INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.53

(05/2003)

SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical fibre maintenance criteria for access networks

ITU-T Recommendation L.53

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Optical fibre maintenance criteria for access networks

Summary

This Recommendation deals with optical fibre maintenance criteria for access networks. It describes the fundamental requirements, maintenance section, testing and maintenance items, and methods for developing a suitable guide to maintaining point-to-multipoint and ring optical networks, respectively.

Source

ITU-T Recommendation L.53 was approved by ITU-T Study Group 6 (2001-2004) under the ITU-T Recommendation A.8 procedure on 14 May 2003.

FOREWORD

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CONTENTS

Introduction

Recently, networks with several types of topology including the passive optical network (PON) and the ring network using add-drop multiplexers (ADM) have been installed in the field because of the diversification of optical communication services. The point-to-multipoint and ring network architectures are very important in terms of constructing optical fibre networks both effectively and inexpensively. However, the testing and maintenance method used for conventional single star networks (see ITU-T Recs L.25 and L.40) cannot be adapted to these network architectures. Optical fibre networks have expanded rapidly because of the increase in IP services. In order to test and maintain optical fibre networks effectively, it is necessary to establish identical maintenance criteria for both point-to-multipoint and ring networks.

ITU-T Recommendation L.53

Optical fibre maintenance criteria for access networks

1 Scope

This Recommendation describes the maintenance section, testing and maintenance functions, methods, and criteria for both point-to-multipoint and ring networks in the access network.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

– ITU-T Recommendation G.652 (2003), *Characteristics of a single-mode optical fibre cable*.

– ITU-T Recommendation G.694.1 (2002), *Spectral grids for WDM applications: DWDM frequency grid*.

– ITU-T Recommendation G.694.2 (2002), *Spectral grids for WDM applications: CWDM wavelength grid*.

– ITU-T Recommendation G.983.1 (1998), *Broadband optical access systems based on Passive Optical Networks (PON)*.

– ITU-T Recommendation G.983.2 (2002), *ONT management and control interface specification for B-PON*.

– ITU-T Recommendation G.983.3 (2001), *A broadband optical access system with increased service capability by wavelength allocation*.

– ITU-T Recommendation G.983.4 (2001), *A broadband optical access system with increased service capability using Dynamic Bandwidth Assignment (DBA)*.

– ITU-T Recommendation G.983.5 (2002), *A broadband optical access system with enhanced survivability*.

– ITU-T Recommendation G.983.6 (2002), *ONT management and control interface specifications for B-PON system with protection features*.

– ITU-T Recommendation G.983.7 (2001), *ONT Management and Control Interface specification for Dynamic Bandwidth Assignment (DBA) B-PON system*.

– ITU-T Recommendation G.983.8 (2003), *B-PON OMCI support for IP, ISDN, video, VLAN tagging, VC cross-connections, and other select functions*.

– ITU-T Recommendation G.984.1 (2003), *Gigabit-capable Passive Optical Networks (GPON): General characteristics*.

– ITU-T Recommendation L.25 (1996), *Optical fibre cable network maintenance*.

– ITU-T Recommendation L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system*.

– ITU-T Recommendation L.41 (2000), *Maintenance wavelength on fibres carrying signals*.

– ITU-T Recommendation L.42 (2003), *Extending optical fibre solutions into the access network*.

– ITU-T Recommendation L.52 (2003), *Deployment of Passive Optical Networks (PON)*.

– IEC 61746 Ed.1.0 (2001), *Calibration of optical time-domain reflectometers (OTDRs)*.

3 Terms and definitions

For the purpose of this Recommendation, the definitions given in ITU-T Recs G.652, G.694.1, G.694.2, G.983.1 to G.983.8, L.25, L.40, L.41, L.42, L.52, and IEC 61746 Ed.1.0 apply.

3.1 access network: A network of optical fibres that extend from a carrier's central office into individual homes and businesses, etc. for FTTH, FTTC, and so on.

3.2 point-to-multipoint access network: The access network accommodating OLT in the central office and several ONUs [L.52].

3.3 ring network: A network of loop optical fibres accommodating OLT in central office and ONU in some customer buildings [L.42].

3.4 maintenance section: An area of optical fibres that is tested and maintained in an access network.

3.5 surveillance: To monitor the condition of network elements (NE). Surveillance has two functions: to inform of NE degradation before trouble occurs, and to inform of NE abnormality when trouble occurs [L.25, L40].

3.6 control: To restore NE to normal or to take action to maintain service quality [L.25, L40].

4 Abbreviations

This Recommendation uses the following abbreviations:

ADM	Add-Drop Multiplexer
B-OTDR	Brillouin Optical Time Domain Reflectometer
CB	Customer Building
CO	Central Office
FTTC	Fibre to the Curb
FTTH	Fibre to the Home
H-OTDR	High spatial resolution Optical Time Domain Reflectometer
ID light	Identification light
OLT	Optical Line Terminal
ONU	Optical Network Unit
OTDR	Optical Time Domain Reflectometer
PON	Passive Optical Network
RT	Remote Terminal

5 Fundamental requirements

5.1 Network topologies

5.1.1 Point-to-multipoint access network

The basic configuration of a point-to-multipoint access network is shown in Figure 1.

Case 1: Indoor splitter in CO;

Case 2: Outdoor splitter (passive and active);

Case 3: Indoor splitter (passive and active) in CB.

5.1.2 Ring access network

The basic configuration of a ring access network is shown in Figure 2.

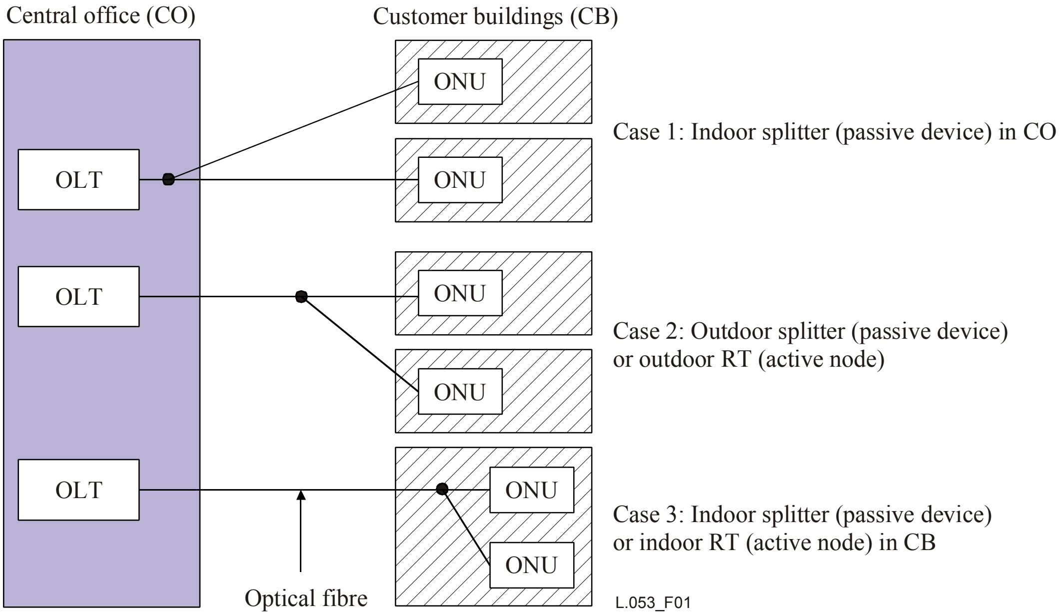

Figure 1/L.53 – Configuration of point-to-multipoint access network

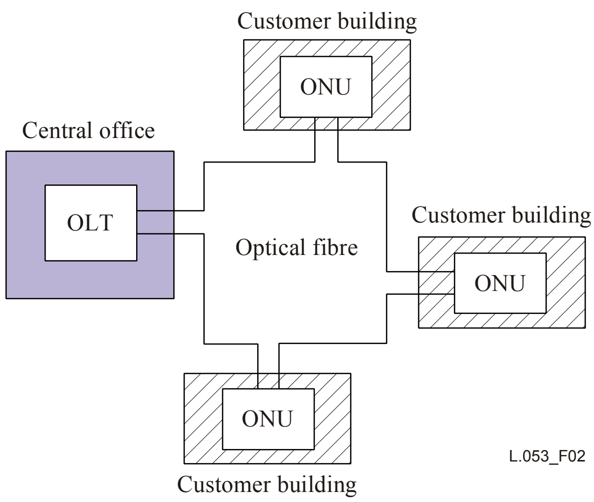

Figure 2/L.53 – Configuration of ring access network

5.2 Maintenance section

A maintenance section is classified as follows:

5.2.1 Maintenance section of point-to-multipoint access network

The maintenance sections of the point-to-multipoint access network in Figure 1 are as follows:

Case 1: Optical fibre between the OLT and the ONU as shown in Figure 1 case 1. (All sections);

Case 2: Optical fibre between the OLT and the ONU as shown in Figure 1 case 2. (All sections);

Case 3: Optical fibre between the OLT and the indoor splitter.

5.2.2 Maintenance section of ring access network

The maintenance section of the ring access network in Figure 2 consists of all sections of the ring access network.

5.3 Testing and maintenance items

5.3.1 Testing and maintenance items for point-to-multipoint access networks

Maintenance items for point-to-multipoint access networks are classified as shown in Table 1.

Table 1/L.53 – Testing and maintenance items for point-to-multipoint access networks

Category	Activity	Testing and maintenance item	Status
Preventative maintenance	Surveillance (e.g., Periodic testing, Continuous testing)	Detection of fibre loss increase Detection of signal power loss increase Detection of water penetration	Optional Optional Optional
	Testing (e.g., Fibre degradation testing)	Measurement of fibre fault location Measurement of fibre strain distribution Measurement of water location	Optional Optional Optional
	Control (e.g., Network element control)	Fibre identification Fibre transfer	Optional Optional
After installation before service or post-fault maintenance	Surveillance (e.g., Reception of transmission system alarm or customer trouble report)	Refer to alarm from path operation system Refer to alarm from customer service operation system	Optional Optional
	Testing (e.g., After installation testing, Fibre fault testing)	Confirmation of fibre condition Fault identification between transmission equipment and fibre network Measurement of fibre fault location	Required Required Required
	Control (e.g., Cable install/repair/ replacement)	Fibre identification Fibre transfer Storage of outside plant database Information on cable route	Required Optional Required Optional

5.3.2 Testing and maintenance items for ring access networks

Maintenance items for ring access networks are classified as shown in Table 2.

Table 2/L.53 – Testing and maintenance items for ring access networks

Category	Activity	Testing and maintenance item	Status
Preventative maintenance	Surveillance	Detection of fibre loss increase	Optional
		Detection of signal power loss increase	Optional
		Detection of water penetration	Optional
	Testing	Measurement of fibre fault location	Optional
		Measurement of fibre strain distribution	Optional
		Measurement of water location	Optional
	Control	Fibre identification	Optional
		Fibre transfer	Optional
After installation before service or post-fault maintenance	Surveillance	Refer to alarm from path operation system	Optional
		Refer to alarm from customer service operation system	Optional
	Testing	Confirmation of fibre condition	Required
		Fault identification between transmission equipment and fibre network	Required
		Measurement of fibre fault location	Required
	Control	Fibre identification	Required
		Fibre transfer	Optional
		Storage of outside plant database	Required
		Information on cable route	Optional

6 Testing and maintenance methods

There are several ways to implement these testing and maintenance items. OTDR testing, loss testing, monitoring a proportion of the signal power (power monitoring) and identification light detection are commonly used. The most common methods are described below.

6.1 Testing and maintenance methods for point-to-multipoint access networks

Table 3/L.53 – Suitable test methods for point-to-multipoint access networks

Category	Activity	Item	Methods
Preventative maintenance	Surveillance	Detection of fibre loss increase	OTDR/loss testing
		Detection of signal power loss increase	Power monitoring
		Detection of water penetration	OTDR testing
	Testing	Measurement of fibre fault location	OTDR testing (Note 1)
		Measurement of fibre strain distribution	B-OTDR testing
		Measurement of water location	OTDR testing (Note 1)
	Control	Fibre identification	OTDR testing (Note 1)/ID light detecting (Note 2)
		Fibre transfer	Switching (Note 3)
After installation before service or post-fault maintenance	Surveillance	Refer to alarm from path operation system	On-line/External medium
		Refer to alarm from customer service operation system	On-line/External medium
	Testing	Confirmation of fibre condition	OTDR/loss testing (Note 1)
		Fault identification between transmission equipment and fibre network	OTDR/loss testing (Note 1)
		Measurement of fibre fault location	OTDR testing (Note 1)
	Control	Fibre identification	OTDR testing (Note 1)/ID light detecting (Note 2)
		Fibre transfer	Switching (Note 3)
		Storage of outside plant database	On-line/External medium
		Information on cable route	On-line/External medium

NOTE 1 – High spatial resolution OTDR (H-OTDR) is available for monitoring optical fibres to and beyond an outside splitter.

NOTE 2 – ID light means an identification light, for example a 270 Hz, 1 kHz, or 2 kHz modulated light.

NOTE 3 – Switching includes mechanical and manual switching.

6.2 Testing and maintenance methods for ring access networks

Table 4/L.53 – Suitable test methods for ring access networks

Category	Activity	Item	Methods
Preventative maintenance	Surveillance	Detection of fibre loss increase	OTDR/loss testing
		Detection of signal power loss increase	Power monitoring
		Detection of water penetration	OTDR testing
	Testing	Measurement of fibre fault location	OTDR testing
		Measurement of fibre strain distribution	B-OTDR testing
		Measurement of water location	OTDR testing
	Control	Fibre identification	ID light detecting (Note 1)
		Fibre transfer	Switching (Note 2)
After installation before service or post-fault maintenance	Surveillance	Refer to alarm from path operation system	On-line/External medium
		Refer to alarm from customer service operation system	On-line/External medium
	Testing	Confirmation of fibre condition	OTDR/loss testing
		Fault identification between transmission equipment and fibre network	OTDR/loss testing
		Measurement of fibre fault location	OTDR testing
	Control	Fibre identification	ID light detecting (Note 1)
		Fibre transfer	Switching (Note 2)
		Storage of outside plant database	On-line/External medium
		Information on cable route	On-line/External medium
NOTE 1 – ID light means identification light such as 270 Hz, 1 kHz, 2 kHz modulated light. NOTE 2 – Switching includes mechanical and manual switching.			

7 Testing and maintaining wavelength

It is important to choose the correct wavelength for monitoring and testing optical fibre networks. Specifically, maintenance functions have to be performed without interfering with data transmission signals. ITU-T Rec. L.41 provides general requirements for the selection of the maintenance wavelength. Table 5 expands on these requirements and appropriate wavelengths for given testing and maintaining items that are the same for both point-to-multipoint and ring access networks.

Table 5/L.53 – Maintenance wavelength selection

Category	Activity	Item	Wavelength
Preventative maintenance	Surveillance	Detection of fibre loss increase	Maintenance wavelength (Note)
		Detection of signal power loss increase	Signal wavelength
		Detection of water penetration	Any wavelength on fibres not carrying signals
	Testing	Measurement of fibre fault location	Any wavelength on fibres not carrying signals
		Measurement of fibre strain distribution	Any wavelength on fibres not carrying signals
		Measurement of water location	Any wavelength on fibres not carrying signals
	Control	Fibre identification	Maintenance wavelength (Note)
		Fibre transfer	None
After installation before service or post-fault maintenance	Surveillance	Refer to alarm from path operation system	None
		Refer to alarm from customer service operation system	None
	Testing	Confirmation of fibre condition	Any wavelength
		Fault identification between transmission equipment and fibre network	Any wavelength
		Measurement of fibre fault location	Any wavelength
	Control	Fibre identification	Any wavelength
		Fibre transfer	None
		Interface with outside plant database	None
		Interface with mapping system	None
NOTE – Refer to ITU-T Rec. L.41, Maintenance wavelength on fibres carrying signals.			

Appendix I

Practical solutions for point-to-multipoint access network

I.1 Japanese experience

This appendix describes a fault identification method using a high-resolution optical time domain reflectometer for point-to-multipoint optical networks.

I.1.1 Introduction

Broadband network provision will require the use of thousands of optical fibres in optical access networks. An optical fibre line testing system is essential for reducing construction and maintenance costs and improving service reliability. We have already developed such a system called AURORA (AUtomatic optical fibeR OpeRAtion support system) [1]. In addition, we have extended the application of this system to various network structures [2]. Now, passive optical networks (PONs) with optical splitters installed in optical closures and cabinets near customers' premises are being introduced into access networks to provide high-speed IP services [3]. However, this testing system is incapable of monitoring the optical fibre cables of PONs with branched optical fibres. Therefore, we designed and evaluated a prototype system that can isolate optical fibre faults in PONs.

I.1.2 Optical fibre line testing system for PON

I.1.2.1 System configuration

Figure I.1 shows the configuration of our optical fibre line testing system for monitoring PON with an optical splitter installed in an aerial optical closure. It consists of test equipment (TE) containing an optical time domain reflectometer (OTDR), optical fibre selectors (FS) that select test fibres, optical couplers and optical filters. The TE and FSs are installed in the cable termination room of a central office. Optical couplers introduce a test light into fibre lines and optical filters installed in the front of an optical line terminal (OLT) and optical network units (ONUs) allow the communication light to pass but cut off the test light. The optical filters installed in the front of the ONUs reflect the test light from the OTDR for isolating fibre fault. The control terminal orders the TE to perform various optical fibre tests through a data communication network (DCN). The TE controls the OTDR and FSs, and returns the test results to the control terminal. This system carries out automatic OTDR measurements, reveals fibre characteristics and isolates faults and their location with no degradation in transmission quality.

There are two methods for monitoring the branched optical fibre network of a PON using an OTDR. One involves measuring backscattered light from branched optical fibres [4]. This approach is suitable for locating fault optical fibres when each branched optical fibre is over 100 m long. We chose the second method, which involves measuring the individual reflection values of optical filters installed in front of the ONU [5] because the length of each branched optical fibre between a splitter and an ONU is less than 100 m.

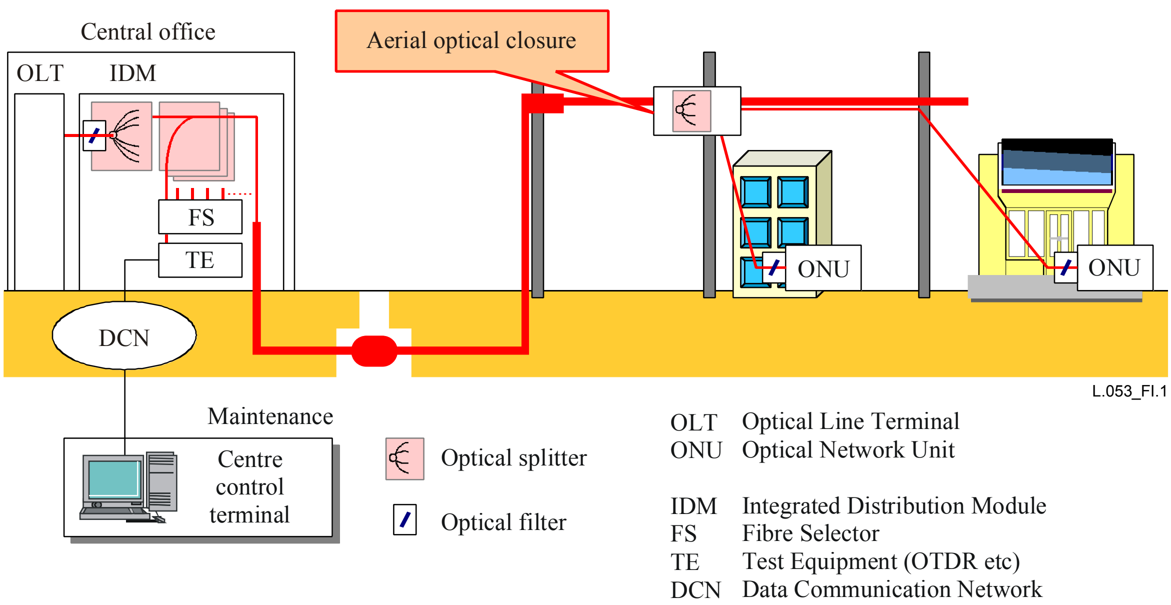

Figure I.1/L.53 – Configuration of optical fibre line testing system for monitoring

I.1.2.2 Fault isolation technique

Figure I.2 shows the fault isolation technique for branched optical fibres with an optical splitter. As the lengths of the branched optical fibres are different, the Fresnel reflections from optical filters #1 and #2 can be distinguished. We can determine that the optical fibre with optical filter #1 is faulty because the reflection value of optical filter #1 changes from its initial level.

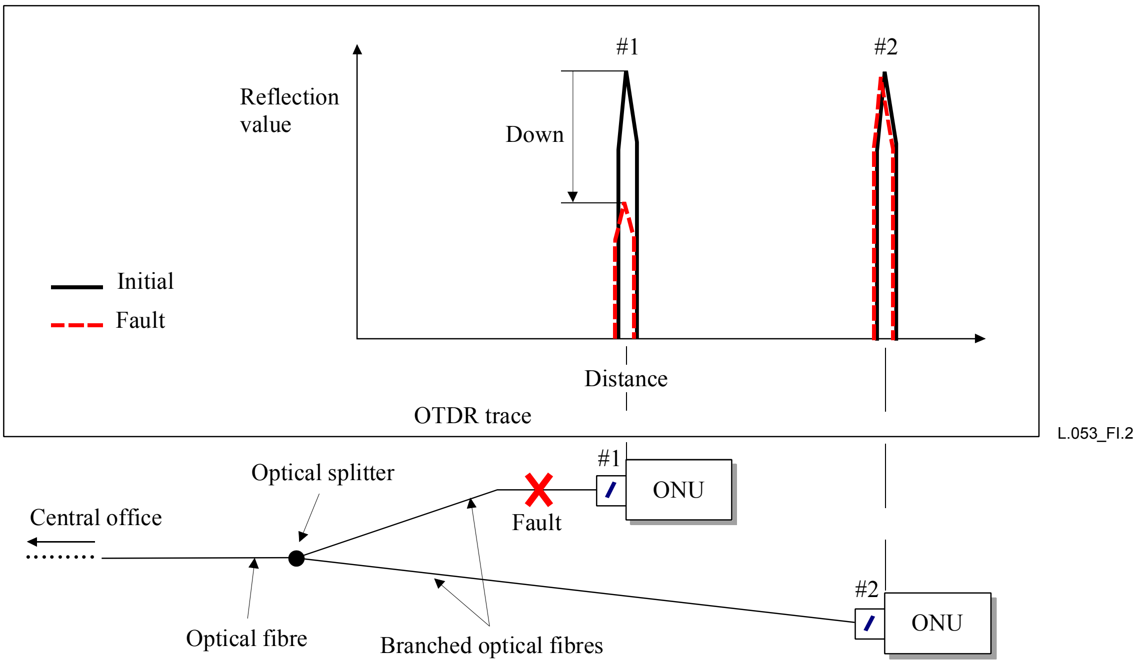

Figure I.2/L.53 – Branched optical fibre fault isolation

I.1.3 Evaluation of prototype system

I.1.3.1 Experimental setup

Figure I.3 shows the experimental setup we used for our prototype system evaluation and a measured high resolution OTDR (H-OTDR) trace of branched optical fibres with a 4-branch optical splitter. The H-OTDR wavelength was 1.65 µm and the pulse width was less than 10 ns. The Fresnel reflection of #1 is from the end of the branched optical fibre. The Fresnel reflections of #2 and #3 are from the optical filters. We applied fibre Bragg grating technologies to the optical filters to obtain a high return loss [6]. The optical filter must also allow communication lights to pass whose wavelengths are 1.3 and 1.55 µm, but cut off the test light whose wavelength is 1.65 µm. The return losses of the end of branched optical fibre #1 and optical filters #2 and #3 were –14.9, –1.5, and –1.8 dB at 1.65 µm, respectively.

I.1.3.2 Comparison of reflection values from optical filters and ends of branched optical fibres

We measured the difference between the insertion losses of branched optical fibres #1 and #2 including a 4-branch optical splitter using a 1.65 µm light source and an optical power meter. The difference was 0.7 dB at 1.65 µm. The reflection value of optical filter #2 was 6.2 dB higher than that of the end of branched optical fibre #1 in the H-OTDR trance. From these results, we confirmed that the reflection value from each optical filter was higher than those from the ends of the branched optical fibres.

I.1.3.3 Fault isolation resolution

We evaluated the fault isolation resolution of this prototype system. Figure I.3 shows that we can distinguish the Fresnel reflections from optical filters #2 and #3 whose distance differed by 2.0 m. We confirmed that our prototype system could isolate a fault in an optical fibre when the difference between the distances of the branched optical fibres is more than 2.0 m.

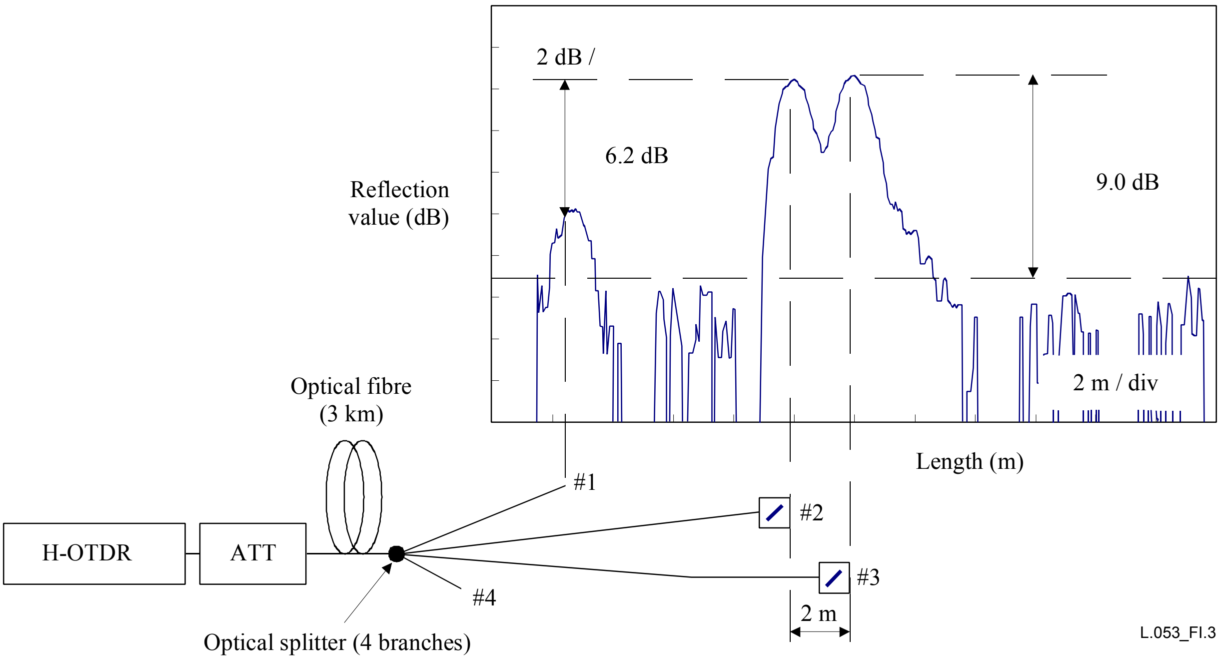

Figure I.3/L.53 – Experimental setup for prototype system evaluation and measured H-OTDR trace

I.1.3.4 System dynamic range

We evaluated the dynamic range of this prototype system. We measured the insertion loss from the H-OTDR to the front of optical filter #3 using a 1.65 µm light source and an optical power meter. The insertion loss was 24.7 dB. The difference between the reflection values of optical filter #3 and the peak noise level was 9.0 dB in the H-OTDR trace. Therefore, the dynamic range of this prototype system was over 31.5 dB at 1.65 µm when the optical filter return loss was over –2.5 dB and the fault isolation threshold value was 1.9 dB. This prototype system could isolate a faulty fibre in a PON with a 32-branch splitter whose insertion loss was 17.5 dB and with 10 km fibres (0.5 dB/km) when the coupling loss including that of an FS and an optical coupler was below 9.0 dB.

I.1.4 Conclusions

We described the fault fibre isolation function of an optical fibre line testing system based an H-OTDR and optical filters using fibre Bragg grating technologies for a PON. We evaluated a prototype system and its dynamic range was over 31.5 dB. We confirmed that this prototype system has sufficient dynamic range for isolating fibre faults in a PON with a 32-branch optical splitter.

References

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Appendix II

Practical solutions for ring access network

II.1 Indonesian experience

This appendix describes the Synchronous Digital Hierarchy (SDH) Test Light module that is used in SDH Ring Optical Access Network (OAN) topology.

II.1.1 Introduction

The module is used mainly in the following situation:

- when it is necessary to bypass an Add Drop Multiplexer (ADM) and carry test light in order to monitor SDH Ring topology.

In this situation, the SDH Test Light module splits the test light (1550 or 1650 nm wavelength) from the information light at the ADM input section to recombine them at the ADM output. This avoids interference or attenuation of the test signal.

II.1.2 SDH test light module

In order to allow the optical overstepping of ADM line terminals, Telkom Automatic Remote Optical Fiber Operation Support System (T-AURORA) – The Indonesian version of Optical Fibre outside plant maintenance support, monitoring, and testing system – or Manual Optical Time Domain Reflectometer (OTDR) system uses SDH Test Light.

This SDH Test Light module is made up of two WDM couplers and is located at the ADM line terminals sites; each WDM 1310/1550 nm arm connects the line to east/west ADM arm, while 1650 nm arms allows the test light sent by the OTDR to step over ADM (Figure II.1.1).

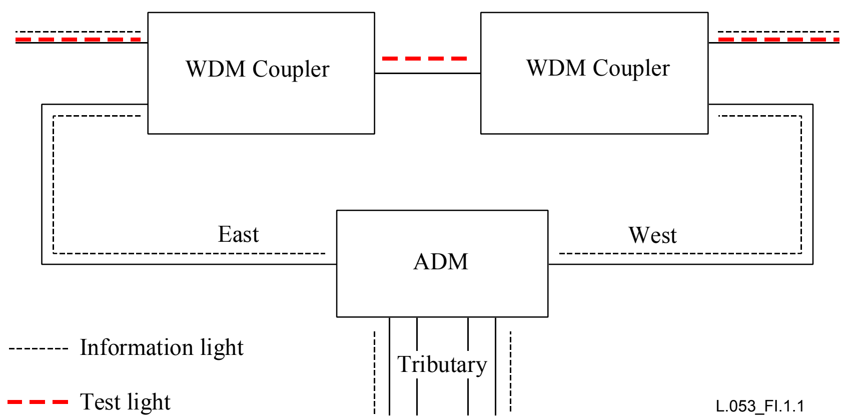


Figure II.1.1/L.53 – SDH test light module

In our case, SDH Test Light module is divided into 2 types (based on the application in the field):

1) **Model A**

   Information and test light use 1310 and 1550 nm wavelength consecutively. The uniqueness of this module is that the input of information light, and the input of test light, can be interchangeable. Non-integrated Operation Support System (OSS) such as Manual OTDR is used as test light source.

2) **Model B**

   This module is suited for supporting T-AURORA system where 1310/1550 nm is used for information light, and 1650 nm wavelength is dedicated to test light.

The differentiation between Model A and B is on the wavelength used for each information light and test light. On implementation, filtering on each ADM input and output is required to avoid the test light entering the ADM.

Prototype of SDH test light module (Model A) is depicted in Figure II.1.2.

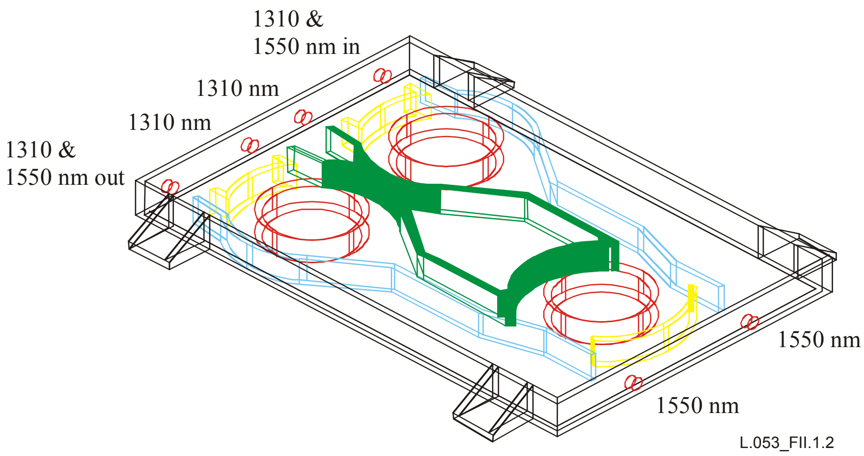


Figure II.1.2/L.53 – Prototype of SDH test light module (Model A)

The insertion of the SDH Test Light module contributes significantly in the monitoring of the physical optical cable in SDH ring topology. Without the SDH test light module, the monitoring capability of OTDR or T-AURORA is limited up to the nearest ADM span (Figure II.1.3).

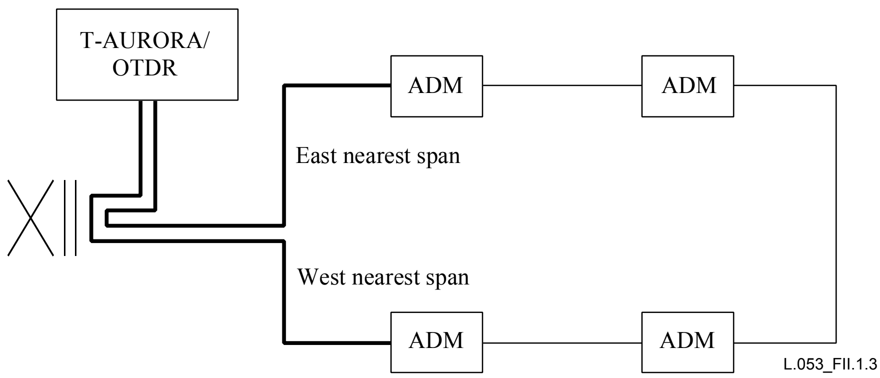


Figure II.1.3/L.53 – Monitoring optical cable without inserting SDH test light

Introduction SDH test light module in SDH ring enhances the capability of carrying test light to all spans in ring by over stepping ADM (Figure II.1.4).

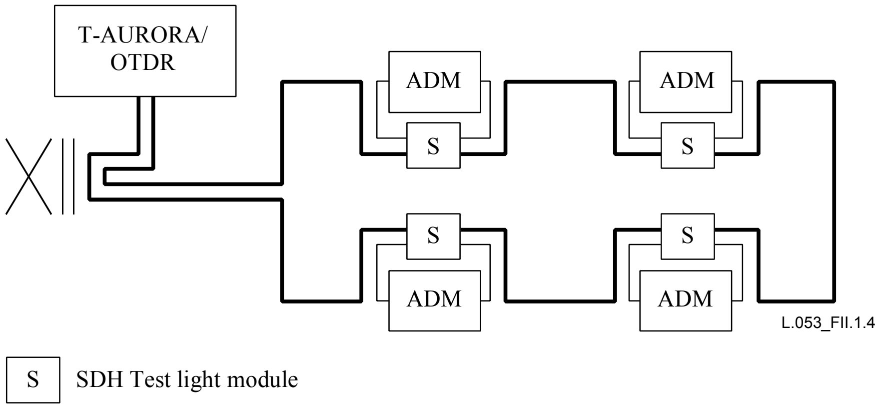


Figure II.1.4/L.53 – Insertion SDH test light in SDH ring OAN

II.1.3 OTDR trace simulation of SDH test light module

The simulation has been set up to analyze the performance and how the SDH test light module works in SDH ring. The configuration is shown in Figure II.1.5.

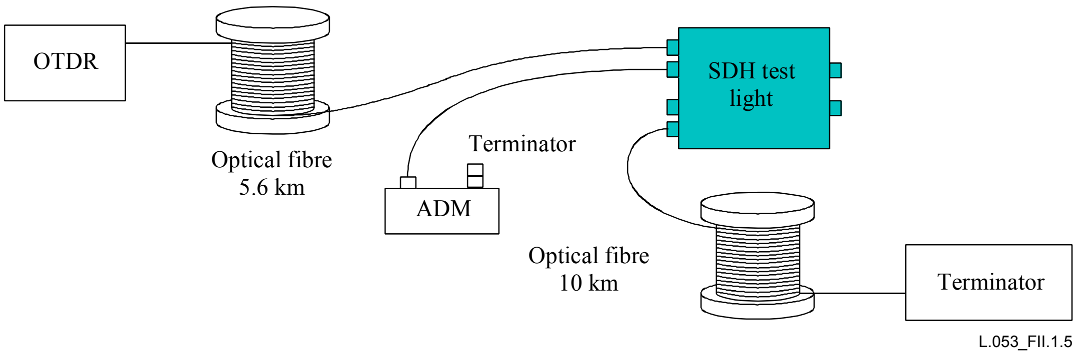
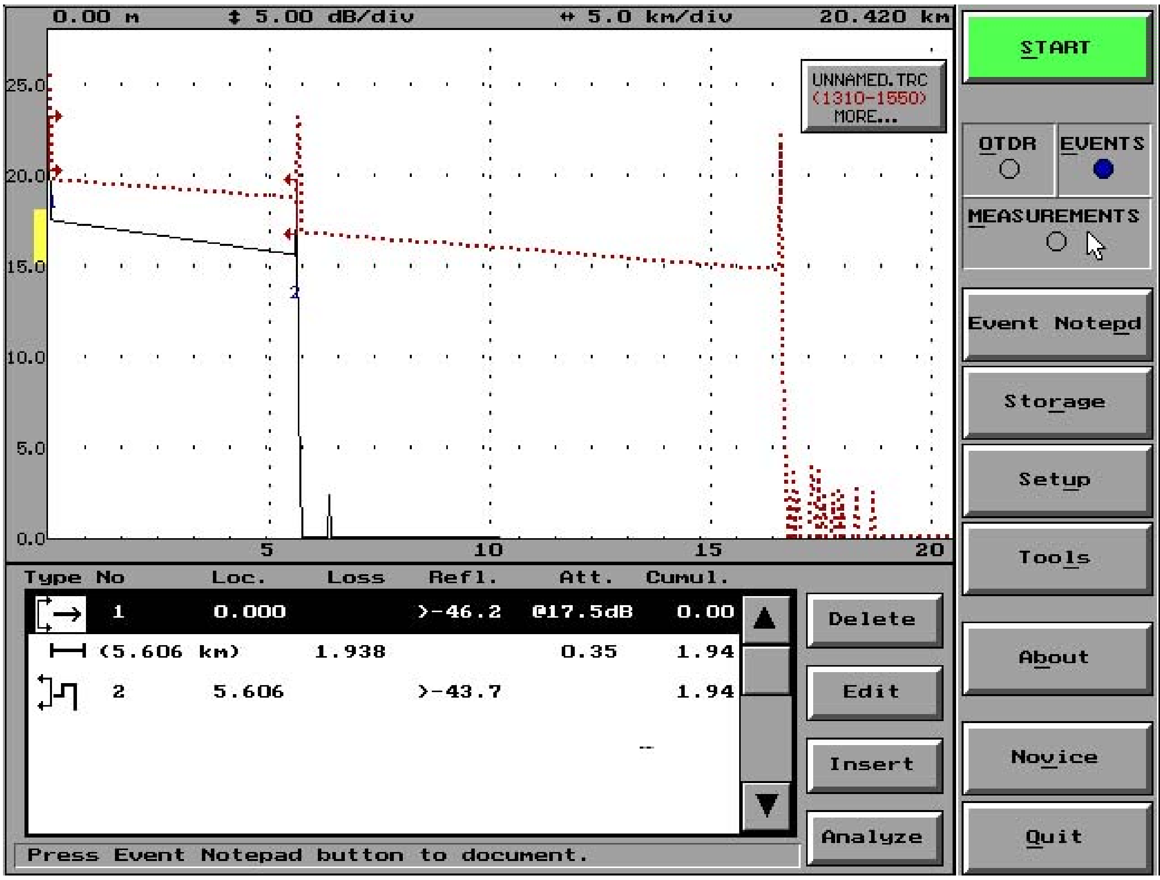


Figure II.1.5/L.53 – OTDR trace simulation of SDH test light module

The result of OTDR trace simulation depicted in the picture below shows that the test light (dotted line) is passed through to the end of the fibre cable, whereas the information light is terminated at 5.6 km (Figure II.1.6).



L.053_FII.1.6

Figure II.1.6/L.53 – Result of OTDR trace simulation

II.1.4 Conclusion

The description of SDH test light module has been given to be accommodated in our OSS for optical cable monitoring. This module can be used to bypass test light from ADM to ensure the continuity of monitoring wavelength path.

This contribution is addressed to share experience relating operation and maintenance process of optical access network.

II.2 Japanese experience

This appendix describes a test light bypass module for monitoring ADM ring optical networks.

II.2.1 Introduction

Ring networks using add/drop multiplexers (ADM), which are installed in central offices and customer buildings, are being introduced into metropolitan areas to provide broadband networks. However, conventional testing method is incapable of monitoring optical fibre cables between customer buildings. Therefore, we suggest a method using the test light bypass module for this purpose.

II.2.2 Testing system configuration

Figure II.2.1 shows the configuration of our optical fibre line testing system with test light bypass modules for monitoring ADM ring networks.

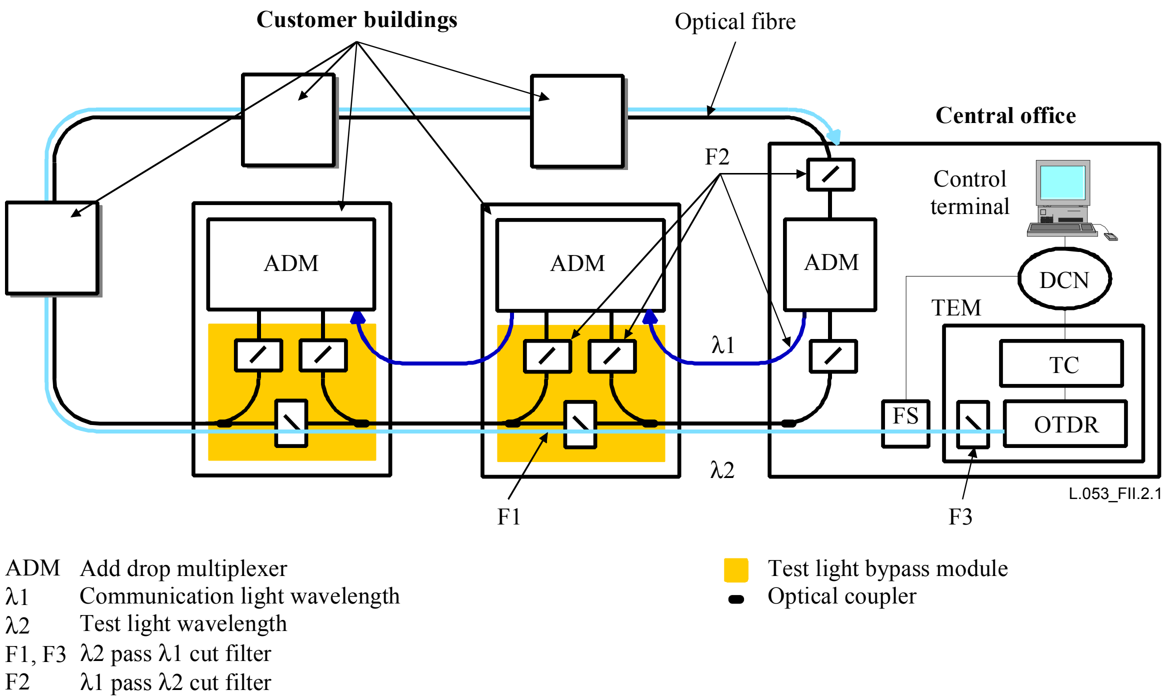


Figure II.2.1/L.53 – Testing system configuration

It consists of a control terminal, test equipment modules (TEM) each of which contains an optical time domain reflectometer (OTDR) and a test equipment controller (TC), optical fibre selectors (FS) that select test fibres, optical couplers and optical filters. The TEMs and FSs are installed in the cable termination room of a central office.

Optical couplers in the central office introduce a test light into fibre lines and optical couplers in customer buildings pass the test light to the next cable. We also installed three kinds of filter, F1, F2 and F3. The F2 filters allow the communication light (λ1) to pass but cut off the test light (λ2). They are arranged in front of the ADM. The F1 and F3 filters allow the test light to pass but cut off the communication light. They are installed between the couplers of the customer buildings and in front of the OTDR, respectively.

The control terminal orders the TC to perform various optical fibre tests through a data communication network (DCN). The TC controls the OTDR and FSs, and returns the test results to the control terminal. This system carries out automatic OTDR measurements and reveals fibre characteristics and fault locations between customers' buildings with no degradation in transmission quality.

II.2.3 Test light bypass module configuration

As we already use the 1.31 µm ad 1.55 µm wavelengths for communication, we use the 1.65 µm wavelength for maintenance testing in accordance with ITU-T Rec. L.41. As the ADM communication light is 1.31 µm and the test light is 1.65 µm, we employed 1.31/1.65 µm wavelength division multiplexing (WDM) couplers to obtain low insertion losses. Moreover, we used the F1 filter that allows 1.65 µm light to pass but cuts off 1.31 µm light and the F2 filters that allows 1.31 µm light to pass but cuts off 1.65 µm light. As the communication light is 1.55 µm, we employed 1.55/1.65 µm wavelength division multiplexing (WDM) couplers, the F1 filter that allows 1.65 µm light to pass but cuts off 1.55 µm light and the F2 filters that allows 1.55 µm light to pass but cuts off 1.65 µm light.

II.2.4 OTDR trace of field optical fibre cable

Figure II.2.2 shows the OTDR trace of a field optical fibre cable with two test light bypass modules located 1.0 and 1.2 km from a central office. Figure II.2.2 confirms that our testing system can monitor cables between buildings.

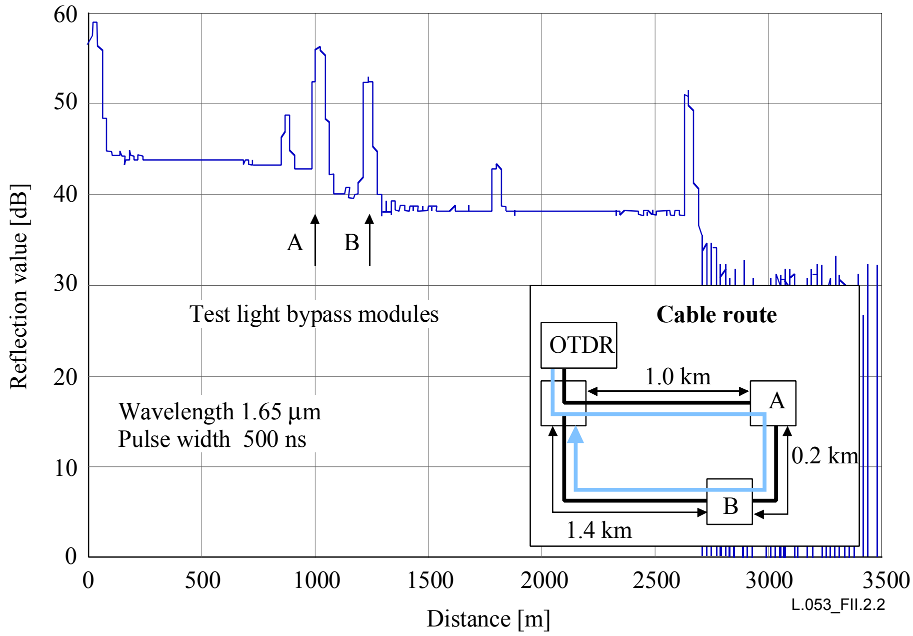


Figure II.2.2/L.53 – OTDR trace of field optical fibre cables with test light bypass modules

II.2.5 Conclusions

We described an optical fibre line testing system that uses test light bypass modules. We confirmed that this system can monitor optical fibre cables of an ADM ring network and causes no degradation in transmission quality.

Appendix III

Information of fibre optic water submersion-detecting sensor

This appendix introduces the Fibre optic water submersion-detecting sensor for water penetration measurement in Japanese access networks. It describes the measurement method of water penetration detection.

III.1 Introduction

The fibre optic water submersion-detecting sensor is attached to a fibre in optical fibre closure. It is designed to cause loss increase in fibre attenuation when water penetrates into the closure. The loss increase is measured by OTDR (Optical Time Domain Reflectometer) so that water penetration and its location can be detected (Figure III.1). The maintenance ribbon fibres are usually adapted.

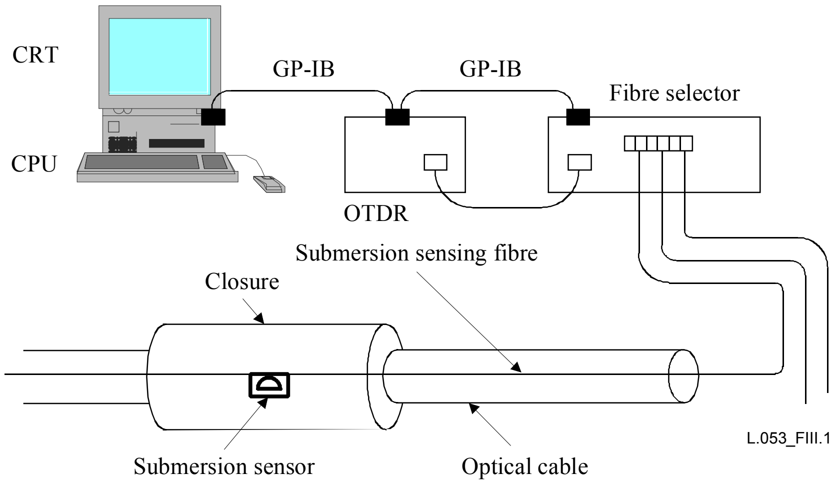


Figure III.1/L.53 – Fibre optic water submersion-detecting sensor

III.2 Structure of the sensor

Figure III.2 shows a structure of the fibre optic water submersion-detecting sensor. The sensor is mainly composed of two parts. One is water absorbent portion and the other is fibre guiding portion. There is a bending guide to bend the fibre in guiding portion. The bending radius is designed depending on the parameter of the optical fibre. This sensor is adapted to ribbon fibres.

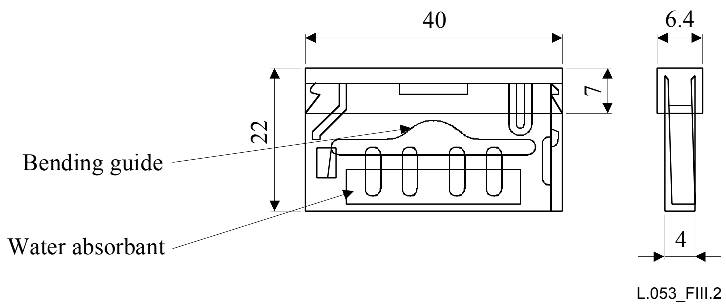


Figure III.2/L.53 – Structure of the water submersion-detecting sensor

III.3 Principle of water detection

Water penetration can be detected as follows:

1) When water penetrates into the closure and the sensor is soaked, the water absorbent of the sensor expands. This sensor is insensitive to water vapor.

2) The expanded water absorbent pushes the bending guide so that the bending guide can bend the fibre and which then causes a loss increase (Figure III.3).

3) To measure the loss increase by OTDR, the water penetration and its location can be detected (Figure III.4).

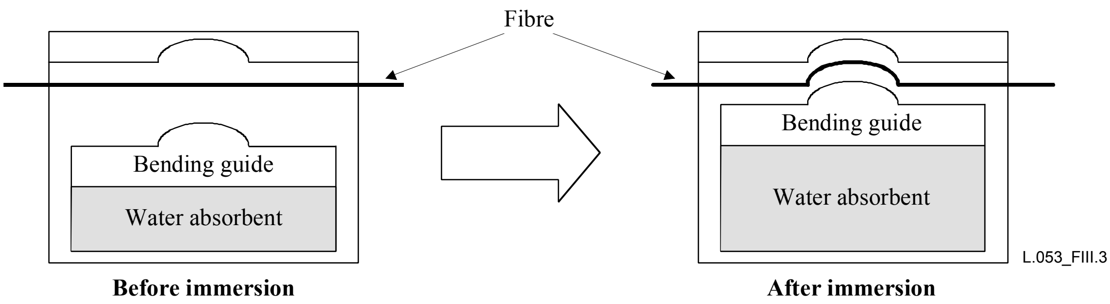


Figure III.3/L.53 – Fibre bending after water absorption

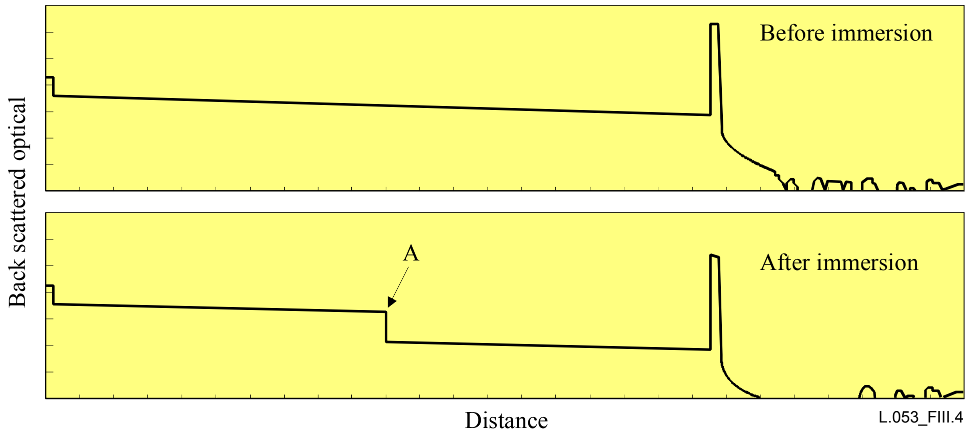


Figure III.4/L.53 – OTDR chart before and after water penetration

III.4 Characteristics of the sensor

Item	Description
Applicable optical fibre	4-fibre ribbon (G.652)
Operating temperature	0 to 40° C
Response time	Within 24 hours
Insertion loss before immersion	0.01 dB
Loss increase at a wavelength of 1.55 µm	more than 2.0 dB
Weight	4 g approx.

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Printed in Switzerland
Geneva, 2003