

Proposal for P802.3dj MPI penalty calculation and specification

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- Frank Chang, Source Photonics
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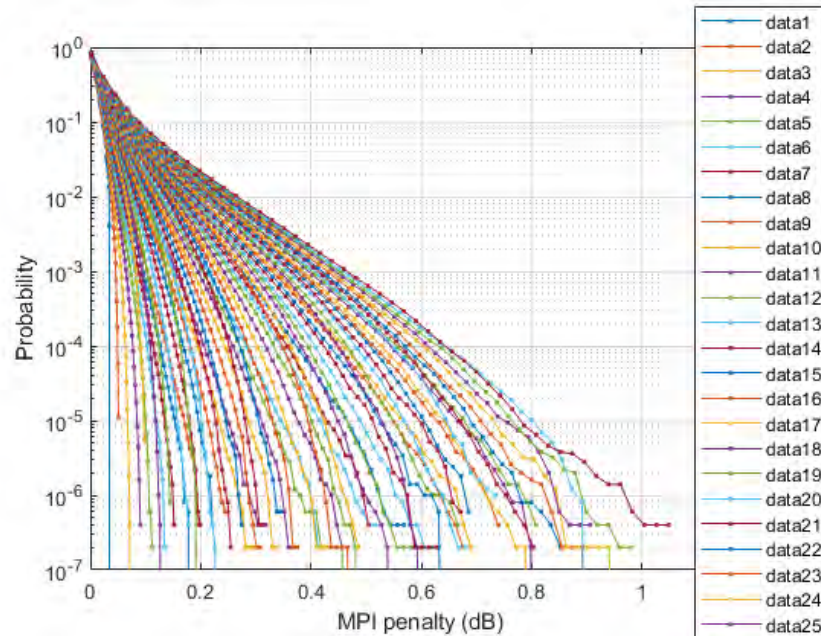
MPI calculation and specification

- [Johnson 3dj 01a 2503](#) discussed the path to consensus on MPI simulation parameters and spec methodology for 3dj PMDs.
- There was consensus that the MPI penalty allocations and the underlying MPI Monte Carlo calculation parameters should be more conservative than what was used in 802.3bs/cd.
 - Use more conservative ER and IL values and keep the 1e-6 confidence level.
 - Non-linear addition of ISI and MPI penalties (Pcross) was raised but is not addressed here.
- There was consensus that the MPI penalty spec method of Table 140-13, included as Table 180-12 in D1.5, should be adopted for all 3dj PMDs.
 - Allows more general fiber cabling models with arbitrary numbers of connectors
 - Allows trading off channel insertion loss for MPI penalty
 - Constructing the table requires definition of two MPI values:
 - MPI penalty budget at maximum channel insertion loss
 - Maximum allowable MPI penalty that can be compensated by channel insertion loss reduction
- This contribution presents a set of proposed MPI calculations and spec changes based on the assumptions listed above, with the goal of submitting them as comments against Working Group draft D2.0.

Summary of MPI calculation parameters

Parameter	802.3bs/cd parameters	Proposed 802.3dj parameters	Approx Δ MPI penalty, dB	Comments
Target SER	4.8e-4	4.56e-4 (FEC _o) 9.6e-3 (FEC _i)	0 -0.15	Penalty is reduced for FEC _i PMDs
Extinction ratio (dB)	4.5	3.5	+0.18	More conservative
Insertion loss (dB)	Max IL at RX end	Half Max IL at mid-span	+0.05	More conservative
Monte Carlo Confidence (Channel Probability)	1e-6		0	No change
Connector Reflectivities (dB)	-26 (TX/RX MDI) -35 (LC) -45 (MPO)		0	No change
Baseline Fiber Cabling Model used in Power Budget	Double link parallel (DRn) Double link duplex (FR4) Triple link duplex (LR4)		0	No change

Cl. 180 – 500m DR1/2/4/8



Cl. 180 – 500m DR1/2/4/8

Target PAM4 SER = 4.56×10^{-4}

Extinction ratio = 3.5 dB

Insertion loss = 1.5 dB at mid-span

Monte Carlo iterations = 50M, conf. level = 1×10^{-6}

Baseline cabling = Double-link, parallel fiber

MPI penalty budget = 0.1 dB

Max allowable MPI penalty = 0.65 dB

MPI Penalty (dB)		Number of -45dB reflections								
Number of -35dB reflections	0	0.04	0.05	0.07	0.09	0.11	0.13	0.15	0.17	0.20
	1	0.10	0.13	0.14	0.17	0.20	0.22	0.24	0.28	0.29
	2	0.20	0.22	0.25	0.27	0.29	0.32	0.35	0.39	0.40
	3	0.31	0.34	0.37	0.40	0.42	0.45	0.48	0.49	0.53
	4	0.43	0.47	0.51	0.53	0.57	0.58	0.63	0.65	0.68
	5	0.58	0.62	0.64	0.66	0.69	0.72	0.72	0.77	0.79
	6	0.73	0.75	0.78	0.84	0.86	0.85	0.90	0.89	0.98

Double-link parallel cabling → MPI penalty budget = 0.1 dB.

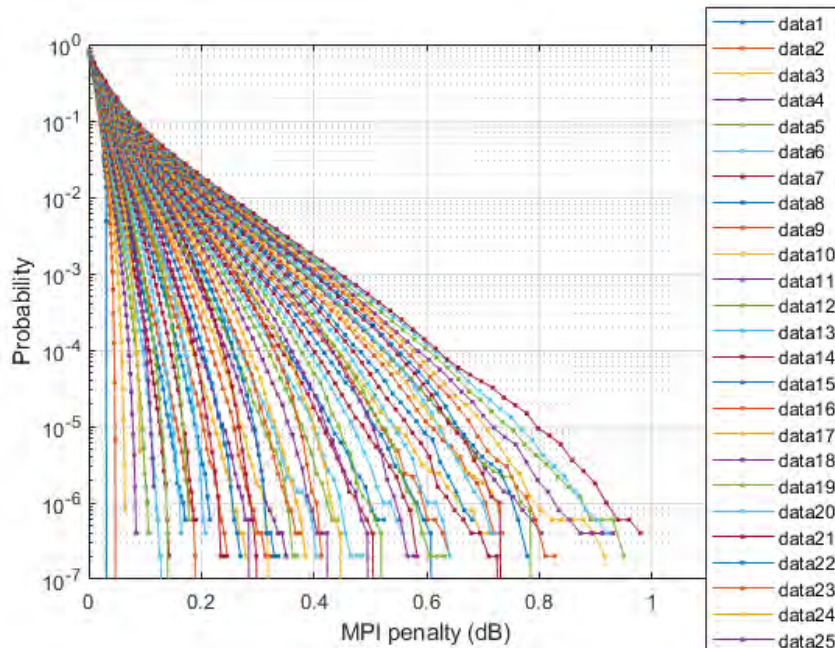
MPI penalty > 0.65 dB highlighted in RED.

Max Channel IL (dB)		Number of -45dB reflections								
Number of -35dB reflections	0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.9
	1	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.8	2.8
	2	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7
	3	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.6
	4	2.7	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.4
	5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.3	2.3
	6	2.4	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.1

Reduce maximum channel insertion loss for MPI penalty > 0.15 dB.

Channels in RED would be disallowed based on MPI penalty > 0.65 dB.

CI. 181 – 800GBASE-FR4-500



CI. 181 – 800GBASE-FR4-500

Target PAM4 SER = 4.56e-4

Extinction ratio = 3.5 dB

Insertion loss = 1.75 dB at mid-span

Monte Carlo iterations = 50M, conf. level = 1e-6

Baseline cabling = Double-link, duplex fiber

MPI penalty budget = 0.4 dB

Max allowable MPI penalty = 0.65 dB

MPI Penalty (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0	0.03	0.05	0.06	0.08	0.10	0.12	0.14	0.17	0.19
	1	0.09	0.12	0.14	0.16	0.19	0.22	0.24	0.26	0.28
	2	0.18	0.20	0.23	0.26	0.29	0.32	0.32	0.35	0.39
	3	0.29	0.32	0.35	0.37	0.40	0.42	0.46	0.48	0.50
	4	0.41	0.44	0.48	0.51	0.52	0.57	0.59	0.61	0.67
	5	0.55	0.59	0.63	0.65	0.67	0.70	0.73	0.77	0.78
	6	0.70	0.72	0.76	0.79	0.80	0.83	0.86	0.88	0.92

Double-link duplex cabling → MPI penalty budget = 0.4 dB.

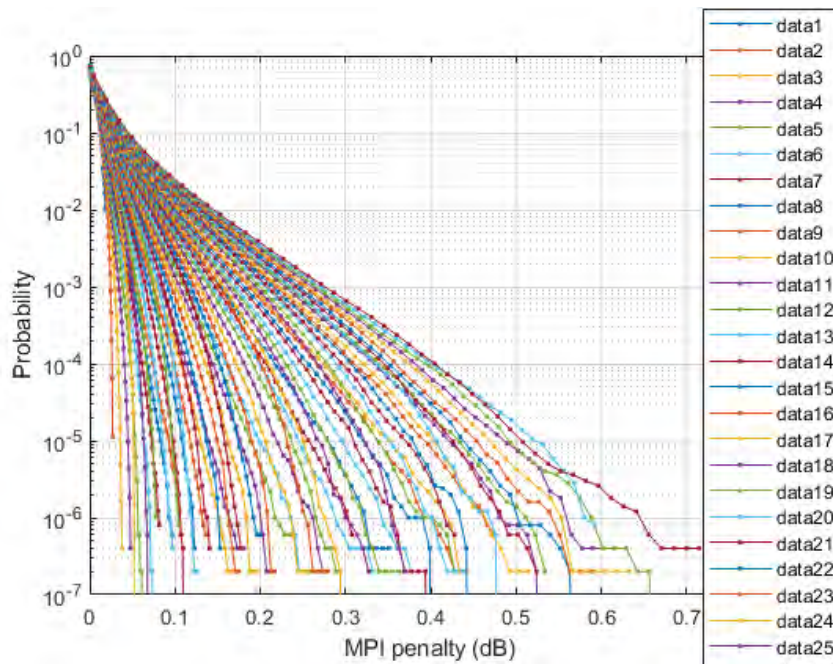
MPI penalty > 0.65 dB highlighted in RED.

Max Channel IL (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	1	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	2	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	3	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4
	4	3.5	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.2
	5	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.1	3.1
	6	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0	3.0

Reduce maximum channel insertion loss for MPI penalty > 0.45 dB.

Channels in RED would be disallowed based on MPI penalty > 0.65 dB.

Cl. 182 – 2km DR1/2/4/8-2



Cl. 182 – 2km DR1/2/4/8-2

Target PAM4 SER = 9.6e-3

Extinction ratio = 3.5 dB

Insertion loss = 2 dB at mid-span

Monte Carlo iterations = 50M, conf. level = 1e-6

Baseline cabling = Double-link, parallel fiber

MPI penalty budget = 0.1 dB

Max allowable MPI penalty = 0.65 dB

MPI Penalty (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.11
	1	0.05	0.07	0.08	0.09	0.11	0.12	0.13	0.16	0.17
	2	0.10	0.12	0.14	0.15	0.16	0.18	0.20	0.22	0.24
	3	0.17	0.20	0.21	0.24	0.27	0.27	0.29	0.31	0.33
	4	0.26	0.28	0.30	0.32	0.34	0.36	0.40	0.39	0.42
	5	0.35	0.39	0.40	0.42	0.44	0.47	0.47	0.49	0.51
	6	0.48	0.49	0.50	0.54	0.55	0.57	0.60	0.62	0.66
	7	0.59	0.60	0.64	0.65	0.67	0.69	0.71	0.70	0.73
	8	0.74	0.76	0.77	0.79	0.80	0.80	0.84	0.84	0.87

Double-link parallel cabling → MPI penalty budget = 0.1 dB.

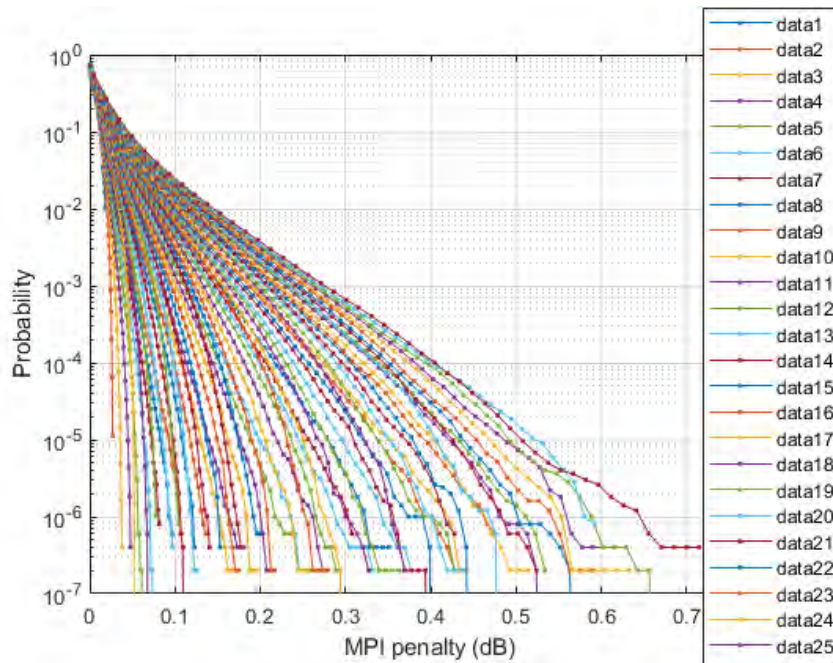
MPI penalty > 0.65 dB highlighted in RED.

Max Channel IL (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9
	2	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9
	3	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8
	4	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7
	5	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6
	6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.4
	7	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4
	8	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2

Reduce maximum channel insertion loss for MPI penalty > 0.15 dB.

Values in RED would be disallowed based on MPI penalty > 0.65 dB.

CI. 183 – 800GBASE-FR4



CI. 181 FR4-500 PMD

Target PAM4 SER = 9.6e-3

Extinction ratio = 3.5 dB

Insertion loss = 2 dB at mid-span

Monte Carlo iterations = 50M, conf. level = 1e-6

Baseline cabling = Double-link, parallel fiber

MPI penalty budget = 0.3 dB

Max allowable MPI penalty = 0.65 dB

MPI Penalty (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.11
	1	0.05	0.07	0.08	0.09	0.11	0.12	0.13	0.16	0.17
	2	0.10	0.12	0.14	0.15	0.16	0.18	0.20	0.22	0.24
	3	0.17	0.20	0.21	0.24	0.27	0.27	0.29	0.31	0.33
	4	0.26	0.28	0.30	0.32	0.34	0.36	0.40	0.39	0.42
	5	0.35	0.39	0.40	0.42	0.44	0.47	0.47	0.49	0.51
	6	0.48	0.49	0.50	0.54	0.55	0.57	0.60	0.62	0.66
	7	0.59	0.60	0.64	0.65	0.67	0.69	0.71	0.70	0.73
	8	0.74	0.76	0.77	0.79	0.80	0.80	0.84	0.84	0.87

Double-link parallel cabling → MPI penalty budget = 0.3 dB.

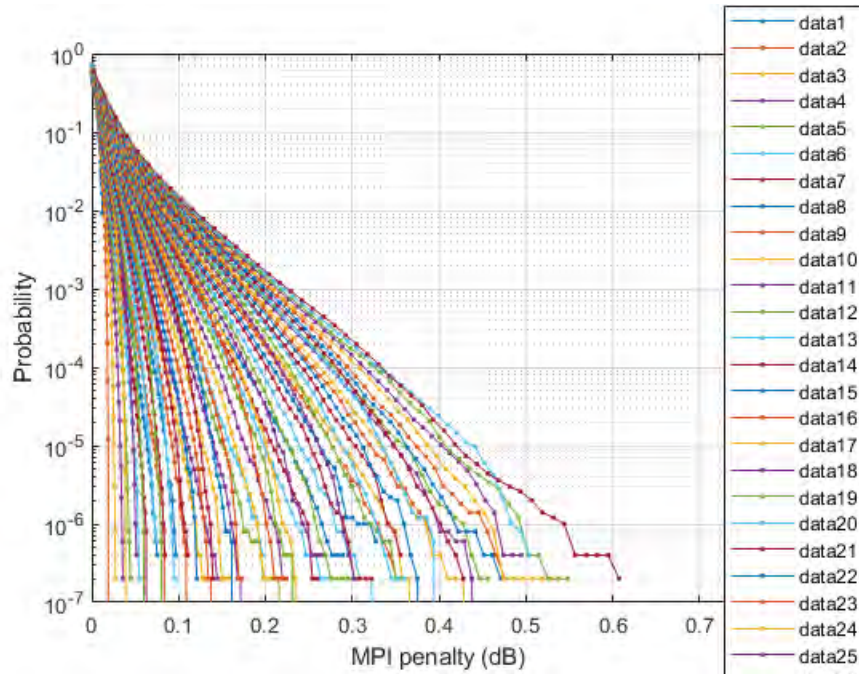
MPI penalty > 0.65 dB highlighted in RED.

Max Channel IL (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0 to 3	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	4	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9
	5	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8
	6	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.6
	7	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4
	8	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2

Reduce maximum channel insertion loss for MPI penalty > 0.35 dB.

Values in RED would be disallowed based on MPI penalty > 0.65 dB.

CI. 183 – 800GBASE-LR4



CI. 183 – 800GBASE-LR4

Target PAM4 SER = 9.6e-3

Extinction ratio = 3.5 dB

Insertion loss = 3.15 dB at mid-span

Monte Carlo iterations = 50M, conf. level = 1e-6

Baseline cabling = Triple-link, duplex fiber

MPI penalty budget = 0.4 dB

Max allowable MPI penalty = 0.65 dB

MPI Penalty (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.08
	1	0.04	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.13
	2	0.08	0.09	0.11	0.12	0.13	0.15	0.16	0.18	0.19
	3	0.14	0.15	0.17	0.19	0.22	0.22	0.24	0.25	0.27
	4	0.21	0.22	0.25	0.26	0.28	0.30	0.33	0.33	0.35
	5	0.29	0.32	0.33	0.35	0.37	0.39	0.39	0.40	0.43
	6	0.39	0.41	0.42	0.44	0.46	0.47	0.50	0.53	0.54
	7	0.51	0.51	0.55	0.55	0.57	0.61	0.60	0.60	0.66
	8	0.59	0.62	0.64	0.67	0.71	0.74	0.68	0.72	0.74
	9	0.73	0.80	0.78	0.76	0.80	0.81	0.82	0.80	0.86

Triple-link duplex cabling → MPI penalty budget = 0.4 dB.

MPI penalty > 0.65 dB highlighted in RED.

Max Channel IL (dB)		Number of -45dB reflections								
		0	1	2	3	4	5	6	7	8
Number of -35dB reflections	0 to 4	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	5	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	6	6.3	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.2
	7	6.2	6.2	6.1	6.2	6.1	6.1	6.1	6.1	6.0
	8	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	6.0
	9	6.0	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.8

Reduce maximum channel insertion loss for MPI penalty > 0.45 dB.

Values in RED would be disallowed based on MPI penalty > 0.65 dB.

MPI and DGD penalty budget proposal

	P802.3dj draft D1.5			Ghiasi_3dj_01_2503		This Proposal	
802.3dj Optical PMD	MPI Penalty Budget (dB)	DGD Penalty Budget (dB)	DGD_max (ps/nm)	MPI Penalty Budget (dB)	DGD Penalty Budget (dB)	MPI Penalty Budget (dB)	DGD Penalty Budget (dB)
Cl. 180 DRn	0.1*		2.24	0.12	0.18	0.1	0.2
Cl. 181 FR4-500	0.5*		2.24	0.41	0.18	0.4	0.2
Cl. 182 DRn-2	0.4*		2.3	0.1	0.18	0.1	0.2
Cl. 183 FR4	0.5*		2.3	N/A	N/A	0.3	0.2
Cl. 183 LR4	0.4	0.7	4	0.3	N/A	0.4	0.7

* Combined MPI+DGD Penalty budget.

- The table at left shows a comparison of existing and proposed MPI and DGD penalty budgets.
 - D1.5 doesn't break out MPI and DGD penalty budgets separately except for 800G-LR4.
 - MPI and DGD penalty budget proposals made by Ali against D1.4 are shown for reference.
- The proposed MPI penalty budget values are very close to those proposed by Ali.
- Pending new data on DGD penalty, propose to adopt the values in [ghiasi 3dj 01 2503](#).
- Where the proposed MPI+DGD penalty budget is different than D1.5, adjustments must be made to the power budget for max TDECQ and TX launch OMA specs.

Additional spec adjustments

	Cl. 180, DRn		Cl. 181, FR4-500		Cl. 182, DRn-2	
Parameter (dB or dBm)	P802.3dj D1.5	This Proposal	P802.3dj D1.5	This Proposal	P802.3dj D1.5	This Proposal
Power Budget						
Power budget (for max TDECQ)	6.5	6.7	7.4	7.5	7.8	7.7
Allocation for penalties (for max TDECQ)	3.5	3.7	3.9	4	3.8	3.7
TX Characteristics						
Average launch power, each lane (min)	-3.3	-3.1	-2.2	-2.1	-3.3	-3.1
Outer Optical Modulation Amplitude (OMA _{outer}), each lane (min) for max(TECQ, TDECQ) < X dB for X dB < max(TECQ, TDECQ) < Y dB	-0.3 -1.2 + TDECQ	-0.1 -1 + TDECQ	0.8 -0.1 + TDECQ	0.9 0 + TDECQ	-0.3 -1.2 + TDECQ	-0.1 -1 + TDECQ
RX Characteristics						
Average receive power, each lane (min)	-6.3	-6.1	-5.7	-5.6	-7.3	-7.1
Receiver sensitivity (OMA _{outer}), each lane (max) for TECQ < X dB for X dB < TECQ < SECQ	—	—	—	—	-4.7 -5.6 + TECQ	-4.4 -5.3 + TECQ
Stressed receiver sensitivity (OMA _{outer}), each lane (max)	—	—	—	—	-2.2	-1.9

- Cl. 180 and Cl. 181 TX OMA are changed to match new power budgets. RX sensitivity is unchanged.
- Cl. 182 TX OMA is changed to be the same as proposed Cl. 180. Adjust RX sensitivity to match new power budget.
- No power budget changes required for Cl. 183 PMDs.
- Associated updates will be needed to some footnotes, equations and OMA vs. TDECQ figures.

Discussion

- This contribution presents a set of proposed MPI calculations and spec changes to be submitted against D2.0.
- The parameters used for the MPI calculations are the same or more conservative than used previously for 802.3bs/cd.
- New tables of max channel insertion loss as a function of connector reflectivity are generated for each PMD.
 - 0.65dB MPI penalty is proposed as an upper limit for allowed insertion loss tradeoff.
- New power budgets are calculated using MPI penalties for baseline fiber cabling models using DGD penalties proposed in [ghiasi 3dj 01 2503](#).
 - The resulting differences in power budgets are $< 0.2\text{dB}$.
- The power budget changes result in small changes to the TX and RX spec tables in Cl. 180, 181 and 182.
 - No changes are required for Cl. 183 because the power budgets are unchanged.

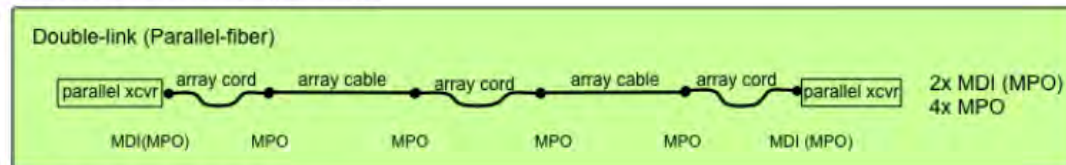
Thank You

Appendix

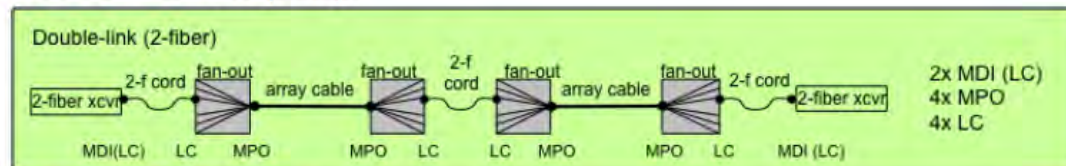
Fiber cabling models adopted by P802.3bs (Nicholl_3bs_01a_0316)

Proposed reference models for 802.3bs

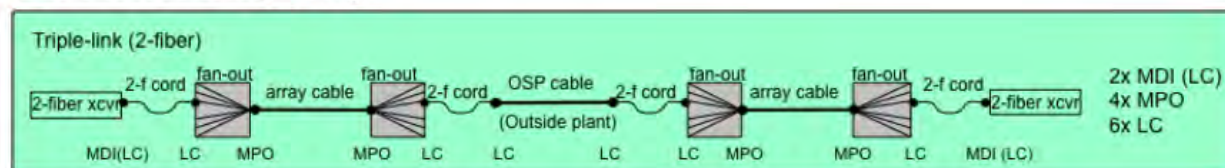
400GBASE-DR4 (500m):



400GBASE-FR8 (2km):



400GBASE-LR8 (10km):



Ref: [kolesar_3bs_01_0514.pdf](#)

Specification Method 2: Variable MPI penalty

- MPI penalty is calculated over a broad range of cable models.
- As MPI penalty increases, link power budget is shifted from channel insertion loss to penalties.
- Pros:
 - Link power budget is a constant.
 - Channel IL is easily measured.
 - More connectors can be accommodated by procuring lower loss connectors and cables.
- Cons:
 - Channel IL is not a constant, complicating network design.

Table 140-13—100GBASE-DR maximum channel insertion loss versus number of discrete reflectances

Maximum channel insertion loss (dB)		MPO connectors Number of discrete reflectances > -55 dB and ≤ -45 dB									
		0	1	2	3	4	5	6	7	8	
LC connectors Number of discrete reflectances > -45 dB and ≤ -35 dB	0	3	3	3	3	3	3	3	3	3	
	1	3	3	3	3	3	3	3	3	3	
	2	3	3	3	2.9	2.9	2.9	2.9	2.9	2.9	
	3	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	— ^a	
	4	2.8	2.8	2.8	2.8	2.7	2.7	2.7	— ^a	— ^a	
	5	2.8	2.8	2.7	2.7	2.7	2.6	— ^a	— ^a	— ^a	
	6	2.6	2.6	— ^a	— ^a	— ^a	— ^a	— ^a	— ^a	— ^a	

^aThe indicated combination of reflectances does not provide a supported maximum channel insertion loss.

No adjustment for
MPI penalty < 0.15 dB

Double link,
duplex fiber case

-35dB and -45dB are used in the simulations, even though these are the worst cases for each class of connector.