Security Level:

# Sensitivity definition and TDP in 802.3ca discussion

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# Supporters:

- Ed Harstead, Nokia

# Background

- The sensitivity of a receiver depends on several factors how you test it, such as the source signal type, source signal quality, extinction ratio of signal , …
- In previous, IEEE PON and ITU-T PON define the sensitivity of receiver in different ways. A same receiver will have different “sensitivity” when is used in IEEE PON and ITU PON.
- Such difference can only result in confusing in industry and divergence of industry chain.
- Adopting a uniform receiver sensitivity between ITU-PON and IEEE PON is a step of PON convergence, which will benefit everyone from long term.

# 10G EPON PR30 vs XGS-PON N1

## 10G EPON

**Table 75–8—PR type ONU PMD transmit characteristics**

| Description | 10GBASE –PR–U1 | 10GBASE –PR–U3 | Unit |
|---|---|---|---|
| Signaling speed (range) | 10.3125 ± 100 ppm | 10.3125 ± 100 ppm | GBd |
| Wavelength (range) | 1260 to 1280 | 1260 to 1280 | nm |
| Side Mode Suppression Ratio (min)[a] | 30 | 30 | dB |
| Average launch power (max) | 4 | 9 | dBm |
| Average launch power (min)[b] | –1 | 4 | dBm |
| Average launch power of OFF transmitter (max) | –45 | –45 | dBm |
| Extinction ratio (min) | 6 | 6 | dB |
| Transmitter and dispersion penalty (max)[d] | 3.0 | 3.0 | dB |

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

| Description | 10GBASE–PR–D1 | 10GBASE–PR–D2, 10GBASE–PR–D3 | Unit |
|---|---|---|---|
| Signaling speed (range) | 10.3125 ± 100 ppm | 10.3125 ± 100 ppm | GBd |
| Wavelength (range) | 1260 to 1280 | 1260 to 1280 | nm |
| Bit error ratio (max)[a] | $10^{-3}$ | $10^{-3}$ | – |
| Average receive power (max) | –1 | –6 | dBm |
| Damage threshold (max)[b] | 0 | –5 | dBm |
| Receiver sensitivity (max) | –24 | –28 | dBm |
| Receiver sensitivity OMA (max) | –23.22 (4.77) | –27.22 (1.90) | dBm (μW) |
| Signal detect threshold (min) | –45 | –45 | dBm |
| Receiver reflectance (max) | –12 | –12 | dB |
| Stressed receive sensitivity (max)[c] | –21 | –25 | dBm |

## XGS-PON

**Table B.9-4 – Optical interface parameters of 9.95328 Gbit/s upstream direction**

| Item | Unit | Value | | | |
|---|---|---|---|---|---|
| **ONU transmitter (optical interface $O_{ru}$)** | | | | | |
| Nominal line rate | Gbit/s | 9.95328 | | | |
| Operating wavelength band | nm | 1260-1280 | | | |
| ODN Class | | N1 | N2 | E1 | E2 |
| Mean launch power minimum (at R/S) (Note 2) | dBm | +4.0 | +4.0 | +4.0 | FFS |
| Mean launch power maximum (at R/S) | dBm | +9.0 | +9.0 | +9.0 | FFS |
| Minimum extinction ratio (Note 2) | dB | 6.0 | | | |
| **OLT receiver (optical interface $O_{lu}$)** | | | | | |
| ODN Class | | N1 | N2 | E1 | E2 |
| Maximum optical path penalty | dB | 1.0 | 1.0 | 1.0 | FFS |
| Bit error ratio reference level | – | $10^{-3}$ (Note 5) | | | |
| ODN Class | | N1 | N2 | E1 | E2 |
| Sensitivity (at S/R) (Note 6) | dBm | -26.0 | -28.0 | -30.0 | FFS |
| Overload (at S/R) | dBm | -5.0 | -7.0 | -9.0 | FFS |

- XGS-PON has the same power budget , ONU transmitter power ,ER with 10G EPON PR30 in upstream, but different OLT sensitivity and path penalty

The definition of receiver sensitivity in 10G EPON is different with that in XGS-PON!

# Sensitivity definition comparison

## 802.3:

**58.7.10 Receiver sensitivity measurements**

Receiver sensitivity is defined for an ideal input signal. The test signal should have negligible impairments such as intersymbol interference (ISI), jitter and RIN (but see the end of this subclause). The test pattern shall be as specified in 58.7.1, 59.7.1 or 60.7.1 as appropriate. Sensitivity is defined by the specified bit error

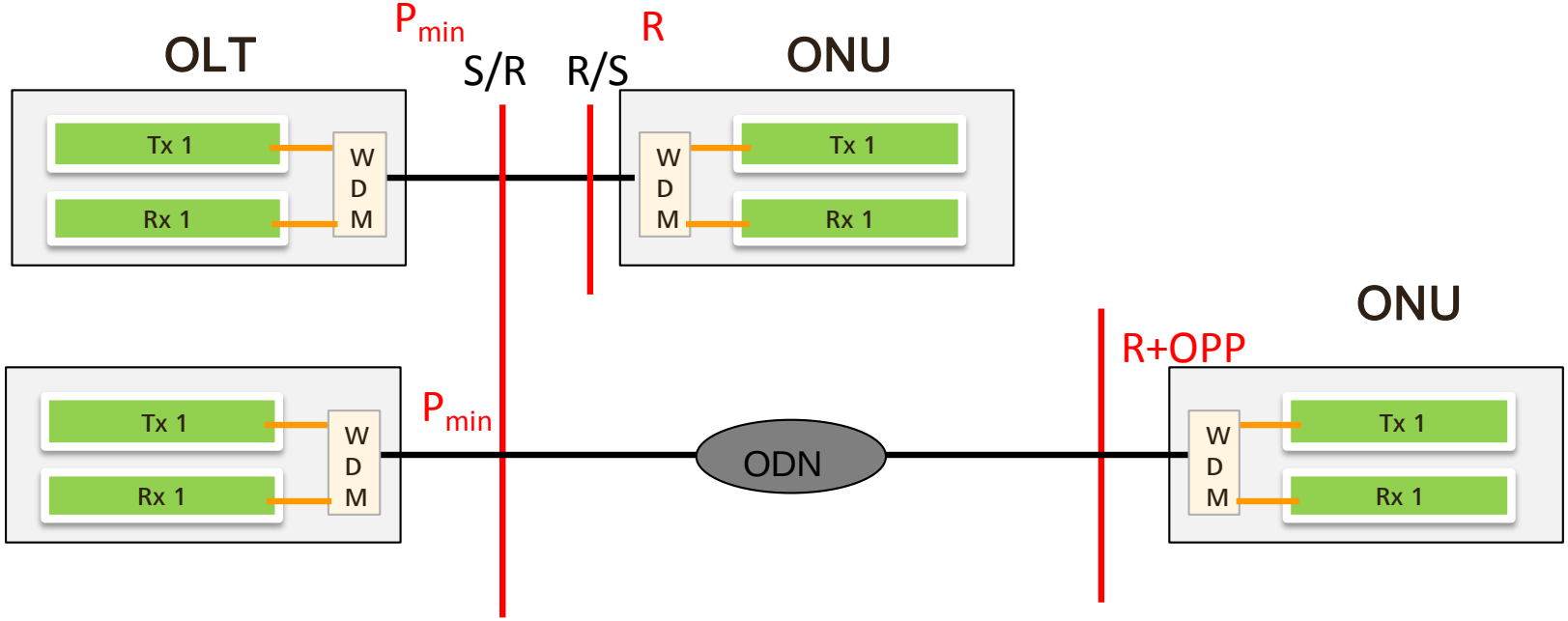
## G.9807.1 XGS-PON:

**3.3.28 Sensitivity:** A receiver parameter equal to the minimum average received optical power that produces the specified BER reference level, referring to the optical power at the appropriate reference point (S/R for upstream direction, R/S for downstream direction) measured with the worst case signal, but without the optical path impairments.

In a word, sensitivity in 802.3 is measured with an ideal input signal ,while sensitivity in ITU-PON is measured with the worst case signal

# OPP in ITU-PON

**3.3.21 Optical path penalty (OPP)**: The apparent degradation of receiver sensitivity due to impairments from fibre transmission and apparent increase in ODN loss due to Raman depletion. The optical path penalty accounts for the effects of reflections, intersymbol interference, mode partition noise, fibre dispersion, and fibre non-linearities.




$P_{min}$ – R – OPP = Power budget (ODN insertion loss)

# TDP in IEEE 802.3

## 58.7.9 Transmitter and dispersion penalty (TDP) measurement

Transmitter and dispersion penalty may be measured with apparatus shown in Figure 58–7, consisting of a reference transmitter, the transmitter under test, a controlled optical reflection, an optical attenuator, a test fiber, and a reference receiver system containing a reference receiver front end (optical to electrical converter), a transversal filter to emulate multimode fiber, if appropriate, and a bit error ratio tester. All BER and sensitivity measurements are made with the test patterns specified for the PMD type, e.g., in 58.7.1

Transmitter and dispersion penalty may be considered as a transmitter penalty (TP) followed by a dispersion penalty, which is also attributable to the transmitter.

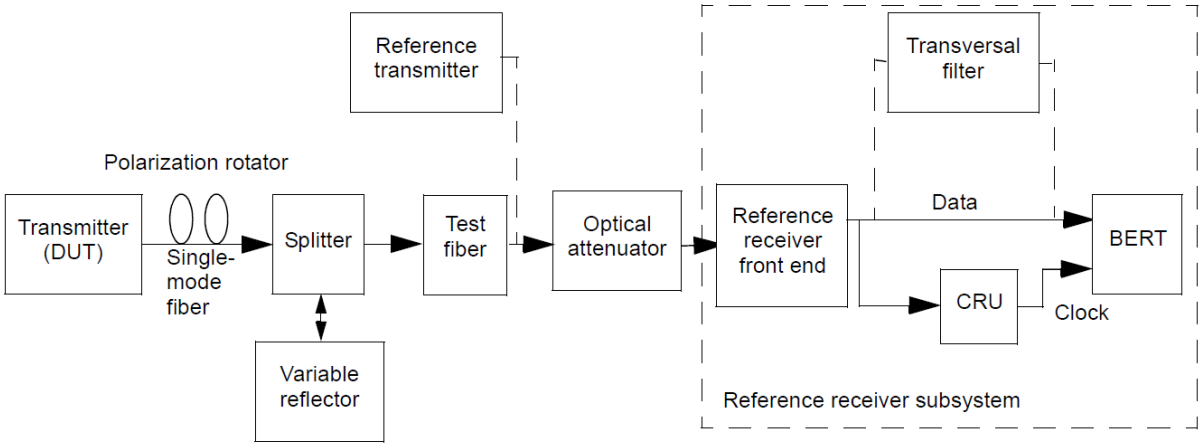



**Figure 58–7—Test setup for measurement of transmitter and dispersion penalty**

$P_{min}$ – R –TDP = Power budget (ODN insertion loss)

# Reference transmitter and receiver

### 58.7.9.1 Reference transmitter requirements

The reference transmitter is a high-quality instrument-grade device, which can be implemented by a CW laser modulated by a high-performance modulator. It should meet the following basic requirements:

a) The rise/fall times should be less than 0.15 UI at 20% to 80%.
b) The output optical eye is symmetric and with good margin to the eye mask test for the transmitter (PMD) type under test.
c) In the center 20% region of the eye, the worst-case vertical eye closure penalty, as defined in 58.7.11.2, is less than 0.5 dB.
d) Jitter less than 0.20 UI peak-peak.
e) $RIN_{12}OMA$ should be minimized to less than –120 dB/Hz for 100BASE-X and –125 dB/Hz for 1000BASE-X.

### 58.7.9.3 Reference receiver requirements

The reference receiver system should have the bandwidth specified for the transmitter optical waveform measurement for the transmitter under test. The sensitivity of the reference receiver system should be limited by Gaussian noise. The receiver system should have minimal threshold offset, deadband, hysteresis, deterministic jitter or other distortions. Decision sampling should be instantaneous with minimal uncertainty and setup/hold properties. When testing 100BASE-X optical transmitters, the receiver should have a passband not extending below 10 kHz at the –3 dBe (electrical) point, so as to emulate the pattern-induced baseline wander expected in a compliant receiver.

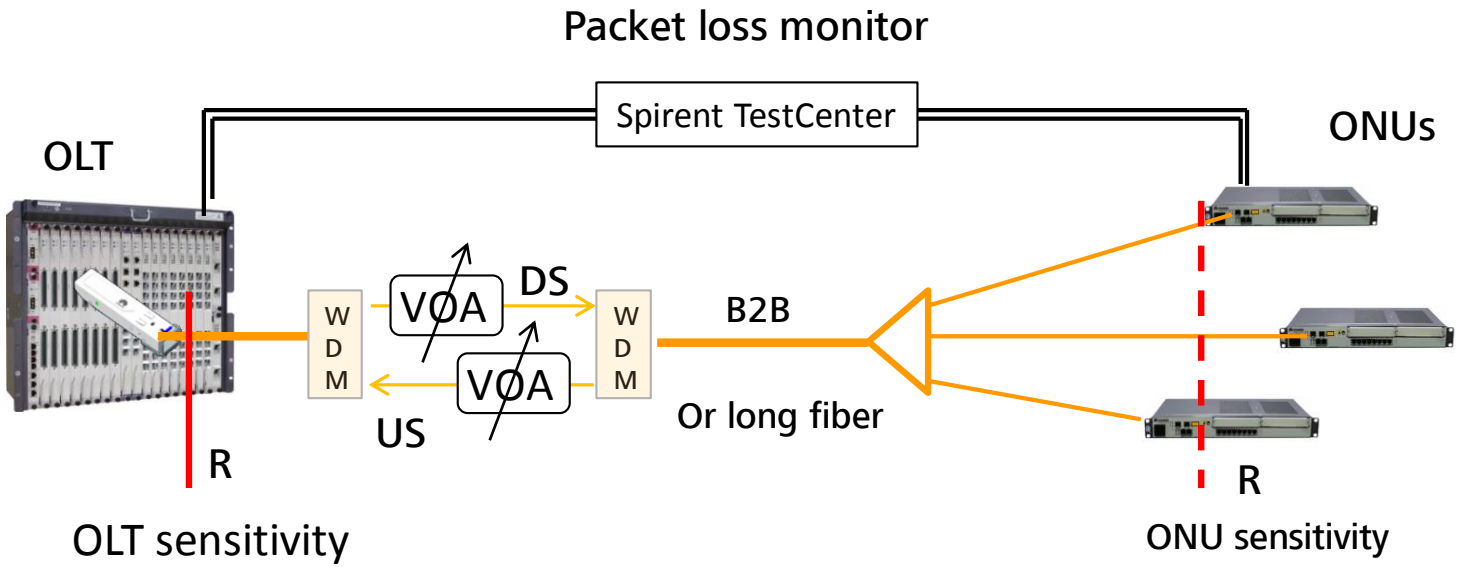
# How module vendors test the sensitivity for acceptance?

What signal source do you use to test sensitivity of PON modules for acceptance?

- Vendors 1: Use a typical OLT module as the source signal when test the ONUs 'sensitivity, vice versa.

- Vendors 2: Use the worst OLT module with the minimum ER to test the ONUs’ sensitivity, vice versa.

# How operators and equipment vendors test the sensitivity




- The operators and equipment vendors use the real OLTs and ONUs to test the sensitivity.
- Both back to back and after long fiber (such as 20km) are need to be tested.

# Dispersion penalty for 10G EPON upstream

10G EPON PR30 ONU transmitters transmission optical penalty after 20km

| 10G EPON OLT burst receiver sensitivity for 10Gb/s upstream | | | |
|---|---|---|---|
| 10G EPON ONU module SN | B2B(dBm) | 20KM(dBm) | DP(dB) |
| S365BG00006 | -30.4 | -30.8 | -0.4 |
| S365BG00009 | -30.3 | -30.3 | 0 |
| S3661G00001 | -30.6 | -31.2 | -0.6 |
| S3661G00002 | -29.5 | -29.8 | -0.3 |
| S3663G00014 | -29.8 | -29.8 | 0 |
| S3663G00015 | -29.4 | -29.9 | -0.5 |

- The dispersion penalty for 10G EPON upstream is negligible or even negative.
- The minimal launch power of 10G EPON PR30 is +4dBm, so the required sensitivity when signal reaches the OLT receiver(stressed sensitivity) is -25dBm .
- **A -28dBm at B2B sensitivity is actually over specified** based on the current test way(using an ONU transmitter as the source signal)

# Discussion

- IEEE 802.3 PON and ITU-T PON define the receiver sensitivity in a different way:
  - IEEE 802.3 defines the sensitivity based on an ideal transmitter
  - ITU-T PON defines the sensitivity based on the worst signal.
- TDP in IEEE 802.3 includes “TP” and “DP”, “OPP” in ITU-PON is equivalent to “DP” in 802.3.
- A uniform way between these two will benefit the PON convergence and the industry chain.

# Straw Poll 1

- Do you prefer to have a uniform definition and measurement on receiver sensitivity for next generation IEEE PON and ITU-T PON after 10G ?

1) : Yes

2): No

3): No opinion

# Straw Poll 2

- Which way do you prefer to define the sensitivity?

1): based on "an ideal transmitter”

2 ): based on the worst signal from the other end

3): others

# Backup– dispersion penalty in 1320nm

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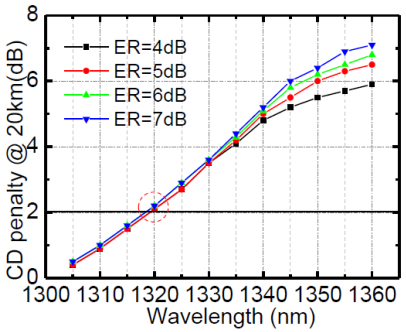
## CD penalty in O band+ after 20km SSMF

| | ER (dB) | | | |
|---|---|---|---|---|
| | 4 | 5 | 6 | 7 |
| ROF @ (B2B) BER = E-3 / dBm | -23.7 | -24.8 | -25.6 | -26.4 |
| wavelength where CD penalty = 2dB after 20 km SMF | ~1320 nm | | | |

*Note: The zero dispersion wavelength, λ0, corresponds to λmin = 1300 nm, with a CD penalty ≈ 0 dB.*




Cons:

1. The receiver sensitivity will decrease as the extinction ratio increases.
2. There still exits a CD penalty (> 2 dB) after 20 km SMF for different ER.
3. In the O band+, when D > 3 ps/nm·km (λ > 1330 nm), the CD penalty will increase as extinction ratio increases.

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Transmitted waveforms

$\lambda_{0\ dispersion}$: **1300**nm

$\lambda_{center}$ : ->**1320**nm

Fiber length: **20**km

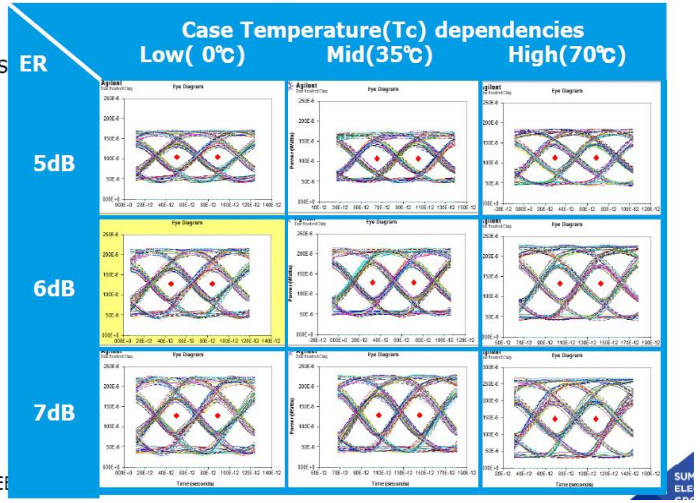
Worst penalty

TDP :2.29dB

DP :2.01dB

SUMITOMO ELECTRIC

IEE




The dispersion penalty for 25G DML is +2dB in worst case ($\lambda_{0\ dispersion}$ = 1300nm)

The “TDP” must take the “TP” account in besides this 2dB DP.

# Thank you

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