Dispersion Limits in 10 GigE Transmission Systems

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Introduction

Ethernet technology supports all types of traffic including data, voice, and video over IP and is currently the most deployed transmission solution for high-performance local area network (LAN) environments and is becoming widely deployed for metropolitan (MAN) and wide area networks (WAN).

With the advent of 10 Gigabit Ethernet (10 GigE) technologies, network and Internet service providers are now able to build single-mode fiber networks reaching 40 km or longer. Single-mode fiber networks can interface with synchronous optical network/synchronous digital hierarchy (SONET/SDH) protocols, asynchronous transfer mode (ATM) networks, and are integrated into dense wavelength division multiplexing (DWDM) systems, allowing medium-haul and high-speed broadband communication transmission.

However, the increased transmission speed of 10 Gbps or more is limited by dispersion phenomenon, specifically, polarization mode dispersion (PMD) and chromatic dispersion (CD). These parameters must be considered when deploying or upgrading to 10 GigE capabilities.

Acceptance Threshold for PMD

In fiber optic communications, the acceptable limit for instantaneous digital group delay (DGD) is defined as one tenth of the bit length, or 10 ps for 10 Gbps SONET/SDH. To convert this figure to a PMD limit, requires knowing the system tolerance for crossing the DGD limit, or the outage probability. The DGD provides an estimated limit based on the worst-case probability. In short, it determines the acceptable DGD (instantaneous) and acceptable bit error rate (BER) for a system, before an outage.

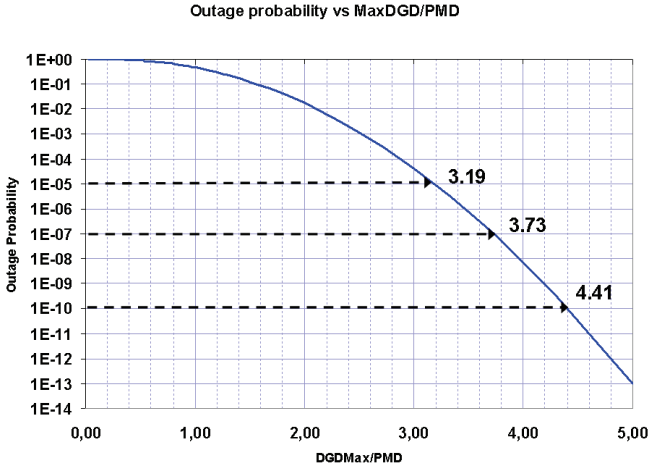

Figure 1. MaxDGD/PMD ratio variation according to outage probability (BER)

For 10 GigE, in 99.99999 percent of the cases, the system will not accept a DGD above the limit, which leads to 1e-7 outage probability, or a 3.73 DGD/PMD ratio. Therefore, as Figure 1 shows, with a DGD maximum of 19 ps for 10 GigE the PMD limit is 19/3.73 = 5.094 ps, or approximately 5 ps.

Comparing 10 Gbps SONET/SDH transmission limits exhibits a tighter dispersion tolerance for 10 GigE, as the IEEE 802.3ae-2002 standard defines. Two primary reasons are responsible for this also apply for CD:

– Forward Error Correction (FEC) is less robust than the one applied to 10 Gbps SONET/SDH

– Acceptable outage probability is lower: $1e^{-7}$ for 10 GigE vs $1e^{-5}$ for SONET/SDH

Below, Figure 2 compares 10 GigE and 10 Gbps SONET/SDH and displays the related outage probability that PMD causes.

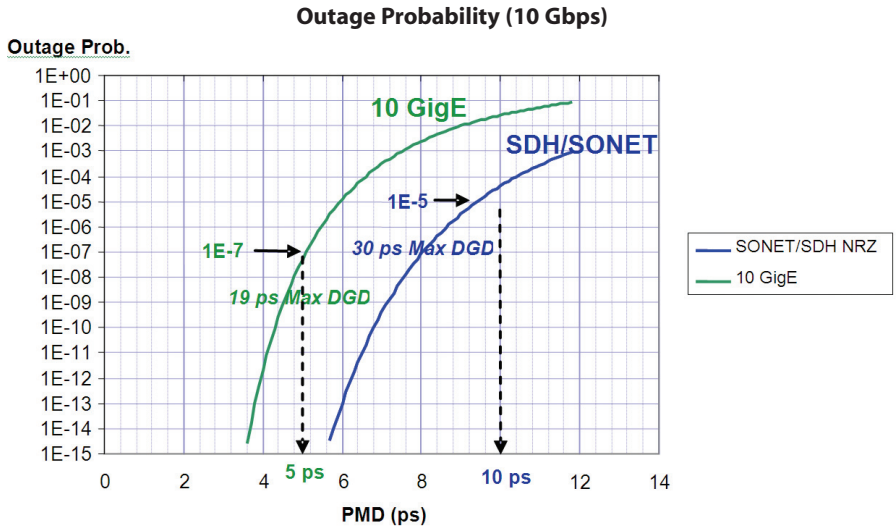

Figure 2. Comparison of 10 GigE and 10 Gbps SONET/SDH outage probabilities

The probability that a DGD value will exceed a given value is directly related to the PMD ratio, often called the Safety (S) ratio.

Figure 2 illustrates that the limit for PMD is much tighter for 10 GigE than for 10 Gbps SONET/SDH. The theoretical PMD limit is down to 5 ps compared to 10 ps for SONET/SDH.

Chromatic Dispersion Limits

Similar reasons for a tighter dispersion tolerance with 10 GigE also apply to CD tolerances with a limit of 1550 nm of 738 ps/nm compared to a 1176 ps/nm for OC-192/STM-64 10 Gbps for a non-return-to-zero (NRZ) coding format.

Obtaining a shorter reach for 10 GigE can be achieved if transmission using a G.652 fiber with a typical CD of 17 ps/nm/km is considered. In the SONET/SDH case, the maximum distance before regeneration or compensation is about 70 km, where it goes down to 40 km for 10 GigE transmission.

Conclusion

Even though 10 GigE transmission is not intended for long or very long hauls, tighter dispersion constraints require detailed fiber characterization with extreme attention to the dispersion results. Furthermore, as transmission nears 1550 nm, as with DWDM, it primarily transmits at a 1310 nm signal. Thus, CD must be qualified at this wavelength as well.

Table 1 below summarizes the dispersion limits for 10 GigE:

Bit Rate/Channel	CD Tolerance @ 1550 nm	PMD Tolerance
10 GigE	738 ps/nm	5 ps

The JDSU Optical Dispersion Measurement (ODM) Module in the MTS/T-BERD 6000 platform, shown in Figure 3, and its associated broadband source enable characterization of CD over the entire wavelength range of 1260-1640 nm and also provides PMD and attenuation profile (AP). This solution is a versatile, high performance tool for dispersion qualification in 10 GigE transmission deployments.

Figure 3. The JDSU ODM module in the MTS/T-BERD 6000 platform

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