Fibre Cabling, Installation and Inspection

Advice Guide

The most important thing we build is trust

Connected – Seamless – Wireless

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Introduction

The purpose of this document is to advise on the correct method of Installing and testing a fibre network. The importance of why this advice should be followed is that failure to complete the points within this advice guide correctly will lead to a) increased time b) increased cost c) poor performance of the communications between equipment (OMU to remote units).

Cobham Wireless advises that only 'End to End' Fibre testing is carried out – Do not just test the core Fibre cable as this is a waste of time and all patch cables / pig tails / jumper cables need to be testing as part of the entire 'End to End' Fibre link.

1. Fibre

It is important to make measurements to ensure a correct installation of the fibre distribution system prior to Installation of any fibre equipment.

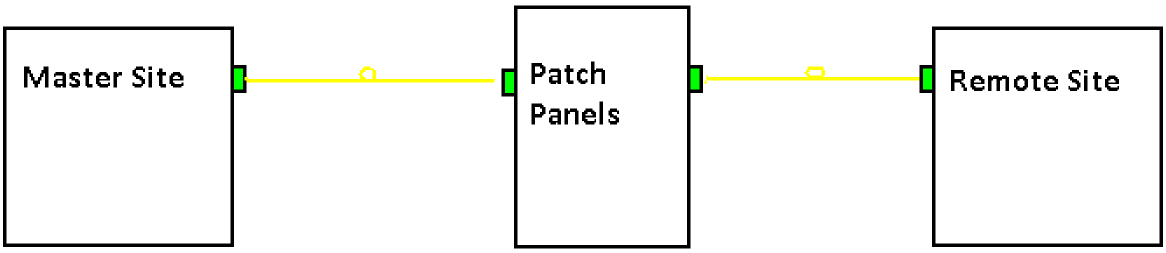
When the fibre cable has been installed, the quality of the optical path should be checked for optical path loss over the entire length (end to end) and the magnitude and location of any reflections. All fibre connectors should be certified to meet industry standards - see 'FO Specification' document.

Cobham Wireless requires Optical Time Domain Reflectometer (OTDR) measurement. Optical reflections can degrade the linearity of a fibre optic link and introduce noise; hence why it is important to confirm your fibre is working within tolerance.

Keep all discrete reflections to > 60 dB.
The SC/APC connectors specified are polished to a return loss >60 dB.

1.1. Fibre Connectors

- All fibres must be terminated with SC/APC (Angled Physical Contact); these with tuned 8º connectors (IEC 60874-14-9) must be used throughout the whole link between the master unit and the repeater.
- The fibre must be Single/Mono mode fibre to ITU-T Recommendation G.652.
- SC/APC connectors complying to endface conditions equal to IEC-61300-3-35 must be used on any ODF connections.

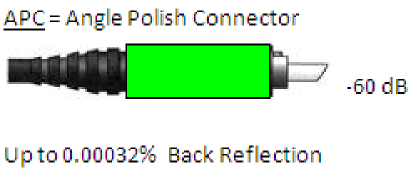


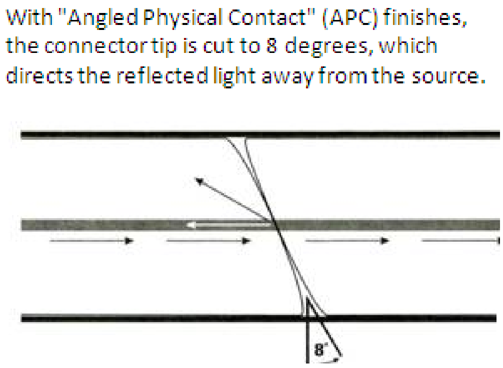
Fibre Infrastructure

1.2. Differences in Fibre connectors

SC/APC:

SC/APC is the correct connector type and can be identified by a green connector boot and a square section. The fibre end is Angle Polished (APC) 8°; this offers a large surface area of contact between both fibres. APC improve coupling efficiency and minimize connector back reflection or return loss characteristics. For inspection of APC connectors an APC microscope tip is required to achieve incident angles suitable for image illumination and viewing.

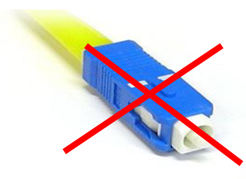


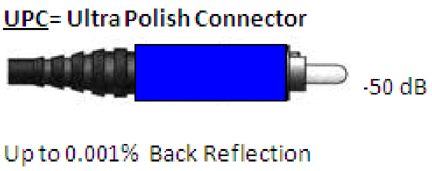


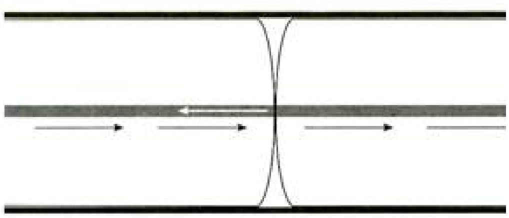
SC/UPC:

SC/UPC is the wrong connector type, it is generally identified by a blue connector boot and uses Physical Contact (PC) 0°.

WARNING
This type of connector must not be used anywhere within the repeater fibre network; the Insertion loss (reflectance) is too high and will disrupt the communications between nodes preventing the system from being commissioned.





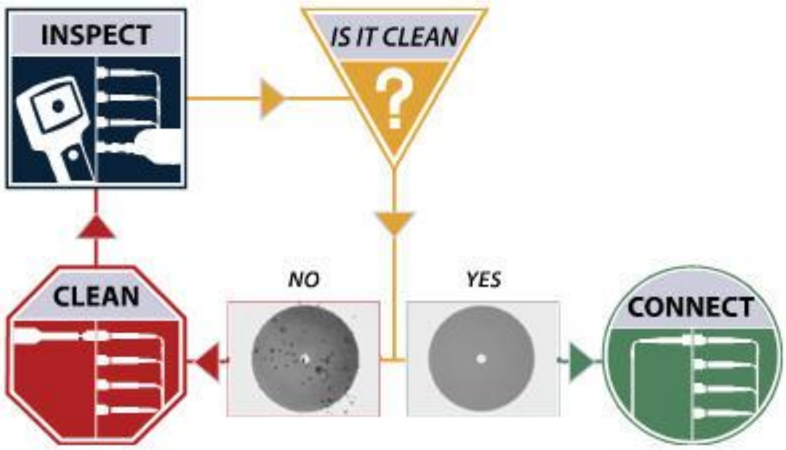


1.3. Avoiding Fibre Contamination

Contamination is the #1 source of troubleshooting in optical networks.

A single particle mated into the core of a Fibre can cause significant back reflection (also known as Return Loss), insertion loss, and can damage equipment. Visual inspection is the only way to determine if Fibre connectors are truly clean before mating them. Cobham Wireless advises 100% visual inspection is carried out on all interfaces.

By implementing a simple yet important process of proactive visual inspection and cleaning, poor optical signal performance and potential equipment damage can be avoided.



Optical Connector Inspect/Clean/Connect Process

Clean optic Fibre components are imperative to the quality of optical performance within any optic Fibre link. It is the most basic and important procedure which has to carried out before mating together any optic Fibre assembly. Any contamination in the Fibre connection can cause failure of that component and even failure of the whole system. Hence, clean components are a necessity for quality connections with optic Fibres.

When cleaning Fibre components, the procedure must be followed correctly, precisely, and carefully with the goal of eliminating any dust or contamination. A clean component will connect properly; a dirty component may transfer contamination to the mating connector, or it may even damage the optical contacts. Remember components are not guaranteed to be clean on receipt from the supplier. A particle that partially or completely blocks the core will generate strong back reflections, which may make a laser system unstable.

It is essential that all optics are cleaned and inspected.

A 1-micrometer dust particle on a single-mode core can block up to 1% of the light (a 0.05dB loss). A 9-micrometer speck can completely block the fibre core.

Other contamination:

- Oils, frequently from human hands
- Film residues, condensed from vapours in the air
- Powdery coatings, left after water or other solvents evaporate away

Particles trapped between fibres faces can:

- Scratch the glass surfaces
- Cause an air gap or misalignment between cores degrading the optical signal

1.3.1. Good Fibre Connection

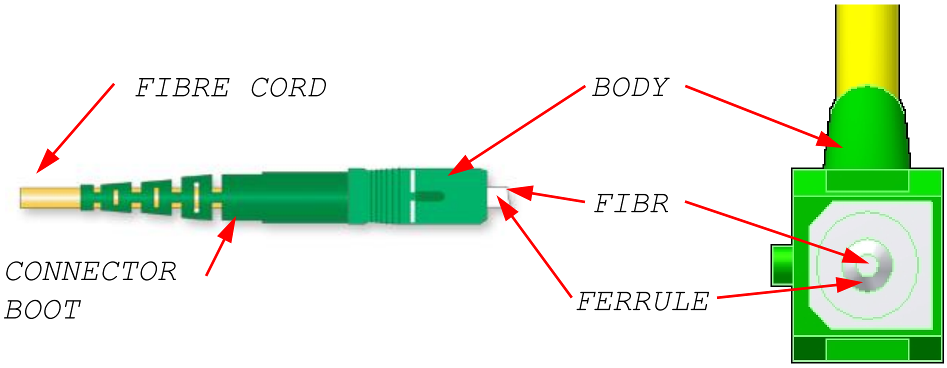
There are 3 basic principles that are critical to achieving an efficient optic Fibre connection:

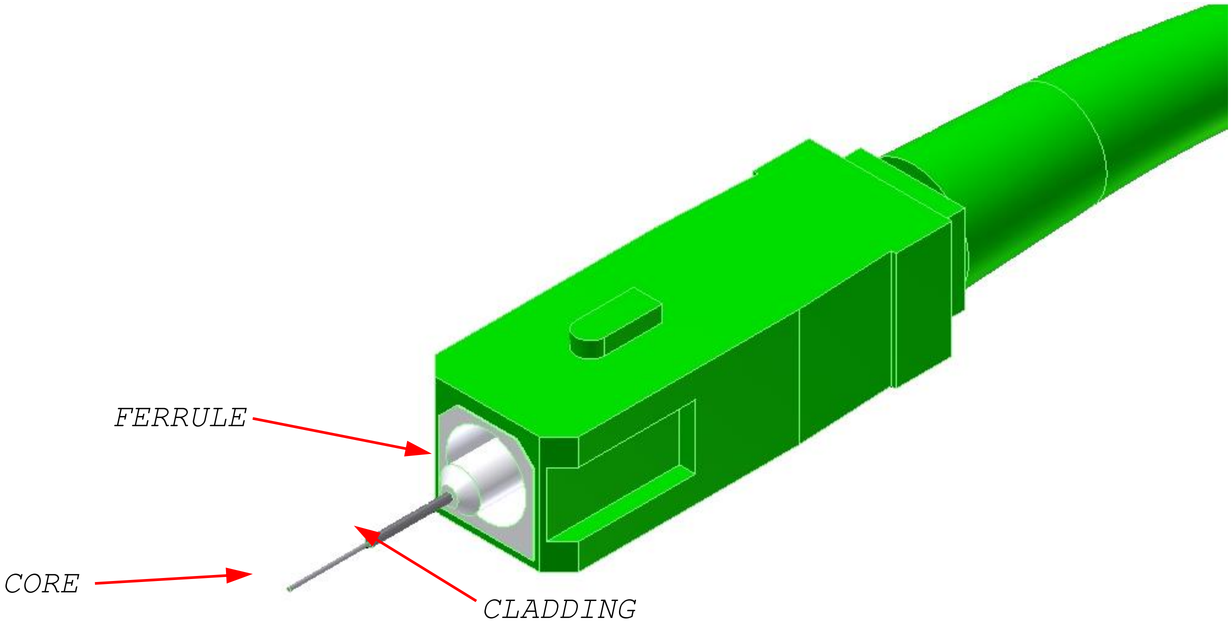
1. Optimal Core Alignment
2. Physical Contact
3. Clean Connector Interface

Today's connector design and production techniques have eliminated most of the challenges to achieving core alignment and physical contact. What remains challenging is maintaining a clean connector interface.

Fibre Connection – Key Terms & Concepts

Fibre connectors enable Fibre-to-Fibre mating by aligning the two optical Fibres. Fibre connectors come in various types and have different characteristics for use in different applications. The main components of a Fibre connector are detailed in the following:





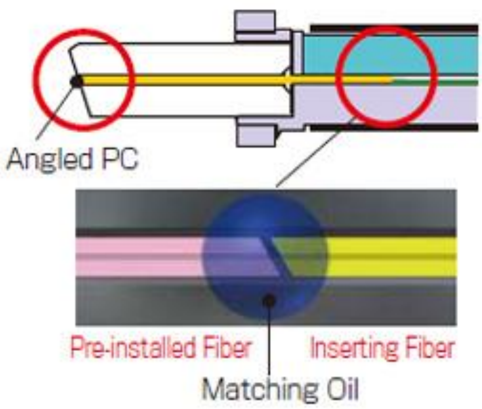
Fibre Connector Components (LCPC Example)

Body: Houses the ferrule that secures the Fibre in place; utilizes a latch and key mechanism that aligns the Fibre and prevents the rotation of ferrules of two mated connectors.

Ferrule: Thin cylinder where the Fibre is mounted and acts as the Fibre alignment mechanism; the end of the Fibre is located at the end of the ferrule which is referred to as the 'endface' throughout this document. The overall diameter of the ferrule depends on the relevant connector type. There are typically two ferrules diameters used: 2.5 mm dia. e.g. SC-APC type connectors and the smaller 1.25 mm dia. e.g. LCPC type connectors.

Fibre: CLADDING: Glass layer surrounding the core, which prevents the signal in the core from escaping (125 um dia. for single connectors

CORE: The critical centre layer of the Fibre; the conduit that light passes through (8 -10 um dia. for single mode connectors).



Fibre Connection (SC-APC Through Connect Example)

1.3.2. Fibre Connector Endface defects

There are many types of defects. Commonly used terminologies include: contamination, particles, pits, chips, scratches, loose contamination and embedded contamination etc.

For this document the defects will form two categories:

1. Scratches: Permanent linear surface features.

2. Non-linear Features: Visible/detectable on the Fibre endface.

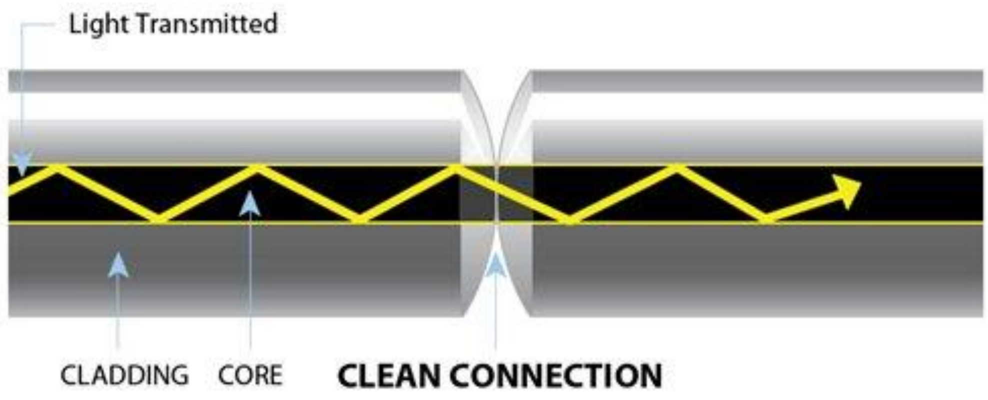
These include contamination particles, debris, pits, chips etc.

1.3.3. Scratches and Non-linear features

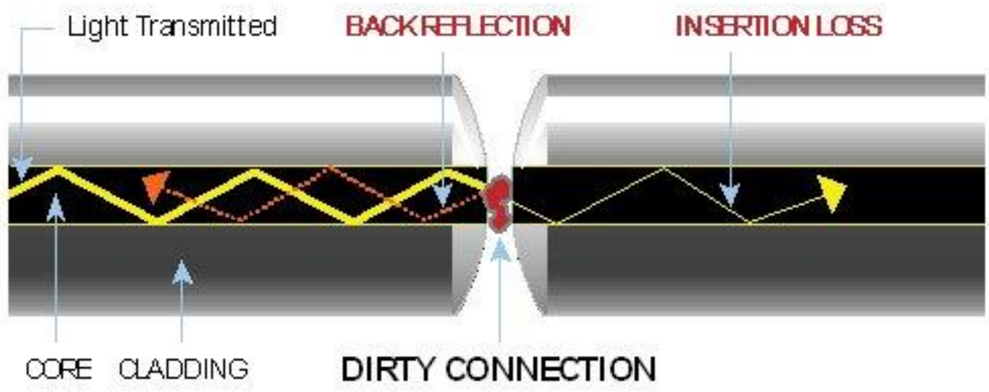
Scratches are typically created during incorrect cleaning practices or mishandling of Fibre connectors. Scratches near and/or across the core are problematic because they create back reflection.

Dirt is everywhere; a typical dust particle (2–15µm in diameter) can significantly affect signal performance and cause permanent damage to the Fibre endface. Most field test failures can be attributed to dirty connectors, and most of them are not inspected until the problem is detected after permanent damage has already occurred.

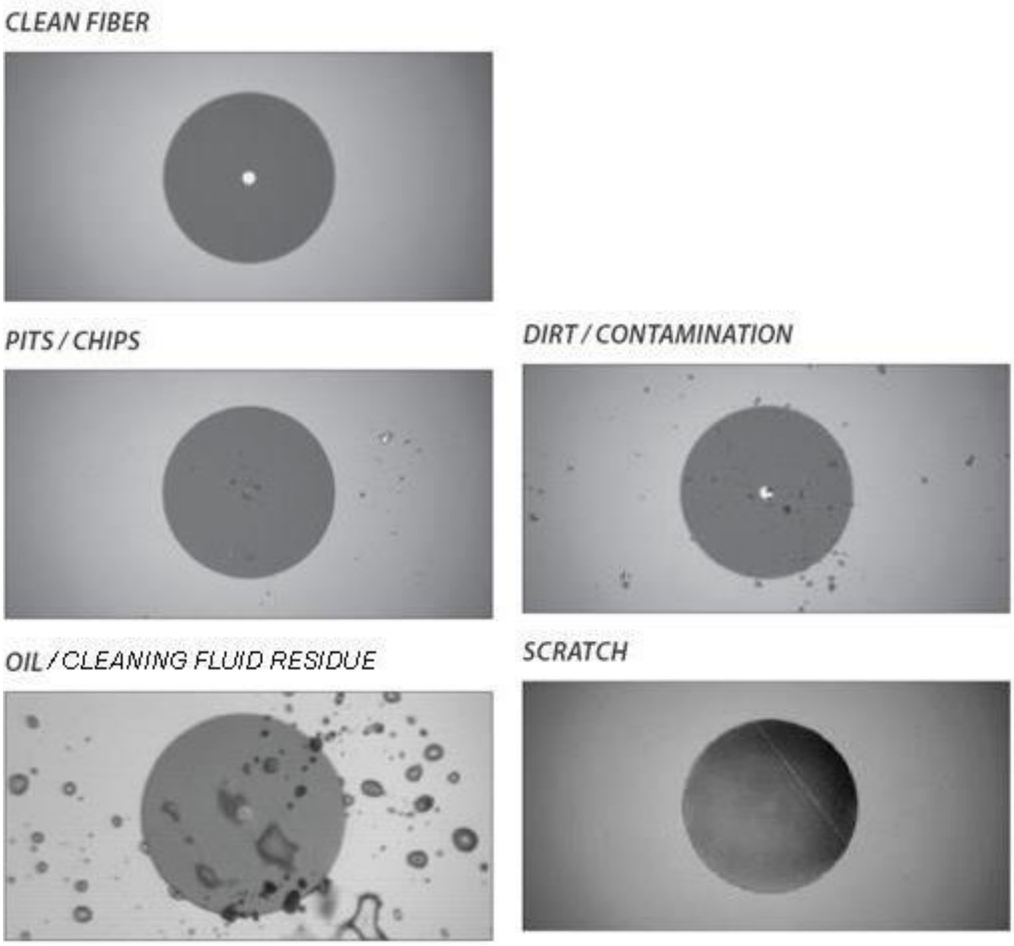
If dirt particles get on the core surface the light becomes blocked, creating unacceptable insertion loss and back reflection (return loss). Furthermore, those particles can permanently damage the glass interface, digging into the glass and leaving pits that create further back reflection if mated. Also, large particles of dirt on the cladding layer and/or the ferrule can introduce a barrier that prevents physical contact and creates an air gap between the Fibres. To further complicate matters, loose particles have a tendency to migrate into the air gap.



Clean Fibre Connection (Minimum Insertion and Return Loss)



Dirty Fibre Connection



Fibre Connection and Various Connector Endface Views

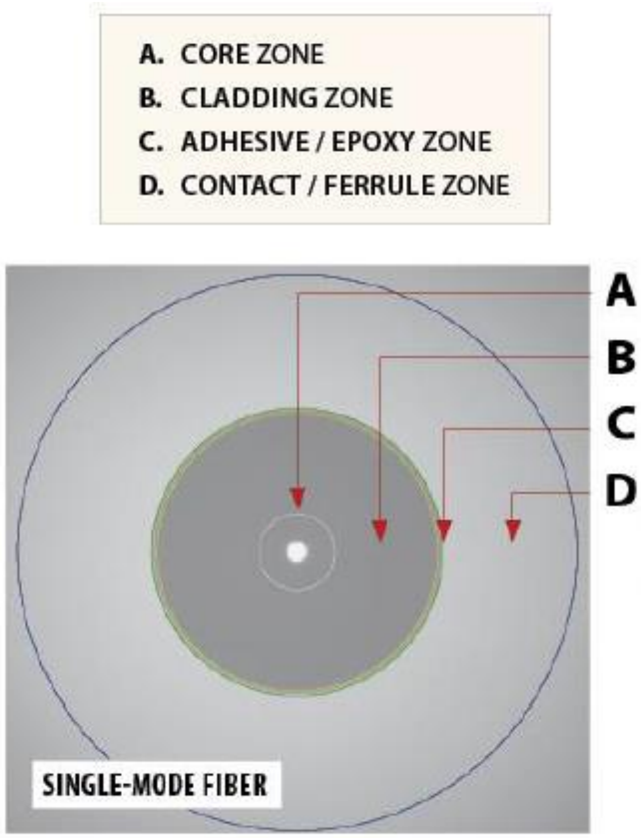
An ideal Fibre endface should be free from defects or scratches as shown in the following.

Microscope View of Clean Connector Endfaces

1.3.4. Fibre Connector Endface Inspection Zones and Grading

Inspection zones are a series of concentric circles that identify areas of interest on the connector end face. The inner-most zones are more sensitive to contamination than the outer zones. It is common to divide the image into a series of concentric circles that begin with a small one centred on the core (also known as zone "A") and then radiate out from there. This creates a "bulls-eye" pattern sometimes called a grading overlay.

The overlay is used to GRADE the Fibre by determining the number and size of each particle that are present in each of the 4 Fibre zones.



Fibre Endface Inspection Zones for Single-Fibre Connection

1.4. Fibre Inspection Acceptance Criteria

Acceptance Criteria are a series of failure thresholds that define defect limits for each zone on the Fibre connector endface. All loose particles must be removed. If defect(s) are non removable, it must be within the criteria specified to be acceptable for use.

The tables below list the Acceptance Criteria standardized by the International Electrotechnical Commission (IEC) for single-mode connectors as documented in IEC 61300-3-35 Ed. 1.0.

All Fibre connectors shall be inspected and a PASS Certification report produced to prove compliancy with these criteria before being activation of the Cobham Wireless Equipment.

Single-Mode (APC)	Zone Name (Diameter)	Scratches	Defects
A	Core Zone (0-25µm)	4< 3µm	None
B	Cladding Zone (25-120µm)	No limit	No limit <2 µm 5 from 2-5 µm None >5 µm
C	Adhesive Zone (120-130µm)	No limit	No limit
D	Contact Zone (130-250µm)	No limit	None =>10 µm

- All loose particles must be removed. If defect(s) are non-removable, it must be within the criteria above to be acceptable for use.
- For scratches the requirements refer to width.
- No visible surface cracks are allowed on the core or cladding zone.
- There are no requirements for the area outside the contact zone since defects in this area have no influence on optical performance. Cleaning loose debris beyond this section is recommended good practice.
- The limit for non-linear non-removable features in the ferrule/contact zone (D) does not apply for metal-alloy ferruled connectors like E2000.

2. Fibre Connector Inspect/Clean/Connect Process

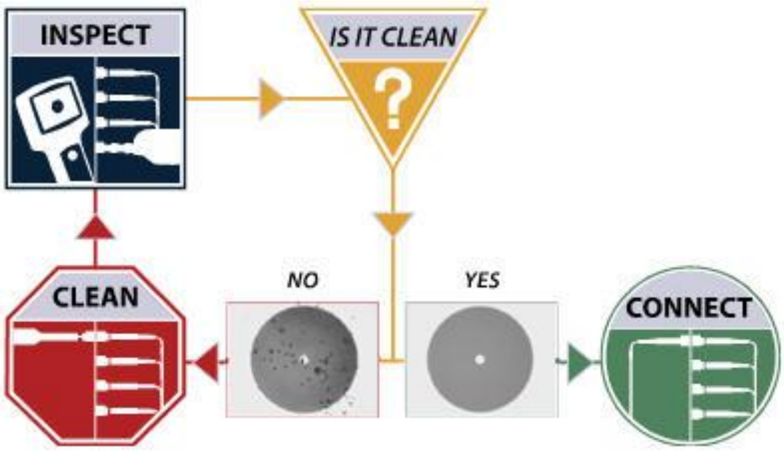
Visual Inspection of Fibre interconnects is the only way to determine if connectors are clean prior to mating them. A video microscope magnifies an image of a connector endface for viewing on either a laptop or portable display depending on the product used.

The requirement to inspect Fibre connectors and clean if necessary before connection is mandatory in all cases; this includes the first use of new cords and transceivers or any equipment/panels with Fibre interfaces.

Inspect/Clean/Connect Process Flow:

Ensure ESD control & prevention techniques are followed.

Employ the inspect/clean/connect process as per the following diagram and steps.



INSPECT

1. Select the appropriate tip for the connector/adaptor you are inspecting. Refer to the relevant inspection microscope user manual.

2. Inspect both connector endfaces (patchcord/bulkhead/pluggable interface) using the microscope.

IS IT CLEAN?

CLEAN
Note 1

No – Upon inspection, **if non-linear features are visible** on the endface, clean using an approved cleaning tool then re-inspect. See cleaning section 9.

CONNECT

Yes – **If non-removable non-linear features and scratches are within acceptance criteria limits**

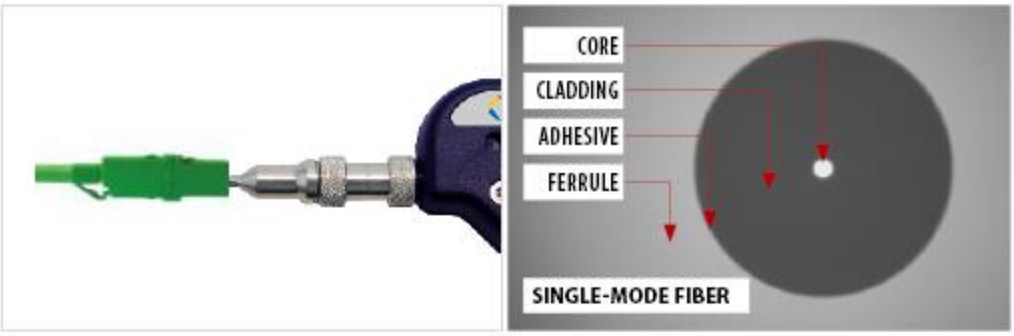
Note 1: Cleaning procedures may be applied up to five (5) times employing dry then damp cleaning processes.

2.1. Optical Fibre Interface Inspection

Fibre endface inspections are performed through two different methods. If the cable assembly is accessible, you can insert the connector ferrule into the microscope to do an inspection; this is generally known as patchcord inspection. If the connector is within a mating adaptor on the device or patch panel, you can use a 'probe' microscope to insert into the open end of the adaptor and view the connector inside; this is known as bulkhead or through adaptor connector inspection.

2.1.1. Patchcord Inspection

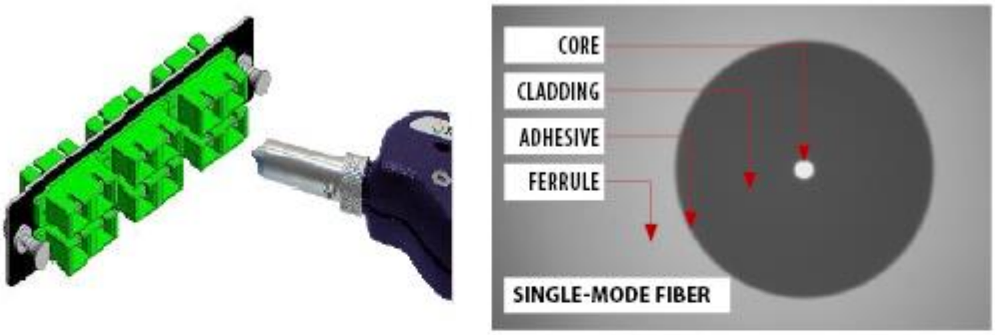
1. Select the appropriate tip that corresponds to the connector type under inspection and fit it on to the microscope.
2. Insert the connector into the tip and adjust focus to inspect.



Patchcord Microscope Inspection

2.1.2. Bulkhead/Through Adaptor Connector Inspection

1. Select the appropriate tip/probe that corresponds to the connector type under inspection and fit it to the probe microscope
2. Insert the probe into the bulkhead and adjust focus to inspect



Bulkhead/Through Adaptor Connector Microscope Inspection

3. Optical Fibre Connector Cleaning Process

This section details the cleanliness requirements used to maintain consistent product quality and performance from manufacturer to installer.

This section describes conventional cleaning methods for optical interconnects.

Conventional cleaning may be used for any fixed optical interface, such as optical connectors, where it is possible to touch the surface with the cleaning material. Conventional cleaning is ineffective on non-contact lens interfaces which are common on optical transceivers.

General optical interface cleaning principles:

- Optical components (e.g. connectors, transceivers) must be clean to work optimally or in some cases at all.
- Use connector end caps. They prevent damage however do not ensure cleanliness.
- Foam and cotton materials are not suitable for cleaning optics; they can break down and deposit debris on the optical end face.
- Compressed air is ineffective in cleaning optical connectors or transceivers and must not be used.
- Cleaning against a hard surface can damage the connector. Designed-for-optics cleaning tools will have a firm yet yielding backing.
- Use solvents only after attempting a dry cleaning method. Most cleaning solvents including IPA will leave an unacceptable residue if not applied and used correctly; use a designed-for-optics solvent or IPA, e.g. 70% IPA Medi-swab.
- Do not saturate the optical interface with solvent. Always follow solvent application with a dry cleaning process.
- Cleaning machines that use solvent without mechanical action may be exempt from the above cautions regarding over use of solvents.
- Inspect before you connect. Every time. This is the only way to ensure that interconnecting optic Fibre interfaces are acceptable for use.

3.1. Optical Fibre (patchcord) Cleaning

Cleaning Wipes and Tools
Dry Cleaning

Simple dry cleaning wipes including many types of lint free wipes and other purpose built wipes are available. This category also includes purpose built optic Fibre connector cleaning cassettes and reels, e.g. Cletop cartridges.

Warning! Exposed wipes can easily become cross-contaminated in the field.

Cleaning material must be protected from contamination until just prior to use.

Damp Cleaning:

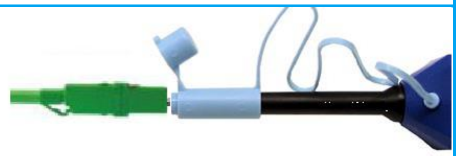
Cleaning fluids or solvents are generally used in combination with wipes in order to provide a combination of chemical and mechanical action to clean the Fibre endface. Also available are pre-soaked wipes supplied in sealed sachets, e.g. IPA Medi-swabs.

- Some cleaning fluids, particularly IPA, can leave a residue which can be difficult to remove.
- Cleaning fluid is only effective when used with mechanical action provided by a wipe.
- The solvent type must be fast drying.
- Follow safe handling procedures.
- Do not over saturate as this will over wet the endface. Only lightly moisten the wipe.
- The ferrule must be cleaned immediately with a clean dry wipe.
- Do not to leave solvent on the side walls of the ferrule as this will transfer onto the optical alignment sleeve during connection.
- Wipes must be used in the hand or on a soft surface or resilient pad.
- Use on a hard surface can cause damage to the Fibre.

Examples of Cleaning Fluid and Wipes

3.2. Patchcord Cleaning

Patchcord or Pigtail Cleaning Process

What Action	How To
1. Select the IBC tool for the connector type. 2. Pull off the guide cap cover.	
Dry Clean 3. Attach the IBC to the connector and push into patchcord 2 times (2 clicks).	
Inspect 4. Attach the patchcord to the FIT 5. Determine whether it is CLEAN or Dirty • IF CLEAN, DO NOT TOUCH IT and CONNECT. • IF DIRTY, either repeat the DRY cleaning or go to a wet-dry cleaning process.	

3.3. Bulkhead Cleaning

Common methods for cleaning optic Fibre endfaces that remain within an alignment sleeve, bulkhead/through adaptor, transceiver, or other receptacle type device.

3.3.1. Bulkhead/Through Adaptor Connector Cleaning Tools

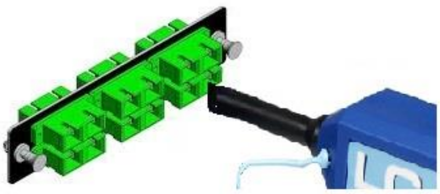
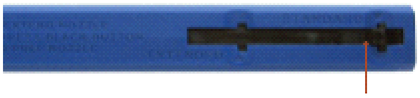
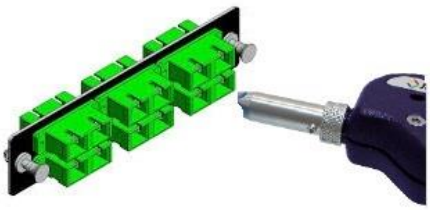
In-adaptor, or "in-situ", connectors are most typically a connector that cannot be readily removed from a bulkhead/through adaptor, and are therefore, more difficult to access. This category includes ferrule interface (or Fibre stubs) and physical contact lens within an optical transceiver, but does not include non-contact lens elements within such devices.

Sticks and bulkhead cleaners are designed to reach into alignment sleeves and other cavities to reach the endface/lens and aid in removal of debris, i.e. moveable non-linear features. These tools allow the cleaning of the endface/lens within the adaptor or in-situ without the removal of the bulkhead connector. When cleaning transceiver or receptacles care must be taken to carefully identify what is within the port prior to cleaning. Caution must be taken when cleaning transceiver flat lenses due to possible damage.

Bulkhead/Through Adaptor Cleaning Tools

Bulkhead Cleaning Process

What Action	How To
1. Select the appropriate cleaning tool for the connector type. 2. Pull off the guide cap	
Dry Clean 3. Push into bulkhead 2 times (2 clicks). Note for hard-to-reach places push the nozzle extender lock and pull the nozzle out.	 
Inspect 4. Insert the FIT into the bulkhead to inspect 5. Determine whether it is CLEAN or DIRTY • IF CLEAN, DO NOT TOUCH IT and CONNECT • IF DIRTY, either repeat the DRY cleaning or go to a wet-dry cleaning process.	

3.4. Cleaning Process

A. Before cleaning

1. Inspect the connector.
2. If it is clean, do not clean it, connect it.

B. If it is dirty, try a dry cleaning method

1. Use approved cleaner.
2. Repeat 2 or 3 times if needed.
3. If the debris remains it is bonded to the surface or mated-in (not removable).
4. Inspect after each Cleaning attempt.

C. If after dry cleaning it is still dirty, try a wet-to-dry cleaning method

1. Use approved solvent.
2. Do not saturate the cloth or tape, damp is effective, soaking wet is not.
3. Wet cleaning must be followed immediately by dry cleaning.
4. Wet-dry can be one step (moving from damp to dry on a wipe) or two steps (damp wipe followed by dry wipe).
5. Repeat 2 or 3 times if needed.
6. If the debris remains it is mated-in (not removable).
7. Inspect after each Cleaning attempt.

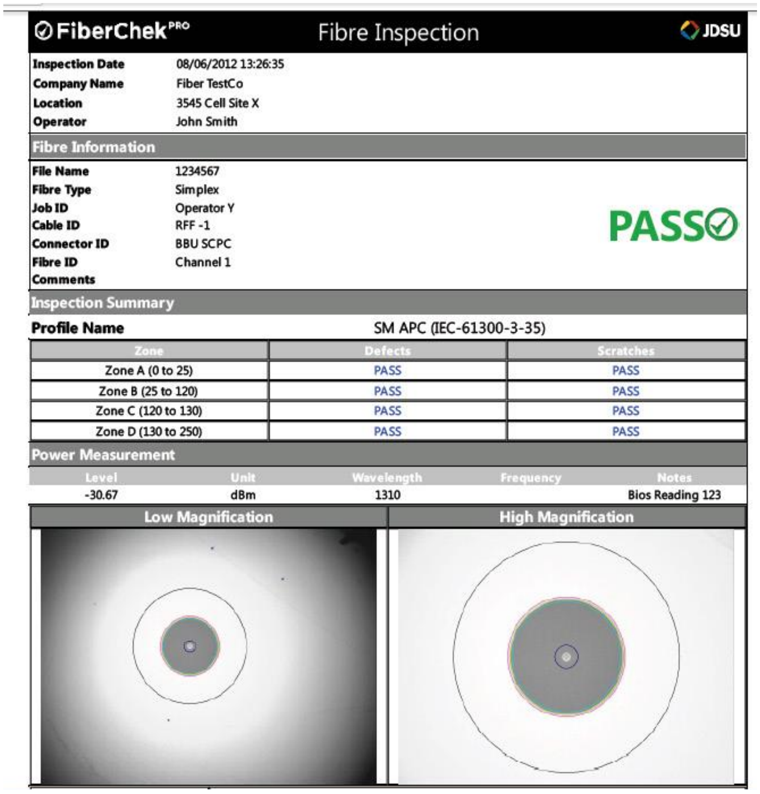
D. If the debris remains non-removable

1. Inspect the connector.
2. Select the appropriate profile and test the connector end face in compliance to the pre-configured Telecom acceptance criteria using FibreChek2, i.e. SM, In-service (IEC-61300-3-35 Table 3) setting.
   (a) If it passes, make the final connection.
   (b) If it fails, can the connector be replaced? If so then replace the connector.
   (c) A failure report (as shown on the following page) must be generated.
   (d) Failure Report to be submitted to your company Quality Assurance Auditor/Manager for submission to QA.

3.5. Fibre Connector Inspection IEC Certification Reporting

It is a mandatory requirement that PASS/FAIL certified inspection reports of each Fibre/connector in a cable plant is provided during link Construction and installation.

The inspection IEC certified PASS/FAIL report provides an archive summary of the final quality of the endface during connector installation acceptance.



FiberChek PRO — Fibre Inspection — JDSU

Inspection Date	08/06/2012 13:26:35
Company Name	Fiber TestCo
Location	3545 Cell Site X
Operator	John Smith

Fibre Information

File Name	1234567
Fibre Type	Simplex
Job ID	Operator Y
Cable ID	RFF -1
Connector ID	BBU SCPC
Fibre ID	Channel 1
Comments	

PASS

Inspection Summary

Profile Name: SM APC (IEC-61300-3-35)

Zone	Defects	Scratches
Zone A (0 to 25)	PASS	PASS
Zone B (25 to 120)	PASS	PASS
Zone C (120 to 130)	PASS	PASS
Zone D (130 to 250)	PASS	PASS

Power Measurement

Level	Unit	Wavelength	Frequency	Notes
-30.67	dBm	1310		Bios Reading 123

Low Magnification | High Magnification

Typical Inspection Report

Note: All disconnected fibres or bulkhead must be ‘capped’ when not in use.

4. Fibre Testing - Loss

The Fibre system can tolerate an optical insertion loss over the fibre of up to 10dBo.

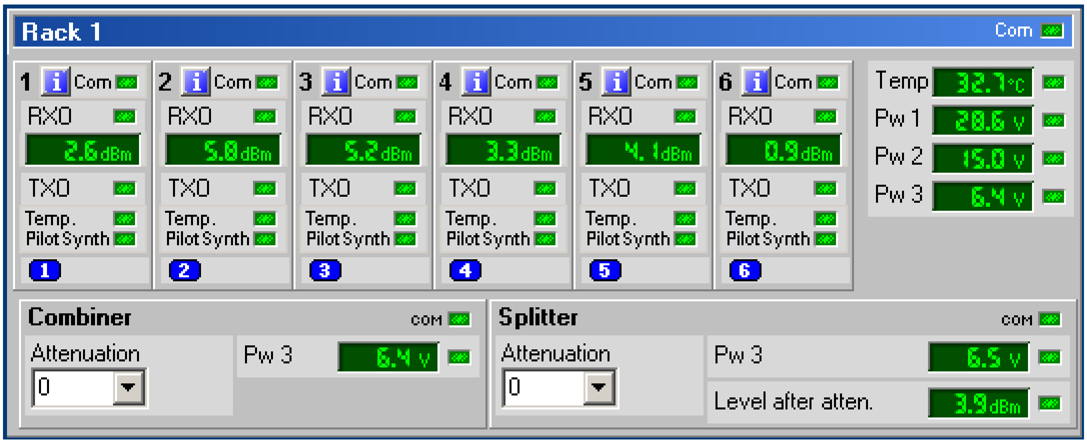
The output of the RF/fibre optic converters is +5dBmo ±2dBmo.

Any measurement of the loss over the fibre should include the fibre patch cords to the master and remote units end to end.

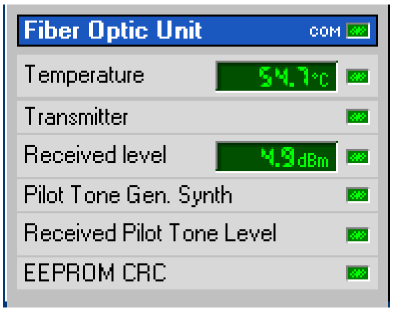
Loss should be measured at 1310/1550nm test wavelengths in both directions.

4.1. Optical Receive Levels

The levels of the received optical signals are displayed on the RF Status page.



OMU



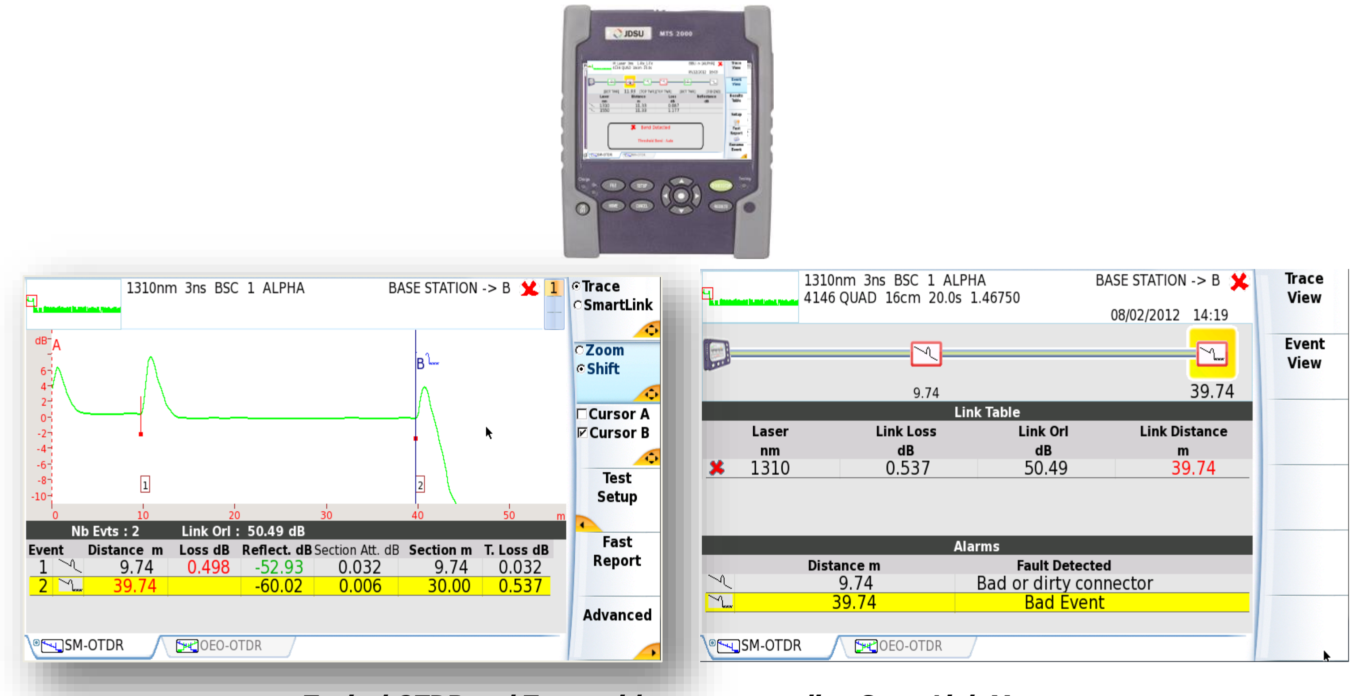
Repeater

4.2. Fibre Testing – OTDR

Fibre testing must be carried out during the fibre installation and before repeater commissioning commences.

Perform an OTDR measurement on the optical links at 1310/1550nm in both directions. All discrete events must meet the defined thresholds as stated in 'FO Specification' document.

The OTDR traces must recorded in industry standard [.SOR] format for all wavelengths and pulse widths and be available for each fibre link end to end and include fibre patches to the master site to the Remote site. Some OTDR's have simplified the OTDR trace analysis using icon based mapping with PASS/FAIL limits making analysis more efficient which Cobham Wireless advises its Customers' to use.

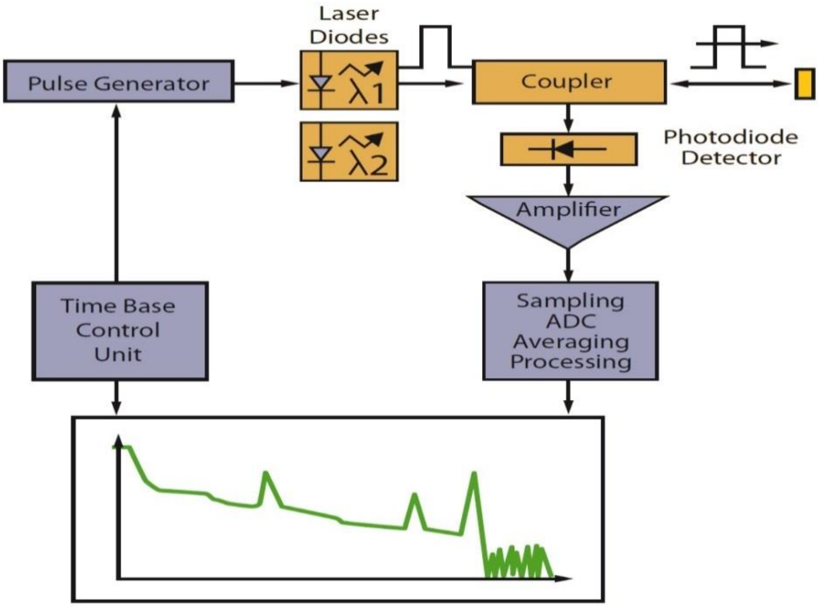


Typical OTDR and Trace with a corresponding SmartLink Map

4.3. Understanding Optical Time Domain Reflectometry

The optical time domain reflectometer (OTDR) injects an optical pulse into one end of the fibre and analyses the returning backscattered and reflected signal.

An operator at one end of a fibre span can measure and localize attenuation, event loss, reflectance, and ORL.



A schematic diagram showing OTDR technology

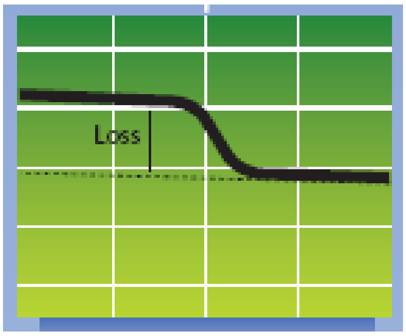
What Does an OTDR Measure?

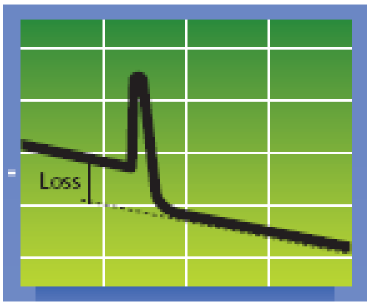
An OTDR detects, locates, and measures events on fibre links, requiring access to only one end of the fibre.

Attenuation (also called fibre loss)
Expressed in dB or dB/km, attenuation represents the loss or the rate of loss between two points along the fibre span.

Event Loss
The difference in the optical power level before and after an event, expressed in dB.

Reflectance
The ratio of reflected power to incident power of an event, expressed as a negative dB value. The higher the reflectance, the more light reflected back, the worse the connection



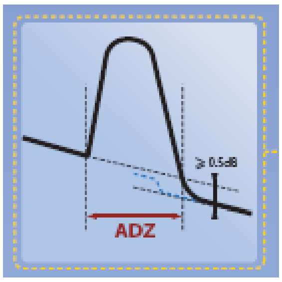


Optical Return Loss (ORL)
The ratio of the reflected power to the incident power from a fibre optic link or system, expressed as a positive dB value. Measure of the amount of light that is reflected back from a feature: forward power to the reflected power. The bigger the number in dBs the less light is being reflected. The OTDR is able to measure not only the total ORL of the link but also section ORL.

4.3.2. How to Configure the Main OTDR Settings

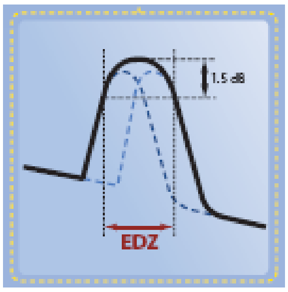
Pulse Width and deadzones
The pulse width controls the amount of light injected into a fibre.

A short pulse width enables high resolution and short dead zones but less dynamic range.
A long pulse width enables high dynamic range but less resolution and large dead zones.



Attenuation Dead Zone (ADZ) is the minimum distance after a reflective event that a non-reflective event can be measured (0.5dB)

- In this case the two events are more closely spaced than the ADZ, and shown as one event
- ADZ can be reduced using shorter pulse widths



Event Dead Zone (EDZ) is the minimum distance where 2 consecutive unsaturated reflective events can be distinguished

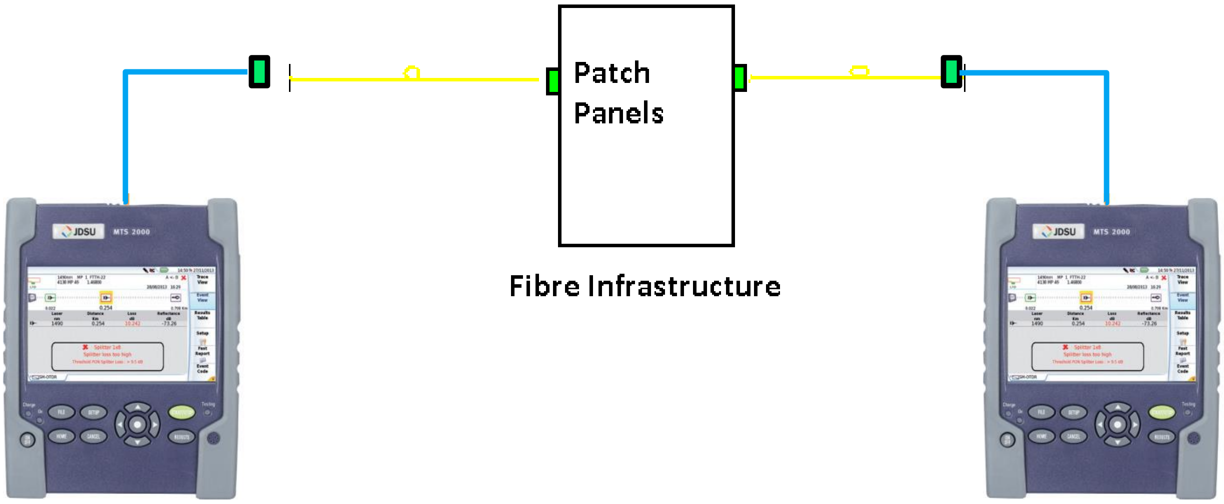
- In this case the two events are more closely spaced than the EDZ, and shown as one event
- EDZ can be reduced using shorter pulse widths

Acquisition Time (Averaging)
The time during which the OTDR acquires and averages data points from the fibre under test. Increasing the acquisition time improves the dynamic range without affecting resolution or dead zones.

Index of Refraction (IoR)
The IoR converts the time that the OTDR measures to distance and displays it on the trace.
Entering the appropriate value for the fibre under test will ensure accurate measurements of fibre length.

Range
This relates to the distance of the fibre under test. Most modern OTDR have automatic length detection. If fibre under test distance is know it should be inserted. Range should be set to 1.5-2 times the distance of the fibre.

Note: To obtain accurate measurements, always ensure to use a long launch lead and inspect and clean all connectors prior to OTDR testing. Some OTDRS are capable of automatic Bi-directional OTDR and IL measurements.



Parameter	Alarms Values
Splice Loss	Typ 0.25dB
Connector Loss	Typ 0.5dB
Connector Reflectance	<-60dB
Link Loss (between OMU and repeater including connection patch cords)	<10dB

Note: While splice and connector loss are recommendation alarm thresholds, overall insertion loss and connector reflectance is a mandatory critical parameter threshold to meet system requirements. Having low loss connections will help improve optical performance and minimize reflections.