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TRANSMISSION MEDIA CHARACTERISTICS

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

ITU-T Recommendation G.653

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. 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, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation G.653 was revised by the ITU-T Study Group XV (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

2 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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CHARACTERISTICS OF A DISPERSION-SHIFTED SINGLE-MODE OPTICAL FIBRE CABLE

(Melbourne, 1988; amended at Helsinki, 1993)

The CCITT,

considering

(a) that dispersion-shifted optical fibre cables are going to be used widely in telecommunication networks;

(b) that the foreseen potential applications may require several kinds of single-mode fibres differing in operation wavelength, geometrical and optical characteristics, and attenuation dispersion and other transmission characteristics,

recommends

a dispersion-shifted single-mode fibre which has a nominal zero-dispersion wavelength close to 1550 nm, and a dispersion coefficient which is monotonically increasing with wavelength. This fibre is optimized for use at wavelengths in the region between 1500 nm and 1600 nm, but may also be used at around 1310 nm subject to the constraints outlined in this Recommendation.

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

1 Fibre characteristics

Only those characteristics of the fibre providing a minimum essential design framework for fibre manufacturers are recommended in this clause. 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.

This Recommendation applies to fibres having a nominally circular mode field.

1.1 Mode field diameter

The nominal value of the mode field diameter at 1550 nm shall lie within the range of 7.0 to 8.3 µm. The mode field diameter deviation should not exceed the limits of ± 10% of the nominal value.

NOTES

1 The choice of a specific value within the above range is not necessarily associated with a specific fibre design.

2 It should be noted that the fibre performance required for any given application is a function of essential fibre and systems parameters, i.e. mode field diameters, cut-off wavelength, chromatic dispersion, system operating wavelength, and bit rate/frequency of operation, and not primarily of the fibre design.

1.2 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.

1.3 Mode field concentricity error

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

NOTE – For some particular jointing techniques and joint loss requirements, tolerances up to 3 µm may be appropriate.

1.4 Non-circularity

1.4.1 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.

1.4.2 Cladding non-circularity

The cladding non-circularity should be less than 2%. For some particular jointing techniques and joint loss requirements, other tolerances may be appropriate.

1.5 Cut-off wavelength

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

a) the cut-off wavelength λ_c of a primary coated fibre according to the relevant fibre RTM;

b) the cut-off wavelength λ_{cc} of a cabled fibre in a deployment condition according to the relevant cable RTM.

The correlation of the measured values of λ_c and λ_{cc} depends on the specific fibre and cable design and the test conditions. While in general $\lambda_{cc} < \lambda_c$, a quantitative relationship cannot easily be established.

Single-mode transmission in the 1550 nm region can be ensured by recommending λ_{cc} to be less than 1270 nm.

NOTE – The above recommendation is not sufficient to ensure 1310 nm region single-mode operation in any possible combination of system operating wavelength, cable length and cable deployment conditions. Suitable limits on λ_c or λ_{cc} should be set in case 1310 nm region operation is foreseen, with particular attention to prevent modal noise effects in minimum cable lengths between repair joints and cable jumpers.

1.6 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 be less than 0.5 dB.

NOTES

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

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.

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

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 shall apply to 100 turns of fibre deployed with this smaller radius.

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.

6 In the event that routine tests are required a small 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.

1.7 Material properties of the fibre

1.7.1 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.

1.7.2 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.

1.7.3 Proofstress level

- The proofstress σ_p shall be at least 0.35 GPa (which approximately corresponds to a proofstrain ~0.5%).
- The dwell-time t_d shall be 1 s. A shorter alternate dwell-time t_a may be chosen; then a larger alternate proofstress σ_a must be chosen according to the following equation:

$$\sigma_a = \sigma_p \left[\frac{t_d}{t_a} \right]^{\frac{1}{n_d}}$$

- The value of the dynamic fatigue parameter n_d is determined by a dynamic fatigue test method.
- For some applications, such as local networks or submarine systems, higher values of proofstress (or proofstrain) may be desired. Values such as 0.7 GPa or 1.4 GPa (or ~1% and ~2%) are for further study.

1.8 Refractive index profile

The refractive index profile of the fibre does not generally need to be known; if one wishes to measure it, the reference test method in Recommendation G.651 may be used.

1.9 Longitudinal uniformity

Under study.

2 Factory length specifications

Since the geometrical and optical characteristics of fibres given in clause 1 are barely affected by the cabling process, this clause 2 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.

2.1 Attenuation coefficient

Optical fibre cables covered by this Recommendation generally have attenuation coefficients in the 1550 nm region below 0.5 dB/km. When they are intended for use in the 1300 nm region, their attenuation coefficient in that region is generally below 1 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.

2.2 Chromatic dispersion coefficient

The following equation specifies the chromatic dispersion $D(\lambda)$, in ps/(nm · km), as:

$$D(\lambda) = (\lambda - \lambda_0) S_0$$

where λ is the wavelength of interest, in nm, λ_0 is the zero-dispersion wavelength in nm, and S_0 is the zero-dispersion slope in ps/(nm^2 · km). The slope S_0, is specified by its maximum value: $S_0 < S_{0max}$. The zero dispersion wavelength, λ_0, is specified by the nominal value of 1550 and its maximum tolerance, $\Delta\lambda_{0max}$, above and below 1550 nm (considered symmetrical):

$$1550 - \Delta\lambda_{0max} < \lambda_0 < 1550 + \Delta\lambda_{0max}$$

In addition, the maximum absolute value of the dispersion coefficient, in D_{max}, in ps/(nm · km), is specified over the specified window width, $\Delta\lambda_w$, in nm, above and below 1550 nm. Then:

$$|D(\lambda)| < D_{max}$$

$$\text{for } 1550 - \Delta\lambda_w < \lambda < 1550 + \Delta\lambda_w$$

Users operating with a transmitter central wavelength separated from 1550 nm (either above or below) by $\Delta\lambda_t$, in nm, may calculate the maximum absolute value of the dispersion coefficient as:

$$D_m(\Delta\lambda_t) = D_{max}(\Delta\lambda_t + \Delta\lambda_{0max}) / (\Delta\lambda_w + \Delta\lambda_{0max}),$$

$$\text{for } 0 \leq \Delta\lambda_t \leq \Delta\lambda_w \text{ and}$$

$$D_m(\Delta\lambda_t) = D_{max} + S_{0max}(\Delta\lambda_t - \Delta\lambda_w),$$

$$\text{for } \Delta\lambda_w \leq \Delta\lambda_t \leq 50 \text{ nm}$$

where $D_{max} = D_m(\Delta\lambda_w)$. Figure 1 schematically illustrates the specification:

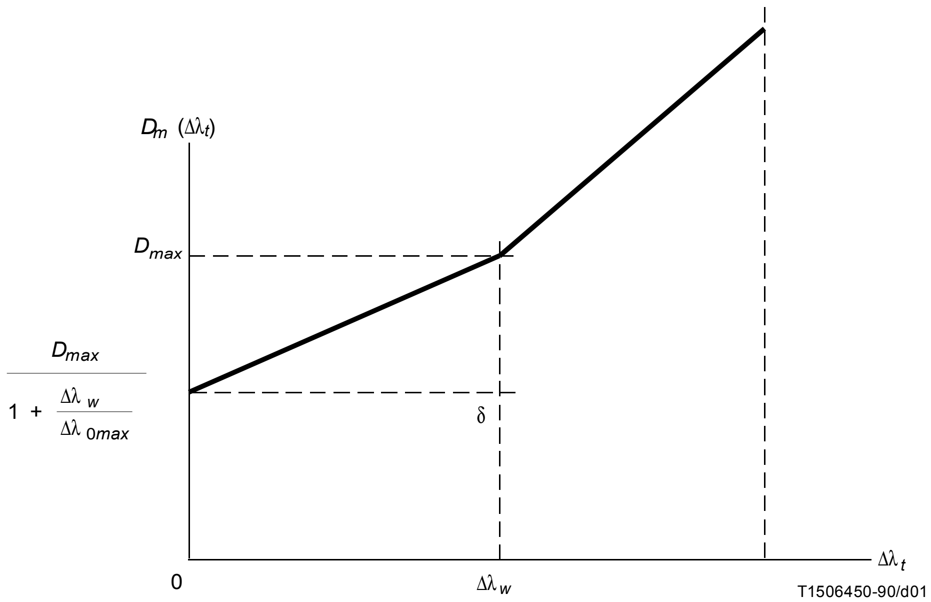

FIGURE 1/G.653

Maxim absolute value of the dispersion coefficient

The specification of the dispersion coefficient for this Recommendation is as follows:

$\Delta\lambda_{0max} \leq 50$ nm

$S_{0max} \leq 0.085$ ps / (nm^2 · km)

$D_{0max} = 3.5$ ps / (nm · km) between 1525 and 1575 nm

$\Delta\lambda_w = 25$ nm

NOTES

1 The values above are provisionally specified in order to give guidance to fibre and system designers. Further study and trade-offs between $\Delta\lambda_{0max}$ and S_{0max} may be needed in the future to improve the fibre dispersion performances in the working wavelength window.

2 It is not necessary to measure the chromatic dispersion coefficient on a routine basis.

3 Elementary cable sections

An elementary cable section usually includes a number of spliced factory lengths. The requirements for factory lengths are given in clause 2. 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 sub-paragraphs in this section should be read with this statistical nature of the various parameters in mind.

3.1 Attenuation

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

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

where

- α_n = attenuation coefficient of nth fibre in elementary cable section;
- L_n = length of 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 a 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 splices and connectors. The attenuation budget used in designing an actual system should account for the statistical variations in these parameters.

3.2 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 2.2).

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