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Applications
Engineering Note

Single-mode Fiber Selection for Telecommunications Links

AEN 45, Revision 6

This note provides guidance for choosing between single-mode, dispersion un-shifted fiber (single-mode fiber), and non-zero dispersion shifted fiber (NZ-DS fiber) for telecommunications links.

Single-mode fiber is the most widely deployed fiber in the world for telecommunications. It is an excellent choice for most applications. However, for links longer than 80 km, links using DWDM, or links operating above OC-192, NZ-DS fiber is usually the better choice.

Modern single-mode fibers comply with ITU-T Recommendation G.652 Table D. Single-mode fiber has been deployed in telecommunications links for over thirty years and it effectively carries 1310 or 1550 nm traffic (or both). Fiber manufacturers design single-mode fiber's chromatic dispersion to coincide with a relative attenuation minimum near 1310 nm. Because of this design and the historic availability of single-mode fiber, transceiver equipment for 1310 nm use is widely available and economical. Transceivers for single-wavelength operation at 1550 nm are also available, albeit at higher cost.

Modern NZ-DS fibers conform to ITU-T Recommendation G.655 Table C or D. Their development was spurred in the mid-1990s by falling prices of 1550 nm lasers, the commercialization of optical amplifiers, and the introduction of dense wave division multiplex (DWDM) transceivers.

DWDM equipment transmits several channels on discrete wavelengths typically spaced around 1550 nm. On ITU-T G.652 single-mode fiber, the chromatic dispersion is too high near 1550 nm for effective DWDM transmission. For dispersion shifted fibers, multiple wavelengths carried too near the zero chromatic dispersion point will interfere with each other, and signal quality is reduced. Thus, fiber manufacturers optimize NZ-DS fibers' zero chromatic dispersion points away from 1550 nm (hence the name NZ-DSF) according to ITU G.655. This minimizes both wavelength interference and chromatic dispersion in the most common DWDM transmission band. DWDM transceivers are available from several vendors and offer tremendous bandwidth, but at considerable initial cost.

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Telecommunications links typically utilize single-mode fiber unless operating requirements necessitate NZ-DS fiber. Chromatic dispersion, polarization mode dispersion (PMD) and attenuation influence this choice.

- Fabry-Perot (FP) lasers are commonly used in premises networks. Chromatic dispersion will be high when using an FP laser due to source spectral width. FP sources are rarely used for telecommunications links, but might be encountered by a telecommunications company leasing fiber directly to an end user. Depending on transceiver limitations, FP lasers may reach tens of kilometers at 1310 nm over single-mode fiber, and because FP lasers are only produced for 1310 usage and are very rarely, if at all, produced for 1550 usage, using FP lasers necessitates selecting single-mode fiber.

- Distributed feedback (DFB) lasers are commonly used for telecommunications links. Using DFB lasers, chromatic dispersion typically limits links to about 80 km over single-mode fiber (for OC-192 (10Gb/S) at 1550 nm). Chromatic dispersion is not usually limiting at lower line rates (OC-48 or less), at either 1310 or 1550 nm, and attenuation limits link lengths. Accordingly, single-mode fiber is usually the best choice for short links that will not exceed OC-192; NZ-DSF should be considered for links over 80 km.

- DWDM transceivers use multiple DFB lasers operating at wavelengths in three bands centered around 1550 nm. Accordingly, NZ-DSF is the best choice for any DWDM link, regardless of line rate. Single-mode fiber can support DWDM operation to a limited degree because of chromatic dispersion. Compensation for chromatic dispersion is possible but at a cost of increased PMD, insertion loss, and price.

- OC-768 (40 Gb/S) transceivers use only DFB lasers. These links tolerate relatively little chromatic dispersion. OC-768 equipment is available only for 1550 nm operation, usually as part of DWDM equipment. Accordingly NZ-DSF is the only choice for OC-768 operation.

- Many network operators are aware that PMD is a concern at higher line rates. However, PMD is usually inconsequential for links below OC-192 (whether single-mode fiber or NZ-DS fiber). Even at OC-192, properly cabled, high quality optical fibers rarely limit link reach due to PMD. At OC-768, tight PMD control is absolutely critical Network operators should work closely with vendors to ensure their physical plant satisfies transceiver limitations. In all instances, though, choosing high quality cabled fiber and optical components is critical for minimizing PMD. For example, the Corning PMD specification is 30% better for NZ-DS fiber than for G.652 products: $PMD_Q \leq 0.04$ ps/km$^{1/2}$ vs. ≤ 0.06 ps/km$^{1/2}$. This improved capability is important for OC-192 and critical for OC-768 transmission.

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Upgrading existing plant to higher line rates invites these same considerations, but precludes managing them by product selection. In such cases, chromatic dispersion, PMD and attenuation should be characterized to quantify link limitations. Discrete devices are available to compensate for chromatic dispersion or to amplify signals, but PMD can be improved only by changes to the physical plant.

More information regarding PMD is available in AE Note 48. For additional information, visit http://www.corning.com or contact Corning Cable Systems at 1-800-743-2671.

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