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OF ITU

G.650.2

Amendment 1
(03/2003)

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

Transmission media characteristics – Optical fibre cables

Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable

Amendment 1

ITU-T Recommendation G.650.2 (2002) – Amendment 1

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ITU-T Recommendation G.650.2

Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable

Amendment 1

Summary

This Amendment 1 to ITU-T Rec. G.650.2 contains a change in the title of the Recommendation and a new Appendix IV dealing with PMD statistics.

Source

Amendment 1 to ITU-T Recommendation G.650.2 (2002) was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 16 March 2003.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. 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 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, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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ITU-T Recommendation G.650.2

Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable

Amendment 1

1) Title

Insert the word "related" into the title of ITU-T Rec. G.650.2, so that the title of the Reccommendation becomes:

Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable.

2) New Appendix IV

Add new Appendix IV as follows:

Appendix IV

Information on polarization mode dispersion statistics

This appendix is provided to summarise some of the statistical calculations for PMD. IEC 61282-3 documents the calculations and theory more completely. This will be given in sections:

- Introduction.
- Data collection.
- Calculation of PMD_Q (Monte Carlo).
- Calculation for DGD_{max} (Monte Carlo).

NOTE – Other calculation methods are allowed and defined in IEC 61282-3. The Monte Carlo method is given here because it is the easiest to describe.

IV.1 Introduction

Polarization mode dispersion (PMD) is a statistical attribute that, for a given fibre, is defined as the average of measured differential group delay (DGD) values across a range of wavelengths. Since the DGD values are random across time and wavelength, there is a theoretical lower limit to achievable reproducibility of the reported PMD value of approximately ±15%. This feature implies that it is not appropriate to select individual fibres or cables to a specification that is tighter than the capability of the process. Such selections are often appropriate for deterministic attributes like attenuation but are not generally appropriate for PMD. This means that a specification on the overall process distribution is most reasonable.

A second consideration regarding the functionality of PMD is that system impairment at a given time and wavelength is controlled by the DGD value, which varies statistically around the PMD value. If one is given the PMD value for a particular cabled fibre, one can calculate the probability that DGD exceeds a given value. It is clear, however, that application of these formulae to a maximum specified value will yield a very inaccurate view of the actual system performance. A statistical specification on PMD, however, can lead to a statistical boundary on the DGD values for the population as a whole. This boundary, defined in terms of probability, leads to a value for use in system design that is approximately 20% lower in DGD value and two orders of magnitude less in probability than the values that would be obtained without a statistical specification.

From the first consideration, it is desirable to define a single statistical metric for the distribution of the PMD values that are measured on optical fibre cables. The metric therefore must incorporate both aspects of process mean and process variability. An upper confidence limit at some probability level is such a metric.

It is known that the PMD coefficient of a set of concatenated cables can be estimated by the computation of the quadrature average of the PMD coefficients of the individual cables. To give the upper confidence limit metric more meaning in terms of application, the upper bound for a concatenated link of twenty cables is computed. This number of cable sections is smaller than that used in most links, but is large enough to be meaningful in terms of projecting DGD distributions for concatenated links. A probability value of 0.01% is also standardized – partially on the basis of obtaining equivalence with the probability that DGD exceeds a bound, which is required to be very low. The upper confidence limit is named PMD_Q, or link design value and this specification type is known as Method 1.

The probability limit for DGD is set at $6.5 \cdot 10^{-8}$ based on various system considerations including the presence of other PMD generating components that may be in the links. IEC 61282-3 describes a method of determining a maximum (defined in terms of probability) so that if a distribution passes the Method 1 requirement, the DGD across links comprised of only optical fibre cable will exceed the maximum DGD with a probability less than $6.5 \cdot 10^{-8}$. The DGD_{max} value is established for a broad range of distribution shapes. This DGD_{max} method of specifying the PMD distribution of optical fibre cables is known as Method 2. Methods of combining the Method 2 parameters with those of other optical components are given in IEC 61282-3.

Method 1 is a metric that is based on what is measured and is therefore somewhat more straightforward for use in trade and commerce as a normative requirement. Method 2 is a means of extrapolating the implications for system design and is therefore included as information for system design.

IV.2 Data collection

The calculations are done with PMD values that are representative of a given cable construction and manufacturing time period. Typically at least 100 values are required. The sample is normally taken on different production cables and different fibre locations within the cables.

The cable distribution can be augmented by measurements of uncabled fibre provided that a stable relationship between uncabled fibre and cable values has been demonstrated for a given construction. One means of such augmentation is to generate several possible cable values from the value of each uncabled fibre. These different values should be selected randomly to represent both the usual relationship and the variability that follows from, for example, measurement reproducibility. Because the range of variations includes reproducibility error, this method of estimating the distribution of cable PMD values can lead to over-estimation of PMD_Q.

The length of the samples measured could seem to have implications on the Method 2 deductions. This has been studied – with the following conclusions. The Method 2 implications remain valid for any link less than 400 km as long as either:

- the installed cable sections are less than 10 km; or
- the measured lengths are less than 10 km.

IV.3 Calculation of PMD_Q (Monte Carlo)

Other methods of calculation are given in IEC 61282-3. The Monte Carlo method is described here because it is the easiest to describe and uses the fewest assumptions.

The measured PMD coefficient values are represented by x_i, with i ranging from 1 to N, the number of measurements. These values will be used to generate 100,000 concatenated link PMD coefficient values, each computed with the quadrature average of 20 individual cable values that are randomly selected from the sample population.

NOTE – When N = 100, there are $5.3 \cdot 10^{20}$ possible link values.

For each link value computation, select 20 random numbers between 1 and N. Select these values and note them with index, k. The link PMD coefficient, y, is calculated as:

$$y = \left(\frac{1}{20} \sum_{k=1}^{20} x_k^2 \right)^{1/2} \qquad \text{(IV-1)}$$

Collect the 100,000 values of y into a high density histogram as they are being computed. When this computation is complete, calculate the cumulative probability function from the histogram and determine the PMD value associated with the 99.99% level. Report this value as PMD_Q. If the computed PMD_Q is less than the specified value (0.5 ps/sqrt(km)), the distribution passes Method 1.

IV.4 Calculation for DGD_{max} (Monte Carlo)

This calculation builds on that of the calculation for PMD_Q. In this calculation, a value of DGD_{max} is predefined (at 25 ps) and a probability of exceeding this value, P_F, is calculated. If the computed probability is less than the specified value ($6.5 \cdot 10^{-8}$), the distribution passes Method 2.

Before beginning the Monte Carlo, calculate the PMD coefficient limit, P_{max}, as:

$$P_{\max} = \frac{DGD_{\max}}{\sqrt{L_{ref}}} = \frac{25}{20} = 1.25$$

For each subsequent pair of 20 cable link concatenation values, y_j and y_{j+1} , a 40-cable concatenation value, z_j, is generated as:

$$z_j = \left(\frac{y_j^2 + y_{j+1}^2}{2} \right)^{1/2} \qquad \text{(IV-2)}$$

NOTE – This yields 50,000 values of z_j, an adequate number.

Calculate the probability of exceeding DGD_{max} on the jth concatenation of 40 links, p_j, as:

$$p_j = 1 - \int_0^{P_{\max}/z_j} 2 \left(\frac{4}{\pi} \right)^{3/2} \frac{t^2}{\Gamma(3/2)} \exp\left[-\frac{4}{\pi} t^2 \right] dt \qquad \text{(IV-3)}$$

Excell™ defines a function that can compute p_j, GAMMADIST(X,ALPHA,BETA,Cumulative). The call to this function should be:

$$PJ = 1 - GAMMADIST(4 * PMAX * PMAX / (PI() * ZI * ZI), 1.5, 1, TRUE) \qquad \text{(IV-4)}$$

The probability of exceeding DGD_{max}, P_F, is given as:

$$P_F = \frac{1}{50000} \sum_j p_j \qquad \text{(IV-5)}$$

If P_F is less than the specified value, the distribution passes Method 2.

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