Transmitter Specifications and COM for 50GBASE-CR

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802.3cd Ad-hoc 1/10/18.

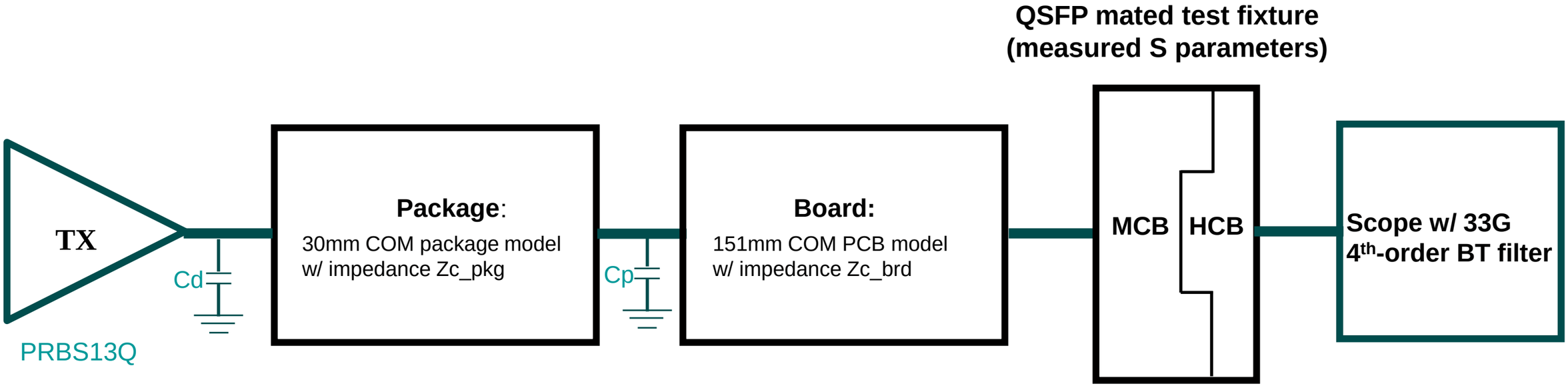
Introduction

- **The specification methodology for the Copper Cable and backplane clauses creates a closed budget by specifying the cable/backplane with COM and calibrating the Rx Interference Tolerance test with COM.**
- **This relies however on**
  - The specifications for the Tx matching (or being more stringent) than the Tx that is used in COM in the cable/backplane test, or there being a difference between the COM value used to specify the cable and the COM value used for calibrating the RX interference tolerance test.
- **This presentation investigates the performance of the Tx used in COM at TP2 and compares this with the specifications at this point.**
- **It also proposes to align the package parameters in the 50GBASE-CR clause with those used in the 50GBASE-KR clause as it is expected that the same ASIC will be used for both, and proposes the use of a 100 Ohm PCB trace in the host (rather than the existing 109.8 Ohm) in order to not encourage cable vendors to tune their cables to a higher impedance to obtain better COM results.**
- **This presentation is related to comments i-161, i-162, and i-163**

Methodology

- The COM channel up to the Tx test points was duplicated as close as possible in Matlab.
- The output waveform at the test point was generated in Matlab using Tx with Av=0.4V and using the risetime used in COM. Absolute voltages can be scaled for other values of Av.
- The resulting waveform was then analyzed using the Tx test methodology to determine the Tx parameters which are compared with the Tx specifications. The effect of RLM was also investigated.
- This was repeated changing the transmitter package to match the one being specified in 50GBASE-KR and using a 100 Ohm Host PCB trace impedance.
- COM was also calculated for three representative cables using both the parameters in draft 3.0 and these changed parameters.

Transmitter simulation block diagram at TP2



Transmitter plus package, board, QSFP mated test fixture and 33GHz 4th-order BT filter

53.125Gbs PAM4 transmitter characteristics @ TP2 w/o TX equalization: measured w/ 4th order 33GHz BT filter

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	Simulated PRBS13Q @ TP2									
Parameters	Gaussian TX Filter Risetime 12ps; 30mm package; 151mm pcb; Cd 0.18pF; Cp 0.11pF; Av 0.4V									**Units**
Rd	55			50			50			ohm
Zc_pkg	90			95			95			ohm
Zc_brd	109.8			109.8			100			ohm
|EB+EC|	0	0	0.1	0	0	0.1	0	0	0.1	N/A
Rlm	0.997	0.947	0.947	0.947	0.997	0.947	0.947	0.997	0.947	N/A
Sigma-e	0.093	0.094	1.498	0.099	0.098	1.582	0.093	0.092	1.587	mV
Vf (steady-state voltage)	0.341	0.341	0.341	0.359	0.359	0.359	0.36	0.36	0.36	V
Pmax (Linear fit pulse peak)	0.165	0.165	0.165	0.174	0.174	0.174	0.174	0.174	0.174	V
Differential Peak to Peak Voltage	0.654	0.653	0.654	0.69	0.69	0.69	0.692	0.692	0.692	V
Pmax/Vf	0.482	0.482	0.482	0.484	0.484	0.483	0.484	0.484	0.484	N/A
SNR_{isi}	31.208	31.196	31.19	32.098	32.091	32.09	32.238	32.229	32.23	dB
SNDR (@ Sigman = 0)	64.976	64.86	40.814	64.85	64.965	40.815	65.476	65.597	40.823	dB
SNDR (TX_SNR=32.5dB)	32.498	32.497	31.903	32.497	32.498	31.903	32.498	32.498	31.904	dB
Sigm-n (for 33.3dB SNDR)	3.557	3.557	3.228	3.758	3.759	3.409	3.772	3.772	3.424	mV
TX_SNR@die(to create above sigman)	33.303	33.303	34.147	33.303	33.303	34.147	33.303	33.303	34.145	dB

PAM4 Levels: L0=-1;L1=(-1+EB)/3;L2=(1+EC)/3;L3=1 Linear fitting: Dp=3;Nb=12;Np=200;Nv=13

Conclusions on waveform simulations.

- The values of SNDR and SNRisi in draft 3.0 would fail the Transmitter used in COM and are therefore more stringent than they need to be.
- The calculations used Nv=13 (same as 120D.3.1.4 and clause 137 by reference). As defined in draft 3.0 the value of Nv would be infinite. If that had been used some of the conclusions would be different.
- The Pmax/Vf ratio is not significantly affected by the various changes and the existing value of 0.49 does not need to be changed. (comment i-161).
- The value in of Vf in draft 3.0 isn't appropriate for the value of 0.45 for Av. It should be changed based on the values of Rd and Av used (and Nv).

COM results

	802.3by COM						802.3cd/D3.0 COM					
	CA-25G-N		CA-25G-S		CA-25G-L		Table 136-15 Rd=55 Zc_pkg=90 Zc_brd=109.8		Table 137-5 Rd=50 Zc_pkg=95 Zc_brd=109.8		Table 137-5 Rd=50 Zc_pkg=95 Zc_brd=100	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
TE QSFP to QSFP 3m 25 AWG	3.35	2.56	4.69	3.88	6.70	6.00	5.05	4.60	5.04	4.54	5.40	4.82
FCI QSFP to Quad SFP 3m 26 AWG	2.57	1.58	4.18	3.24	6.21	5.33	4.34	3.80	4.39	3.62	4.54	3.72
Molex zQSFP to zQSFP 3m 26AWG	4.16	3.22	5.56	4.63	7.56	6.63	6.06	5.42	6.04	5.32	6.23	5.55

Overall Conclusions.

- The draft 3.0 cable COM specification is more relaxed than that for the 25GBASE-CR-N and 25GBASE-CR-S cables implying that some tightening would be possible while maintaining the 3meter objective.
- Changing the parameters to match the 50GBASE-KR specification and the host PCB to 100 Ohm is desirable but doing just that would relax the cable specification further. Also it would require tighter specifications on the Tx than the existing worst case values making it difficult to make host Tx's.
- Note that there isn't any margin for Tx host noise (or impedance mismatch if the PCB is changed to 100 Ohm) as neither are included in the COM calculations.
- The next slide lists the proposed changes that will close the budget, correcting existing issues and making the desired changes.

Proposed Changes. (These supercede those in my comments)

- COM parameters
  - RD=50 Ohms (was 55)
  - Zc package = 95 Ohm
  - Av/Ane= 0.415
  - Afe=0.604
- COM pass/fail criterion 3.3dB for Cable test, 3.0dB for interference calibration.
- TX specifications
  - Add a sentence to 136.9.3.1.2 stating that Nv=13.
  - Vf(min) = 0.354V
  - SNRisi=31.2dB
  - SNDR=32dB

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Back-up.

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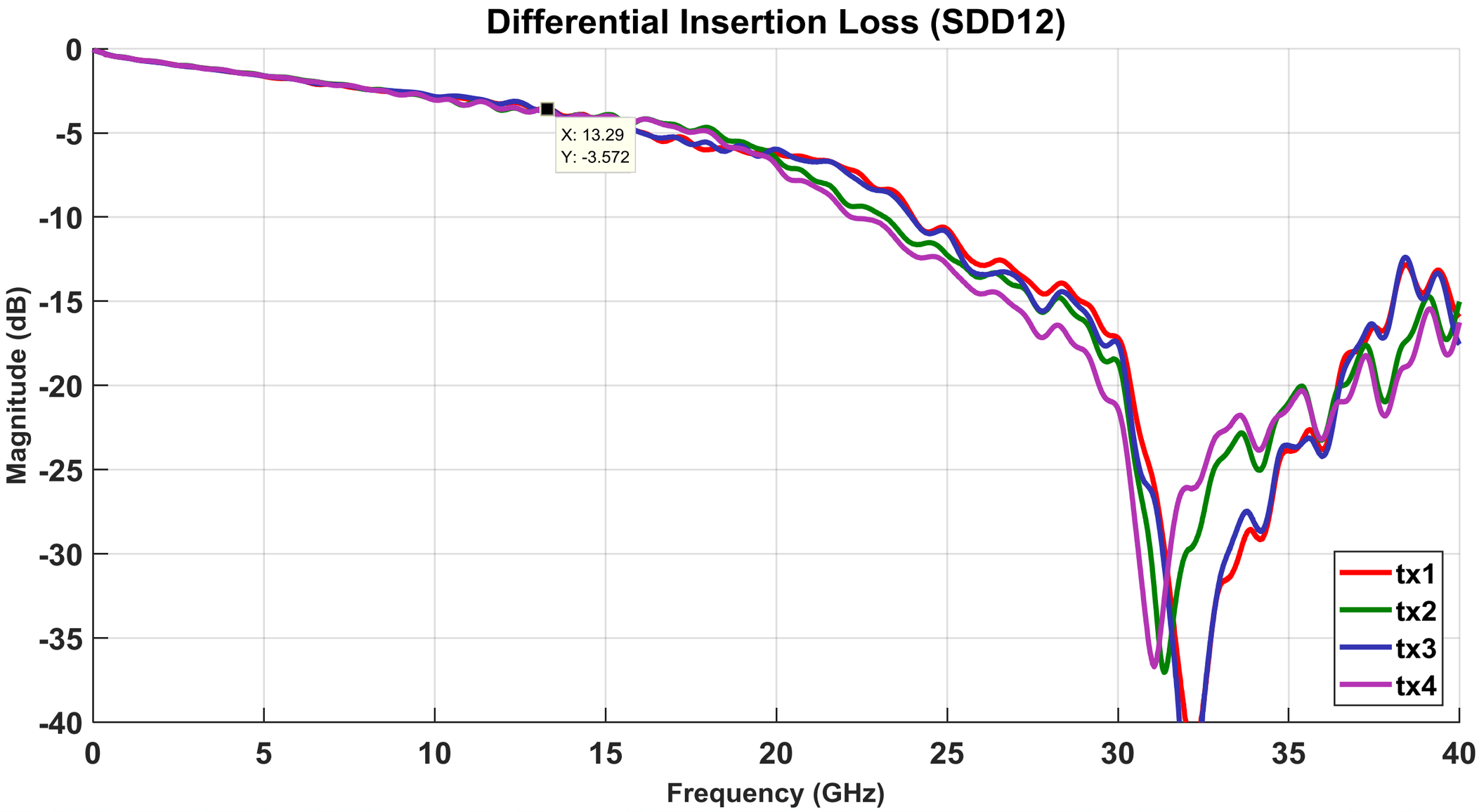
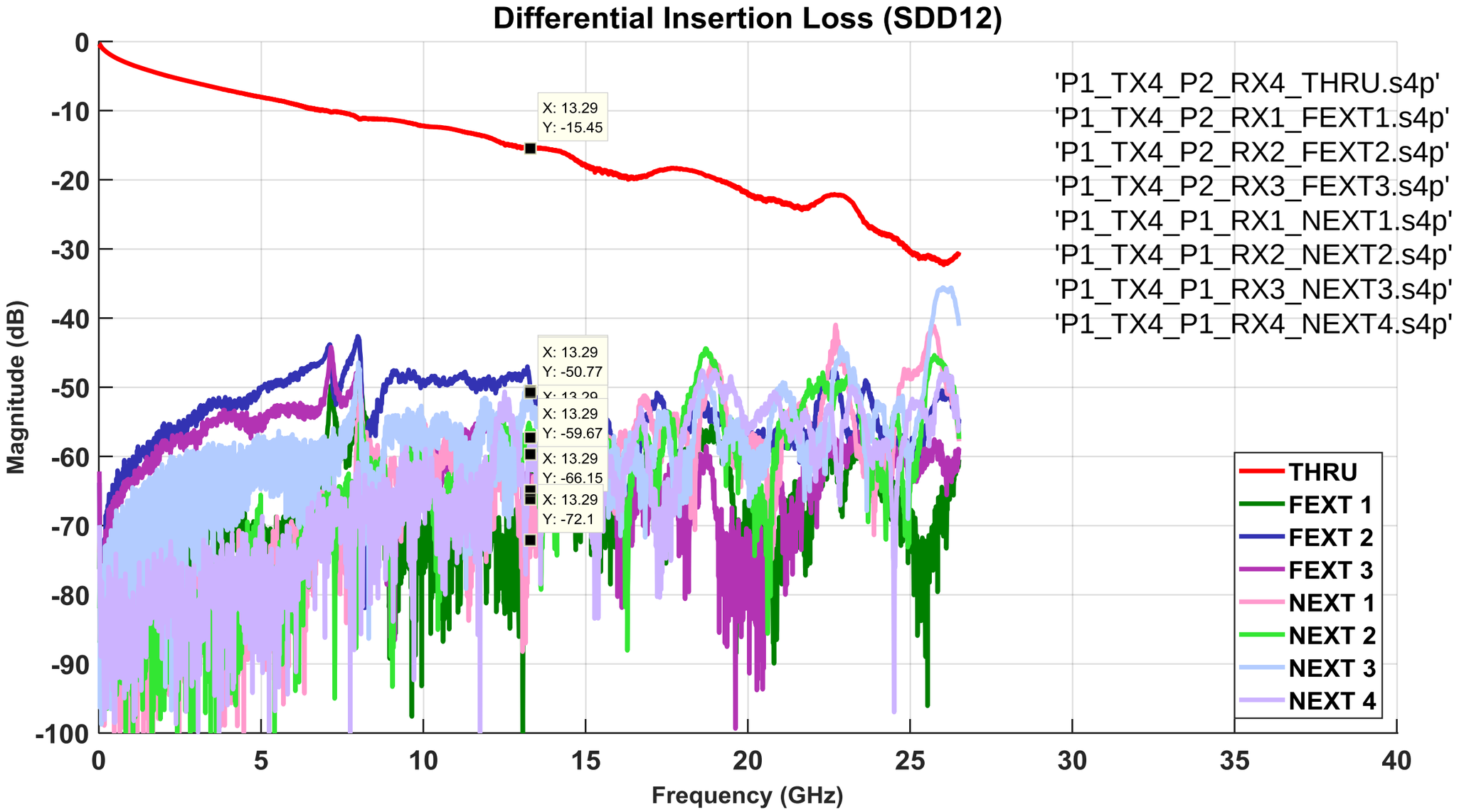
Channel performance.

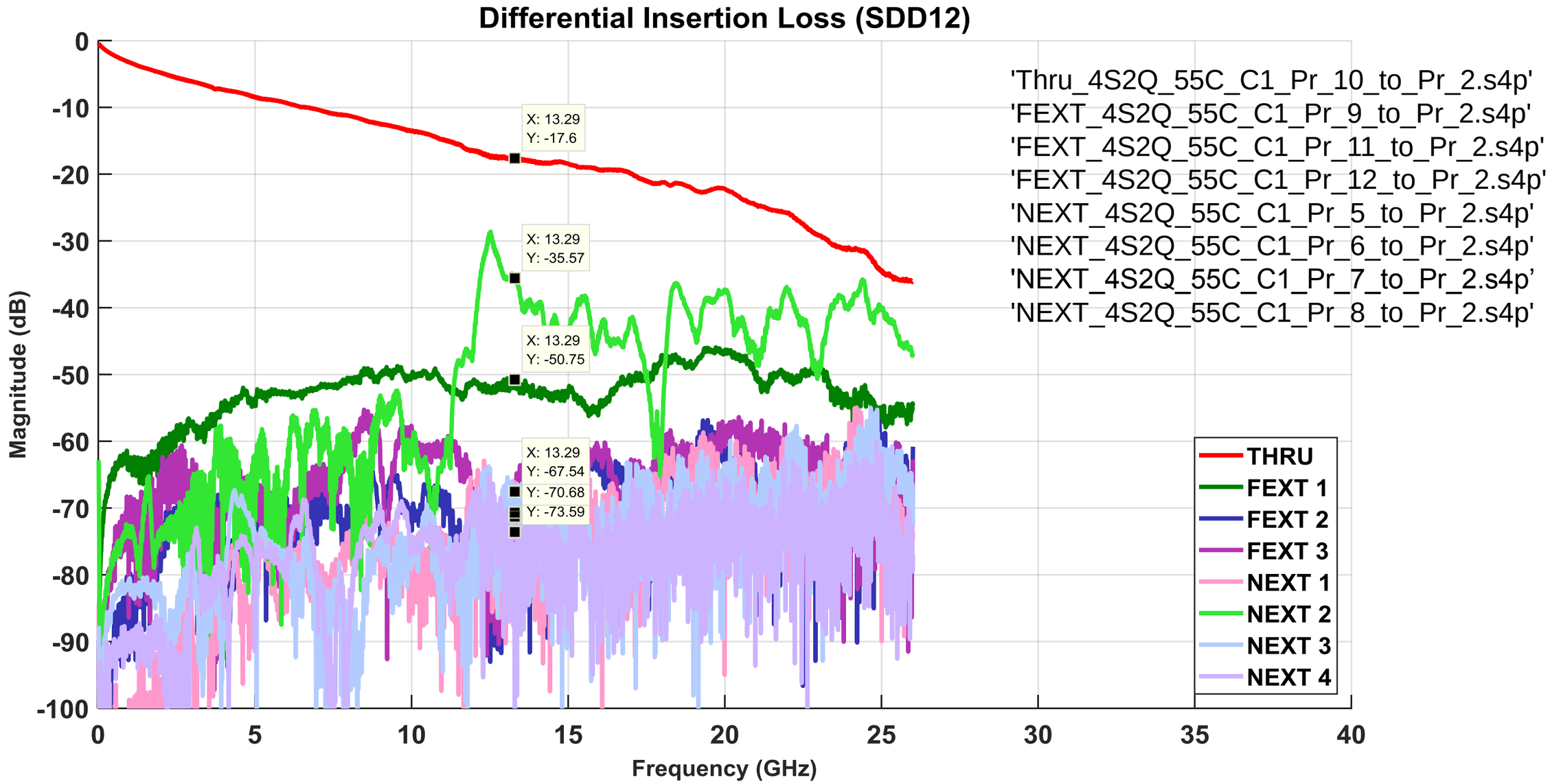
QSFP mated test fixture



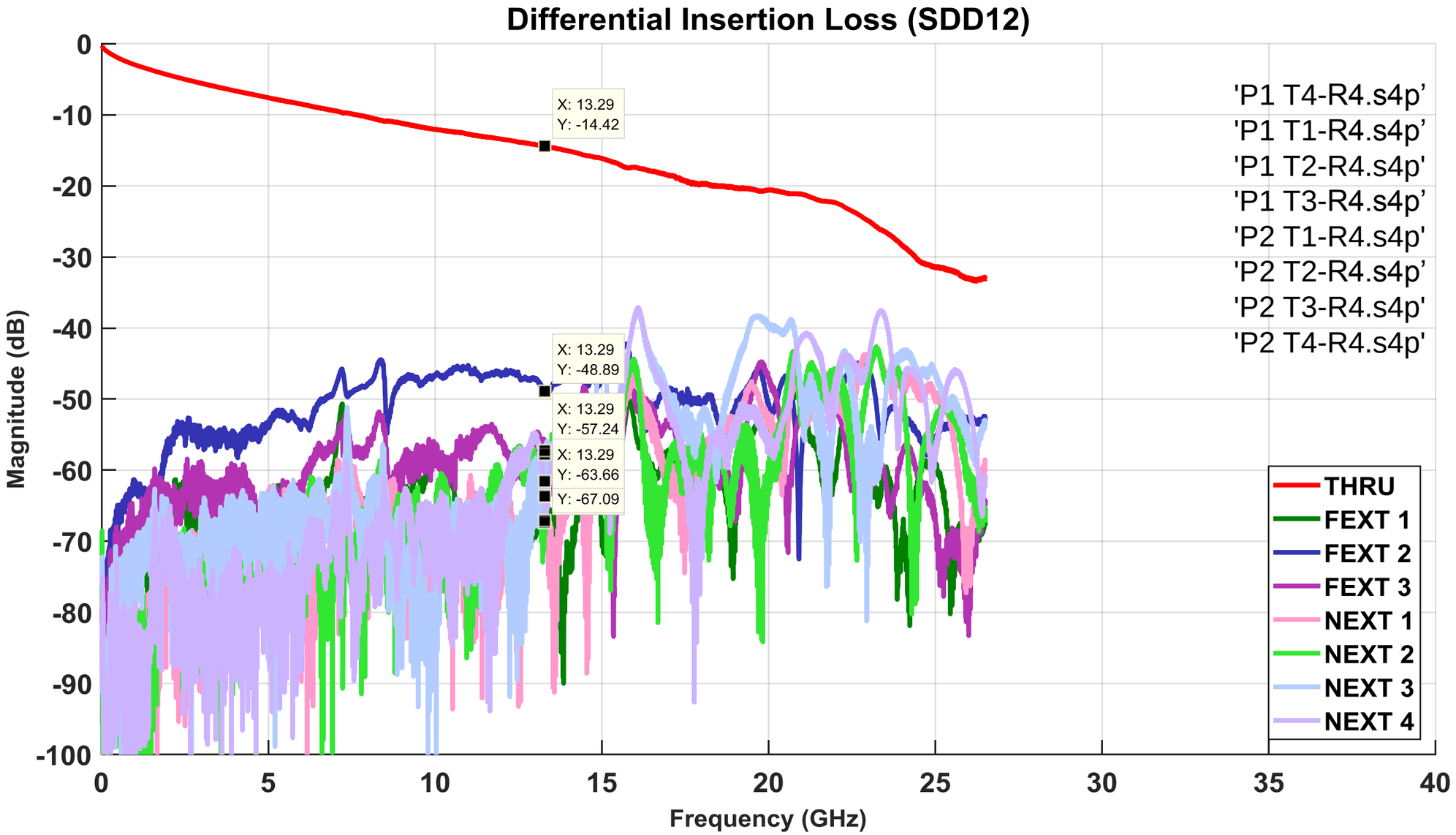
TE QSFP to QSFP cable 3m 25awg cable



FCI QSFP to Quad SFP 3m 26 AWG cable at 55C



Molex zQSFP to zQSFP 3m 26AWG



802.3cd COM table

802.3cd/D3.0 Table 136-15

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	[1 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	[55 55]	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	0.45	V	tdr selected
A_fe	0.45	V	tdr selected
A_ne	0.63	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	
Include PCB	1	Value	0, 1, 2
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	0	logical
DISPLAY_WINDOW	0	logical
Display frequency domain	0	logical
CSV_REPORT	0	logical
RESULT_DIR	.\results\D1p3_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	CR_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	1	logical
TR_TDR	0.0189	ns
TDR_duration	5	
TDR_f_BT_3db	19.921875	GHz
TDR_Butterworth	1	logical

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	90	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
board_Z_c	109.8
z_bp (TX)	151
z_bp (NEXT)	110
z_bp (FEXT)	110
z_bp (RX)	151

802.3cd/D3.0 Table 137-5

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	[1 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	
Include PCB	1	Value	0, 1, 2
g_DC_HP	[-6:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	0	logical
DISPLAY_WINDOW	0	logical
Display frequency domain	0	logical
CSV_REPORT	0	logical
RESULT_DIR	.\results\D1p3_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	CR_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	1	logical
TR_TDR	0.0189	ns
TDR_duration	5	
TDR_f_BT_3db	19.921875	GHz
TDR_Butterworth	1	logical

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	109.8	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	110	mm
z_bp (FEXT)	110	mm
z_bp (RX)	151	mm

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802.3by COM table

802.3by Table 110-11 CA-25G-N

Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	25.78125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[2.5e-4 2.5e-4]	nF	[TX RX]
z_p select	[1 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	[1.8e-4 1.8e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[55 55]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.62		min
c(-1)	[-0.18:0.02:0]		[min:step:max]
c(1)	[-0.38:0.02:0]		[min:step:max]
g_DC	[-16:1:0]	dB	[min:step:max]
f_z	6.4453125	GHz	
f_p1	6.4453125	GHz	
f_p2	25.78125	GHz	
A_v	0.4	V	
A_fe	0.6	V	
A_ne	0.6	V	
L	2		
M	32		
N_b	14	UI	
b_max(1)	0.35		
b_max(2..N_b)	0.35		
sigma_RJ	0.01	UI	
A_DD	0.05	UI	
eta_0	5.20E-08	V^2/GHz	
SNR_TX	29	dB	
R_LM	1		
DER_0	1.00E-12		
Operational control			
COM Pass threshold	2.2	dB	
Include PCB	1	Value	0, 1, 2

set to 3 if cable loss than 12 dB

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\test\	
SAVE_FIGURES	0	logical
SAVE_RESP	0	logical
Port Order	[1 3 2 4]	
RUNTAG	_CR_N	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	8.00E-03	ns
T_r_meas_point	0	logical
T_r_filter_type	1	logical
Non standard control options		
INC_PACKAGE	1	logical
IDEAL_RX_TERM	0	logical
INCLUDE_CTLE	1	logical
INCLUDE_TX_RX_FILTER	1	logical

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	78.2	Ohm

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	109.8	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	72	mm
z_bp (FEXT)	72	mm
z_bp (RX)	151	mm

802.3by Table 110-11 CA-25G-S

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Table 93A-1 parameters			
Parameter	**Setting**	**Units**	**Information**
f_b	25.78125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[2.5e-4 2.5e-4]	nF	[TX RX]
z_p select	[1 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	[1.8e-4 1.8e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[55 55]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.62		min
c(-1)	[-0.18:0.02:0]		[min:step:max]
c(1)	[-0.38:0.02:0]		[min:step:max]
g_DC	[-13:1:0]	dB	[min:step:max]
f_z	6.4453125	GHz	
f_p1	6.4453125	GHz	
f_p2	25.78125	GHz	
A_v	0.4	V	
A_fe	0.6	V	
A_ne	0.6	V	
L	2		
M	32		
N_b	14	UI	
b_max(1)	0.5		
b_max(2..N_b)	0.5		
sigma_RJ	0.01	UI	
A_DD	0.05	UI	
eta_0	5.20E-08	V^2/GHz	
SNR_TX	29	dB	
R_LM	1		
DER_0	1.00E-08		
Operational control			
COM Pass threshold	3	dB	
Include PCB	1	Value	0, 1, 2

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\test\	
SAVE_FIGURES	0	logical
SAVE_RESP	0	logical
Port Order	[1 3 2 4]	
RUNTAG	_CR_S	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	8.00E-03	ns
T_r_meas_point	0	logical
T_r_filter_type	1	logical
Non standard control options		
INC_PACKAGE	1	logical
IDEAL_RX_TERM	0	logical
INCLUDE_CTLE	1	logical
INCLUDE_TX_RX_FILTER	1	logical

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	78.2	Ohm

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	109.8	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	72	mm
z_bp (FEXT)	72	mm
z_bp (RX)	151	mm

802.3by Table 110-11 CA-25G-L

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Table 93A-1 parameters			
Parameter	Setting	Units	Information
f_b	25.78125	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[2.5e-4 2.5e-4]	nF	[TX RX]
z_p select	[1 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	[1.8e-4 1.8e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[55 55]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.62		min
c(-1)	[-0.18:0.02:0]		[min:step:max]
c(1)	[-0.38:0.02:0]		[min:step:max]
g_DC	[-13:1:0]	dB	[min:step:max]
f_z	6.4453125	GHz	
f_p1	6.4453125	GHz	
f_p2	25.78125	GHz	
A_v	0.4	V	
A_fe	0.6	V	
A_ne	0.6	V	
L	2		
M	32		
N_b	14	UI	
b_max(1)	1		
b_max(2..N_b)	1		
sigma_RJ	0.01	UI	
A_DD	0.05	UI	
eta_0	5.20E-08	V^2/GHz	
SNR_TX	29	dB	
R_LM	1		
DER_0	1.00E-05		
Operational control			
COM Pass threshold	3	dB	
Include PCB	1	Value	0, 1, 2

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\test\	
SAVE_FIGURES	0	logical
SAVE_RESP	0	logical
Port Order	[1 3 2 4]	
RUNTAG	_CR_L	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	8.00E-03	ns
T_r_meas_point	0	logical
T_r_filter_type	1	logical
Non standard control options		
INC_PACKAGE	1	logical
IDEAL_RX_TERM	0	logical
INCLUDE_CTLE	1	logical
INCLUDE_TX_RX_FILTER	1	logical

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	78.2	Ohm

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	109.8	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	72	mm
z_bp (FEXT)	72	mm
z_bp (RX)	151	mm

References for cable s parameters

- "Cable Assembly Measurement Data 3 Meter – no FEC Consensus Building",IEEE802.3by, Megha Shanbhag, Nathan Tracy, July 14,2015. http://grouper.ieee.org/groups/802/3/by/public/channel/TE_QSFP_QSFP_3m_25AWG_MaxLossExample_15p25dB.zip
- "3 meter 26AWG 4xSFP to QSFP without FEC at 0°C, 25°C, and 55°C", IEEE P802.3by 25 Gb/s Ethernet Task Force Ad Hoc, Andy Zambell, September 2nd, 2015. http://grouper.ieee.org/groups/802/3/by/public/channel/FCI_4xSFP_QSFP_3m_26AWG.zip
- “Sample Cable Data for 50Gbps Ethernet”, 50 Gb/s Ethernet Study Group Ad hoc Area, Chris Roth, Jan, 2015. http://grouper.ieee.org/groups/802/3/50G/public/channel/Molex_zQSFP-zQSFP_3m_26awg.zip


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