

TESTING AND MEASUREMENT PROCEDURE

 UNSERE GRÜNE GLASFASER	TESTING AND MEASUREMENT PROCEDURE	TECHNICAL NORMATIVE	JANUARY 2024 3 rd Edition
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1. INTRODUCTION

This document aims to define the procedures and measures to be carried out in the installations of an optical fiber cable for its acceptance and maintenance in the UGG optical fiber network.

1.1 REFERENCE

- ITU-T Recommendation G.652: Characteristics of a single-mode optical fibre and cable
- ITU-T Recommendation G.657: Characteristics of a bending-loss insensitive single-mode optical fibre and cable.

1.2 REVISIONS

EDITION	DATE	REVISED SECTIONS	CHANGES	OBSERVATIONS
1 st	OCTOBER 2020			
2 nd	JULY 2022	1. Introduction	Reference to UGG optical fiber network	
		2.1.1 Attenuation 5.1 Optical fiber attenuation 6.1 Optical fiber attenuation	Updated attenuation value at 1550nm	
		6.2 Splice measurements	Additional margin added if the measure can be done only in one direction	
		ANNEX 1: OTDR Measurement configuration guidelines	New annex	
		ANNEX 2: OTDR Reports, formats, and general considerations	New annex	
3 rd	JANUARY 2024	All	New codification of the document	The document is codified with the document code: TEF-NORM-00003. The logo of UGG is updated in the page header. Document reorganization

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EDITION	DATE	REVISED SECTIONS	CHANGES	OBSERVATIONS
3 rd	JANUARY 2024	6. Distributed Splitting Architecture Measurement	New section	The measures that must be carried out in the Distributed Splitting Architecture are included
		Annex 1: OTDR measurement configuration guidelines	Changes in OTDR configuration	The average time of measurements is reduced New configurations for Distributed Splitting Architecture

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2. GENERAL

Measurements must be carried out on all the optical fiber cables and elements after installation, to verify that the transmission parameters: attenuation, return loss and dispersion are correct. In some cases, measurements before installations must also be required.

Depending on the case, measurements must be done in the 2nd and 3rd window (1310 and 1550 nm) or 4th window (1625 nm). The measurement methods should be non-destructive.

In the measurement of an optical fiber cable connection, the connectors and adapters must be checked and, if necessary, cleaned before each patch. After the measurement procedure is finished, they must be checked and cleaned again before the connection is redone. If a connector or an adapter is not used, it must be covered with the protective caps to prevent them from damage or dirt.

All measurements by Optical Time Domain Reflectometer (OTDR) must be performed with a launch fiber that presents the same properties as the one in network (same ITU standard: Single mode G.652 or G.657).

The measuring devices must be calibrated.

2.1 TRANSMISSION PARAMETERS

2.1.1 ATTENUATION

The different causes of losses that must be considered are:

- Optical fiber attenuation (dB/Km)
- Attenuation of passive elements: Splices, connectors and splitters (dB)

Optical fiber attenuation (α) must be verified that is within the specified limits. For optical cables and fiber units these limits are:

- λ : 1310 nm, $\alpha_{\max} \leq 0,37$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,24$ dB/Km
- λ : 1625 nm, $\alpha_{\max} \leq 0,26$ dB/Km

Attenuation in the fiber could be increased due to tension, torsion or excessive bending during installation. The maximum tension and minimum radius of curvature in optical cables and fiber units must always be respected.

Losses due to splices and connectors must be measured to verify that they do not exceed the limits of 0,10 dB on average and 0,25 dB respectively.

Losses due to splitters depend on the level of division they have.

- Splitter 1 to 2, Att. $\leq 3,7$ dB
- Splitter 1 to 4, Att. $\leq 7,8$ dB
- Splitter 1 to 8, Att. ≤ 11 dB

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- Splitter 1 to 16, Att. ≤ 14,2 dB
- Splitter 1 to 32, Att. ≤ 17,6 dB
- Splitter 1 to 64, Att. ≤ 21 dB

The attenuation of the connectors (0,25 dB) must be added in the case of splitters with connectorized ends.

2.1.2 DISPERSION

Dispersion is the effect that distorts the signal being propagated. In single mode fibers two types are considered:

- Chromatic dispersion (CD)
- Polarization mode dispersion (PMD)

Chromatic dispersion is an intrinsic parameter in fiber optic which is not usually affected by cable manufacturing or the installation process. It will not be necessary to measure it, except in the cases indicated.

Polarization mode dispersion (PMD) limits the operation of high-speed systems over long distances. It is associated with asymmetry in geometry and/or the distribution of stress at the core of the fiber. It is a magnitude that varies randomly with wavelength and over time due to vibrations, fiber movements or temperature changes or mechanical optical fiber disturbances.

PMD coefficient is defined as a function of the length of the optical fiber and is expressed in ps/Km^{1/2}. PMD coefficient measured must be ≤ 0,20 ps/km ^{1/2}.

2.1.3 RETURN LOSS

Return loss is another important parameter that affects the fiber optical transmission system.

The return loss is a parameter that depends on the quality and kind of the optical connectors used in the installation and must meet the following return loss values:

- For PC¹ connectors: RL ≥ 45 dB
- For APC² connectors: RL ≥ 60 dB

The return loss due to splitters must be higher than 55 dB.

¹ PC connector is a flat polished connector: Identified by its blue color

² APC connector is an angled polished connector: Identified by its green color

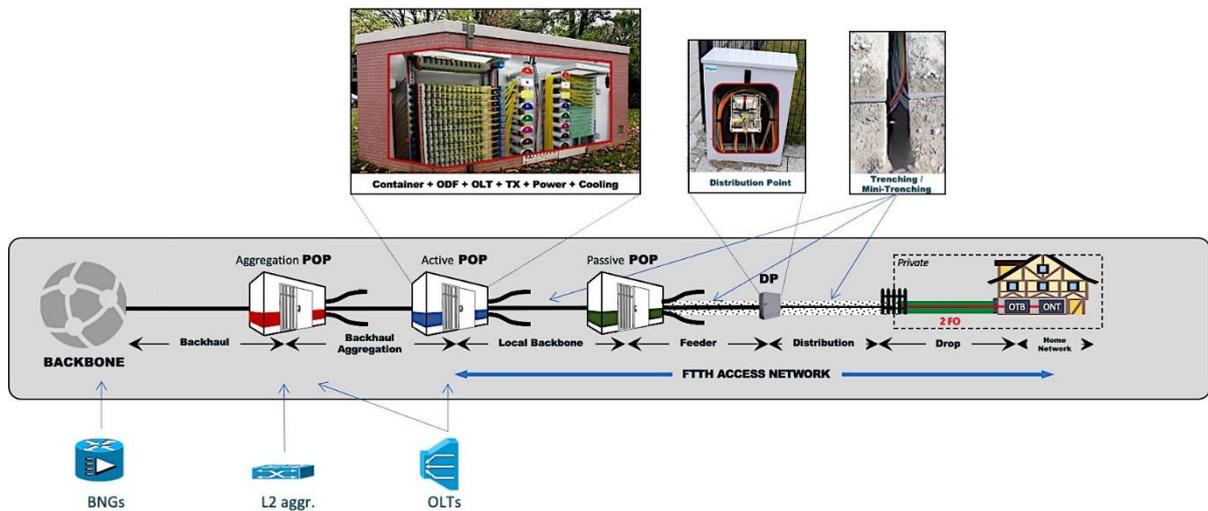
3. NETWORK ARCHITECTURES

Two different network architectures can be identified in UGG:

- Centralized Splitting Architecture
- Distributed Splitting Architecture

3.1 CENTRALIZED SPLITTING ARCHITECTURE

This network architecture consists of backhaul, local backbone, feeder network, distribution network and customer's drop.



These sections are separated by two network elements: The Point of Presence (POP), between backhaul and feeder sections, and the Distribution Point (DP), between feeder and distribution sections.

In this architecture all network splitters are located in the POP.

For measurement purposes, the optical fiber cable installations could be divided into:

1. Backhaul network: backhaul, backhaul aggregation and local backbone
2. Access network: feeder, distribution and customer's drop

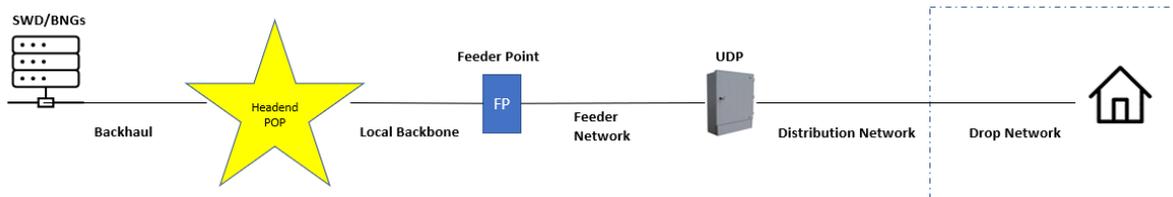
Backhaul network consists of the optical cables (up to 288 optical fibers) that link the different POPs, both in urban and intercity areas, ending these cables in the Optical Distribution Frame (ODF).

Access network consists of the optical cables (up to 96 optical fibers) that link the POP to the DP and optical fiber units that link the DP to the customer's outlet.

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3.2 DISTRIBUTED SPLITTING ARCHITECTURE

This network architecture consists of five sections: Backhaul (from Headend POP to SWD or other Headend POPs), Local Backbone, Feeder Network, Distribution Network and Customer Drop.



These sections are separated by different elements: Headend POP, between backhaul and local backbone, Feeder Point (FP), between local backbone and feeder network, and Urban Distribution Point (UDP), between feeder network and distribution network.

This network architecture distributes the splitters between the UDP and the Optical Termination Box (OTB), according to the capacity of the client buildings.

For measurement purposes, the optical fiber cable installations could be divided, by the Headend POP, into:

1. Backhaul network: Backhaul

Backhaul network consists of the optical cables (up to 288 optical fibers) that link the different Headend POPs or SWD/BNG, both in urban and intercity areas, ending these cables in the Optical Distribution Frame (ODF).

2. Access network: Local backbone, feeder, distribution and drop network.

- Local backbone network connects each Headend POP with the Feeder Point (FP) located in the area using optical cables of up to 192 optical fibers.
- The feeder network connects the FP with the different UDPs, normally using an optical cable with 24 optical fibers.
- Lastly, the distribution and drop networks connect each UDP with the OTBs or Optical Termination Outlet (OTO) using an optical fiber unit. In the OTBs and OTOs the optical fibers are terminated in connectors.

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4. OPTICAL CABLE RECEPTION AND INSTALLATION

4.1 VISUAL INSPECTION

Before starting the installation, it must be checked that the coils have not been damaged during transport and storage. Optical cables should not have any manufacturing defects.

In this regard, any anomaly detected must be communicated. In no case it could be alleged if the optical cable has already been installed unless the defects are hidden.

At the reception of optical cable coils, and in general any element for installation, a visual inspection must be carried out to detect any anomaly that can be seen externally, both in the material and in the packaging.

All optical cable coils will be accompanied by a test certificate from the manufacturer including the attenuation coefficient measurements on all the fibers of the finished cable. The optical cable mustn't be installed without checking that the test measurements are in accordance with the specified limits defined in this document.

Connectors and adapters installed must be verified to be properly protected against impact and dust and no damage. They must be checked and cleaned if necessary and if any defect is observed, they must be replaced by others.

If there is any doubt about a possible damage to the optical cable, all the optical fibers must be measured in 2nd and 3rd window (1310 and 1550 nm) using an Optical Time Domain Reflectometer (OTDR).

In any case, a sampling should be carried out on all fibers in a 10% of the total coils, comparing the results with the values given in the factory test certificate. Attenuation measured in 2nd and 3rd window (1310 and 1550 nm) by an OTDR.

4.2 VERIFICATION MEASURE

Once the optical cable has been installed and before making the splices, it is convenient to make a verification measure if the optical cable may have suffered any damage during installation, for example, due to twisting or excessive stresses.

In this case, the measurement must be done in the 3rd window (1550 nm) using an OTDR over all the fibers of the cable. It should be checked: The continuity of the optical fibers, possible point irregularities or the attenuation increase in all or in a part of the fiber under test.

The limits detailed must not be exceeded.

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5. CENTRALIZED SPLITTING ARCHITECTURE MEASUREMENT

5.1 BACKHAUL NETWORK MEASUREMENT

Once the installation has been completed, the backhaul network optical links must be certificated. For the certification, the characteristics to be checked are:

- Optical fiber attenuation
- Splices insertion loss
- Connector's insertion and return loss
- Maximum insertion loss
- PMD (If required)

5.1.1 OPTICAL FIBER ATTENUATION

Optical fiber attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm) using an OTDR.

All the optical fiber of the installed cable must be measured.

Attenuation measurement must be done between two points as far away as possible within the linear zone of the reflectometric trace. Attenuation limits are:

- λ : 1310 nm, $\alpha_{\max} \leq 0,37$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,24$ dB/Km
- λ : 1625 nm, $\alpha_{\max} \leq 0,26$ dB/Km

All sections or linear zones must be measured.

The distance will be measured in each section, specifying the refractive index of the fiber. If the refractive index value is unknown, a value of $n = 1,465$ should be considered.

In the 10 % of the sections the following limits could be admitted:

- λ : 1310 nm, $\alpha_{\max} \leq 0,42$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,29$ dB/Km

Average value of all sections of an optical fiber must be always less than the attenuation limits.

Measurement in 4th window (1625 nm) could be required.

5.1.2 SPLICE MEASUREMENTS

All splices must be measured using an OTDR from both ends of the link. Attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm).

Splice attenuation value is calculated as the medium value between the measured values from both ends, measured sign must be respected.

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Splice attenuation must always be lower than 0,15 dB in 1310 and 1550 nm. If a splice exceeds the previous limit, it must be repeated.

If splices are very close and cannot be measured individually, they must be measured as one. The whole value must be lower than 0,25 dB.

Average splice losses in an optical fiber link must be lower than 0,10 dB.

5.1.3 CONNECTOR MEASUREMENTS

Initial connectors of the section must be measured using a launch fiber finished on a compatible connector and adaptor. This launch fiber must be long enough to save the dead zone of the measurement equipment.

Internal connectors of the section must be measured as a splice, without any launch fiber.

All connectors must be measured by OTDR from both ends. Attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm). Connector attenuation value is calculated as the medium value between the measured values from both ends, measured sign must always be respected.

Connector attenuation must be always lower than 0,35 dB in 1310 and 1550 nm. This value includes the pigtail splice.

Return loss must be measured in 2nd and 3rd window (1310 and 1550 nm) from one end. Connector return loss must be higher than 45 dB (for PC connector) and 60 dB (for APC connector).

If a connector exceeds the previous limit, it must be cleaned or substituted.

5.1.4 MAXIMUM INSERTION LOSS

Total attenuation must be measured between connectors finished on an Optical Distribution Frame (ODF) using a laser source and a power meter.

The measuring devices must be calibrated.

Measurement must be done on each optical fiber at the working wavelengths. In general, the measurement should be done at 1310 and 1550 nm, unless otherwise indicated in the project.

Maximum attenuation allowed is determined by the following formula:

$$A = (L \times \alpha_T) + (N_S \times \alpha_S) + (N_C \times \alpha_C)$$

where:

- **L**: Fiber length (km)
- **α_T** : maximum fiber attenuation coefficient according to the limits in paragraph 5.1.1
- **N_S** : splices number. Pigtail splices must be included
- **α_S** : 0,10 dB
- **N_C** : connections number
- **α_C** : 0,25 dB

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This test will always be done between connectors.

5.1.5 *PMD*

If required in the project, PMD must be measured.

PMD coefficient measured must be $\leq 0,20 \text{ ps/km}^{1/2}$.

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5.2 ACCESS NETWORK MEASUREMENT

Access network consists of the optical cable that links POP to DP and the optical fiber unit that links DP to customer's outlet.

In the DP, a fusion splice is made between the fiber of the cable from the ODF and the fiber of the fiber unit that reaches the customer's home.

Once both installations have been completed, the access network optical links must be certificated. It is possible to independently certify both sections of the access network.

For the certification the characteristics to be checked are:

- Optical fiber attenuation
- Splices insertion loss
- Connectors insertion and return loss
- Maximum insertion loss

5.2.1 OPTICAL FIBER ATTENUATION

Optical fiber attenuation must be measure in 2nd and 3rd window (1310 and 1550 nm).

All the optical fibers of the installed cable must be measured.

The attenuation measurement must be done from ODF to the customer's site using an OTDR. Attenuation limits are:

- λ : 1310 nm, $\alpha_{\max} \leq 0,37$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,24$ dB/Km
- λ : 1625 nm, $\alpha_{\max} \leq 0,26$ dB/Km

All sections or linear zones must be measured.

The distance will be measured in each section, specifying the refractive index of the fiber. If the refractive index value is unknown, a value of $n = 1,465$ should be considered.

5.2.2 SPLICE MEASUREMENTS

In the access network there will only be splices in the ODF, the DP and the customer's outlet, if the customer has requested the service.

All splices must be measured from the ODF to DP or customer's house. Attenuation is measured using an OTDR in 2nd and 3rd window (1310 and 1550 nm).

Splice attenuation must be lower than 0,15 dB in 1310 and 1550 nm.

If a splice exceeds the previous limit or it has apparent gain higher than 0,30 dB the measurement must be repeated from the opposite end (if possible). Splice attenuation value is the means between the measured values from both ends, measured sign must be respected.

NOTE: Only if it is not possible to measure the splice from both ends, attenuation must be less than 0,35 dB in 1310 nm and 1550 nm. (Nominal attenuation is 0,15 dB and 0,20 dB is the additional margin for measuring in one direction)

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If the splice exceeds the limit, it must be repeated.

If splices are very close and cannot be measured individually, they must be measured as one. The whole value must be lower than 0,25 dB (0,20 dB additional margin could be added if the measure can be done only in one direction).

5.2.3 CONNECTOR MEASUREMENTS

Initial connectors of the network must be measured using a launch fiber finished on a compatible connector and adapter. This launch fiber must be long enough to save the dead zone of the measurement equipment.

Internal connectors of network could be measured as a splice, without any launch fiber.

Connectors must be measured by OTDR from the ODF. Attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm). If required, connectors could be also measured from the customer's outlet or OTB.

Connector attenuation must always be lower than 0,55 dB in 1310 and 1550 nm, this value includes the pigtail splice (Nominal attenuation is 0,35 dB and 0,20 dB is the additional margin for measuring in one direction).

If required, return loss must be measured in 2nd and 3rd window (1310 and 1550 nm) from one end. Connector return loss must be higher than 45 dB (for PC connector) and 60 dB (for APC connector).

If a connector exceeds the previous limit, it must be cleaned or substituted.

5.2.4 MAXIMUM INSERTION LOSS

As a summary of the above points, the maximum attenuation allow is determinate by the following formula:

$$A = (L \times \alpha_T) + (N_S \times \alpha_S) + (N_C \times \alpha_C)$$

where:

- **L**: Fiber length (km)
- **α_T** : maximum fiber attenuation coefficient according to the table in paragraph 5.2.1
- **N_S** : splices number. Pigtail splices must be included
- **α_S** : 0,10 dB
- **N_C** : connections number
- **α_C** : 0,25 dB

Their causes (splices, optical fiber attenuation, connectors) must be analyzed if maximum attenuation is higher.

Measurement could be done using a laser source and a power meter, from the ODF to the outlet if the customer has requested the service or using an OTDR from the ODF.

It must be done at the working wavelengths. In general, the measurement is done at 1310 and 1550 nm, unless otherwise indicated.

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6. DISTRIBUTED SPLITTING ARCHITECTURE MEASUREMENT

6.1 BACKHAUL NETWORK MEASUREMENT

Once the installation has been completed, the backhaul network optical links must be certificated. For certification the characteristics to be checked are:

- Optical fiber attenuation
- Splices insertion loss
- Connector's insertion and return loss
- Maximum insertion loss
- PMD (If required)

6.1.1 OPTICAL FIBER ATTENUATION

Optical fiber attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm) using an OTDR.

All the optical fiber of the installed cable must be measured.

Attenuation measurement must be done between two points as far away as possible within the linear zone of the reflectometric trace. Attenuation limits are:

- λ : 1310 nm, $\alpha_{\max} \leq 0,37$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,24$ dB/Km
- λ : 1625 nm, $\alpha_{\max} \leq 0,26$ dB/Km

All sections or linear zones must be measured.

The distance will be measured in each section, specifying the refractive index of the fiber. If the refractive index value is unknown, a value of $n = 1,465$ should be considered.

In the 10 % of the sections the following limits could be admitted:

- λ : 1310 nm, $\alpha_{\max} \leq 0,42$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,29$ dB/Km

Average value of all sections of an optical fiber must be always less than the attenuation limits.

Measurement in 4th window (1625 nm) could be required.

6.1.2 SPLICE MEASUREMENTS

All splices must be measured using an OTDR from both ends of the link. Attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm).

Splice attenuation value is calculated as the medium value between the measured values from both ends, measured sign must be respected.

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Splice attenuation must always be lower than 0,15 dB in 1310 and 1550 nm. If a splice exceeds the previous limit, it must be repeated.

If splices are very close and cannot be measured individually, they must be measured as one. The whole value must be lower than 0,25 dB.

Average splice losses in an optical fiber link must be lower than 0,10 dB.

6.1.3 CONNECTOR MEASUREMENTS

Initial connectors of the section must be measured using a launch fiber finished on a compatible connector and adaptor. This launch fiber must be long enough to save the dead zone of the measurement equipment.

Internal connectors of the section must be measured as a splice, without any launch fiber.

All connectors must be measured by OTDR from both ends. Attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm). Connector attenuation value is calculated as the medium value between the measured values from both ends, measured sign must always be respected.

Connector attenuation must be always lower than 0,35 dB in 1310 and 1550 nm. This value includes the pigtail splice.

Return loss must be measured in 2nd and 3rd window (1310 and 1550 nm) from one end. Connector return loss must be higher than 45 dB (for PC connector) and 60 dB (for APC connector).

If a connector exceeds the previous limit, it must be cleaned or substituted.

6.1.4 MAXIMUM INSERTION LOSS

Total attenuation must be measured between connectors finished on an Optical Distribution Frame (ODF) using a laser source and a power meter.

The measuring devices must be calibrated.

Measurement must be done on each optical fiber at the working wavelengths. In general, the measurement should be done at 1310 and 1550 nm, unless otherwise indicated in the project.

Maximum attenuation allowed is determined by the following formula:

$$A = (L \times \alpha_T) + (N_S \times \alpha_S) + (N_C \times \alpha_C)$$

where:

- **L**: Fiber length (km)
- **α_T** : maximum fiber attenuation coefficient according to the limits in paragraph 6.1.1
- **N_S** : splices number. Pigtail splices must be included
- **α_S** : 0,10 dB
- **N_C** : connections number
- **α_C** : 0,25 dB

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This test will always be done between connectors.

6.1.5 *PMD*

If required in the project, PMD must be measured.

PMD coefficient measured must be $\leq 0,20 \text{ ps/km}^{1/2}$.

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6.2 ACCESS NETWORK MEASUREMENT

Access network includes:

- The optical cable that connect the Headend POP and the Feeder Point (FP)
- The optical cable that links the FP and the Urban Distribution Point (UDP)
- The optical fiber unit that connect the UDP and the Optical Termination Box (OTB), Optical Termination Outlet (OTO) or Indoor DP64.

The splitters could be located centralized in the UDP, distributed in the UDP and OTB or centralized in the Indoor DP64.

In the FP, a fusion splice is made between the fiber of the optical cable from the ODF and the fiber of the optical cable that reaches the UDP.

In the UDP, a fusion splice is made with the input fiber of the splitters and the fiber of the cables from the FP. Another fusion splice is made between the output fibers of the splitters and the fibers of optical fiber units that reaches the OTB or OTO. An additional fusion splice is needed to connect the two levels of splitting if they are centralized in the UDP.

In the OTB, a fusion splice is made between the input fiber of the splitter and the fiber of the fiber unit from the UDP.

In the OTO the optical fiber is connectorized in a pigtail LC/APC by a fusion splice.

In case an Indoor DP64 is needed, the splitters located in the UDP are not used. In the UDP a fusion splice is made between the fiber of the optical cable from the FP and the fiber of the fiber units that reaches the Indoor DP64. Two levels of splitting are located in the indoor DP64, so the fiber of the fiber unit must be spliced with the input fiber of the first level of splitters. An additional fusion splice is needed to connect the two levels of splitting.

In this way, various fusion splices and splitters can be identified in the access network.

The access network optical links and installation must be certificated in two sections:

- Certification of the link between the Headend POP to the UDP.
- Certification of the link and installation between the OTB/OTO/Indoor DP64 and Headend POP.

6.2.1 HEADEND POP – UDP CERTIFICATION

Once the installation of the FP, UDP and the cables from the Headend POP to the UDP have been completed, it must be certificated.

For the certification the characteristics to be checked are:

- Optical fiber attenuation
- Splices insertion loss
- Connectors insertion and return loss
- Maximum insertion loss

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NOTE: In case an Indoor DP64 is needed, the measurement must be carried out up to the Indoor DP64.

That is, the measurement must always be carried out from de Headen POP to the first level of splitting.

NOTE: This measurement must not evaluate the splitters.

6.2.1.1 OPTICAL FIBER ATTENUATION

Optical fiber attenuation must be measure in 2nd and 3rd window (1310 and 1550 nm). All the optical fibers of the installed cable must be measured.

The attenuation measurement must be done from ODF to the UDP or Indoor DP64 using an OTDR. Attenuation limits are:

- λ : 1310 nm, $\alpha_{\max} \leq 0,37$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,24$ dB/Km
- λ : 1625 nm, $\alpha_{\max} \leq 0,26$ dB/Km

All sections or linear zones must be measured.

The distance will be measured in each section, specifying the refractive index of the fiber. If the refractive index value is unknown, a value of $n = 1,465$ should be considered.

6.2.1.2 SPLICE MEASUREMENTS

In this section of the access network there will be splices in the ODF, the FP, the UDP and the Indoor DP64.

All splices must be measured from the ODF to UDP or Indoor DP64. Attenuation is measured using an OTDR in 2nd and 3rd window (1310 and 1550 nm).

NOTE: It is not possible evaluate the fusion splice in the input fiber of the first level of splitting.

Splice attenuation must be lower than 0,15 dB in 1310 and 1550 nm.

If a splice exceeds the previous limit or it has apparent gain higher than 0,30 dB the measurement must be repeated from the opposite end (if possible). Splice attenuation value is the means between the measured values from both ends, measured sign must be respected.

NOTE: Only if it is not possible to measure from both ends the splice, attenuation must be less than 0,35 dB in 1310 nm and 1550 nm. (Nominal attenuation is 0,15 dB and 0,20 dB is the additional margin for measuring in one direction)

If the splice exceeds the limit, it must be repeated.

If splices are very close and cannot be measured individually, they must be measured as one. The whole value must be lower than 0,25 dB (0,20 dB additional margin could be added if the measure can be done only in one direction).

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6.2.1.3 CONNECTOR MEASUREMENTS

Initial connectors of the network must be measured using a launch fiber finished on a compatible connector and adapter. This launch fiber must be long enough to save the dead zone of the measurement equipment.

Connectors must be measured by OTDR from the ODF. Attenuation must be measured in 2nd and 3rd window (1310 and 1550 nm).

Connector attenuation must always be lower than 0,55 dB in 1310 and 1550 nm, this value includes the pigtail splice (Nominal attenuation is 0,35 dB and 0,20 dB is the additional margin for measuring in one direction).

If required, return loss must be measured in 2nd and 3rd window (1310 and 1550 nm) from one end. Connector return loss must be higher than 45 dB (for PC connector) and 60 dB (for APC connector).

If a connector exceeds the previous limit, it must be cleaned or substituted.

6.2.1.4 MAXIMUM INSERTION LOSS

As a summary of the above points, the maximum attenuation allow is determinate by the following formula:

$$A = (L \times \alpha_T) + (N_S \times \alpha_S) + (N_C \times \alpha_C)$$

where:

- **L**: Fiber length (km)
- **α_T** : maximum fiber attenuation coefficient according to the table in paragraph 6.2.1.1
- **N_S** : splices number. Pigtail splices must be included
- **α_S** : 0,10 dB
- **N_C** : connections number
- **α_C** : 0,25 dB

Their causes (splices, optical fiber attenuation, connectors) must be analyzed if maximum attenuation is higher.

Measurement could be done using an OTDR from the ODF to the UDP or Indoor DP64. That is, the measurement must always be carried out from de Headen POP to the first level of splitting.

It must be done at the working wavelengths. In general, the measurement is done at 1310 and 1550 nm, unless otherwise indicated.

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6.2.2 OTB - HEADEND POP CERTIFICATION

Once all the installation from the Headend POP to the OTB/OTO/Indoor DP64 has been completed, it must be certificated.

For the certification the characteristics to be checked are:

- Optical fiber attenuation
- Splices insertion loss
- Splitters insertion
- Connectors insertion and return loss
- Maximum insertion loss

In this case, the certification measure must be carried out from the OTB/OTO/Indoor DP64 to the ODF located in the Headend POP.

6.2.2.1 OPTICAL FIBER ATTENUATION

Optical fiber attenuation must be measure in 4th window (1625 nm). At least, one optical fiber of each second level splitter must be measured.

The attenuation measurement must be done from the OTB/OTO/Indoor DP64 to the ODF using an OTDR. Attenuation limits are:

- λ : 1310 nm, $\alpha_{\max} \leq 0,37$ dB/Km
- λ : 1550 nm, $\alpha_{\max} \leq 0,24$ dB/Km
- λ : 1625 nm, $\alpha_{\max} \leq 0,26$ dB/Km

All sections or linear zones must be measured.

The distance will be measured in each section, specifying the refractive index of the fiber. If the refractive index value is unknown, a value of $n = 1,465$ should be considered.

6.2.2.2 SPLICE MEASUREMENTS

In this section of the access network there will be splices in the ODF, the FP, the UDP and OTB/OTO or Indoor DP64.

All splices must be measured from the OTB/OTO or Indoor DP64 to the ODF. Attenuation must be measured using an OTDR in 4th window (1625 nm).

NOTE: It is not possible evaluate the fusion splice made in the fibers of the splitters. They must be evaluated together with the splitter attenuation.

Splice attenuation must be lower than 0,15 dB in 1625 nm.

If a splice exceeds the previous limit or it has apparent gain higher than 0,30 dB the measurement must be repeated from the opposite end (if possible). Splice attenuation value is the means between the measured values from both ends, measured sign must be respected.

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NOTE: Only if it is not possible to measure from both ends the splice, attenuation must be less than 0,35 dB in 1625 nm. (Nominal attenuation is 0,15 dB and 0,20 dB is the additional margin for measuring in one direction)

If the splice exceeds the limit, it must be repeated.

If splices are very close and cannot be measured individually, they must be measured as one. The whole value must be lower than 0,25 dB (0,20 dB additional margin could be added if the measure can be done only in one direction).

6.2.2.3 SPLITTER MEASUREMENTS

The splitters could be located centralized in the UDP, distributed in the UDP and OTB or centralized in the Indoor DP64.

Splitters must be measured by OTDR from the OTB/OTO or Indoor DP64. Attenuation must be measured using an OTDR in 4th window (1625 nm).

Splitter attenuation depend on the level of division. In the UGG access network only splitters 1x4 and 1x16 are used and it must always be lower than:

- Splitter 1 to 4, Att. \leq 7,8 dB
- Splitter 1 to 16, Att. \leq 14,2 dB

If the splitters are very close and cannot be measured individually, they could be measured as one. The whole value must be lower than 22 dB

The attenuation of the connectors (0,25 dB) or fusion splice (0,1 dB) must be added in each case.

6.2.2.4 CONNECTOR MEASUREMENTS

Initial connectors of the network must be measured using a launch fiber finished on a compatible connector and adapter. This launch fiber must be long enough to save the dead zone of the measurement equipment.

Connectors must be measured by OTDR from the OTB/OTO or Indoor DP64. Attenuation must be measured in 4th window (1625 nm).

Connector attenuation must always be lower than 0,55 dB in 1625 nm, this value includes the pigtail splice (Nominal attenuation is 0,35 dB and 0,20 dB is the additional margin for measuring in one direction).

If required, return loss must be measured in 4th window (1625 nm) from one end. Connector return loss must be higher than 45 dB (for PC connector) and 60 dB (for APC connector).

If a connector exceeds the previous limit, it must be cleaned or substituted.

6.2.2.5 MAXIMUM INSERTION LOSS

Total attenuation could be measured between the ODF connectors and the OTO, OTB or Indoor DP64 connectors using a laser source and a power meter.

The measuring devices must be calibrated.

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Measurement must be done on each optical fiber at the working wavelengths. In general, the measurement should be done at 1310 and 1550 nm, unless otherwise indicated in the project.

The maximum attenuation allow is determinate by the following formula:

$$A = (L \times \alpha_T) + (N_S \times \alpha_S) + (N_C \times \alpha_C) + \alpha_{sp.1} + \alpha_{sp.2}$$

where:

- **L**: Fiber length (km)
- **α_T** : maximum fiber attenuation coefficient according to the table in paragraph 6.2.2.1
- **N_S** : splices number. Pigtail splices must be included
- **α_S** : 0,10 dB
- **N_C** : connections number
- **α_C** : 0,25 dB
- **$\alpha_{sp.1}$** : maximum attenuation of the first level of splitting (dB)
- **$\alpha_{sp.2}$** : maximum attenuation of the second level of splitting (dB)

Their causes (splices, optical fiber attenuation, connectors and splitters) must be analyzed if maximum attenuation is higher.

This measurement could also be carried out using an OTDR from the OTB/OTO or Indoor DP64 to the ODF. It must be done at the supervision wavelengths (4th window, 1625 nm) because the OLT could be operating.

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OLT OPTICAL POWER MEASUREMENT

Once the whole network from the Headend POP to the OTB/OTO or Indoor DP64 has been completed, the optical signal from the OLT (Optical Line Termination) could be measured in the OTB/OTO or Indoor DP64.

It is necessary that the OLT is operating and the connection in the ODF between the IPV and the OPV is done.

The optical signal from the OLT must be measured in the OTB/OTO or Indoor DP64 connectors using an optical power meter in 1490 nm (OLT transmission wavelength).

The measuring device must be calibrated.

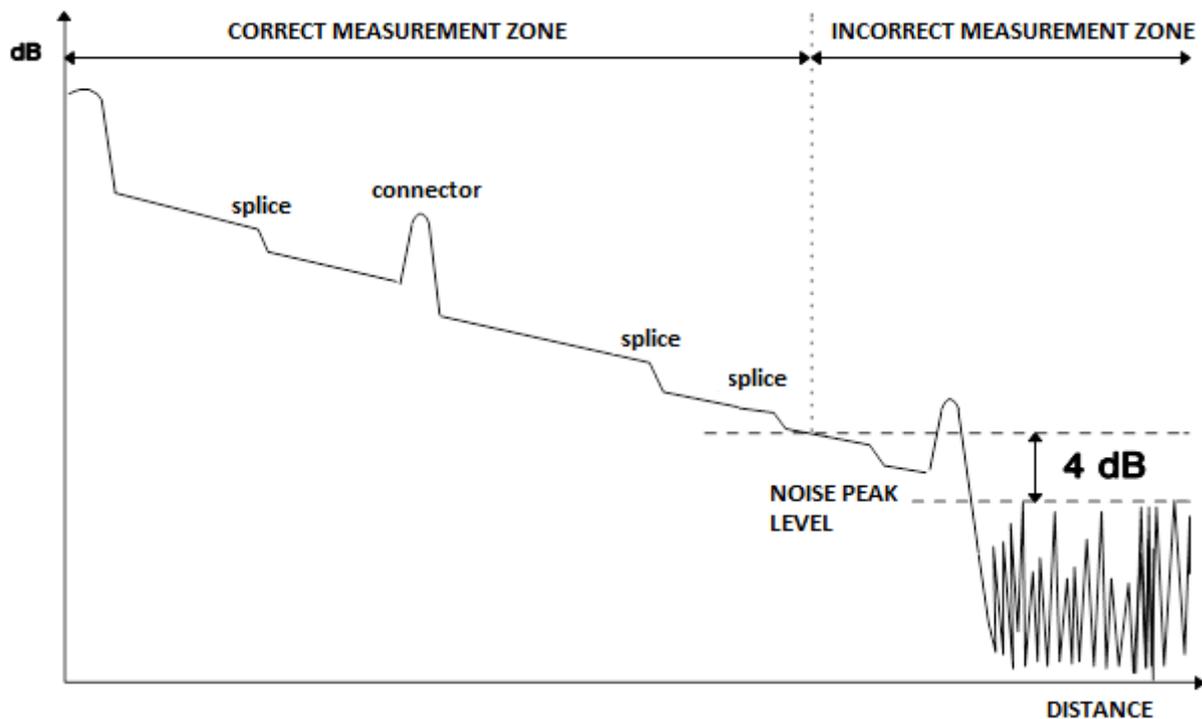
ANNEX 1: OTDR MEASUREMENT CONFIGURATION GUIDELINES

The measurement using OTDR (Optical Time Domain Reflectometer) is based on the analysis of reflections and scattering (Rayleigh) that occur along the optical fiber when sending a pulsed light signal.

Through OTDR measurement, it is possible to evaluate the continuity of optical fibers, detect faults and measure splices, connectors, attenuation between two points, linear attenuation, length, and punctual return losses.

OTDR measurements can be performed at different wavelengths: 1310 nm, 1550 nm or 1625/1650 nm, i.e. 2nd, 3rd or 4th optical window. In the 3rd and 4th window, the measurements are more sensitive to possible curvatures or tensions in the fiber, which allows installation defects to be detected more easily than in the 2nd window.

The optical signal level received by the OTDR in the measurements is very low, and it decreases as the distance increases, so the signal to noise ratio also decreases with it. The accuracy of the measurement at a given point depends on the signal/noise ratio at that point. **To ensure reliability, all measurements must be made 4 dB above the peak noise level and the final ripple lower than 0,2 dB.**



For this reason, it is essential to use OTDR equipment with sufficient dynamic range. Dynamic range determines the total optical loss that an OTDR can analyze. The higher the dynamic range, the greater the distance an OTDR can analyze, while if the dynamic range is insufficient, the measurement of splice or connector losses or far-end fiber optic attenuation will not be accurate. **As a rule, the dynamic range of an OTDR should be at least 8 dB greater than the maximum expected loss of the link.**

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The “signal to noise ratio” (SNR) can be improved by increasing the number of averages and increasing the width of the OTDR's measurement pulse. However, the spatial resolution of the measurements depends on the width of the pulses used. There is a trade-off between better resolution and measurement range.

Therefore, it is essential to properly configure the OTDR measurement parameters to obtain accurate and reliable measurements. **As a rule, the pulse width used will be the smallest possible as long as the condition of 4 dB above the noise peak level and the final ripple lower than 0,2 dB is met.**

MEASUREMENT PROCEDURE

Before starting the measurement, it must be ensured that the OTDR equipment has sufficient dynamic range to perform the measurement correctly and that it complies with the regulations corresponding to metrological control.

Additionally, due to the Fresnel effect, OTDRs present a “blind zone” at the beginning of the traces in which no type of measurement can be made. To avoid this phenomenon, a launch fiber of at least 1000 meters in length must be used. This fiber must not have fusions and will be directly connected with the appropriate connector for the installation and the measurement equipment.

The personnel who carry out the measurements must comply with the Safety and Hygiene at Work Regulations regarding precautions to avoid eye risks.

During the manipulation of equipment connectors, distributors and pigtails, maximum cleanliness must be maintained to guarantee the adequate measurement. The cleaning and verification procedures for connectors must be always followed.

The OTDR measurement should always be carried out bidirectionally (if it is possible), that is, in both directions of the link to guarantee an adequate evaluation of the results and that the attenuation values obtained are reliable. The measurement must be carried out, if possible, with the same OTDR equipment and its configuration must be identical for each of the direction.

OTDR SETUP

The most important parameters that must be conveniently configured for measurement with an OTDR device are detailed below:

PULSE WIDTH

It will try to select the shortest possible pulse width to maximize the resolution of the measurement, making it easier to discriminate events that are closer together, and minimize the output energy of the measurement by reducing the "blind zone".

Shorter pulse widths result in smaller dead zones, making it more likely to detect events near a connection or splice. Larger pulse widths are needed for longer distances since more energy is required to produce sufficient backscattering over long distances.

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It is recommended to use the following pulse widths depending on the length of the link:

Length	Pulse width
< 20 km	≤ 100 ns
20 km ≤ L < 80 km	≤ 3 μs
≥ 80 km *	≤ 10 μs

*** No measurement is required at the 1310 nm wavelength. Due to the long length of this section, measurement is only required at the 1550 nm wavelength.**

In OTB - HEADEND POP certification, the measurement from the OTB/OTO/Indoor DP64 to the ODF must be carried out with a pulse width wider than its equivalent length due to splitters attenuation. In this case, it is recommended to use a pulse width of at least 1 μs.

The pulse width must be adjusted in such a way that the condition of 4 dB above the noise peak level is guaranteed. The fiber end must be clearly visible with a ripple lower than 0,2 dB.

DISTANCE RANGE

The distance range defines the pulse emission rate, so that each pulse has time to return to the detector before the next one is sent.

The value immediately greater than the expected length of the link should be selected.

If the immediately superior range is very close to the length of the link, it may be necessary to increase the selected distance range.

AVERAGE TIME

The long averaging times allow to increase the accuracy of the measurement by improving the signal/noise ratio. The greater the distance, the greater the averaging time must be.

The longest possible averaging time should be used, being at least 30 seconds.

OTHER PARAMETERS

In addition to parameterizing the OTDR equipment based on the characteristics of the installation to be characterized, the intrinsic parameters of the optical fiber must also be properly configured. For a standard single mode optical fiber according to the ITU-T Recommendation G.652.D, it is recommended to establish the following parameters:

- | | |
|--------------------|---------------------------|
| • Refractive index | • Backscatter coefficient |
| ○ 1310nm: 1,467 | ○ 1310nm: -79.4dB |
| ○ 1550nm: 1,468 | ○ 1550nm: -81.7dB |
| ○ 1625nm: 1,468 | ○ 1625nm: -82.5dB |

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ANNEX 2: OTDR REPORTS, FORMATS AND GENERAL CONSIDERATIONS

For all the OTDR fiber measurements, the following information must be provided:

- **Traces in (.sor) format:** it is essential to deliver the traces in original format (.sor) for the two wavelengths (1310 nm and 1550 nm) or the supervision wavelength (1625 nm) for each fiber and whenever possible in both directions.

- **Reports in (.pdf) format:** it is essential to provide a report in .pdf format, which must include the graphic representation of the OTDR trace and a list of events already identified with their values.

CONSIDERATIONS FOR THE (.PDF) REPORTS

Since each equipment manufacturer (for example: Viavi, Anritsu, Exfo, etc.) has its own OTDR measurement reporting application built into the measurement equipment, a specific format for PDF reports will not be required. However, these reports must include all the information relevant to the measure, although the manner of presentation may be different.

The following information or rules must be complied by the OTDR PDF report:

- **Report language:** English or German.

Note: The language must be consistent throughout the document.

- **Cable/fiber identification:**

- Cable identification. (The official name of the cable that has UGG in the project)
- Fiber identification / Fiber number. (The fiber number inside the cable).
- Origin and destination. (Origin and destination of the measure).

Note: bi-directional measurements are required (where it is possible. i.e if there are connectors at both ends), and the average of the traces in opposite directions should be reported.

- **Equipment used.** Information about the equipment used to do the measurements:
 - Brand/model and serial number. If it is integrated by interchangeable modules (brand/model and serial number of each element).
 - Date of calibration and validity period.
- **Date of realization of the measurement.**
- **Company and Technician:**
 - Company name.
 - Technician name or technician number.

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- **Measurement configuration:**

- Measurement wavelength.
- Pulse width.
- Distance Range
- Averaging time.
- Refraction index

- **Defined thresholds**

Values defined for:

- Connectors. Threshold for connector: 0.35 dB. (Fusion splice attenuation included)
- Fusion Splices. Threshold for splices: 0.15 dB.

Note 1: Threshold could be increased if the measurement can only be done in one direction (0,20 dB).

Note 2: Reports with absurd thresholds will not be accepted.

- **Link information (automatic trace analysis):**

- Total link loss (dB)
- Link return loss (dB)
- Distance to the end of the fiber
- Direction (if measurements are made in both directions, the report must include both).
- Number of events detected.
- List of events, with information on:
 - Attenuation and ORL of each event
 - Distance from the origin to the event.
 - PASS/ KO verdict