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SERIES O: SPECIFICATIONS OF MEASURING EQUIPMENT

Equipment for the measurement of optical channel
parameters

Q-factor test equipment to estimate the transmission performance of optical channels

ITU-T Recommendation O.201

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ITU-T Recommendation O.201

Q-factor test equipment to estimate the transmission performance of optical channels

Summary

This Recommendation describes the requirements of Q-factor measurement equipment (QFME) currently based on the level shifting method used for estimating the digital transmission performance of an optical channel.

Source

ITU-T Recommendation O.201 was approved by ITU-T Study Group 4 (2001-2004) under the ITU-T Recommendation A.8 procedure on 22 July 2003.

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BER, Bit Error Ratio, decision threshold, Optical Transport Network, Q-factor, Q-factor Measurement Equipment, Signal-to-Noise Ratio.

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Q-factor test equipment to estimate the transmission performance of optical channels

1 Scope

Q-factor measurement is an established method for characterization of optical channels (see e.g., ITU-T Recs G.972 [7] and G.976 [8]). Particularly at low bit error rates the method has the advantage of taking less time than a traditional BER measurement, where bit errors need to be counted over a statistically significant time period.

The Q-factor is defined as the (electrical) signal-to-noise ratio at the decision circuit of a digital signal receiver (see Annex A, Appendix I and [B1]).

There are various methods of implementing Q-factor measurements, which can be mathematically related to the bit error ratio (see also the methods referred to in ITU-T Recs G.972 [7] and G.976 [8] for submarine systems). This Recommendation deals with the level shifting method and applies to QFME using it.

The objectives of this Recommendation with regard to Q-factor measuring equipment (QFME) are:

- **Compatibility between measurement equipment produced by different manufacturers:**
Optical channel transmission performance measurements made by QFME compliant to this Recommendation shall provide results to within the specified accuracy limits defined in this Recommendation.
- **Estimate of the actual system performance:**
The objective of an estimate by QFME of the bit error ratio (BER) achievable over a given optical channel is to provide the minimum BER that can be achieved with an optimally designed piece of network equipment.

This Recommendation does not intend to define the particular applications of the Q-factor measurement method. Some possible fields of applications are described in the appendices of this Recommendation.

While requirements are given for the QFME, the realization of the equipment configuration is not covered and should be given careful consideration by the designer and user.

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.

- [1] ITU-T Recommendation G.691 (2000), *Optical interfaces for single channel STM-64, STM-256 and other SDH systems with optical amplifiers*.
- [2] ITU-T Recommendation G.707/Y.1322 (2000), *Network node interface for the synchronous digital hierarchy (SDH)*.

- [3] ITU-T Recommendation G.709/Y.1331 (2001), *Interfaces for the Optical Transport Network (OTN)*.
- [4] ITU-T Recommendation G.825 (2000), *The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH)*.
- [5] ITU-T Recommendation G.8251 (2001), *The control of jitter and wander within the optical transport network (OTN)*.
- [6] ITU-T Recommendation G.957 (1999), *Optical interfaces for equipment and systems relating to the synchronous digital hierarchy*.
- [7] ITU-T Recommendation G.972 (2000), *Definition of terms relevant to optical fibre submarine cable systems*.
- [8] ITU-T Recommendation G.976 (2000), *Test methods applicable to optical fibre submarine cable systems*.
- [9] ITU-T Recommendation O.3 (1992), *Climatic conditions and relevant tests for measuring equipment*.
- [10] ITU-T Recommendation O.181 (2002), *Equipment to assess error performance on STM-N interfaces*.
- [11] IEC 61300-3-29, *Measurement techniques for characterising the amplitude of the spectral transfer functions of DWDM components*.

3 Definitions

This Recommendation defines the following term:

3.1 Q-factor: Electrical Signal-to-Noise Ratio (ESNR) at the input of a receiver's decision circuit (see Annex A and Appendix I).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

AGC	Automatic Gain Control
APD	Avalanche Photo Diode
BER	Bit Error Ratio
BERT	Bit Error Ratio Tester
DFB	Distributed Feed-Back
DWDM	Dense Wavelength Division Multiplex
EDFA	Erbium Doped Fibre Amplifier
ER	Extinction Ratio
ESNR	Electrical Signal-to-Noise Ratio
FEC	Forward Error Correction
IEC	International Electrotechnical Commission
ISI	Inter-Symbol Interference
ISO	International Organization for Standardization
OADM	Optical Add-Drop Multiplexer

OCh	Optical Channel
OSA	Optical Spectrum Analyzer
OSNR	Optical Signal-to-Noise Ratio
OTM	Optical Termination Multiplexer
OTN	Optical Transport Network
OTUk	Optical Transport Unit-k
OXC	Optical Cross Connect
QFME	Q-factor Measurement Equipment
PRBS	Pseudo-Random Binary Sequence
RX	Receiver
SNR	Signal-to-Noise Ratio
SPM	Self Phase Modulation
STM-N	Synchronous Transport Module-N
TIA	Telecommunications Industry Association
WDM	Wavelength Division Multiplex

5 Introduction to Q-factor

In Annex A and Appendix I, the theory of the Q-factor evaluation is described. Under ideal conditions, it is assumed that the Q-factor is given by the logic levels μ_0 and μ_1 and Gaussian noise distributions around the logic levels, which are described by the standard deviations σ_0 and σ_1 . The overlap region of the distribution tails represents the probability for the occurrence of errored decisions. In Appendix IV, some methods for the measurement of the noise distributions and the determination of the Q-factor are described.

In practice, there are a number of influences causing distortions with the effect that the shape of distributions no longer is Gaussian (see list of influences in Appendix III). However, it can be shown, that these distortions mainly affect the top regions of the distribution, while the tails can still be very accurately approximated by Gaussian distribution.

The applicability of a Gaussian tail approximation shall be confirmed by calculating the correlation coefficient according to Annex A. For every Q-factor measurement that is required to meet the accuracy limits of clause 6, the correlation coefficient shall be in the range 0.95 to 1.0.

While the Gaussian fit is the basic proven method for "tail extrapolation" there may exist more sophisticated distribution models, which also meet the accuracy requirements defined in clause 6. Such models are for further study.

6 Requirements of Q-factor measurement equipment

6.1 Physical interfaces and bit rates

6.1.1 Interfacing to the transmission systems

The Q-factor measurement equipment shall be capable of operating at optical amplifier monitoring points in the case of in-service measurements and, additionally, as a replacement for the system receivers in the case of out-of-service measurements.

In the first case, care has to be taken that the signal at the monitoring point is properly dispersion compensated.