Investigation of IEEE 802.3ck Baseline Reference Receiver Candidates

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Background

- Two goals of the reference receivers:
  - Configuration spreadsheet for COM
    - No need to imply implementation. No implementation details for consensus building.
    - DFE, FFE-lite, FFE-heavy are all supported by [COM 2.53](#).

  - DFE error propagation model and FEC performance analysis
    - Reference receiver impacts the PCS and FEC design.
      - Should we use interleaved FEC to guarantee performance in consideration of extra latency and complexity?
      - Should interleaved FEC be mandatory or optional, configurable or negotiable?
    - Narrow down to 1-tap DFE (FFE-heavy) and n-tap DFE (FFE-lite) based receivers.

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Table of Contents

- Observed consensus from the Bangkok meeting

- Baseline reference receiver candidates and channels under investigation

- Control of b(1) for DFE and FFE-lite receiver with MM-PD and Modified PD

- Performance comparison of DFE-, FFE-lite, FFE-heavy with COM

- Comparison of COM reference receivers with different configurations

- Summary and Suggestions

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Observed Consensus from Bangkok meeting

- ## Contributions related to COM reference receiver modeling
  - li_3ck_02a_1118 (Intel) & wu_3ck_01_1118 (MediaTek), show that FFE-lite and FFE-heavy give similar COM.
  - lu_3ck_01_1118 (Huawei) shows that **the difference between FFE- and DFE-based receiver is in the pre-cursor cancellation**. Since FFE-lite addresses the difference, its COM values are similar to FFE-heavy.
  - kareti_3ck_01a_1118 (Cisco) shows that DFE has performance concerns and un-constrained DFE and floating tap DFE improves the performance.
  - heck_3ck_01_1118 (Intel) shows that at least 20-tap DFE is required in RX EQ, and even with 24 taps we don't meet 3dB for all channels.
  - sakai_3ck_01a_1118 (Socionext) shows that using no Rx FFE pre-taps degrades COM in 0.55~0.96dB.

- ## All these independent simulation results are consistent!

- ## Consensus that we may derive from the simulations:
  - DFE has performance concerns and needs to be improved.
  - FFE is needed in the receiver while FFE-heavy and FFE-lite give similar COM.
  - Both FFE-heavy and FFE-lite are usable for COM, they are highly correlated.

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Baseline reference receiver candidates and channels under investigation

#	Arch.	Reference Receiver	Configurations in the simulation
DFE	DFE-based	DFE-Only	24 taps
FFE-lite	FFE-based	'm-pre & 0-post' FFE + n-tap DFE	3-pre & 0-post FFE & 24-tap DFE
FFE-heavy	FFE-based	'm-pre & n-post' FFE + 1-tap DFE	3-pre & 24-post FFE + 1-tap DFE

Channel	ID	IL fitted (dB)	ICN (mV)	FOM_ILD (dB)	COM (dB) DFE $b\_max=0.7$ MM-PD	DFE $b\_max=1.0$ MM-PD	DFE $b\_max=1.0$ Modified PD	FFE-lite $b\_max=0.7$ MM-PD	FFE-lite $b\_max=0.7$ Modified PD	FFE-lite $b\_max=0.6$ Modified PD	FFE-heavy $b\_max=0.7$
mellitz_3ck_adhoc_02_081518 Opt1	26	-23.79	0.56	0.23	4.19	4.53	4.53	5.03	5.15	5.06	5.13
	27	-27.59	0.42	0.26	2.53	3.28	3.28	4.09	3.99	3.86	4.06
	28	-31.36	0.33	0.29	0.49	1.67	1.61	2.67	2.36	1.90	2.41
mellitz_3ck_adhoc_02_081518 Opt2	29	-22.98	0.66	0.46	3.72	4.45	4.17	5.02	5.13	5.07	5.08
	30	-26.72	0.49	0.51	2.93	3.38	3.35	4.21	4.15	4.00	4.23
	31	-30.42	0.37	0.58	0.96	1.77	1.77	2.83	2.68	2.36	2.75
tracy_100GEL_04_0118	32	-22.94	0.36	1.28	4.73	4.99	4.99	5.33	5.39	5.34	5.22
tracy_100GEL_05_0118	33	-23.90	0.54	1.50	3.46	3.25	3.25	4.38	4.37	4.28	4.35
zambell_100GEL_02_0318	34	-27.40	0.29	0.27	2.92	2.90	2.86	4.18	4.36	4.22	4.29
mellitz_3ck_adhoc_02_072518	35	-28.01	0	0.03	3.07	4.37	4.28	5.32	4.84	4.43	4.61
	36	-27.98	0	0.00	2.88	3.81	3.81	4.55	4.34	4.07	4.33

Total **106** channels including 96 new channels from zambell_3ck_01_1118, kareti_3ck_01a_1118, and heck_3ck_01_1118 are considered. The package configuration is the same as lu_3ck_01_1118.
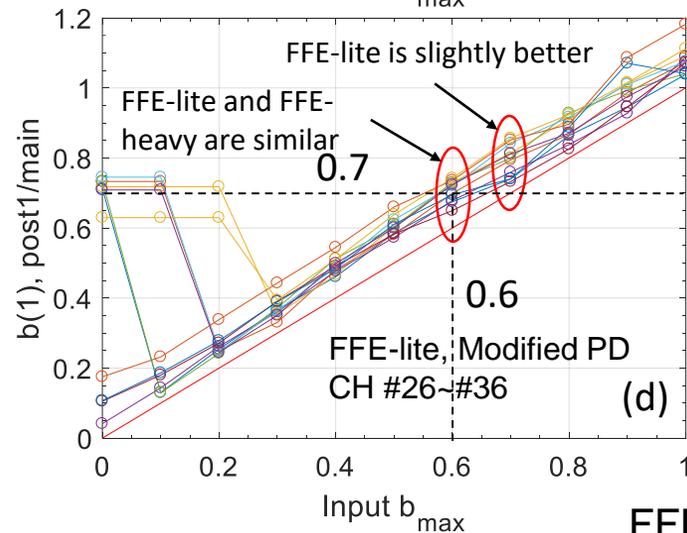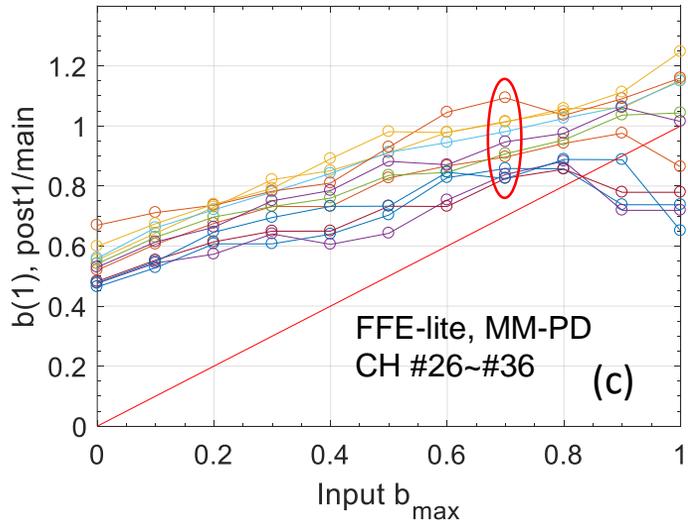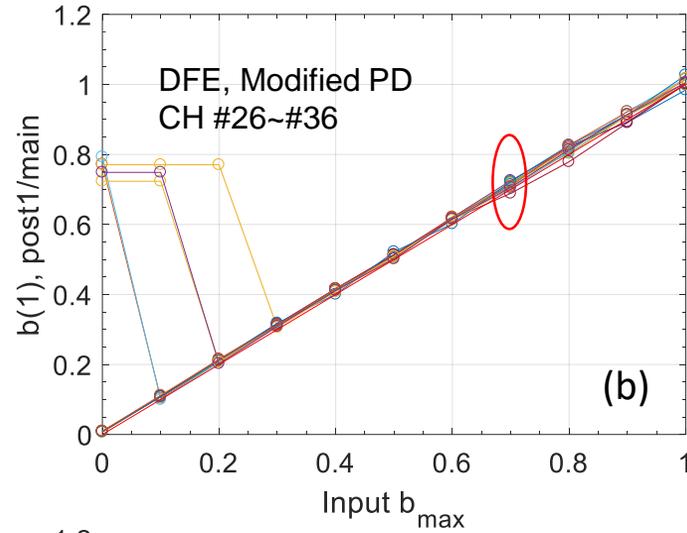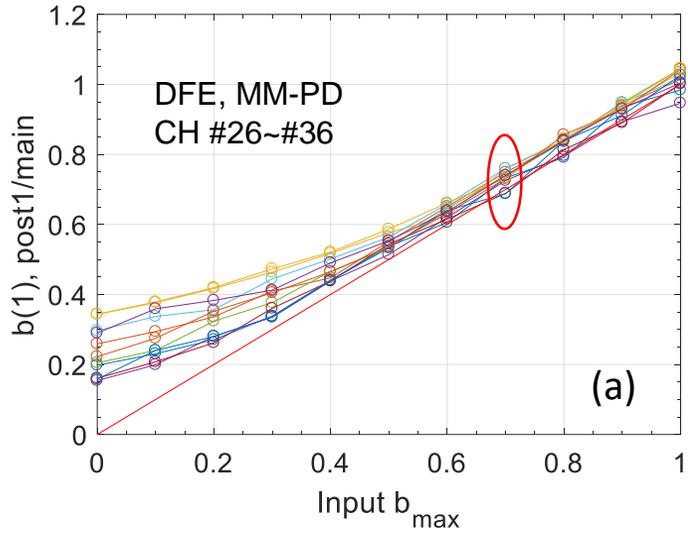
MM-PD : $h(t_s - Tb) = h(t_s + Tb) - h(t_s)b(1)$, Annex(93A)
Modified PD : $0 = h(t_s + Tb) - h(t_s)b(1)$, Remove the impact of pre-1 cursor (New).

Modified PD has better control of b(1) for DFE- and FFE-lite receiver

$$h(t_s - T_b) = h(t_s + T_b) - h(t_s)b(1)$$

$$0 = h(t_s + T_b) - h(t_s)b(1)$$

(a) DFE, MM-PD CH #26~#36

(b) DFE, Modified PD CH #26~#36

(c) FFE-lite, MM-PD CH #26~#36

(d) FFE-lite, Modified PD CH #26~#36 — FFE-lite is slightly better; FFE-lite and FFE-heavy are similar; 0.7; 0.6

(f) FFE-heavy CH #26~#36 — Perfect control of b(1). FFE-only for C2M

- DFE and FFE-lite relies on the sampling phase to control the b(1), i.e. Post1/Main.
  - MM-PD has worse control of b(1), varies from 0.8 to 1.1.
  - Modified PD gives better control of b(1).
- FFE-heavy can achieve precise b(1) control over a wide range of sampling phase. Set b_max=0 FFE-heavy can switch off DFE to support C2M.

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Performance comparison of DFE-, FFE-lite, FFE-heavy with COM
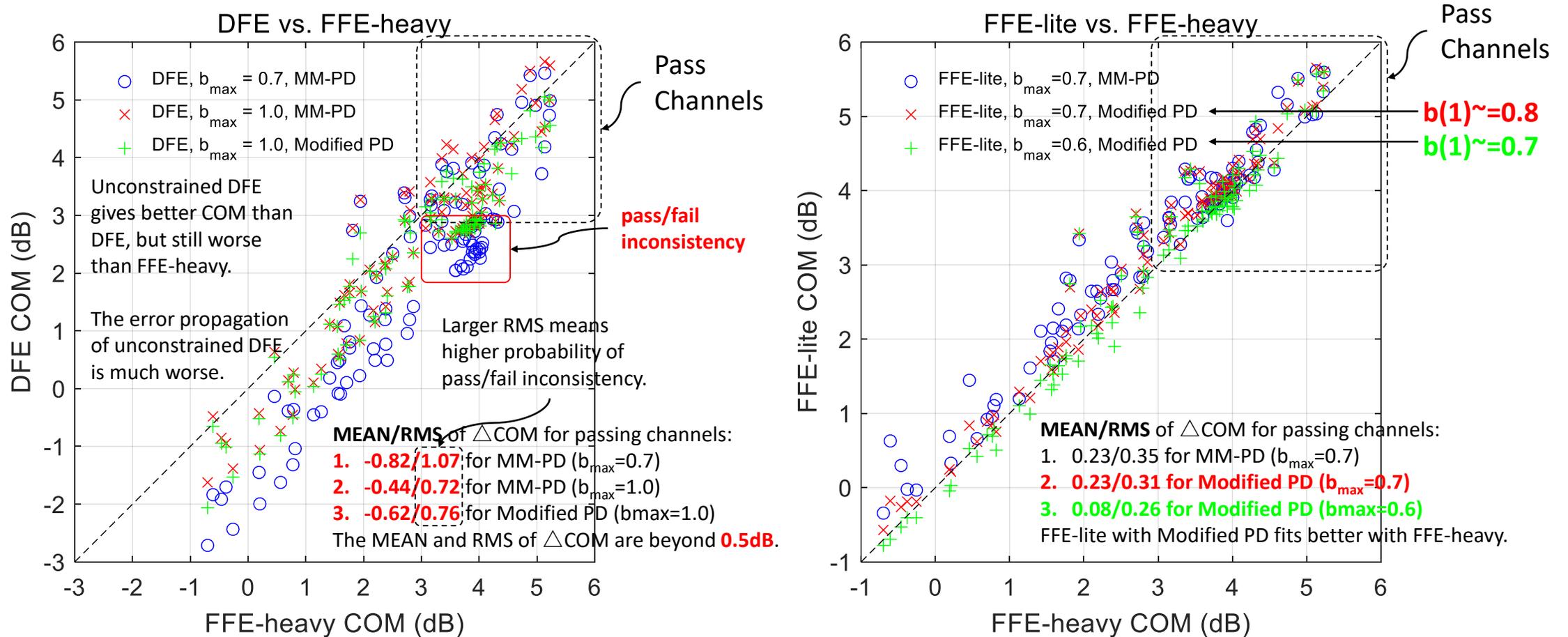

DFE vs. FFE-heavy

- ○ DFE, b_{max} = 0.7, MM-PD
- × DFE, b_{max} = 1.0, MM-PD
- + DFE, b_{max} = 1.0, Modified PD

Unconstrained DFE gives better COM than DFE, but still worse than FFE-heavy.

The error propagation of unconstrained DFE is much worse.

Pass Channels

pass/fail inconsistency

Larger RMS means higher probability of pass/fail inconsistency.

MEAN/RMS of △COM for passing channels:
1. **-0.82/1.07** for MM-PD (b_{max}=0.7)
2. **-0.44/0.72** for MM-PD (b_{max}=1.0)
3. **-0.62/0.76** for Modified PD (bmax=1.0)
The MEAN and RMS of △COM are beyond **0.5dB**.

FFE-lite vs. FFE-heavy

- ○ FFE-lite, b_{max}=0.7, MM-PD
- × FFE-lite, b_{max}=0.7, Modified PD
- + FFE-lite, b_{max}=0.6, Modified PD

Pass Channels

b(1)~=0.8
b(1)~=0.7

MEAN/RMS of △COM for passing channels:
1. 0.23/0.35 for MM-PD (b_{max}=0.7)
2. **0.23/0.31 for Modified PD (b_{max}=0.7)**
3. **0.08/0.26 for Modified PD (bmax=0.6)**
FFE-lite with Modified PD fits better with FFE-heavy.

Total 106 channels including 96 new channels from zambell_3ck_01_1118, kareti_3ck_01a_1118 and heck_3ck_01_1118.
Unconstrained DFE results are consist with kareti_3ck_01a_1118 (Cisco). FFE-lite results are consist with li_3ck_02a_1118 (Intel) & wu_3ck_01_1118 (MediaTek).

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Comparison of COM reference receivers with different configurations

#	A: DFE n-tap DFE		B: FFE-lite 'm-pre & 0-post' FFE + n-tap DFE			C: FFE-heavy 'm-pre & n-post' FFE + 1-tap DFE
Sampling Phase	MM-PD	MM-PD/ Modified PD	MM-PD	Modified PD	Modified PD	Do not care.
b_max	0.7	1.0	0.7	0.7	0.6	0.7
Performance	Lowest ✗	Low ✗	High ✓	High ✓	High ✓	High ✓
Control of b(1)	Good 0.7~0.8	Better ~0.7	Worst 0.8~1.1 ✗	Good 0.73~0.86	Better 0.65~0.74 ✓	Best =0.7 ✓
Correlation with others	Less COM correlation with FFE-based receivers ✗		Highly correlated with each other ✓			
Support C2M FFE receiver	No ✗	No ✗	Yes (set b_max=0, and adjust FFE configuration.) ✓			Yes (set b_max=0) ✓
DFE error propagation modeling complexity	High	High	High	High	High	Low
Post-FEC performance	Low?	Low?	Low?	Low?	Low?	High
Implementation Compliance	Good	Good	Low	Low	Low	High
Implementation Complexity	Low	Low	High	High	High	Low

- DFE based receiver has performance concern, even removes the 'b_max=0.7' constrain.
- Modified PD is recommended to achieve better b(1) control for FFE-lite and DFE receivers.
- Both FFE-lite and FFE-heavy are usable as COM reference receiver, the correlations of these two receivers are high.

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Summary and Suggestions

- ## Summary
  - DFE-base receiver underperforms, even removes the 'b_max=0.7' constrains.
  - Both FFE-heavy and FFE-lite are usable as COM reference receiver.
    - Using 'Modified PD' and 'b_max=0.6' in FFE-lite receiver can achieve b(1) ~=0.7.
    - If 'b(1)~=0.7' is satisfied, the COM difference between FFE-heavy and FFE-lite is minor.
  - FFE-lite has bad control of b(1) with MM-PD, but can be improved with modified PD.
    - Even with MM-PD the COM difference between FFE-lite and FFE-heavy receivers are acceptable.
  - Same modeling complexity, since they are all supported by [COM 2.53](#).

- ## Suggestions
  - Move forward with FFE-heavy or FFE-lite reference receiver (they give similar COM).
  - Recommend to include the 'Modified PD' to improve the control of b(1) for FFE-lite receiver. Using 'Modified PD' and 'b_max=0.6' in FFE-lite receiver gives b(1) ~=0.7 to further reduce the COM difference between FFE-lite and FFE-heavy receivers.
  - **Retain the 'b(1)=0.7' criteria, because it was the baseline of IEEE 802.3bj/802.3bs/802.3cd.**
  - **Further investigate the DFE error propagation with FFE-lite reference receiver, and provide the reference DFE weight configurations for DFE error propagation investigation.**

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