106Gbps LR COM Investigation (V)

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Intel

Recap of the Basic Assumptions Used In Previous Investigations

Past Investigations

- Investigation (I):http://www.ieee802.org/3/ck/public/18_09/li_3ck_02_0918.pdf
- Investigation (II): http://www.ieee802.org/3/ck/public/18_11/li_3ck_02a_1118.pdf
- Investigation (III): http://www.ieee802.org/3/ck/public/19_01/li_3ck_01_0119.pdf
- Investigation (VI): http://www.ieee802.org/3/ck/public/19_05/li_3ck_01_0519.pdf

Observations

- Most of 802.3ck LR receivers will be ADC-based designs containing long FFE and short DFE
- Straw polls and trends indicated that 802.3ck is to adapt DFE-only baseline RX with increased bmax1 range
- COM evaluations on available 802.3ck channels indicated 20~24 post-taps are needed for adequate link performance
- Floating DFE taps is capable and efficient in improving link performance
- New die termination model proposed: http://www.ieee802.org/3/ck/public/adhoc/jun12_19/healey_3ck_adhoc_01_061219.pdf [1]

Investigation in this study

- Investigate reference RX architectures with various floating tap configurations
- Investigate 2 die termination schemes
- Analysis of 2 critical channels and their impacts on ref RX performance

106Gbps LR COM with Floating Tap DFEs and Termination Schemes

- TX
  - T_r=6.16ps, A_DD = 0.02UI, sigma_RJ = 0.01UI
  - TX EQ
    - 3 pre-taps + 1 post-tap
  - RLM = 0.95, SNR_{TX}=33dB
- RX
  - RX input referred noise (eta_0): 8.2e-9 V^2/GHz
  - Equalization
    - CTLE
      - f_z = f_p1 = 21.25GHz
      - f_p2 = 53.125 GHz
      - f_HP_PZ: 0.664 GHz
  - DFE Configuration
    - 12~24 fixed post-taps plus 1/2/3 banks of 3/4 grouped floating taps to up 40 UI or 80 UI span
    - DFE tap coef.: Fixed Taps: Tap 1 ≤ 0.85, others ≤ 0.3; Floating Taps: ≤0.1
- Package/TX/RX Capacitance and Termination
  - Length: 31/29mm (TX/RX) T-line + 1.8mm PTH
    - T-line/PTH parameters: a1=0.0009909, a2= 0.0002772, tau=6.14e-3 ns/mm, $Zc_{T\text{-}line}$=87.5Ω, Zc_{PTH}=92.5Ω
  - Case 1: *[1]*
    - Cd = 120fF, Ls=120pH, Cb=30fF
    - Cp = 87fF
  - Case 2
    - Cd = 90fF
    - Cp = 87fF
  - Rd: 50 Ohms

802.3ck LR COM Configuration

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	[1.2e-4 1.2e-4]	nF	[TX RX]
L_s	[0.12, 0.12]	nH	[TX RX]
C_b	[0.3e-4 0.3e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (NEXT)	[12 29; 1.8 1.8]	mm	[test cases]
z_p (FEXT)	[12 31; 1.8 1.8]	mm	[test cases]
z_p (RX)	[12 29; 1.8 1.8]	mm	[test cases]
C_p	[0.87e-4 0.87e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.413	V	vp/vf=.694
A_fe	0.413	V	vp/vf=.694
A_ne	0.6081425	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.5		min
c(-1)	[-0.3:0.02:0]		[min:step:max]
c(-2)	[0:0.02:0.12]		[min:step:max]
c(-3)	[-0.06:0.02: 0]		[min:step:max]
c(1)	[-0.2:0.05:0]		[min:step:max]
N_b	12	UI	
b_max(1)	0.85		
b_max(2..N_b)	0.3		
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	21.25	GHz	
f_p1	21.25	GHz	
f_p2	53.125	GHz	
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	0	logical
DISPLAY_WINDOW	0	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\100GEL_KR_{date}\	
SAVE_FIGURES	1	logical
Port Order	[1 3 2 4]	
RUNTAG	KR_eval_	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	10	dB
DER_0	1.00E-04	
T_r	6.16E-03	ns
FORCE_TR	1	logical
Include PCB	0	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	0	logical
TR_TDR	0.01	ns
N	3000	
beta_x	2.53E+09	
rho_x	**0.25**	
fixture delay time	0	s
TDR_W_TXPKG	0	
N_bx	24	UI
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	8.20E-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 0.0009909 0.0002772]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm

Table 92–12 parameters 5.2dB at 26.56GHz		
Parameter	Setting	
board_tl_gamma0_a1_a2	*[0 0.000599 0.0001022]*	1.286 dB/in or 0.0506 dB/mm at 100 ohms
board_tl_tau	*6.200E-03*	ns/mm
board_Z_c	90	Ohm
z_bp (TX)	*102.7*	mm
z_bp (NEXT)	*102.7*	mm
z_bp (FEXT)	*102.7*	mm
z_bp (RX)	*102.7*	mm

Floating Tap Control		
N_bg	**3**	**0 1 2 or 3 groups**
N_bf	*4*	taps per group
N_f	40	UI span for floating taps
bmaxg	0.1	max DFE value for floating taps

COM v2.7 is used in this study.

802.3ck Critical Channels

CH#	Description	Reference Document	IL (dB) at 26.56GHz
1	Cable_BKP_28dB\Cable_BKP_28dB_0p575m	heck_3ck_01_1118.pdf	29.0
2	Cable_BKP_16dB\Cable_BKP_16dB_0p575m_more_isi	heck_3ck_01_1118.pdf	15.2
3	CaBP_BGAVia_Opt2_28dB\CaBP_BGAVia_Opt2_28dB	mellitz_3ck_adhoc_02_081518.pdf	26.3
4	tracy_3ck_03_0119_tradBP\Std_BP_12inch_Meg7	Tracy_3ck_01_0119	15.8
5	tracy_3ck_02_0119_orthoBP\DPO_IL_12dB	Tracy_3ck_01_0119	12.2
6	kareti_3ck_01_1118_ortho\OAch4 (updated)	kareti_3ck_01a_1118.pdf	27.7
7	kareti_3ck_01_1118_cabledBP\CAch3_b2	kareti_3ck_01a_1118.pdf	28.4
8	kareti_3ck_01_1118_backplane_2\Bch2_b7p5_7	kareti_3ck_01a_1118.pdf	28.9

All channel data are from IEEE 802.3ck Task Force Tools & Channels page: http://www.ieee802.org/3/ck/public/tools/index.html

COM Analysis Results w/ Cd-Ls-Cb Termination [1]

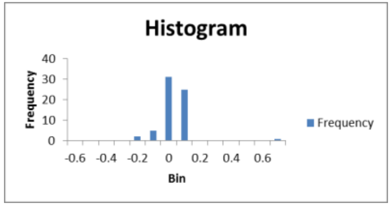
							Channel							
Ref RX Type	DFE (Fixed)	Float	Float Bank	Float Max	TX/RX Term	Pkg (TX/RX)	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
1	24	0	0	40	Cd=120fF, Ls=120pH, Cb=30fF	31/29	3.07	5.78	4.91	3.98	6.45	2.9	4.15	3.01
5	**12**	**4**	**3**	**40**		**31/29**	**3.07**	**5.92**	**4.91**	**4**	**6.61**	**3.19**	**4.17**	**3.09**
9	20	4	1	40		31/29	3.07	5.78	4.91	3.98	6.49	2.91	4.15	3.09
10	16	4	2	40		31/29	3.07	5.84	4.91	4	6.57	3.14	4.17	3.09
11	16	4	2	80		31/29	3.07	5.84	4.93	4.46	6.68	3.3	4.39	3.17
17	**12**	**4**	**2**	**40**		**31/29**	**3.02**	**5.8**	**4.88**	**3.96**	**6.56**	**3.07**	**4.11**	**2.94**
18	**12**	**3**	**3**	**40**		**31/29**	**3.05**	**5.83**	**4.9**	**3.99**	**6.54**	**3.14**	**4.12**	**3.06**

- Initial Observations
  - CH6 (OAch4) remains the toughest channel in the test
    - CH8 is slightly worse than CH6 for some ref RX types
  - Ref RX type 5, 10, 11, 18 are able to pass 3dB COM threshold for all critical channels
  - Ref RX type 17 can achieve 3dB COM except CH8

COM Analysis Results
Comparisons between 2 Termination Schemes

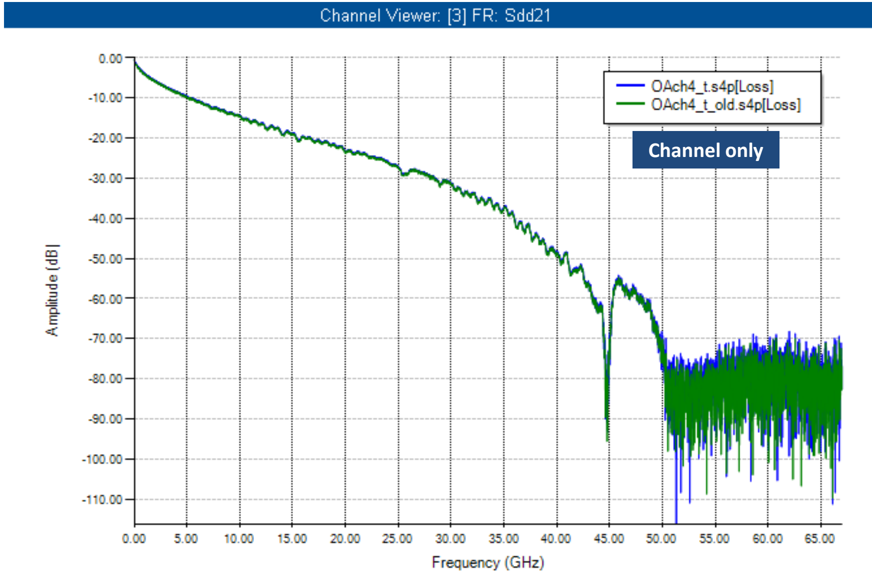
Ref RX Type	DFE (Fixed)	Float	Float Bank	Float Max	TX/RX Term	Pkg (TX/RX)	Channel							
							CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
1	24	0	0	40	Cd=90fF	31/29	3.06	5.87	4.91	4.06	6.34	2.9	4.12	3.02
5	**12**	**4**	**3**	**40**		**31/29**	**3.09**	**5.95**	**4.91**	**4.06**	**6.45**	**3.17**	**4.12**	**3.01**
9	20	4	1	40		31/29	3.06	5.87	4.91	4.06	6.37	2.95	4.12	3.02
10	16	4	2	40		31/29	3.06	5.87	4.91	4.06	6.45	3.12	4.12	3.01
11	16	4	2	80		31/29	3.06	5.87	4.93	4.5	6.45	3.31	4.34	3.14
17	**12**	**4**	**2**	**40**		**31/29**	**3.01**	**5.85**	**4.9**	**4.01**	**6.43**	**3.07**	**4.08**	**2.9**

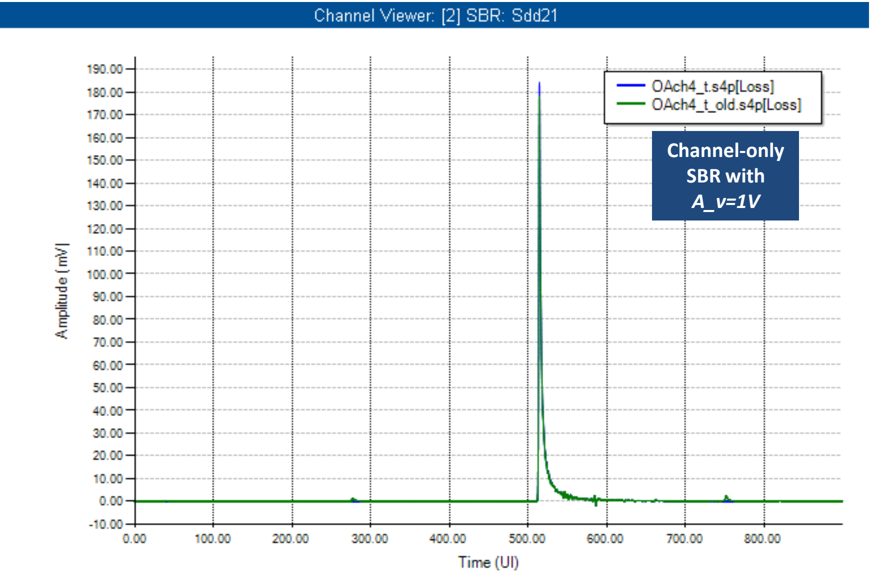
Compared to Cd-Ls-Cb Termination [1]: Mean Difference = 0.0dB, Std. = 0.11dB



Focused/Detailed Analysis of
2 Critical Channels:
CH6 (OAch4) and CH8 (Bch2_b7p5_7)

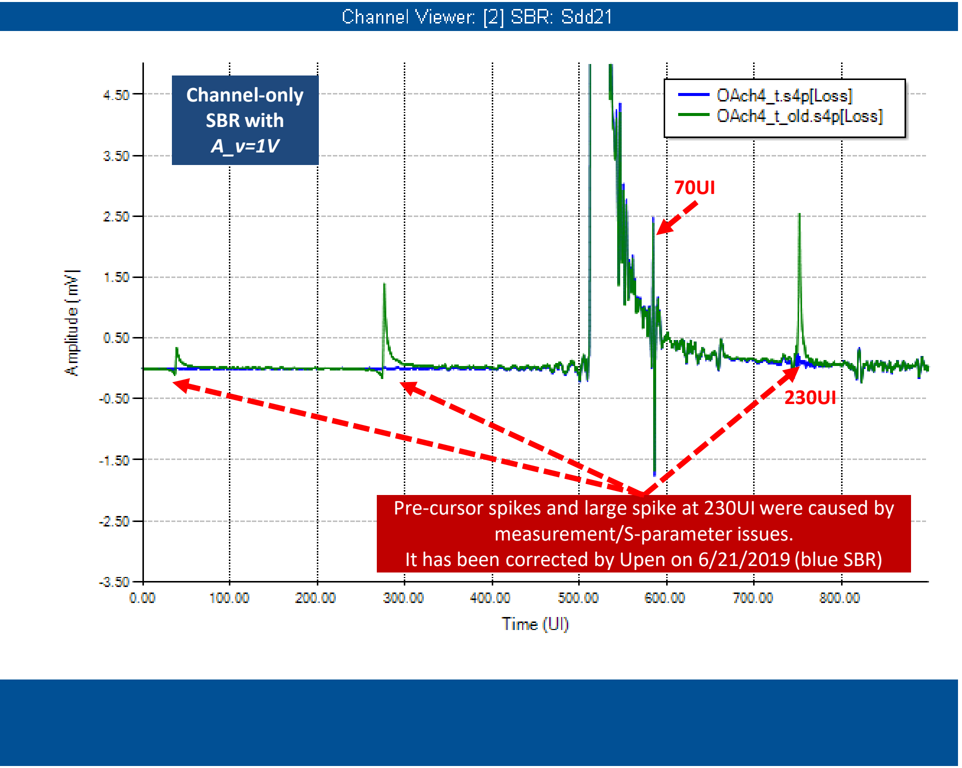
Channel Characteristics Comparison between original and updated OAch4_t (CH6)

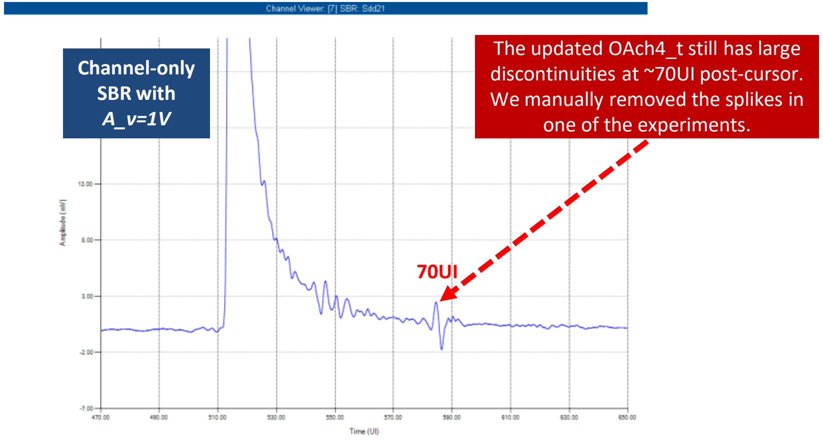


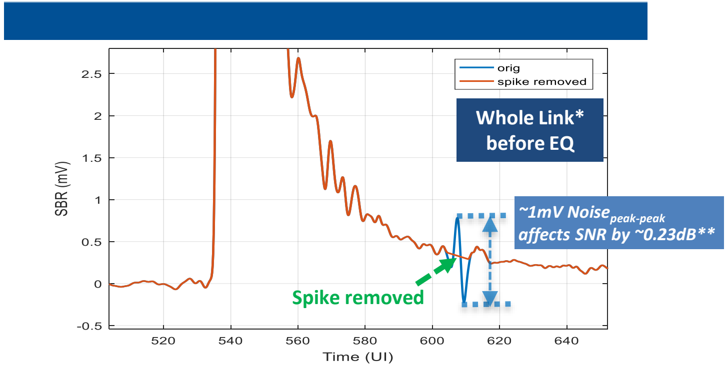


Note: The original channel file has non-causal and ~230UI (after main cursor) spikes caused by measurement/S-parameter issues. It has been corrected by Upen on 6/21/2019 (blue SBR)

Comparison among original, updated, and “spike removed at 70UI” OAch4_t (CH6)







*Notes: *: Includes amplitude (A_v=0.413V), TX filter (H_t), RX noise filter (H_r), and TX/RX packages.*
***: Gross estimate. Assume the whole link has 3dB SNR and then re-calculate the SNR without the 1mV ISI noise. Peak amplitude of whole link SBR is ~54mV.*

COM Analysis Results w/ OAch4 (CH6) updated vs. “spike removed at ~70UI”

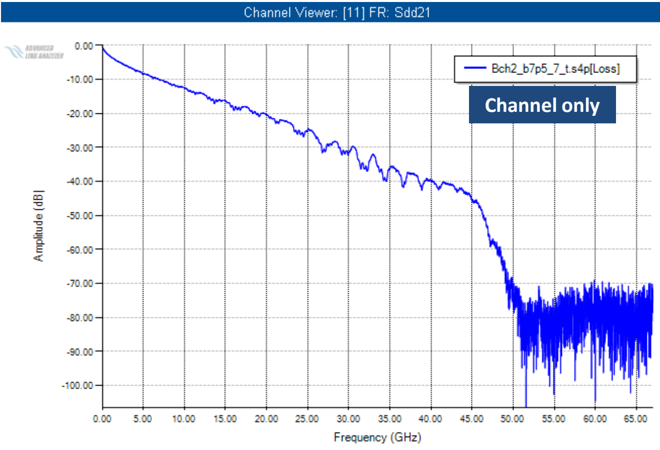
Ref RX Type	DFE (Fixed)	Float	Float Bank	Float Max	TX/RX Term	Pkg (TX/RX)	COM (dB)	COM (dB, w/ “spike” removal at 70UI)
1	24	0	0	40	Cd=120fF, Ls=120pH, Cb=30fF	31/29	2.9	3.34
5	**12**	**4**	**3**	**40**		**31/29**	**3.19**	**3.65**
9	20	4	1	40		31/29	2.91	3.34
10	16	4	2	40		31/29	3.14	3.58
11	16	4	2	80		31/29	3.3	3.58
17	**12**	**4**	**2**	**40**		**31/29**	**3.07**	**3.53**
18	**12**	**3**	**3**	**40**		**31/29**	**3.14**	**3.58**

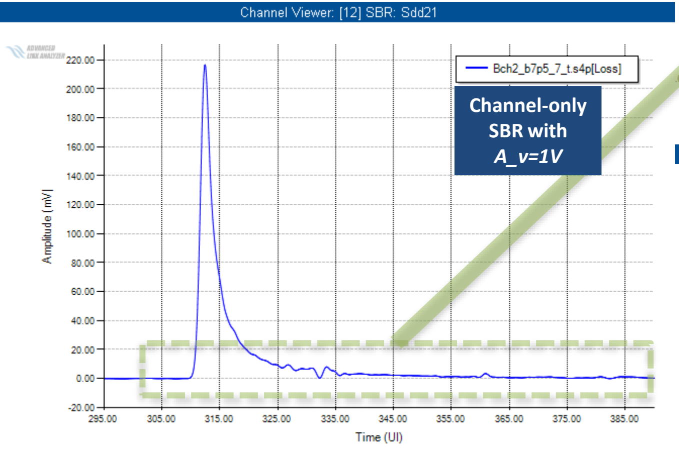
– OAch4_t has significant discontinuities at ~70UI (from the main cursor)
  - Removing the 70UI reflections yields ~0.43dB COM improvement and more relaxed reference RX architecture and better COM margins
  - Some other channels (kareti_3ck_01a_1118.pdf) also exhibit this type of discontinuities

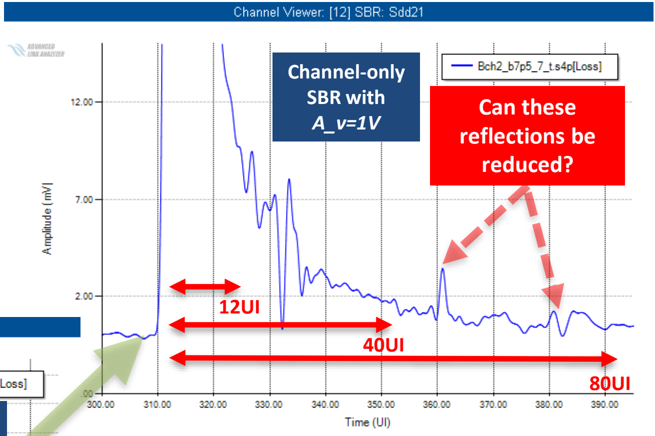
Bch2_b7p5_7_t (CH8) Detailed Analysis

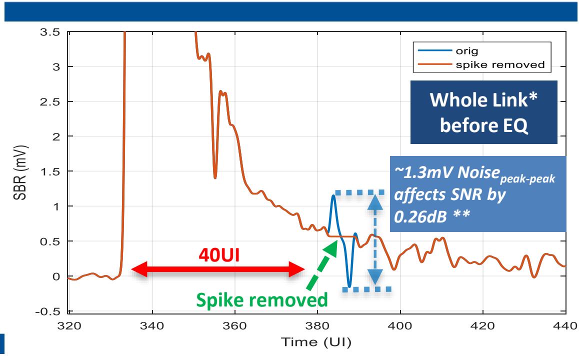
Observations

- CH8 is shown to be one of the worst channels
- CH8 is also shown to have large reflections at >40UI



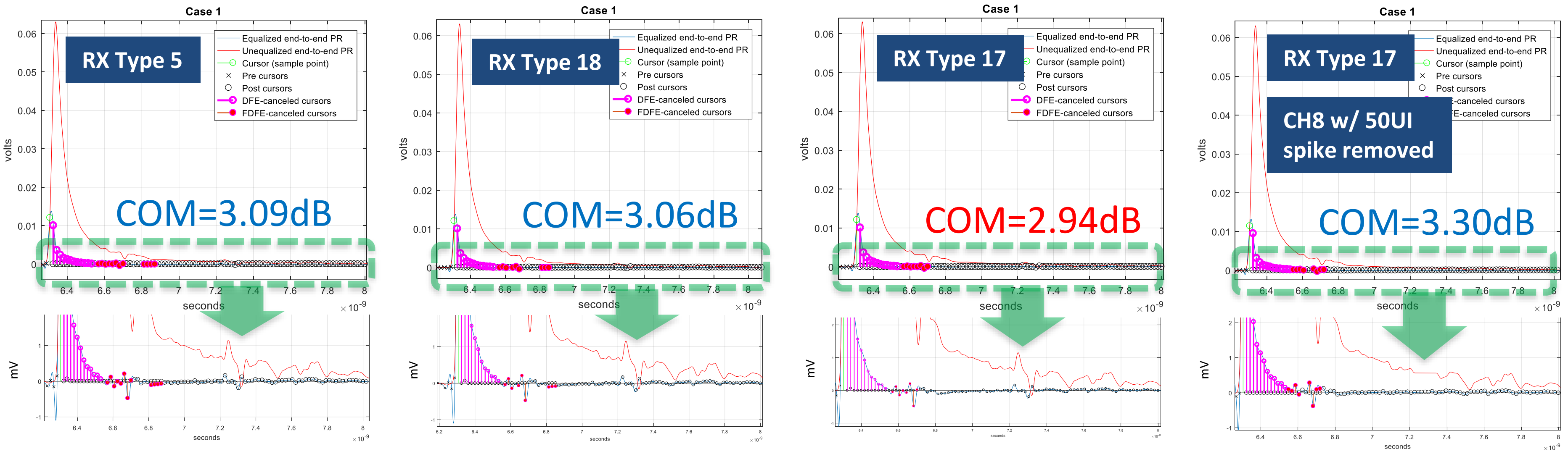






*Notes: *: Includes amplitude (A_v=0.413V), TX filter (H_t), RX noise filter (H_r), and TX/RX packages.*
***: Gross estimate. Assume the whole link has 3dB SNR and then re-calculate the SNR without the 1.3mV ISI noise. Peak amplitude of whole link SBR is ~63mV.*

Bch2_b7p5_7_t (CH8) Detailed Analysis *(cont.)*



Observations

- Though CH8 is shown to need 3 floating tap banks (within 40 taps) to achieve 3dB COM with Ref RX Type 5 and 18, the improvement by the 3rd bank is very small.
- With large reflections at ~50UI removed, Ref RX Type 17 passes 3dB COM with 0.3 dB margin

COM Analysis Results w/ Bch2_b7p5_7 (CH8) original vs. “spike removed at ~50UI”

Ref RX Type	DFE (Fixed)	Float	Float Bank	Float Max	TX/RX Term	Pkg (TX/RX)	COM (dB)	COM (dB, w/ “spike” removal at 50UI)
1	24	0	0	40	Cd=120fF, Ls=120pH, Cb=30fF	31/29	3.01	3.41
5	**12**	**4**	**3**	**40**		**31/29**	**3.09**	**3.45**
9	20	4	1	40		31/29	3.09	3.45
10	16	4	2	40		31/29	3.09	3.45
11	16	4	2	80		31/29	3.17	3.45
17	**12**	**4**	**2**	**40**		**31/29**	**2.94**	**3.30**
18	**12**	**3**	**3**	**40**		**31/29**	**3.06**	**3.43**

- Bch2_b7p5_7 has significant discontinuities at ~50UI (from the main cursor)
  - Removing the ~50UI reflections yields ~0.36dB COM improvement and more relaxed reference RX architecture and better COM margins

Summary and Conclusions

Ref RX Type	DFE (Fixed)	Float	Float Bank	Float Max	TX/RX Term	Pkg (TX/RX)
1	24	0	0	40	Cd=120fF, Ls=120pH, Cb=30fF	31/29
5	**12**	**4**	**3**	**40**		**31/29**
9	20	4	1	40		31/29
10	16	4	2	40		31/29
11	16	4	2	80		31/29
17	**12**	**4**	**2**	**40**		**31/29**
18	**12**	**3**	**3**	**40**		**31/29**

- Evaluated different ref. RX types and 2 die termination models
  - Suggest to adopt Cd-Ls-Cb termination model [1] in the baseline as it is more consistent with 802.3ck SerDes design
  - Ref RX with 3 banks of floating DFE taps works, but the improvement from the 3rd bank is insignificant compared with RX with 2 banks of floating DFE taps, with the same 12 fixed DFE taps
- Analyzed the two most difficult channels (CH6 and CH8) in detail
  - Found that these 2 channels have significant reflections at >40UI
    - It is desirable that those reflection be removed or minimized via improved channel design
  - Simpler ref RX, such as RX Type 17, can achieve 3dB COM with > 0.36 dB margin for all 8 critical channels by reducing/removing significant reflections at > 40UI
- Considering lower power, area, and latency, which are equally important for 802.3ck applications, ref. RX Type 17 (i.e. DFE: 12 fixed taps + 2 banks of 4 floating taps) would be the optimal choice to support the 802.3ck critical channels with > 0.35 dB COM margin
  - Given that channels supported do not have large reflections at > 40UI

References

[1] http://www.ieee802.org/3/ck/public/adhoc/jun12_19/healey_3ck_adhoc_01_061219.pdf

Thank You !