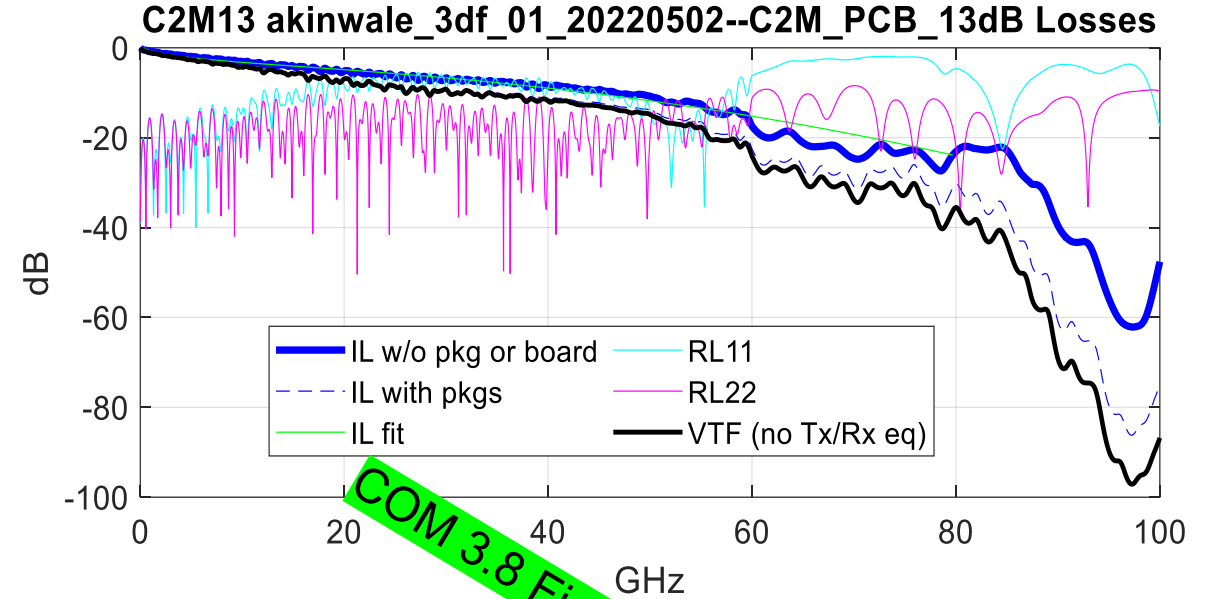
200G KR COM similar to li_3df_02_220322

Table 93A-1 parameters			2
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	[.13 .15 .14; .13 .15 .14]	nH	[TX RX]
C_b	[.3e-4 .3e-4]	nF	[TX RX]
z_p select	[2]		[test cases to run]
z_p (TX)	[15 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[15 29; 1.8 1.8]	mm	[test cases]
z_p (FEXT)	[15 31; 1.8 1.8]	mm	[test cases]
z_p (RX)	[15 29; 1.8 1.8]	mm	[test cases]
C_p	[0.5e-4 0.5e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.408	V	
A_fe	0.408	V	
A_ne	0.608	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.6	min	
c(-1)	[-0.34:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.2]		[min:step:max]
c(-3)	[-0.1:0.02: 0]		[min:step:max]
c(1)	[-0.1:0.02:0]		[min:step:max]
N_b	24	UI	
b_max(1)	0.85		
b_max(2..N_b)	0.3		
b_min(1)	-0.85		
b_min(2..N_b)	-0.3		
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	42.5	GHz	
f_p1	42.5	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-8:1:0]		[min:step:max]
f_HP_PZ	1.0625	GHz	
Raised_Cosine	1	logical	1 is an enabel
Butterworth	0	logical	1 is an enabel
RC_end	79.7E+9	Hz	End of Tukey range
RC_start	42.5E+9	Hz	Begin Tukey range

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\200G_kR_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	R200_eval	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	10.5	dB
DER_0	1.00E-04	
T_r	2.50E-03	ns
FORCE_TR	1	logical
Local Search	2	
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	6000	
beta_x	0	
rho_x	0.618	
fixture delay time	[0 0]	[port1 port2]
TDR_W_TXPKG	0	
N_bx	36	UI
Z_t	50	ohm
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	4.10E-09	V^2/GHz
SNR_TX	33	dB
R_LM	0.95	

Table 93A–3 parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 8.4e-4 1.1e-4]	2.75 dB /in at 56G
package_tl_tau	6.14E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
Table 92–12 parameters		
Parameter	Setting	
board_tl_gamma0_a1_a2	[0 6.44084e-4 3.6036e-05]	1.5 dbpi at 56G
board_tl_tau	0.00579	ns/mm
board_Z_c	100	Ohm
z_bp (TX)	40	mm
z_bp (NEXT)	40	mm
z_bp (FEXT)	40	mm
z_bp (RX)	40	mm
C_0	[0.2e-4]	nF
C_1	[0.1e-4]	nF
Include PCB	0	**logical**
Floating Tap Control		
N_bg	3	0 1 2 or 3 groups
N_bf	6	taps per group
N_f	60	UI span for floating taps
bmaxg	0.2	max DFE value for floating taps
B_float_RSS_MAX	0.2	rss tail tap limit
N_tail_start	25	(UI) start of tail taps limit
ICN parameters		
f_v	0.890	*Fb
f_f	0.890	*Fb
f_n	0.890	*Fb
f_2	79.688	GHz
A_ft	0.600	V
A_nt	**0.600**	V

This was used for comparative analysis and is not a proposal per se.

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KR analysis Used Available Files

❑ Strategy: consider relative comparisons

❑ Start with 9 channels from mellitz_3df_elec_01_220502

Proto-type Grade KR channels

End of line test point

1.0 mm "SMA"

2" 5" 8"

TP0

1.85 mm "SMA"

Layer 28 via with break out

'''For_3df_noxtk--Via_28mm__12dB_1000mm_NVAC_thru'''
'''For_3df_noxtk--Via_28mm__12dB_1500mm_NVAC_thru'''
'''For_3df_noxtk--Via_28mm__12dB_500mm_NVAC_thru'''
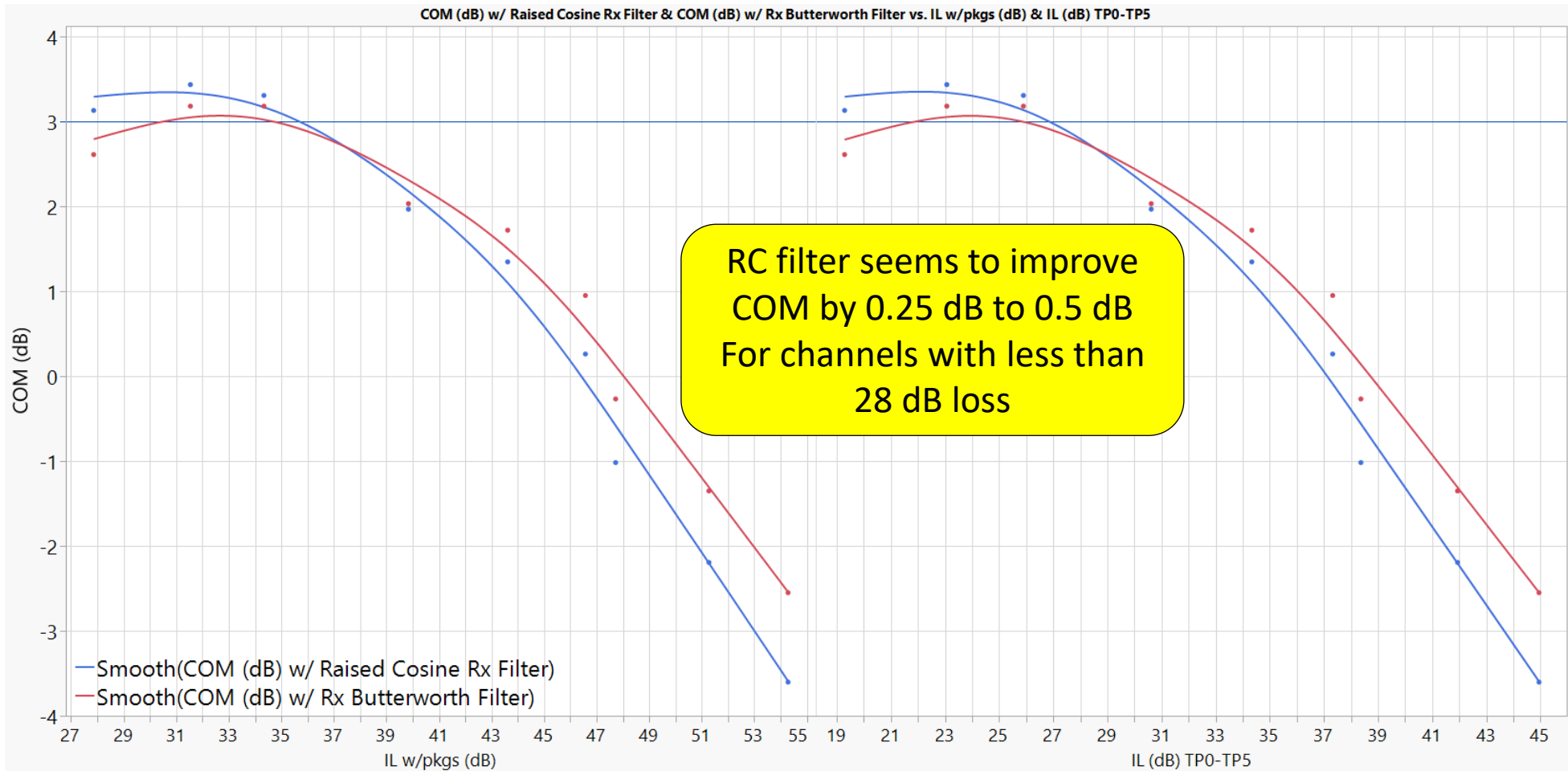'''For_3df_noxtk--Via_28mm__3.2dB_1000mm_NVAC_thru'''
'''For_3df_noxtk--Via_28mm__3.2dB_1500mm_NVAC_thru'''
'''For_3df_noxtk--Via_28mm__3.2dB_500mm_NVAC_thru'''
'''For_3df_noxtk--Via_28mm__8dB_1000mm_NVAC_thru'''
'''For_3df_noxtk--Via_28mm__8dB_1500mm_NVAC_thru'''
'''For_3df_noxtk--Via_28mm__8dB_500mm_NVAC_thru'''

0.5 1.0 1.5 m cable

TP5

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COM Comparison Between RCF and BWF

COM (dB) w/ Raised Cosine Rx Filter & COM (dB) w/ Rx Butterworth Filter vs. IL w/pkgs (dB) & IL (dB) TP0-TP5

RC filter seems to improve COM by 0.25 dB to 0.5 dB For channels with less than 28 dB loss

Smooth(COM (dB) w/ Raised Cosine Rx Filter)
Smooth(COM (dB) w/ Rx Butterworth Filter)

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C2M files

❑ rabinovich_3df_022422: KEY_C2M_200G_120G_2p5HCB_022422_Thru.s4p

❑ rabinovich_3df_022422: KEY_C2M_200G_120G_4p0HCB_022422_Thru.s4p

❑ akinwale_3df_01_20220502: C2M_PCB_10dB.s4p

❑ akinwale_3df_01_20220502: C2M_PCB_11dB.s4p

❑ akinwale_3df_01_20220502: C2M_PCB_12dB.s4p

❑ akinwale_3df_01_20220502: C2M_PCB_13dB.s4p

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KR vs C2M experiment differences

❑ Raised cosine bandwidth
- KR: RC_Start is defaulted to $f_b/2$
- C2M: RC_Start is defaulted to $f_b/2.5$
- RC_end is defaulted to f_b*f_r

❑ C2M Comparison uses VEC and EH between RCF (raised cosine filter) and BWF (Butterworth filter), not COM

❑ 2 C2M Configuration templates
- Aggressive
  - 3 groups of 6 floating taps
  - Higher SNR_Tx: 34 dB
  - Higher DER0: 5e-5
- Less Aggressive
  - no floating taps
  - lower SNR_Tx: 32.5 dB
  - lower DER0 1e-5

Less Aggressive C2M Configuration Template

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 0 0]	nF	[TX RX]
L_s	[.12 .15 .14; 0 0 0]	nH	[TX RX]
C_b	[.3e-4 0]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[15 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[0 0; 0 0]	mm	[test cases]
z_p (FEXT)	[15 31; 1.8 1.8]	mm	[test cases]
z_p (RX)	[0 0; 0 0]	mm	[test cases]
C_p	[0.4e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.408	V	vp/vf=
A_fe	0.408	V	vp/vf=
A_ne	0.608	V	
L	4		
M	32		

filter and Eq

Parameter	Setting	Units	Information
f_r	0.75	*fb	
c(0)	0.65		min
c(-1)	[-0.2:0.02:0]		[min:step:max]
c(-2)	[0:.02:0.1]		[min:step:max]
c(-3)	[-0.1:.02:0]		[min:step:max]
c(1)	[-0.2:0.02:0]		[min:step:max]
N_b	8	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	0.15		As/dfe2..N_b
b_min(1)	0		As/dffe1
b_min(2..N_b)	-0.15		As/dfe2..N_b
g_DC	[-13:1:0]	dB	[min:step:max]
f_z	42.5	GHz	
f_p1	42.5	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	1.0625	GHz	

Receiver testing

Parameter	Setting	Units	Information
RX_CALIBRATION	0	logical	
Sigma BBN step	5.00E-03	V	
Raised_Cosine	0	logical	1 is an enable
Butterworth	1	logical	1 is an enable

I/O control

Parameter	Setting	Units
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\c2m106_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2M TP1a	
COM_CONTRIBUTION	0	logical

Operational

Parameter	Setting	Units
ERL Pass threshold	10	dB
VEC Pass threshold	12.5	db
DER_0	1.00E-05	
T_r	2.35E-03	ns
FORCE_TR	1	logical
Min_VEO_Test	1	mV
PHY_type	C2M	
EH_min	10	Value
EH_max	1000	Value
T_O	50	mUI
samples_for_C2M	100	samples/UI
Dynamic TXFFE	1	
FloatingDFE_Development	1	
EW	1	

TDR and ERL options

Parameter	Setting	Units
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	6000	
TDR_Butterworth	1	logical
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	
N_bx	8	UI
fixture delay time	[0 0.2e-9]	
Tukey_Window	1	

Noise, jitter

Parameter	Setting	Units
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	2.05E-08	V^2/GHz
SNR_TX	32.5	dB
R_LM	0.95	

Table 93A–3 parameters

Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 8.4e-4 1.1e-4]	2.75 dB /in at 56G
package_tl_tau	6.14E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
board_tl_gamma0_a1_a2	[0 6.44084e-4 3.6036e-05]	1.5 db/in @ 56G
board_tl_tau	5.790E-03	ns/mm
board_Z_c	100	Ohm
z_bp (TX)	50	mm
z_bp (NEXT)	0	mm
z_bp (FEXT)	50	mm
z_bp (RX)	0	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)

Parameter	Setting	
Histogram_Window_Weight	gaussian	
QL	2.5	

ICN parameters

Parameter	Setting	Units
f_v	0.278	Fb
f_f	0.278	Fb
f_n	0.278	Fb
f_2	79.688	GHz
A_ft	0.450	V
A_nt	0.450	V

Floating Tap Control

Parameter	Setting	
N_bg	0	0 1 2 or 3 groups
N_bf	6	taps per group
N_f	64	span for floating tap
bmaxg	0.05	DFE value for floating
B_float_RSS_MAX	0.02	rss tail tap limit
N_tail_start	9	) start of tail taps lin

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Aggressive C2M Configuration Template

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 0 0]	nF	[TX RX]
L_s	[.12 .15 .14; 0 0 0]	nH	[TX RX]
C_b	[.3e-4 0]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[15 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[0 0; 0 0]	mm	[test cases]
z_p (FEXT)	[15 31; 1.8 1.8]	mm	[test cases]
z_p (RX)	[0 0; 0 0]	mm	[test cases]
C_p	[0.4e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.408	V	vp/vf=
A_fe	0.408	V	vp/vf=
A_ne	0.608	V	
L	4		
M	32		

filter and Eq

Parameter	Setting	Units	Information
f_r	0.75	*fb	
c(0)	0.65	min	
c(-1)	[-0.2:0.02:0]		[min:step:max]
c(-2)	[0:.02:0.1]		[min:step:max]
c(-3)	[-0.1:.02:0]		[min:step:max]
c(1)	[-0.2:0.02:0]		[min:step:max]
N_b	8	UI	
b_max(1)	0.85		As/dffe1
b_max(2..N_b)	0.15		As/dfe2..N_b
b_min(1)	0		As/dffe1
b_min(2..N_b)	-0.15		As/dfe2..N_b
g_DC	[-13:1:0]	dB	[min:step:max]
f_z	42.5	GHz	
f_p1	42.5	GHz	
f_p2	106.25	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	1.0625	GHz	

Receiver testing

Parameter	Setting	Units	Information
RX_CALIBRATION	0	logical	
Sigma BBN step	5.00E-03	V	
Raised_Cosine	0	logical	1 is an enable
Butterworth	1	logical	1 is an enable

I/O control

DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\c2m106_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2M TP1a	
COM_CONTRIBUTION	0	logical

Operational

ERL Pass threshold	10	dB
VEC Pass threshold	12.5	db
DER_0	5.00E-05	
T_r	2.35E-03	ns
FORCE_TR	1	logical
Min_VEO_Test	1	mV
PHY_type	C2M	
EH_min	10	Value
EH_max	1000	Value
T_O	50	mUI
samples_for_C2M	100	samples/UI
Dynamic TXFFE	1	
FloatingDFE_Development	1	
EW	1	

TDR and ERL options

TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	6000	
TDR_Butterworth	1	logical
beta_x	0	
rho_x	0.618	
TDR_W_TXPKG	0	
N_bx	8	UI
fixture delay time	[0 0.2e-9]	
Tukey_Window	1	

Noise, jitter

sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	2.05E-09	V^2/GHz
SNR_TX	34	dB
R_LM	0.95	

Table 93A-3 parameters

Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 8.4e-4 1.1e-4]	2.75 dB /in at 56G
package_tl_tau	6.14E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Parameter	Setting	
board_tl_gamma0_a1_a2	[0 6.44084e-4 3.6036e-05]	1.5 db/in @ 56G
board_tl_tau	5.790E-03	ns/mm
board_Z_c	100	Ohm
z_bp (TX)	125	mm
z_bp (NEXT)	0	mm
z_bp (FEXT)	125	mm
z_bp (RX)	0	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
QL	2.5

ICN parameters

f_v	0.278	Fb
f_f	0.278	Fb
f_n	0.278	Fb
f_2	79.688	GHz
A_ft	0.450	V
A_nt	0.450	V

Floating Tap Control

N_bg	6	0 1 2 or 3 groups
N_bf	3	taps per group
N_f	64	UI span for floating taps
bmaxg	0.2	max DFE value for floating
B_float_RSS_MAX	0.1	rss tail tap limit
N_tail_start	9	(UI) start of tail taps limit

EH improves using RCF
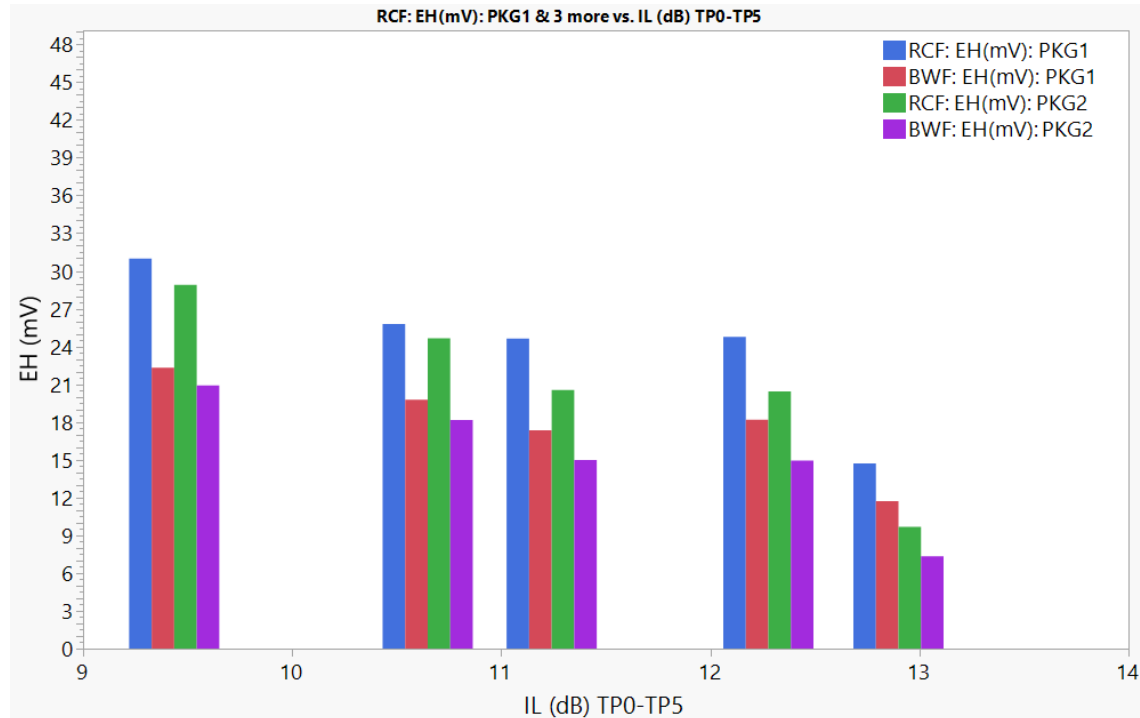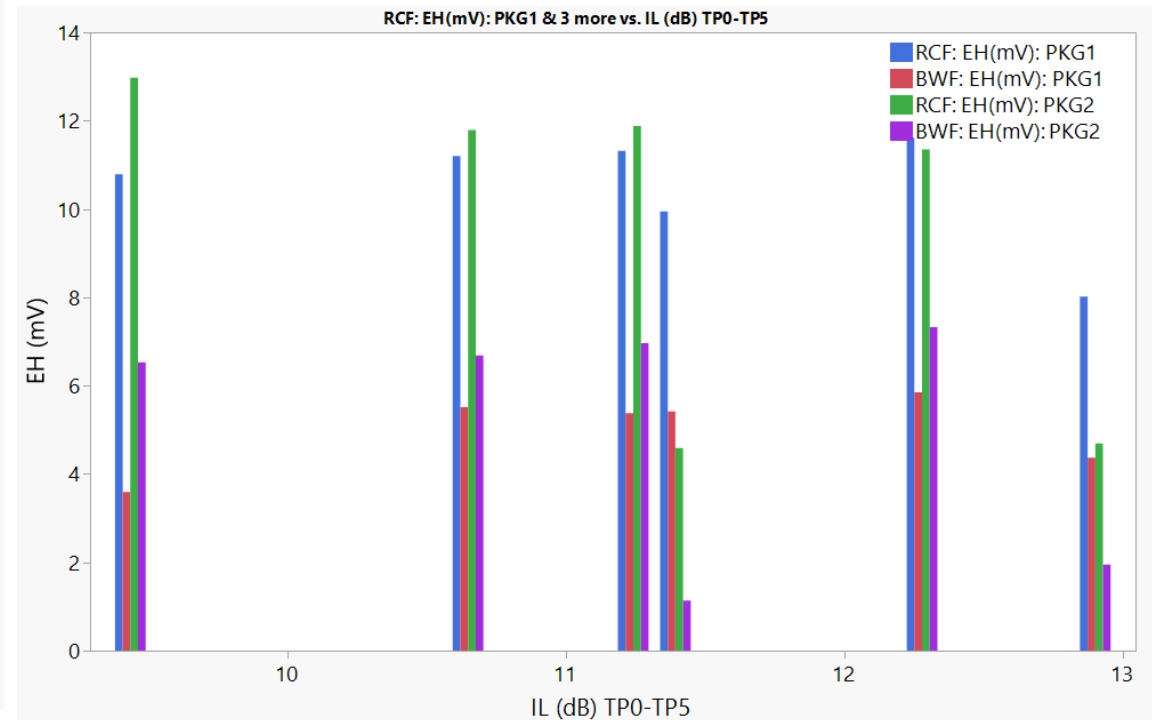
Aggressive C2M Configuration

Less Aggressive C2M Configuration

IEEE P802.3df 200 Gb/s, 400 Gb/s, 800 Gb/s, and 1.6 Tb/s Ethernet Task Force

VEC improves using RCF

Aggressive C2M Configuration

Less Aggressive C2M Configuration

IEEE P802.3df 200 Gb/s, 400 Gb/s, 800 Gb/s, and 1.6 Tb/s Ethernet Task Force

One more experiment

Less Aggressive C2M Configuration

IEEE P802.3df 200 Gb/s, 400 Gb/s, 800 Gb/s, and 1.6 Tb/s Ethernet Task Force

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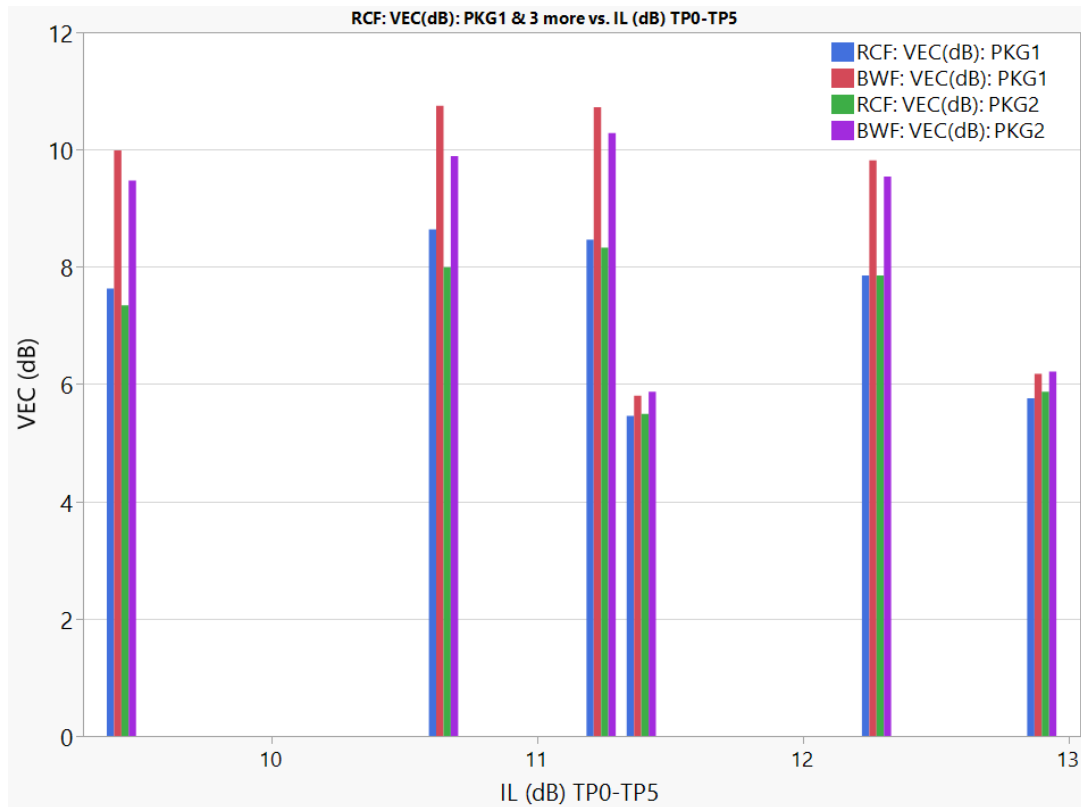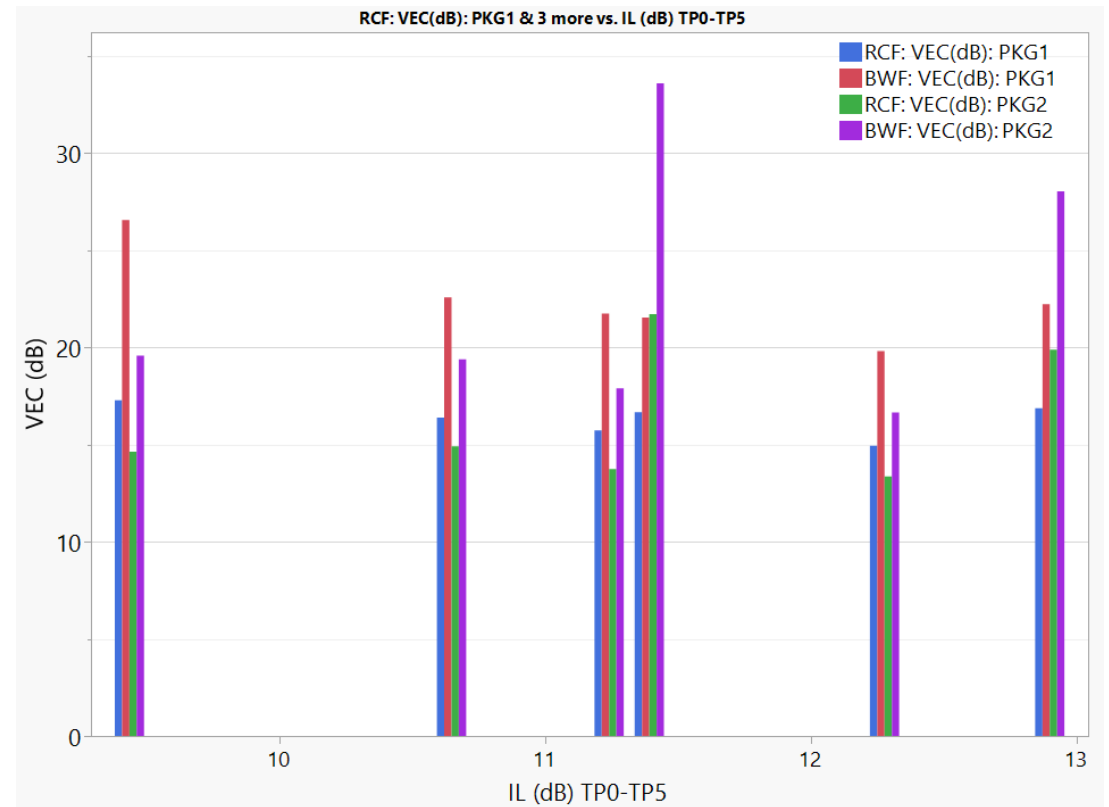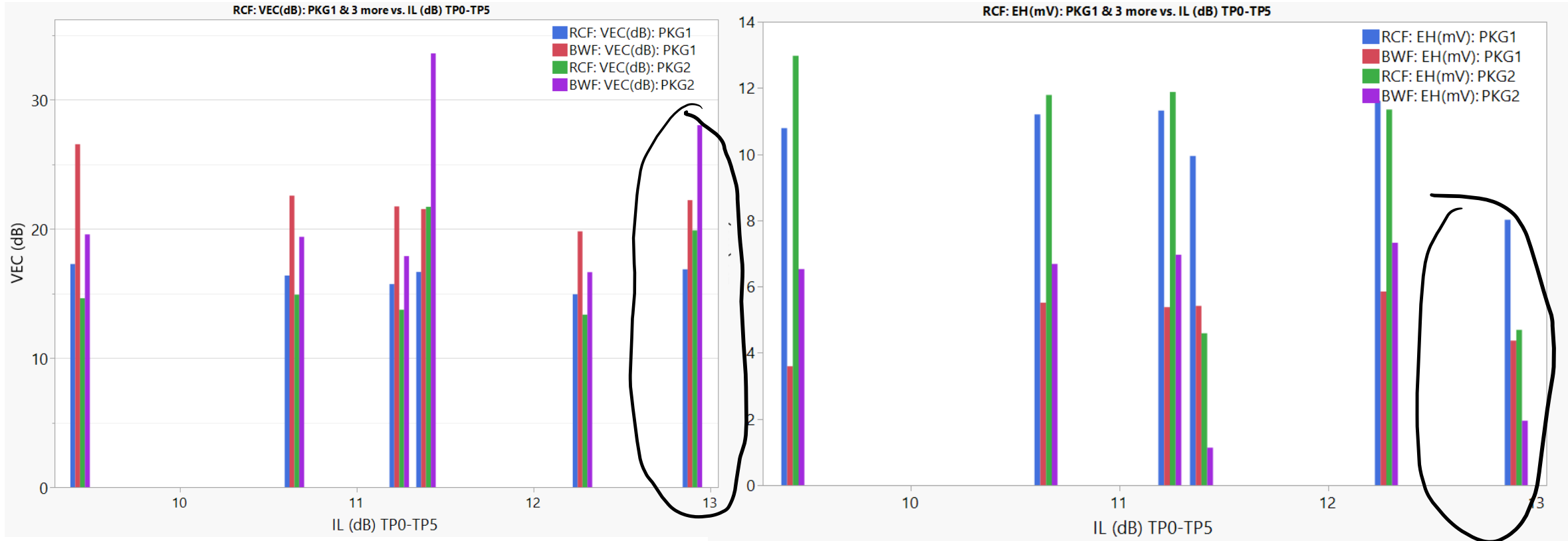
Reduce BWF Bandwidth (f_r) from $0.75f_b$ to $0.5f_b$

IEEE P802.3df 200 Gb/s, 400 Gb/s, 800 Gb/s, and 1.6 Tb/s Ethernet Task Force
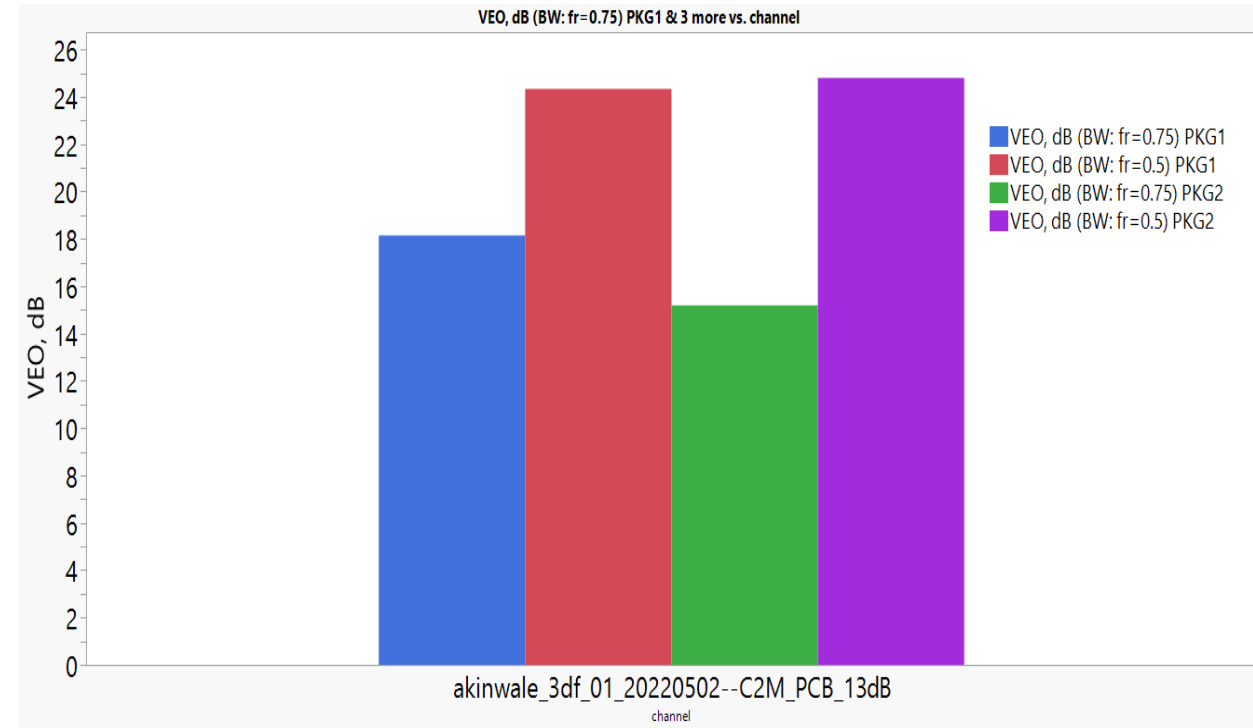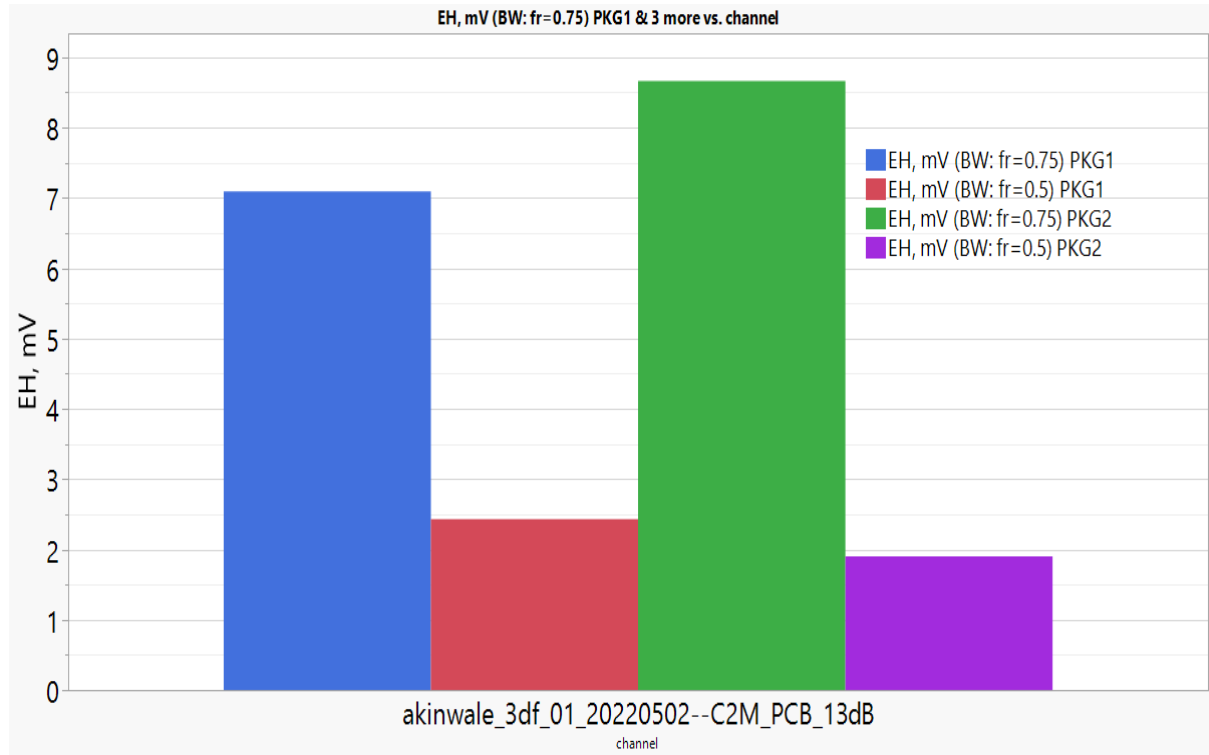
Summary

❑ A raised cosine reference receive filter can improve 200 G performance

- Compared to the Butterworth filter used in COM computations

❑ More work may be needed to refine receiver filter parameters

- Especially with more published channels.

❑ A raised cosine filter may alleviate measurement concerns

❑ Need to explore other issues resulting from specifying a raised cosine reference receive filter

Thank You!