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100Gb/s C2M Channel Simulation

IEEE802.3ck

July, 2018

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Agenda

1. Overview
2. C2M Channel Simulation
   - 2.1 Simulation Conditions
   - 2.2 Channel for Simulation
   - 2.3 Simulation Results
3. Conclusion

1. Overview

- Feasibility of 100Gb/s C2M transmission with additional channels and equalizer configurations.
- Comparison with COM (test version) results
- Simple IL (insertion loss) discussion is not enough.

channels simulated

#	Contributor	module	IL (noPKG)	SDD22	PSXT	note
7	Mellitz *	QSFP	-9.5dB	-18.3dB	-36.4dB	9dB_BC
8			-10.8dB	-10.6dB	-33.8dB	10dB_WC
9			-11.7dB	-20.6dB	-37.9dB	11dB_BC
10			-12.1dB	-16.6dB	-34.5dB	12dB_WC
11			-13.9dB	-18.9dB	-40.0dB	13dB_BC
12			-14.2dB	-13.2dB	-38.0dB	14dB_WC

* http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

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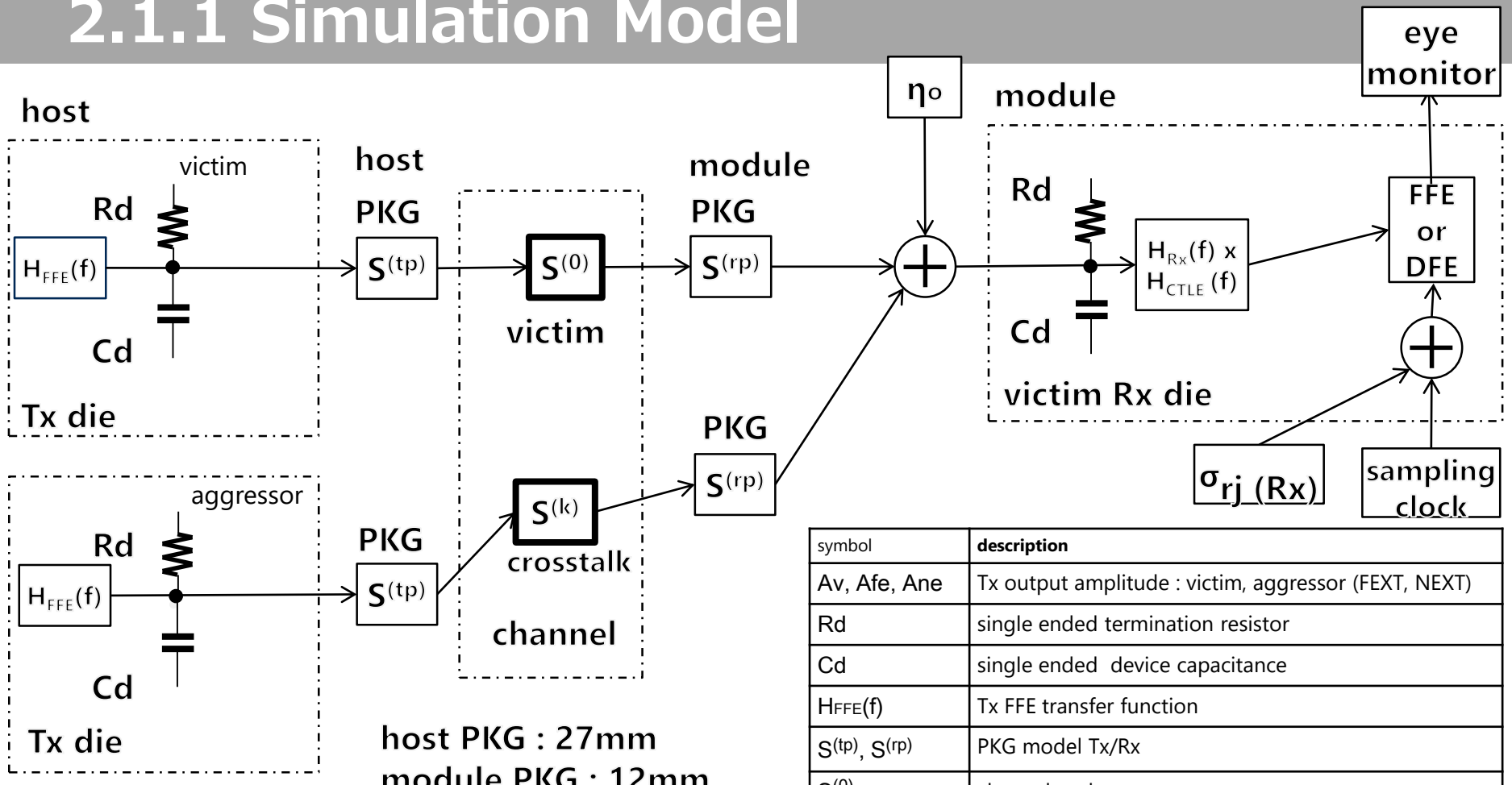
2. C2M Channel simulation

2.1 Simulation Conditions

2.1.1 Simulation Model



host PKG : 27mm
module PKG : 12mm
simulated model

symbol	description
Av, Afe, Ane	Tx output amplitude : victim, aggressor (FEXT, NEXT)
Rd	single ended termination resistor
Cd	single ended device capacitance
$H_{FFE}(f)$	Tx FFE transfer function
$S^{(tp)}$, $S^{(rp)}$	PKG model Tx/Rx
$S^{(0)}$	channel under test
$H_{Rx}(f)$	Rx noise filter
$H_{CTLE}(f)$	Rx CTLE transfer function
η_0	one-sided noise spec
Add	Dual-Dirac jitter, peak to peak Tx : before FFE Rx : considered as eye margin
σrj	random jitter, RMS Tx : before FFE Rx : before FFE/DFE

2.1.2 Simulation Set Up

- ✓ Static Channel Model Simulation
- ✓ Behavior model using MatLab
- ✓ PAM4 at 58.0Gbd to see margin and other applications. (conservative)
- ✓ Jitter, noise and crosstalk are considered.
- ✓ Tx jitter, (DJ, RJ) included
- ✓ RJrms is the same as 50G-PAM4 (conservative).
- ✓ Rx/CDR jitter (DJ) are considered as eye opening margin. (EW5, EH5)
- ✓ Crosstalk noise in channel S-parameter
- ✓ Impedance are nominal : 50-ohm single ended

- ✓ T-spaced FFE
  - ✓ Rx FFE parameters are set to minimize ISI.
- ✓ CTLE coefficients are optimized for each channel. (See back up slides.)
- ✓ PKG model is based on current design and material (GZ41).

item	value	unit
modulation	PAM4	
pattern	PRBS13Q	
baud rate	58	Gbd
DJ_Tx	60, 0	mUI
RJ_Tx	10, 0	mUI_rms
EOJ_Tx	0	UI
SNR_Tx	32.5, none	dB
Rt_Tx	50	ohm
Tx_FFE	4/2	tap/pre
Cd_Tx/Rx	100	fF
Cp Tx/Rx	extracted	fF
Rx FFE + DFE	5/0 + 0 1/0 + 1	FFE tap/pre + DFE tap
Rx fr	3/4 fb	
Av	0.8	Vppd
AVx	1.2	Vppd
BER	1.0E-5	
η_0 eta0	8.2E-09, 0	V^2/GHz
DJ_Rx	0	UI
RJ_Rx	10, 0	mUI_rms
Rt_Rx	50	ohm

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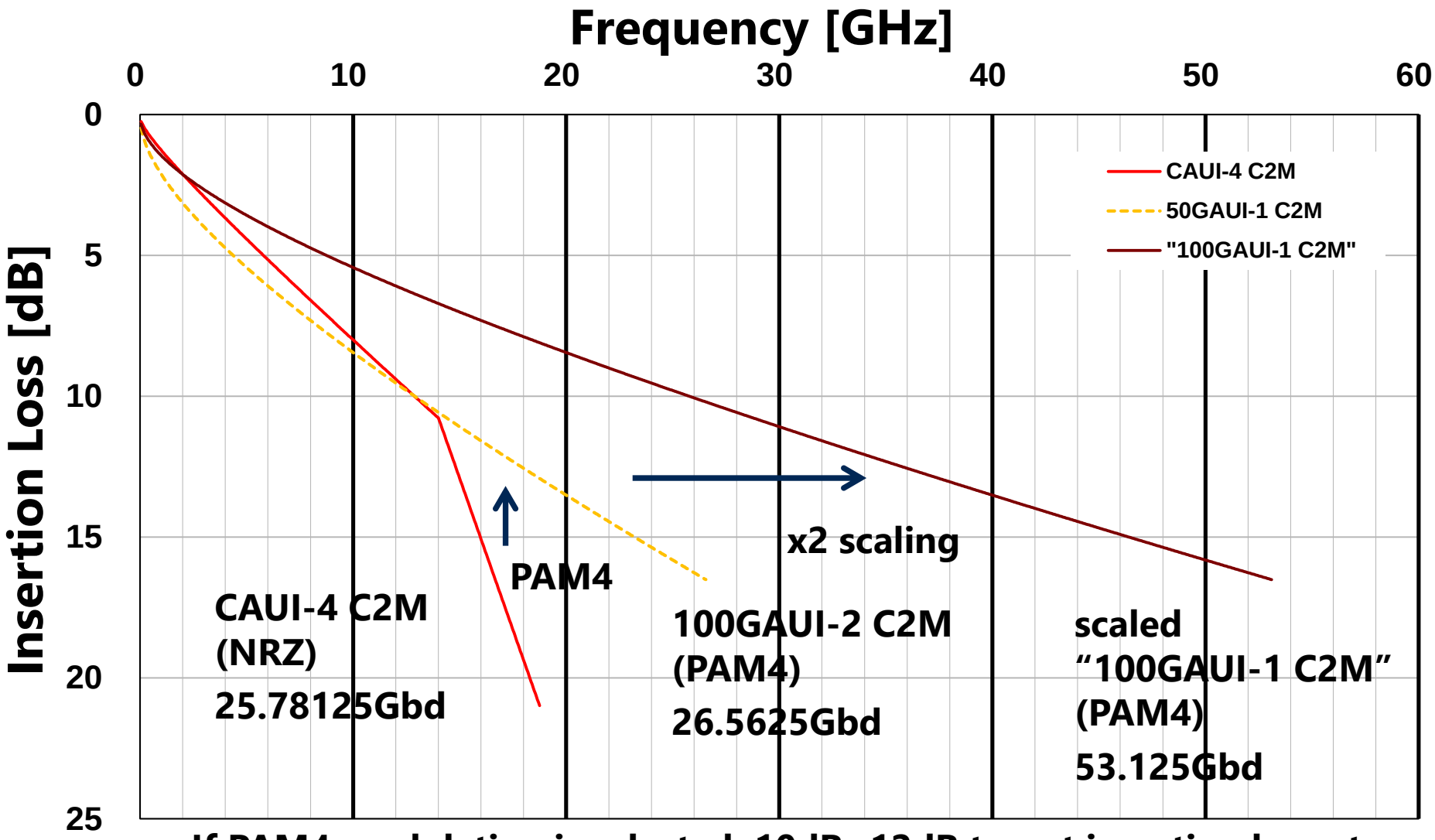
2. Channel simulation

2.2 Channel for Simulation

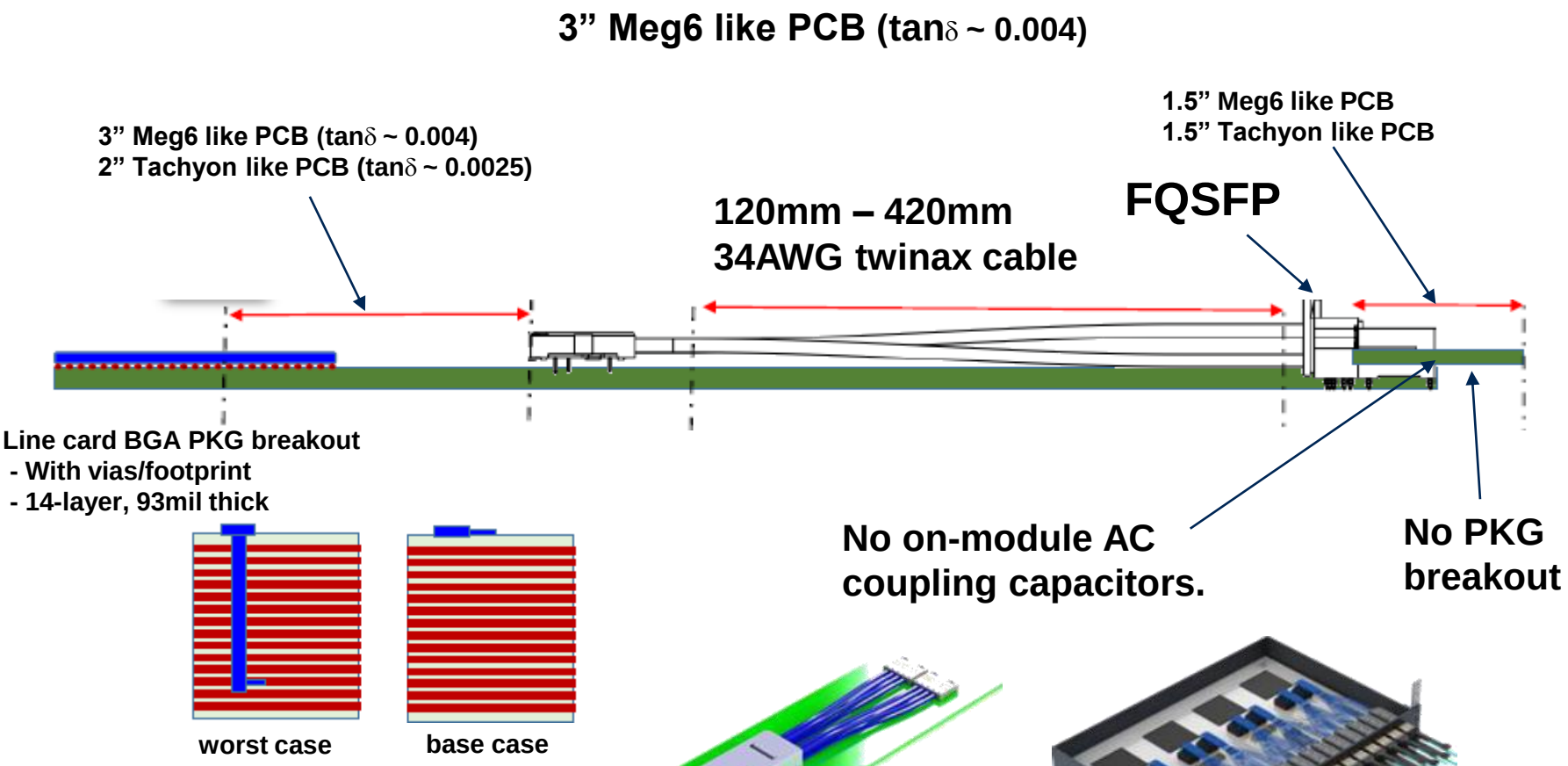
2.2 C2M : channel insertion loss



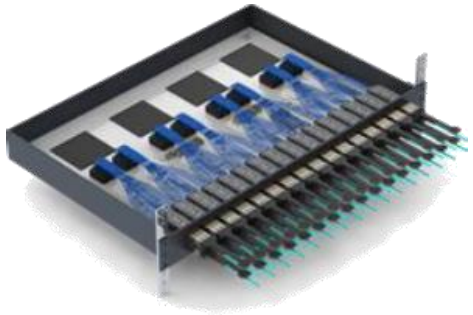
If PAM4 modulation is selected, 10dB~12dB target insertion loss at Nyquist frequency (26.5625GHz, scaled frequency) is an option.

2.2.1 Channel Configuration #7~12, Mellitz*

"Flyover" cable

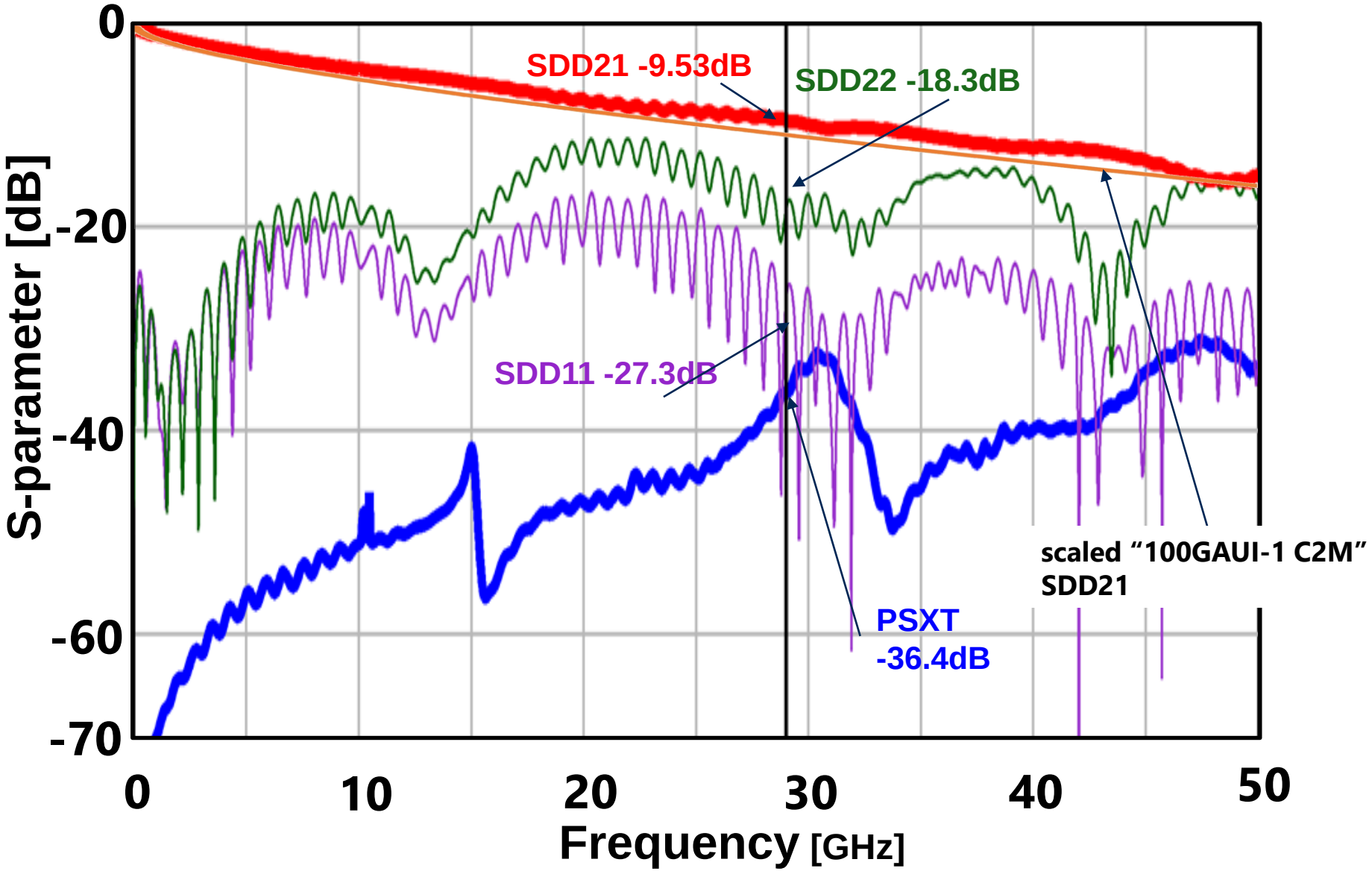


added PKG model
host (Tx) : 27mm PKG
module (Rx) : 12mm PKG
both design extracted



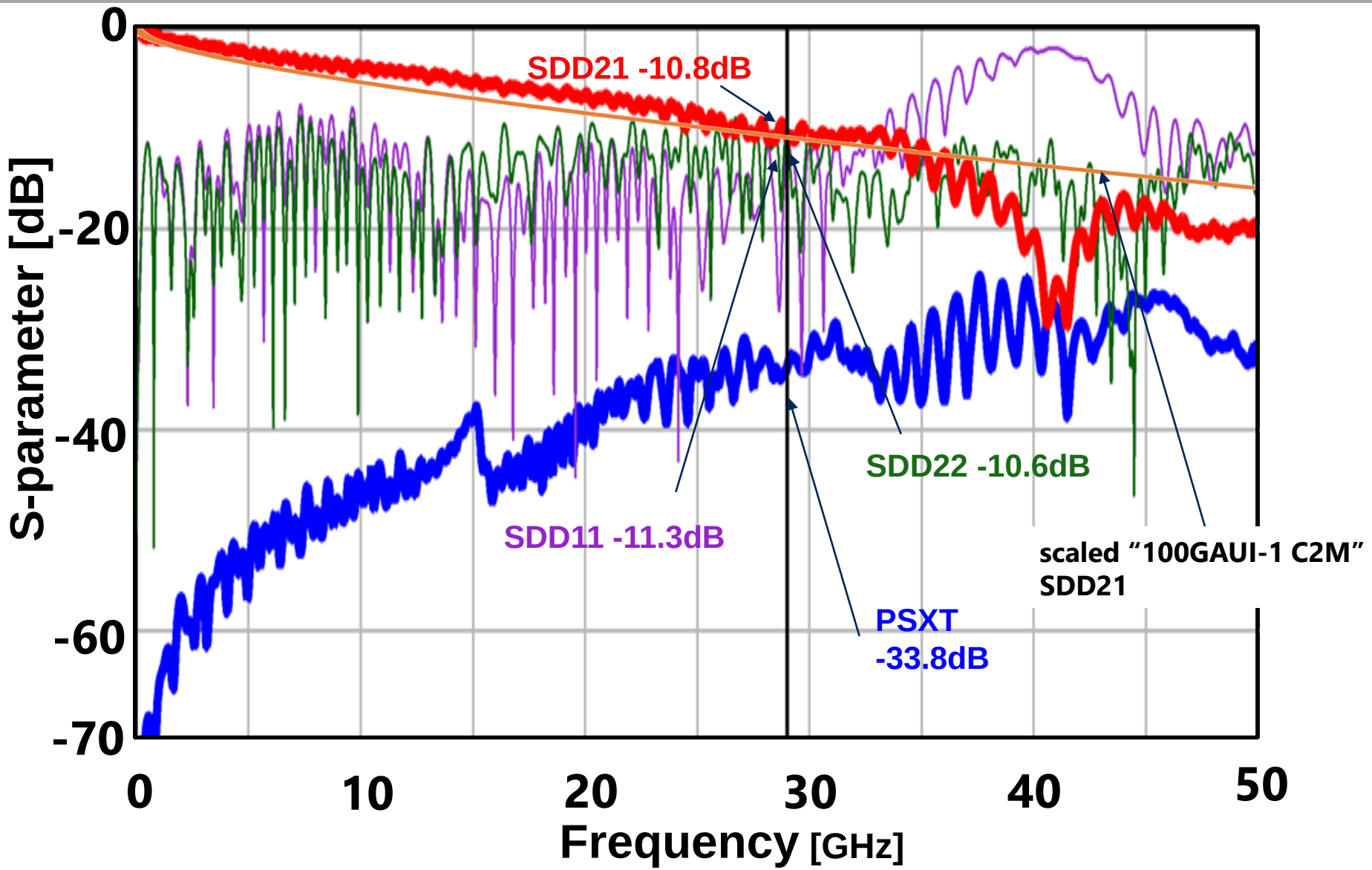
* : http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics (#7,9dB_BC)



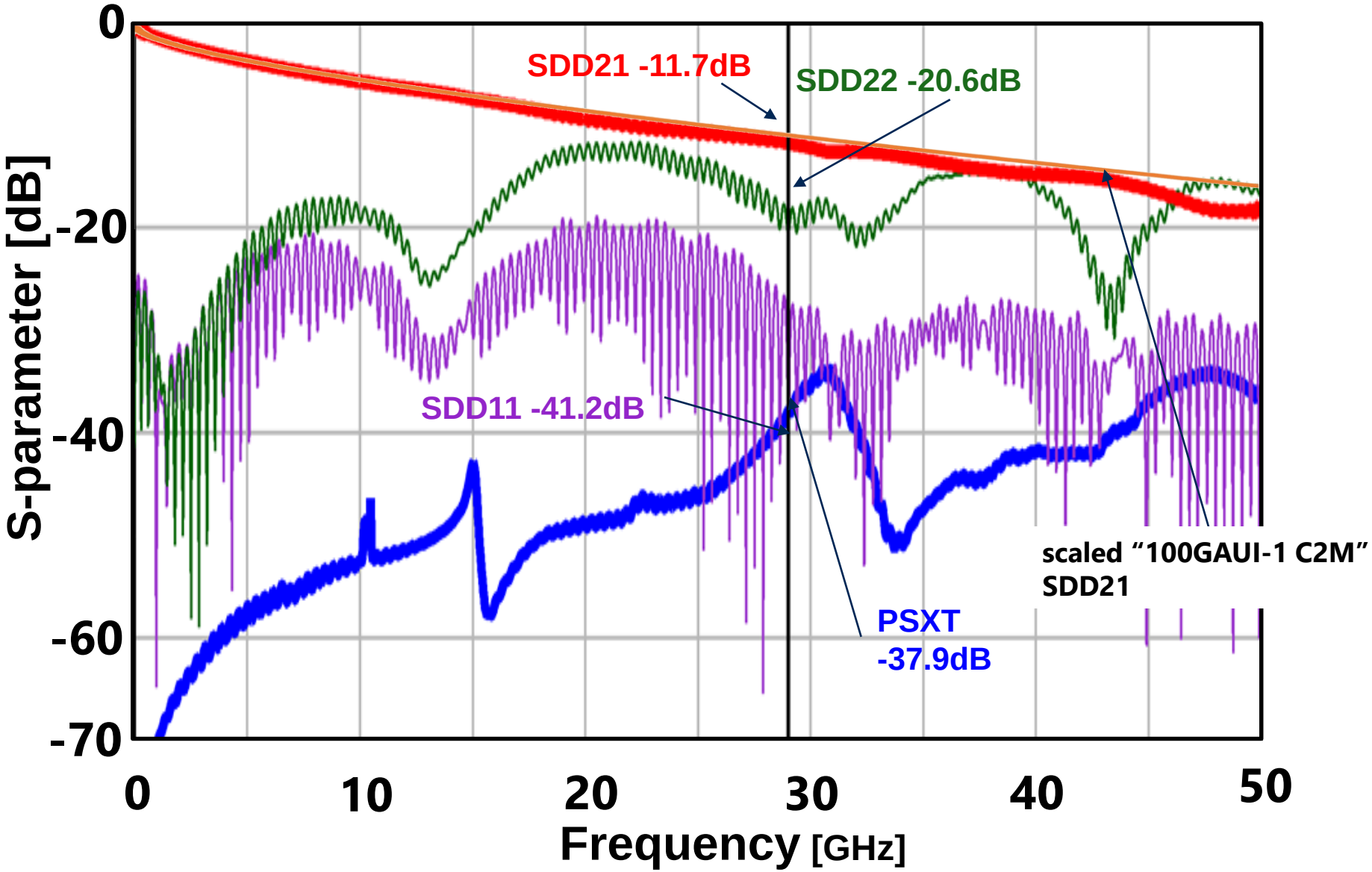
http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics (#8,10dB_WC)



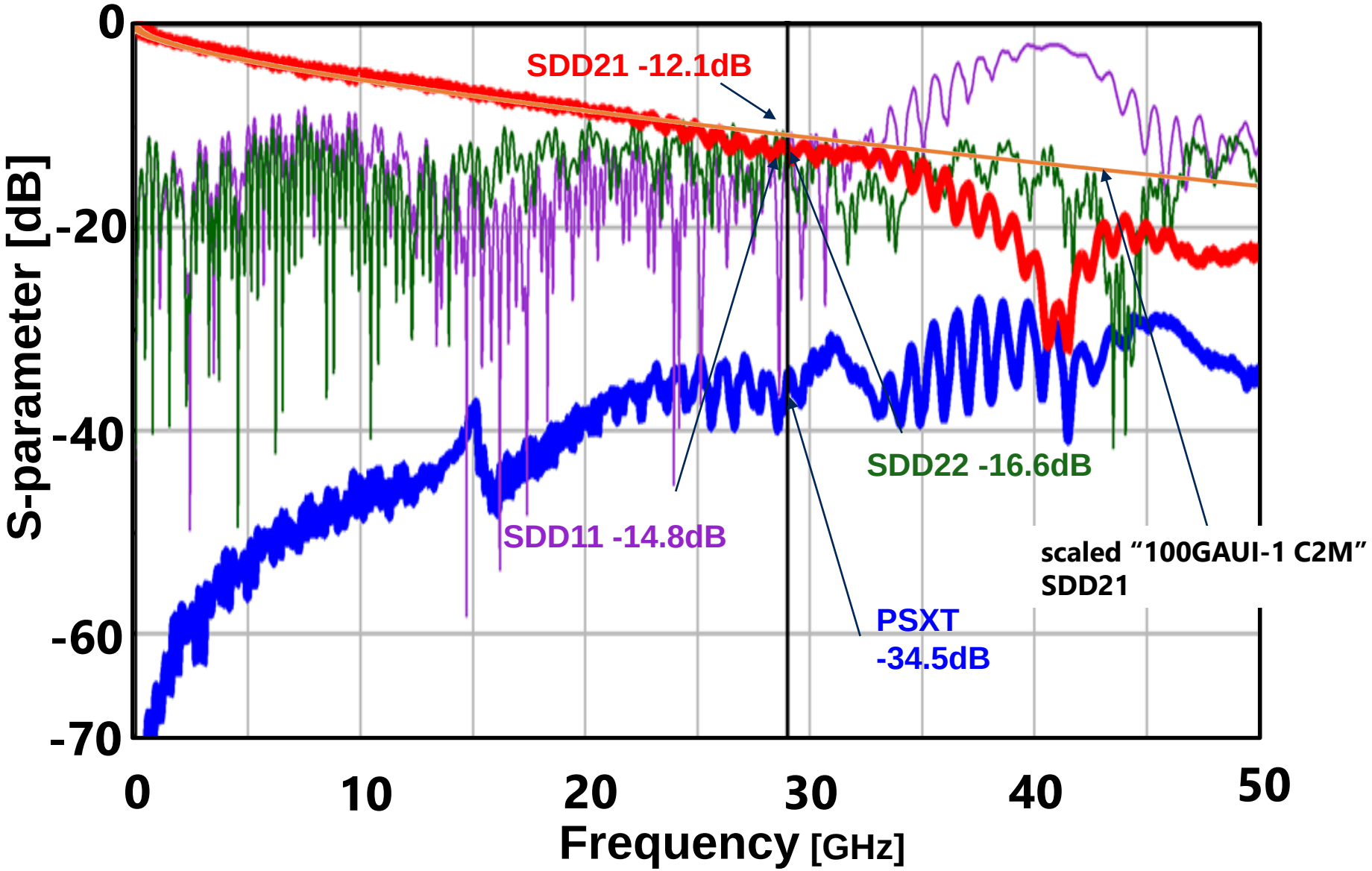
http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics (#9,11dB_BC)



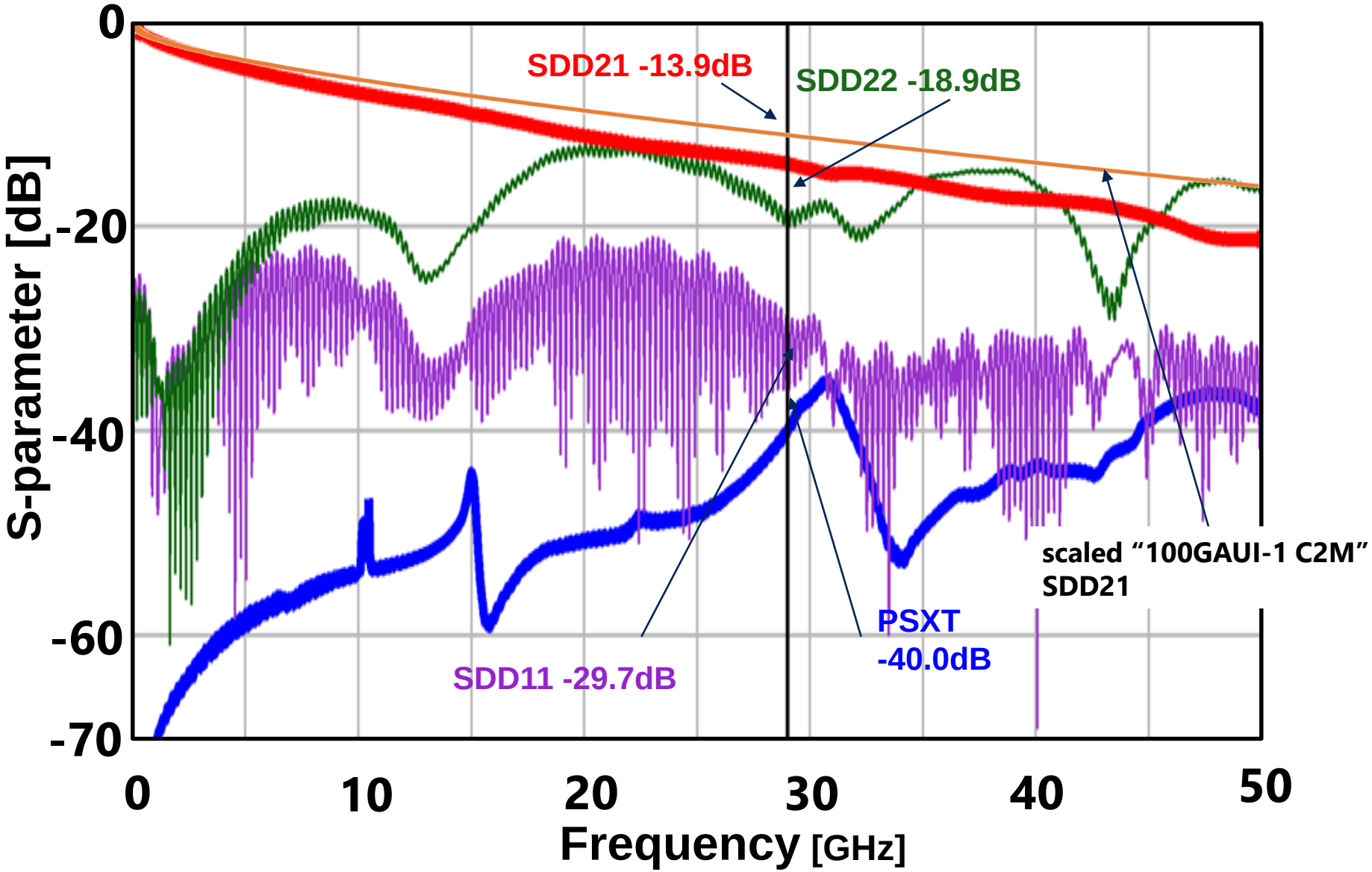
http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics (#10,12dB_WC)



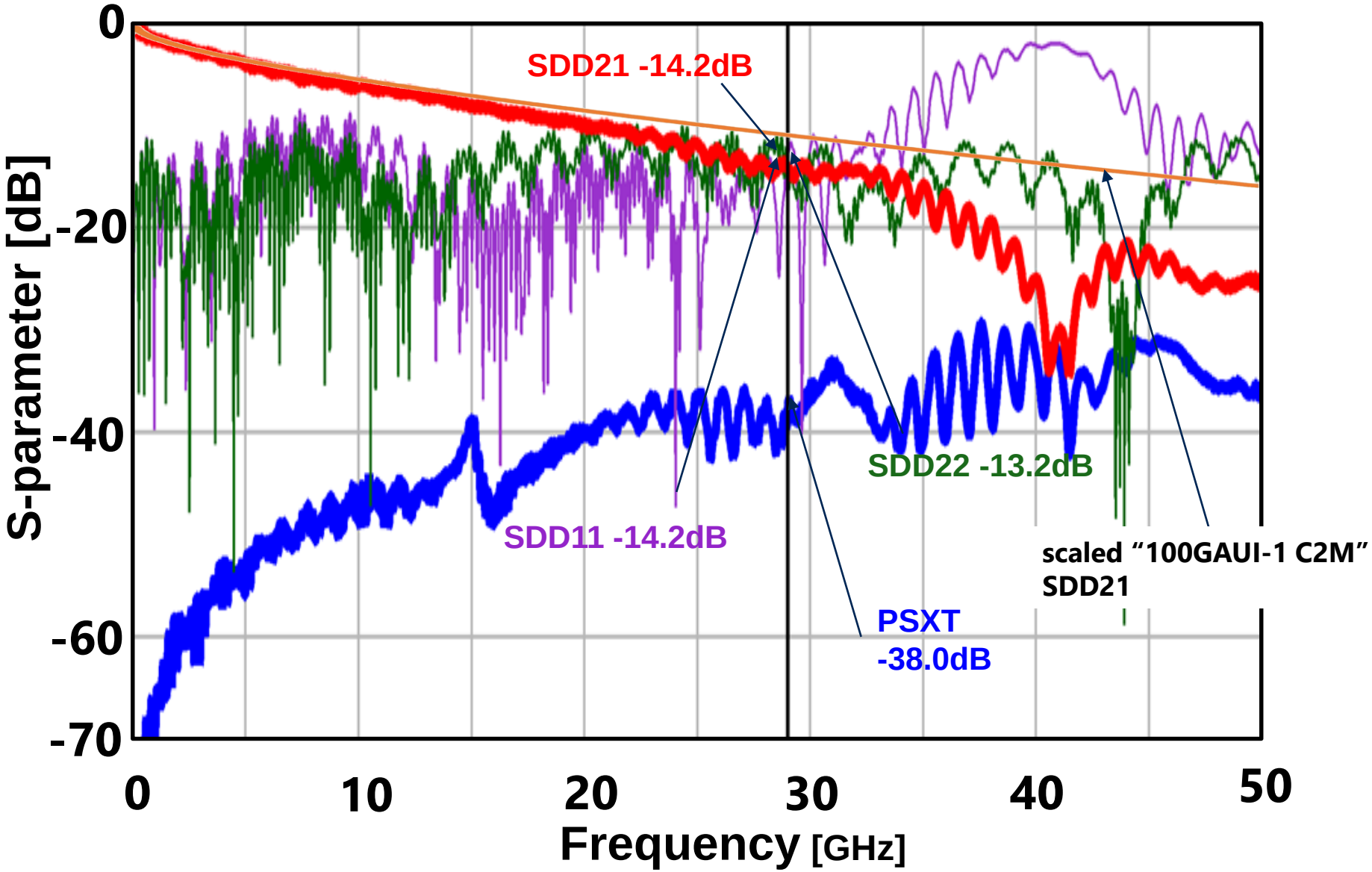
http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics (#11,13dB_BC)



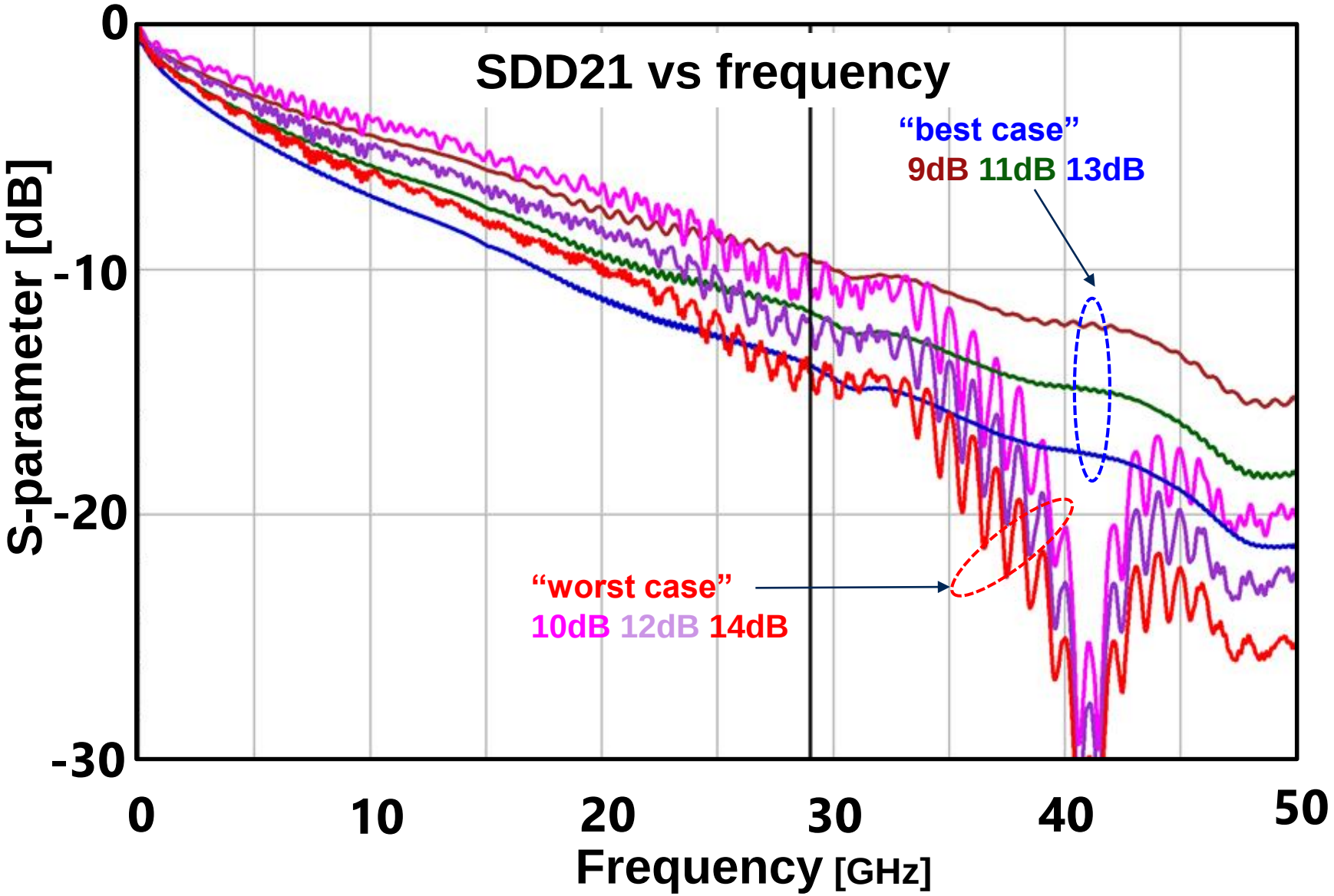
http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics (#12,14dB_WC)



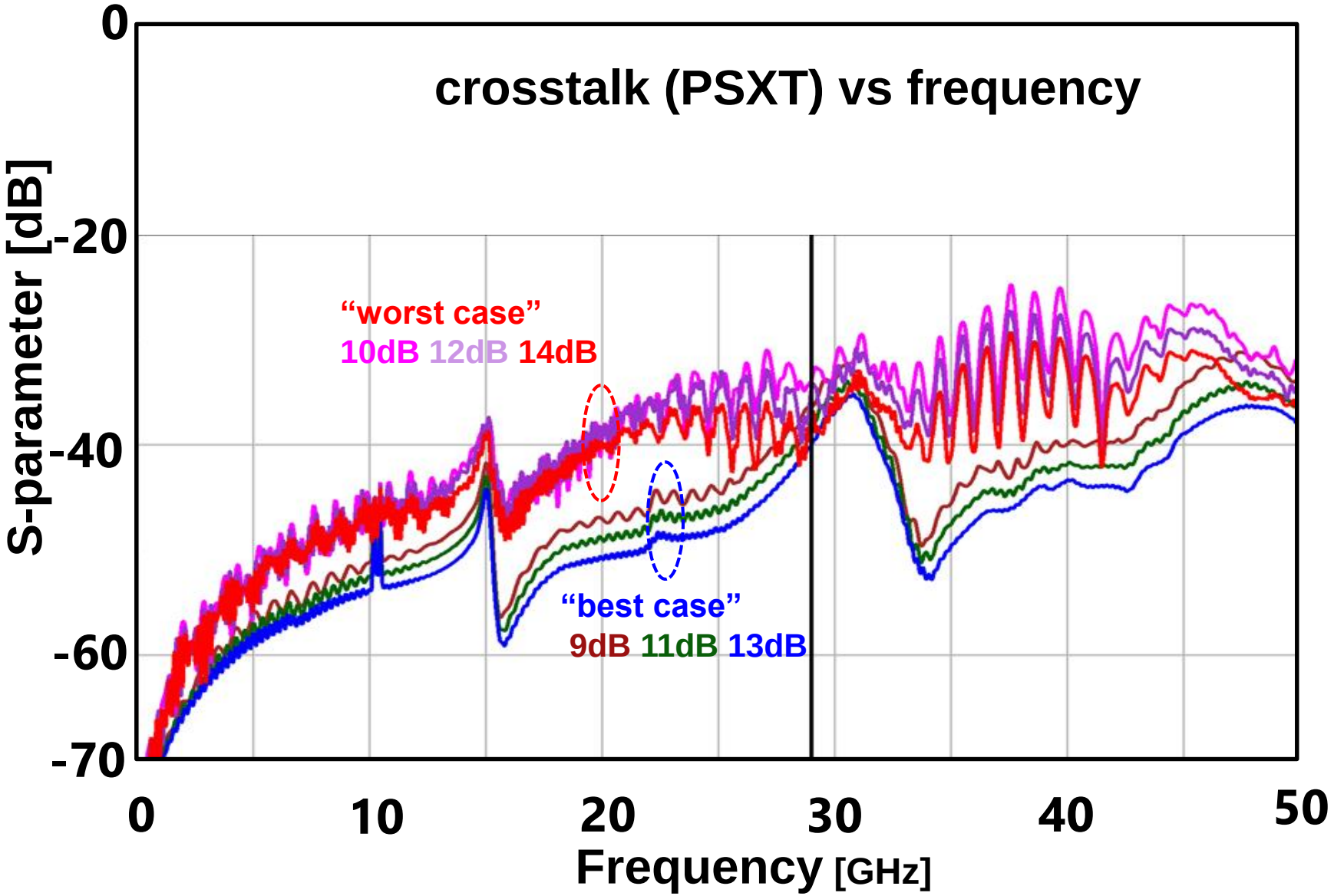
http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics : IL (SDD21)



http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.2.1 Channel Characteristics : crosstalk

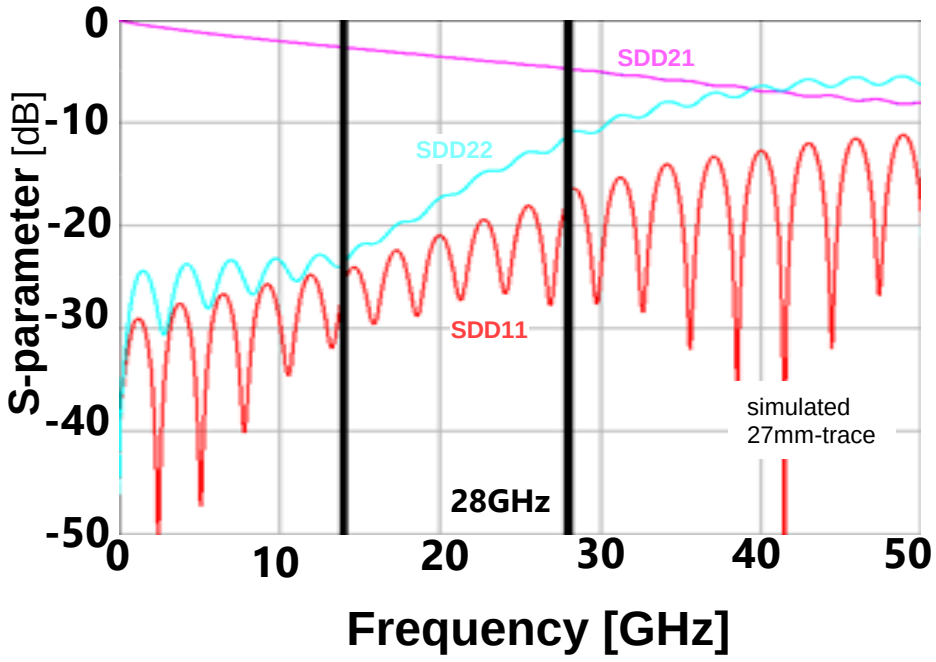


http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

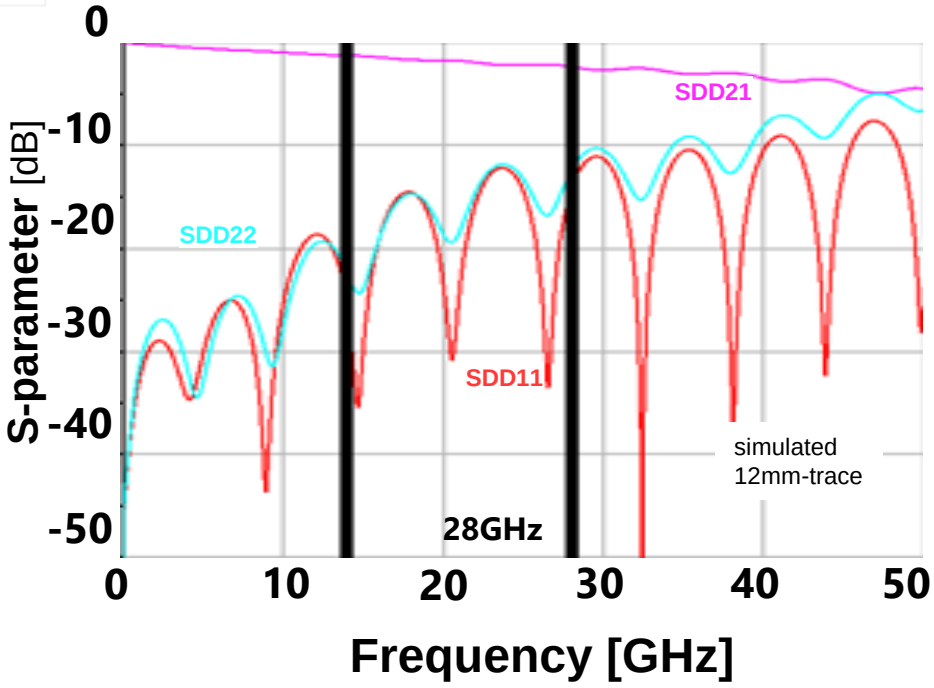
2.2.2 PKG Characteristics

Designed PKG models are used.

27mm PKG (FCBGA, designed)
SDD21: -4.81dB @28GHz
SDD22: -11.1dB @28GHz



12mm PKG (FCBGA, designed)
SDD21: -2.40dB @28GHz
SDD22: -12.5dB @28GHz



note : No xtalk is considered in these PKG models.

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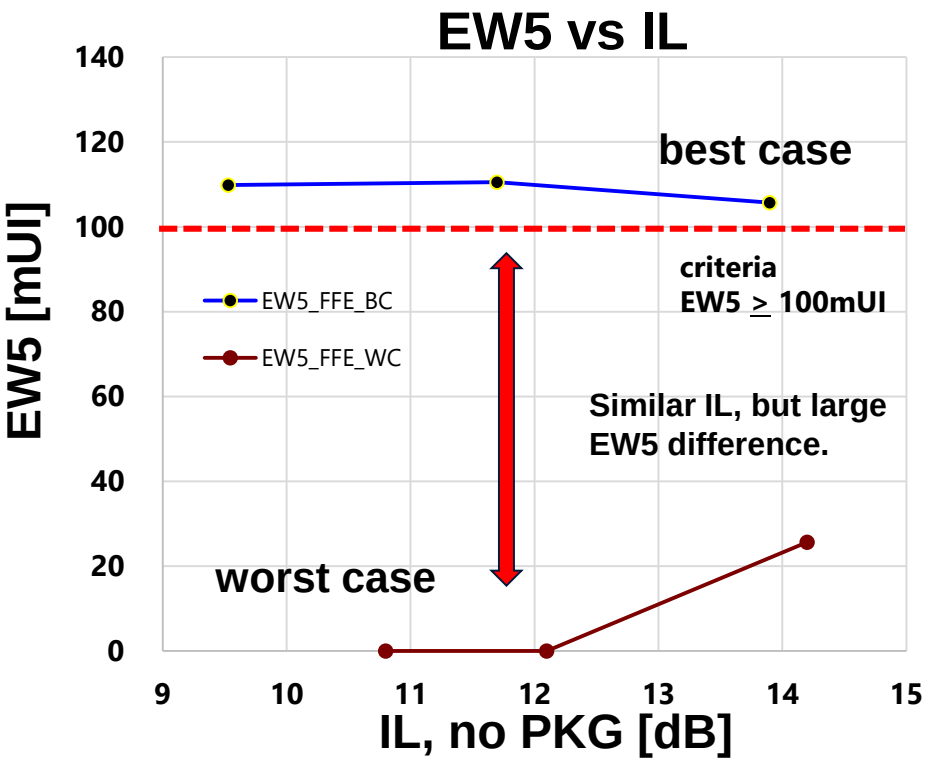
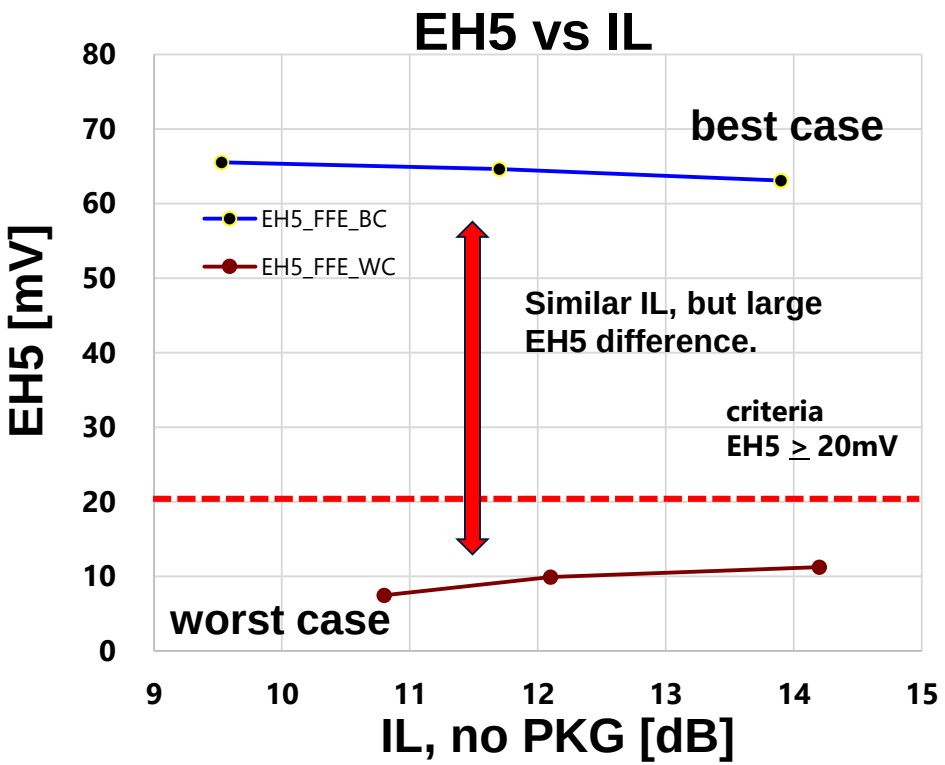
2. Channel simulation

2.3 Simulation Results

2.3.1 EW5/EH5 vs IL

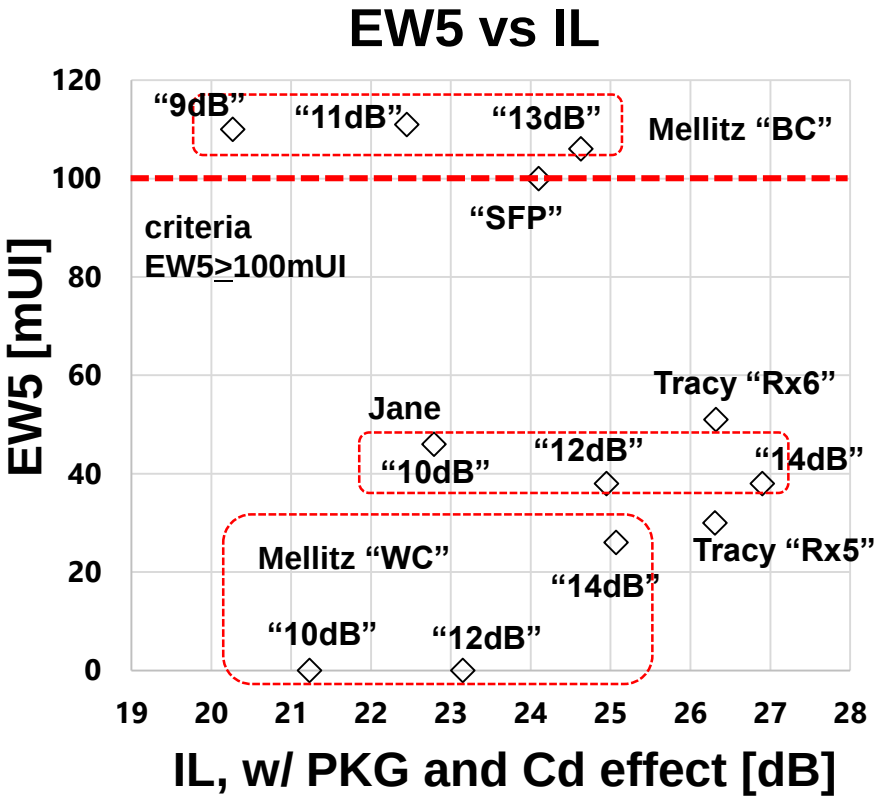


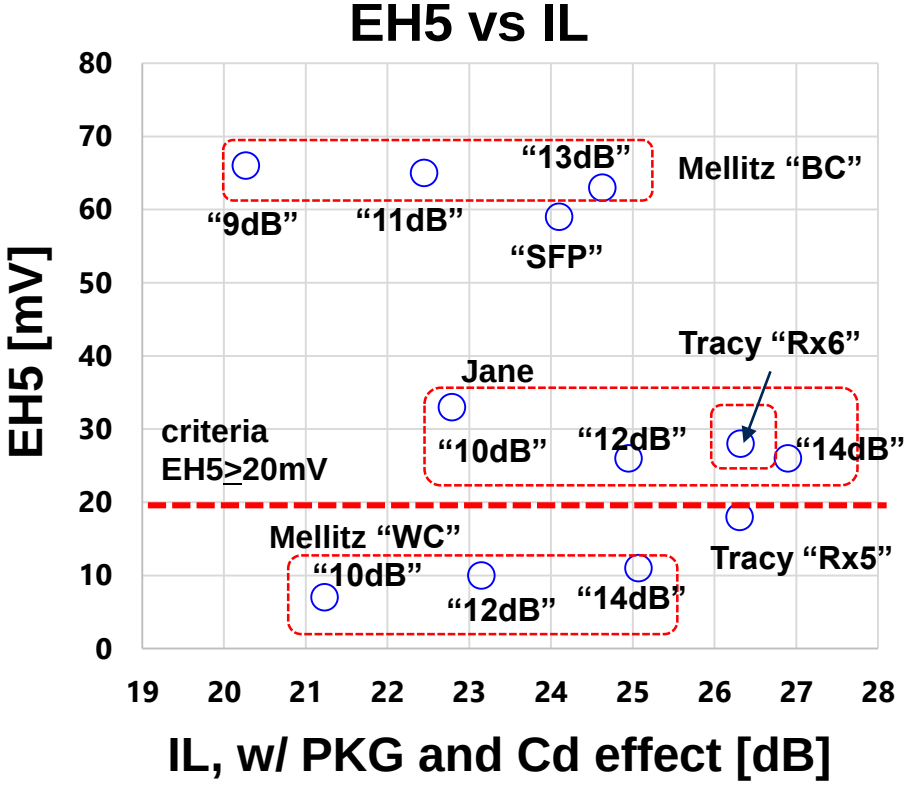


item			unit	#221	#223	#225	#227	#229	#231
channel			type	9dB_BC	10dB_WC	11dB_BC	12dB_WC	13dB_BC	14dB_WC
IL @29GHz, no-PKG			dB	9.53	10.8	11.7	12.1	13.9	14.2
eye	EW5	upp	mUI	122	0	114	22	116	26
		mid		124	21	128	38	120	33
		low		110	30	111	0	106	35
	EH5	upp	mV	71	7	65	11	63	11
		mid		68	9	68	15	63	14
		low		66	12	67	10	63	13

channel_http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.3.1 EW5/EH5 vs IL (with PKG, Cd effect)

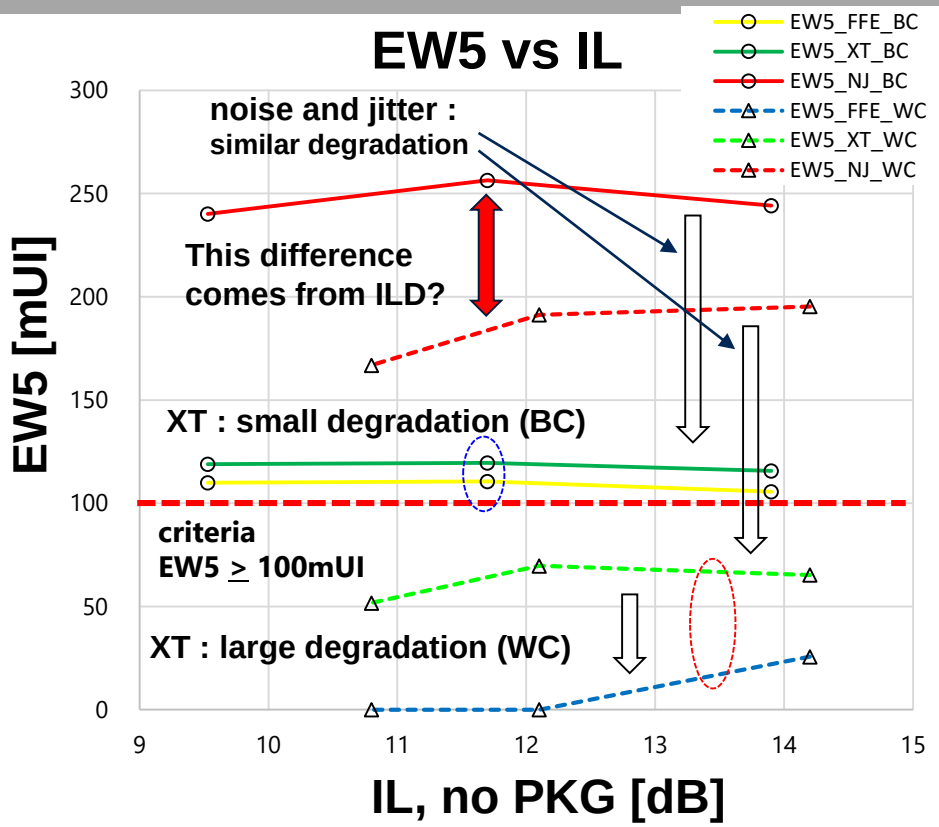


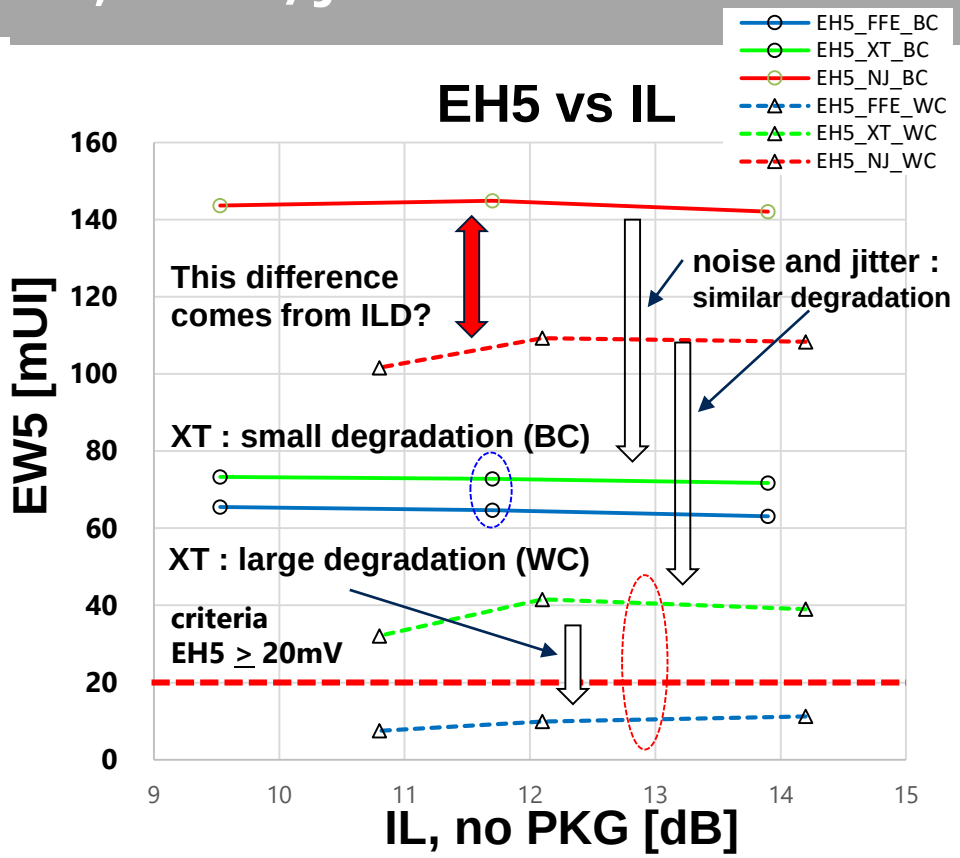


- The effect of IL (insertion loss) is not so obvious.
- Other factors, like crosstalk, ILD and/or reflection affect.
- It may be useful to utilize "COM" as a reference to design channels, even if it is as "informative" spec.

Mellitz : http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf
Tracy : http://www.ieee802.org/3/100GEL/public/18_01/tracy_100GEL_01a_0118.pdf
Jane : http://www.ieee802.org/3/100GEL/public/tools/c2m/lim_100GEL_02_0318.zip
"SFP" : http://www.ieee802.org/3/ck/public/18_05/sakai_3ck_01a_0518.pdf

2.3.1 EW5/EH5 vs IL (no PKG) : XT, noise/jitter effect



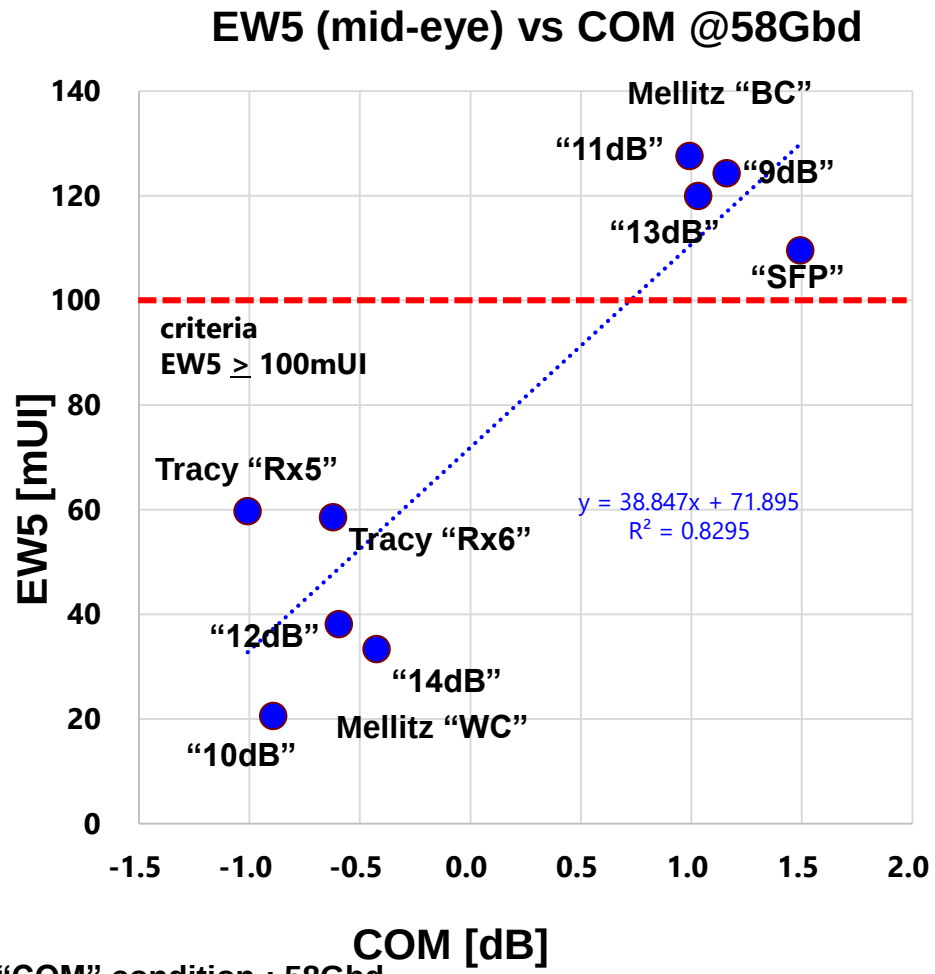


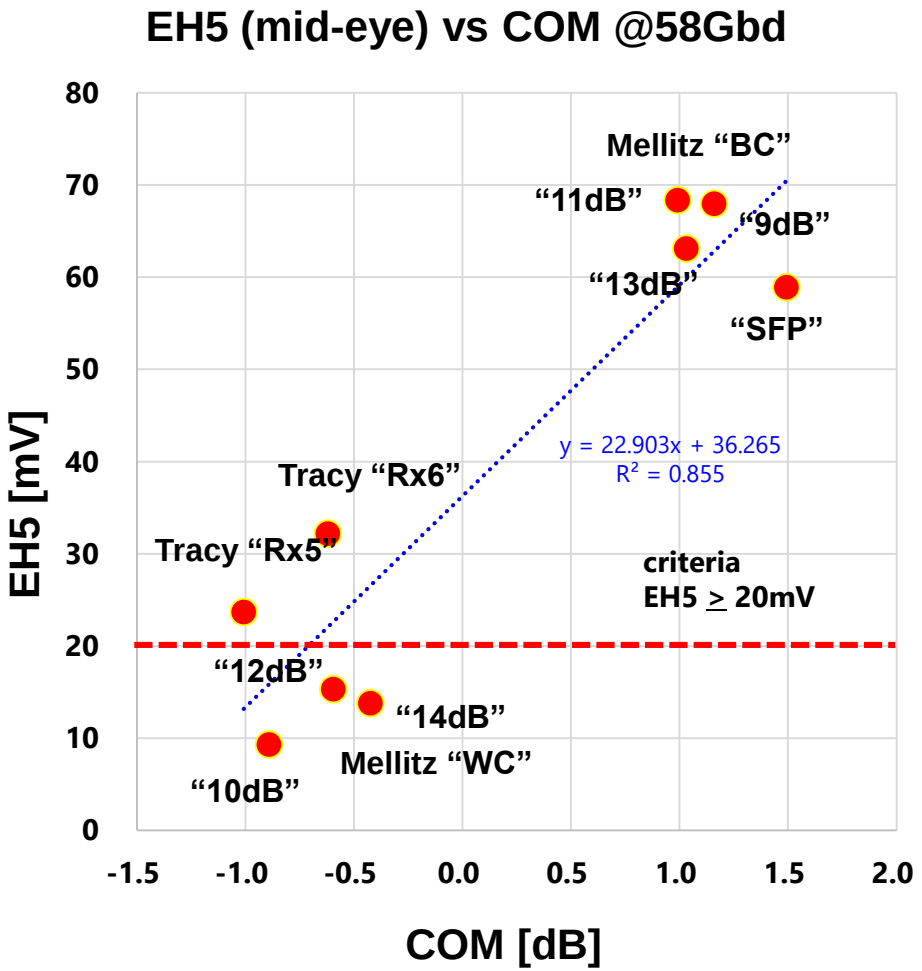
item		unit	#221	#233	#234	#223	#235	#236	#225	#237	#238	#227	#239	#240	#229	#241	#242	#231	#243	#244
channel (IL, dB)			9dB_BC (9.5)			10dB_WC (10.8)			11dB_BC (11.7)			12dB_WC (12.1)			13dB_BC (13.9)			14dB_WC (14.2)		
XT, Noise/Jitter			X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO
eye EW5	upp	mUI	122	133	265	0	54	171	114	124	260	22	70	191	116	127	260	26	65	195
	mid		124	136	265	21	52	167	128	139	273	38	79	208	120	131	269	33	81	212
	low		110	119	240	30	80	212	111	120	256	0	74	212	106	116	244	35	75	212
eye EH5	upp	mV	71	80	151	7	32	106	65	73	145	11	42	115	63	72	142	11	39	117
	mid		68	77	144	9	36	102	68	77	149	15	49	113	63	72	146	14	44	108
	low		66	73	153	12	40	103	67	76	155	10	42	109	63	72	153	13	44	108

X,NJ : with crosstalk and noise/jitter
NJ : no crosstalk, with noise/jitter
NO : no crosstalk, no noise/jitter

channel http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

2.3.1 EW5/EH5 vs COM





"COM" condition : 58Gbd
- Rx-FFE (5-tap, 4-post) included
  (test version COM 2.34 by Mellitz)
- CTLE pole and zero, fb/2.5(fp1,fz), fb(fp2), fb/80(LF)

"COM" values are well correlated to EW5/EH5.
- For C2M channel estimation, "COM" can a good tool.
- These "COM" values for C2M channels are not direct criteria of "good" or "bad" channels, for now.

Mellitz : http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf
Tracy : http://www.ieee802.org/3/100GEL/public/18_01/tracy_100GEL_01a_0118.pdf
"SFP" : http://www.ieee802.org/3/ck/public/18_05/sakai_3ck_01a_0518.pdf

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3. Conclusion

3. Conclusion

1. C2M channel discussion is often based on IL (insertion loss) only.
   - However, as this result shows, other factors affect eye opening significantly.
   - Using “COM” may be a solution, even as “informative”.
2. The degradation of eye opening depends on XT and non-noise(N)/jitter(J) factors.
   - Without XT and N/J, there still difference between “BC” channel and “WC” channel with same IL.
     - It may come from ILD or higher than Nyquist IL “suck”. Need further investigation.
3. Further investigation needed.
   - Comparison with COM including Rx FFE
   - Equalization
   - PKG parameters (COM PKG model or “standard” PKG S-parameter)
   - Other Channel models, parameters

Thank you!

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backup slides

A1 Simulation Summary (Mellitz *, C2M 9dB~14dB)

item			unit	#221	#222	#223	#224	#225	#226	#227	#228	#229	#230	#231	#232
Channel		type		9dB_BC		10dB_WC		11dB_BC		12dB_WC		13dB_BC		14dB_WC	
		IL noPKG [dB]		9.5		10.8		11.7		12.1		13.9		14.2	
		PSXT [dB]		-36.4		-33.8		-37.9		-34.5		-40.0		-38.0	
Tx	FFE	c(-2)		0.03	0.02	0.046	0.036	0.033	0.025	0.045	0.031	0.04	0.021	0.053	0.035
		c(-1)		-0.26	-0.25	-0.28	-0.27	-0.26	-0.25	-0.27	-0.26	-0.26	-0.25	-0.28	-0.27
		c(0)		0.72	0.74	0.68	0.70	0.71	0.72	0.68	0.71	0.70	0.73	0.66	0.70
		c(1)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rx	CTLE	p1_HF		0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
		p2_HF		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		z_HF		0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		p_LF		0.11	0.19	0.12	0.25	0.09	0.16	0.10	0.20	0.08	0.13	0.10	0.17
		z_LF		0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01
	FFE	ffe(0)		0.904	---	0.945	---	0.935	---	0.899	---	0.947	---	0.969	---
		ffe(1)		0.009	---	-0.016	---	-0.026	---	-0.006	---	-0.055	---	-0.056	---
		ffe(2)		0.090	---	0.091	---	0.099	---	0.110	---	0.112	---	0.107	---
		ffe(3)		0.010	---	-0.022	---	0.006	---	-0.011	---	0.007	---	-0.026	---
		ffe(4)		-0.013	---	0.002	---	-0.014	---	0.009	---	-0.011	---	0.005	---
	DFE	tap		0	1	0	1	0	1	0	1	0	1	0	1
eye	EW5	upp	mUI	**122**	**91**	**0**	**0**	**114**	**91**	**22**	**21**	**116**	**80**	**26**	**0**
		mid		**124**	**125**	**21**	**0**	**128**	**124**	**38**	**45**	**120**	**112**	**33**	**30**
		low		**110**	**106**	**30**	**0**	**111**	**106**	**0**	**0**	**106**	**95**	**35**	**0**
	EH5	upp	mV	**71**	**45**	**7**	**13**	**65**	**47**	**11**	**9**	**63**	**41**	**11**	**8**
		mid		**68**	**49**	**9**	**14**	**68**	**51**	**15**	**15**	**63**	**42**	**14**	**11**
		low		**66**	**51**	**12**	**16**	**67**	**51**	**10**	**13**	**63**	**45**	**13**	**12**

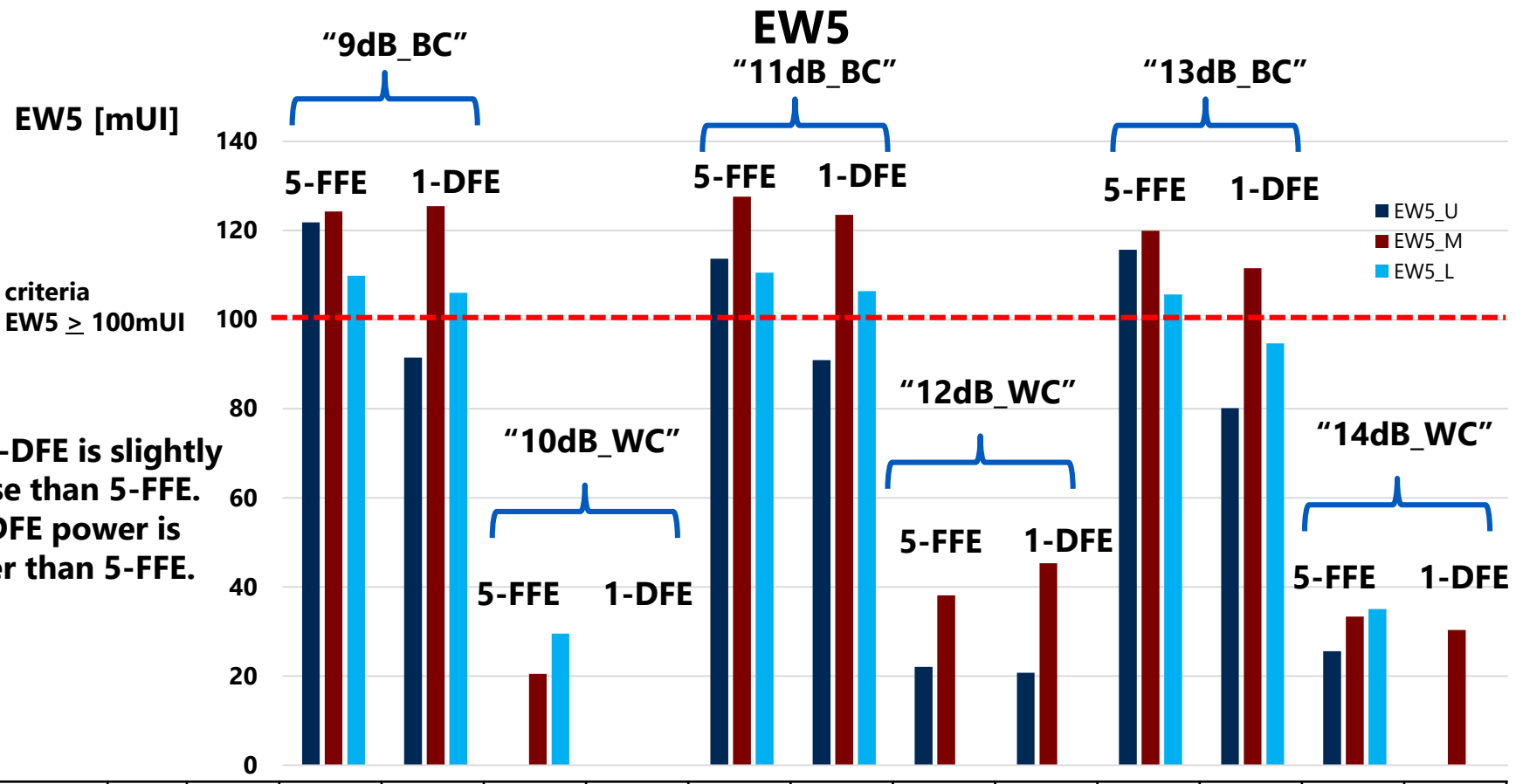
channel http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A2 Simulation Summary (Mellitz C2M, XT, noise/jitter)

item			unit	#221	#233	#234	#223	#235	#236	#225	#237	#238	#227	#239	#240	#229	#241	#242	#231	#243	#244
Channel		type		9dB_BC			10dB_WC			11dB_BC			12dB_WC			13dB_BC			14dB_WC		
		IL noPKG [dB]		9.5			10.8			11.7			12.1			13.9			14.2		
		XT		yes	no		yes	no		yes	no		yes	no		yes	no		yes	no	
Tx	SNDR	[dB]		32.5		N/A	32.5		N/A	32.5		N/A	32.5		N/A	32.5		N/A	32.5		N/A
	RJrms	[mUI]		10		0	10		0	10		0	10		0	10		0	10		0
	DJ	[mUI]		50		0	50		0	50		0	50		0	50		0	50		0
Rx	eta0	[v^2/GHz]		8.2E-9		0	8.2E-9		0	8.2E-9		0	8.2E-9		0	8.2E-9		0	8.2E-9		0
	RJrms	[mUI]		10		0	10		0	10		0	10		0	10		0	10		0
Tx	FFE	c(-2)		0.030	0.030	0.030	0.046	0.046	0.046	0.033	0.033	0.033	0.045	0.045	0.045	0.036	0.036	0.036	0.053	0.053	0.053
		c(-1)		-0.255	-0.255	-0.255	-0.277	-0.277	-0.277	-0.259	-0.259	-0.259	-0.274	-0.274	-0.274	-0.260	-0.260	-0.260	-0.283	-0.283	-0.283
		c(0)		0.715	0.715	0.715	0.677	0.677	0.677	0.708	0.708	0.708	0.683	0.683	0.683	0.704	0.704	0.704	0.664	0.664	0.664
		c(1)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rx	CTLE	p1_HF		0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
		p2_HF		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
		z_HF		0.028	0.028	0.028	0.030	0.030	0.030	0.023	0.023	0.023	0.025	0.025	0.025	0.019	0.019	0.019	0.021	0.021	0.021
		p_LF		0.106	0.106	0.106	0.124	0.124	0.124	0.093	0.093	0.093	0.099	0.099	0.099	0.080	0.080	0.080	0.097	0.097	0.097
		z_LF		0.022	0.022	0.022	0.025	0.025	0.025	0.018	0.018	0.018	0.020	0.020	0.020	0.015	0.015	0.015	0.016	0.016	0.016
	FFE	ffe(0)		0.904	0.904	0.904	0.945	0.945	0.945	0.935	0.935	0.935	0.899	0.899	0.899	0.947	0.947	0.947	0.969	0.969	0.969
		ffe(1)		0.009	0.009	0.009	-0.016	-0.016	-0.016	-0.026	-0.026	-0.026	-0.006	-0.006	-0.006	-0.055	-0.055	-0.055	-0.056	-0.056	-0.056
		ffe(2)		0.090	0.090	0.090	0.091	0.091	0.091	0.099	0.099	0.099	0.110	0.110	0.110	0.112	0.112	0.112	0.107	0.107	0.107
		ffe(3)		0.010	0.010	0.010	-0.022	-0.022	-0.022	0.006	0.006	0.006	-0.011	-0.011	-0.011	0.007	0.007	0.007	-0.026	-0.026	-0.026
		ffe(4)		-0.013	-0.013	-0.013	0.002	0.002	0.002	-0.014	-0.014	-0.014	0.009	0.009	0.009	-0.011	-0.011	-0.011	0.005	0.005	0.005
	DFE	tap		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
eye	EW5	upp	mUI	122	133	265	0	54	171	114	124	260	22	70	191	116	127	260	26	65	195
		mid		124	136	265	21	52	167	128	139	273	38	79	208	120	131	269	33	81	212
		low		110	119	240	30	80	212	111	120	256	0	74	212	106	116	244	35	75	212
	EH5	upp	mV	71	80	151	7	32	106	65	73	145	11	42	115	63	72	142	11	39	117
		mid		68	77	144	9	36	102	68	77	149	15	49	113	63	72	146	14	44	108
		low		66	73	153	12	40	103	67	76	155	10	42	109	63	72	153	13	44	108

channel_http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A3.1 Simulation Summary (EW5, Mellitz* 9dB~14dB)

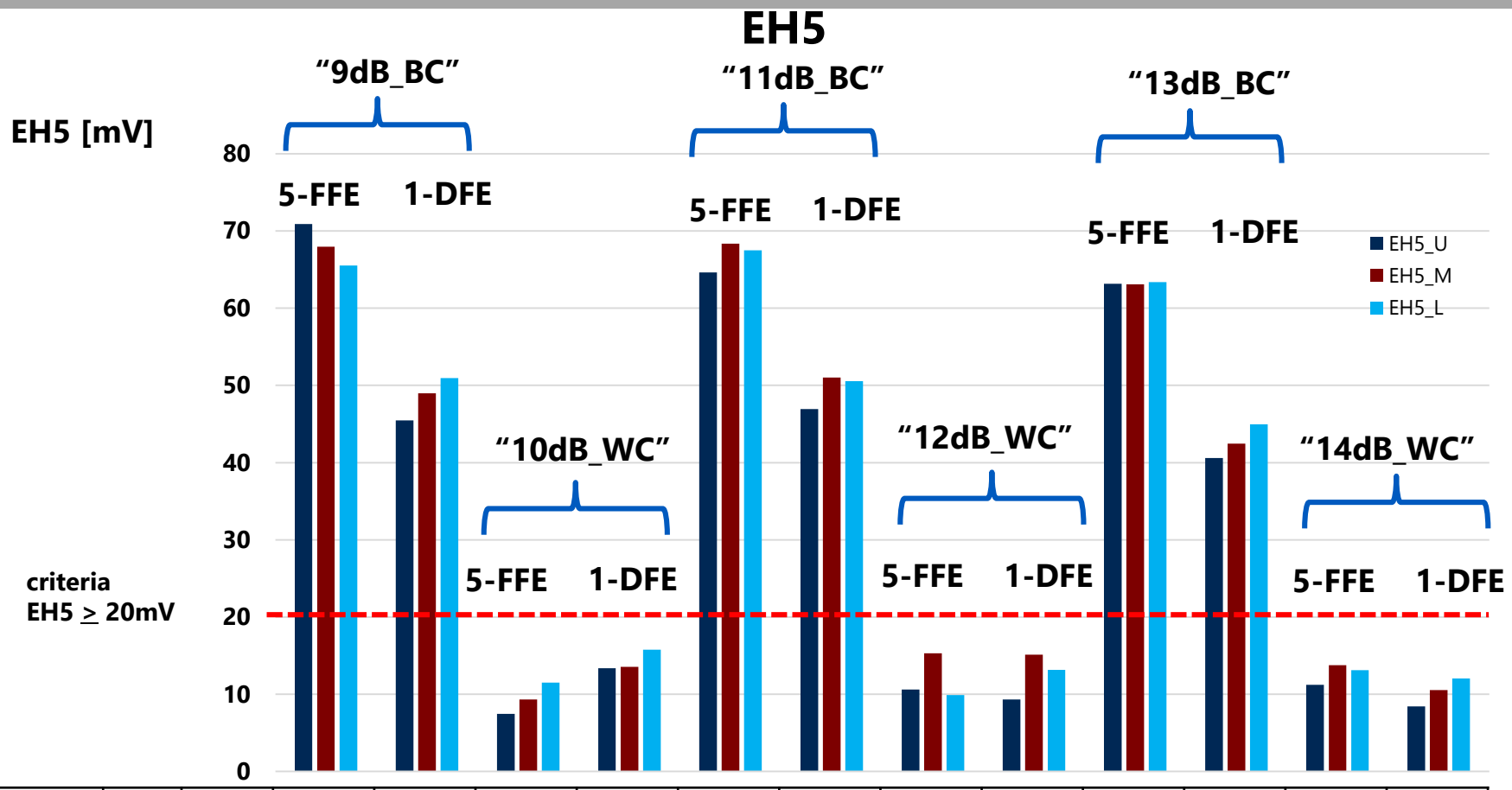


Rx 1-DFE is slightly worse than 5-FFE.
- 1-DFE power is lower than 5-FFE.

item			unit	#221	#222	#223	#224	#225	#226	#227	#228	#229	#230	#231	#232
channel		Samtec		"9dB_BC"		"10dB_WC"		"11dB_BC"		"12dB_WC"		"13dB_BC"		"14dB_WC"	
Rx_FFE		pre/post		0/4	0/0	0/4	0/0	0/4	0/0	0/4	0/0	0/4	0/0	0/4	0/0
Rx_DFE		tap		0	1	0	1	0	1	0	1	0	1	0	1
eye	EW5	upp	mUI	122	91	0	0	114	91	22	21	116	80	26	0
		mid		124	125	21	0	128	124	38	45	120	112	33	30
		low		110	106	30	0	111	106	0	0	106	95	35	0
	EH5	upp	mV	71	45	7	13	65	47	11	9	63	41	11	8
		mid		68	49	9	14	68	51	15	15	63	42	14	11
		low		66	51	12	16	67	51	10	13	63	45	13	12

* http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A2.2 Simulation Summary (EH5, Mellitz* 9dB~14dB)

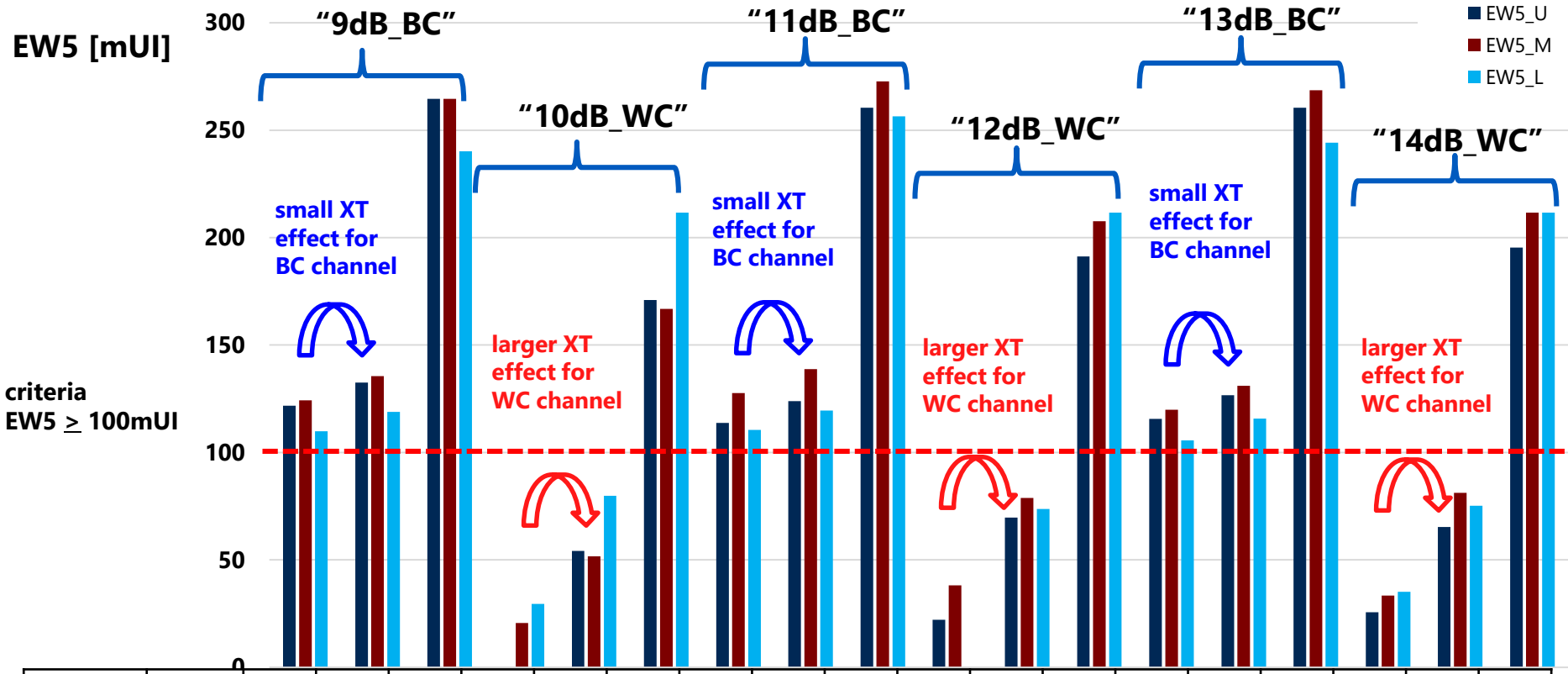


item		unit	#221	#222	#223	#224	#225	#226	#227	#228	#229	#230	#231	#232
channel	Samtec		"9dB_BC"		"10dB_WC"		"11dB_BC"		"12dB_WC"		"13dB_BC"		"14dB_WC"	
Rx_FFE	pre/post		0/4	0/0	0/4	0/0	0/4	0/0	0/4	0/0	0/4	0/0	0/4	0/0
Rx_DFE	tap		0	1	0	1	0	1	0	1	0	1	0	1
eye	EW5	upp	122	91	0	0	114	91	22	21	116	80	26	0
		mid	124	125	21	0	128	124	38	45	120	112	33	30
		low	110	106	30	0	111	106	0	0	106	95	35	0
	EH5	upp	71	45	7	13	65	47	11	9	63	41	11	8
		mid	68	49	9	14	68	51	15	15	63	42	14	11
		low	66	51	12	16	67	51	10	13	63	45	13	12

eye	unit
EW5	mUI
EH5	mV

* http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A4.1 Simulation Summary (channel, EW5 vs XT,Noise/Jitter)

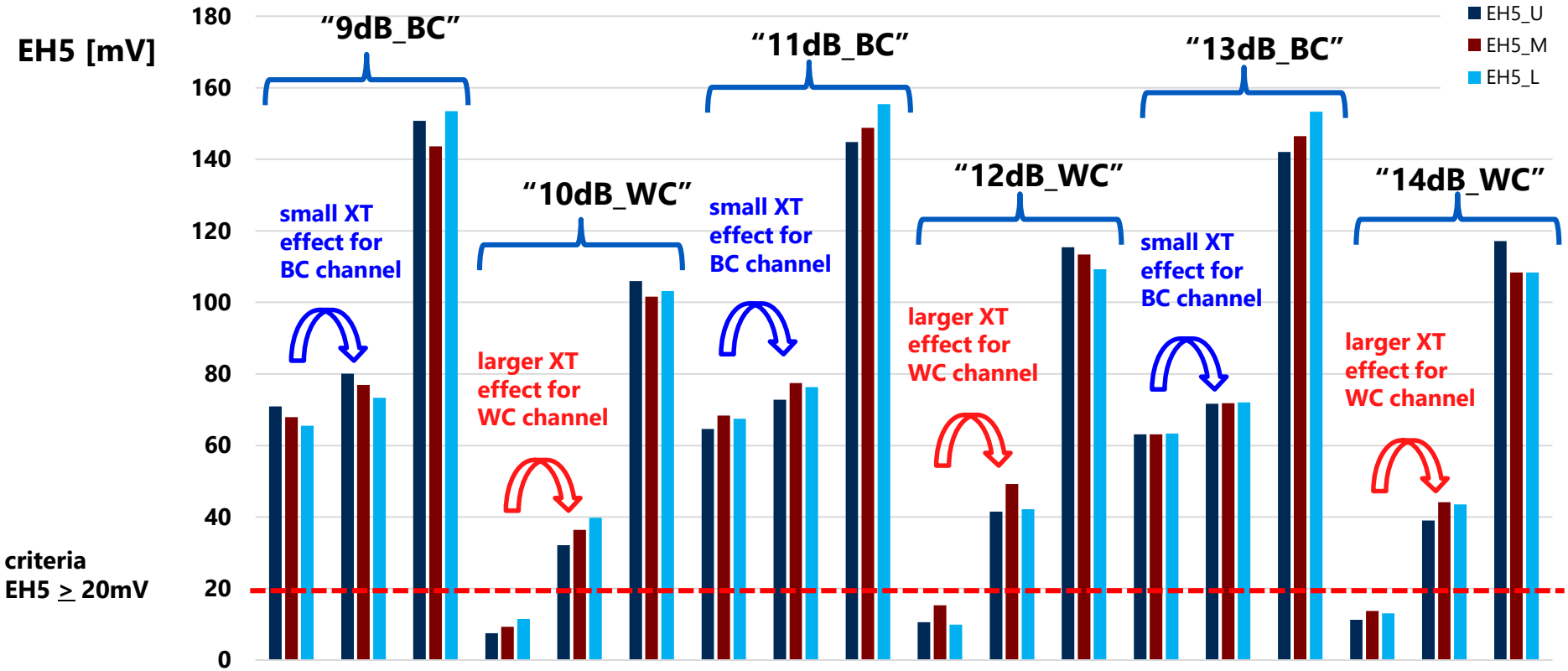


item		unit	#221	#233	#234	#223	#235	#236	#225	#237	#238	#227	#239	#240	#229	#241	#242	#231	#243	#244
channel (IL, dB)			9dB_BC (9.5)			10dB_WC (10.8)			11dB_BC (11.7)			12dB_WC (12.1)			13dB_BC (13.9)			14dB_WC (14.2)		
XT, Noise/Jitter			X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO
eye EW5	upp	mUI	122	133	265	0	54	171	114	124	260	22	70	191	116	127	260	26	65	195
	mid		124	136	265	21	52	167	128	139	273	38	79	208	120	131	269	33	81	212
	low		110	119	240	30	80	212	111	120	256	0	74	212	106	116	244	35	75	212
eye EH5	upp	mV	71	80	151	7	32	106	65	73	145	11	42	115	63	72	142	11	39	117
	mid		68	77	144	9	36	102	68	77	149	15	49	113	63	72	146	14	44	108
	low		66	73	153	12	40	103	67	76	155	10	42	109	63	72	153	13	44	108

X,NJ : with crosstalk and noise/jitter
NJ : no crosstalk, with noise/jitter
NO : no crosstalk, no noise/jitter

channel : http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A4.2 Simulation Summary (channel, EH5 vs XT,Noise/Jitter)



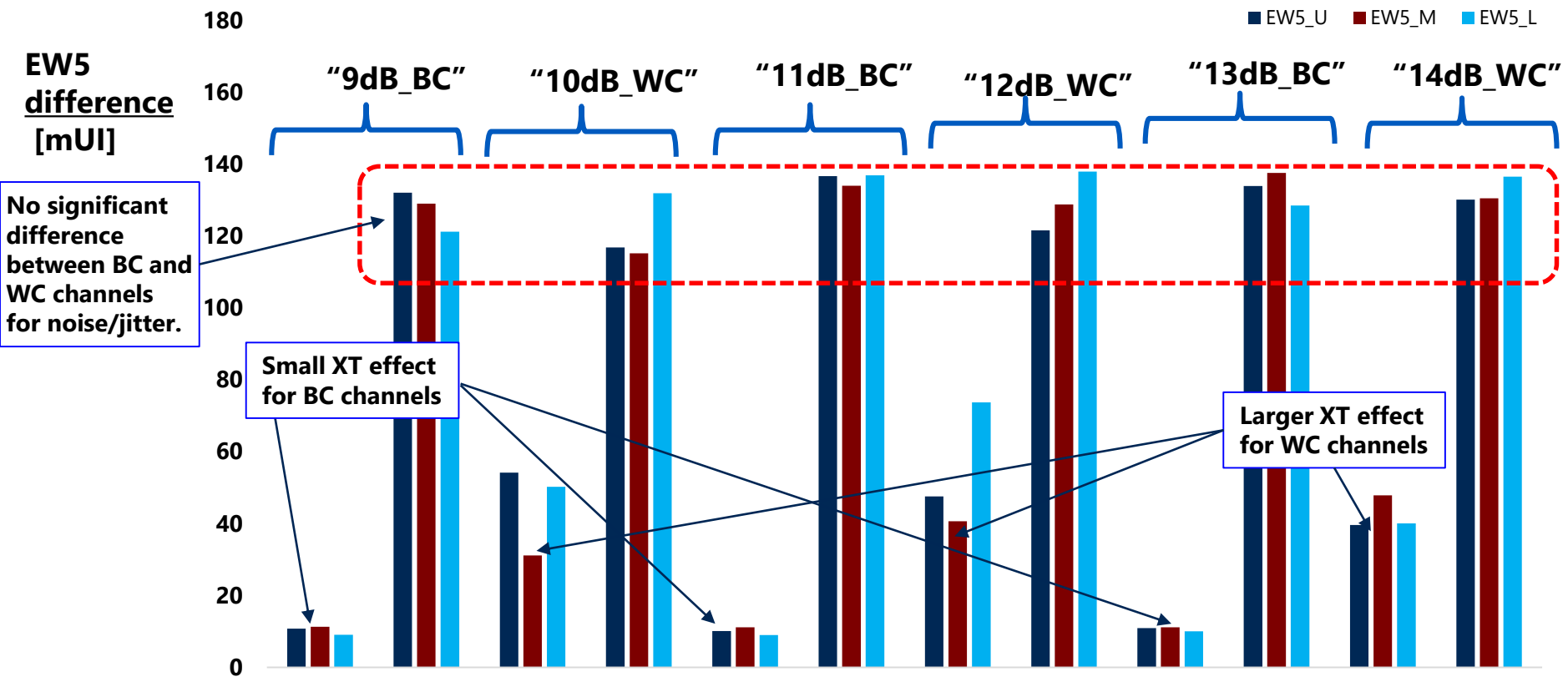
item	unit	#221	#233	#234	#223	#235	#236	#225	#237	#238	#227	#239	#240	#229	#241	#242	#231	#243	#244
channel (IL, dB)		9dB_BC (9.5)			10dB_WC (10.8)			11dB_BC (11.7)			12dB_WC (12.1)			13dB_BC (13.9)			14dB_WC (14.2)		
XT, Noise/Jitter		X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO	X,NJ	NJ	NO
eye EW5	upp	122	133	265	0	54	171	114	124	260	22	70	191	116	127	260	26	65	195
	mid	124	136	265	21	52	167	128	139	273	38	79	208	120	131	269	33	81	212
	low	110	119	240	30	80	212	111	120	256	0	74	212	106	116	244	35	75	212
eye EH5	upp	71	80	151	7	32	106	65	73	145	11	42	115	63	72	142	11	39	117
	mid	68	77	144	9	36	102	68	77	149	15	49	113	63	72	146	14	44	108
	low	66	73	153	12	40	103	67	76	155	10	42	109	63	72	153	13	44	108

mUI / mV

X,NJ : with crosstalk and noise/jitter
NJ : no crosstalk, with noise/jitter
NO : no crosstalk, no noise/jitter

channel http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A4.3 Simulation Summary (channel, EW5 vs XT,Noise/Jitter)



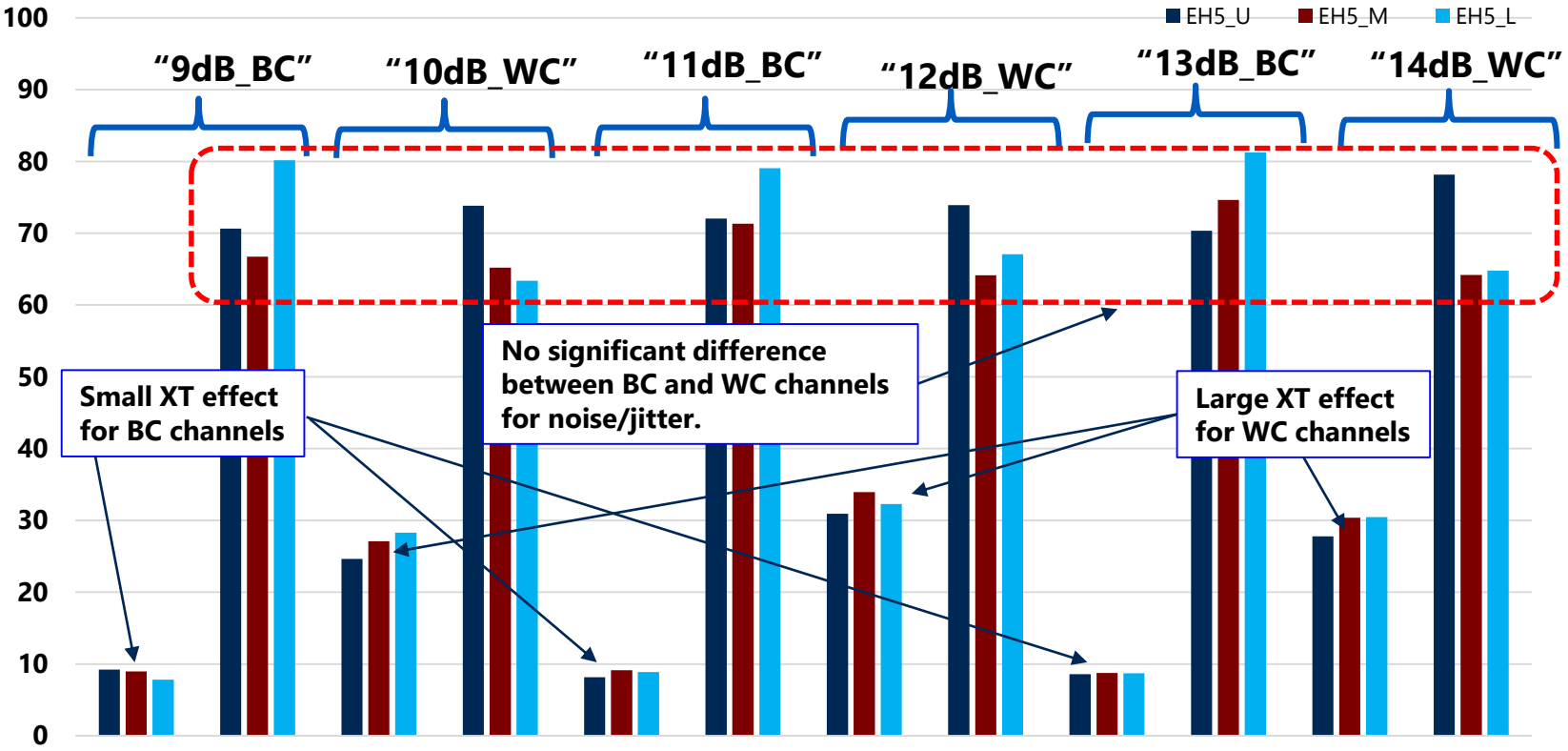
item	unit	#233-#221	#234-#233	#235-#223	#236-#235	#237-#225	#238-#237	#239-#227	#240-#239	#241-#229	#242-#241	#243-#231	#244-#243
channel (IL, dB)		9dB_BC (9.5)		10dB_WC (10.8)		11dB_BC (11.7)		12dB_WC (12.1)		13dB_BC (11.7)		14dB_WC (12.1)	
XT, Noise/Jitter		XT	NJ	XT	NJ	XT	NJ	XT	NJ	XT	NJ	XT	NJ
eye EW5 diff	upp	11	132	54	117	10	137	48	122	11	134	40	130
	mid	11	129	31	115	11	134	41	129	11	138	48	130
	low	9	121	50	132	9	137	74	138	10	128	40	137
eye EH5 diff	upp	9	71	25	74	8	72	31	74	9	70	28	78
	mid	9	67	27	65	9	71	34	64	9	75	30	64
	low	8	80	28	63	9	79	32	67	9	81	30	65

mUI / mV

XT : difference between with and without crosstalk
NJ : difference between with and without noise/jitter

channel http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A4.4 Simulation Summary (channel, EW5 vs XT,Noise/Jitter)

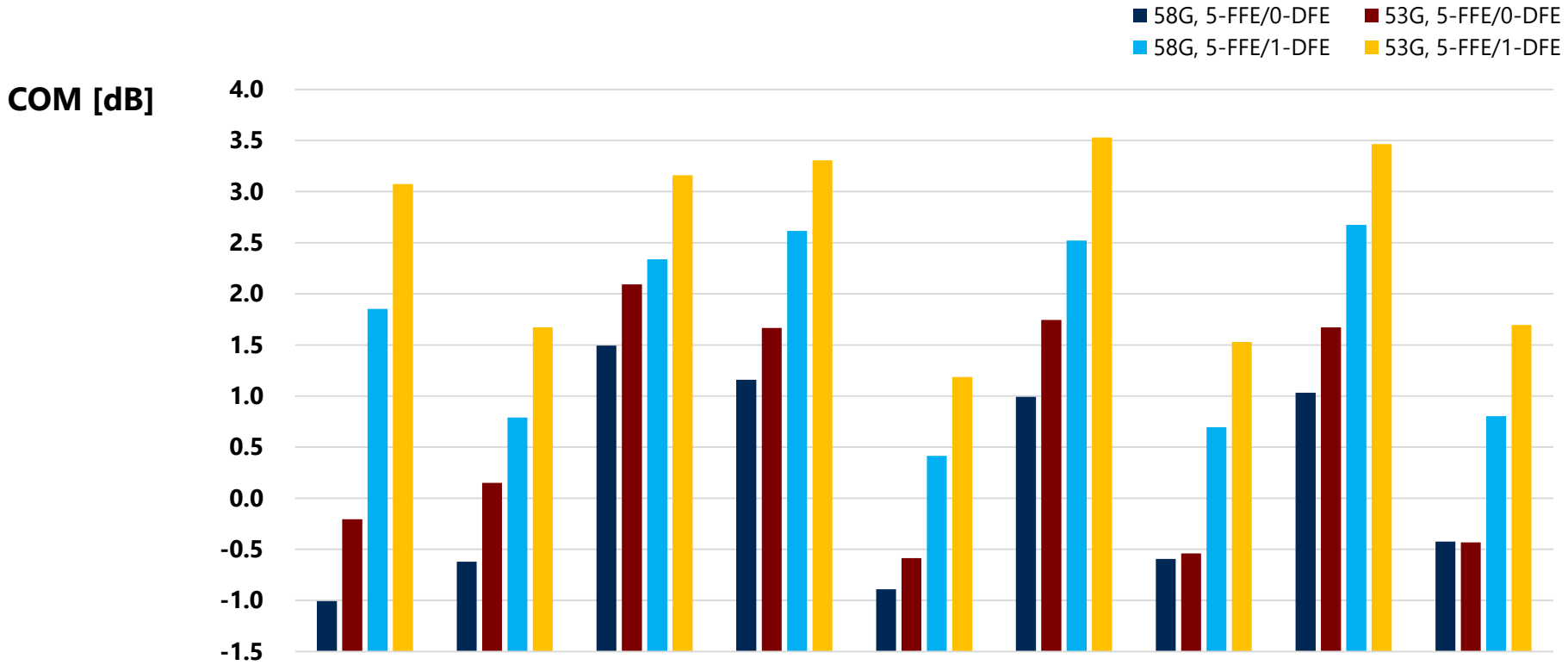


item	unit		#233-#221	#234-#233	#235-#223	#236-#235	#237-#225	#238-#237	#239-#227	#240-#239	#241-#229	#242-#241	#243-#231	#244-#243
channel (IL, dB)			9dB_BC (9.5)		10dB_WC (10.8)		11dB_BC (11.7)		12dB_WC (12.1)		13dB_BC (11.7)		14dB_WC (12.1)	
XT, Noise/Jitter			XT	NJ	XT	NJ	XT	NJ	XT	NJ	XT	NJ	XT	NJ
eye EW5 diff	upp	mUI	11	132	54	117	10	137	48	122	11	134	40	130
	mid		11	129	31	115	11	134	41	129	11	138	48	130
	low		9	121	50	132	9	137	74	138	10	128	40	137
eye EH5 diff	upp	mV	9	71	25	74	8	72	31	74	9	70	28	78
	mid		9	67	27	65	9	71	34	64	9	75	30	64
	low		8	80	28	63	9	79	32	67	9	81	30	65

XT : difference between with and without crosstalk
NJ : difference between with and without noise/jitter

channel http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf

A5.1 Simulation Summary (COM sim, fb and DFE effect)

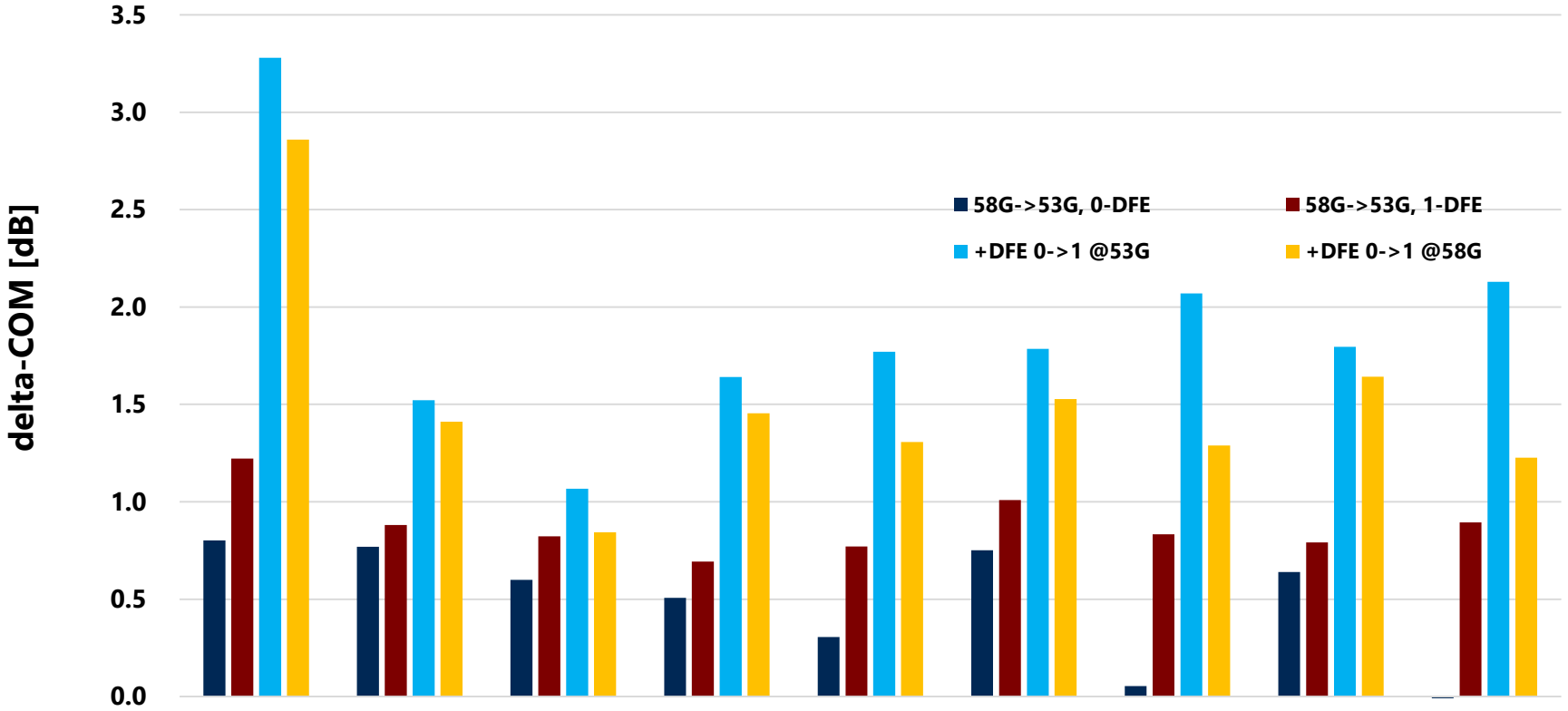


COM [dB]				Tracy_Rx5	Tracy_Rx6	"SFP"	Mellitz_ 9dB_BC	Mellitz_ 10dB_WC	Mellitz_ 11dB_BC	Mellitz_ 12dB_WC	Mellitz_ 13dB_BC	Mellitz_ 14dB_WC
IL [dB]		@ 29GHz		16.94	16.31	13.14	9.53	10.85	11.69	12.15	13.91	14.17
		@ 26GHz		14.57	14.59	12.43	8.95	9.96	11.16	12.18	13.12	13.87
fb [Gbd]	58	DFE	0	-1.01	-0.62	1.49	1.16	-0.89	0.99	-0.59	1.03	-0.42
	53		0	-0.21	0.15	2.09	1.67	-0.59	1.74	-0.54	1.67	-0.43
	58		1	1.85	0.79	2.34	2.61	0.41	2.52	0.70	2.67	0.80
	53		1	3.07	1.67	3.16	3.31	1.19	3.53	1.53	3.47	1.70

With 5-FFE + 1-DFE, COM values become better, however, it requires more power and area.

Mellitz : http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf
Tracy : http://www.ieee802.org/3/100GEL/public/18_01/tracy_100GEL_01a_0118.pdf
"SFP" : http://www.ieee802.org/3/ck/public/18_05/sakai_3ck_01a_0518.pdf

A5.2 Simulation Summary (COM sim, fb and DFE effect)



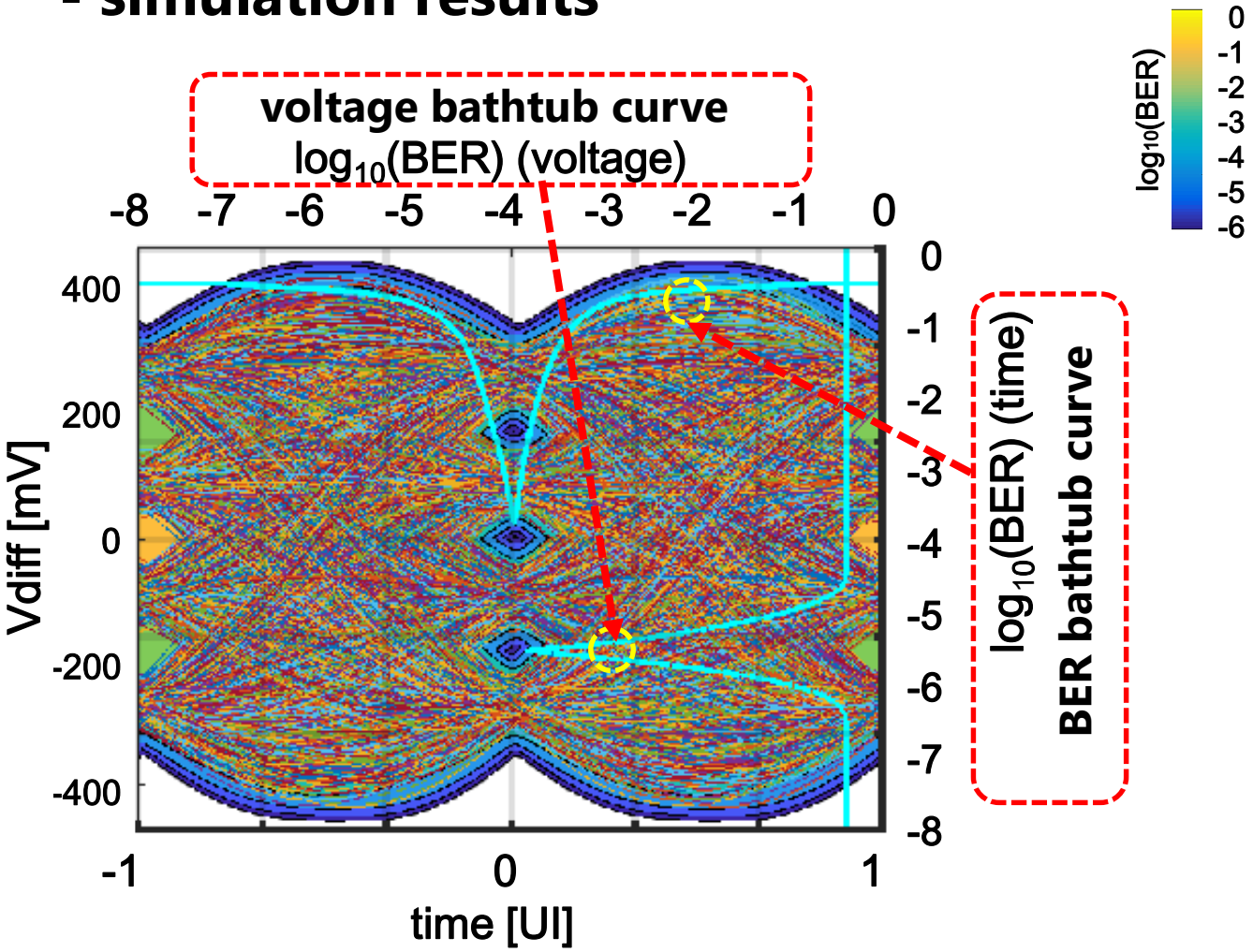
delta COM [dB]		Tracy_Rx5	Tracy_Rx6	"SFP"	Mellitz_ 9dB_BC	Mellitz_ 10dB_WC	Mellitz_ 11dB_BC	Mellitz_ 12dB_WC	Mellitz_ 13dB_BC	Mellitz_ 14dB_WC
IL [dB]	@29GHz	16.94	16.31	13.14	9.53	10.85	11.69	12.15	13.91	14.17
	@26GHz	14.57	14.59	12.43	8.95	9.96	11.16	12.18	13.12	13.87
58G->53G, 0-DFE		0.80	0.77	0.60	0.51	0.31	0.75	0.05	0.64	-0.01
58G->53G, 1-DFE		1.22	0.88	0.82	0.69	0.77	1.01	0.83	0.79	0.89
+DFE 0->1 @53G		3.28	1.52	1.07	1.64	1.77	1.79	2.07	1.80	2.13
+DFE 0->1 @58G		2.86	1.41	0.84	1.45	1.31	1.53	1.29	1.64	1.23

With 5-FFE + 1-DFE, COM values become better, however, it requires more power and area. And the effect is channel dependent.

Mellitz : http://www.ieee802.org/3/ck/public/18_05/mellitz_3ck_02_0518.pdf
Tracy : http://www.ieee802.org/3/100GEL/public/18_01/tracy_100GEL_01a_0118.pdf
"SFP" : http://www.ieee802.org/3/ck/public/18_05/sakai_3ck_01a_0518.pdf

B-0 Rx FFE/DFE output eye

- simulation results

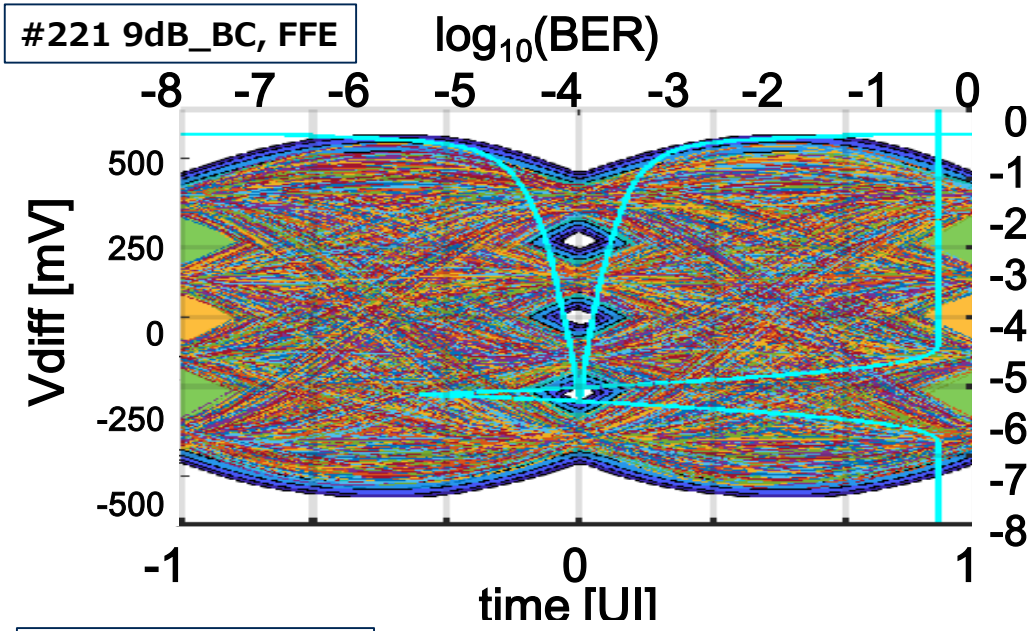


1UI = 17.24ps @58Gbd

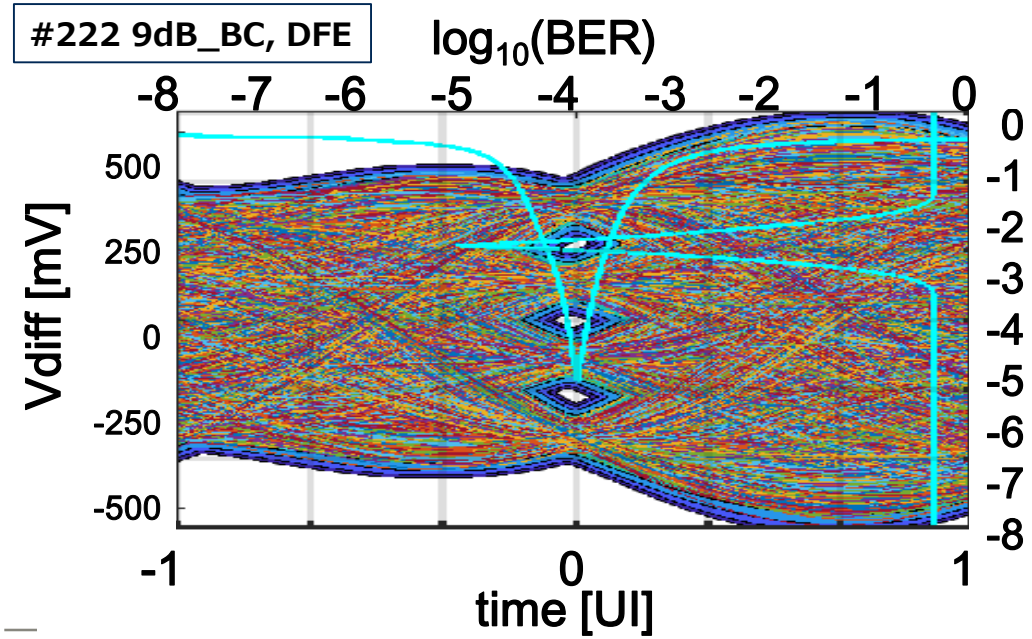
"Colors" are corresponding to each "line" BER.

B-1 Simulation Result (#221/#222)

#221 9dB_BC, FFE



#222 9dB_BC, DFE



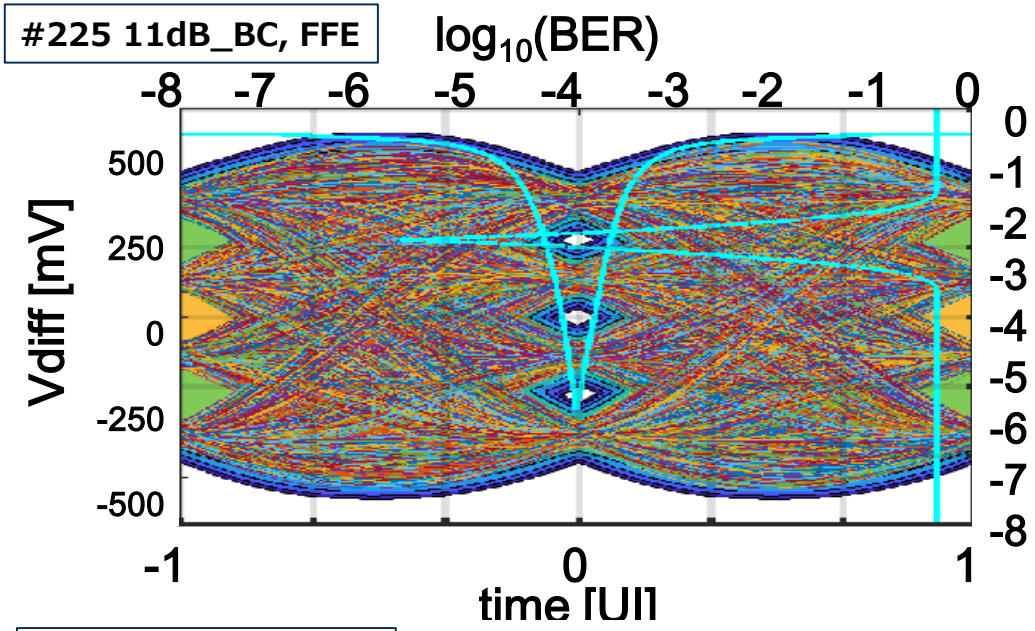
item		unit	#221	#222	#225	#226	#229	#230
ch	type		9dB_BC		11dB_BC		13dB_BC	
	IL [dB]*		9.5		11.7		13.9	
	PSXT [dB]		-36.4		-37.9		-40.0	
Rx FFE	pre/post		0/4	0/0	0/4	0/0	0/4	0/0
Rx DFE	tap		0	1	0	1	0	1
eye EW5	upp	mUI	122	91	114	91	116	80
	mid		124	125	128	124	120	112
	low		110	106	111	106	106	95
eye EH5	upp	mV	71	45	65	47	63	41
	mid		68	49	68	51	63	42
	low		66	51	67	51	63	45

criteria
EW5 ≥ 100mUI
EH5 ≥ 20mV

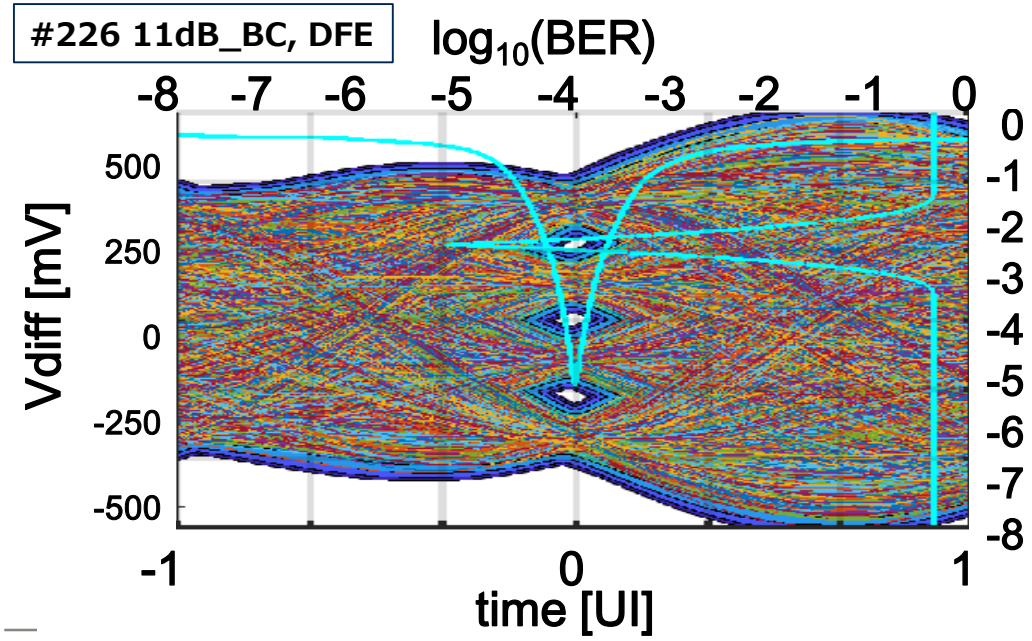
*** : No PKG**

B-2 Simulation Result (#225/#226)

#225 11dB_BC, FFE



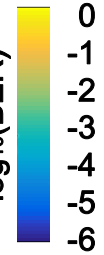
#226 11dB_BC, DFE



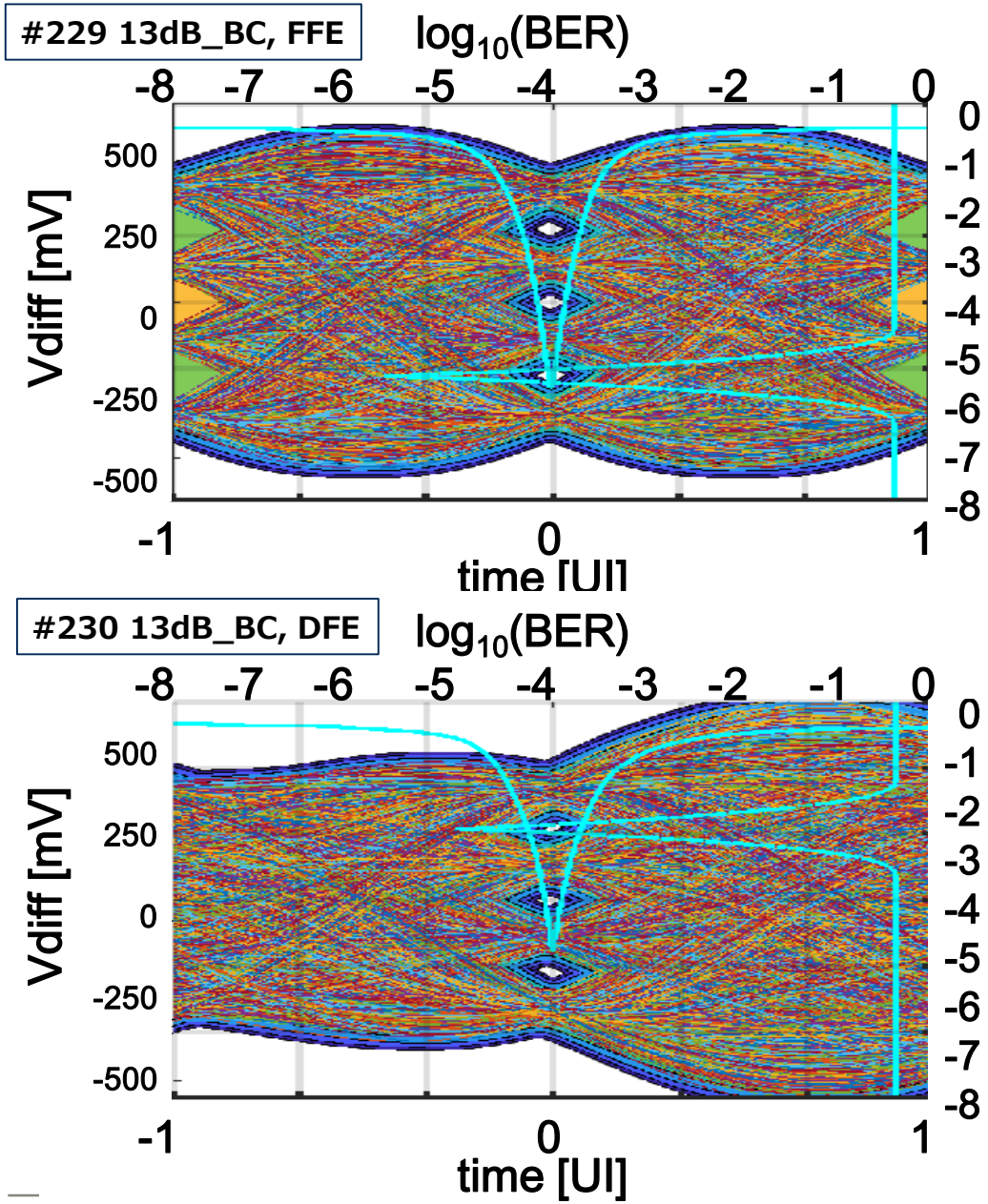
item		unit	#221	#222	#225	#226	#229	#230
ch	type		9dB_BC		11dB_BC		13dB_BC	
	IL [dB]*		9.5		11.7		13.9	
	PSXT [dB]		-36.4		-37.9		-40.0	
Rx FFE	pre/post		0/4	0/0	0/4	0/0	0/4	0/0
Rx DFE	tap		0	1	0	1	0	1
eye EW5	upp	mUI	122	91	114	91	116	80
	mid		124	125	128	124	120	112
	low		110	106	111	106	106	95
eye EH5	upp	mV	71	45	65	47	63	41
	mid		68	49	68	51	63	42
	low		66	51	67	51	63	45

criteria
EW5 ≥ 100mUI
EH5 ≥ 20mV

*** : No PKG**



B-3 Simulation Result (#229/#230)



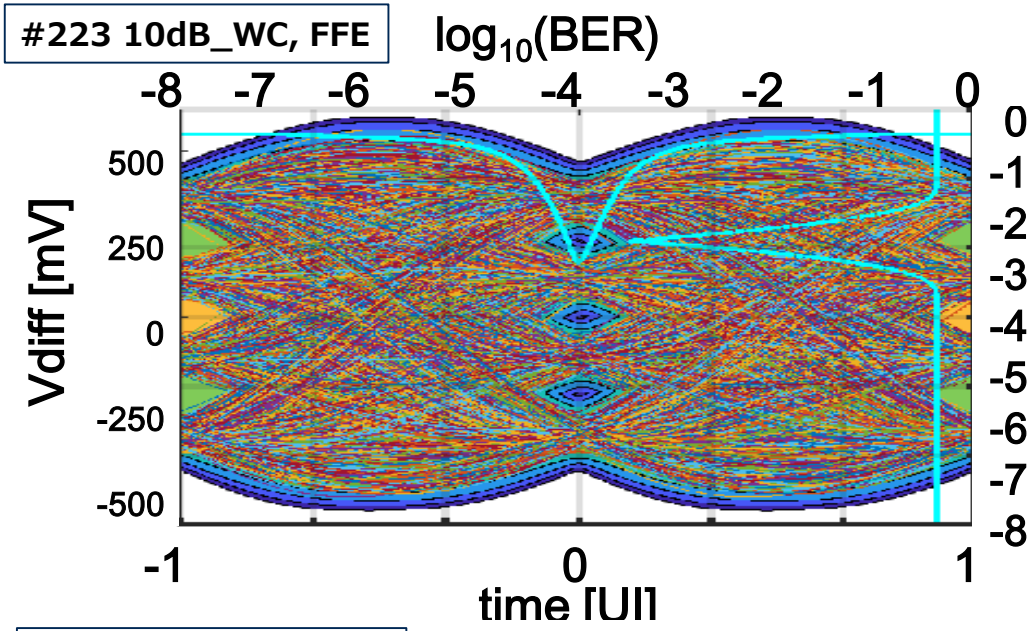
item		unit	#221	#222	#225	#226	#229	#230
ch	type		9dB_BC		11dB_BC		13dB_BC	
	IL [dB]*		9.5		11.7		13.9	
	PSXT [dB]		-36.4		-37.9		-40.0	
Rx FFE	pre/post		0/4	0/0	0/4	0/0	0/4	0/0
Rx DFE	tap		0	1	0	1	0	1
eye EW5	upp	mUI	122	91	114	91	116	80
	mid		124	125	128	124	120	112
	low		110	106	111	106	106	95
eye EH5	upp	mV	71	45	65	47	63	41
	mid		68	49	68	51	63	42
	low		66	51	67	51	63	45

criteria
EW5 ≥ 100mUI
EH5 ≥ 20mV

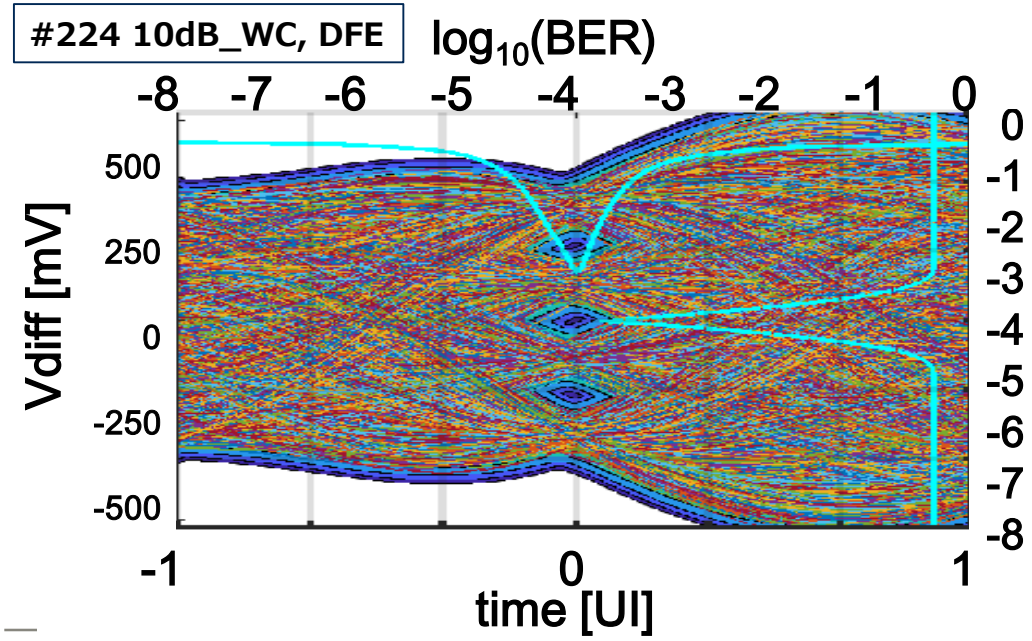
*** : No PKG**

B-4 Simulation Result (#223/#224)

#223 10dB_WC, FFE



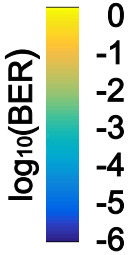
#224 10dB_WC, DFE



item		unit	#223	#224	#227	#228	#231	#232
ch	type		10dB_WC		12dB_WC		14dB_WC	
	IL [dB]*		10.8		12.1		14.2	
	PSXT [dB]		-33.8		-34.5		-38.0	
Rx FFE	pre/post		0/4	0/0	0/4	0/0	0/4	0/0
Rx DFE	tap		0	1	0	1	0	1
eye EW5	upp	mUI	**0**	**0**	**22**	**21**	**26**	**0**
	mid		**21**	**0**	**38**	**45**	**33**	**30**
	low		**30**	**0**	**0**	**0**	**35**	**0**
eye EH5	upp	mV	**7**	**13**	**11**	**9**	**11**	**8**
	mid		**9**	**14**	**15**	**15**	**14**	**11**
	low		**12**	**16**	**10**	**13**	**13**	**12**

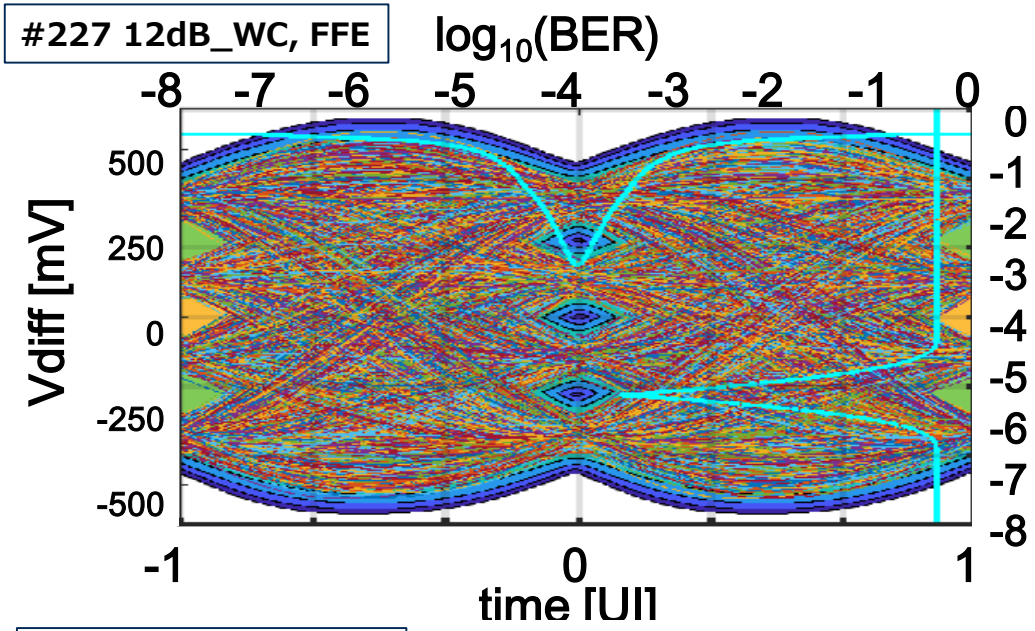
criteria
EW5 ≥ 100mUI
EH5 ≥ 20mV

*** : No PKG**

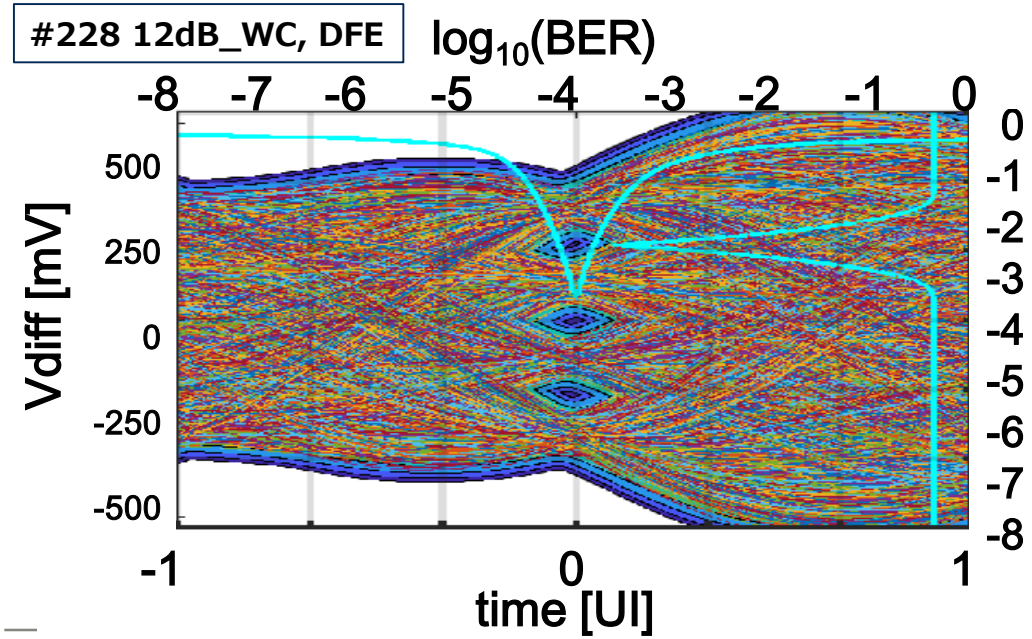


B-5 Simulation Result (#227/#228)

#227 12dB_WC, FFE



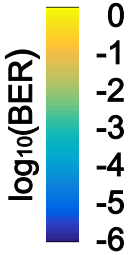
#228 12dB_WC, DFE



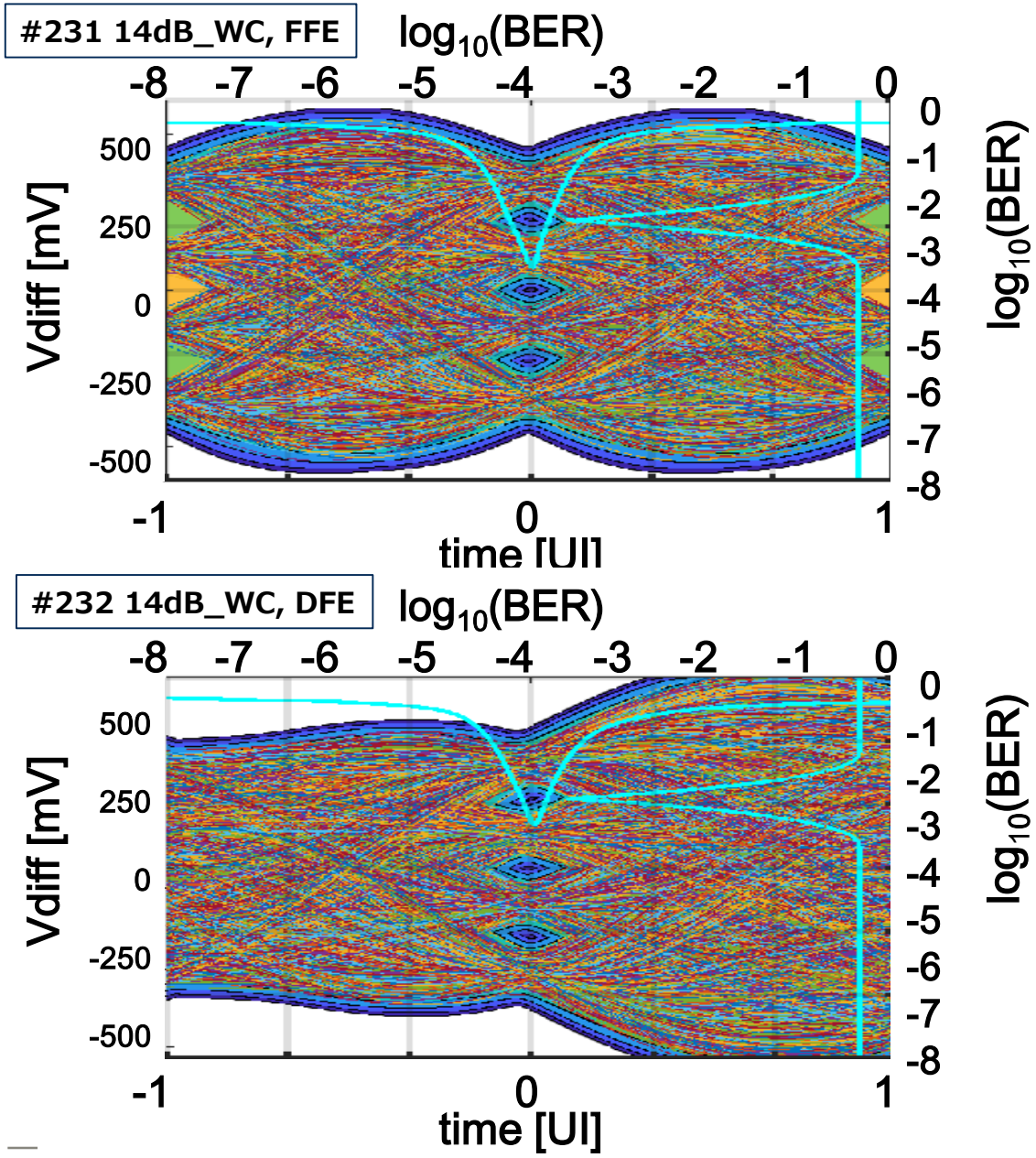
item		unit	#223	#224	#227	#228	#231	#232
ch	type		10dB_WC		12dB_WC		14dB_WC	
	IL [dB]*		10.8		12.1		14.2	
	PSXT [dB]		-33.8		-34.5		-38.0	
Rx FFE	pre/post		0/4	0/0	0/4	0/0	0/4	0/0
Rx DFE	tap		0	1	0	1	0	1
eye EW5	upp	mUI	**0**	**0**	**22**	**21**	**26**	**0**
	mid		**21**	**0**	**38**	**45**	**33**	**30**
	low		**30**	**0**	**0**	**0**	**35**	**0**
eye EH5	upp	mV	**7**	**13**	**11**	**9**	**11**	**8**
	mid		**9**	**14**	**15**	**15**	**14**	**11**
	low		**12**	**16**	**10**	**13**	**13**	**12**

criteria
EW5 ≥ 100mUI
EH5 ≥ 20mV

*** : No PKG**



B-6 Simulation Result (#231/#232)



item		unit	#223	#224	#227	#228	#231	#232
ch	type		10dB_WC		12dB_WC		14dB_WC	
	IL [dB]*		10.8		12.1		14.2	
	PSXT [dB]		-33.8		-34.5		-38.0	
Rx FFE	pre/post		0/4	0/0	0/4	0/0	0/4	0/0
Rx DFE	tap		0	1	0	1	0	1
eye EW5	upp	mUI	**0**	**0**	**22**	**21**	**26**	**0**
	mid		**21**	**0**	**38**	**45**	**33**	**30**
	low		**30**	**0**	**0**	**0**	**35**	**0**
eye EH5	upp	mV	**7**	**13**	**11**	**9**	**11**	**8**
	mid		**9**	**14**	**15**	**15**	**14**	**11**
	low		**12**	**16**	**10**	**13**	**13**	**12**

criteria
EW5 ≥ 100mUI
EH5 ≥ 20mV

*** : No PKG**

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