TECHNICAL REPORT

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Fibre optic communication system design guides –

Part 2: Multimode and single-mode Gbit/s applications – Gigabit ethernet model

Guides de conception des systèmes de communication à fibres optiques –

Partie 2: Applications Gbit/s multimodales et unimodales – Modèle Gigabit Ethernet

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FOREWORD

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IEC 61282-2, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86C/448/DTR	86C/520/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

The enterprise networking environment has changed significantly in recent years and the available bandwidth to the desktop has greatly increased. This is due to the shift to switch-based networks from hub-based networks that allow the desktop to have full-duplex access to the available link bandwidth. Added to this is the relatively recent increase in the available link bandwidth to the desktop from 10 Mb/s to 100 Mb/s.

One of the drivers for the growth in enterprise bandwidth is the increased use of applications that send large amounts of data over private intranets and the internet. Network traffic is no longer limited to just messages or file transfers; now data streams, such as audio and video, are becoming common, as well as messages with large embedded files. The growth of corporate intranets and the internet has also made network traffic patterns very unpredictable; large files can be accessed from distant places. Within private intranets, there is a growing trend towards using centralized servers. By their very nature, these servers need very high bandwidth connectivity in order to operate effectively.

Due to all these drivers, there is need to increase the bandwidth of enterprise backbone links so that the networks can support the increased demands of the users and prevent congestion. Due to this demand, IEEE 802.3 (ethernet) have developed the next generation standard in the ethernet hierarchy - gigabit ethernet. In the development of gigabit ethernet, it was considered vital that the standard continue to support the installed media base so that network managers can preserve their installation investments. The building backbone links in many Intranets are typically based on optical fibre. The majority of these links are multimode fibre (MMF), however some singlemode fibre (SMF) is also present. Of the current installed base, the dominant type of MMF has a core diameter of 62,5 µm and can have link lengths up to 500 m (550 m including jumper cables).

Gigabit ethernet utilizes an 8B10B code that adds a 25 % overhead to the bit rate resulting in a baud rate of 1,25 Gb/s. The finite modal bandwidth of multimode fibre, particularly 62 MMF at short wavelength, makes meeting the desired bandwidth distance product for gigabit ethernet a serious technical challenge. Added to this, Gb/s rates preclude the use of LEDs due to their slow response times. While lasers have faster response times, their coherence results in additional impairments to link performance such as modal noise and mode partition noise (MPN).

A model was developed as a tool to assist the physical layer committee of the gigabit ethernet (IEEE 802.3z) standard to understand potential trade-offs between the various link penalties associated with laser-based backbone links. An objective for the model was for it to be uncomplicated and able to be implemented in a simple form so that many users could work with it. Another objective of the model is to be applicable to both multimode fibre and single-mode fibre links. The purpose of this technical report is to document the model as used by gigabit ethernet and to identify how it was used to develop the standard specifications.

This technical report presents the theoretical model. Experimental verification is also presented for links operating at valid gigabit ethernet wavelengths of 780 nm, 850 nm and 1 300 nm.

The model is an extension of previously reported models for LED based links [1,2][1)]. Power penalties are calculated to account for the effects of intersymbol interference (ISI), mode partition noise (MPN), extinction ratio (ER) and relative intensity noise (RIN). In addition, a power penalty allocation is made for modal noise and the power losses due to fibre attenuation, connectors and splices are included. The model is applicable to single-mode and multimode fibre-based links that incorporate multimode, Fabry Perot or vertical cavity surface emitting laser (VCSEL) lasers. Operation at wavelengths in the 1 300 nm transmission window on multimode fibre includes effects of fibre attenuation, ISI (due to the chromatic and the modal bandwidth of the fibre) and MPN.

Such operation is a more stringent test of the model when compared to operation at wavelengths near 1 310 nm on singlemode fibre. This is because, for the single mode case, fibre attenuation and MPN are the limiting terms. Experimental results for MPN limited operation near wavelengths of 1 310 nm on singlemode fibre can be found in scientific literature [6]. Therefore, this report only includes experimental verification of the model for operation on multimode fibre. In addition, it should be noted that as part of the development of the gigabit ethernet standard, interoperation of single mode fibre links to at least 5 km using transceivers compliant to the IEEE 802.3z specification was demonstrated in agreement with the predictions of the link model.

However, the model described in this report has several limitations as follows.

a) The model ignores chirp. Therefore it should *not* be used to predict dispersion penalties of links incorporating singlemode fibre and directly modulated single frequency lasers since such links are often chirp limited.

b) Optical amplifiers and nonlinear effects, especially significant for dense-WDM (DWDM) systems, and polarization-mode dispersion (PMD), both important for long cable lengths between regenerators, are not treated.

c) Interferometric and reflection-induced power penalties are not included.

d) The model assumes the link components have been designed such that baseline wander is negligible.

e) The model simply adds power penalties or losses in dB. However, for the noise-like terms (MN, MPN, RIN) the variances should have been added and an overall power penalty calculated. However, the error introduced can be shown to be small and within measurement error.

f) For operation on multimode fibre, if single frequency lasers and a non-restricted launch into the fibre are used, the modal noise power penalty allocation may not be correct.

As such the model is intended for non-optically amplified, single-channel systems using multimode lasers (Fabry Perot or VCSEL) and may be used for bit rates up to 10 Gb/s.

[1)] Numbers in brackets refer to the Bibliography.

FIBRE OPTIC COMMUNICATION SYSTEM DESIGN GUIDES –

Part 2: Multimode and single-mode Gbit/s applications – Gigabit ethernet model

1 Scope

This part of IEC 61282 describes a model developed as a tool to assist the physical layer committee of the gigabit ethernet (IEEE 802.3z) standard to understand potential trade-offs between the various link penalties associated with laser-based backbone links. The purpose of this technical report is to document the model as used by gigabit ethernet and to identify how it was used to develop the standard specifications.

This technical report presents the theoretical model. Experimental verification is also presented for links operating at valid gigabit ethernet wavelengths of 780 nm, 850 nm and 1 300 nm.

The technical report is organized as follows. In Clause 2, a simple theoretical prediction of laser-driven links is presented. Clause 3 contains the description of the experimental measurements and the experimental verification of the theoretical predictions. Finally, Clause 4 contains some example calculations and discussion of the results and use of the model.