100 GEL C2M Flyover Host Files: Tp0 to Tp2, With and Without Manufacturing Variations, for Losses 9, 10, 11, 12, 13, and 14 dB

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IEEE 802.3 100 Gb/s per Lane Electrical Study Group

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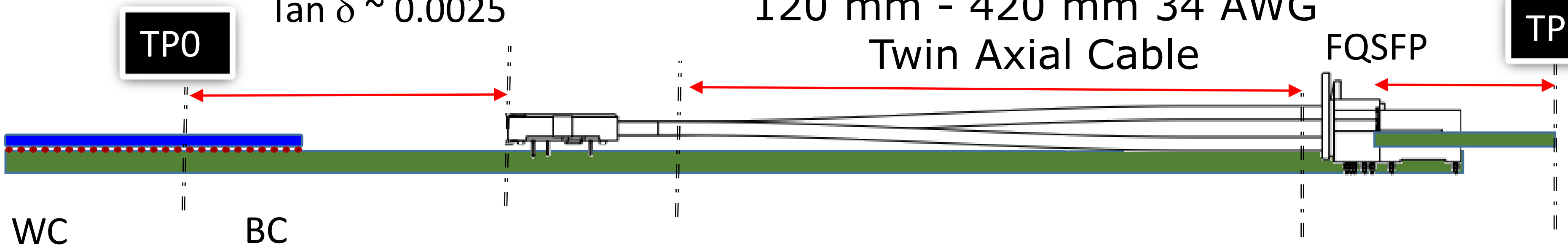
System Topology Overview: C2M

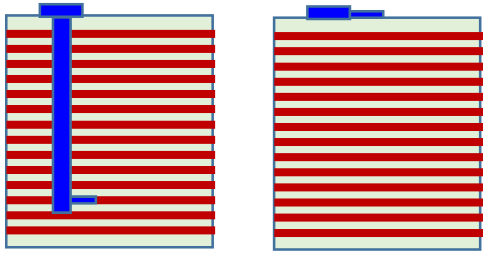
using FLYOVER Cable

3” Megtron 6 ‘like‘ PCB
Tan δ ~ 0.004
2” in Tachyon ‘like‘ PCB
Tan δ ~ 0.0025

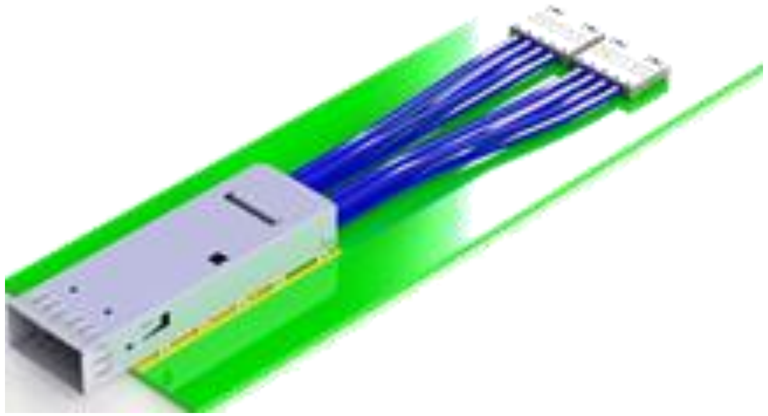
120 mm - 420 mm 34 AWG
Twin Axial Cable

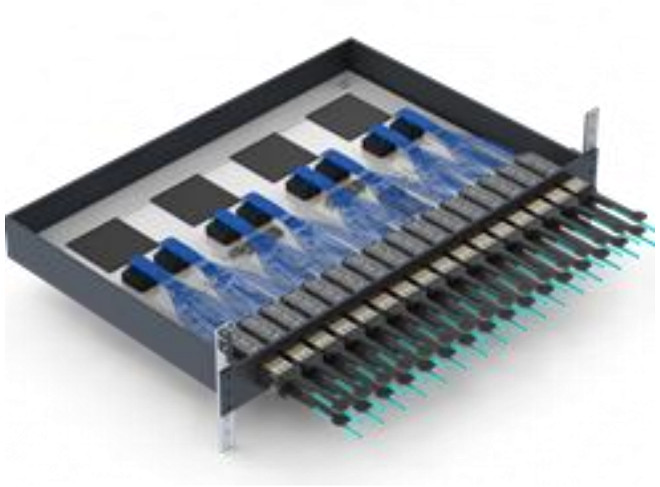
1.5” Megtron 6 ‘like‘ PCB
Tan δ ~ 0.004
1.5” in Tachyon ‘like‘ PCB
Tan δ ~ 0.0025



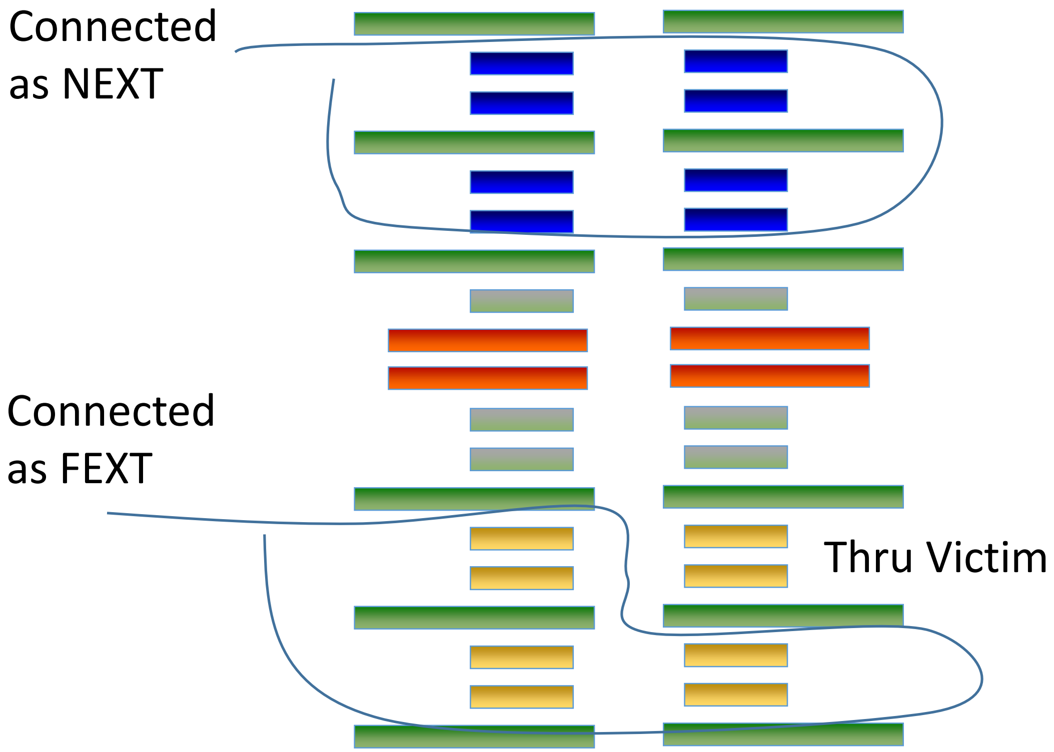


Line Card BGA
Break Out Region (BOR)
14 layer 093 mil thick

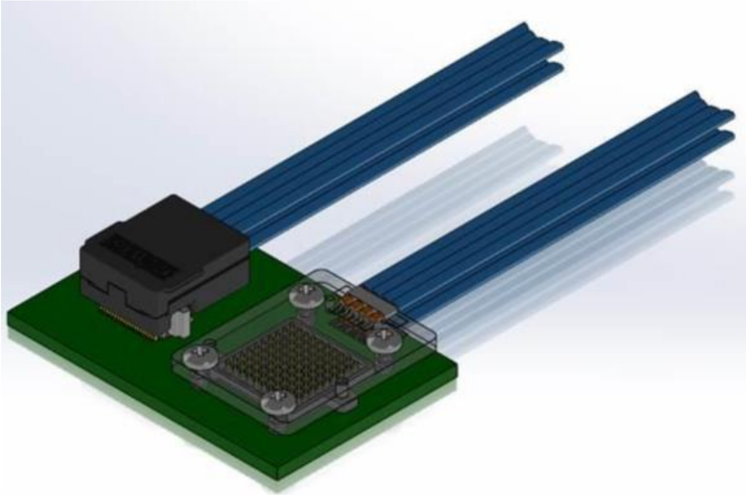




Channel Example



Tx and Rx on separate cable bundles makes for very low NEXT

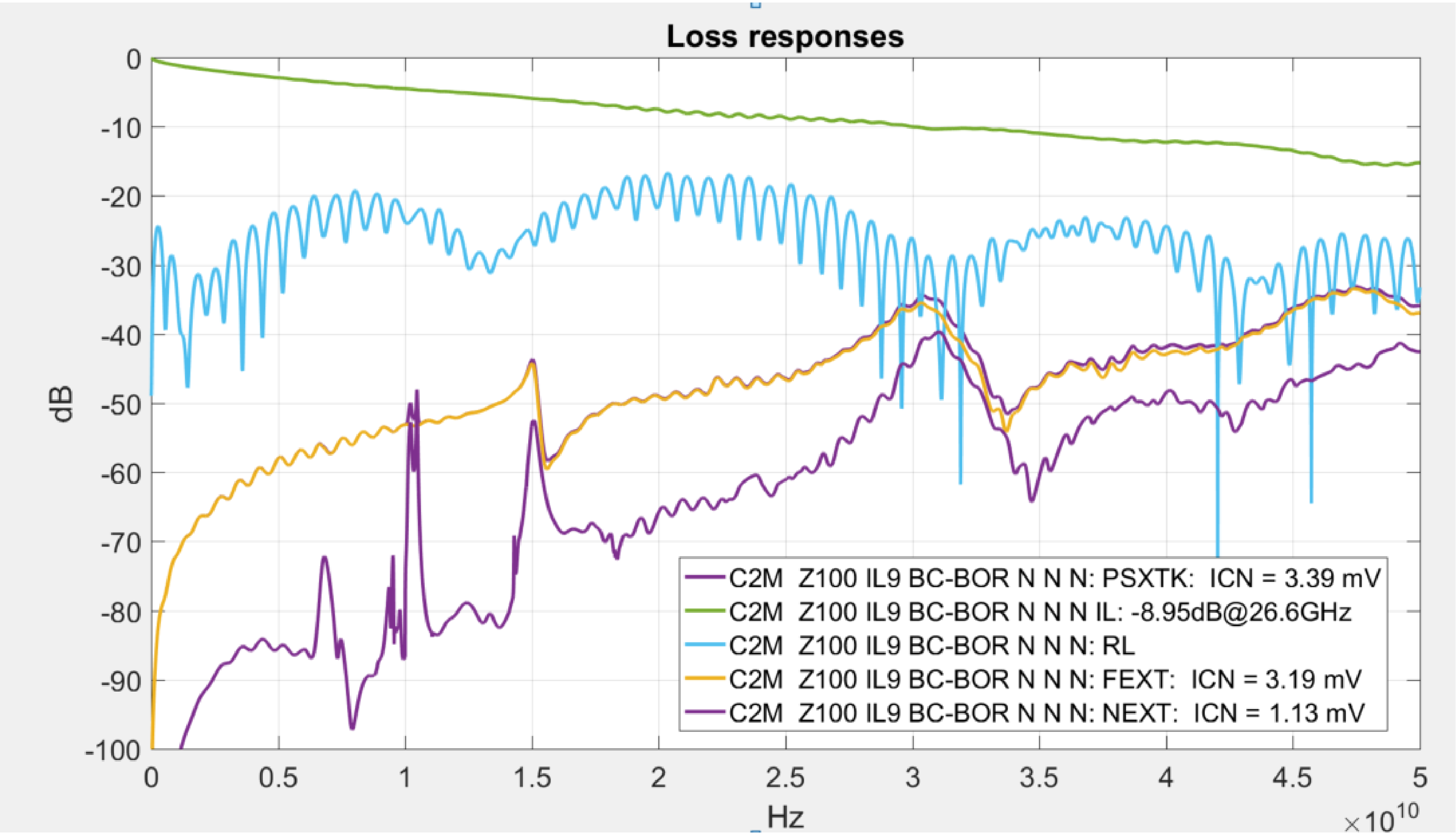


File Key

IL (dB)	9	10	11
BGA	BC	WC	BC
variation	N-N-N	H-N-H	N-N-N
	C2M__Z100_IL19_BC-BOR_N_N_N_THRU.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_THRU.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_THRU.s4p
	C2M__Z100_IL19_BC-BOR_N_N_N_NEXT4.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_NEXT4.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_NEXT4.s4p
	C2M__Z100_IL19_BC-BOR_N_N_N_NEXT3.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_NEXT3.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_NEXT3.s4p
	C2M__Z100_IL19_BC-BOR_N_N_N_NEXT2.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_NEXT2.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_NEXT2.s4p
	C2M__Z100_IL19_BC-BOR_N_N_N_NEXT1.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_NEXT1.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_NEXT1.s4p
	C2M__Z100_IL19_BC-BOR_N_N_N_FEXT3.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_FEXT3.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_FEXT3.s4p
	C2M__Z100_IL19_BC-BOR_N_N_N_FEXT2.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_FEXT2.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_FEXT2.s4p
	C2M__Z100_IL19_BC-BOR_N_N_N_FEXT1.s4p	C2M__Z100_IL10_WC-BOR_H_L_H_FEXT1.s4p	C2M__Z100_IL11p2_BC-BOR_N_N_N_FEXT1.s4p

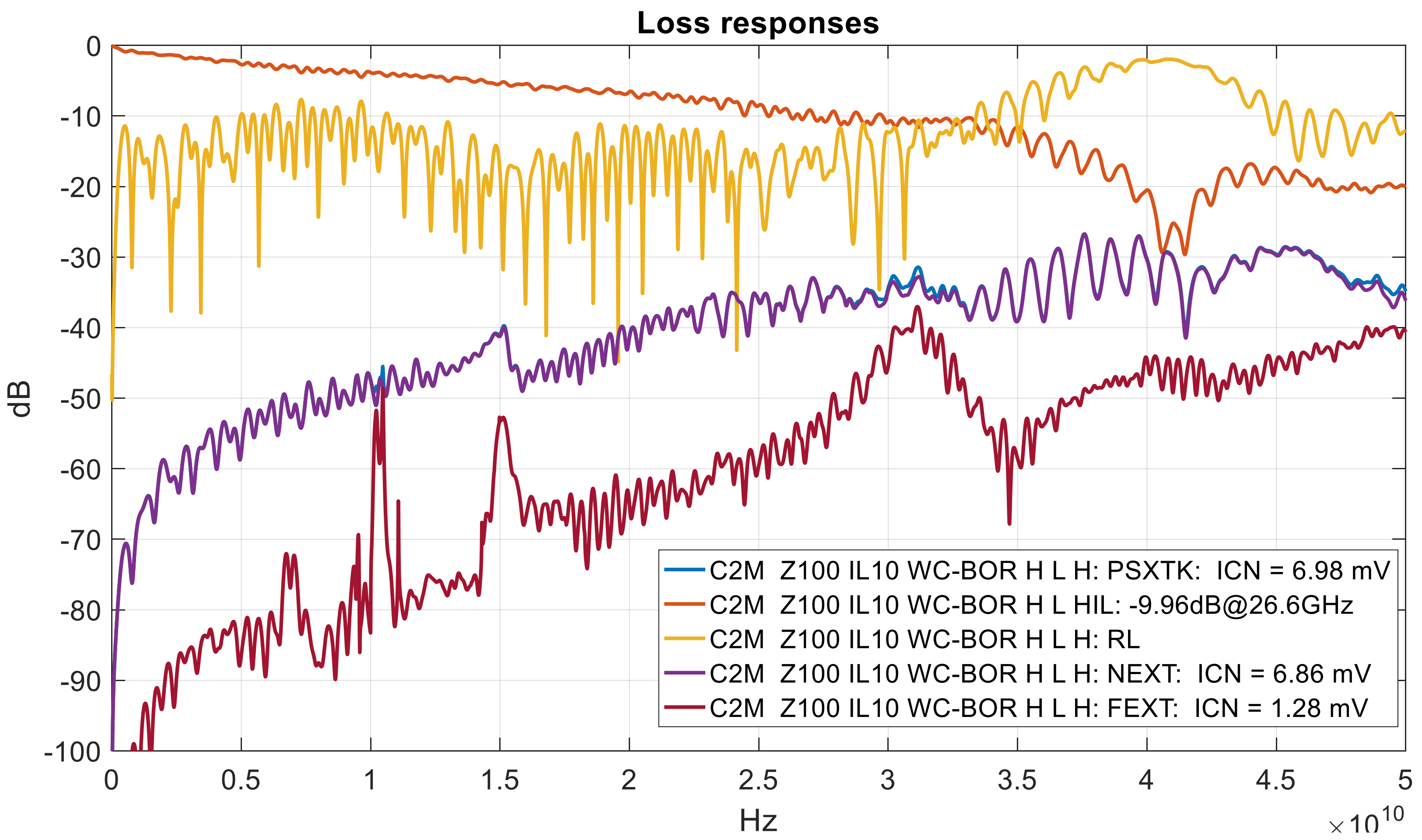
IL (dB)	12	13	14
BGA	WC	BC	WC
variation	H-N-H	N-N-N	H-N-H
	C2M__Z100_IL12_WC-BOR_H_L_H_THRU.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_THRU.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_THRU.s4p
	C2M__Z100_IL12_WC-BOR_H_L_H_NEXT4.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_NEXT4.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_NEXT4.s4p
	C2M__Z100_IL12_WC-BOR_H_L_H_NEXT3.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_NEXT3.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_NEXT3.s4p
	C2M__Z100_IL12_WC-BOR_H_L_H_NEXT2.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_NEXT2.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_NEXT2.s4p
	C2M__Z100_IL12_WC-BOR_H_L_H_NEXT1.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_NEXT1.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_NEXT1.s4p
	C2M__Z100_IL12_WC-BOR_H_L_H_FEXT3.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_FEXT3.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_FEXT3.s4p
	C2M__Z100_IL12_WC-BOR_H_L_H_FEXT2.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_FEXT2.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_FEXT2.s4p
	C2M__Z100_IL12_WC-BOR_H_L_H_FEXT1.s4p	C2M__Z100_IL13_BC-BOR_N_N_N_FEXT1.s4p	C2M__Z100_IL14_WC-BOR_H_L_H_FEXT1.s4p

9 dB Channel

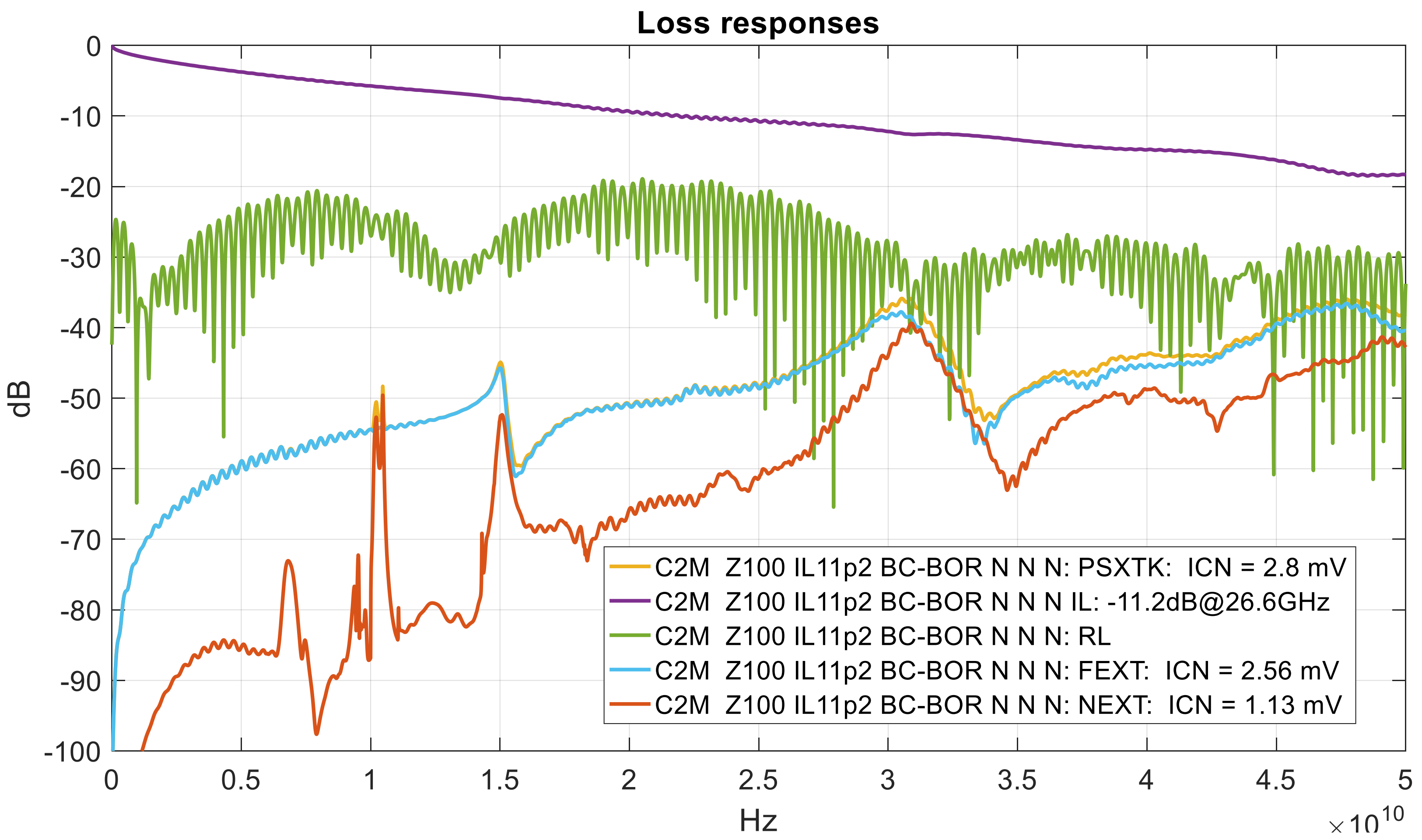


Loss responses
dB
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Hz
×10^10
C2M Z100 IL9 BC-BOR N N N: PSXTK: ICN = 3.39 mV
C2M Z100 IL9 BC-BOR N N N IL: -8.95dB@26.6GHz
C2M Z100 IL9 BC-BOR N N N: RL
C2M Z100 IL9 BC-BOR N N N: FEXT: ICN = 3.19 mV
C2M Z100 IL9 BC-BOR N N N: NEXT: ICN = 1.13 mV

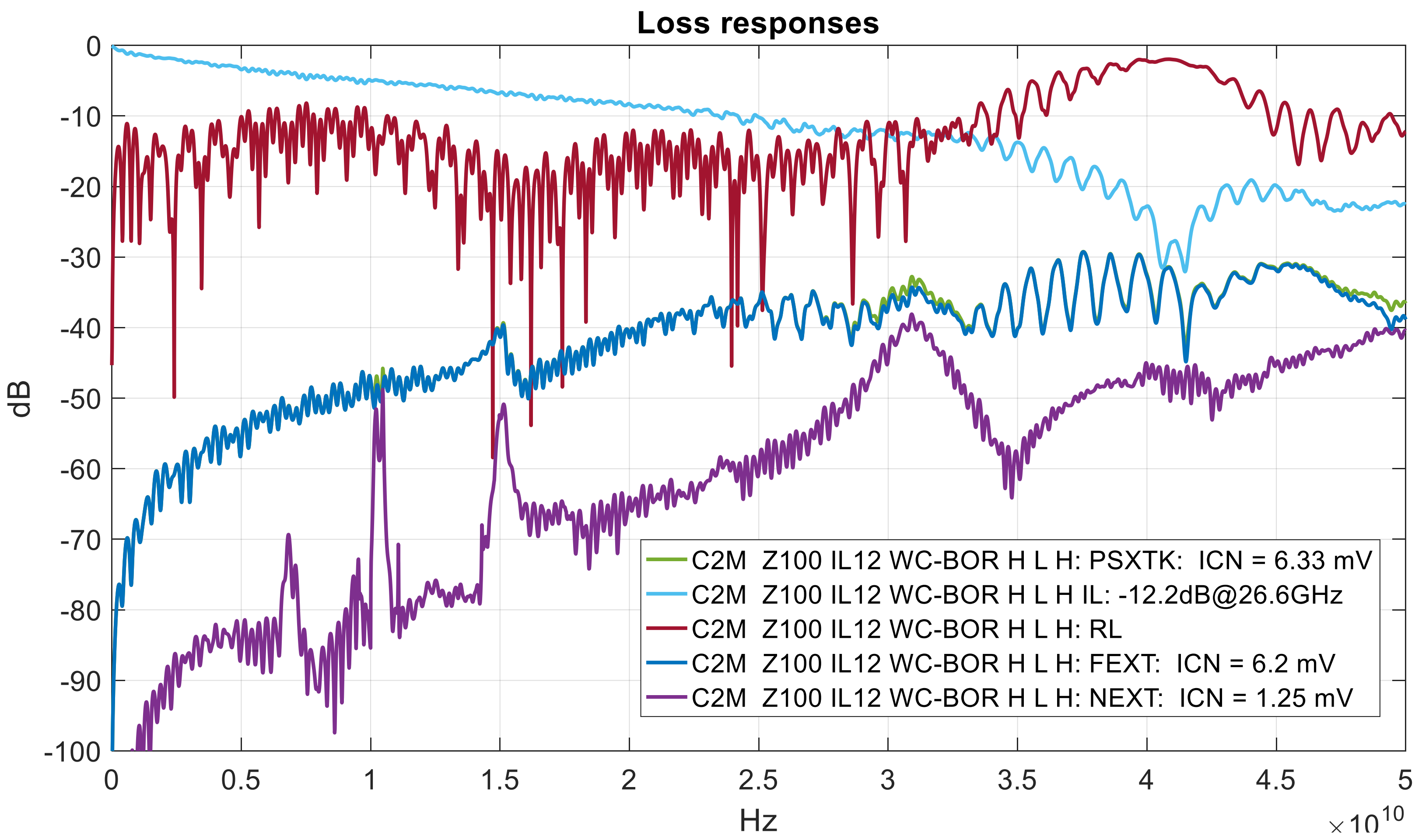
10 dB Channel



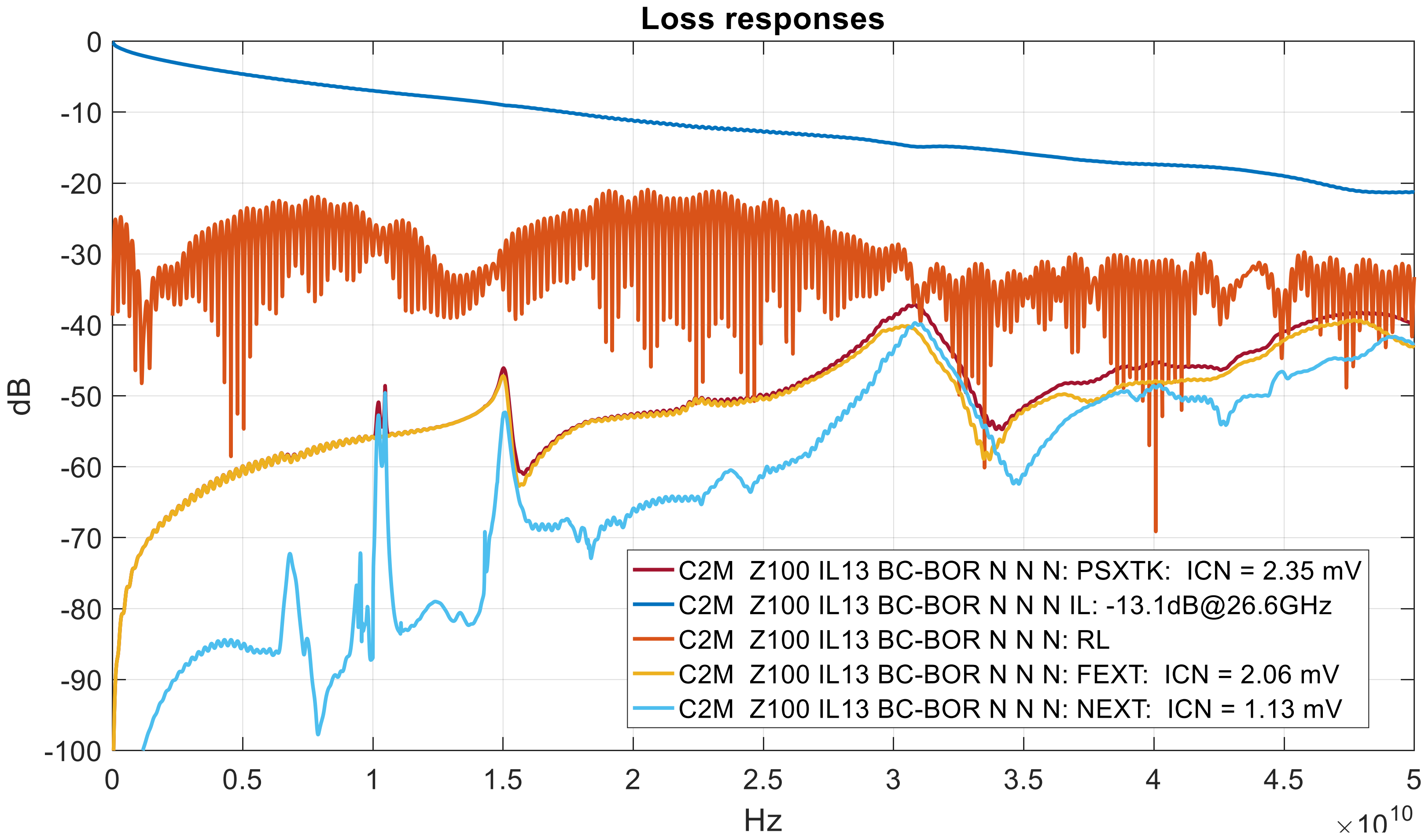
11 dB Channel



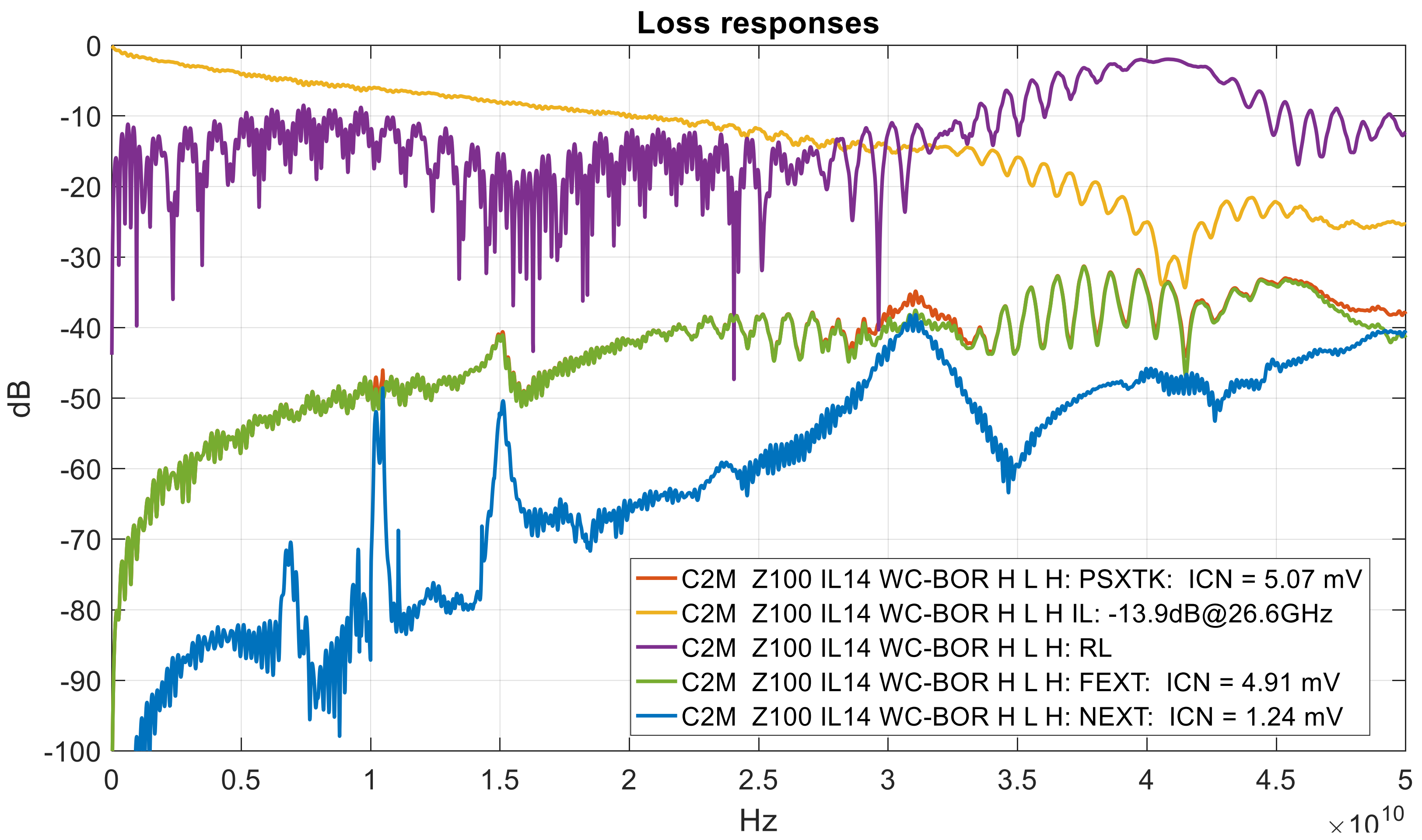
13 dB Channel



13 dB Channel



14 dB Channel



1 Tap DFE COM example test sheet

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	[1.3e-4 0]	nF	[TX RX]
z_p select	[2]		[test cases to run]
z_p (TX)	[12 30]	mm	[test cases]
z_p (NEXT)	[0 0]	mm	[test cases]
z_p (FEXT)	[12 30]	mm	[test cases]
z_p (RX)	[0 0]	mm	[test cases]
C_p	[1.1e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.6		min
c(-1)	[-0.25:0.05:0]		[min:step:max]
c(-2)	[0:0.025:0.15]		
c(-3)	0		
c(1)	[-0.25:0.05:0]		[min:step:max]
sigma_RJ	0.01	UI	
A_DD	0.02	UI	
eta_0	0.00E+00	V^2/GHz	
SNR_TX	32.5	dB	
R_LM	0.95		
DER_0	1.00E-04		

I/O control			
DIAGNOSTICS	1	logical	
DISPLAY_WINDOW	1	logical	
Display frequency domain	1	logical	
CSV_REPORT	1	logical	
RESULT_DIR	.\results\100G_Study_Group_{date}\		
SAVE_FIGURES	0	logical	
Port Order	[1 3 2 4]		
RUNTAG	100G_Study_Group_C2M_tp0_tp2_		
Receiver testing			
RX_CALIBRATION	0	logical	
Sigma BBN step	5.00E-03	V	
IDEAL_TX_TERM	0	logical	
T_r	8.00E-03	ns	
FORCE_TR	1	logical	
Non standard control options			
COM_CONTRIBUTION	0	logical	
TDR	0	logical	
CTF			
g_DC	-[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9]*2	dB	[min:step:max]
f_z	[8.359 8.159 7.995 7.604 6.713 6.421 6.155 5.733 5.353 5.007 4.691 4.399 4.13 3.88 3.647 3.43 3.228]*2	GHz	
f_p1	[18.6 18.6 18.6 18.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6]*2	GHz	
f_p2	[14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1 14.1]*2	GHz	
f_HP_P	[1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2]*2	GHz	
f_HP_Z	[1.2 1.15 1.1 1.075 1.05 1.025 1 1 1 1 1 1 1 1 1 1 1]*2	GHz	

Table 93A–3 parameters			
Parameter	Setting	Units	
package_tl_gamma0_a1_a2	[0 1.734e-3 1.455e-4]		
package_tl_tau	6.141E-03	ns/mm	
package_Z_c	95	Ohm	
Operational control		1	
COM Pass threshold	5	dB	
Include PCB	0	Value	0, 1
PHY_type	C2M		
EH_min	5	Value	EH limit
EH_max	1000	Value	EH limit
Table 93A-1 parameters			
A_v	0.41	V	
A_fe	0.41	V	
A_ne	0.6	V	
L	4		
M	32		
N_b	1	UI	
b_max(1)	0.7		
b_max(2..N_b)	0.2		

Adding a very simple Rx FFE improves VEO

- ❑ Zero forcing inside the loop for Tx FFE and CTF
- ❑ Adjust Zero forcing for crosstalk to avoid too much FFE noise amplification
- ❑ 12 FFE post cursors with 0.01 step size
- ❑ Add COM parameter for the simple Rx FFE

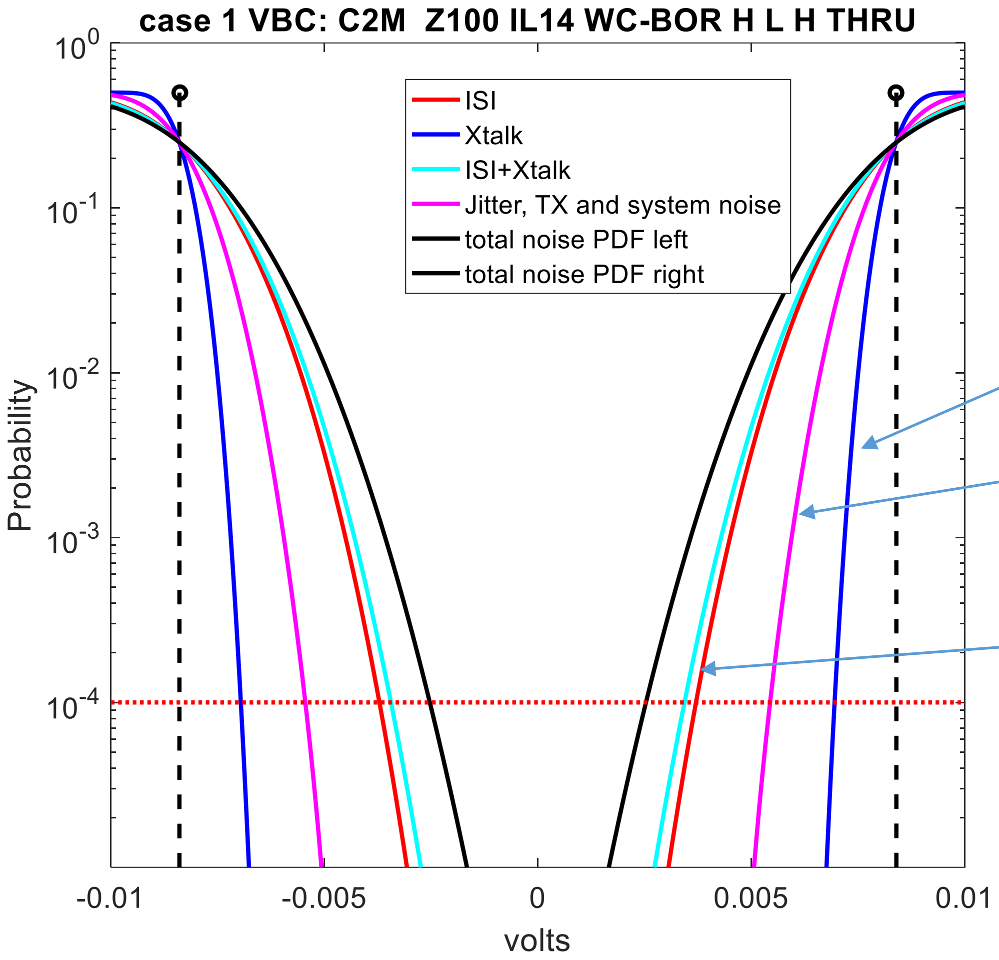
RxFFE_cmx	0		
RxFFE_cpx	12		
RxFFE_stepz	0.01		

- ❑ COM codes available but very much in flux
  - Still in debug
  - Will address COM algorithm in other meetings

COM Vertical Eye Opening (VEO)

Channel	VEO (mV)	VEO (mV) w RxFFE
C2M_tp0_tp2_ _10-May-2018--C2M__Z100_IL9_BC-BOR_N_N_N_THRU	9.8	17.4
C2M_tp0_tp2_ _10-May-2018--C2M__Z100_IL10_WC-BOR_H_L_H_THRU	9.6	14.4
C2M_tp0_tp2_ _10-May-2018--C2M__Z100_IL11p2_BC-BOR_N_N_N_THRU	6.6	10.2
C2M_tp0_tp2_ _10-May-2018--C2M__Z100_IL12_WC-BOR_H_L_H_THRU	7.0	14.5
C2M_tp0_tp2_ _10-May-2018--C2M__Z100_IL13_BC-BOR_N_N_N_THRU	4.3	13.7
C2M_tp0_tp2_ _10-May-2018--C2M__Z100_IL14_WC-BOR_H_L_H_THRU	4.5	11.7

Vertical Bath Tub Eye Opening Analysis without RxFFE



Crosstalk is low as expected

Jitter, Tx, and noise is moderate

Residual ISI is high.
More Eq. would help

Summary

- ❑ A number of C2M designs are feasible with present technology
- ❑ 6 FLYOVER QSFP host design channels are provided
  - Insertion loss ranges from 9 dB to 14 dB at 26.56 GHz
- ❑ DFE 1 and CTF opens EYE at TP2
  - But not much
  - Rx FFE helps

Backup Material

Simple Zero Forcing

Let the pulse response be h0(t)

Apply CFT setting

Find sample point ts and resample as hisi(n)

Example pulse response is 20 UI

```
hisi=[ hisi1, hisi2, hisi3, hisi4, hisi5, hisi6, hisi7, hisi8, hisi9, hisi10, hisi11, hisi12, hisi13,
hisi14, hisi15, hisi16, hisi17, hisi18, hisi19, hisi20]
```

Example: Let hisi(9) correspond to the sample point

Example; 2 pre cursors, 5 post cursors

C is the set of cursors (c1… cn)

Zero pad hisi in preparation for the circshift function

[0, 0, hisi1, hisi2, hisi3, hisi4, hisi5, hisi6, hisi7, hisi8, hisi9, hisi10, hisi11, hisi12, hisi13, hisi14, hisi15, hisi16, hisi17, hisi18, hisi19, hisi20, 0, 0, 0, 0, 0]

Simple Zero Forcing

Define HH array of shifted hisi vectors: HH =

```
[ hisi9, hisi10, hisi11, hisi12, hisi13, hisi14, hisi15, hisi16, hisi17]
[ hisi8,  hisi9, hisi10, hisi11, hisi12, hisi13, hisi14, hisi15, hisi16]
[ hisi7,  hisi8,  hisi9, hisi10, hisi11, hisi12, hisi13, hisi14, hisi15]
[ hisi6,  hisi7,  hisi8,  hisi9, hisi10, hisi11, hisi12, hisi13, hisi14]
[ hisi5,  hisi6,  hisi7,  hisi8,  hisi9, hisi10, hisi11, hisi12, hisi13]
[ hisi4,  hisi5,  hisi6,  hisi7,  hisi8,  hisi9, hisi10, hisi11, hisi12]
[ hisi3,  hisi4,  hisi5,  hisi6,  hisi7,  hisi8,  hisi9, hisi10, hisi11]
[ hisi2,  hisi3,  hisi4,  hisi5,  hisi6,  hisi7,  hisi8,  hisi9, hisi10]
```

FV is the forcing vector , FV =

```
[ 0, 0, hisi9, 0, 0, 0, 0, 0]
```

Such that

```
FV =HH.'*C.’
```

And we solve for C

```
C=((HH'*HH)^-1*HH')'*FV’;
```

Quantize C to FFE steps sizes. If C(-1) of C(-2) is too large then move to Tx and redo.

modifications

- For DFE =1 remove sample for ts+1 in Hisi
- Full grid the CTF and Tx FFE settings to determine best FOM
- For each setting determine the vector C, apply to filtered pulse response and determine FOM like in eq 93A-36
  - Readjust C for best FOM considering
- C is applied to NEXT and FEXT
- Consider using icn for crosstalk sigma_xt to speed up processing