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

Optical fibre attenuators

ITU-T Recommendation L.31

(Previously CCITT Recommendation)

ITU-T L-SERIES RECOMMENDATIONS

CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

For further details, please refer to ITU-T List of Recommendations.

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation L.31 was prepared by ITU-T Study Group 6 (1993-1996) and was approved by the WTSC (Geneva, 9-18 October 1996).

NOTES

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

2. The status of annexes and appendices attached to the Series L Recommendations should be interpreted as follows:

- an *annex* to a Recommendation forms an integral part of the Recommendation;
- an *appendix* to a Recommendation does not form part of the Recommendation and only provides some complementary explanation or information specific to that Recommendation.

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SUMMARY

This Recommendation describes the main features of optical attenuators, in terms of types, field of application and configurations.

Moreover, this Recommendation examines the optical, mechanical and environmental characteristics of optical fibre attenuators, advising on general requirements and testing methods.

OPTICAL FIBRE ATTENUATORS

(Geneva, 1996)

1 Scope

This Recommendation:

- gives general information on fundamental types of optical fibre attenuator, their field of application and the main requirements about their characteristics in terms of optical, mechanical and environmental behaviour;
- makes a classification of these components in terms of the configurations used in optical fibre plants;
- reports all the important optical parameters and gives general specifications on the optical, mechanical and environmental performances of optical fibre attenuators;
- reports the main testing methods of optical fibre attenuators.

This Recommendation refers to single-mode optical fibre attenuators only because this fibre is mostly used in present telecommunication systems.

2 Abbreviations

This Recommendation uses the following abbreviations:

PON Passive Optical Network

BER Bit Error Rate

IEC International Electrotechnical Commission

3 General information

Optical fibre attenuators are passive optical components that are often required in an optical fibre transmission link to reduce the optical power incident on the photodetector.

They can introduce a fixed level of attenuation (*fixed attenuators*) or they may have a tuning control to set the level of attenuation into a range of selectable values (*variable attenuators*).

Typical applications for optical fibre attenuators are:

a) to assure the linear behaviour of optical fibre receivers avoiding optical power overloading;

b) to balance the optical power into Passive Optical Network (PON) branches;

c) to make measurements on an optical telecommunication system.

Regarding the first application, the optical power emitted by the source in a transmission system usually exceeds the needed power budget: the aim is to guarantee the operating condition of the system even if some degradation phenomena occur in the link. The direct control of the optical emission of the sources can be made only for a limited dynamic range and may produce undesired modification of the characteristics of the emitted optical beam, like modal distribution or change of central wavelength. Therefore, attenuators are used in optical telecommunication systems to limit the optical power level at the receiver.

The second application of these components is justified by the non-uniformity of the link losses in a real point-to-multipoint network. In fact, due to the topology of the network, different optical paths may suffer different losses so that specific optical attenuators may be needed in some branches of the network to assure the same linear operating range at each optical receiver.

Finally, the third application mainly concerns variable optical attenuators. In fact, these kinds of components can be very important for making several measurements in an optical telecommunication system, for example, each time the performance (BER) as a function of the received optical power has to be characterized.

Every type of optical attenuator is normally inserted at the receiving end of the link: in fact, light intensity regulation at the transmitting end would require remote power monitoring of the received level of the optical signal.

Since optical fibre attenuators may be used in central offices or in every type of outside closure, they should be able to operate in both controlled and uncontrolled environments.

In particular, the ideal attenuator should have a stable attenuation over a wide temperature range and under mechanical stresses; it should be independent of wavelength and state of polarization and should not cause reflection or interference of the optical signal.

In addition, other desired characteristics for an ideal variable attenuator are low insertion loss, wide attenuation range and accurate mechanical or non-mechanical control of attenuation.

The most common types of attenuator that are permanently installed in optical fibre plant are fixed. Therefore, technological efforts are mainly aimed to optimize the reliability and to minimize the dimensions of fixed attenuators.

4 Configurations

A classification of optical fibre attenuators can be made considering whether they have attached optical fibre pigtails or not.

If the attenuator has fibre pigtails, it is an attenuating patch-cord. It can have one or two permanently attached fibre pigtails, which may or may not be connectorized. Then, this kind of attenuator may also be directly spliced into the optical fibre link. Attenuators without fibre pigtails may be defined as *attenuating adapters* and they are used for insertion in connectorized optical fibre cables. They can be made in a female-female configuration (*connector receptacle*) or male-female configuration (*optical pad*). Optical attenuators without pigtails are preferred in most applications because of their compactness. In particular, the most widely used configuration is the male-female; this is due to its intrinsic versatility. In fact, it is the only configuration that permits the connection or disconnection into the optical link, avoiding any other modification of the plant.

Previously described configurations apply to both fixed and variable attenuators even if most used variable attenuators are patch-cord connectors.

A variable attenuator can be calibrated or uncalibrated. It may be continuously variable or adjustable in discrete steps.

Most variable attenuators have a mechanical control, for example, a screw or a knob for tuning, but there are also either electrically, magnetically, acoustically or optically controlled variable attenuators. However, while the field of application of non-mechanically controlled variable attenuators is essentially R&D, they should not be considered for use in telecommunication plants.

Moreover, as mechanically variable attenuators are normally only temporarily used in telecommunication systems (so they cannot be considered an integrated part of the telecommunication plant), in the following we restrict our interest to fixed attenuators only.

Additional details on principles of operation and technological aspects of attenuators can be found in the ITU-T Handbook *Construction, installation, jointing and protection of optical fibre cables,* 1994 edition.

5 Parameters and performance specifications

The fundamental optical parameters of a fixed attenuator for telecommunications are:

- available nominal value of attenuation;
- operating wavelength ranges;
- attenuation tolerances;
- polarization sensitivity;
- optical power linearity;

– modal noise amplitude;
– return loss.

The minimum mandatory specifications that are required to describe the environmental and mechanical performances of optical attenuators should be:

– mechanical endurance;
– vibration;
– cold;
– dry heat;
– damp heat;
– climatic sequence.

Values of nominal attenuation, attenuation tolerance, operating wavelength ranges, polarization sensitivity and return loss, are given in Table 6.3/G.671.

A linear response of the attenuator, without permanent damage of the attenuating zone, should be assured at least for input power up to + 15 dBm and up to + 20 dBm will be allowed in some cases.

For some advanced applications, an estimate of the modal noise introduced by the attenuator should be done. This can be made by calculating the amplitude of oscillations in the spectral response and then, to determine both the operating wavelength ranges and modal noise, a measurement of the spectral attenuation is recommended. For most applications, if the above-mentioned attenuation tolerances are met over the whole previously reported operating wavelength ranges, the modal noise effect *introduced by the attenuator* is negligible. Conversely, a modal noise estimate is fundamental whenever a wavelength operating range smaller than the half period of the spectral attenuation oscillations is accepted.

Finally, during the mechanical and environmental tests, a maximum variation of 10% on the actual value of attenuation in both operating wavelength ranges should be tolerated. After the test the measured attenuation values should meet the above-mentioned tolerances.

6 Test methods

The reference document for all the procedures that should be considered in testing optical fibre attenuators:

– IEC 869-1 (2nd ed.) *Generic specification for optical fibre attenuators.*

For measurement of polarization sensitivity, the only reference is the IEC Publication 1300-3-2.

Moreover, the following details should be considered for mechanical and environmental tests:

– *Mechanical endurance*: a cycle of 1000 repeated matings. The value of the attenuation should be measured during the test, after every 25 matings and at the end of the test.
– *Vibration*: the frequency of sinusoidal vibrations should be continuously variable in the range 10 to 55 to 10 Hz with a cycle duration of 60 s; the amplitude should be 0.75 mm and the duration of the test should be 0.5 h per axis.
– *Cold*: the test should be carried out at a temperature of – 25 °C for 16 h.
– *Dry heat*: temperature of testing + 70 °C for 16 h.
– *Damp heat*: temperature of testing + 40 °C for 16 h at a relative humidity of 93 ± 3%.
– *Climate sequence*: the sequence should be:

	External	**Internal**
High temperature Low temperature	+ 70 °C – 40 °C	+ 40 °C + 10 °C
Duration of extreme temperature	1 hour	1 hour
Number of cycles	12	12
Rate of temperature change	± 1 °C/min	± 1 °C/min

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