Return Loss (RL), Effective Return Loss (ERL), and COM Variations

For Resolution of Comments 25, 26, 27, & 28

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- ❑ Illustrate ERL (Effective Returns Loss) connection to return loss vectors
- ❑ Show ERL correlation to package parameters
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- ❑ Recommendation

For explanation the DOE methods, definitions, and related graphic explanations please refer to:

- http://www.ieee802.org/3/cd/public/adhoc/archive/mellitz_083017_3cd_adhoc.pdf

For a description of ERL refer to:

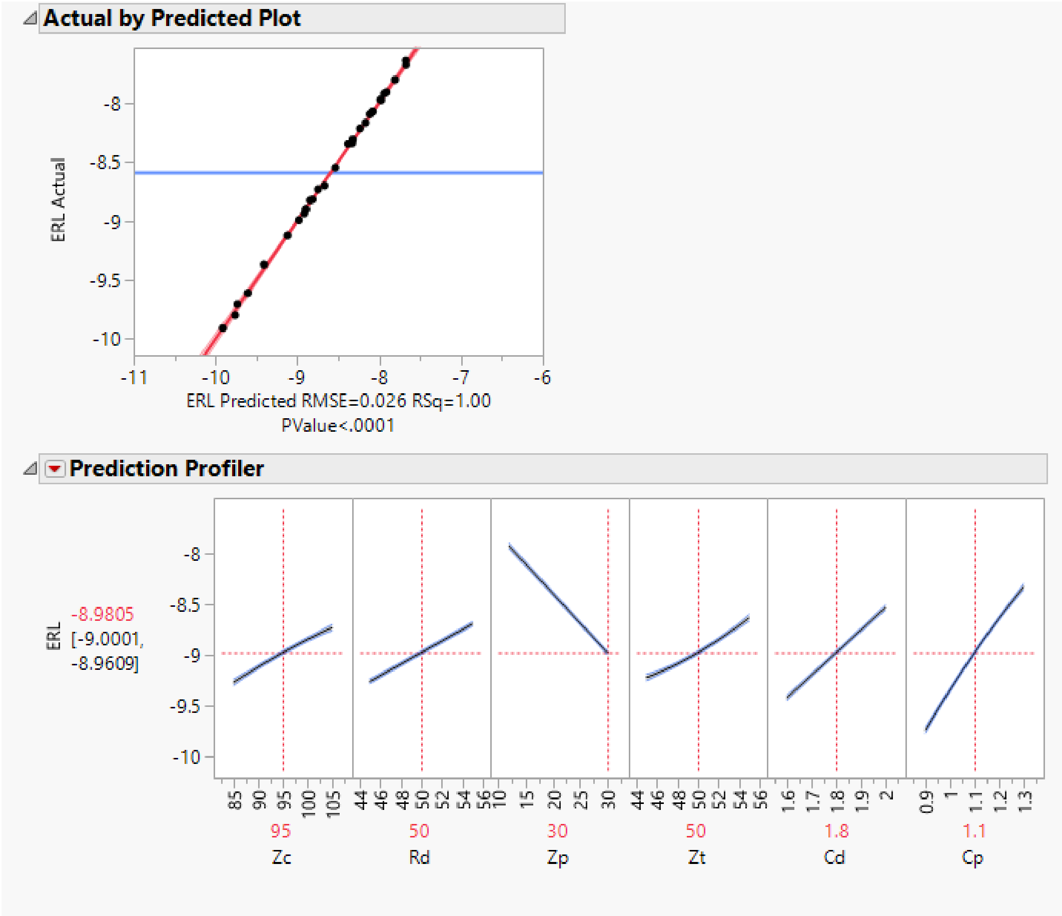
- http://www.ieee802.org/3/bs/public/17_07/mellitz_3bs_01a_0717.pdf, slides 13 to 19
- http://www.ieee802.org/3/cd/public/adhoc/archive/mellitz_060717_3cd_02_adhoc.pdf slides 5-8

Effective Return Loss (ERL) Experiment

- X variables are COM package parameters centered on D2.1 COM table
- Y is the computed ERL for the specified Zt
- From mellitz_060717_3cd_02_adhoc
- This is for package/device ERL
- ERL for the channel is discussed later and is called ERL Tx and ERL Rx
  - (11 and 22 ports respectively)

x						y
Zc Ohms	Rd Ohms	Zp Ohms	Zt Ohms	Cd 1e-10 F	Cp 1e-10 F	ERL dB
95	50	30	50	1.8	1.1	-9.0
95	50	30	50	1.8	1.1	-9.0
96	51	30	50	1.8	1.1	-8.9
96	51	30	50	1.8	1.1	-8.9
94	48	30	50	1.8	1.1	-9.1
94	48	30	50	1.8	1.1	-9.1
85	45	12	55	2	0.9	-7.9
95	55	30	55	1.6	1.3	-8.2
95	45	30	50	1.6	0.9	-10.5
85	45	30	55	2	1.3	-8.0
105	45	12	45	1.6	1.3	-8.6
105	55	12	45	2	1.3	-6.9
85	50	30	55	1.8	0.9	-9.7
105	55	30	45	2	0.9	-8.8
105	45	30	45	1.8	1.1	-9.4
85	45	12	45	1.6	0.9	-9.9
85	55	12	55	2	1.3	-6.4
85	55	12	45	2	0.9	-8.1
85	45	30	45	2	0.9	-10.2
105	50	12	55	2	1.1	-7.0
105	45	12	45	2	0.9	-8.8
95	50	30	45	2	1.3	-8.2
85	45	30	45	1.6	1.3	-9.6
105	55	30	50	1.8	1.3	-7.8
105	45	30	55	1.6	1.3	-8.3
105	55	12	55	1.6	0.9	-8.3
85	50	12	50	1.6	1.3	-7.9
95	55	21	55	2	0.9	-8.1
85	45	21	55	1.6	1.1	-8.9
105	45	30	55	2	0.9	-8.9
105	45	21	50	2	1.3	-7.6
95	55	12	45	1.6	1.1	-8.3
85	55	12	55	1.6	0.9	-8.7
85	55	30	50	2	1.1	-8.5
105	50	21	45	1.6	0.9	-9.8
85	55	21	45	1.8	1.3	-8.0
95	45	12	55	1.8	1.3	-7.2
85	45	12	45	2	1.3	-7.7
85	55	30	45	1.6	0.9	-10.5
105	45	12	55	1.6	0.9	-8.7

ERL fit is very closely tied to package parameters: RMS error is 0.026 dB



ERL Prediction Equation

$$
\begin{gathered}
(-22.9371813122759) + 0.0180921056094042 * Zc + \\
0.0568325927712985 * Rd +-0.0589245893510021 * Zp + \\
0.0680408952372635 * Zt + 2.29551955640816 * \\
Cd+3.2956494591755 * Cp + (Zc - 94.5) * ((Zc - 94.5) * - \\
0.000232738951785374) + (Zc - 94.5) * ((Rd - 49.575) * \\
0.000677332168959554) + (Zc - 94.5) * ((Zp-22.125) * \\
0.00111325213652863) + (Zc - 94.5) * ((Zt - 49.875) \\
*0.000238892775679064) + (Rd - 49.575) * ((Zt - 49.875) * \\
-0.00396965785082018) + (Zp - 22.125) * ((Zt - 49.875) * - \\
0.00103701659658663) + (Zt - 49.875) * ((Zt-49.875) * \\
0.00196432071730769) + (Zc - 94.5) * ((Cd - 1.805) *- \\
0.0153551291854686) + (Rd - 49.575) * ((Cd - 1.805) * \\
0.0130086172404367) + (Zp - 22.125) * ((Cd - 1.805) * - \\
0.00883864973187424) + (Zt - 49.875) * ((Cd - 1.805) * - \\
0.00345591899210246) + (Zc - 94.5) * ((Cp - 1.095) * - \\
0.0130281234843095) + (Rd - 49.575) * ((Cp - 1.095) * - \\
0.00811355551678069) + (Zp - 22.125) * ((Cp -1.095) * \\
0.0321656771693624) + (Cd - 1.805) * ((Cp - 1.095) * - \\
0.841281482352236) + (Cp - 1.095) * ((Cp - 1.095) * - \\
1.47094118647978)
\end{gathered}
$$

Package ERL for variation for the COM package

	Zc 95 ohms (D2.1) Rd 50 ohms (D2.1) Cd 0.18 pF (D2.1) Cp 0.11 pF (D2.1)	Zc 85 ohms Rd 45 ohms Cd 0.16 pF Cp 0.09 pF	Zc 105 ohms Rd 55 ohms Cd 0.2 pF Cp 0.13 pF	Zc 85 ohms Rd 45 ohms Cd 0.18 pF (D2.1) Cp 0.11 pF (D2.1)	Zc 105 ohms Rd 55 ohms Cd 0.18 pF (D2.1) Cp 0.11 pF (D2.1)
ERL 12 mm pkg (Zp)	-7.9 dB	-9.5 dB	-6.4 dB	-8.2 dB	-7.6 dB
ERL 30 mm pkg (Zp)	-9 dB	-10.8 dB	-7.4 dB	-9.5 dB	-8.4 dB

Q: Could this be a basis for a specification?

ERL metric

- ERL is a way to turn the return loss vector into a single number
- ERL eliminates the “spike up near the mask” issue
- Now the question is: What is the relative importance of return loss?
- Since RL is reduced to a number, correlation to performance and performance variability can be assessed

Channel Data (in .3cd Public Channel Lib)

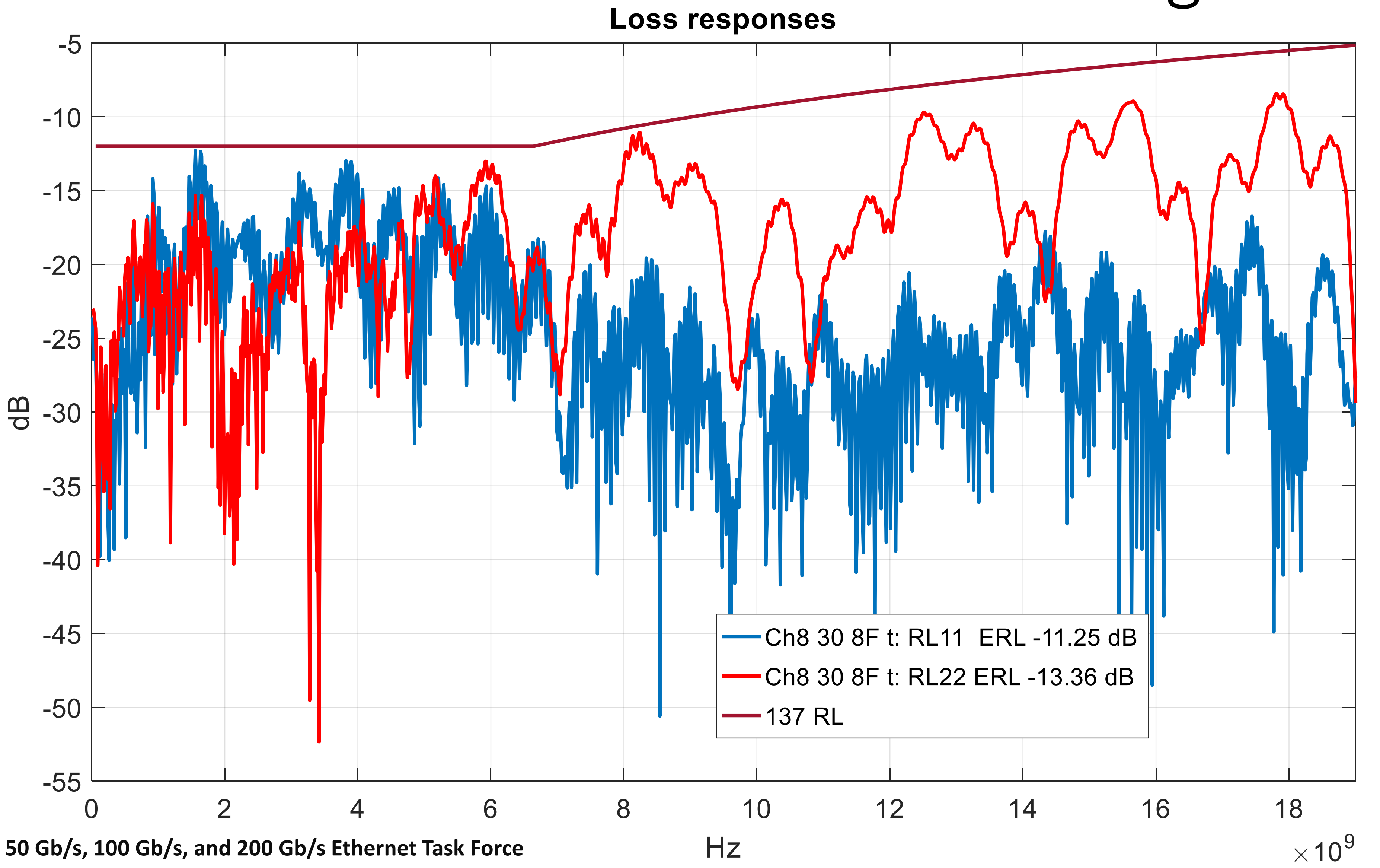
	Channel	COM (dB) D2.1 Table	ERL11 (dB)	ERL22 (dB)	IL (dB)
1	'5F3N--Ch1_10_5F3N_t	6.07	-10.69	-11.62	9.8
2	'TEC_STRADAWhisper11p75in_Meg6_Channel_IEEE802_3_cd_Cu_07282016--TEC_Whisper11p75in_THRU_G14G15-07212016	6.75	-13.76	-13.34	10.5
3	'mellitz_01_021716_10dB_6_channels--PAM4_2conn_MP_v2_100ohm_10dB_Nom_thru	5.25	-8.79	-5.68	10.4
4	'mellitz_01_021716_10dB_6_channels--PAM4_2conn_MP_v2_100ohm_10dB_HzLzHz_thru	5.53	-8.98	-5.36	10.5
5	'mellitz_01_021716_10dB_6_channels--PAM4_2conn_MP_v2_100ohm_10dB_LzHzLz_thru	4.57	-7.11	-4.94	10.4
6	'mellitz_01_021716_10dB_6_channels--PAM4_2conn_MP_v2_85ohm_10dB_Nom_thru	7.19	-10.45	-7.39	9.8
7	'mellitz_01_021716_10dB_6_channels--PAM4_2conn_MP_v2_85ohm_10dB_HzLzHz_thru	6.67	-9.03	-6.01	10.0
8	'mellitz_01_021716_10dB_6_channels--PAM4_2conn_MP_v2_85ohm_10dB_LzHzLz_thru	6.64	-8.28	-6.07	9.8
9	'5F3N--Ch4_20_5F3N_t	5.60	-10.31	-13.27	20.0
10	'TEC_STRADAWhisper27in_Meg6_Channel_IEEE802_3_cd_Cu_07282016--TEC_Whisper27in_THRU_G14G15_07202016	4.78	-14.48	-13.71	22.3
11	'mellitz_01_021716_20dB_6_channels--PAM4_2conn_MP_v2_100ohm_20dB_Nom_thru	5.87	-10.81	-7.25	20.4
12	'mellitz_01_021716_20dB_6_channels--PAM4_2conn_MP_v2_100ohm_20dB_HzLzHz_thru	5.37	-11.29	-6.67	20.4
13	'mellitz_01_021716_20dB_6_channels--PAM4_2conn_MP_v2_100ohm_20dB_LzHzLz_thru	5.27	-9.19	-6.37	20.3
14	'mellitz_01_021716_20dB_6_channels--PAM4_2conn_MP_v2_85ohm_20dB_Nom_thru	6.71	-12.33	-8.33	19.6
15	'mellitz_01_021716_20dB_6_channels--PAM4_2conn_MP_v2_85ohm_20dB_HzLzHz_thru	6.20	-10.74	-7.10	19.8
16	'mellitz_01_021716_20dB_6_channels--PAM4_2conn_MP_v2_85ohm_20dB_LzHzLz_thru	5.99	-10.48	-7.00	19.7
17	'5F3N--Ch8_30_5F3N_t	3.07	-11.25	-13.76	29.5
18	'TEC_STRADAWhisper40in_Meg6_Channel_IEEE802_3_cd_Cu_07282016--TEC_Whisper40in_THRU_G14G15_07202016	1.68	-14.90	-14.08	32.7
19	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_100ohm_30dB_Nom_thru	2.76	-11.35	-7.40	30.4
20	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_100ohm_30dB_HzLzHz_thru	2.58	-11.86	-6.89	30.4
21	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_100ohm_30dB_LzHzLz_thru	2.58	-9.91	-6.54	30.3
22	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_Nom_thru	3.41	-13.07	-8.56	29.7
23	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_HzLzHz_thru	3.06	-11.35	-7.43	30.0
24	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_LzHzLz_thru	3.19	-11.32	-7.19	29.6
25	'20dB_HghZ--20dB_HighZ_thru	3.15	-17.17	-16.71	19.3
26	'20dB_HghZ_Nom_HighZ--20dB_HighZ_Nom_HighZ_thru	3.27	-18.95	-18.45	19.2
27	'30dB_HighZ--30dB_HighZ_thru	3.16	-17.34	-17.08	29.5

Cull to Channels of Interest

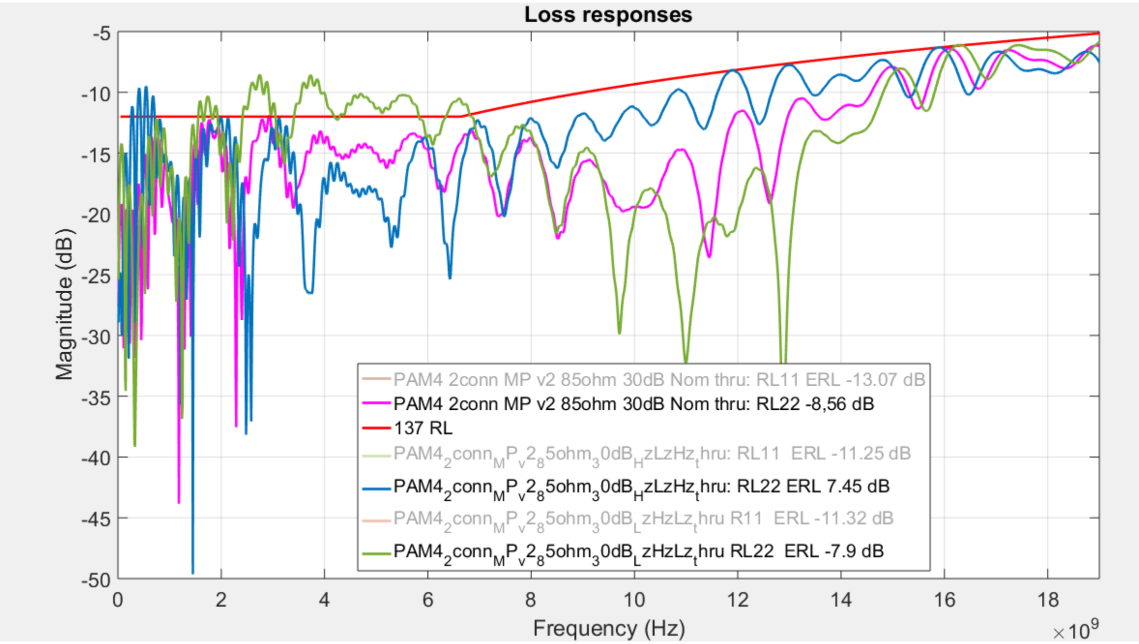
- Omit channels above 4 dB COM
- Omit channels below 3 dB COM

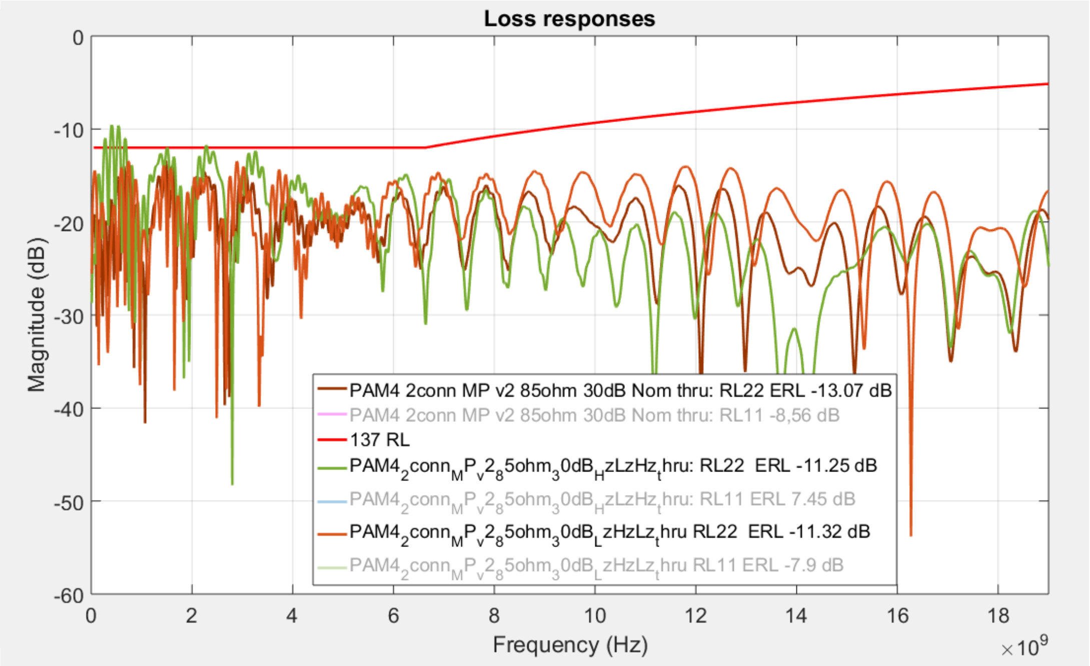
	Channel	COM (dB) D2.1 Table	ERL11 (dB)	ERL22 (dB)	IL (dB)
17	'5F3N--Ch8_30_5F3N_t	3.07	-11.25	-13.76	29.5
22	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_Nom_thru	3.41	-13.07	-8.56	29.7
23	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_HzLzHz_thru	3.06	-11.35	-7.43	30.0
24	'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_LzHzLz_thru	3.19	-11.32	-7.19	29.6
25	'20dB_HghZ--20dB_HighZ_thru	3.15	-17.17	-16.71	19.3
26	'20dB_HghZ_Nom_HighZ--20dB_HighZ_Nom_HighZ_thru	3.27	-18.95	-18.45	19.2
27	'30dB_HighZ--30dB_HighZ_thru	3.16	-17.34	-17.08	29.5

ERL for Channel 17 has is higher (less negative) and is close to CL 137 limit line on average

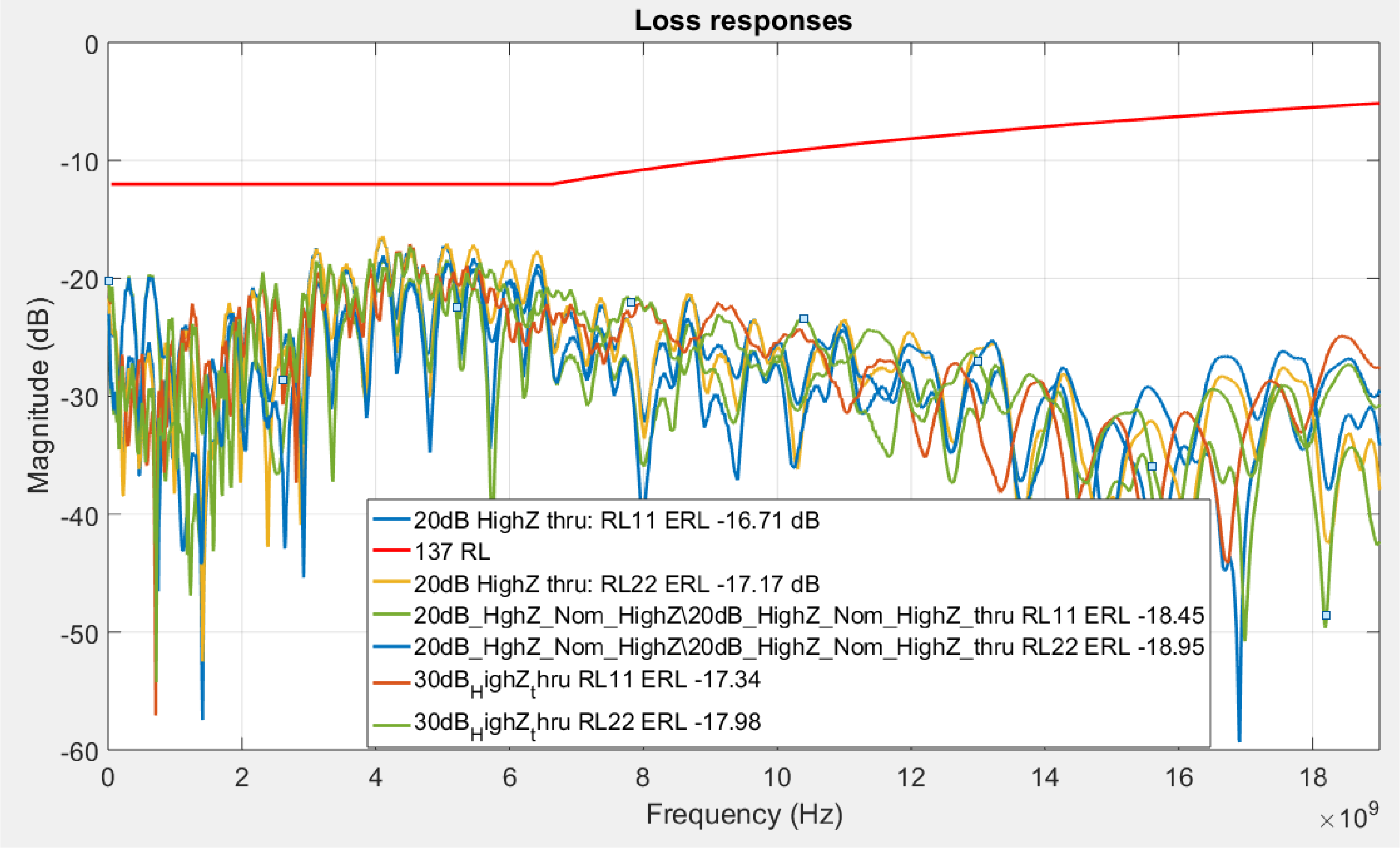


Channel 22,23, and 24: Higher (less negative) ERL is over the limit line





CH 25, 26, 27: Lower RL yields lower ERL



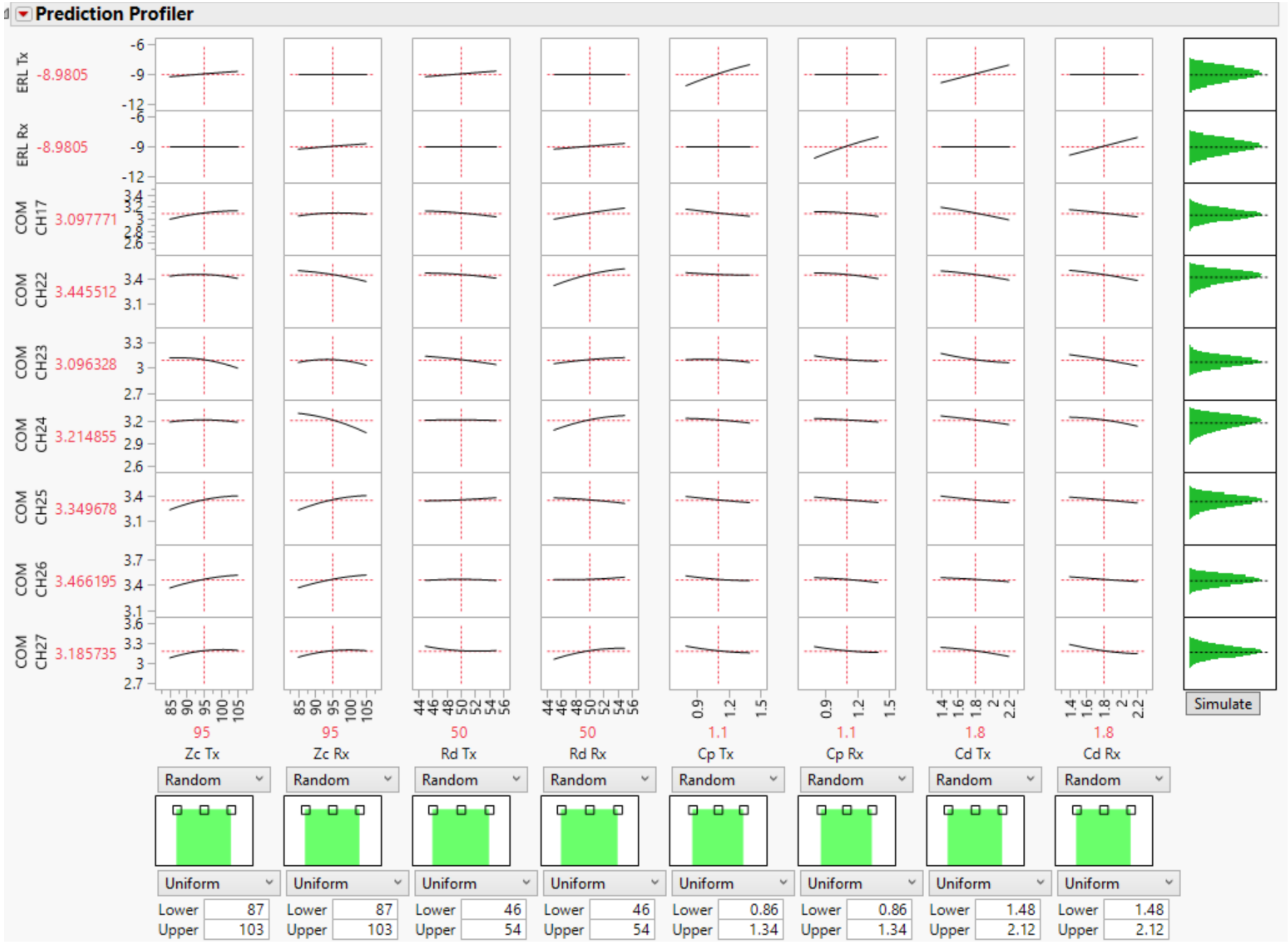
Little Correlation Between COM and ERL

- High return loss, high ERL (less negative) channels can pass COM
- High return loss, High ERL (less negative) channels have nearly as much variability as lower ERL channels with less return loss
- This makes a RL spec very difficult

Channel	COM (dB) D2.1 Table	ERL11 (dB)	ERL22 (dB)	com min from D2.1 delta dB	IL (dB)
'5F3N--Ch8_30_5F3N_t	**3.07**	**-11.25**	**-13.76**	**0.28**	**29.5**
'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_Nom_thru	**3.41**	**-13.07**	**-8.56**	**0.43**	**29.7**
'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_HzLzHz_thru	**3.06**	**-11.35**	**-7.43**	**0.29**	**30.0**
'mellitz_01_021716_30dB_6_channels--PAM4_2conn_MP_v2_85ohm_30dB_LzHzLz_thru	**3.19**	**-11.32**	**-7.19**	**0.57**	**29.6**
'20dB_HghZ--20dB_HighZ_thru	**3.15**	**-17.17**	**-16.71**	**0.37**	**19.3**
'20dB_HghZ_Nom_HighZ--20dB_HighZ_Nom_HighZ_thru	**3.27**	**-18.95**	**-18.45**	**0.40**	**19.2**
'30dB_HighZ--30dB_HighZ_thru	**3.16**	**-17.34**	**-17.08**	**0.25**	**29.5**

Device ERL

- ❑ 1 million combinations of the COM package models were considered
- ❑ The columns of graphs represent 8 package parameters each and has its' own x scale
- ❑ The top first 2 rows are ERL for the Tx package and Rx package
- ❑ The remaining rows are the predicated COM for the corresponding selected channels
- ❑ Green graphs are the distribution of a million combinations
- ❑ Z_t wat 50 ohms

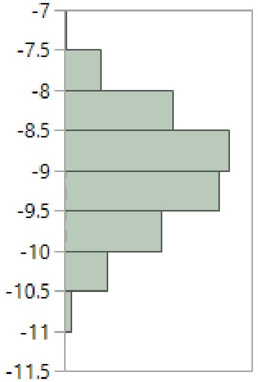


Variability of a million COM 30 mm package combinations

- This is a closer look at last column (distributions) on the previous slide
- Next step: Select only cases with ERL less than 9 dB
- 9 dB represent the ERL for the 30 mm package used in COM 2.1

Distributions

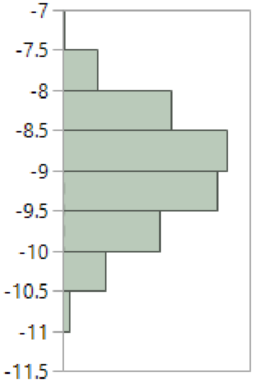
ERL Tx



Summary Statistics

Mean	-9.014181
Std Dev	0.6647367
Std Err Mean	0.0006647
Upper 95% Mean	-9.012879
Lower 95% Mean	-9.015484
N	1000000

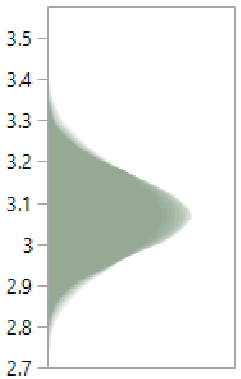
ERL Rx



Summary Statistics

Mean	-9.014862
Std Dev	0.6641512
Std Err Mean	0.0006642
Upper 95% Mean	-9.01356
Lower 95% Mean	-9.016164
N	1000000

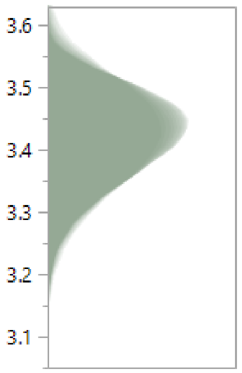
COM CH17



Summary Statistics

Mean	3.0707577
Std Dev	0.088859
Std Err Mean	8.8859e-5
Upper 95% Mean	3.0709318
Lower 95% Mean	3.0705835
N	1000000

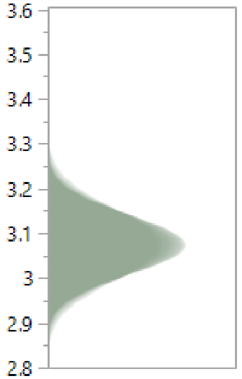
COM CH22



Summary Statistics

Mean	3.4185711
Std Dev	0.0706301
Std Err Mean	7.063e-5
Upper 95% Mean	3.4187096
Lower 95% Mean	3.4184327
N	1000000

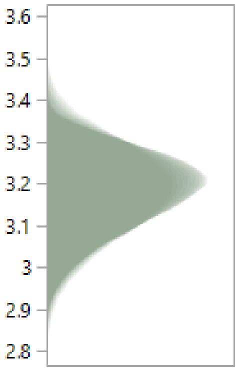
COM CH23



Summary Statistics

Mean	3.0746777
Std Dev	0.0611897
Std Err Mean	6.119e-5
Upper 95% Mean	3.0747977
Lower 95% Mean	3.0745578
N	1000000

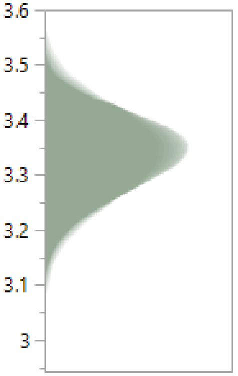
COM CH24



Summary Statistics

Mean	3.1799537
Std Dev	0.0884056
Std Err Mean	0.0000884
Upper 95% Mean	3.180127
Lower 95% Mean	3.1797804
N	1000000

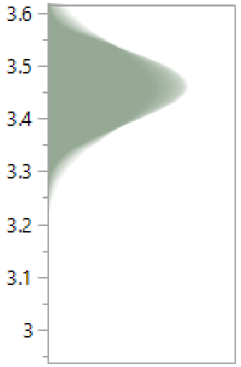
COM CH25



Summary Statistics

Mean	3.3349422
Std Dev	0.0671416
Std Err Mean	6.7142e-5
Upper 95% Mean	3.3350738
Lower 95% Mean	3.3348106
N	1000000

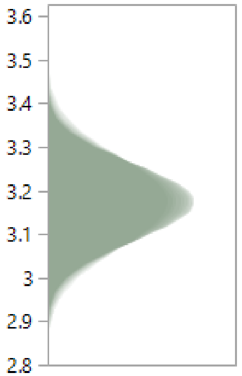
COM CH26



Summary Statistics

Mean	3.4553896
Std Dev	0.0565429
Std Err Mean	5.6543e-5
Upper 95% Mean	3.4555004
Lower 95% Mean	3.4552788
N	1000000

COM CH27

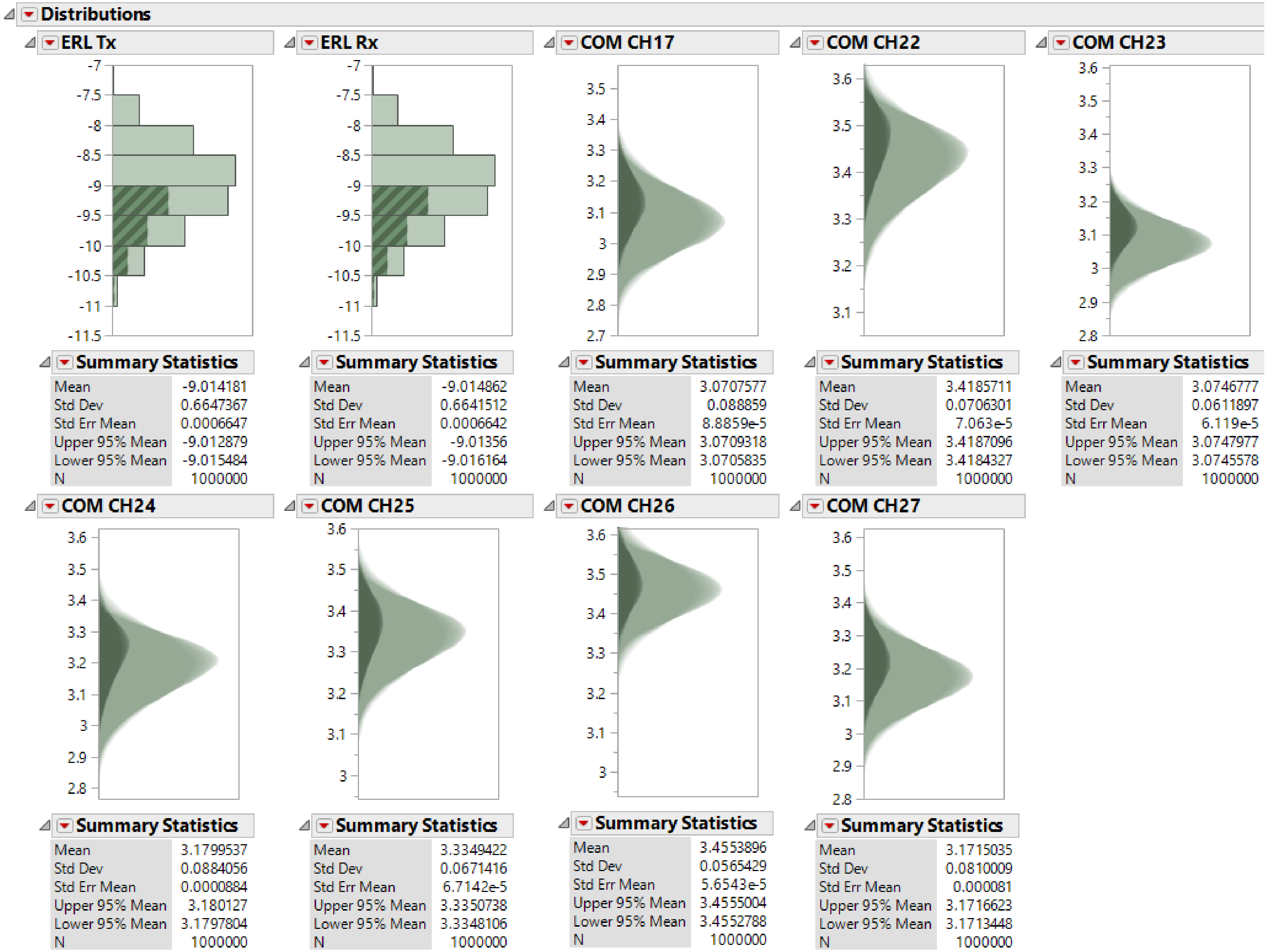


Summary Statistics

Mean	3.1715035
Std Dev	0.0810009
Std Err Mean	0.000081
Upper 95% Mean	3.1716623
Lower 95% Mean	3.1713448
N	1000000

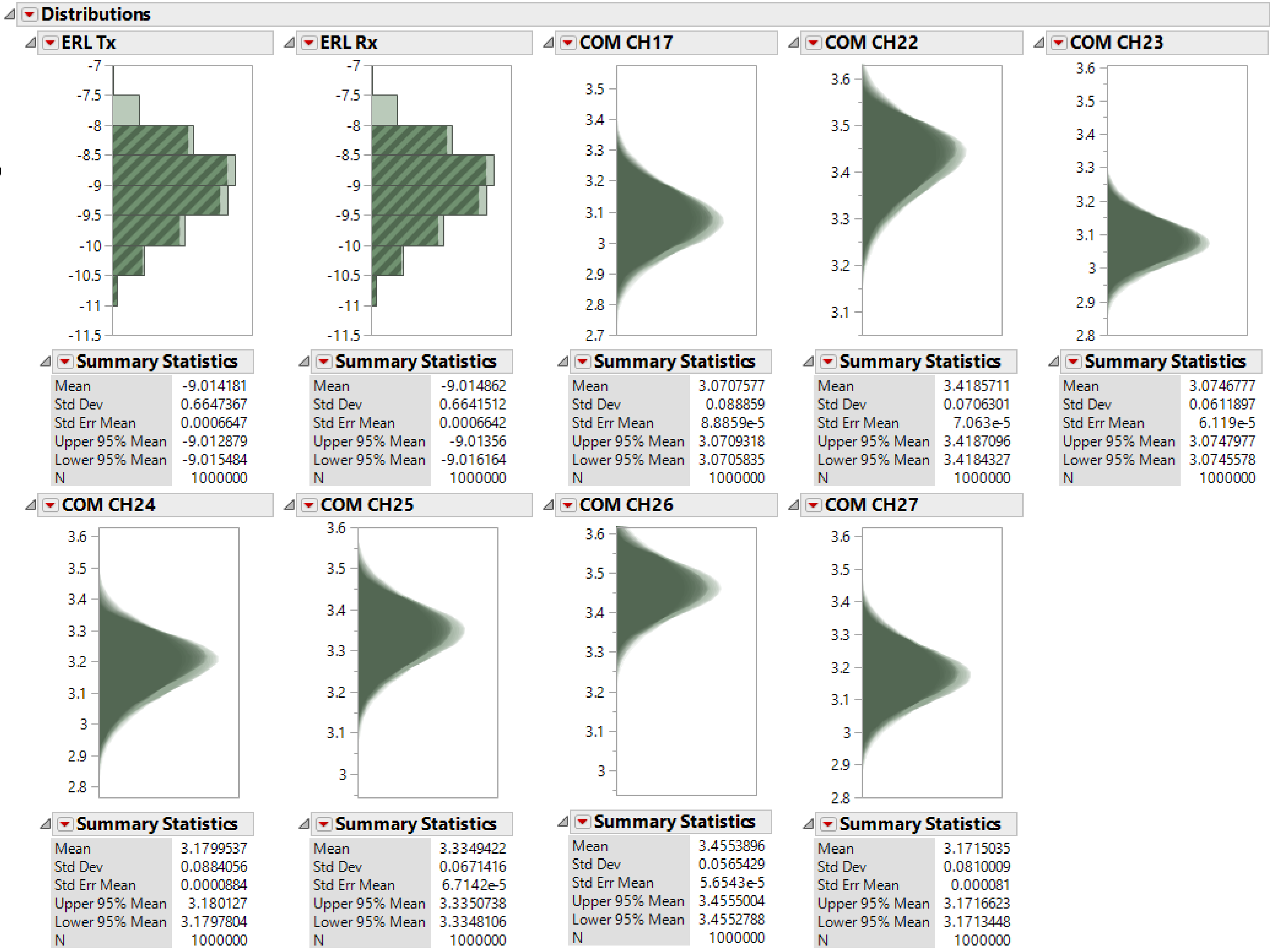
Restricting ERL limits COM variability

- The dark green represents cases which use packages with less than -9 dB ERL.
- But …



Now consider shorter packages

- Shorter packages have more return loss
- This might force an ERL limit to be nearly -8 dB
- The dark green represents cases which use packages with less than -8 dB ERL
- Little restriction in variability



Summary Statistics	ERL Tx	ERL Rx	COM CH17	COM CH22	COM CH23	COM CH24	COM CH25	COM CH26	COM CH27
Mean	-9.014181	-9.014862	3.0707577	3.4185711	3.0746777	3.1799537	3.3349422	3.4553896	3.1715035
Std Dev	0.6647367	0.6641512	0.088859	0.0706301	0.0611897	0.0884056	0.0671416	0.0565429	0.0810009
Std Err Mean	0.0006647	0.0006642	8.8859e-5	7.063e-5	6.119e-5	0.0000884	6.7142e-5	5.6543e-5	0.000081
Upper 95% Mean	-9.012879	-9.01356	3.0709318	3.4187096	3.0747977	3.180127	3.3350738	3.4555004	3.1716623
Lower 95% Mean	-9.015484	-9.016164	3.0705835	3.4184327	3.0745578	3.1797804	3.3348106	3.4552788	3.1713448
N	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000

Recommendation

- ❑ Remove differential return loss requirement for channels
  - Original thought: limiting channel RL would limit COM variability
  - This does not appear to be true
- ❑ Or pass channels only with ERL < -7 dB if COM is < 4 dB

- ❑ ERL for the Tx and Rx device
  - Change differential return loss to "recommended" from "required"
  - Use de-embedding to measure return loss
  - Make the recommended return loss requirement ERL < -9 dB for Tx and Rx device and add annex which describes ERL
    - http://www.ieee802.org/3/bs/public/17_07/mellitz_3bs_01a_0717.pdf, slides 13 to 19
- ❑ Or make the return loss requirement ERL < -7.9 dB for Tx and Rx device and add an annex which describes ERL
- ❑ Re-adjust limits if ERL limit if a test fixture is required rather than de-embedding