CDAUI-8 Chip-to-Module (C2M): Reference RX Proposal

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Introduction

- We propose a revised LFEQ+CTLE reference receiver for CDAUI-8 C2M
  - **Correspondingly, we've submitted comments against 120E.3.1.6.1 and 120E.3.2.1.1 in Draft 1.1**

Proposed Reference Receiver

- $$H(f) = \frac{GP_1P_2P_{LF}}{Z_1Z_{LF}} \times \frac{j2\pi f + Z_1}{(j2\pi f + P_1)(j2\pi f + P_2)} \times \frac{j2\pi f + Z_{LF}}{j2\pi f + P_{LF}}$$

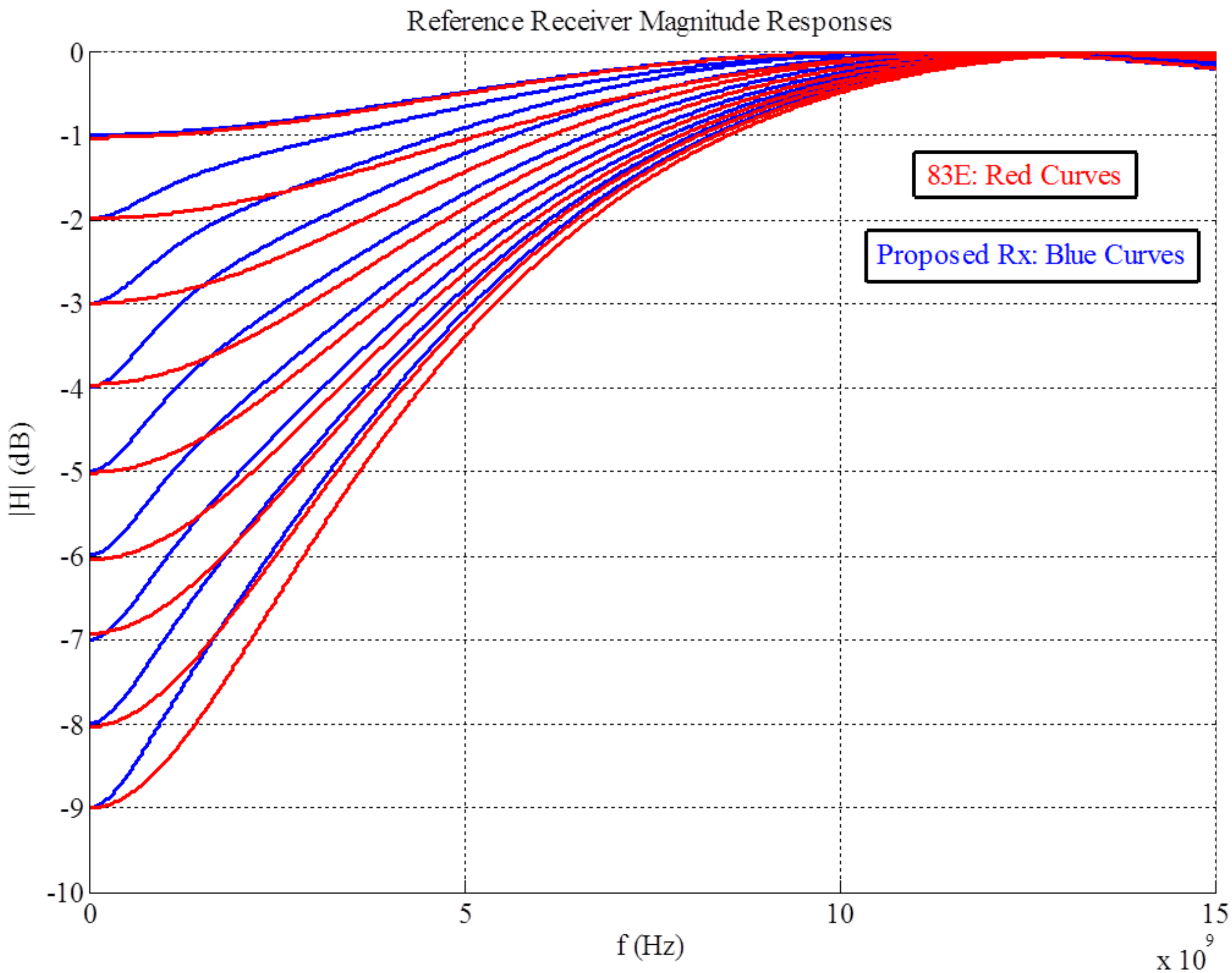
  - 83E CTLE + (1Z,1P) Low-Frequency Equalizer
  - CTLE+LFEQ provides better compensation of low-frequency skin effect; in time-domain, LFEQ is a long-tail equalizer
  - Due to sensitivity to residual ISI, 0.5dB steps are proposed

Proposed Reference Receiver

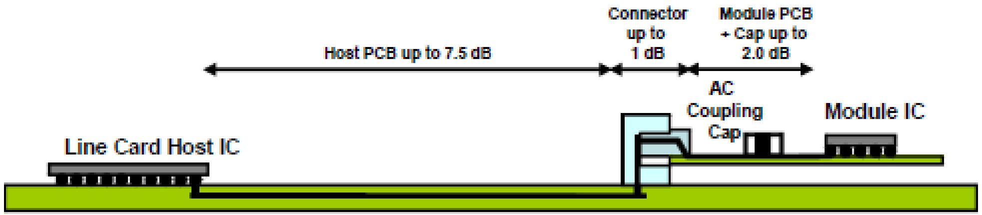
Peaking (dB)	G	$\frac{P_1}{2\pi}$	$\frac{P_2}{2\pi}$	$\frac{Z_1}{2\pi}$	$\frac{P_{LF}}{2\pi}$	$\frac{Z_{LF}}{2\pi}$
1	0.89125	18.6	14.1	8.359	1.2	1.2
1.5	0.84140	18.6	14.1	8.159	1.2	1.15
2	0.79433	18.6	14.1	7.995	1.2	1.1
2.5	0.74989	18.6	14.1	7.604	1.2	1.075
3	0.70795	15.6	14.1	6.713	1.2	1.05
3.5	0.66834	15.6	14.1	6.421	1.2	1.025
4	0.63096	15.6	14.1	6.155	1.2	1
4.5	0.59566	15.6	14.1	5.733	1.2	1
5	0.56234	15.6	14.1	5.353	1.2	1
5.5	0.53088	15.6	14.1	5.007	1.2	1
6	0.50119	15.6	14.1	4.691	1.2	1
6.5	0.47315	15.6	14.1	4.399	1.2	1
7	0.44668	15.6	14.1	4.130	1.2	1
7.5	0.42170	15.6	14.1	3.880	1.2	1
8	0.39811	15.6	14.1	3.647	1.2	1
8.5	0.37584	15.6	14.1	3.430	1.2	1
9	0.35481	15.6	14.1	3.228	1.2	1

Reference Receiver Magnitude Responses

- For clarity of figure, only 1dB steps are shown



System Model



- Host TX model:
  - 800 mV differential peak-to-peak
  - TX SNR = 31 dB (peak-to-rms)
  - RLM = 0.92
  - RJ = 0.01 UIrms
  - DJ = 0.05 UI peak-to-peak
  - 2-tap TXFIR (i.e., pre+cursor)

- To evaluate the merits of the proposed reference RX, we compute COM margins for the C2M link
  - **The “83E CTLE” used in the following has 0.5dB steps**
  - **The “83E+OptLFEQ” in the following slides refers to the combination of an “83E CTLE” (with 0.5dB steps) plus an LFEQ that is optimized for every choice of channel+CTLE (as opposed to the channel independent LFEQ in our proposed reference RX)**

COM Margins **(DER=1E-6)**

- Fixed TXFFE: [-0.1,0.9]

Channel Index	1	2	3	4	5	6	7	8	9
83E CTLE	2.53	2.66	2.02	1.77	2.80	2.42	2.67	2.41	2.01
Proposed Ref RX	3.46	3.77	2.73	2.25	3.74	3.32	3.23	2.87	2.32
83E+OptLFEQ	3.54	3.56	2.87	2.58	3.64	3.39	3.31	3.07	2.56

- Optimized TXFFE

Channel Index	1	2	3	4	5	6	7	8	9
83E CTLE	2.53	2.74	2.83	1.77	3.65	2.42	2.67	2.45	2.08
Proposed Ref RX	3.46	3.77	3.21	2.25	4.22	3.32	3.18	3.19	2.57
83E+OptLFEQ	3.33	3.84	3.56	2.58	4.45	3.39	3.29	3.14	2.54

- The gain of the proposed reference receiver (relative to the 83E CTLE) is ~0.5dB to 1dB in most cases

CTLE Peaking Step Size: 0.5dB vs 1dB

- The advantage of the LFEQ is most clearly exhibited when all candidate receivers use a 0.5dB peaking resolution
  - Otherwise, quantization effects occasionally cloud the benefits of the LFEQ
  - Furthermore, PAM4 sensitivity to residual ISI suggests a higher resolution is sensible
- Fixed TXFFE: [-0.1,0.9]

Channel Index	1	2	3	4	5	6	7	8	9
83E CTLE (0.5dB)	2.53	2.66	2.02	1.77	2.80	2.42	2.67	2.41	2.01
Proposed Ref RX (0.5 dB)	3.46	3.77	2.73	2.25	3.74	3.32	3.23	2.87	2.32
Proposed Ref RX (1 dB)	3.35	3.28	2.73	2.42	3.74	2.64	2.98	2.87	2.32
83E (0.5dB)+OptLFEQ	3.54	3.56	2.87	2.58	3.64	3.39	3.31	3.07	2.56

COM Margins (DER=1E-6)

- No TXFFE

Channel Index	1	2	3	4	5	6	7	8	9
83E CTLE	0.82	0.87	2.15	0.38	2.82	0.78	-0.05	-0.47	-0.77
Proposed Ref RX	1.23	1.53	2.28	0.66	2.82	1.29	0.30	-0.11	-0.82
83E+OptLFEQ	1.41	1.44	2.57	0.87	3.33	1.22	-0.05	-0.47	-1.27

- The benefit of the proposed reference RX is small in the absence of a TXFFE (but so are the margins….)

- Note: The COM is computed for the configuration that maximizes the figure of merit
  - Due to heuristic nature of this approach, sometimes “optimization” reduces the COM, especially when margins are poor

COM Margins (DER=1E-5)

- Fixed TXFFE: [-0.1,0.9]

Channel Index	1	2	3	4	5	6	7	8	9
Proposed Ref RX	4.31	4.63	3.61	3.10	4.64	4.18	4.07	3.70	3.11
83E CTLE	3.38	3.52	2.88	2.62	3.67	3.29	3.54	3.27	2.83

- Relaxing DER from 1E-6 to 1E-5 + Fixed TXFFE + Proposed Ref RX results in > 3dB COM for all channels

Conclusions

- We are proposing an improved reference RX for CDAUI-8 C2M
  - Maintains peaking range from 1 to 9 dB, but uses 0.5 dB steps
- The gain in margin is channel-dependent
- In most cases, the improvement relative to the CTLE-only solution is ~0.5dB to 1dB
  - Not surprisingly, the “boost” in margin is largest with a TXFFE
    - Otherwise, the large pre-cursor ISI drowns out the smaller improvement in post-cursor residual ISI

Backup Slide: Channel Models

CHANNEL	FEXT	NEXT	IL @ 13.28125 GHz (dB)	ILD (dBrms)
From IEEE 802.3bs shanbhag_3bs_14_0623:				
(1) Nelco 4000-13SI Host PCB + next gen 28Gb/s high density SMT IO	5	0	8.7	0.110
(2) EM-888 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	8.9	0.051
From IEEE 802.3bs shanbhag_3bs_01_1014:				
(3) 4in Megtron6 Host PCB + next gen 28Gb/s high density SMT IO	5	0	4.3	0.110
(4) 10in Megtron6 Host PCB + next gen 28Gb/s high density SMT IO	5	0	8.8	0.106
(5) 4in Megtron6 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	4.5	0.051
(6) 10in Megtron6 Host PCB + next gen 28Gb/s press-fit stacked IO	7	0	9.0	0.052
Cisco Channels:				
(7) Cisco 3” (De-embedded)	0	0	9.3	0.154
(8) Cisco 4” (De-embedded)	0	0	10.3	0.142
(9) Cisco 5” (De-embedded)	0	0	11.6	0.097

Backup Slide: 83E CTLE

$$H(f) = \frac{GP_1P_2}{Z_1} \times \frac{j2\pi f + Z_1}{(j2\pi f + P_1)(j2\pi f + P_2)}$$

where

- $H(f)$ is the CTLE transfer function
- G is the CTLE gain
- P_1, P_2 are the CTLE poles in Grad/s
- Z_1 is the CTLE zero in Grad/s
- j is the square root of –1
- f is the frequency in GHz

Table 83E–2—Reference CTLE coefficients

Peaking (dB)	G	$\frac{P_1}{2\pi}$	$\frac{P_2}{2\pi}$	$\frac{Z_1}{2\pi}$
1	0.89125	18.6	14.1	8.364
2	0.79433	18.6	14.1	7.099
3	0.70795	15.6	14.1	5.676
4	0.63096	15.6	14.1	4.9601
5	0.56234	15.6	14.1	4.358
6	0.50119	15.6	14.1	3.844
7	0.44668	15.6	14.1	3.399
8	0.39811	15.6	14.1	3.012
9	0.35481	15.6	14.1	2.672