OMA relaxation for high extinction ratio transmitters

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Supporters

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ER dependence of APD noise

- As documented in umeda_3ca_2a_0518, APD RX sensitivity depends on extinction ratio (ER) due to avalanche multiplication noise.
- The currently accepted baseline APD receiver sensitivities assume that all TX have worst-case extinction ratio.
  - To minimize optical component cost and power dissipation, it makes sense for TX with higher ER to be able to launch lower power.
  - For cost-sensitive ONUs in particular, the current spec method requires TX with higher than minimum ER to launch higher optical power than necessary.
- This contribution proposes to introduce relaxed launch OMA requirements for ONU and OLT TX with higher ER.

This contribution is in support of comments by the author against draft D1.1.

Method of Umeda_3ca_2a_0518

$$\sigma_{APD} = \sqrt{2q(i + i_d)FM^2B} \qquad \text{(A)}$$

q : elementary charge (=1.602x10^{-19} C)

M : APD multiplication gain

i : APD current (M=1) (A)

i_d : APD dark current (M=1) (A)

B : receiver bandwidth (Hz)

F: excess noise factor

$$F = kM + (2 - 1/M)(1 - k) \qquad k:$$

Total noise of APD and TIA is:

$$\sigma_1 = \sqrt{\sigma_{1APD}{}^2 + \sigma_{TIA}{}^2}$$

$$\sigma_0 = \sqrt{\sigma_{0APD}{}^2 + \sigma_{TIA}{}^2}$$

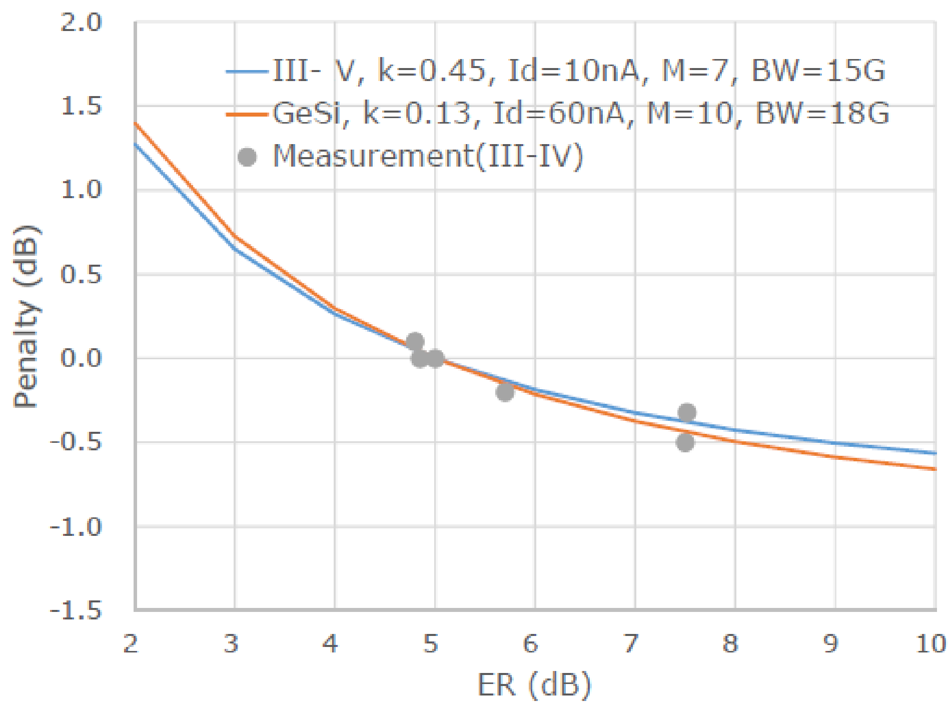
ER dependent penalty of OMA sensitivity is:

$$Penalty = 10\log\left(\frac{Q(ER)}{Q(ER=5dB)}\right)$$

$$Q(ER) = \frac{I_1 - I_0}{\sigma_1 + \sigma_0}$$

Representative parameter values

Parameter	III-V	GeSi	Unit
P_{OMA} (1)	-24.83		dBm
k	0.45	0.13	
i_d (2)	10	60	nA
M (2)	7	10	
R	0.7		A/W
B (2)	15	18	GHz
σ_{TIA} (3)	1.22	1.34	uA



Measurement plots are from tanaka_3ca_1_1116.pdf

Specification method

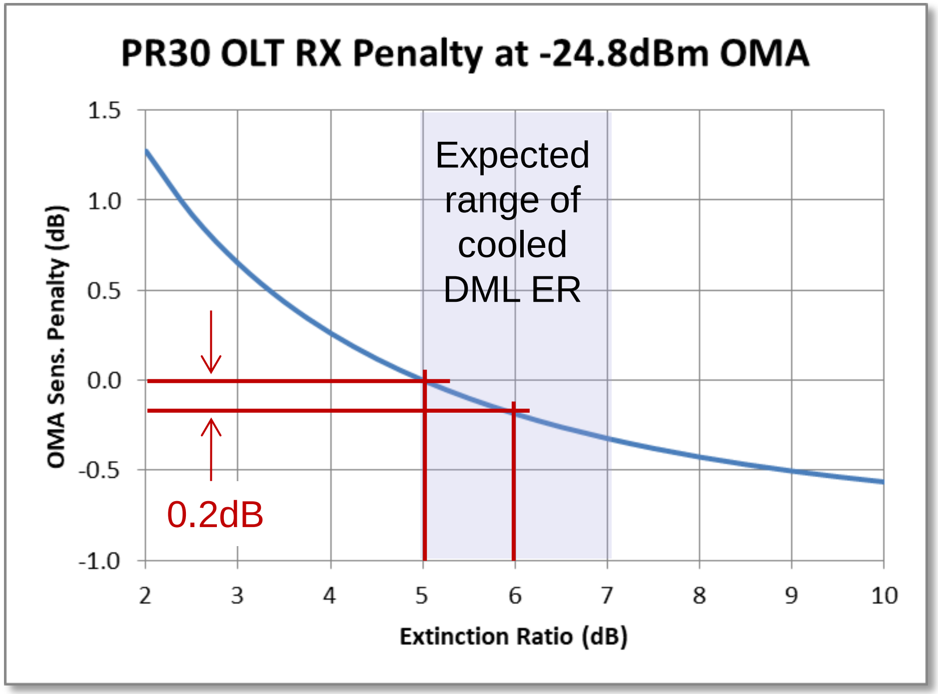
- To account for ER-dependent APD noise, the min TX OMA should depend on ER.
  - One way to accomplish this is to split the min OMA minus TDP line into one value for "high" ER and another value for "low" ER.
  - This specification method is already in use to account for ER-dependent MPI penalty for PAM4 optical PMDs.

Table 122–9—200GBASE-FR4 and 200GBASE-LR4 transmit characteristics

Description	200GBASE-FR4	200GBASE-LR4	Unit
Launch power in OMA_{outer} minus TDECQ, each lane (min):			
for extinction ratio ≥ 4.5 dB	−2.6	−1.8	dBm
for extinction ratio < 4.5 dB	−2.5	−1.7	dBm

- This is a simpler method than providing a formula or other means, and is relatively accurate as long as the expected ER range and OMA penalties are small.
- The key is to choose an appropriate ER break point to separate the "high" and "low" ER ranges.

PR30 US: Cooled ONU TX



Current PR30 ONU TX Spec:

Description	Value	Unit
Launch power in OMA minus TDP, each lane (min)	4.2	dBm

Proposed PR30 ONU TX Spec:

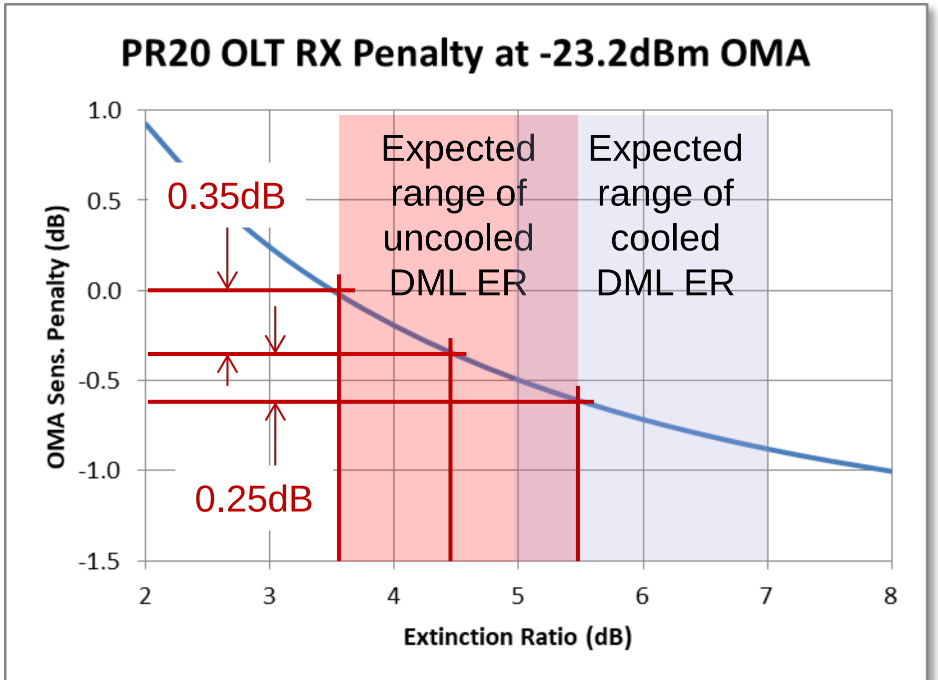
Description	Value	Unit
Launch power in OMA minus TDP, each lane (min): for extinction ratio ≥ 6 dB for extinction ratio < 6 dB	 4 4.2	dBm

- RX OMA Sens. (min) = -24.8dBm at minimum ER = 5dB.
- ONU TX is expected to be a **cooled DML** for PR30 PMDs
- Cooled DML ER can range from 5dB (min) to ~7dB at the high end.

- ONU TX with ER ≥ 6dB need **0.2dB lower OMA** for same OLT RX sensitivity as an ONU TX with ER = 5dB.

- **Propose relaxation of 0.2dB in OMA minus TDP (min) for PR30 ONU TX with ER ≥ 6dB.**

PR20 US: Uncooled ONU TX



Current PR20 ONU TX Spec:

Description	Value	Unit
Launch power in OMA minus TDP, each lane (min)	0.8	dBm

Proposed PR20 ONU TX Spec:

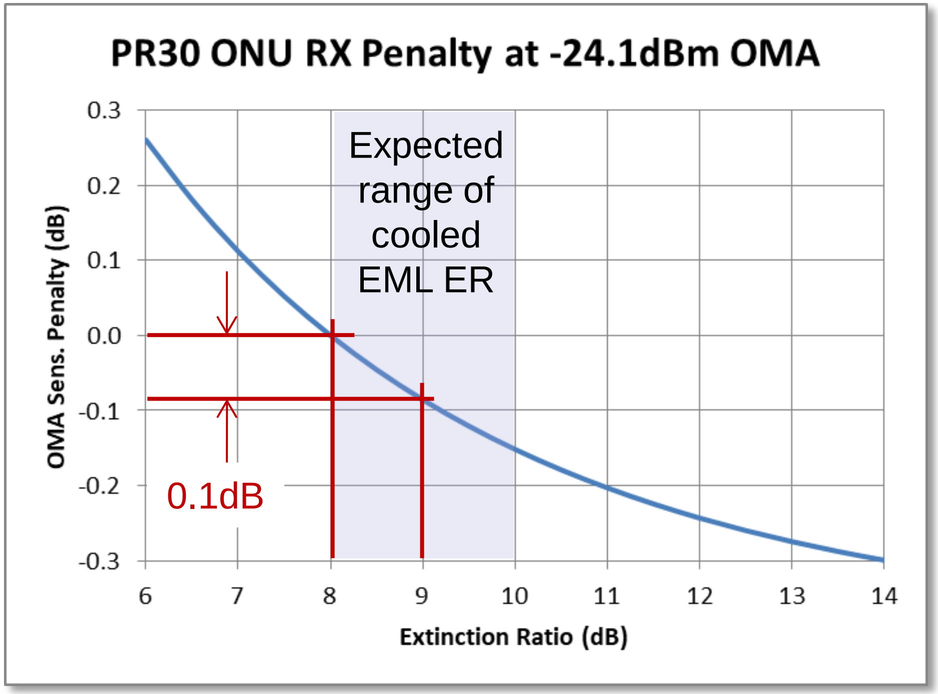
Description	Value	Unit
Launch power in OMA minus TDP, each lane (min):		
for extinction ratio ≥ 5.5 dB	0.2	
for extinction ratio ≥ 4.5 dB	0.5	dBm
for extinction ratio < 4.5 dB	0.8	

- RX OMA Sens. (min) = -23.2dBm at minimum ER = 3.5dB.
- ONU TX is expected to be an **uncooled DML** for PR20 25G PMDs, but 50/50G ONUs may use **cooled DMLs** to overcome mux losses**.**
- Uncooled DML ER can range from 3.5dB (min) to ~5.5dB at the high end. Cooled DML ER can be up to ~7dB.

- ONU TX with ER > 4.5dB need **0.35dB lower OMA** for same OLT RX sensitivity as an ONU TX with ER = 3.5dB. (Cooled) ONU TX with ER > 5.5dB need 0.6dB lower OMA.

- **Propose relaxation of 0.3dB in OMA minus TDP (min) for PR20 ONU TX with ER ≥ 4.5dB, and 0.6dB relaxation for ER ≥ 5.5dB.**

PR30 DS: Cooled EML TX



Current PR30 OLT TX Spec:

Description	Value	Unit
Launch power in OMA minus TDP, each lane (min)	4.9	dBm

Proposed PR30 OLT TX Spec:

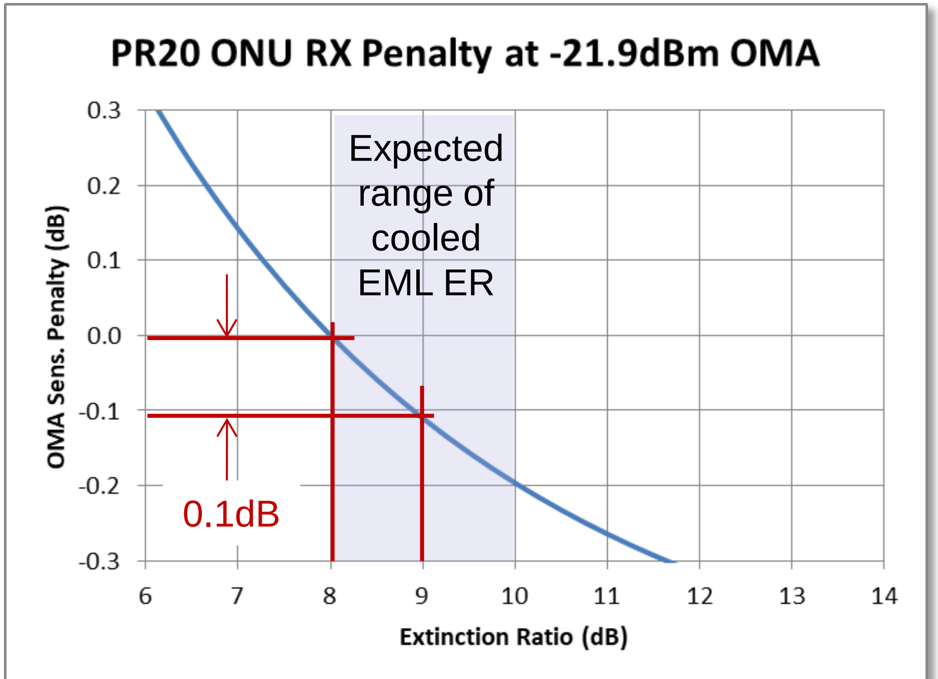
Description	Value	Unit
Launch power in OMA minus TDP, each lane (min):		
for extinction ratio ≥ 9 dB	4.8	dBm
for extinction ratio < 9 dB	4.9	

- RX OMA Sens. (min) = -24.1dBm at minimum ER = 8dB.
- OLT TX is expected to be a **cooled EML**.
- Cooled EML ER can range from 8dB (min) to ~10dB at the high end.

- OLT TX with ER > 9dB need **0.1dB lower OMA** for same ONU RX sensitivity as an OLT TX with ER = 8dB.

- **Propose relaxation of 0.1dB in OMA minus TDP (min) for PR30 OLT TX with ER ≥ 9dB.**

PR20 DS: Cooled EML TX



Current PR20 OLT TX Spec:

Description	Value	Unit
Launch power in OMA minus TDP, each lane (min)	2.1	dBm

Proposed PR20 OLT TX Spec:

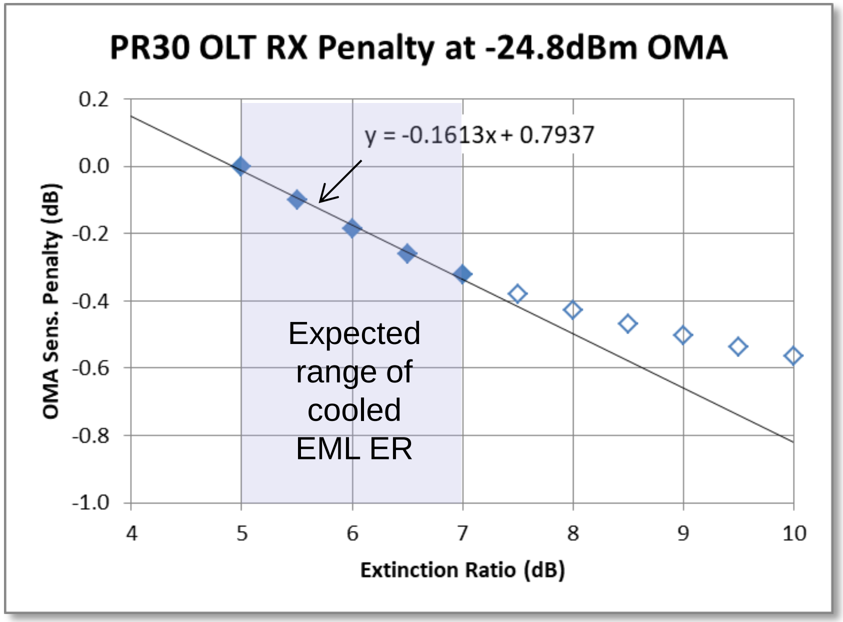
Description	Value	Unit
Launch power in OMA minus TDP, each lane (min):		
for extinction ratio ≥ 9 dB	2	dBm
for extinction ratio < 9 dB	2.1	

- RX OMA Sens. (min) = -21.9dBm at minimum ER = 8dB.
- OLT TX is expected to be a **cooled EML**.
- Cooled EML ER can range from 8dB (min) to ~10dB at the high end.
- OLT TX with ER > 9dB need **0.1dB lower OMA** for same ONU RX sensitivity as an OLT TX with ER = 8dB.
- **Propose relaxation of 0.1dB in OMA minus TDP (min) for PR20 OLT TX with ER ≥ 9dB.**

Alternative spec methods

Define OMA relaxation by a formula

- For a ~2dB range of ER, a simple linear approximation is sufficient.
- Example for PR30 ONU TX,
  - OMA minus TDP (min) = max(4.2 – 0.16 * (ER(dB) - 5), 3.9) dBm.
- Pros:
  - Proportional OMA relaxation for arbitrary ER
- Cons:
  - Implied more accurate measurements of ER and OMA than typical ± 0.1dB to achieve significant benefit over the two-range spec method.
  - Wider ER range requires quadratic fit which doesn't have an intuitive slope.



Define OMA relaxation by a new table

- The TX OMA minus TDP (min) would point to a new table, e.g. "See Table 141-X"
- Example for PR30 ONU TX shown at right
- Pros:
  - More control of granularity than a formula.
  - Cover extended ER ranges without quadratic formulas.
- Cons:
  - Not as visible or convenient as keeping all of the values in the main table.

Table 141 – X

TX ER (dB)	OMA minus TDP (min)
5	4.2
5.5	4.1
6	4.0
6.5	3.9
7	3.9
7.5	3.8
8	3.8
8.5	3.7
9	3.7

Summary

- APD RX sensitivity depends on extinction ratio due to avalanche multiplication noise.
- The currently accepted baseline APD receiver sensitivities assume that all TX have worst-case ER.
  - To minimize optical component cost and power dissipation, it makes sense for TX with higher ER to be able to launch lower optical power.
  - By allowing lower minimum OMA minus TDP for TX with extinction ratios 1dB higher than the minimum, the required launch power is reduced by 0.2 to 0.6dB for ONU TX and 0.1dB for OLT TX.
- It's recommended that the P802.3ca Task Force accept the proposed changes in minimum OMA minus TDP shown in slides 6, 7, 8 and 9, in support of comments by the author against D1.1.