Practical Device Test Fixtures for 100G KR … or Not and the Impact on ERL and P_{max}/V_f (ref: comment 19, 20, 21, 25)

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Agenda

- ❑ Test fixture background
- ❑ Impact of small perturbations on hypothetical test fixtures
- ❑ Measurement variably due to a few simple UUT (package) impedance variations across the hypothetical fixtures
- ❑ Realistic device variations suggest ERL_{min} and P_{max}/V_f specs
- ❑ Summary/Recommendation

The Test Fixture Reference was Basically a Transmission Line

Clause 93

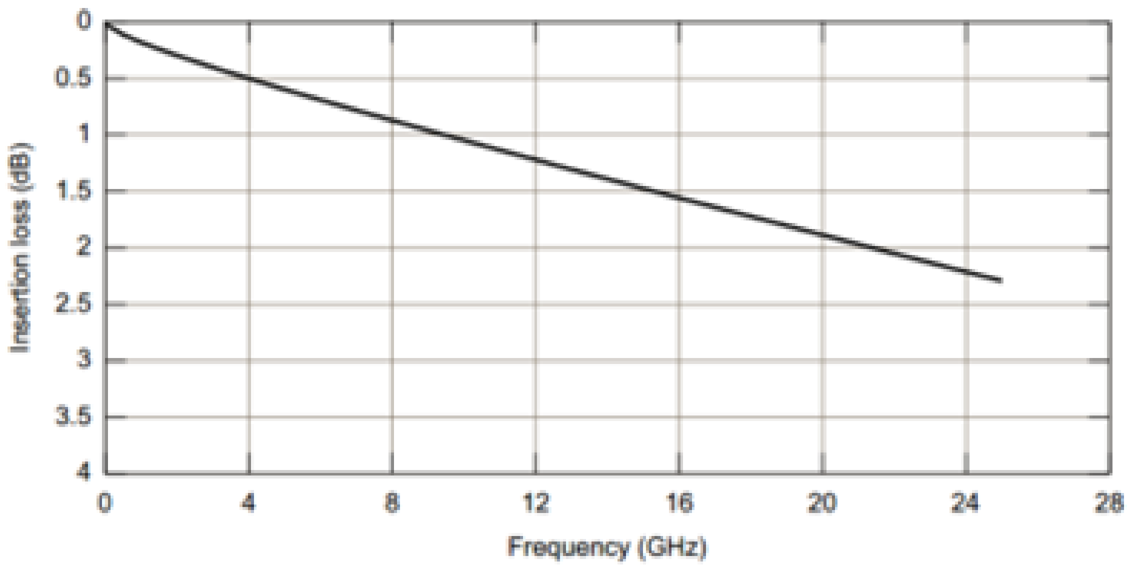
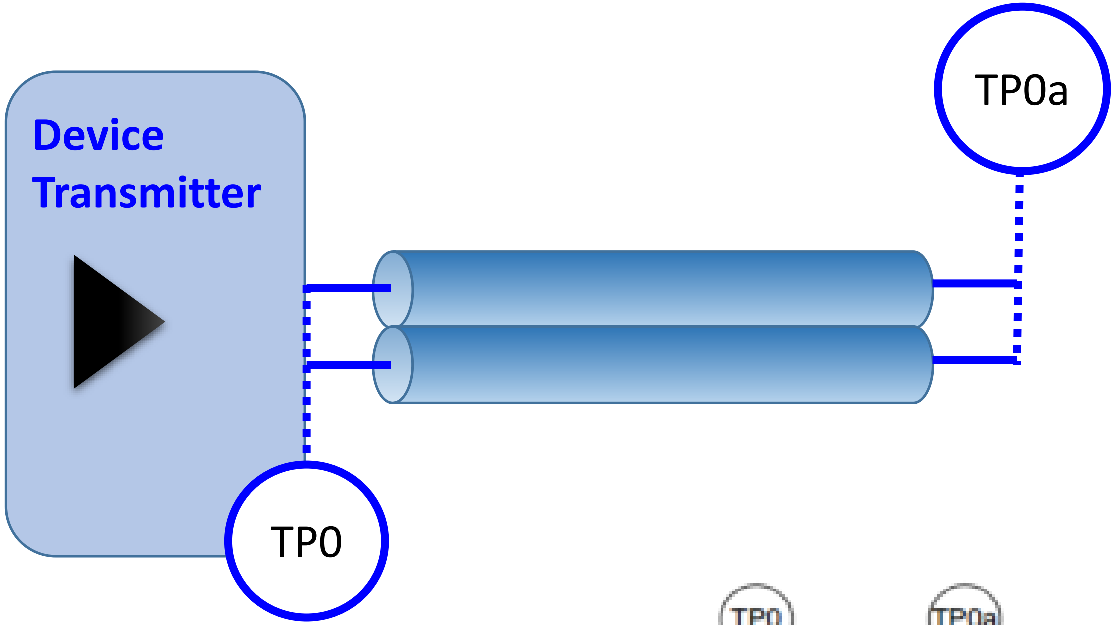


Figure 93–3—Test fixture reference insertion loss



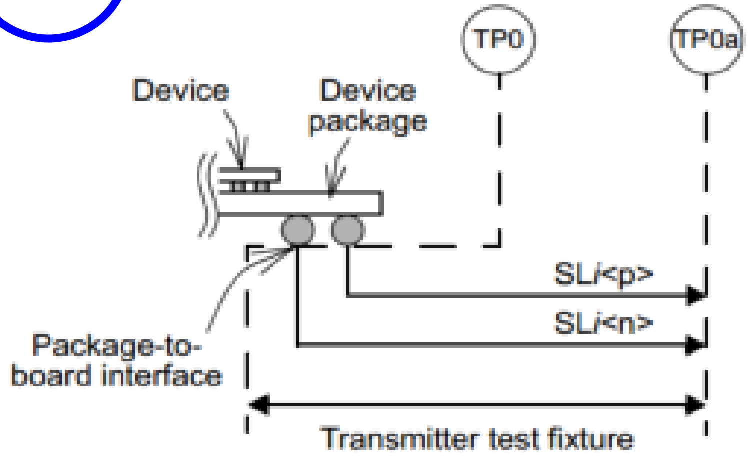
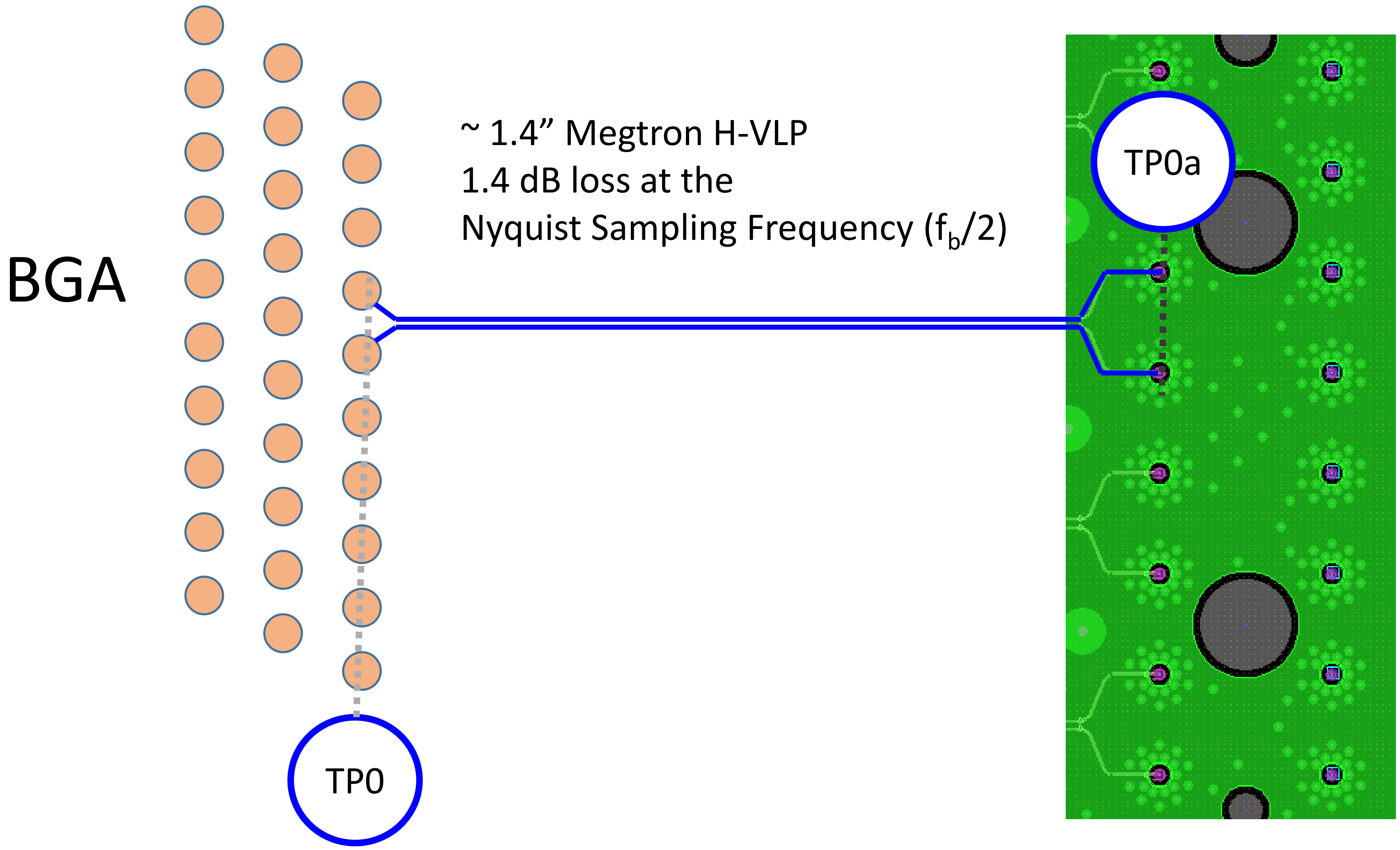
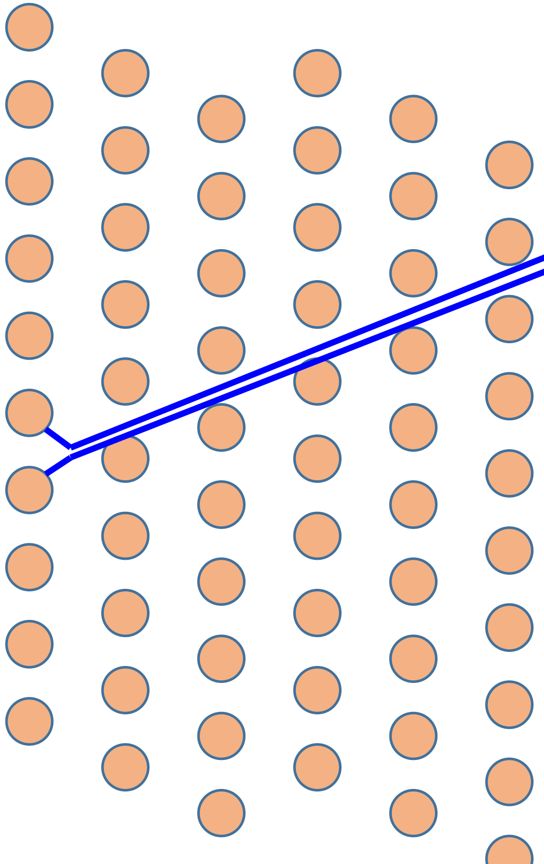


Figure 93–5—Transmitter test fixture and test points

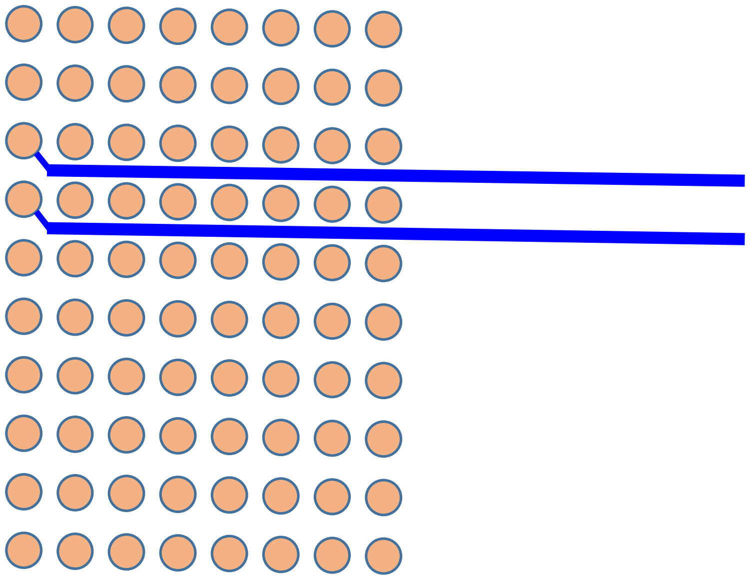
Ideally a Test Fixture Layout Might Look Like This



Variability does exist



- ❑ 70 mm x 70 mm packages have many pins out which require a variety of ways to break out
- ❑ 600 μm to 800 μm pin pitch may force trace only between pins



Thoughts for practical fixtures

- ❑ Limit loss at (f_b/2) to be between 1.2 and 1.6 dB
- ❑ Limit return loss
- ❑ Limit IL ripple to 0.1 dB
  - Called FOM_{ILD}

Variability is allowed … BUT

Clause 93

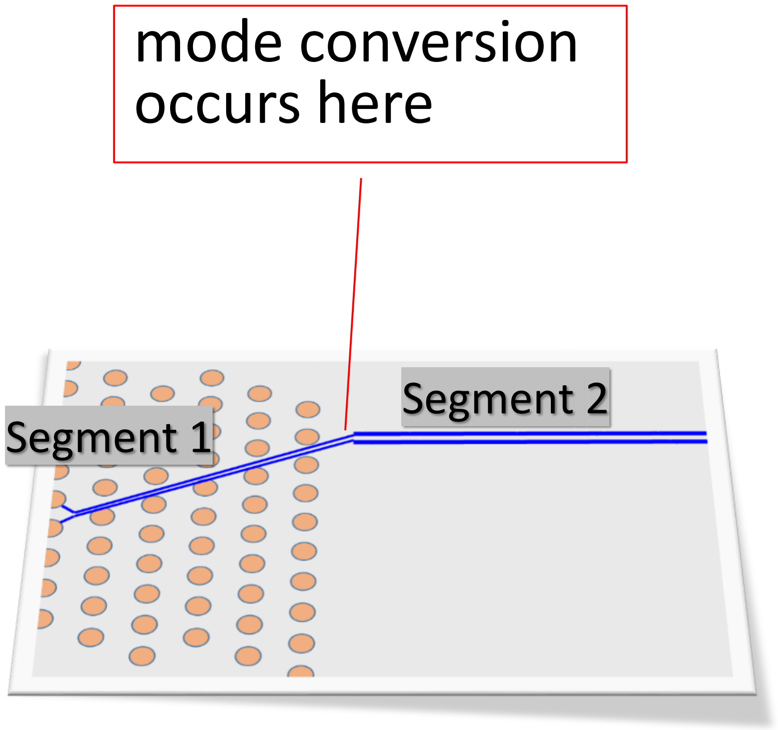
$$IL_{ref}(f) = -0.0015 + 0.144\sqrt{f} + 0.069f \text{ dB} \qquad 0.05 \le f \le 25 \qquad (93\text{–}1)$$

The effects of differences between the insertion loss of an actual test fixture and the reference insertion loss are to be accounted for in the measurements. The reference insertion loss is illustrated in Figure 93–3.

- ❑ The standard allows variability but specs are for the **exact** reference fixture.
- ❑ It's the implementer responsibility to adjust
  - "The bridge doesn't care that the truck height has variability"
- ❑ Question:
  - How much margin does a perfect fixture cost?

Hypothetical Fixture Models Used To Investigate Examples Of Variability

- 1. 4 dB at 100 ohm (differential) Megtron 7 H-VLP (idea for a reference fixture)
- 1.2 dB fixture consisting of 2 segments
  - 105 ohm section (~0.4“) and 95 ohm section (~0.8”)
  - 30 fF between sections representing mode conversion
- 1.6 dB fixture consisting of 2 segments
  - 105 ohm section (~0.4“) and 95 ohm section (~1.2”)
  - 30 fF between sections representing mode conversion

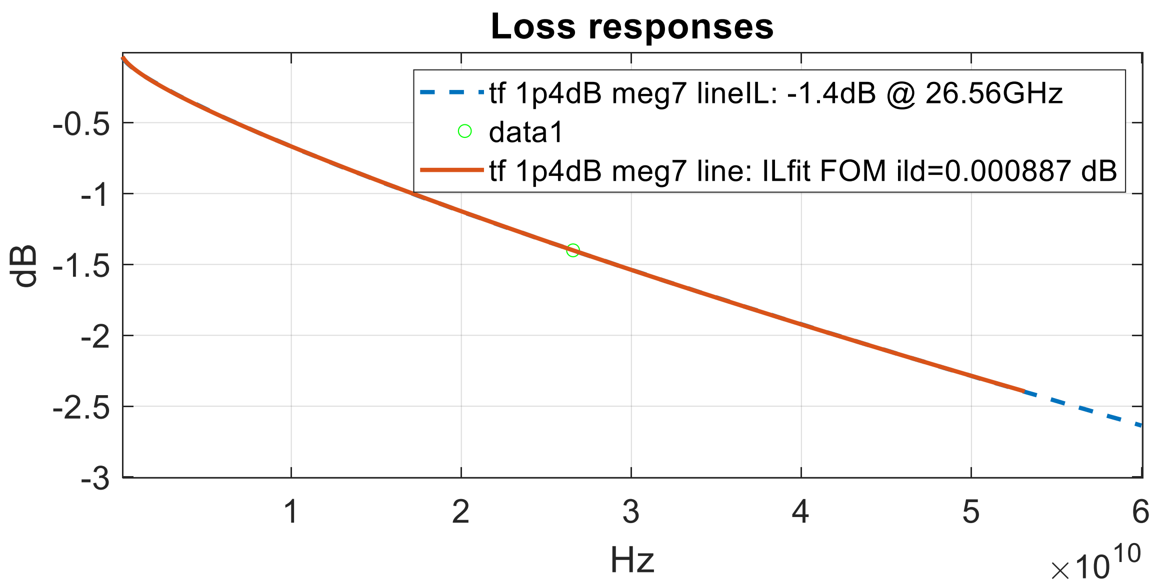


Idea: 1.4 dB (@ 26.56 GHz) Fixture Strawman

- For this experiment replace equation 93-1

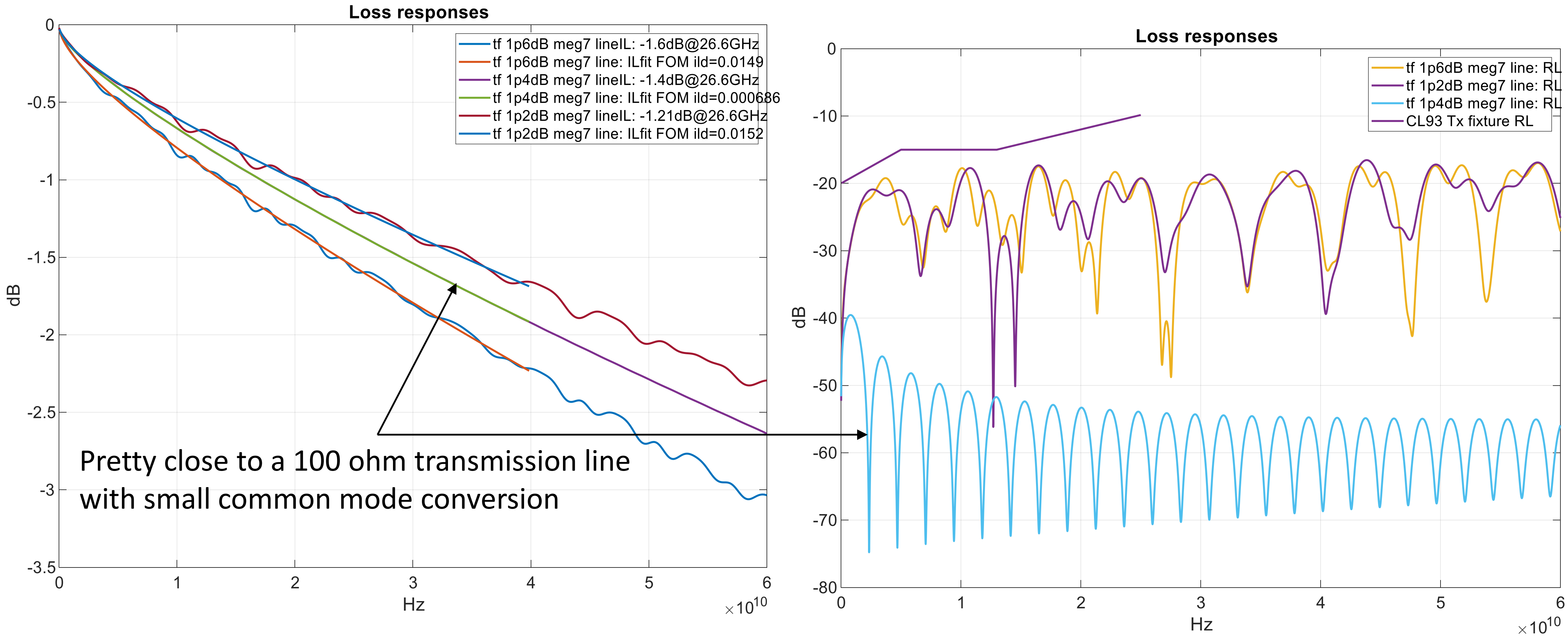
$$IL_{ref}(f) = -0.0015 + 0.144\sqrt{f} + 0.069f \text{ dB} \qquad 0.05 \le f \le 25 \qquad (93\text{–}1)$$

- With
  - $IL_{ref} = 0.0037 + 0.1052\sqrt{f} + 0.0337f$



- 1.4 dB at 100 ohm (differential) Megtron 7 H-VLP (strawman for reference fixture)
- Dotted blue line is the actual measurement
- Red line is the fit with above coefficients

Even the 2 test fixtures don't look too bad



- So how much variability do they cause?

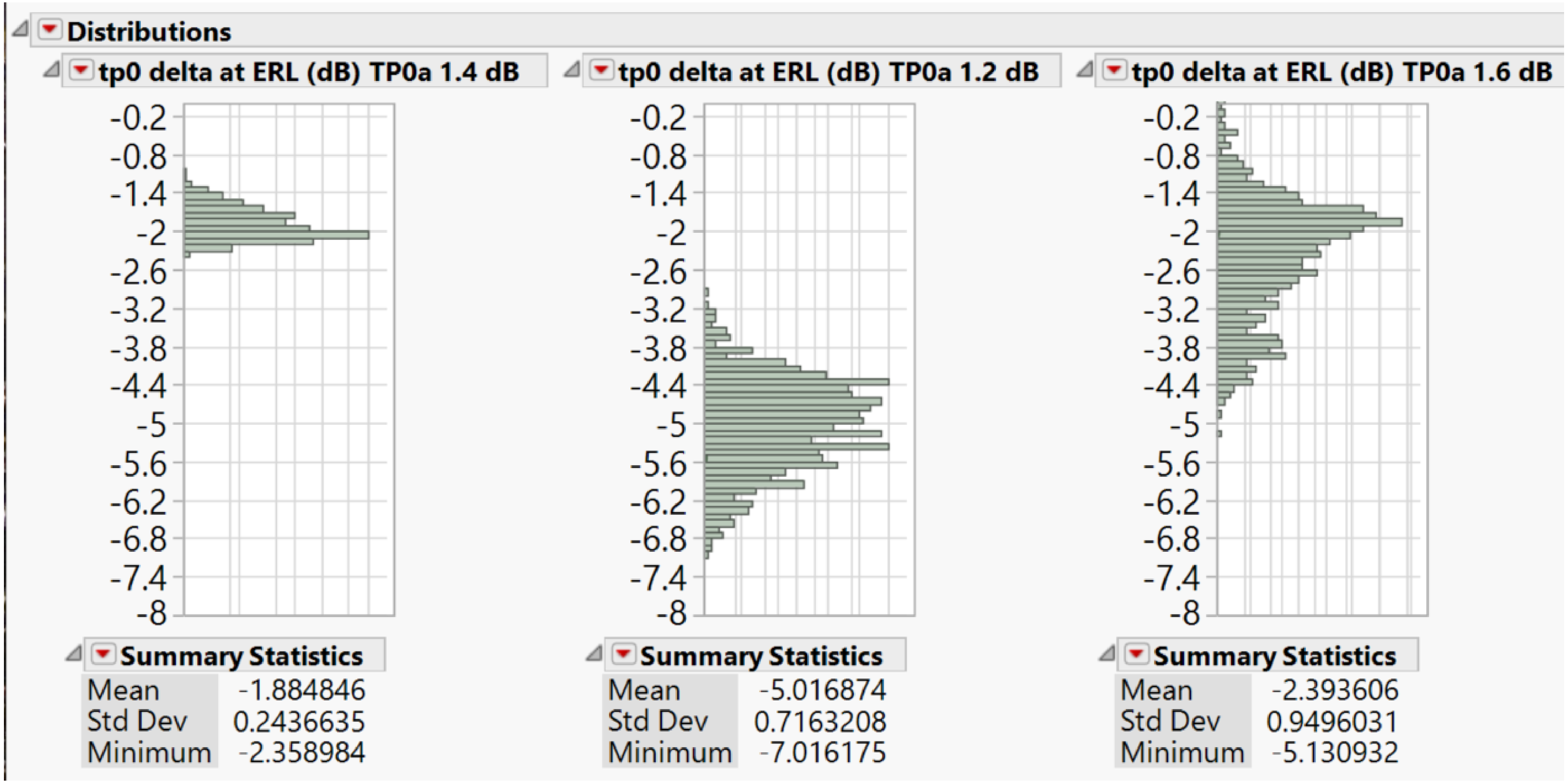
First Set of Data to Illustrate Variability Experiment

- For each of test fixture, measure (TP0a)
  - ERL
  - V_f
  - P_{max}/V_f
- Also measure ERL, Vf, Pmax/V_f at TP0
- Sweep Package length and perform a DOE for package impedances
  - That's only 3 variables in this limited experiment
    - z_p: 8 mm to 32 mm in 0.25 mm steps
    - z_c: 87.5 Ω +/- 10%
    - z_{c1}: 92.5 Ω +/- 10%
    - More variable added later to determine specification
- Goal is to determine spec impact for the above 3 parameters for each of the test fixtures

Recommended Parameters for Computing ERL, Vf, Pmax/V_f

- ERL parameters
  - N_{bx} = 21 (comment 22 modified)
    - Seems to be consensus here: 21 = $N_b + N_f{*}N_g$
  - β_X = 2.4 GHz (comment 21)
  - ρ_x = 0.32 (comment 21 modified)
    - Seems to be consensus to keep same as .3cd
  - N = 200
- V_f parameters (comment 25, see mellitz_3ck_01b_0919)
  - N_v = 200
    - In practice when computing from s-parameters and a computed step response this value may need to lower because of some data may not have sufficient low frequency data.
    - Produces a V_f more like a real steady state voltage
  - k = -3 to 1
  - D_p = 4

Point by point case differences between ERL at TP0 and TP0a for discussion in next slide



The Fixtures Introduce an Offset and Variability

- The reference fixture has the least amount of variably.
- Even the very good 100 ohm test fixture has variability
- Accounting for practical test fixture variability test dwarfs the limit we would want set
- Recommend:
  - Specify transmitter at a TP0 and receiver ERL at TP5
  - Remove test fixture references
  - Modified remedy for comment 19

P_{max}/V_f is impacted when tp0 is the test point

Draft Amendment to IEEE Std 802.3-2018
IEEE P802.3ck Task Force name Task Force

IEEE *Draft* P802.3ck/D1.0
12th December 2019

Table 163–5—Summary of transmitter specifications at TP0a *(continued)*

Parameter	Reference	Value	Units
AC common-mode RMS voltage (max.)[1]	93.8.1.3	30	mV
Effective return loss (ERL) (min.)	163.9.2.1	TBD	dB
Common-mode return loss (min.)	93.8.1.4	TBD	dB
Transmitter steady-state voltage, v_f (min.) Transmitter steady-state voltage, v_f (max.)	162.9.3.1.2	0.4 0.6	V
Linear fit pulse peak (min.) P_{max}	162.9.3.1.2	TBD × v_f	V
Level separation mismatch ratio R_{LM} (min.)	120D.3.1.2	0.95	—

Add a few more parameter to determine spec's

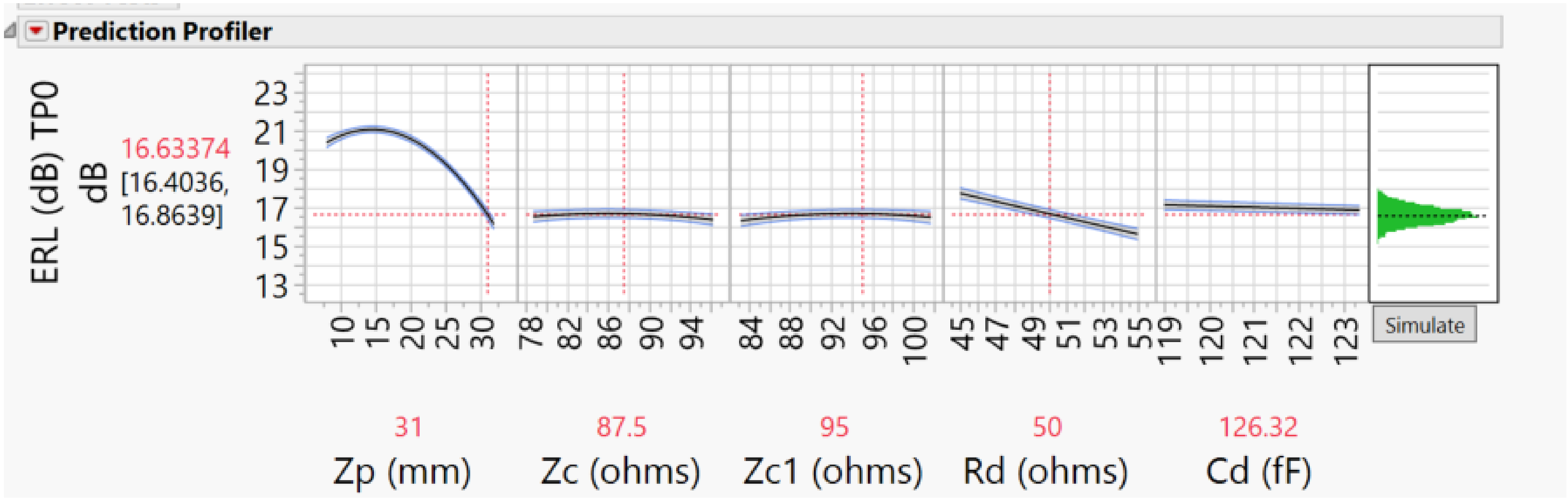
- Use 5 variables in to determine ERL and P_{max}/V_f variability,
  - z_p: 8 mm to 32
  - z_c: 87.5 Ω +/- 10%
  - z_{c1}: 92.5 Ω +/- 10%
  - R_d: 50 Ω +/- 10%
  - C_d: 126 ff +/- 10%
  - L_s: 126 pH -/+ 10%

ERL fit to parameter is pretty good and P_{max}/V_f fits are excellent.

- ❑ Lock the Z_p to 31 as in the COM reference
  - This is the max loss package
- ❑ Use manufacturing variably and fit uncertainty to determine ERL and P_{max}/V_f specifications

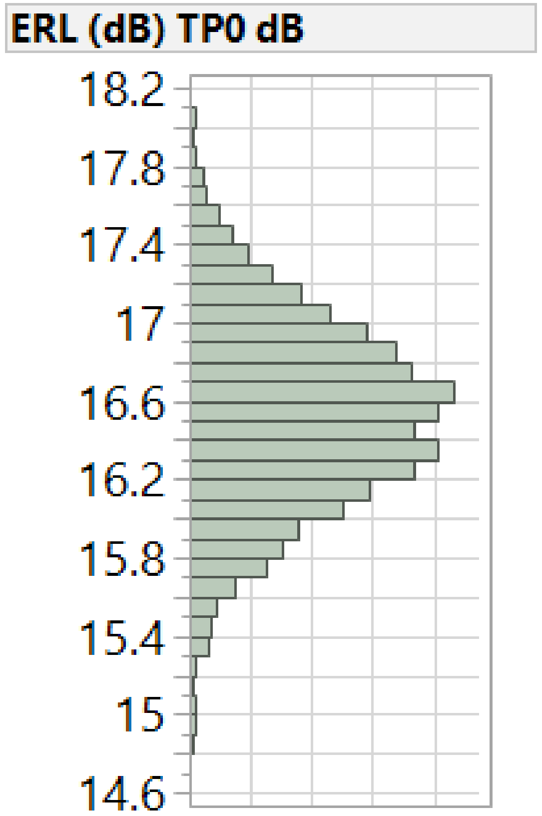
ERL Fit is pretty good

- the RMS fits error at Z_p=31mm is < 0.2 dB
- This RMS uncertainty is used to lower the spec.



ERL_{min} Recommendation

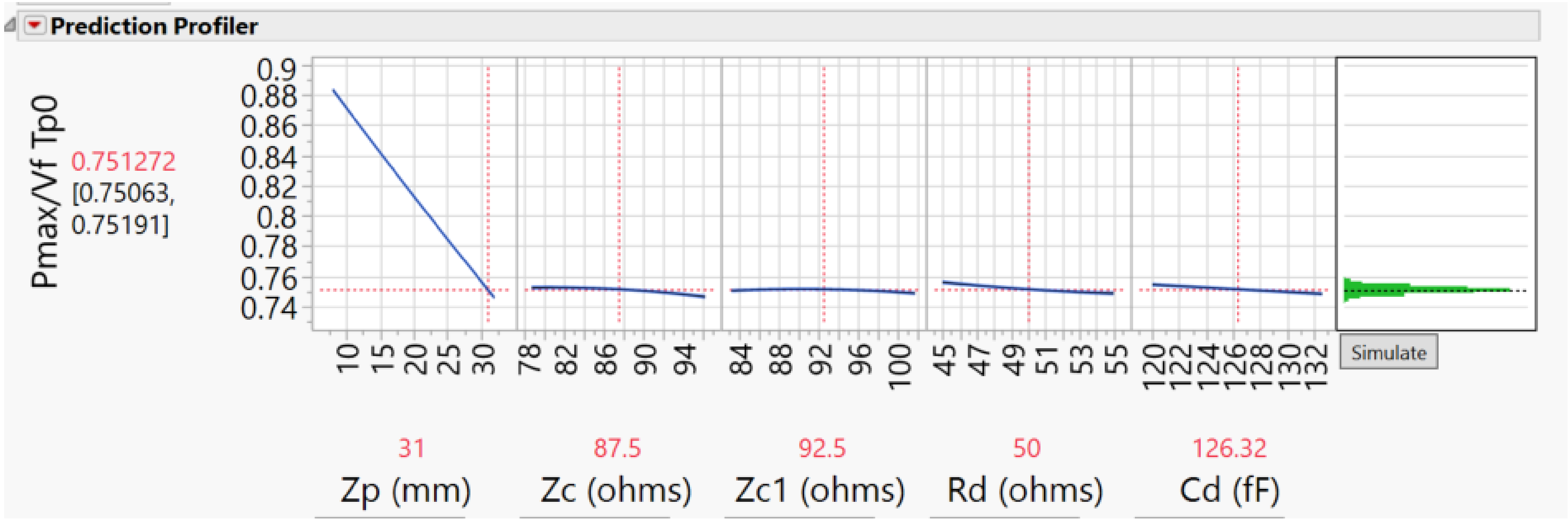
- For 50000 cases manufacturing cases the minimum ERL is 14.65 dB
- Subtract 0.2 dB for fit uncertainty
- Recommend ERL_{min} = 14.45 dB
  - Measured at tp0 (and TP5)



Summary Statistics	
Mean	16.531803
Std Dev	0.4858061
Minimum	14.655186

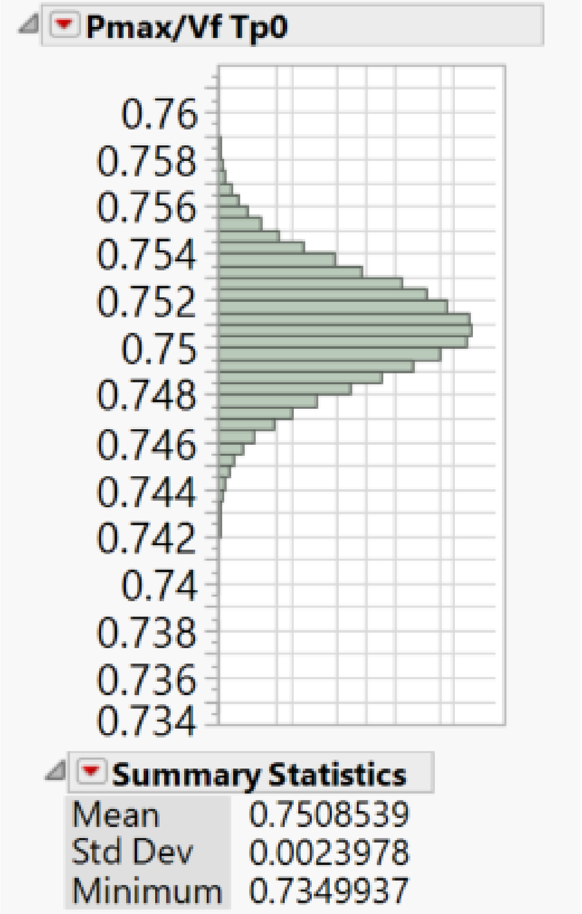
P_{max}/V_f Fit is excellent

- To put another way it is a good measure of package and termination insertion loss.
- The RMS fits error at Z_p=31mm is < 0.002 dB
- This RMS uncertainty used to lower the spec



P_{max}/V_f Recommendation

- For 50000 cases manufacturing cases the minimum V_{peak}/V_f is 0.734
- Subtract 0.002 dB for fit uncertainty
- Recommend P_{max}/V_f min = 0.73
  - Measured at TP0 (and TP5)



Summary/Recommendation

- ❑ Specify ERL, Vf, and Pmax at tp0
- ❑ Specify P_{max}/V_f min = 0.73
- ❑ Specify ERL_{min} = 14.45 dB for Tx and Rx
- ❑ Remove reference to tp0a and Tp5a test fixtures for transmitter testing and receiver ERL.

Backup

COM template configuration used to compute ERL, V_f, P_{max}/V_f

Z_p and Z_c are set by experiment control

Channel s parameters are an ideal thru (No RL and no IL)

A_v becomes the Vf spec at TP0.

Table 93A-1 parameters			
Parameter	Setting	Units	Information
f_b	53.125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.2e-4 0]	nF	[TX RX]
L_s	[0.12, 0]	nH	[TX RX]
C_b	[0.3e-4 0]	nF	[TX RX]
z_p select	1		[test cases to run]
z_p (TX)	[11; 1.8]	mm	[test cases]
z_p (NEXT)	[0; 0]	mm	[test cases]
z_p (FEXT)	[0; 0]	mm	[test cases]
z_p (RX)	[0; 0]	mm	[test cases]
C_p	[0.87e-4 0]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
A_v	0.415	V	vp/vf=.694
A_fe	0.415	V	vp/vf=.694
A_ne	0.608	V	
L	4		
M	32		
filter and Eq			
f_r	0.75	*fb	
c(0)	0.54		min
c(-1)	0		[min:step:max]
c(-2)	0		[min:step:max]
c(-3)	0		[min:step:max]
c(1)	0		[min:step:max]
N_b	0	UI	
b_max(1)	0.85		
b_max(2..N_b)	0.2		
g_DC	0	dB	[min:step:max]
f_z	200	GHz	
f_p1	200	GHz	
f_p2	400	GHz	
g_DC_HP	0		[min:step:max]
f_HP_PZ	0.0001	GHz	

I/O control		
DIAGNOSTICS	0	logical
DISPLAY_WINDOW	0	logical
CSV_REPORT	0	logical
RESULT_DIR	.\results\100GEL_CR_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	CR_eval_	
COM_CONTRIBUTION	0	logical
Operational		
COM Pass threshold	3	dB
ERL Pass threshold	10	dB
DER_0	1.00E-04	
T_r	6.16E-03	ns
FORCE_TR	1	logical
TDR and ERL options		
TDR	1	logical
ERL	1	logical
ERL_ONLY	1	logical
TR_TDR	0.01	ns
N	200	
beta_x	2.4000E+09	
rho_x	0.32	
fixture delay time	[0 0]	[port1 port2]
TDR_W_TXPKG	1	
N_bx	21	UI
N_v	200	UI
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
Noise, jitter		
sigma_RJ	0.01	UI
A_DD	0.02	UI
eta_0	8.2E-09	V^2/GHz
SNR_TX	33	dB
R_LM	0.95	

Table 93A–3 parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 0.0009909 0.0002772]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	[87.5 87.5 ; 92.5 92.5]	Ohm
benartsi_3ck_01_0119 & mellitz_3ck_01_0119		
Table 92–12 parameters		
Parameter	Setting	
board_tl_gamma0_a1_a2	*[0 3.8206e-04 9.5909e-05]*	
board_tl_tau	*5.790E-03*	ns/mm
board_Z_c	100	Ohm
z_bp (TX)	*110.3*	mm
z_bp (NEXT)	*110.3*	mm
z_bp (FEXT)	*110.3*	mm
z_bp (RX)	*110.3*	mm
C_0	[0.29e-4]	nF
C_1	[0.19e-4]	nF
Include PCB	**0**	**logical**
Floating Tap Control		
N_bg	0	0 1 2 or 3 groups
N_bf	3	taps per group
N_f	40	UI span for floating taps
bmaxg	0.2	max DFE value for floating taps
cable assemblies require this for each HCB		
ICN parameters (v2.73)		
f_f	12.919	
f_n	12.919	
f_2	39.844	
A_ft	0.600	
A_nt	**0.600**	
heck_3ck_03b_0319	**Adopted Mar 2019**	COM V2.77 but can do same on COM 2.76 by setting N_b to 200
walker_3ck_01a_0719	**Adopted July 2019**	
result of R_d=50		
benartsi_3ck_01a_0719	**no used for KR**	
mellitz_3ck_03_0919		