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G-PON interoperability test plan between optical line terminations and optical network units

ITU-T G-series Recommendations – Supplement 46

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**G-PON interoperability test plan between optical
line terminations and optical network units**

Summary

Supplement 46 to ITU-T G-series Recommendations defines a test plan whose purpose is to verify interoperability between a G-PON OLT and ONU. Emphasis is placed on test cases that address the G-PON physical layer (ITU-T G.984.2), the TC layer (ITU-T G.984.3) and low-level components of the management layer (ITU-T G.984.4).

Service layer test cases are out of scope for this supplement.

Interoperability testing is conducted by or on behalf of four interests: the OLT vendor, the ONU vendor, one or more network operators who are potential customers, and possibly a third-party testing lab.

For each test case, the supplement provides detailed information on:

- purpose;
- reference standard;
- preconditions and dependencies;
- test set-up;
- test equipment;
- test procedure;
- pass – fail criteria.

Source

Supplement 46 to ITU-T G-series Recommendations was agreed on 15 May 2009 by ITU-T Study Group 15 (2009-2012).

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Introduction

This supplement defines a test plan whose purpose is to verify interoperability between a G-PON OLT and ONU. Emphasis is placed on test cases that address the G-PON physical layer (ITU-T G.984.2), the TC layer (ITU-T G.984.3) and low-level components of the management layer (ITU-T G.984.4).

In this supplement, the OLT is regarded as the baseline equipment, against which the ONU is evaluated. This is not to be understood as an assertion that the OLT is necessarily right in the event of incompatibility, merely to reflect the reality that a network operator is likely to have OLTs in place and is interested in qualifying additional ONUs for use on these OLTs. From this perspective, the unit under test is an ONU.

Interoperability testing is conducted by or on behalf of four interests: the OLT vendor, the ONU vendor, one or more network operators who are potential customers, and possibly a third-party testing lab. As a preliminary to an interoperability testing campaign, all interests are expected to agree on features, functions and configurations. Only the features supported by both OLT and ONU need be tested but all test cases need to be addressed with either a test result or an indication why there is no result (not supported, etc.). As to test configurations, the vendors may be requested to supply equipment (of a given vintage), and the network operator may be interested in testing in the presence of other ONU makes and models, or with particular ODN characteristics. The testing lab needs to have the necessary power, space, test equipment and expertise for the agreed campaign.

In this supplement, the manufacturers are referred to as the OLT vendor and the ONU vendor respectively, while tests are deemed to be conducted by a test operator. The term *ONU* includes ONTs as well, and the term *OLT* includes the entire network element at the head end of the PON, not just the G.984 interface.

G-PON interoperability test plan between optical line terminations and optical network units

1 Scope

This clause describes the scope of G-PON interoperability testing. It is important to understand what an interoperability test plan is not, as well as what it is.

- An interoperability test project includes only features and capabilities that are claimed to be supported by both the OLT and the ONU. To apply a single interoperability test plan to all equipment combinations, the test report lists features and capabilities that are not claimed to be supported by one or both of the equipments, but tests of such cases are not to be regarded as failures. The reader of the test report determines the importance of a not-supported feature.
- An interoperability test plan evaluates the ability of an OLT and an ONU to deliver subscriber services. Services are standardized to a greater or lesser extent; the definition of a DS1 leaves very little to the imagination. However, services frequently have performance aspects that are more suitable for characterization than for Pass/fail results. An example might be the sustainable throughput of an Ethernet port or the echo performance of a voice channel. This supplement is based on ITU-T G.984.x-series of Recommendations and other standards. It expects that deviations from standards be recorded in the test results. Many test cases also characterize the quality or performance of service delivery. Compliance with standards is neither wholly necessary nor sufficient to guarantee that an OLT-ONU combination is suitable for a network provider's needs.
- An interoperability test plan confirms that a given ONU functions properly when installed on an ODN with other ONUs. In general, the other ONUs can differ arbitrarily in make, model and capability from the ONU under test. The vendors and the test lab should agree in advance on a representative population of ONUs.
- An interoperability test plan verifies that an ONU can be fully managed through the OLT, within the scope of capabilities it claims to support. This includes all pertinent FCAPS functions, for example initialization, provisioning, testing, fault isolation and maintenance, PM, backup, restoration and software upgrade.
- An interoperability test plan is not a gauge of standards compliance. A proprietary combination of OLT and ONU could well be completely interoperable. However, the standards form the basis of the interoperability test plan, in the expectation that they will closely describe most OLTs and ONUs.
- An interoperability test plan assumes a black-box view of the OLT-ONU combination. Information visible only through mechanisms such as debug ports is not valid as a test criterion. From a black-box perspective, some tests are clearly not possible, for example the ability for the OLT to controllably inject faults such as bit errors or send invalid PLOAM messages. Some of the test cases are nevertheless written to use such capabilities, if they exist. If the equipments do not expose such specialized mechanisms, it may be simply impossible to perform the test cases, and there is to be no implication that somehow it should have been possible.
- Ancillary equipment such as an uninterruptible power supply (UPS) or a DSL modem is not intrinsically within the scope of an OLT-ONU interoperability test plan. However, if a vendor always recommends a given ancillary equipment for use with an ONU or OLT, the ancillary equipment can be included by agreement. The test is not intended to resolve to a level as to isolate the operability of ancillary equipment or the OLT-ONU.
- With the exception of stress testing, in which the purpose of the test case is to oversubscribe resources of the network under test, any test case can fail if the test causes disruption to services that are not part of the test case.
- For the purpose of interoperability testing, it is assumed that all testing is performed with the temperature in the range of 60 to 80°F (16 to 27°C) and the relative humidity in the range of 20% to 60%. If testing is performed under different environmental conditions, then any such deviations should be clearly noted in the resulting test report. If different environmental conditions are required for a specific test case within this supplement, then these conditions will be explicitly stated in the test case.

2 Unlabelled

This clause intentionally left blank.

3 Interoperability guidelines

3.1 Overview

In preparation for interoperability test cycles, this clause provides ONU and OLT vendors with implementation guidelines created to enable multi-vendor interoperability. Interoperability testing between the ONU and OLT uses the ITU-T G.984.x-series Recommendations as the guidelines for all tests. This clause identifies the functionality to be implemented based on these specifications. Both vendors should complete PICS documents for [ITU-T G.984.2], [ITU-T G.984.3] and [ITU-T G.984.4] as a first step in planning the test campaign.

3.2 PON initialization and management

3.2.1 PON initialization

An ONU must be able to successfully initialize with the OLT using the activation method described in [ITU-T G.984.3].

3.2.2 Support of equipment management entities

The ONU/OLT should support OMCI and the managed entities defined in [ITU-T G.984.4]. The test plan assumes that OMCI is supported.

3.2.3 Downstream encryption

Downstream encryption is an integral part of the security of the system. It is evaluated to verify that it does not adversely affect service.

4 Test configuration and equipment

4.1 Network configuration

Figure 1 shows the test configuration for the interoperability testing of the OLT and ONU.

While data service interoperability is out of scope for this test plan, several test cases do rely on the ability to establish a basic data traffic flow between the OLT and ONU. The OLT and ONU vendors will be expected to work together to support this pre-condition. Data test sets should be available for each side of the network.

Temperature and humidity within the laboratory work spaces should be monitored using calibrated temperature and humidity indicators, and should be recorded throughout the testing.

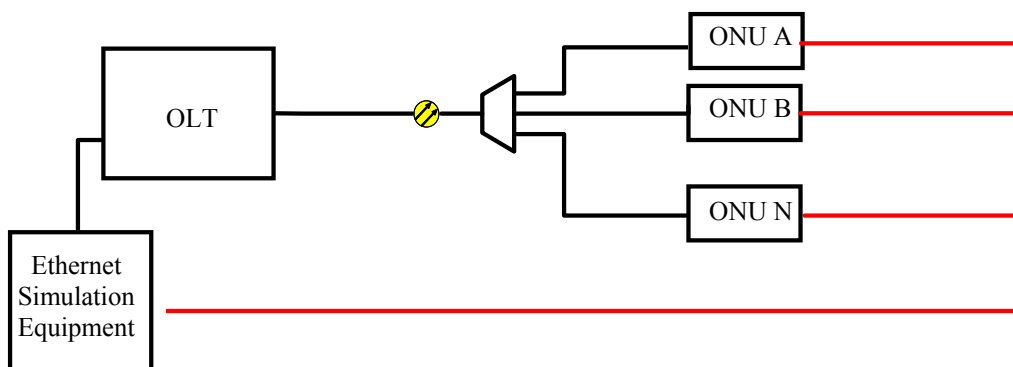


Figure 1 – Interoperability test configuration

4.2 Equipment requirements

The following test equipment is required:

Data test equipment – A single test unit with two interfaces should be available

ONU – At least three systems should be available to complete testing. Additional ONUs may be desired to fully build out the capacity of an OLT. The number of ONUs would be dependent upon the type of ONU.

OLT – Only one OLT is required for testing. Management must be provided with the OLT. The OLT vendor will be responsible for providing the management interface. Two examples of such a management interface are (1) a craft terminal with a description of all commands needed to perform the test cases in this supplement and (2) EMS access. It is at the discretion of the lab performing the test plan to have a pre-condition requiring that EMS be used to perform all relevant test cases.

Video – EDFA, optical combiner, with ability to present the required optical signal level to the ONU. These are only required if test cases involving the RF overlay will be executed.

4.3 Network equipment matrix

This matrix should be completed with all lab/test equipment used in the execution of the test plan.

Equipment type	Quantity	Manufacturer	Model	Software version	Hardware Rev.	Hardware serial number
Data traffic generator	1					
OLT	1					
ONU	3					
Video EDFA (optional)						

4.4 Vendor features comparison matrix

G-PON ONU and OLT vendors are encouraged to complete an implementation conformance statement (ICS) showing supported features. A comparison of the statements from both vendors will help identify the portions of this test plan that should be executed for a given OLT-ONU combination. The comparison will identify what optional and conditional G.984 features and functions are in common between the OLT and ONU implementations, in addition to the mandatory features and functions that both implementations must support. PICS (*protocol implementation conformance statement*) documents for G-PON are for future study (FFS) and are not included in this supplement.

5 Physical layer compatibility verification

The tests in this area verify fundamental PMD layer conformance to [ITU-T G.984.2] to ensure that subsequent interoperability test results are not biased by physical layer issues or non-conformances of the EUT. Generally speaking, the test procedures are the same as those used in conformance testing (possibly including the insertion of variable reflectance generators to simulate operation over a worst-case ODN), although the EUT is connected to the baseline OLT (and not to an OLT emulator).

5.1 Mean launch power

This clause provides test cases for measuring the OLT and ONU transmitter launch power as specified in [ITU-T G.984.2].

5.1.1 ONU mean launch power – TX off

Test case # 5.10

Purpose:

To determine the ONU output power with no input to the transmitter (i.e., transmitter "off"), but powered on. Measurements are made for two states:

- 1) ONU ranged; and
- 2) ONU un-ranged.

This test case helps ensure that a powered ONU does not generate excessive optical signal leakage on the ODN when not transmitting (i.e., when waiting for a bandwidth allocation from the OLT or for the start of the ranging process (if un-ranged)).

Standard (criteria): Clause 8.2.6.3 of [ITU-T G.984.2], clause III.3 of [ITU-T G.984.2] Amendment 1, and Appendix V of [ITU-T G.984.2] Amendment 2.

Preconditions and dependencies:

The test described in this clause is directly applicable to the ONU. However, it can only be performed if the appropriate equipment is available; e.g., an oscilloscope with sufficient sensitivity to determine conformance to the applicable specification (i.e., -33 to -43 dBm, depending on the particular bit rate, class and whether or not power levelling is supported), or an optical filter to isolate the oscilloscope from the OLT transmitter.

Test set-up:

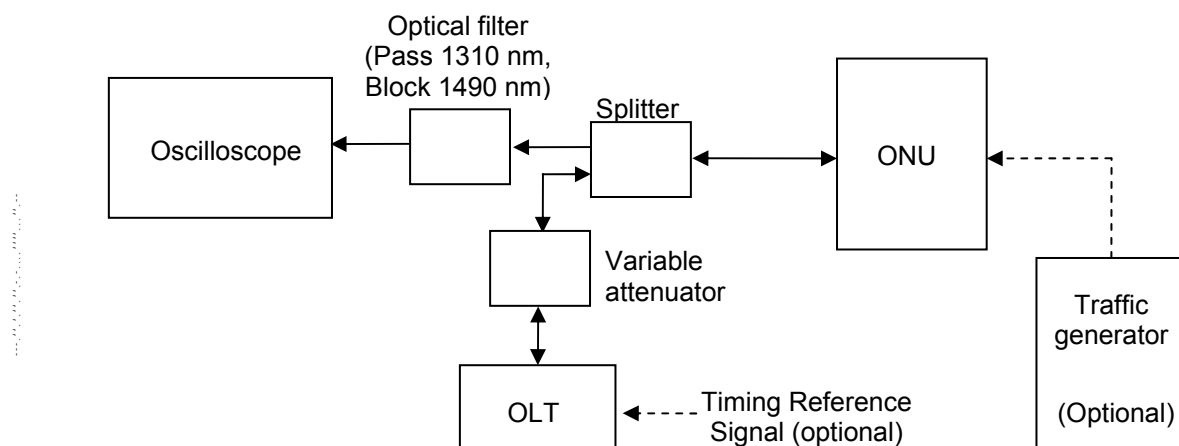


Figure 2 – ONU mean launched power test configuration – *ONU ranged, TX off*

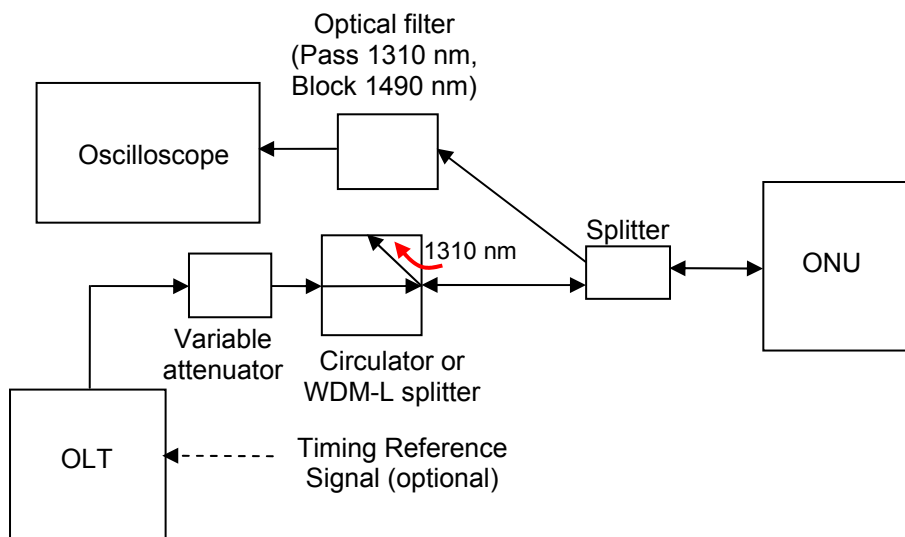


Figure 3 – Disabled ONU mean launched power test configuration – *ONU Un-ranged*

- 1) Follow local procedures for cleaning all fibre connectors before making any fibre connections, and configure the system as shown in Figure 3.
- 2) Note that the configuration of the traffic generator shown in Figure 3 is not of particular importance, and could be omitted entirely, instead relying on (scrambled) idle data in the upstream.
- 3) Several correction factors will need to be determined for use in calculating the actual output power level from the measured value. These include:

- The insertion loss of the splitter for the output fibre connected to the oscilloscope (i.e., the difference between the input optical power to the splitter and the output power from that output fibre).
- The insertion loss (in the 1310-nm region) of the optical filter used to isolate the oscilloscope from the 1490-nm signal transmitted by the OLT¹.
- The level displayed on the oscilloscope when there is no input signal.

The first two of these correction factors (the optical path loss factors) can be determined using a transmitter that transmits continuously at a wavelength approximately equal to that of the ONU transmitter (i.e., 1310 nm), and can be expressed in units of dB so that they can simply be added to the measured power level when it is expressed in dBm. The third correction factor (the oscilloscope offset factor) can be obtained by disconnecting (from the optical filter's output port or fibre) the fibre jumper that provides the input signal to the oscilloscope, capping the end of that fibre so that no ambient light can enter the fibre and reach the oscilloscope, configuring the oscilloscope to trigger on some other source (e.g., "internal"), and measuring any offset between the zero/ground level and the "no light" trace. Unlike the first two correction factors, this value should be a constant in linear units (rather than in dB), and therefore must be subtracted from the measured power level when it is expressed in linear units (e.g., microwatts).

Test equipment:

- 1) Oscilloscope.
- 2) Optical splitters.
- 3) Optical filter.
- 4) Optical attenuator.
- 5) Optical circulator or WDM-L splitter.
- 6) Optical power meter.

Test procedure:

- 1) Adjust the variable attenuator such that the power of the signal reaching the ONU receiver is slightly greater than the minimum level that results in essentially error-free operation of that receiver.
NOTE – For an ONU that supports the power levelling mechanism defined in [ITU-T G.984.2], this should also result in the power of the signal reaching the OLT to be close to its minimum specified level, causing the OLT to instruct the ONU to operate in Mode 0 (no attenuation).
- 2) Configure the oscilloscope to display at least several divisions of the transmitter signal received prior to the trigger event, and to trigger on the start of the burst signal transmitted by the ONU.
- 3) Record, in Table 1, the power level of the "no signal" portion of the trace as measured on the oscilloscope.
- 4) Apply any applicable correction factors and compare the results to the applicable specification (see pass/fail criteria below).
- 5) If it appears that the ONU does not meet the specification, decrease the attenuation provided by the variable attenuator to verify that the portion of signal reaching the oscilloscope that originates at the OLT transmitter is negligible. If it is not negligible (e.g., if the measured power level increases significantly when the attenuation is decreased by 3 dB), then the results should be discarded or corrected to account for the presence of the OLT's signal.
- 6) Disconnect the ONU from the test ODN and power off the ONU.
- 7) Insert a circulator between the variable attenuator and the splitter so that the configuration is as shown in Figure 3 and the ONU's output signal will *not* reach the OLT. Reconnect the ONU to the test ODN as shown in Figure 3 and power on the ONU.
- 8) If supported by the G-PON OLT, configure the OLT to set the default ONU transmit power level to "normal" (via the *Upstream_Overhead* PLOAM message transmitted by the OLT). Configure the OLT to periodically generate *Serial_Number Request* events, allowing ONU to respond in an attempt to join the PON.
- 9) Repeat steps 2 through 5.

¹ While the optical splitter provides isolation of the oscilloscope from the 1490 nm OLT downstream signal, further isolation is provided by the optical filter to avoid adversely affecting the ONU transmitter disabled power measurement.

Table 1 – ONU mean launched power results

Status	Measured output power (μW)	Oscilloscope offset correction factor (μW)	Optical path loss correction factors (dB)	Corrected output power (dBm)	Pass/fail result (Note)
Ranged ONU Tx-Off					
Un-ranged ONU Tx-Disabled					
NOTE – See pass/fail criteria below.					

Pass/fail criteria:

Allowable ONU output power levels with no input to the transmitter are a function of minimum OLT receiver sensitivity and:

- the OLT-ONU system line rate being considered in the test campaign;
- the ODN Class(es) (e.g., A, B, B+, or C) operation being considered in the test campaign;
- whether video wavelength overlay is being considered in the test campaign.

ONU output power levels with no input to the transmitter are specified in [ITU-T G.984.2] and its Amendment 1. The maximum ONU output power level with no input to the transmitter is the minimum OLT receiver sensitivity, less 10 dB. These values for G-PON ONUs are shown below:

Upstream rate	Class A	Class B/B+	Class C	Class C+ (Note)
1244 Mb/s (w/o power levelling)	–34 or possibly –38 dBm (if APD-based OLT RX)	–38 dBm	–39 dBm	–38 dBm
1244 Mb/s (w/ power levelling)	–33 dBm or possibly –38 dBm (if APD-based OLT RX)	–38 dBm	–39 dBm	–38 dBm
NOTE – Appendix V of [ITU-T G.984.2] states that "the ONU specifications should be achievable with ONU optics that are substantially similar to those described in Appendix III, except for the difference in upstream wavelength (described in [ITU-T G.984.5]) and operation with FEC (described in [ITU-T G.984.3])". Hence, this Class C+ ONU parameter is assumed to be the same as that for a Class B+ ONU.				

5.1.2 ONU mean launch power – TX enabled

Test case # 5.20

Purpose:

To determine the mean launched power level of the ONU transmitter when it is in the transmit-enabled state and in the presence of the specified worst-case reflection. (Note that if the ONU transmitter can be externally controlled to transmit continuously, the procedure described in clause 5.1.3 may be used instead.)

Standard (criteria): Clause 8.2.6.3 of [ITU-T G.984.2], clause III.3 of [ITU-T G.984.2] Amd.1, and Appendix V of [ITU-T G.984.2] Amendment 2.

Preconditions and dependencies:

The ONU-OLT combination needs to be able to successfully activate, and a data port (e.g., Ethernet) must be provisioned on the ONU for connection of a traffic generator.

This test is directly applicable in cases where a calibrated optical power meter or oscilloscope with sufficient wavelength and input power ranges to measure the ONU output optical signal is available. If the maximum input power level of the power meter or oscilloscope is less than the ONU output power level, then an optical attenuator with a known insertion loss must be inserted between the transmitter and the power meter.

In addition, the splitters (or other optical equipment) that are used to (1) extract the signal transmitted by the ONU from the optical fibre carrying the bidirectional traffic between the OLT and the ONU, (2) isolate the variable reflection generator from the downstream path and (3) isolate ONU-to-power-measurement-equipment optical paths must have minimal polarization dependent loss and be calibrated at a wavelength approximately equal to that of the ONU's output (or have minimal wavelength dependence).

Test set-up:

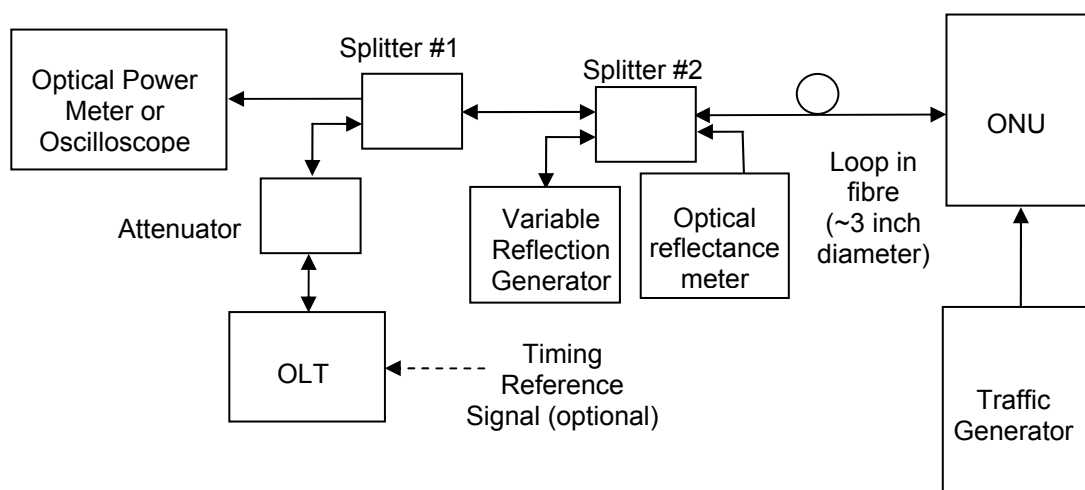


Figure 4 – ONU mean launched power test configuration²

- 1) Follow local procedures for cleaning all fibre connectors before making any fibre connections.
- 2) Configure the system as shown in Figure 4, and set the variable reflection generator so the ORL as seen at the transmitter under test is approximately 15 dB.
NOTE – In general, the ORL must be verified using a separate configuration (e.g., a configuration similar to that shown in Figure 4 with the OLT replaced by a laser having a central wavelength in the 1310-nm range).
- 3) Adjust the attenuator in the downstream path to ensure ONU is operating within the attenuation range of the ODN class of interest (e.g., class A, B, B+, C).
- 4) For a G-PON ONU transmitting at 1244 or 2488 Mb/s, [ITU-T G.984.2] defines a power levelling mechanism that may or may not be supported by the OLT. If such a mechanism is supported, the attenuator shown in Figure 4 must be adjusted so that the level of the signal reaching the OLT ensures the ONU is operating in mode 0 (normal power – *no attenuation*)³.
- 5) Note that although the data pattern for this test is specified to be pseudo random, the scrambling process provided at the TC layer should minimize the dependence of the results on the particular pattern that is used. On the other hand, if the system utilizes dynamic bandwidth allocation (DBA), then the traffic generator shown in Figure 4 will generally need to be configured to insert traffic at an appropriate rate (e.g., at a rate that maximizes the duration of the ONU's bursts).

Power meter vs. oscilloscope considerations: In general, it is necessary to first determine whether a power meter (or spectrum analyser with power averaging) can be used to measure the power, or whether an oscilloscope is required. In particular:

- If the ONU can be made to transmit for a consistent portion of the available time (and the power meter's measurement time is long compared to the burst length and repetition rate so that each measurement covers multiple periods (e.g., 100) during which a signal is or is not present), then a power meter can be used.
- If the ONU cannot be made to transmit for a consistent portion of the available time, then an oscilloscope must be used (assuming the optical signal can be displayed and the relationship between the trace amplitude and the power level can be established at the wavelength of interest).

² The loop in the fibre connecting the ONU to the test ODN is included in the test set-up so that any optical power that gets launched into the cladding of the fibre (rather than the core) is dissipated before reaching the measurement equipment. This is important for the output power measurement because that power is not useful in a real-world situation (i.e., it leaks away before the signal gets to the receiver), but might otherwise make it through the short fibre used in the test and make the transmitter look hotter than it effectively is.

³ This may require knowledge of the OLT power levelling threshold(s) or that the ONU provides a local mechanism to determine its power mode (0, 1, 2) upon completion of the activation process.

In the latter case, the approximate average optical power level can be calculated as:

$$P \approx 10 \times \log[(P_1 + P_0)/2] \text{ dBm}$$

- where P_1 is the average power in milliwatts for the central 20% of a logic '1' pulse period (i.e., the average "high" level) and P_0 is the average power in milliwatts for the central 20% of a logic '0' pulse period (i.e., the average "low" level).

Correction factors: One or more correction factors must be determined to calculate the actual output power levels from the measured values. These include:

- The insertion loss of the splitters for the output fibres that are in the ONU-to-power-measurement-equipment optical path (i.e., the difference between the input optical power to splitter #2 and the output power on the appropriate output fibre from splitter #1), which can be determined using a transmitter that transmits continuously at a wavelength approximately equal to that of the ONU transmitter.
- If the ONU transmits for a consistent portion of the available time and the measurement is going to be made using a power meter, then the ratio of the times during which transmission is enabled and disabled (which should be able to be determined using an oscilloscope configured for a relatively slow sweep rate to monitor the optical output signal).

Both of these correction factors can be expressed in units of dB so that they can simply be added to the measured power level (which in turn can be measured directly in units of dBm, or measured in linear units and converted to dBm). For example, if the ONU transmits for X out of every Y μ s, the corresponding correction factor for the power measured at a power meter would be:

$$\Delta P_{\text{On/Off}} = -10 \times \log(X/Y) \text{ dB}$$

Test equipment:

- 1) Optical power meter or oscilloscope.
- 2) Optical splitters.
- 3) Optical attenuator.
- 4) Variable reflection generator.
- 5) Traffic generator.
- 6) Optical reflectance meter.

Test procedure:

- 1) Record the power measured by the power meter or calculated from the high and low levels measured on the oscilloscope, as illustrated in Table 2.
- 2) Disconnect, clean and reconnect the fibre at the ONU's input/output connector, and repeat these steps until 5 values have been recorded⁴.
- 3) Add any applicable correction factors, calculate the average output optical power, and compare the individual and average power results to the applicable specification.
- 4) *Optional – this is applicable only for ONU which supports power levelling.* Reduce the attenuation provided by the attenuator shown in Figure 4 so that the OLT instructs the ONU to operate in mode 1 (3 dB of attenuation), and repeat the preceding steps.
- 5) *Optional – this is applicable only for ONU which supports power levelling.* Reduce the attenuation provided by the attenuator shown in Figure 4 so that the OLT instructs the ONU to operate in mode 2 (6 dB of attenuation), and repeat the preceding steps.

A test results table is provided in Table 2, as a tabular illustration of the measurement steps described in the test procedure.

⁴ The primary purpose of making multiple measurements of the output optical power is to verify the reproducibility of the connection between the equipment under test and the optical fibre. Significant variations in the measured power level could indicate a low-quality or damaged connector. In addition, any single measurement that is greater than the maximum power allowed by the specification would indicate a non-conformance to that specification (even if the average of the five measurements is within the specified range).

Table 2 – ONU mean launched power test results

Trial	Mode <G-PON- only>	Measured output power (dBm)	Correction factors (dB)	Corrected output power (dBm)	Max. and average output power (dBm)	Pass/ fail result (Note)
1 2 3 4 5	N/A or 0					
1 2 ...	1					
1 2 ...	2					
NOTE – See pass/fail criteria below.						

Pass/fail criteria:

Allowable transmit power levels are a function of:

- the OLT-ONU system line rate considered in the test campaign;
- the ODN class(es) (e.g., A, B, B+, or C) operation considered in the test campaign;
- whether video wavelength overlay is considered in the test campaign.

Average output power levels are specified in clauses 8.2.6, III.3 and Appendix V of [ITU-T G.984.2]. The ONU mean launched power specifications for 1244 Mb/s are as shown below:

Rate	Mode	Class A	Class B	Class B+/C+ (Note)	Class C
1244 Mb/s	N/A	–3 to +2 dBm	–2 to +3 dBm	+0.5 to +5 dBm	+2 to +7 dBm
1244 Mb/s	0	–3 to +2 dBm	–2 to +3 dBm	+0.5 to +5 dBm	+2 to +7 dBm
1244 Mb/s	1	–6 to –1 dBm	–5 to 0 dBm	–2.5 to +2 dBm	–1 to +4 dBm
1244 Mb/s	2	–9 to –4 dBm	–8 to –1 dBm	–5.5 to –1 dBm	–4 to +1 dBm
NOTE – Appendix V of [ITU-T G.984.2] states that "the ONU specifications should be achievable with ONU optics that are substantially similar to those described in Appendix III, except for the difference in upstream wavelength (described in [ITU-T G.984.5]) and operation with FEC (described in [ITU-T G.984.3])", Hence this Class C+ ONU parameter is assumed to be the same as that for a Class B+ ONU.					

Test report: Pass _____ Fail _____ Not supported _____

Observation:

Last modified: August 18, 2008.

5.1.3 OLT mean launch power

Per the introductory remarks, the equipment under test is considered to be an ONU, with the OLT considered as the baseline equipment. An OLT power measurement test case is provided to allow the organization executing the interoperability tests to verify that the reference OLT is operating within an acceptable range of previously benchmarked values. If results vary from the previously benchmarked values by more than an acceptable deviation (e.g., 2 dB), then investigative/corrective action should be undertaken by the test operator to resolve the discrepancy before proceeding with additional testing.

This OLT measurement can be considered an in-service quality verification check of the OLT, the OLT against which the ONU equipment under test interoperability will be assessed. This measurement should be considered a part of the lab's overall ISO/IEC 17025 quality program.

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Test case # 5.30

Purpose:

To determine the mean launched power level of the OLT optical transmitter in the presence of the specified worst-case reflection. (Note that this procedure can also be used to determine the mean launched power level of an ONU transmitter if that transmitter can be externally controlled to transmit continuously (i.e., placed in a special test mode). Otherwise, see clause 5.1.2 for the ONU mean launch power test procedure.)

In the context of an ONU-centric interoperability test plan, measuring OLT transmit power is an in-service quality verification check.

Standard (criteria): Clauses 8.2.6, III.3 and Appendix V of [ITU-T G.984.2].

Preconditions and dependencies:

This test is directly applicable in cases where a calibrated optical power meter with sufficient wavelength and input power ranges to measure the OLT output optical signal is available. If the maximum input power level of the power meter is less than the OLT output power level, then an optical attenuator with a known insertion loss will need to be inserted between the transmitter and the power meter.

Test set-up:

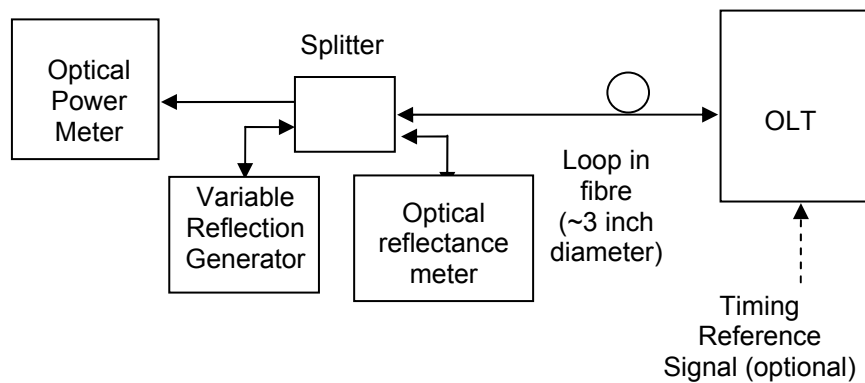


Figure 5 – OLT mean launched power test configuration

- 1) Follow local procedures for cleaning all fibre connectors before making any fibre connections.
- 2) Configure the system as shown in Figure 5, and set the variable reflection generator so the ORL as seen at the transmitter is approximately 15 dB⁵. In general, the ORL can be verified by inserting a reflection meter between the splitter and the transmitter under test.
- 3) Determine the insertion loss of the splitter for the output fibre connected to the power meter (i.e., the difference between the input optical power to the splitter and the output power from that output fibre) for use in correcting the power measurements obtained during the tests.
- 4) Although the data pattern for this test is specified in ITU-T G.984.x series of Recommendations to be pseudo random, the scrambling process provided at the TC layer should provide a sufficiently randomized pattern, even when the OLT is primarily transmitting idle data.

Test equipment:

- 1) Optical reflectance meter.
- 2) Optical power meter.
- 3) Optical splitter.
- 4) Variable reflection generator.

⁵ A transmitter has to meet its output power, spectral characteristics, and eye-related specifications in the presence of a -15 dB reflectance (placed immediately downstream from the input/output connector), per clause 8.2.6.7 of [ITU-T G.984.2].

Test procedure:

- 1) Record the power measured by the power meter, as illustrated in Table 3.
- 2) Disconnect, clean and reconnect the fibre at the OLT's input/output connector, and repeat these steps until 5 values have been recorded⁶.
- 3) Add any applicable correction factors, calculate the average output optical power, and compare the individual and average power results to the applicable specification.

Table 3 – OLT mean launched power test results

Tx	Trial	Measured output power (dBm)	Correction factors (dB)	Corrected output power (dBm)	Pass/fail result (Note)
OLT #1	1				
	2				
	3				
	4				
	5				
NOTE – See pass/fail criteria below.					

Pass/fail criteria:

In the context of an ONU-centric interoperability test plan, measuring OLT transmit power is an in-service quality verification check. As such the measurement results are compared to transmit power levels previously collected during the laboratory benchmarking of the baseline OLT. Deviations greater than 2 dB from the benchmark transmit power levels are effectively a "fail" and indicate that investigative/corrective action should be undertaken to resolve the discrepancy before proceeding with additional testing.

Generally speaking, OLTs are expected to comply with the transmit power specifications of [ITU-T G.984.2] and its associated amendments.

Test report: Pass _____ Fail _____ Not supported _____

Observation:

Last modified: July 25, 2006.

5.2 Receiver sensitivity

This clause provides test cases for assessing ONU and OLT receiver sensitivity. OLT assessment is performed in the context of an in-service quality check.

5.2.1 ONU receiver sensitivity**Test case # 5.40****Purpose:**

This test case assesses whether the ONU is able to operate at a bit error ratio (BER) at or below 10^{-10} when the received signal is at the minimum acceptable average power specified in ITU-T G.984.x series of Recommendation. The specified procedure measures BER at levels in excess of 10^{-10} (e.g., starting at 10^{-7}) and then uses these measurement results to estimate the receiver power level at which a 10^{-10} BER is likely to be achieved.

NOTE – This extrapolation technique has been used for many years with SONET/SDH-based systems, applies to receivers whose performance is thermal noise limited, and helps reduce overall testing times relative to procedures that attempt to directly assess receiver performance at a 10^{-10} BER. The extrapolation technique is based on that technique described in step 4.9 of [TIA-526.3], "OFSTP-3 "Fibre optic terminal equipment receiver sensitivity and maximum receiver input".

Examining physical layer transmission performance (BER) helps ensure the underlying PON physical layer transport mechanism is sound before assessing service-level performance.

Standard (criteria): Clauses 8.2.6, III.3 and Appendix V of [ITU-T G.984.2].

⁶ The primary purpose of making multiple measurements of the output optical power is to verify the reproducibility of the connection between the equipment under test and the optical fibre. Significant variations in the measured power level could indicate a low-quality or damaged connector.

Preconditions and dependencies:

This measurement requires that the OLT-ONU combination be activated and that a data port be provisioned at both the ONU (customer facing interface) and OLT ("V" interface). If estimated ONU receiver BER performance data is available at the OLT (based on the ONU's REI PLOAM messages), then it may be more efficient to use this data in assessing the ONU receiver sensitivity rather than using external test equipment to estimate the BER. Accessing this data typically requires OLT management system or craft interface access. Additionally, any correction factors that need to be applied in order to calculate the power level at the ONU receiver from the power level measured at the power meter or oscilloscope must be determined in advance.

Test set-up:

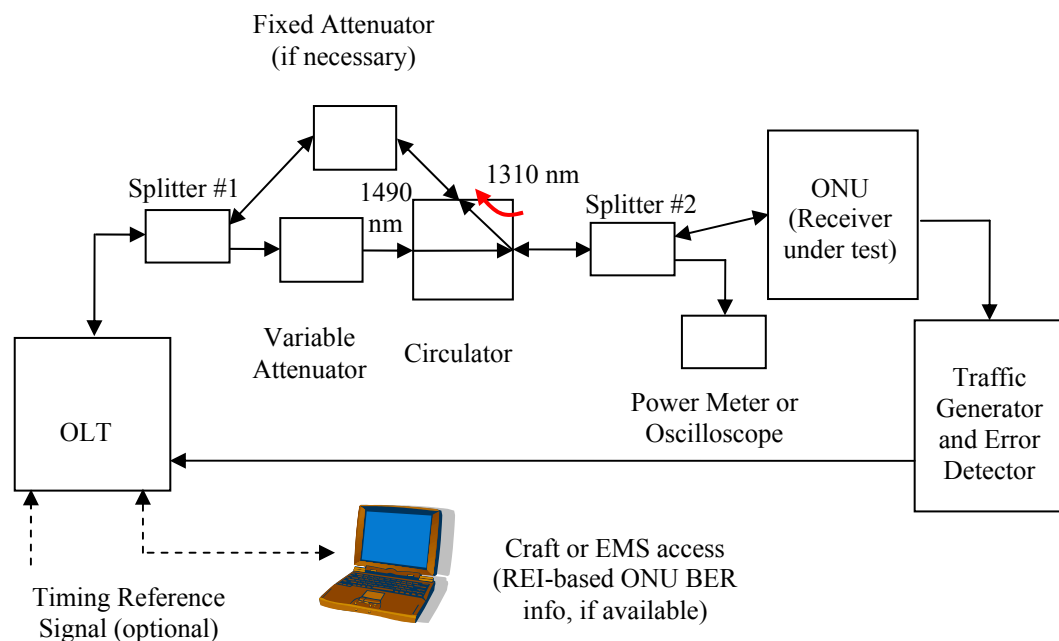


Figure 6 – Receiver sensitivity test configuration

- 1) Follow local procedures for cleaning all fibre connectors before making any fibre connections.
- 2) Configure the system as shown in Figure 6 and select the fixed attenuator so that the power of the signal reaching the OLT receiver (travelling in the non-test direction) is well within its specified limits, and set the variable attenuator such that the power of the signal reaching the ONU receiver is within that receiver's limits.
- 3) While a circulator is required, one optimized for operation at 1490 nm should be used if available. The circulator provides an ODN with an asymmetrical attenuation characteristic that helps ensure that degradations in the non-test direction of transmission (i.e., ONU => OLT) do not affect the test results.
- 4) Configure the traffic generator to insert packets for transmission from the OLT to the ONU.

Reflectance issues – It is important that the directivity of "Splitter #2" and the reflectance characteristics of the circulator (and any connectors located between those two components) be such that the portion of the ONU's optical output signal that reaches the power meter or oscilloscope is negligible. If it is not negligible, then it will be necessary to correct the various power measurements for the returned/reflected power, or to move Splitter #2 such that it is located on the other side of the circulator. (In the latter case, in order to determine the power of the signal reaching the ONU's receiver, it will be necessary to adjust the power levels measured at the power meter or oscilloscope by the loss that occurs through the circulator.)

Traffic capacity and error measurement issues – To reduce the time required to perform this test, the traffic generator should be set to transmit packets (i.e., frames or cells) at a rate that is *slightly* less than the maximum rate that can be continuously supported by the system.

In those cases when PLOAM-based REI messages from the ONU are not used to estimate ONU bit error performance, then the packet loss may need to be measured in lieu of bit errors. Direct measurement of bit errors may not be possible as packets that are errored during transmission may be discarded by the ONU, rather than being passed downstream to the UNI (error detector). In such cases the traffic generator and error detector would need to be configured such that the number of packets sent to the OLT (for transmission through the system) can be compared to the number of packets

received from the ONU (packet loss). A technique to estimate bit errors from the number of lost packets is described below.

BER calculation issues – This BER calculation discussion is applicable in those cases when PLOAM-based REI messages from the ONU are *not* used to estimate ONU bit error performance, in which case packet loss will be used to estimate ONU bit error performance.

The BER can be approximated by dividing the number of packets that were errored (or lost) by the product of the number of packets transmitted and the number of bits ("N") per packet that, if errored, would cause the packet to be detected as errored (or discarded).

$$\text{BER} \sim \text{PL} / [\text{PT} \times \text{N}], \text{ where}$$

PL = Packets Lost.

PT = Packets Transmitted.

N = # of bits within a packet that, if errored, would result in a lost packet.

"N" typically will not include the GEM header, as that portion of the signal is required to be protected against errors via a header error correction (HEC) function.

As an example, for a 512 byte Ethernet frame with no FEC:

$$N = 8 \text{ bits/byte} \times 512 \text{ bytes} = 4096 \text{ bits.}$$

This formula is derived by expressing the packet loss probability, P(PL), as a function of the bit error probability, P(B). Specifically, $P(\text{PL}) = N \times P(\text{B})$. P(L) can be approximated by PL/PT (# lost packets / # packets transmitted). Hence, $\text{PL}/\text{PT} \approx N \times \text{BER}$ and $\text{BER} \approx \text{PL} / (\text{PT} \times \text{N})$.

Power measurement issues – In receiver sensitivity tests, it is generally recommended (and in some cases, essential) that the test set-up include equipment that allows a signal whose power level is proportional to the power of the signal reaching the receiver to be continuously monitored (e.g., to detect optical power fluctuations, either random or as a result of the power levelling function, that could have a significant impact on the short-term BER). In the test set-up shown in Figure 6, this function is provided by "Splitter #2" and the "Power meter or oscilloscope". In the ideal case, the signal would be continuously present (so that its power level could be measured directly with a power meter), and the power of the signal reaching the receiver under test would be equal to the power of the signal reaching the power meter. However, in practice at least one correction factor, to account for the difference in the powers of the signals appearing on the splitter's output fibres, typically needs to be applied.

Test equipment: See Figure 6.

Test procedure:

Depending on the type of traffic and the test set used to generate and detect errors or lost packets on that traffic, the test set may display the BER directly. Also, estimated ONU receiver BER performance data may be available at the OLT (estimated via received REI PLOAM messages). In such cases, it will generally not be necessary to record and calculate certain values as described in this procedure.

- 1) Ensure that downstream FEC is disabled.
- 2) Gradually increase the attenuation until bit errors begin to occur at a significant rate (e.g., at a BER of approximately 10^{-7}) and the measured power is at a convenient level for plotting purposes. This is the starting point for a series of BER measurements.
- 3) Clear the error or transmitted and received packet counters, and cause the traffic generator to send a known number of packets in the test direction.
- 4) Record the power level displayed by the optical power meter (or oscilloscope), the BER estimate retrieved from the OLT (if supported), or the number of packets transmitted and the number of packets errored (or lost) during transmission (if OLT-based retrieval of ONU BER performance data is not available)⁷.
- 5) Calculate the power level of the signal at the ONU receiver and (if OLT-based retrieval of ONU BER performance data is not available) the approximate BER at that power level.

⁷ It is recommended that the BER measurement at any particular power level be continued until at least 10 (or better yet, 100) errors have been detected. However, due to transmitter output stability issues and traffic capacity and time limitations, this may not be possible in some situations. Data collected during shorter test periods should be carefully evaluated.

- 6) If any packets were errored (or lost) at the test power level (or REI data received by the OLT), decrease the attenuation by approximately 0.5 dB (or if desired 0.25 dB) and return to step 5. Continue this process of decreasing the attenuation until *at least* five RX power/BER data points have been recorded. If no errors are encountered before five data points have been collected, then repeat steps 4 through 8, this time decreasing the attenuation in smaller steps.
- 7) Plot the recorded BER versus received power data on graph paper equivalent to that shown in Figure 7. (Note that the y-axis scale used for this graph paper is not a standard linear or log scale. Instead, it is a scale that is based on the complementary error ("Q") function and is specifically derived for plotting BER versus received power data for typical optical receivers per [TIA-526.3].)
- 8) Fit a line through the data points and determine the power level at which that line crosses the BER level of 10^{-10} .
- 9) Compare the result to the applicable criteria or specifications for that receiver. In general, the measured sensitivity for a new receiver should be several dB better than the value given in the criteria, to allow for the effects of aging. (see ITU-T G.957 Amendment 2 for more on aging effects).
- 10) If the OLT supports FEC encoding, then enable downstream FEC encoding at the OLT.
 - a) If the ONU EUT does not support FEC decoding, simply spot-check several of the previously recorded (BER, RX) power data points (recorded when OLT FEC encoding = was set to OFF) to verify no ONU RX performance change is evident (the ONU is expected to ignore the OLT-insert FEC parity inserted by the OLT and operate with the same RX performance as with OLT FEC encoding OFF).
 - b) If the ONU EUT supports FEC decoding, repeat steps 4 through 10. In step 4 the likely observable non-zero BER will be closer to 10^{-3} . As attenuation is decreased from the starting point measurement, select an appropriate attenuation step granularity to produce enough BER versus received power data points to fit a line to, per step 10 (the line is likely to be very steep). Also, fluctuations in the power received by the ONU (for a given attenuation) should be very carefully monitored to ensure that power variations do not skew the BER data. (When the BER versus received power line is very steep, a relatively short period in which the received power is less than the setpoint can cause a large increase in the average BER.)

A test results table is provided in Table 4 as a tabular illustration of the measurement steps described in the test procedure. In cases where FEC encoding (and possibly decoding) is supported, results tables should be completed for each case tested.

Table 4 – Receiver sensitivity test results

Measured power (dBm)	Correction factors (dB)	Received power (dBm)	Packets sent	Packets errored or lost	BER (Note 1)	Calc. Sens. (dBm) and pass/fail results (Note 2)
NOTE 1 – The number of bits per packet (for use in the denominator of the BER calculation) is _____. (See the discussion in the "set-up" paragraph above regarding the determination of the appropriate value.)						
NOTE 2 – See pass/fail criteria paragraph below.						

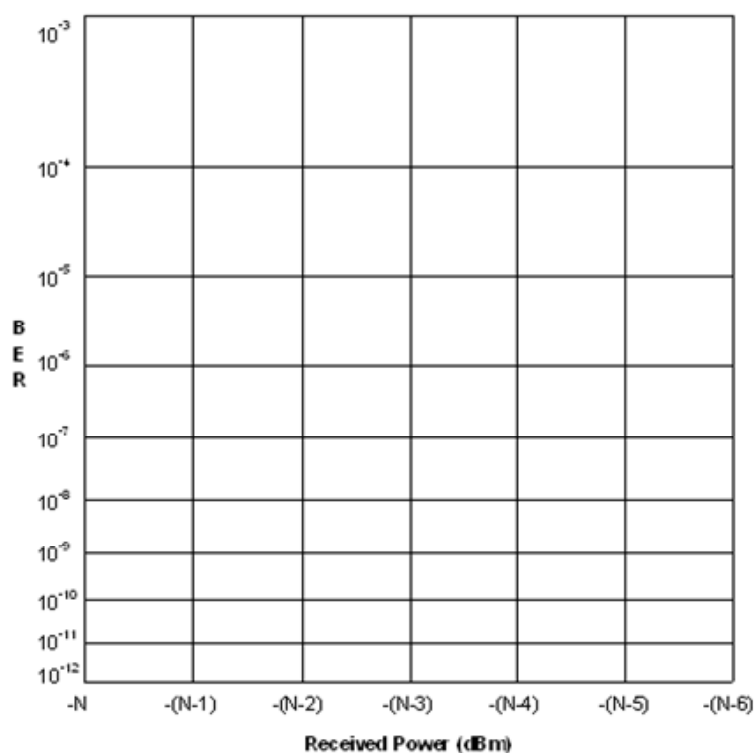


Figure 7 – BER Versus Received Power Plotting Paper

Pass/fail criteria:

The receiver sensitivity specifications are that the BER must be 1×10^{-10} or better when the power at the ONU receiver is as shown below. Receivers are expected to display several dB of margin to allow for the effects of aging, the use of a transmitter with a better than worst-case extinction ratio and pulse rise and fall times, and the absence of the worst-case ORL at the transmitter.

ONU receiver sensitivity criteria are specified in Table 2c, Table III.1 and Table V.1 of [ITU-T G.984.2].

Downstream rate	Class A	Class B	Class B+	Class C	Class C+ (Note)
2488 Mb/s	−21 dBm	−21 dBm	−27 dBm	−28 dBm	−30 dBm
NOTE – Appendix V of [ITU-T G.984.2] states "The ONU sensitivity assumes the use of the optional RS(255,239) FEC capability of the G-PON TC layer with the current class B+ ONU detector technology". A pre-FEC Bit error ratio of 10^{-4} is specified.					

Test report: Pass ____ Fail ____ Not supported ____

Observation:

Last modified: August 18, 2008.

5.2.2 OLT receiver sensitivity

Test case # 5.50

Purpose: This OLT measurement can be considered an in-service quality verification check of the OLT, helping to ensure that no unexpected degradations have occurred in the OLT, against which ONU interoperability is assessed. In addition, this measurement may highlight unexpected upstream transmission performance issues related to the specific characteristics of the ONU's transmitted signal.

Standard: Clauses 8.2.6, III.3 and Appendix V of [ITU-T G.984.2].

Preconditions and dependencies: The measurement requires that the OLT-ONU combination be activated and that a data port be provisioned at both the ONU (customer facing) and OLT ("V" interface).

Test set-up: See Figure 6 with the OLT now in the position of the receiver under test and a circulator optimized for operation at 1310 nm. Configure the traffic generator to insert packets for transmission from the ONU to the OLT.

Test procedure: See ONU test case procedure of clause 5.2.1, with OLT substituted for ONU. Note that the power correction factor equivalent to $\Delta P_{On/Off}$ (see clause 5.1.2) will also need to be applied when measuring the received power (ONU upstream burst) at the OLT using an optical power meter. OLT receiver performance data may be directly accessible via a craft/EMS terminal, in which case the use of an external error counter at the SNI is not required.

If the OLT and ONU support FEC, then initially perform the test with upstream FEC encoding OFF (disabled). Then repeat the test with upstream FEC ON. The downstream FEC encoding status is inconsequential as this is the non-test direction, with relatively modest attenuation present.

Pass fail criteria: In the context of an ONU-centric interoperability test plan, measuring OLT receiver sensitivity is an in-service quality verification check. As such the measurement results are compared to receiver sensitivity previously collected during the benchmarking of the baseline OLT. Degradations greater than 2 dB from the benchmark receiver sensitivity are effectively a fail, and indicate that investigative/corrective action should be undertaken before proceeding with additional testing.

Generally speaking, OLTs are expected to comply with the receiver sensitivity specifications of clause 8.2.8 of [ITU-T G.984.2].

The OLT receiver sensitivity criteria are (see clause 8.2.8 of [ITU-T G.984.2]):

Upstream rate	Class A	Class B	Class B+	Class C	Class C+ (Note)
1244 Mb/s	−24 dBm	−28 dBm	−28 dBm	−29 dBm	−32 dBm
NOTE – Appendix V of [ITU-T G.984.2] states "The OLT sensitivity assumes the use of the optional RS(255,239) FEC capability of the G-PON TC layer, as well as intrinsic detector technology improvements, e.g., SOA preamplification". A pre-FEC Bit error ratio of 10^{-4} is specified.					

Test report: Pass _____ Fail _____ Not supported _____

Observation:

Last modified: August 18, 2008.

5.3 Receiver overload

This clause provides test cases for assessing ONU and OLT receiver overload. The test cases seek to determine the maximum average received power levels at which the OLT and ONU receivers are able to operate (i.e., maintain a BER of 10^{-10} or better). OLT assessment is performed in the context of an in-service quality check.

Receiver overload is measured against a signal with worst-case G.984 extinction ratio and pulse rise and fall times. For the purpose of interoperability testing, however, receiver overload is measured when the incoming signal is from a real OLT (or ONU) implementation (i.e., not using a test transmitter with controlled transmitted signal characteristics). This implies the transmitter may have better-than-worst-case extinction ratio. While one might consider applying a correction factor for measurements made with transmitters with better-than-worst-case extinction ratio, this is deemed difficult or impossible because of the complicated relationship between the eye diagram degradations (which result in errors at the receiver) and the power and extinction ratio of a high-power input signal.

COMMENT: Due to the very steep slope of the BER versus received power line in the high power region for most receivers, some believe that FEC encoding/decoding will not have a significant impact on the receiver overload test results. Therefore, no discussions of FEC or FEC-related steps have been added to receiver overload procedures. If such steps are desired, they can be based on the steps that have been added to the receiver sensitivity test case. Some minor editorial changes are, however, suggested below.

5.3.1 ONU receiver overload

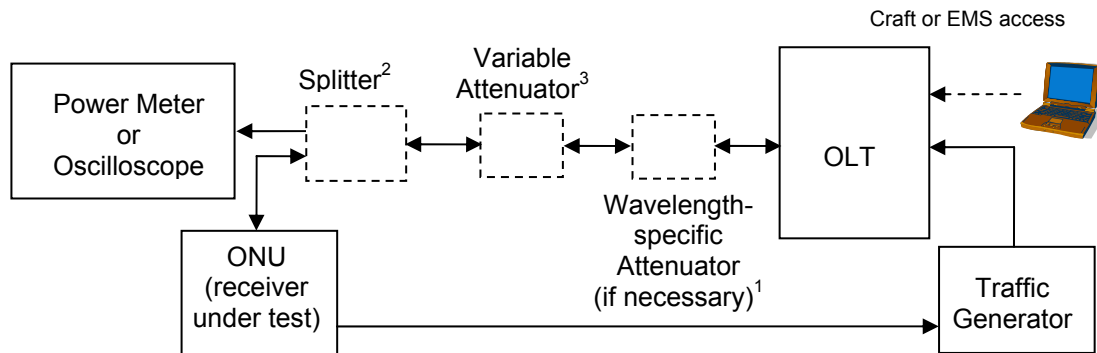
Test case # 5.60

Purpose: To determine the maximum average received power level at which the ONU receiver is able to operate (i.e., maintain a BER of 10^{-10} or better) when receiving a signal from the baseline OLT transmitter.

Standard: Clauses 8.2.6, III.3 and Appendix V of [ITU-T G.984.2].

Preconditions and dependencies: The measurement requires that the OLT-ONU combination successfully activate, and that a data port be successfully provisioned at both the ONU (customer facing interface) and OLT ("V" interface). If estimated ONU receiver BER performance data is available at the OLT (based on the ONU's REI PLOAM messages), then it may be more efficient to use this data in assessing the ONU receiver overload rather than using external test equipment to estimate the BER. Accessing this data typically requires OLT management system or craft interface access.

Test set-up:



NOTE 1 – The purpose of the wavelength-specific attenuator (or equivalent equipment such as an optical filter or a fixed attenuator located between a pair of circulators) is to reduce the power of the 1310-nm signal generated by the ONU to a level that can be tolerated by the OLT receiver (non-test direction), while simultaneously allowing the 1490 nm signal generated by the OLT to pass through with minimal attenuation.

NOTE 2 – If the test equipment insertion losses are such that the power level of a minimally attenuated signal is less than that at which overload occurs (or the minimum specified overload power level), then it may be necessary to perform the BER and power measurements separately using different test configurations. For example, each BER measurement could be made with the splitter removed from the set-up, and then the splitter could be inserted for the corresponding power measurement (which would then need to be corrected for the splitter's insertion loss).

NOTE 3 – If after removing the splitter (Note 2) the power level is still insufficient for completion of the test (and an unattenuated signal will not cause damage to the receiver), then the variable attenuator can also be removed.

Figure 8 – Receiver overload test configuration

- 1) Follow local procedures for cleaning all fibre connectors before making any fibre connections.
- 2) Configure the system as shown in Figure 8 and set the variable attenuator such that the power of the signal reaching the ONU receiver is within that receiver's limits. If necessary, the (1310 nm) wavelength specific attenuator (or functional equivalent) should be configured such that the power of the signal reaching the OLT receiver (in the non-test direction) is kept within that receiver's limits through the expected range of the variable attenuator adjustments.

Traffic capacity and error measurement, BER calculation, and power measurement issues – See clause 5.2.1, ONU receiver sensitivity.

Test equipment: See Figure 8.

Test procedure:

Depending on the type of traffic and the test set used to generate and detect errors or lost packets on that traffic, the test set may display the BER directly. Also, estimated ONU receiver BER performance data may be available at the OLT (estimated via received REI PLOAM messages). In such cases, it will generally not be necessary to record and calculate certain values as described in this procedure.

- 1) Determine the correction factors that must be applied in order to calculate the power level at the ONU receiver from the power level measured at the power meter or oscilloscope.
- 2) Configure the traffic generator to insert packets for transmission from the OLT to the ONU.
- 3) Gradually decrease the attenuation until bit errors begin to occur at a significant rate (e.g., at a BER of approximately 10^{-7}) and the measured power is at a convenient level for plotting purposes. This is the starting point for a series of BER measurements.
- 4) Clear the error or transmitted and received packet counters, and cause the traffic generator to send a known number of packets in the test direction.
- 5) Record the power level displayed by the optical power meter (or oscilloscope), the BER estimate retrieved from the OLT (if supported), or the number of packets transmitted and the number of packets

errored (or lost) during transmission (if OLT-based retrieval of ONU BER performance data is not available)⁸.

- 6) Calculate the power level of the signal at the ONU receiver and (if OLT-based retrieval of ONU BER performance data is not available) the approximate BER at that power level.
- 7) If any packets were errored (or lost) at the test power level (or REI data received by the OLT indicated that errors occurred), increase the attenuation by approximately 0.2 dB and return to step 4. (Note that for most receivers the BER versus received power curve is expected to be very steep at high power levels, and therefore it may be necessary to utilize small changes in the received power. In addition, it may not be necessary to plot the results as indicated in the following step.)
- 8) Plot the recorded BER versus received power data on graph paper equivalent to that shown in Figure 7. (Note that the y-axis scale used for this graph paper is not a standard linear or log scale. Instead, it is a scale that is based on the complementary error function and is specifically derived for plotting BER versus received power data for typical optical receivers (per [TIA-526.3]).)
- 9) Fit a curve through the data points and determine the power level at which that curve crosses the BER level of 10^{-10} .

Table 5 – Receiver overload test results

Measured power (dBm)	Correction factors (dB)	Received power (dBm)	Packets sent	Packets errored or lost	BER (Note 1)	Calc. Sens. (dBm) and pass/fail results (Note 2)
NOTE 1 – The number of bits per packet (for use in the denominator of the BER calculation) is _____. (See the discussion in the "Set-up" paragraph of clause 5.2.1, <i>ONU receiver sensitivity</i> above regarding the determination of the appropriate value.)						
NOTE 2 – See pass/fail criteria paragraph below.						

Pass/fail criteria:

The receiver overload specifications are that the BER must be 10^{-10} or better when the power at the ONU receiver is as shown below.

G-PON receiver overload criteria are specified in clause 8.2.8 of [ITU-T G.984.2].

Downstream rate	Class A	Class B	Class B+	Class C	Class C+ (Note)
2488 Mb/s	–1 dBm	–1 dBm	–8 dBm	–8 dBm	–8 dBm
NOTE – ITU-T G.984.2, Appendix V states "The ONU overload is set at –8 dBm to be common with the class B+ value, even though in this application –10 dBm is sufficient".					

Test report: Pass ____ Fail ____ Not supported ____

Observation:

Last modified: August 18, 2008.

5.3.2 OLT receiver overload

Test case # 5.70

Purpose: This OLT measurement can be considered an in-service quality verification check of the OLT, helping to ensure that no unexpected degradations have occurred in the OLT, against which the ONU equipment under test interoperability is assessed. In addition, this measurement may highlight unexpected upstream transmission performance issues related to the specific characteristics of the ONU's transmitted signal (e.g., pulse characteristics and extinction ratio).

Standard (criteria): Clauses 8.2.6, III.3 and Appendix V of [ITU-T G.984.2].

⁸ In almost all cases it is recommended that the BER measurement at any particular power level be continued until at least 10 (or better yet, 100) errors have been detected. However, due to transmitter output stability issues and traffic capacity and time limitations, this may not be possible in some situations. Data collected during shorter test periods should be carefully evaluated.

Preconditions and dependencies: The measurement requires that the OLT-ONU combination successfully activate, and that a data port be successfully provisioned at both the ONU (customer facing) and OLT ("V" interface).

Test set-up: See Figure 8 with the OLT now in the position of the receiver under test and a 1490-nm wavelength-specific attenuator.

Test equipment: See Figure 8.

Test procedure: See ONU test case procedure of clause 5.3.1, with OLT substituted for ONU.

Pass/fail criteria: In the context of an ONU-centric interoperability test plan, measuring OLT receiver overload is an in-service quality verification check. As such the measurement results are compared to receiver overload previously collected during the benchmarking of the baseline OLT. Degradations greater than 2 dB from the benchmark receiver overload are effectively a "fail" and indicate that investigative/corrective action should be undertaken before proceeding with additional testing.

Generally speaking, OLTs are expected to comply with the receiver overload specifications of clause 8.2.8 of [ITU-T G.984.2].

The receiver overload specifications based on clauses 8.2.6, III.3 and Appendix V of [ITU-T G.984.2] are shown below.

Upstream rate	Class A	Class B	Class B+	Class C	Class C+
1244 Mb/s	-3 dBm	-7 dBm	-8 dBm	-8 dBm	-12 dBm

Test report: Pass ____ Fail ____ Not supported ____

Observation:

Last modified: August 18, 2008.

5.4 OLT and ONU emission wavelengths

This clause provides test cases for measuring the nominal OLT and ONU emission wavelengths as specified in [ITU-T G.984.2]. Nominal wavelengths are those observed at the environmental test conditions specified in clause 1.

5.4.1 Nominal OLT emission wavelength

Test case # 5.80

Purpose:

To measure the OLT emission wavelength for each PON interface of the OLT. In the context of an ONU-centric interoperability test plan, measuring OLT emission wavelength is a quality verification check, since the OLT does serve as the reference source for the ONU receiver test cases. As such, this test case serves as a preliminary/reference test to verify that the OLT emission wavelength meets the G.984.2 specifications.

Standard (criteria): Table 2c of [ITU-T G.984.2].

Preconditions and dependencies:

The test described in this clause is directly applicable to the OLT. Each equipment used for this measurement has to work in the ideal conditions (temperature, power) recommended by the provider (equipment specifications).

Test set-up:

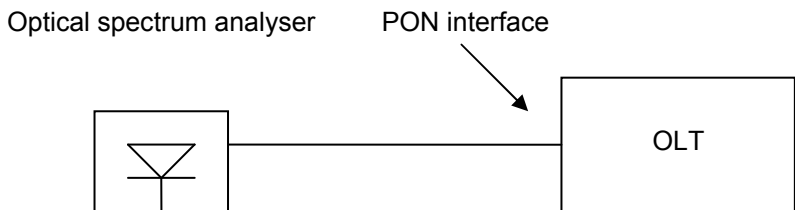


Figure 9 – OLT emission wavelength test configuration

Test equipment:

- 1) Optical spectrum analyser.

Test procedure:

- 1) Activate OLT PON interface.
- 2) Establish an optical connection between OLT and optical spectrum analyser via Input connector.
- 3) Record the wavelength measured by the analyser, as illustrated in Figure 9.
- 4) Disconnect, clean and reconnect the fibre at the OLT's input/output connector, and repeat these steps until 5 values have been recorded.

Table 6 – OLT emission wavelength results

Measurement number	Measured wavelength (nm)	Pass/fail result (Note)
1		
2		
3		
4		
5		
NOTE – See pass/fail criteria below.		

Pass/fail criteria:

Allowable OLT emission wavelengths fall within the range specified by Table 2c of [ITU-T G.984.2] (1480-1500 nm).

- Pass if wavelength is between 1480 nm and 1500 nm.
- Fail if wavelength is <1480 nm or >1500 nm.

Test report: Pass ____ Fail ____ Not supported ____

Observation:

Last modified: January 2, 2009.

5.4.2 Nominal ONU emission wavelength

Test case # 5.90

Purpose:

To measure the ONU emission wavelength.

Standard (criteria): Table 2f of [ITU-T G.984.2]. Optionally, Table 1 of [ITU-T G.984.5] may be used if the ONU under test is designed to comply with either the reduced wavelength band option or the narrow wavelength band option, both of which are defined in [ITU-T G.984.5].

Preconditions and dependencies:

The measurement requires that the OLT-ONU combination successfully activate, and that a data port be successfully provisioned at both the ONU (customer facing) and OLT ("V" interface). A traffic generator is also connected to the ONU in order to generate upstream traffic. Each equipment used for this measurement has to work in the ideal conditions (temperature, power) recommended by the provider (equipment specifications).

Test set-up:

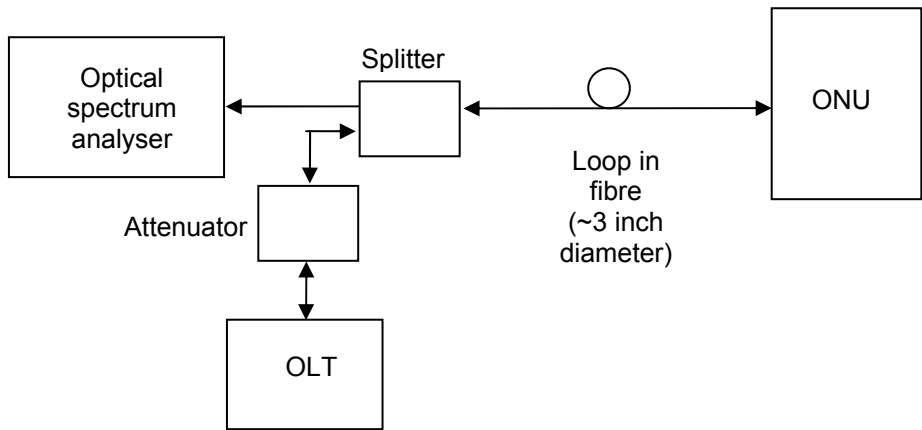


Figure 10 – ONT emission wavelength test configuration

Test equipment:

- 1) Optical spectrum analyser.
- 2) Optical splitter.
- 3) Optical attenuator (if necessary).
- 4) Traffic generator.

Test procedure:

- 1) Record the wavelength measured by the analyser, as illustrated in Figure 10.
- 2) Disconnect, clean and reconnect the fibre at the ONU's input/output connector, and repeat these steps until 5 values have been recorded.

Table 7 – ONU emission wavelength results

Measurement number	Measured wavelength (nm)	Standard reference (G.984.2, G.984.5 reduced band option, or G.984.5 narrow-band option)	Pass/fail result (Note)
1			
2			
3			
4			
5			
NOTE – See pass/fail criteria below.			

Pass/fail criteria:

Allowable ONU emission wavelengths fall within the range specified by Table 2f of [ITU-T G.984.2] (1260-1360 nm).

- Pass if wavelength is between 1260 nm and 1360 nm.
- Fail if wavelength is <1260 nm or >1360 nm.

If the ONU is being tested against the reduced wavelength band option (1290-1330 nm) specified in [ITU-T G.984.5], then the following criteria apply:

- Pass if wavelength is between 1290 nm and 1330 nm.
- Fail if wavelength is <1290 nm or >1330 nm.

If the ONU is being tested against the narrow wavelength band option (1300-1320 nm) specified in [ITU-T G.984.5], then the following criteria apply:

- Pass if wavelength is between 1300 nm and 1320 nm.
- Fail if wavelength is <1300 nm or >1320 nm.

Test report: Pass _____ Fail _____ Not supported _____

Observation:

Last modified: January 2, 2009.

6 ONU turn-up and management

This test area considers fundamental PON functionality, both for turn-up and ONU management as described in [ITU-T G.984.3]. The test cases are generally characterized by the pair-wise nature of the testing (i.e., a single ONU interoperating with the OLT).

6.1 ONU start-up

Unlike B-PON, there is only one method for ONU discovery in G-PON. It requires an automatic detection mechanism of the serial number of the ONU.

Activation of an ONU may be initiated in two possible ways:

- The network operator enables the activation process to start when it is known that a new ONU has been connected. After successful ranging (or a time-out), ranging is automatically stopped.
- The OLT periodically and automatically initiates the activation process, testing to see if any new ONUs have been connected. The frequency of polling is programmable such that ranging can occur every millisecond to every second.

6.1.1 Cold PON – Cold ONU

This situation exists when no upstream traffic is running on the PON and the ONUs have not yet received PON-IDs from the OLT.

Test case # 6.10

Initialization, cold PON, cold ONU.

Purpose:

To verify that the OLT initializes the ONU.

Standard:

Clause 10 of [ITU-T G.984.3].

Preconditions:

Three ONUs not connected to the PON and powered down. OLT auto detects the ONU serial numbers of the ONUs under test. EMS or craft terminal on the OLT to recognize the presence of the ONU.

Test equipment:

None.

Test set-up:

Default test set-up as shown in Figure 1.

Test procedure:

Automatic activation:

- 1) Power up ONU1.
 - 2) After the ONU1 completes its boot process connect ONU1 to the fibre.
 - 3) ONU shall range in 30 s.
 - 4) Disconnect ONU1 from the fibre and power down.
- Repeat for ONU2 and ONU3.

Manual activation:

- 1) Power up ONU1.
 - 2) After the ONU1 completes its boot process connect ONU1 to the fibre.
 - 3) Manually start the ranging process.
 - 4) ONU shall range in 30 s.
 - 5) Disconnect ONU1 from the fibre and power down.
- Repeat for ONU2 and ONU3.

Pass/fail criteria:

Fail if any ONU does not range or if the ranging times exceed the requirement.

Test report: Pass _____ Fail _____ Not supported _____

Observations:

Elapsed time, power on to ranging complete (min, average, max).

Last modified: July 25, 2006.

6.1.2 Warm PON and cold ONU

This situation is characterized by the addition of new ONU(s) which have not been previously ranged, or by the addition of previously active ONU(s) having power restored and coming back to the PON while traffic is running on the PON.

Test case # 6.20

Purpose:

To verify that the OLT initializes the ONU.

Standard:

Clause 10 of [ITU-T G.984.3].

Preconditions:

Three ONUs not connected to the PON and powered down plus one additional ONU connected and ranged to PON. OLT auto detects the ONU serial numbers of the ONUs under test. The PON has at least one ONU connected and ranged with upstream traffic. EMS or craft terminal on the OLT to recognize the presence of the ONU.

Test equipment:

Traffic generator.

Test set-up:

Default test set-up as shown in Figure 1 with an additional ONU connected and active during test iterations. A traffic generator is also connected to the additional ONU in order to generate upstream traffic.

Test procedure:

Automatic activation:

- 1) Connect ONU1 to fibre and power up.
- 2) ONU shall range within 30 s.
- 3) Power down and disconnect ONU1 fibre.
Repeat for ONU2 and ONU3.

Manual activation:

- 1) Connect ONU1 to fibre and power up.
- 2) Manually start ranging.
- 3) ONU shall range within 30 s.
- 4) Power down and disconnect ONU1 fibre.
Repeat for ONU2 and ONU3.

Pass/fail criteria:

Fail if any ONU does not range or if the ranging times exceed the requirement or if the upstream traffic on the additional ONU is disrupted.

Test report: Pass ____ Fail ____ Not supported ____

Observations:

Elapsed time, power on to ranging complete (min, average, max).

Last modified: December 16, 2008.

6.1.3 ONU ranging – Various cable lengths

The following test cases verify start-up interoperability between OLTs and ONUs for ranging at various fibre lengths. The tests are iterations of test case 6.10 with different ODN characteristics.

Test cases are performed with 10 km and 20 km of fibre between the OLT and the splitter. Optional test cases are included that incorporate an extender box and use 40 km and 60 km between the OLT and the splitter.

Test set-up:

The basic test set-up for the ONU start-up tests is shown in Figure 11. It consists of a single ONU connected to the OLT, except as noted in certain test cases, with either 10 or 20 km of fibre between the OLT and the splitter. Note that the splitting ratio will vary according to the optical class. The figure below shows a 1 x 32 splitter for reference only.

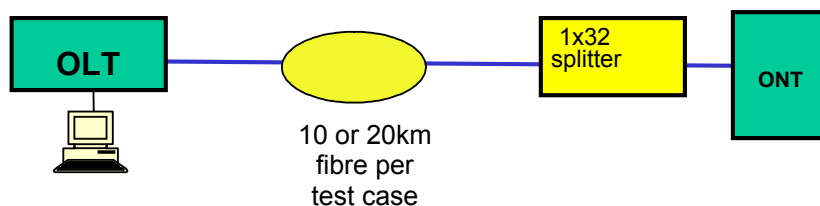


Figure 11 – ONU ranging test configuration

Figure 12 shows the test set-up for the optional test cases that use 40 or 60 km of fibre between the OLT and splitter.