Mitigating Interaction Problems of Impedance Matching between Channel and Rx (#70/71/72/113)

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Overview

- Interaction Problems of Z Matching between Channel and Rx
  - Difficult to test Channel in the worst case for unknown Rx impedance
  - Difficult to test Rx in the worst case for unknown Channel impedance
    - Impedance matching significantly affects the performance (e.g. COM value)
    - Impedance variation is inevitable in actual manufacturing
  - These problems have been discussed in P802.3cd since last November

- Two Proposals to Mitigate these Problems (need both)
  - Use nominal values for COM impedance parameters (i.e. Rd and Zc)
    - Tighten Channel Variation
  - Specify return loss (RL) of test channel for Rx Interference Tolerance Test
    - Tighten Rx Variation
    - Ensure some margin for interoperability

- This presentation is a summary of three presentations in Ad Hoc
  - hidaka_061417_3cd_01_adhoc.pdf : nominal values for COM Z parameters
  - hidaka_061417_3cd_02_adhoc-v2.pdf, hidaka_070517_3cd_01_adhoc.pdf : RL of test channel for Rx ITT

Nominal Values for COM Z Parameters (Rd, Zc)

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- Regardless of whether interoperability margin is enough or not, there are problems to use high Rd and low Zc
  - Problems to use high Rd and low Zc
    - It is not the worst case at all
    - It is biased positive (favoring) to some channels, negative (penalizing) to some channels, and neither positive nor negative to many channels
      - It increases variation of channel characteristics, degrading margin for interoperability
    - It gives misleading impression and illusion of max impedance tolerance
  - Advantages to use nominal Rd and nominal Zc
    - It is not biased to any channels
      - It reduces variation of channel characteristics, improving margin for interoperability
    - It gives a warning that max impedance tolerance is not specified
- COM value will be slightly adjusted so that change of Rd and Zc generally will not affect pass/fail status of existing channels

Tightening Variation by Nominal Reference

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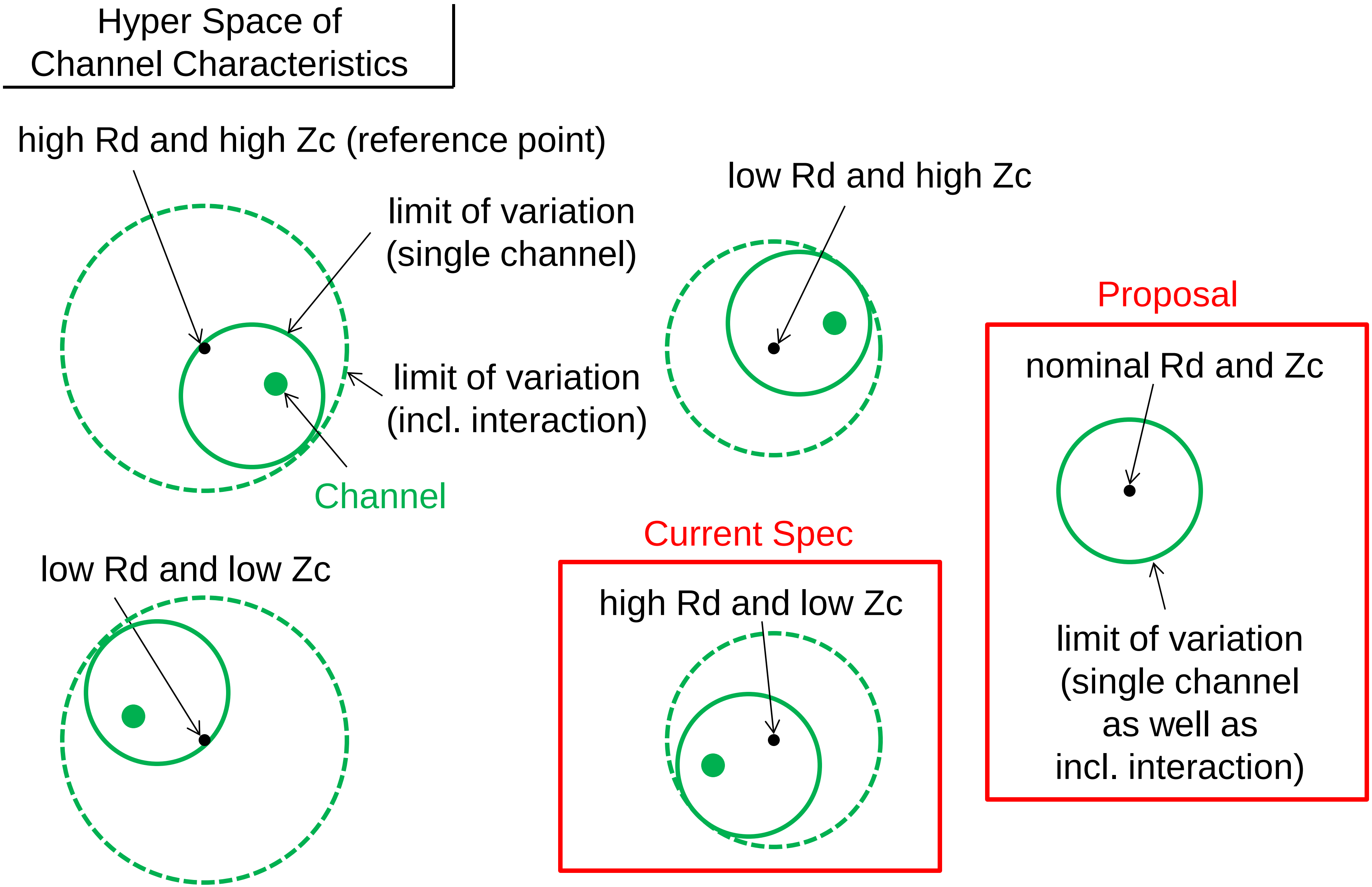

Return Loss (RL) of Test Channel for Rx ITT

- In Clause 93, RL of test channel for Rx ITT was specified to meet EQ (93-2)
  - EQ (93-2) is RL of test fixture, that is rather good
  - With good RL of test channel, broadband noise (BBN) is always injected
  - *Overstress* of BBN may be one reason of ample interoperability margin of existing 25G NRZ SerDes
    - BBN (a.k.a. Gaussian noise) has *infinite* range of noise-amplitude distribution
    - Reflection and crosstalk have *limited* range of noise-amplitude distribution

- Lack of RL spec of test channel for Rx ITT may seriously degrade interoperability margin of 50G PAM4 SerDes

- Since we defined RL of test channel as test-fixture grade for Clause 93, we should do the same in Annex 120D, Clause 137, and Clause 136
  - It is also feasible, because we just re-use the same RL mask

Conclusion

- Proposal 1 : Use nominal Rd and Zc values
  - Adjust Ave, Afe, Ane not to change vf value at TP0a
  - Adjust Channel COM generally not to affect pass/fail of existing channels

	Annex 120D	Clause 137	Clause 136
Rd	50 Ω	50 Ω	50 Ω
PKG Zc	95 Ω	95 Ω	95 Ω
PCB Zc	N/A	N/A	100 Ω
Av	0.418 V	0.415 V	0.415 V
Afe	0.418 V	0.415 V	0.415 V
Ane	0.604 V	0.604 V	0.604 V
Channel COM	3.1dB	3.0dB	3.3dB

- Proposal 2 : Specify return loss of test channel for Rx ITT by
  - EQ (93-2) for Annex 120D and Clause 137
  - EQ (92-38) for Clause 136

Back up Slides

- Effects of nominal Rd and Zc values on COM values
  - Simulation results not to affect pass/fail of existing channels
  - Reported in hidaka_061417_3cd_01_adhoc.pdf
- Feasibility to use EQ 92-38 for test channel of CL136
  - Reported in hidaka_070517_3cd_adhoc.pdf

COM Parameters for Clause 137 (Common)

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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)	[-0.15:0.05:0]		[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	
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	1.64E-08	V^2/GHz	
SNR_TX	32.5	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	0	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\V165_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	V164	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	1.20E-02	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
COM_CONTRIBUTION	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	
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

- Yellow cells were changed as the following slide

COM Parameters for Clause 137 (Difference)

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- Based on slide 10 of hidaka_060717_3cd_adhoc-v2.pdf
  - D2.0mod and Zc90/93/95/100 were calibrated at TP0a
  - D2.0mod is same as D2.0 except Tx amplitude for fair comparison

Label	D2.0	D2.0mod	Zc90	Zc93	Zc95	Zc100
R_d	55	55	50	50	50	50
Z_c	90	90	90	93	95	100
A_v	0.45	0.438	0.416	0.415	0.415	0.414
A_fe	0.45	0.438	0.416	0.415	0.415	0.414
A_ne	0.63	0.634	0.604	0.604	0.604	0.604
z_p	30	30	30	30	30	30

16 Channels for Simulation for Clause 137

Category	CH #	IL 13.28G	Description	Channel Data Source
A	8	30.1dB	Cisco Backplane	P802.3cd 50/100/200GbE TF (Cisco_Backplane_channel_data.zip)
B	23,24,25	~30dB	Intel 100Ω Backplane	50G/NGOATH Study Group (mellitz_01_021716_30dB_6_channels.zip)
C	38,39,40	~30dB	Intel 85Ω Backplane	
D	43	32.0dB	TE Backplane	P802.3cd 50/100/200GbE TF (TEC_STRADAWhisper40in_Meg6_*.zip)
E	46, 47	~30dB	Cavium Backplane	P802.3cd 50/100/200GbE TF (Cavium_30dB_H*.zip)
H	56	28.7dB	Amphenol FCI BP (Link 1)	P802.3cd 50/100/200GbE TF (Amphenol_Link_?.zip)
	57	29.6dB	Amphenol FCI BP (Link 2)	
	58	26.0dB	Amphenol FCI BP (Link 3)	
	59	29.6dB	Amphenol FCI BP (Link 4)	
	60	28.0dB	Amphenol FCI BP (Link 5)	
	61	29.8dB	Amphenol FCI BP (Link 6)	

- CH56,57,58 are claimed as not expected to pass

Results for Clause 137

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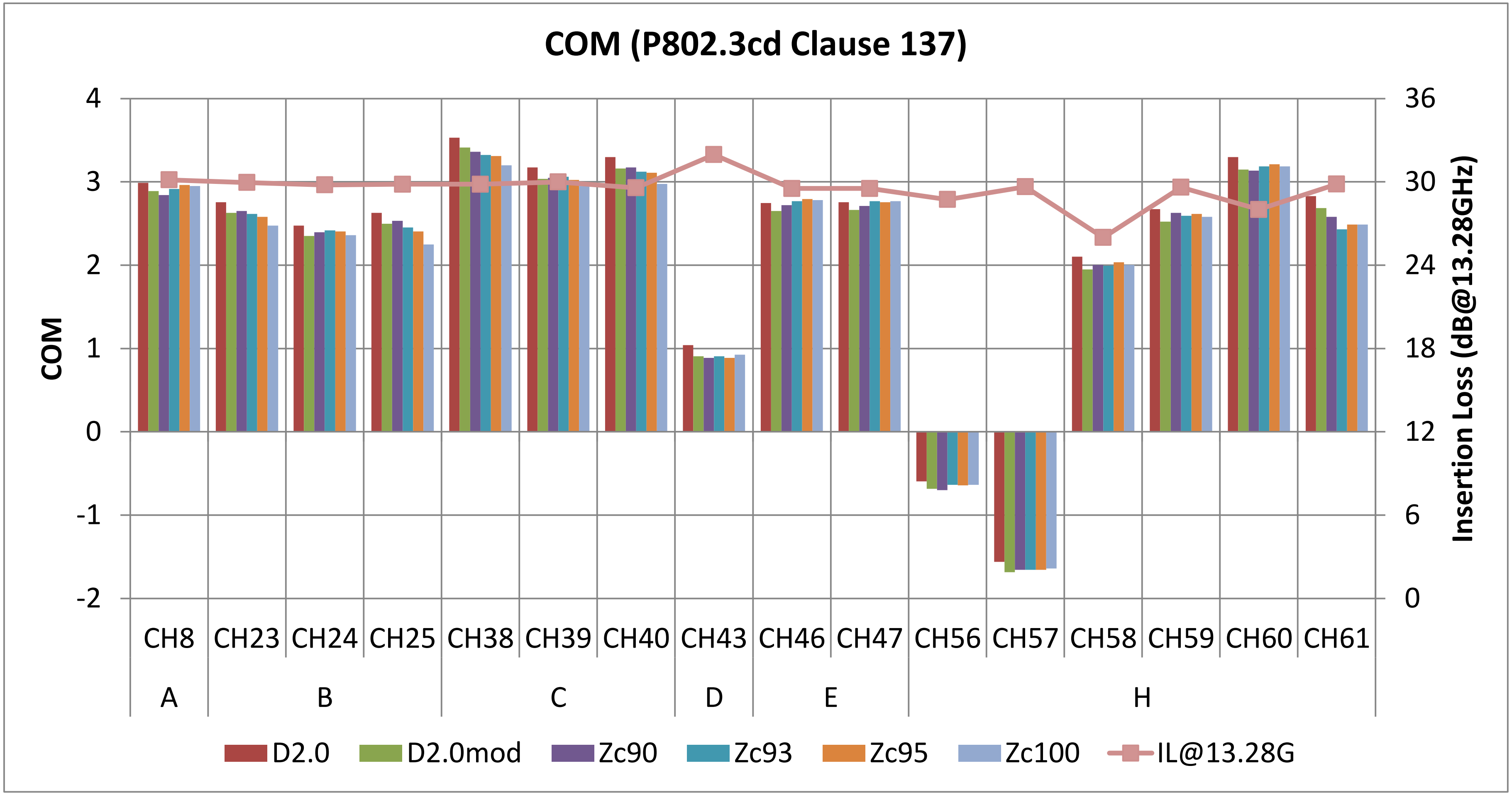

- Some channels have lower COM than others, mainly due to
  - CH43 : Extra insertion loss
  - CH56,57,58 : Extra crosstalk and extra reflection

Results for Clause 137 (ΔCOM from D2.0mod)

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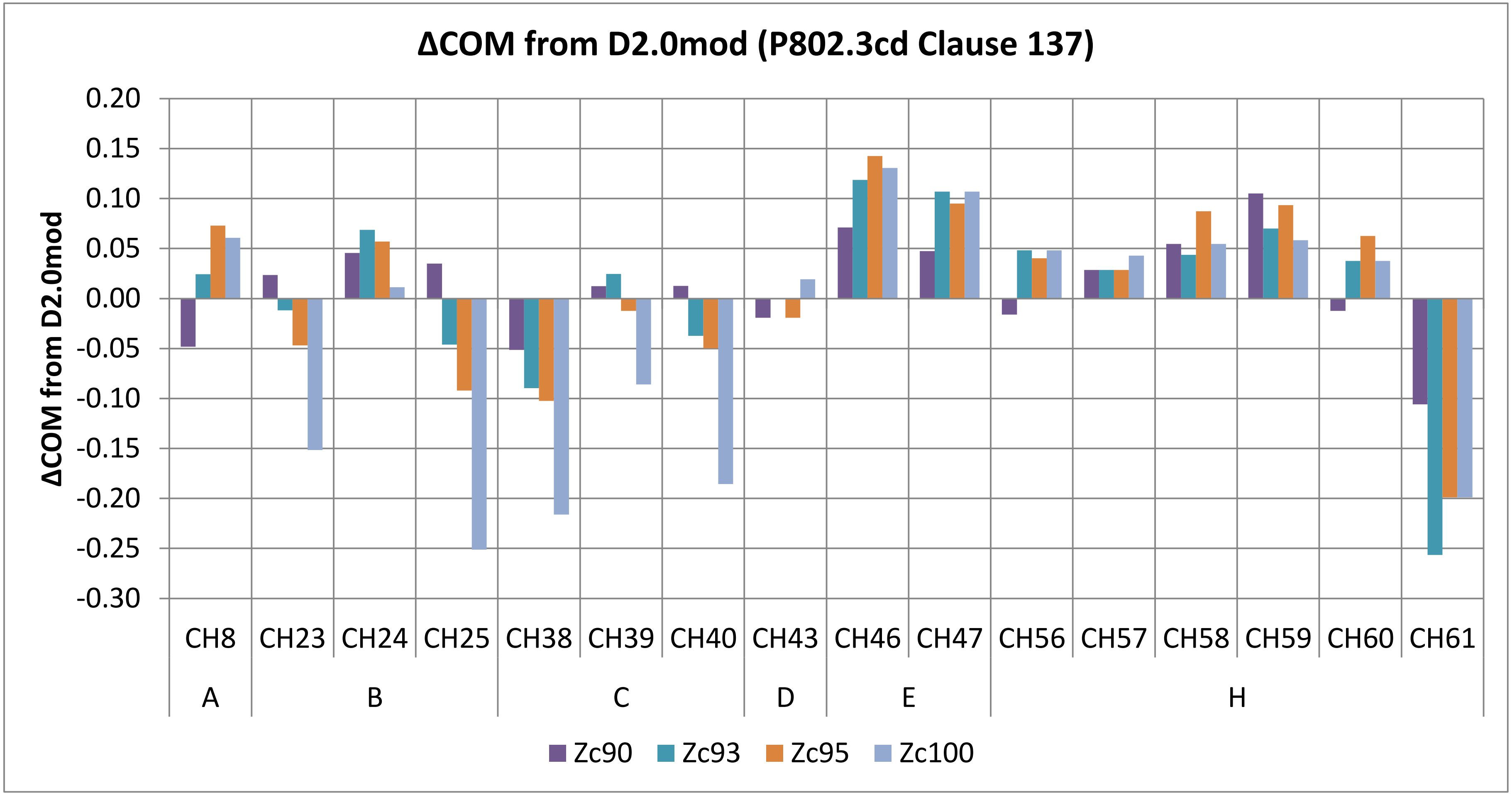

- Zc = 95Ω and COM = 3.0dB seems a reasonable choice
  - My proposal for Clause 137 is based on this result

COM Parameters for Clause 136 (Common)

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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)	[-0.15:0.05:0]		[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	
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	1.64E-08	V^2/GHz	
SNR_TX	32.5	dB	
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	1	logical
DISPLAY_WINDOW	0	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	.\results\V165_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	V164	
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
COM_CONTRIBUTION	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	
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

- Yellow cells were changed as the following slide

COM Parameters for Clause 136 (Difference)

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- Based on slide 12 of hidaka_060717_3cd_adhoc-v2.pdf
  - D2.0mod and Zc90/93/95/100 were calibrated at TP0a per Clause 136A
    - Assuming Tx spec of Clause 136 will be calibrated to align with Clause 136A
  - D2.0mod is same as D2.0 except Tx amplitude for fair comparison

Label	D2.0	D2.0mod	Zc90	Zc93	Zc95	Zc100
R_d	55	55	50	50	50	50
PKG Z_c	90	90	90	93	95	100
PCB Z_c	109.8	109.8	100	100	100	100
A_v	0.45	0.438	0.416	0.415	0.415	0.414
A_fe	0.45	0.438	0.416	0.415	0.415	0.414
A_ne	0.63	0.634	0.604	0.604	0.604	0.604
z_p	30	30	30	30	30	30

18 Channels for Simulation for Clause 136

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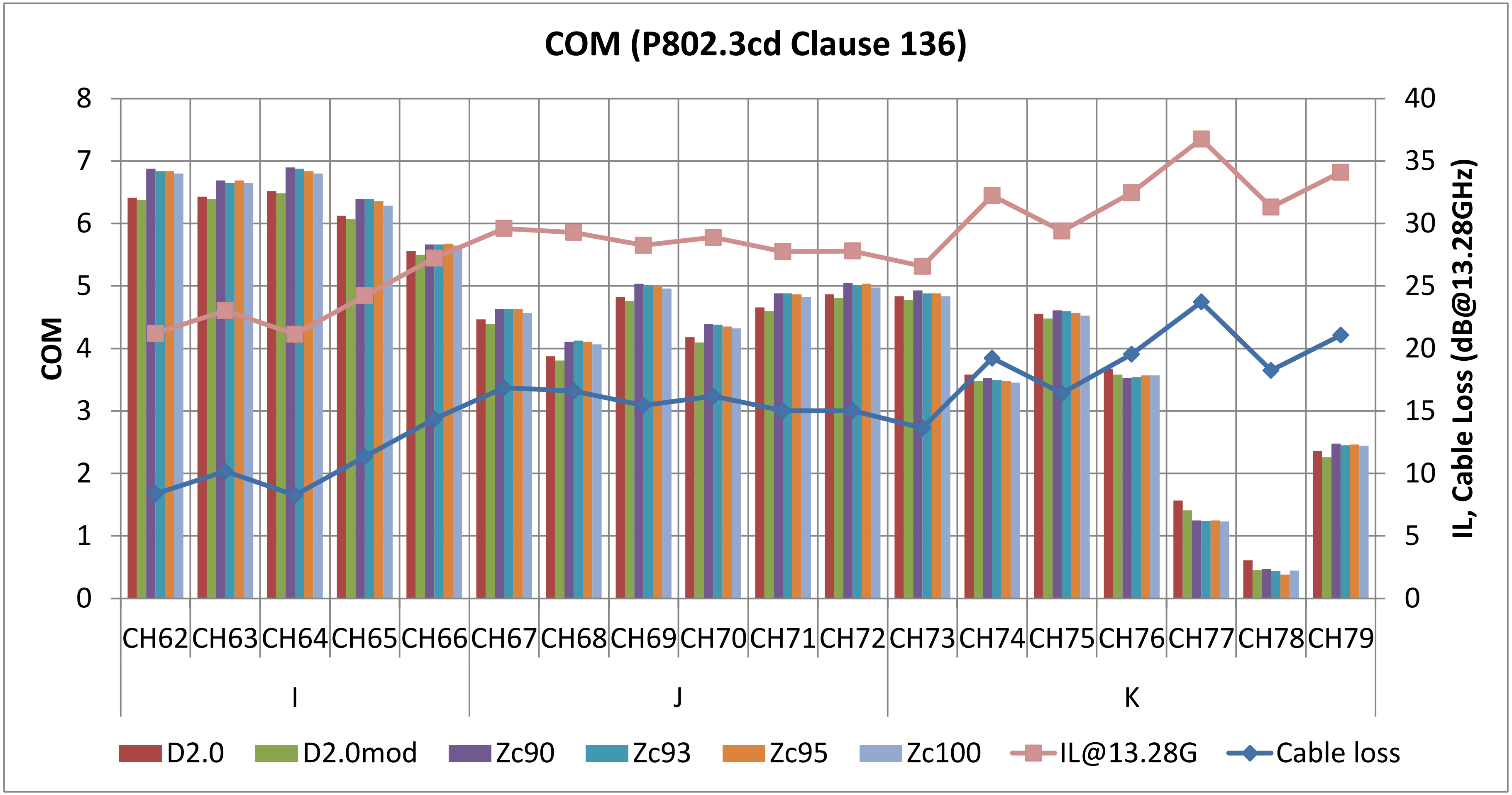
Category	CH #	Cable Loss 13.28G	Description	Channel Data Source
I	62	8.4dB	Molex zQSFP (.5m AWG32)	50G/NGOATH Study Group (Molex_zQSFP-zQSFP_*.zip)
	63	10.2dB	Molex zQSFP (1m AWG30)	
	64	8.3dB	Molex zQSFP (1m AWG26)	
	65	11.3dB	Molex zQSFP (2m AWG26)	
	66	14.4dB	Molex zQSFP (3m AWG26)	
J	67,68	~17dB	TEC QSFP (3m AWG26)	P802.3by 25GbE TF (TE_QSFP_QSFP_3m_*.zip)
	69,70	~16dB	TEC QSFP (3m AWG25)	
	71,72	~15dB	TEC QSFP (3m AWG24)	
K	73	13.6dB	Molex zQSFP (2m AWG30)	P802.3bj 100GbE Cu TF (bugg_02_0511.zip)
	74	19.2dB	Molex zQSFP (3m AWG30)	
	75	16.4dB	Molex zQSFP (3m AWG26)	
	76	19.5dB	Molex zQSFP (4m AWG26)	
	77	23.7dB	Molex zQSFP (5m AWG26)	
	78	18.2dB	Molex zQSFP (5m AWG24 A)	P802.3bj 100GbE Cu TF (cablea_bugg_0[23]_0312.zip)
	79	21.1dB	Molex zQSFP (5m AWG24 B)	

Results for Clause 136



- All cables up to 4 meter significantly exceed 3dB COM
  - CH77, 78, 79 are 5 meter cables

Results for Clause 136 (ΔCOM from D2.0mod)

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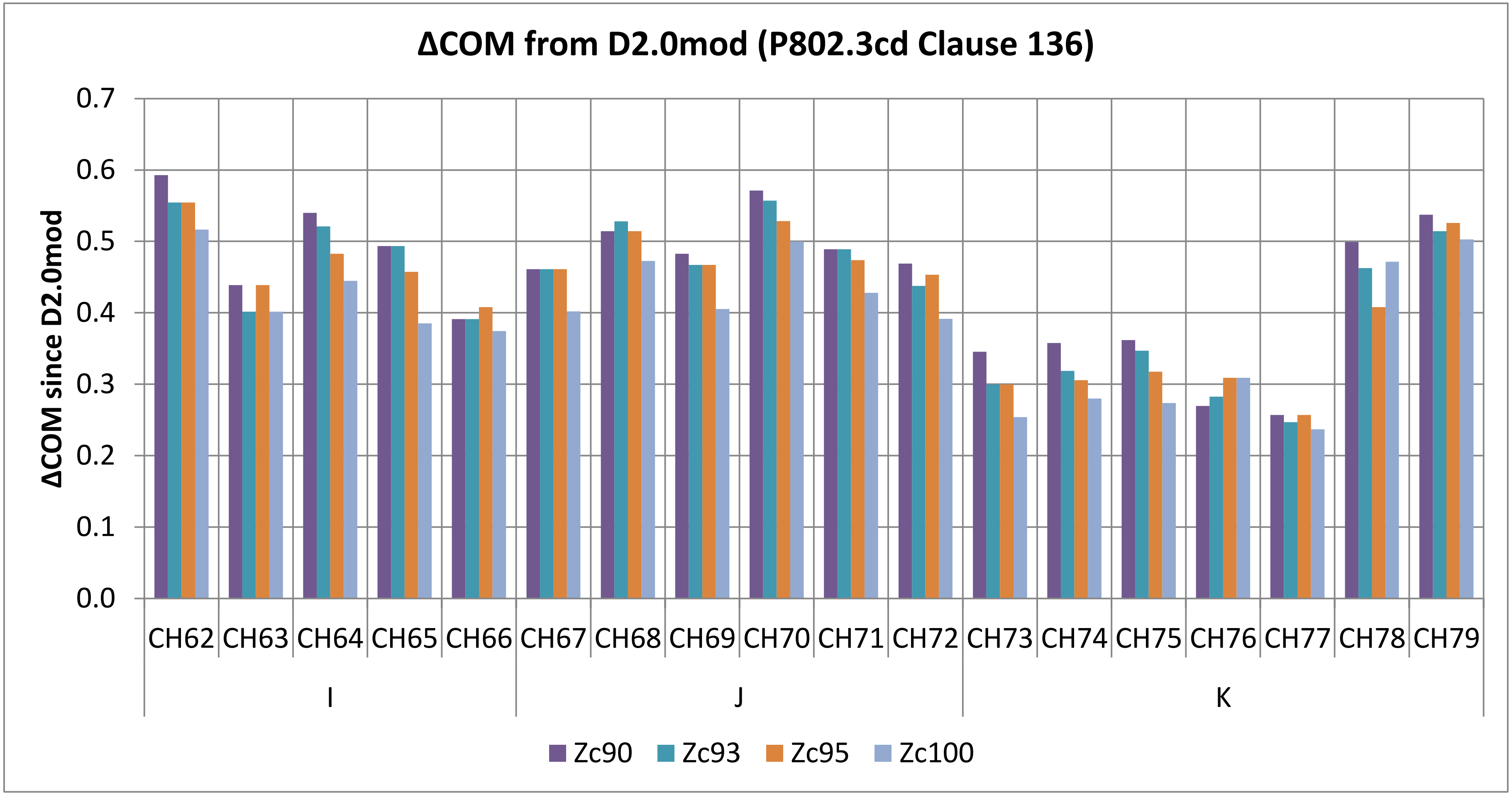


- Zc = 95Ω and COM = 3.3dB seems a reasonable choice
  - My proposal for Clause 136 is based on this result

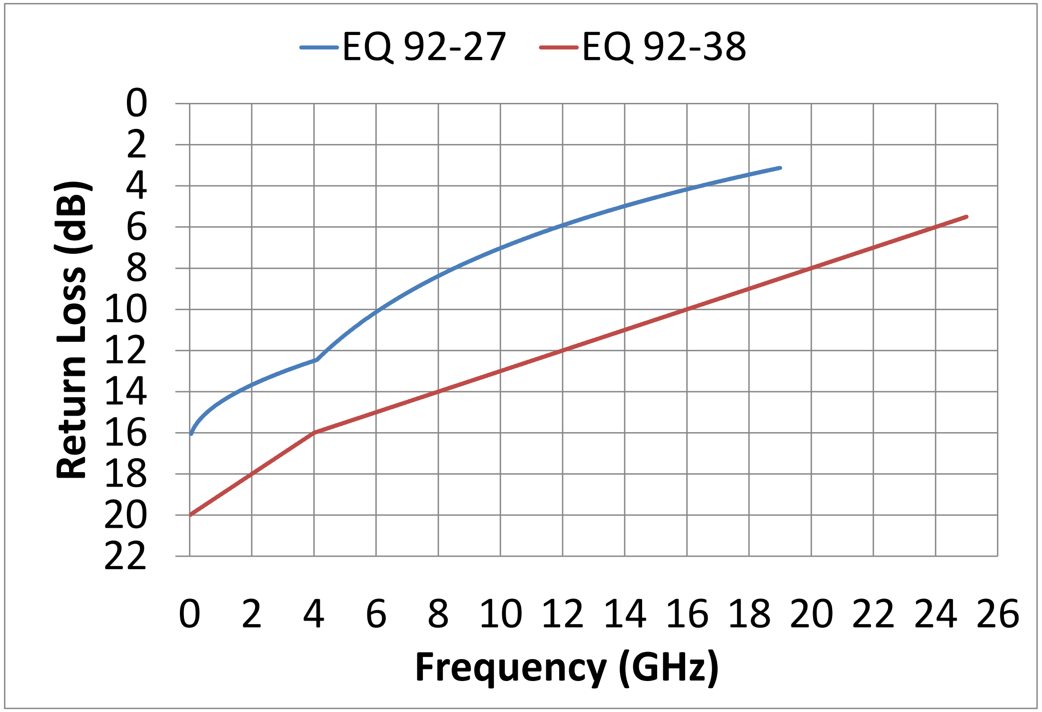
EQ 92-27 vs EQ 92-38

- EQ 92-27 : cable assembly differential return loss

$$Return\_Loss(f) \geq \begin{cases} 16.5 - 2\sqrt{f} & 0.05 \leq f < 4.1 \\ 10.66 - 14\log_{10}(f/5.5) & 4.1 \leq f \leq 19 \end{cases}$$

- EQ 92-38 : mated test fixture differential return loss

$$Return\_Loss(f) \geq \begin{cases} 20 - f & 0.01 \leq f < 4 \\ 18 - 0.5f & 4 \leq f \leq 25 \end{cases}$$



Test Data for Feasibility Study

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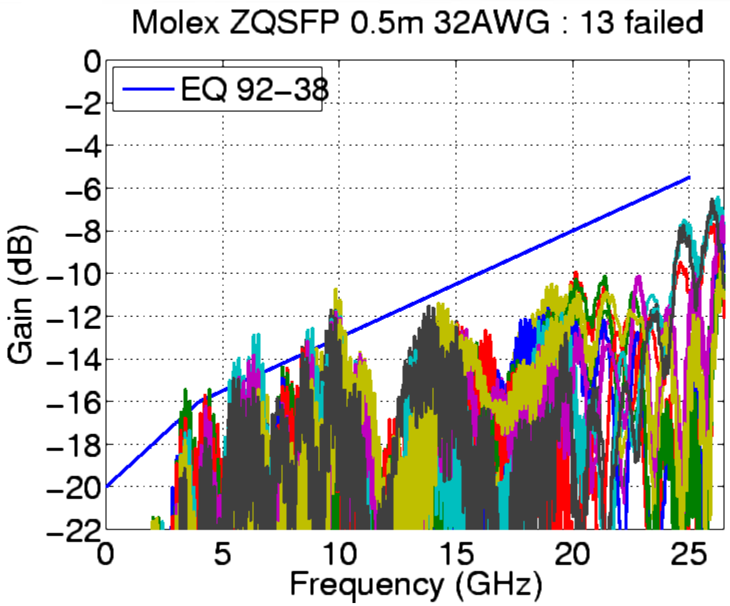
- Molex zQSFP to zQSFP cable data
  - Measured between TP1 and TP4 using MCBs at both ends
  - Contribution to 50G and NGOATH Study Group by Chris Roth (Molex)
  - http://www.ieee802.org/3/50G/public/channel/index.html
- 5 cable types (8 THRU channels for each cable type)

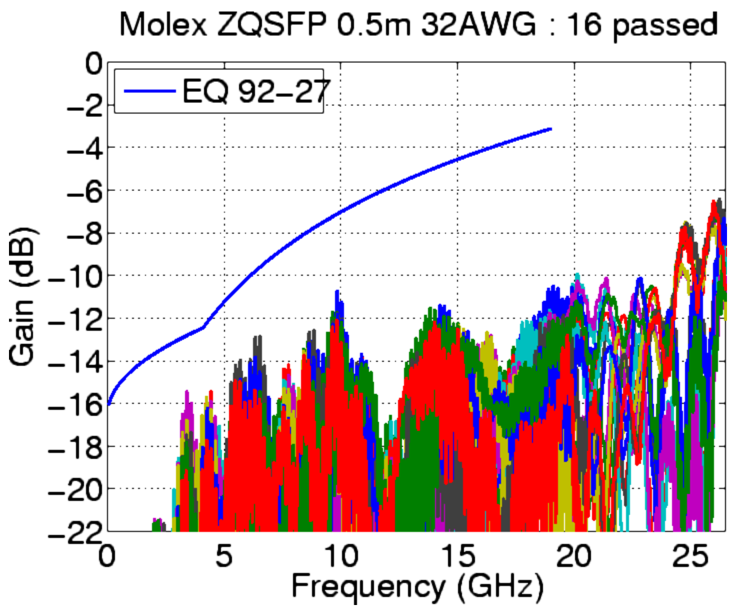
Type		Insertion Loss at 13.28GHz (dB)			Relevant Rx ITT Test Column in Table 136-13
		min	typ	max	
A	0.5 meter 32 AWG	8.2360	8.4142	8.7035	Test 1 (8-10dB)
B	1 meter 30 AWG	9.9715	10.2465	10.5423	N/A
C	1 meter 26 AWG	7.9745	8.2035	8.3921	Test 1 (8-10dB)
D	2 meter 26 AWG	11.1135	11.3041	11.5613	N/A
E	3 meter 26 AWG	14.3190	14.4033	14.5195	Test 2 (14.06-16.06dB)

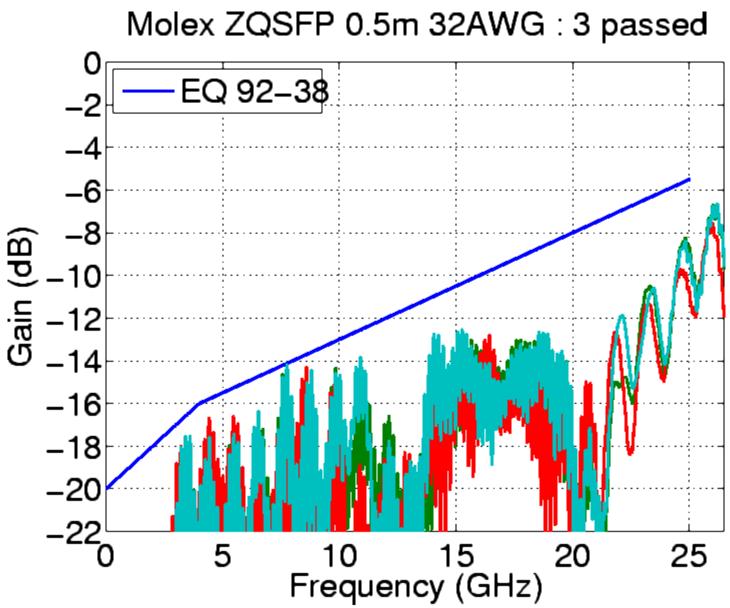
- Checked all 16 ports for each cable type
  - Checked both of S11dd and S22dd for each of all 8 THRU channels

Type A: 0.5 meter 32 AWG

- EQ 92-27 (graph below)
  - 0 failed, 16 passed
- EQ 92-38 (graphs on right)
  - 13 failed, 3 passed
    - Worst violation 2.3248 dB







Type B: 1 meter 30 AWG

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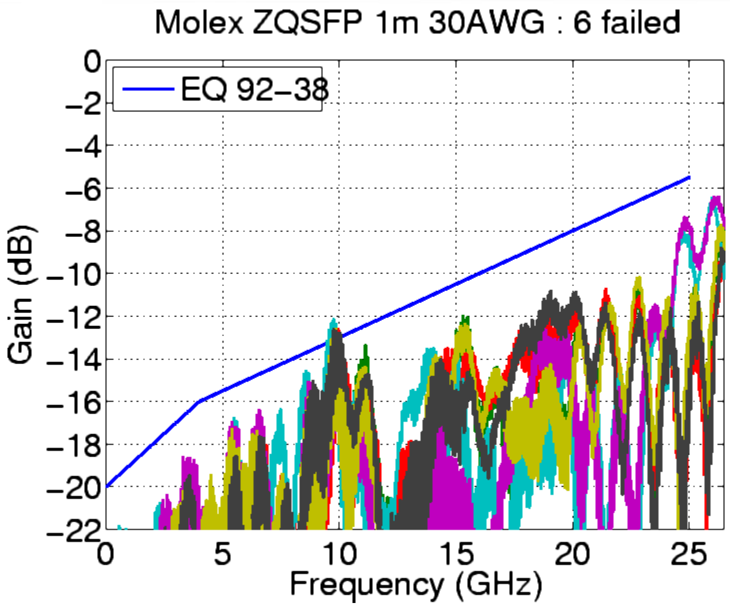
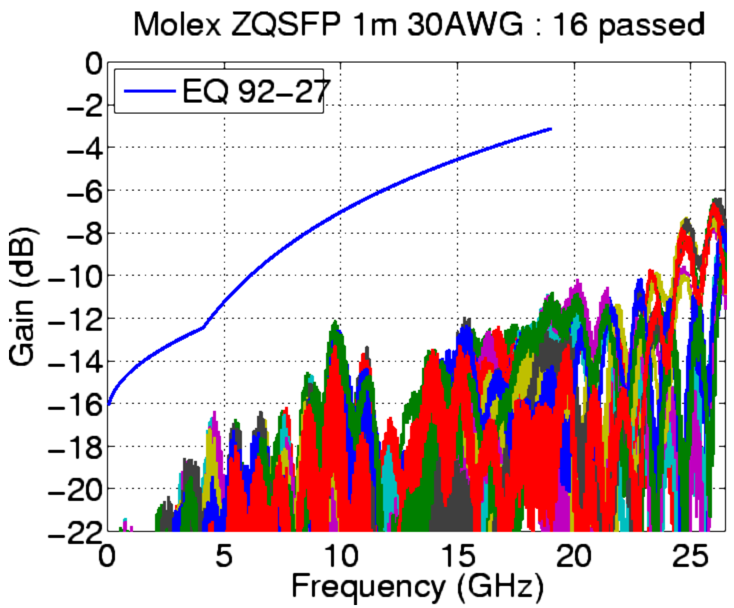
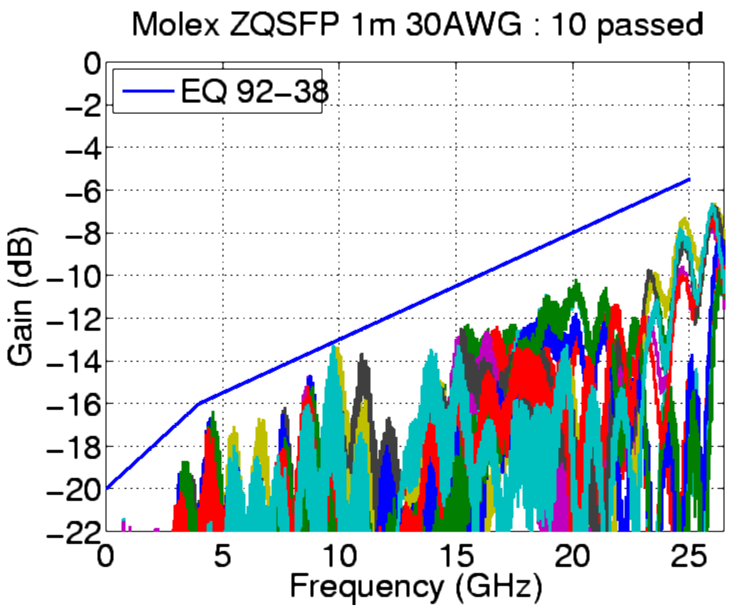
- EQ 92-27 (graph below)
  - 0 failed, 16 passed
- EQ 92-38 (graphs on right)
  - 6 failed, 10 passed
    - Worst violation 0.9652 dB







Type C: 1 meter 26 AWG

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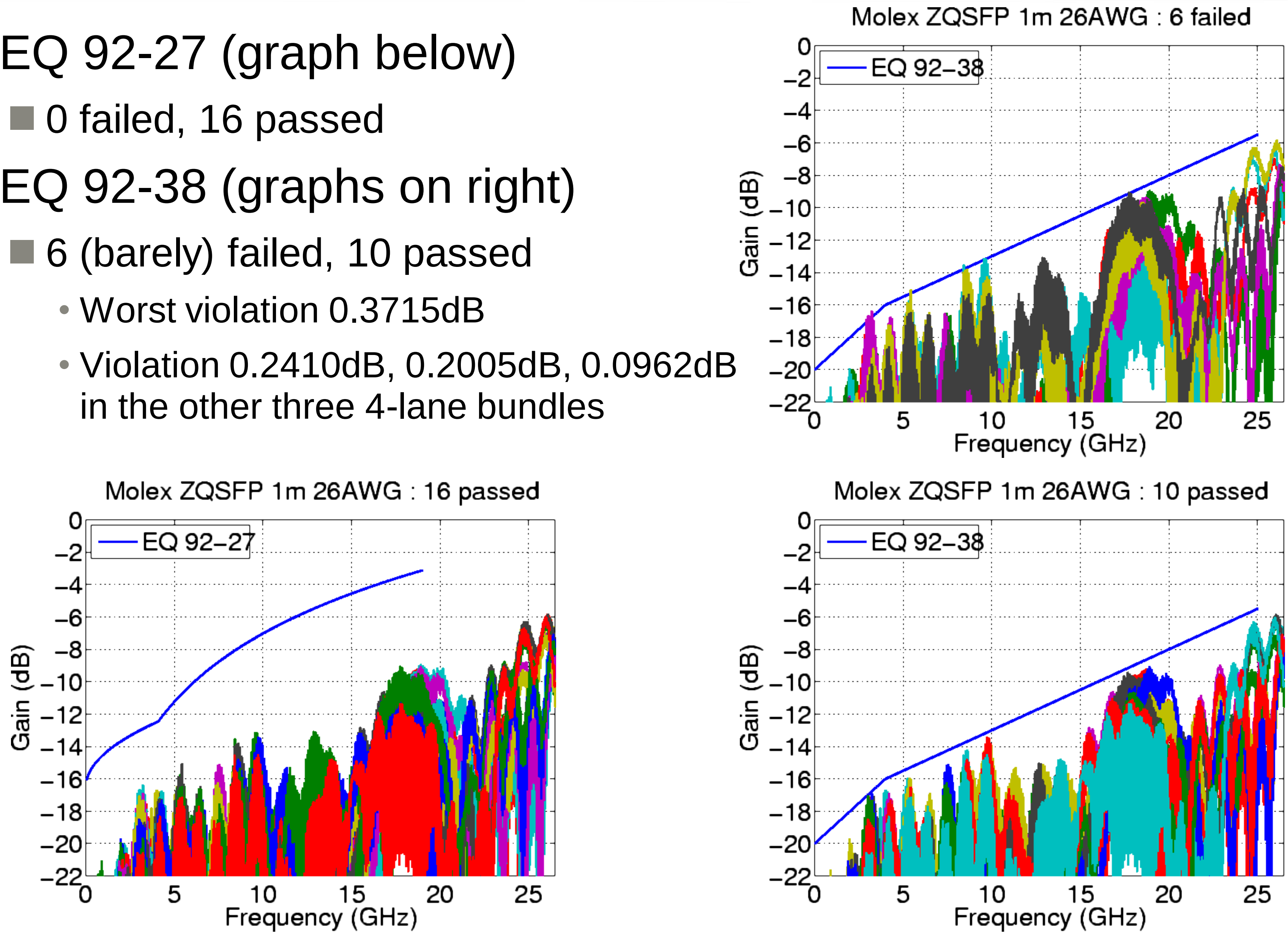
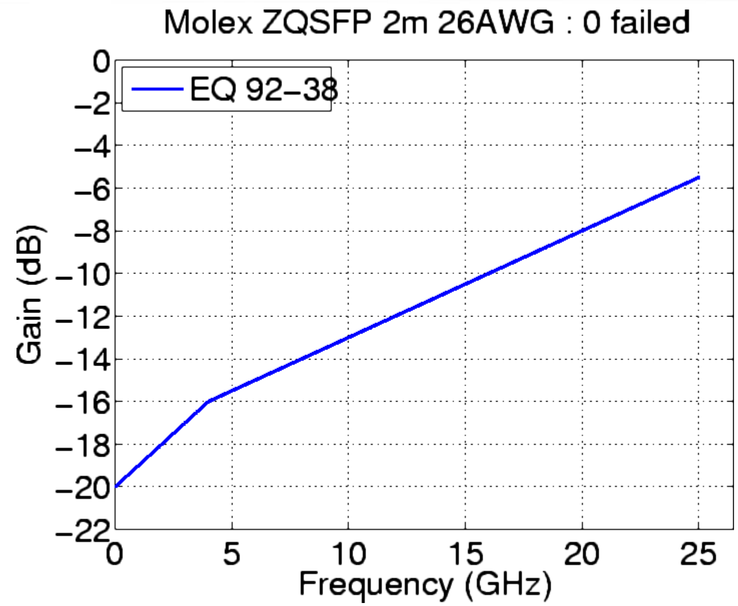
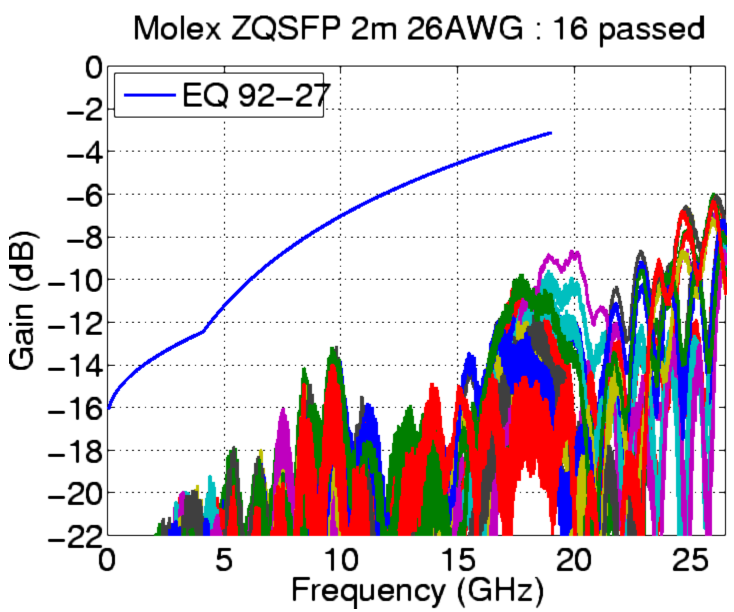
- EQ 92-27 (graph below)
  - 0 failed, 16 passed
- EQ 92-38 (graphs on right)
  - 6 (barely) failed, 10 passed
    - Worst violation 0.3715dB
    - Violation 0.2410dB, 0.2005dB, 0.0962dB in the other three 4-lane bundles

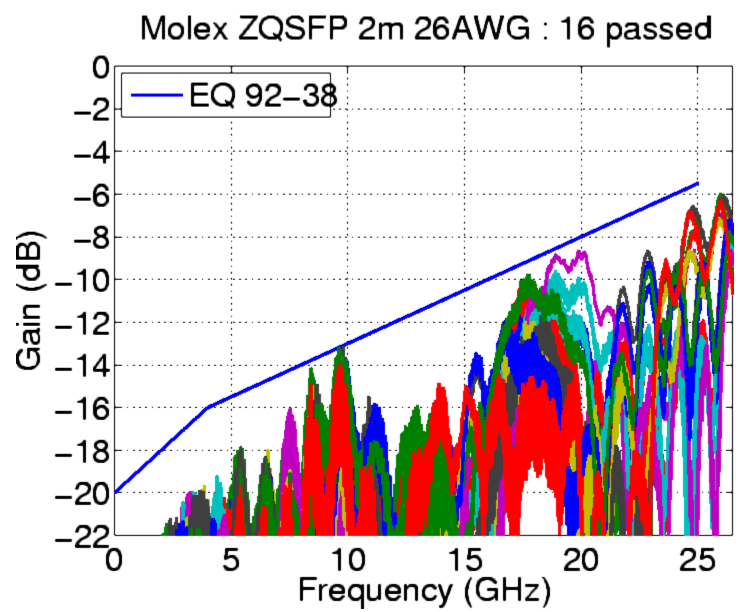


Type D: 2 meter 26 AWG

- EQ 92-27 (graph below)
  - 0 failed, 16 passed
- EQ 92-38 (graphs on right)
  - 0 failed, 16 passed

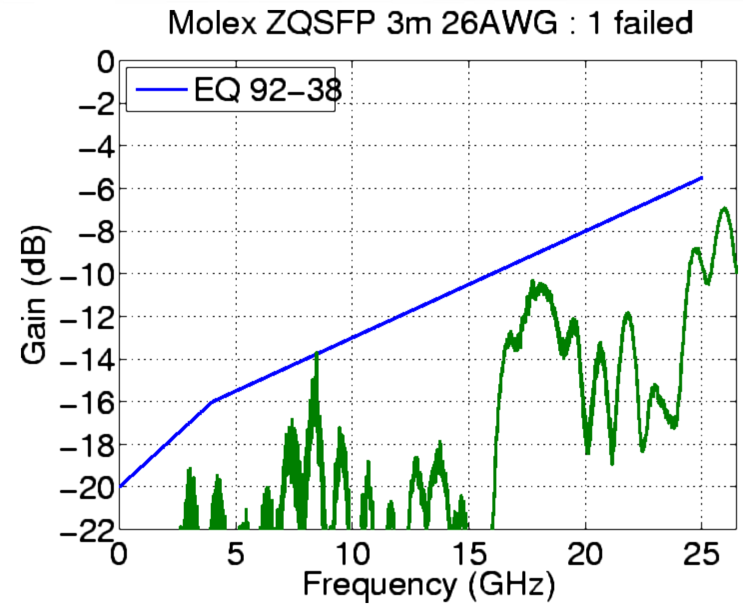


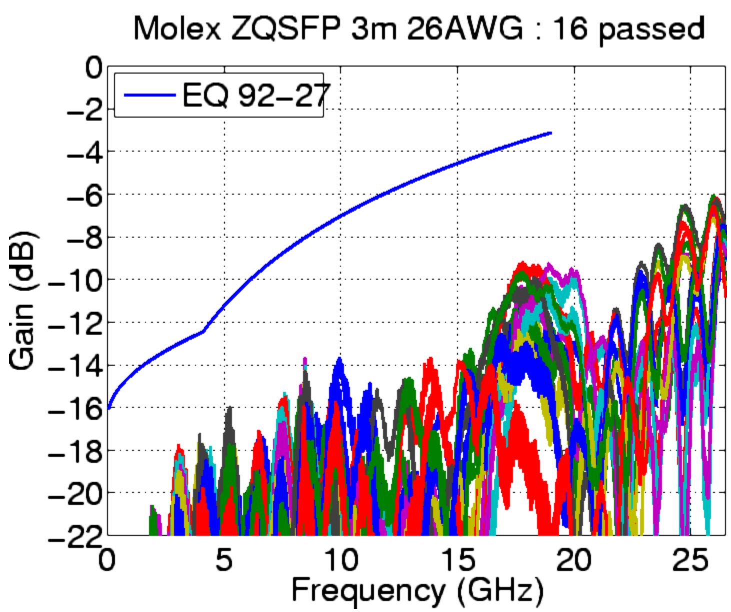


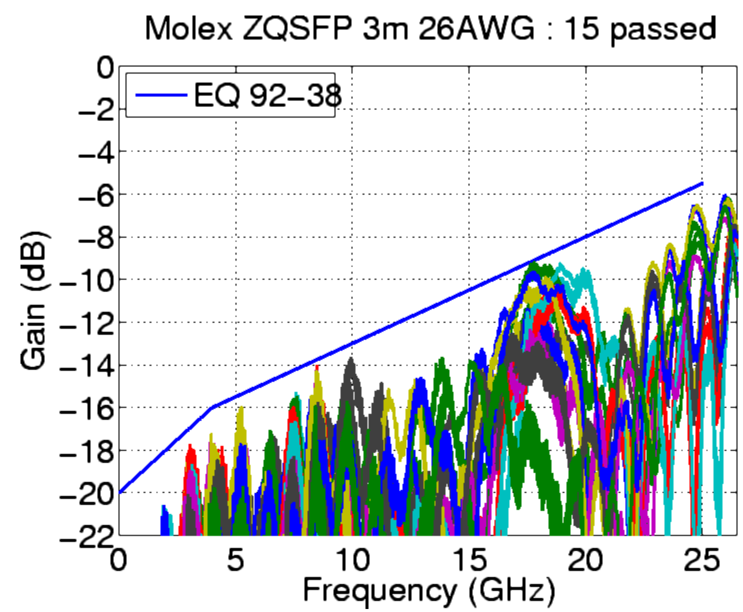


Type E: 3 meter 26 AWG

- EQ 92-27 (graph below)
  - 0 failed, 16 passed
- EQ 92-38 (graphs on right)
  - 1 barely failed, 15 passed
    - Worst violation 0.0649 dB
      - Just at one data point







Thank you