



R&M Installers Handbook

Generic Cabling

2022-2023

English

 **R&M**

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1. Pre-Installation

1.1 Copper

1.1.1 Channel Standards

Differences between class and category in today's standards

ISO / EN		TIA	
System	Components	Components	System
Class D	Category 5	Category 5e	Category 5e
Class E	Category 6	Category 6	Category 6
Class E _A	Category 6 _A	Category 6A	Category 6A
Class F	Category 7	Not recognized	Not recognized
Class F _A	Category 7 _A	Not recognised	Not recognised
Class I	Category 8.1	Category 8	Category 8
Class II	Category 8.2	Not recognised	Not recognised

Standard differences

1.1.2 Component Standards

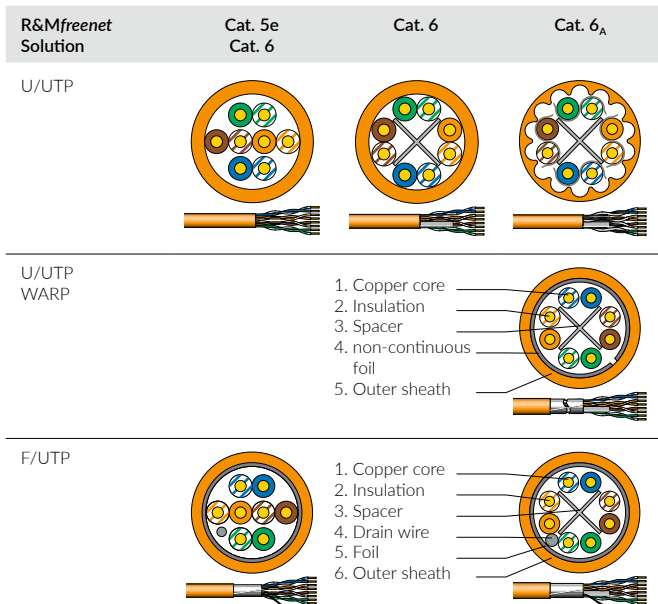
Connector link performance

R&M System	Permanent Link (PL)	Channel (CH)
Cat. 5e	Class D	Class D
Cat. 6	Class E	Class E
Cat. 6 real 10 (screened)	Class E	Class E _A
Cat. 6 _A EL	Class E _A	Class E _A
Expected NEXT margin min. 2dB		
Cat. 6 _A ISO	Class E _A	Class E _A
Expected NEXT margin min. 4dB		
Cat. 8.1	Class I	Class I

R&M *freenet* connector link classification

1.1.3 Cable Performance and Construction

The cable nomenclature holds 2 key parameters, the first letter describes the sheath screening and the second letter the type of screened of the individual pairs.



Twisted pair cable construction

1. Pre-Installation

R&Mfreenet
Solution

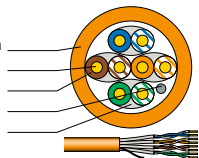
Cat. 5e
Cat. 6

Cat. 6

Cat. 6_A / 7 / 7_A

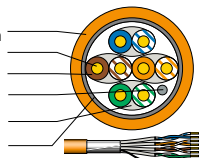
U/FTP

1. Outer sheath
2. Copper core
3. Insulation
4. Drain wire
5. Foil

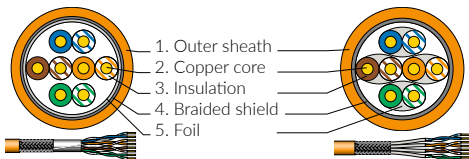


F/FTP

1. Outer sheath
2. Copper core
3. Insulation
4. Drain wire
5. Foil
6. Foil



SF/UTP
S/FTP



Twisted pair cable construction

AWG	18	19	20	21	22	23	24	25	26	27	28	29	30
Ø (mm)	1.013	0.866	0.772	0.688	0.610	0.546	0.485	0.432	0.384	0.358	0.318	0.284	0.251

AWG

1.2 Fiber

1.2.1 Fiber Optic Cable Construction and Properties

The cable designation varies from manufacturer to manufacturer. In most cases, however, the cables have an imprint that describes how many fibers and which fiber type the cable contains.

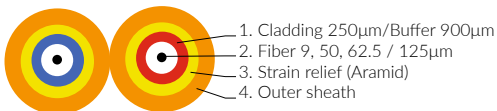
- Single-mode indoor cables are green, yellow or black.
- Multimode indoor cables are usually colored according to the OM class. OM3 aqua, OM4 magenta, OM5 lime green.
- Outdoor cables are usually black, with two orange markings on the outer sheath and relatively stiff.
- Examples for printed cable identifications: 12x9/125, 12E9/125 OS2, 12x50 OM2, OM3, OM4, OM5
- The first number describes the number of fibers, the second the fiber type, the third identifier the class.

1. Pre-Installation

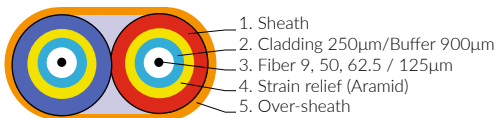
R&Mfreenet Solution

Cable construction

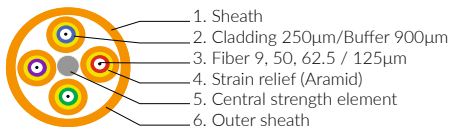
Duplex Cable
Figure 8



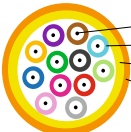
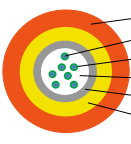
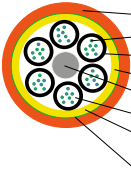
Duplex Cable
Figure 0



Breakout
Cable



Fiber cable construction

R&Mfreenet Solution	Cable construction
Mini Breakout & Mini Core Cable	 <ol style="list-style-type: none"> 1. Fiber 9, 50, 62.5 / 125μm 2. Cladding 250μm/Buffer 900μm 3. Strain relief (Aramid) 4. Sheath (Mini core cable also with double outer sheath available)
Loose tube Cable	 <ol style="list-style-type: none"> 1. Outer sheath 2. Fiber 9, 50, 62.5 / 125μm 3. Cladding 250μm 4. Gel filling 5. Loose tube 6. Rodent protection / filling material
Stranded Loose tube cable	 <ol style="list-style-type: none"> 1. Outer sheath 2. Fiber 9, 50, 62.5 / 125μm 3. Cladding 250μm 4. Loose tube 5. Central strength member 6. Gel filling 7. Rodent protection / filling material 8. Steel armouring (optional)

Fiber cable construction

There is a very large variety of fiber optic cables available on the market, therefore not all cable types are reproduced here. However, the most common cables are shown above and cover most applications

1. Pre-Installation

1.2.2 Fiber Color Coding

Fiber No.	IEC	TIA	DIN	CH
1	Blue	Blue	Red	Red
2	Yellow	Orange	Green	Green
3	Red	Green	Blue	Yellow
4	White	Brown	Yellow	Blue
5	Green	Slate	White	White
6	Violet	White	Slate	Violet
7	Orange	Red	Brown	Orange
8	Slate	Black	Violet	Black
9	Aqua	Yellow	Aqua	Slate
10	Black	Violet	Black	Brown
11	Brown	Rose	Orange	Rose
12	Rose	Aqua	Rose	Aqua

Fiber color coding

1.2.3 Standard Link Polarity

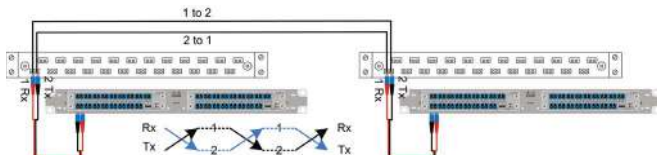
There are 2 possible ways of planning the polarity of your network; both systems have their advantages and disadvantages. It is very important to approve the polarity concept with the end customer.



1. Pre-Installation

Everything Crossed

Because duplex patch cords are always crossed and Tx is required to be connected with Rx there should be an odd number of crosses in the link. Therefore if the pairs are crossed in the fixed link, all patch cords can be used without changing their formation. Here the responsibility lies with the installer to ensure correct polarity.



FO crossed backbone polarity

Advantage:

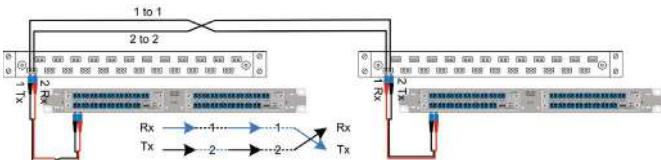
- No need to change the duplex patch cords
- Same polarity configuration if mixed with MPO/cassette links in method B & S

Disadvantage:

- Coordination during installation which side has the polarity change
- Difficulties in polarity assurance with even amount of links, e.g. CP/ZD
- The polarity concept will have an influence on how preterminated links are ordered and/or the pigtail configuration in the PP

Fixed Link Straight

In this case the fixed line is installed one-to-one according to the color code required. So the pairs in one of the patch cords must be crossed in order to connect Tx with Rx. Here the responsibility lies with the IT administrator to ensure correct polarity.



FO straight backbone polarity

Advantage:

- The fixed cable can be terminated according to the same color code on both sides
- Same polarity when combining with MPO/cassette links in method A.

Disadvantage:

- Strict procedures to be written to define where the technician needs to change the polarity of the patch cord
- Difficulties in polarity assurance with multiple links, e.g. CP/ZD or 2 links

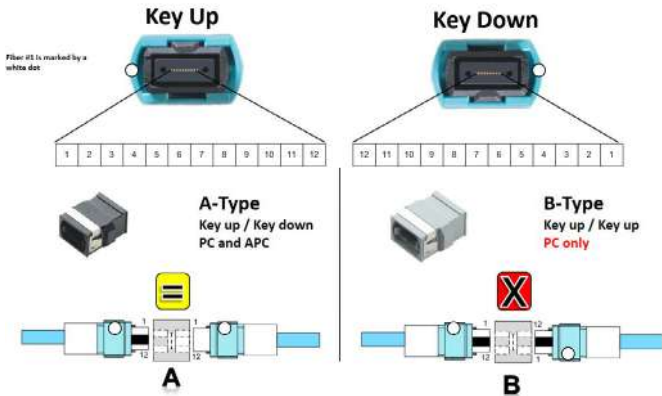
1. Pre-Installation

1.2.4 MPO Polarity

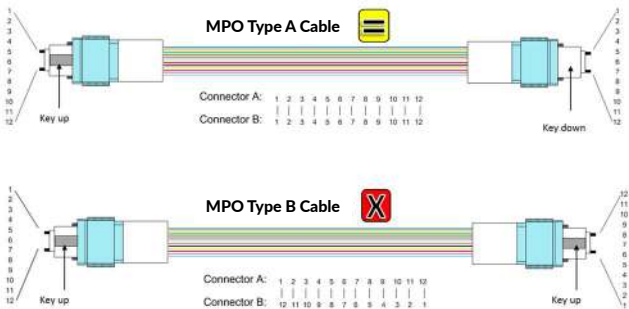
While coding on the plugs and couplings ensures correct orientation of the plug connection throughout, the polarity methods A, B and C defined according to TIA-568-C should guarantee the correct bidirectional assignment. Depending on the manufacturer, there are a large number of different polarity methods that can sometimes cause confusion. In addition, customer-specific variants can also be created. MPO plugs continue to be scratched out and manufacturers are trying to fit more and more fibres into the plug. There are already prototypes with up to 72 fibers in a single connector. The picture below shows a 24 fiber MPO connector with two rows of 12 fibers each.



MPO with 24 fibers – female



Key Up and Key Down



MPO Type A and MPO Type B Cables

2. Installation

2.1 Copper

2.1.1 Copper Cable Installation

It is very important to install cables carefully to achieve the values specified in the standards. Symmetrical installation cables are intended to be installed only once. Margins are so tight in today's data cable design that performance deterioration caused by improper installation can already lead to failures during the acceptance tests.

The following requirements must therefore be strictly adhered to when installing a cable

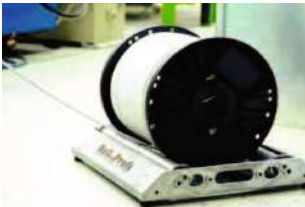
- Do not cause deformation of the cable jacket
- Install inhouse cable inside only
- Install special outdoor cables for outdoor installations
- Keep away from water and moisture (during storage, installation and operation)
- On big projects do interim tests to discover faults before project end
- Loose lay the cables where possible. Bundle cables only in racks/cabinets, on vertical installations and on direction changes

Cable Tensile Forces

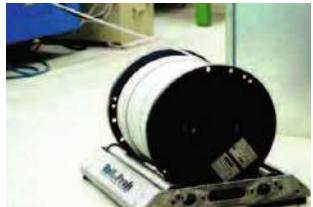
Always refer to the relevant data sheet for cable tensile maximum forces. With special tools it is not possible to exceed a certain pulling force. These tools always assure the quality of the twisted pair cable.

In order to further reduce the tensile force in the installation cable when unrolling, it is advisable to assist the unrolling process by turning the reel. That is, whenever possible, the reel should be manually unrolled rather than rely on the tensile strength of the cable to turn the whole reel.

For cables in boxes don't tug if cables are snagging, don't exceed the tensile forces of the cable.



Proper direction for unrolling



Wrong direction for unrolling

When routing installation cables in vertical shafts or risers, gravity should be used – instead of pulling the cables up the shaft where possible, lower them from above. This avoids unnecessary tensile stress.

2. Installation

Cable Bending Radius

The following bending radii rule of thumb for R&M *freenet* copper installation cables:

Category	Installation	Installed
Cat. 5e	50 mm	25 mm
Cat. 6 / 6 _A	60 mm	30 mm
Cat. 7 / 7 _A / 8.1 / 8.2	70 mm	35 mm
Real10 U/UTP	70 mm	60 mm

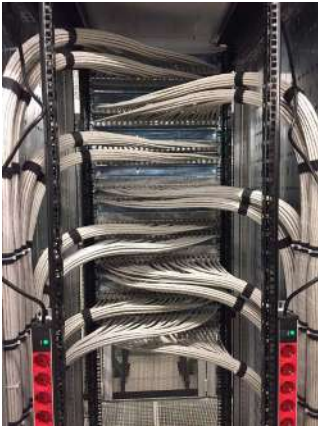
Sample copper cabling bending radius

Always refer to the relevant data sheet for exact figures. When bend radii are too tight, especially in cable installation, they can alter the mechanical structure of the twisted pairs within a cable, and this has a negative effect on the cable's transmission characteristics (mostly NEXT, FEXT and RL).

If cables are routed across any edges where they bend or branch, ensure that the minimum specified bending radius for the respective cable type is maintained when pulling the cable. If cables must be pulled across edges, ensure that the outer cable jacket is not damaged by abrasion or tensile stress. Ensure that the total weight of all installed cables does not damage the installation cables on the bottom.

Cable Management

There are different possibilities for drawing installation cables from their cable entry through the distributor cabinet to the connection modules. It needs to be made certain that the cables are sufficiently tension-relieved and run in a loop, allowing the elements to be taken out easily from the front (cable reserves are used for maintenance or a later upgrade to higher categories).



Proper rack cable management



Wrong rack cable management, to big bundles

2. Installation

2.1.2 Copper Cable Preparation

Copper cables should only be prepared and connected using suitable tools. If, for example, a knife or an unsuitable stripping tool is used when stripping the cables, there is a risk that the wires in the cable may be damaged or their insulation cut. If this is the case, it is highly likely that shielding, short-circuits or other sources of error are then caused. It is also important to use a side cutter that allows the wires to be cut cleanly and flush. You should make sure that all modules or plugs, regardless of their design, are connected cleanly and carefully.

R&M offers various connection, stripping and auxiliary tools that enable clean stripping and termination of cables and modules.

However, R&M products are also good and easy to process with most conventional tools. However, special care should then be taken to work carefully and cleanly.



Tools for terminating copper cables

2. Installation

2.1.3 Modules

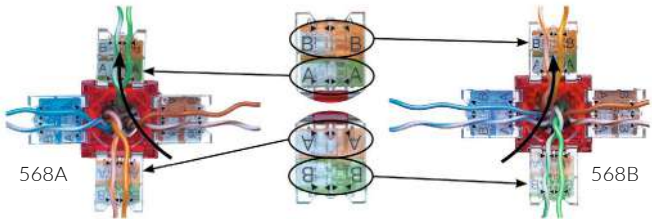
A major problem source is the incorrect termination of R&M connection modules. Please follow the enclosed installation instructions to correctly wire the connection module.



Untwist wire pair and insert color code



EL Module



ISO Module

The conductor pairs should be led directly into the module from the cable jacket, without crossing over another pair. Faultless measuring for the acceptance test can only be ensured through correct wiring. The cable jacket should be fixed on the module as shown in the installing description. The cable tie should not exert any pressure that causes deformation of the cable jacket.

2. Installation

2.2 Fiber

2.2.1 Fiber Cable Installation

All optical fiber cables are sensitive to damage during handling & installation. Here are some of the important parameters that need special attention during cable installation.

Always refer to the relevant data sheet for cable tensile maximum forces.

Unprofessional laying, for example across the edges of wall ducts, narrow cable tracks, and cable twisting while pulling it, must be avoided. Critical locations therefore need to be treated with utmost care. We recommend random sample testing of admissible bending radii in generic cabling systems after installation. All cables that are exposed to water during installation must be replaced. Fiber cables should be cut back by 1.5m after installation, as this removes the section that has borne the majority of the tensile stress. Allow 6m of slack after installation for handling terminations and / or splicing.

Cable Bending Radius

When fiber bending radii are too tight during installation and also in cable duct and outlet boxes micro cracks can occur. It results in higher attenuation and will decrease the lifetime of the fiber drastically. The bending radius needs to be constantly checked when laying an installation cable.

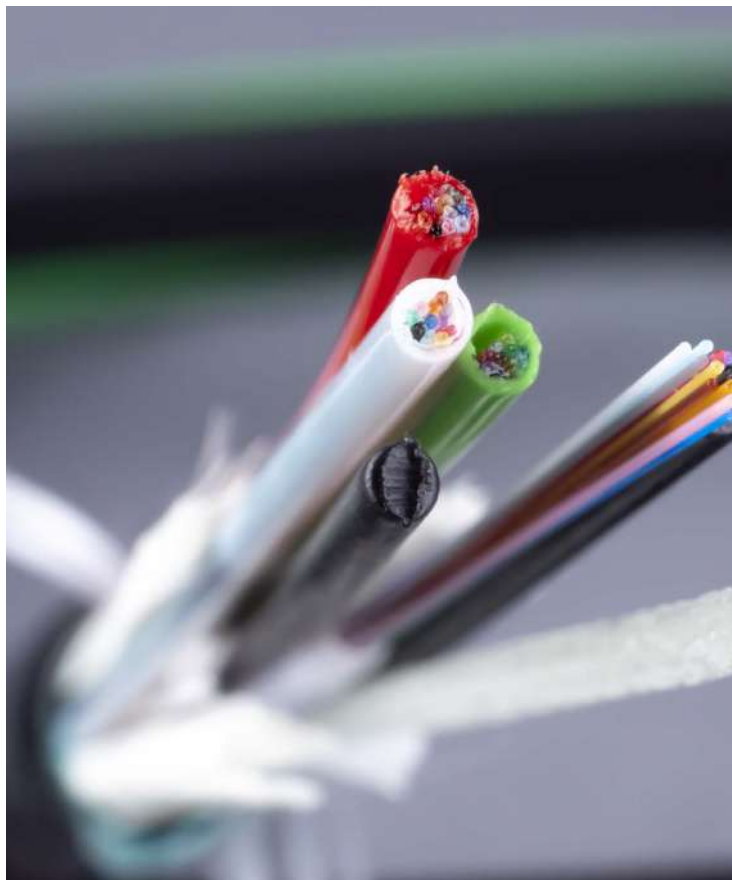
2.2.2 Fiber Cable Preparation

- Always use appropriate cable preparation tools otherwise risk damaging the fiber cable.
- Always use the tear threads (if any) when stripping the outer sheathing. If there are two tearing threads, both should be used.
- If the cable has filling material or rodent protection, it should be cut back to where the outer sheath was removed. Depending on the application, it is recommended to remove up to 4m of the cable sheath.
- The stripped cable should be fixed well and the loose tubes, if they are twisted, should be treated with a hot air dryer so that they run straight and no longer have a twist.
- Fibers must be thoroughly cleaned until no gel residue is left.
- At the point where the loose tube is inserted into a splice cassette, a suitable adhesive tape (fiberglass tape or fabric tape) must be wrapped around the loose tube, as cable ties do not have the necessary grip. Commercial insulating tape is not recommended, as this can become detached over time and in warmer temperatures.
- The coating of the fiber should be removed with a special stripper (miller pliers), then the bare fiber must be cleaned with a lint-free cloth and isopropyl alcohol before further preparation.

2. Installation



Tools for preparation and termination of fiber cables



3. Post-Installation

3.1. Copper

3.1.1 Approved Certification Test Equipment

Warranty application requires valid calibration certification for test equipment (typically once per year). Testers that show the latest calibration date in the test reports do not require separate calibration certificate submission.

The listed test equipment is approved for executing certification measurements and producing an original measurement file, which is needed to apply for a warranty (see “Appendix 1 to the warranty program” chapter 4.2.).

Class D / Cat 5e MHz 1-100	Class E / Cat 6 MHz 1-250	Class EA / Cat 6A MHz 1-500	
AEM TestPro CV100	AEM TestPro CV100	AEM TestPro CV100	
Fluke DSX- 600/5000/8000 VersivTM	Fluke DSX- 600/5000/8000 VersivTM	Fluke DSX- 600/5000/8000 VersivTM	
Ideal LanTEK II, LanTEK III, LanTEK IV (≥V1.34)	Ideal LanTEK II, LanTEK III, LanTEK IV (≥V1.34)	Ideal LanTEK II, LanTEK III, LanTEK IV (≥V1.34)	
Softing WireXpert WX4500 WireXpert WX500	Softing WireXpert WX4500 WireXpert WX500	Softing WireXpert WX4500 WireXpert WX500	
VIAVI Certifier 10G, Certifier 40G	VIAVI Certifier 10G, Certifier 40G	VIAVI Certifier 10G, Certifier 40G	

Test equipment accepted for warranty applications

Notes:

- Class E_A and Cat. 6A do not specify the same performance
- This is the status at time of release of the document.
The current valid status of the list can be found on the R&M website: www.rdm.com
- Test equipment must be regularly referenced
- The manufacturer's calibration interval must be observed.
- All pre-terminated cables must be tested after installation, especially for warranty application

Module	Cable	PL & CH Class E / Cat. 6 (ISO/EN/TIA)	PL & CH Class E _A / Cat. 6A (ISO/EN/TIA)	PL & CH Class I / Cat. 8.1 (ISO/EN/TIA)
Cat. 6		OK	-	-
Cat. 6 _A EL	Minimum cables approved for 500MHz and more	OK	OK	-
Cat. 6 _A ISO		OK	OK*	-
Cat. 8.1	Cables approved for 2000MHz	OK	OK	OK

Test equipment adaptor selection

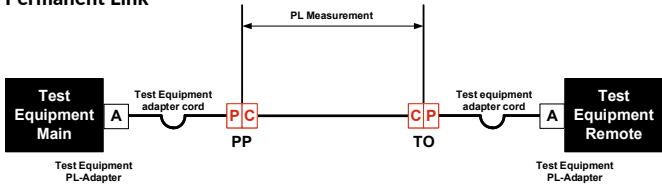
*Best in Class

3. Post-Installation

3.1.2 Test Link Configurations

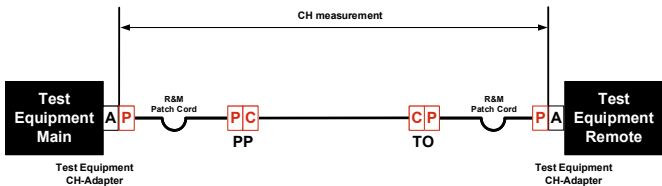
The warranty program provides for the following test set-ups for copper cabling.

Permanent Link



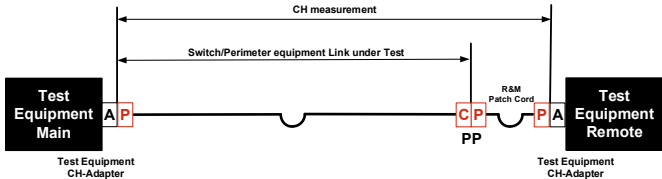
Sample test link PL

Channel



Sample test link CH

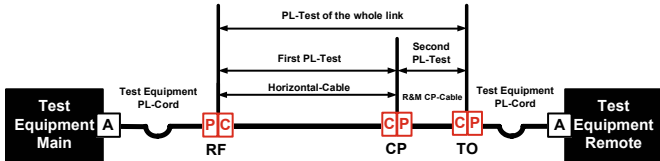
MPTL



Switch link testing configuration

The MPTL (Modular Plug Terminated Link) is now a recognized connection method within the standards. It allows to test a link with a plug at one side and a module at the other side. Make sure that the test equipment manufacturers requirements for this kind of test are fulfilled.

Consolidation Point



Sample test link PL with CP

It is not always possible to enter the distribution room later to test a complete link. In this case the CP link can be tested separately as follows. In the first step the permanent link between distribution room and CP is measured. In the second step the CP-Link is measured. This is where the MPTL test can be conducted, where there is a plug at one and a module at the other end of the link. Tested this way, the 2-connector permanent link and the 3-connector CP link are under warranty. If there is access to the distribution room, the whole link can be measured as a PL. It should be noted, however, that for class E_A the correct standard is selected in the measurement device, which is PL3 class E_A .

3. Post-Installation

3.1.3 Test Procedure

Step 1:

A low battery level can have a negative influence on the test results. This influence varies from test equipment to test equipment. It is therefore best practice to avoid low battery levels on your test equipment. Have the routine of charging the TE whenever there is a long break or at the end of the day.

Step 2:

Certain test equipment allow pre-programming of the test limits per project, making sure there is no confusion when using the same TE for different projects. If this is not the case, make sure the correct standard and link configuration is chosen. Keep in mind ISO and EN identify channels as a «Class» and the TIA identify channels as a «Category», but all standards bodies identify components as a «Category».

Step 3:

Select the type of cable that will be tested, i.e. unshielded (U/UTP) or shielded (U/FTP, F/UTP, F/FTP, S/FTP), if you are not sure check the cable sheath. Unless otherwise required, it is easier to select the generic type of cable and then manually adjust the cable's NVP (step 5). With shielded cable it is desired to test the shielding continuity

Step 4:

Choose the cable's category; this is marked on the cable sheath.

Step 5:

Set the NVP value, which is also marked on the cable sheath. This parameter is important to make sure the correct electrical cable length is shown and to troubleshoot the correct location when there are problems with the link.

Step 6:

To ensure maximum accuracy of copper cable test results, perform the reference procedure every 30 days. Most customers set the reference daily.

Step 7:

Make sure that the correct adapters for the link under test are used, i.e. do not use Cat6 adapters to test Class E_A links. Certain manufacturers have dedicated PL and CH adapters, so they should not be mixed or channel adapters be used for PL tests for example.

Step 8:

Measure the Link under test, while doing this make sure the nomenclature and labeling is all conform to the requirements and standards.

Step 9:

Analyze the test results and check if they are conformant to the projects requirements are the known component performances. E.g. links with the R&M *freenet* Cat6_A module should have a NEXT margins of above 4dB, lesser values reflect issues with the connectivity. Very low RL margins could be an indication there are issues with the cable. If there are problems with a link, write them down and report them to the team leader so further corrective actions can be taken

Step 10:

Save the good test results with the correct nomenclature under the appropriate folder

3. Post-Installation

3.2 Fiber

3.2.1 Approved Certification Test Equipment for Fiber

R&M accept all forms of test equipment suitable for measuring optical fibers, both the LSPM (Light Source Power Meter) and the OTDR (Optical Time Domain Reflectometer), all makes and models are acceptable.

R&M recommends the use of an LSPM for results measuring, as this provides more accurate figures and is generally quicker to test.

All of the test equipment used for testing needs to be calibrated according to the manufacturer's documented procedures. The calibration frequency is in general yearly. The proof of calibration needs to be included when applying for a warranty if the test software does not mention it.

All measurements in the field must be tested with 2 wavelengths and with reference measurement cables.

The measurement instruments must be able to store the test results in electronic form. The original results can then be managed more easily and must be transmitted electronically in the case of a warranty application. Manually written tables or PDF's are not accepted!

OTDR measurements that are not evaluated and properly documented, that make it impossible to trace the installed routes, will not be accepted and rejected for warranty requests.

3.2.2 Inspection and Cleaning

ICC
INSPECT, CLEAN (if necessary) then CONNECT

The performance and reliability of an optical fiber system depends strongly on the cleanliness of the connection components. Small impurities like dirt, dust, etc. can possibly destroy a fiber optic connector. Therefore the following procedure is strongly recommended: Visual inspection of the surface (with microscope). Clean the surface following the instruction of the manufacturer. After cleaning inspect again the surface, if clean then make the connection.

The following cleaning materials should be used:



Cleaning-equipment

- Active microscope
- Lint-free rods
- Lint-free wipes
- Isopropyl alcohol



Inspection

- Dry cleaning tape
- IBC cleaner
- Cletop cleaner

3. Post-Installation

3.2.3 FO Test Conditions

In order to get reliable and repeatable measurements of FO cabling and its component it is important to use a good test system, adapters and reference connectors.

Reference measurement cables

The measuring standard ISO 14763-3 stipulates that reference measurement cables must be used for measuring installations. These special cables are equipped with reference plugs on the end that is connected to the installation to be measured. Reference connectors have special properties and much smaller manufacturing tolerances. The fiber is perfectly centered in the ferrule of the connector for greater accuracy and repeatability when measuring fiber optic installations. If normal (random) connectors with higher tolerances were to be used for measuring, larger accuracy deviations would occur. It is possible that with two connected plugs the cores are perfectly aligned and a very good measurement could be falsely perceived. In the next case, the cores may be further apart due to the higher tolerances, which would result in a very poor result. For this reason, reference measurement cables must be used when measuring fiber optic installations.

Test Cords and Adapters

The components of test cords and the adapters used shall have the same or better performance specifications than those used in the link under test. The connectors on the test cords that will connect to the cabling under test must have reference connectors according the specifications in ISO 14763-3.

Connector Type	Cylindrical connector style		Rectangular connector style	
Mode	MMF	SMF	MMF	SMF
Attenuation (dB)	≤ 0.10	≤ 0.20	≤ 0.10	≤ 0.20
Return Loss (dB)	≥ 35	≥ 45 (PC), ≥ 60 (APC)	≥ 35	≥ 45 (PC), ≥ 60 (APC)

Reference-Reference mating loss budget

3. Post-Installation

3.2.4 LSPM Testing

To get a system warranted from R&M, the optical system must be measured according to the requirements of **ISO/IEC 14673-3** and equivalent standards.

Direction

For compliance testing of a channel or link, bi-directional testing **MUST** be conducted if the link is spliced or if there are multiple connectors. If it is a pre-assembled link (fixed line with associated connectors), without splicing, unidirectional measurement is possible, provided that the test cables have the same fiber properties as the installed link. Best general advice: **Test Bi-Directionally**

Reference Configuration

For LSPM testing, only the “one jumper” and the “extended three jumper” method are accepted.

For R&Mfreenet fiber optic permanent link warranty application the 2 & 3 jumper testing procedure will not be accepted.

For LSPM Channel certification keep in mind that the patch cords must remain connected after the tests.

Settings

Certain LSPM test equipment will allow the setting of link parameters in order to immediately check if the measured attenuation is within a certain standard's limit. Here is an overview of some of these parameters:

- Standard Limit: determines the loss budgets limits for a link
- Fiber type: this parameter will use the fiber loss parameters
- Bi-directional: for LSPM the R&M *freenet* warranty program requires bi-directional measurements
- Number of adapters: this is the amount of adapters present in the link under test, for a pre-term link this will be 2, for a link with MPO trunk cables and cassettes this will be 4.
- Number of Splices: the amount of splices present in the link
- Connector type: The type of connector used in the link, this parameter is informative and has no bearing on the test limit calculation.

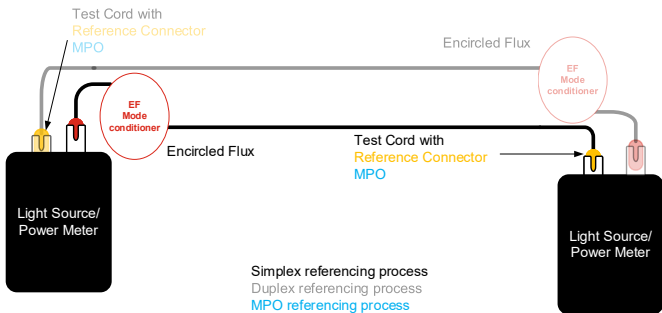
3. Post-Installation

Reference

For LSPM test methods a reference needs to be set between the light source and the power meter. The following referencing methods are accepted. The illustration shows the referencing and the measuring process with unidirectional (ignore faded connections) and with bidirectional (include faded connections) measuring devices.

«One jumper» method & «Extended 3-Jumper» method

The cords used to set the reference must fulfill the standards requirements. To measure all possible connector types, all necessary adapters for the appropriate connectors should be available.

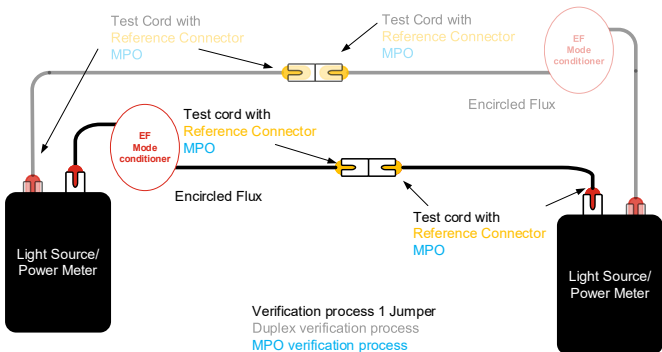


one-Jumper-reference-method

Verification

After referencing the LSPM and lead calibration cord, ensure the reference connectors of the launch and tail cords are of good quality. Make the following test setup and measure the link, this one needs to be less than 0.1 dB for MMF and less than 0.2 dB for SMF. Save the measured value and add it to the test documentation for the warranty application. Repeat this step after each reference setting or when the measurement results are deteriorating.

«One jumper» method

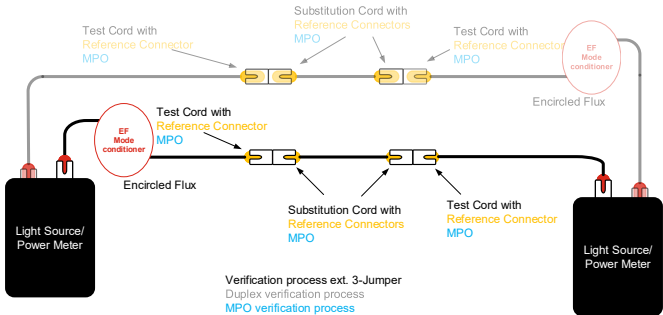


«one Jumper» method verification

3. Post-Installation

«Extended 3-Jumper» method

This method is only allowed when the link has different connectors on each end. After doing the reference attach a substitution cord with matching reference connectors on each end. Check the loss on the power meter, it needs to be less than 0.2 dB for MMF and less than 0.4 dB for SMF.

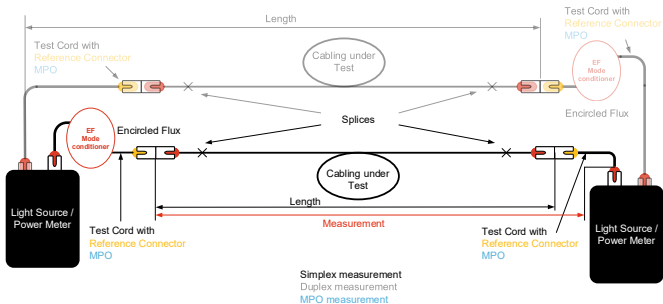


«extended 3-Jumper» method verification

Important: Don't do a new reference with the substitution cord (putting the power meter to 0dB) this step is only for verification that the connector quality is good enough.

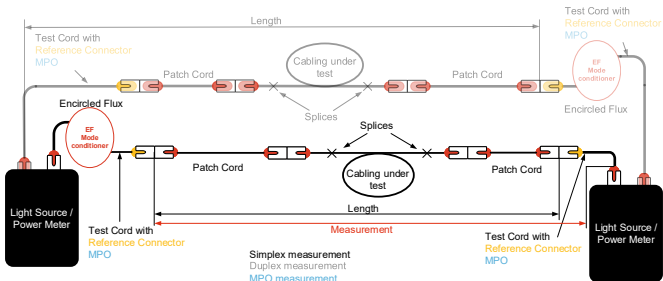
Measuring

The «cabling under test» can now be measured by connecting the launch and tail test cord to each end of the link. When «Extended 3-Jumper» method is used for referencing and validation, remove the substitution cord and replace it with the link that should be tested.



Measurement of a PL

An example for a channel measurement:



Measurement of a CH

3. Post-Installation

3.2.5 Test Procedure LSPM

Step 1:

A low battery level can have a negative influence on the test results. This influence varies from test equipment to test equipment. It is therefore best practice to avoid low battery levels on the test equipment. Have the routine of charging the TE whenever taking a long break or at the end of the day. The LSPM test equipment needs about 15min of temperature acclimatization before the light source will have stable performance.

Step 2:

Some test equipment allows the setting of parameters that will allow the TE to calculate the power budget for the link, these are the parameters described previously, i.e. test limit, fiber loss, amount adapters/splices, type of connector, index of refraction.

Step 3:

Set the reference, i.e. the one jumper reference with one test cord between light source and power meter (reference connector)

Step 4:

Remove the test cord from the power meter and add another test cord between the power meter and the first test cord for PL testing. Make sure both reference connectors are mated against each other with a SMF coupler.

This test is to verify the quality of the reference connectors on the test cords, they should be better than MMF IL $\leq 0.10\text{dB}$, SMF IL $\leq 0.20\text{dB}$, MMF/SMF PC RL $\geq 35/45\text{dB}$, SMF APC RL $\geq 60\text{dB}$.

This step should be done regularly or when replacing any of the test cords. For channel testing remove the equipment cord from the power meter and add the other equipment cord to the power meter. No verification testing is needed for channel testing.

Step 5:

ICC of the link end faces and test cord end faces. When measuring, it should be ensured that the nomenclature, direction and labeling is all conformant to the requirements and standards. Checking for no apparent defects or broken parts must be undertaken at this stage.

Step 6:

The test results must be analyzed that they are conformant to the project and the known component performance requirements . For channel testing both equipment cords connected to the link must remain in place.

Step 7:

The good test results must be saved with the correct nomenclature under the appropriate folder «Installation & testing guidelines».

3. Post-Installation

3.2.6 OTDR Testing

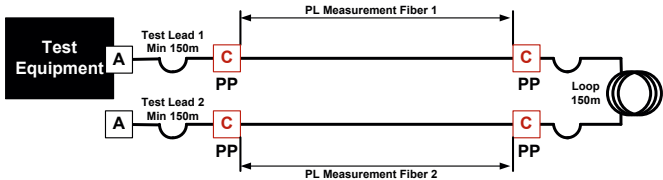
Direction

Multimode and singlemode fiber transmission lines must be measured bidirectionally, as there may be differences in the core diameters and backscatter coefficients of the test cables and the installed cabling. If splices or other plug connections are present on the installed line, bi-directional measurement is mandatory according to ISO/IEC 14763-3 & IEC 61280-4-1&2. In addition, with bidirectional measurements, the launch and tail fibers must remain connected and only the OTDR must be shifted so that a clean averaging of the values is possible. The launch fiber of measurement A-B thus becomes the tail fiber of measurement B-A and vice versa. The difference in core diameter can lead to optimistic results on the one hand and pessimistic results on the other, so that it is not possible to determine the actual loss of an event in unidirectional measurements.

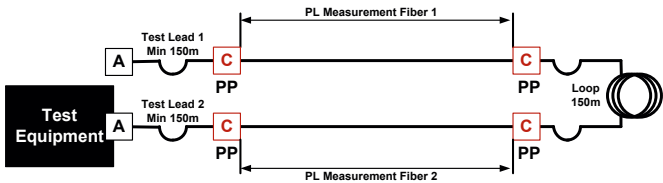
Unidirectional measurements are only permitted if there are no splices or other plug connections on the measured distance. In addition, the launch fiber and tail fiber must have the same properties as the installed link.

Loop Measurement

Loop measurements are allowed. Be aware that the loop fiber must have reference connectors on both sides and should have the same length as launch and tail cord. This means that a duplex link can be tested simultaneously, multiple loops are not permitted for warranty applications. However it is important to realize that loop measurements do not warrant the polarity of the installed cabling and that any verification of this needs to be done separately.



OTDR Loop measurement A to B



OTDR Loop measurement B to A

3. Post-Installation

Settings

Range

The range shall be set in such a way it at least covers all test cords and the cabling under test, e.g. If there are 2 test cords of 500m and the longest link under test is 350m, the range will be at least 1350m.

Dynamic range

The dynamic range determines the maximum observable length of a fiber and is an OTDR specific parameter. It is an extrapolation of the backscatter trace compared to the noise level, the better the SNR the better the trace and event detection. If fiber links with high attenuation require to be tested, it is better to check with the TE manufacturer if the equipment is suited.

Wavelength

Every link **MUST** be tested at the upper and lower frequency windows, i.e. MMF @ 850nm & 1300nm and SMF @ 1310nm & 1550nm. It can be that the end customer requires additional wavelengths to be tested.

Pulse width

The pulse width gives an indication of the power sent into the fiber; the larger the pulse the more power is transmitted. A wide pulse will allow further travel along the fiber, but also means that the width of the reflections becomes wider. A wider reflection will also hide more of the backscatter signal, i.e. it will increase the event and attenuation dead zone.

The pulse width must be adapted to the cable length. If necessary, set the pulse width in the tester to «Automatic» and adjust the measurement range as accurately as possible to the cable length.

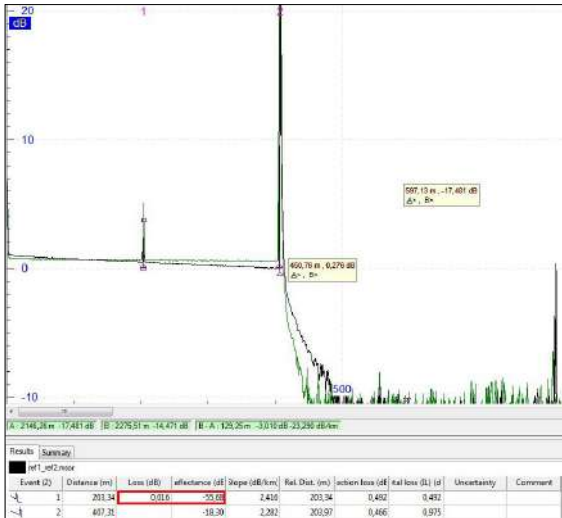
Averaging time

This function defines the time it takes to sample the link, the longer the time the better the SNR and characterization of the trace. The time chosen should allow good analysis of the cabling under test. This time is dependent upon the equipment but the general accepted min time is 20s. If the distances are less than 100m, 10 seconds can be set, for distances over 100m, at least 20 seconds must be set. With SMF it is generally recommended to measure at least 20 seconds

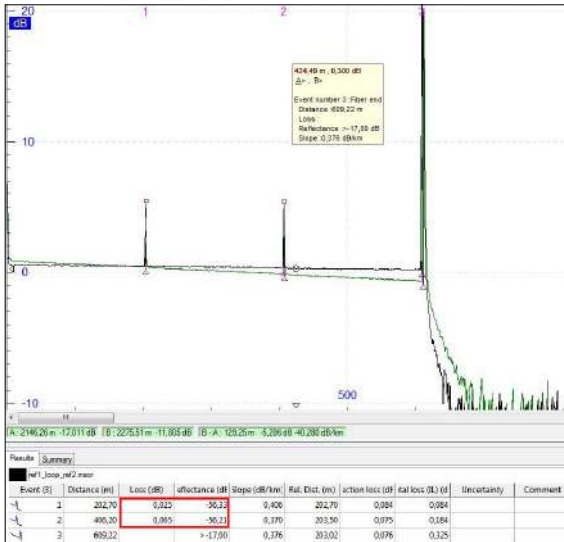
3. Post-Installation

Verification of Test Cords

In order to comply with the fiber optic test conditions verification that the test cords that are used (launch, tail and loop) to perform the tests are within the specifications. This verification needs to be done and recorded at the start of each test sequence is required.



Test lead 1 & 2 reference connector verification



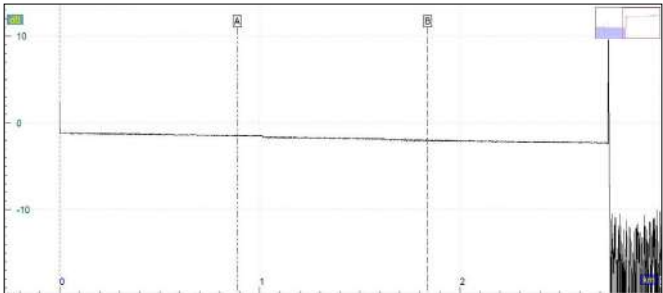
Test leads and loop reference connector verification

Make the following test setup and measure the link, the connector losses must be 0.1dB for MMF and 0.2dB for SMF or less. Save the measured value and add it to the test documentation for the warranty application.

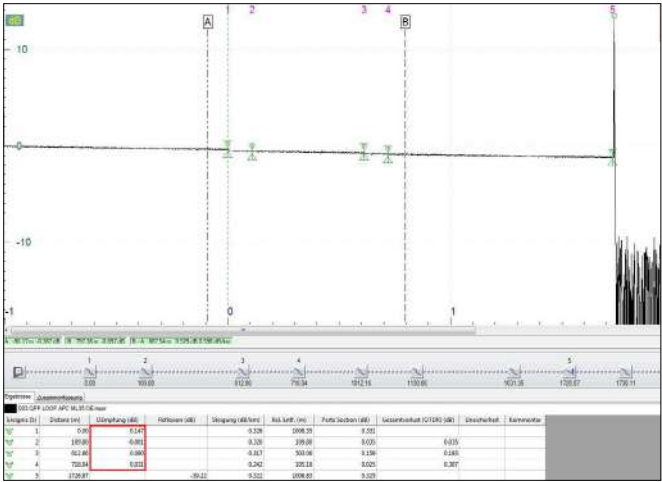
3. Post-Installation

When testing links with APC connectors it is very difficult to determine the start and end of the test cords and links under test. Therefore we require also the individual test trace of each test cords used in the warranty application. Therefore, inclusion of the trace of the first test cord, the second test cord and the loop test cord, if used, in the application documentation is required.

It is therefore particularly important that the measurement technician sets the events correctly when measuring with the OTDR. If there are several events (as is the case with a loop measurement, for example) and the measurement device does not recognize all events automatically, the events must be set manually. The OTDR recognizes most events by itself, but this is not always the case with good APC connections. This simplifies the later evaluation and documentation of the measurements on the PC enormously.



Test cables 1 & 2 and link 3 with APC connectors (events not set, i.e. not visible)



Test cables 1 & 2 and link 3 with APC connectors (events set and therefore visible)

3. Post-Installation

Analysis of Measurement Results

Once fulfilling the test conditions for fiber link testing it is important to analyze the results, more so when using an OTDR, as all elements of the link can be observed. There are 5 major elements need to be observed when analyzing an OTDR trace and if the sequence is followed detailed troubleshooting can be avoided where it is not needed. The following sequence reflects best practices and probability of most common failures.

Length

Check if the length of the trace is that of the combined length of the test cords and the link under test. This can already be done while the test is in progress and if the length of the trace is shorter then it is obvious that the link is interrupted and faulty. If for example, there is a link of 150 m with 2 test cords of 150 m, then the trace should be circa 450 m. When the trace is only 300 m, it is obvious there is a problem at the far side, either the polarity is wrong or there is a problem with the connector/splice. When there is a problem at this stage the testing can be stopped to solve the problem, there is no point in wasting time by running the complete test.

Trace Image

In general high peaks should not be observed in the trace, the higher the peak the more return loss of the events there is, especially when testing a link with APC connectors. Also this analysis can be done while the test is running. If an unusually high peak is observed where there is a splice, then that splice needs to be redone. If an adapter displays a high peak this could either, indicate a dirty connector(s) or a damaged connector/adapter. Also here the test can be halted at this stage when a problem occurs.

Amount of events

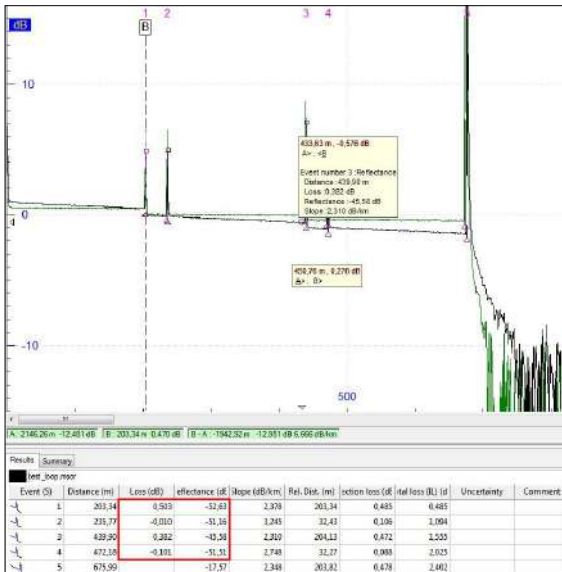
Once the test is completed the individual events can be observed, first of all the amount of events need to correspond with the quantity of elements in the link under test i.e. amount of adaptors, splices (pigtail splices are often not detectable as they fall within the attenuation dead zone of the test equipment). Depending on the setting of the OTDR (pulse width), the attenuation dead zones become larger or smaller. For example, if there is a transmission path with pigtails at both ends and 3 events are detected, one of which is an attenuation in the middle of the transmission path, there is a problem.

3. Post-Installation

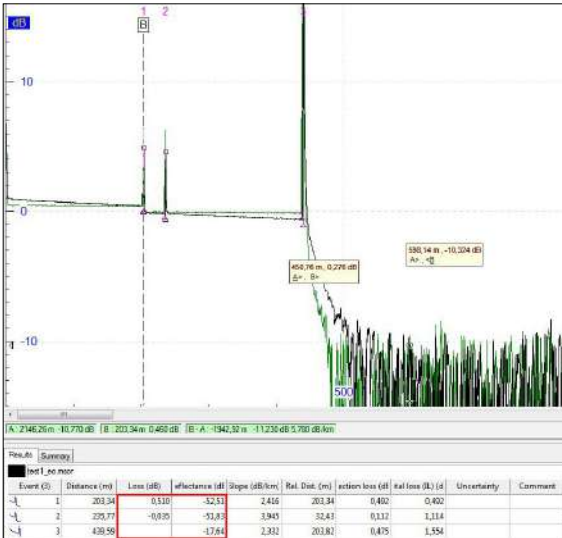
Note

Pigtail splices are often undetectable as their proximity to the connector at the other end of the pigtail is too close to detect separate events. The setting of the OTDR (pulse width) allows variation of the attenuation dead zone to detect such events. R&Ms recommendation of 10ns pulse width, generally allows the best trace analysis up to 2km.

Trace examples with events:

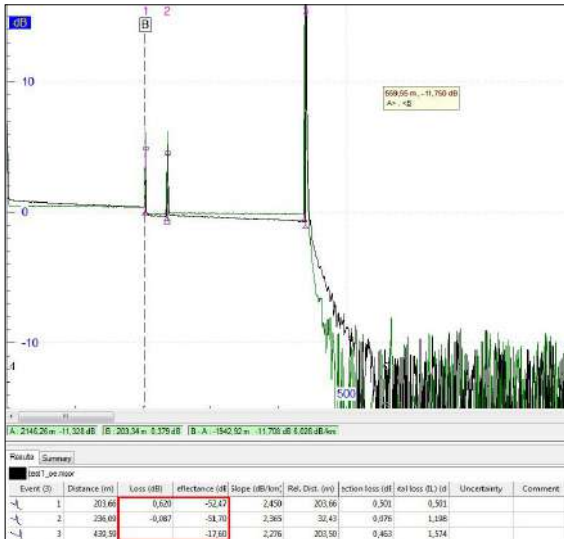


Unidirectional loop measurement



MMF measurement origin to end

3. Post-Installation



MMF measurement end to origin

Event Signature

Make sure that each event parameter corresponds with those given in the manufacturer datasheet. Keep in mind to take the average when performing bi-directional measurements, these are mandatory for all SMF links and all MMF links when using test leads that have different characteristics than the link under test.

Performance limits for fiber optic events (dB)

Standard	ISO/IEC 11801-1 ISO/IEC 14763-3	ISO/IEC 11801-1 ISO/IEC 14763-3
Splice	≤ 0.30	N/A
Single-Mode	Attenuation (dB)	Return Loss (dB)
APC connector Reference - Reference	≤ 0.20	≥ 60
APC connector Reference - Random	≤ 0.75	≥ 60
APC connector Random - Random	≤ 0.75	≥ 60
PC connector Reference - Reference	≤ 0.20	≥ 45
PC connector Reference - Random	≤ 0.75	Not available Recommend ≥ 35
PC connector Random - Random	≤ 0.75	≥ 35
MPO Connector Random - Random	Not available Recommend ≤ 0.75	Not available Recommend ≥ 60
Multi-Mode	Attenuation (dB)	Return Loss (dB)
PC connector Reference - Reference	≤ 0.10	≥ 35
PC connector Reference - Random	≤ 0.50	Not available Recommend ≥ 35
PC connector Random - Random	≤ 0.75	≥ 20
MPO connector Random - Random	Not available Recommend ≤ 0.75	Not available Recommend ≥ 26

R&M *freenet* event attenuation

3. Post-Installation

Cable

The last element to check is the cable attenuation; this might not always be possible for short links. If the link is too short to get a trustworthy reading of the cable attenuation, the total link attenuation can be observed to see if the link is ok. With SMF links, macro and micro bends will manifest themselves in increased attenuation at 1550nm and 1625nm compared to 1310nm trace signature.

Detailed Step Description:

Step 1

Ensure good battery levels. Low battery levels can have a negative influence on the test results. This influence varies from test equipment to test equipment. It is therefore best practice to avoid low battery levels on test equipment. The OTDR test equipment needs about 15min of temperature acclimatization before the laser will have stable performance.

Step 2

The range shall be set in such a way it at least covers all test cords and the cabling under test.

Step 3

The pulse width must be set according the length of the link and the detail of the trace required. R&Mfreenet warranty applications recommends 10ns.

Step 4

This function defines the time it takes to sample the link, the longer the time the better the characterization of the trace. The time chosen should allow good analysis of the cabling under test. This time is dependent upon the equipment but the general accepted min time is 20s.

Step 5

Index of refraction	850 nm	1300 nm	1310 nm	1550 nm	1625 nm
OM3/4/5	1,482	1,477			
OS2			1,467	1,467	1,468

FO cable index of refraction

Step 6

Save an OTDR trace for each of the test cords used and a trace of the test cords against each other. This test is to verify the quality of the reference connectors on the test cords, they should be better than MMF IL $\leq 0.10\text{dB}$, SMF IL $\leq 0.20\text{dB}$, PC MM/SM RL $\geq 45\text{dB}$, APC SM RL $\geq 60\text{dB}$. This step should be done daily or when replacing any of the test cords.

Step 7

Measure the Link under test, while doing this make sure the nomenclature, direction and labeling is all conformant to the requirements and standards. Check if there are no apparent defects or broken parts. It is extremely important that the file naming functions of the tester is used (Cable ID, Fiber number, Lamda, Direction etc.) and not simply rename the file name on the PC afterwards. Most OTDRs store this information in the measurement file. When renaming on the PC, this can lead to problems when evaluating via OTDR software, since without the above-mentioned file information there are difficulties in assigning the measurement results.

3. Post-Installation

Step 8

Analyze the test results and check if they are conformant to the projects requirements and the known component performances. Confirm there are no defective or damaged parts. ICC of the link end faces and test cord end faces.

Step 9

Save the good test results with the correct nomenclature under the appropriate folder.

3.2.7 Documentation of Fiber Optic Measurements

Unfortunately, it is often the case that the project managers or the measurement technicians think that the work is done after the measurements have been saved on the device. Unfortunately, this is not the case with fiber optic measurements, as the measurements must then be documented on the PC with the analysis software. Otherwise there is only the raw data with which the customer cannot really do much.

Using Fluke as an example, the associated software for evaluation is the familiar Linkware. The measured files are loaded from the device to the PC and processed with Linkware. The software now enables the measurements to be checked and is in a clean order with documentation of the measured project.

The multitude of fiber optic measurement instruments available today also brings with it a multitude of evaluation software. Basically, the purchase of a fiber optic measurement device should be accompanied by the appropriate evaluation software. Even more important is training on how to use this software correctly. Please contact the instrument vendor if you have not received training on the appropriate evaluation software or contact them directly if you purchase a new instrument.

The measurements are to be imported from the instrument into the software. Once the measurements have been made most of the work has already been done.

Step 1

Import the measurement data and open with the editing software.

Step 2

Set the limits required by the standard in the software or set the limits according customer-specific limit values. For warranty claims we require that at least the limit values of the measurement standard ISO/IEC 14763-3 and ISO/IEC 11801-1 are observed.

Step 3

Check the events and edit them if necessary. In OTDR measurements, it can happen that the OTDR does not recognize all events automatically. Single-mode APC connections are often so good that no event is detected.

Step 4

See that for bi-directional measurements the averaging of the measured values can be done. If the events are not set in the correct place, the program cannot carry out the averaging of the values. In this case, repeat step 3 for the relevant measurements.

Step 5

Place the cursor A-B / B-A at the beginning and end of the measured link.
Start = transition from launch lead to fiber link / end = transition from fiber link to tail lead

Step 6

Perform steps 3-4 for each fiber tested. Most evaluation diagrams can take over the events of one fiber for another to save time, as long as they have the same properties and events.

Step 7

Check that all fibers meet the required set limits.

3. Post-Installation

Step 8

Use the software to create a report of the project that is being worked on. Practically all evaluation programs can generate PDF's and EXCEL tables. Use this function to provide the customer with clean documentation.

Step 9

Add the desired project descriptions and company information to the report. Create a title page or a general overview as desired or specified by the customer.

Step 10

Create a collective directory or a zip in which you collect the measurement files and the documentation of the project. Hand them over to the customer and to R&M for the warranty requests.

4. Abbreviation Description

Key	Description
AC	Alternate Current
APC	Angled Physical Contact
BN	Bonded Network
CBN	Central Bonded Network
CRAC	Computer Room Air Conditioning
DC	Direct Current
DC-I	DC Isolated distribution system
DC-C	DC Common distribution system
EMC	Electro-Magnetic Compatibility
ER	Equipment Room
HF	High Frequency
ICC	Inspect Clean Connect
MEP	Mechanical, Electrical and Plumbing
MMF	Multi Mode Fiber
MPO	Multi-fiber Push-On connector
OLT	Optical Line Terminal
ONT	Optical Network Terminal
OTO	Optical Telecommunication Outlet
PC	Physical Contact

Key	Description
PE	Protective Earth
PoE	Power over Ethernet
RCD	Residual-Current Device or residual-current circuit breaker (RCCB)
SMF	Single Mode Fiber
SNR	Signal to Noise Ratio
TN-C	A combined PEN conductor fulfils the functions of both a PE and an N conductor
TN-C-S	Part of the system uses a combined PEN conductor, which is at some point split up into separate PE and N lines
TN-S	PE and N are separate conductors that are connected together only near the power source
TP	Twisted Pair
TT	In a TT (Terra-Terra) earthing system, the protective earth connection for the consumer is provided by a local earth electrode, and there is another independently installed at the generator

5. Picture Key

Key	Description
C	Connector
EQP	Active Equipment
FD	Floor Distributor
CD	Campus Distributor
BD	Building Distributor
TO	Telecommunication Outlet
CP	Consolidation Point
TE	Terminal Equipment
ZD	Zone Distributor
MD	Main Distributor
LDP	Local Distribution Point
EO	Equipment Outlet
Core	Core Switch Equipment
SVR	Server

Key	Description
Spl	Splice
OLT	Optical network Line Terminal
ONT	Optical Network Termination
Rx	Receive
Tx	Transmit
A	Adapter
P	Plug
PP	Patch Panel
MPO	MPO connector
EF	Encircled Flux

6. Fiber Cable Descriptions

Use	Indoor		In- / Outdoor	
Type of cable	Breakout	Mini-Breakout	Central Loose Tube	Stranded Loose Tube
Cable description DIN-VDE 0888	I-V(ZN)HH	I-V(ZN)BH	I/A-DQ(ZN) BH	I/A-DQ(ZN) BH
Fiber count	8-24	4-24	4-24	12-144
Outer sheath	FireRes® LSZH	FireBur® LSZH	FireBur® LSZH	FireBur® LSZH
Sheath colour	green	green	green	green
Armouring	Aramid	Glass yarn	Glass yarn	Glass yarn
Rodent protection	-	+	+	+
Tertiary cabling	✓	✓		
Building BB		✓	✓	✓
Campus BB				
WAN				
Trunking	✓	✓		
Ducts, Trays	✓	✓	✓	✓
Building riser		✓	✓	✓
Raised floor		✓	✓	✓
Empty tube	✓	✓	✓	
Ducts				✓
Directly in ground				
Blowing				
On site termination	✓	✓		
Splicing		✓	✓	✓
VARIOline			✓	

Use	Outdoor				
	Central Loose Tube	Stranded Loose Tube	Central Loose Tube	Stranded Loose Tube	Stranded Loose Tube
Cable description DIN-VDE 0888	A-DQ(ZN) B2Y	A-DQ(ZN) B2Y	A-D(ZN) W2Y	A-DF(ZN) 2YW2Y	A-DF(ZN) YQ(ZN)2Y
Fiber count	4-24	12-144	6-24	12-96	12-96
Outer sheath	LLDPE	MDPE	MDPE	MDPE	HDPE
Sheath colour	Black	Black	Black	Black	Black
Armouring	Glass yarn	Glass yarn	Corrugated steel	Corrugated steel	Aramid
Rodent protection	++	++	+++	+++	-
Tertiary cabling					
Building BB					
Campus BB	✓	✓			
WAN			✓	✓	✓
Trunking					
Ducts, Trays					
Building riser					
Raised floor					
Empty tube	✓				
Ducts	✓	✓	✓	✓	
Directly in ground			✓	✓	
Blowing	✓	✓	✓	✓	
On site termination					
Splicing	✓	✓	✓	✓	✓
VARIOline	✓				

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We are represented by more than 2000 qualified partners
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