Exploration of DGD Penalty for 400GBASE-LR4

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Background

- Jialong Shuai's presentation (shuai_3cu_adhoc_050119) to the P802.3cu ad-hoc call on 1st May 2019 brought up the question of DGD penalty for 400GBASE-LR4
  - DGD_max = 8 ps, Penalty ~ 0.6 dB
- This presentation reviews how DGD_max has been specified for previous 10km (LR) IEEE interfaces and suggests how DGD_max could be addressed for 400GBASE-LR4
- The same approach could be used for 100GBASE-LR

Previous 10 km SMF DGD_max Values

- 802.3ae 10GBASE-LR
  - DGDmax = 10 ps, Penalty ~ 0.1 dB
  - Equivalent to 0.8 ps/sqrt(km) with S=3.75 (2.6 sec per year)
- 802.3ba 40GBASE-LR4
  - Uses the same 10 ps as 10GBASE-LR
- 802.3ba 100GBASE-LR4
  - Initially the same 10 ps as 10GBASE-LR with a 0.4 dB penalty
  - During comments, DGDmax reduced to 8 ps with a 0.2 dB penalty
    - Equivalent to a PMD coefficient of ~ 0.7 ps / sqrt(km) at S=3.75 (2.6 sec per year)
- 802.3bs/802.3cd
  - All 10 km PMDs (50GBASE-LR, 200GBASE-LR4, 400GBASE-LR8) use the same 8 ps for DGDmax. Equivalent to ~ 0.7 ps / sqrt(km) at S=3.75 (2.6 sec per year)
  - Penalties ?
- Note that all of these DGD_max values are based on fibers with PMD_Q of 0.5 ps/sqrt(km). The equivalent values of ~ 0.7 to 0.8 ps/sqrt(km) may be too aggressive for single strands of these fiber types.

G.652 SMF Fibers

- G.652 (2009) fiber has two categories of PMD limit:
  - For G.652.A&C Max. PMD_Q = 0.5 ps/sqrt(km)
  - For G.652.B&D Max. PMD_Q = 0.2 ps/sqrt(km)
  - Where PMD_Q is the PMD coefficient that will be exceeded by less than 0.01% of links made up of 20 cable sections in series.
- The latest G.652 (2016) only lists types B&D with PMD_Q = 0.2 ps/sqrt(km).

400GBASE-LR4 Example Baseline Tables with 2 fiber types

- Following 2 tables show examples of link power budgets and channel characteristics for the 2 fiber types (G.652.A&C and G.652.B&D)
- Align the G.652.A&C channel with previous assumptions but for a shorter reach of 8 km. The saving in insertion loss is then available for additional penalties such as the expected DGD penalty from shuai_3cu_adhoc_050119.
- Specify the G.652.B&D channel for a 10 km reach based on the actual PMD_Q value of 0.2 ps/sqrt(km) found in G.652. Expected penalty should be similar to previous 10 km PMDs.

Example Illustrative Link Power Budgets

Description	G.652.A/C	G.652.B/D	Unit
Power budget (for max TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 10.7 10.8	 10.7 10.8	dB
Operating distance	8.0	10.0	km
Channel insertion loss[a]	5.4	6.3	dB
Maximum discrete reflectance	See Table xx	See Table xx	dB
Allocation for penalties[b] (for max TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 5.3 5.4	 4.4 4.5	dB
Additional insertion loss allowed	0	0	dB

Example Fiber optic cabling (channel) characteristics

Description	G.652.A/C	G.652.B/D	Unit
Operating distance (max)	8	10	km
Channel insertion loss [a,b] (max)	5.4	6.3	dB
Channel insertion loss (min)	0	0	dB
Positive dispersion[b] (max)	26.7	33.5	ps/nm
Negative dispersion[b] (min)	-47.6	-59.5	ps/nm
DGD_max[c]	7.2	2.4	ps
Optical return loss (min)	22	22	dB
[a] These channel loss values include cable, connectors and splices.			
[b] Over the wavelength range 1264.5 to 1337.5 nm.			
[c] Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.			

7.2 ps is scaled from previous 8 ps / 10km: 8 * sqrt(8) / sqrt(10)

2.4 ps is 3.75 * 0.2 * sqrt(10)

Summary

- Example tables for 2 fiber types presented
- G.652.A&C for 8 km reach with additional penalties due to higher PMD coefficient
- G.652.B&D for 10 km reach with reduced penalties (similar to previous 10 km interfaces)
  - based on PMD coefficient of 0.2 ps/sqrt(km)
- Further work is needed to confirm the DGD penalties for the two fiber types.