6. Recommendation G.651

CHARACTERISTICS OF A 50/125 μm MULTIMODE GRADED INDEX OPTICAL FIBRE CABLE

The CCITT,

considering that

(a) multimode optical fibre cables are used widely in telecommunication networks;

(b) the foreseen potential applications may require multimode fibres differing in:

- nature of material
- geometrical characteristics
- operating wavelength region(s)
- transmission and optical characteristics
- mechanical and environmental aspects;

(c) Recommendations on different kinds of multimode fibres can be prepared when practical use studies have sufficiently progressed;

recommends

a graded index, multimode fibre, which may be used in the region of 850 nm or in the region of 1300 nm or alternatively may be used in both wavelength regions simultaneously.

This fibre can be used for analogue and for digital transmission.

Its geometrical, optical, and transmission characteristics are described below.

The meaning of the terms used in this Recommendation is given in Annex A and the guidelines to be followed in the measurements to verify the various characteristics are indicated in Annex B.

Annexes A and B may become separate Recommendations as additional multimode fibre Recommendations are agreed upon.

1. Fibre characteristics

The fibre characteristics dealt with in § 1 are those which ensure the interconnection of fibres with acceptable low losses.

Only the intrinsic fibre characteristics (not depending on the cable manufacture) are recommended in § 1. They will apply equally to individual fibres, fibres incorporated into a cable wound on a drum, and fibres in installed cables.

1.1 Geometrical characteristics of the fibre

1.1.1 Core diameter

The recommended nominal value of the core diameter is 50 µm.

The core diameter deviation should not exceed the limits of ± 6% (± 3 µm).

1.1.2 Cladding diameter

The recommended nominal value of the cladding diameter is 125 µm.

The cladding diameter deviation should not exceed the limits of ± 2.4% (± 3 µm).

2.2.1 Modal distortion bandwidth: amplitude response

The modal bandwidth amplitude response is specified in the form of -3 dB optical (-6 dB electrical) points of the bandwidth of the total amplitude/frequency curve corrected for chromatic dispersion. A more complete curve of the total bandwidth response should also be given.

2.2.3 Chromatic dispersion

When required the manufacturer of the optical fibres should indicate the chromatic dispersion coefficient values of the fibre type in the operating wavelength region(s). The test method is contained in Annex B, section V, to Recommendation G.652.

Note 1 - For multimode fibres the dominant chromatic dispersion mechanism is material dispersion.

Note 2 - Typical values of the chromatic dispersion coefficient for high grade silica optical fibres are the following:

3.2 Baseband response (overall -3dB optical bandwidth)

The baseband response is given in the frequency domain and includes the effects of both modal distortion and chromatic dispersion and can be represented by the expression:

$$B_T = [B_{modal}^{-2} + B_{chromatic}^{-2}]\ {-½}$$

where

B_T = overall bandwidth (including modal distortion and chromatic dispersion)

B_{modal} = modal distortion bandwidth

$B_{chromatic}$ = chromatic dispersion bandwidth (see Note 3)

Note 1 - Both the fibre modal distortion baseband response and the source spectrum are assumed to be Gaussian.

Note 2 - For certain applications the effect of chromatic dispersion is negligible, in which case chromatic dispersion can be ignored.

Note 3 - $B_{chromatic}$, the chromatic bandwidth, is inversely proportional to the section length and, if the source spectrum is assumed to be Gaussian, can be expressed as:

$$B_{chromatic}\ (MHz) = (\triangle╪ \bullet D(╪) \bullet 10^{-6} \bullet L/0.44)^{-1}$$

where

△╪ = FWHM source line width (nm)

D(╪) = chromatic dispersion coefficient (ps/(nm.km))

L = section length (km)

3.2.1 Modal distortion bandwidth

The modal distortion bandwidth values for individual cable lengths in an elementary cable section are obtained from the relevant fibre specification. However, the overall modal distortion bandwidth of the elementary cable section may not be a linear addition of the individual responses due to mode coupling and other effects at splices and, sometimes, along the length of the fibre.

The modal distortion bandwidth for an elementary cable section is therefore given by:

$$B_{modal\ total} = \left[\sum_{1}^{x} B_{modal}^{-1/n} \right]^{-n}$$

where

$B_{modal\ total}$ = overall modal distortion bandwidth of an elementary cable section

A.1 **alternative test method (ATM)**

A test method in which a given characteristic of a specified class of optical fibres or optical fibre cables is measured in a manner consistent with the definition of this characteristic and gives results which are reproducible and relatable to the reference test method and to practical use.

A.2 **attenuation coefficient**

In an optical fibre it is the attenuation per unit length.

Note - The attenuation is the rate of decrease of average optical power with respect to distance along the fbire and is defined by the equation:

$$P(z) = P(0)\ 10^{-(\alpha z/10)}$$

where

$P(z)$ = power at distance z along the fibre

$P(0)$ = power at $z = 0$

α = attenuation coefficient in dB/km if z is in km.

From this equation the attenuation coefficient is:

$$\alpha = \frac{-10 \log_{10} [P(z)/P(0)]}{Z}$$

This assumes that ∝ is independent of z.

A.3 **bandwidth (of an optical fibre)**

That value numerically equal to the lowest frequency at which magnitude of the baseband transfer function of an optical fibre decreases to a specified fraction, generally to -3dB optical (-6dB electrical), of the zero frequency value.

Note - The bandwidth is limited by several mechanisms: mainly modal distortion and chromatic dispersion in multimode fibres.

A.4 **chromatic dispersion**

The spreading of a light pulse in an optical fibre caused by the different group velocities of the different wavelengths composing the source spectrum.

Note - The chromatic dispersion may be due to one or more of the following: material dispersion, waveguide dispersion, profile dispersion. Polarization dispersion does not give appreciable effects in circularly-symmetric fibres.

A.5 **chromatic dispersion coefficient**

The chromatic dispersion per unit source spectrum width and unit length of fibre. It is usually expressed in ps/(nm.km).

A.6 **cladding**

That dielectric material of an optical fibre surrounding the core.

A.7 **cladding mode stripper**

A device that encourages the conversion of cladding modes to radiation modes.

A.8 **core**

The central region of an optical fibre through which most of the optical power is transmitted.

A.9 **core area**

For a cross section of an optical fibre the area within which the refractive index everywhere (excluding any index dip) exceeds that of the innermost homogeneous cladding by a given fraction of the difference between the maximum of the refractive index of the core and the refractive index of the innermost homogeneous cladding.

Note - The core area is the smallest cross-sectional area of a fibre excluding any index dip, which is contained within the locus of points where the refractive index n_3 is given by

$n_3 = n_2 + k(n_1 - n_2)$ (see Figure A-1/G.651)

where

n_1 = maximum refractive index of the core

n_2 = refractive index of the innermost homogeneous cladding

k = a constant

Note - Unless otherwise specified a k value of 0.05 is assumed.

A.10 **core (cladding) centre**

For a cross-section of an optical fibre it is the centre of that circle which best fits the outer limit of the core area (cladding).

Note 1 - These centres may not be the same.

Note 2 - The method of best fitting has to be specified.

A.11 **core (cladding) diameter**

The diameter of the circle defining the core (cladding) centre.

A.12 **core (cladding) diameter deviation**

The difference between the actual and the nominal values of the core (cladding) diameter.

A.13 **core/cladding concentricity error**

The distance between the core centre and the cladding centre divided by the core diameter.

A.14 **core (cladding) tolerance field**

For a cross-section of an optical fibre it is the region between the circle circumscribing the core (cladding) area and the largest circle, concentric with the first one, that fits into the core (cladding) area. Both circles shall have the same centre as the core (cladding).

$$NA_{t\ max} = (n_1^2 - n_2^2)^{½}$$

where

n_1 = maximum refractive index of the core

n_2 = refractive index of the innermost homogeneous cladding

Note - The relationship between NA (see A.21) and $NA_{t\ max}$ is given in section I of Annex B, § B.2.2.

A.18 **mode filter**

A device designed to accept or reject a certain mode or modes.

A.19 **mode scrambler; mode mixer**

A device for inducing transfer of power between modes in an optical fibre, effectively scrambling the modes.

Note - Frequently used to provide a mode distribution that is independent of source characteristics.

A.20 **non-circularity of core (cladding)**

The difference between the diameters of the two circles defined by the core (cladding) tolerance field divided by the core (cladding) diameter.

A.21 **numerical aperture**

The numerical aperture NA is the sine of the vertex half-angle of the largest cone of rays that can enter or leave the core of an optical fibre, multiplied by the refractive index of the medium in which the vertex of the cone is located.

A.22 **reference surface**

The cylindrical surface of an optical fibre to which reference is made for jointing purposes.

Note - The reference surface is typically the cladding or primary coating surface. In rare circumstances it could be the core surface.

A.23 **reference test method (RTM)**

A test method in which a given characteristic of a specified class of optical fibres or optical fibre cables is measured strictly according to the definition of this characteristic and which gives results which are accurate, reproducible and relatable to practical use.