Comparison of KR/CR Reference Receivers

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Introduction

- There are discussions regarding performance of different KR/CR reference receivers.

- This contribution presents COM simulation results for all **115** KR/CR channels submitted to 802.3ck project (including 100GEL) with the three reference receivers under discussion.
  - A: Existing long DFE receiver.
  - B: Long FFE + 1-tap DFE receiver.
  - C: 3-tap FFE precursor + long DFE post cursor receiver.

- DFE first tap weight (b1) was limited to 0.7 in existing COM tool. This contribution shows DFE receiver performance is much better if b1max is relaxed to 0.85 or 1.0.
  - b2 becomes more positive for larger b1 and alleviates error propagation. The values of b1, b2, and b3 can be controlled for real receivers.
  - Interleaved FEC (if adopted) can tolerate more burst errors.

- TX FIR resolution impact is studied.

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Simulation Conditions

Model Name		DFE (DFE-based)	PDFE (DFE + 3 pre-taps)	FFE (FFE-based)
# of taps	DFE	20	20	1
	FFE	0	4 (3-pre + 0-post)	24 (3-pre + 20-post)
	TX FIR	5 (3-pre + 1-post)		
Step	RX DFE, FFE	0%		
	TX FIR pre	1.5% / 2.0% / 2.5%	1.5% / 2.5%	1.5% / 2.0% / 2.5%
	TX FIR post	5%		
DFE b1max		0.7 / 0.85 / 1.0	0.7 / 0.85 / 1.0	0.7 / 0.85

- Label of Simulation Condition: Prefix + Model Name + Suffix
  - Prefix: step of TX FIR pre taps
    - None: 1.5%, C (coarse): 2.5%, M (Medium): 2.0%
  - Suffix: DFE b1max value

  - Example
    - CDFE0.85: DFE-based with DFE b1max=0.85 and 2.5% step of TX FIR pre taps
    - PDFE0.7: DFE + pre-taps with DFE b1max=0.7 and 1.5% step of TX FIR pre taps

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Other Simulation Conditions

- RX FFE tap range
  - main_min = 0.7, pre1_max = 0.3, post1_max = 0.3, tapn_max = 0.125
- Package Model (Tx and Rx)
  - 30mm @ 87.5Ω + 1.8mm @ 92.5Ω
  - C_d = 110fF, C_p = 70fF, R_d = 50Ω
- Noise, jitter
  - η_0=8.20E-9V^2/GHz, SNR_{TX}=32.5dB, σ_{RJ}=0.01UI, A_{DD}=0.02UI, R_{LM}=0.95
- COM Tool version
  - v2.53 + local modification to fix bugs

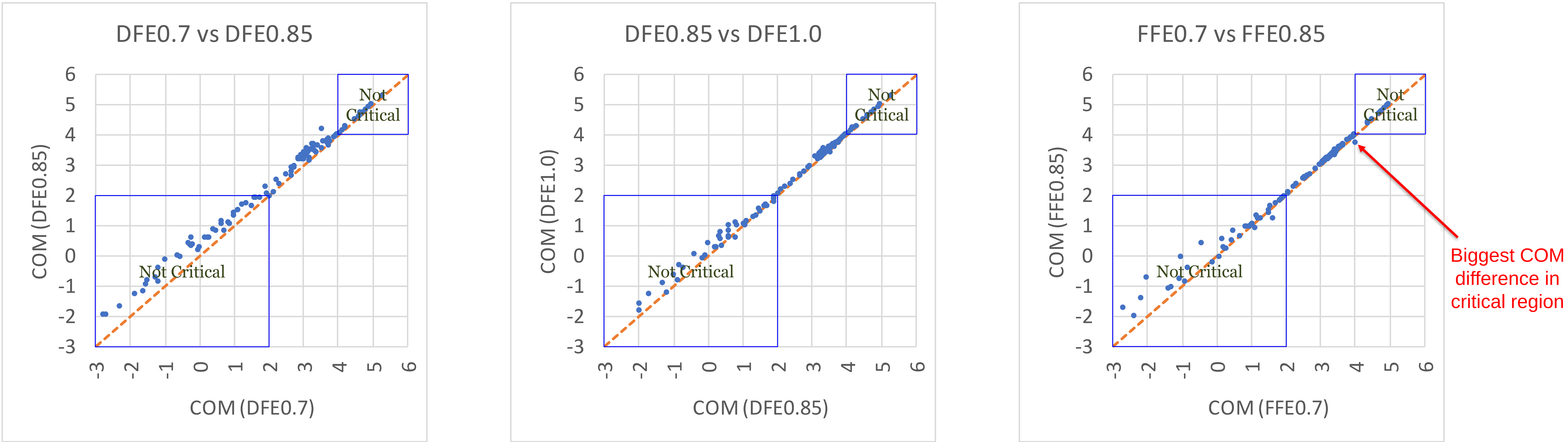
Channel Data for Simulation

➢ Simulation was done for the following publicly available 115 LR channels

CH #	Group	Description	Reference Document
1-2	RM1	Two Very Good 28dB Loss Ideal Transmission Lines	mellitz_3ck_adhoc_02_072518.pdf
3-8	RM2	24/28/32dB Cabled Backplane Channels including Via	mellitz_3ck_adhoc_02_081518.pdf
9-10	RM3	Synthesized CR Channels (2.0m and 2.5m 28AWG Cable)	mellitz_100GEL_adhoc_01_021218.pdf
11-13	RM4	Best Case 3”, 13”, 18” Tachyon Backplane	mellitz_100GEL_adhoc_01_010318.pdf
14-15	NT1	Orthogonal or Cabled Backplane Channels	tracy_100GEL_03_0118.pdf
16	AZ1	Orthogonal Backplane Channel	zambell_100GEL_01a_0318.pdf
17-19	HH1	Initial Host 30dB Backplane Channel Models	heck_100GEL_01_0118.pdf
20-35	HH2	16/20/24/28dB Cabled Backplane Channels	heck_3ck_01_1118.pdf
36-54	UK1	Measured Traditional Backplane Channels	kareti_3ck_01a_1118.pdf
55-73	UK2	Measured Cabled Backplane Channels	
74-88	UK3	Measured Orthogonal Backplane Channels	
89-115	AZ2	Measured Orthogonal Backplane with Varied Impedances	zambell_3ck_01_1118.pdf

All channel data are taken from IEEE 100GEL Study Group and P802.3ck Task Force – Tools and Channels pages.
i.e. http://www.ieee802.org/3/100GEL/public/tools/index.html and http://www.ieee802.org/3/ck/public/tools/index.html

Receiver Performance with Relaxed b1max

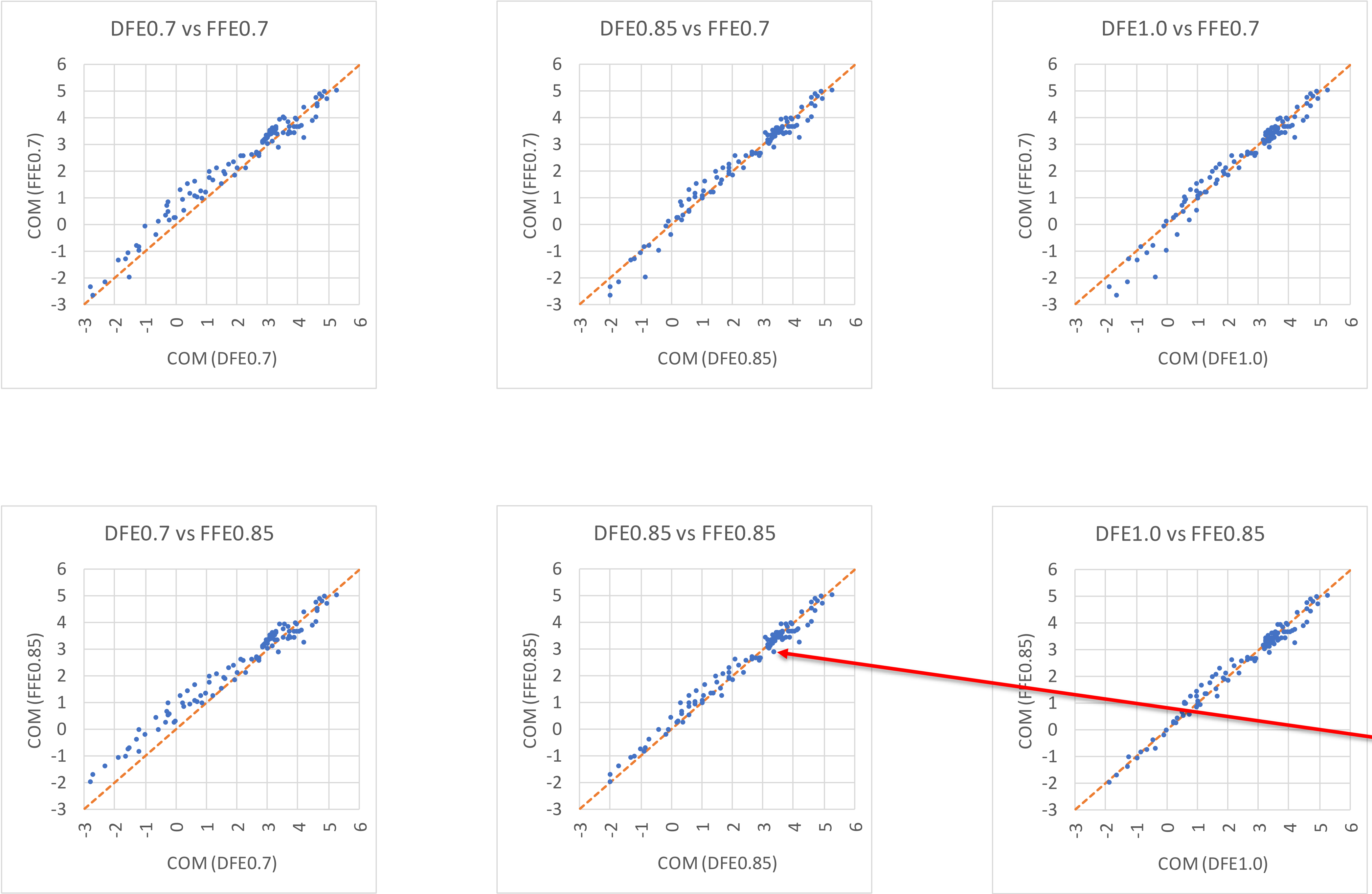


- Performance difference close to 3dB threshold is more critical for channel qualification purpose.
- In critical region, DFE receiver performance can be ~0.5dB better with b1max relaxed from 0.7 to 0.85.
- In critical region, DFE receiver performance can be ~0.2dB better if b1max is relaxed from 0.85 to 1.00.
- Relaxing b1max does not help FFE as much.
  - The biggest COM difference is FFE0.7 performs about 0.3dB better than FFE0.85.

Performance Comparison of DFE and FFE Receivers

DFE* vs FFE0.7

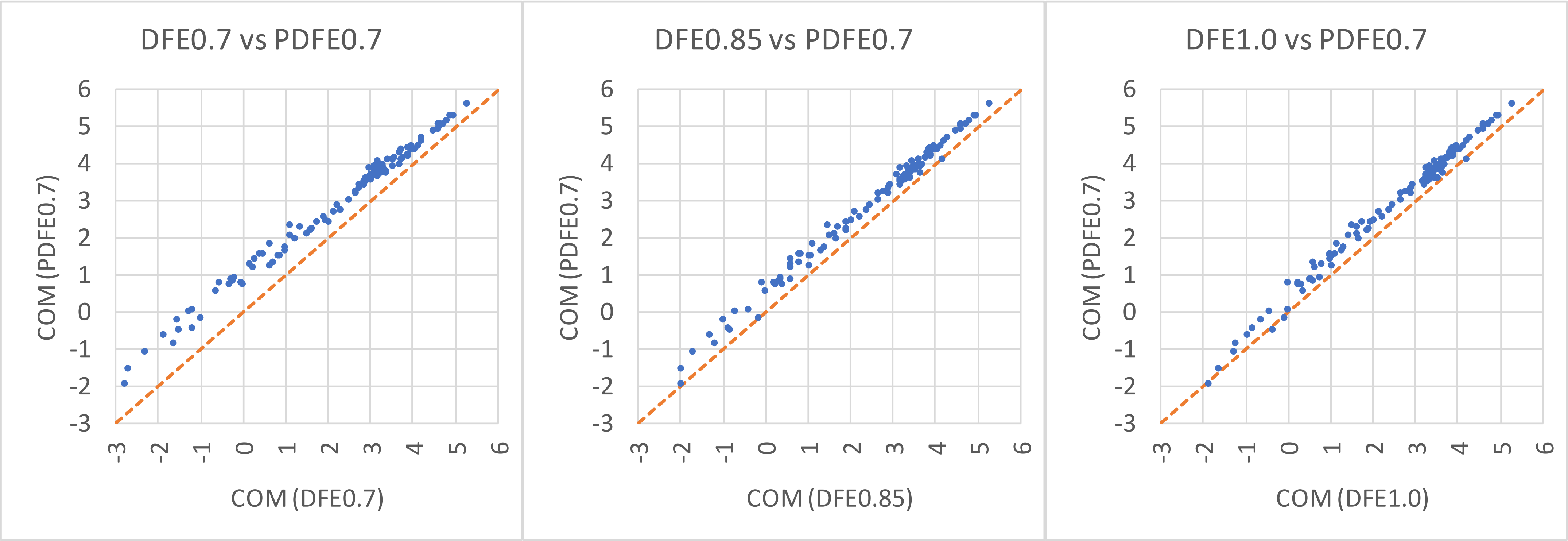
DFE* vs FFE0.85



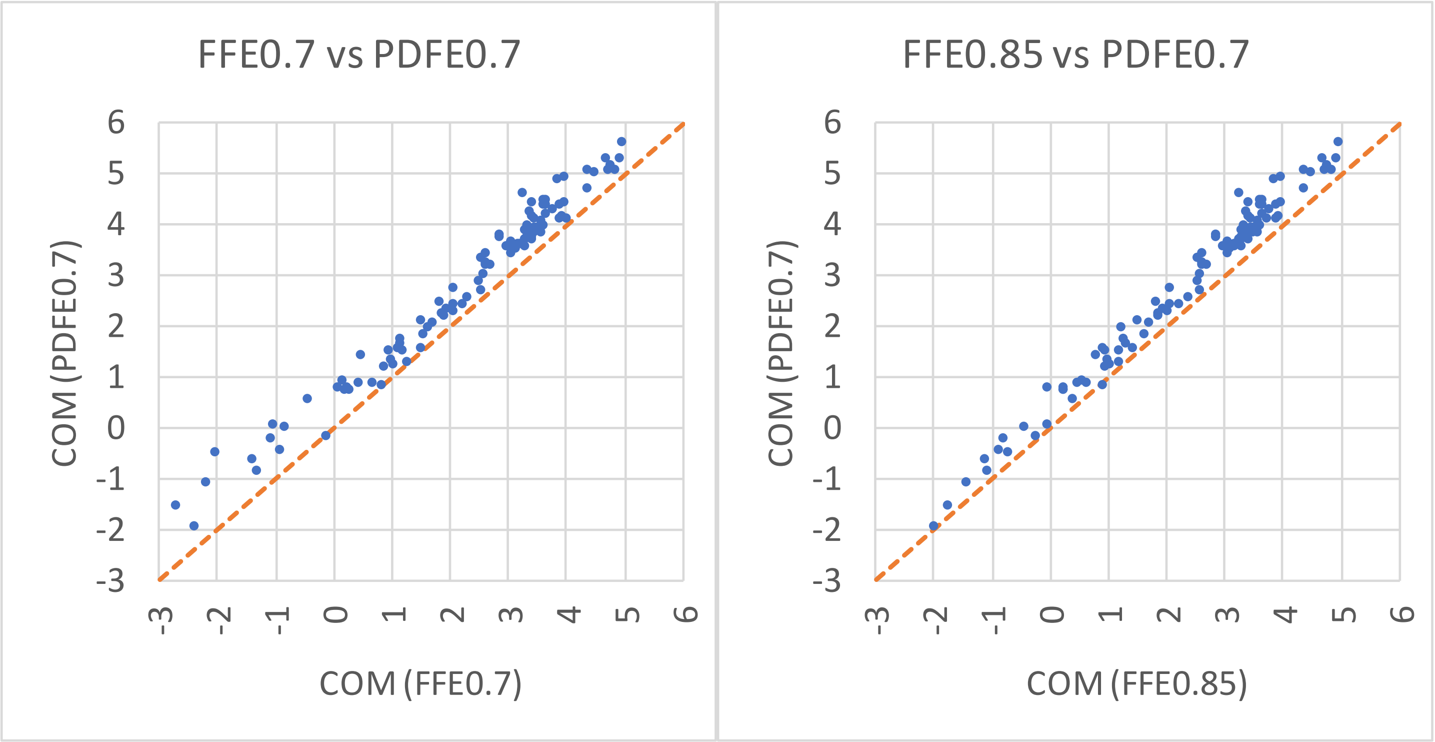
The only channel FFE and DFE give inconsistent pass/fail result.

- Performance of DFE is similar to FFE when COM is close to 3dB (2.5 to 3.5)
- With b1max=0.85, COM difference is within ~0.5dB for FFE and DFE receivers.
  - The only pass/fail inconsistency is one channel passed by DFE receiver but failed very marginally by FFE receiver.

PDFE Receiver Performance



DFE* vs PDFE0.7

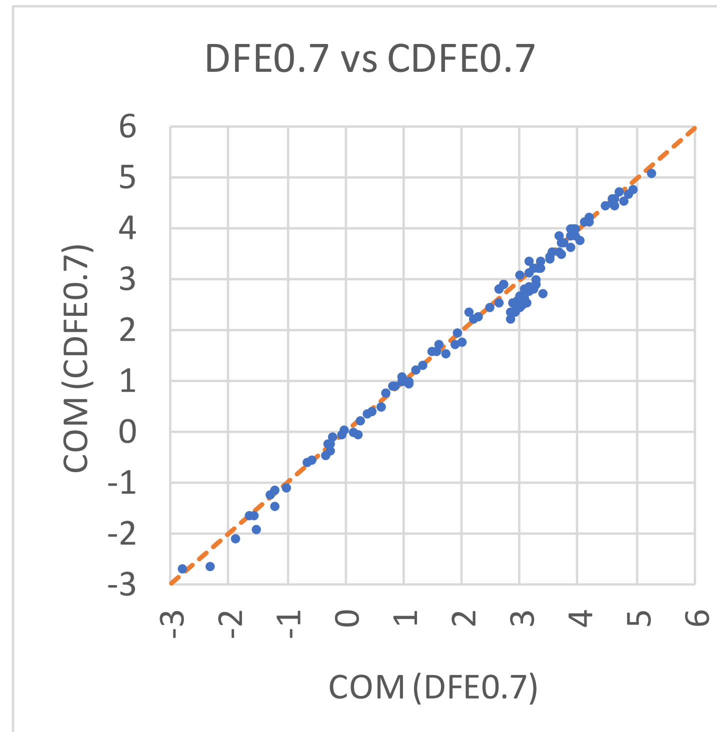


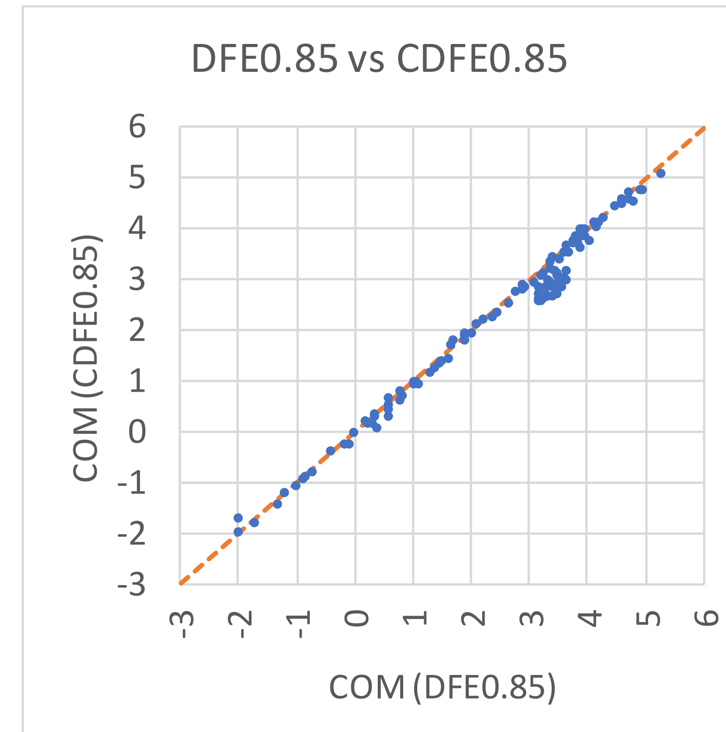
FFE* vs PDFE0.7

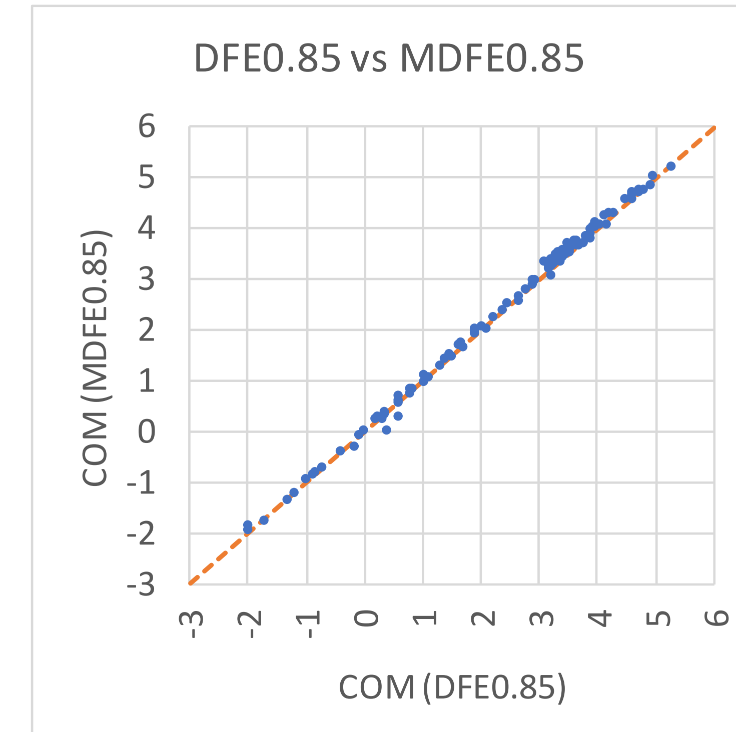
- PDFE is always better than DFE or FFE
  - Even PDFE0.7 (b1max=0.7) is mostly better than DFE0.85 and FFE0.85.
    - PDFE0.85 and PDFE1.0 are always better than PDFE0.7 (shown in backup)
- PDFE is an ideal analog SERDES architecture
  - It has implementation penalties which is not captured by this ideal reference model.
- PDFE passes channels that cannot be supported by typical DFE or FFE receivers.

TX Resolution Impact

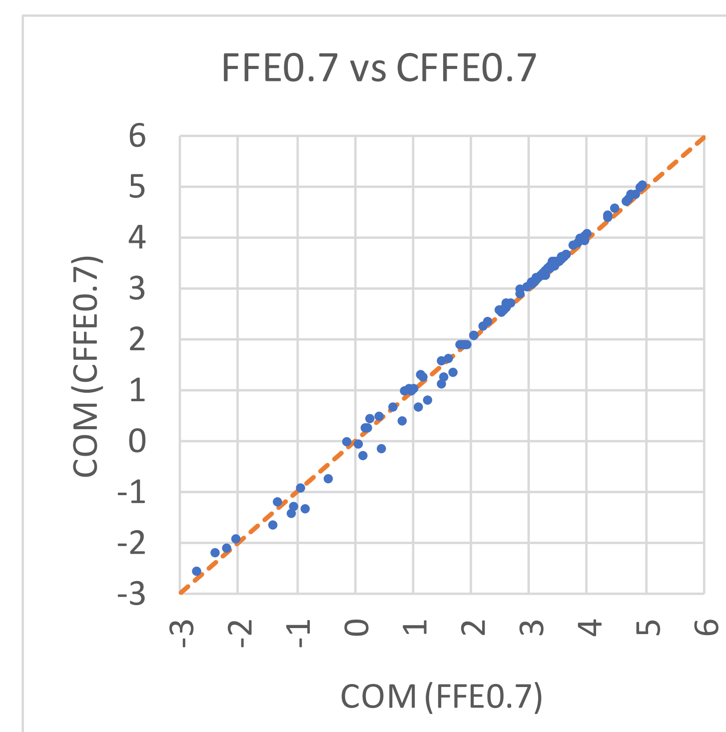
DFE vs [CM]DFE

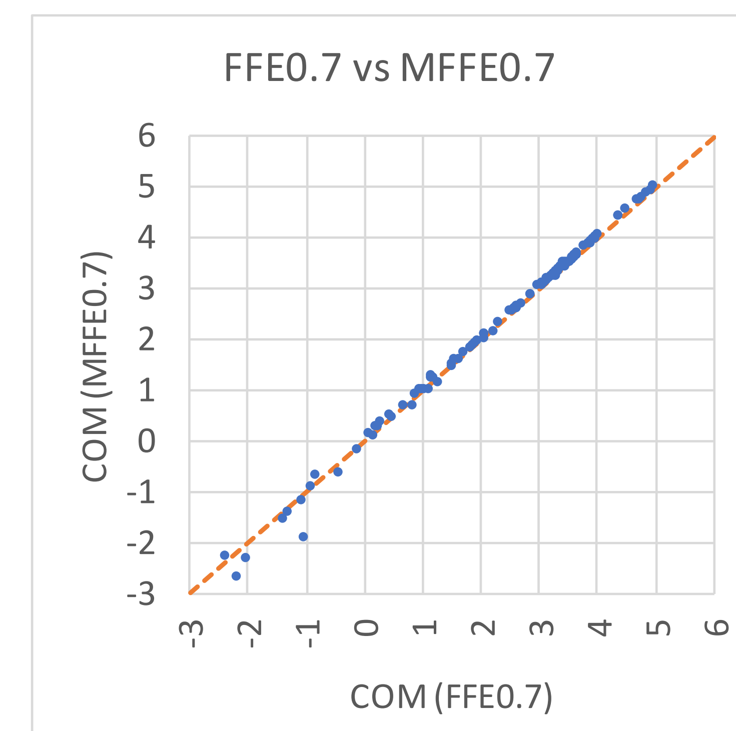






FFE vs [CM]FFE





- 2.5% (CDFE and CFFE) are often much worse than 1.5% (DFE and FFE)
- 2.0% (MDFE and MFFE) are close to 1.5% (DFE and FFE)

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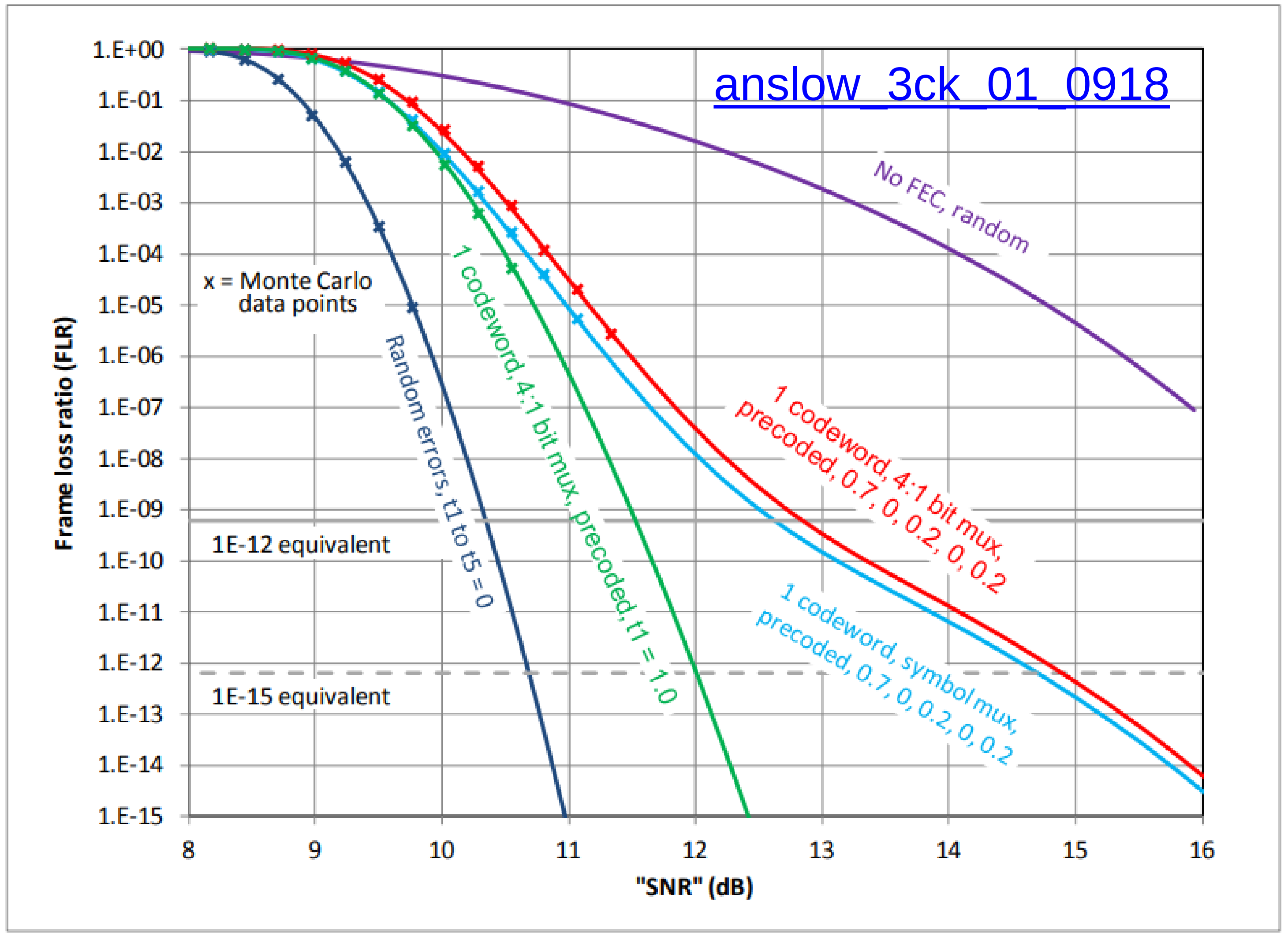
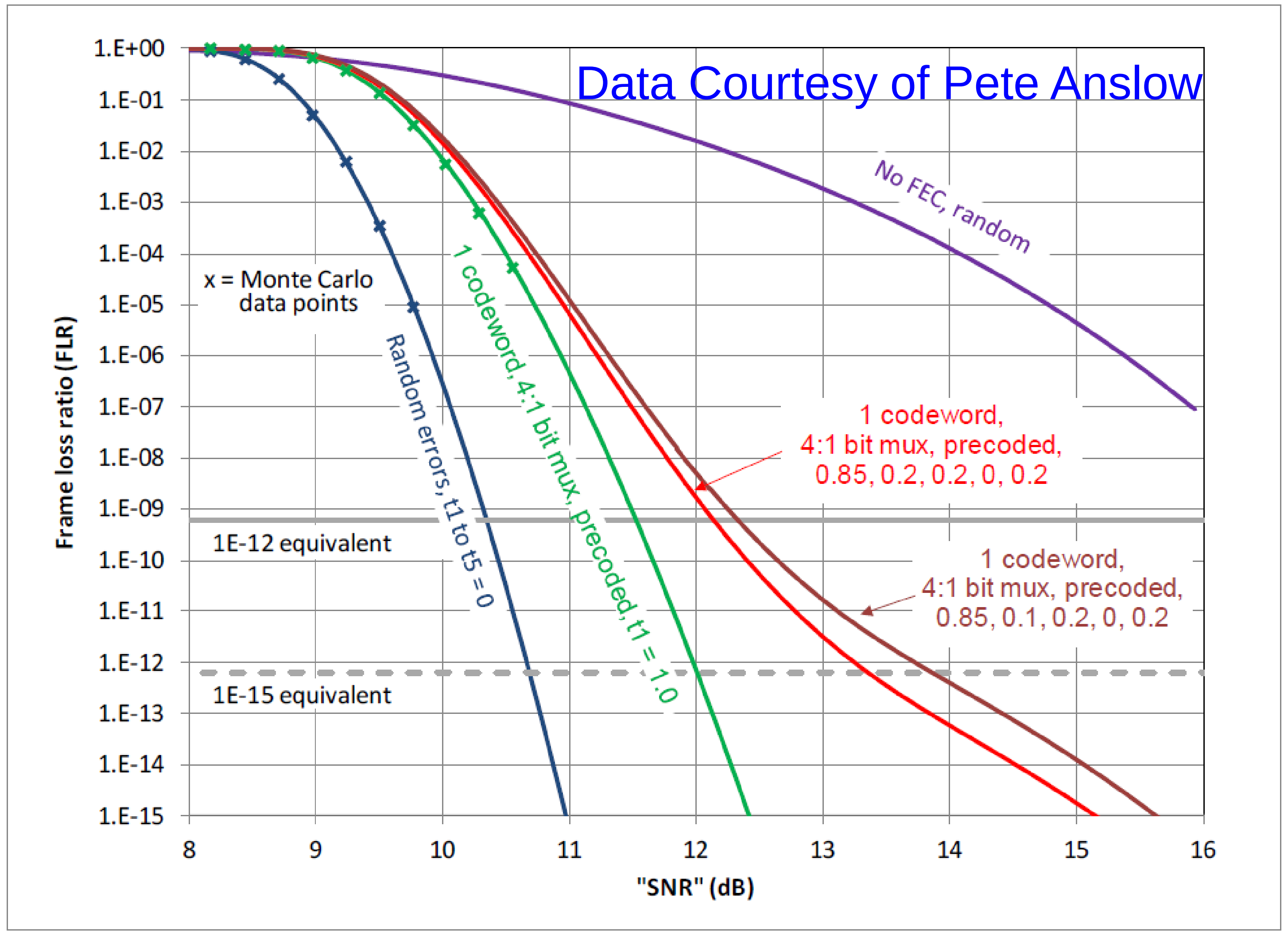
DFE Tap Weight Impact on FEC Performance

100G 5-tap DFE results (0.7, 0, 0.2, 0, 0.2) with precoding



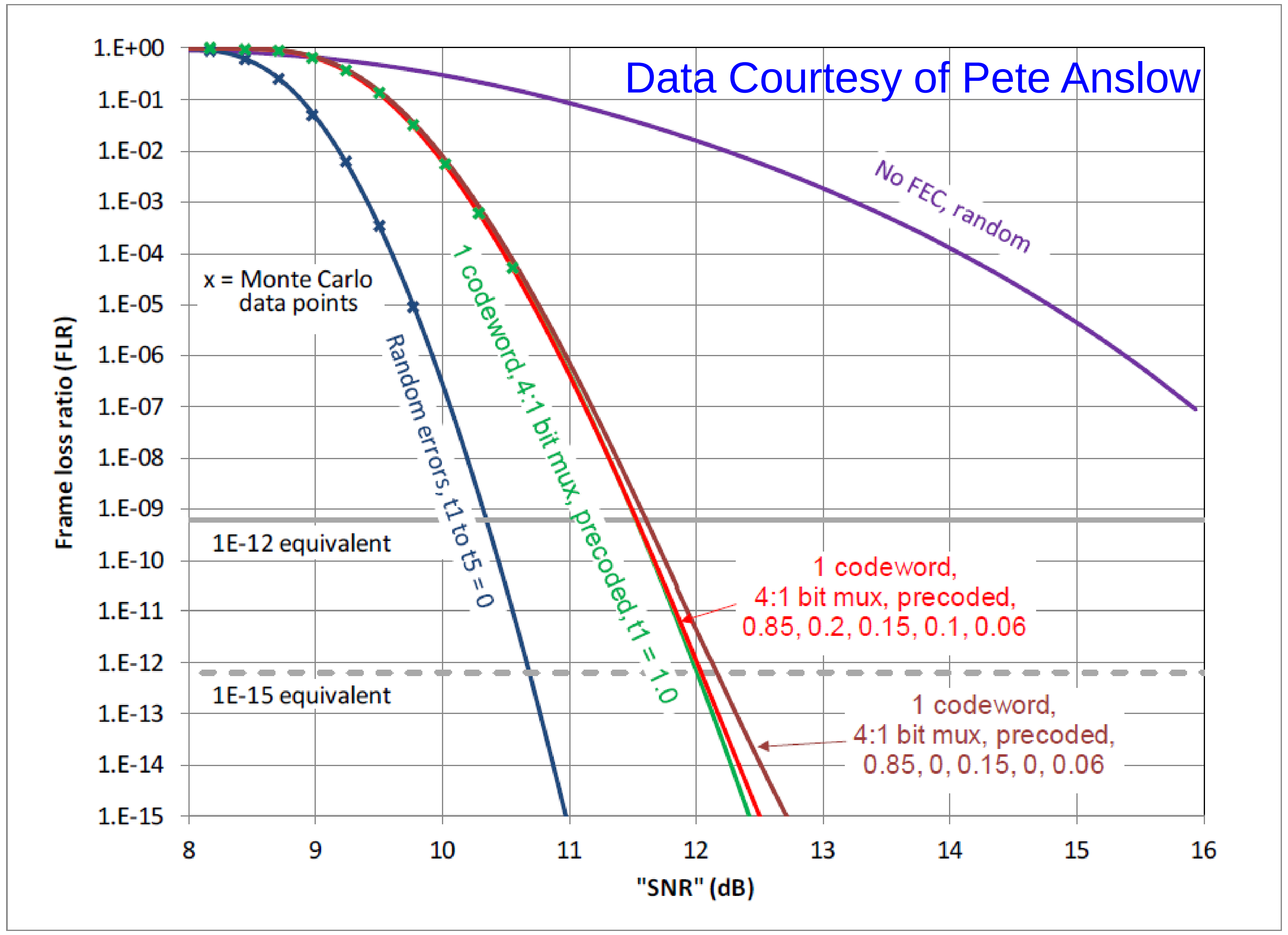
100G with 5-tap DFE (0.85, 0.2 or 0.1, 0.2, 0, 0.2)



- [0.85, 0.1/0.2, 0.2, 0, 0.2] has less burst error penalty than [0.7, 0.0, 0.2, 0, 0.2]. Positive h2 alleviates error propagation.

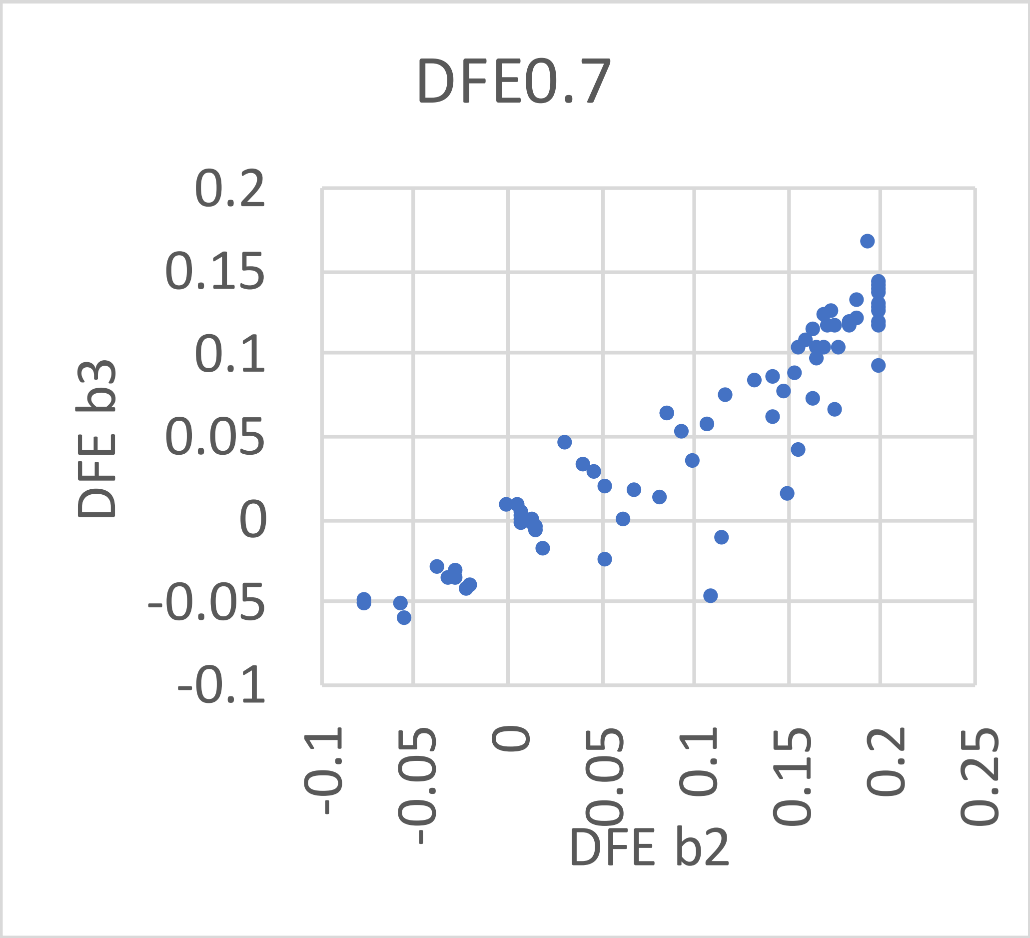
DFE Tap Weight Impact on FEC Performance Cont.

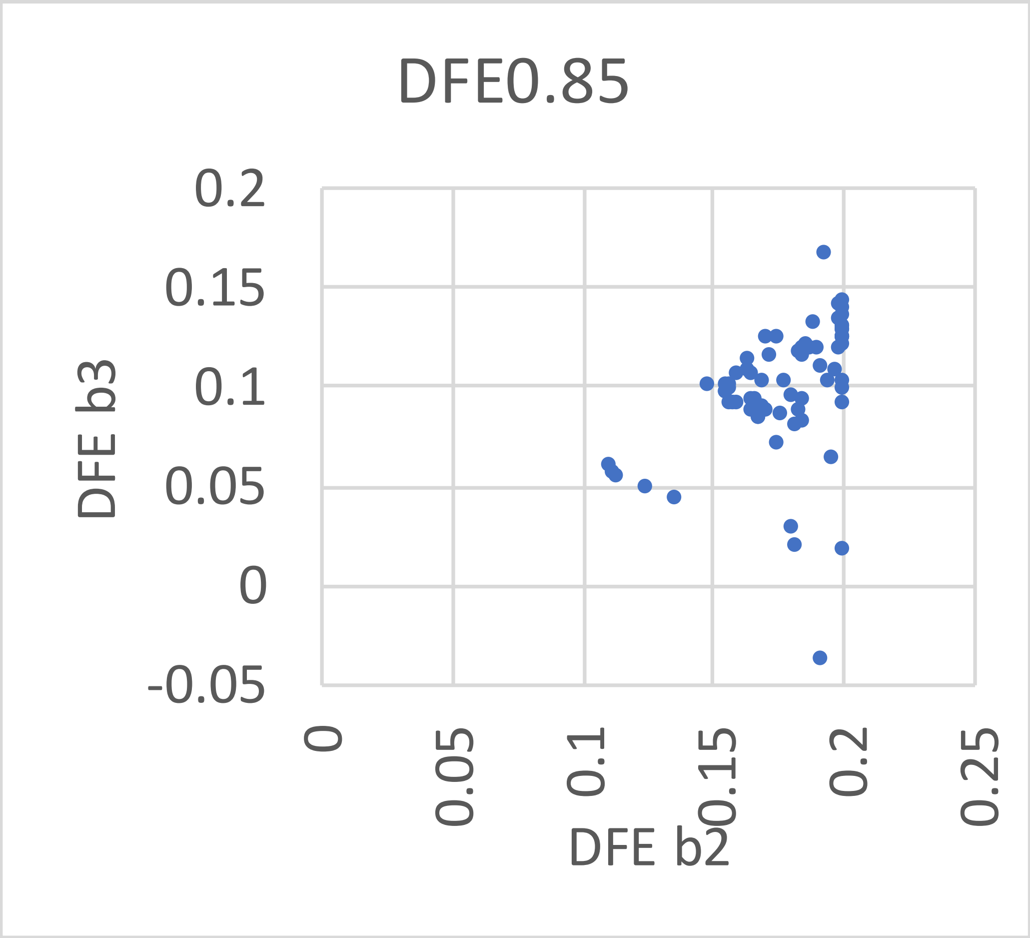
100G with 5-tap DFE (0.85, 0.2 or 0, 0.15, 0.1 or 0, 0.06)

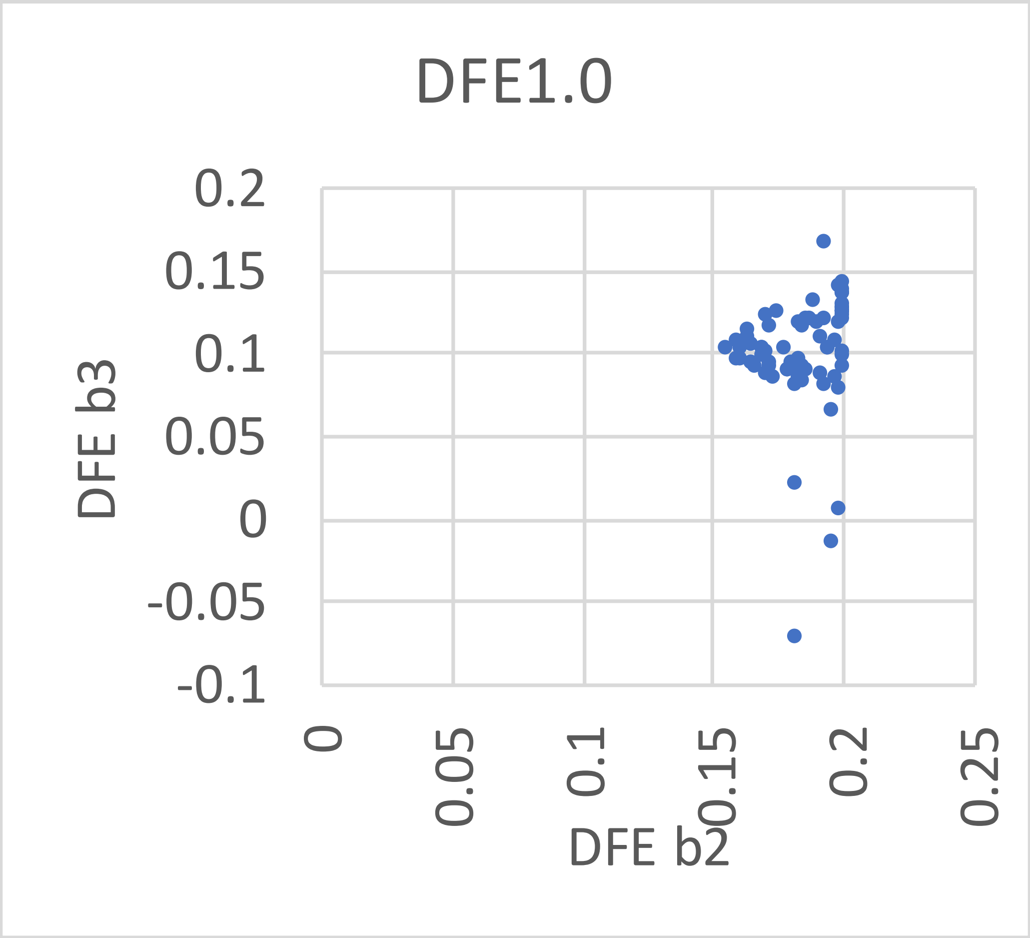


- Precoding becomes effective for smaller DFE tail weight or when DFE tail taps cancel each other. DER required by a single-tap or multi-tap DFE becomes similar.
- Precoding is less effective for burst caused by heavy DFE tail and slow noise.
  - PAM4 clock content issue may cause burst errors?
  - These factors need to be considered in link budget calculation.

DFE Tap Weight b2, b3 Statistics







- For reasonable channels (COM ≥ 2dB), b2min is observed to be more positive with larger b1.
  - b2 ≥ 0.10 with b1max = 0.85
  - b2 ≥ 0.15 with b1max = 1.0

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Conclusions

- COM simulation shows similar performance of DFE and FFE receivers with proper b1max.
  - Parameter b1max was limiting DFE receiver performance and can be relaxed.

- A receiver with DFE + FFE precursor (PDFE) is an ideal analog SERDES architecture. But as a reference model it passes channels that cannot be supported by typical architectures A and B.

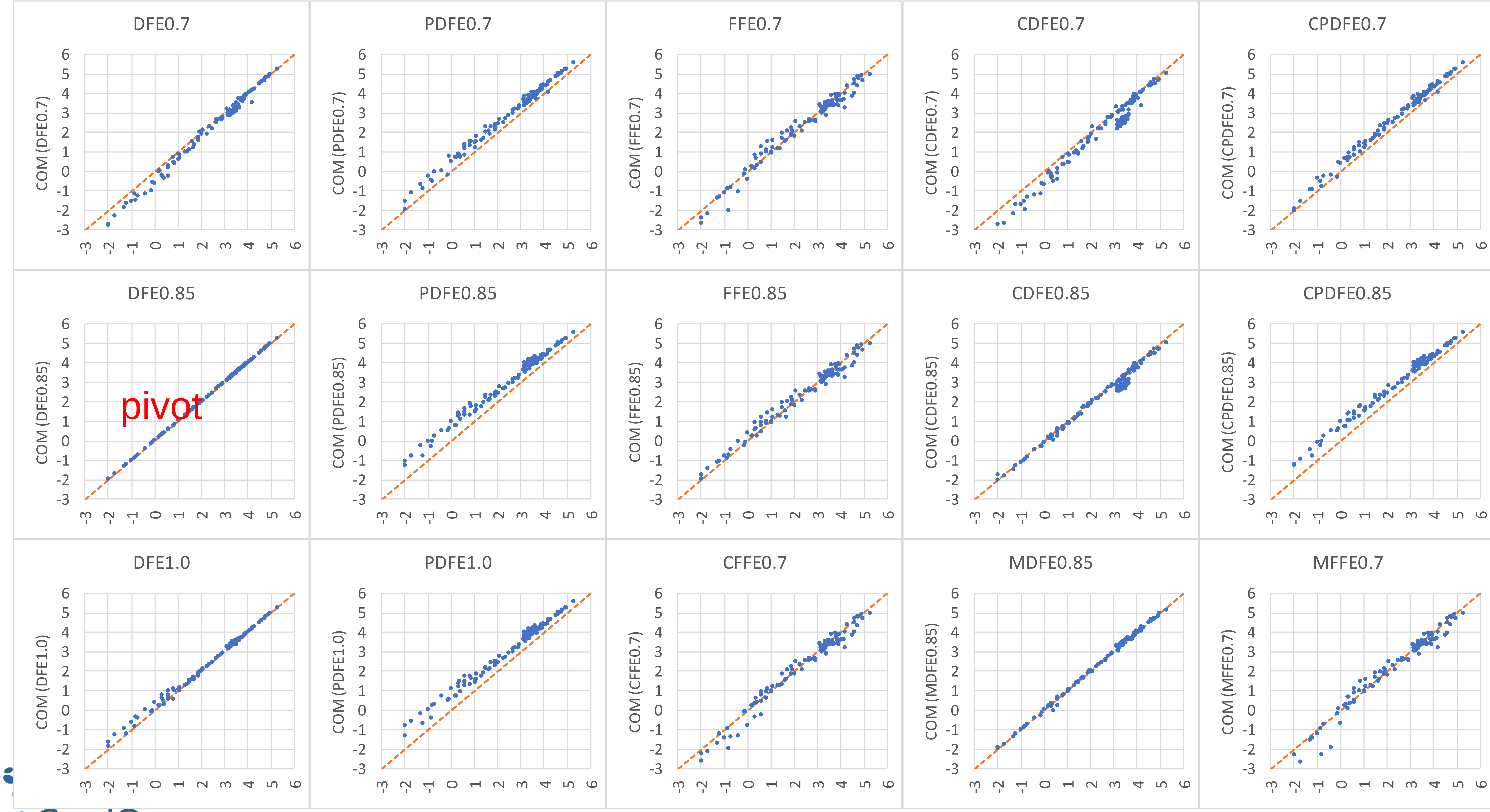
- Existing DFE reference receiver has some desired features:
  - COM tool has an elegant simple algorithm for DFE receiver, but does not always work properly for long FFE receivers.
  - DFE tail provides a tool for burst error penalty and precoding analysis.
  - DFE based reference model checks TX FIR impact which could be overlooked by the other two models.

- 2% or finer TX FIR resolution is recommended.

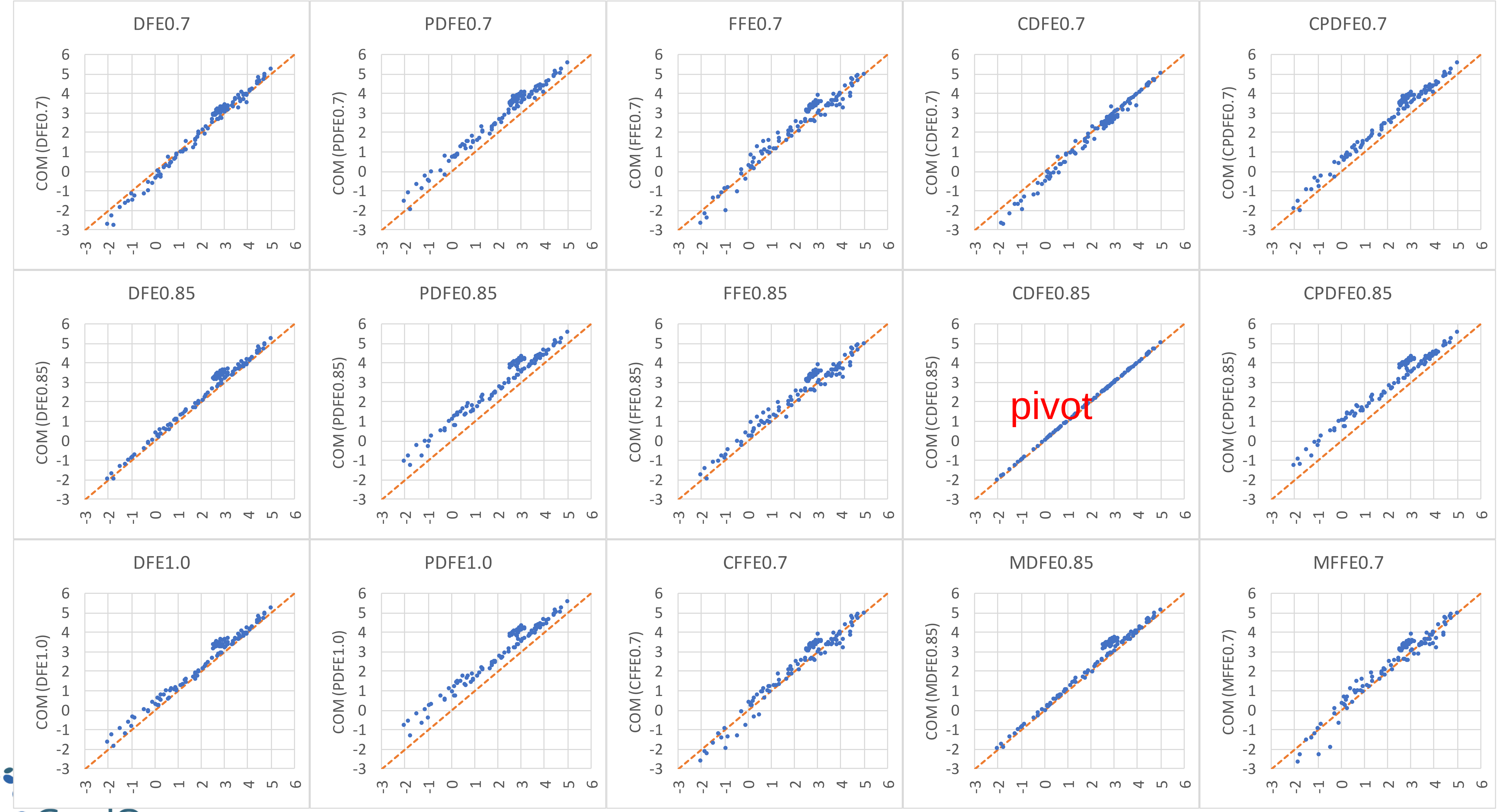
- Future work includes checking impact of implementation penalties, e.g. ADC ENOB (~5.5 bit).
  - DFE and FFE receiver performance tracks each other. Compared to existing COM receiver, relaxing b1max or using FFE is equivalent to relaxing 3dB COM threshold to ~2.5dB.
  - This is to check whether 3dB COM is proper with a stronger reference model. Detailed implementation penalty model may be too complicated to be put in COM tool.

Backup Slides

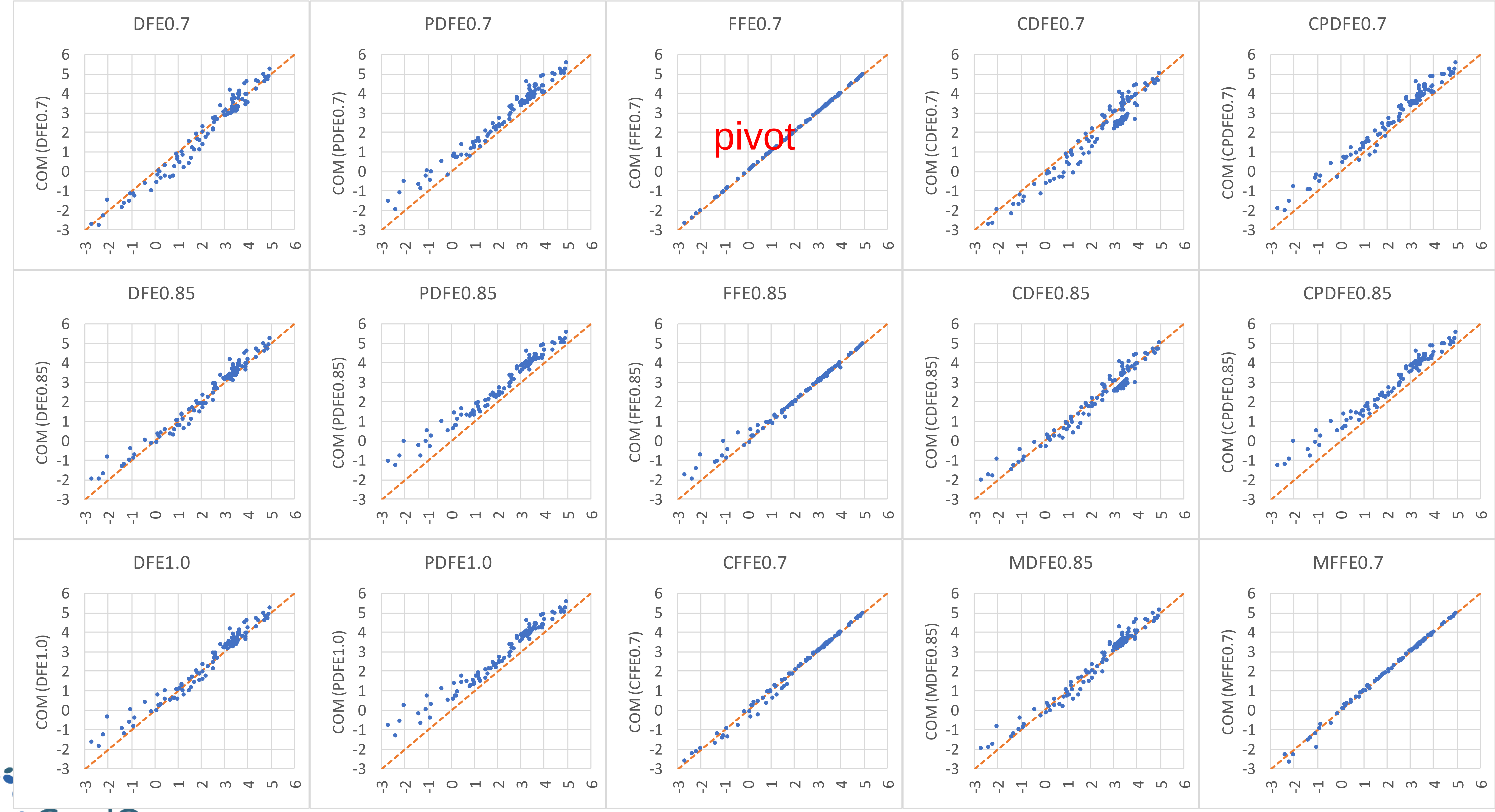
Comparison with COM (DFE0.85) as X axis



Comparison with COM (CDFE0.85) as X axis



Comparison with COM (FFE0.7) as X axis



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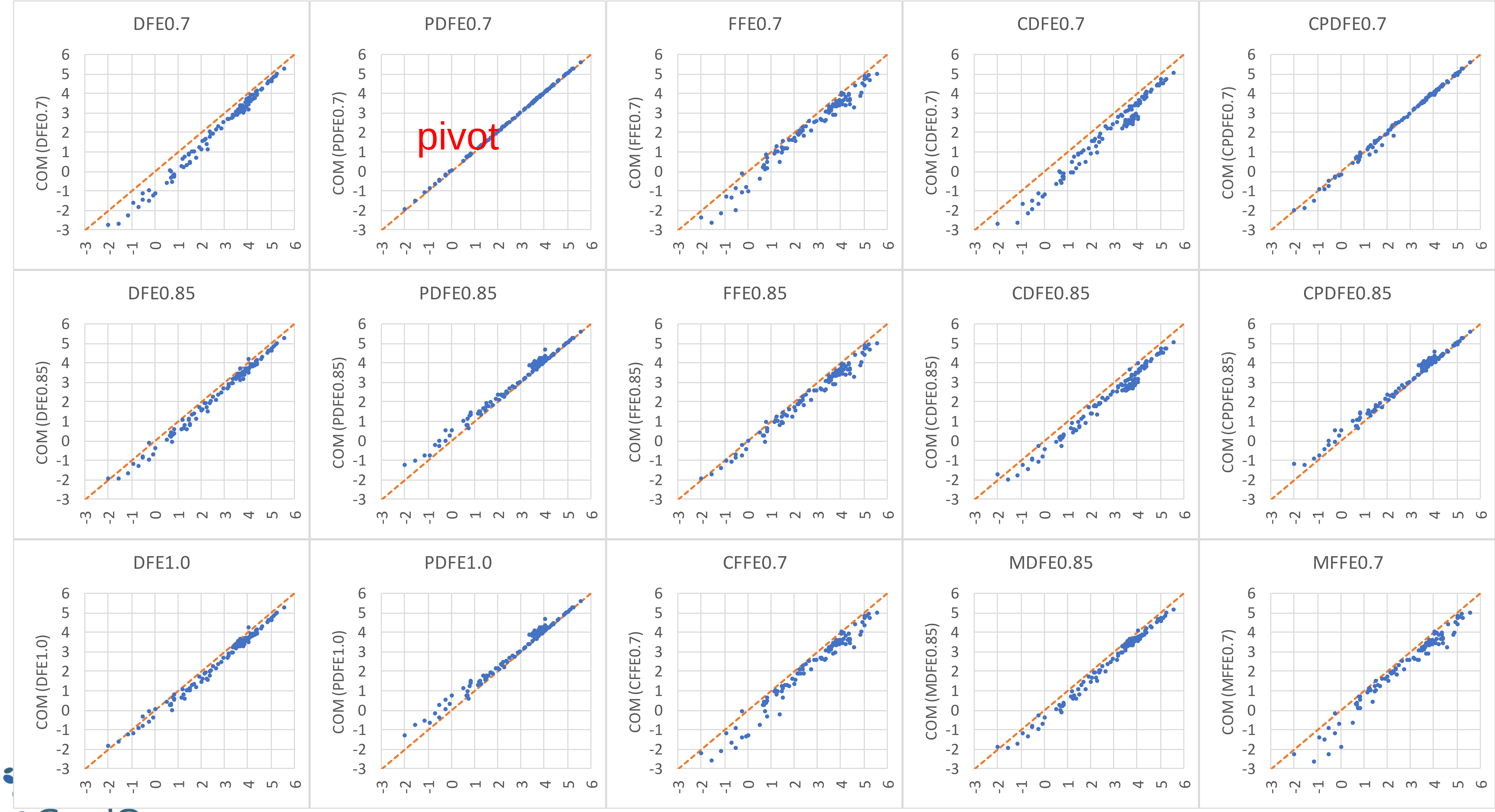
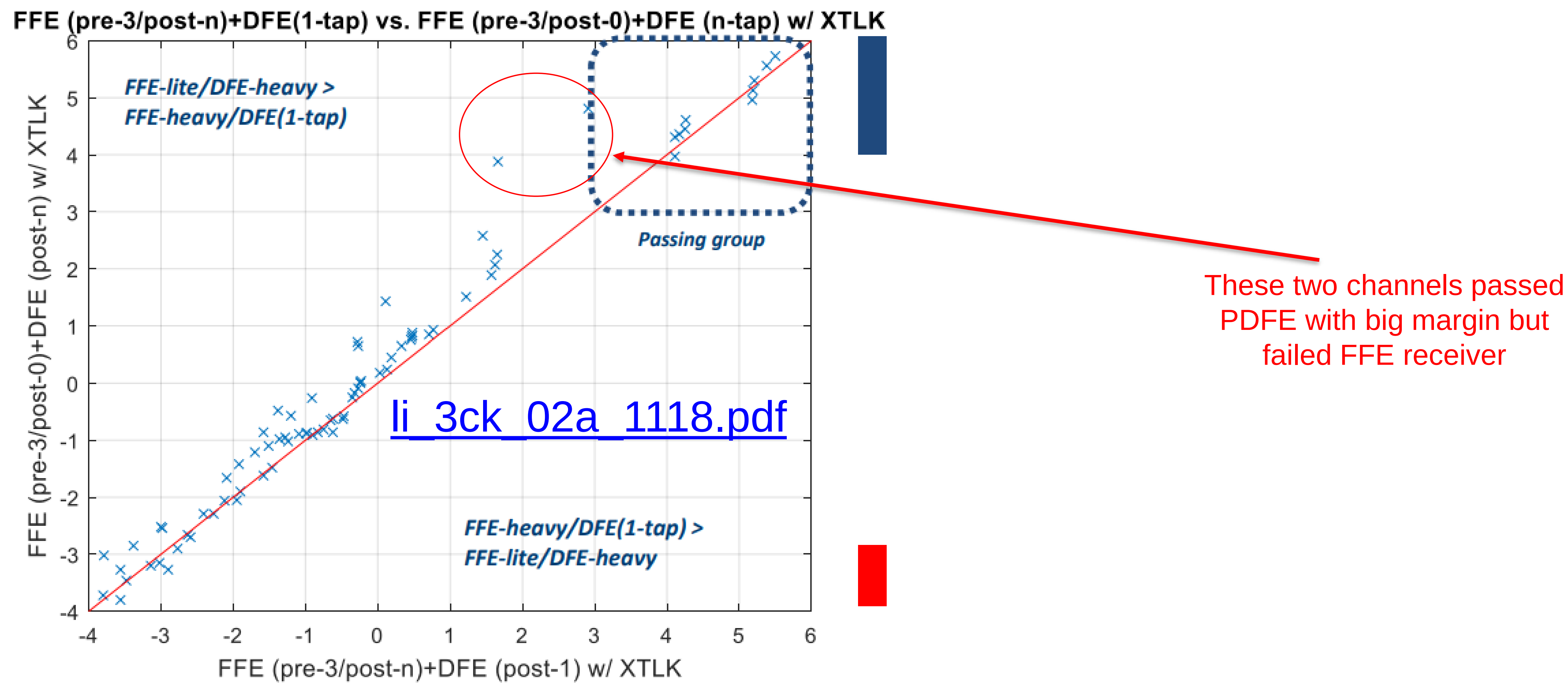
Comparison with COM (PDFE0.7) as X axis



PDFE Receiver Performance Cont.



- Other contributions also showed PDFE passes channels that cannot be supported by FFE receivers.
  - li_3ck_02a_1118, sakai_3ck_01a_1118