ERL and System Performance for 50GBASE-CR (draft)

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Presented at 802.3cd ad hoc 5/16/18.

Introduction

- This presentation is related to comment r02-15, and also investigates the effect on system performance as measured by COM of changes in ERL parameters and specifications. It builds on work presented in dudek_3cd_01_0318.
- No cable S parameters are available on the web site for cables with ERL close to the specification limit so Cavium CA2 was created to see what the effect would be on system performance with hosts with different ERL. The creation method and more details of this cable and the others used in the analysis are given in the back-up.
- Various changes to the ERL parameters have been proposed by Mellitz in comment r02-21 which will effect the values of ERL. This presentation looks at the effect of these changes on ERL.

Comment r02-21

Cl **136** *SC* **136.9.4** *P* **226** *L* **13** # r02-21

Mellitz, Richard — Samtec, Inc.

Comment Type **TR** *Comment Status* **X**

In http://www.ieee802.org/3/cd/public/adhoc/archive/mellitz_3cd_032118_adhoc-v2.pdf changes to Grr were suggest and new more meaningful values of beta_x and rho_x are required. This is a cross-clause comment with clause 137. See proposed changes.

Values for these were presented in http://www.ieee802.org/3/cd/public/adhoc/archive/mellitz_040418_3cd_adhoc-v2.pdf and subsequent meetings.

Presentation to review will be provided at the interim.

SuggestedRemedy

In table 136-13 page 226 change beta x to 1.7 and rho_x to 0.3
In table 136-15 page 232 change beta x tp 1.7 and rho_x to 0.25
In table 137-5 page 249 change beta x to1.7 and rho_x to 0.32
In table 137-7 page 253 change beta x to1.7 and rho_x to 0.18

Proposed Response *Response Status* **O**

Cable assembly:
Effect of parameter changes on ERL

Comment

In table 136-15 page 232 change beta x tp 1.7 and rho_x to 0.25

136.11.4 Cable assembly ERL

ERL of the cable assembly at TP1 and at TP4 are computed using the procedure in 93A.5 with the values in Table 136–17. Parameters that do not appear in Table 136–17 take values from Table 136–18. The value of T_{fx} is twice the delay associated with the cable assembly test fixture being used. N_{bx} is set to the value of N_b in Table 136–18.

Table 136–17—Cable assembly ERL parameter values

Parameter	Symbol	Value	Units
Transition time associated with a pulse	T_r	0.0189	ns
Incremental available signal loss factor	β_x	10.7	GHz
Permitted reflection from a transmission line external to the device under test	ρ_x	0.44	—
Length of the reflection signal	N	1000	—

Cable assembly ERL at TP1 and at TP4 shall be greater than or equal to 11 dB.

Editor's note: The value of ERL is to be confirmed.

Cable ERL results and conclusions

			D3.2		D3.2 comments	
	COM TX 12mm (dB)	COM TX 30mm (dB)	ERL11 (dB)	ERL22 (dB)	ERL11 (dB)	ERL22 (dB)
TE	4.58	4.19	19.18	17.31	20.52	19.47
FCI	4.21	3.70	15.19	19.19	15.95	20.66
CAVIUM CA2	3.89	3.56	9.72	14.23	10.70	16.13

The Changes have increased the ERL values by between 0.76dB and 2.2dB. As there is technical justification for the parameter changes we recommend they are adopted and the ERL pass/fail criterion is set based on these changed parameters.

Host Tx and system performance

Comment

In table 136-13 page 226 change beta x to 1.7 and rho_x to 0.3

136.9.3.4 Transmitter effective return loss (ERL)

ERL of the transmitter at TP2 is computed using the procedure in 93A.5 with the values in Table 136–13. Parameters that do not appear in Table 136–13 take values from Table 136–18. The value of T_{fx} is twice the delay associated with the TP2 test fixture being used. N_{bx} is set to the value of N_b in Table 136–18.

Table 136–13—Transmitter and receiver ERL parameter values

Parameter	Symbol	Value	Units
Transition time associated with a pulse	T_r	0.0189	ns
Incremental available signal loss factor	β_x	10.7	GHz
Permitted reflection from a transmission line external to the device under test	ρ_x	0.44	—
Length of the reflection signal	N	300	—

Transmitter ERL at TP2 shall meet Equation (136–6).

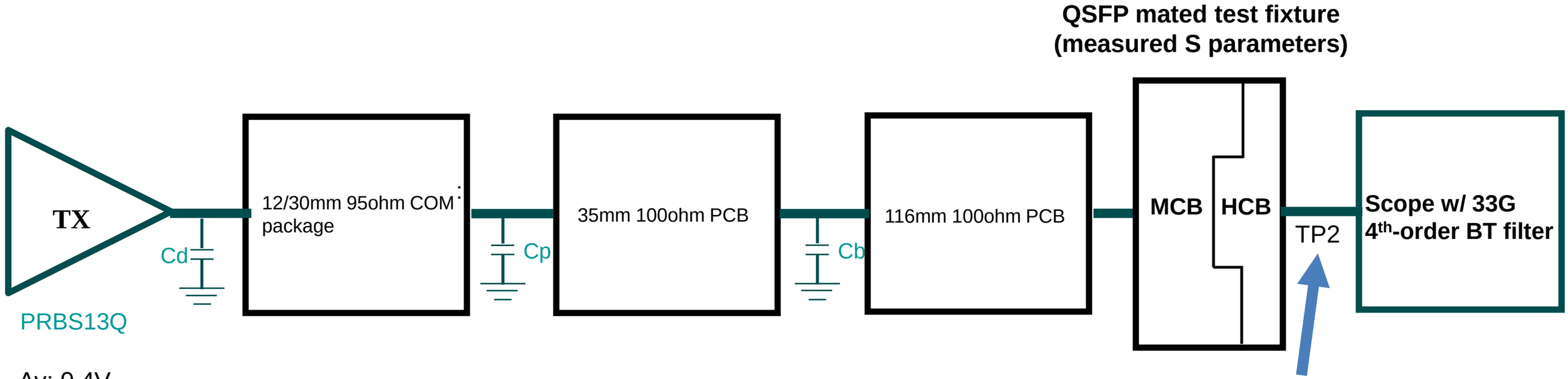
$$ERL \geq 8 + 40\log_{10}\left(\frac{v_f}{\max\limits_k (p(k))}\right) \quad \text{(dB)} \qquad (136\text{–}6)$$

Where

v_f is the steady-state voltage, defined in 136.9.3.1.2

$p(k)$ is the linear fit pulse at preset 1 (no equalization) (see 136.9.3.1.2)

Transmitter parameters at TP2



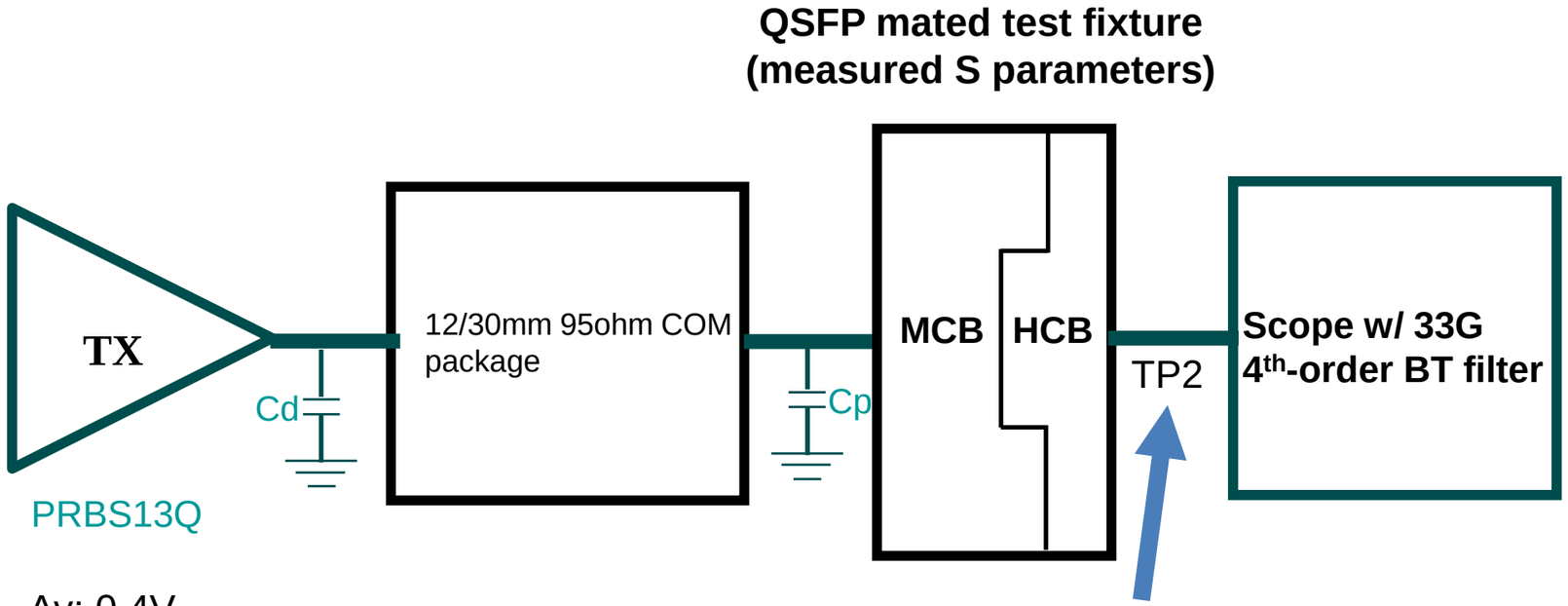
Av: 0.4V
Rd: 50ohm
Risetime: 12pS
Cd: 0.18pF
Cp: 0.11pF

Sweep Cb 0 to 1pF w/0.1pF step

Extract transmitter parameters at TP2:

- SNDR
- SNRisi
- Pmax/Vf
- ERL

Transmitter parameters at TP2 w/o host trace

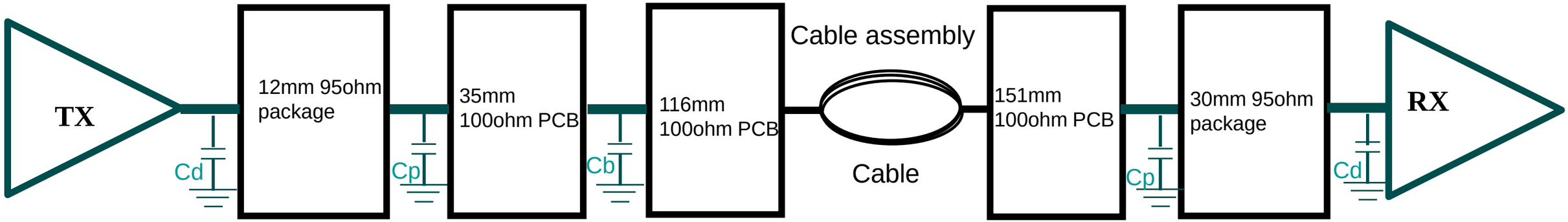


Av: 0.4V
Rd: 50ohm
Risetime: 12pS
Cd: 0.18pF
Cp: 0.11pF

Extract transmitter parameters at TP2:

- SNDR
- SNRisi
- Pmax/Vf
- ERL

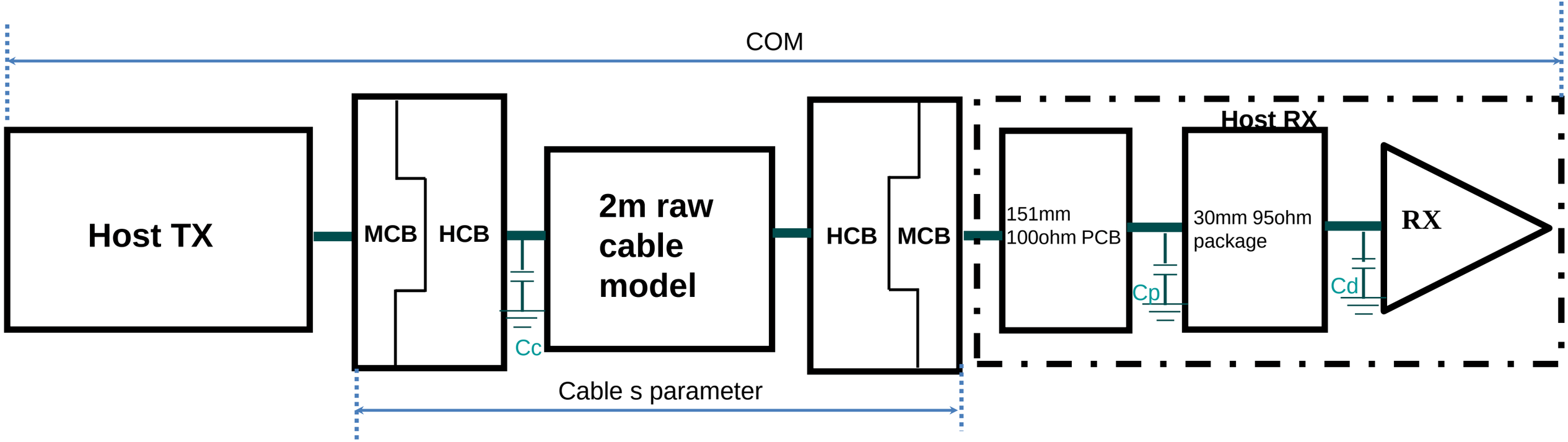
COM



Av: 0.415V
Afe：0.415V
Ane：0.604V
Rd: 50ohm
Cd: 0.18pF
Cp: 0.11pF

Thru channel includes Cb on TX host trace. XTALK channels don’t include Cb.
Run COM by sweeping Cb 0 to 1.0pF w/0.1pF step
Other parameters refer to table 136-15

COM for Cavium CA2



Av: 0.415V
Afe：0.415V
Ane：0.604V
Rd: 50ohm
Cd: 0.18pF
Cp: 0.11pF
Cc: 0.27pF

D3.2: rho=0.44 beta_x=10.7 N=300 Grr_limit=1

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Hosts	Cb(pF)	Pmax/Vf	SNRisi(dB)	ERL22(dB)	ERL+ 40LOG10(pmax/vf) (dB)	COM TE (dB)	COM FCI (dB)	COM CAVIUM CA2 (dB)
12mm TX pkg+ 151mm host + Mated QSFP test fixture	0.00	0.51	34.27	21.87	10.24	4.58	4.21	3.89
	0.10	0.51	32.76	20.96	9.20	4.11	4.00	3.49
	0.20	0.50	30.13	19.18	7.07	3.39	3.45	2.88
	0.30	0.48	28.09	17.63	5.02	2.63	2.75	2.09
	0.40	0.47	26.39	16.41	3.26	1.88	1.95	1.33
	0.50	0.45	25.32	15.39	1.67	1.17	1.19	0.56
30mm TX pkg + 151mm host + Mated QSFP test fixture	0.00	0.48	32.18	22.19	9.44	4.19	3.70	3.56
12mm TX pkg + Mated QSFP test fixture	0.00	0.72	27.78	16.22	10.56	5.16	6.14	3.72
30mm TX pkg + Mated QSFP test fixture	0.00	0.67	28.99	17.00	10.09	5.10	5.80	3.92

This is the Standard 30mm COM configuration

D3.2 comment: rho=0.3 beta_x=1.7 N=300 Grr_limit=1

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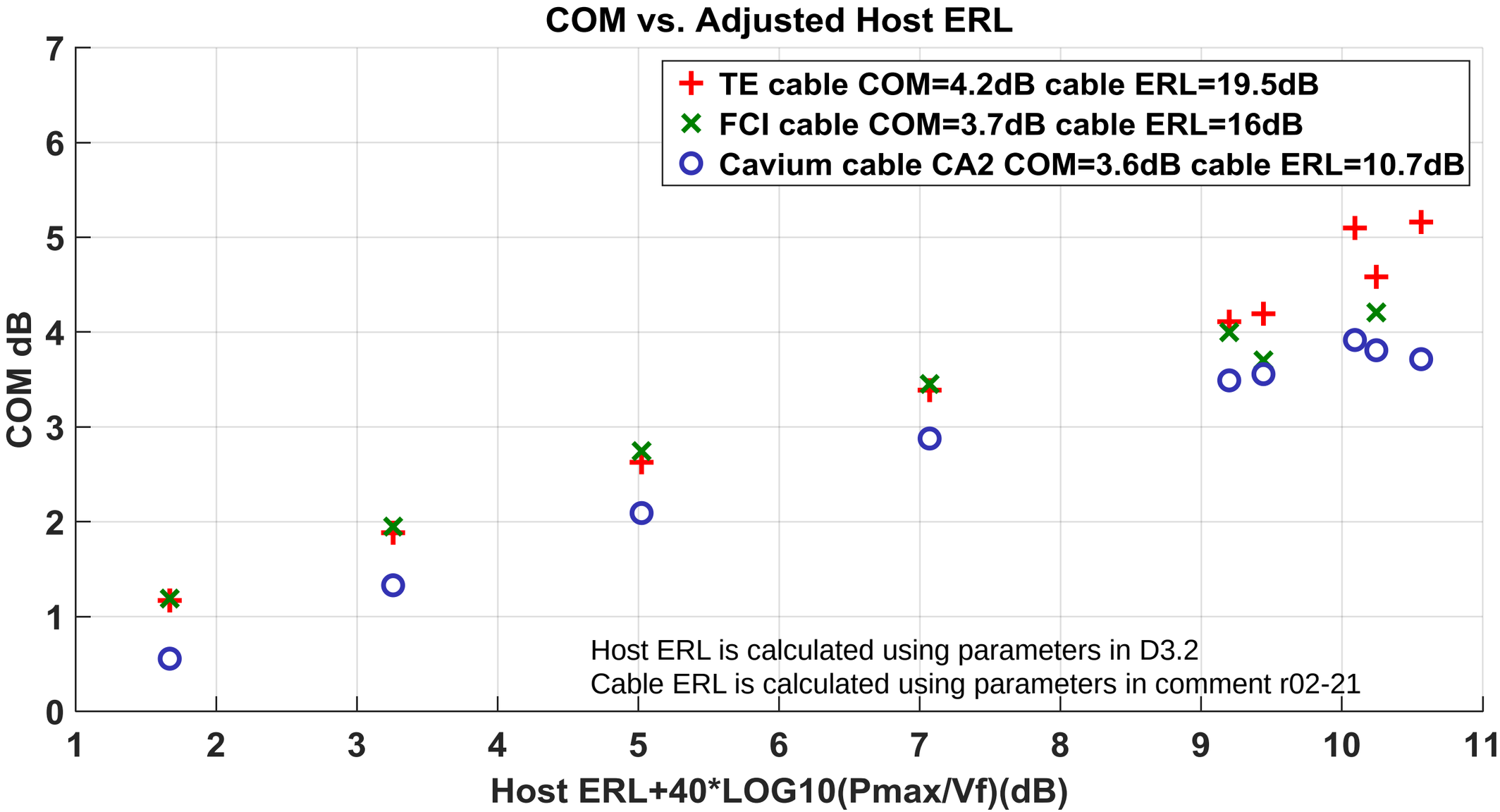
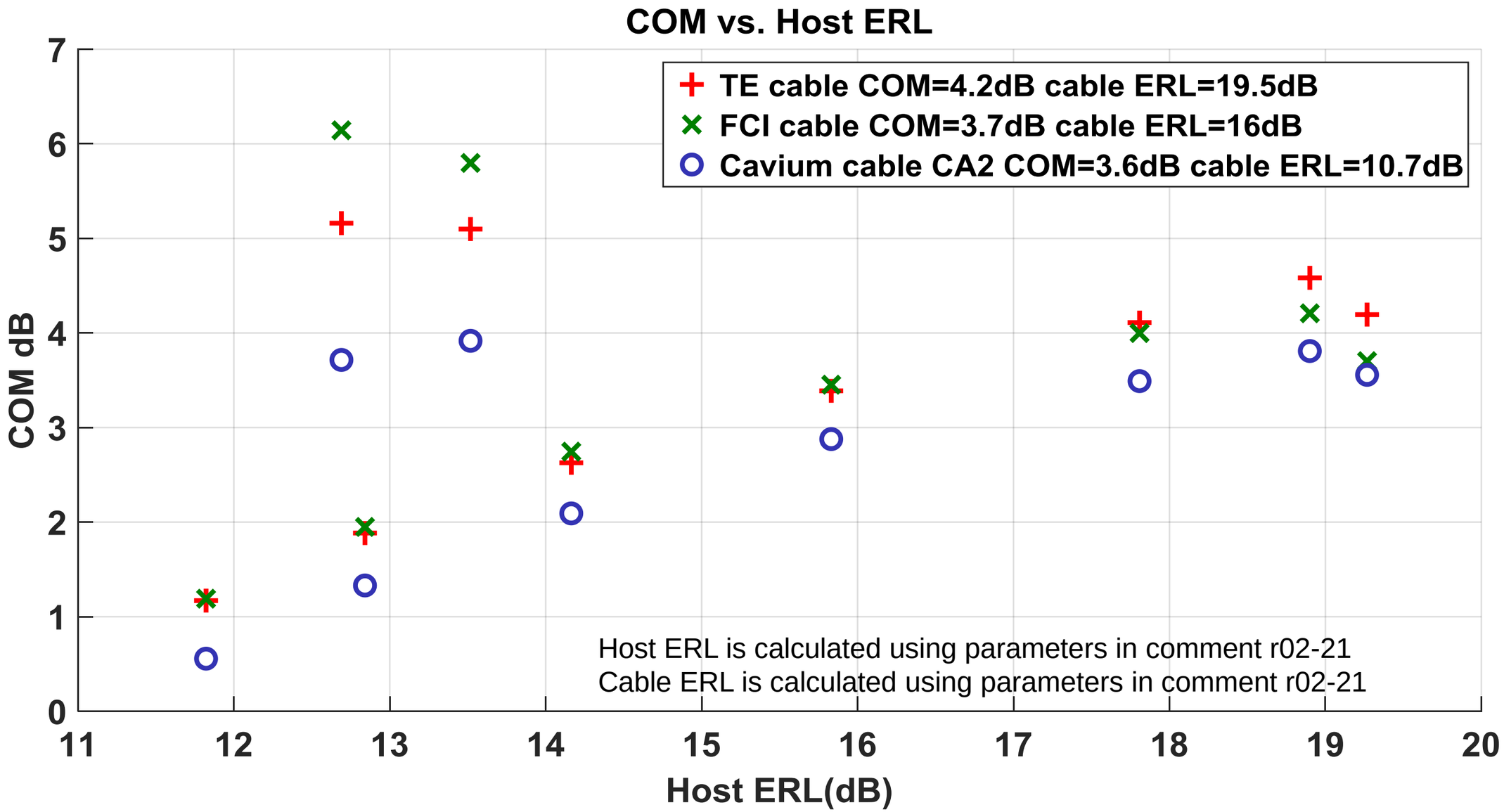
Hosts	Cb(pF)	Pmax/Vf	SNRisi(dB)	ERL22(dB)	ERL+ 40LOG10(pmax /vf) (dB)	COM TE (dB)	COM FCI (dB)	COM CAVIUM CA2 (dB)
12mm TX pkg+ 151mm host + Mated QSFP test fixture	0.00	0.51	34.27	18.90	7.27	4.58	4.21	3.89
	0.10	0.51	32.76	17.81	6.04	4.11	4.00	3.49
	0.20	0.50	30.13	15.83	3.72	3.39	3.45	2.88
	0.30	0.48	28.09	14.16	1.56	2.63	2.75	2.09
	0.40	0.47	26.39	12.84	-0.31	1.88	1.95	1.33
	0.50	0.45	25.32	11.82	-1.90	1.17	1.19	0.56
30mm TX pkg + 151mm host + Mated QSFP test fixture	0.00	0.48	32.18	19.27	6.52	4.19	3.70	3.56
12mm TX pkg + Mated QSFP test fixture	0.00	0.72	27.78	12.69	7.03	5.16	6.14	3.72
30mm TX pkg + Mated QSFP test fixture	0.00	0.67	28.99	13.52	6.61	5.10	5.80	3.92

This is the Standard 30mm COM configuration

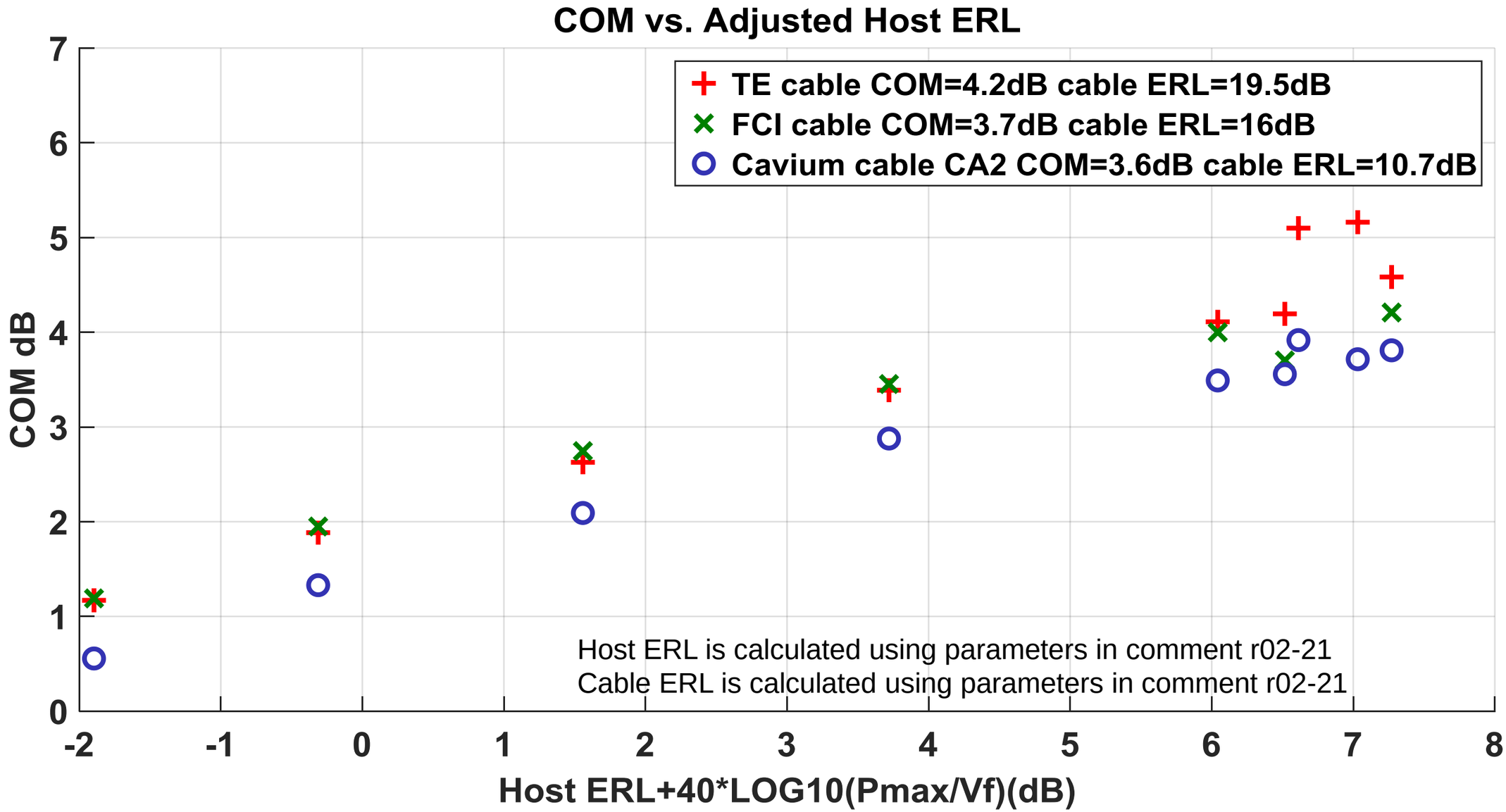
COM vs. Adjusted Host ERL (d3.2: rho=0.44 beta_x=10.7 N=300 Grr_limit=1)



COM vs. Host ERL (comment: rho=0.3 beta_x=1.7 N=300 Grr_limit=1)



COM vs. adjusted Host ERL (comment: rho=0.3 beta_x=1.7 N=300 Grr_limit=1)



Conclusions on host Tx.

- The proposed changes to the ERL parameters result in different ERL values (approximately 3dB lower). There are technical justifications for the changes and we recommend they are accepted but the ERL pass/fail limit needs to be adjusted.
- The short hosts provide good system performance on these cables and are a likely implementation. They should pass the Tx specification.
- The long host with the Cb capacitance at 0.3pF provides bad system performance on all these cables (and particularly CaviumCA2). It should fail the Tx specification.
- It has been proposed that the specification should be a single value of ERL, a single value of SNRisi or a combination of a single value of ERL plus a single value of SNRisi however no single values for these parameters exists that will not have false passes or false fails with these hosts.

Proposal.

- **The new ERL parameters should be adopted.**
- **A specification of ERL >= 4dB – 40 *Log_{10}(Pmax/Vf) should then be adopted.**
- **Note that it has been suggested that it is inconvenient having this combined specification as ERL is generally measured with a VNA and post processing and Pmax/Vf is measured with an oscilloscope and post processing. With this specification however test engineering could choose to use fixed pass/fail values for the testing of their product depending on the product type with a choice of paired values. E.g.**
  - Pmax/Vf >=0.49 ERL>=16.4
  - Pmax/Vf >=0.55 ERL>= 14.4
  - Pmax/Vf >=0.63 ERL>=12.0

Host Rx

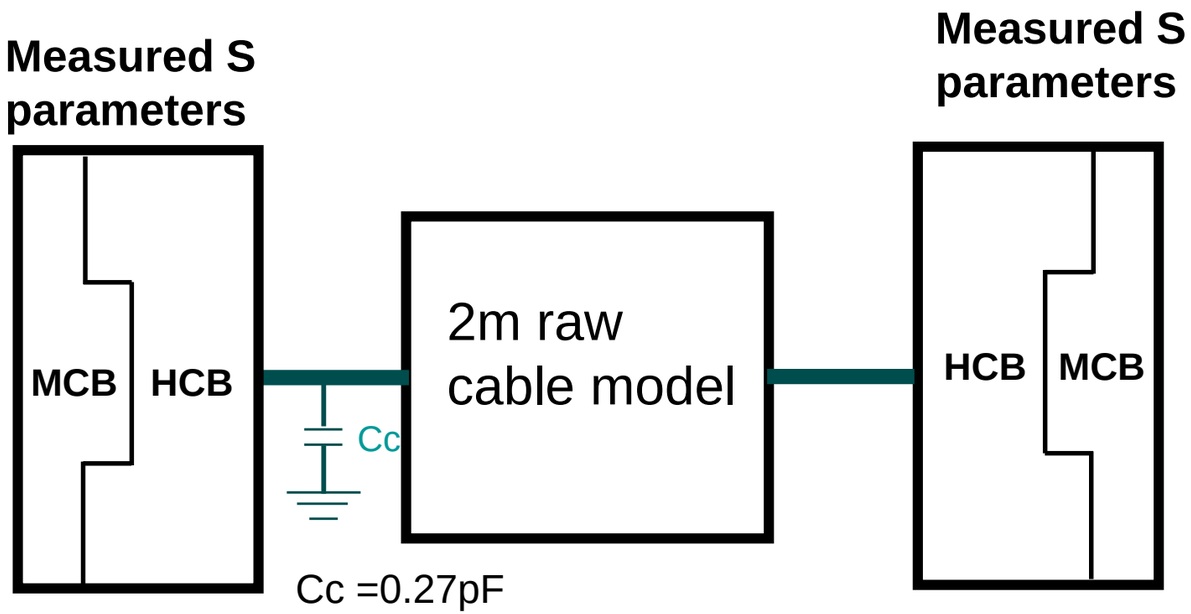
Comments.

- Degradations caused by reflections within the host Rx are present during the interference tolerance test therefore they have to be compensated by the receiver having better other performance. (e.g. can work with lower COM).
- The improved Rx performance required for reflections within the host Rx is somewhat similar to requiring higher Pmax/Vf when the ERL is poorer.
- ERL is required to limit reflections from the host Rx that are re-reflected by the cable.
- A fixed ERL of 12dB (with the revised ERL parameters) is proposed for the Rx.

Back-up

Cable creation.

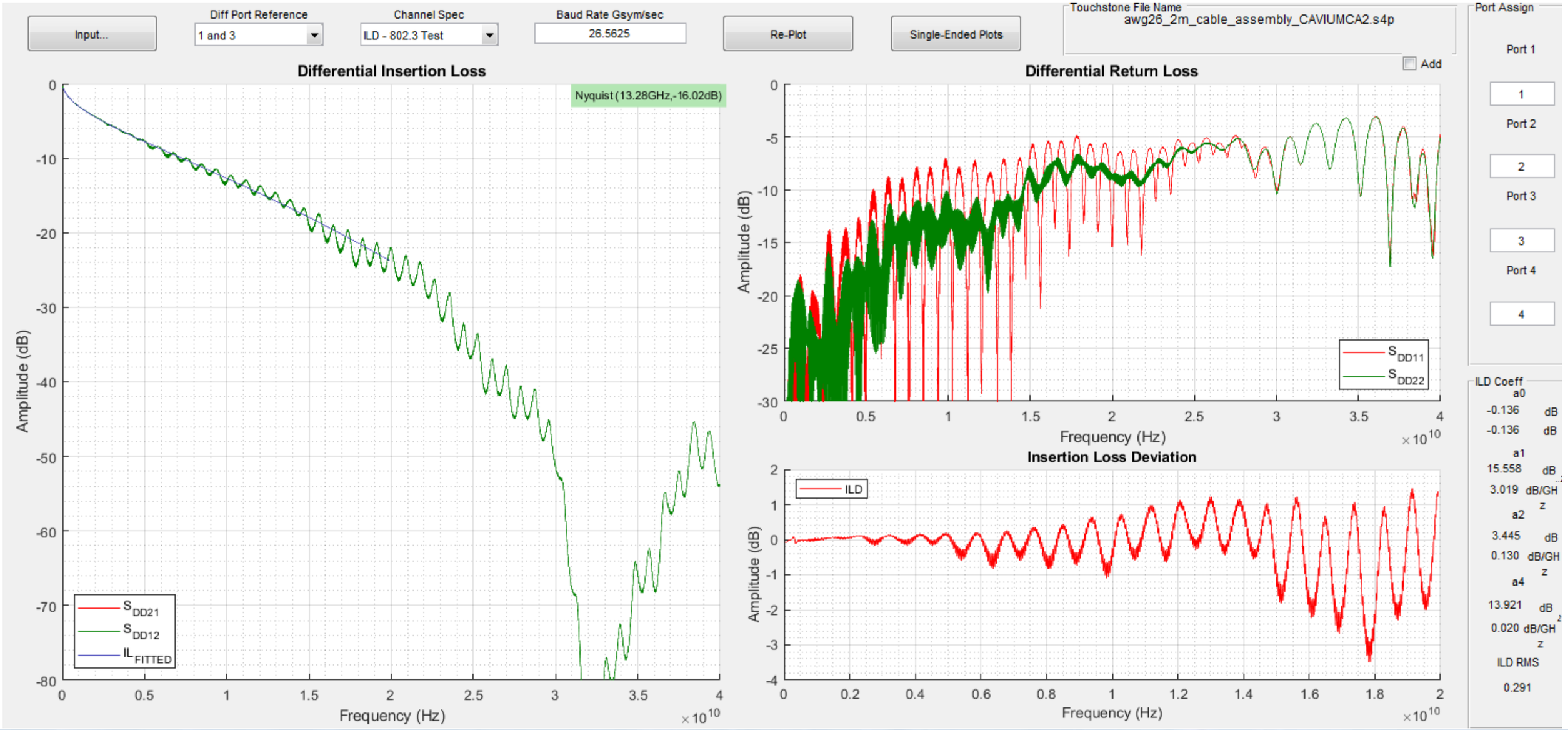
Block diagram of cable assembly CaviumCA2



The raw cable model uses the transmission line model in Clause 93A with parameters provided by Rich Mellitz for a 26AWG cable.

Cable Frequency Domain Performance

CaviumCA2 cable



CaviumCA2 cable (ERL 10.7dB using new parameters) comparison to draft 3.2 informative return loss 92.10.3.

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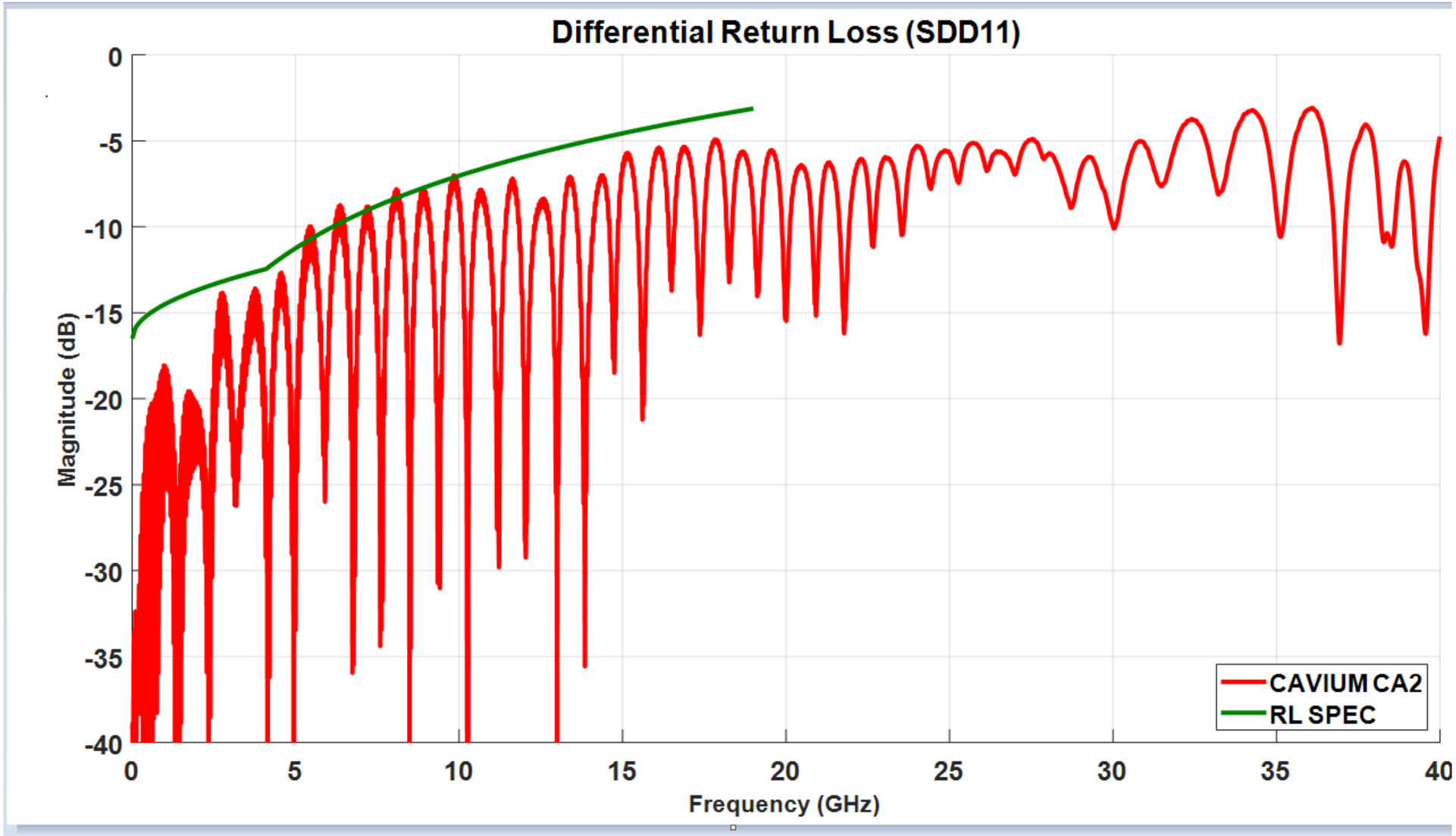
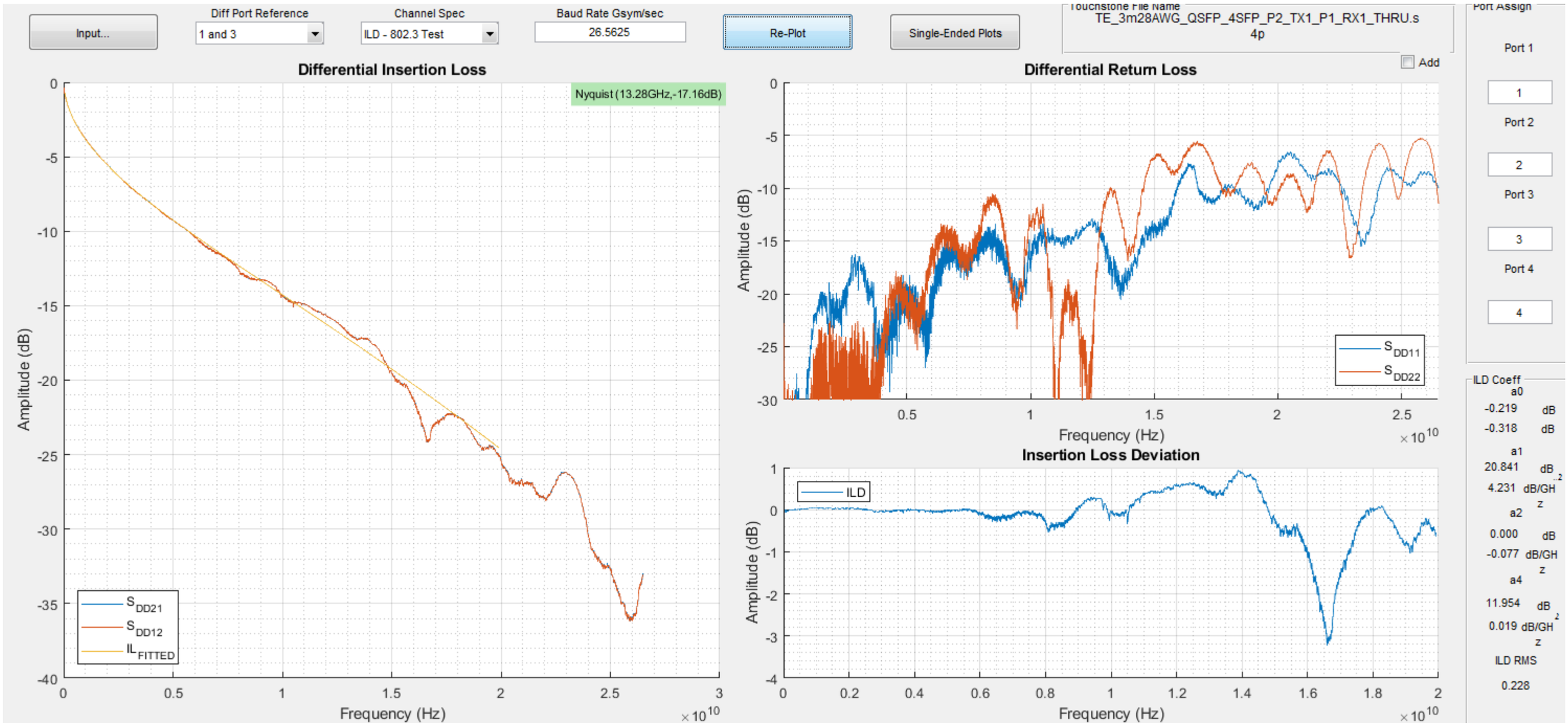
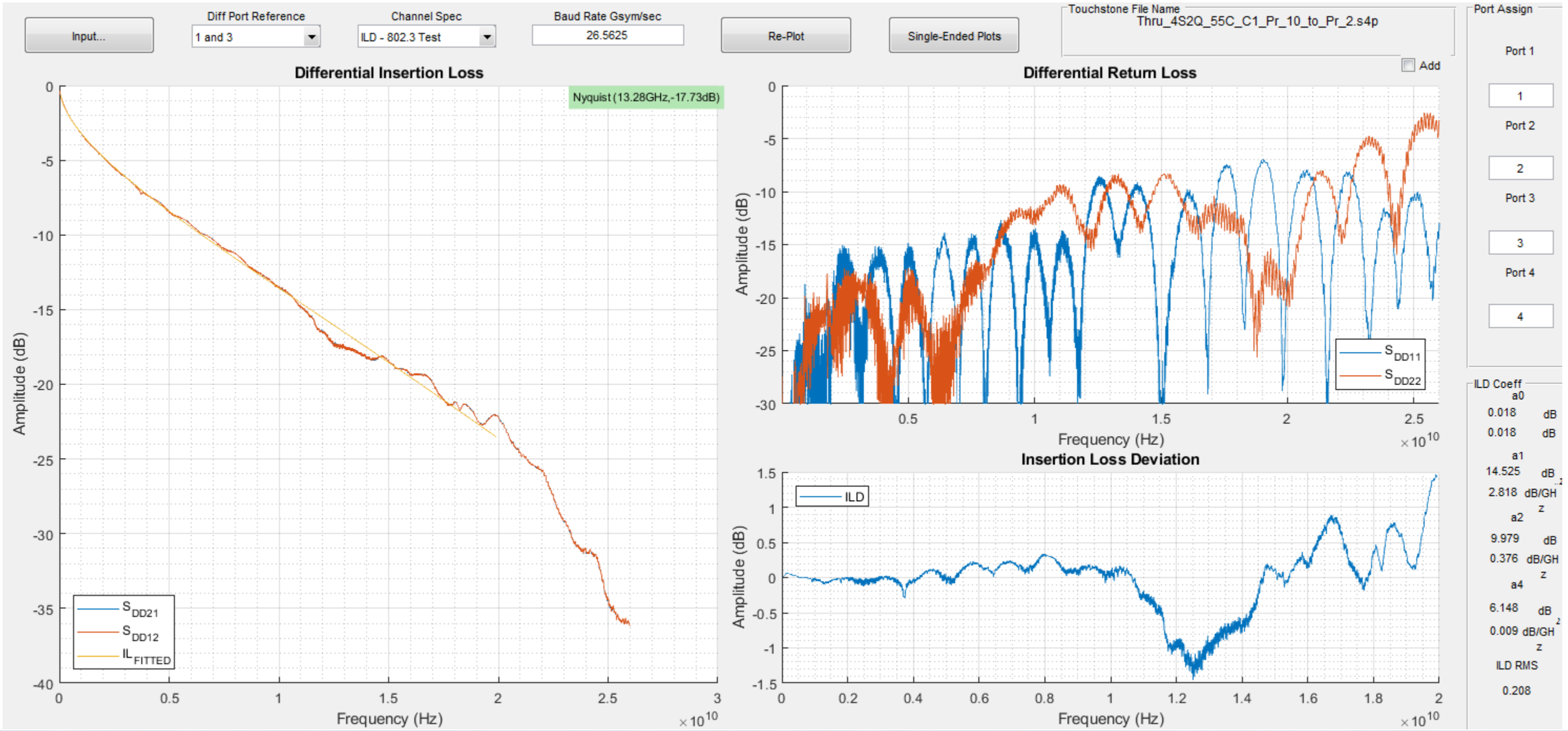


TE cable


Input...
Diff Port Reference
1 and 3
Channel Spec
ILD - 802.3 Test
Baud Rate Gsym/sec
26.5625
Re-Plot
Single-Ended Plots
Touchstone File Name
TE_3m28AWG_QSFP_4SFP_P2_TX1_P1_RX1_THRU.s4p
Add
Port Assign
Port 1
1
Port 2
2
Port 3
3
Port 4
4
Differential Insertion Loss
Nyquist (13.28GHz,-17.16dB)
Amplitude (dB)
Frequency (Hz)
×10^10
S_DD21
S_DD12
IL_FITTED
Differential Return Loss
S_DD11
S_DD22
Insertion Loss Deviation
ILD
ILD Coeff
a0
-0.219 dB
-0.318 dB
a1
20.841 dB
4.231 dB/GHz
a2
0.000 dB
-0.077 dB/GHz
a4
11.954 dB
0.019 dB/GHz
ILD RMS
0.228

FCI cable


Input...
Diff Port Reference
1 and 3
Channel Spec
ILD - 802.3 Test
Baud Rate Gsym/sec
26.5625
Re-Plot
Single-Ended Plots
Touchstone File Name
Thru_4S2Q_55C_C1_Pr_10_to_Pr_2.s4p
Add
Port Assign
Port 1
1
Port 2
2
Port 3
3
Port 4
4
Differential Insertion Loss
Nyquist (13.28GHz,-17.73dB)
Amplitude (dB)
Frequency (Hz)
S_{DD21}
S_{DD12}
IL_{FITTED}
Differential Return Loss
S_{DD11}
S_{DD22}
Insertion Loss Deviation
ILD
ILD Coeff
a0
0.018 dB
0.018 dB
a1
14.525 dB
2.818 dB/GHz
a2
9.979 dB
0.376 dB/GHz
a4
6.148 dB
0.009 dB/GHz
ILD RMS
0.208

Some information on Clause 137 Device

137.9.2.1 Transmitter ERL

ERL of the transmitter at TP0a is computed using the procedure in 93A.5 with the values in Table 137–5. Parameters that do not appear in Table 137–5 take values from Table 137–6. The value of T_{fx} is twice the delay from TP0 to TP0a. N_{bx} is set to the value of N_b in Table 137–6.

Comment

In table 137-5 page 249 change beta x to1.7 and rho_x to 0.32

Table 137–5—Transmitter and receiver ERL parameter values

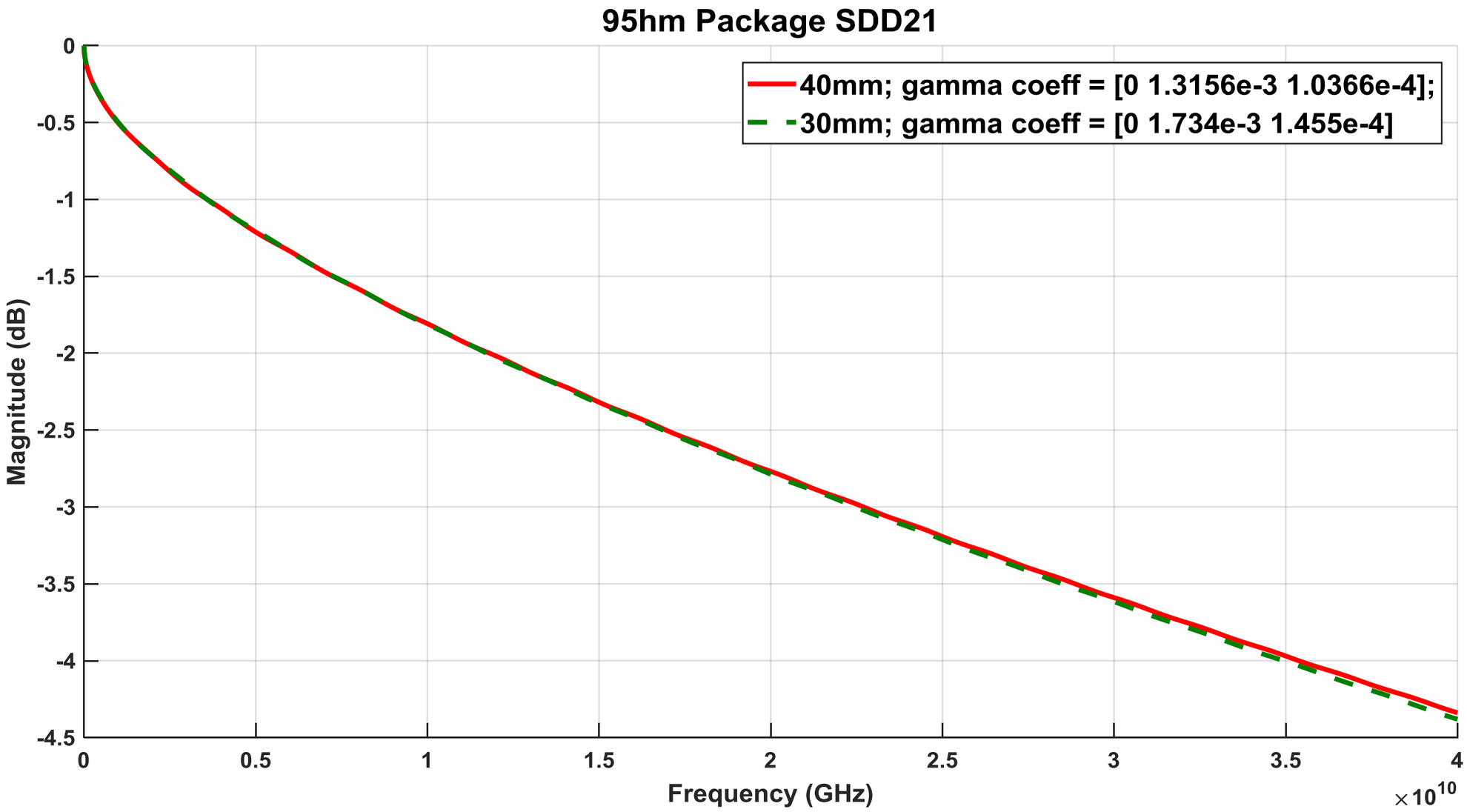
Parameter	Symbol	Value	Units
Transition time associated with a pulse	T_r	0.0189	ns
Incremental available signal loss factor	β_x	10.7	GHz
Permitted reflection from a transmission line external to the device under test	ρ_x	0.44	—
Length of the reflection signal	N	100	—

Transmitter ERL at TP0a shall be greater than or equal to 16.1 dB.

Investigation of the effect of package length on ERL and SNRisi

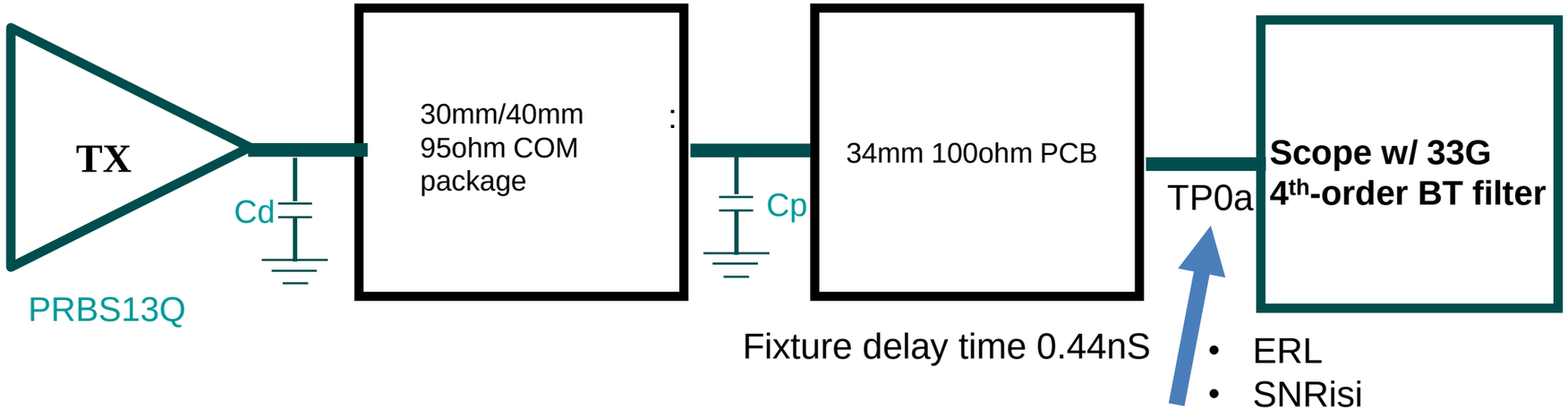
- **The 30mm package is the standard COM model package.**
- **The values of the parameters in the transmission line model were modified to create a 40mm package with the same insertion loss.**
- **ERL and SNRisi were measured for both packages.**

30mm and 40mm TX packages



Transmitter parameters at TP2

Av: 0.4V
Rd: 50ohm
Risetime: 12pS
Cd: 0.18pF
Cp: 0.11pF



Channels	ERL D3.2	ERL Comment
pkg30mm_tp0_tp0a	19.188	21.917
pkg40mm_tp0_tp0a	15.831	15.551

Channels	Risetime (pS)	Sigma-e(mV)	Vf(V)	Pmax(V)	Differential peak to peak voltage(V)	Pmax/Vf	SNRisi(dB)	SNDR(sigma-n=0)(dB))	Sigm-n(SNDR 33.3dB) (dB)
pkg30mm_tp0_tp0a	19.205	0.048	0.388	0.324	0.785	0.835	52.256	76.573	7.011
pkg40mm_tp0_tp0a	19.051	0.047	0.389	0.324	0.786	0.833	34.182	76.815	7.009

COM config

Table 93A-1 parameters			
Parameter	Setting	Units	Information
f_b	26.5625	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.8e-4 1.8e-4]	nF	[TX RX]
z_p select	[2]		[test cases to run]
z_p (TX)	[12 30]	mm	[test cases]
z_p (NEXT)	[12 12]	mm	[test cases]
z_p (FEXT)	[12 30]	mm	[test cases]
z_p (RX)	[12 30]	mm	[test cases]
C_p	[1.1e-4 1.1e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX] or selected
f_r	0.75	*fb	
c(0)	0.6		min
c(-1)	[-0.25:0.05:0]		[min:step:max]
c(-2)	[0:0.025:0.1]		[min:step:max]
c(1)	[-0.25:0.05:0]		[min:step:max]
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	10.625	GHz	
f_p1	10.625	GHz	
f_p2	53.125	GHz	
A_v	0.415	V	tdr selected
A_fe	0.415	V	tdr selected
A_ne	0.604	V	tdr selected
L	4		
M	32		
N_b	12	UI	
b_max(1)	0.7		
b_max(2..N_b)	0.2		
sigma_RJ	0.01	UI	
A_DD	0.02	UI	
eta_0	1.64E-08	V^2/GHz	
SNR_TX	32.5	dB	tdr selected
R_LM	0.95		
DER_0	1.00E-04		
Operational control			
COM Pass threshold	3	dB	
ERL Pass threshold	11	dB	
Include PCB	0	Value	0, 1
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\KR_50G_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	KR_50G_PAM4	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	0.012	ns
FORCE_TR	1	logical
Non standard control options		
COM_CONTRIBUTION	0	logical
TDR	1	logical
ERL	1	logical
Z_t	50	ohms
ERL_ONLY	0	logical
TR_TDR	0.0189	ns
TDR_duration	10	
TDR_f_BT_3db	19.921875	GHz
TDR_Butterworth	1	logical
beta_x	10700000000	
rho_x	**0.44**	
fixture delay time	0.00E+00	set to zero for no fixture for KR channel

Table 93A–3 parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 1.734e-3 1.455e-4]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	95	Ohm (tdr sel)

Table 92–12 parameters		
Parameter	Setting	
board_tl_gamma0_a1_a2	[0 4.114e-4 2.547e-4]	
board_tl_tau	6.191E-03	ns/mm
board_Z_c	110	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	72	mm
z_bp (FEXT)	72	mm
z_bp (RX)	151	mm

TX PKG 30mm gamma_coeff = [0 1.734e-3 1.455e-4]
TX PKG 40mm gamma_coeff = [0 1.3156e-3 1.0366e-4]