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

Transmission media and optical systems characteristics – Optical fibre cables

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Characteristics of a bending-loss insensitive single-mode optical fibre and cable

Recommendation ITU-T G.657

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Recommendation ITU-T G.657

Characteristics of a bending-loss insensitive single-mode optical fibre and cable

Summary

Worldwide, technologies for general transport network and broadband access networks are advancing rapidly. Among these, the technology applying single-mode fibre provides for a high-capacity transmission medium which can answer the growing demand for high speed and broadband services.

The experience with the installation and operation of single-mode fibre and cable-based networks is huge and Recommendation ITU-T G.652, which describes its characteristics, has been adapted to this experience. Nevertheless, the specific use in an optical access network puts different demands on the fibre and cable which impacts its optimal performance characteristics. Differences with respect to the use in the general transport network are mainly due to the high density network of distribution and drop cables in the access network. The limited space and the many manipulations ask for operator-friendly fibre performance and low bending sensitivity. In addition, the cabling in the crowded telecom offices where space is a limiting factor has to be improved accordingly. Yet, certain areas of the general transport network can also be described as space limited, where bend optimized cabling can be advantageous.

It is the aim of Recommendation ITU-T G.657 to support this optimization by recommending strongly improved bending performance compared with the existing ITU-T G.652 single-mode fibre and cables. This is done by means of two categories of single-mode fibres, one of which, category A, is fully compliant with the ITU-T G.652 single-mode fibres and can be deployed throughout the general transport network as well as the access network. The other, category B, is not necessarily compliant with Recommendation ITU-T G.652, but is capable of low values of macrobending losses at very low bend radii and is intended for application in the access network inside buildings or near buildings (e.g., outside building riser cabling). These category B fibres are system compatible with ITU-T G.657.A (and ITU-T G.652.D) fibres in access networks.

This fourth edition of Recommendation ITU-T G.657 modifies, amongst other things, the usage of category A fibres for all applications (access networks as well as general transport networks) where ITU-T G.652.D fibres are used, now with improved bending characteristics.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.657	2006-12-14	15	11.1002/1000/8976
2.0	ITU-T G.657	2009-11-13	15	11.1002/1000/10391
2.1	ITU-T G.657 (2009) Amd. 1	2010-06-11	15	11.1002/1000/10931
3.0	ITU-T G.657	2012-10-29	15	Chromatic dispersion and PMD specifications have been introduced for sub-category G.657.B fibres. The attenuation and MFD specifications for B sub-category fibres have been modified. Also the new Appendix I (agreed in 2010 and published as Amendment 1 (06/2010) has been introduced. 11.1002/1000/11769

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

4.0	ITU-T G.657	2016-11-13	15	The title and scope have been modified to include the usage of sub-category G.657.A macrobending loss improved fibres for all applications (access networks as well as general transport networks) where G.652.D fibres are used. Added new clause 5 "Conventions". Following clause numbers have been renumbered. In clause 6.10 the text concerning chromatic dispersion for G.657.A fibres has been modified in harmonization with G.652.D fibres. In Table 1 and 2 (G.657.A & B) the nominal mode field diameter upper range has been reduced. In Table 1 (G.657.A) new specification has been introduced for chromatic dispersion in harmonization with G.652.D fibres. Appendix I of Edition 3 has been moved to Appendix I of [ITU-T G-Sup.59] 11.1002/1000/13078

Keywords

Bending-loss insensitive optical fibre, dispersion un-shifted optical fibre, optical fibre and cable, single-mode optical fibre.

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.

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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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Introduction

Worldwide, technologies for broadband access networks and general transport networks are advancing rapidly. Among these, the technology applying single-mode fibre provides for a high-capacity transmission medium which can answer the growing demand for high speed networks.

The experience with the installation and operation of single-mode fibre and cable-based networks is huge and Recommendation ITU-T G.652, which describes its characteristics, has been adapted to this experience. Nevertheless, the specific use in an optical access network and some particular areas of general transport networks puts different demands on the fibre and cable. Due to dense distribution and drop-cable network, limited space and the many manipulations in parts of these networks, fibre and cable requirements may be optimized for improved macrobending loss. It is the aim of this Recommendation to support this optimization by recommending different attribute values for the existing ITU-T G.652 single-mode fibre and cables and by recommending other categories of single-mode fibre types.

As for the network structures in which the single-mode optical fibre cable is used, users are referred to the extensive information that is available in the references listed in the bibliography.

Recommendation ITU-T G.657

Characteristics of a bending-loss insensitive single-mode optical fibre and cable

1 Scope

This Recommendation describes two categories of single-mode optical fibre cable with improved bending loss performance compared with that of ITU-T G.652 fibres. ITU-T G.657 fibre was originally developed for use in access networks, including inside buildings at the end of these networks. Both categories A and B contain two subcategories which differ in macrobending loss.

Category A fibres are optimized for reduced macrobending loss compared to ITU-T G.652.D fibres and can be deployed throughout the access network. These fibres are suitable for use in the O-, E-, S-, C- and L-band (i.e., throughout the 1 260 nm to 1 625 nm range). Fibres and requirements in this category are a subset of ITU-T G.652.D and are therefore compliant[1] with ITU-T G.652.D fibres and have the same transmission and interconnection properties. Thus, ITU-T G.657.A fibres can be used for all networks where ITU-T G.652.D fibres are specified.

Subcategory ITU-T G.657.A1 fibres are appropriate for a minimum design radius of 10 mm.

Subcategory ITU-T G.657.A2 fibres are appropriate for a minimum design radius of 7.5 mm.

Category B fibres are optimized for further reduced macrobending loss and therefore are capable of being used at very low values of bend radius. These fibres are intended for short reach distances (less than 1 000 m) at the end of access networks, in particular inside buildings or near buildings (e.g., outside building riser cabling). The application length of ITU-T G.657.B fibre depends on the deployment strategy of each network operator. These fibres are suitable for use in the O-, E-, S-, C- and L-band (i.e., throughout the 1 260 nm to 1 625 nm range). Category B fibres are not necessarily compliant with ITU-T G.652.D]in terms of chromatic dispersion coefficient and polarization mode dispersion (PMD) specifications. These fibres, however, are system compatible[2] with ITU-T G.657.A (and ITU-T G.652.D) fibres in access networks.

Subcategory ITU-T G.657.B2 fibres are appropriate for a minimum design radius of 7.5 mm.

Subcategory ITU-T G.657.B3 fibres are appropriate for a minimum design radius of 5 mm.

This Recommendation and the different performance categories found in Tables 1 and 2 in clause 8 are intended to support the following related system Recommendations:

Category	Recommendations
Optical line systems for local and access networks	[b-ITU-T G.987.2], [b-ITU-T G.989.2]

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 [ITU-T G.650.1] and [ITU-T G.650.2].

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1 Compliance here means adherence to the referenced Recommendation ([ITU-T G.652], category D) meeting or exceeding the values of the specified attributes.

2 Compatibility means here that the product in this category will introduce negligible system impairment or deployment issues but may not be compliant with the referenced Recommendation ([ITU-T G.652], category D).

The characteristics of these fibre categories, 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; 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.

[ITU-T G.650.1] Recommendation ITU-T G.650.1 (2010), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable*.

[ITU-T G.650.2] Recommendation ITU-T G.650.2 (2015), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

[ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T L.103] Recommendation ITU-T L.103 (2016), *Optical fibre cables for indoor applications*.

[IEC 60793-1-47] IEC 60793-1-47:2009, *Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss*.

[IEC 60793-2-50] IEC 60793-2-50:2015, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres.*

[ISO 80000-1] ISO 80000-1 (2009), *Quantities and units – Part 1: General.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the terms defined in [ITU-T G.650.1] and [ITU-T G.650.2].

3.2 Terms defined in this recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DGD Differential Group Delay

PMD Polarization Mode Dispersion

5 Conventions

Values shall be rounded to the number of digits given in the recommended values in Tables 1 and 2 before conformance is evaluated. The conventional rule of "rounding half away from zero" is used, which is described in rule B of Annex B, of [ISO 80000-1]. Only the first digit beyond the number of significant digits is used in determining the rounding.

6 Fibre attributes

The optical fibre characteristics that provide the essential design framework for fibre manufacture, system design and use in outside plant networks are recommended in [ITU-T G.652]. In this clause, the emphasis is on attributes that optimize the fibre and cable in macrobending behaviour which supports small volume fibre managements systems and low radius mounting e.g., in telecom offices and customer premises in apartment buildings and single dwelling houses.

Also, for completeness, those characteristics of the fibre that provide a minimum essential design framework for fibre manufacture are recommended in this clause. Ranges or limits on values are presented in Tables 1 and 2 in clause 8. Of these, cable manufacture or installation may significantly affect the cabled fibre cut-off wavelength and polarization mode dispersion (PMD). 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.

6.1 Mode field diameter

Both a nominal value and tolerance about that nominal value shall be specified at 1 310 nm. The nominal value that is specified shall be within the range found in Tables 1 and 2 in clause 8. The specified tolerance shall not exceed the value in Tables 1 and 2 in clause 8. The deviation from nominal shall not exceed the specified tolerance.

6.2 Cladding diameter

The recommended nominal value of the cladding diameter is 125 μm. A tolerance is also specified and shall not exceed the value in Tables 1 and 2 in clause 8. The cladding deviation from the nominal shall not exceed the specified tolerance.

6.3 Core concentricity error

The core concentricity error shall not exceed the value specified in Tables 1 and 2 in clause 8.

6.4 Non-circularity

6.4.1 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.

6.4.2 Cladding non-circularity

The cladding non-circularity shall not exceed the value found in Tables 1 and 2 in clause 8.

6.5 Cut-off wavelength

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

a) cable cut-off wavelength λ_{cc}

b) fibre cut-off wavelength λ_c.

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 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 1 260 nm, or for the worst-case length and bends by recommending a maximum fibre cut-off wavelength λ_c to be 1 260 nm.

The cable cut-off wavelength, λ_{cc}, shall be less than the maximum specified in Tables 1 and 2 in clause 8.

6.6 Macrobending loss

Macrobending loss observed in uncabled fibres varies with wavelength, bend radius and the number of turns about a mandrel with a specified radius. Macrobending loss shall not exceed the maximum value given in Tables 1 and 2 in clause 8 for the specified wavelength(s), bend radii and number of turns.

The actual low radius exposure of the fibre is on relatively short lengths only. As the typical choice of the bending radius and the length of the bent fibre may vary depending upon the design of the fibre management system and the installation practice, a specification at one single bending radius is no longer sufficient. Although modelling results on various fibre types have been published, no generally applicable bending loss model is available to describe the loss versus bend radius behaviour. For this reason, the recommended maximum macrobending loss is specified at different bend radii in Tables 1 and 2 in clause 8.

While a baseline on macrobending performance can be established for uncabled fibres, the actual design and materials of cable construction can contribute to the resulting performance in the field. Macrobending loss in cabled fibre may differ from that observed in uncabled fibre measurements because of the bend-limiting effect of the cable structure on the fibre bend. The study into the macrobending effects of cabling is ongoing, which may result in the need for any additional cable specifications or parameters in the future.

Macrobending loss of installed cabled fibres in in-building networks may depend on the installation technique used. According to [ITU-T L.103], any fibre bend radius remaining after cable installation is recommended to be large enough to limit the macrobending loss and long-term strain that would reduce the lifetime of the fibre. For that purpose, certain demanding installation techniques are not recommended (e.g., stapling indoor cable using flat staples).

As optical bending losses increase with wavelength, a loss specification at the highest envisioned wavelength, i.e., either 1 550 nm or 1 625 nm, suffices. If required, a customer and supplier can agree on a lower or higher specification wavelength.

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

NOTE 2 – If another number of turns than that recommended is chosen for implementation, it is assumed that the maximum loss that occurs in that deployment is proportional to the specified number of turns.

NOTE 3 – If routine tests are required, deviating loop diameters can be used instead of the recommended test, for accuracy and measurement ease. 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 recommended test and allowed loss.

NOTE 4 – In general, the macrobending loss is influenced by the choice of the values for other fibre attributes, such as the mode field diameter, chromatic dispersion coefficient and the fibre cut-off wavelength. Optimization with respect to macrobending losses usually involves a trade-off between the values of these fibre attributes.

NOTE 5 – A mandrel winding method (method A), which is described in [IEC 60793-1-47], can be utilized as a measurement method for macrobending loss by substituting the bending radius and number of turns specified in Tables 1 and 2 in clause 8.

6.7 Material properties of the fibre

6.7.1 Fibre materials

The substances from 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.

6.7.2 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 a single-jacketed fibre, similar indications shall be given.

6.7.3 Proof stress level

The specified proof stress, σ_p, shall not be less than the minimum specified in Tables 1 and 2 in clause 8.

NOTE 1 – The definitions of the mechanical parameters are contained in clauses 3.2 and 5.6 of [ITU-T G.650.1].

NOTE 2 – See also Appendix I on this subject.

NOTE 3 – The failure probability for fibre under 30 mm of radius bend as described in [ITU-T G.652] increases with decreasing bend radius. The mechanical reliability of optical fibre in this application space is a function of the characteristics of the cable structure, the installation techniques and deployment conditions. Care should be given that, for some installations, additional constraints on installation, such as higher fibre proof test levels or other factors may be required to ensure the full expected life.

NOTE 4 – It is recommended that the proof stress level applied to fibre and the required reliability level during its lifetime are agreed between the supplier and customer.

6.8 Refractive index profile

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

6.9 Longitudinal uniformity of chromatic dispersion

This attribute is usually less relevant for applications in the access network. For more details, see [ITU-T G.652].

6.10 Chromatic dispersion

For sub-category ITU-T G.657.A fibres the chromatic dispersion parameters indicated in Table 1 in clause 8 are specified in order to bind the chromatic dispersion values from 1 260 nm to 1 625 nm. This allows more accurate system design in which dispersion compensating schemes are incorporated. When specifying the chromatic dispersion coefficient parameters of ITU-T G.657 fibres only by the three-term Sellmeier coefficients in the 1 310 nm region, the dispersion coefficient may not be sufficiently accurate when extrapolated to the 1 550 nm region. In order to bind the minimum/maximum chromatic dispersion coefficients of ITU-T G.657.A fibres, combining the first derivative of the three-term Sellmeier fitting on group delay from 1 260 nm to 1 460 nm and linear fitting on chromatic dispersion (i.e., the first derivative of the quadratic fitting on group delay) from 1 460 nm to 1 625 nm is appropriate.

From 1 260 nm to 1 460 nm, chromatic dispersion coefficient $D(\lambda)$ at wavelength λ is bound by the following three inequalities:

$$\frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\max}}{\lambda}\right)^4\right] \le D(\lambda) \le \frac{\lambda S_{0\min}}{4}\left[1-\left(\frac{\lambda_{0\min}}{\lambda}\right)^4\right] \qquad (\lambda \le \lambda_{0\min}) \qquad \text{(6-1a)}$$

$$\frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\max}}{\lambda}\right)^4\right] \le D(\lambda) \le \frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\min}}{\lambda}\right)^4\right] \qquad (\lambda_{0\min} \le \lambda \le \lambda_{0\max}) \qquad \text{(6-1b)}$$

$$\frac{\lambda S_{0\min}}{4}\left[1-\left(\frac{\lambda_{0\max}}{\lambda}\right)^4\right] \le D(\lambda) \le \frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\min}}{\lambda}\right)^4\right] \qquad (\lambda_{0\max} \le \lambda). \qquad \text{(6-1c)}$$

The minimum chromatic dispersion slope, $S_{0\min}$, has been added in order to bind both the minimum and maximum chromatic dispersion coefficients.

From 1 460 nm to 1 625 nm, chromatic dispersion coefficient $D(\lambda)$ at wavelength λ is bound by the following inequality:

$$8.625 + 0.052(\lambda - 1\,460) \le D(\lambda) \le 12.472 + 0.068(\lambda - 1\,460) \qquad \text{(6-2)}$$

A survey on ITU-T G.652.D products (including ITU-T G.657.A fibres) was conducted to determine the chromatic dispersion parameter specifications and consequences in terms of the dispersion envelope. The results are summarized in Appendix II of [ITU-T G.652].

For sub-category ITU-T G.657.B fibre, the chromatic dispersion coefficient, $D(\lambda)$, is specified by putting limits on the parameters of a chromatic dispersion curve that is a function of wavelength in the 1 310 nm region. The chromatic dispersion coefficient limit for any wavelength, λ, is calculated from the minimum zero-dispersion wavelength, $\lambda_{0\min}$, the maximum zero-dispersion wavelength, $\lambda_{0\max}$, and the maximum zero-dispersion slope, $S_{0\max}$, according to:

$$D(\lambda) \le \frac{\lambda S_{0\max}}{4}\left[1-\left(\frac{\lambda_{0\min}}{\lambda}\right)^4\right] \qquad \text{(6-3)}$$

The values of $\lambda_{0\min}$, $\lambda_{0\max}$ and $S_{0\max}$ shall be within the limits indicated in Table 2 in clause 8.

NOTE 1 – It is not necessary to measure the chromatic dispersion coefficient of single-mode fibre on a routine basis.

NOTE 2 – The chromatic dispersion for category B fibres is generally not critical for the application of this category of fibre, and therefore its value can be more relaxed compared to that of category A fibres.

7 Cable attributes

Since the geometrical and optical characteristics of fibres given in clause 6 are barely affected by the cabling process, this clause gives 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.

7.1 Attenuation coefficient

The attenuation coefficient is specified with a maximum value at one or more wavelengths in both the 1 310 nm and 1 550 nm regions. The optical fibre cable attenuation coefficient values shall not exceed the values found in Tables 1 and 2 in clause 8.

NOTE – The attenuation coefficient may be calculated across a spectrum of wavelengths, based on measurements at a few (three to four) predictor wavelengths. This procedure is described in clause 5.4.4 of [ITU-T G.650.1] and an example is given in Appendix III of [ITU-T G.650.1].

7.2 Polarization mode dispersion coefficient

When required, cabled fibre PMD shall be specified on a statistical basis, not on an individual fibre basis. The requirements pertain only to the aspect of the link calculated from cable information. The metrics of the statistical specification are found in this clause. Methods of calculation are found in [b-IEC/TR 61282-3] and are summarized in Appendix IV of [ITU-T G.650.2].

The manufacturer shall supply a PMD link design value, PMD_Q, that serves as a statistical upper bound for the PMD coefficient of the concatenated optical fibre cables within a defined possible link of M cable sections. The upper bound is defined in terms of a small probability level, Q, which is the probability that a concatenated PMD coefficient value exceeds PMD_Q. For the values of M and Q given in Tables 1 and 2 in clause 8, the value of PMD_Q shall not exceed the maximum PMD coefficient specified in Tables 1 and 2 in clause 8.

Measurements and specifications on uncabled fibres are necessary, but not sufficient to ensure the cabled fibre specification. The maximum link design value specified on uncabled fibres shall be less than or equal to that specified for the cabled fibres. The ratio of PMD values for uncabled fibres to cabled fibres depends on the details of the cable construction and processing, as well as on the mode-coupling condition of the uncabled fibres. [ITU-T G.650.2] recommends a low mode coupling deployment requiring a low tension wrap on a large diameter spool for uncabled fibre PMD measurements.

The limits on the distribution of PMD coefficient values can be interpreted as being nearly equivalent to the limits on the statistical variation of the differential group delay (DGD), that varies randomly with time and wavelength. When the PMD coefficient distribution is specified for optical fibre cable, equivalent limits on the variation of DGD can be determined. The metrics and values for link DGD distribution limits are found in Appendix I of [ITU-T G.652].

NOTE 1 – A PMD_Q specification would be required only where cables are employed for systems that have the specification of the max DGD, i.e., for example, a PMD_Q specification would not be applied to systems recommended in this Recommendation.

NOTE 2 – A PMD_Q should be calculated for various types of cables, and they should usually be calculated using sampled PMD values. The samples would be taken from cables of similar construction.

NOTE 3 – The PMD_Q specification should not be applied to short cables such as jumper cables, indoor cables and drop cables.

NOTE 4 – The PMD coefficient for category B fibres is generally not critical for the application of this category of fibres and therefore its value can be more relaxed compared to that of category A fibres.

8 Recommended value tables

Tables 1 and 2 summarize the recommended values for the subcategories of fibres in categories A and B that satisfy the objectives of this Recommendation.

Table 1, ITU-T G.654.A attributes, contains the recommended attributes and values needed to support optimized access network installations and general transport networks with respect to macrobending loss, while the recommended values for the other attributes still remain within the range recommended in ITU-T G.652.D. This category has two subcategories with different macrobending requirements: ITU-T G.657.A1 fibre and ITU-T G.657.A2 fibre.

Table 2, category B attributes, contains the recommended attributes and values needed to support optimized access network installation with very small bending radii applied in fibre management systems and mainly utilized at the end of access networks in particular inside or near buildings. This category has two subcategories with different macrobending requirements: ITU-T G.657.B2 fibre and ITU-T G.657.B3 fibre.

Table 1 – ITU-T G.657.A attributes

Fibre attributes							
Attribute	**Detail**	**Value**					**Unit**
Mode field diameter	Wavelength	1 310					nm
	Range of nominal values	8.6-9.2					µm
	Tolerance	±0.4					µm
Cladding diameter	Nominal	125.0					µm
	Tolerance	±0.7					µm
Core concentricity error	Maximum	0.5					µm
Cladding non-circularity	Maximum	1.0					%
Cable cut-off wavelength	Maximum	1 260					nm
Uncabled fibre macrobending loss (Notes 1, 2)		**ITU-T G.657.A1**		**ITU-T G.657.A2**			
	Radius	15	10	15	10	7.5	mm
	Number of turns	10	1	10	1	1	
	Max. at 1 550 nm	0.25	0.75	0.03	0.1	0.5	dB
	Max. at 1 625 nm	1.0	1.5	0.1	0.2	1.0	dB
		ITU-T G.657 category A					
Proof stress	Minimum	0.69					GPa
Chromatic dispersion parameter 3-term Sellmeier fitting (1 260nm to 1 460 nm)	λ_{0min}	1 300					nm
	λ_{0max}	1 324					nm
	S_{0min}	0.073					ps/(nm^2 × km)
	S_{0max}	0.092					ps/(nm^2 × km)
Linear fitting (1 460 nm to 1 625 nm)	Min. at 1 550 nm	13.3					ps/(nm × km)
	Max. at 1 550 nm	18.6					ps/(nm × km)
	Min. at 1 625 nm	17.2					ps/(nm × km)
	Max. at 1 625 nm	23.7					ps/(nm × km)
Cable attributes							
Attenuation coefficient (Note 3)	Maximum from 1 310 nm to 1 625 nm (Note 4)	0.40					dB/km
	Maximum at 1 383 nm ±3 nm after hydrogen ageing (Note 5)	0.40					dB/km
	Maximum at 1 530–1 565 nm	0.30					dB/km
PMD coefficient	*M*	20					cables
	Q	0.01					%
	Maximum PMD_Q	0.20					ps/km^{½}

Table 1 – ITU-T G.657.A attributes

NOTE 1 – ITU-T G.652 fibres deployed at a radius of 15 mm generally can have macrobending losses of several dB per 10 turns at 1 625 nm. NOTE 2 – The macrobending loss can be evaluated using a mandrel winding method (method A of [IEC 60793-1-47]), substituting the bending radius and the number of turns specified in this table. NOTE 3 – Due to the lack of accuracy in measuring the attenuation coefficient of a short cable, its value can be taken from that of the original longer donor cable. NOTE 4 – This wavelength region can be extended to 1 260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm. NOTE 5 – Hydrogen ageing is a type test that shall be done to a set of sampled fibres, according to [IEC 60793-2-50] regarding the B1.3 fibre category.

Table 2 – ITU-T G.657.B attributes

Fibre attributes								
Attribute	**Detail**	**Value**						**Unit**
Mode field diameter	Wavelength	1 310						nm
	Range of nominal values	8.6-9.2						µm
	Tolerance	±0.4						µm
Cladding diameter	Nominal	125.0						µm
	Tolerance	±0.7						µm
Core concentricity error	Maximum	0.5						µm
Cladding non-circularity	Maximum	1.0						%
Cable cut-off wavelength	Maximum	1 260						nm
Uncabled fibre macrobending loss (Notes 1, 2)		**ITU-T G.657.B2**			**ITU-T G.657.B3**			
	Radius	15	10	7.5	10	7.5	5	mm
	Number of turns	10	1	1	1	1	1	
	Max. at 1 550 nm	0.03	0.1	0.5	0.03	0.08	0.15	dB
	Max. at 1 625 nm	0.1	0.2	1.0	0.1	0.25	0.45	dB
Proof stress	Minimum	0.69						GPa
Chromatic dispersion parameter	λ_{0min}	1 250						nm
	λ_{0max}	1 350						nm
	S_{0max}	0.11						ps/(nm^2 × km)

Table 2 – ITU-T G.657 category B attributes

Cable attributes			
Attenuation coefficient (Notes 3, 4)	Maximum from 1 310 nm to 1 625 nm (Note 5)	0.40	dB/km
	Maximum at 1 383 nm ± 3 nm after hydrogen ageing (Note 6)	0.40	dB/km
	Maximum at 1 530-1 565 nm	0.30	dB/km
PMD coefficient	*M*	20	cables
	Q	0.01	%
	Maximum PMD_Q	0.50	ps/km½

NOTE 1 – The macrobending loss can be evaluated using a mandrel winding method (method A of [IEC 60793-1-47]), substituting the bending radius and the number of turns specified in this table.

NOTE 2 – While a baseline on macrobending performance can be established for uncabled fibres, the actual design and materials of cable construction can contribute to the resulting performance in the field. The study into the macrobending effects of cabling is ongoing, which may result in the need for any additional cable specifications or parameters in the future.

NOTE 3 – Operators may decide that compliance of ITU-T G.657.B category fibres to spectral attenuation characteristics of [ITU-T G.657].A category fibres (or ITU-T G.652.D fibres) may not be necessary in their (particular) networks. For example small differences in the attenuation coefficient specification around 1380 nm (e.g., as can be found in Figure 10-4 of [b-ITU-T G-Sup.39]) may not introduce system impairments or deployment issues (negligible effect on the total system performance) when applying these fibres at the end of the access network.

NOTE 4 – Due to the lack of accuracy in measuring the attenuation coefficient of a short cable, its value can be taken from that of the original longer donor cable.

NOTE 5 – This wavelength region can be extended to 1 260 nm by adding 0.07 dB/km induced Rayleigh scattering loss to the attenuation value at 1 310 nm.

NOTE 6 – Hydrogen ageing is a type test that shall be done to a set of sampled fibres, according to [IEC 60793-2-50] regarding the B1.3 fibre category.

To illustrate the different macrobending specifications of the various subcategories defined in this clause, the recommended values have been represented in Figures 1 and 2.

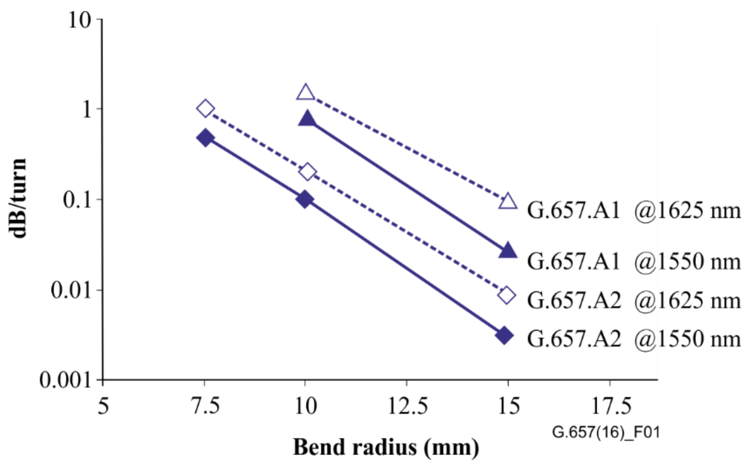

Figure 1 – Macrobending loss data from Table 1, category ITU-T G.657.A

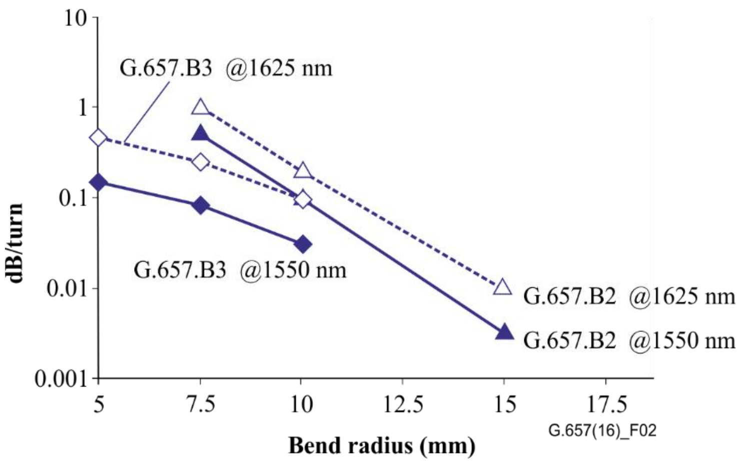

Figure 2 – Macrobending loss data from Table 2, category ITU-T G.657.B

Appendix I

Lifetime expectation in the case of small radius bending of single-mode fibre

(This appendix does not form an integral part of this Recommendation.)

NOTE – This appendix has been transferred to [b-ITU-T G-Sup.59].

Bibliography

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