INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.655

(10/96)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

Transmission media characteristics – Optical fibre cables

Characteristics of a non-zero dispersion shifted single-mode optical fibre cable

ITU-T Recommendation G.655

(Previously CCITT Recommendation)

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TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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ITU-T RECOMMENDATION G.655

CHARACTERISTICS OF A NON-ZERO DISPERSION SHIFTED SINGLE-MODE OPTICAL FIBRE CABLE

Summary

This Recommendation describes a single-mode fibre whose chromatic dispersion (absolute value) is required to be greater than some non-zero value throughout the wavelength range of anticipated use. This dispersion suppresses the growth of four-wave mixing, a non-linear effect that can be particularly deleterious in dense Wavelength-Division Multiplexing (WDM).

Source

ITU-T Recommendation G.655 was prepared by ITU-T Study Group 15 (1993-1996) and was approved by the WTSC (Geneva, October 9-18, 1996).

FOREWORD

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NOTE

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

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Recommendation G.655

CHARACTERISTICS OF A NON-ZERO DISPERSION SHIFTED SINGLE-MODE OPTICAL FIBRE CABLE

(Geneva, 1996)

1 Scope

This Recommendation describes a single-mode fibre whose chromatic dispersion (absolute value) is required to be greater than some non-zero value throughout the wavelength range of anticipated use. This dispersion suppresses the growth of four-wave mixing, a non-linear effect that can be particularly deleterious in dense Wavelength-Division Multiplexing (WDM).

This fibre is optimized for use at wavelengths in a prescribed region between 1500 nm and 1600 nm. Its geometrical, optical, transmission and mechanical parameters are described below.

The meaning of the terms used in this Recommendation and the guidelines to be followed in the measurement to verify the various characteristics are given in Recommendation G.650. The characteristics of this fibre, including the definitions of the relevant parameters, their test methods and relevant values, will be refined as studies and experience progress.

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; all 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.

- ITU-T Recommendation G.650 (1993), *Definition and test methods for the relevant parameters of single-mode fibres*.
- ITU-T Recommendation G.652 (1993), *Characteristics of a single-mode optical fibre cable*.
- ITU-T Recommendation G.653 (1993), *Characteristics of a dispersion-shifted single-mode optical fibre cable*.
- ITU-T Recommendation G.654 (1993), *Characteristics of a 1550 nm wavelength loss-minimized single-mode optical fibre cable*.
- ITU-T Recommendation G.663 (1996), *Application related aspects of optical fibre amplifier devices and sub-systems*.

3 Terms and definitions

For the purposes of this Recommendation, the definitions given in Recommendation G.650 apply.

4 Abbreviations

This Recommendation uses the following abbreviations:

GPa Gigapascals

SDH Synchronous Digital Hierarchy

WDM Wavelength Division Multiplexing

5 Fibre characteristics

Only those characteristics of the fibre providing a minimum essential design framework for fibre manufacturers are recommended in clause 5. Of these, the cabled fibre cut-off wavelength may be significantly affected by cable manufacture or installation. Otherwise, the recommended characteristics will apply equally to individual fibres, fibres incorporated into a cable wound on a drum, and fibres in an installed cable.

5.1 Mode field diameter

The nominal mode field diameter at 1550 nm shall lie within the range of 8 μm to 11 μm. For a given nominal mode field diameter, the mode field deviation from nominal should not exceed the limits of ± 10%.

5.2 Cladding diameter

The recommended nominal value of the cladding diameter is 125 μm. The cladding deviation should not exceed the limits of ± 2 μm.

For some particular jointing techniques and joint loss requirements, other tolerances may be appropriate.

5.3 Mode field concentricity error

The recommended mode field concentricity error at 1550 nm should not exceed 1 μm.

NOTE – A one-to-one mapping to concentricity at other wavelengths, including white light, has been observed.

5.4 Non-circularity

5.4.1 Mode field non-circularity

In practice, the mode field non-circularity of fibres having nominally circular mode fields is found to be sufficiently low that propagation and jointing are not affected. It is therefore not considered necessary to recommend a particular value for the mode field non-circularity. It is not normally necessary to measure the mode field non-circularity for acceptance purposes.

5.4.2 Cladding non-circularity

The cladding non-circularity should not exceed 2%. For some particular jointing techniques and joint loss requirements, other tolerances may be appropriate.

5.5 Cut-off wavelength

Three useful types of cut-off wavelength can be distinguished:

a) Cable cut-off wavelength, λ_{cc}.

b) Fibre cut-off wavelength, λ_c.

c) Jumper cable cut-off wavelength, λ_{cj}.

NOTE – For some specific submarine cable applications, other cable cut-off wavelength values may be required.

The correlation of the measured values of λ_c, λ_{cc}, and λ_{cj} depends on the specific fibre and cable design and the test conditions. While in general, $\lambda_{cc} < \lambda_{cj} < \lambda_c$, a general quantitative relationship cannot be easily established. The importance of ensuring single-mode transmission in the minimum cable length between joints at the minimum operating wavelength is paramount. This may be performed by recommending the maximum cable cut-off wavelength λ_{cc} of a cabled single-mode fibre to be 1480 nm, or for typical jumpers by recommending a maximum jumper cable cut-off to be 1480 nm, or for worst case length and bends by recommending a maximum fibre cut-off wavelength to be 1470 nm.

5.6 1550 nm bend performance

The loss increase for 100 turns of fibre, loosely wound with 37.5 mm radius and measured at 1550 nm, shall not exceed 0.5 dB.

For SDH and WDM applications, the fibre may be used at wavelengths exceeding 1550 nm. The 0.5 dB maximum loss shall apply at the maximum wavelength of anticipated use (i.e. wavelengths ≤ 1580 nm). The loss at this wavelength may be projected from a loss measurement at 1550 nm, using either spectral loss modeling or a statistical database for that particular fibre design. Alternatively, a qualification test at the longer wavelength may be performed.

NOTE 1 – A qualification test may be sufficient to ensure that this requirement is being met.

NOTE 2 – The above value of 100 turns corresponds to the approximate number of turns deployed in all splice cases of a typical repeater span. The radius of 37.5 mm is equivalent to the minimum bend-radius widely accepted for long-term deployment of fibres in practical systems installations to avoid static-fatigue failure.

NOTE 3 – If for practical reasons fewer than 100 turns are chosen to implement this 37.5 mm radius test, it is suggested that not less than 40 turns, and a proportionately smaller loss increase be used.

NOTE 4 – If bending radii smaller than 37.5 mm are planned to be used in splice cases or elsewhere in the system (for example R = 30 mm), it is suggested that the same loss value of 0.5 dB shall apply to 100 turns of fibre deployed with this smaller radius.

NOTE 5 – The 1550 nm bend-loss recommendation relates to the deployment of fibres in practical single-mode fibre installations. The influence of the stranding-related bending radii of cabled single-mode fibres on the loss performance is included in the loss specification of the cabled fibre.

NOTE 6 – In the event that routine tests are required, a smaller diameter loop with one or several turns can be used instead of the 100-turn test, for accuracy and measurement ease of the 1550 nm bend sensitivity. In this case, the loop diameter, number of turns, and the maximum permissible bend loss for the several-turn test should be chosen so as to correlate with the 0.5 dB loss recommendation of the 37.5 mm radius 100-turn functional test.

5.7 Material properties of the fibre

5.7.1 Fibre materials

The substances of which the fibres are made should be indicated.

NOTE – Care may be needed in fusion splicing fibres of different substances. Provisional results indicate that adequate splice loss and strength can be achieved when splicing different high-silica fibres.

5.7.2 Protective materials

The physical and chemical properties of the material used for the fibre primary coating and the best way of removing it (if necessary) should be indicated. In the case of single jacketed fibre, similar indications shall be given.

5.7.3 Proofstress level

The specified proofstress, σ_p, shall be at least 0.35 GPa, which corresponds to a proofstrain of approximately 0.5%. Proofstress is often specified as 0.69 GPa.

NOTE – The definitions of the mechanical parameters are contained in 1.2/G.650 and 2.6/G.650.

5.8 Refractive index profile

The refractive index profile of the fibre does not generally need to be known.

5.9 Longitudinal uniformity

Under study.

NOTE – At a particular wavelength, the local absolute value of dispersion coefficient can vary away from the value measured on a long length. If the value decreases to a small value at a wavelength that is close to an operating wavelength in a WDM system, four-wave mixing can induce the propagation of power at other wavelengths, including, but not limited to, other operating wavelengths. The magnitude of the four-wave mixing power is a function of the absolute value of dispersion coefficient, the dispersion slope, the operating wavelengths, the optical power, and the distance over which four-wave mixing occurs.

6 Factory length specifications

Since the geometrical and optical characteristics of fibres given in clause 1 are barely affected by the cabling process, clause 6 will give recommendations mainly relevant to transmission characteristics of cabled factory lengths.

Environmental and test conditions are paramount and are described in the guidelines for test methods.

6.1 Attenuation coefficient

Optical fibre cables covered by this Recommendation generally have attenuation coefficients in the 1550 nm region below 0.35 dB/km.

NOTE – The lowest values depend on the fabrication process, fibre composition and design, and cable design. Values in the range of 0.19-0.25 dB/km in the 1550 nm region have been achieved.

6.2 Chromatic dispersion coefficient

The chromatic dispersion coefficient D shall obey:

$$D_{min} \leq |D(\lambda)| \leq D_{max} \text{ for } \lambda_{min} \leq \lambda \leq \lambda_{max}$$

NOTE 1 – Values of λ_{min}, λ_{max}, D_{min}, and D_{max} are under study, but may be specified to meet the requirements of a WDM system provided:

0.1 ps/nm•km $\leq D_{min} \leq D_{max} \leq$ 6.0 ps/nm•km and 1530 nm $\leq \lambda_{min} \leq \lambda_{max} \leq$ 1565 nm.

NOTE 2 – D_{min} does not necessarily occur at λ_{min} and D_{max} does not necessarily occur at λ_{max}.

NOTE 3 – Dispersion uniformity should be consistent with the functioning of the system.

NOTE 4 – The sign of D does not change over the above wavelength range for a given fibre, but it may change from one fibre to another within a system.

NOTE 5 – Depending on the system design and transmission type, it may be necessary to specify the sign of D.

NOTE 6 – The requirements on dispersion follow from WDM system design, which must balance first order dispersion with various non-linear effects, such as four-wave mixing, cross-phase modulation, modulation instability, stimulated Brillouin scattering, and soliton formation (see Recommendation G.663).

NOTE 7 – It is not necessary to measure the chromatic dispersion coefficient on a routine basis.

6.3 Polarization mode dispersion coefficient

Under study.

NOTE – Optical fibre cables covered by this Recommendation generally have a polarization mode dispersion coefficient below 0.5 ps/km$^{1/2}$. This corresponds to a PMD-limited transmission distance (1 dB penalty) of about 400 km for STM-64 systems.

Systems with lower bit rate-distance products can tolerate higher values of PMD coefficient without impairment.

7 Elementary cable sections

An elementary cable section usually includes a number of spliced factory lengths. The requirements for factory lengths are given in clause 6. The transmission parameters for elementary cable sections must take into account not only the performance of the individual cable lengths, but also, amongst other factors, such things as splice losses and connector losses (if applicable).

In addition, the transmission characteristics of the factory length fibres as well as such items as splices and connectors, etc. will all have a certain probability distribution which often needs to be taken into account if the most economic designs are to be obtained. The following subparagraphs in this section should be read with this statistical nature of the various parameters in mind.

7.1 Attenuation

The attenuation A of an elementary cable section is given by:

$$A = \sum_{n=1}^{m} \alpha_n L_n + \alpha_s \chi + \alpha_c y$$

where:

- α_n = attenuation coefficient of the nth fibre in elementary cable section
- L_n = length of the nth fibre
- m = total number of concatenated fibres in elementary cable section
- α_s = mean splice loss
- χ = number of splices in elementary cable section
- α_c = mean loss of line connectors
- y = number of line connectors in elementary cable section (if provided)

A suitable allowance should be allocated for suitable cable margin for future modifications of cable configurations (additional splices, extra cable lengths, ageing effects, temperature variations, etc.). The above equation does not include the loss of equipment connectors.

The mean loss is used for the loss of the splices and connectors. The attenuation budget used in designing an actual system should account for the statistical variations in these parameters.

7.2 Chromatic dispersion

The chromatic dispersion in ps can be calculated from the chromatic dispersion coefficients of the factory lengths, assuming a linear dependence on length, and with due regard for the signs of the coefficients and system source characteristics (see 6.2).

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