Delivering 100 Gbps Solutions for Chip-to-Module and Direct Attach Copper (DAC) Cable Implementations

This session was presented as part of the DesignCon 2019 Conference and Expo

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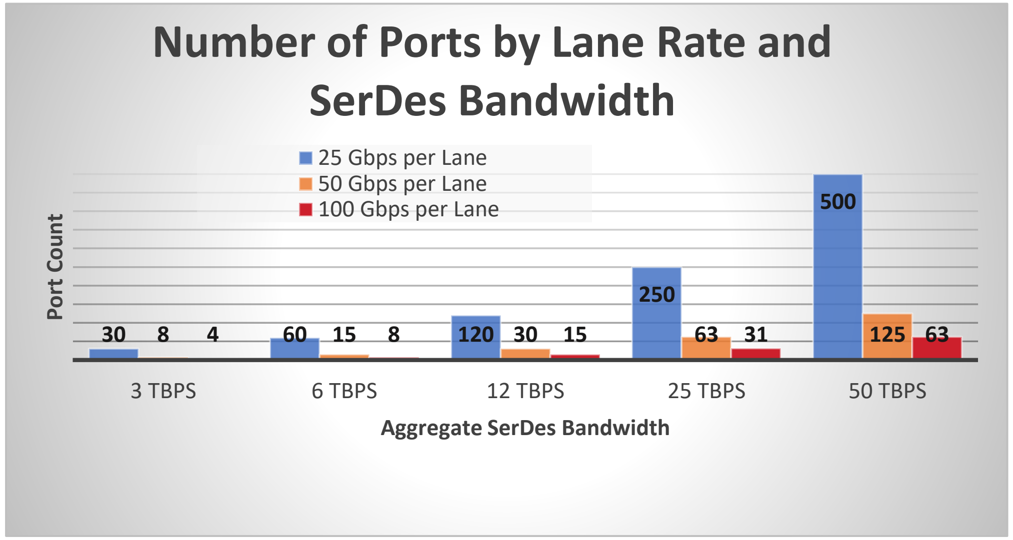
Presentation Outline

- Introduction
- Skew Impact on S_{dd21} & S_{cd21}
- Mating Zone Reflections
- Measured results of 112 Gbps DAC
  - Impact of skew and reflections
- Measured results of 112 Gbps C2M
  - Impact of skew and reflections
- Conclusion

Introduction: Why 100G?

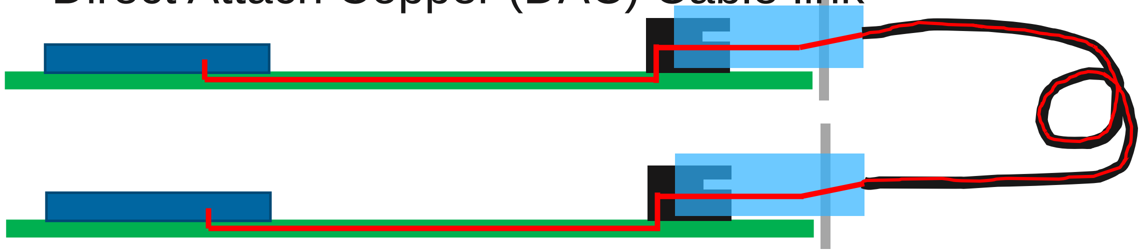
100 Gbps rate enables reasonable port counts and aligns with roadmaps

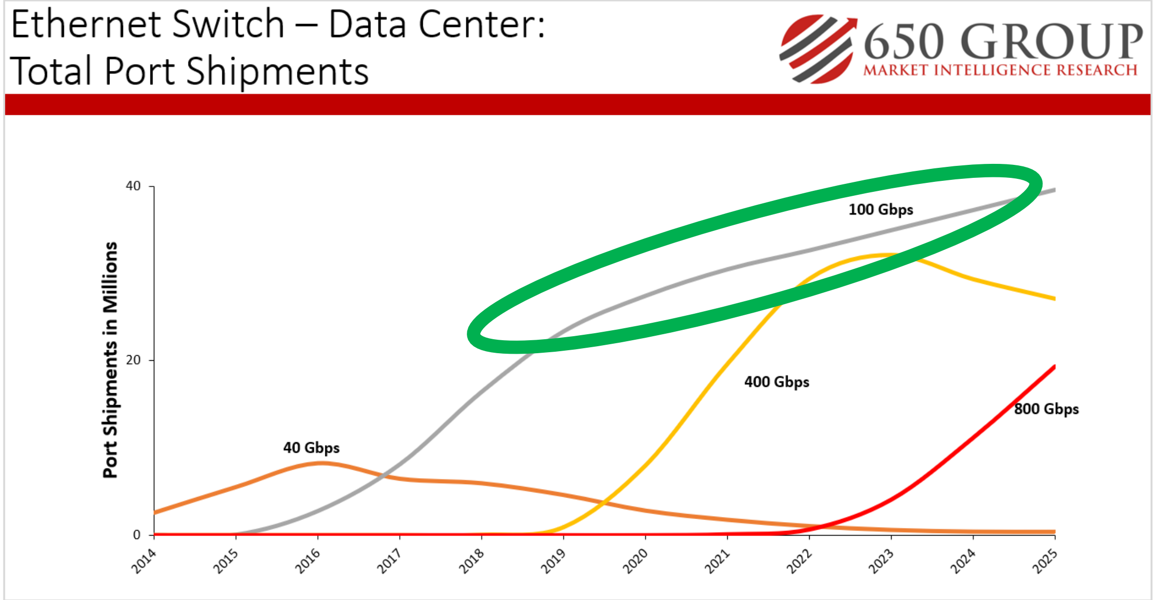


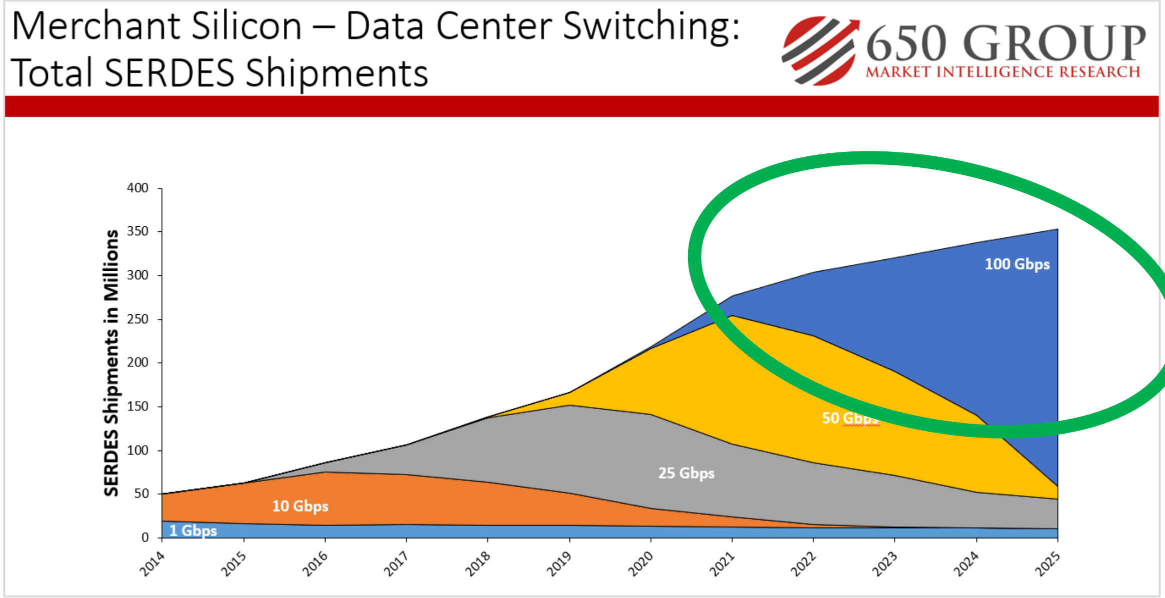
Is 100G electrical difficult?

VSR (chip to module) link

Direct Attach Copper (DAC) Cable link







Charts used with the permission of 650 Group, LLC, Dec 2018

Skew Impact on S_{dd21} & S_{cd21}

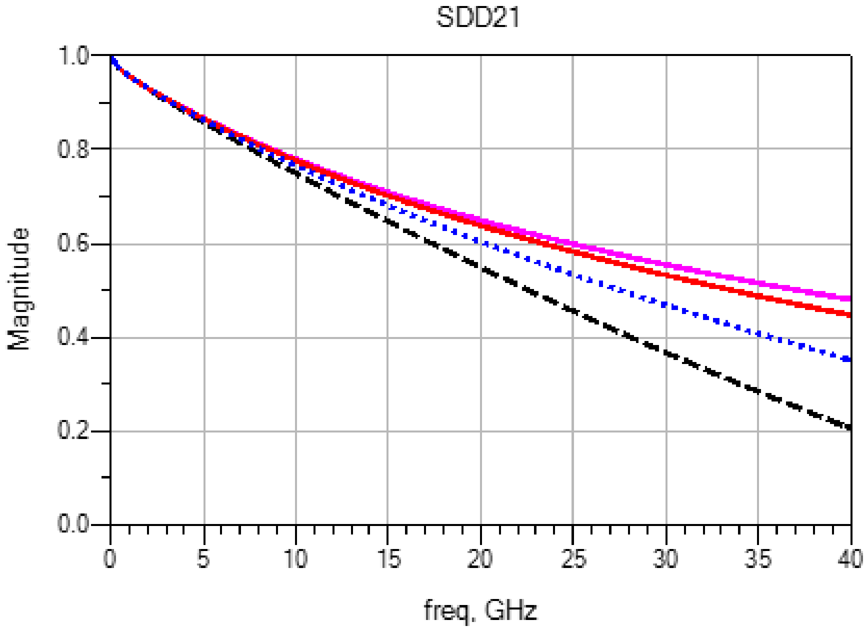
$$S_{dd21} = \frac{|S_{21}|e^{j\theta_{21}} + |S_{43}|e^{j\theta_{43}} - |S_{41}|e^{j\theta_{41}} - |S_{23}|e^{j\theta_{23}}}{2}$$

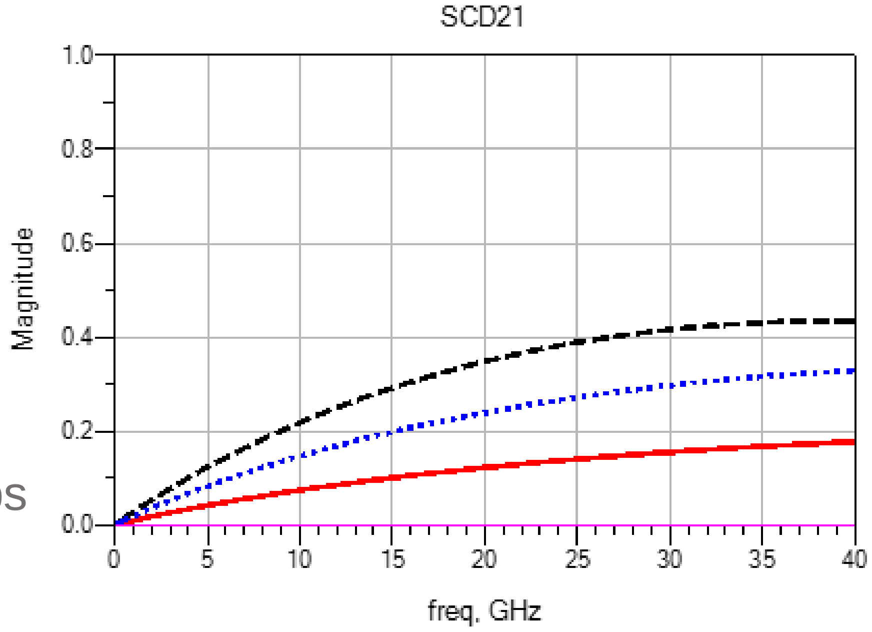
$$S_{dd21} = |IL|cos\left(\frac{\Delta\theta}{2}\right)e^{j\theta_{21}} - |X|cos\left(\frac{\Delta\theta_X}{2}\right)e^{j\theta_{41}}$$

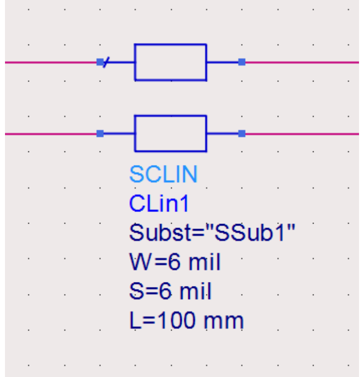
$$S_{cd21} = \frac{|S_{21}|e^{j\theta_{21}} - |S_{43}|e^{j\theta_{43}} + |S_{41}|e^{j\theta_{41}} - |S_{23}|e^{j\theta_{23}}}{2}$$

$$S_{cd21} = |IL|\left[-jsin\left(\frac{\Delta\theta}{2}\right)\right]e^{j\theta_{21}} + |X|\left[-jsin\left(\frac{\Delta\theta_X}{2}\right)\right]e^{j\theta_{41}}$$

- S_{dd21} is modified by cosine function
- S_{cd21} is modified by sine function
- Higher frequencies impacted more than lower frequencies as skew increases
- Skew impacts 112 Gbps channels more than 56 Gbps channels







Skew

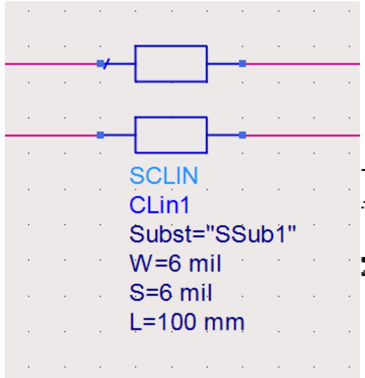
0 ps (Pink)
3 ps (Red)
6 ps (Blue)
9 ps (Black)

Skew Impact on S_{dd21} & S_{cd21}

Modifiers

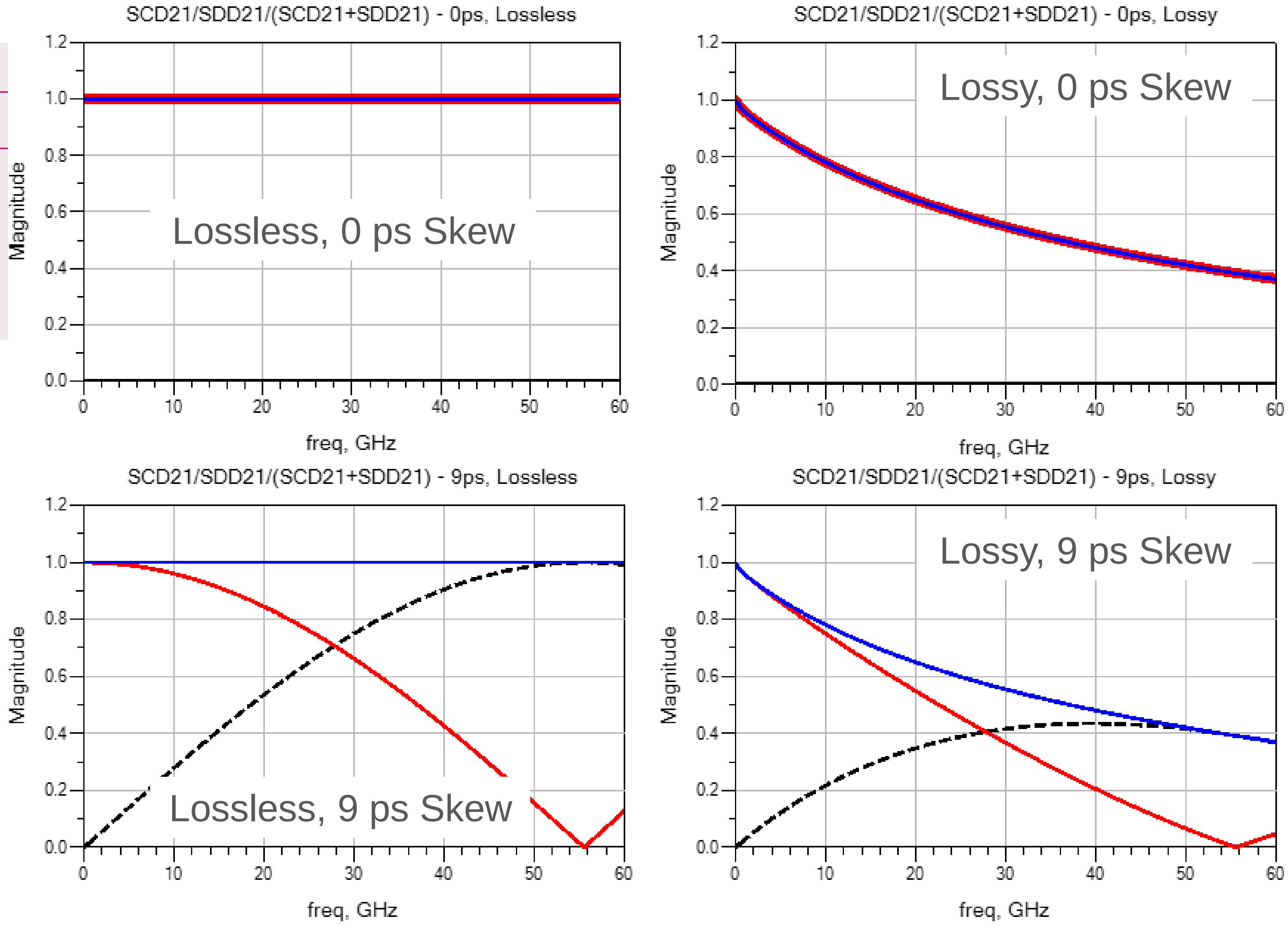
$$S_{dd21Mod} = cos\left(\frac{\Delta\theta}{2}\right)$$

$$S_{cd21Mod} = -jsin\left(\frac{\Delta\theta}{2}\right)$$



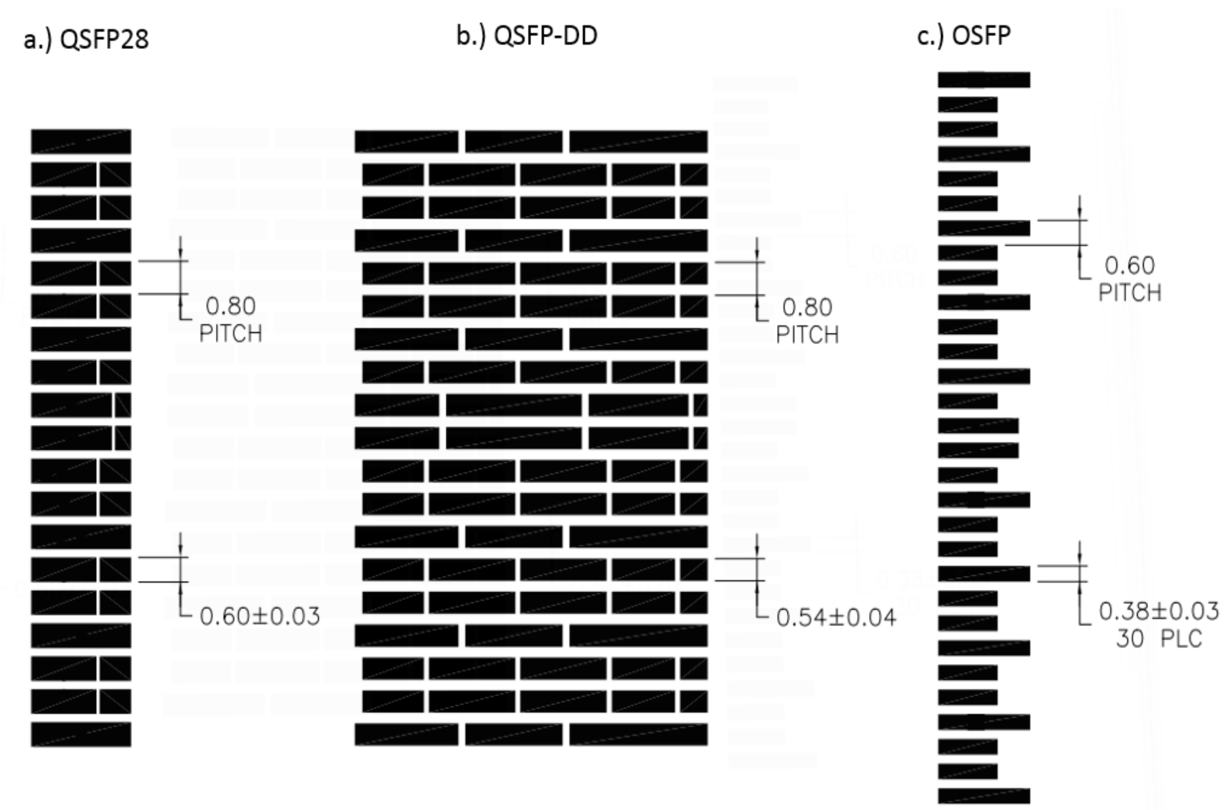
- Lossless cases
  - $S_{dd21} + S_{cd21} = 1$
- For 0 ps of skew $\Delta\theta = 0$
- For 9 ps of skew $\Delta\theta \neq 0$
- Lossy cases
  - $S_{dd21} + S_{cd21} \neq 1$
  - Due to conductive & dielectric losses

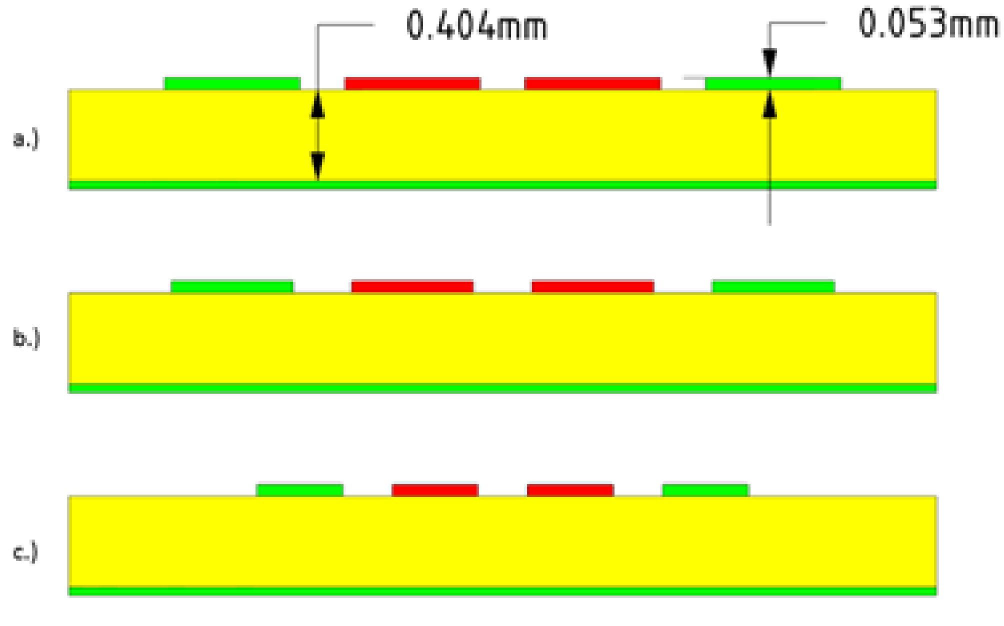
- Skew converts differential energy to common mode energy
- To maximize reach of channel, skew must be minimized



S_{dd21}(Red), S_{cd21}(Black), S_{dd21}+S_{cd21}(Blue)

Mating Zone Impedance (Mating Zone Reflections)





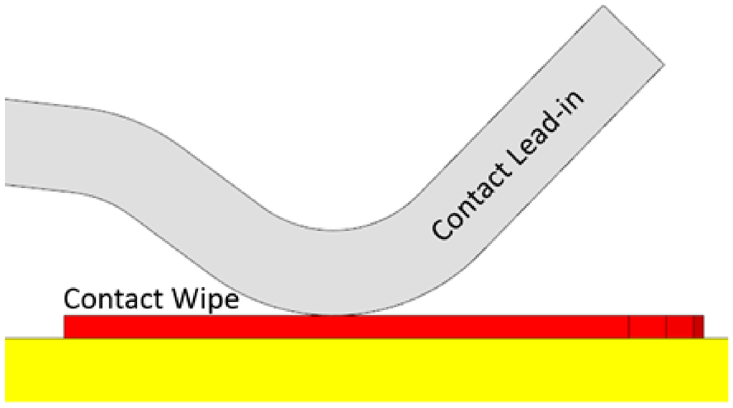
Form Factor	Impedance (Ohms)
QSFP28	82
QSFP-DD	92
OSFP	101

- OSFP, lowest pad width-to-pitch ratio = 0.63
- 2D field solver used to calculate characteristic impedance of ONLY the mating pads acting as microstrip traces
- 10% reduction in pad width b/w QSFP28 & QSFP-DD
  - Yields 10 ohm improvement

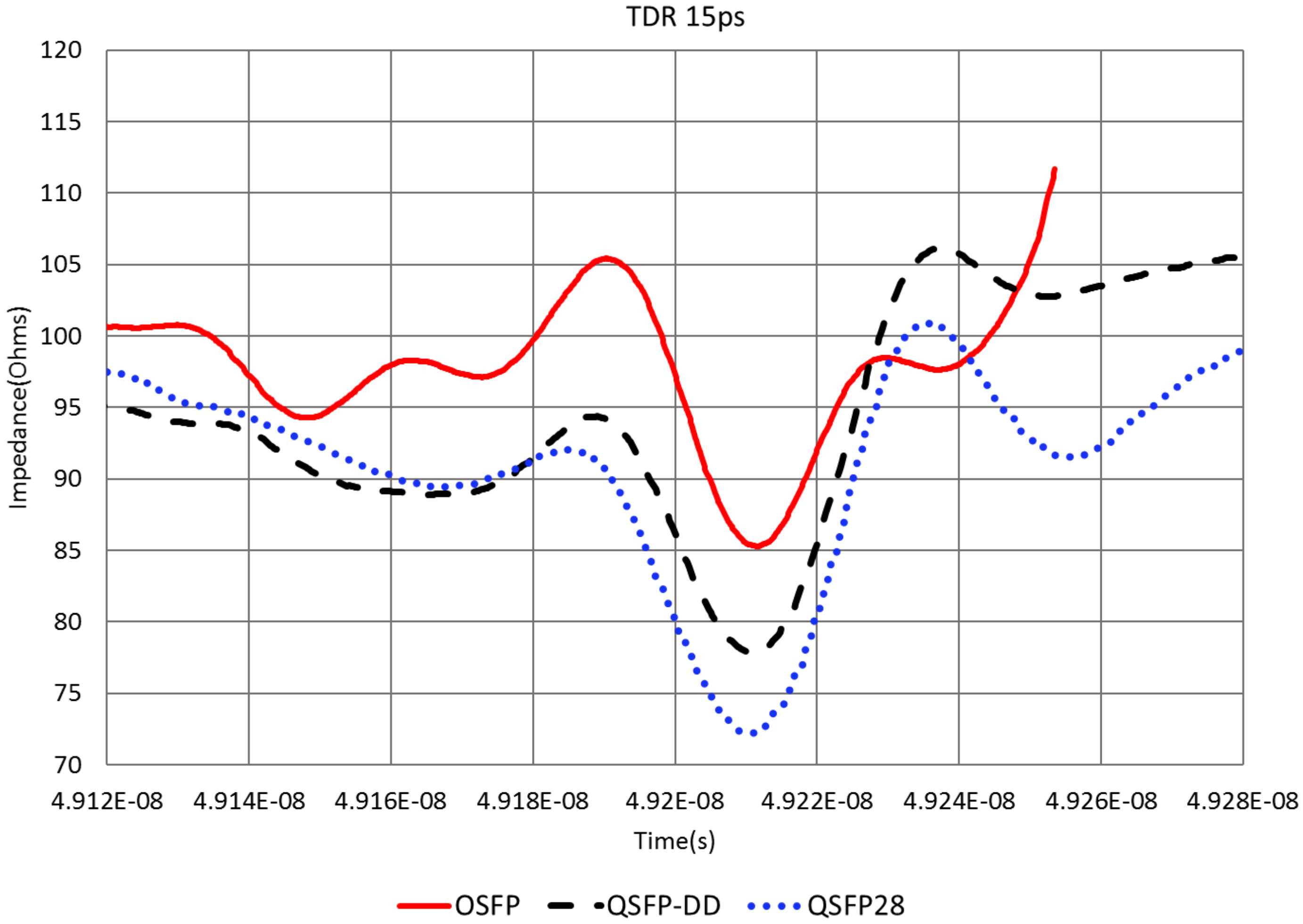
Mating Zone Impedance (Mating Zone Reflections)

Form Factor	Modeled Z_o without Rcpt (Ω)	Measured Z_{diff} with Rcpt (Ω)	Δ
QSFP28	82	72	10
QSFP-DD	92	77	15
OSFP	101	86	15

- Largest impact on mating interface impedance comes from contact lead-in and PCB pad stub from contact wipe

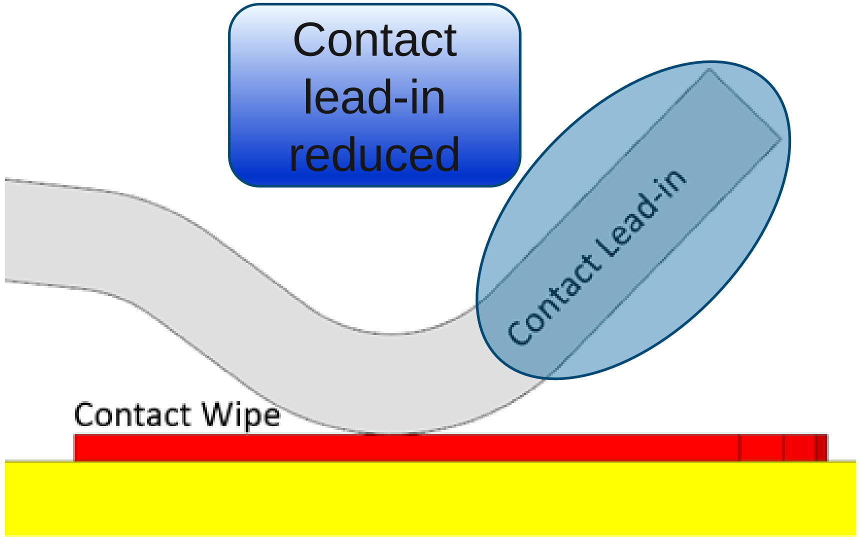


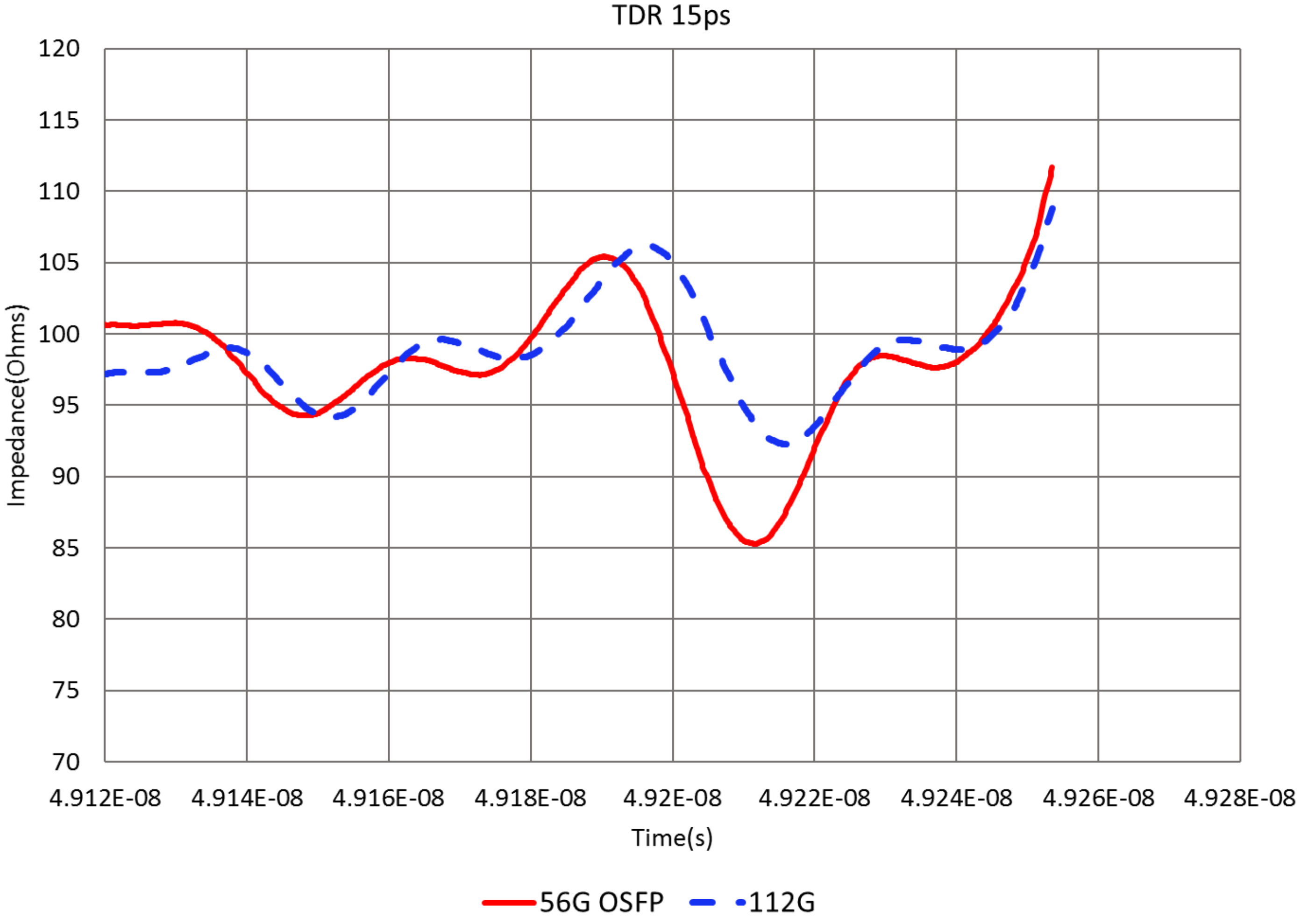
Measured results of mating zone
(Plug-in card mated to Receptacle)



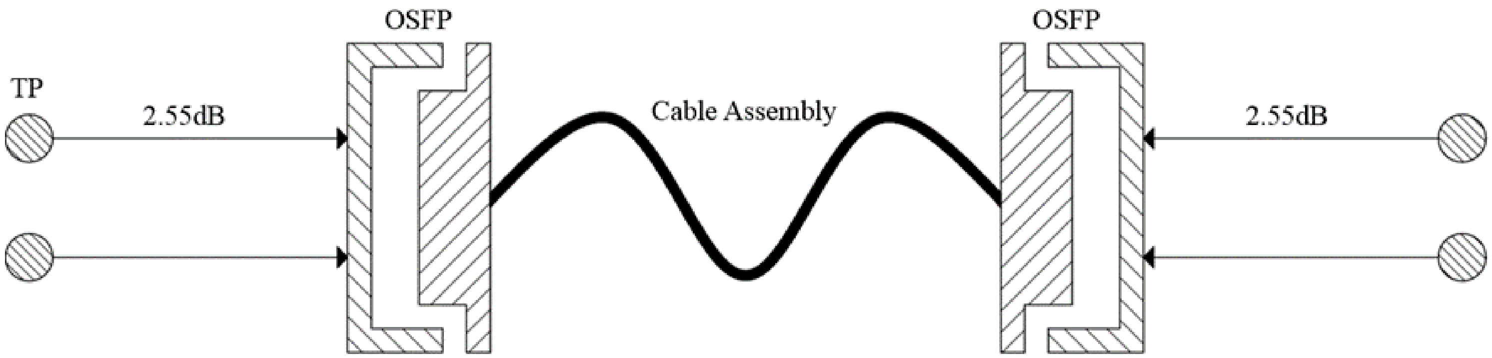
Mating Zone Impedance (Mating Zone Reflections)

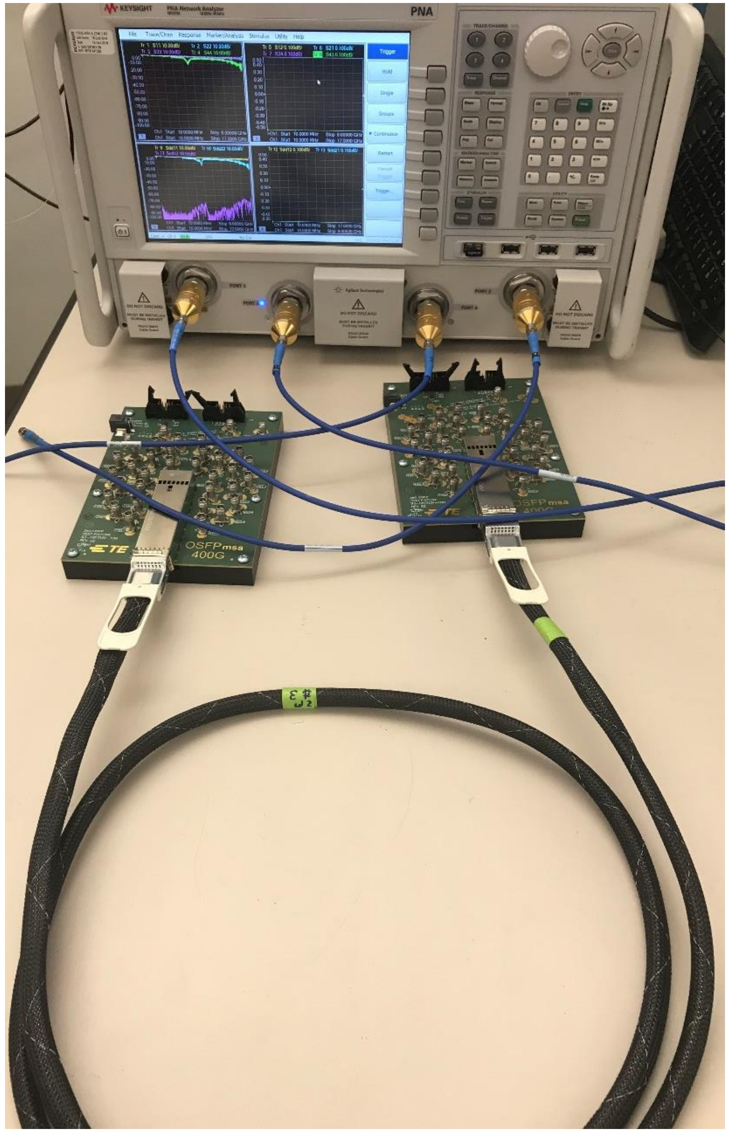
- 56 Gbps OSFP connector modified by reducing contact lead-in (referred to as 112 Gbps connector moving forward)
- 7 ohm improvement observed when contact lead-in is reduced
- Following slides show impact of improved mating zone for 112 Gbps channels





Impact of Skew & Reflections, OSFP 112 Gbps DAC, Test Set-up





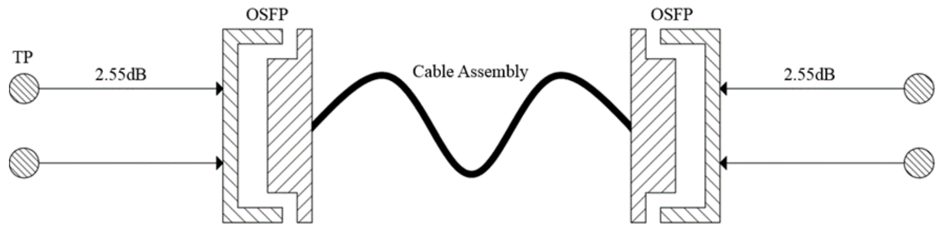
Victim
FEXT Aggressor
NEXT Aggressor

OSFP Pin Map

Pin #	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31
	G	Tx1+	Tx1-	G	Tx3+	Tx3-	G	Tx5+	Tx5-	G	Tx7+	Tx7-	G	SB	SB	SB	SB	G	Rx8-	Rx8+	G	Rx6-	Rx6+	G	Rx4-	Rx4+	G	Rx2-	Rx2+	G
	G	Tx2+	Tx2-	G	Tx4+	Tx4-	G	Tx6+	Tx6-	G	Tx8+	Tx8-	G	SB	SB	SB	SB	G	Rx7-	Rxy+	G	Rx5-	Rx5+	G	Rx3-	Rx3+	G	Rx1-	Rx1+	G
Pin #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Pin #	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31
	G	Tx1+	Tx1-	G	Tx3+	Tx3-	G	Tx5+	Tx5-	G	Tx7+	Tx7-	G	SB	SB	SB	SB	G	Rx8-	Rx8+	G	Rx6-	Rx6+	G	Rx4-	Rx4+	G	Rx2-	Rx2+	G
	G	Tx2+	Tx2-	G	Tx4+	Tx4-	G	Tx6+	Tx6-	G	Tx8+	Tx8-	G	SB	SB	SB	SB	G	Rx7-	Rxy+	G	Rx5-	Rx5+	G	Rx3-	Rx3+	G	Rx1-	Rx1+	G
Pin #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

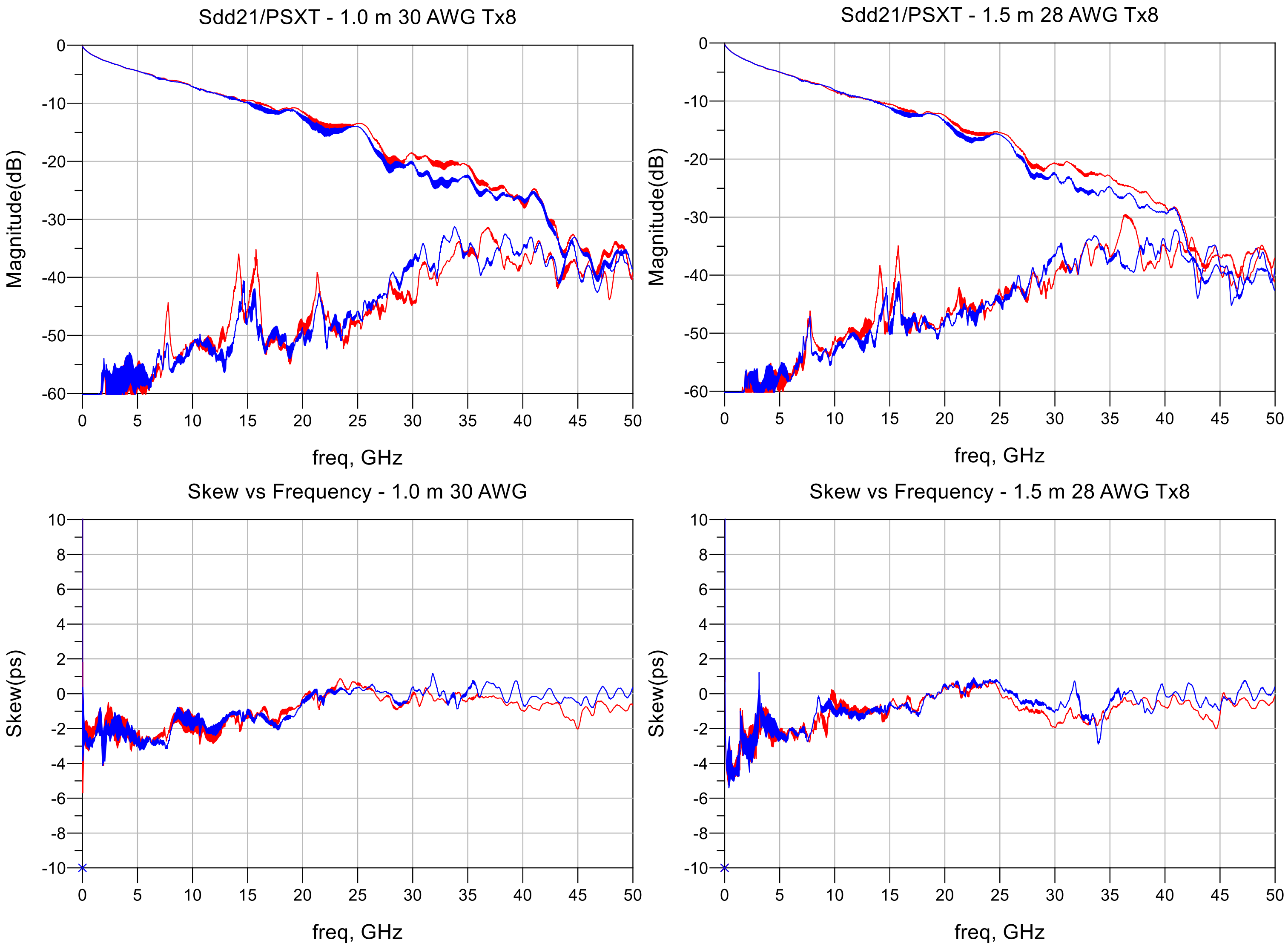
Impact of Skew & Reflections, OSFP 112 Gbps DAC, Measurement Results



Results at 26.56 GHz

	Conn	S_{dd21}	PSXT
1.0 m 30 AWG	112	-16.38	-45.06
1.0 m 30 AWG	56	-18.26	-44.00
1.5 m 28 AWG	112	-17.73	-42.22
1.5 m 28 AWG	56	-19.41	-41.31

- Measurement results shown for
  - 1.0m 30 AWG Tx8 lane
  - 1.5m 28 AWG Tx8 lane
- 112 Gbps connector improves differential insertion loss at higher frequencies
- Test fixture skew included in measurement results



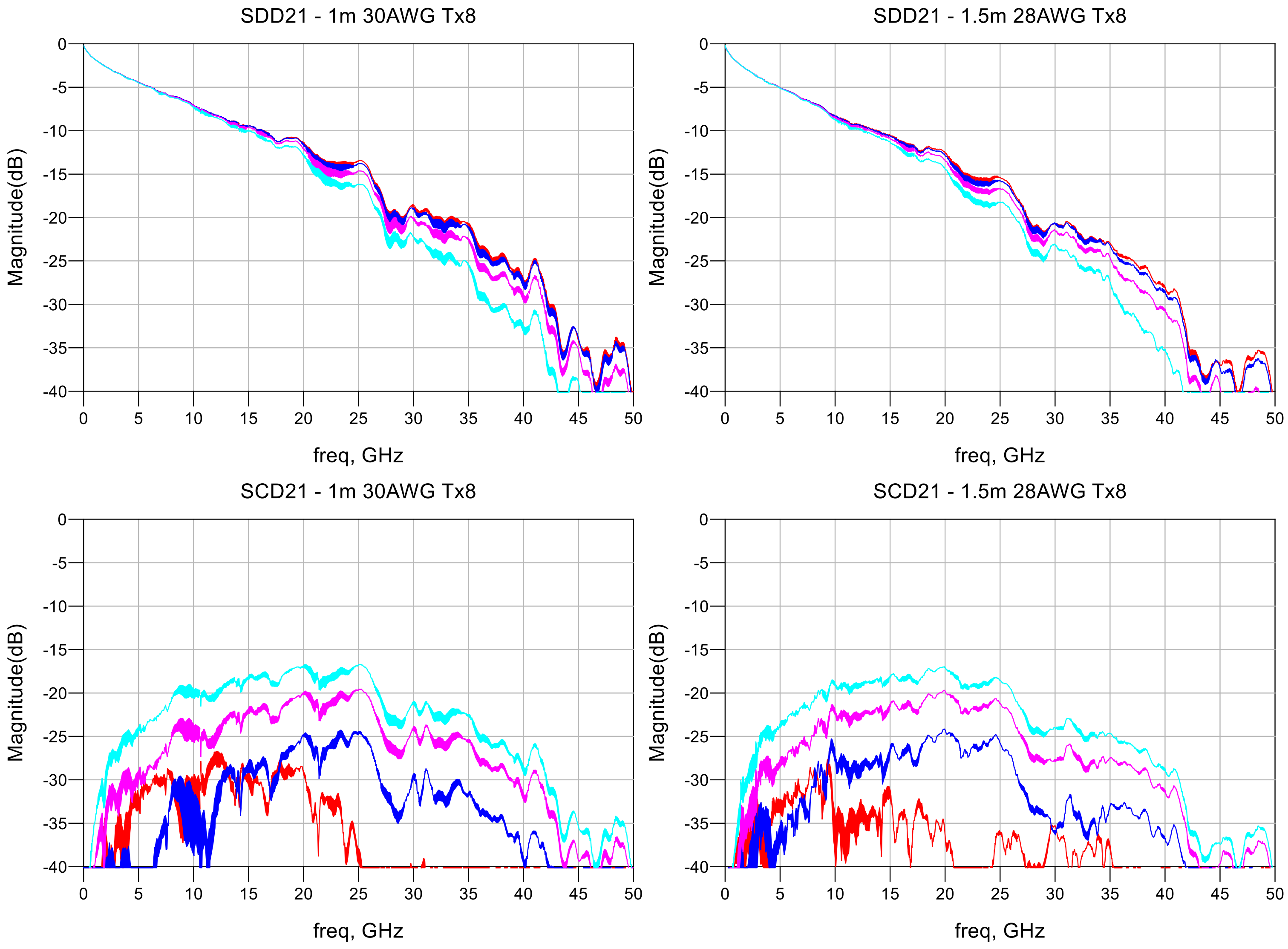
Measured Channel w/ 56 Gbps Conn (Blue)

Measured Channel w/ 112 Gbps Conn (Red)

Impact of Skew & Reflections, OSFP 112 Gbps DAC

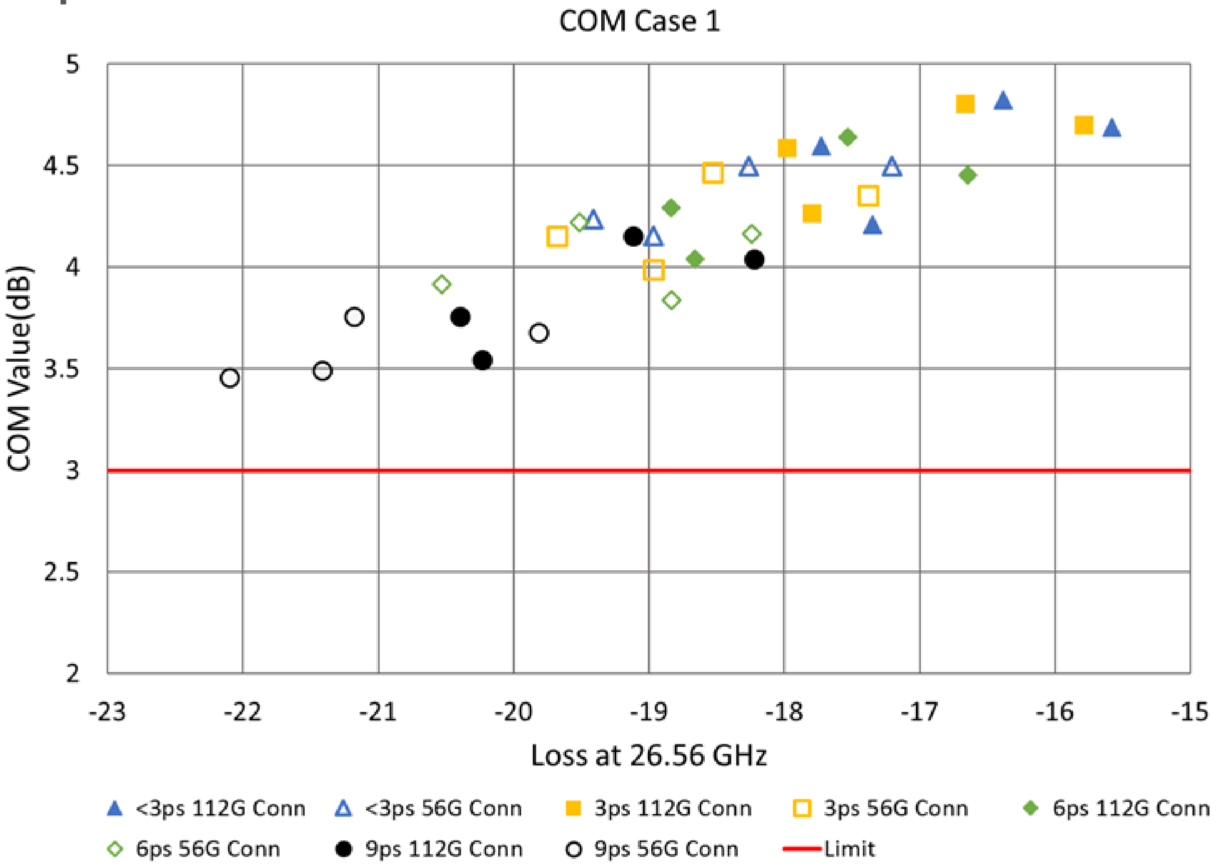
	Added Skew	S_{dd21} (dB)	S_{cd21} (dB)
1.0 m 30 AWG	0 ps	-16.38	-49.10
1.0 m 30 AWG	3 ps	-16.66	-28.39
1.0 m 30 AWG	6 ps	-17.53	-22.71
1.0 m 30 AWG	9 ps	-19.12	-19.68
1.5 m 28 AWG	0 ps	-17.73	-37.08
1.5 m 28 AWG	3 ps	-17.98	-29.36
1.5 m 28 AWG	6 ps	-18.84	-23.99
1.5 m 28 AWG	9 ps	-20.40	-21.00

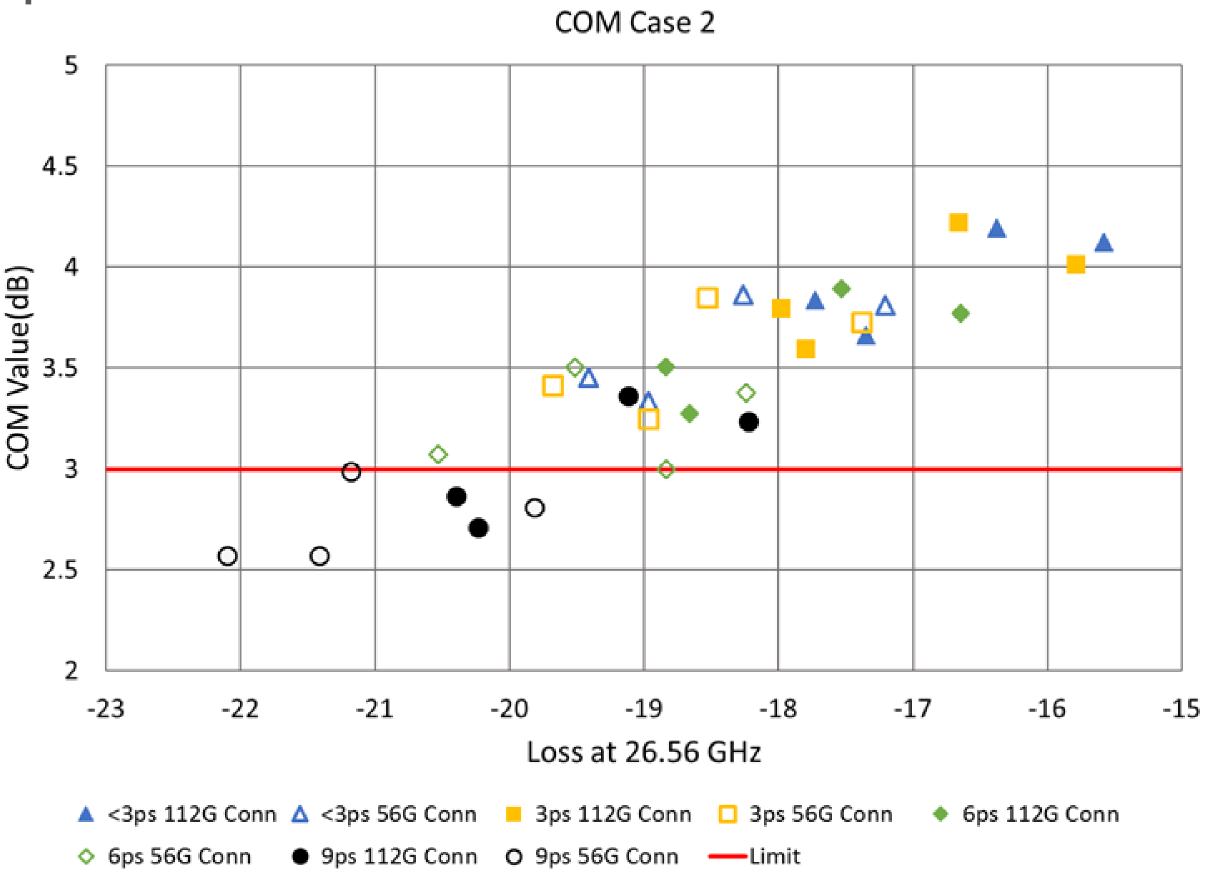
- Skew added using Keysight ADS tool
- Added skew degrades S_{dd21} and S_{cd21}
- Test fixture skew included in measurement results



0ps Added Skew (Red), 3ps Added Skew (Blue)
6ps Added Skew (Pink) 9ps Added Skew (Light Blue)

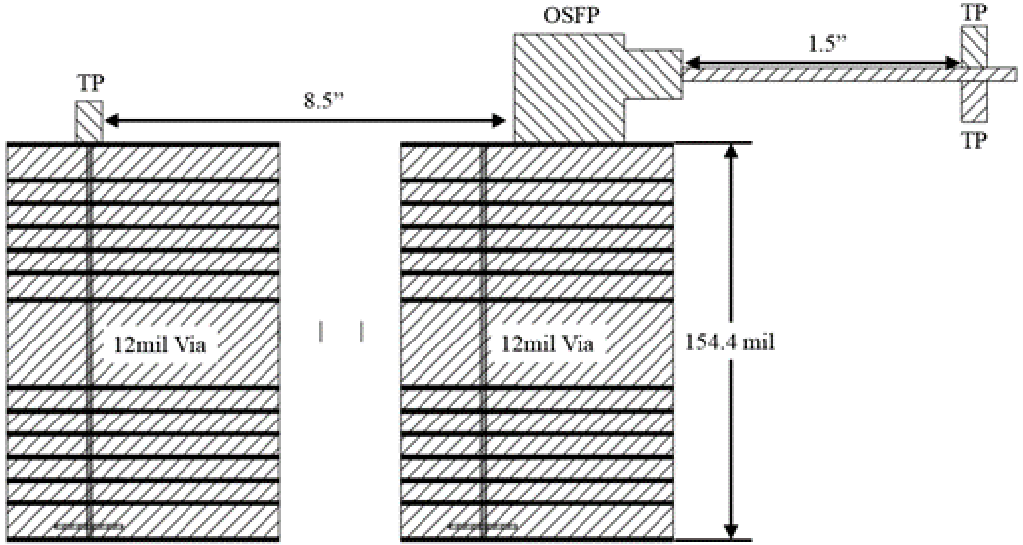
Impact of Skew & Reflections, OSFP 112 Gbps DAC, COM Calculation

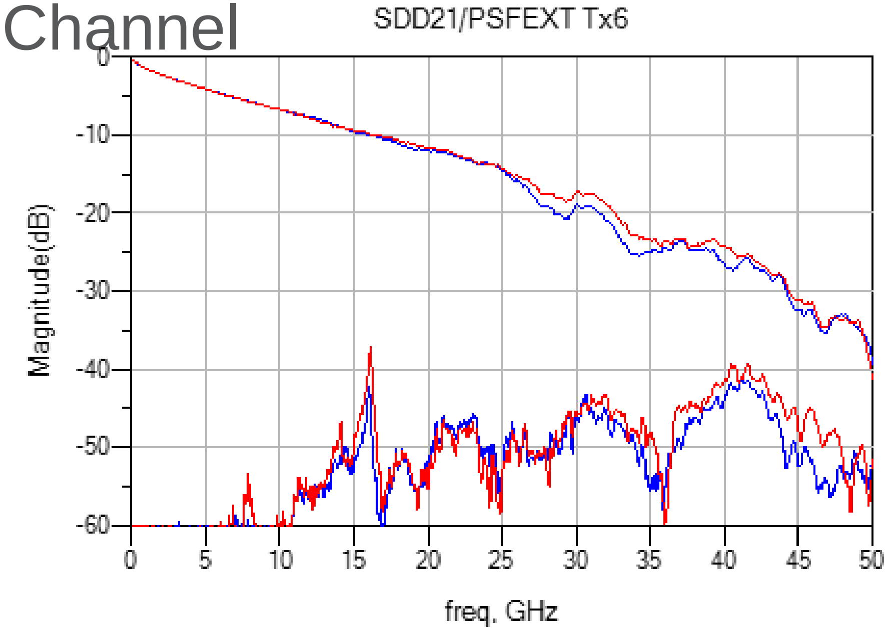




- COM calculated using Version 2.51 COM script developed for IEEE 802.3ck specification
- Results for 32 lanes (Tx7 & Tx8 lanes/30 & 28 AWG/ 56 & 112 Gbps Connector/ 0, 3, 6, and 9 ps added skew)
- All instances pass COM Case 1 (shorter package length)
- Failures for COM Case 2, 56 Gbps conn w/ 9 ps of skew & 2 instances of 112 Gbps conn w/ 9 ps of skew
- Channels with increased differential insertion loss exhibit lower COM value
- Minimizing mating zone reflections made channels more tolerant of skew

Impact of Skew & Reflections, OSFP 112G VSR (C2M) Channel

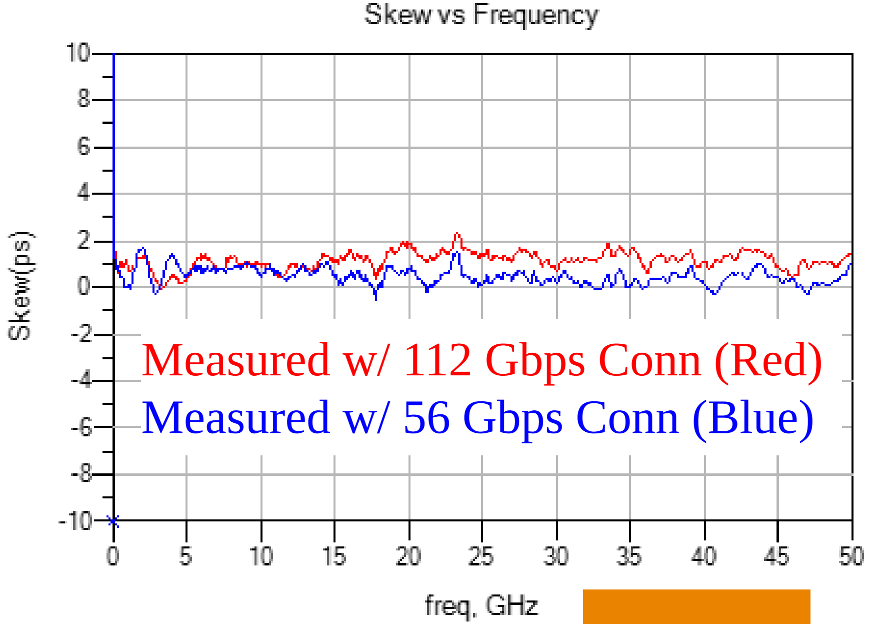




- 8.5" of 5.3-6.45-5.3 diff traces on host
- 1.5" of 6.3mil SE traces on module
- MEGTRON 7N HVLP material used
- Host uses 12mil differential vias down to a Layer 15 route-out

Results at 26.56 GHz

Conn	S_{dd21}	PSXT
112	-15.61	-47.74
56	-16.51	-48.90



OSFP Pin Map

Pin #	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31
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	G	Tx2+	Tx2-	G	Tx4+	Tx4-	G	Tx6+	Tx6-	G	Tx8+	Tx8-	G	SB	SB	SB	SB	G	Rx7-	Rxy+	G	Rx5-	Rx5+	G	Rx3-	Rx3+	G	Rx1-	Rx1+	G
Pin #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

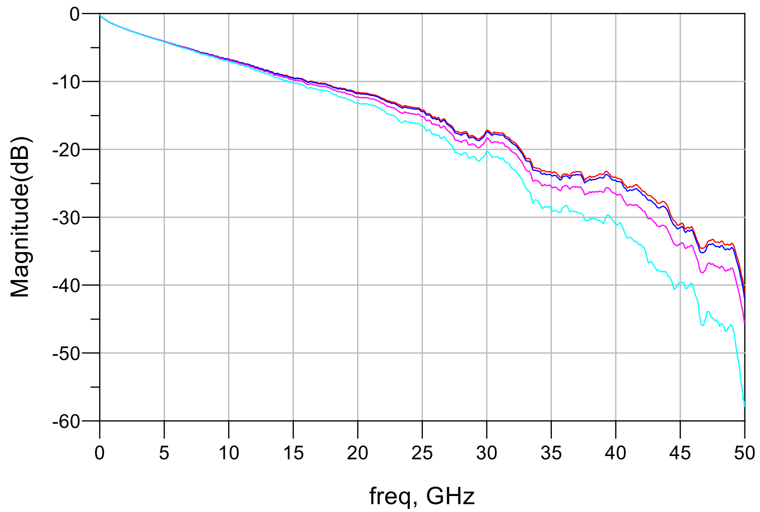
Victim (Tx6+, Tx6-) — FEXT Aggressor (Tx3±, Tx4±, Tx5±, Tx7±, Tx8±)

Impact of Skew & Reflections, 112G VSR (C2M) Channel

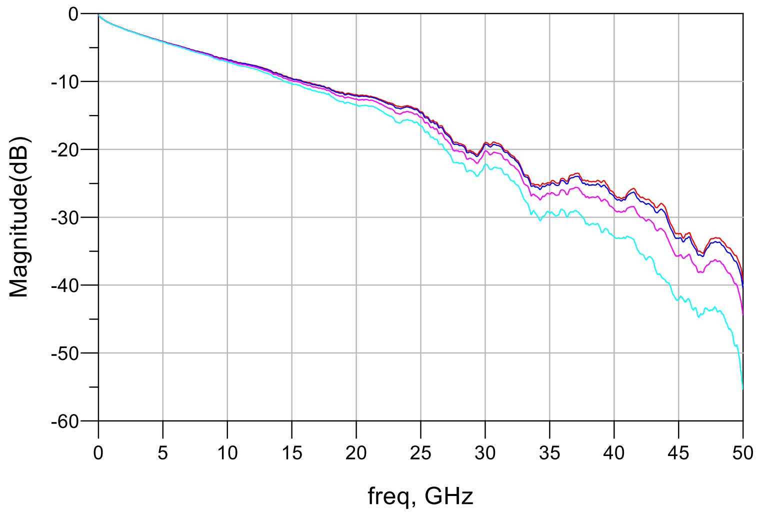
	Added Skew	S_{dd21} (dB)	S_{cd21} (dB)
112 Gbps Conn	0 ps	-15.61	-34.74
112 Gbps Conn	3 ps	-15.84	-27.64
112 Gbps Conn	6 ps	-16.70	-21.92
112 Gbps Conn	9 ps	-18.29	-18.87
56 Gbps Conn	0 ps	-16.51	-41.47
56 Gbps Conn	3 ps	-16.78	-28.60
56 Gbps Conn	6 ps	-17.64	-22.87
56 Gbps Conn	9 ps	-19.22	-19.82

- Skew added using Keysight ADS tool
- Added skew degrades S_{dd21} and S_{cd21}
- Test fixture skew included in measurement results

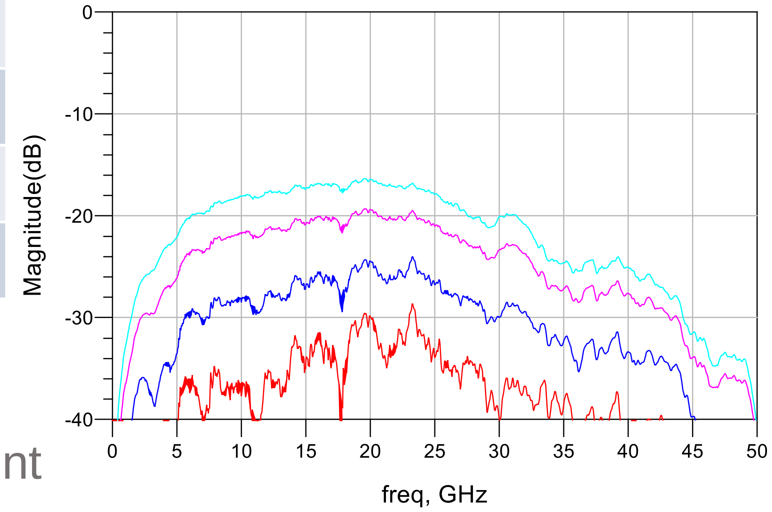
SDD21 - 112 Gbps Connector



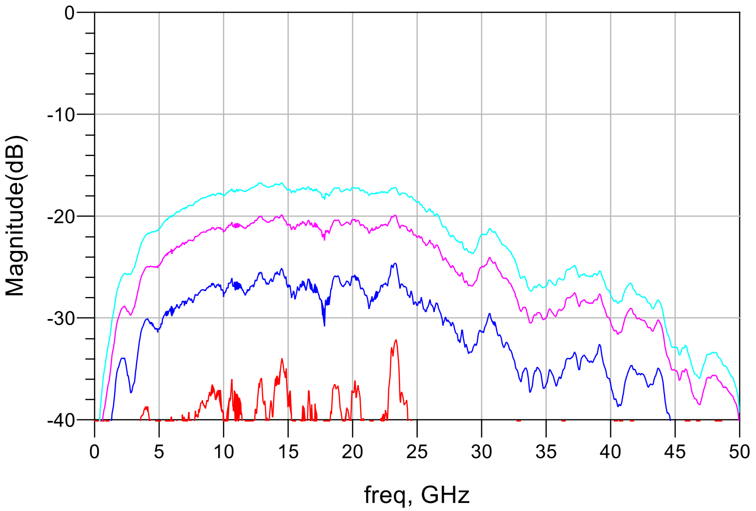
SDD21 - 56 Gbps Connector



SCD21 - 112 Gbps Connector

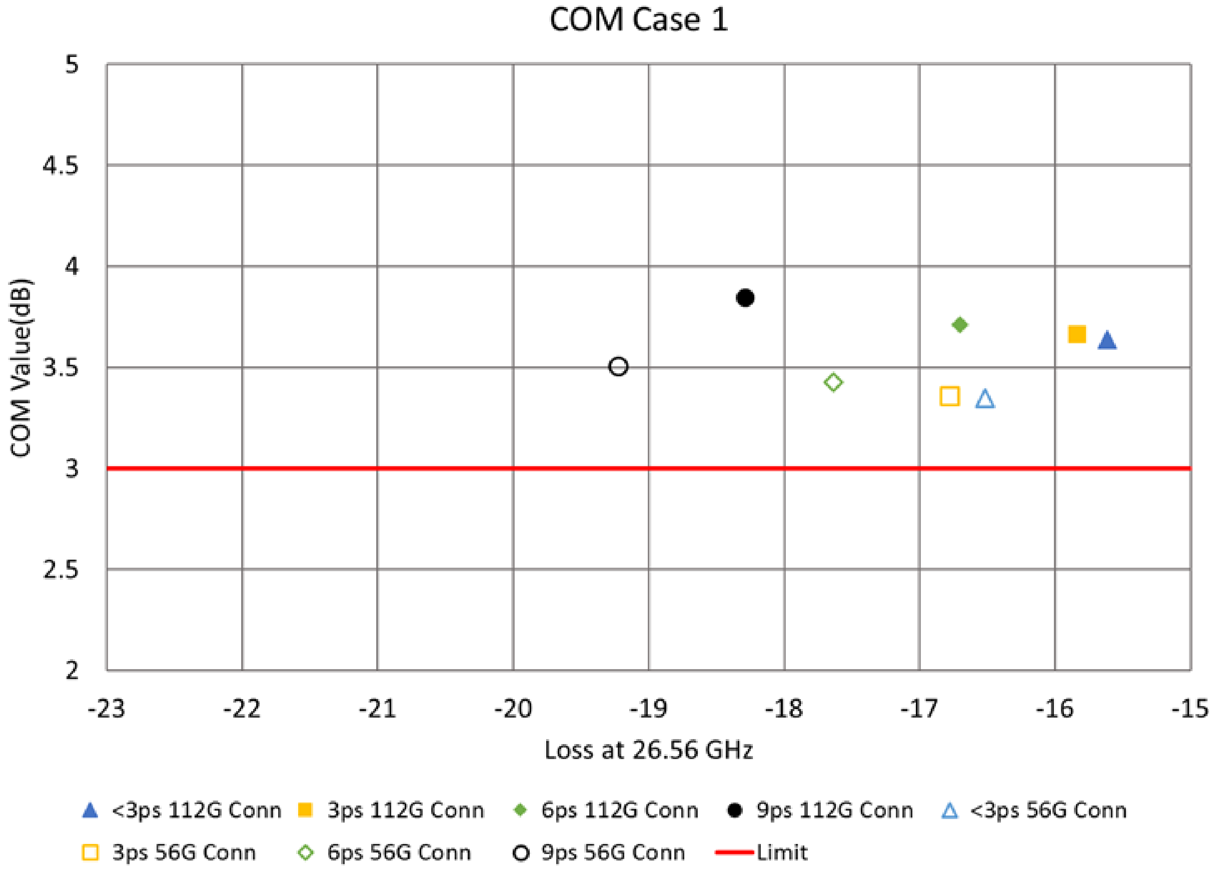


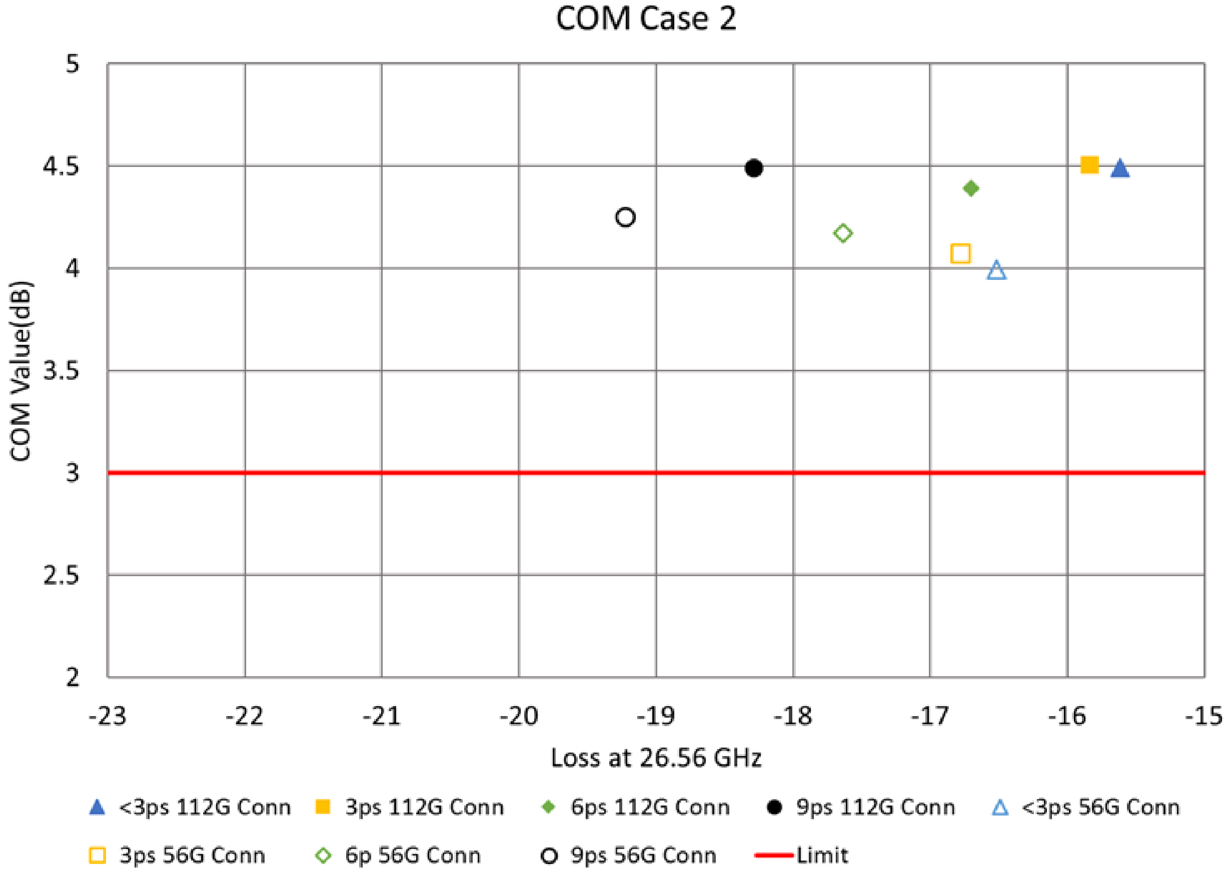
SCD21 - 56 Gbps Connector



0ps Added Skew (Red), 3ps Added Skew (Blue)
6ps Added Skew (Pink) 9ps Added Skew (Light Blue)

Impact of Skew & Reflections, 112G VSR (C2M), COM Calculation





- COM calculated using Version 2.41 COM script developed for IEEE 802.3ck specification
- Results for 8 lanes (56 & 112 Gbps Connector/ 0, 3, 6, and 9 ps added skew)
- All instances pass COM Case 1 & COM Case 2
- Unlike DAC channel, C2M does not exhibit differential insertion loss sensitivity

Conclusions

- Two main drivers in extending reach are skew and mating zone reflections
- Skew, differential insertion loss, and mode conversion are interrelated
- By minimizing skew, less differential energy is converted to common mode energy, and differential throughput can be maximized
- For any degree of skew one can relate the change in differential insertion loss to the change in mode conversion
- It was only when skew was added to the DAC channel that failures started to occur because of the increased differential insertion loss
- If mating zone reflections can be minimized, a channel can be more tolerant of skew from a differential insertion loss standpoint
- Minimizing both skew and mating zone reflections are strong drivers in being able to maximize channel reach for 112G.

References

[1] S. Farrahi, V. Kunda, Y. Li, X. Zhang, G. Blando and I. Novak, "Does Skew Really Degrade SERDES Peformance," in DesignCon, Santa Clara, 2015.

[2] R. Mellitz, "COM 2.41 with 100GEL Update," 2018. [Online]. Available: http://www.ieee802.org/3/ck/public/adhoc/aug15_18/mellitz_3ck_adhoc_01_081518.pdf.

[3] R. Mellitz, "COM 2.51 with rxFFE updates," 2018. [Online]. Available: http://www.ieee802.org/3/ck/public/adhoc/oct03_18/mellitz_3ck_adhoc_01_100318.pdf.