APPENDIX C

Differential Mode Delay

When an unconditioned laser source designed for operation on a single-mode fiber (SMF) cable is directly coupled to a multimode fiber (MMF) cable, differential mode delay (DMD) might occur. DMD can degrade the modal bandwidth of the fiber-optic cable. This degradation causes a decrease in the link span (the distance between the transmitter and the receiver) that can be reliably supported.

The Gigabit Ethernet specification (IEEE 802.3z) outlines parameters for Ethernet communications at a gigabit-per-second rate. The specification describes a higher-speed version of Ethernet for backbone and server connectivity using existing deployed MMF cable. It does this by defining the use of laser-based optical components to propagate data over MMF cable.

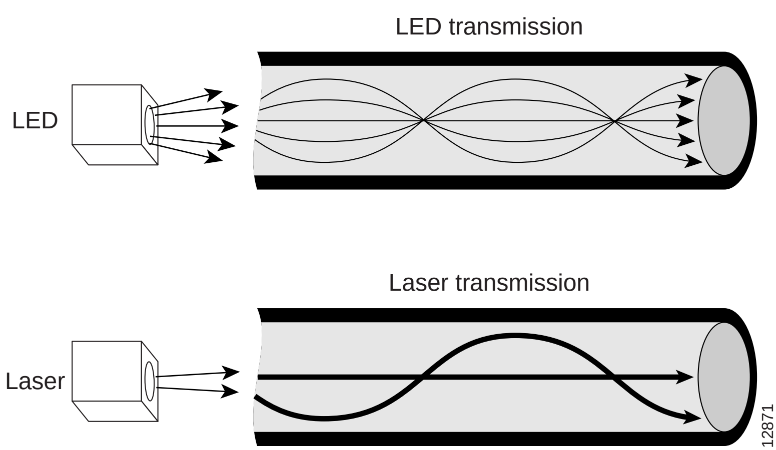
Lasers function at the baud rates and longer distances required for Gigabit Ethernet. The IEEE 802.3z Gigabit Ethernet Task Force has identified the DMD condition that occurs in certain circumstances with particular combinations of lasers and MMF cable. The resulting characteristics create an additional element of jitter, which limits the reach of Gigabit Ethernet over MMF cable.

When DMD occurs, a single laser light pulse excites a few modes equally within an MMF cable. These modes, or light pathways, then follow two or more different paths. The paths might have different lengths and transmission delays as the light travels through the cable. When DMD occurs, a distinct pulse propagating down the cable no longer remains distinct or, in extreme cases, might become two independent pulses. Strings of pulses tend to interfere with each other, making it difficult to recover data in a reliable fashion.

DMD does not occur in all deployed fibers; rather, it occurs with certain combinations of worst-case fibers and worst-case transceivers. Gigabit Ethernet is the first technology to experience this problem because of its very high baud rate and its long MMF cable lengths. SMF cable and copper cable are not affected by DMD.

MMF cable has been tested for use only with LED sources. LEDs create a condition within a fiber-optic cable referred to as an *overfilled launch* condition. The overfilled launch condition describes the way LED transmitters couple light into the fiber-optic cable in a broad spread of modes. Similar to a light bulb radiating light in a dark room, the generated light that shines in multiple directions can overfill the existing cable space and excite a large number of modes. (See Figure C-1.)

Figure C-1 LED Transmission Compared to Laser Transmission



Lasers launch light in a more concentrated fashion. A laser transmitter couples light into only a fraction of the existing modes or optical pathways present in the fiber-optic cable. (See Figure C-1.)

The solution to DMD in this case is to condition the laser light launched from the source (transmitter) so that it spreads the light evenly across the diameter of the fiber-optic cable, making the launch look more like an LED source to the cable. The objective is to scramble the modes of light to distribute the power more equally in all modes and prevent the light from being concentrated in just a few modes. This is in contrast to an unconditioned launch, which, in the worst case, might concentrate all of its light in the center of the fiber-optic cable, exciting only two or more modes equally.

A significant variation in the amount of DMD is produced from one MMF cable to the next. No reasonable test can be performed to survey an installed cable plant to assess the effect of DMD. Therefore, you must use a mode-conditioning patch cord for all interfaces using MMF when the link span exceeds 984 feet (300 meters). For link spans less than this, you can omit the patch cord (there is no problem using it on short links).