Baseline proposals for 200G/L PMD specifications for single wavelength 500m and 2km standards

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Overview

- Continuation of work shown in welch_3dj_02b_2303
  - Average launch and receive powers (min) for Single Wavelength 500m PMDs are now based on infinite extinction ratio, as used for Single Wavelength 2 km PMDs
  - RIN_OMA revised to – 139 dB/Hz from -137 dB/Hz, to reflect the doubling in measurement bandwidth from 100G (RIN_OMA for 100G was -136 dB/Hz)
  - TDECQ reference receiver revised to FFE9 from FFE5, with tap weight restrictions

- Two PMD types under consideration:
  - Single Wavelength 500m: 200GBASE-DR1, 400GBASE-DR2, 800GBASE-DR4, 1.6TBASE-DR8
  - Single Wavelength 2km: 200GBASE-FR1, 400GBASE-DR2-2, 800GBASE-DR4-2, 1.6TBASE-DR8-2

- Proposing to support BOTH RS(544,514) only and RS(544,514)+Inner Code FEC options
  - See welch_3dj_03a_0523 for details
  - Option A (Type 1[†]): Use RS(544,514) FEC protection for PMD
  - Option B (Type 2[†]): Use RS(544,514) + Inner Code (128,120) FEC protection for PMD

  † From brown_3dj_01a_2303.pdf

BER Requirements

This contribution does not recommend a specific option on the FEC architecture. FEC options are under study and still require more information.
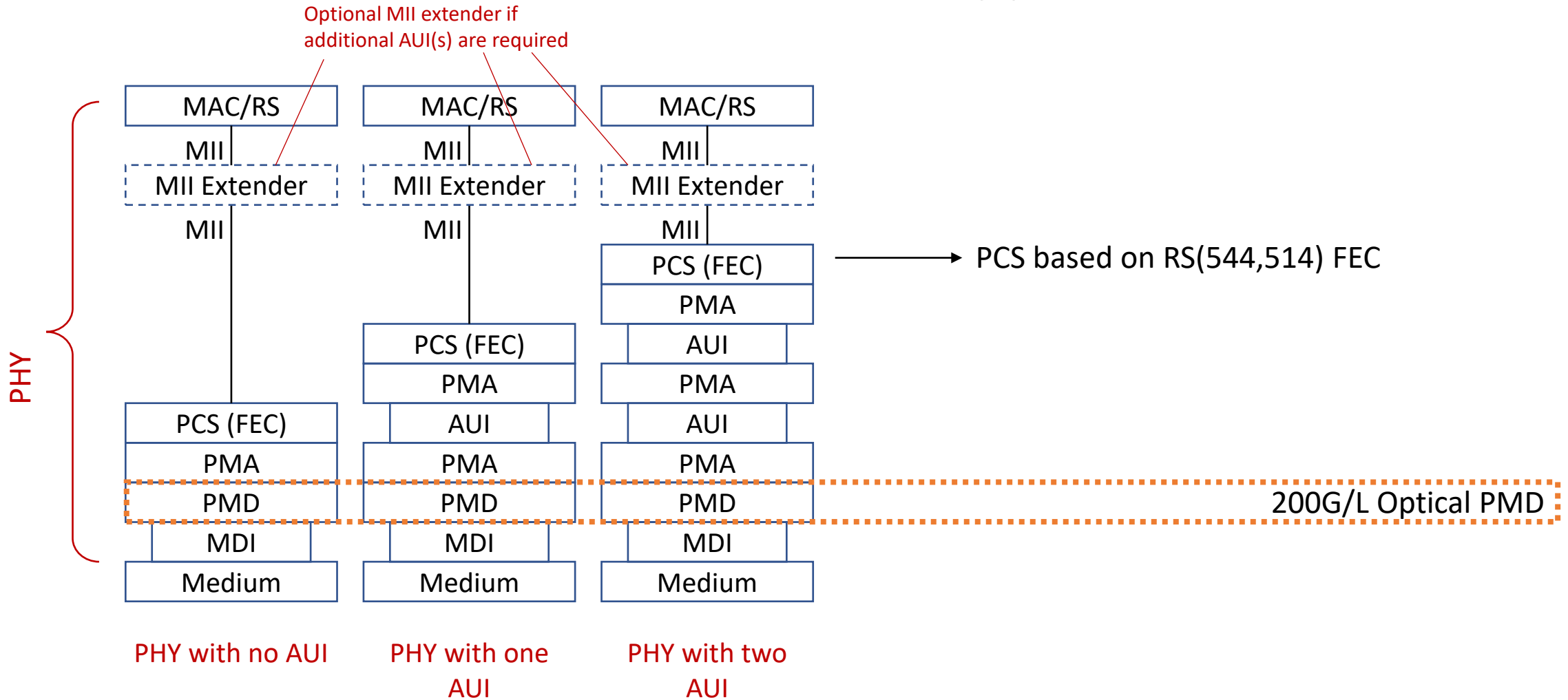
- **Option A**: The BER of the PMD link shall be less than **2.4×10^{-4}** provided that the error statistics are sufficiently random that this results in a frame loss ratio of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap when processed with an 800GBASE-R/1.6TBASE-R PCS.

- **Option B**: The BER of the PMD link shall be less than **4.85×10^{-3}** provided that the error statistics are sufficiently random that this results in a frame loss ratio of less than 1.7×10^{-12} for 64-octet frames with minimum interpacket gap when processed with an 800GBASE-R/1.6TBASE-R PCS and inner code FEC sublayer.
  - Note: Exact pre-FEC BER level for Option B is not finalized. Convolutional interleaver bypass options may yield pre-FEC BER level $\lesssim$ **2×10^{-3}** .

TDECQ/TECQ/SECQ Reference Receiver

- TDECQ reference filter expanded from FFE5 (1 main + 4 pre/post cursors) to FFE9 (1 main + 8 pre/post cursors)
  - Maintain the same absolute FFE length (as 100G/L) to manage reflection concerns

- Introduce tap weight limits of +/- .25 for first pre-post cursor and +/- 0.1 for all other taps (measured relative to the main tap).
  - Mitigate concerns of extreme TX BW restriction that could have deleterious effects on receiver performance/design

- Open question on target SER for inner code: Can soft-decision performance be assumed in a reference receiver?
  - Alternatively, we could codify hard-decision target SER for TDECQ/TECQ/SECQ.

Option A (Type 1): RS(544,514)

Location in Ethernet Stack: Type 1

Optional MII extender if additional AUI(s) are required

PHY

PHY with no AUI	PHY with one AUI	PHY with two AUI
MAC/RS	MAC/RS	MAC/RS
MII	MII	MII
MII Extender	MII Extender	MII Extender
MII	MII	MII
		PCS (FEC)
		PMA
	PCS (FEC)	AUI
	PMA	PMA
PCS (FEC)	AUI	AUI
PMA	PMA	PMA
PMD	PMD	PMD
MDI	MDI	MDI
Medium	Medium	Medium

PCS based on RS(544,514) FEC

200G/L Optical PMD

Proposed Transmitter Specifications

Option A: RS(544,514), Pre-FEC BER = 2.4e-4	500m	2km	
Description	**200GBASE-DR1** **400GBASE-DR2** **800GBASE-DR4** **1.6TBASE-DR8**	**200GBASE-FR1** **400GBASE-DR2-2** **800GBASE-DR4-2** **1.6TBASE-DR8-2**	**Unit**
Signaling rate, each lane (Range)	106.25 ± 50 ppm	106.25 ± 50 ppm	GBd
Modulation Format	PAM4	PAM4	
Lane wavelengths (range)	1304.5 to 1317.5	1304.5 to 1317.5	nm
Side-mode suppression ratio (SMSR), (min)	30	30	dB
Average launch power, each lane (max)	4	4	dBm
Average launch power, each lane (min)	-2.8	-2.1	dBm
Outer Optical Modulation Amplitude (OMA$_{outer}$), each lane(max)	4.2	4.2	dBm
Outer Optical Modulation Amplitude (OMA$_{outer}$), each lane(min) for TDECQ < 1.4dB for 1.4 dB ≤ TDECQ ≤ 3.4 dB	0.2 -1.2+TDECQ	0.9 -0.5+TDECQ	dBm dBm
Transmitter and dispersion eye closure (TDECQ), each lane (max)	3.4[†]	3.4[†]	dB
TECQ (max)	3.4[†]	3.4[†]	dB
| TDECQ - TECQ| (max)	2.5	2.5	dB
Average launch power of OFF transmitter, each lane (max)	-15	-15	dBm
Extinction ratio, each lane, (min)	3.5	3.5	dB
Transmitter transition time (max)	8.5	8.5	ps
Transmitter over/under-shoot (max)	22	22	%
RIN$_x$ OMA (max)	-139	-139	dB/Hz
Optical return loss tolerance (max)	21.4 (15.5 for DR1)	21.4 (17.1 for FR1)	dB
Transmitter reflectance (max)	-26	-26	dB

† Measured with FFE9 reference equalizer with tap weight restrictions of +/- 0.25 for 1st pre/post cursor, +/- 0.1 for all other taps (relative to the main tap), and SER = 4.8e-4

Option A: RS(544,514)

Proposed Receiver Specifications

Option A: RS(544,514), Pre-FEC BER = 2.4e-4	500m	2km	Unit
Description	200GBASE-DR1 400GBASE-DR2 800GBASE-DR4 1.6TBASE-DR8	200GBASE-FR1 400GBASE-DR2-2 800GBASE-DR4-2 1.6TBASE-DR8-2	Unit
Signaling rate, each lane (Range)	106.25 ± 50 ppm	106.25 ± 50 ppm	GBd
Modulation Format	PAM4	PAM4	
Lane wavelengths (range)	1304.5 to 1317.5	1304.5 to 1317.5	nm
Damage threshold, each lane	5	5	dBm
Average receive power, each lane (max)	4	4	dBm
Average receive power, each lane (min)	-5.8	-6.1	dBm
Receive power, each lane (OMA_{outer}) (max)	4.2	4.2	dBm
Receiver reflectance (max)	-26	-26	dBm
Receiver sensitivity (OMA_{outer}), each lane (max) for TECQ < 1.4dB for 1.4 dB ≤ TECQ ≤ 3.4 dB	-2.9 -4.3+TECQ	-3.5 -4.9+TECQ	dBm dBm
Stressed receiver sensitivity (OMA_{outer}), each lane (max)[†]	-0.9	-1.5	dBm
Conditions of stressed receiver sensitivity test:			
SECQ	3.4[†]	3.4[†]	dB
OMA_{outer} of each aggressor lane[‡]	4.2	4.2	dBm

[†] Measured with FFE9 reference equalizer with tap weight restrictions of +/- 0.25 for 1st pre/post cursor, +/- 0.1 for all other taps (relative to the main tap), and SER = 4.8e-4
[‡] No aggressors needed for 200GBASE-DR1 or 200GBASE-FR1

Option A: RS(544,514)

Proposed Link Budget

| Option A: RS(544,514), Pre-FEC BER = 2.4e-4	500m	2km	
Description	**200GBASE-DR1** **400GBASE-DR2** **800GBASE-DR4** **1.6TBASE-DR8**	**200GBASE-FR1** **400GBASE-DR2-2** **800GBASE-DR4-2** **1.6TBASE-DR8-2**	**Unit**
Power budget (for max TDECQ)	6.5	7.8	dB
Operating distance	500	2000	m
Channel insertion loss	3	4	dB
Maximum discrete reflectance	-35	-35	dB
Allocation for penalties (for max TDECQ)	3.5	3.8	dB
Additional insertion loss allowed	0	0	dB

Option A: RS(544,514)

Illustrative Spec

Option A : 500m
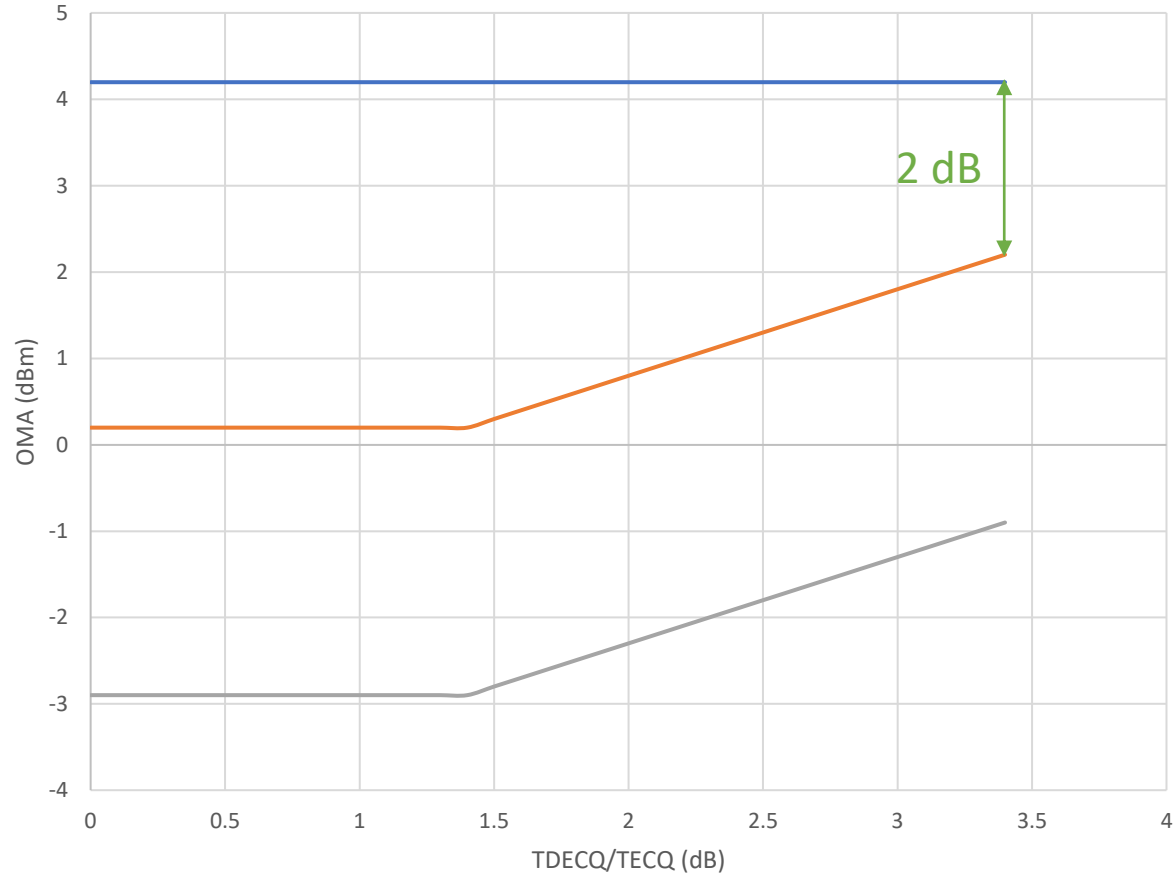
Option A : 2km
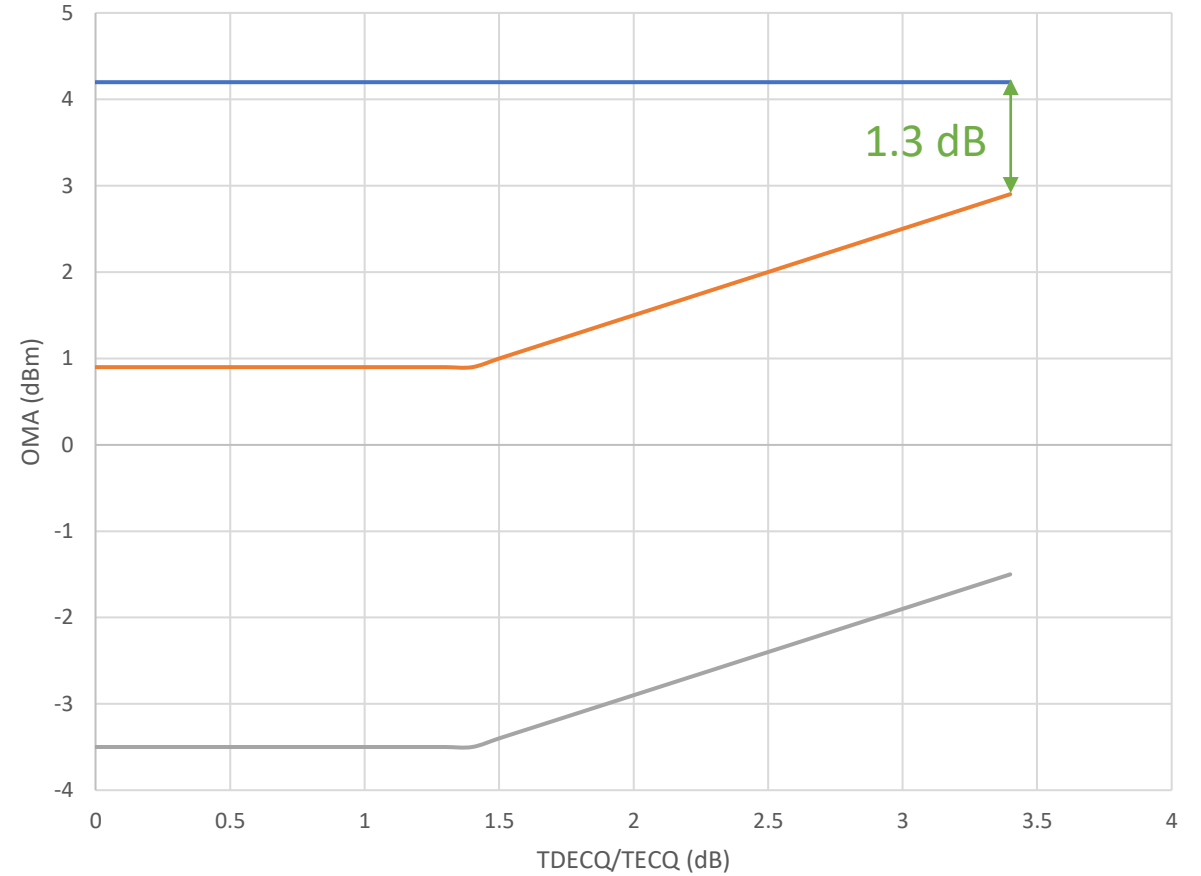
Option B (Type 2): RS(544,514) + Inner Code (128,120)

Location in Ethernet Stack: Type 2

Optional MII extender if additional AUI(s) are required

PHY

PHY with no AUI

| MAC/RS |
| MII |
| MII Extender |
| MII |
| PCS (FEC$_O$) |
| FEC$_I$ |
| PMA |
| PMD |
| MDI |
| Medium |

PHY with one AUI

| MAC/RS |
| MII |
| MII Extender |
| MII |
| PCS (FEC$_O$) |
| PMA |
| AUI |
| PMA |
| FEC$_I$ |
| PMA |
| PMD |
| MDI |
| Medium |

PHY with two AUI

| MAC/RS |
| MII |
| MII Extender |
| MII |
| PCS (FEC$_O$) |
| PMA |
| AUI |
| PMA |
| AUI |
| PMA |
| FEC$_I$ |
| PMA |
| PMD |
| MDI |
| Medium |

PCS based on RS(544,514) FEC

Inner Code (128,120)

200G/L Optical PMD

Proposed Transmitter Specifications

Option B: RS(544,514) + Inner Code (128,120), Pre-FEC BER = 4.85e-3	500m	2km	
Description	**200GBASE-DR1** **400GBASE-DR2** **800GBASE-DR4** **1.6TBASE-DR8**	**200GBASE-FR1** **400GBASE-DR2-2** **800GBASE-DR4-2** **1.6TBASE-DR8-2**	**Unit**
Signaling rate, each lane (Range)	112.5 -113.4375 ± 50 ppm	112.5 -113.4375 ± 50 ppm	GBd
Modulation Format	PAM4	PAM4	
Lane wavelengths (range)	1304.5 to 1317.5	1304.5 to 1317.5	nm
Side-mode suppression ratio (SMSR), (min)	30	30	dB
Average launch power, each lane (max)	4	4	dBm
Average launch power, each lane (min)	-2.9	-2.2	dBm
Outer Optical Modulation Amplitude (OMA$_{outer}$), each lane(max)	4.2	4.2	dBm
Outer Optical Modulation Amplitude (OMA$_{outer}$), each lane(min) for TDECQ < 1.3dB for 1.3 dB ≤ TDECQ ≤ 2.8 dB	0.1 -1.2+TDECQ	0.8 -0.5+TDECQ	dBm dBm
Transmitter and dispersion eye closure (TDECQ), each lane (max)	2.8[†]	2.8[†]	dB
TECQ (max)	2.8[†]	2.8[†]	dB
| TDECQ - TECQ| (max)	1.9	1.9	dB
Average launch power of OFF transmitter, each lane (max)	-15	-15	dBm
Extinction ratio, each lane, (min)	3.5	3.5	dB
Transmitter transition time (max)	8.0	8.0	ps
Transmitter over/under-shoot (max)	22	22	%
RIN$_x$ OMA (max)	-139	-139	dB/Hz
Optical return loss tolerance (max)	21.4 (15.5 for DR1)	21.4 (17.1 for FR1)	dB
Transmitter reflectance (max)	-26	-26	dB

[†] Measured with FFE9 reference equalizer with tap weight restrictions of +/- 0.25 for 1st pre/post cursor, +/- 0.1 for all other taps (relative to the main tap), and SER = 9.7e-3

Option B: RS(544,514) + Inner Code (128,120)

Proposed Receiver Specifications

Option B: RS(544,514) + Inner Code (128,120), Pre-FEC BER = 4.85e-3	500m	2km	Unit
Description	**200GBASE-DR1** **400GBASE-DR2** **800GBASE-DR4** **1.6TBASE-DR8**	**200GBASE-FR1** **400GBASE-DR2-2** **800GBASE-DR4-2** **1.6TBASE-DR8-2**	**Unit**
Signaling rate, each lane (Range)	112.5 -113.4375 ± 50 ppm	112.5 -113.4375 ± 50 ppm	GBd
Modulation Format	PAM4	PAM4	
Lane wavelengths (range)	1304.5 to 1317.5	1304.5 to 1317.5	nm
Damage threshold, each lane	5	5	dBm
Average receive power, each lane (max)	4	4	dBm
Average receive power, each lane (min)	-5.9	-6.2	dBm
Receive power, each lane (OMA$_{outer}$) (max)	4.2	4.2	dBm
Receiver reflectance (max)	-26	-26	dBm
Receiver sensitivity (OMA$_{outer}$), each lane (max) for TECQ < 1.3dB for 1.3 dB ≤ TECQ ≤ 2.8 dB	 -3 -4.3+TECQ	 -3.6 -4.9+TECQ	 dBm dBm
Stressed receiver sensitivity (OMA$_{outer}$), each lane (max)[†]	-1.5	-2.1	dBm
Conditions of stressed receiver sensitivity test:			
SECQ[†]	2.8	2.8	dB
OMA$_{outer}$ of each aggressor lane[‡]	4.2	4.2	dBm

[†] Measured with FFE9 reference equalizer with tap weight restrictions of +/- 0.25 for 1st pre/post cursor, +/- 0.1 for all other taps (relative to the main tap), and SER = 9.7e-3
[‡] No aggressors needed for 200GBASE-DR1 or 200GBASE-FR1

Option B: RS(544,514) + Inner Code (128,120)

Proposed Link Budget

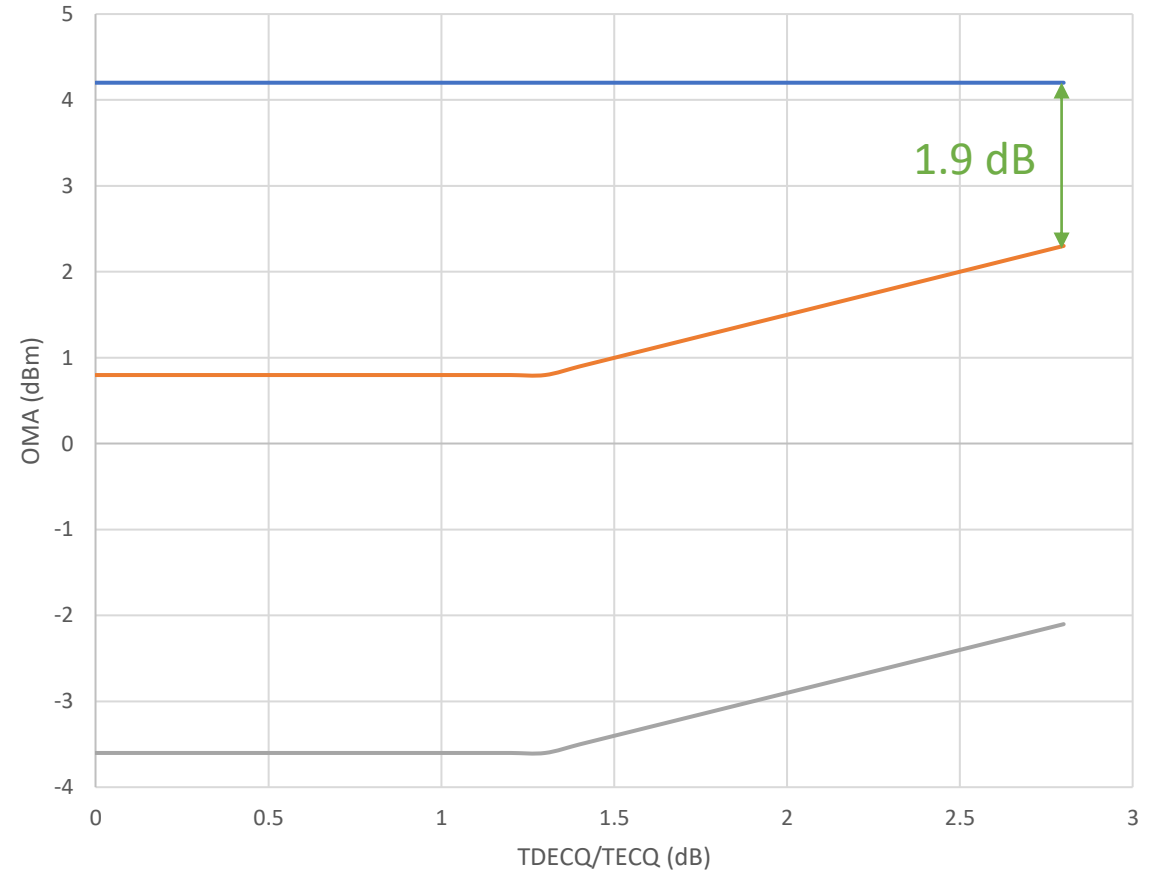| Option B: RS(544,514) + Inner Code (128,120), Pre-FEC BER = 4.85e-3	500m	2km	
Description	**200GBASE-DR1** **400GBASE-DR2** **800GBASE-DR4** **1.6TBASE-DR8**	**200GBASE-FR1** **400GBASE-DR2-2** **800GBASE-DR4-2** **1.6TBASE-DR8-2**	**Unit**
Power budget (for max TDECQ)	5.9	7.2	dB
Operating distance	500	2000	m
Channel insertion loss	3	4	dB
Maximum discrete reflectance	-35	-35	dB
Allocation for penalties (for max TDECQ)	2.9	3.2	dB
Additional insertion loss allowed	0	0	dB
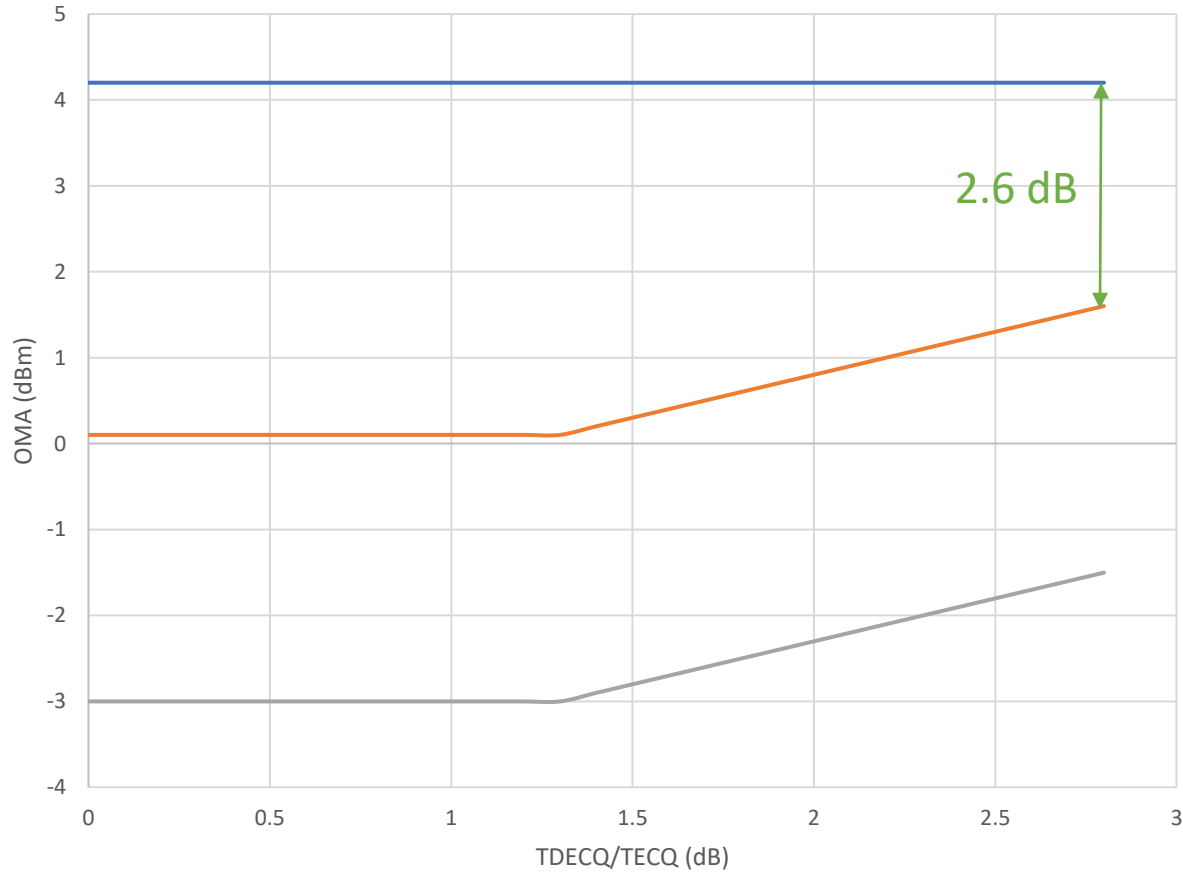
Option B: RS(544,514) + Inner Code (128,120)

Illustrative Spec

Option B : 500m

Option B : 2km

Summary

- Baseline proposals are presented for 500m and 2km 200G/L single wavelength reach objectives, for two different FEC options [RS(544,514) only vs. RS(544,514) + Inner Code (128,120)]
    - Options differ from each other in signaling rate and BER/SER specifications (and affiliated specifications).