

# **TRANSCEIVER MODULE DATA IN SUPPORT OF COMMENTS #396 AND 397 AGAINST D1.2**

Roberto Rodes, Coherent

# INTRODUCTION

- **This presentation is in support of comments #396 and 397 against Draft 1.2 on TECQ/TDECQmax TBD specs**
- **This presentation responds to the task force's request for real-world 200G/lane module data.**
- **Module data with >3.4dB TECQ was used to:**
  - Evaluate test equipment repeatability of TECQ
  - Measure receiver post-innerFEC BER waterfall
  - Measure Codeword error distribution at Rx Sensitivity
- **Additional module data on same Tx and Rx with and w/o innerFEC to:**
  - Compare TECQ vs SER
  - Compare Rx sensitivity
- **Future discussion on TDECQ improvement: Histogram spacing**

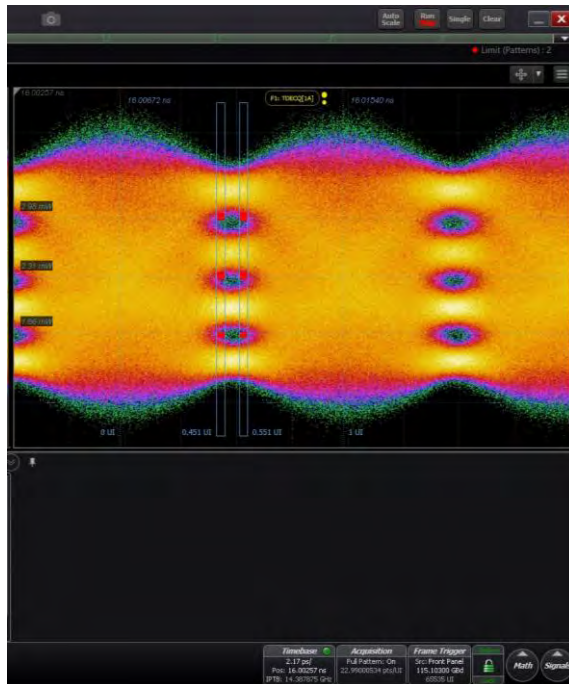
# **HIGH TECQ MODULE TESTING WITH INNER FEC**

# HIGH TECQ MODULE AT 200G/LANE

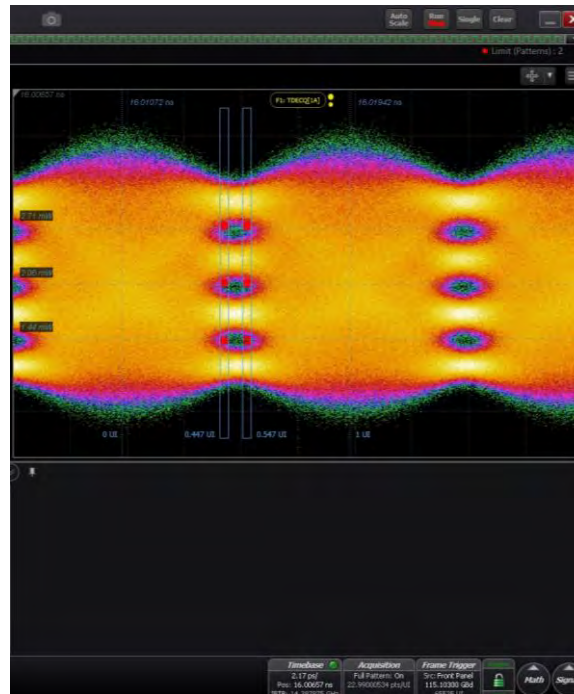
- 800G-FR4 module with inner FEC
- 115GBd
- SSPRQ
- 15-tap TECQ
- All lanes > 3.5 dB TECQ @ 9.6e-3 SER

CH	SER	TECQ	Ceq
0	9.60E-03	4.95	1.41
0	6.00E-03	-	1.43
1	9.60E-03	3.72	1.31
1	6.00E-03	4.18	1.35
2	9.60E-03	4.39	1.34
2	6.00E-03	4.47	1.36
3	9.60E-03	3.54	1.25
3	6.00E-03	3.99	1.3

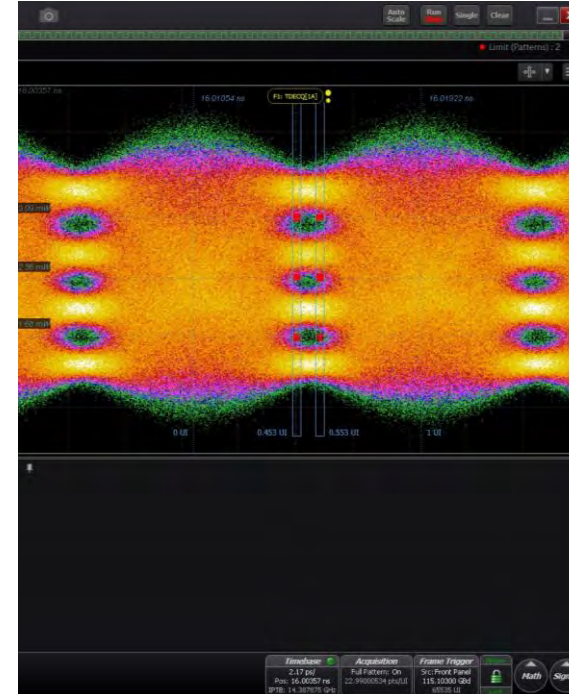
Lane0



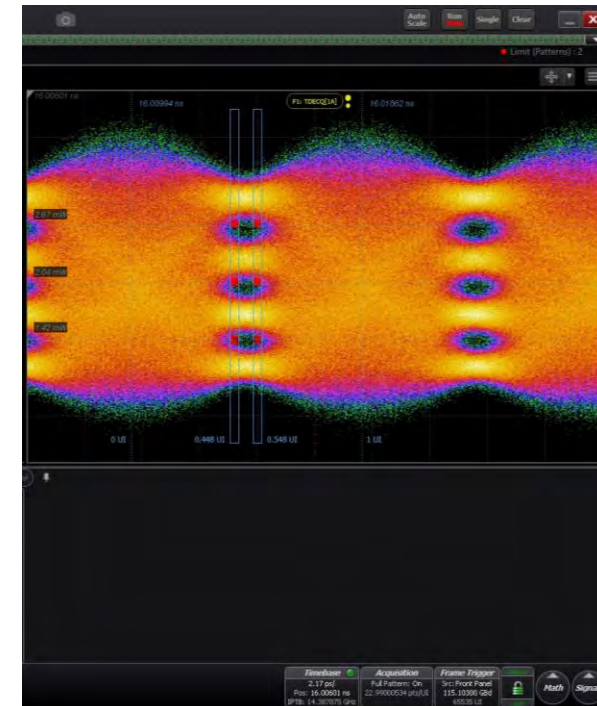
Lane1



Lane2



Lane3



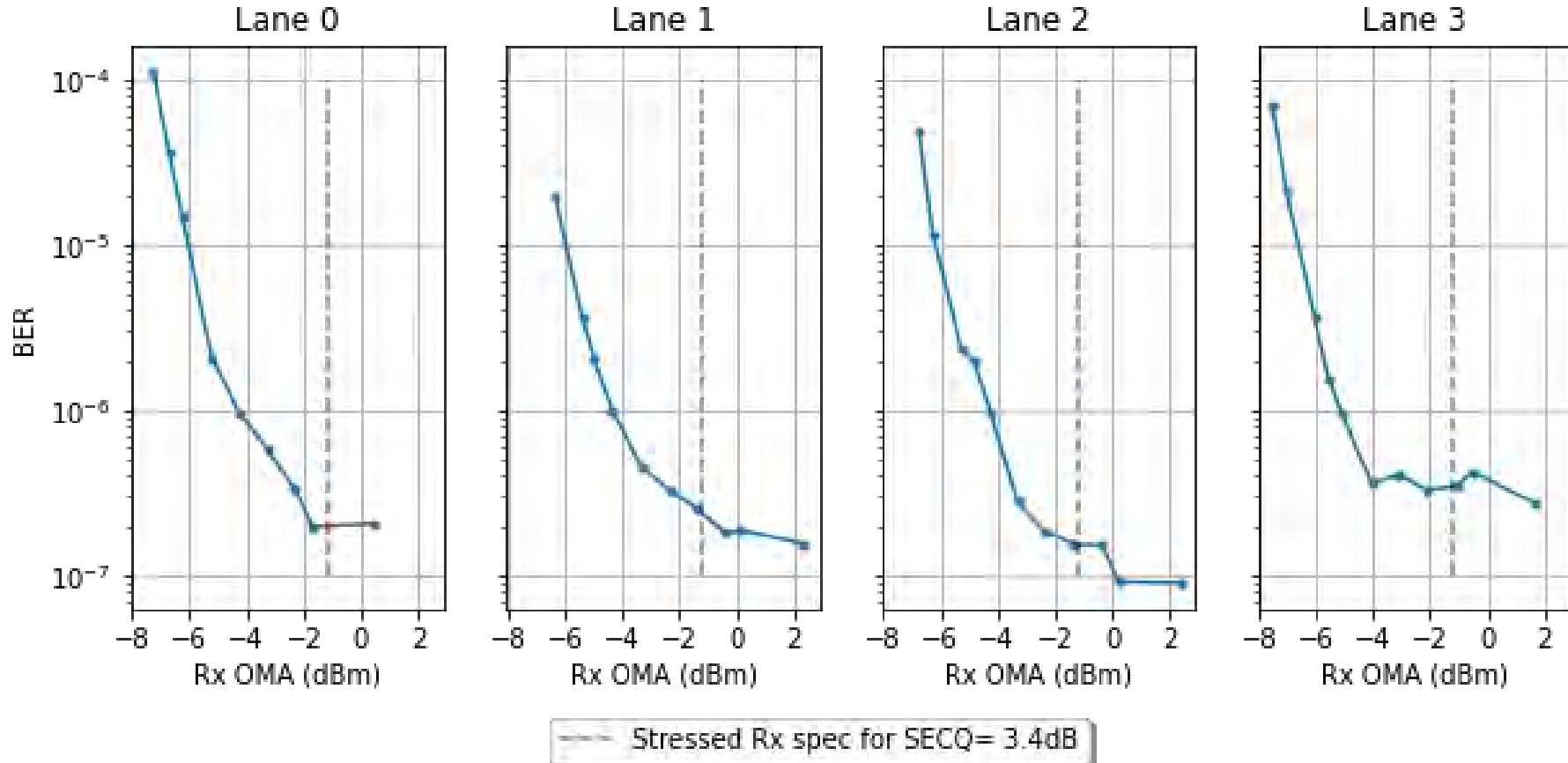
# IS TECQ TEST REPEATABILITY AT HIGH SER AN ISSUE?

TECQ testing in the DCA shows good repeatability with  $\sim\pm 0.15$  dB variation

CH	Iteration	SER	TECQ	Ceq
0	1	9.60E-03	4.95	1.41
0	2	9.60E-03	5.16	1.39
0	3	9.60E-03	4.99	1.44
0	4	9.60E-03	4.96	1.43
0	5	9.60E-03	5.05	1.43
1	1	9.60E-03	3.72	1.31
1	2	9.60E-03	3.51	1.31
1	3	9.60E-03	3.55	1.35
1	4	9.60E-03	3.45	1.29
1	5	9.60E-03	3.53	1.29

# WATERFALL POST INNER FEC BER

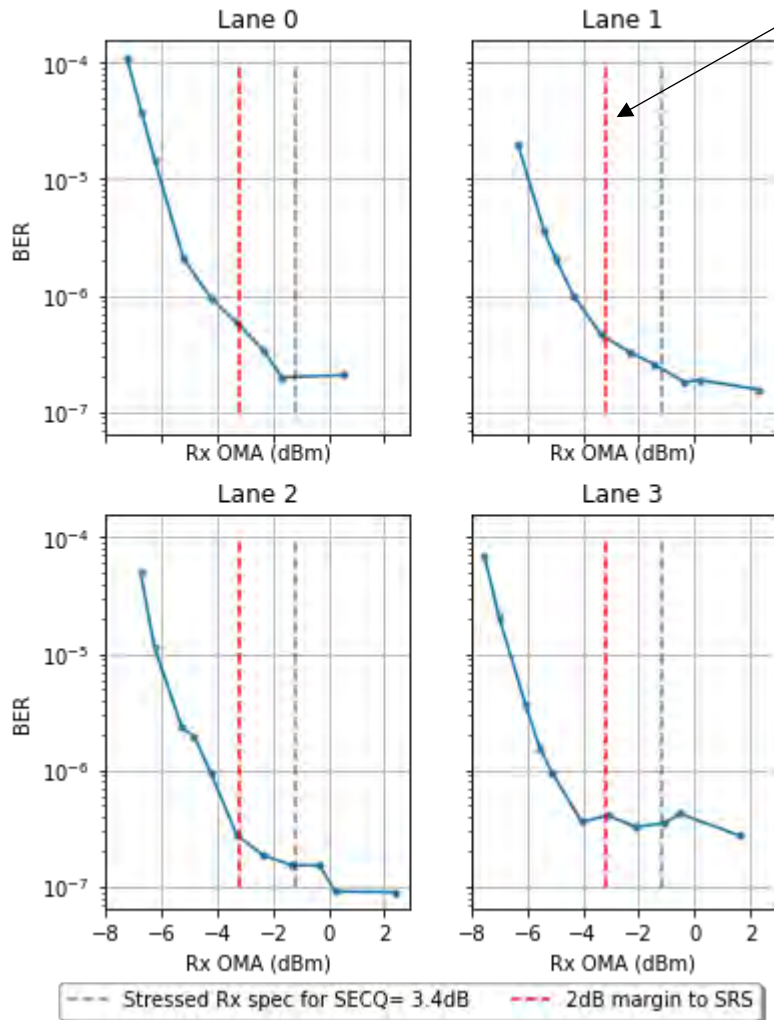
All receivers show < 1e-6 BER the SRS spec limit of -1.2\* dBm



\*assumes proposed SECQ/TECQmax= 3.4dB

# POST FEC PERFORMANCE

Codeword error ratios measured 2dB margin to SRS spec



FEC Statistics  
PHY # 1 RX

Table View All Codewords Histogram Correctable Codewords

Symbol Errors per Codeword

Symbol Errors per Codeword	Codeword Count	All Codewords Percentage
0	2,352,109,805	99.857399
1	2,942,914	0.124940
2	384,949	0.016343
3	30,280	0.001286
4	779	0.000033
5	23	0.000001
6	0	*
7	0	*
8	0	*
9	0	*
10	0	*
11	0	*
12	0	*
13	0	*
14	0	*
15	0	*
>=16	0	*

FEC Statistics  
PHY # 2 RX

Table View All Codewords Histogram Correctable Codewords

Symbol Errors per Codeword

Symbol Errors per Codeword	Codeword Count	All Codewords Percentage
0	2,362,463,880	99.800461
1	4,292,011	0.181313
2	400,203	0.016906
3	30,535	0.001290
4	853	0.000036
5	18	0.000001
6	0	*
7	0	*
8	0	*
9	0	*
10	0	*
11	0	*
12	0	*
13	0	*
14	0	*
15	0	*
>=16	0	*

FEC Statistics  
PHY # 3 RX

Table View All Codewords Histogram Correctable Codewords

Symbol Errors per Codeword

Symbol Errors per Codeword	Codeword Count	All Codewords Percentage
0	2,369,223,828	99.921135
1	1,664,010	0.070179
2	193,711	0.008170
3	11,902	0.000502
4	296	0.000012
5	3	0.000000
6	0	*
7	0	*
8	0	*
9	0	*
10	0	*
11	0	*
12	0	*
13	0	*
14	0	*
15	0	*
>=16	0	*

FEC Statistics  
PHY # 4 RX

Table View All Codewords Histogram Correctable Codewords

Symbol Errors per Codeword

Symbol Errors per Codeword	Codeword Count	All Codewords Percentage
0	2,352,869,559	99.889656
1	2,311,949	0.098152
2	265,579	0.011275
3	21,223	0.000901
4	429	0.000018
5	11	0.000000
6	0	*
7	0	*
8	0	*
9	0	*
10	0	*
11	0	*
12	0	*
13	0	*
14	0	*
15	0	*
>=16	0	*

All lanes show good codeword error ratio with margin <sup>7</sup>

# **TDECQ WITH AND WITHOUT INNER FEC**



# COMPARING TECQ FOR SAME TX WITH & W/O INNER FEC

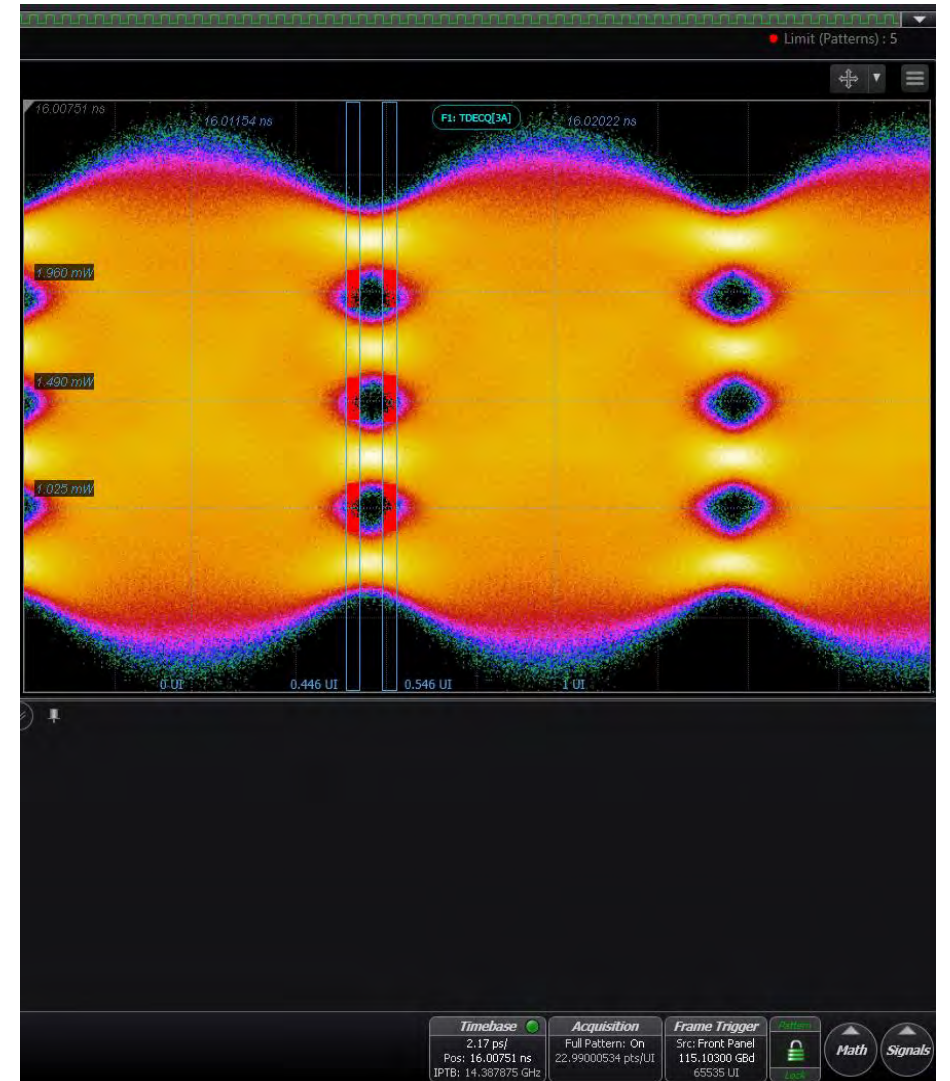
Different module than previous section to meet TECQ with and w/o inner FEC

Using same  $4.8e-4$  will make innerFEC spec significantly more challenging for the same Tx

SER of  $6e-3$  shows a similar TECQ value when operating at innerFEC baudrate compared to no innerFEC at  $4.8e-4$

Baudrate	SER	TECQ	Ceq
107GBd	$4.8e-4$	3.11	1.14
115GBd	$4.8e-4$	4.41	1.57
115GBd	$6e-3$	2.81	1.57
115GBd	$9.6e-3$	2.6	1.6

800G-FR4 module lane#3



# RX PERFORMANCE WITH AND WITHOUT INNER FEC. RX SENSITIVITY

Same 800G-FR4 module is tested with and without innerFEC in loopback configuration. Reducing Rx OMA until lane#3 hits same BER (1e-5) on both configurations. The same receiver, shows ~2dB better Rx sensitivity with the Transmitter when using innerFEC. TECQ , which correlates with Rx sensitivity, should reflect that improvement.

preKP4 BER  
**without** Inner FEC

Total FEC Errors / Ratio				
PHY#	Uncorr. CW Error	Corr. CW Error	Corr. Symbol Err.	Corr. Bit Error
1	*	1.469E-2	3.534E-5	3.561E-6
2	*	3.490E-3	8.405E-6	8.435E-7
3	*	2.896E-3	7.210E-6	7.253E-7
4	*	6.486E-2	1.625E-4	1.634E-5

Lane#3 Rx OMA= -3.2 dBm

preKP4 BER  
**with** Inner FEC

Total FEC Errors / Ratio				
PHY#	Uncorr. CW Error	Corr. CW Error	Corr. Symbol Err.	Corr. Bit Error
1	*	1.413E-3	3.411E-6	3.590E-7
2	*	5.100E-4	1.269E-6	1.390E-7
3	*	1.247E-4	2.953E-7	3.353E-8
4	*	5.091E-2	1.286E-4	1.522E-5

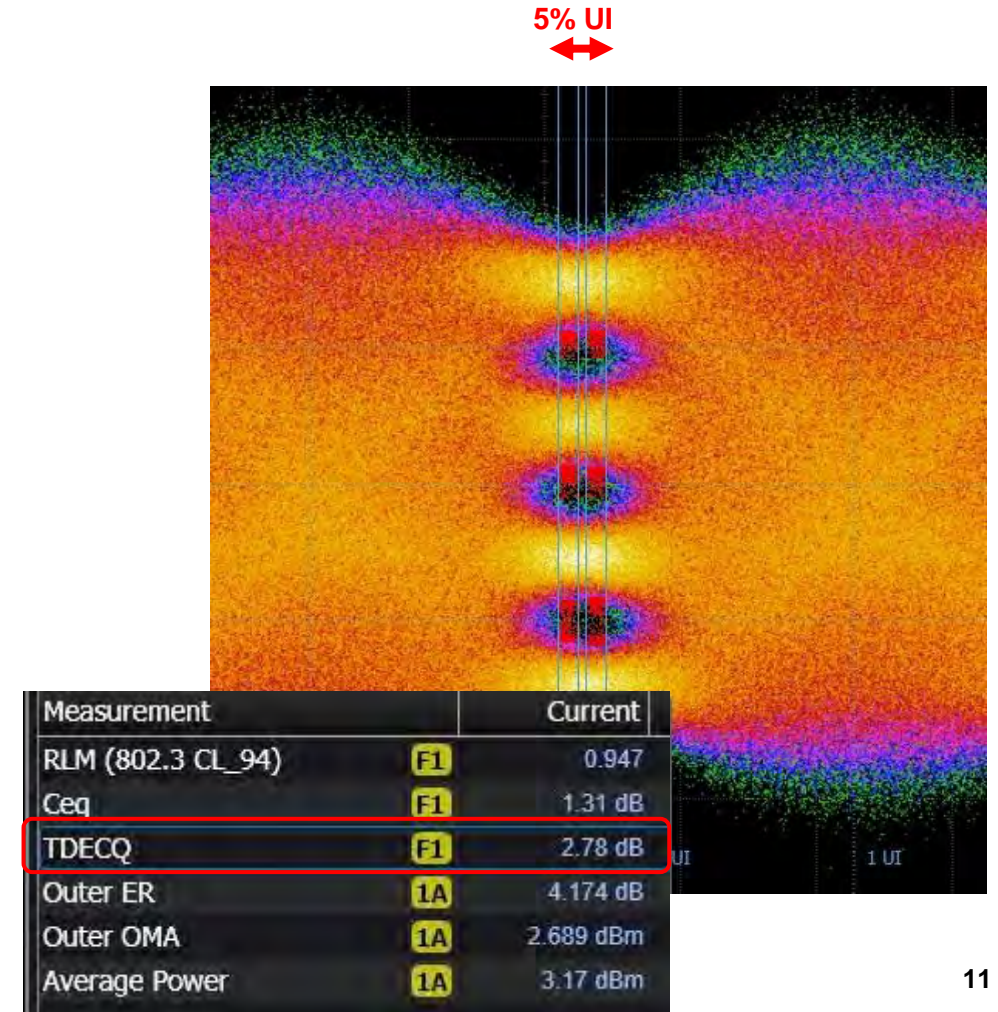
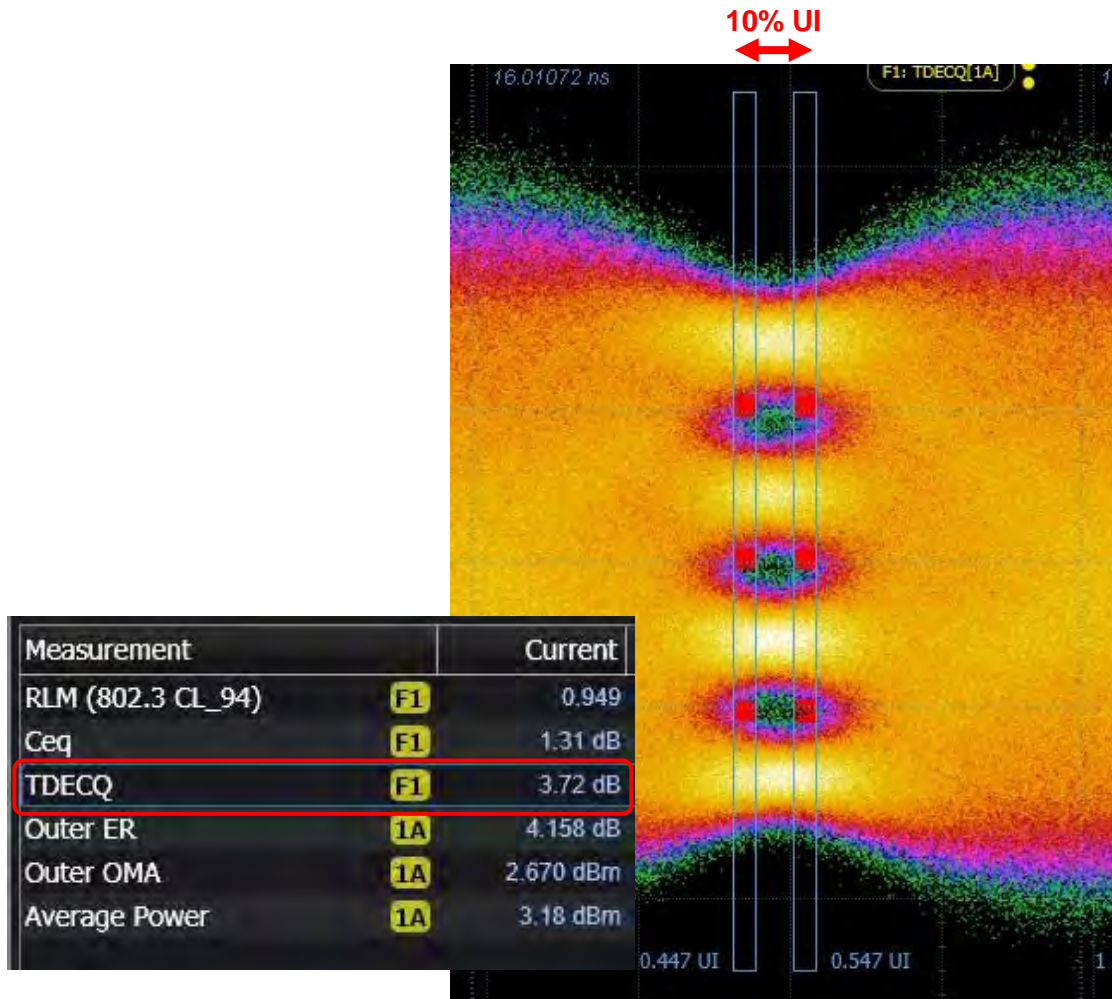
Lane#3 Rx OMA= -5.1 dBm

# FUTURE TDECQ DISCUSSION: HIDDEN MARGIN OF TDECQ, HISTOGRAM SPACING

TDECQ Reference receiver ONLY considers the outlier samples of the eye.

Therefore, histogram spacing has a very large impact on TDECQ value.

Future work: Consider using entire eye center, or reduce spacing of the windows



# CONCLUSION

- Receivers do work with TECQ = 3.4dB when using innerFEC
- DCA testing shows good repeatability
- Same Transmitter shows 0.5dB TECQ improvement when using innerFEC and  $9.6e-3$  SER, while the receiver sensitivity performance improved by 1.9dB
- SER target of  $9.6e-3$  does not overly reduce the TECQ value