Polarization Mode Dispersion (PMD) Simplified

Francis Audet, Eng., Product Manager

What Exactly Is PMD?

Here's a simple analogy. When someone makes a telephone call, what normally happens between telephone 1 and telephone 2 (see Figure 1)?

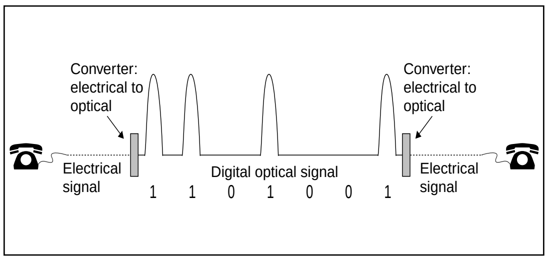

Figure 1. Pulses in a 2.5 Gb/s system are isolated.

We assume that the sequence of seven pulses in Figure 1 means "Hello" and that we are in a 2.5 Gb/s system. When we refer to digital optical signals (1-1-0-1-0-0-1), pulses are called bits. In a 10 Gb/s system, the time interval between each pulse or bit is reduced by a factor of 4 since 10 Gb/s is four times faster than 2.5 Gb/s (see Figure 2).

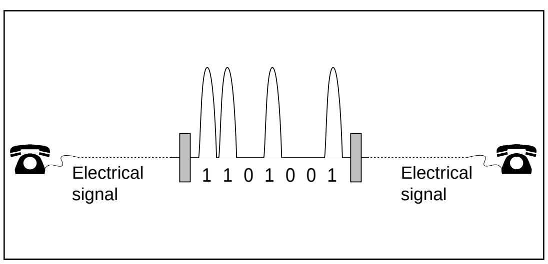

Figure 2. Pulses in a 10 Gb/s system are closer.

The Polarization States of a Pulse

To better understand PMD, we will enlarge one of the pulses and study it closely. We then recognize that a standard pulse's energy (see Figure 3) is the sum of two pulse components (see Figure 4). Both components of the pulse are in a polarization state.

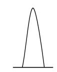

Figure 3. The standard pulse

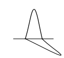

Figure 4. The polarization states of a single pulse

If we look at the cross section of a fiber, we see that the polarization states are perpendicular to each other:

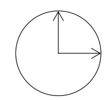

Figure 5. Propagation of polarization states in a fiber

The Effect of Fiber Irregularities

Now that we know what constitutes an individual pulse, we will enlarge fiber sections for further examination:

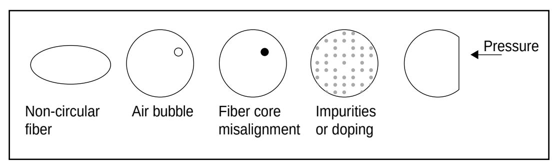

Figure 6. Fiber irregularities

Anywhere along a fiber span, the fiber could be non-circular, contain impurities (see Figure 6) or be subject to environmental stress such as local heating or movement (for instance, trains passing). From the pulse's perspective, these irregularities present obstacles along its path. Suppose there are two runners beginning a race at the same time and one has a clear track, while the other has to go through a forest or pass an area with a low ceiling or any other obstacle. Assuming that both run at identical speeds, we understand that the runner facing obstacles will be delayed. This is exactly what happens to pulses in a fiber. Due to fiber irregularities, one pulse component (i.e., one state of polarization) will arrive before the other.

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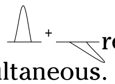
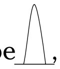
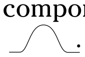
Two pulse components  result in this shape , if their arrival is simultaneous. If one component is delayed, the result is a broadened pulse .

PMD is the broadening of a pulse due to the time delay (in picoseconds) of one of the two pulse components. Please note the difference between Figure 1 and Figure 7.

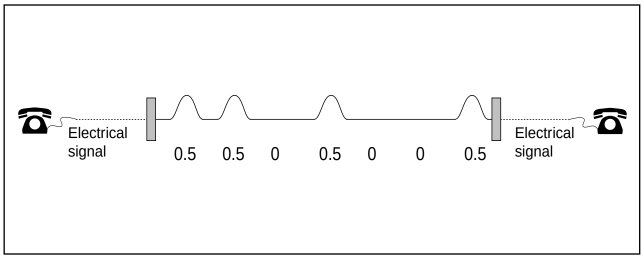


Figure 7. PMD-affected pulses in a 2.5 Gb/s system are still distinct.

Even though the value 1 has lost power and becomes 0.5, the broadened pulses can still be differentiated from 0. The communication can still be understood.

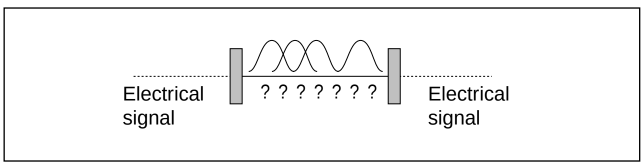


Figure 8. PMD-affected pulses in a 10 Gb/s system overlap.

At 10 Gb/s (figure 8), two 1 values can close the gap 0 between them. One of the 1 values loses height and becomes 0.5. The value 0 augments and becomes 0.5. The system no longer knows if the pulse or bit has a value of 1 or of 0. This increases the bit error rate (BER). The communication “hello” could be heard as “yellow” or become altogether incomprehensible. In an ordinary telephone conversation, impacts will not be great, but what if we are transferring money to a bank account? The consequences could be much worse.

Why Should We Test for PMD?

At 10 Gb/s, a delay as low as 10 picoseconds causes a significant increase in BER. Your system may function well and transmit clear communications at 2.5 Gb/s, but can it withstand a higher information rate? When you test for PMD, you obtain a clear answer.

1 800 663-3936
info@exfo.com
www.exfo.com

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CORPORATE HEADQUARTERS 465 Godin Avenue, Vanier (Quebec) G1M 3G7 CANADA Tel.: (418) 683-0211 Fax: (418) 683-2170
EXFO AMERICA 1201 Richardson Drive, Suite 260, Richardson, TX, 75080, USA Tel.: 1 800 663-3936 Fax: (972) 907-2297
EXFO EUROPE Centre d'Affaires Les Metz, 100, rue Albert Calmette, 78353, Jouy-en-Josas, FRANCE Tel.: +33.1.34.63.00.20 Fax: +33.1.34.65.90.93
EXFO ASIA PACIFIC 151 Chin Swee Road #3-29, Manhattan House SINGAPORE 169876 Tel: +65 333 8241 Fax: +65 333 8242