25G EPON PR20 loss budget, updated

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Supporters

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Update of harstead_3ca_1_0518

- Changes in the following slides from harstead_3ca_1_0518 are shown in highlighted text
- To address errors identified by Hanhyub Lee
  - Receiver sensitivity adjustment from 5e-5 to 1e-2 BER
  - Account for insertion loss of PON diplexer and WBF
- Also, Daiske Umeda pointed out the error on slide 10G EPON OLT transmit ER on slide 10. It has been corrected, but has not effect on the proposed values for 25G EPON.
- In the end, the only change to the proposed specification is an adjustment of 0.5 dB to the downstream loss budget
  - 0.5 dB improved ONU receiver sensitivity
  - OLT launch power decreased from 2.5 to 2 dBm– which aligns exactly with 10G EPON PR30 and XGS-PON N1.

Deriving PR20 from PR30

No change

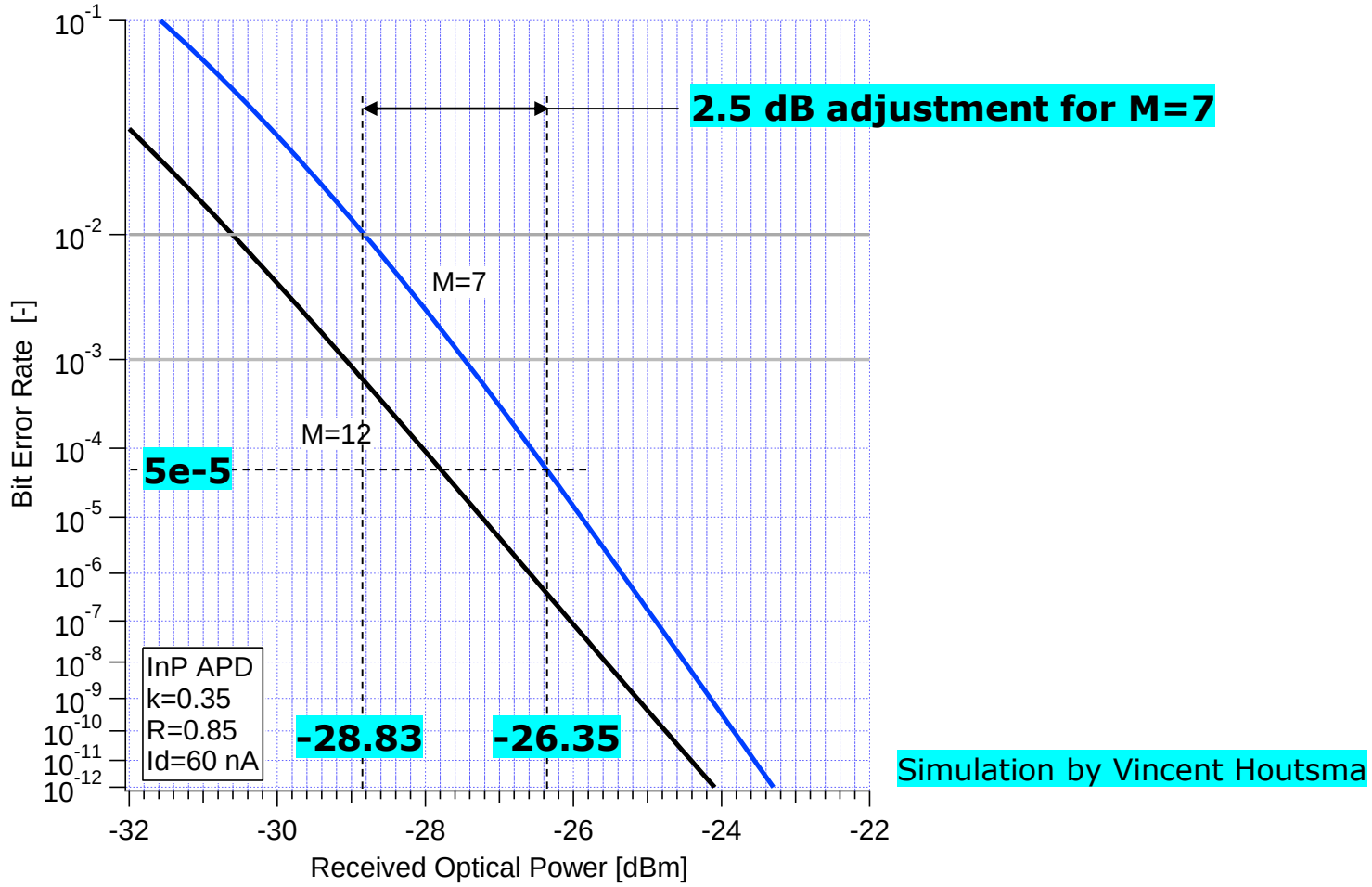
- PR30 loss budget: 29 dB
- PR20 loss budget: 24 dB
- PR20: 5 dBs to give back to OLT and/or ONU
  - This will allow for significant cost reduction in the optics
- Methodologies to consider
  - ✗ ITU-T GPON and XGS-PON keep all power budget class ONUs the same and only vary the OLT. To do the same with 25G EPON, we would give all those dBs to the OLT. But the 25G EPON ONU needs some relief.
  - ✗ Give all 5 dB to ONUs. Only one flavor of OLT—good! But this does not optimize cost. There are diminishing returns on the ONU side (the ONU does not need 5 dBs).
  - ✓ **Spread the 5 dBs across OLT and ONU to cost-optimize.**

Downstream: ONU sensitivity

- **Starting point:** PR30 receiver sensitivity, average power(max)= -25.7 at BER = 1e-2, ER = 8 dB.
- Proposal: relax ONU sensitivity to be in line with 25G APD-based Ethernet specifications. Then the PR20 ONU would require no performance improvements with respect to existing 25G APD-based receivers.
  - 4WDM MSA 40km (formerly "ER4-lite")
    - Receiver sensitivity (OMA), each lane (max) = -18.5 dBm at 5e-5 BER
    - Adjust for 1:4 demux loss. Assume 2 dB.
    - Effective receiver sensitivity after demux (OMA) (max) = -20.5 dBm
  - 25GBASE-ER
    - Receiver sensitivity (OMA) (max) = –19 dBm at 5e-5 BER
- These must be converted to average power at BER = 1e-2 and ER = 8 dB.
- Also, they are two-fiber interfaces, and must be adjusted to reflect BOSA insertion loss of PON one-fiber interface.

Sensitivity: BER adjustment

- Need to adjust receiver sensitivities from 5e-5 to 1e-2 BER
- For InP-based APDs, sensitivity BER adjustment= 2.5 dB



Simulation by Vincent Houtsma

APD sensitivity dependence on OMA

No change

- APD sensitivity is OMA dependent. Adjust for ER = 8 dB.

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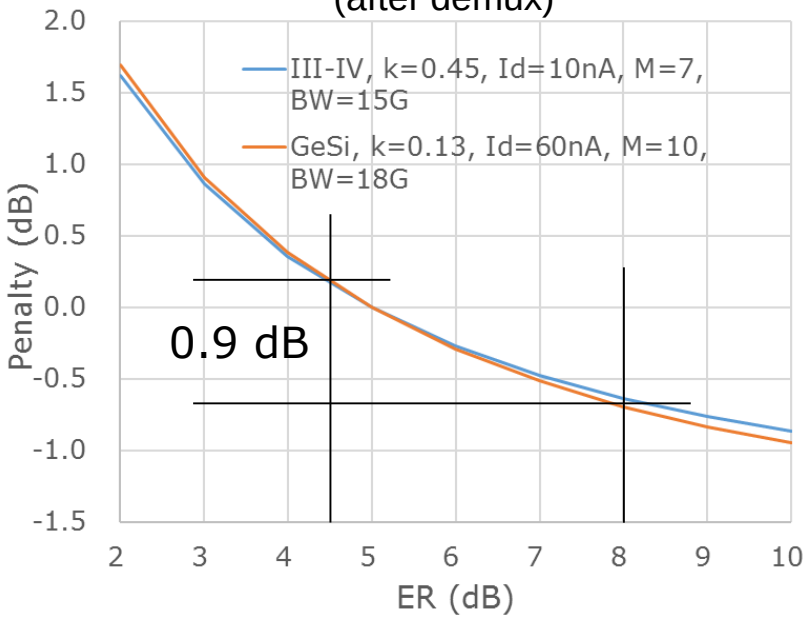
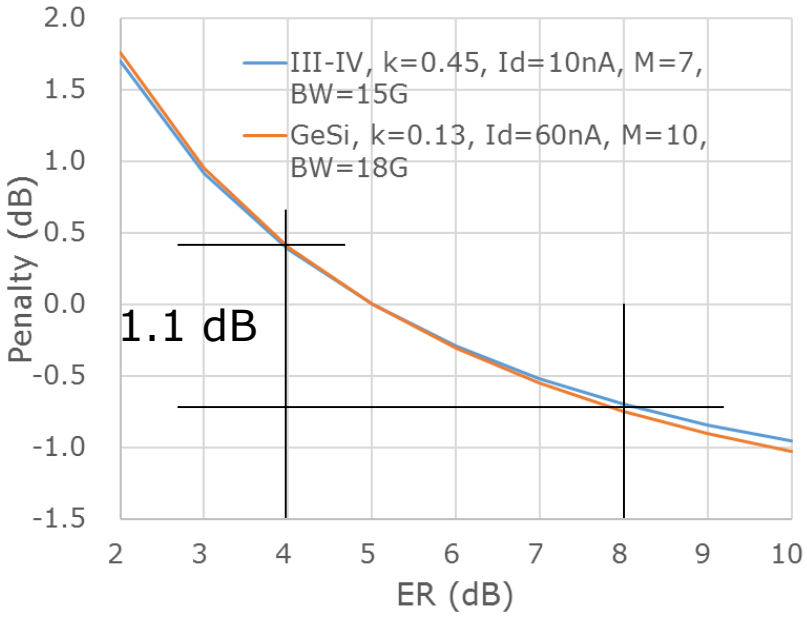
P_{OMA} = -20.5 dBm
(4WDM MSA 40km)
(after demux)



P_{OMA} = -19.0 dBm
(25GBASE-ER)



Specification	ER min (dB)	Sensitivity improvement for ER=8 dB
25G EPON downstream	8	
4WDM-40	4.5	0.9 dB
25GBASE-ER	4	1.1 dB

Adjust for PON BOSA insertion loss

- PON transceivers are single fiber interfaces with additional insertion losses from the BOSA diplexer and receiver wavelength blocking filter.
- These losses can be 0.5 – 1.0 dB. Let's say 0.7 dB typical.

Adjusted receiver sensitivities

Parameter	4WDM MSA 40km	25GBASE-ER
Spec: Sensitivity, OMA, max., at 5e-5 BER	-18.5 dBm	–19.0 dBm
Adjust for 1:4 demux loss. Assume 2 dB.	-20.5 dBm	NA
Convert to avg. power, max, ER = 8 dB	-22.1 dBm	-20.6 dBm
Adjust for 1e-2 BER	-2.5 dB	-2.5 dB
Average power, max, 1e-2 BER, ER = 8 dB	-24.6 dBm	-23.1 dBm
Adjust for APD sensitivity dependence on OMA	-0.9 dB	-1.1 dB
Adjust for PON BOSA insertion loss	+0.7 dB	+0.7 dB
Sensitivity, avg. power, max, 1e-2 BER, ER = 8 dB	-24.8 dBm	-23.5 dBm

- **Proposal**: The 25GBASE-ER specification is the most relaxed. For the ONU, adopt the equivalent 25GBASE-ER specification, -23.5 dBm.

Downstream: OLT launch power

- **Starting point:** PR30 OLT AVPmin = 4.8 dBm (ER = 8 dB)
- PR20 receiver sensitivity = -23.5 dBm (and TDP = 1.5 dB)
- Therefore PR20 OLT AVPmin = 2 dBm (ER = 8 dB).
- This minimum launch power is aligned exactly 10G EPON PR30 and XGS-PON N1, both established as low cost.

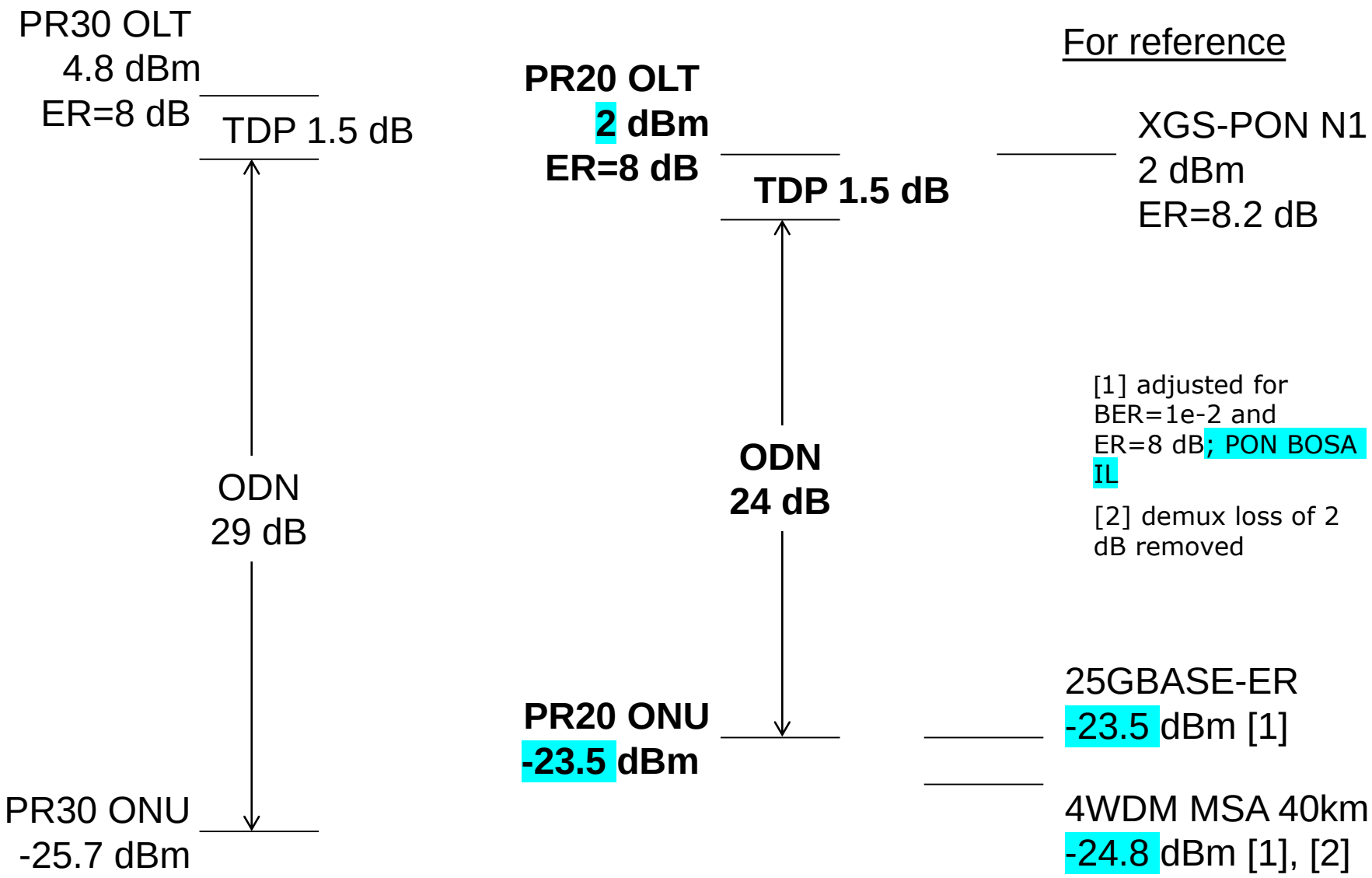
Standard	Loss budget	Min Tx power	ER
10G EPON	PR30	2 dBm	9 dB
XGS-PON	N1	2 dBm	8.2 dB

(Differences in ER can be absorbed when this is converted into the normative OMA specification)

Downstream: PR20 proposal

- PR20 ONU receiver sensitivity (average power, max) = -23.5 dBm (BER = 1e-2, ER = 8 dB).
  - Equivalent to the most relaxed 25G APD-based receiver sensitivity specification, 25GBASE-ER
- PR20 OLT AVPmin= 2 dBm (retain ER = 8 dB)
  - Aligned with low cost 10G EPON and XGS-PON OLT EML modules

Downstream: PR20 proposal



[1] adjusted for BER=1e-2 and ER=8 dB; PON BOSA IL

[2] demux loss of 2 dB removed

Upstream: 25G ONU launch power

No change

- **Starting point:** PR30 (AVP minus TDP)min = 4.0 dBm. For TDP = 2 dB, then AVPmin = 6 dBm.
- The target for PR20 is the use of an uncooled DML in the ONU.
- 10G EPON PR30 and XGS-PON modules are already low cost and use uncooled DMLs with **4 dBm** min. launch power.
- From the vendor questionnaire harstead_3ca_3_0917

AVPmin (dBm)	number	mean	σ
EML	7	4.6	0.6
EML+SOA	3	8.7	2.0
cooled DML	6	6.5	0.5
uncooled DML	5	4.7	1.0

The minimum vendor response for the 25G uncooled DML was **4 dBm**

- Proposal: relax ONU launch power to **4 dBm**.

Upstream: 25G ONU ER

No change

- **Starting point:** PR30 ONU ER = 5 dB.
- Proposal: relax ER to 3.5 dB to be aligned with the largest volume DML specifications

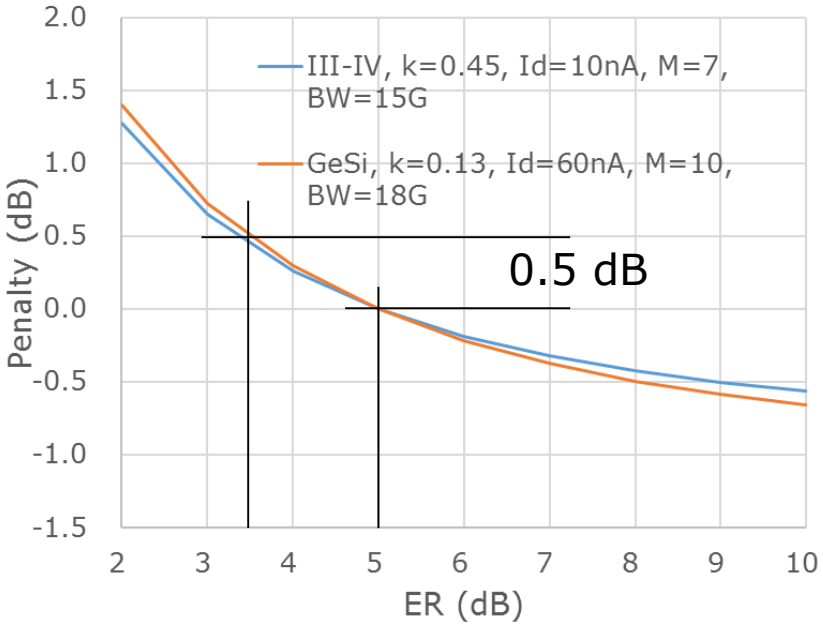
Specification	ER min (dB)
100GBASE–ER4	8
4WDM-40	4.5
100GBASE–LR4	4
25GBASE-ER	4
100G CWDM4	3.5
100G CLR4	3.5
100G PSM4	3.5
25GBASE-LR	3

Largest volumes

Upstream: OLT sensitivity

No change

- **Starting point:** PR30 receiver sensitivity, average power(max)= -25 dBm at BER = 1e-2, ER = 5 dB.
- PR20 ONU AVPmin = 4 dBm
- Therefore PR20 OLT sensitivity = -22 dBm (at ER = 3.5 dB.)
- This is 3 dB higher than PR30. But it is not a 3 dB relaxation.
  - 1.3 dB is required to absorb the reduction of ER from 5 to 3.5 dB
  - 0.5 dB is required to absorb the APD penalty for lower ER (below)



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Upstream: PR20 proposal

No change

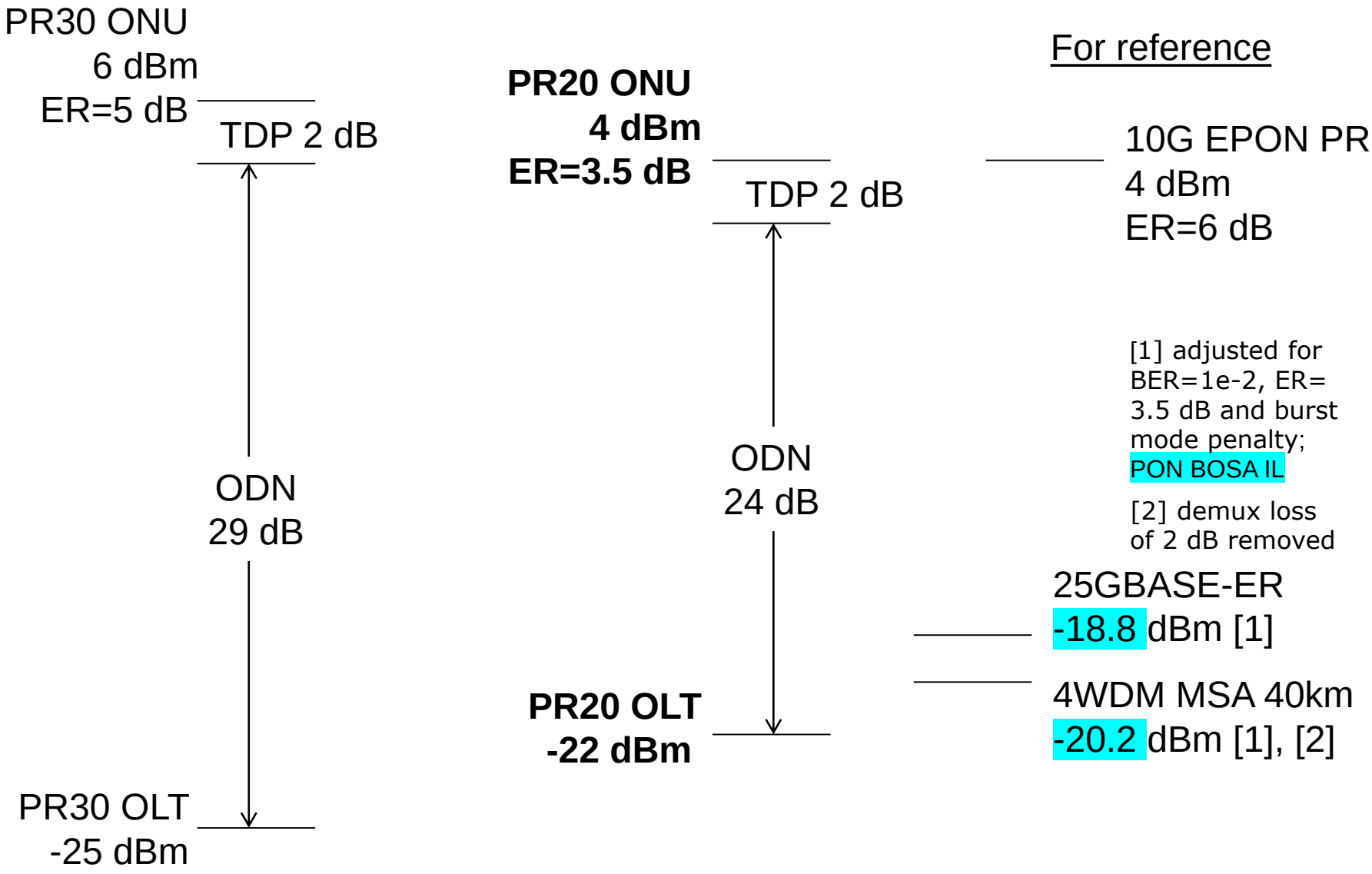
- PR20 ONU AVPmin = 4.0 dBm
  - Requires 2.0 dB of the 5 dB relaxation.
- PR20 ONU ER = 3.5 dB
  - Requires 1.8 dB of the 5 dB relaxation.
- PR20 OLT sensitivity = -22 dBm
  - Leaves 1.2 dB of actual relaxation for the OLT receiver.

For comparison: Adjusted receiver sensitivities

Parameter	4WDM MSA 40km	25GBASE-ER
Spec: Sensitivity, OMA, max., at 5e-5 BER	-18.5 dBm	–19.0 dBm
Adjust for 1:4 demux loss. Assume 2 dB.	-20.5 dBm	NA
Convert to avg. power, max, ER = 3.5 dB	-19.3 dBm	-17.8 dBm
Adjust for 1e-2 BER	-2.5 dB	-2.5 dB
Average power, max, 1e-2 BER, ER = 3.5 dB	-21.8 dBm	-20.3 dBm
Adjust for APD sensitivity dependence on OMA	+0.4 dB	+0.3 dB
Adjust for burst mode penalty (minimum)	+0.5 dB	+0.5 dB
Adjust for PON BOSA insertion loss	+0.7 dB	+0.7 dB
Sensitivity, avg. power, max, 1e-2 BER, ER = 3.5 dB	-20.2 dBm	-18.8 dBm

The proposed -22 dBm PR20 OLT receiver sensitivity is still 1.8 dB stricter than the best existing Ethernet specification.

Upstream: PR20 proposal



Backup

4WDM MSA receiver specs

Table 2-4: 4WDM-10 receive characteristics

Description	4WDM-20	4WDM-40	Unit
Signaling rate, each lane (range) 100GE	25.78125 ± 100 ppm		GBd
Line wavelengths (range)	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19		nm
Damage threshold, each lane (min) [a]	5.5	-2.5	dBm
Average receive power, each lane (max)	4.5	-3.5	dBm
Average receive power, each lane [b] (min)	-14.5	-20.5	dBm
Receive power, each lane (OMA) (max)	4.5	-3.5	dBm
Receiver reflectance (max)	-26		dB
Receiver sensitivity (OMA), each lane (max) at 5 x 10^{-5} BER [c]	-12.5	-18.5	dBm
Stressed receiver sensitivity (OMA), each lane [d] (max)	-10.0	-16.0	dBm
Conditions of stressed receiver sensitivity test:			
Vertical eye closure penalty, [e] each lane	2.5		dB
Stressed eye J2 Jitter, [e] each lane	0.33		UI
Stressed eye J4 Jitter, [e] each lane	0.48		UI
SRS eye mask definition [e] { X1, X2, X3, Y1, Y2, Y3}	{0.39, 0.5, 0.5, 0.39, 0.39, 0.4}		

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical signal having this average power level

[b] 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.

[c] Receiver sensitivity (OMA), each lane (max) at 5 x 10^{-5} BER is a normative specification.

[d] Measured with conformance test signal at TP3 (see 3.10) for BER = 5x10^{-5}.

[e] Vertical eye closure penalty, stressed eye J2 Jitter, stressed eye J4 Jitter, and SRS eye mask definition are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

25GBASE-ER receiver 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.

10G EPON ONU Tx

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, 0.40, 0.45, 0.25, 0.28, 0.40}			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]	3.0	3.0	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 75–8.

[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 3.0 dB – TDP for 10GBASE-PR-U1 and 10GBASE-PR-U3 and 2 dB – TDP for 10G-BASE-PR-U4.

XGS-PON ITU-T G.9807.1 ONU Tx

Table B.9.3 – Optical interface parameters of 9.95328 Gbit/s downstream direction

Item	Unit	Value			
OLT transmitter (optical interface Old)					
Nominal line rate	Gbit/s	9.95328			
Operating wavelength (Note 1)	nm	1 575-1 580			
Line code	–	Scrambled NRZ			
Mask of the transmitter eye diagram	–	See clause B.9.2.7.6.1			
Maximum reflectance of equipment at S/R, measured at transmitter wavelength	dB	NA			
Minimum ORL of ODN at O_{lu} and O_{ld} (Notes 2 and 3)	dB	More than 32			
ODN class		N1	N2	E1	E2
Mean launched power MIN	dBm	+2.0	+4.0	+6.0	FFS
Mean launched power MAX	dBm	+5.0	+7.0	+9.0	FFS
Launched optical power without input to the transmitter	dBm	NA			
Minimum extinction ratio	dB	8.2			
Transmitter tolerance to reflected optical power (Note 7)	dB	More than -15			
Dispersion range	ps/nm	0-400			