Transmitter power and penalty specification

John Johnson, Broadcom Ltd.

Supporters

- Daisuke Umeda, SEI
- Vincent Houtsma, Nokia
- …

Motions passed in Geneva

1/24/2018 3:15 PM Break, reconvened 3:37 PM

Motion #8
The normative transmitter power and penalty specifications shall be in the form of minimum launch power minus transmitter and dispersion penalties. Informative text should be added to the standard to explain alternate simplified field measurements.
Moved: John Johnson Second: Ed Harstead
For: 22 Against: 0 Abstain: 9
Technical (≥ 75%) Motion Passed

The Task Force reviewed Table 122-10 from 802.3bs D3.5 which illustrates a use of Avg. launch Power minus TDP. In this case there are informative notes about OMA Rx Sensitivity, Tx Power and Stressed Rx Sensitivity.

Motion #9
802.3ca specify the transmitter power and penalty specifications in the following form: 1) specify the minimum launch power as normative 2) specify the maximum TDP as normative
Moved: Dekun Liu Second: Frank Effenberger
For: 18 Against: 0 Abstain: 10
Technical (≥ 75%) Motion Passed

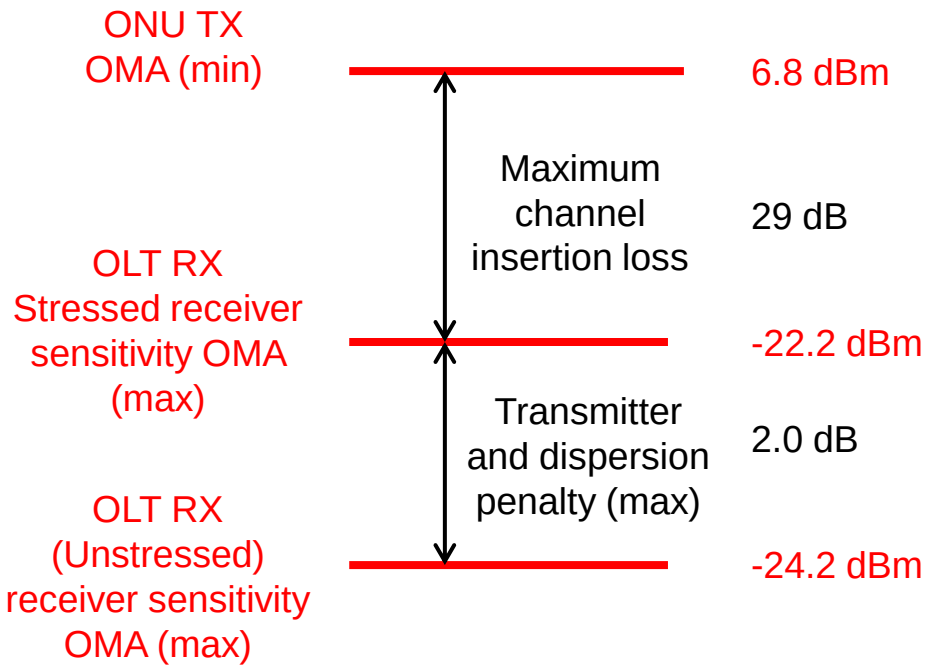
This contribution will demonstrate how these motions should be implemented in the P802.3ca PMD specifications and practical optics testing.

Comparison of spec methods

	802.3-2015 Cl. 75, 10G-EPON	e.g., P802.3cc Cl. 114, 25GBASE-LR
Transmitter Specifications		
Average launch power (min)	NORMATIVE, at reference ER assuming worst case TDP	*INFORMATIVE, corresponding to min ER and min OMA*
Optical Modulation Amplitude (min)	NORMATIVE, at reference ER assuming worst case TDP	NORMATIVE, must be met even with TDP < reference value specified in footnote.
Launch power in OMA minus TDP (min)	N/A	NORMATIVE
Transmitter and dispersion penalty (max)	NORMATIVE	NORMATIVE
Extinction ratio (min)	NORMATIVE	NORMATIVE
Receiver Specifications		
Average receive power (min)	NORMATIVE, at reference ER	*INFORMATIVE, does not represent ideal unstressed sensitivity*
Receiver sensitivity OMA (max)	NORMATIVE, at reference ER	*INFORMATIVE, corresponding to (OMA-TPD)min and max channel insertion losses*
Stressed receiver sensitivity OMA (max)	NORMATIVE, with VECP = max TDP and specified Jitter	NORMATIVE, with VECP ~ max TDP and specified Jitter

Legacy method upstream

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



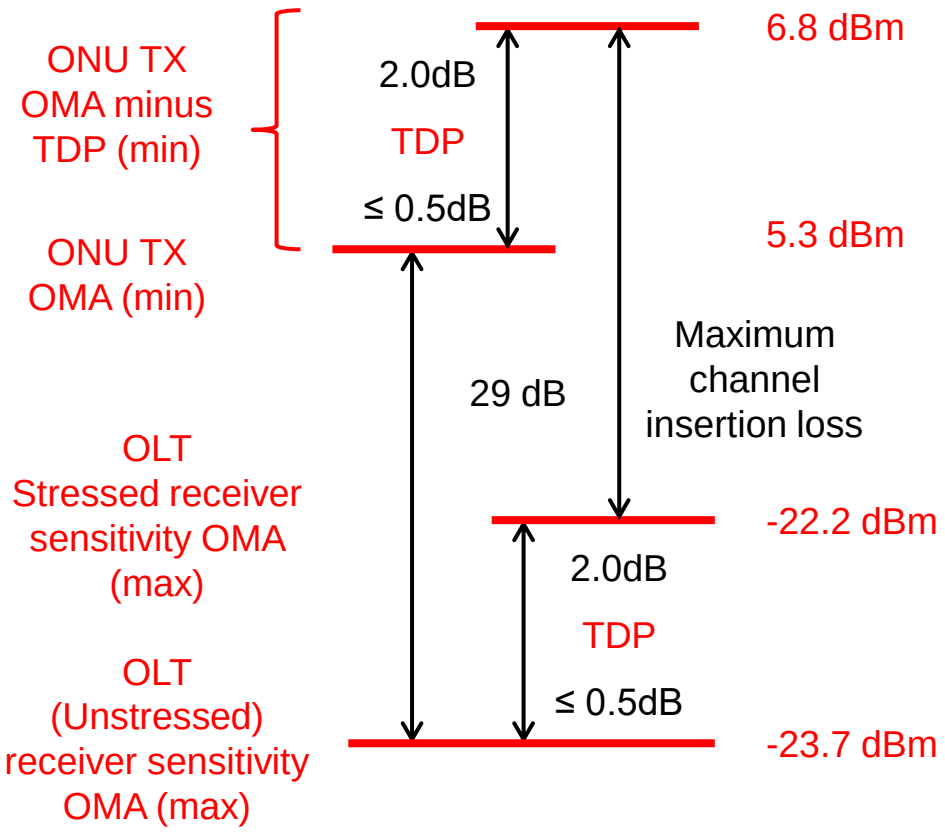
OMA(min) is NORMATIVE for all ONU TX. Must be met even if TDP is < 2dB.

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

URS(max) is NORMATIVE for all OLT RX. Defined for an ideal input signal quality with the specified extinction ratio, i.e. ER=5dB and TP=DP=0dB.

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.

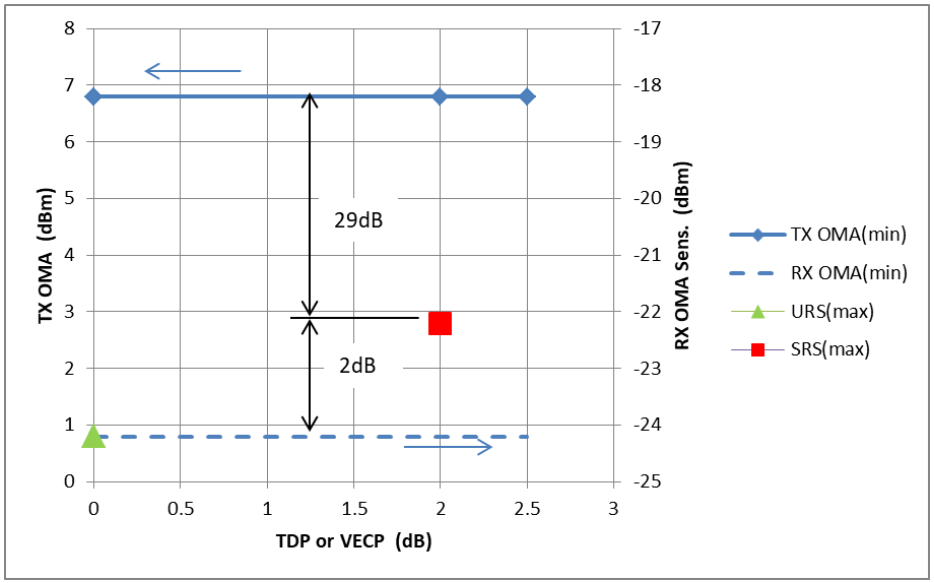
OMA(min) is NORMATIVE for all ONU TX. **Must be met even if TDP is < 0.5dB** to insure compliance even if DP over long fiber spans is negative.

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.

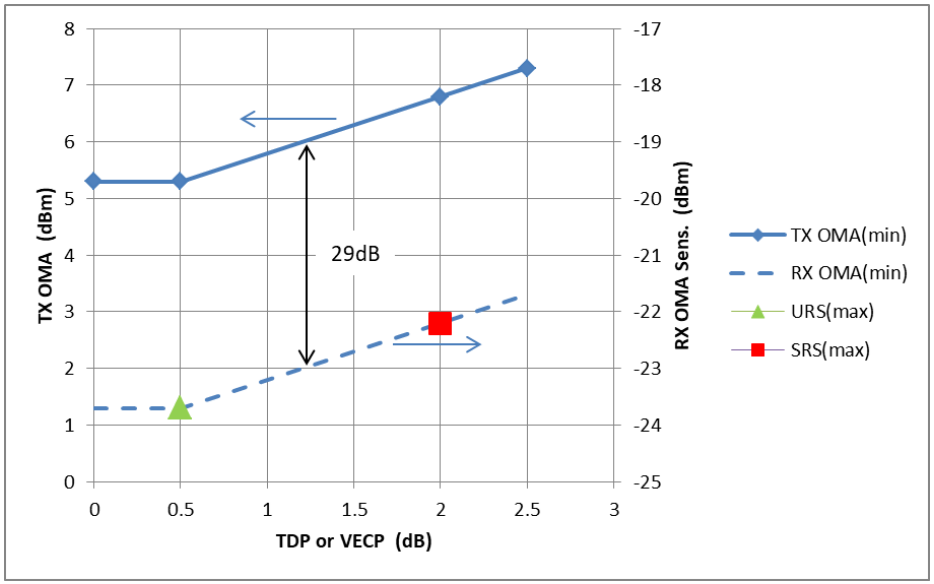
Comparison of upstream specs

Legacy Method



- All ONU TX must launch OMA ≥ 6.8 dBm
- Unstressed ONU receiver sensitivity defined for ideal TX with TP = 0dB
  - URS OMA(max) = -24.2dBm
- Stressed ONU receiver sensitivity defined for worst case TX with TDP = 2dB
  - SRS OMA(max) = -22.2dBm

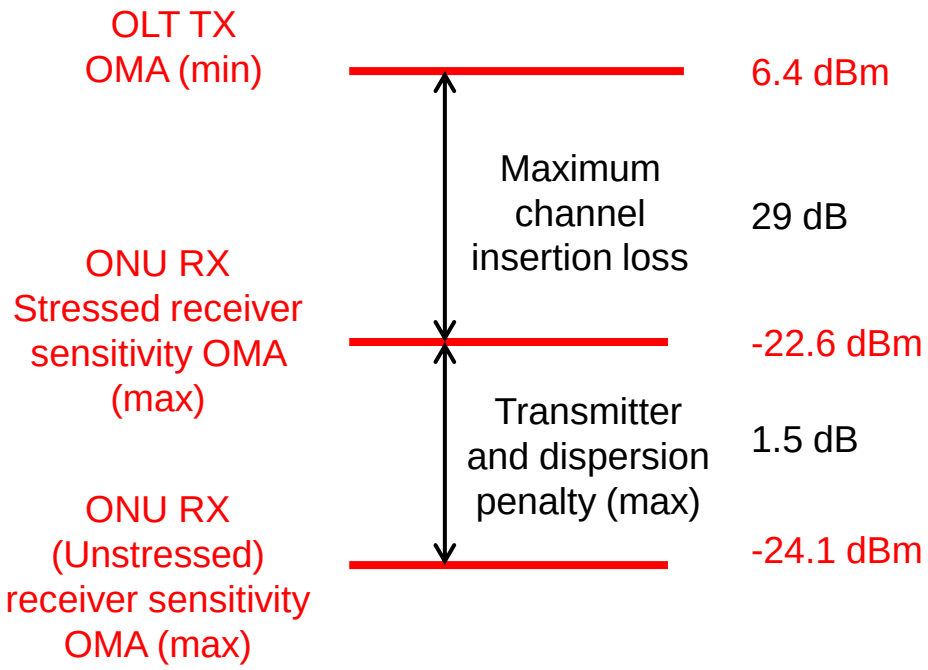
Power minus Penalty Method



- 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 ONU receiver sensitivity is defined for worst case TX with VECP = 2dB
  - SRS OMA(max) = -22.2dBm

Legacy method downstream

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



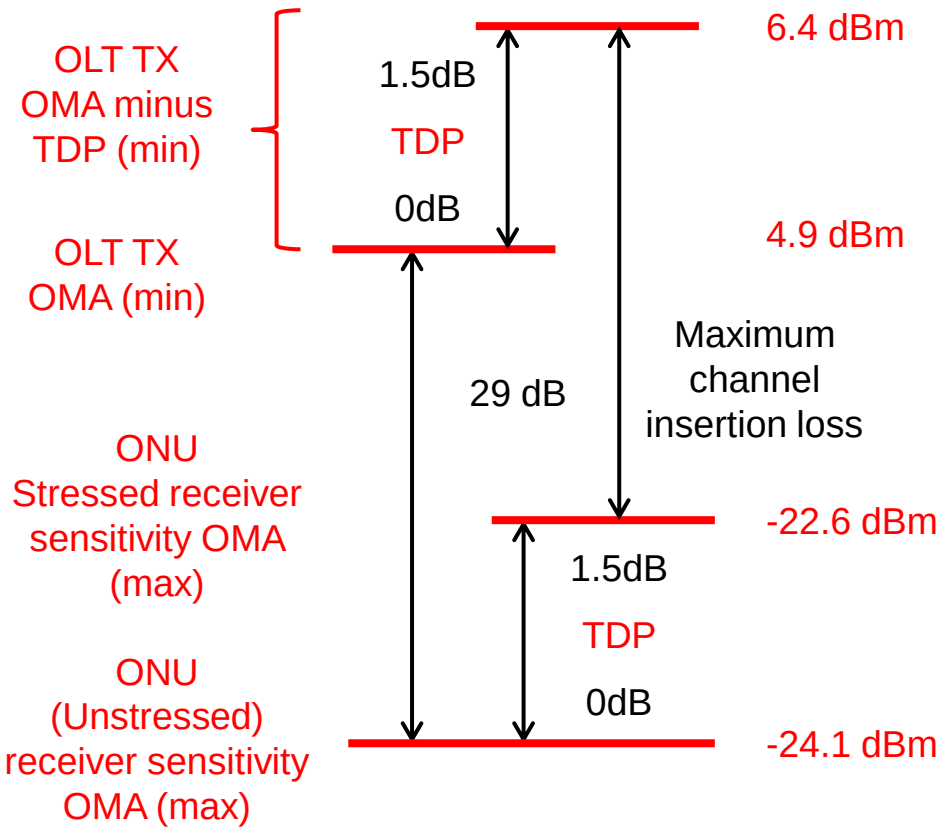
OMA(min) is NORMATIVE for all OLT TX. Must be met even if TDP is < 1.5dB.

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

URS(max) is NORMATIVE for all ONU RX. Defined for an ideal input signal quality with the specified extinction ratio, i.e. ER=8dB and TP=DP=0dB.

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.

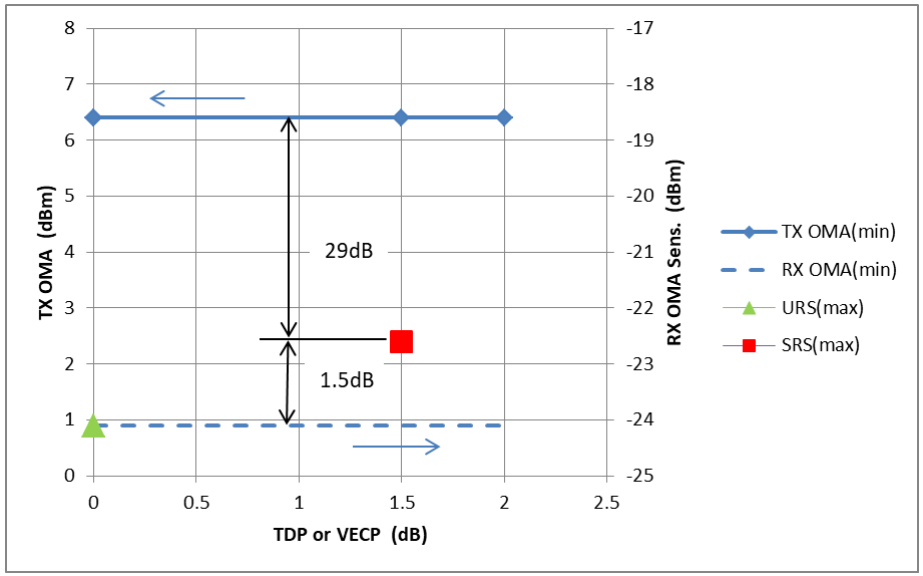
OMA(min) is NORMATIVE for all ONU TX. **Must be met even if TDP is < 0dB** to insure compliance even if TDP is negative.

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.

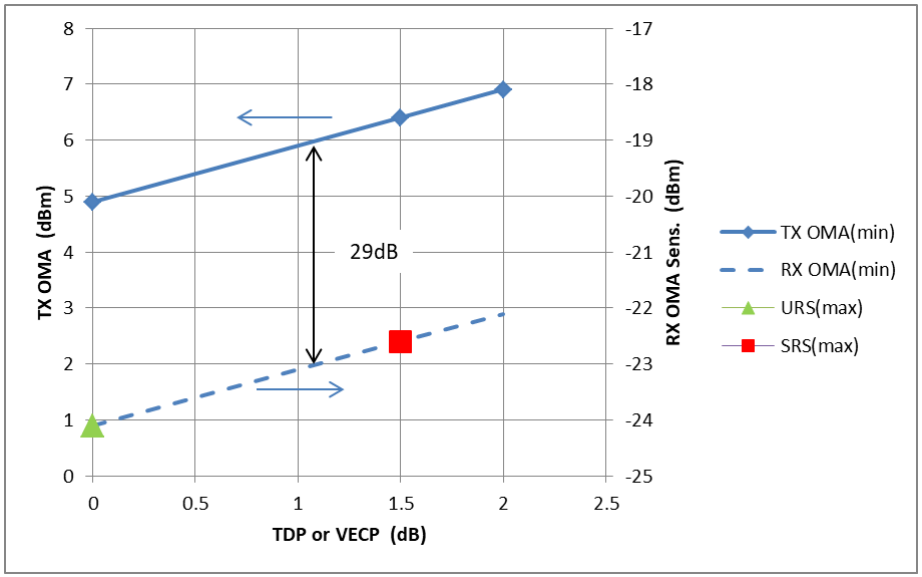
Comparison of downstream specs

Legacy Method



- All OLT TX must launch OMA ≥ 6.4 dBm
- Unstressed ONU receiver sensitivity defined for ideal TX with TP = 0dB
  - URS OMA(max) = -24.1dBm
- Stressed ONU receiver sensitivity defined for worst case TX with TDP = 1.5dB
  - SRS OMA(max) = -22.6dBm

Power minus Penalty Method



- ONU 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

Choice of reference TP value

- The use of a minimum reference level for transmitter penalty (TP) or vertical eye closure is based on the observations that
  - "Ideal" TX don't exist in the real world, especially for DML TX.
  - Worst case TDP may occur for shorter reaches when dispersion is negative.
  - Since "ideal" TX don't exist, defining unstressed RX sensitivity with one isn't a realistic use condition.
  - Defining unstressed OLT RX sensitivity with non-zero SEC allows testing with a real DML TX source that has been adequately characterized.
- For 25G upstream ONU using a DML TX,
  - Transmitter penalty (TP) will likely never be less than 0.5dB for cooled TX or 1.0dB for uncooled TX back to back (B2B).
  - Upstream channels at different wavelengths can experience positive or negative dispersion, or no significant dispersion if the span is very short.
    - For US0-B DP(20km) ≤ 0dB so B2B is the worst case TDP.
    - For US0-A and US1 DP(20km) ≥ 0dB so B2B is the best case TDP.
  - Capping TX OMA(min) based on a minimum reference TDP insures that the minimum OLT RX power is met even if DP < 0dB over fiber.
  - The choice of reference TDP(VECP) = 0.5dB is consistent with the expected best case for cooled DML TP and is proposed as a starting value for the ONU TX and OLT RX specs.
- For 25G downstream OLT using an EML TX,
  - EML eyes have high ER with fast rise/fall times, and are much more ideal than DMLs.
  - Chirp is lower than for DMLs so through fiber ISI is relatively less.
  - DS0 and DS1 are both in positive dispersion territory, so B2B is the best case and through fiber is the worst case for TDP.
  - The choice of 0dB for reference TDP is consistent with the expected performance of the best OLT transmitters.

Practical TX testing

- Concerns have been raised about the added complexity of specifying minimum TX power minus penalties.
- In the legacy method, TX power can be set independently of testing for TDP.
  - As mentioned, this simplicity is at the expense of assuming all TX have worst case TDP.
  - This is practical for 1Gb/s and 2.5Gb/s, less so for 10Gb/s, but will be difficult for 25Gb/s.
- In the power minus penalties method similar assumptions can be made to simplify testing.
  - Manufacturers can still set TX power before measuring TDP based on their knowledge of the TDP distribution of the TX being tested.
    - The TX channel and whether it is cooled or uncooled.
    - Known TP and DP distributions of the specific lasers used.
  - ONU TX OMA would be set based on the minimum of 5.3dBm or 4.8dBm plus the 3-sigma (or other) value of worst case TDP up to a maximum of 6.8dBm.
    - Worst case TDP may occur B2B or through fiber, depending on the channel and whether the TX is cooled or uncooled.
  - OLT TX OMA would be set based on the minimum of 4.9dBm plus the 3-sigma (or other) value of worst case TDP up to a maximum of 6.4dBm.

Practical RX testing

- Stressed RX sensitivity (SRS) measurement is the same in the legacy and power minus penalty methods.
  - Sinusoidal jitter is added to the ideal clock
  - An ideal TX eye is low-pass filtered and sinusoidal interference added to synthesize an eye with a specified vertical eye closure penalty (VECP).
  - It's common in the industry to use a real "worst case" TX eye to measure SRS, but this is insufficient on it's own to guarantee interoperability without careful calibration.
- Unstressed RX sensitivity (URS) is normative in the legacy 10G-EPON standard.
  - URS is specified for an "ideal" source signal with the specified ER.
  - URS is often not measured in industry practice due the difficulty of constructing an "ideal" TX source (TP = 0dB), and the irrelevance of the measurement to the sensitivity for real ONU TX signals.
  - High bandwidth EMLs exist which make constructing an ideal TX for URS measurement more practical for ONU RX testing.
- In newer 802.3 standards, URS is informative and may be defined for non-zero VECP.
  - Testing is not mandatory, but the non-zero VECP makes it more practical to test using real transmitters.

Summary

- Upstream and downstream PMD specs have been proposed based on the method of optical power minus penalties accepted at the Jan. 2018 meeting in Motion #8.
- The downstream power budget is based on accepted Jan. 2018 Motion #7.
  - For OLT cooled EML transmitters, a reference TDP value of 0dB is proposed.
- The upstream power budget is based on the proposed motion of harstead_3ca_2_0318.
  - For ONU DML transmitters, a reference TDP value of 0.5dB is proposed.

Backup Slides

10G-EPON: ONU TX specs

Table 75–8—PR type ONU PMD transmit characteristics

Description	10GBASE –PR–U1	10GBASE –PR–U3	10GBASE –PR–U4	Unit
Signaling speed (range)	10.3125 ± 100 ppm			GBd
Wavelength (range)	1260 to 1280			nm
Side Mode Suppression Ratio (min)[a]	30			dB
Average launch power (max)	4	9	9	dBm
Average launch power (min)[b]	–1	4	6	dBm
Average launch power of OFF transmitter (max)	–45			dBm
Extinction ratio (min)	6			dB
$RIN_{15}OMA$ (max)	–128			dB/Hz
Launch OMA (min)[b]	–0.22 (0.95)	4.78 (3.01)	6.78 (4.77)	dBm (mW)
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}[c]	{0.25, 0.4, 0.45, 0.25, 0.28, 0.4}			UI
T_{on} (max)	512			ns
T_{off} (max)	512			ns
Optical return loss tolerance (max)	15			dB
Transmitter reflectance (max)	–10			dB
Transmitter and dispersion penalty (max)[d]	3	3	2	dB
Decision timing offset for transmitter and dispersion penalty	±0.0625			UI

[a]Transmitter is a single longitudinal mode device. Chirp is allowed such that the total optical path penalty does not exceed that found in Table 75B–2.
[b]Minimum average launch power and minimum launch OMA are valid for ER = 6 dB (see Figure 75–5 for details).
[c]As defined in Figure 75–6.
[d]If a transmitter has a lower TDP, the minimum transmitter launch OMA (OMA_{min}) and average minimum launch power (AVP_{min}) may be relaxed by the amount 3 dB – TDP for 10GBASE-PR-U1 and 10GBASE-PR-U3 and 2 dB – TDP for 10G-BASE-PR-U4.

The relationship between OMA, extinction ratio and average power is described in 58.7.6 and illustrated in Figure 75–5 for a compliant transmitter. Note that the OMA_{min} and AVP_{min} are calculated for ER = 6 dB. The transmitter average launch power specifications are further relaxed by allowing ER higher than 6 dB while maintaining the OMA_{min} constant. The shaded area indicates a compliant part.

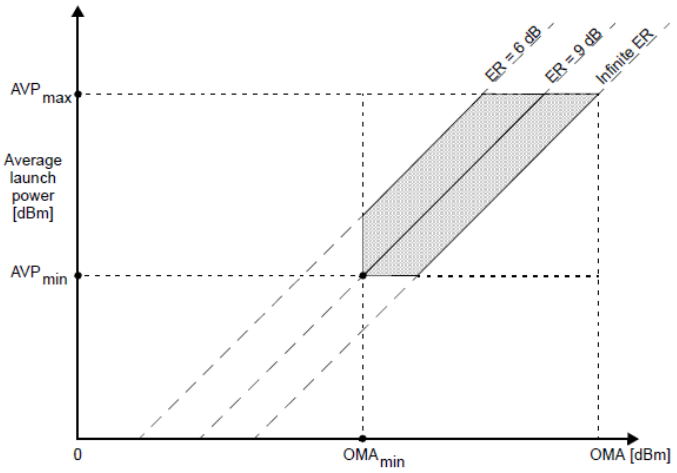


Figure 75–4—Graphical representation of region of PR–D type transmitter compliance

10G-EPON: OLT RX specs

Table 75–6—PR type OLT PMD receive characteristics

Description	10GBASE–PR–D1	10GBASE–PR–D2, 10GBASE–PR–D3	10GBASE–PR–D4	Unit
Signaling speed (range)	10.3125 ± 100 ppm			GBd
Wavelength (range)	1260 to 1280			nm
Bit error ratio (max)[a]	10^{-3}			–
Average receive power (max)	–1	–6	–9	dBm
Damage threshold (max)[b]	0	–5	–8	dBm
Receiver sensitivity (max)	–24	–28	–29	dBm
Receiver sensitivity OMA (max)	–23.22 (4.77)	–27.22 (1.9)	–28.22 (1.51)	dBm (µW)
Signal detect threshold (min)	–45			dBm
Receiver reflectance (max)	–12			dB
Stressed receive sensitivity (max)[c]	–21	–25	–27	dBm

Table 75–6—PR type OLT PMD receive characteristics *(continued)*

Description	10GBASE–PR–D1	10GBASE–PR–D2, 10GBASE–PR–D3	10GBASE–PR–D4	Unit
Stressed receive sensitivity OMA (max)	–20.22 (9.51)	–24.22 (3.79)	–26.22 (2.39)	dBm (µW)
Vertical eye–closure penalty[d]	2.99			dB
$T_{receiver\_settling}$ (max)[e]	800			ns
Stressed eye jitter	0.3			UI pk-pk
Jitter corner frequency for a sinusoidal jitter	4			MHz
Sinusoidal jitter limits for stressed receiver conformance test (min, max)	(0.05, 0.15)			UI

[a] The BER of 10^{-12} is achieved by the utilization of FEC as described in 76.3.
[b] Direct ONU–OLT connection may result in damage of the receiver.
[c] The stressed receiver sensitivity is mandatory.
[d] Vertical eye closure penalty and the jitter specifications are test conditions for measuring stressed receiver sensitivity. They are not required characteristics of the receiver.
[e] $T_{receiver\_settling}$ represents an upper bound. Optics with better performance may be used in compliant implementations, since the OLT notifies the ONUs of its requirements in terms of the $T_{receiver\_settling}$ time via the syncTime parameter (see 77.3.3.2).

SRS measurement method

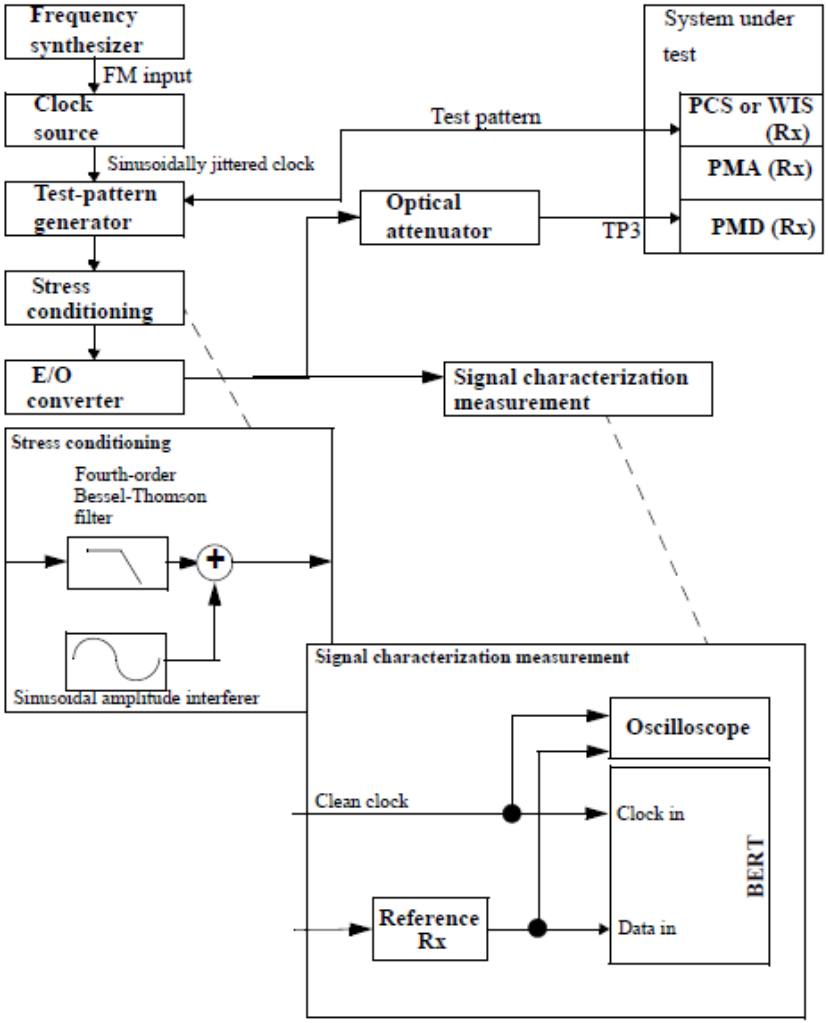


Figure 52–10—Stressed receiver conformance test block diagram

10G-EPON Cl. 75.7.12 specifies the SRS measurement method of Cl. 52.9.9 for 10Gb/s PHYs.

25GBASE-LR: TX specs

Table 114–6—25GBASE-LR and 25GBASE-ER transmit characteristics

Description	25GBASE-LR	25GBASE-ER	Unit
Signaling rate (range)	25.78125 ± 100 ppm		GBd
Center wavelength (range)	1295 to 1325	1295 to 1310	nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Average launch power (max)	2	6	dBm
Average launch power[a] (min)	–7	–3	dBm
Optical Modulation Amplitude (OMA), (max)	2.2	6	dBm
Optical Modulation Amplitude (OMA)[b], (min)	–4	0	dBm
Launch power in OMA minus TDP (min)	–5	–1	dBm
Transmitter and dispersion penalty (TDP), (max)	2.7	2.7	dB
Average launch power of OFF transmitter (max)	–20		dBm
Extinction ratio (min)	3	4	dB
$RIN_{20}OMA$ (max)	–130		dB/Hz
Optical return loss tolerance (max)	20		dB
Transmitter reflectance[c] (max)	–26		dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} hits per sample.	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}		

[a]Average launch power (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 < 1 dB, the OMA (min) must exceed this value.
[c]Transmitter reflectance is defined looking into the transmitter.

25GBASE-LR: RX specs

Table 114–7—25GBASE-LR and 25GBASE-ER receive characteristics

Description	25GBASE-LR	25GBASE-ER	Unit
Signaling rate (range)	25.78125 ± 100 ppm		GBd
Center wavelength (range)	1295 to 1325		nm
Damage threshold[a] (min)	3	–3	dBm
Average receive power (max)	2	–4	dBm
Average receive power[b] (min)	–13.3	–21	dBm
Receive power (OMA), (max)	2.2	–4	dBm
Receiver reflectance (max)	–26		dB
Receiver sensitivity (OMA)[c], (max)	–12	–19	dBm
Stressed receiver sensitivity (OMA)[d], (max)	–9.5	–16.5	dBm
Conditions of stressed receiver sensitivity test			
Stressed eye closure[e]	2.5	2.5	dB
Stressed eye J2 Jitter[e]	0.27	0.27	UI
Stressed eye J4 Jitter[e]	0.39	0.39	UI
SRS eye mask definition {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} hits per sample.	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}		

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level.
[b]Average receive power (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.
[c]Receiver sensitivity (OMA), (max) is informative.
[d]Measured with conformance test signal at TP3 (see 114.7.10) for the BER specified in 114.1.1.
[e]Stressed eye closure, stressed eye J2 Jitter, and stressed eye J4 Jitter are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

Table 114–8—25GBASE-LR and 25GBASE-ER illustrative link power budgets

Parameter	25GBASE-LR	25GBASE-ER		Unit
Power budget (for maximum TDP)	9.7	20.7		dB
Operating distance	10	30	40[a]	km
Channel insertion loss	6.3[b]	15[b]	18[a] minus insertion loss values per Table 114–12	dB
Maximum discrete reflectance	–26[c]	See Table 114–12		dB
Allocation for penalties[d] (for maximum TDP)	3.4	2.7		dB
Additional insertion loss allowed	0	3 minus insertion loss values per Table 114–12	0	dB

[a]Links longer than 30 km are considered engineered links. Attenuation for such links needs to be less than the worst case for cables containing IEC 60793-2-50 type B1.1, type B1.3, or type B6_a single-mode cabled optical fiber.
[b]The channel insertion loss is calculated using the maximum distance specified in Table 114–5 for 25GBASE-LR and fiber attenuation of 0.43 dB/km at 1295 nm plus an allocation for connection and splice loss given in 88.11.2.1.
[c]The number of discrete reflectances in the range > –35 dB and ≤ –26 dB is at most 3; the number of discrete reflectances ≤ –35 dB is at most 6; and the total number of discrete reflectances is at most 6.
[d]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.