More Insights of IEEE 802.3ck Baseline Reference Receivers

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Summary of the contributions about COM reference receivers

- Contributions related to COM reference receivers
  - 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 main difference between FFE- and DFE-based receivers
    - **Pre-cursor cancellation for 'insertion loss' dominant channels (FFE-lite addresses this difference).**
    - **FFE noise amplification for 'noise dominant' channels (Crosstalk, residue ISI).**
  - 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.
  - sun_3ck_adhoc_01a_120518 (Credo) shows with "2% or fine TX FIR resolution" and "relaxed b1max" the performance of DFE receiver may catch up with the FFE receivers. It also shows **FFE-lite may pass channels with large margins which can not be supported by FFE-heavy receivers**.
- Consensus that we may derive from the simulations:
  - Receivers based on DFE and FFE are architecturally different. Different models should be used.
  - DFE has performance concerns and needs to be improved.
  - FFE-heavy and FFE-lite generally give similar COM for most of the LR channels (Insertion loss dominant). **Exceptions have been observed (FFE-lite COM is much larger for 'reflection dominant' LR channels)**.

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

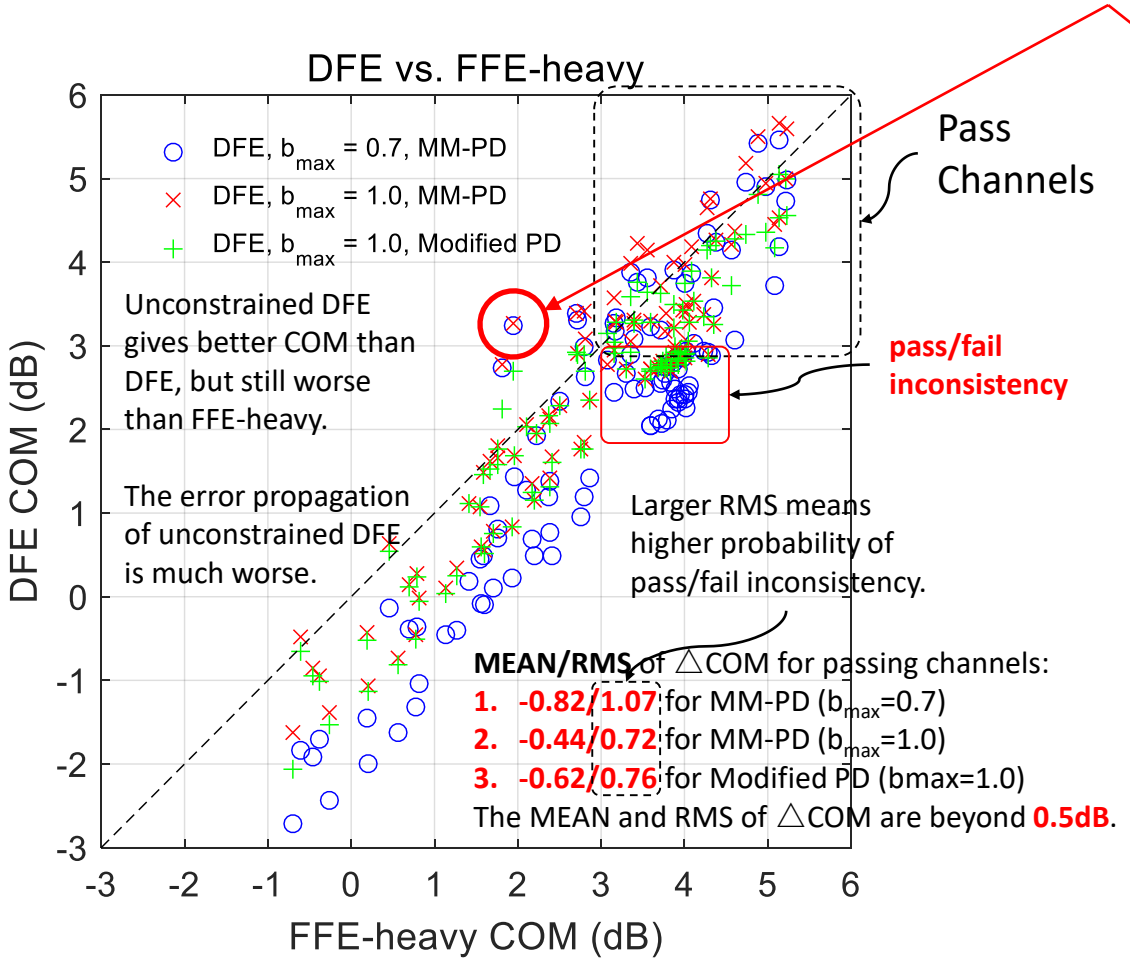
Total **106** channels including 96 new channels from zambell_3ck_01_1118, kareti_3ck_01a_1118, and heck_3ck_01_1118 are considered. The package configuration is the same as lu_3ck_01_1118.

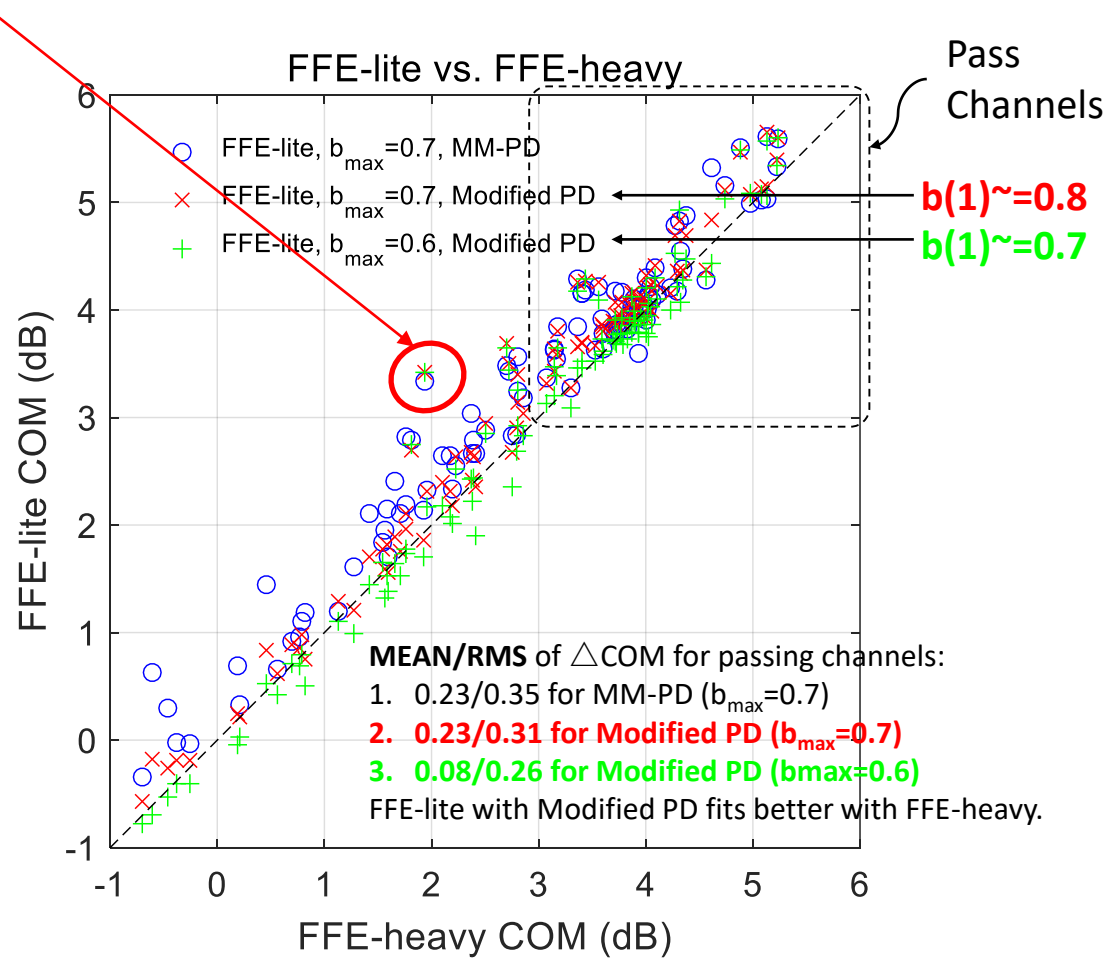
MM-PD : $h(t_s - Tb) = h(t_s + Tb) - h(t_s)b(1)$, Annex(93A)

Modified PD : $0 = h(t_s + Tb) - h(t_s)b(1)$, Remove the impact of pre-1 cursor (New).

New concern of long DFE receivers (i.e. DFE- and FFE-lite receivers)

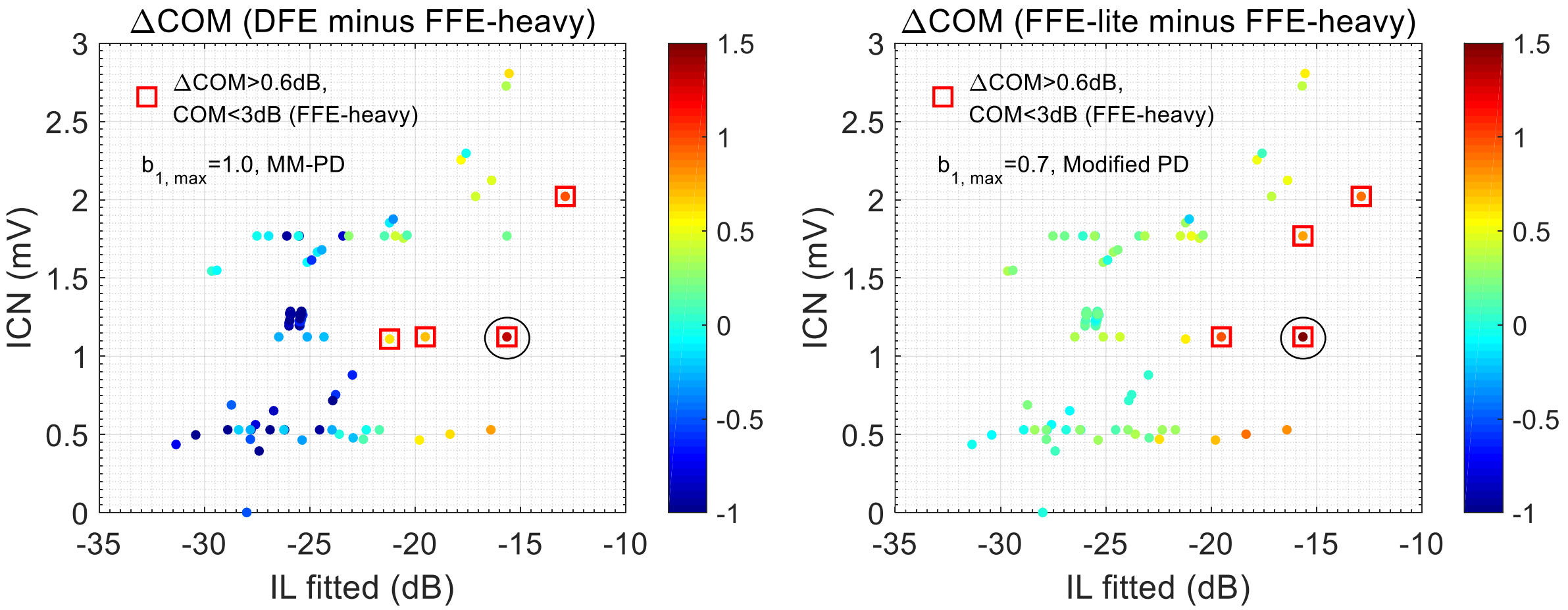
Long DFE receivers may pass channels with large margin which is not supported by FFE-heavy receiver!





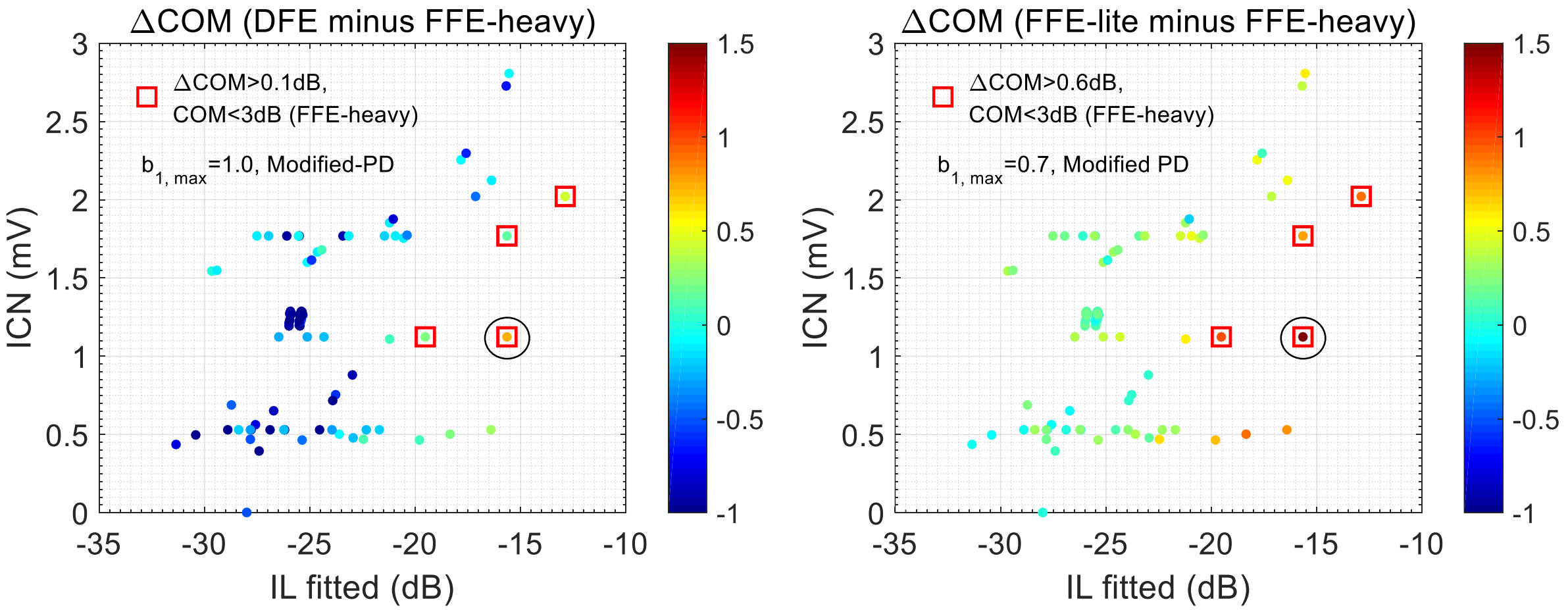
Total 106 channels including 96 new channels from zambell_3ck_01_1118, kareti_3ck_01a_1118 and heck_3ck_01_1118.
Unconstrained DFE results are consist with kareti_3ck_01a_1118 (Cisco). FFE-lite results are consist with li_3ck_02a_1118 (Intel) & wu_3ck_01_1118 (MediaTek).

Insertion loss and crosstalk of the “abnormal” channels



- DFE may pass the same channels as FFE-lite with large margins which can not be supported by FFE-heavy receivers. This is due to the long DFE that exists in both receivers.

Insertion loss and crosstalk of the “abnormal” channels



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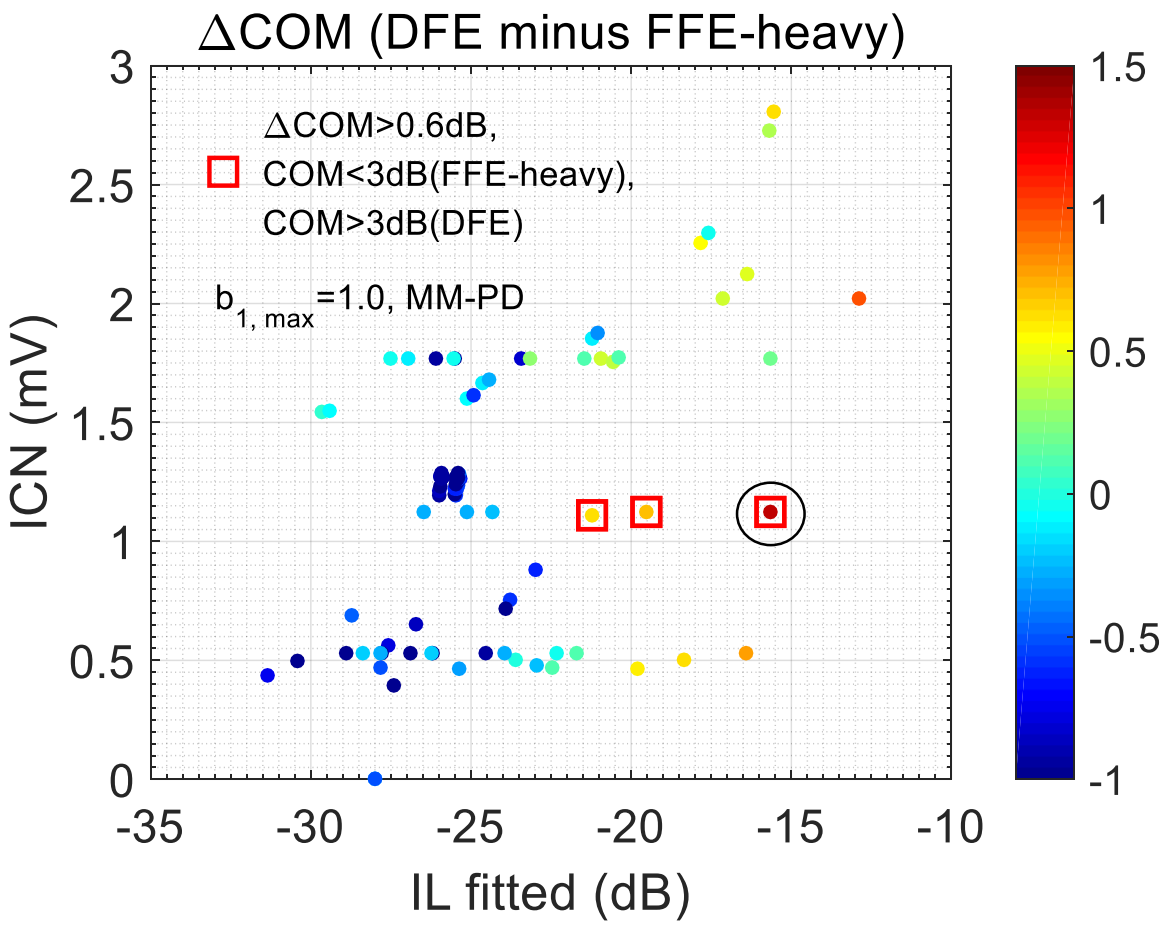
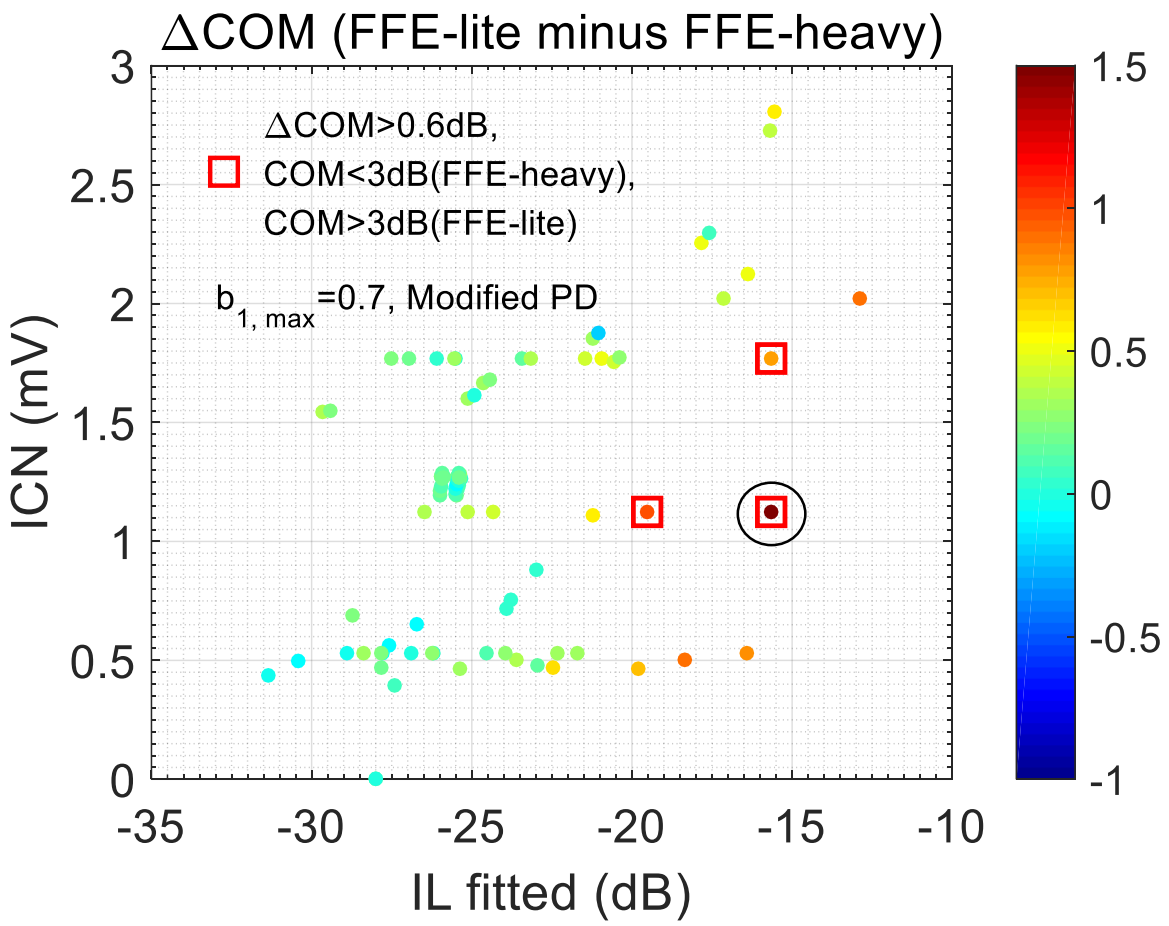
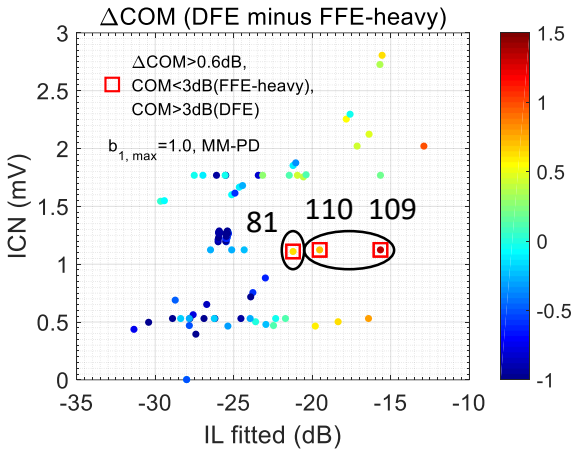
Insertion loss and crosstalk of the “abnormal” channels





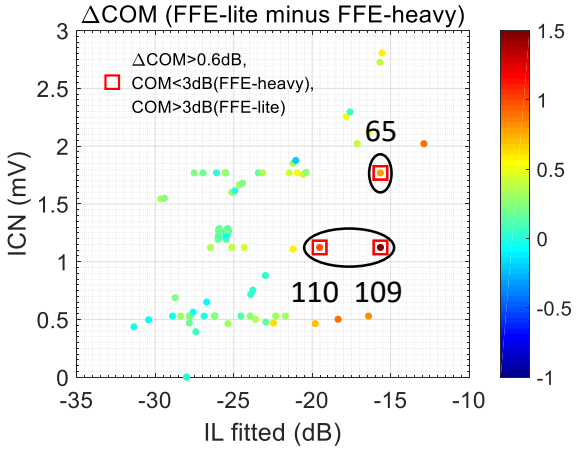
- DFE may pass the same channels as FFE-lite with large margins which can not be supported by FFE-heavy receivers. This is due to the long DFE that exists in both receivers.

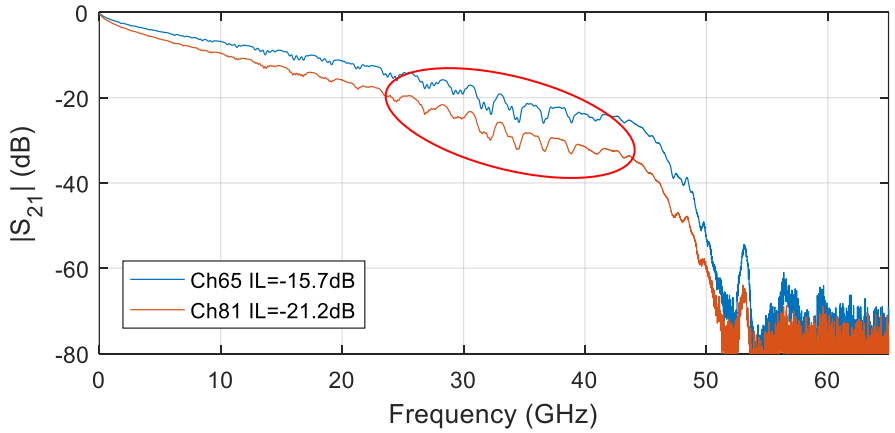
Details of the “abnormal” channels

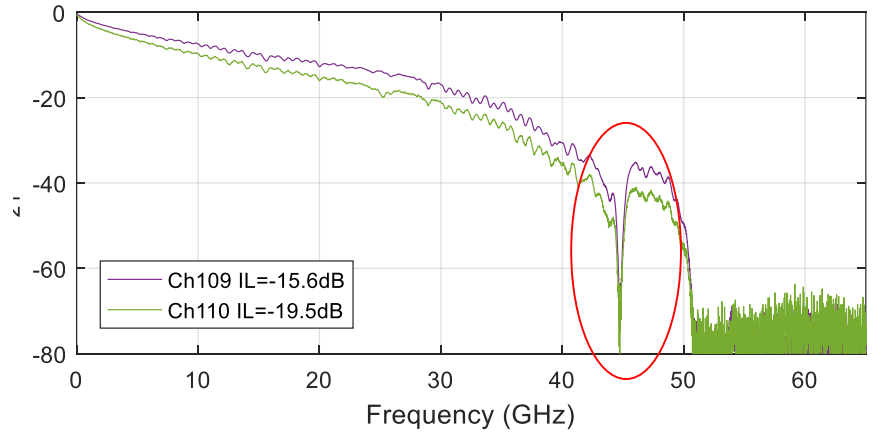


Channel		ID	IL fitted (dB)	ICN (mV)	FOM_ILD (dB)	COM (dB)			
						DFE b_max=0.7 MM-PD	DFE b_max=1.0 MM-PD	FFE-lite b_max=0.7 Modified PD	FFE-heavy b_max=0.7
kareti_3ck_01_1118 backplane	Bch2_7	65	-15.65	1.77	0.47	3.31	2.91	3.50	2.73
	Bch3_14	81	-21.21	1.11	0.45	2.99	3.41	3.40	2.80
kareti_3ck_01_1118 ortho	Och1	109	-15.65	1.12	0.69	3.24	3.27	3.42	1.94
	Och2	110	-19.52	1.12	0.73	3.39	3.39	3.69	2.70

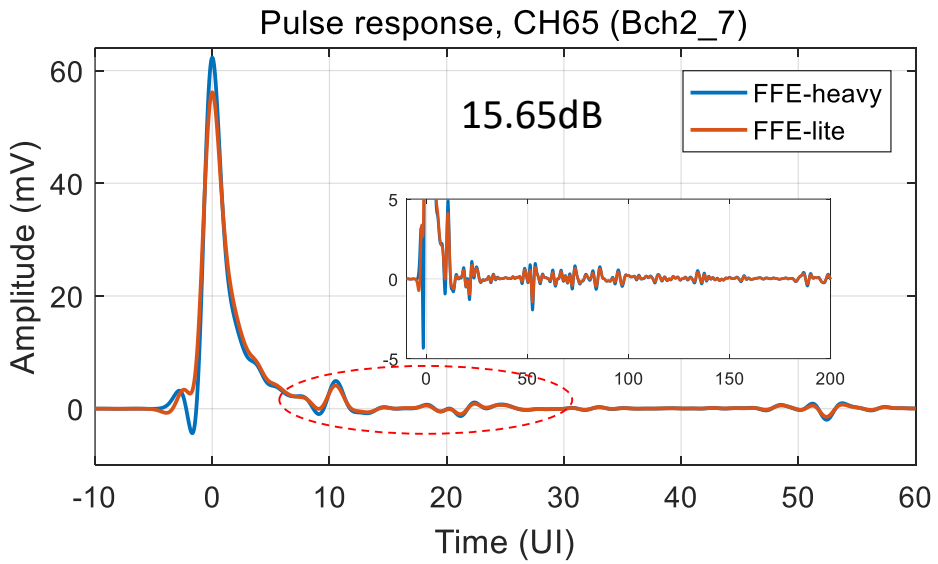
Ch 110 and 81 are not VSR channels, these two channels cannot rule out by other metrics such as ILD.

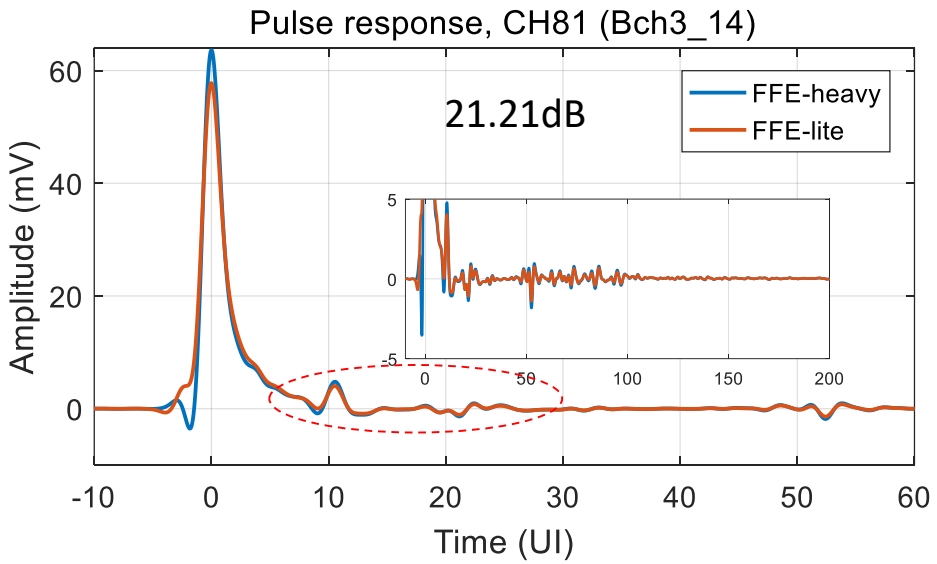


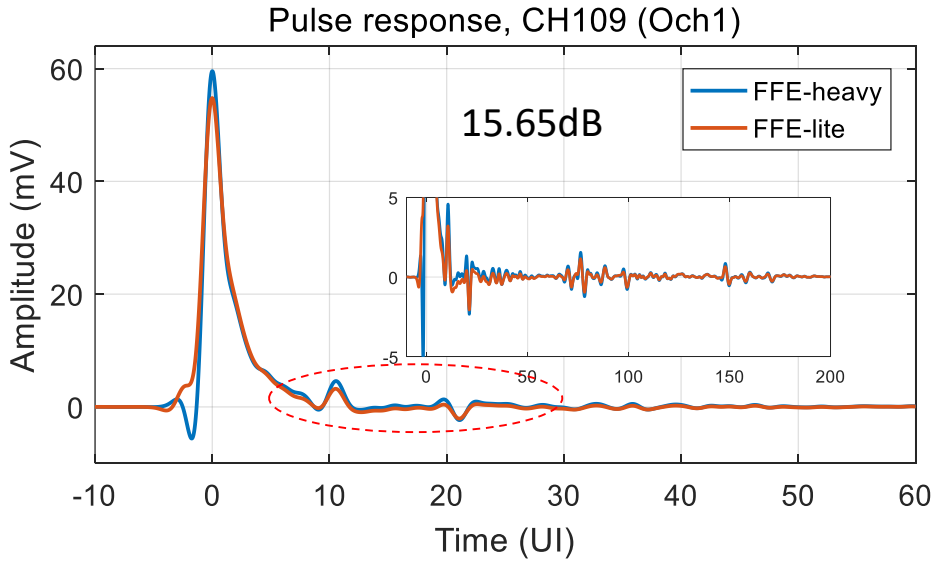


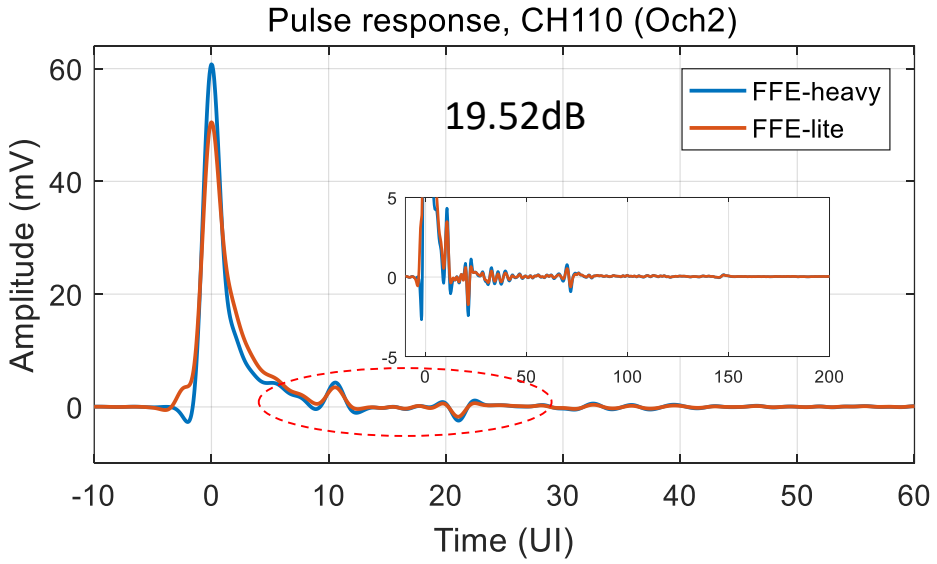


Time domain analysis of the “abnormal” channels: Pulse Response

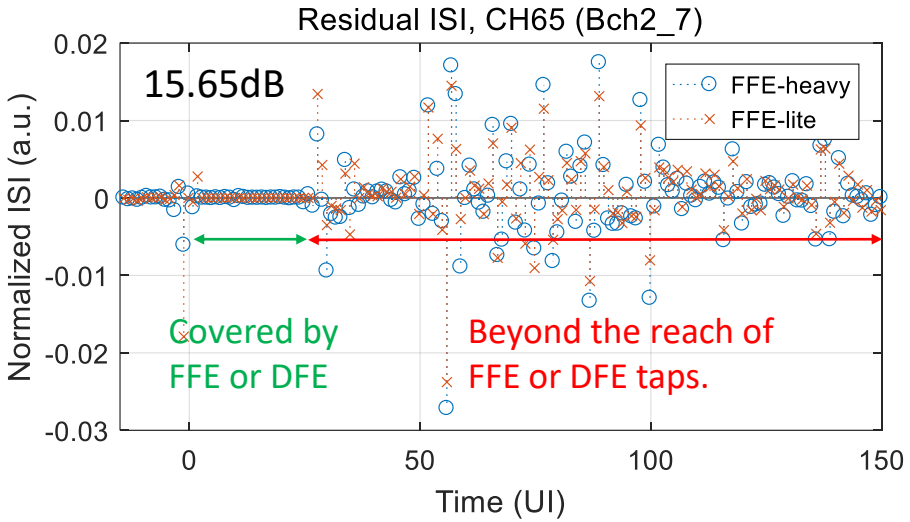


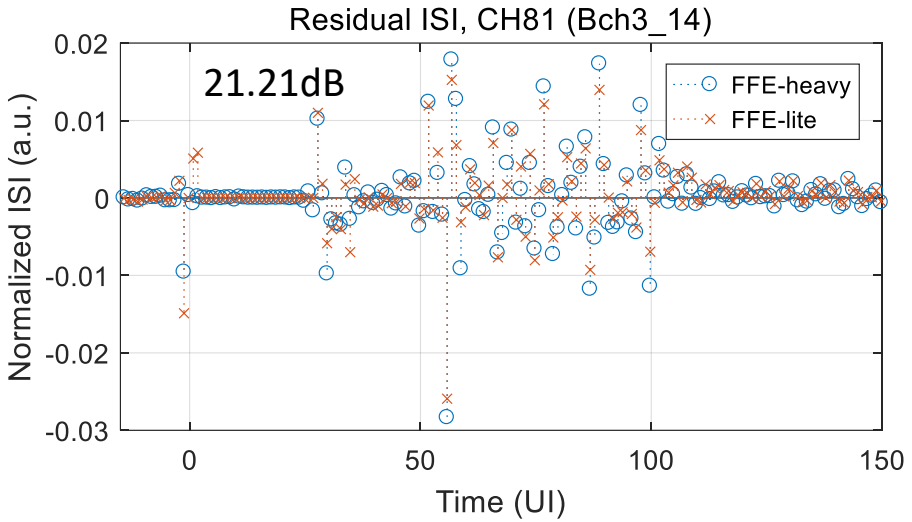


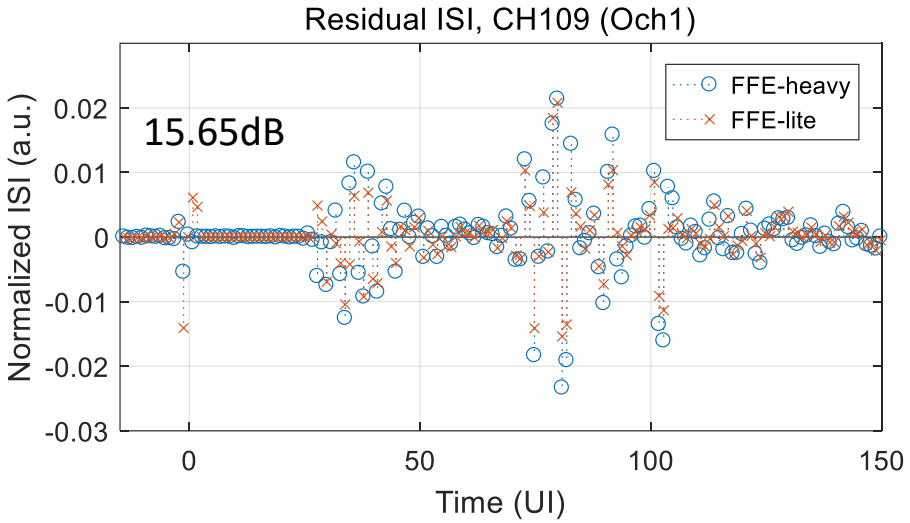


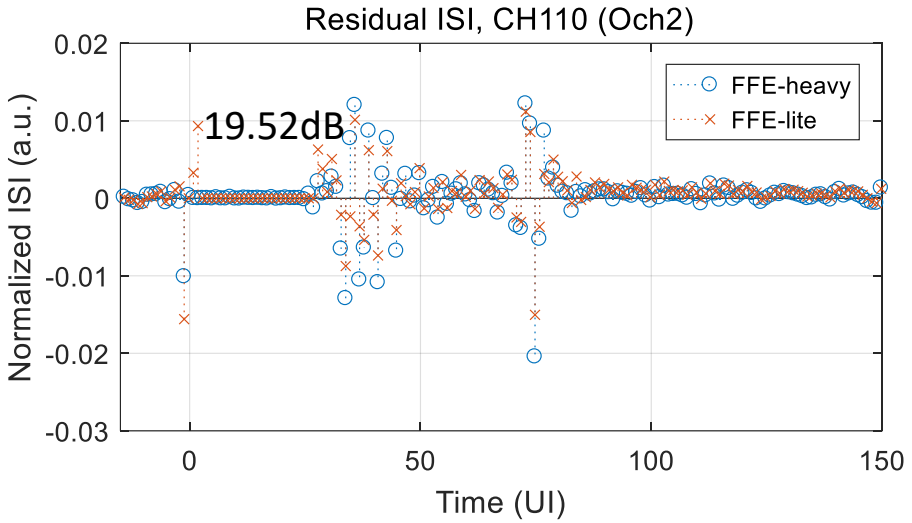


Time domain analysis of the “abnormal” channels: Residue ISI









Main cursor is normalized to 1.

Unsolved Issues tracking

FFE-lite receiver inherits advantages from FFE-heavy receiver and disadvantages from DFE receiver.

<table>
<tr><th>#</th><th>A: DFE
n-tap DFE</th><th>B: FFE-lite
‘m-pre & 0-post’ FFE +
n-tap DFE</th><th>C: FFE-heavy
‘m-pre & n-post’ FFE
+ 1-tap DFE</th></tr>
<tr><td>Pre cursor equalizer</td><td>TX FFE</td><td>TX FFE + RX Pre-tap FFE</td><td>TX FFE + RX Pre-tap FFE</td></tr>
<tr><td>Post cursor equalizer</td><td>Long DFE</td><td>Long DFE</td><td>Long FFE + 1-tap DFE</td></tr>
<tr><td>Additional Requirements</td><td colspan="2">1. 2% or finer TX FFE resolution.
2. b1max=0.85 or higher.</td><td>None</td></tr>
<tr><td rowspan="5">Known Unresolved Issues</td><td colspan="2">It may pass some ‘noise dominant’ channels, while FFE receiver fail.
It may pass channels that should fail due to crosstalk or reflection.
It is architecture difference between long DFE and long FFE.
Case A: High crosstalk, low insertion loss;
Case B: High reflection, low/medium insertion loss;
Case C: mixture of case A and case B.</td><td rowspan="5">None</td></tr>
<tr><td>Lower performance in general. Large COM difference deviation with respect to FFE-based receivers.</td><td rowspan="4">None</td></tr>
<tr><td>Fine TX FFE resolution will slow down COM simulation. 2.5%→1.5% TX FFE needs 66% more time to search for the optimal FOM.</td></tr>
<tr><td>Feasibility and power&area&latency ‘penalty’ of fine resolution TX FFE should be studied.</td></tr>
<tr><td>‘b1max>0.7’ will introduce more severe error propagation.</td></tr>
</table>

Summary of the reference receiver candidates

- **FFE-heavy** receiver **has already been used as a benchmark**. All the concerns seem to have been resolved.
- **FFE-lite** receiver is a good compromise to replace FFE-heavy receiver.
  - It generally gives similar COM compared with FFE-heavy, it has small mean/deviation of ‘COM Delta’.
  - Most of the concerns have been resolved, including the ‘b(1) control’ and ‘outperform’ issue.
  - **It may pass channels that should fail due to crosstalk or reflection.**
- **DFE** receiver has more concerns:
  - Low performance in general. Large COM difference deviation with respect to FFE receiver.
  - **It may pass channels that should fail due to crosstalk or reflection.**
  - Too many requirements to make DFE receiver work.
    - 2% or finer TX FFE resolution (Cannot pass COM with 2.5% TX FFE resolution for some 28dB channels).
    - Relax the “b1max=0.7” constrain to 0.85 or higher (Introduces more severe burst errors).
  - 2.5%→1.5% TX FFE needs 66% more time to search for the optimal FOM.
  - 2.5%→1.5% TX FFE needs extra TX power, area and latency without obvious benefits.
  - Feasibility of changing TX FFE resolution from 2.5% to 1.5% is questionable.
  - 0.85 or higher b1max will introduce more severe error propagation.

Recommendations

- Find more concerns about FFE-heavy (‘m-pre & n-post’ FFE + 1-tap DFE) receiver and resolve it. **If there is no more concerns, adopt FFE-heavy receiver as baseline reference receiver.**

- FFE- and DFE-based receivers are architecturally different, **exceptions can always be found**! We should go for a general receiver to cover most cases.
  - FFE-based receiver gives better COM in loss dominant channels (Precursor cancellation).
  - DFE-based receiver gives better COM in noise dominant channels (FFE noise amplification).
  - **DFE-based receiver gives better COM in reflection dominant channels (Reflection cancellation).**
    - DFE-based receivers are more efficient than FFEs when processing reflections within their reach.
    - The reflections beyond the reach of FFE/DFE taps can be viewed as background noise.
    - Reflection cancellation is independent of TX FFE. Fine resolution TX FFE does not help.
- **Although DFE based may give better COM in some cases (crosstalk or reflection dominant channels), it generally has lower performance.** Meanwhile, the model integrity is questionable, and may not provide reliable results in channel quality assessment.

- **Move forward with FFE-based receiver. Even all the issues of DFE-based receivers are resolved, it may not give ‘better results’.**

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