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

Optical fibre outside plant maintenance support, monitoring and testing system

ITU-T Recommendation L.40

(Formerly CCITT Recommendation)

ITU-T Recommendation L.40

Optical fibre outside plant maintenance support, monitoring and testing system

Summary

Outdoor optical fibre maintenance is important to create networks and to maintain their reliability. As traffic increases, higher capacity fibre cables are installed. Recently, optical fibre cables with over 100 cores have become common, so many transmission systems use the same optical fibre cable. Minimal levels of maintenance and testing are required to provide high reliability and quick response.

After a cable is installed, functions like fibre monitoring and control have to be done without interfering with the data transmission signals. By monitoring dark fibres (that is, without signal traffic) an indication is given of the performance of the in-service fibres as the degradation and breaks that a cable undergoes affects all fibres in the same way. Nevertheless greater reliability is achieved by monitoring the fibres with traffic. Also fibre identification is important to control fibre networks because several fibres may have to be chosen from within a cable, even if the cable has many fibres in-service.

Source

ITU-T Recommendation L.40 was prepared by ITU-T Study Group 6 (1997-2000) and approved by the World Telecommunication Standardization Assembly (Montreal, 27 September – 6 October 2000).

This Recommendation includes Appendices I to V approved on 9 March 2001.

FOREWORD

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Optical fibre outside plant maintenance support, monitoring and testing system

1 Scope

This Recommendation deals with outdoor optical fibre maintenance support, monitoring and testing systems for both trunk and access optical fibre cable networks. It describes fundamental requirements, principles, and architecture to develop a suitable guide to design systems.

2 Fundamental requirements

2.1 Functions

The system has functions shown in Table 1.

Table 1/L.40 – Functions and status

Category	Activity	Functions	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)	• Interface with path operation system • Interface with customer service operation system	Optional Optional
	Testing (e.g. After installation testing, Fibre fault testing)	• Confirmation of fibre condition • Fault distinction 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 • Interface with outside plant database • Interface with mapping system	Required Optional Required Optional

2.2 Interface

The system can be controlled by human or by other systems. The system shall be able to be remotely controlled. So operation terminals with HMI (human-machine interface) should be included in the system.

The system shall be able to gather data about outdoor fibres from the outside plant database and it should have interface with path operation and customer service system.

The interface may be implemented in a variety of ways, for example:

1) standard on-line interface;
2) proprietary on-line interface;
3) an external storage medium such as magnetic optical disc or floppy disc.

3 Testing and maintaining principle

3.1 Methods

There are several ways to implement these functions. OTDR testing, loss testing, monitoring a proportion of the signal power (power monitoring) and identification light detection are commonly used. Table 2 shows the most common methods.

Table 2/L.40 – Suitable test methods

Category	Activity	Functions	Methods
Preventative maintenance	Surveillance	• Detection of fibre loss increase • Detection of signal power loss increase • Detection of water penetration	OTDR/loss testing Power monitoring OTDR/loss testing
	Testing	• Measurement of fibre fault location • Measurement of fibre strain distribution • Measurement of water location	OTDR testing B-OTDR testing OTDR testing
	Control	• Fibre identification • Fibre transfer	ID light detecting[a)] Switching[b)]
After installation before service or post-fault maintenance	Surveillance	• Interface with path operation system • Interface with customer service operation system	On-line/external medium On-line/external medium
	Testing	• Confirmation of fibre condition • Fault distinction between transmission equipment and fibre network • Measurement of fibre fault location	OTDR/loss testing OTDR/loss testing OTDR testing
	Control	• Fibre identification • Fibre transfer • Interface with outside plant database • Interface with mapping system	ID light detecting Switching[b)] On-line/external medium On-line/external medium

a) ID light means identification light such as 270 Hz, 1 kHz, 2 kHz modulated light.

b) Switching includes mechanical and manual switching.

3.2 Wavelength

It is important to choose the correct wavelength. Specifically, maintenance functions have to be performed without interfering with data transmission signals. Table 3 shows appropriate wavelengths for given functions.

Table 3/L.40 – Wavelength selection

Category	Activity	Functions	Wavelength
Preventative maintenance	Surveillance	• Detection of fibre loss increase • Detection of signal power loss increase • Detection of water penetration	Maintenance wavelength[a)] Signal wavelength Any wavelength on fibres not carrying signals
	Testing	• Measurement of fibre fault location • Measurement of fibre strain distribution • Measurement of water location	Any wavelength on fibres not carrying signals Any wavelength on fibres not carrying signals Any wavelength on fibres not carrying signals
	Control	• Fibre identification • Fibre transfer	Maintenance wavelength[a)] None
After installation before service or post-fault maintenance	Surveillance	• Interface with path operation system • Interface with customer service operation system	None None
	Testing	• Confirmation of fibre condition • Fault distinction between transmission equipment and fibre network • Measurement of fibre fault location	Any wavelength Any wavelength Any wavelength
	Control	• Fibre identification • Fibre transfer • Interface with outside plant database • Interface with mapping system	Any wavelength None None None

a) Refer to "Recommendation of Maintenance wavelength on fibres carrying signals (ITU-T L.41)".

4 Fundamental architecture

4.1 General system architecture

Systems (see Figure 1) must have at least an operation terminal and optical testing module (OTM). The minimum system consists of only these two items. This type of system is convenient for initial installation. A server can improve performance by keeping outside plant, test results, and interfaces with other systems. The server can also control OTMs.

There are several choices for Data Communication Network (DCN), including POTS, ISDN and X.25. Traffic analysis is important for an economical high-performance system.

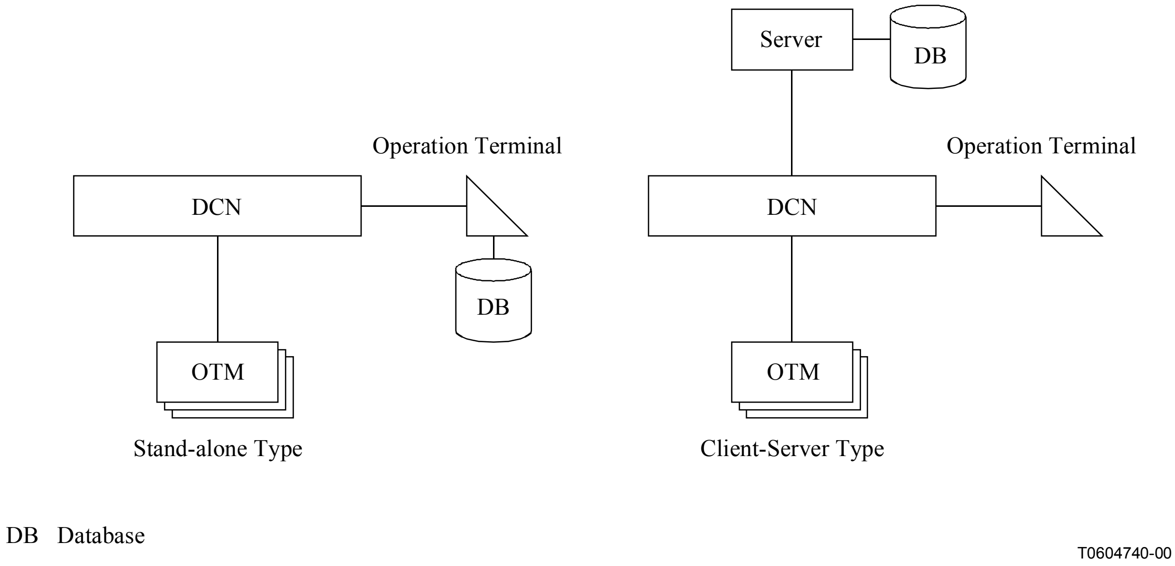


Figure 1/L.40 – System architectures

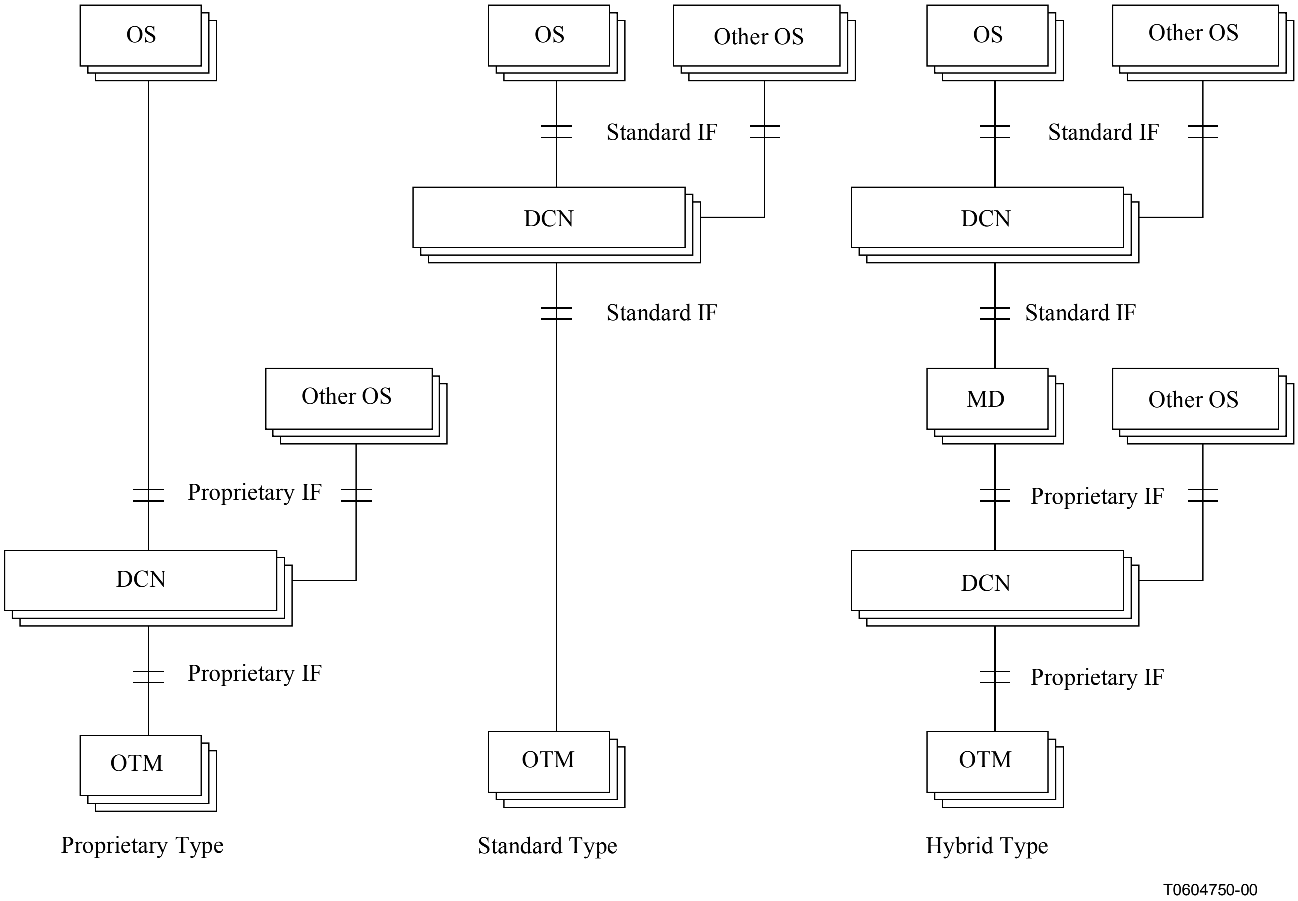
Figure 2 shows these system interfaces. There are several kinds of interface between an operating system (OS), which runs on an operation terminal or server, and OTM. A proprietary interface is convenient for closed systems. Standard interfaces are useful for open systems. A hybrid type is also possible.

The system has to have interfaces with other systems. This may be done in a variety of ways, for example:

1) standard on-line interface;

2) proprietary on-line interface;

3) an external storage medium such as magnetic optical disc or floppy disc.



MD Mediation Device

Figure 2/L.40 – System interfaces

4.2 Optical testing module (OTM)

The optical testing module (OTM) consists of a controller, an optical testing unit (OTU), fibre selectors (FS), optical couplers, filters, water sensors and by path units.

1) The controller controls the OTU, communicates with the server or the operation terminal, and analyses test results, along with performing several other functions.
2) The OTU is used for the actual testing. It comprises an Optical Time Domain Reflection meter (OTDR) and other instruments, light sources, power meters and a controller for these devices.
3) Fibre selectors (FS) are installed within a fibre termination frame and/or an OTU frame. Their function is to select the fibre to be tested under instruction from the OTU.
4) An optical coupler is installed within a fibre termination frame. Its function is to inject and detect a test light in the optical fibre or to detect a proportion of the signal for monitoring proposes.
5) A filter is installed to protect transmission equipment from being affected by the test light.
6) A water sensor is installed at the optical fibre cable joints to detect the water penetration.
7) A bypath unit is used to make a roundabout route to avoid a transmission device.

APPENDIX I

United States experience regarding remote fibre monitoring and testing

I.1 Introduction

Based on our experience with customers in the United States, many of the larger network providers that predominantly provide local telephony services do not use Remote Fibre Test Systems (RFTSs). These companies rely on transmission system equipment alarms, ring topology and protection switching. In response to an alarm, traffic is switched to an alternate fibre, and after applying proprietary maintenance analyses an OTDR is used to determine the location of a cable break. These companies have historical and landmark data available for fault location. Network providers that are predominantly long-distance providers do use some level of remote fibre testing systems in their networks.

The RFTSs range from the basic dark fibre systems to identify and roughly locate fibre breaks to more sophisticated systems that can monitor working systems, detect degradation of the network before it fails and accurately locates fibre faults. RFTSs may be controlled locally, regionally or at a central maintenance centre of a network provider. In the case of the dark fibre system, the main purpose is to reduce the time to locate faults and thus reduce the time of circuit outages. The sophisticated systems are integrated into the network surveillance operational system that monitors the transmission, switching equipment and the RFTS. These systems can also determine degradation of the fibre network and sound alarms before the network is out of service.

I.2 Remote fibre testing and monitoring architectures

I.2.1 Basic dark fibre remote test systems (RFTSs)

The basic dark fibre Remote Fibre Test System (RFTS), shown in Figure I.1, consists of three elements. The first is an Optical Test Access Unit (OTAU), which is essentially a remotely controlled optical switch. The size of the switch depends on the number of fibres under test, a common size is 72 fibres, but larger switches are used. The switch connects the test fibres to the second element, the Remote Test Unit (RTU), which is a remotely controlled OTDR that provides the test signal and makes the OTDR measurements. The third element is the Test System Controller (TSC), which selects the test fibre and operates the RTU. This architecture is typical of the dark fibre monitoring in use today in the United States. The test operating system may be integrated into a surveillance operational system using proprietary software.

In a stand-alone system the TSC contains a database for the fibres under test that includes prior OTDR trace data and related geographic data of the fibre routes. In these systems only dark fibres are tested. The RFTS is capable of fault detection based on a process where the TSC cycles through each fibre connected to it. One TSC can control multiple RTUs. This means that a TSC may not discover a cable break for some time if the number of fibres connected to it is very large and if the fibres of that cable were tested shortly before the break occurred. The TSC may be connected to a Test Operating System (Test OS), which is located in a maintenance centre where other alarms from the network terminate. Operators there analyse the alarms coming from the TSC and other sources, such as transmission alarms, determine the root cause of the problem and obtain OTDR trace information from the TSC before dispatching a repair crew. If a transmission alarm is received first, the TOS can interrupt the test cycling, and direct the TSC to make a scan of the fibre with a transmission fault.

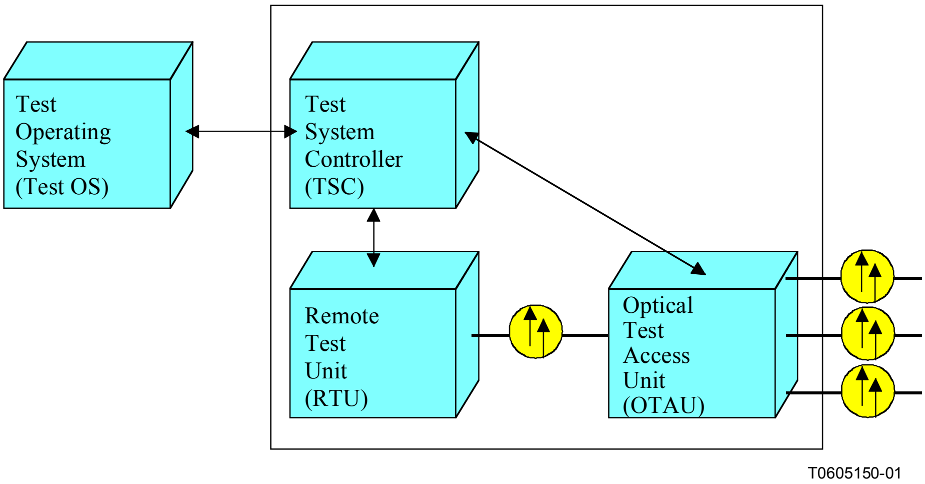


Figure I.1/L.40 – Basic dark fibre remote fibre test system (RFTS)

Many of the current systems in use today are vendor specific and not compatible with other vendor products on a system or component basis. Requirements for RFTSs that will overcome this problem in new systems put into use in the United States have been developed [1], [2] and [3].

Monitoring only the dark fibres cannot assure detection of faults that may occur with the working fibres. For example if water entered the cable and freezing occurred, some of the working fibres could experience high loss while the monitored dark fibres are unaffected. This problem can be overcome with monitoring of more fibres, including the active fibres. Of course, the number of fibres monitored increases the cost, which places a practical limit on how many fibres are monitored. Typically, only one or two fibres are monitored per cable.

I.2.2 Remote fibre test systems with active fibre monitoring and testing

The transmitted and/or received signal can be monitored full time and an OTDR test signal, which is out of the transmission band, can be injected into the OSP fibre without interference with the transmission by placing a WDM device between the transmission equipment and the OSP fibre. Figure I.2 illustrates this architecture and is representative of systems in use today [4]. The sophistication of the system depends upon the RFTS manager function that is discussed in I.2.3.

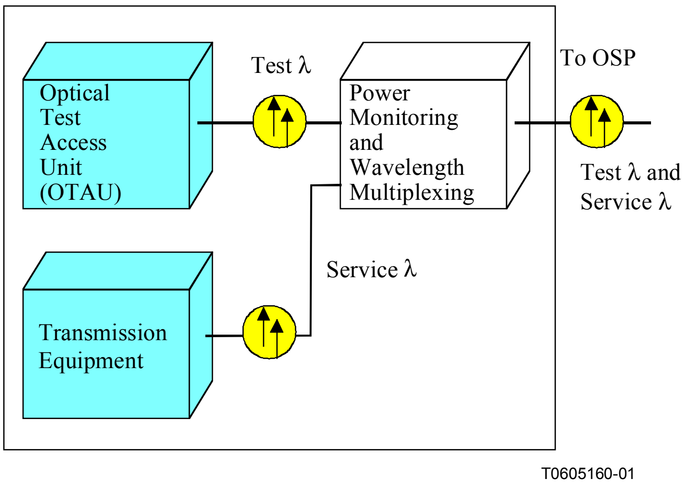


Figure I.2/L.40 – Power monitoring and wavelength division multiplexing an OTDR test signal with service transmission

With this architecture there are a number of benefits:

1) The RTU need only be used to locate faults that are detected by loss of signal power.

2) The detection of signal loss would be essentially instantaneous; with the detection of loss of power, the monitoring circuitry can signal the TSC to direct the RTU and the OATU to make a test and locate the fault.

3) Both active and dark fibres can be batch tested.

4) Power monitoring as well as routine OTDR test data can be used to do proactive maintenance. It can support the detection of transmission quality degradation and observe the quality of the fibre over long periods of time for failure prediction.

I.2.3 RFTS manager

The RFTS manager, generally a PC with special fibre application software (FAS), communicates with the surveillance operations system (SOS), but it can also be accessed locally and directly from the field. The RFTS manager controls the RFTS equipment and stores data on the fibres monitored in its system, such as landmarks and other geographical information, OTDR traces, statistical data, alarm policy, and monitoring and test data. When an alarm is received, the manager directs the RFTS equipment (TSC, RTU and OTAU) to make a test. It processes the test data, and forwards to the SOS the location of the fault relative to landmark data for the repair crews. During a cable break, the SOS receives alarm information from the transmission equipment, from the protection switching equipment (if protection switching is used) and from the RFTS manager. With suitable correlation algorithms at both the RFTS manager and the SOS the several alarms can be sorted and only one alarm prevails. In the case of a cable break, it is the RFTS alarm with the necessary fault location information to dispatch a repair crew. Figure I.3 below illustrates this process.

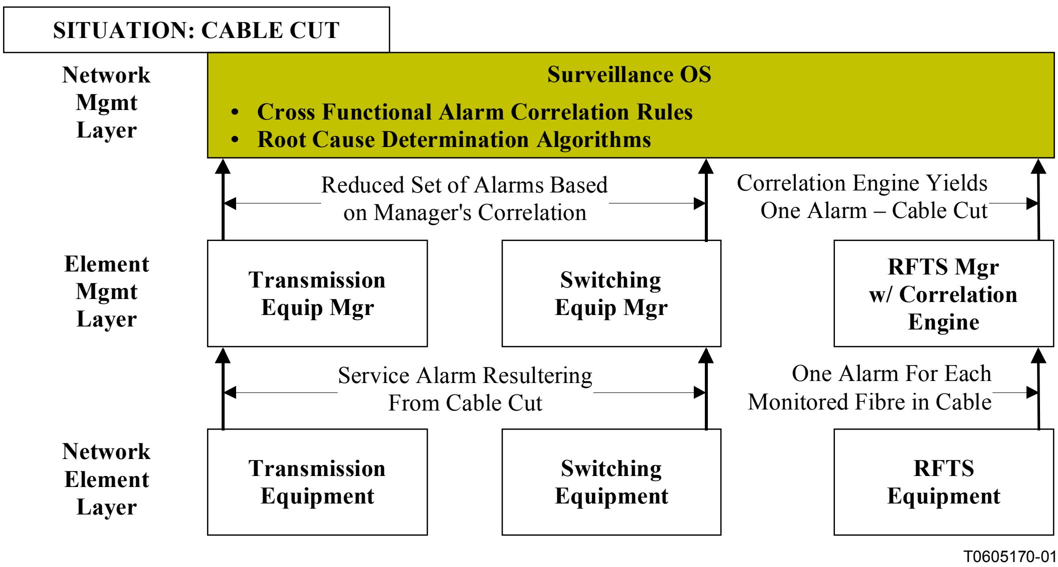


Figure I.3/L.40 – Telecommunications maintenance hierarchy with focus on alarm correlation

I.2.4 Alarms

For the most sophisticated systems, the FAS software provides an extensive set of alarm capabilities to alert maintenance personnel to fibre related issues. Fibres alarms are pre-set to detect changes in fibre path performance associated with comparative batch testing or power monitoring. The system also provides alarm information associated with equipment and other environmental fault conditions. All alarm information may be accessed via alarm lists maintained by the RFTS manager. A remote paging capability may also be preprogrammed to "beep" craft in the event of a fibre or equipment issue.

I.2.4.1 Alarm levels

Typically, there are two levels of alarm criticality:

Major Alarm – A major alarm is generated when there is a transmission failure. It can be generated when power monitoring detects a power drop below a set threshold or through batch testing. Batch testing generates a major alarm when there is an event loss greater than 3 dB (or another threshold set by the user). The problem is assumed to be a fibre break or of similar criticality. Major alarms require action by the maintenance personnel and most likely a field operation such as a cable repair.

Minor Alarm – A minor alarm can be signalled when a batch OTDR test has detected that the fibre trace has violated a threshold for attenuation, attenuation coefficient, reflectance, or a new event has been discovered. A minor event is also signalled when power monitoring detects a signal above or below the dynamic range or when the laser power is not stable. Minor alarms should be watched to determine if the condition is getting progressively worse, but do not require immediate site investigation.

I.2.4.2 OTDR alarms

Alarms are triggered during an OTDR test when the alarm threshold level is crossed. There are default threshold crossing alarms for: end-to-end loss, an event loss, an event reflection, a new event, an event changes from non-reflection to reflection, and change in the attenuation coefficient of the fibre. Typical default alarm threshold values determined from experience are shown in Table I.1.

Table I.1/L.40 – Typical default alarm threshold values

End-to-end loss	3.0 dB change
Event loss	0.5 dB change
Event reflection	5 dB
New event	1.0 dB
Attenuation coefficient	0.5 dB/km
Non-reflection to reflection	>1.0 dB

I.2.4.3 Power alarms

Power alarms are triggered whenever the power level or the variation in power level crosses an alarm threshold. The typical minor default threshold for power level is 1.0 dB, and a major default threshold for power level is 3.0 dB.

I.3 Conclusions

Network providers in the United States either use no RFTSs or they use RFTSs to monitor dark fibres or both dark and active fibres. Those providers who do not use any RFTSs rely on transmission equipment alarms, protective switching, ring topology, and OTDR traces with landmarks to locate the fault. Alternate routing through protective switching and ring topology allows time for normal location and restoration. Those who use power monitoring and out-of-band OTDR scans consider the faster restoration, the statistical and predictive information are worth the added operational costs for the RFTSs.

I.4 References

[1] *Generic Requirements for Remote Fibre Testing Systems (RFTSs)*, Telecordia, BR-GR 1295-Core Issue 02 2000-02-07.

[2] *OTGR Section 6.6 TSC/RTS and OTAU Generic Requirements for Remote Optical Fibre Testing*, Telecordia, BR-GR 1309-Issue 01 1995/06.

[3] *Generic Requirements for Fibre Optic Branching Components*, Telecordia, BR-GR 1209-CORE issue 02 1998/02/01.

[4] *A Next Generation Fibre Test and Surveillance System*, Lucent Technologies, ITU, COM 6-60-E, Study Period 1997-2000.

APPENDIX II

Optical fibre outside plant maintenance support and testing system

II.1 Abstract

This Recommendation describes fundamental requirements, principles, and architecture to develop a suitable guide to design systems. This appendix presents a Japanese system derived from this Recommendation.

II.1.1 Fundamental requirements

II.1.1.1 Functions

The Japanese system has functions shown in Table II.1.

Table II.1/L.40 – Functions and status

Category	Activity	Functions	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	X X X
	Testing (e.g. Fibre degradation testing)	• Measurement of fibre fault location • Measurement of fibre strain distribution • Measurement of water location	X Optional X
	Control (e.g. Network element control)	• Fibre identification • Fibre transfer	X Optional
After installation before service or post-fault maintenance	Surveillance (e.g. Reception of transmission system alarm or customer trouble report)	• Interface with path operation system • Interface with customer service operation system	Optional Optional
	Testing (e.g. After installation testing, Fibre fault testing)	• Confirmation of fibre condition • Fault distinction between transmission equipment and fibre network • Measurement of fibre fault location	X X X
	Control (e.g. Cable install/repair/ replacement)	• Fibre identification • Fibre transfer • Interface with outside plant database • Interface with mapping system	X Optional X None

II.1.1.2 Interface

The Japanese system can be remotely controlled by human or by other systems, and operation terminals with HMI (human-machine interface) are included in the system.

The Japanese system shall be able to gather data about outdoor fibres from the outside plant database and it should have interface with customer service system.

The interface is implemented in a proprietary online interface. An external storage medium such as magnetic optical disc or floppy disc shall be also possible.

II.1.2 Testing and maintaining principle

II.1.2.1 Method

See Table II.2.

Table II.2/L.40 – Suitable test methods

Category	Activity	Functions	Methods
Preventative maintenance	Surveillance	• Detection of fibre loss increase • Detection of signal power loss increase • Detection of water penetration	OTDR testing Power monitoring OTDR testing
	Testing	• Measurement of fibre fault location • Measurement of fibre strain distribution • Measurement of water location	OTDR testing B-OTDR testing OTDR testing
	Control	• Fibre identification • Fibre transfer	ID light detecting[a)] Mechanical switching
After installation before service or post-fault maintenance	Surveillance	• Interface with path operation system • Interface with customer service operation system	Online/ external medium Online/ external medium
	Testing	• Confirmation of fibre condition • Fault distinction between transmission equipment and fibre network • Measurement of fibre fault location	OTDR/loss testing OTDR/loss testing OTDR testing
	Control	• Fibre identification • Fibre transfer • Interface with outside plant database • Interface with mapping system	ID light detecting Mechanical switching Online None

a) ID light means identification light such as 270 Hz modulated light.

II.1.2.2 Wavelength

See Table II.3.

Table II.3/L.40 – Wavelength selection

Category	Activity	Functions	Wavelength
Preventative maintenance	Surveillance	• Detection of fibre loss increase • Detection of signal power loss increase • Detection of water penetration	1310/1550/1650 1310/1550 1550/1650
	Testing	• Measurement of fibre fault location • Measurement of fibre strain distribution • Measurement of water location	1310/1550/1650 1550/1650
	Control	• Fibre identification • Fibre transfer	1550/1650 None
After installation before service or post-fault maintenance	Surveillance	• Interface with path operation system • Interface with customer service operation system	None None
	Testing	• Confirmation of fibre condition • Fault distinction between transmission equipment and fibre network • Measurement of fibre fault location	1310/1550/1650 1310/1550/1650 1310/1550/1650
	Control	• Fibre identification • Fibre transfer • Interface with outside plant database • Interface with mapping system	1310/1550/1650 None None None
NOTE – Refer to ITU-T L.41 "Maintenance wavelength on fibres carrying signals".			

II.1.3 Fundamental architecture

II.1.3.1 General system architecture

The Japanese system architecture is shown in Figure II.1.

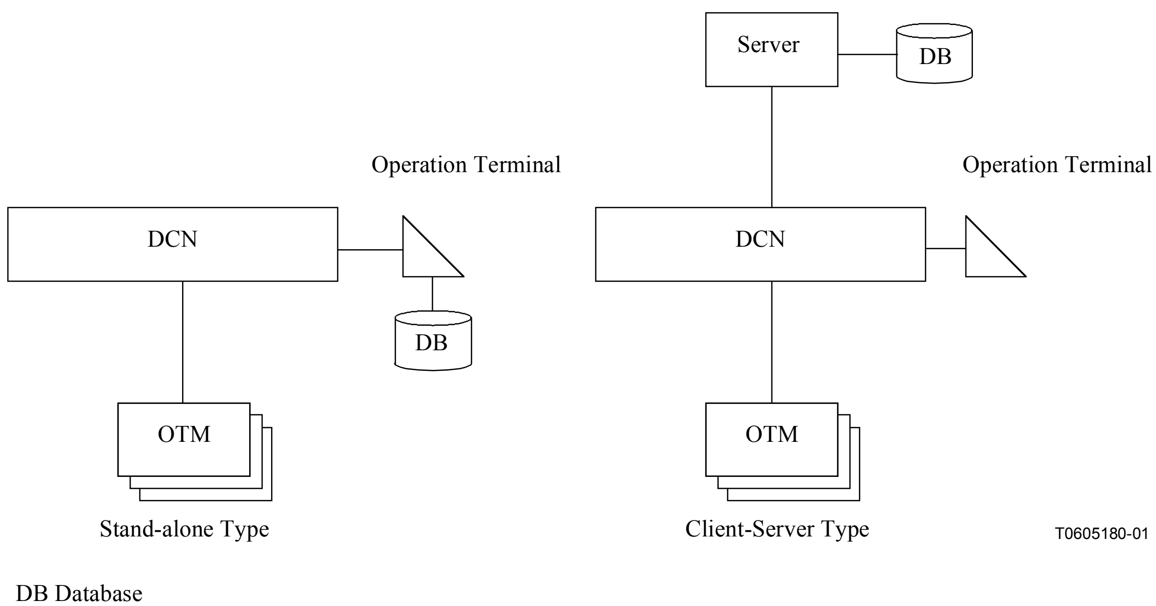


Figure II.1/L.40 – System architectures

Figure II.2 shows the Japanese system interfaces. The system has proprietary online interfaces with other systems. An external storage medium such as magnetic optical disc or floppy disc shall also be possible.

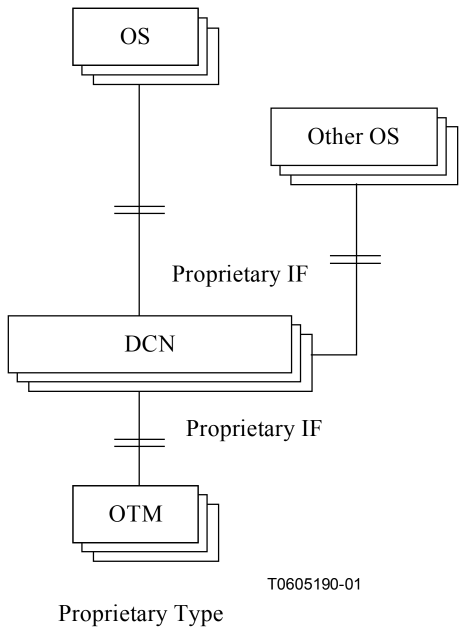


Figure II.2/L.40 – System interfaces

II.1.3.2 Optical testing module (OTM)

The optical testing module (OTM) of the Japanese system shall conform completely with this Recommendation.

II.2 Detail of the system

II.2.1 Purposes

The purposes of the automatic remote fibre testing system are efficient construction, maintenance and operation of optical fibre cable. The system supports the various tasks involved in the construction of optical fibre cables and installation on the customer's premises before they are put in service, and in the periodic work of fault location and changing over of fibres within the optical fibre cable while they are in service.

II.2.2 System functions

The system has the functions listed below.

1) Remote OTDR testing, section loss testing and fibre identification during optical fibre cable construction or installation on customer premises.
2) Support for remote fault location and repair.
3) Periodic OTDR testing for fibre faults.
4) Loss measurement (OTDR testing) before and after fibre changing over.

II.2.3 System configuration

The system is configured as described below.

1) A server and database is located in the administrative office for management of the system.

2) An operations terminal is installed in the maintenance operations centre for remote control of testing operations.

3) A Test Equipment Module (referred to as TEM in this appendix) is used for the actual testing. It comprises measurement instruments, including an Optical Time Domain Reflection meter (OTDR), a light source and a controller for them.

4) A Fibre Termination Frame (referred to as FTM in this appendix) terminates the optical fibre cable in the central office.

5) A Fibre Selector is installed within the FTM. Its function is to select the fibre to be tested under instruction from the TEM.

6) A Test Access Module (referred to as TAM in this appendix) is installed within the FTM. It is an optical coupler whose function is to inject a test light into the optical fibre.

7) A filter is installed on the customer premises so as to protect customer transmission equipment from being affected by the test light and to locate breakdown close to customer premises by detecting change in reflection from the filter.

8) A water sensor is installed at the optical fibre cable joints to detect the presence of water.

The operations terminal is connected to the TEM in the central office via the server and data communication networks. Under the direction of the Operations Terminal, the TEM controls the Fibre Selector so as to select any of the optical fibres for the purpose of performing the various types of tests. The test light from the TEM is injected into the optical fibre cable by the TAM, making it possible to conduct various tests.

A water sensor is installed at the joints of the optical fibre cable, making it possible to detect the submergence of the joints in water by running an OTDR test.

A filter is placed immediately in front of the transmitter on the customer premises so as to block the testing light and prevent any effect on the communication lines, thus making in-service testing possible.

The general configuration of the system is described in Figure II.3.

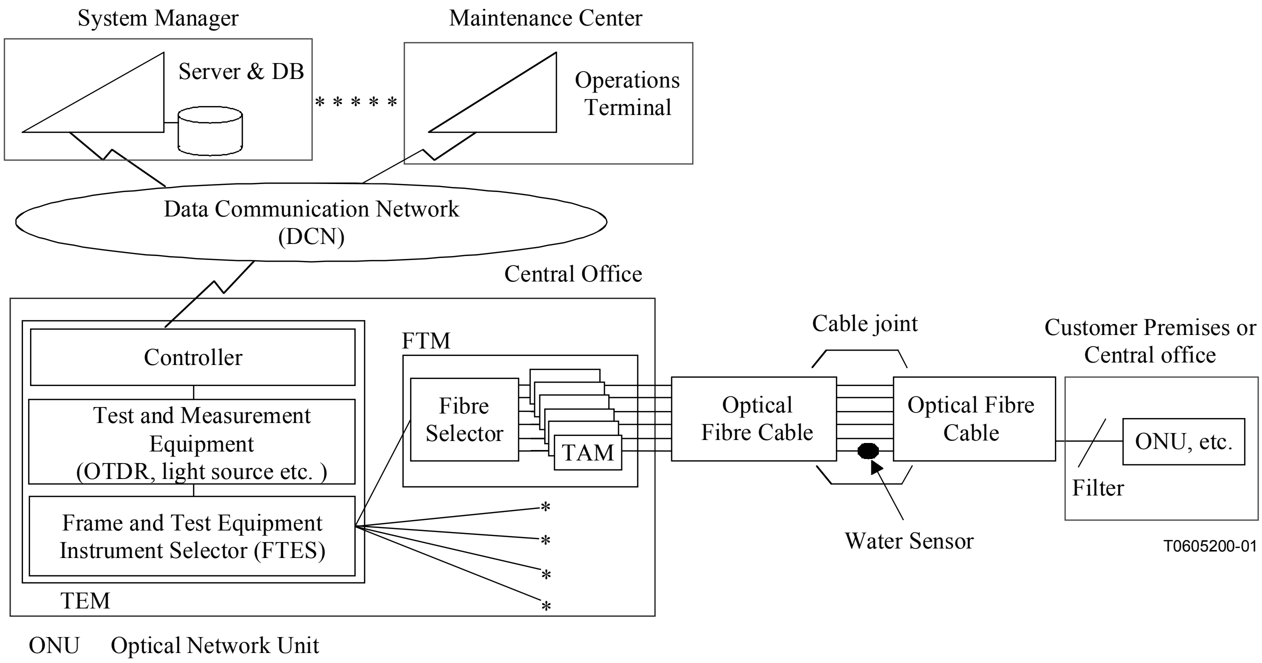


Figure II.3/L.40 – Overall system configuration

II.2.4 Control system overview

The Operations Terminal and the TEM can communicate via the data communication network. One Operations Terminal can control multiple TEMs. One TEM can control multiple Fibre Selectors.

An overview of the control system is given in Figure II.4.

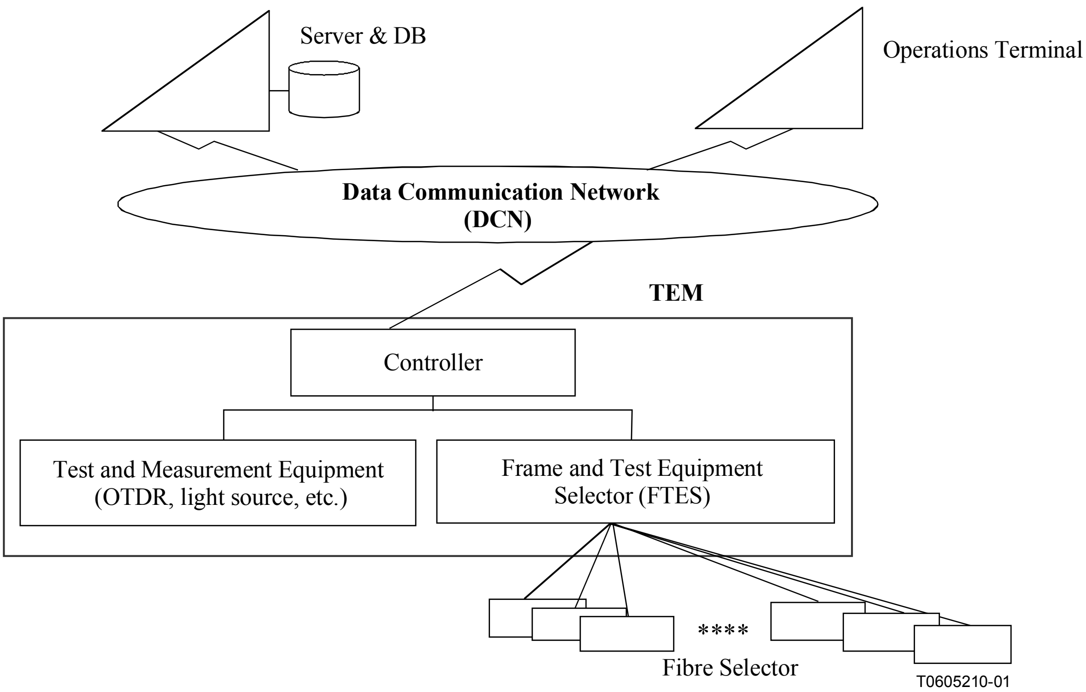


Figure II.4/L.40 – Control system

II.2.5 Testing and measurement principles

II.2.5.1 OTDR test

In the OTDR test, a test light from the TEM is injected into a communication line by the TAM to determine the status of the optical cable section. The test light is blocked at the customer premises by a filter, so the test light does not affect the customer's communication.

An overview of the OTDR test is given in Figure II.5.

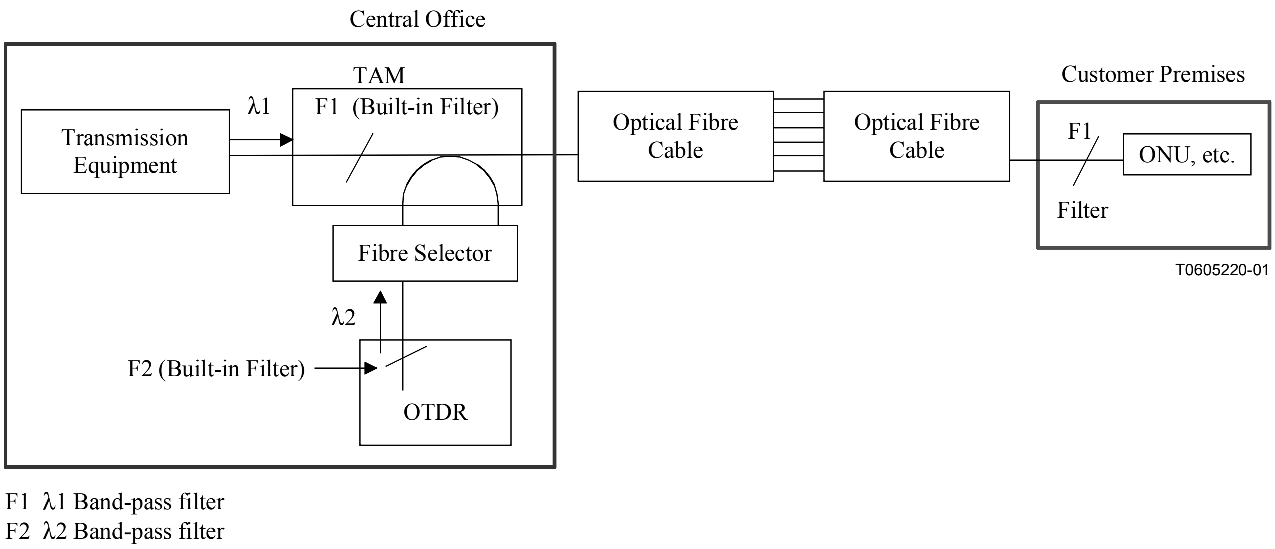


Figure II.5/L.40 – OTDR test

II.2.5.2 Section loss test

A test light from the TEM for measuring loss in the fibre is injected into the transmission line by the TAM and its optical power is measured by a handy power meter either at the terminal on the customer premises or at an intermediate cable joint.

An overview of the section loss test is given in Figure II.6.

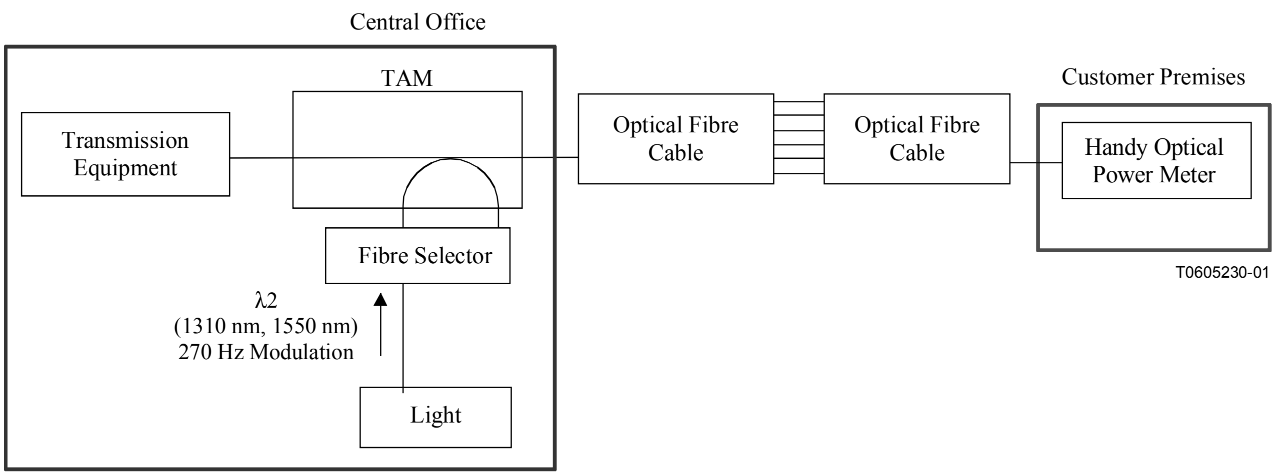
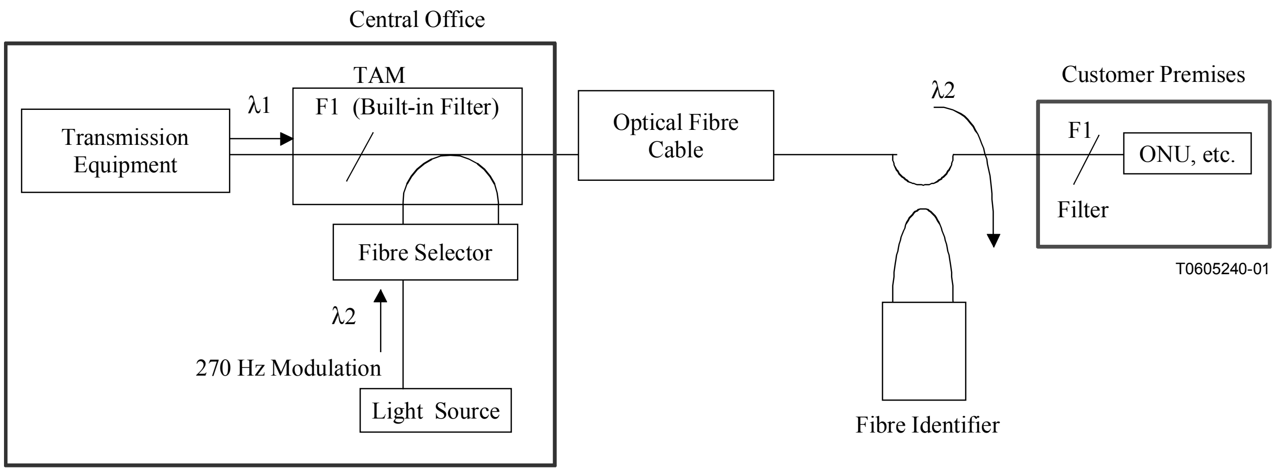


Figure II.6/L.40 – Section loss test

II.2.5.3 Fibre identification

The light is injected into the in-service fibre via the TAM. And a Fibre identifier detects leaked light.

An overview of fibre identification is given in Figure II.7.



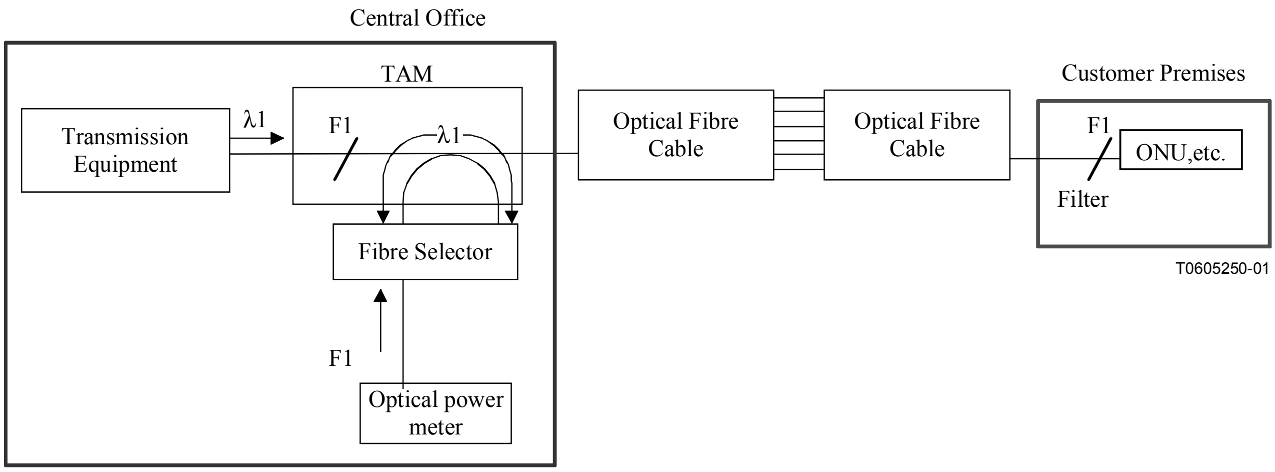
F1 λ1 Band-pass filter

Figure II.7/L.40 – Fibre identification

II.2.5.4 Optical power monitoring

A communication light (1310 nm/1550 nm) between transmission equipment and an ONU is split by the TAM and its optical power is measured by an optical power meter to check the status of the inside optical cable section.

An overview of optical power monitoring is given in Figure II.8.



F1 λ1 Band-pass filter

Figure II.8/L.40 – Optical power monitoring

II.3 Mandatory conditions

The system shall be capable of testing the following facilities.

II.3.1 Network topologies

The system is for testing the optical access networks and trunk networks.

The testable topologies of the access network shall be the single star configuration, the passive double star configuration, and the ring configuration (cable ring and SDH ring). If an optical splitter is installed outside the central office, then the passive double star configuration shall be testable up to the splitter.

The testable topologies of the trunk network shall be the single star configuration.

II.3.2 Capacities

The components of the system shall be capable of accommodating equipment as specified below.

1) The server shall be capable of accommodating 100 000 optical fibres.
2) The TEM shall be capable of accommodating max. 10 000 optical fibres.
3) The FTM shall be capable of accommodating max. 2000 optical fibres for access networks and max. 600 optical fibres for trunk networks.
4) The Fibre Selector shall be capable of accommodating max. 2000 optical fibres for access networks and max. 600 optical fibres for trunk networks.

II.3.3 Test wavelength

It shall be possible to conduct the following tests at the wavelength specified below for each test.

1)	OTDR test	1310 nm, 1550 nm and 1650 nm
2)	Section loss test	1310 nm and 1550 nm
3)	Fibre identification	1550 nm and 1650 nm

II.3.4 System data management

The system shall be capable of storing data for use in the direction of remote testing and test result confirmation.

II.3.4.1 Data for use in testing

The system shall be capable of storing the items of data listed below.

1) Central office name.
2) Cable name.
3) Fibre number.
4) Cable length.
5) Jointing point.
6) Additional information (e.g. man-hole name, service number).

II.3.4.2 Test results

The system shall be capable of storing the results of one OTDR test and section loss test for each optical fibre.

II.3.4.3 Loss and reflection measurement

The system shall determine from the OTDR test the location of a cable joint and distinguish whether the joint is a fusion splice or a connector. It shall calculate the loss and display the result on the screen of the Operations Terminal.

The system shall compare the calculated coupling loss and reflection with reference values for each connection type specified within the system. If calculated coupling loss is over the reference values, the system shall send a warning to the screen of the Operations Terminal.

The system shall be capable of displaying the measurement results together with stored test results.

II.3.5 Interface

II.3.5.1 Interface between the server and the Operations Terminal and between the server and the TEM

The interface between the server and the Operations Terminal and between the server and the TEM shall employ data communication networks, e.g. ISDN.

II.3.5.2 Interface between the server and other systems

The server shall be able to get outside plant data from the outside plant database system via data communication networks.

APPENDIX III

Optical fibre outside plant maintenance support and testing system

Abstract

This appendix, based on the Italian experience and on information collected by European operators, deals with the benefits offered by an optical fibre cable supervisory system based on the principle of continuous monitoring of attenuation. The purpose is to describe the requirements, the system architecture and the GUI (Graphical User Interface) features of this kind of optical cable supervisory system.

III.1 Introduction

The OTDR-based monitoring systems are capable of periodic measurements of the fibres' attenuation coefficient and, when integrated with transmission equipment alarms, they are capable of immediate reporting fault location data in case of cable damage.

Other monitoring systems, through the continuous monitoring of the power level received at the end of the optical fibre (just before the receiving equipment), are able to collect and store power-level data and provide an immediate detection of fibre faults through the activation of an OTDR function when the monitored power decreases below a certain level.

Both these systems are designed to minimize the service outages as well as the economic loss through the immediate location of failures at alarm generation and, at different degrees, are intended to predict failures due to the degradation of fibre performance.

The proposal of this appendix, based on practical solutions from the Italian experience, aims to provide a description of an integrated and comprehensive approach to the optical cable network supervision in order to enhance preventive maintenance capabilities of the most valuable resource in the network – the optical fibre, adding to the aforementioned solutions the integration of the continuous monitoring on the fibre optical attenuation.

III.2 Scenario

Fibre optic business is evolving rapidly worldwide, and new scenarios are arising.

As regards outside plant maintenance, not only incumbent network operators must be taken into account, but also new actors which may have different needs and perspectives with respect to the management of fibre optic cables.

In order to have a reference scheme, the most important actors and their perspectives are listed in Table III.1.

Table III.1/L.40 – Actors and perspectives for outside plant maintenance

Actors	Perspective
Incumbent Network Operators	Main business: transport of the service traffic. They provide operation and maintenance of their own optical networks. They own the transmission systems and the optical cables. Their main goal is to get a better quality of maintenance activities with reduced costs.
Newcomers (e.g. utilities – gas, water and energy suppliers – railways and highways)	Main TLC business: service provisioning (IP, bandwidth or dark fibre). They own an optical infrastructure already deployed, but they are starting with the provisioning/selling of TLC services, including dark fibre leasing. Often they do not have a proper maintenance organization able to completely manage the outside plant and they may decide to pay for outsourcing maintenance activities. As for dark fibre leasing, they have to comply with contracts, where bearer availability parameters are put into as a physical-level SLA.
Installation and maintenance companies	Main business: installation, bringing-into-service, surveillance and repair services. They provide these services to both incumbent and new operators, and they have to guarantee a defined quality of the installation/maintenance services. Their main goal is to comply with contracts' requirements relevant to parameters such as Time-To-Locate, Time-To-Repair, which are getting increasingly strict.

For all the categories listed above, the approach to preventive maintenance is very important especially in an ever increasing competitive market, where the quality of service can be a business leverage.

III.3 Benefits of attenuation continuous monitoring

As regards preventive maintenance, whose principles are described in ITU-T L.25, continuous monitoring of optical fibres' performance (based on attenuation detection through the measure of a fraction of the optical power flowing along the fibre) provides the following benefits:

- **Fault/anomaly complete detection capabilities**

  All degradation phenomena producing a loss increase are detected, independently from their duration and nature, which may not affect, at a first stage, DWDM or SDH service. This feature allows an important cost saving: in fact, when degradation gets worse repair activities are more complex, in particular when the first warnings of a potential critical situation consist of transient effects (e.g. strong vibrations on splices) that are not detected by periodic measurements.

  Up to 20% of preventable faults shows an initial stage where anomalies can be completely detected only by attenuation continuous monitoring.

- **Non-intrusiveness**

  Continuous monitoring on in-service traffic based on tapping and measuring a small fraction of the signal avoids the use of external, high power optical pulses to be inserted into the fibre at a different wavelength. OTDRs are necessary for event location function when a problem occurs, but they should not be used for in-service activities, because of both their potential intrusive characteristics and the operational requirements of WDM and Optical Filters.

  In particular, if continuous monitoring applies, OTDR can be used only on a subset of fibres (typically dark ones) with a statistical coverage of all the cable events: it is estimated that one fibre per internal tube/groove can highlight an average of more than 90% of sudden faults (cable cuts), reducing system costs and granting service security with respect to intermodulation phenomena. This is very important, taking into account that new transmission systems will emit higher power signals and enlarged spectrum.

- **Real-time fault location**

  Continuous monitoring of fibre attenuation guarantees immediate activation of location OTDR measurement, in a far more reliable and quick way than any other measurement techniques, which try to cope with real-time response to faults by the integration of equipment relay alarm contacts. Since relay alarm contacts generally provide very poor information about the faulty fibre, the integration between equipment and cable maintenance support system may be complicated and transmission technology life-cycle is quite shorter than optical OSP lifetime; so an autonomous system, providing fastest reaction to faults, should be a better solution, even when SDH and DWDM protection schemes are operating. In Europe, customers show a great interest in achieving a reliable and immediate separation between cable or equipment responsibility when a fault occurs; furthermore, they fix requirements, in terms of time-to-locate, to post-fault maintenance activities, which can be assigned to both internal and external staff. It is estimated that the identification of a trouble in the optical network, performed by a preventive maintenance support system based on continuous attenuation monitoring, saves more than one hour than systems based on periodic measurement, not integrated with service alarms. Real-time fault location based on continuous attenuation monitoring is even more important for third party companies providing installation and maintenance services to the optical infrastructure's owners. They can provide a better service and be compliant with lower intervention times if they are completely independent in supervisioning the optical network. Some recent contracts for optical network maintenance state that the maintenance provider shall guarantee less than three hours to reach the faulty point, sometimes with no visibility on transport quality parameters available to the network operator through the transmission management system. Continuous attenuation monitoring allows them to anticipate network operators alarm notifications and to respect the maintenance contract with lower investment in the in-field maintenance crew.

- **Dark fibre leasing quality control**

  Following the United States market trend, the European market of dark fibre leasing is gaining importance, since a lot of new actors bought dark fibres in order to get an operating optical network, avoiding problems and delays related to outside plant deployment. Continuous and non-intrusive attenuation monitoring can represent the best way for dark fibre owners to be sure of the profitability of their asset and to comply with SLA contracts, including the penalties foreseen when the level of "bearer availability" is not reached. This is very important because the new actors usually cannot make any assumption based on when the customer is going to transport information on their fibres and they would not like to rely on customer complaints to determine this. Moreover attenuation monitoring represents a value added option (and thus a competitive leverage) in the dark fibre offering.

Table III.2 is intended to cross-correlate actors and attenuation continuous monitoring key-benefits.

Table III.2/L.40 – Cross-correlation among actors and monitoring key-benefits

	Fault/anomaly complete detection capabilities	Non-intrusiveness	Real-time fault location	Dark fibre leasing quality control
Incumbent Network Operators	Important	Important	Important	–
Newcomers/Dark fibre providers	Important	Important	Important	Very important
Installation/maintenance companies	–	Important	Vital	–

III.4 Basic principles of the optical cable supervisory system

The optical cable supervisory system proposed in this appendix is based on the fundamental concept of the continuous monitoring of optical attenuation.

Attenuation is calculated by measuring optical power levels at both ends of the optical fibre, before the transmission equipment, and calculating the relevant power loss. Attenuation represents the key parameter of optical fibre performance, because fibre attenuation degradation is the most dangerous threat to the profitability of the most important investment in optical networks.

Continuous monitoring of attenuation on both out-of-service (dark) and in-service (lit) fibres (in the last case without affecting service traffic) allows a full-time surveillance of this key parameter, introducing complete detecting capabilities of all type of degradation effects, whatever nature and duration they have. In particular both casual and periodic optical power loss variations or fluctuations, even if very rapid, can be detected and an accurate analysis of the problem can be performed prior to the transmission equipment alarm generation and consequent user acknowledgement.

Moreover, continuous monitoring of optical attenuation can automatically activate an OTDR function in order to perform fault and degradation location when a sudden power loss along the cable is detected.

III.5 Requirements of the optical cable supervisory system

The integrated optical cable supervisory system shall be designed according to a general principle of complete transparency towards the optical network it has to supervise.

In particular, considering the forecast of one or more transmission equipment upgrades during the expected lifetime of the optical cable (25-30 years) and the current evolution trend in optical transmission technology, an optical cable supervisory system must guarantee the transparency over all the available optical band. In this way the installed supervisory system will not set limitations on the operating windows that optical transmission technology will demand in the future to the installed optical fibre.

As far as **maintenance objectives** are concerned, the most important are:

- a clear separation between transmission equipment and optical cables management responsibility; in particular, as for leased fibres, a clear distinction of responsibility between cable owners and fibre leaseholders;
- the availability of a fibre quality level certification tool, wherever a boundary between operators or between a customer and an operator is defined;

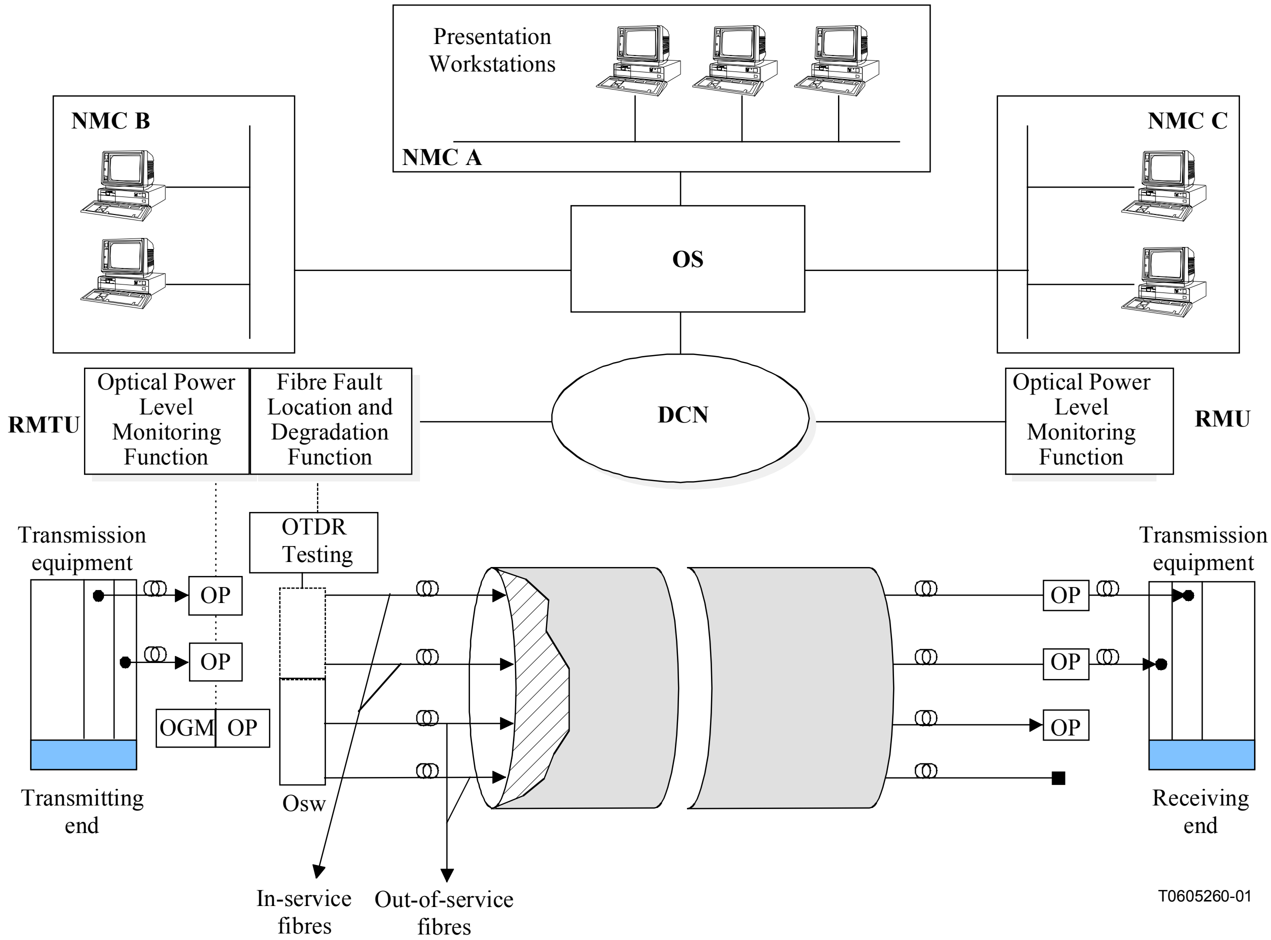
- system independence from equipment alarms;
- provision of an easy-to-use tool for a real-time identification of degradation effects in the optical network, in order to help operators to perform an effective preventive maintenance process;
- provision of an easy-to-use tool for a real-time identification and precise location of faults, in order to support operators in the corrective maintenance procedures' activation;
- provision of a comprehensive trend analysis tool, able to continuously capture optical network performance data; these performance data can be used for the evaluation of:
  – network optical cables potential profitability;
  – quality of materials;
  – installation procedures.

The **main features** of the optical cable supervisory system allowing the attainment of the mentioned maintenance objectives are listed below:

- **non-intrusiveness** on the service traffic, due to the design of a completely passive optical probe: non-intrusiveness is a key characteristic of the monitoring system, especially where cable owners are not permitted to adopt an OTDR-based monitoring process on in-service fibres (e.g. leased fibres);
- **sensitivity** to even very rapid degradation effects, which can have a negative influence on optical fibre performance in the long period (e.g. mechanical vibrations due to road and railway traffic);
- **real-time alarm reporting**: optical power and attenuation threshold-crossing events are immediately detected and reported to the system presentation interface, in order to fully exploit preventive maintenance capabilities;
- **automated OTDR measurement activation** when a threshold-crossing event referring to a variation of attenuation is reported, in order to have a minimum location time when a sudden fault or anomaly is faced;
- **permanent storage of monitoring results** and fibre reference traces, in order to enable a powerful analysis of the optical fibre attenuation trend;
- **modularity and easiness of installation** of optical probes along the optical cables;
- **system cost-effectiveness** with respect to different network topologies, ranging from trunk networks to access networks and leased fibres;
- **scalability** in terms of number of managed network elements and of available functions.

System architecture

Figure III.1 shows overall system configuration.



OGM Optical Generation Module
OP Optical Probe
Osw Optical switches
RMTU Remote Monitoring and Testing Unit
RMU Remote Monitoring Unit

Figure III.1/L.40 – Overall system configuration

– All the system management functions, i.e. attenuation monitoring, testing and surveillance functions, should be performed by a centralized Operating System (OS); the OS should also manage the databases necessary to the system operation.

– Network Maintenance Centres (NMCs) should be located where monitoring, testing and surveillance activities are requested; these activities should be performed using Operation Terminals.

– Remote Controlled Units, located at the network nodes where optical cables are terminated, should perform monitoring and testing activities. The functions performed by the mentioned units should be the following:

  a) optical power level monitoring function;

  b) fibre fault and degradation location function.

  Depending on the surveillance requirements of each node, monitoring and testing functions should be grouped in a single mechanical unit that constitutes the Remote Controlled Unit; the most usual types of Remote Controlled Units should be:

  - Remote Monitoring and Testing Unit (RMTU), containing a) and b) monitoring functions.
  - Remote Monitoring Unit (RTU), containing a) monitoring functions.

– The optical power level monitoring function a) should be performed by Optical probes (Ops) which are based on a splitter device tapping a small portion of light and measuring indirectly the optical power level of the whole light carried on the fibre.

  Particular care should be taken in designing the probes, so that maintenance activities (e.g. substitution of faulty parts) shall not affect the service traffic.

– Remote Controlled Units (RMTUs or RMUs) collect optical power values from the Ops; the OS is in charge of calculating the fibre attenuation, calculating power values referring to the end of the fibre.

– As for out-of-service fibres, the optical power level monitoring function a) should be enabled, by means of an Optical Generation Module (OGM), designed to inject a reference light into the dark fibre.

– The Optical probes (Ops) should access to any number of fibres in the cable, according to customer's requirements.

  In particular, all in-service fibres and a proper selection of dark fibres in a cable (considering cable geometry and structure) should be monitored in order to achieve a good characterization of the optical cable.

– Continuous monitoring of fibre attenuation should provide complete detection capabilities over all degradation effects, whatever nature and duration they have. So preventive maintenance is able to achieve early troubles' notification, prior to the transmission equipment alarm generation and prior to the consequent user acknowledgement.

– OTDR-based fibre fault location function b) should be performed on all the monitored fibres of the cable. Location measurements on in-service fibre require installation of WDMs in order to prevent effects of high optical OTDR pulses on the transport traffic. For economic reasons, a subset of the monitored fibres should be considered for location purpose. The selection of the location fibres should follow basically cable geometry and structure (e.g. one fibre per bundle or even just one fibre per cable). System costs are optimized if dark fibres are chosen for location. This approach is justified by the following reasons:

  • most of the non-preventable faults (e.g. dig-ups) have a high probability to affect all the fibres of the same cable and so the OTDR automatic function, using just few fibres or even just one fibre per each cable, can guarantee a good coverage of fault location in a cost-effective way;

  • attenuation continuous monitoring grants preventable fault and degradation detection on all the monitored fibres, so Maintenance Centres are always and promptly alerted. When degradation phenomena affect only a subset of the fibres in the cable and consequently OTDR automatic fault location cannot be properly used, maintenance and location operation could be scheduled before a fault location occurrence. Manual set-up of OTDR based fibre fault location function b) should be also used for focused test.

GUI features

The OS is based on a client-server architecture with centralized server functions and a number of clients geographically distributed accordingly to network operators' organizational needs.

The main OS functions are listed below:

• GIS (Geographic Information System).

• Easy-to-use tools for the configuration of the supervisory system equipment and the access to the optical network.

• Monitoring threshold configuration, applying to optical attenuation/power level.

• Real-time highlights of anomalies and faults.

- Direct access to the optical data generated by the probes at the optical link ends: real-time display of both fibre and cable attenuation (global view of attenuation values of all the fibres in the cable).
- Views of monitoring results stored in OS database.
- Trend analysis tools.
- Integrated view of the overall network status.
- Automatic OTDR measurement at configured threshold crossing, detected by the monitoring system (immediate fault/degradation location).
- OTDR measurements on user's request.
- Optical fibre trace management: view of the last trace of an optical fibre, automatic comparison with the baseline trace, permanent storage in a standardized format of multiple traces per fibre, event characterization (connectors, splices, etc.).
- Complete system auto-diagnostics management.

III.6 Conclusions

This appendix is addressed to present the Italian experience about the principles and requirements needed for an optical cable monitoring system.

The main advantage of a completely autonomous system is the capability to integrate a full-coverage approach with respect to preventive maintenance.

It allows:

- continuous monitoring of the optical link attenuation, non-intrusive on in-service fibres;
- fault/degradation location on demand, applying preferably on an out-of-service fibre per cable;
- permanent storage of all the collected data.

It offers considerable advantages relevant to:

- the definition of a reliable management competence over optical links;
- the implementation of an effective preventive maintenance procedure, guaranteeing the optical carrier service level;
- the progressive deployment of the supervisory system thanks to the modularity of its elements and the reduced impact on central office plants;
- the scalability of the system according to the number of managed optical cables and nodes, providing smart solutions for both small and large networks.

APPENDIX IV

The Indonesian experience on optical fibre cable operation and maintenance support system

IV.1 Introduction

Optical fibre cables have been extensively used in the telecommunications network to support high speed and broadband communications services. In the future, optical access network will be widely deployed due to its high potential to provide many kinds of services for both business and ordinary customers.

This appendix introduces the Indonesian experience in optical fibre operation and maintenance support system which is developed for effective and efficient operation and maintenance activities, and also to keep a high reliable optical access network.

IV.2 Fundamental requirements

The optical fibre cable operation and maintenance support system shall support various tasks involved in the constructions of optical fibre cables and installation on the customer's premises before they are put in service. After optical fibre cables are in service, it shall support the work of fault detection and repair, periodic fibre monitoring, and changing over of fibres.

The system supports several measurement functions such as described in Table IV.1:

Table IV.1/L.40 – System's measurement functions

Measurement	Test method	Purpose of test
Loss and Reflection of Connection and Cable	OTDR	• Measuring loss and reflection at cable jointing • Judging test result based on reference value of loss and reflection • Locating fault • Measuring loss and reflection fluctuation cause by deterioration at cable jointing
Section Loss	Light Source and Power Meter	• Measuring section loss of fibre optic cable • Judging test result based on reference value of section loss
Fibre Identification	Light Source and Fibre Identifier	• Identification of a designated fibre at cable jointing or cable end

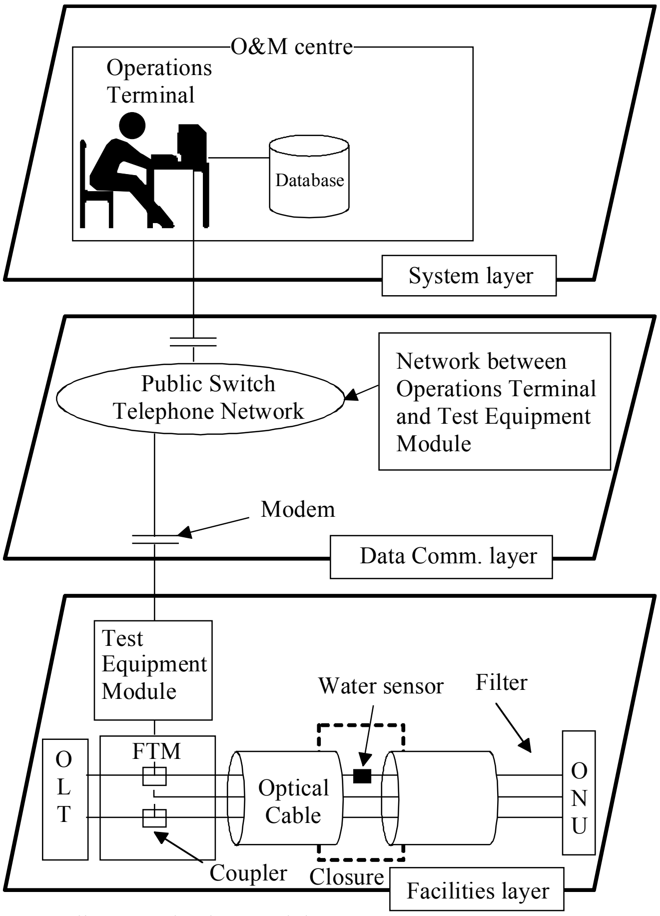
IV.3 System's basic configuration

The measurement system's physical networks consist of 3 layers (see Figure IV.1):

– System Layer, consists of Operations Terminal and Database.

– Data Communication Layer, consists of public telecommunications network and modems.

– Facilities Layer, consists of optical components such as coupler, water sensor, filter, fibre selector, and test measuring instrument. The optical coupler is connected to each fibre to be tested. Optical couplers are arranged inside Test Access Modules (TAMs) which are installed within Fibre Termination Module. Test light is inserted into fibre through fibre selector and the coupler. The Test Equipment Module (TEM) includes the fibre selector, main controller, and test measuring instrument such as OTDR and Light Source. The main Controller is a personal computer supported by a database whose functions are to control test measuring instruments and process the measurement data automatically.



FTM Fibre Termination Module
OLT Optical Line Termination
ONU Optical Network Unit

Figure IV.1/L.40 – System's basic configuration

IV.4 Functions of main units

The optical fibre cable operation and maintenance support system consists of three main units:

- Operations Terminal.
- Test Equipment Module.
- Fibre Termination Module.

Detailed functions of each main unit are described in Table IV.2.

Table IV.2/L.40 – Functions of the main units

No.	Main unit	Function
1	Operations Terminal	• Registers, enquires and changes data required in performing the test and information on each unit. Also deletes those that are no longer required. • Instructs test for the specified fibre, displays the test result, and outputs it as a document.
2	Test Equipment Module (TEM)	• Controls the test equipment according to instructions from the operations terminal, tests optical fibre, analyses the test result, and sends the result to the operations terminal. • Performs periodical OTDR test for specified fibre at the specified interval, according to instructions from the operations terminal. Also sends the test result to the operations terminal.
3	Fibre Termination Module (FTM)	• Selects fibre to be tested from multiple optical fibres terminated according to instruction from the TEM.

IV.5 System's hardware configuration

The system's hardware configuration is shown in Figure IV.2 below.

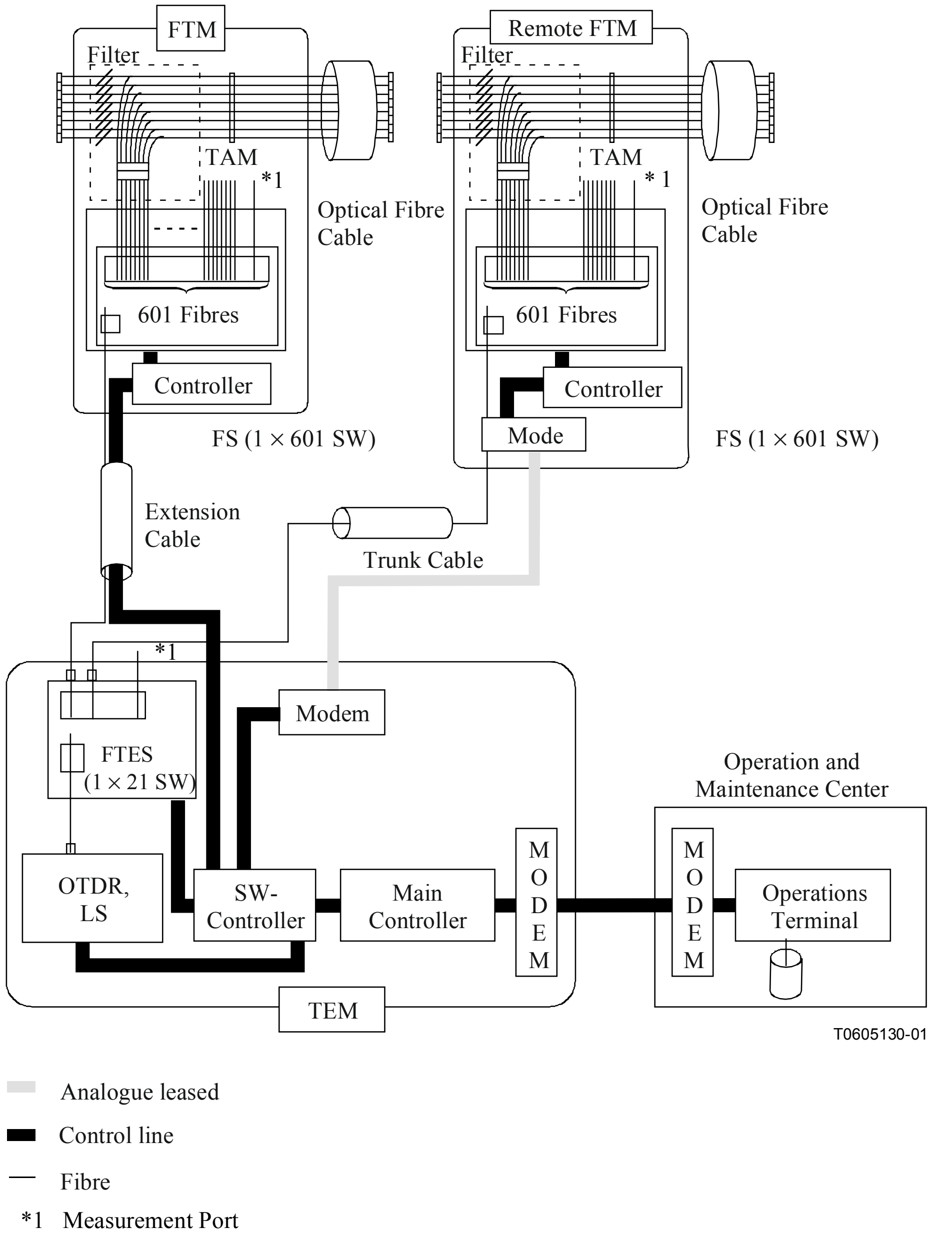


Figure IV.2/L.40 – Hardware Configuration

IV.6 General specification of optical fibre cable O&M support system

The optical fibre operation and maintenance support system shall satisfy the following conditions.

IV.6.1 Test scope

The system is basically for testing the optical access network.

The testable topologies of the network between the telephone office and the facilities on the customer premises shall be the single star configuration, the passive double star configuration, and the ring configuration (cable ring and SDH ring). If an optical splitter is installed outside the telephone office, then the passive double star configuration shall be testable up to the splitter.

Application to trunk facilities shall also be considered.

IV.6.2 Capacities

The components of the system shall be capable of accommodating equipment as specified below.

a) The Operations Terminal shall be capable of controlling 10 TEMs.

b) The TEM shall be capable of accommodating 20 FTMs.

c) The FTM shall be capable of accommodating 600 optical fibres.

d) The Fibre Selector shall be capable of accommodating 600 optical fibres.

IV.6.3 Test wavelength

It shall be possible to conduct the following tests at the wavelength specified below for each test.

a) OTDR test 1650 −10, +20 nm

b) Section loss test 1650 −10, +20 nm

c) Fibre identification 1650 −10, +20 nm

IV.6.4 Test distance restrictions

The restrictions on testing distance are as specified in Table IV.3.

Table IV.3/L.40 – Testing distance

Test	Maximum distance	Measurement conditions
OTDR test	20 km	Wavelength: 1650 −10, +20 nm Pulse width: 1 μs or less
Section loss test	20 km	Wavelength: 1650 −10, +20 nm Modulation light: 270 Hz
Fibre identification	20 km	Wavelength: 1650 −10, +20 nm Modulation light: 270 Hz

IV.6.5 System data management

The system shall be capable of storing data for use in the direction of remote testing and test result confirmation.

The system shall be capable of storing the items of data listed below as data for use in testing.

a) TEM number.

b) Fibre Selector number.

c) Fibre number.

d) Cable number.

e) Additional information (e.g. cable length).

The system shall be capable of storing the results of one OTDR test and section loss test for each optical fibre.

IV.6.6 Coupling loss and reflection measurement

The T-AURORA system shall determine from the OTDR test the location of a cable joint and distinguish whether the joint is a fusion splice or a connector. It shall calculate the coupling loss and display the result on the screen of the Operations Terminal.

The system shall compare the calculated coupling loss and reflection with reference values for each connection type specified within the system. If calculated coupling loss is over the reference values, the system shall send a warning to the screen of the Operations Terminal.

The system shall be capable of displaying the measurement results together with stored test results.

IV.6.7 Transmission conditions

The interface between the Operations Terminal and the TEM shall employ analogue telephone lines.

The TEM shall be able to control remotely located Fibre Selectors.

The maximum distance at which communication between the TEM and the Fibre Selector is possible shall be 10 km.

IV.6.8 System use conditions

It shall be possible to use each of the components of the system other than the Water Sensor under the environmental conditions listed below.

a) Ambient temperature 10° C to 50° C

b) Humidity 20% to 95% RH with no condensation

c) Power supply 220 V AC±10% (single phase, 50 Hz)

IV.7 Application software

The application software will be installed on personal computers at the Operation and Maintenance Centre and central office. The main functions of the application software are described in Table IV.4.

Table IV.4/L.40 – Main system functions of application software

No.	Function	Description
1	Test Operations	• Performs the OTDR test, Section Loss test, and Fibre Identification remotely from the operations terminal. • Performs the periodical OTDR test to determine whether fibres are normal.
2	Test data and result management	• Registers, enquires and changes data required in performing the tests. Also deletes data that are no longer required. • Outputs the test result of fibres and prints the result.
3	Security	• Registers, enquires, changes and deletes information of operations terminal. • Registers, enquires, changes and deletes information of operator (end user).
4	System reports management	• Enquires fibre alarms detected during the continuous OTDR test or periodical test. • Enquires failures caused in the TEM.

The detailed functional configuration of application software is shown in Figure IV.3.

Functions of application software

- 7.1 Test Operations Function
  - 7.1.1 Fibre Identification
  - 7.1.2 Section Loss test
  - 7.1.3 OTDR test
  - 7.1.4 Continuous OTDR test
  - 7.1.5 Preventive Maintenance
  - 7.1.6 Result reception
- 7.2 Test Data and Result Management Function
  - 7.2.1 Central office information management
  - 7.2.2 Test equipment module information management
  - 7.2.3 Fibre selector information management
  - 7.2.4 Cable information management
  - 7.2.5 Fibre information management
  - 7.2.6 Test result management
- 7.3 Security Function
  - 7.3.1 Operations terminal information management
  - 7.3.2 Operator information management
  - 7.3.3 Password management
- 7.4 System Reports Management Function
  - 7.4.1 Alarm history inquiry
  - 7.4.2 Failure history inquiry

Figure IV.3/L.40 – Functional configuration of application software

APPENDIX V

Spain's experience of an optical fibre monitoring system (OFMS)

V.1 Introduction

The growing importance of transmission systems using optical fibre as a physical carrier is resulting in an increase in economic resources that telecommunication providers are dedicating to the corrective and preventive maintenance of those systems and carriers. The essential objective of such maintenance is to achieve the highest quality and best economic output from the said systems and carriers.

Automatic and centralized monitoring systems, unlike manual operators, provide rational and exhaustive control of the plant or designated elements thereof.

Existing automatic monitoring systems, dedicated to optical fibre monitoring, are based on the development of specific elements and the availability of optical switches with a large number of channels that, in conjunction with the gradual reduction in price of auxiliary passive elements, make for flexible systems at very competitive prices, with a high degree of modularity.

In addition, the possibility of the system working in the fourth transmission window extends monitoring not only to fibres working in the second window but also to those working in the third and even in both.

V.2 General

The basic parameters of an optical fibre from the point of view of transmission, are attenuation, which limits the length of the transmission path, and dispersion, which determines the bandwidth.

The whole length of an optical fibre cable is exposed to an infinite number of sources of disturbance that mainly affect attenuation in the link; this is also influenced by the loss from typical interconnection components (splices and connectors).

The easiest alternatives for monitoring an optical fibre cable are those based on measurement of its vacant fibres, since many degradations and breaks affect all the fibres in the cable. This means that monitoring one of these fibres provides general information on the condition of the cable with a reliability percentage above 60%.

Nevertheless, exhaustive monitoring of the cable with a greater degree of reliability requires monitoring of fibres carrying traffic. This implies that the monitoring system wavelength is higher than that of the transmission equipment.

V.3 Optical fibre monitoring system (OFMS) – General description

The optical fibre monitoring system used by Telefónica de España meets its demands and specifications. This makes for a system that is totally focused on monitoring and management of the optical fibre plant, with maximum output and efficiency in all its functions.

The system manages the reception of alarms in the fibres when these are generated by breaks or degradations. The system also conducts a series of measurements aimed at identifying the state of the fibres at any time.

The system is composed of all the optical fibre plant terminals (OFPT) strategically distributed over the plant to be monitored. These terminals collect information on the state of the fibres and, by comparing the actual state with a determined threshold, generate an alarm situation when the state referred to requires it.

The information collected by the plant terminals assigned to a specified monitoring area is sent to the control centre responsible for maintenance and conservation of the area in question.

V.4 System performance

Analysed from the operational point of view, the optical fibre monitoring system described in this appendix has the following functions:

- Monitoring of vacant fibres as well as fibres in service by means of reflectometric techniques in the second, third and fourth transmission windows.
- Detection and location (using the corresponding mathematical algorithm) of degradations and breaks in the fibres.
- Automatic execution of measurements in the event of alarms in the line transmission equipment (LTE).
- Execution of measurements on request from a higher hierarchy (remote control centre, operation site).
- Recording of singular points (splices, manhole, etc.) that allow the events of the trace to be associated with their geographical location.
- Assignment of vacant fibres to various transmission systems with the purpose of executing measurements in these fibres when any alarm occurs in the LTE and in regenerators that are not connected to the fibres.
- Recording of historical and reference measurements enabling a provisional evolution analysis.

- Capture of the reflectometric trace of the fibre.
- Urgent and non-urgent alarm management, when attenuation of the link exceeds the acceptable threshold.
- Execution of attenuation measurements in splices and reflection measurements in connectors.
- Back-up optical fibre system enabling communication with control centres to be re-established through a secondary system, should the principal system fail.
- Obtaining database texts and reports by means of Internet facilities.
- Geographical information system that shows in graphic form information relating to the optical fibre plant at different levels (national, territorial and local) according to set parameters.

V.5 System

The hardware architecture of the monitoring system required to carry out the functions defined in the previous clause is shown in Figure V.1.

The diagram shows the following basic elements:

– **Control system**: This element implements and controls all management, monitoring and control functions of the optical fibre plant.

– **Remote control centre**: Controls the functionality and operability of the system's remote users.

– **Operations terminal**: Workstation assigned to the system user which can be physically connected to the control sub-system or to a remote control centre.

– **Multiplexor (MUX)**: This element can be seen as a communication concentrator through which the whole management of OFPT communication with the different operation points of the system is undertaken. The connection between MUX and OFPT is usually point-to-point (PTP), using the basic telephony network when back-up lines are necessary, in cases where PTP communication is unavailable.

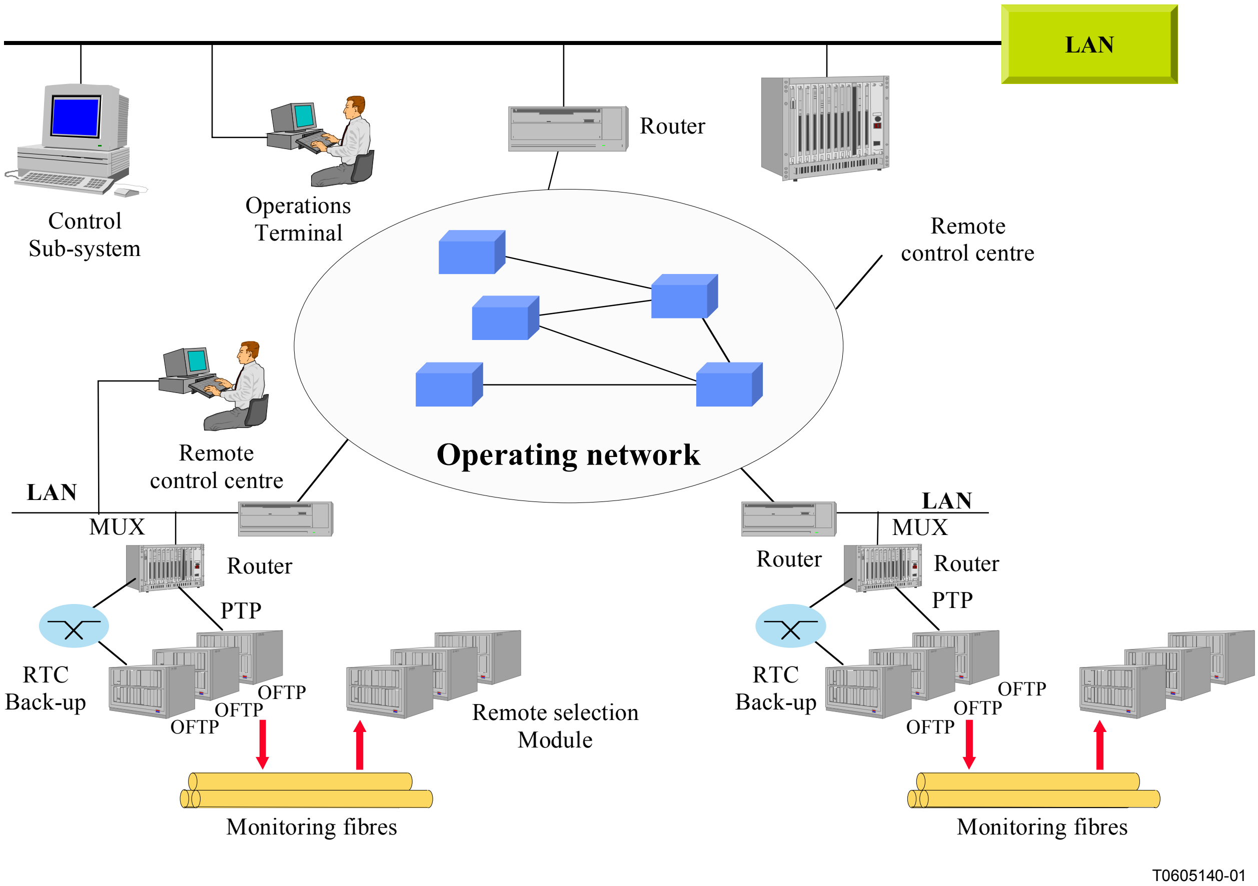


Figure V.1/L.40 – OFMS architecture

– **OFTP**: Consists of three different modules (communication control, reflectometric measurements and local selection), controls the state of the assigned fibre, generating an alarm (which is communicated to the corresponding control centre) when the recorded measurement is outside the reference limits of the previously defined system.

– **Remote selection module**: This module is connected by means of an optical fibre to the OFTP to allow monitoring of the fibre (or section of the fibre) when it is some distance from the OFTP.

V.6 Incorporation of the system in the centralized monitoring structure

As explained in detail above, the optical fibre monitoring system is a plant management and control system which has to be incorporated in the centralized monitoring structure of the plant currently in operation.

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