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DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Optical fibre
submarine cable systems

Test methods applicable to optical fibre submarine cable systems

Recommendation ITU-T G.976



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Recommendation ITU-T G.976

Test methods applicable to optical fibre submarine cable systems

Summary

It is to be recognized that numerous test methods are specific to particular optical fibre submarine cable system designs and are, therefore, proprietary information of the system designer/supplier. However, a common understanding needs to be met between the system designer/supplier and the system purchaser/operator on the general purpose of testing and the meaning of the results.

Recommendation ITU-T G.976 highlights the purpose of testing in optical fibre submarine cable systems and lists the main test methods applicable to these systems. Specific test methods are described.

This edition of the Recommendation includes the addition of test regarding vibration and shock resistance.

History

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

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Recommendation ITU-T G.976

Test methods applicable to optical fibre submarine cable systems

1 Scope

Testing is of high importance for optical fibre submarine cable systems since, together with a proper design and a careful definition of technologies, it is the only way to guarantee that the quality, lifetime and reliability performance of an optical fibre submarine cable system shall be met.

It is to be recognized that numerous test methods are specific to particular system designs and are therefore proprietary information of the system designer/supplier. However, a common understanding needs to be met between the system designer/supplier and the system purchaser/operator on the general purpose of testing and the meaning of the results.

Insofar as they are applicable to optical fibre submarine cable systems, general test methods recommended by the ITU-T should be applied. It should be recognized that these methods may need adaptation to the specific characteristics of optical fibre submarine systems. It should also be recognized that some test methods are specific to optical fibre submarine cable systems and are of little or no use elsewhere.

The purpose of this Recommendation is to highlight the testing of optical fibre submarine cable systems by listing the main tests applicable to these systems and by describing test methods specific to these systems.

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.

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|-----------------|--|
| [ITU-T G.650.1] | Recommendation ITU-T G.650.1 (2010), <i>Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable.</i> |
| [ITU-T G.650.2] | Recommendation ITU-T G.650.2 (2007), <i>Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable.</i> |
| [ITU-T G.661] | Recommendation ITU-T G.661 (2007), <i>Definitions and test methods for the relevant generic parameters of optical amplifier devices and subsystems.</i> |
| [ITU-T G.671] | Recommendation ITU-T G.671 (2012), <i>Transmission characteristics of optical components and subsystems.</i> |
| [ITU-T G.702] | Recommendation ITU-T G.702 (1988), <i>Digital hierarchy bit rates.</i> |
| [ITU-T G.780] | Recommendation ITU-T G.780/Y.1351 (2010), <i>Terms and definitions for synchronous digital hierarchy (SDH) networks.</i> |
| [ITU-T G.783] | Recommendation ITU-T G.783 (2006), <i>Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks.</i> |
| [ITU-T G.810] | Recommendation ITU-T G.810 (1996), <i>Definitions and terminology for synchronization networks.</i> |

- [ITU-T G.821] Recommendation ITU-T G.821 (2002), *Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an Integrated Services Digital Network.*
- [ITU-T G.823] Recommendation ITU-T G.823 (2000), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy.*
- [ITU-T G.826] Recommendation ITU-T G.826 (2002), *End-to-end error performance parameters and objectives for international, constant bit-rate digital paths and connections.*
- [ITU-T G.828] Recommendation ITU-T G.828 (2000), *Error performance parameters and objectives for international, constant bit-rate synchronous digital paths.*
- [ITU-T G.959.1] Recommendation ITU-T G.959.1 (2012), *Optical transport network physical layer interfaces.*
- [ITU-T G.971] Recommendation ITU-T G.971 (2010), *General features of optical fibre submarine cable systems.*
- [ITU-T G.972] Recommendation ITU-T G.972 (2011), *Definition of terms relevant to optical fibre submarine cable systems.*
- [ITU-T G.973] Recommendation ITU-T G.973 (2010), *Characteristics of repeaterless optical fibre submarine cable systems.*
- [ITU-T G.977] Recommendation ITU-T G.977 (2011), *Characteristics of optically amplified optical fibre submarine cable systems.*
- [ITU-T L.12] Recommendation ITU-T L.12 (2008), *Optical fibre splices.*
- [IEC 61290] IEC 61290, *Optical fibre amplifiers – Test methods series.*
- [IEC/TR 62284] IEC/TR 62284 ed1.0 (2003), *Effective area measurements of single-mode optical fibres – Guidance.*
- [IEC/TR 62285] IEC/TR 62285 ed2.0 (2005), *Application guide for non-linear coefficient measuring methods.*
- [IEC/TR 62324] IEC/TR 62324 ed2.0 (2007), *Single-mode optical fibres – Raman gain efficiency measurement using continuous wave method – Guidance.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

- 3.1.1 optical fibre amplifier (OFA)** [ITU-T G.661].
- 3.1.2 plesiochronous digital hierarchy (PDH)** [ITU-T G.702].
- 3.1.3 synchronous digital hierarchy (SDH)** [ITU-T G.780].

Other terms used in this Recommendation are defined in [ITU-T G.972].

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

APD	Avalanche Photodiode
ATM	Alternative Test Method
BBER	Background Block Error Ratio
BER	Bit Error Ratio
CBL	Cable Breaking Load
CF	Compression Factor
COTDR	Coherent Optical Time Domain Reflectometry
DC	Direct Current
DOHB	Draw Off/Hold Back
ESR	Errored Second Ratio
FA	Fixed Analyser
FWM	Four-Wave Mixing
GF	Gain Flatness
IOR	Index Of Refraction
LW	Lightweight
LWP	Lightweight Protected
MFD	Mode Field Diameter
NF	Noise Figure
NG	Nominal Gain
NOTS	Nominal Operating Tensile Strength
NPTS	Nominal Permanent Tensile Strength
NSIP	Nominal Signal Input Power
NSOP	Nominal Signal Output Power
NTTS	Nominal Transient Tensile Strength
OA	Optical Amplifier
OFA	Optical Fibre Amplifier
O-E	Opto-Electro
OSR	Optical Submarine Repeaters
OTDR	Optical Time Domain Reflectometry
PDG	Polarization Dependent Gain
PDH	Plesiochronous Digital Hierarchy
PDL	Polarization Dependent Loss
PFE	Power Feeding Equipment
PHB	Polarization Hole Burning
PIN	P Intrinsic N

PMD	Polarization Mode Dispersion
RTM	Reference Test Method
SCI	Self-Compensated Interferometric
SDH	Synchronous Digital Hierarchy
SESR	Severely Errored Second Ratio
SNR	Signal-to-Noise Ratio
SOA	Semiconductor Optical Amplifier
SOP	State Of Polarization
SPM	Self-Phase Modulation
SSG	Small Signal Gain
TM	Test Method
TTE	Terminal Transmission Equipment
UV	Ultra Violet
XPM	Cross-Phase Modulation

5 Conventions

This clause is intentionally left blank.

6 Purpose of testing in optical fibre submarine cable systems

Testing is to be made at different periods in a system's life; during development, manufacturing and operation, for different purposes. A large amount of testing is of interest for the system designer and supplier only and is not relevant to this Recommendation. However, testing is also of concern for a system purchaser and operator. The latter includes qualification tests, quality assurance tests, installation tests, commissioning tests, and maintenance tests.

6.1 Qualification tests

Qualification tests are made as part of the development programme so as to choose proper designs and technologies and, once they are chosen, to demonstrate that they adequately satisfy the performance, reliability and lifetime requirement of the system. They are made on every component, material, subassembly, piece of equipment, and on the system itself. Tests conducted by the manufacturer supplying components or materials are often adequate and, therefore, used. The testing programme is defined for each item, taking into account its own characteristics and the experience already gained on similar items. Qualification tests generally include appropriate performance characterization, technology characterization and qualification, and life tests.

6.1.1 Performance characterization tests

Performance characterization is intended to demonstrate that the item satisfies the transmission requirement within the whole range of specified environmental conditions.

6.1.2 Technology characterization tests

Technology characterization is intended to evaluate the ruggedness of the technology, to identify the potential failure mechanisms (with a potential feedback on the design or technology so as to avoid dangerous mechanisms), and to establish models which permit prediction of the behaviour of devices. These tests may provide the conditions of use for the various items, and permit the establishment of screening and selection procedures, so as to eliminate devices which would exhibit

early failure, or not satisfy the lifetime requirement. Some tests are made with the item operating, others in storage condition. High stress (such as severe temperature, mechanical, electrical or optical conditions), sometimes with an increased level of stress, and with a fast or slow time variation may be applied.

6.1.3 Technology qualification tests

Technology qualification is intended to confirm the quality of the technology and the adequacy of the selection procedure. The test conditions are chosen taking into account the results of the characterization tests. For example, tests can be made at several temperatures which permit the evaluation of an activation energy and/or an acceleration factor.

6.1.4 Life tests

Ageing tests are intended to evaluate the lifetime and reliability of a system with reference to end-of-life criteria chosen, taking into account the characteristics of the system's operation. Acceleration by temperature or other means, using an established or derived model, may be used. Part of the life tests may be made in conditions similar to the operating conditions of the system.

6.1.5 Testing programmes

The testing programmes for these different tests should indicate the number of devices to be tested, the description of the test conditions, and the methodology of the tests.

However, most testing programmes are the proprietary information of suppliers.

6.2 Quality assurance tests

Reference to ISO standards may be required.

Quality assurance tests are made during the manufacturing so as to demonstrate that the manufacturing process shall maintain the inherent quality and reliability provided by the design. It includes manufacturing control tests, component selection or acceptance tests, subassembly, subunit or equipment acceptance tests.

6.2.1 Manufacturing control tests

Manufacturing control tests are made during the manufacturing programme, including manufacture of components, subassemblies, equipment, optical fibres and cable, so as to ensure that the manufacturing operation is compatible with the required quality. Manufacturing control tests include part or all of the following:

- manufacturing process qualification tests which consist of manufacturing an industrial prototype according to the defined manufacturing procedure, prior to the start of manufacture, to finalize the manufacturing process and to verify its adequacy;
- manufacturing tools qualification tests which are periodically made, after tool recalibration during manufacture, to ensure that the performance of the manufacturing tools are in accordance with the manufacturing specification; these tests may consist of manufacturing devices which are submitted to tests which may be destructive;
- operator qualification tests, made initially after training and periodically during manufacture, to ensure the ability of an operator to accomplish tasks according to the specification; these tests may consist of manufacturing devices which are submitted to tests which may be destructive;
- visual inspection, made at identified stages of the manufacturing process, on each production item to visually check the result of an operation or a sequence of operations; these tests are non-destructive and may be made using inspection tools such as optical microscopy, radioscopy, etc.

6.2.2 Component selection tests

Each component (e.g., electronic, optoelectronic or optical component, including the optical fibre, and raw material) to be used in an optical fibre submarine cable system is individually tested so as to ensure that it will present the required performance during the system design life. The testing procedure is defined during the qualification, taking into account the results of the technology characterization tests. Depending on the nature of the component, the selection or acceptance tests may include part or all of the following:

- batch qualification tests, which are high-stress destructive tests made on a few samples from the batch, and which are intended to ensure that the general ruggedness of the batch is satisfactory, so as to be able to eliminate unsatisfactory batches;
- stabilization tests, which are high-stress tests applied to all the components, and which result in the stabilization of the characteristics;
- screen tests, made on all the components of selected batches, to identify weaker devices which would present early failure and to eliminate them; the level of stress should be such that it will not significantly reduce the component reliability or lifetime;
- long duration tests, applied during a sufficiently long period to a few samples, or to all the components if necessary, with conditions close to the condition of operation in the system, to monitor the evolution of their characteristics and to eliminate components which would present an insufficient lifetime.

6.2.3 Subassembly, subunit or equipment factory tests

Tests are made in the factory on each subassembly (e.g., printed circuit board), subunit (e.g., repeater electronic unit, or power feeding equipment (PFE) power converter) and piece of equipment (e.g., cable length, repeater or terminal equipment). It consists of testing the equipment performance (e.g., transmission performance, functional performance) in the nominal environmental conditions specified for the item.

6.3 Installation tests

These tests take place during a portion of the assembly (or on the completely submerged plant), during subsequent loading on the cable ship, during laying of the submerged plant, during and after installation of the terminal station equipment. Their purpose is to verify that, at each important period of the system installation, the functionality and the performance of the installed equipment meets the specifications necessary to ensure the successful completion of the whole cable system.

6.3.1 Tests during submarine portion assembly

General

At each jointing operation (cable-to-cable, cable to repeater/amplifier, etc.), tests on mechanical and electrical (if applicable) quality of the joint are performed.

Regenerated systems

The performances tests, including transmission quality assessment, supervisory and functional tests (for example, loop-back, transmitter change-over, etc.), are done on each individual repeater, and after connection to the assembled sections. The results should ascertain that the transmission quality is met with the specified margins on each section of regeneration, that the supervisory system meets its requirements, and that the repeater's functionality works correctly. Comparison is made between the test results and the manufacturer claims.

Prior to the loading of the fully assembled submerged portion, transmission quality tests (including end-to-end bit-error ratio, individual error count in each repeater, etc.), and supervisory and repeater functional tests are used to demonstrate that the required specifications are met.

Amplified systems

Since the transmission quality measured on an amplified section does not represent the whole link, or portion thereof, these tests make use of measurements and techniques proven to be adequate during the development process. It is recognized that, environmental conditions being different from those on the sea bottom, these tests are not fully representative of the system performances. They may include tests on individual optical amplifiers (noise figure, gain and peak gain wavelength, supervisory), and individual cabled fibre section (loss, chromatic dispersion, polarization mode dispersion, etc.). As a minimum, optical signal transmission, supervisory, and functional (for example, loop-back, pump laser change-over, etc. if applicable) tests are performed while jointing each optical amplifier or on assembled portions to ensure they function in accordance with the system design.

At the end of the portion assembly, it is verified that the interface specifications with the other portions are met (this can be done via measurement or calculation of the Q factor, optical signal-to-noise ratio, optical spectrum, cumulated chromatic dispersion, cumulated polarization mode dispersion, etc. or any other parameter measurement or calculation representative of transmission quality). If applicable, all the functionalities implemented in the amplifiers are also checked through the supervisory system. It is preferred, particularly when the whole submerged plant is to be laid at once, that performance measurements also be made with the possible use of temporary compensation techniques (for example, on chromatic dispersion) to account for environmental conditions different from those on the sea bottom.

It must be recognized that since the amplified technology is new and in continuous progress, the nature of the tests to be performed may change significantly.

Repeaterless systems

These tests are mainly related to the optical characteristics of the cabled fibres in order to ascertain that the optical power budget and propagation impairments, when applicable, will provide the transmission quality with sufficient margins. When techniques such as remote pumping of in-line amplifying fibre are used, other tests such as pump signal transmission may be necessary.

6.3.2 Testing during submarine portion loading and laying

Regenerated and amplified systems

During the loading of the submarine portion on the cable ship, the system may be powered in order to check that the submarine portion is free from damage. After loading completion, the portion will be powered and tests will be carried out in order to check the stability of the portion performances over a sufficient time period.

During the laying operations, the system should be powered to the greatest extent possible, consistent with personal safety, in order to test the system and to verify that no fault or significant degradation which may jeopardize final performance has occurred. At the end of the complete installation of a submerged portion, the necessary interface performance will be checked in order to ensure that subsequent jointing with the other portions will provide the required performances. These interface tests are particularly important if the cable system is provided on a multisupplier basis since different portions may use different designs.

Repeaterless systems

As a minimum, the transmission quality of the fibres is continuously or periodically monitored during the laying operations. If techniques like remote pumping of submerged amplifying fibres are used, specific tests will be performed in complement.

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6.3.3 Tests after terminal equipment installation

After completion of the equipment installation in each cable station, functional (including alarms), performance and safety tests should be carried out in order to verify that the specifications are met in the environmental conditions of each terminal station. These tests should verify the performances, functionalities and maintenance facilities of each equipment and their interworking performances. The following conditions should be considered as a minimum:

- power feed equipment working on a dummy load (except for repeaterless systems);
- terminal transmission equipment in a loop-back configuration;
- computerized maintenance controller connected to the terminal transmission equipment (TTE) and to the PFE.

6.4 Cable system commissioning tests

These tests take place after the terminal equipment installation test in each station and after the laying of the submerged plant. They will verify that the as-installed system is compliant with the technical specifications, including a verification of the margins required at the beginning of life to warrant transmission performances, maintenance and repair operations during the specified design life. The following tests should be considered:

End-to-end performance and functionality tests

These tests are performed between the input/output ports of the cable system in order to verify that the technical specifications are met for transmission quality and functionality of the cable system as a whole.

Submerged plant performance and functional tests

Functional and transmission quality tests on the repeaters/amplifiers are performed to ensure that sufficient margins exist at the installation of the system. Tests of the supervisory system and of fault localization are also performed. Tests parameters may vary with the system design and the transmission technique (see clause 6.3.1). Transmission and margins demonstration tests use the installed terminal transmission equipment and supervisory system. For amplified systems, indirect parameters such as the Q factor, optical signal-to-noise ratio and optical spectrum may also be used. The commissioning tests include a stability period over which all the relevant parameters of the installed cable system are recorded. These results provide a baseline or reference data as necessary for future operation, maintenance or repair of the system.

Terminal station equipment tests

These performance and functional tests are performed on this equipment (TTE, PFE, maintenance controller) in their operational configuration, together with the submerged plant.

6.5 Maintenance tests

These tests are done throughout the operational life of the system during normal and maintenance operations. They are used to periodically check the performances of the system for preventive maintenance, for fault localization and to evaluate the possible margin degradations due to repairs.

6.5.1 Routine tests

These tests are performed on the submerged plant from the terminal stations with the help of the supervisory system. They are done in service, either automatically or on operator request. Their results are used for comparison with previous baseline data. They must not degrade the transmission quality below the specified levels. These tests are not applicable to repeaterless systems.

Similar routine tests are also performed on the terminal equipment.

6.5.2 Tests used for fault location on the submerged plant

These tests may be performed out-of-service from the terminal station using the supervisory system or with the help of external means (e.g., OTDR, coherent OTDR, resistance or capacitance measurements on the conductor, etc.). They are used to locate and to identify the fault with the maximum precision. Generally, an optical time domain reflectometry (OTDR) is employed for this purpose, especially a coherent optical time domain reflectometry (COTDR) is usually used in long distance optical fibre amplifier (OFA) systems fault location because of its higher sensitivity and higher frequency selectivity.

From the cable ship, before recovery of the faulty piece of cable or submerged equipment, tests for cable location can be used, for example, by electroding when applicable.

6.5.3 Tests made during and after a repair on the submerged plant

After recovery of the cable near the fault location, tests are carried out in order to more accurately determine the location and the nature of the fault. They can include optical time domain reflectometry and insulation measurements.

After a repair, tests are performed to check the mechanical, electrical and transmission quality of this repair prior to laying. For regenerated systems, the power margins on the repaired section are measured using the information on transmission quality given by the supervisory system. For amplified systems, methods similar to those used during system installation and commissioning tests may be used.

7 List of tests to be made on optical fibre submarine cable systems and applicable test methods

This clause contains references to test methods specific to submarine systems, and references to general test methods studied under other questions and which are directly applicable to optical fibre submarine cable systems.

7.1 Tests on the optical fibres of the optical fibre submarine cable

7.1.1 General

This clause lists and describes tests on the optical fibres of the optical fibre submarine cable. General descriptions of tests of single-mode optical fibres are found in [ITU-T G.650.1] and [ITU-T G.650.2]. The aim of this clause is to list the tests on the optical fibres of the optical fibre submarine cable. The tests listed here are closely related to the transmission characteristics of optical fibre submarine cable systems. All the test items, relevant Recommendations, applicable fibre types, and relevant systems are summarized in Table 1.

Table 1 – Lists of typical tests on the optical fibres of the optical fibre submarine cable

Tests	Defined in	Described in	Applicable to	Relevant systems
Mode field diameter (MFD)	Clause 3.3.2 of [ITU-T G.650.1]	Clause 5.1 of [ITU-T G.650.1]	F	All systems
Cladding diameter	Clause 3.4.3 of [ITU-T G.650.1]	Clause 5.2 of [ITU-T G.650.1]	F	All systems
Core concentricity error	Clause 3.4.8 of [ITU-T G.650.1]	Clause 5.2 of [ITU-T G.650.1]	F	All systems
Cladding non-circularity	Clause 3.4.6 of [ITU-T G.650.1]	Clause 5.2 of [ITU-T G.650.1]	F	All systems