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Transmission media characteristics – Optical fibre cables

Characteristics of a dispersion-shifted single-mode optical fibre and cable

ITU-T Recommendation G.653

ITU-T

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ITU-T Recommendation G.653

Characteristics of a dispersion-shifted single-mode optical fibre and cable

Summary

This Recommendation describes the geometrical, mechanical and transmission attributes of a single-mode optical fibre and cable with zero-dispersion wavelength shifted into the 1550 nm wavelength region. This is the latest revision of the Recommendation that was first created in 1988.

This revision clarifies chromatic dispersion characteristics in Table 2 (G.653.B). This category limits the chromatic dispersion coefficient by a pair of bounding curves vs wavelength for the range of 1460 nm to 1625 nm. The extension to these wavelengths is intended to provide information to support coarse wavelength division multiplexing applications which do not have significant non-linear impairments.

Source

ITU-T Recommendation G.653 was approved on 14 December 2006 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

History

1988 Version 1.

1993 Version 2.

1997 Version 3.

2000 Version 4. This revision changed the Recommendation structure, in accordance with other fibre Recommendations such as G.652, G.654 and G.655.

2003 Version 5. This revision changed description of chromatic dispersion coefficient for ease to understand. Also, in accordance with the agreement on spectral band description, the upper limit of L-band is changed from 16xx nm to 1625 nm. Terms of base subcategory and subcategory are revised to base category and category, respectively. A new category which has reduced PMD limit (compared to 0.5 ps/√km), G.653.B, is created. For the macrobending test, mandrel diameter is reduced to 30 mm radius.

2006 Version 6. In accordance with communications from the other Questions, bounding curves for the chromatic dispersion coefficient rather than "box specifications" have been implemented in Table 2 (G.653.B). For Table 2, the other attributes have been updated to be consistent with ITU-T Recs G.652 (2005) and G.655 (2006).

As seen above, this Recommendation has evolved considerably over the years; therefore the reader is warned to consider the appropriate version to determine the characteristics of already deployed product, taking into account the year of production. In fact, products are expected to comply with the Recommendation that was in force at the time of their manufacture, but may not fully comply with subsequent versions of the Recommendation.

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ITU-T Recommendation G.653

Characteristics of a dispersion-shifted single-mode optical fibre and cable

1 Scope

This Recommendation describes a dispersion-shifted single-mode optical fibre and cable 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 in the 1550 nm region, but may also be used at around 1310 nm subject to the constraints outlined in this Recommendation. Some provisions are made to support transmission at higher wavelengths up to 1625 nm and lower wavelengths down to 1460 nm. Chromatic dispersion coefficient values at these wavelengths may be specified to support Coarse Wavelength Division Multiplexing (CWDM) systems that do not have significant impairment due to non-linear effects. The geometrical, optical, transmission and mechanical parameters are described below in three categories of attributes:

– fibre attributes are those attributes that are retained throughout cabling and installation;
– cable attributes that are recommended for cables as they are delivered;
– link attributes that are characteristics of concatenated cables, describing estimation method of system interface parameters based on measurements, modelling, or other considerations. Information for link attribute and system design are in Appendix I.

This Recommendation, and the different performance categories found in the tables of clause 7, is intended to support the following related system Recommendations:

- G.957.
- G.691.
- G.692.
- G.693.
- G.959.1.
- G.977.
- G.695.
- G.698.1.

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 [G.650.1] and [G.650.2]. 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.

2 References

2.1 Normative 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.

[G.650.1] ITU-T Recommendation G.650.1 (2004), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable*.

[G.650.2] ITU-T Recommendation G.650.2 (2005), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

2.2 Informative references

The following ITU-T Recommendations contain provisions which, through reference in this text, constitute other relevant information.

[G.663] ITU-T Recommendation G.663 (2000), *Application related aspects of optical amplifier devices and subsystems*.

[G.691] ITU-T Recommendation G.691 (2006), *Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers*.

[G.692] ITU-T Recommendation G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers*.

[G.693] ITU-T Recommendation G.693 (2006), *Optical interfaces for intra-office systems*.

[G.695] ITU-T Recommendation G.695 (2006), *Optical interfaces for coarse wavelength division multiplexing applications*.

[G.698.1] ITU-T Recommendation G.698.1 (2006), *Multichannel DWDM applications with single-channel optical interfaces*.

[G.957] ITU-T Recommendation G.957 (2006), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.

[G.959.1] ITU-T Recommendation G.959.1 (2006), *Optical transport network physical layer interfaces*.

[G.977] ITU-T Recommendation G.977 (2006), *Characteristics of optically amplified optical fibre submarine cable systems*.

3 Terms and definitions

For the purposes of this Recommendation, the definitions given in [G.650.1] and [G.650.2] apply. Values shall be rounded to the number of digits given in the tables of recommended values before conformance is evaluated.

4 Abbreviations

This Recommendation uses the following abbreviations:

CWDM Coarse Wavelength Division Multiplexing

DGD Differential Group Delay

GPa GigaPascal

PMD Polarization Mode Dispersion

PMD_Q Statistical parameter for link PMD

SDH Synchronous Digital Hierarchy

TBD To be determined

WDM Wavelength Division Multiplexing

5 Fibre attributes

Only those characteristics of the fibre providing a minimum essential design framework for fibre manufacture are recommended in this clause. Ranges or limits on values are presented in the tables of clause 7. Of these, cable manufacture or installation may significantly affect the cabled fibre cut-off wavelength and 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.

5.1 Mode field diameter

Both a nominal value and tolerance about that nominal value shall be specified at 1550 nm. The nominal that is specified shall be within the range found in clause 7. The specified tolerance shall not exceed the value in clause 7. The deviation from nominal shall not exceed the specified tolerance.

5.2 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 clause 7. The cladding deviation from nominal shall not exceed the specified tolerance.

5.3 Core concentricity error

The core concentricity error shall not exceed the value specified in clause 7.

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 shall not exceed the value specified in clause 7.

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}.

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 1270 nm, or for typical jumpers by recommending a maximum jumper cable cut-off to be 1270 nm, or for worst case length and bends by recommending a maximum fibre cut-off wavelength, λ_c.

The cable cut-off wavelength, λ_{cc}, shall not exceed the maximum specified in clause 7.

NOTE 1 – For some specific submarine cable applications, other cable cut-off wavelength values may be required.

NOTE 2 – 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 in minimum cable lengths between repair joints and cable jumpers.

5.6 Macrobending loss

Macrobending loss varies with wavelength, bend radius and number of turns about a mandrel with a specified radius. Macrobending loss shall not exceed the maximum given in clause 7 for the specified wavelength(s), bend radius, and number of turns.

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

NOTE 2 – The recommended number of turns corresponds to the approximate number of turns deployed in all splice cases of a typical repeater span. The recommended radius 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 the recommended number of turns are chosen to implement, it is suggested that not less than 40 turns, and a proportionately smaller loss increase be required.

NOTE 4 – The macrobending 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 5 – In the event that routine tests are required a small diameter loop with one or several turns 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 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 not be less than the minimum specified in clause 7.

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

5.8 Refractive index profile

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

5.9 Longitudinal uniformity of chromatic dispersion

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.

5.10 Chromatic dispersion coefficient

The measured group delay or chromatic dispersion per unit fibre length versus wavelength shall be fitted by the quadratic equation as defined in Annex A of [G.650.1]. (See 5.5 of [G.650.1] for guidance on the interpolation of dispersion values to unmeasured wavelengths.)

Depending on accuracy requirements, for wavelength intervals of up to 35 nm, the quadratic equation is allowed in the 1550 nm region. For longer wavelength intervals, either the 5-term Sellmeier model or the 4th order polynomial model is recommended. It is not meant to be used in the 1310 nm region.

There are two methods for specifying the limits, the original method, which is a box-like specification, and a newer method, in which the dispersion coefficient values are bound both by a pair of curves.

NOTE – It is not necessary to measure the chromatic dispersion coefficient and zero-dispersion wavelength on a routine basis.

5.10.1 Original specification form

This specification form applies to Table 1 in clause 7.

The chromatic dispersion coefficient, $D(\lambda)$, is specified within a wavelength range by stating a range of allowed absolute values of the chromatic dispersion coefficient. The form of the specification is:

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

where:

$$1525 \text{ nm} \leq \lambda_{min} \leq \lambda_{max} \leq 1575 \text{ nm}$$

At the same time, zero-dispersion wavelength, λ_0, and zero-dispersion slope, S_0, are specified by the following equations:

$$\lambda_{0min} \leq \lambda_0 \leq \lambda_{0max}$$

$$S_0 \leq S_{0max}$$

Values for D_{max}, λ_{min}, λ_{max}, λ_{0min}, λ_{0max} and S_{0max} shall be within the ranges given in clause 7.

5.10.2 Specification based on a pair of limiting curves

This specification form applies to Table 2 in clause 7.

For each wavelength, λ, the chromatic dispersion coefficient, $D(\lambda)$, shall be restricted to a range of values associated with two limiting curves, $D_{min}(\lambda)$ and $D_{max}(\lambda)$, for a specified wavelength range from λ_{min} to λ_{max}. In addition, the dispersion limits may be given explicitly for one or more specific wavelengths.

An example set of curves is represented symbolically as a pair of straight lines:

$$D_{min}(\lambda) = a_{min} + b_{min}\,(\lambda - 1525) \qquad (\text{ps/nm} \cdot \text{km})$$

$$D_{max}(\lambda) = a_{max} + b_{max}\,(\lambda - 1575) \qquad (\text{ps/nm} \cdot \text{km})$$

$$D_{min}(\lambda) \leq D(\lambda) \leq D_{max}(\lambda) \qquad (\text{ps/nm} \cdot \text{km})$$

The bounding curves may vary from one wavelength range to another.

6 Cable attributes

Since the geometrical and optical characteristics of fibres given in clause 5 are barely affected by the cabling process, this clause 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

The attenuation coefficient is specified with a maximum value at one or more wavelengths in the 1550 nm region. When they are intended for use in the 1300 nm region, their attenuation coefficient in that region is generally below 0.55 dB/km. The optical fibre cable attenuation coefficient values shall not exceed the values found in clause 7.

NOTE – The attenuation coefficient may be calculated across a spectrum of wavelengths, based on measurements at a few (3 to 4) predictor wavelengths. This procedure is described in 5.4 of [G.650.1] and an example for G.652 fibre is given in Appendix III of [G.650.1].

6.2 Polarization mode dispersion coefficient (PMD)

When required, cabled fibre polarization mode dispersion 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 below. Methods of calculations are found in IEC 61282-3, and are summarized in Appendix IV of [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 clause 7, the value of PMD_Q shall not exceed the maximum PMD coefficient specified in clause 7.

Measurements and specifications on uncabled fibre are necessary, but not sufficient to ensure the cabled fibre specification. The maximum link design value specified on uncabled fibre shall be less than or equal to that specified for the cabled fibre. The ratio of PMD values for uncabled fibre to cabled fibre depends on the details of the cable construction and processing, as well as on the mode coupling condition of the uncabled fibre. [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 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.

NOTE 1 – 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, PMD_Q specification would not be applied to systems recommended in [G.957].

NOTE 2 – 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.

7 Tables of recommended values

The following tables summarize the recommended values for a number of categories of fibres that satisfy the objectives of this Recommendation. These categories are largely distinguished on the basis of PMD requirements and chromatic dispersion specifications. See Appendix I for information about transmission distances and bit-rates relative to PMD requirement. Table 1, G.653.A attributes, is the base category for a dispersion-shifted single-mode optical fibre and cable, and retains the original "box-type" specification for the dispersion coefficient. This category is suitable for the systems in [G.691], [G.692], [G.693], [G.957] and [G.977] with an unequal channel spacing in the 1550 nm wavelength region.

Many submarine applications can utilize this category. For some submarine applications, the full optimization can lead to choosing different limits than are found here. One example could be to allow cable cut-off wavelength to values as high as 1500 nm.

Table 2, G.653.B attributes, is similar to G.653.A, but the more stringent PMD requirement allows STM-64 systems to lengths longer than 400 km and G.959.1 STM-256 applications.

Table 2, G.653.B attributes, defines the chromatic dispersion coefficient requirements as a pair of bounding curves vs wavelength for wavelengths from 1460 nm to 1625 nm. This category may support CWDM applications as well as mentioned in Table 1. The PMD requirement allows STM-64 systems to lengths longer than 400 km and G.959.1 STM-256 applications.

Table 1/G.653 – G.653.A attributes

Fibre attributes		
Attribute	**Detail**	**Value**
Mode field diameter	Wavelength	1550 nm
	Range of nominal values	7.8-8.5 µm
	Tolerance	± 0.8 µm
Cladding diameter	Nominal	125 µm
	Tolerance	±1 µm
Core concentricity error	Maximum	0.8 µm
Cladding non-circularity	Maximum	2.0%
Cable cut-off wavelength	Maximum	1270 nm
Macrobend loss	Radius	30 mm
	Number of turns	100
	Maximum at 1550 nm	0.5 dB
Proof stress	Minimum	0.69 GPa
Chromatic dispersion coefficient	λ_{min}	1525 nm
	λ_{max}	1575 nm
	D_{max}	3.5 ps/(nm × km)
	λ_{0min}	1500 nm
	λ_{0max}	1600 nm
	S_{0max}	0.085 ps/(nm^2 × km)
Uncabled fibre PMD coefficient	Maximum	(Note)
Cable attributes		
Attribute	**Detail**	**Value**
Attenuation coefficient	Maximum at 1550 nm	0.35 dB/km
PMD coefficient	M	20 cables
	Q	0.01%
	Maximum PMD_Q	0.5 ps/√km
NOTE – According to 6.2, a maximum PMD_Q value on uncabled fibre is specified in order to support the primary requirement on cabled PMD_Q.		

Table 2/G.653 – G.653.B attributes

Fibre attributes		
Attribute	**Detail**	**Value**
Mode field diameter	Wavelength	1550 nm
	Range of nominal values	7.8-8.5 µm
	Tolerance	± 0.6 µm
Cladding diameter	Nominal	125 µm
	Tolerance	±1 µm
Core concentricity error	Maximum	0.6 µm
Cladding non-circularity	Maximum	1.0%
Cable cut-off wavelength	Maximum	1270 nm
Macrobend loss	Radius	30 mm
	Number of turns	100
	Maximum at 1550 nm	0.1 dB
Proof stress	Minimum	0.69 GPa
Chromatic dispersion coefficient (ps/nm × km)	$D_{min}(\lambda)$: 1460-1525 nm	0.085*(λ – 1525) – 3.5
	$D_{min}(\lambda)$: 1525-1625 nm	3.5/75*(λ – 1600)
	$D_{max}(\lambda)$: 1460-1575 nm	3.5/75*(λ – 1500)
	$D_{max}(\lambda)$: 1575-1625 nm	0.085*(λ – 1575) + 3.5
Uncabled fibre PMD coefficient	Maximum	(Note)
Cable attributes		
Attribute	**Detail**	**Value**
Attenuation coefficient	Maximum at 1550 nm	0.35 dB/km
PMD coefficient	M	20 cables
	Q	0.01%
	Maximum PMD_Q	0.20 ps/√km
NOTE 1 – According to 6.2, a maximum PMD_Q value on uncabled fibre is specified in order to support the primary requirement on cabled PMD_Q. NOTE 2 – Larger PMD_Q values (e.g., ≤ 0.5 ps/√km) can be agreed for particular applications between the manufacturer and user.		

Appendix I

Information for link attribute and system design

A concatenated link usually includes a number of spliced factory lengths of optical fibre cable. The requirements for factory lengths are given in clauses 5 and 6. The transmission parameters for concatenated links must take into account not only the performance of the individual cable lengths but also the statistics of concatenation.

The transmission characteristics of the factory length optical fibre cables will have a certain probability distribution which often needs to be taken into account if the most economic designs are to be obtained. The following clauses should be read with this statistical nature of the various parameters in mind.

Link attribute values are affected by factors other than optical fibre cables by such things as splices, connectors and installation. These factors cannot be specified in this Recommendation. For the purpose of link attribute values estimation, typical values of optical fibre links are provided in I.5.

The estimation method of fibre parameters needed for link design is provided based on measurements, modelling or other considerations.

I.1 Attenuation

The attenuation A of a link is given by:

$$A = \alpha L + \alpha_s x + \alpha_c y$$

where:

α = typical attenuation coefficient of the fibre cable in a link;

L = link length;

α_s = mean splice loss;

x = number of splices in a link;

α_c = mean loss of line connectors;

y = number of line connectors in a link (if provided).

A suitable margin should be allocated 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 typical values found in I.5 are for the attenuation coefficient of optical fibre link. The attenuation budget used in designing an actual system should account for the statistical variations in these parameters.

I.2 Chromatic dispersion

The chromatic dispersion in ps/nm 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 (see 5.10).

Zero-dispersion wavelength, λ_{0typ}, and dispersion slope coefficient, S_{0typ}, at λ_{0typ} may be found in I.5. These values, together with link length, L_{Link}, can be used to calculate the typical dispersion for use in optical link design.

$$D_{Link}(\lambda) = L_{Link}[S_{0typ}(\lambda - \lambda_{0typ})] \quad \text{(ps/nm)}$$

I.3 Differential group delay (DGD)

The differential group delay is the difference in arrival times of the two polarization modes at a particular wavelength and time. For a link with a specific PMD coefficient, the DGD of the link varies randomly with time and wavelength as a Maxwell distribution that contains a single parameter, which is the product of the PMD coefficient of the link and the square root of the link length. The system impairment due to PMD at a specific time and wavelength depends on the DGD at that time and wavelength. So, means of establishing useful limits on the DGD distribution as it relates to the optical fibre cable PMD coefficient distribution and its limits have been developed and are documented in IEC 61282-3. The metrics of the limitations of the DGD distribution follow:

NOTE – The determination of the contribution of components other than optical fibre cable is beyond the scope of this Recommendation, but is discussed in IEC 61282-3.

Reference link length, L_{Ref}: A maximum link length to which the maximum DGD and probability will apply. For longer link lengths, multiply the maximum DGD by the square root of the ratio of actual length to the reference length.

Typical maximum cable length, L_{Cab}: The maxima are assured when the typical individual cables of the concatenation or the lengths of the cables that are measured in determining the PMD coefficient distribution are less than this value.

Maximum DGD, DGD_{max}: The DGD value that can be used when considering optical system design.

Maximum probability, P_F: The probability that an actual DGD value exceeds DGD_{max}.

I.4 Non-linear coefficient

The effect of chromatic dispersion is interactive with the non-linear coefficient, n_2/A_{eff}, regarding system impairments induced by non-linear optical effects (see [G.663] and [G.650.2]). Typical values vary with the implementation. The test methods for non-linear coefficient remain under study.

I.5 Table of common typical values

The values in Tables I.1 and I.2 are representative of concatenated optical fibre links according to I.1 and I.3, respectively. The implied fibre induced maximum DGD values in Table I.2 are intended for guidance with regard to the requirement for other optical elements that may be in the link.

Table I.1/G.653 – Representative value of concatenated optical fibre link

Attribute	Detail	Value
Attenuation coefficient	Wavelength	Typical link value (Note)
	1550 nm	0.275 dB/km
	1625 nm	TBD
Chromatic dispersion parameters	λ_{0typ}	1550 nm
	S_{0typ}	0.07 ps/(nm^2 × km)
NOTE – Typical link value corresponds to the link attenuation coefficient used in [G.957] and [G.691].		

Table I.2/G.653 – Differential group delay

Maximum PMD_Q (ps/√km)	Link length (km)	Implied fibre induced maximum DGD (ps)	Channel bit rates
No specification			Up to 2.5 Gbit/s
0.5	400	25.0	10 Gbit/s
	40	19.0 (Note)	10 Gbit/s
	2	7.5	40 Gbit/s
0.20	3000	19.0	10 Gbit/s
	80	7.0	40 Gbit/s
0.10	> 4000	12.0	10 Gbit/s
	400	5.0	40 Gbit/s
NOTE – This value applies also for 10 Gigabit Ethernet systems.			

NOTE – Cable section length is 10 km except for the 0.10 ps/√km / > 4000 km link, where it is set to 25 km, the probability level is 6.5×10^{-8}.

I.6 Chromatic dispersion coefficient limits for Table 2

The equations bounding the chromatic dispersion coefficient vs wavelength are specified by using the original "box-type" specification for the dispersion coefficient, D_{max}, λ_{min}, λ_{max}, λ_{0min}, λ_{0max} and S_{0max}. Maximum values between λ_{0min} of 1500 nm and λ_{max} of 1575 nm have been linked linearly from the zero dispersion at 1500 nm to the maximum dispersion, D_{max}, of 3.5 ps/nm × km at 1575 nm. The slope value of this line corresponds to 0.0467 ps/nm^2 × km. For wavelengths below 1500 nm this line is extended with the same slope. Maximum values above 1575 nm have been added by drawing a line with a slope equal to the maximum slope, S_{0max}, of 0.085 ps/nm^2 × km. Minimum dispersion coefficient values have also been generated with a second pair of straight lines in the same manner. In Figure I.1 the solid lines are the limiting curves. The broken lines represent the original "box-type" specification, in which absolute values of chromatic dispersion coefficient are lower than D_{max} of 3.5 ps/nm × km between λ_{min} of 1525 nm and λ_{max} of 1575 nm. The specification based on limiting curves for Table 2 is comparable to the original "box-type" specification for Table 1.

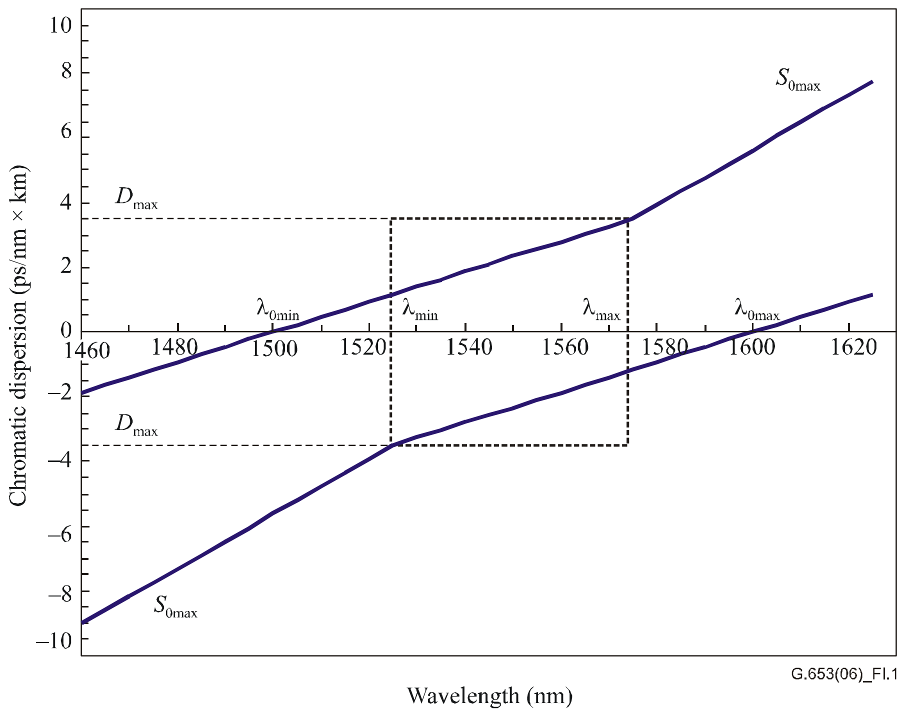

Figure I.1/G.653 – Table 2 fibre dispersion boundary

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