COM Sensitivity Analysis of PKG Model

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Outline

- Background & motivation
- Physical vs. COM correlation
- COM sensitivity analysis
  - Transmission line parameters
  - Device & package capacitances
- Summary & suggestions

Background and Motivation

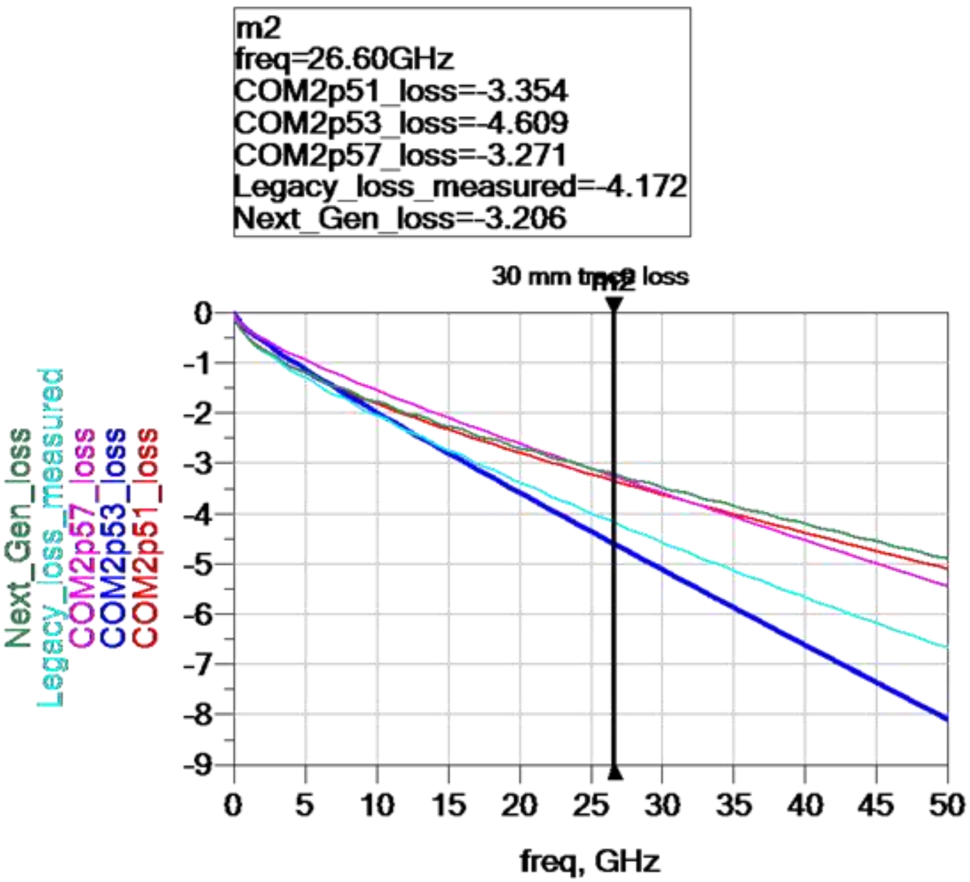
- For reference package (PKG) model in COM, Liav and Richard had presented a lot of contributions to the group
- A correlation study between COM reference PKG and physical PKG extracted model was shown in (benartsi_3ck_01_0518.pdf)
  - Highlighted 'noticeable performance difference' among 56G legacy COM PKG model and extracted PKG
- They proposed '2-segments flexible PKG model' in (mellitz_3ck_01_0918.pdf, benartsi_3ck_01_1118.pdf)
  - 87.5/92.5/97.5 Ohm trace + 92.5 Ohm PTH
- Latest PKG model discussion in (benartsi_3ck_adhoc_01_121218.pdf)
  - Updated parameters of trace model
- We presented works on PKG model, including
  - Correlation of measured/estimated Physical models to COM for transmission line model parameters (in Table 93A-3)
  - COM performance impact due to different TL (transmission line) models
  - COM performance impact due to device/package capacitances

Physical Extracted Model vs. COM Model

- By changing the following PKG parameters, to correlate physical PKG model to COM model
  - ‘package_tl_gamma0_a1_a2’, ‘package_tl_tau’
- There are two kind of physical extracted PKG models here
  - ‘**Legacy**’: Legacy PKG substrate design technology
  - ‘**NG**’: Next-generation (NG) PKG substrate design technology
- Three PKG models in COM
  - COM2p51, COM2p53, & COM2p57
  - Compared them with different TL parameters, but keep others the same as COM2p57
- Actions
  - Try to analyze which kind of parameters are better matched to ‘Legacy’ and ‘NG’ PKG substrate technologies
  - Apply COM analysis to show the performance difference among different PKG models

Transmission Line Model Benchmark

Parameter Setting	COM2p57	COM2p51	COM2p53
package_tl_gamma0_a1_a2	**[0 0.9909e-3 2.772e-4]**	[0 1.734e-3 1.455e-4]	**[0 0.7901838e-3 5.0925e-4]**
package_tl_tau	6.140E-03	6.141E-03	**6.325E-03**
IL @ 26.6GHz [30mm trace]	3.271	3.354	4.609



- PHY extracted models
  - Legacy: existing & used for 50Gb/s
  - Next_Gen: surface roughness improvement
- COM2p51 & COM2p57 have similar loss @ 26.6GHz
  - ~3.3 - 3.4dB
  - Close to ‘Next_Gen’ ~= 3.2dB
  - COM2p51 meets ‘Next_Gen’ better
- COM2p53 is slightly worse than even ‘Legacy’
  - COM2p53 may be too worse
- Q: COM analysis among COM2p57, 2p51, & 2p53?

COM Sensitivity Analysis – Settings

- We tried to compare COM values of the following three TL parameters

Parameter Setting	COM2p57	COM2p51	COM2p53
package_tl_gamma0_a1_a2	**[0 0.9909e-3 2.772e-4]**	[0 1.734e-3 1.455e-4]	**[0 0.7901838e-3 5.0925e-4]**
package_tl_tau	6.140E-03	6.141E-03	**6.325E-03**
IL @ 26.6GHz [30mm trace]	3.271	3.354	4.609

- Baseline COM2p57 excel sheet
  - Followed 'config_com_ieee8023_93a=100GEL-KR_DFE_121918.xls' file, except changing
    - Set both sides the same trace length
    - Zp = 30mm & 40mm (for large package case)
- Tried three different ref. Rx cases
    - DFE-only, Lite-FFE, & Heavy-FFE
    - N_b = 24

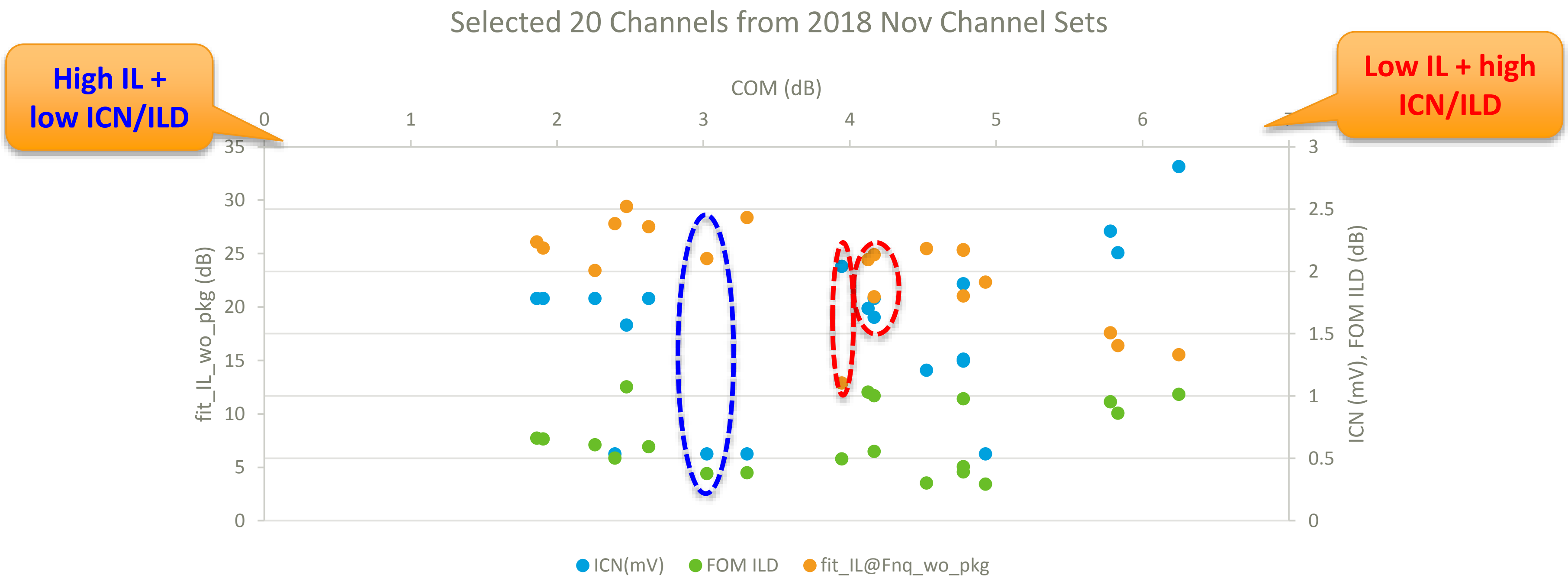
Parameters	DFE	LFFE	HFFE
N_b	24	24	1
ffe_pre_tap_len	0	3	3
ffe_post_tap_len	0	0	24

- Total 36 IEEE channels selected for analysis
  - 16 before 2018 Nov.
  - 20 from 2018 Nov.

Channel List

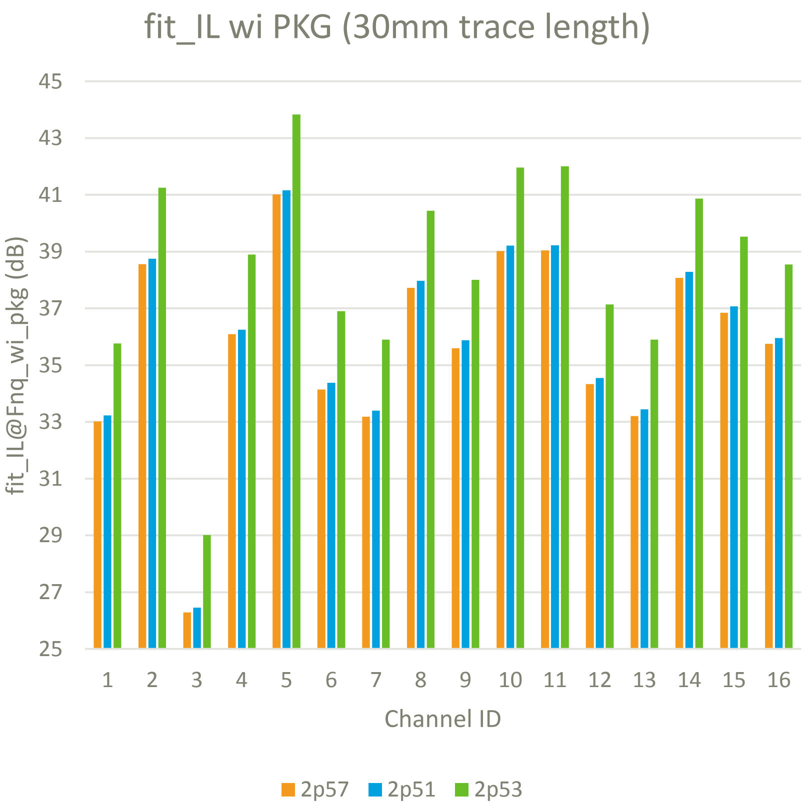
Selected Channels Policy

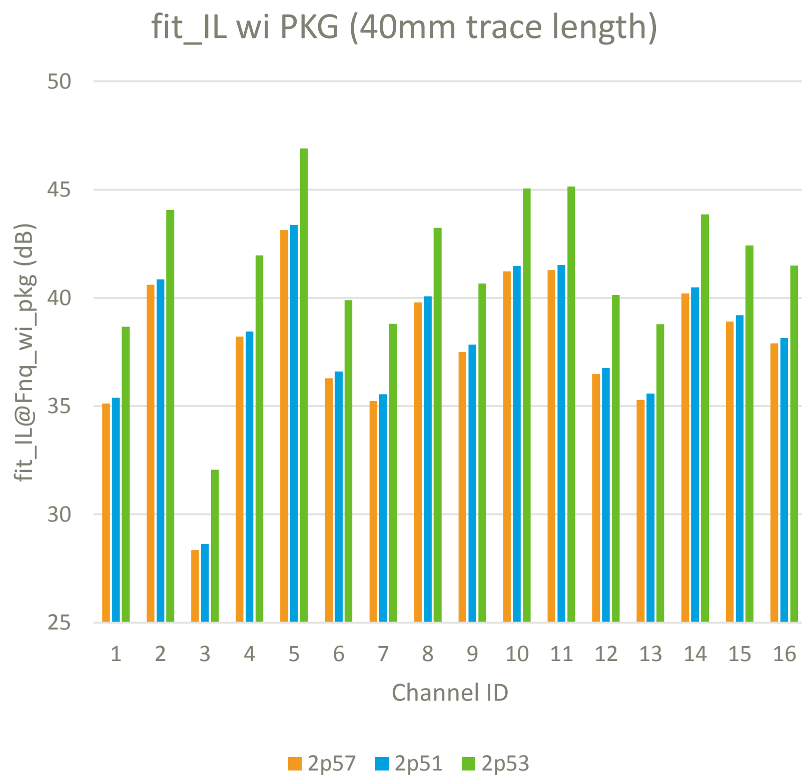
- Select 20 channels from IEEE Nov. channels
  - Try to cover wide ranges from different perspectives
  - IL (ball-2-ball): 13 – 30 dB
  - COM: 1.8 – 6.2 dB
- Some low IL with high ICN/ILD channels
  - IL = 13 dB, ICN = 2.0mV
- Some high IL with low ICN/ILD channels
  - IL = 24.5 dB, ICN = 0.5mV, ILD = 0.4 dB



IL Impact – 30mm & 40mm

- By 16 channels
- Compare the fitted IL @ Nyquist freq wi PKG (bump-2-bump IL)
- COM2p53 induces larger IL than COM2p57
  - In average 2.75dB (for 30mm) & 3.60dB (for 40mm)
- COM2p51 have slightly (~0.21dB for 30mm & ~0.28dB for 40mm) larger IL than COM2p57

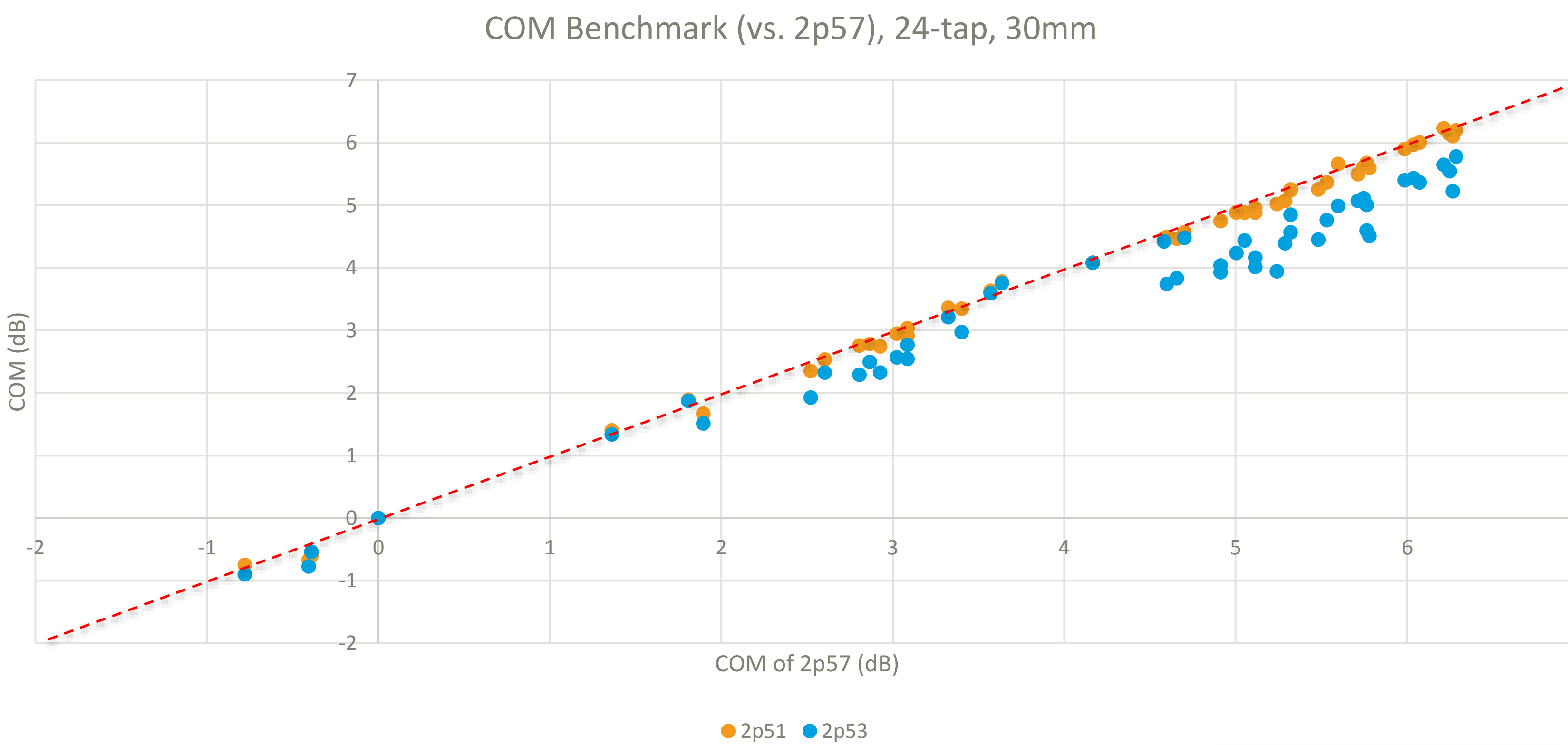




COM Benchmark – 24-tap, 30mm

- 16 channels only
- Including DFE, LFFE (Lite-FFE), & HFFE (Heavy-FFE)
- COM2p57 outperforms COM2p53
- COM2p57 is slightly better than COM2p51

COM diff (dB, mean)	DFE	LFFE	HFFE
2p57-2p51	0.08	0.11	0.12
2p57-2p53	0.57	0.53	0.61

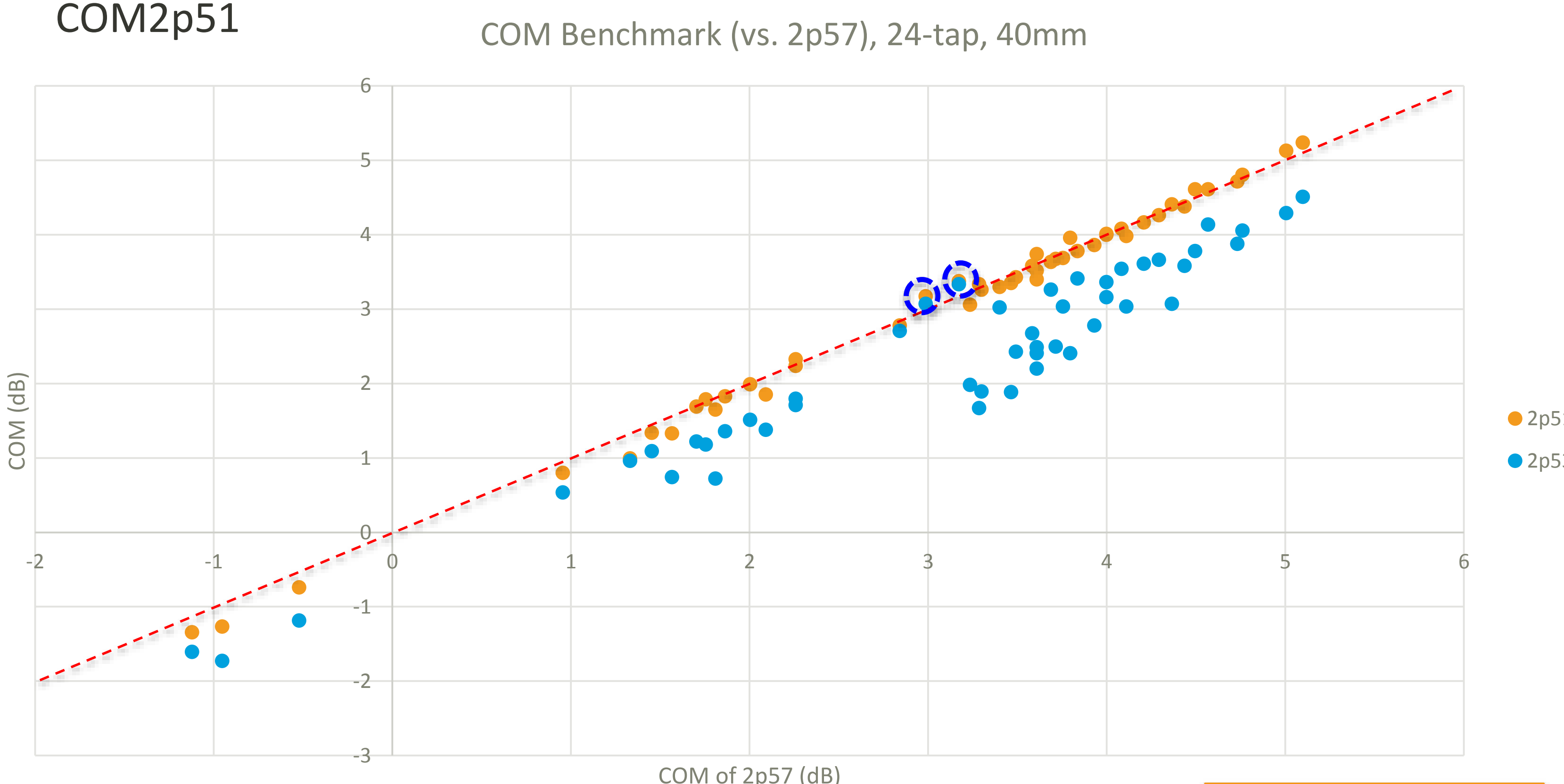


Run Time

COM Benchmark – 24-tap, 40mm

- 16 channels only
- Including DFE, LFFE (Lite-FFE), & HFFE (Heavy-FFE)
- COM2p57 outperforms COM2p53
- COM2p57 is slightly better than COM2p51

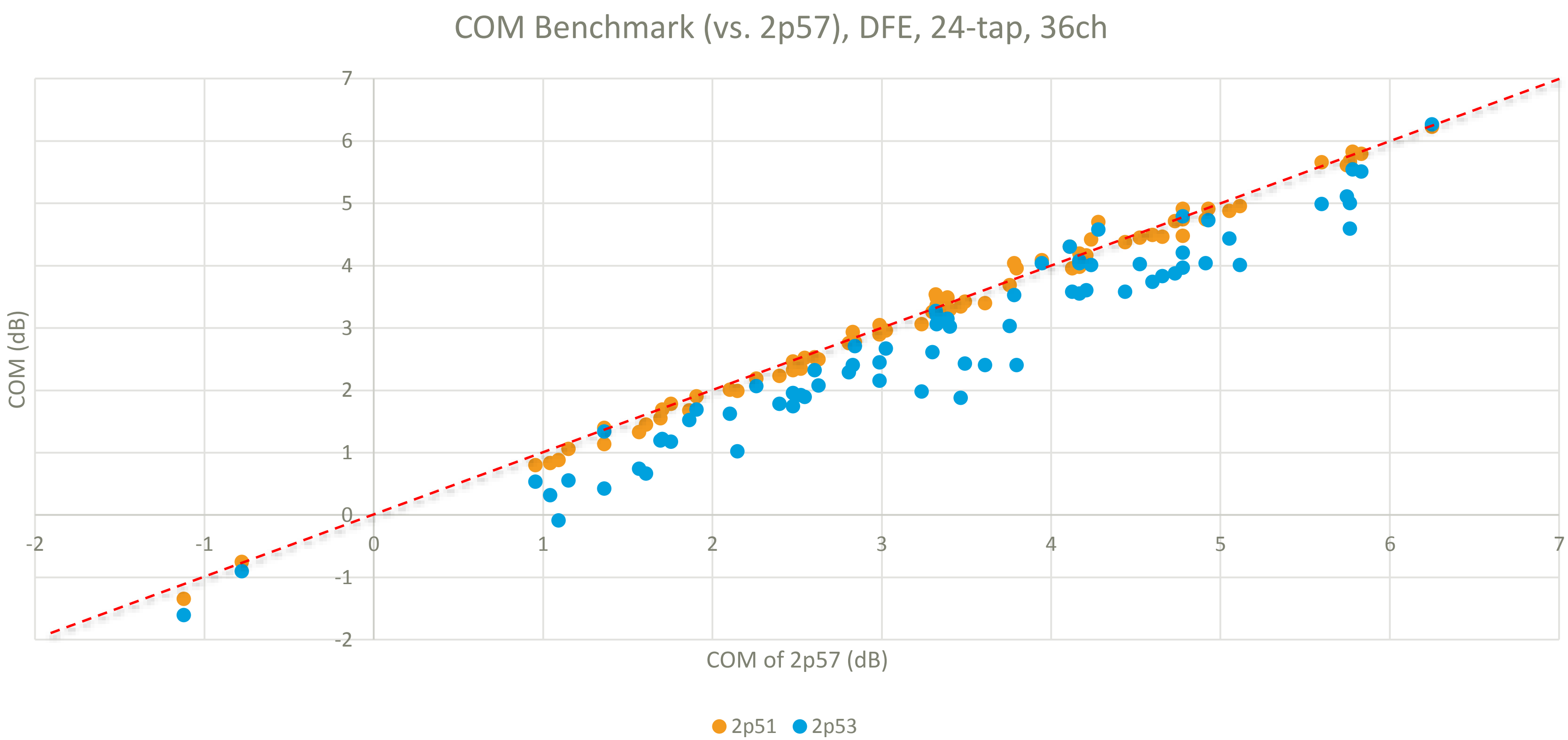
COM diff (dB, mean)	DFE	LFFE	HFFE
2p57-2p51	0.08	0.02	0.02
2p57-2p53	0.80	0.68	0.79



COM Benchmark – DFE, 24-tap

- All 36 channels, DFE only
- COM2p57 outperforms COM2p53
- COM2p57 is slightly better than COM2p51

COM diff (dB, mean)	DFE, 30mm	DFE, 40mm
2p57-2p51	0.07	0.03
2p57-2p53	0.46	0.63



COM Sensitivity to TL Parameters

Parameter Setting	COM2p57	COM2p51	COM2p53
package_tl_gamma0_a1_a2	**[0 0.9909e-3 2.772e-4]**	[0 1.734e-3 1.455e-4]	**[0 0.7901838e-3 5.0925e-4]**
package_tl_tau	6.140E-03	6.141E-03	**6.325E-03**
IL @ 26.6GHz [30mm trace]	3.271	3.354	4.609

- COM correlate to TL insertion loss
  - Extra 1.3dB package loss (2p57 → 2p53) cause 0.5 – 0.8 dB COM loss
- COM2p53 is too worse
- COM2p51 is most close to Next-Gen. substrate technology
- COM2p57 is close to COM2p51

COM diff (dB, mean)	30mm trace			40mm trace		
Ref. Rx	DFE	LFFE	HFFE	DFE	LFFE	HFFE
2p57-2p51	0.07	0.11	0.12	0.03	0.02	0.02
2p57-2p53	0.46	0.53	0.61	0.63	0.68	0.79
Sensitivity (COM/TL IL)	0.34 dB/dB	0.40 dB/dB	0.46 dB/dB	0.47 dB/dB	0.51 dB/dB	0.59 dB/dB

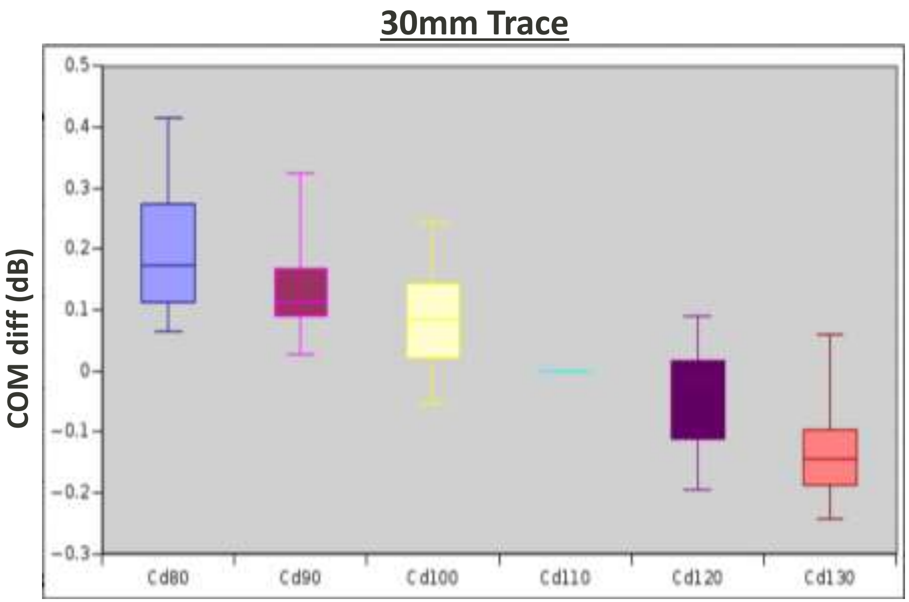
COM Sensitivity to Capacitance – Settings

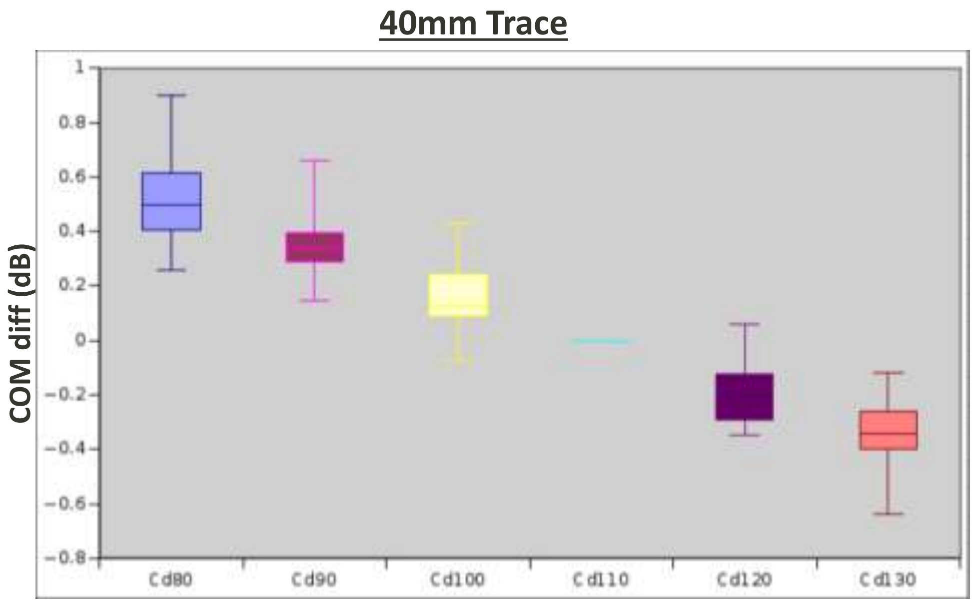
- Baseline configurations
  - COM2p57 [Cd = 110 fF, Cp = 87 fF, Zc = 87.5 Ohm]
  - Zp = 30mm & 40mm
  - 24-tap (N_b) DFE
- Selected 20 IEEE Nov. channels
  - 2018 Nov., COM ~= 1.8 – 6.2 dB
- Check COM sensitivity to 'Cd' and 'Cp'
  - Sweep Cd & Cp as tables below

Parameters	1	2	3	4	5	6	7
Cd (fF)	80	90	100	110	120	130	
Cp (fF)	80	84	87	90	93	96	100

COM Sensitivity to ‘Cd’ – Distributions

- D_COM = COM difference to ‘Cd=110fF’
  - COM (Cd = ***y*** fF) – COM (Cd = 110 fF)
- Distributions of Delta COM (D_COM)
  - It shows clear trend of impact to COM from ‘Cd’

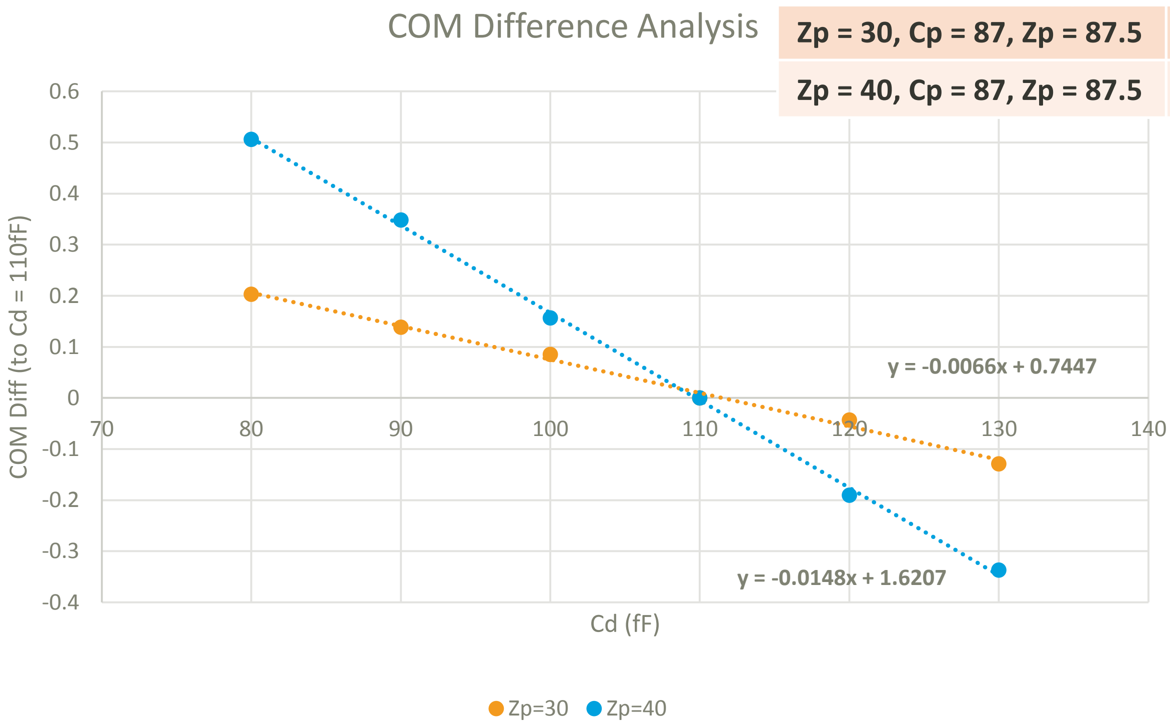




COM Sensitivity to 'Cd' – Mean

- Analyze COM sensitivity to 'Cd' by mean of D_COM in previous page
- COM sensitivity
  - 30mm: ~ 0.07 dB per 10 fF Cd change
  - 40mm: ~ 0.15 dB per 10 fF Cd change
- 40mm trace is more sensitive

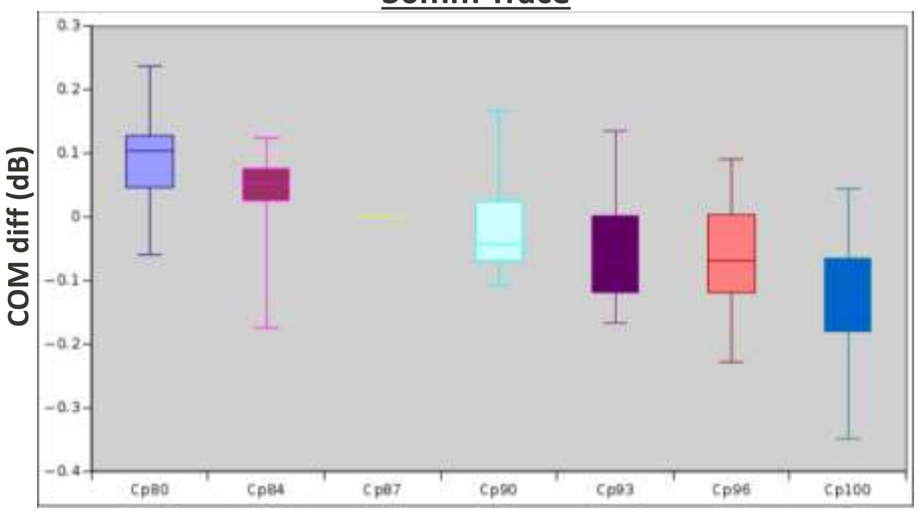
mean(D_COM) (dB)	Cd (fF)	80	90	100	110	120	130
Zp = 30, Cp = 87, Zp = 87.5		0.20	0.14	0.09	0	-0.04	-0.13
Zp = 40, Cp = 87, Zp = 87.5		0.51	0.35	0.16	0	-0.19	-0.34



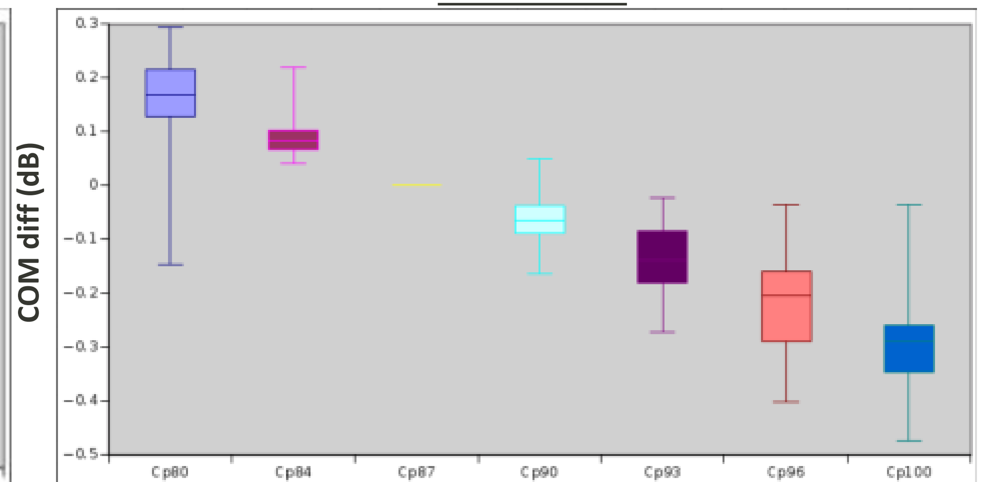
COM Sensitivity to 'Cp' – Distributions

- D_COM = COM difference to 'Cp=87fF'
  - COM (Cp = ***y*** fF) – COM (Cp = 87 fF)
- Distributions of Delta COM (D_COM)
  - They show the trend of impact to COM from 'Cp'
  - More obvious trend from '40mm Trace' case

30mm Trace



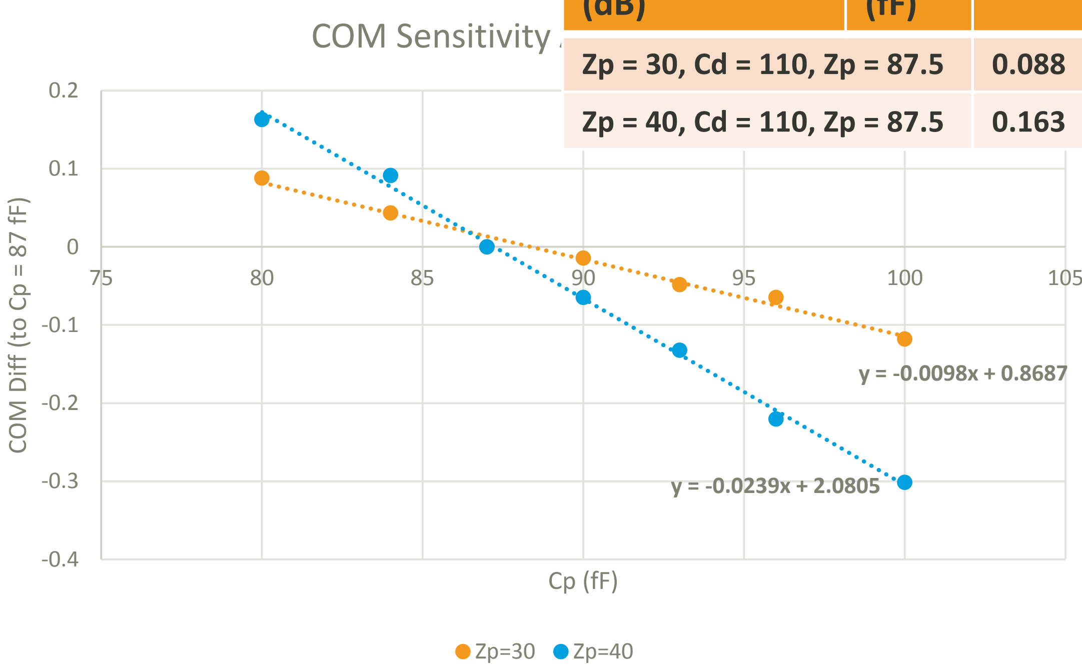
40mm Trace



COM Sensitivity to ‘Cp’ – Mean

- Analyze COM sensitivity to ‘Cp’ by mean of D_COM in previous page
- COM sensitivity
  - 30mm: ~ 0.10 dB per 10 fF Cp change
  - 40mm: ~ 0.24 dB per 10 fF Cp change
- COM is more sensitive to ‘Cp’ than ‘Cd’

mean(D_COM) (dB)	Cp (fF)	80	84	87	90	93	96	100
Zp = 30, Cd = 110, Zp = 87.5		0.088	0.044	0	-0.014	-0.048	-0.064	-0.118
Zp = 40, Cd = 110, Zp = 87.5		0.163	0.092	0	-0.065	-0.132	-0.220	-0.302



COM Sensitivity Analysis – Summary

COM diff (dB, mean)	30mm trace			40mm trace		
Ref. Rx	DFE	LFFE	HFFE	DFE	LFFE	HFFE
Sensitivity (COM/TL IL)	0.34 dB/dB	0.40 dB/dB	0.46 dB/dB	0.47 dB/dB	0.51 dB/dB	0.59 dB/dB
Sensitivity (COM/Cd)	0.07 dB/10fF	N/A	N/A	0.15 dB/10fF	N/A	N/A
Sensitivity (COM/Cp)	0.10 dB/10fF	N/A	N/A	0.24 dB/10fF	N/A	N/A

- COM is sensitive to IL of package trace
  - Need to select TL parameters carefully
  - Shall consider next-generation technology (COM2p51 or COM2p57)
- COM is not so sensitive to ‘Cp’ or ‘Cd’
  - More sensitive to ‘Cp’
  - More sensitive for 40mm trace case
- Next step – explore sensitivity to other parameters
  - PKG trace length (Zp)

Summary & Suggestions

- Explore three different TL parameters in different versions of COM model
  - COM2p57 & COM2p51 is close to 'Next-Gen.' PKG technology
  - COM2p53 is worse than 'Legacy' PKG technology
- COM sensitivity analysis
  - COM2p57 outperforms COM2p53 by 0.5~0.8 dB in average
  - COM2p51 is similar to COM2p57 by ~0.1 dB in average
  - COM is sensitive to PKG IL
    - Needs to consider 'Next-Gen.'
  - COM is not so sensitive to 'Cd' and 'Cp'
    - Let's get consensus on these values first
- Suggestions
  - Consider to adopt COM2p51 or COM2p57
  - Get consensus on 'Cd' and 'Cp' settings first

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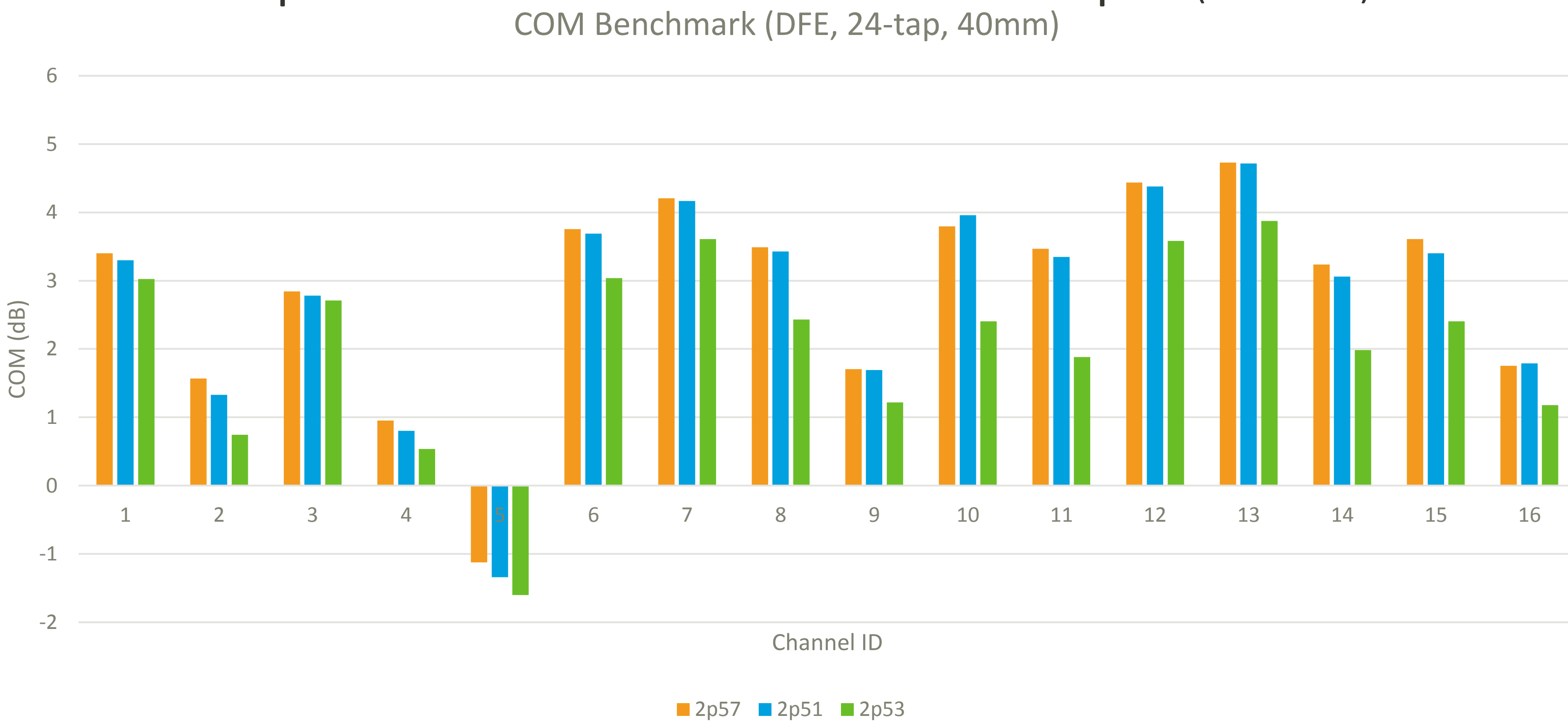
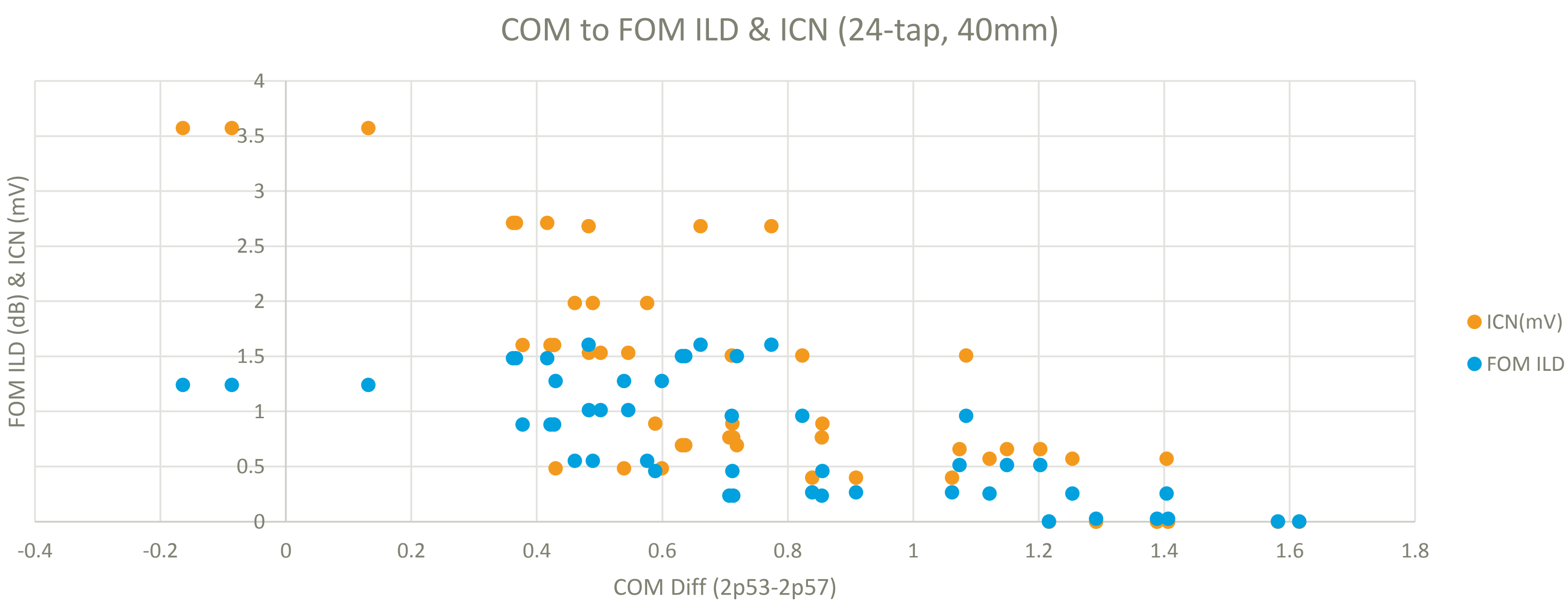
COM Benchmark – DFE, 24-tap, 40mm

- By 16 channels
- COM2p57 outperforms COM2p53 (0.1~1.5 dB)
  - In average 0.80 dB
  - COM2p51 shares similar COMs with COM2p57 (~< 0.2 dB)



COM Difference to FOM ILD & ICN Correlation (2p53 vs. 2p57)

- Different TL parameters cause different total bump-to-bump IL
- For those low FOM ILD (reflection) & ICN (crosstalk) channels
  - COM is sensitive to IL, therefore, sensitive to TL parameters
- For those high FOM ILD or ICN – dominate COM
  - COM is less sensitive to IL, therefore, less sensitive to TL parameters



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COM – Machine Run Time

- Collect machine run time information during COM execution
- By one server CPU with Matlab

Ref. RX	DFE	LFFE	HFFE
Run Time per channel (min.)	5.6	12.4	26.3
Ratio	1.0x	2.2x	4.7x

Channels in this COM Analysis

Description
Mellitz, Initial Backplane Models – Best case Tachyon backplane (Link)
Mellitz, Synthesized CR End-to-End Models (Link)
Tracy, Orthogonal & Cabled Backplane (Link)
Zambell, ExaMAX+ Direct-Mate Orthogonal Backplane (Link)
Mellitz, Ideal Transmission Lines for Backplane (Link)
Mellitz, Initial BP – Best case Tachyon BP, 3'' & 13'' IL15to16 (Link)
Mellitz, Cabled BP & PCB Design Impact Using 112G Ready Connectors, Opt1_24dB (Link)
Zambell, Trace and Chassis Tolerances vs. COM, 12-Nov-2018 (Link)
Kareti, Measured Cabled & Orthogonal Backplane channels, 8-Nov-2018 (Link)
Heck, Server Cabled Backplane, 8-Nov-2018 (Link)

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