Populating 25G-EPON PR30 PMD Tables

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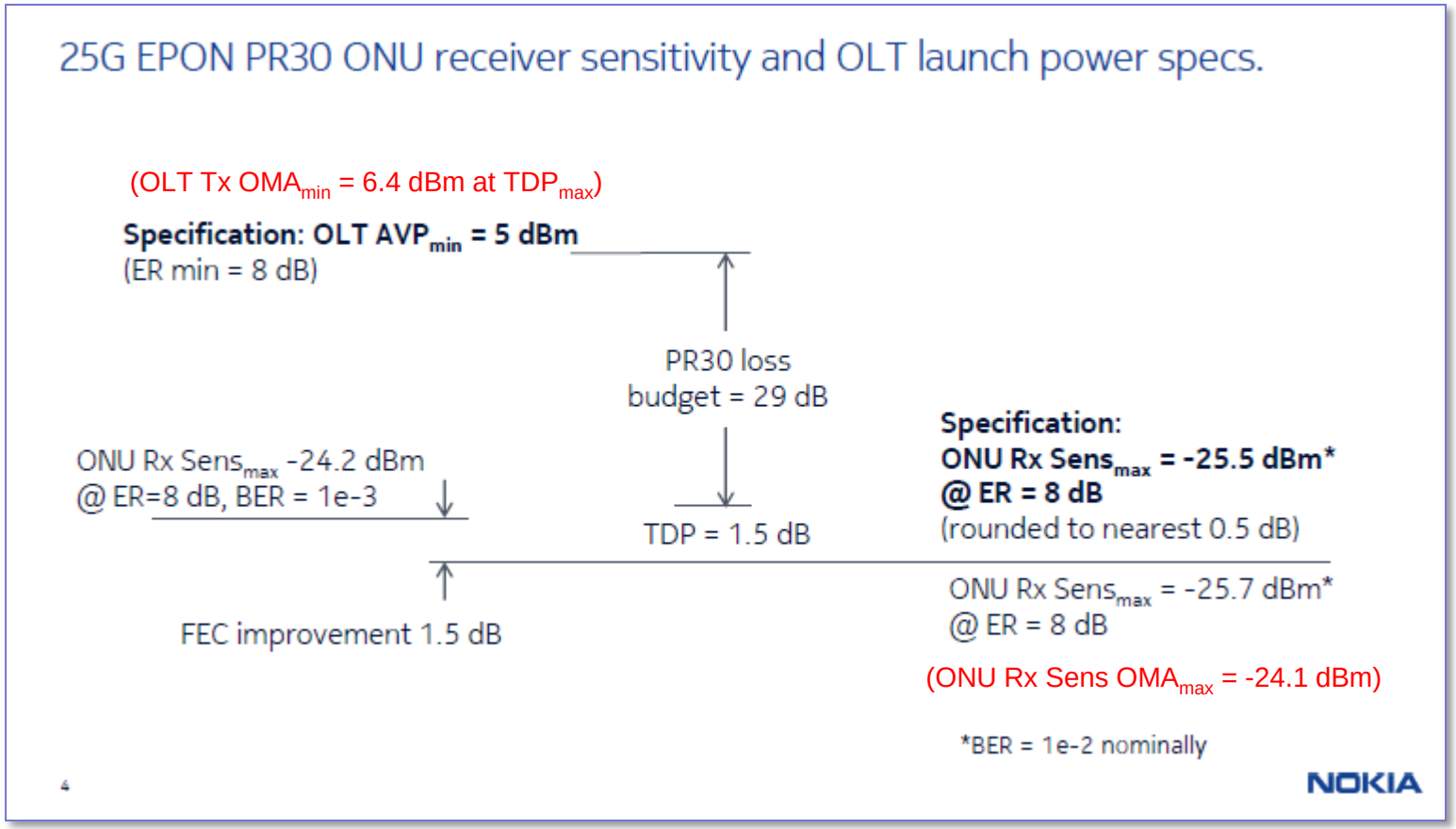
25G-EPON PMD Progress

- Consensus over the last several meeting cycles has provided sufficient definition to be able to generate a complete set of P802.3ca 25G-EPON PR30 PMD tables for downstream and upstream.
  - July 2017 Motion#5: US0 wavelengths
  - Jan. 2018 Motion#12: US0-A wavelength
  - Jan. 2018 Motion#15: US1 wavelength
  - March 2018 Motion#3: DS wavelengths
  - March 2018 Motion#7: US power budget
  - Jan. 2018 Motion#7: DS power budget
  - Jan. 2018 motion#8: Use Tx power minus penalties method of specification

DS power budget

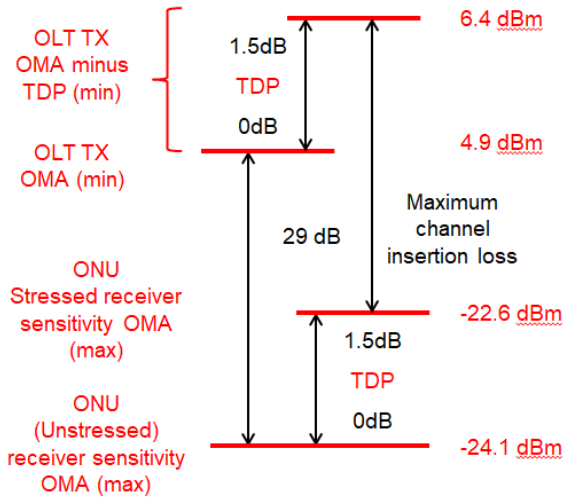


7	**Transmitter launch power and receiver sensitivity values**	The 25G EPON PR30 specifications proposed in harstead_3ca_1b_0118 ▪ 25G ONU receiver sensitivity: -25.7 dBm at BER= 1e-2 and ER=8 dB ▪ 25G OLT transmitter: AVPmin = 4.8 dBm and ER min = 8 dB shall be adopted.

DS Tx power minus penalties

Power minus penalty method DS

Using 25G-EPON downstream power budget of Jan. 2018 Motion #7, converted to OMA.



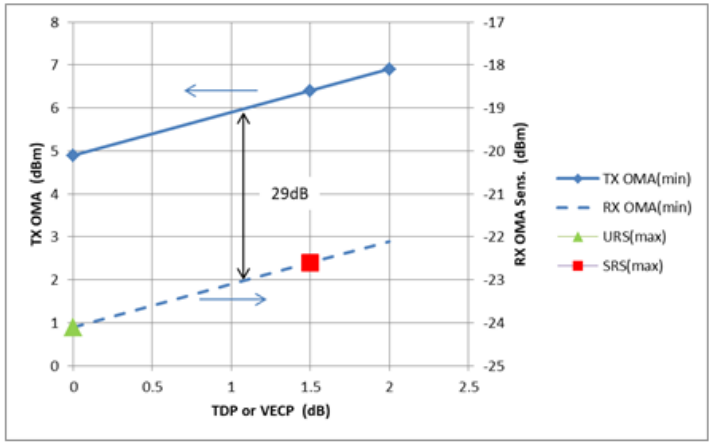
(OMA-TDP)(min) is NORMATIVE for all OLT TX. **Reference TDP=0dB is chosen based on TP of a best-case real EML TX.** Other values can be considered.

OMA(min) is NORMATIVE for all ONU TX. **Must be met even if TDP is < 0dB** to insure compliance even if TDP is negative.

SRS(max) is NORMATIVE for all ONU RX. Defined for a signal with specified vertical eye closure penalty (VECP) and jitter characteristics. Typically VECP = TDP(max).

URS(max) is INFORMATIVE for ONU RX. Defined for a TX with reference VECP = 0dB and max channel insertion loss.

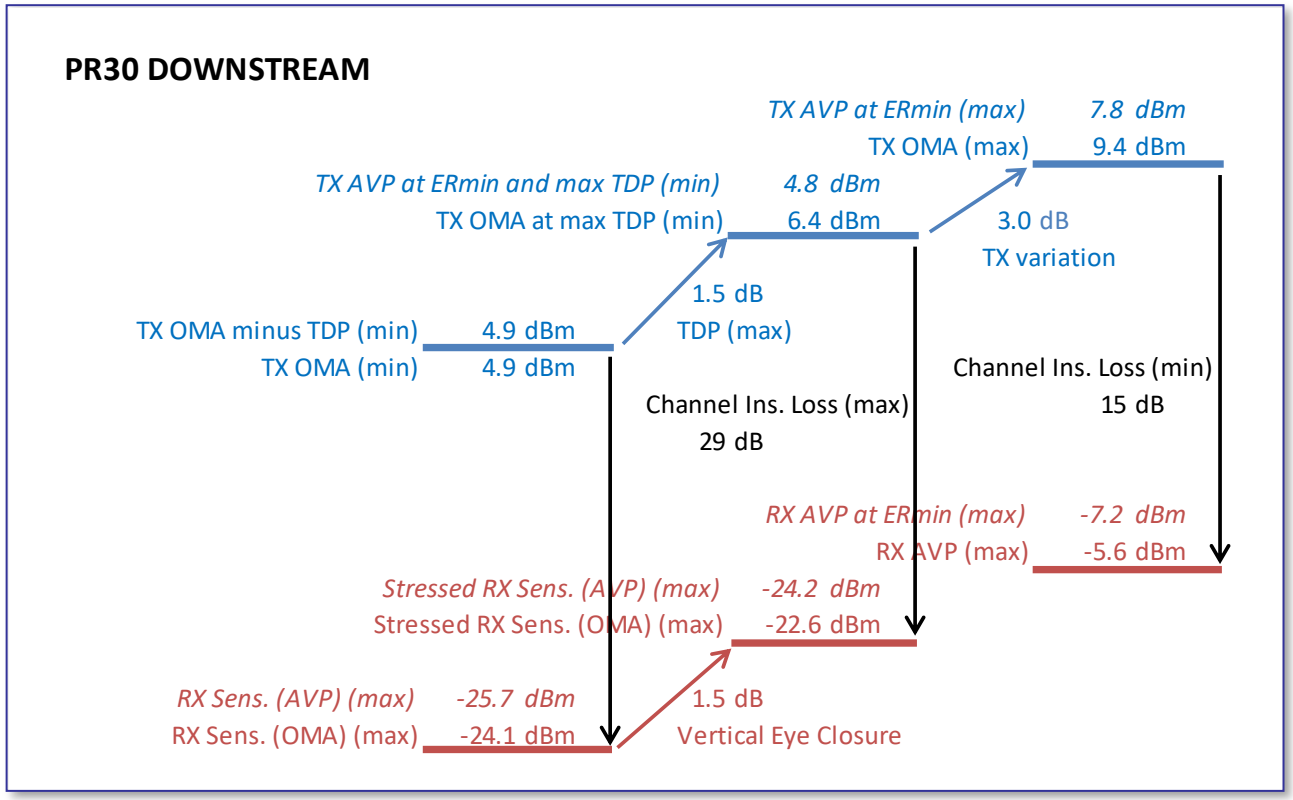
Power minus Penalty Method



- OLT TX OMA(min) depends on TDP
  - TX with TDP = 0dB only needs 4.9 dBm
  - Worst case TX (TDP=1.5dB) must launch 6.4 dBm
- Assumes real-world EML TX have TP ≥ 0dB
  - All OLT TX must launch OMA ≥ 4.9dBm
  - URS OMA(max) = -24.1dBm at VECP = 0dB
- Stressed ONU receiver sensitivity is defined for worst case TX with VECP = 1.5dB
  - SRS OMA(max) = -22.6dBm

Conversion of the DS power budget of Jan. 2018 Motion #7 was presented in johnson_3ca_1a_0318.pdf.

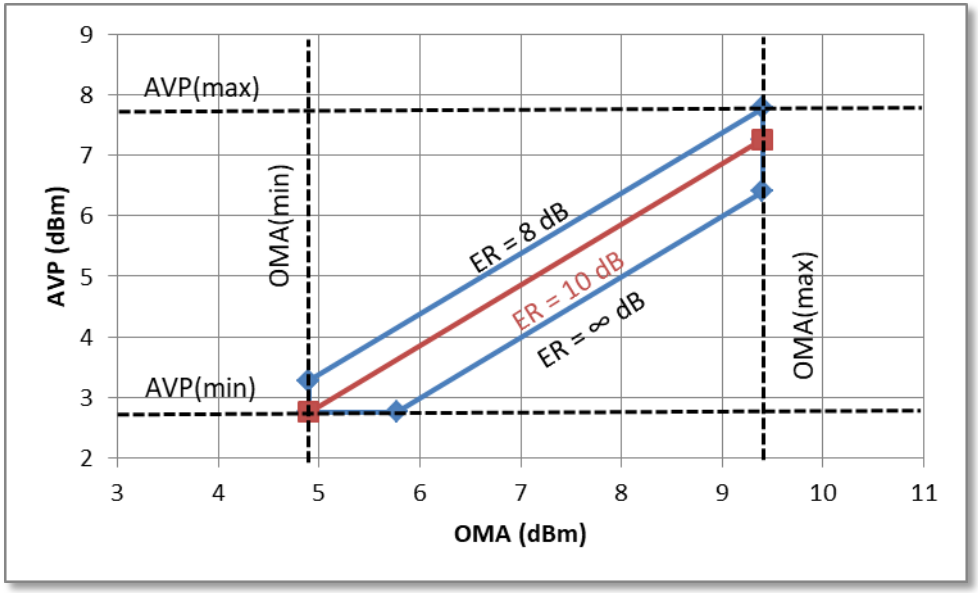
PR30 DS power budget - expanded



Expanding on the analysis to include maximum values:

- Propose max OLT TX OMA is 3 dB higher than OMA at max TDP → 9.4 dBm.
  - 3dB is less than the 5dB range used in other standards, but such high 25G TX power is extremely unlikely.
- Assume the minimum channel insertion loss is 15 dB, same as 10G-EPON. This determines the maximum OMA at the ONU RX = -5.6 dBm.

OLT TX AVP, OMA and ER



- The foregoing analysis uses OMA at the minimum extinction ratio ER = 8 dB.
- Informative minimum Average Power (AVP) is proposed based on ER = 10dB at the value of minimum OMA, giving 2.8 dBm minimum.
- Maximum Average Power (AVP) is proposed based on ER = 8dB at the value of maximum OMA, giving 7.8 dBm maximum.
- All OLT TX must have both OMA > 4.9 dBm and AVP > 2.8 dBm. Only OMA is normative in the sense that AVP > 2.8dBm is necessary but not sufficient for compliance.

OLT Transmit Characteristics

Table 141-8 — OLT PMD Transmit Characteristics

Description	25/10GBASE-PQ11G-D3 25/10GBASE-PQ11X-D3 25GBASE-PQ11G-D3 25GBASE-PQ11X-D3	Unit	Comment
Signaling speed (range)	25.78125 ± 100 ppm	GBd	P802.3ca Motion #5, Mar. 2017
Lane wavelengths (range)	1356 to 1360	nm	P802.3ca Motion #3, Mar. 2018
Side Mode Suppression Ratio (min)	30	dB	Common to all singlemode PMDs
Total average launch power (max)	—	dBm	Placeholder for 50G
Average launch power, each lane (max)	7.8	dBm	OMA(max) at ER = 8 dB
Average launch power, each lane [a] (min)	2.8	dBm	OMA(min) at ER = 10 dB
Optical Modulation Amplitude (OMA), each lane (max)	9.4	dBm	OMA(min)+TDP(max)+3dB
Optical Modulation Amplitude (OMA), each lane (min) [b]	4.9	dBm	P802.3ca Motion #7, Jan. 2018
Difference in launch power between any two lanes (OMA) (max)	—	dB	Placeholder for 50G
Launch power in OMA minus TDP, each lane (min)	4.9	dBm	harstead_3ca_1c_0118
Transmitter and dispersion penalty (TDP), each lane (max)	1.5	dB	harstead_3ca_1c_0118
Average launch power of OFF transmitter, each lane (max)	TBD	dBm	
Extinction ratio (min)	8	dB	harstead_3ca_1c_0118
$RIN_{15}OMA$ (max)	TBD	dB/Hz	
Optical return loss tolerance (max)	TBD	dB	
Transmitter reflectance [c] (max)	TBD	dB	
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	TBD	UI	
Decision timing offset for transmitter and dispersion penalty	TBD	UI	

a Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
b Even if the TDP < 0 dB, the OMA (min) must exceed this value.
c Transmitter reflectance is defined looking into the transmitter.

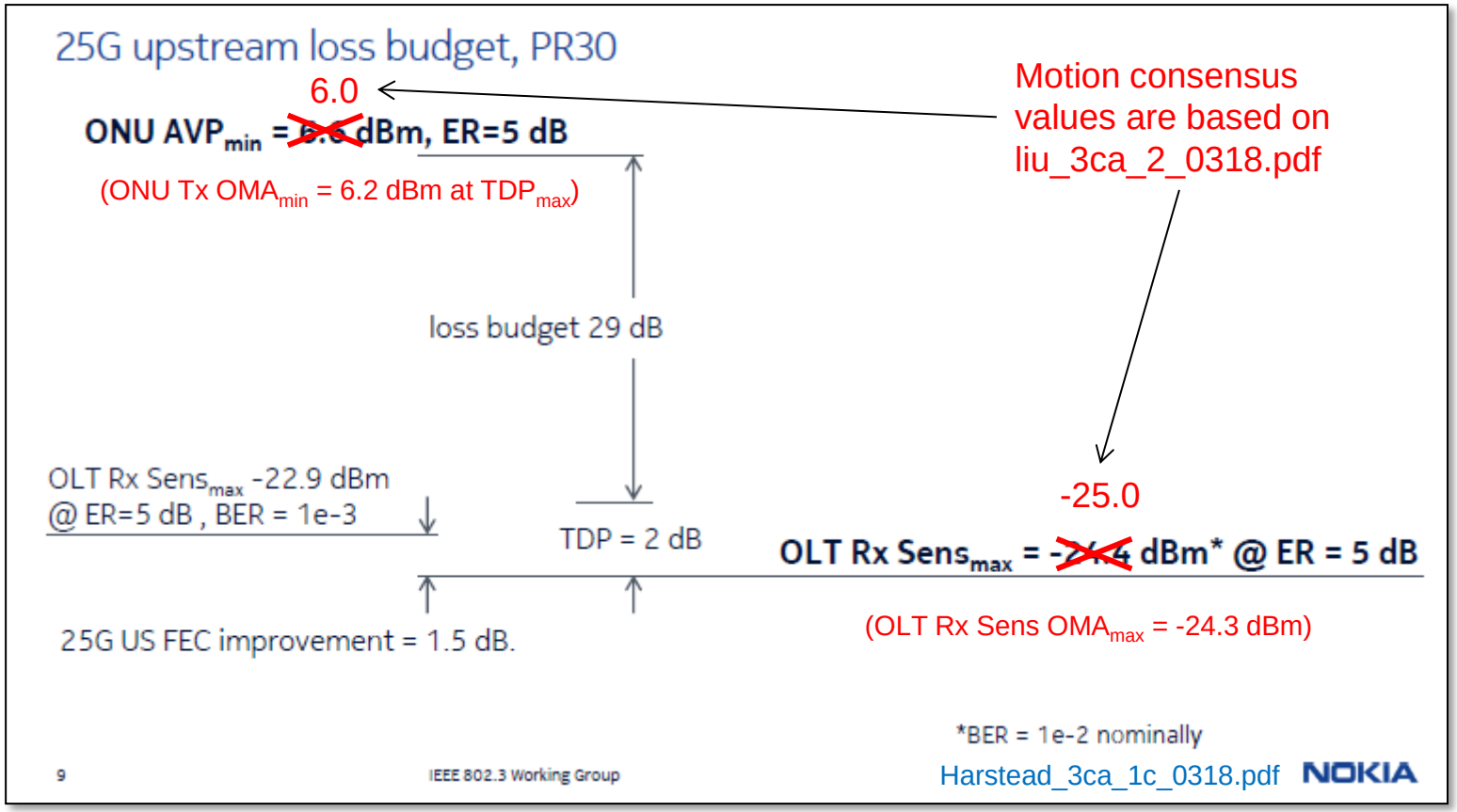
ONU Receive Characteristics

Table 141-14 — ONU PMD Receive Characteristics

Description	25/10GBASE-PQ11G-U3 25/10GBASE-PQ11X-U3 25GBASE-PQ11G-U3 25GBASE-PQ11X-U3	Unit	Comment
Signaling speed (range)	25.78125 ± 100 ppm	GBd	P802.3ca Motion #5, Mar. 2017
Lane wavelengths (range)	1356 to 1360	nm	P802.3ca Motion #3, Mar. 2018
Bit error ratio (max) [a]	10^{-2}	-	LDPC FEC
Damage threshold [b]	-6.2	dBm	APV(max) + 1 dB
Average receive power, each lane (max)	-7.2	dBm	OMA(max) at ER = 8 dB
Average receive power, each lane [c] (min)	-26.2	dBm	harstead_3ca_1c_0118
Receive power, each lane (OMA) (max)	-5.6	dBm	TX OMA(max) - 15 dB
Receiver reflectance (max)	TBD	dB	
Receiver sensitivity (OMA), each lane [d] (max)	-24.1	dBm	harstead_3ca_1c_0118
Signal detect threshold, each lane (min)	TBD	dBm	
Stressed receiver sensitivity (OMA), each lane [e] (max)	-22.6	dBm	harstead_3ca_1c_0118
Conditions of stressed receiver sensitivity test:			
Vertical eye closure penalty,[f] each lane	1.5	dB	harstead_3ca_1c_0118
Stressed eye J2 Jitter,[f] each lane	TBD	UI	
Stressed eye J9 Jitter,[f] each lane	TDB	UI	

a The BER of 10^{-12} is achieved by the utilization of FEC as described in 142.2.2.5.
b The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level. Direct ONU–OLT connection may result in damage of the receiver.
c Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
d Receiver sensitivity (OMA), each lane (max) is informative.
e Measured with conformance test signal at TP3 (see 141.7.12) for BER = 10^{-2}.
f Vertical eye closure penalty, stressed eye J2 Jitter, and stressed eye J9 Jitter are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

US power budget

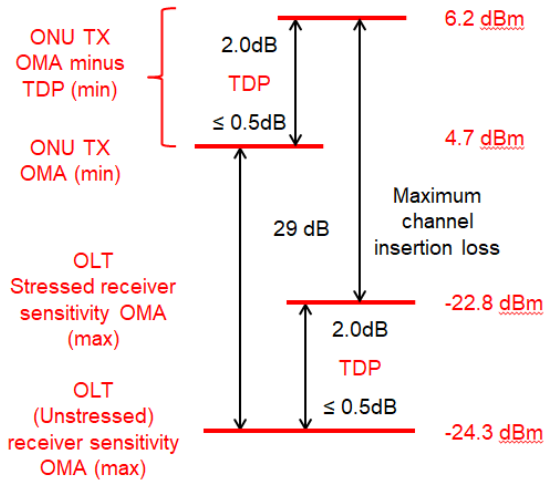


7	**25G PR30 upstream specifications**	Adopt the following 25G EPON PR30 upstream specifications: ▪ 25G OLT receiver sensitivity: -25.0 dBm at BER = 1e-2 and ONU Tx ER = 5 dB, ▪ 25G ONU transmitter: ERmin = 5 dB, (AVP minus TDP)min = 4.0dBm and update the draft.

US power minus penalties

Power minus penalty method US

Using proposed 25G-EPON upstream power budget of harstead_3ca_2_0318, converted to OMA.



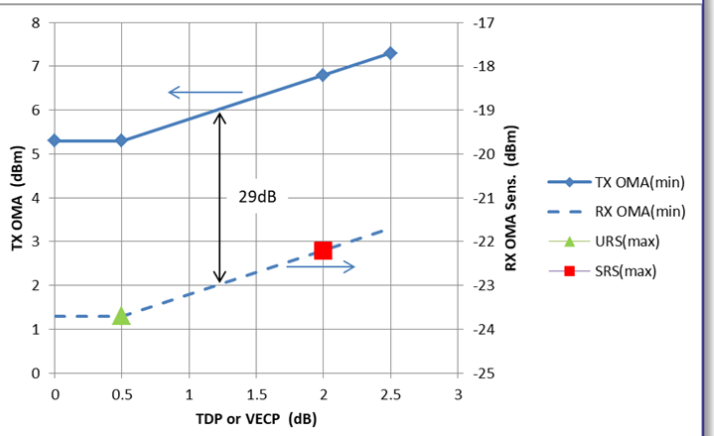
(OMA-TDP)(min) is NORMATIVE for all ONU TX. **Reference TDP=0.5dB is chosen based on TP of a best-case real DML TX.** Other values can be considered.

OMA(min) is NORMATIVE for all ONU TX. **Must be met even if TDP is < 0.5dB** to insure compliance even if DP over long fiber spans is negative.

SRS(max) is NORMATIVE for all OLT RX. Defined for a signal with specified vertical eye closure penalty (VECP) and jitter characteristics. Typically VECP = TDP(max).

URS(max) is INFORMATIVE for OLT RX. Defined for a TX with reference VECP = 0.5dB and max channel insertion loss.

Power minus Penalty Method

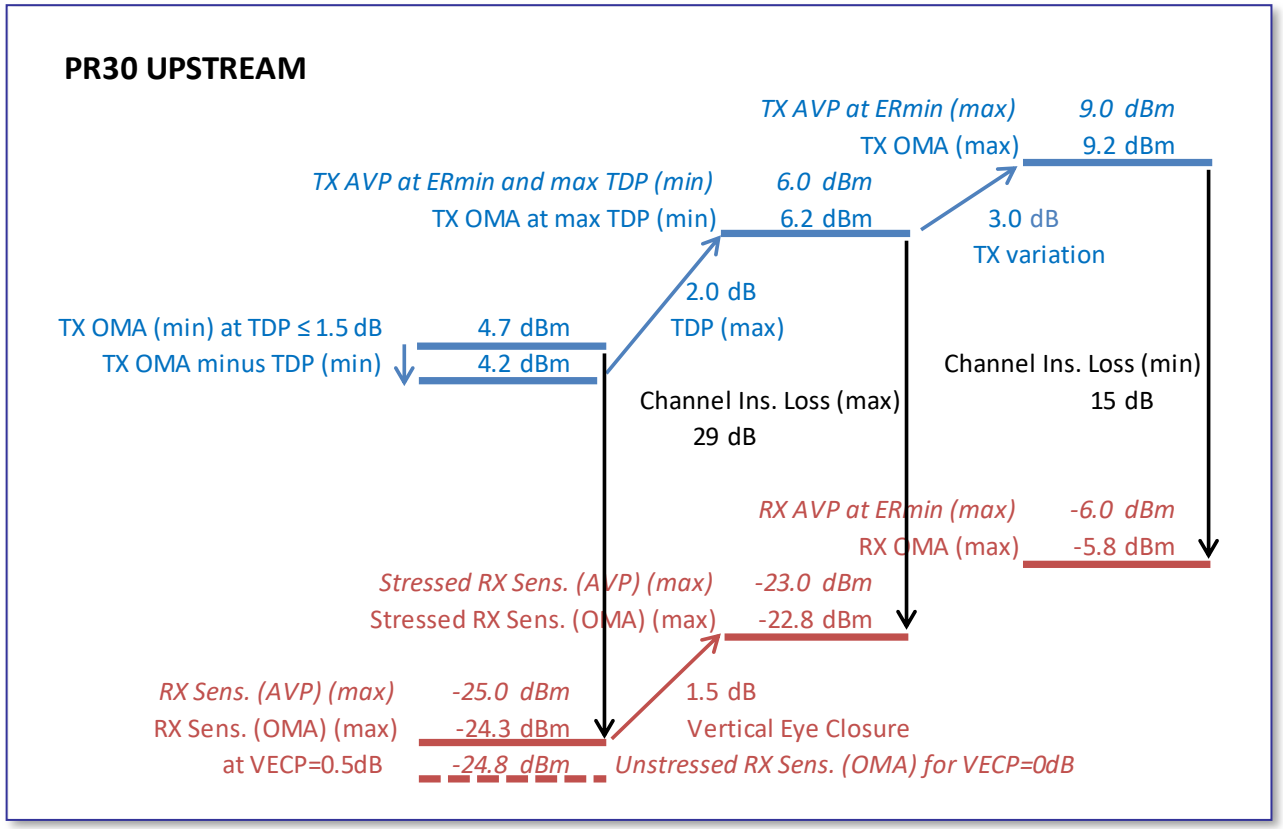


- ONU TX OMA(min) depends on TDP
  - TX with TDP ≤ 0.5dB only needs 5.3 dBm
  - Worst case TX (TDP = 2dB) must launch 6.8 dBm
- Assumes real-world DML TX have TP ≥ 0.5dB
  - All ONU TX must launch OMA ≥ 5.3dBm
  - URS OMA(max) = -23.7dBm at VECP = 0.5dB
- Stressed OLT receiver sensitivity is defined for worst case TX with VECP = 2dB
  - SRS OMA(max) = -22.2dBm

Conversion of the US power budget of harstead_3ca_2_0318 was presented in johnson_3ca_1a_0318.pdf.

The numerical values shown here have been modified to be in agreement with the final values in March 2018 Motion #7.

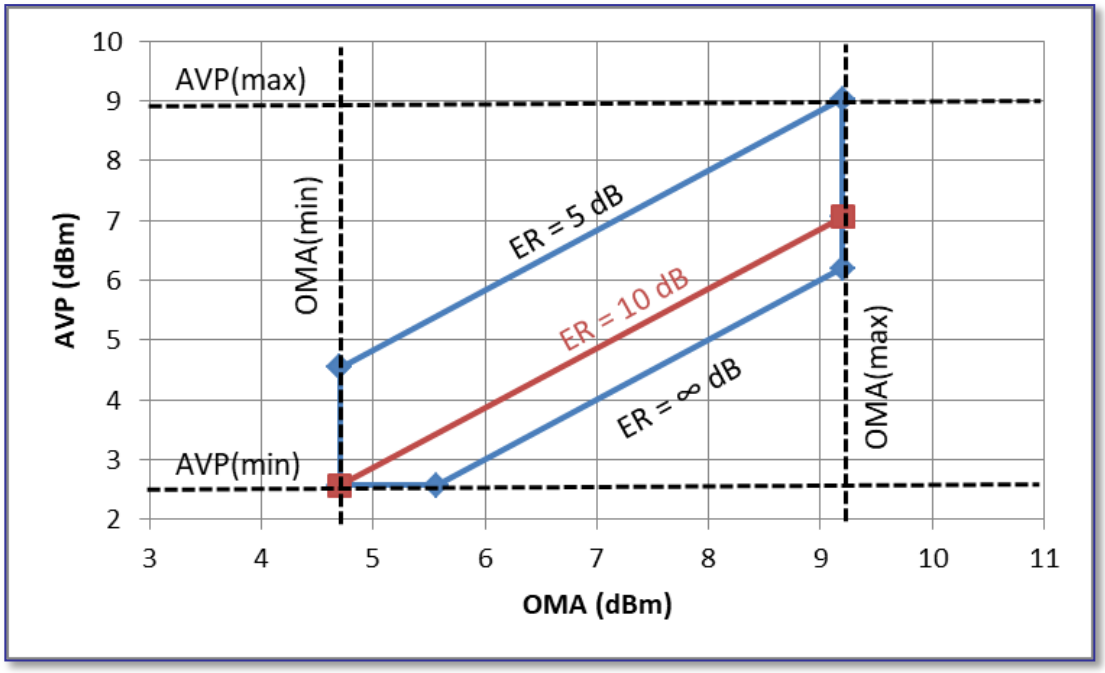
PR30 US power budget - expanded



Expanding on the analysis to include maximum values:

- Propose max ONU TX OMA is 3 dB higher than OMA at max TDP → 9.2 dBm.
  - 3dB is less than the 5dB range used in other standards, but such high 25G TX power is extremely unlikely
- Assume the minimum channel insertion loss is 15 dB, same as 10G-EPON. This determines the maximum OLT RX OMA = -5.8 dBm.

ONU TX AVP, OMA and ER



- The foregoing analysis uses OMA at the minimum extinction ratio ER = 5 dB.
- Informative minimum Average Power (AVP) is proposed based on ER = 10 dB at the value of minimum OMA, giving 2.6 dBm minimum.
- Informative maximum Average Power (AVP) is proposed based on ER = 5 dB at the value of maximum OMA, giving 9 dBm maximum.
- All ONU TX must have both OMA > 4.7 dBm and AVP > 2.6 dBm, although only OMA is normative.

ONU Transmit Characteristics

Table 141-12 — ONU PMD Transmit Characteristics

Description	25GBASE-PQ11G-U3 50/25GBASE-PQ21G-U3	25GBASE-PQ11X-U3 50/25GBASE-PQ21X-U3	Unit	Comment
Signaling speed (range)	25.78125 ± 100 ppm		GBd	P802.3ca Motion #5, Mar. 2017
Lane wavelengths (range)	1260 to 1280	1290 to 1310	nm	P802.3ca Motion #5, Mar. 2017 P802.3ca Motion #12, Jan. 2018
Side Mode Suppression Ratio (min)	30		dB	Common to all singlemode PMDs
Total average launch power (max)	—		dBm	Placeholder for 50G
Average launch power, each lane (max)	9		dBm	OMA(max) at ER = 5 dB
Average launch power, each lane [a] (min)	2.6		dBm	OMA(min) at ER = 10 dB
Optical Modulation Amplitude (OMA), each lane (max)	9.2		dBm	OMA(min)+TDP(max)+3dB
Optical Modulation Amplitude (OMA), each lane (min) [b]	4.7		dBm	P802.3ca Motion #7, Mar. 2018
Difference in launch power between any two lanes (OMA) (max)	—		dB	Placeholder for 50G
Launch power in OMA minus TDP, each lane (min)	4.2		dBm	P802.3ca Motion #7, Mar. 2018
Transmitter and dispersion penalty (TDP), each lane (max)	2		dB	P802.3ca Motion #7, Mar. 2018
Average launch power of OFF transmitter, each lane (max)	TBD		dBm	
Extinction ratio (min)	5		dB	P802.3ca Motion #7, Mar. 2018
$RIN_{15}OMA$ (max)	TBD		dB/Hz	
Optical return loss tolerance (max)	TBD		dB	
Transmitter reflectance [c] (max)	TBD		dB	
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	TBD		UI	
Turn-on time (max)	128		ns	P802.3ca Motion #5, May 2018
Turn off time (max)	128		ns	P802.3ca Motion #5, May 2019
Decision timing offset for transmitter and dispersion penalty	TBD		UI	

a Average launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
b Even if the TDP < 0.5 dB, the OMA (min) must exceed this value.
c Transmitter reflectance is defined looking into the transmitter.

OLT Receive Characteristics

Table 141-10 — OLT PMD Receive Characteristics

Description	25GBASE-PQ11G-D3 50/25GBASE-PQ21G-D3	25GBASE-PQ11X-D3 50/25GBASE-PQ21X-D3	Unit	Comment
Signaling speed (range)	25.78125 ± 100 ppm		GBd	P802.3ca Motion #5, Mar. 2017
Lane wavelengths (range)	1260 to 1280	1290 to 1310	nm	P802.3ca Motion #5, Mar. 2017 P802.3ca Motion #12, Jan. 2018
Bit error ratio (max) [a]	10^{-2}		-	LDPC FEC
Damage threshold [b]	-5		dBm	AVP(max) + 1 dB
Average receive power, each lane (max)	-6		dBm	OMA(max) at ER = 8 dB
Average receive power, each lane [c] (min)	-26.4		dBm	P802.3ca Motion #7, Mar. 2018
Receive power, each lane (OMA) (max)	-5.8		dBm	TX OMA(max) - 15 dB
Receiver reflectance (max)	TBD		dB	
Receiver sensitivity (OMA), each lane [d] (max)	-24.3		dBm	P802.3ca Motion #7, Mar. 2018
Signal detect threshold, each lane (min)	TBD		dBm	
Stressed receiver sensitivity (OMA), each lane [e] (max)	-22.8		dBm	P802.3ca Motion #7, Mar. 2018
Receiver settling time (max)	TBD		ns	
Conditions of stressed receiver sensitivity test:				
Vertical eye closure penalty,[f] each lane	2		dB	P802.3ca Motion #7, Mar. 2018
Stressed eye J2 Jitter,[f] each lane	TBD		UI	
Stressed eye J9 Jitter,[f] each lane	TBD		UI	

a The BER of 10^{-12} is achieved by the utilization of FEC as described in 142.2.2.5.
b The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level. Direct ONU–OLT connection may result in damage of the receiver.
c Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
d Receiver sensitivity (OMA), each lane (max) is measured with a signal with VECP = 0.5 dB and is informative.
e Measured with conformance test signal at TP3 (see 141.7.12) for BER = 10^{-2}.
f Vertical eye closure penalty, stressed eye J2 Jitter, and stressed eye J9 Jitter are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

Additional considerations

- Several potential modifications were proposed by email before and after the ad-hoc presentation.
- If consensus is reached at this meeting to make any of these changes, this contribution will be updated appropriately before the motion to accept the tables.
- Some proposed modifications:
  - Remove OMA (max) and keep only AVP (max) for both TX and RX.
  - Increase DS and US TDP (max) by 0.5dB.
  - Define OLT TX OMA(min) at TDP = 0.5dB.
  - Modify the TX OMA and RX sensitivity specs to vary with extinction ratio to account for the dependence of APD noise on ER.

Remove OMA(max), Keep AVP(max)

- It was suggested to delete specs for max OMA and keep only specs for max AVP.
- For purposes of RX overload, AVP matters more than OMA, so this appears to be a reasonable suggestion.
- Example of implementation for the DS direction is shown below:

Table 141-8 — OLT PMD Transmit Characteristics

Description	25GBASE-PR30-D	Unit
Signaling speed (range)	25.78125 ± 100 ppm	GBd
Lane wavelengths (range)	1356 to 1360	nm
Side Mode Suppression Ratio (min)	30	dB
Total average launch power (max)	—	dBm
Average launch power, each lane (max)	7.8	dBm
Average launch power, each lane [a] (min)	2.8	dBm
Optical Modulation Amplitude (OMA), each lane (max)	9.4	dBm

Table 141-14 — ONU PMD Receive Characteristics

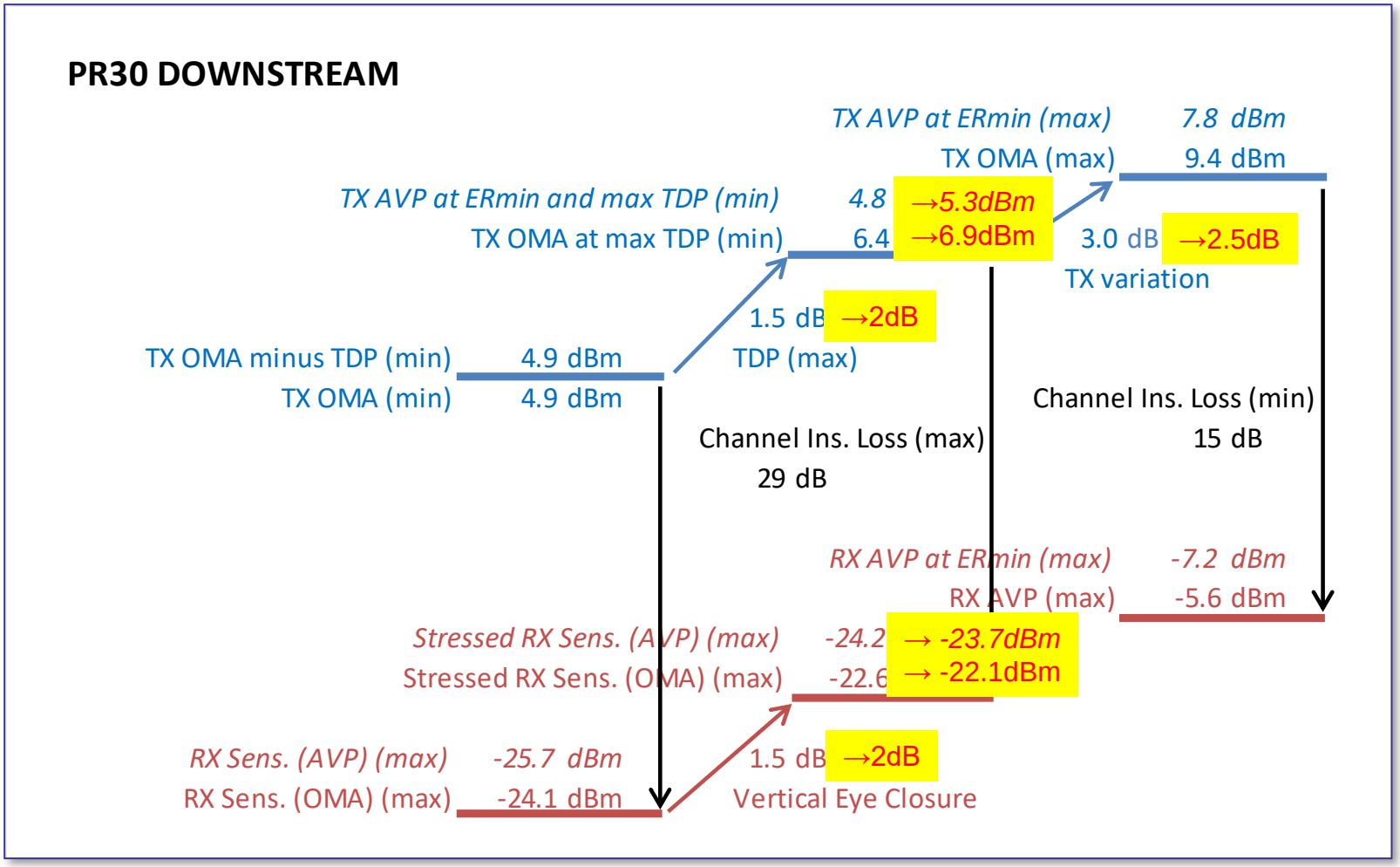
Description	25GBASE-PR30-U	Unit
Signaling speed (range)	25.78125 ± 100 ppm	GBd
Lane wavelengths (range)	1356 to 1360	nm
Bit error ratio (max) [a]	10^{-2}	-
Damage threshold [b]	-6.2	dBm
Average receive power, each lane (max)	-7.2	dBm
Average receive power, each lane [c] (min)	-26.2	dBm
Receive power, each lane (OMA) (max)	-5.6	dBm

Recommend that this change be accepted to further simplify the PMD specs and clarify the power levels to be used for RX overload testing.

Increase TX TDP by 0.5dB

- It was suggested to increase OLT and ONU TX TDP by 0.5dB to enable the possibility of not needing to test TDP.
  - Since OMA minus TDP is being used, this has no effect on TX that take advantage of lower (tested) TDP to reduce launch OMA.
  - Vendors choosing not to test TDP must set min OMA based on a statistically worst case TDP. The higher OMA would partially negate the benefit of not testing TDP.
  - Max TX AVP would need to increase 0.5dB or the TX variation range would be further reduced from 3dB to 2.5dB to avoid increasing the RX overload power.
- All RX must interoperate with TX signals having the max TDP, so this change burdens all RX with higher stressed eye closure (VECP) for SRS testing, even if the vendor is not making use of the higher TDP spec.
- The impact of increasing TDP by 0.5dB on the DS power budget is shown on the next slide to illustrate these trade-offs.

Impact of increasing TDP in DS



Based on these observations, this proposal is not such a clear improvement. More discussion will be required.

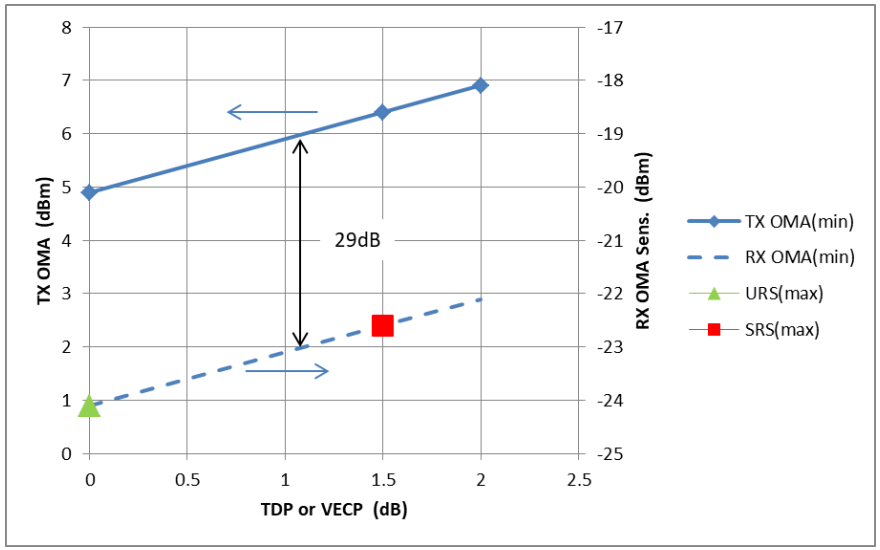
OLT TX OMA(min) at TDP-0.5dB

- It was suggested to define OLT TX OMA(min) and the "unstressed" ONU RX sensitivity at a reference TDP value of 0.5dB instead of 0dB.
- This is the same as what has already been presented for the ONU TX.
- It presumes that most OLT TX will have TDP ≥ 0.5dB which is reasonable based on estimates of umeda_3ca_1_0316.pdf and tanaka_3ca_1_0516.pdf.
- The impact of this proposal is illustrated on the next slide.

Recommend that this change be accepted to better represent expected real OLT TX performance, and to make the TX used for ONU "unstressed" RX sensitivity more realistic.

Impact of increasing OLT ref TDP

Reference TDP = 0 dB → Reference TDP = 0.5 dB



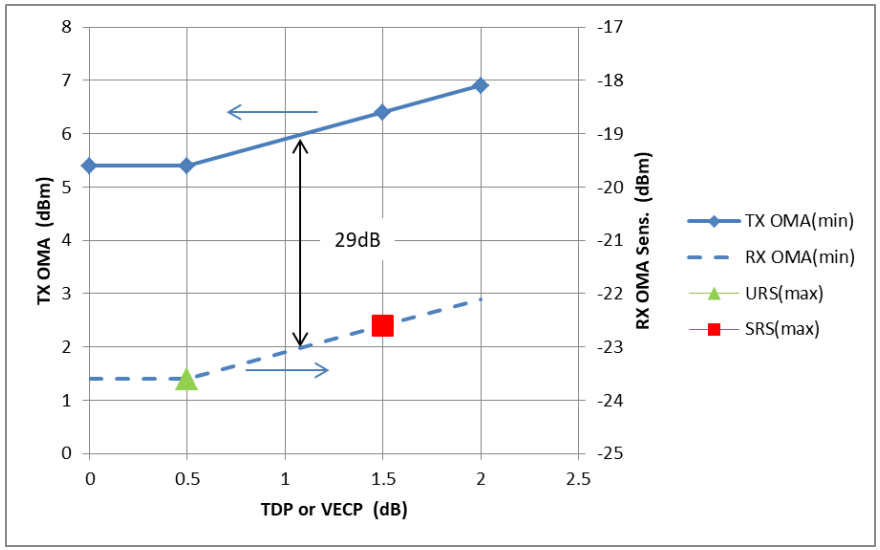


Table 141-8 — OLT PMD Transmit Characteristics

Description	25GBASE-PR30-D	Unit
Signaling speed (range)	25.78125 ± 100 ppm	GBd
Lane wavelengths (range)	1356 to 1360	nm
Side Mode Suppression Ratio (min)	30	dB
Total average launch power (max)	–	dBm
Average launch power, each lane (max)	7.8	dBm
Average launch power, each lane [a] (min)	2.8 → 3.3	dBm
Optical Modulation Amplitude (OMA), each lane (max)	9.4	dBm
Optical Modulation Amplitude (OMA), each lane (min) [b]	4.9 → 5.4	dBm
Difference in launch power between any two lanes (OMA) (max)	–	dB
Launch power in OMA minus TDP, each lane (min)	4.9	dBm
Transmitter and dispersion penalty (TDP), each lane (max)	1.5	dB
Average launch power of OFF transmitter, each lane (max)	TBD	dBm
Extinction ratio (min)	8	dB

b Even if the TDP < **0.5** dB, the OMA (min) must exceed this value.

Table 141-14 — ONU PMD Receive Characteristics

Description	25GBASE-PR30-U	Unit
Signaling speed (range)	25.78125 ± 100 ppm	GBd
Lane wavelengths (range)	1356 to 1360	nm
Bit error ratio (max) [a]	10^{-2}	-
Damage threshold [b]	-6.2	dBm
Average receive power, each lane (max)	-7.2	dBm
Average receive power, each lane [c] (min)	-26.2 → -25.7	dBm
Receive power, each lane (OMA) (max)	-5.6	dBm
Receiver reflectance (max)	TBD	dB
Receiver sensitivity (OMA), each lane [d] (max)	-24.1 → -23.6	dBm
Signal detect threshold, each lane (min)	TBD	dBm
Stressed receiver sensitivity (OMA), each lane [e] (max)	-22.6	dBm
Conditions of stressed receiver sensitivity test:		
Vertical eye closure penalty, [f] each lane	1.5	dB

Vary TX OMA specs with ER

- As documented in umeda_3ca_2_0518.pdf, APD RX sensitivity depends on ER due to APD shot noise in the one and zero rails.
- The currently accepted baseline power budgets assume all ER dependence is included in OMA.
- To account for ER-dependent 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.

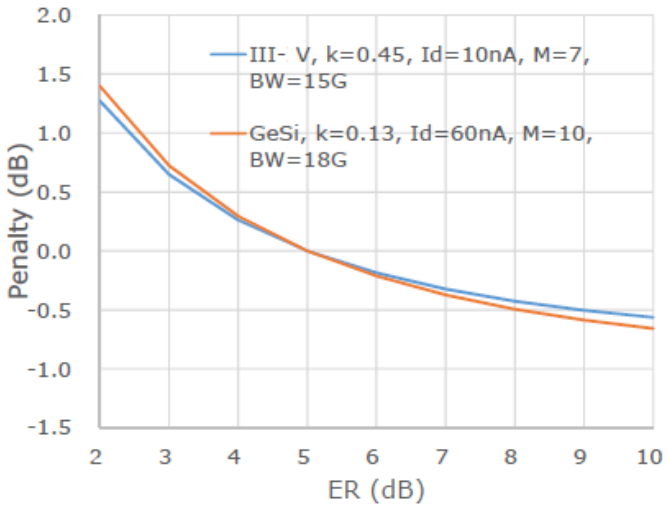
Table 122–9—200GBASE-FR4 and 200GBASE-LR4 transmit characteristics

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, as long as the OMA differences are small.
  - It's necessary to choose a "reference" ER to separate the "high" and "low" ER ranges.

Example of OMA relaxation at high ER

Source: umeda_3ca_2_0518.pdf, slide 7



P_{OMA} = -24.83 dBm
(25G OLT sensitivity @BER=1e-2)

- The current US power budget and OLT RX sensitivity assumes ER = 5 dB.
- For ER > 5dB, the APD receiver noise penalty is reduced at constant OMA.
- ONU TX with ER ≥ 6 dB can launch 0.2dB lower OMA at the same OLT RX OMA sensitivity.

This provides yet another method to de-embed margin from the PMD specs. Recommend that it be considered as a future comment along with a more detailed contribution with specific values.

Table 141-12 — ONU PMD Transmit Characteristics

Description	25GBASE-PR30-D	Unit
Launch power in OMA minus TDP, each lane (min)	4.2	dBm

Current ONU TX PMD table.

Description	25GBASE-PR30-D	Unit
Launch power in OMA minus TDP, each lane (min)		
for extinction ratio ≥ 6 dB	4	dBm
for extinction ratio < 6 dB	4.2	dBm

Example modified ONU TX PMD table with two ER ranges.

Summary

- Consensus over the last several meeting cycles has provided sufficient definition to be able to generate a nearly complete set of P802.3ca 25G-EPON PR30 PMD tables for downstream and upstream.
- Recommend that the PMD tables illustrated in this contribution be accepted by the Task Force for inclusion in P802.3ca draft D1.1.
  - If there is consensus to accept any of the proposed modifications described in slides 16-23, a revised contribution with updated PMD tables will be generated before making the motion.

Motion #N

- Move that the P802.3ca Task Force adopt the PMD tables of johnson_3ca_1a_0518.pdf slides 8, 9, 14 and 15 as the baseline text for P802.3ca draft Tables 141-8, -10, -12 and -14.

- Moved: John Johnson
- Seconded:

- Technical (≥75% to PASS)
- For: Against: Abstain: