

Study of Channel Operating Margin for Backplane and Direct Attach Cable Channels

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Supporters

- Joel Goergen, Cisco
- Richard Mellitz, Samtec
- Ali Ghiasi, Ghiasi Quantum LLC
- James Fife, etopus
- Scott Sommers, Molex
- Tom Palkert, Molex, MACOM
- Yasuo Hidaka, Fujitsu

Presentation overview

- Continuation of the work from [kareti_50GE_NGOATH_01b_0316](#)
- Identify major barriers to improved Channel Operating Margin (COM)
 - Begin with the parameter set from the previous presentation
 - Consider possible enhancements
 - Improve package and device termination
 - Optimize equalization
 - Reduce Gaussian noise contributors
 - Observe impact of these enhancements on COM for backplane and direct attach copper cable channels
 - Include channels in the vicinity of the 30 dB insertion loss objective

Initial COM parameters

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	[2.3e-4 2.3e-4]	nF	[TX RX]
z_p select	[1]		[test cases to run]
z_p (TX)	[30]	mm	[test cases]
z_p (NEXT)	[12]	mm	[test cases]
z_p (FEXT)	[30]	mm	[test cases]
z_p (RX)	[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]
f_r	0.75	*fb	
c(0)	0.6		min
c(-1)	[-0.15:0.05:0]		[min:step:max]
c(-2)	[-0.15:0.05:0]		[min:step:max]
c(1)	[-0.35:0.05:0]		[min:step:max]
g_DC	[-20:1:0]	dB	[min:step:max]
f_z	10.625	GHz	
f_p1	10.625	GHz	
f_p2	1.00E+99	GHz	
A_v	0.45	V	
A_fe	0.45	V	
A_ne	0.65	V	
L	4		
M	32		
N_b	15	UI	
b_max(1)	0.5		
b_max(2..N_b)	0.2		
sigma_RJ	0.01	UI	
A_DD	0.02	UI	
eta_0	2.60E-08	V ² /GHz	
SNR_TX	31.1	dB	
R_LM	0.95		
DER_0	1.00E-04		
Operational control			
COM Pass threshold	3	dB	
Include PCB	0	Value	0, 1, 2
g_DC_HP	[-7:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\COM50_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 2 3 4]	
RUNTAG	_CDAUI-8	
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_filter_type	0	logical
T_r_meas_point	0	logical

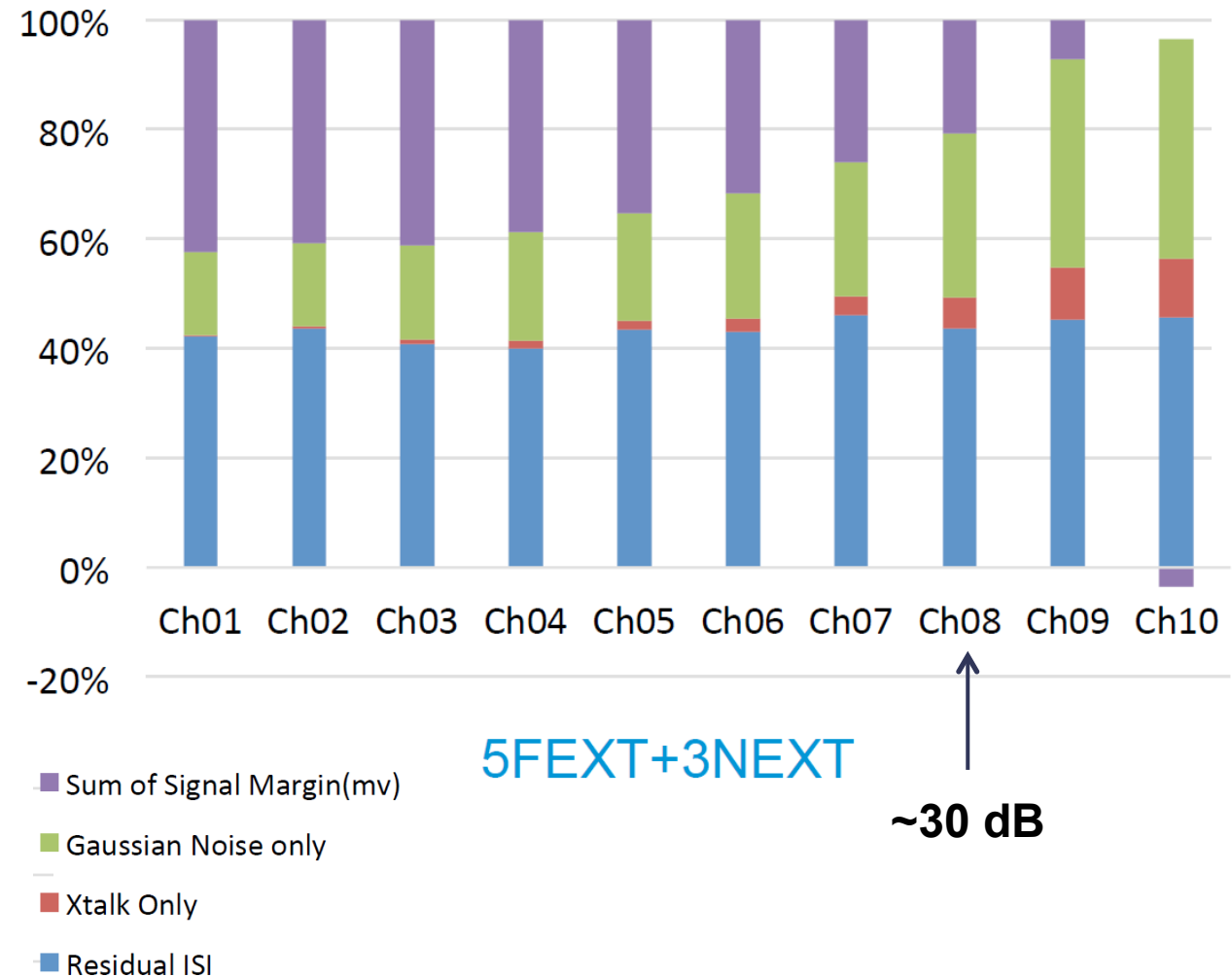
Non standard control options		
INC_PACKAGE	1	logical
IDEAL_RX_TERM	0	logical
INCLUDE_CTL	1	logical
INCLUDE_TX_RX_FILTER	1	logical
COM_CONTRIBUTION	0	logical
CDR_OVERSAMPLED	0	logical

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

Table 92-12 parameters		
Parameter	Setting	Units
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

Observations from kareti 50GE NGOATH 01b 0316

- Residual ISI is consistently the largest impairment
- As loss increases, the Gaussian noise terms become significant



Improve package and device termination

- Consider reducing device capacitance C_d to 180 fF
- Note the package transmission line impedance $package_Z_c$ is 90 Ohms in the initial parameters
- Note that the initial parameters do not include the transmitter rise time filter added by IEEE Std 802.3by-2016 and subsequently employed by CDAUI-8 chip-to-chip

Optimize equalization

- Considerations for the transmitter
 - Change $c(-2)$ sweep so that it has higher resolution (2.5%) and sign opposite to $c(-1)$
- Considerations for the receiver
 - Extend range of g_DC (to -22 dB) and g_DC_HP (to -8 dB)
 - Consider finer resolution for g_DC and g_DC_HP (0.5 dB steps)
 - Increase the range of the first DFE tap $b_max(1)$ but leave $b_max(2..N_b)$ at 0.2 (this is consistent with “dominant 1st tap” assumption used for precoding analysis)
 - Optimize the DFE length N_b to the smallest value that provides the majority of the benefit (12)

Reduce Gaussian noise contributors

- Consider increasing transmitter signal-to-noise ratio SNR_TX and/or reducing one-sided noise spectral density eta_0
- Sweep SNR_TX across the values 31.1 dB, 32.5 dB, and 33.4 dB
- Sweep eta_0 from 1.3×10^{-8} to 2.6×10^{-8} V²/GHz in 0.5 dB steps
- Jitter parameters are unchanged

Results for backplane channels

		CISCO Channels										TE Connectivity Channels			
		Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch1	Ch2	Ch3	Ch4
	Insertion Loss @ NQ, dB	10.7876	12.4579	17.3145	20.874	22.3474	25.3573	27.6685	30.1441	32.859	34.9828	32.0325	31.1419	31.9702	33.173
	FOM_ILD	0.31042	0.30047	0.28196	0.31335	0.28224	0.3028	0.31005	0.30382	0.31247	0.34579	0.27181	0.14762	0.26931	0.27802
	ICN, mV	1.2534	1.1147	0.81725	0.72664	0.69128	0.64907	0.60807	0.57276	0.55667	0.54711	0.77071	0.77071	0.77071	0.77071
	Change Log	COM @ DER_0 = 1e-4													
1	Initial COM parameters	4.7856	4.5463	4.5937	4.259	3.7685	3.3116	2.6154	2.0145	0.63969	-0.32395	1.0317	1.9057	0.88624	0.89587
2	+ T_r filter : 13 ps Gaussian w/ beta = 2	4.4121	4.1437	4.0116	3.8358	3.1353	2.7217	2.1248	1.0906	-0.21448	-1.229	0.3365	1.0513	0.15777	0.1401
3	+ C_d = 180 fF; c(-2) = [0:0.025:0.1]; g_DC(min) = -22; g_DC_HP(min) = -8	5.2627	4.9626	5.0527	4.8218	4.1382	3.7551	2.926	2.0915	0.88624	-0.41551	1.2999	2.0145	1.0808	1.0024
4	+ eta_0 = 1.3e-08; N_b = 12; b_max(1) = 1; b_max(2..N_b) = 0.2	5.2627	4.9929	5.1211	5.0829	4.3937	4.2225	3.5828	3.0733	2.3381	1.6499	3.0856	3.596	2.7932	2.9626
5	+ g_DC(min) = -20; g_DC_HP(min) = -6; 0.5 dB step size; b_max(2..N_b) = 1	5.2558	5.0205	5.1211	5.0829	4.4515	4.2225	3.6223	3.1105	2.3609	1.6709	3.1353	3.6223	2.8534	2.9748
6	+ eta_0 = 1.64e-08; SNR_TX = 32.5; b_max(1)=0.7; b_max(2..N_b)=0.2	5.6924	5.4024	5.519	5.4329	4.7314	4.4081	3.7551	3.1229	2.2589	1.4116	2.9139	3.5697	2.5336	2.7454
7	+ eta_0 = 1.84e-08; SNR_TX = 33.4;	5.9294	5.6212	5.725	5.5968	4.8673	4.4951	3.8088	3.1105	2.1916	1.2899	2.8413	3.5305	2.5104	2.6861

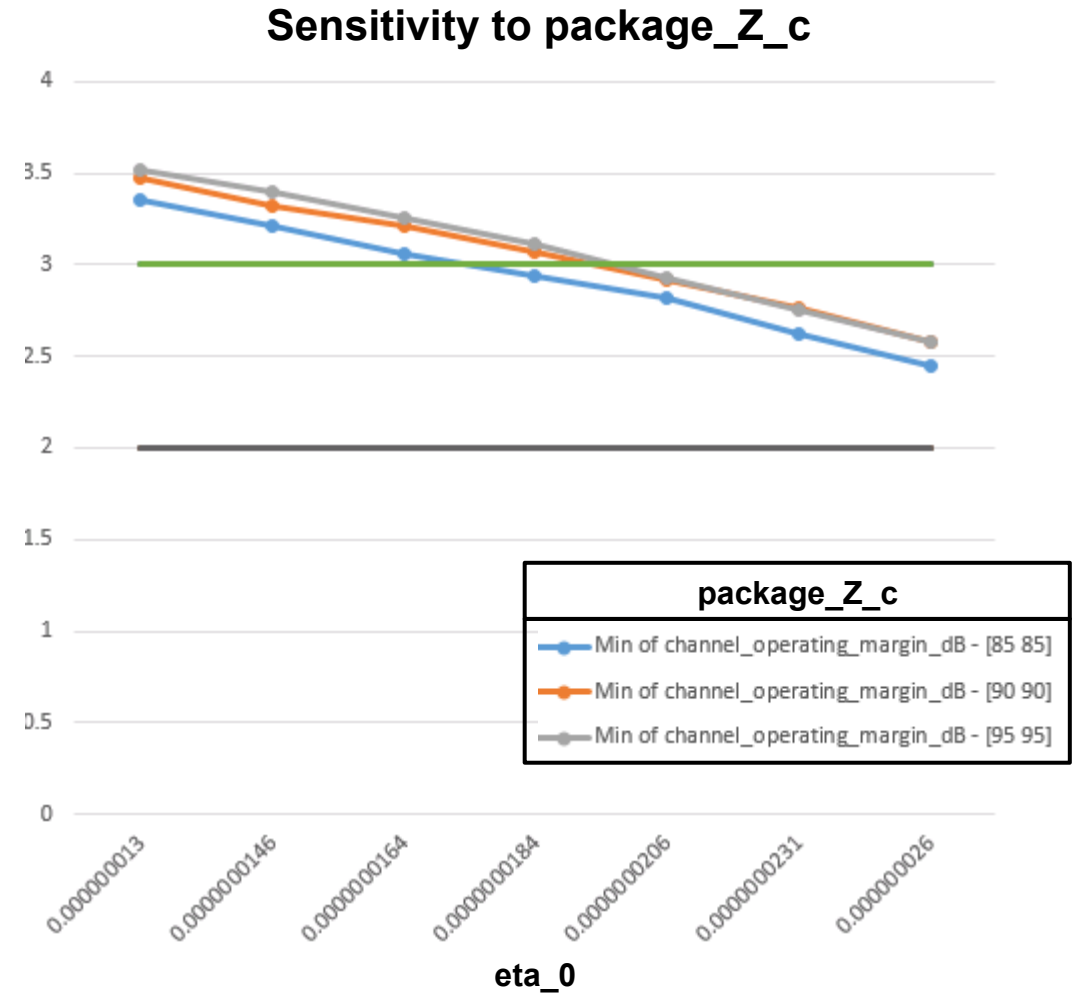
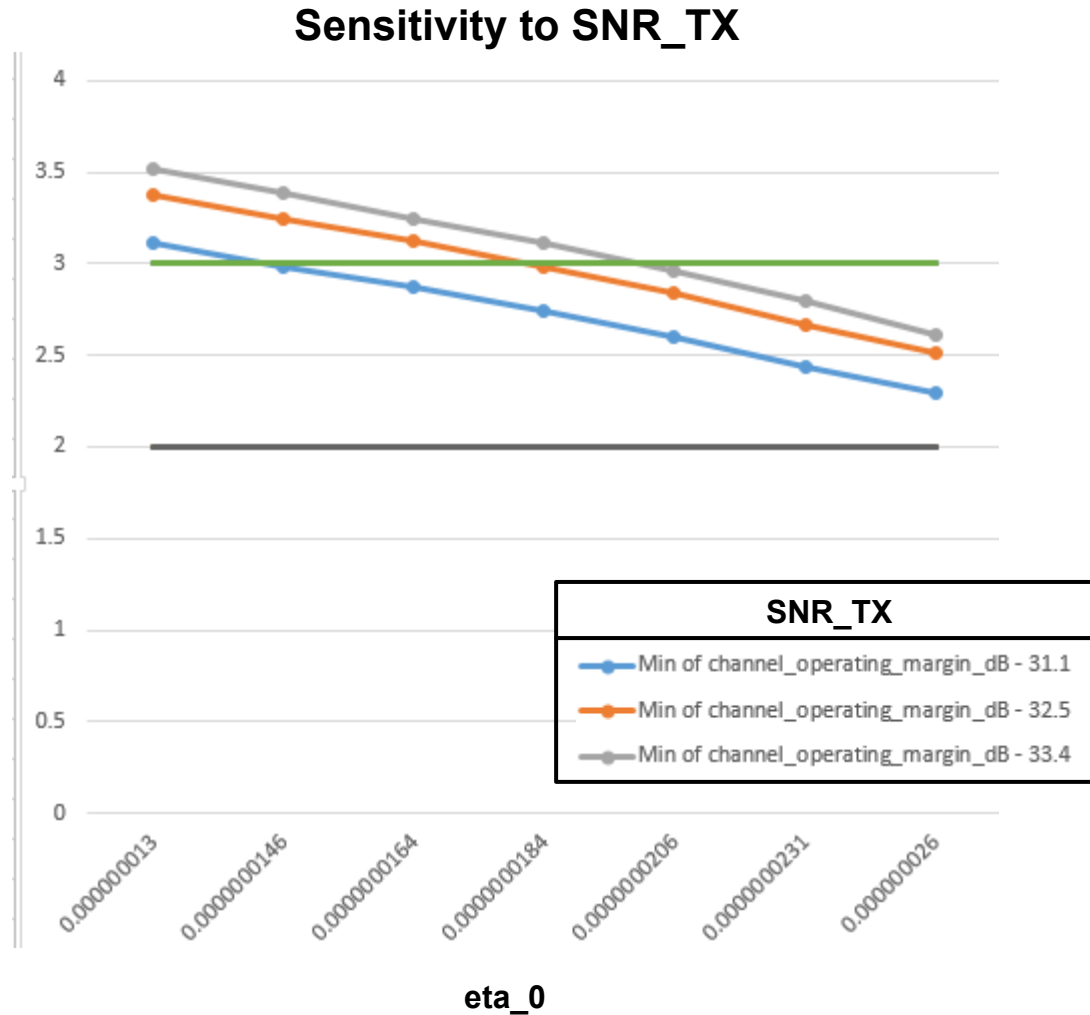
Acknowledgement: Thanks to TE Connectivity for providing available measured channels for this analysis

Results for direct attach cable channels

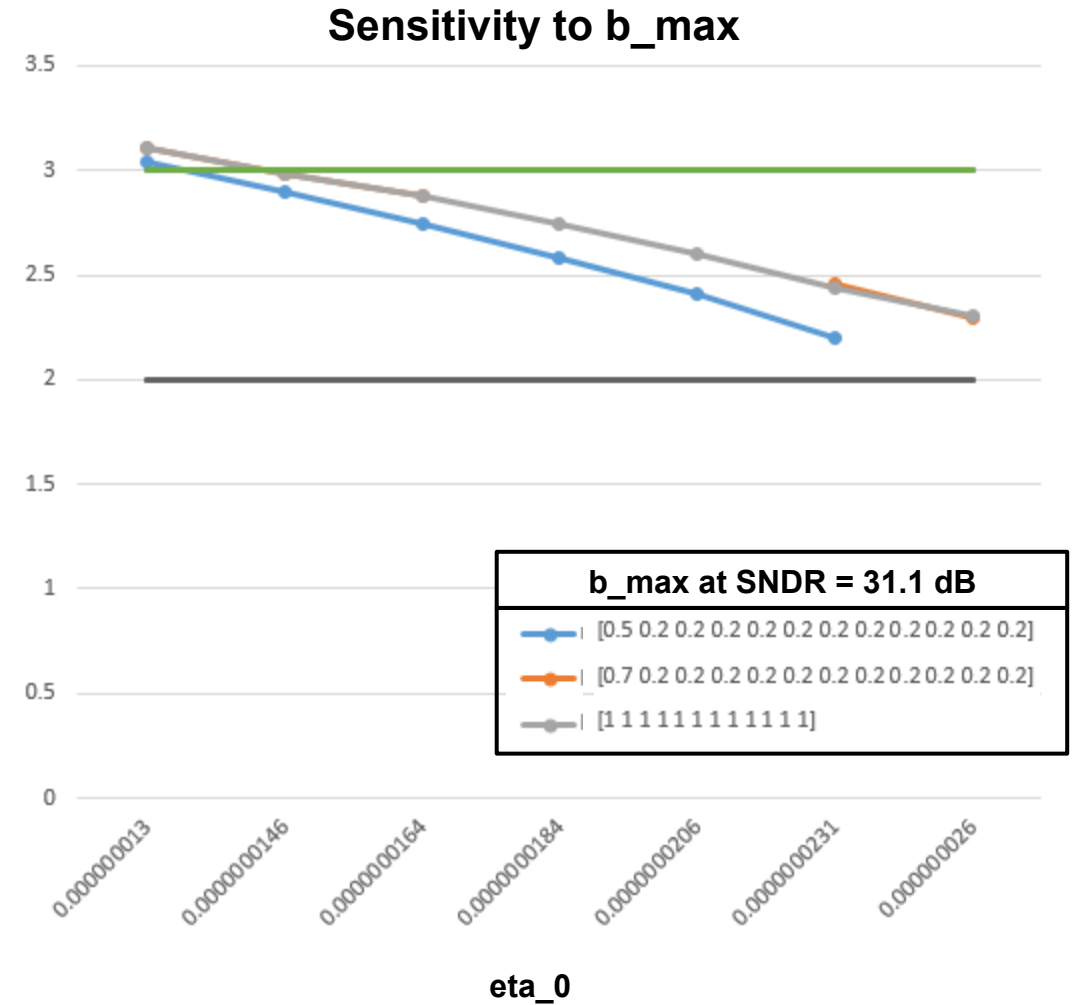
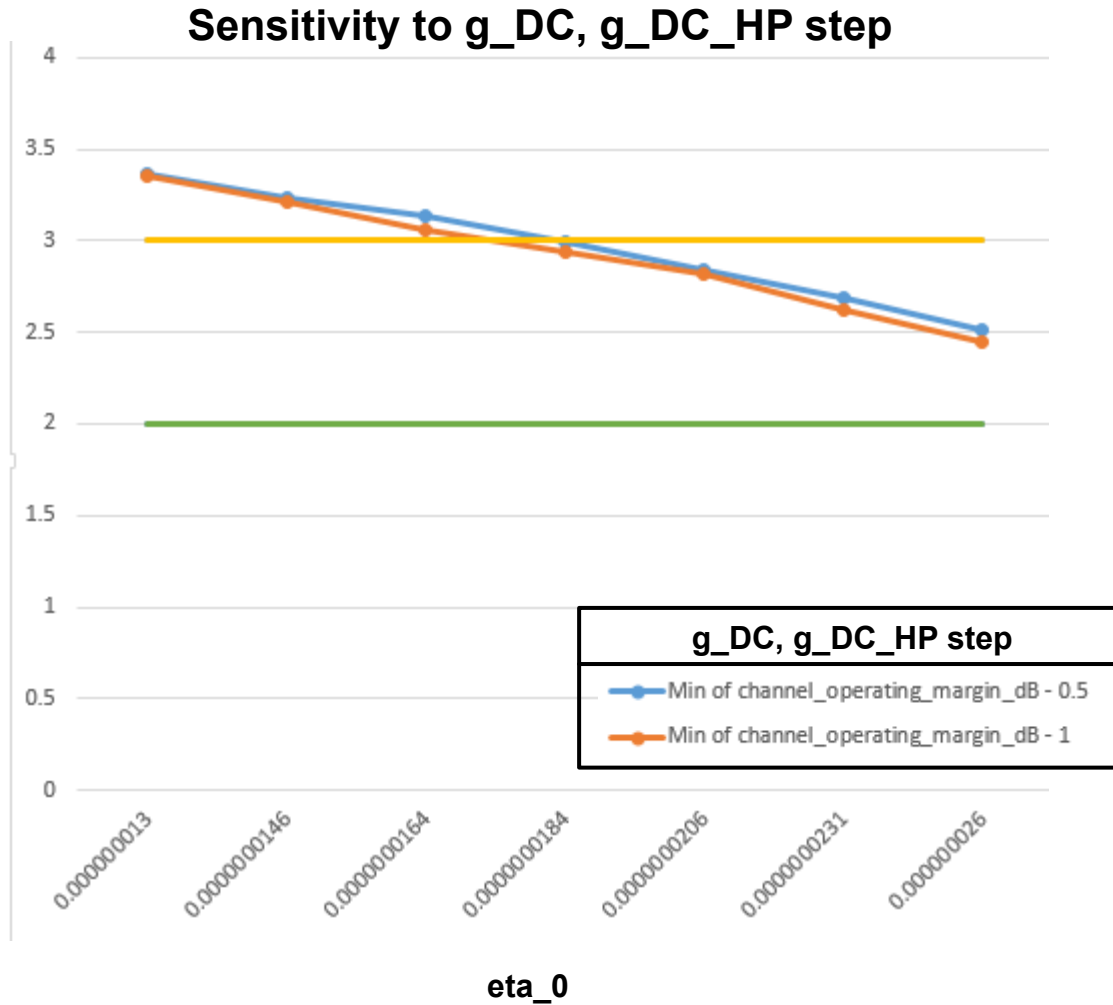
		3 m Cables						
		TE Connectivity			Amphenol	Generic	Molex	FCI
Cable Gauge		26 AWG	28 AWG	30 AWG	26 AWG	26 AWG	26 AWG	26 AWG
	Insertion Loss @ NQ, dB	27.5009	30.0043	32.1525	28.8481	28.8481	27.2336	27.9278
	FOM_ILD	0.19026	0.27513	0.23573	0.2976	0.2976	0.1363	0.18498
	ICN, mV	0.62665	0.46826	0.42365	0.86665	1.5935	0.86358	0.49285
	Change Log	COM @ DER_0 = 1e-4						
1	Initial COM parameters	4.1242	2.926	1.841	2.6743	2.1026	3.9309	4.0685
2	+ T_r filter : 13 ps Gaussian w/ beta = 2	3.2735	2.0915	0.87663	1.9057	1.4116	3.223	3.2609
3	+ C_d = 180 fF; c(-2) = [0:0.025:0.1]; g_DC(min) = -22; g_DC_HP(min) = -8	4.1662	2.8413	1.841	2.7693	2.1359	4.0408	4.027
4	+ eta_0 = 1.3e-08; N_b = 12; b_max(1) = 1; b_max(2..N_b) = 0.2	5.0673	4.1102	3.5305	3.8358	3.098	4.8978	4.8978
5	+ g_DC(min) = -20; g_DC_HP(min) = -6; 0.5 dB step size; b_max(2..N_b) = 1	5.0673	4.1522	3.5436	3.8358	3.1105	5.0053	4.9283
6	+ eta_0 = 1.64e-08; SNR_TX = 32.5; b_max(1)=0.7; b_max(2..N_b)=0.2	5.1927	4.1943	3.4139	3.8764	3.1353	5.1927	5.0829
7	+ eta_0 = 1.84e-08; SNR_TX = 33.4;	5.2561	4.1802	3.3116	3.89	3.1478	5.2561	5.1612

TE Connetivity, Amphenol and FCI data from their respective contributions to [IEEE P802.3by Task Force](#). Molex data from their contribution to [IEEE 802.3 50G/NGOATH Ethernet Study Groups](#). Results include transmitter and receiver host board models.

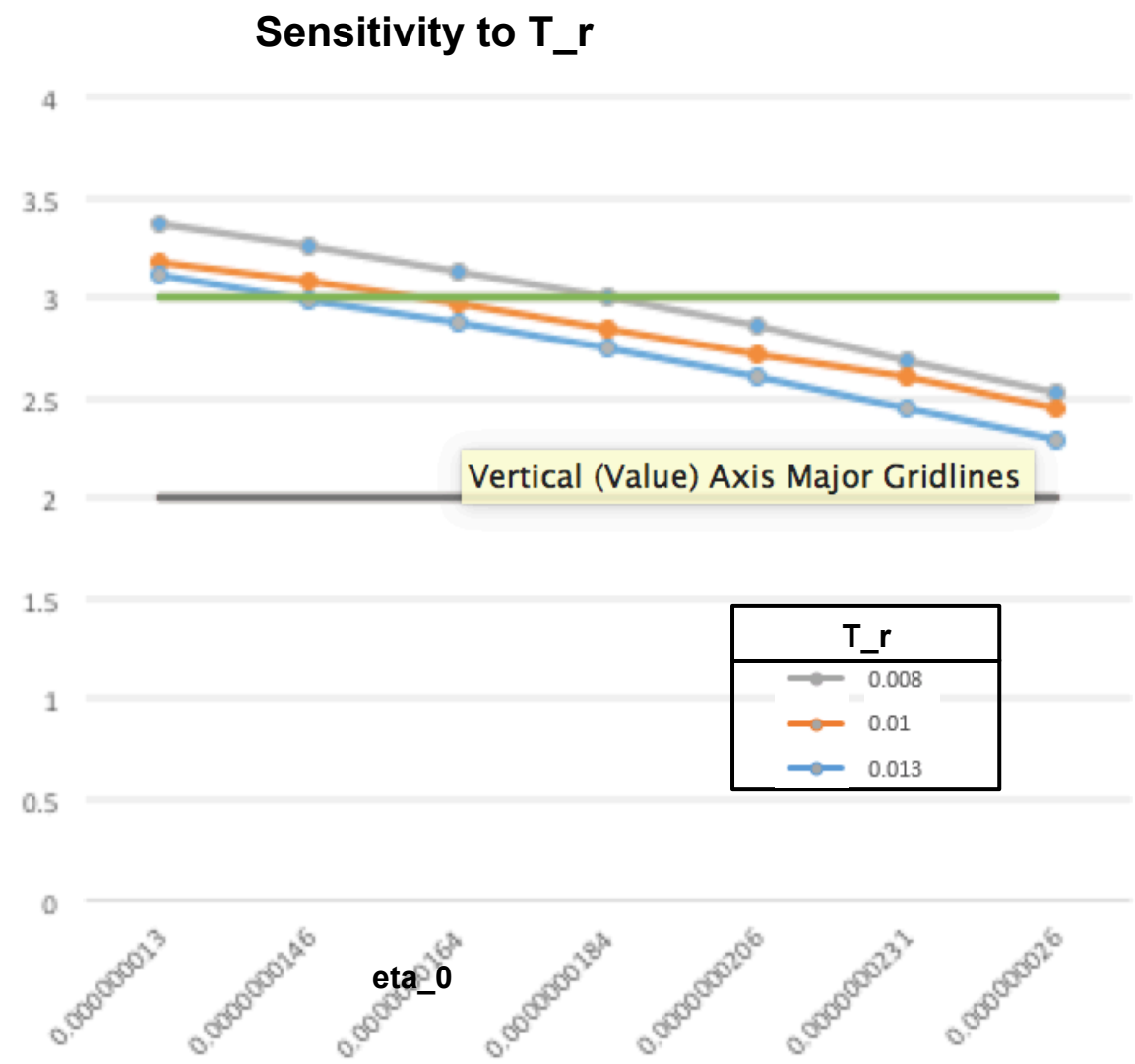
Sensitivity analysis for Ch8 (~30 dB)



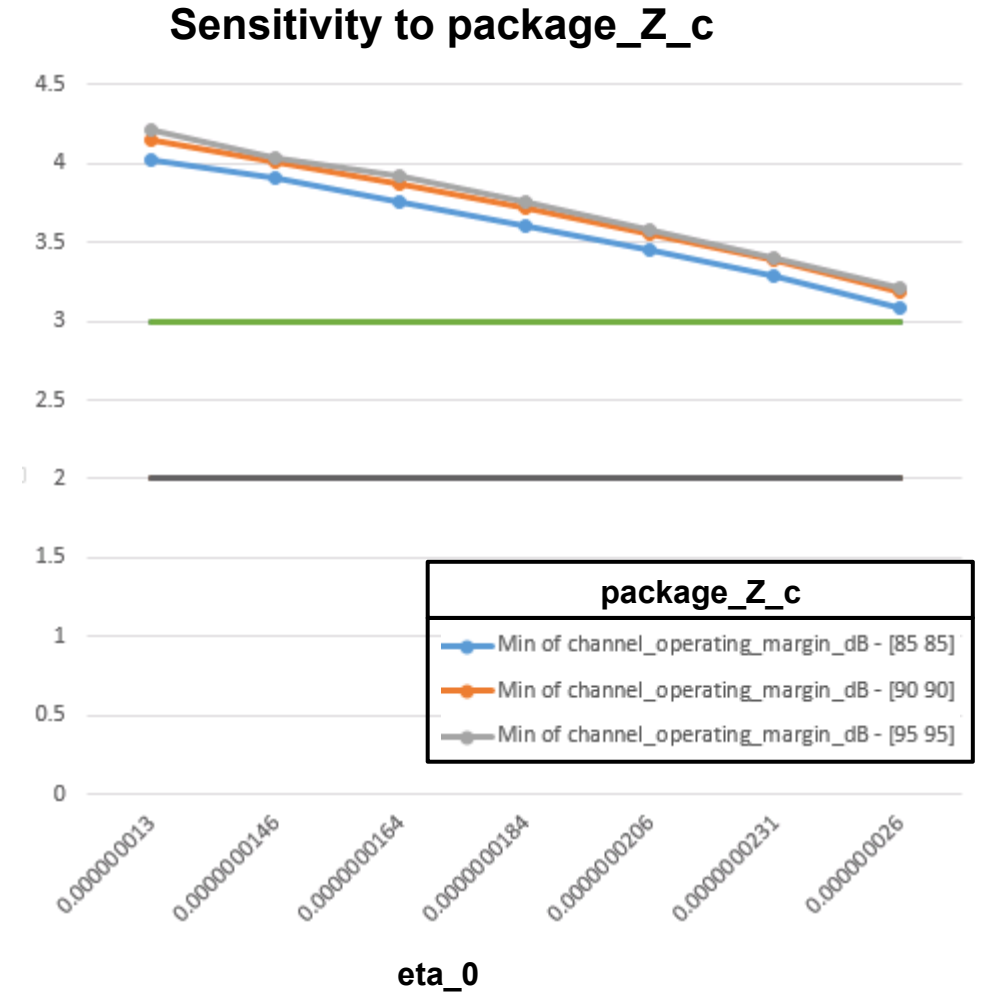
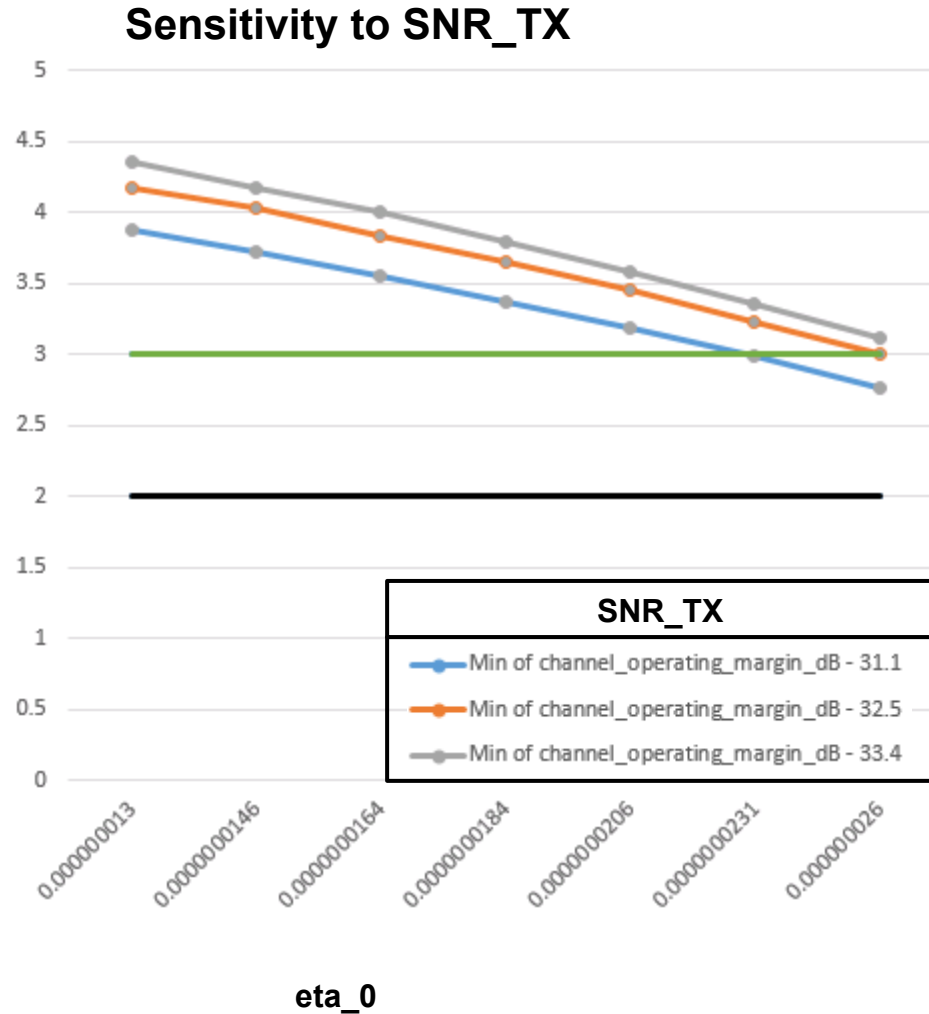
Sensitivity analysis for Ch8 (~30 dB), continued



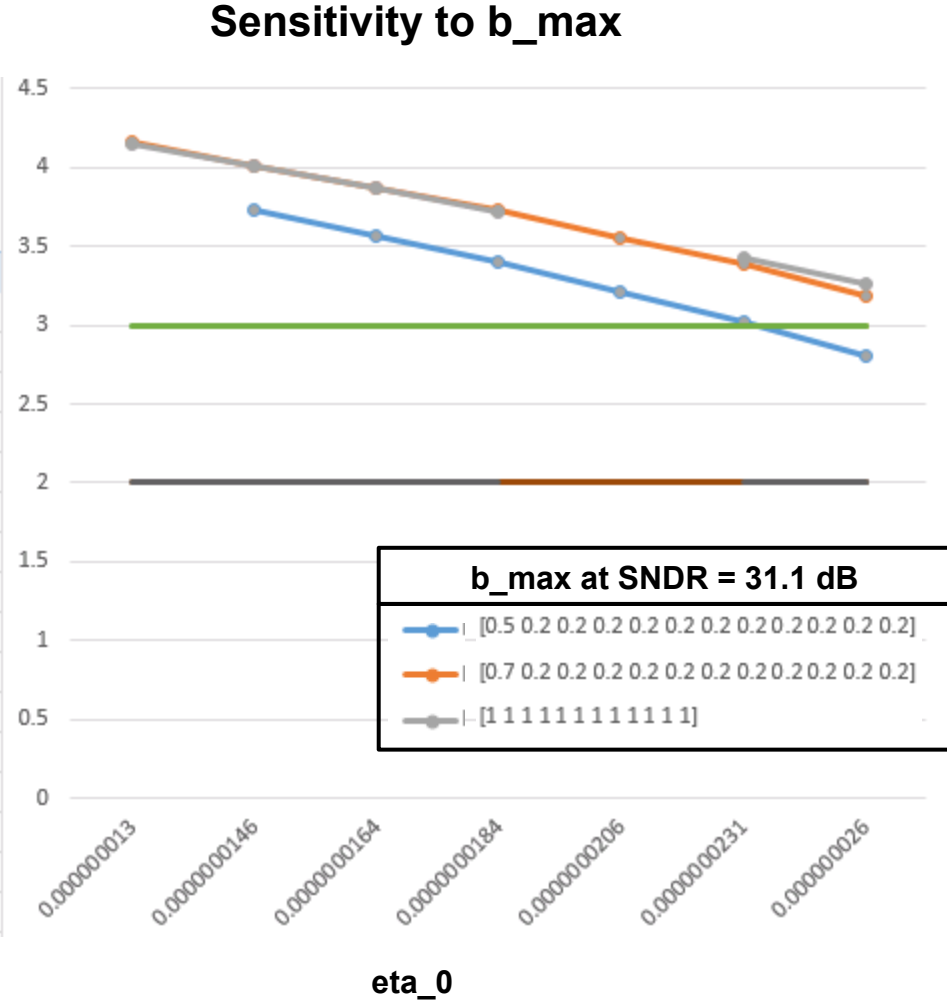
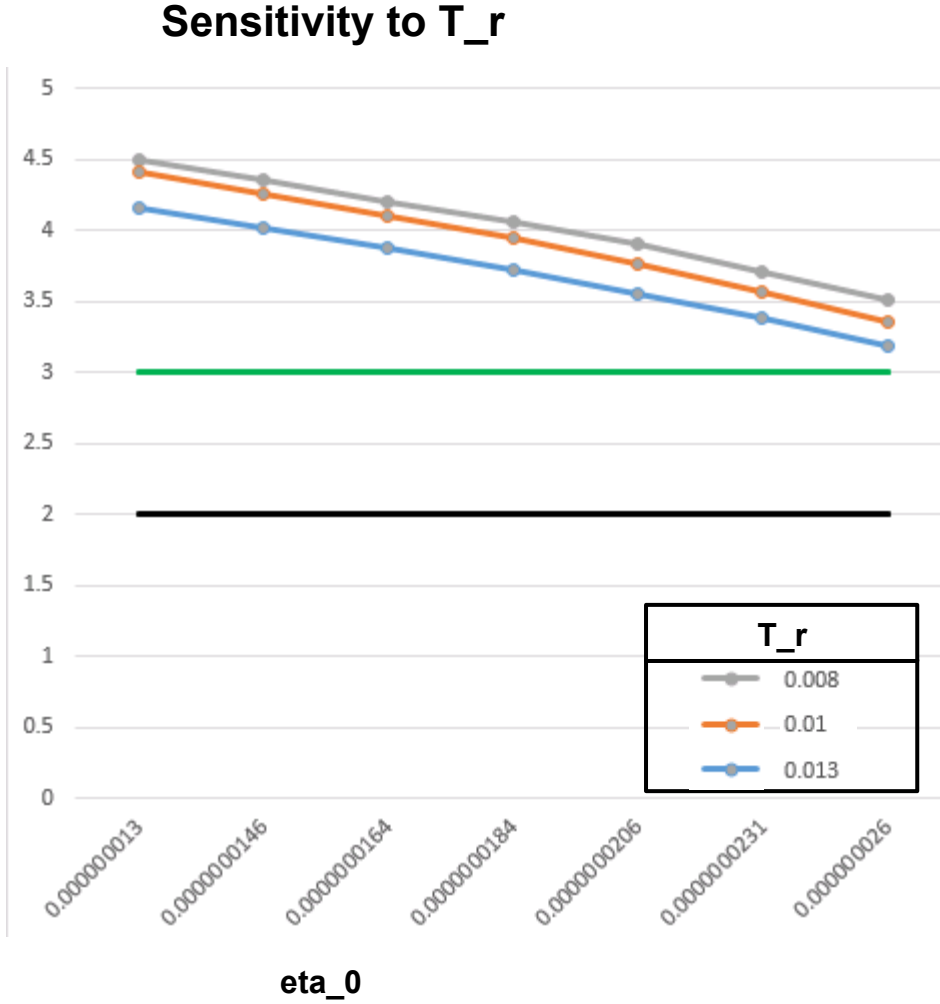
Sensitivity analysis for Ch8 (~30 dB), continued



Sensitivity analysis for TE 3m 28 AWG (~30 dB)



Sensitivity analysis for TE 3m 28 AWG (~30 dB), continued



Summary of observations

- Enhancements to equalization were considered
 - Biggest gains from new $c(-2)$ range, increasing $b_{\max}(1)$ to 0.7, extending range for g_{DC} and $g_{\text{DC_HP}}$ (only to a point), and increasing N_b to 12 (mostly to curb residual package reflection)
 - Small (or no) benefit for further relaxation of DFE constraints, higher g_{DC} and $g_{\text{DC_HP}}$ resolution, or higher N_b (unless N_b becomes large)
- Reductions in noise were considered and significant gains shown
 - SNR_{TX} reduction implies more stringent transmitter requirements
 - Reduction in η_0 is no different than a reduction in the COM limit – they both imply larger broadband noise amplitudes for the receiver interference tolerance test

Summary of observations, continued

- Other factors
 - Changing package Z_c from 85 to 90 Ohms shows a visible benefit
 - However, there is little value in pushing it further
 - Similar observations made for C_p (not presented)
- A solution suitable for 30 dB backplane seems more than adequate for 3 m direct attach copper cables
- Results indicate a solution does exist
 - Trade-offs between transmitter, channel, and receiver requirements must be carefully considered as we work toward a baseline proposal

New basis for further work?

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]		[test cases to run]
z_p (TX)	[30]	mm	[test cases]
z_p (NEXT)	[12]	mm	[test cases]
z_p (FEXT)	[30]	mm	[test cases]
z_p (RX)	[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]
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	1.00E+99	GHz	
A_v	0.45	V	
A_fe	0.45	V	
A_ne	0.63	V	
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	TBD (2.60E-08)	V ² /GHz	
SNR_TX	TBD (31.1)	dB	
R_LM	0.95		
DER_0	1.00E-04		
Operational control			
COM Pass threshold	3	dB	
Include PCB	0	Value	0, 1, 2
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
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\COM50_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 2 3 4]	
RUNTAG	_CDAUI-8	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	1.30E-02	ns
T_r_filter_type	1	logical
T_r_meas_point	0	logical

Non standard control options		
INC_PACKAGE	1	logical
IDEAL_RX_TERM	0	logical
INCLUDE_CTL	1	logical
INCLUDE_TX_RX_FILTER	1	logical
COM_CONTRIBUTION	0	logical
CDR_OVERSAMPLED	0	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

Table 92-12 parameters		
Parameter	Setting	Units
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

Thanks !!