International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.650.3

Amendment 1
(02/2011)

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

Transmission media and optical systems characteristics – Optical fibre cables

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Test methods for installed single-mode optical fibre cable links

Amendment 1

Recommendation ITU-T G.650.3 (2008) – Amendment 1

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Recommendation ITU-T G.650.3

Test methods for installed single-mode optical fibre cable links

Amendment 1

Summary

Amendment 1 to Recommendation ITU-T G.650.3 (2008) adds a new Appendix III, which describes a method for differentiating splice loss and macrobending loss in installed links. The method is based on OTDR measurement at two wavelengths, and it is recommended to use a bidirectional OTDR method which is able to determine the exact loss at the splice point. This optional method can be used to identify the main loss factor when large loss is observed in an OTDR trace.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.650.3	2007-07-29	15
2.0	ITU-T G.650.3	2008-03-29	15
2.1	ITU-T G.650.3 (2008) Amend. 1	2011-02-25	15

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.

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1) Appendix III

Add the following Appendix III:

Appendix III

Method for differentiating splice loss and macrobending loss in installed links

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

III.1 General

When large loss is observed at a fusion splice point after cable installation by OTDR measurement, it is usually inferred that the loss is due to low quality fusion splice or other causes such as fibre macrobending in a closure. Fibre macrobending in a closure is caused by rough fibre handling following fusion splice in cable installation or by other causes, e.g., fibre axial strain.

Optical system performance might be degraded at longer wavelengths for an optical fibre cable link with fibre macrobending. Hence, it is quite important to identify the location of fibre macrobending for a cable link.

This appendix describes a simple method for differentiating splice loss and macrobending loss in installed links. The method is based on OTDR measurement at two wavelengths, and it is recommended to use a bidirectional OTDR method which is able to determine the exact loss at the splice point. This optional method can be used to identify the main loss factor when large loss is observed in an OTDR trace in the vicinity of a splice.

The application of the method is limited to ITU-T G.652 fibres. A general application of the method to ITU-T G.657 fibres is difficult to implement, because of low bending loss, and is not recommended.

Moreover, if the users do not know the exact fibre types in the link, it is difficult to apply this method since the method is only effective for ITU-T G.652 fibres.

III.2 Theory

III.2.1 Definition of macrobending indicator

Measurement of the *macrobending indicator* is based on an OTDR measurement at two different wavelengths. The macrobending indicator k is defined as follows [b-Ryu]:

$$k = (A_1 - A_2)/(\lambda_1 - \lambda_2) \text{ (dB/nm)} \quad \text{(III-1)}$$

In Equation III-1, it is assumed that OTDR measurement is performed at wavelengths of λ_1 and λ_2 (nm) and that the measured loss at a fibre splice point at each wavelength is A_1 and A_2 (dB), respectively. The λ_1 and λ_2 should be set at values longer than the cable cutoff wavelength.

Figure III.1 shows examples of the calculation results of the macrobending indicator using the theory [b-Marcuse-JOSA], and [b-Sharma] when a fibre is wound one turn with a radius of R (mm). In the calculation, λ_1 was fixed at 1310 nm and λ_2 was changed and shown in the horizontal axis.

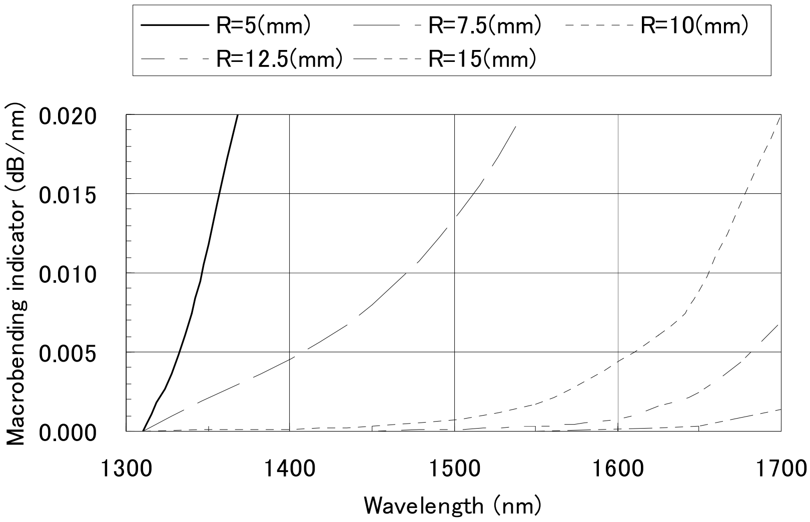

Figure III.1 – Macrobending indicator vs wavelength (λ_2) for various bending radii (λ_1 = 1310 nm)

From Figure III.1, it is clear that as λ_2 increases, the macrobending indicator becomes larger, which means that the detection sensitivity of macrobending has improved.

III.2.2 Features of macrobending indicator

As is described in Appendix I, in the OTDR measurement, accurate loss values can be derived by averaging bidirectional measurement results. The necessity for bidirectional measurement is due to different Rayleigh backscattering coefficients of the spliced fibres.

Figure III.2 shows an OTDR set-up for measuring the macrobending indicator. In the set-up, Fibre A and Fibre B are spliced. Macrobending exists at the Fibre B side.

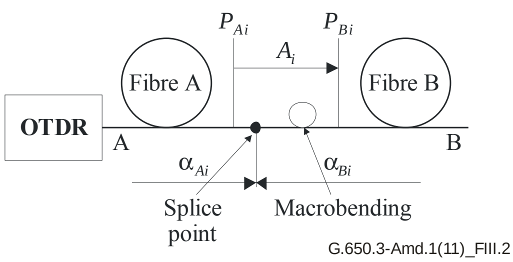

Figure III.2 – Measurement set-up of macrobending indicator

Here it is assumed that the OTDR measurement is carried out from side A and that P_{Ai} is optical power immediately before the splice point at a wavelength λ_i (i = 1, 2), and P_{Bi} is power right after the point with macrobending. It is also assumed that the splice loss for this case is negligibly small. Rayleigh backscattering coefficients for Fibre A and Fibre B at a wavelength λ_i are assumed to be

α_{Ai} and α_{Bi}, respectively. It is well known that α_{Ai} and α_{Bi} are inversely proportional to λ_i^4, so that they can be expressed as:

$$\alpha_{Ai} = \alpha_A / \lambda_i^4 \tag{III-2}$$

$$\alpha_{Bi} = \alpha_B / \lambda_i^4 \tag{III-3}$$

The loss A_i at a wavelength λ_i can be derived as:

$$A_i = 10\log_{10}\{(\alpha_{Ai}P_{Ai})/(\alpha_{Bi}P_{Bi})\} = 10\log_{10}\{(\alpha_A P_{Ai})/(\alpha_B P_{Bi})\} \tag{III-4}$$

From Equations III-1 and III-4, the macrobending indicator becomes:

$$k = \{10\log_{10}(P_{A1}/P_{B1}) - 10\log_{10}(P_{A2}/P_{B2})\}/(\lambda_1 - \lambda_2) \tag{III-5}$$

In Equation III-5, the influence of Rayleigh backscattering coefficient has been cancelled due to the differential operation in the definition of k. Equation III-5 shows that k is only dependent on the exact power before and after the fibre macrobending point at each wavelength.

The results above show that bidirectional measurement is not necessary for the determination of k. This feature is quite important since it is not always easy to perform OTDR measurement from both sides of the cable because both end points are at different locations geographically.

Then a case with the splice loss is taken into account. Regarding the splice loss, if the fibres with a different mode field diameter (MFD) are spliced, the loss due to MFD mismatch is observed. The influence of the loss-increase due to MFD mismatch is discussed in clause III.4.2. Figure III.3 shows a measurement configuration for such a case.

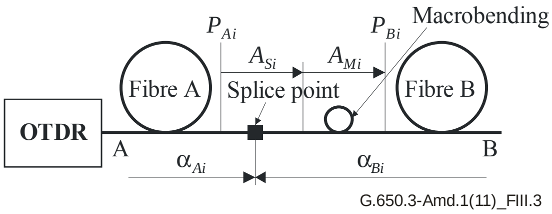

Figure III.3 – Macrobending indicator measurement set-up with both macrobending and splice loss

The optical power P_{Ai} and P_{Bi} are assumed as in Figure III.2. A_{Si} and A_{Mi} denote the loss due to the splice and macrobending, respectively. The macrobending indicator k becomes:

$$k = (A_{S1} - A_{S2})/(\lambda_1 - \lambda_2) + (A_{M1} - A_{M2})/(\lambda_1 - \lambda_2) \tag{III-6}$$

The macrobending indicator due to the splice loss is defined as:

$$k_S = (A_{S1} - A_{S2})/(\lambda_1 - \lambda_2) \tag{III-7}$$

and that due to the macrobending is:

$$k_M = (A_{M1} - A_{M2})/(\lambda_1 - \lambda_2) \tag{III-8}$$

From Equations III-6, III-7, and III-8:

$$k = k_S + k_M \tag{III-9}$$

From Equation III-9, it can be said that the total macrobending indicator is the summation of both contributions.

III.3 Considerations on practical applicability

This clause discusses a practical detection limit of the macrobending indicator. Regarding conventional OTDR systems, the detection limit of optical loss is δ (dB) considering the accuracy of the OTDR equipment.

The detection limit of the macrobending indicator k_{min} can be expressed as:

$$k_{\min} = \delta/(\lambda_2 - \lambda_1) \text{ (dB/nm)} \qquad \text{(III-10)}$$

Figure III.4 shows applicable measurement conditions of the macrobending indicator with one turn for various bending radii when δ is assumed to be 0.1 (dB), considering the accuracy of the conventional OTDR measurement.

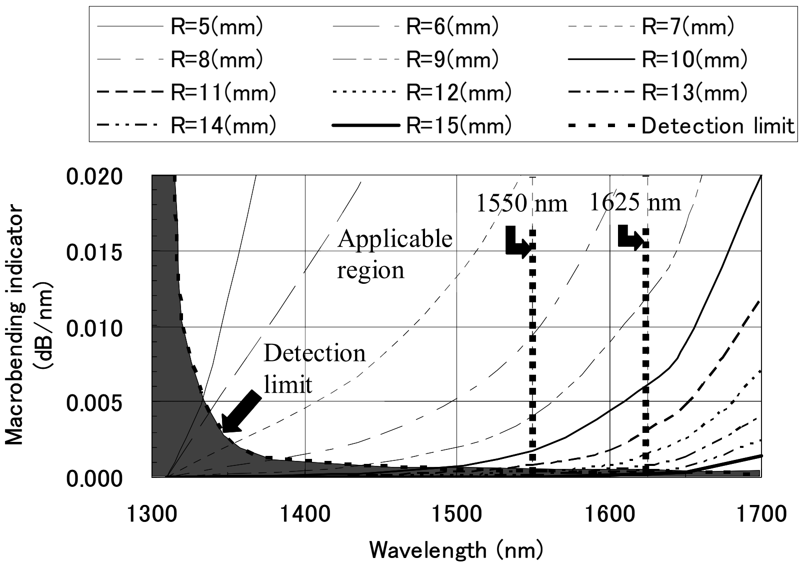

Figure III.4 – Applicable measurement conditions

It can be made clear from Figure III.4 that as λ_2 becomes longer, the macrobending with a larger radius can be detected. In other words, the detection sensitivity becomes improved for longer λ_2.

From Figure III.4, an approximate detection limit of the maximum bending radius can be summarized as in Table III.1.

Table III.1 – Detection limit of maximum bending radius

Wavelength λ_2 (nm)	1550	1625
Maximum detection limit of bending radius (mm)	11	13

III.4 Measurement examples and influence of various conditions on measurement results

In this clause, some measurement examples are shown in terms of the influence of various conditions on the measurements results.

III.4.1 High splice loss

Table III.2 shows splice loss of two ITU-T G.652 fibres when they are spliced with the fibre core axis misalignment to emulate a large splice loss condition. It is known from Table III.2 that splice loss decreases as the wavelength becomes longer. This is because at longer wavelength the MFD becomes larger, thus the loss increase due to the core axis misalignment is alleviated. Figure III.5

shows the macrobending indicator calculated from Table III.2. It can be seen from Figure III.5 that the macrobending indicator becomes a negative value due to the reasons above. In this case, applicable measurement conditions in Figure III.4 may be degraded since the macrobending indicator is the summation of both splice and macrobending losses as shown in Equation III-9.

Table III.2 – Splice loss in case of fibre core axis misalignment

Wavelength (nm)	Loss (from side A) (dB)	Loss (from side B) (dB)	Average (dB)
1310	0.89	1.29	1.09
1450	0.79	1.18	0.99
1550	0.74	1.13	0.93
1625	0.69	1.10	0.90

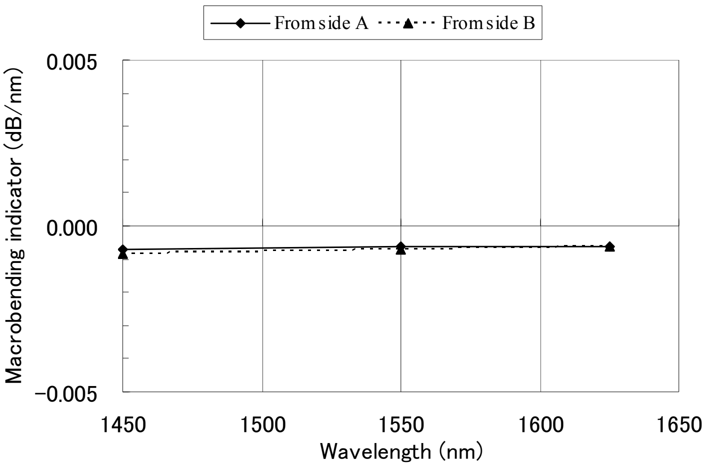

Figure III.5 – Macrobending indicator with large splice loss

III.4.2 Mode field diameter mismatch

This clause discusses the influence of the MFD mismatch on the macrobending indicator since the MFD of the commercial ITU-T G.652 fibres is different from one fibre to another as far as the MFD is within the specified values in [ITU-T G.652].

According to [ITU-T G.652], the MFD at 1310 nm is specified as follows:

– Range of nominal values: 8.6-9.5 µm;

– Tolerance: ±0.6 µm.

So, for the consideration of the influence of the MFD mismatch, it is sufficient to consider the MFD range 8.0-10.1 µm.

Figure III.6 shows the calculation results of the macrobending indicator considering the splice loss theory [b-Marcuse-BSTJ] when fibres with MFD of 8.0 µm and 10.1 µm are spliced.

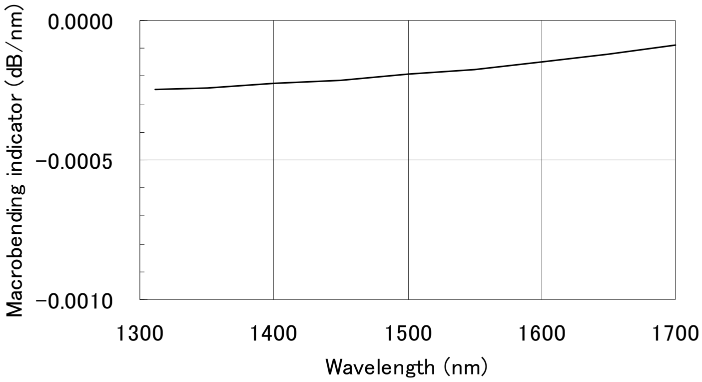

Figure III.6 – Macrobending indicator when different MFD fibres are spliced

From Figure III.6, it can be seen that the macrobending indicator becomes a negative value, and the minimum value is about –0.00025 dB/nm. The absolute value of the macrobending indicator is fairly small as compared with the detection limit discussed in clause III.3. Hence, it can be concluded that the influence of the MFD mismatch on the macrobending indicator can be neglected in practical applications.

2) Bibliography

Add the following entries to the Bibliography:

[b-ITU-T G.657] Recommendation ITU-T G.657 (2009), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network*.

[b-Marcuse-BSTJ] Marcuse, D. (1977), *Loss analysis of single-mode fibre splices*, Bell System Technical Journal, Vol. 56, No. 5, pp. 703-718.

[b-Marcuse-JOSA] Marcuse, D. (1976), *Curvature loss formula for optical fibres*, Journal of Optical Society of America, Vol. 66, No. 3, pp. 216-220.

[b-Ryu] Ryu S., and Yagi, M., (2010), *Macrobending indicator for evaluation of fibre macrobending and splice loss*, OECC2010, 7P-33.

[b-Sharma] Sharma, A. B., Al-Ani, A. H., and Halme, S. J. (1984), *Constant-curvature loss in monomode fibres: an experimental investigation*, Applied Optics, Vol. 23, No. 19, pp. 3297-3301.

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