# A Guide to Attenuation Specifications in OFS Fiber and Cables

## Application Note AN-111A

**Background**

There has been confusion in the telecommunications industry regarding fiber and cable attenuation (loss) specifications for decades. Manufacturers provide different descriptive terms to describe performance, such as the difference between "typical", "specified", and "characterized" values. Manufacturers can also use different numbers of significant figures in specifications to legally, technically, and accurately describe their products' performance, but unfamiliar customers may not fully appreciate the extent to which these techniques can ultimately change the actual performance of the finally deployed product. This document is a basic guide to how OFS specifies attenuation in optical fibers and cables.

**Fiber Attenuation specifications**

The image to the right is part of the AllWave® One fiber specification.

Some key points to note:

| Optical Characteristics | |
|---|---|
| Attenuation | Maximum |
| at 1310 nm | ≤ 0.33 dB/km |
| at 1385 nm | ≤ 0.31 dB/km |
| at 1490 nm | ≤ 0.21 dB/km |
| at 1550 nm | ≤ 0.18 dB/km |
| at 1625 nm | ≤ 0.20 dB/km |

OFS specifies attenuation at 5 individual wavelengths, and each number is a "maximum" with two significant figures. All fibers are manufactured with a statistical distribution of performance. Only a small portion of the fibers are made with the maximum value, and most fibers have attenuation values well below the maximum. This performance is only specified for uncabled fiber.

**Cabled fiber attenuation specifications**

Many end users of fiber don't realize that cabling optical fibers can impact attenuation. This is why manufacturers may specify different attenuation values for various cable designs. For fibers used primarily in long-distance routes, OFS defines two terms for cabled fibers - the first is the maximum attenuation for any cabled fiber, and the second is the link design value (LDV) for attenuation which describes the expected performance in an installed system. More detailed definitions are below:

**Maximum Attenuation**

"Maximum" has a clear definition. If a **maximum** specified value is 0.33 dB at 1310 nm, the highest attenuation of any **individual** fiber will be no greater than 0.334 dB/km, as defined by standard rounding rules. Contrast that to a competitor who may specify 0.4 dB/km. Since 0.4 dB/km has only one significant figure, attenuation of a single fiber may be as high as 0.44 dB/km using the same rounding rules.

Maximum attenuation is a useful property for assessing worse case optical performance of individual spools and short distance links. That said, sometimes "maximum" is not the best way to characterize performance. Attenuation in the final cable is often well-below the maximum specified value. Selecting the transmitters, receivers and amplifiers used in a long-distance optical link based on the maximum cabled fiber attenuation can potentially increase network costs by requiring spacing electronics more closely together or using more powerful transmitters and amplifiers than if a more representative attenuation value is used. An alternative method is to use Link Design Value (LDV) for attenuation.

**Link Design Value (LDV) for attenuation**

In general, LDV is a way of evaluating a parameter that has a distribution of values throughout the network, such as the attenuation of an optical fiber. LDV is a statistical methodology that can be used to determine the maximum expected attenuation for a given optical link based on assumptions with a known confidence level. The methodology used by OFS assumes that 8 random optical cables concatenated together will have attenuation less than or equal to the LDV for attenuation 99.99% of the time. This methodology has been shown to be a reasonably conservative estimate for links greater than or equal to 40 km[1]. It is a more realistic look at what the actual attenuation of the network will be once it is installed versus using the maximum attenuation method and is more commonly provided for fiber types associated with longer distance links.

Conservatism is good and important in network design. Passive equipment (including fiber) manufacturers add safety factors, as do electronics manufacturers. Engineering firms, being properly cautious, often include additional safety margin when designing networks. However, an inadvertent consequence of many levels of conservatism is that it can inadvertently drive up network costs by forcing shorter amplifier spacings or requiring higher performance optics for a given link. Traditional loss budgets using “maximum’ values is conservative, with levels of safety margin built into network attenuation (optical loss) calculations.

A comparison highlighting the differences between the “maximum attenuation” and LDV attenuation is shown below. The maximum attenuation method allows a maximum individual loss of 0.25 dB/km, where the actual link attenuation is based on the distribution of manufactured product, and is 0.21 dB/km.

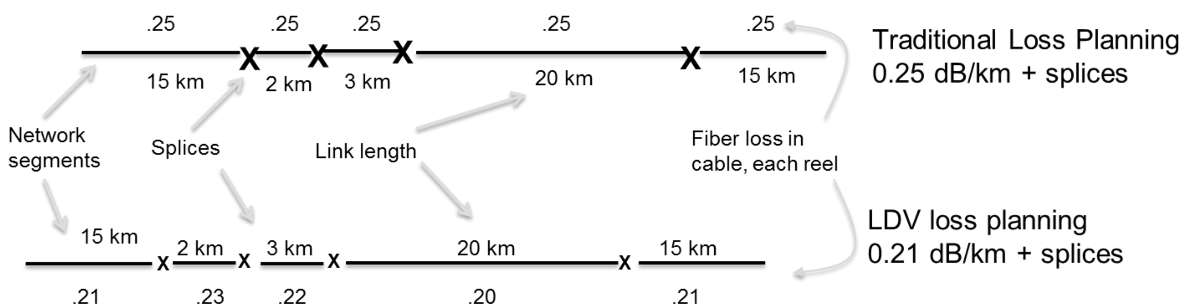


**Figure 1: Difference between traditional maximum attenuation and LDV attenuation specifications**

The probability of every cable being at the maximum value is highly unlikely, as very few cabled fibers are at the limit. Using the LDV method, we can determine the probability of that occurrence, and provide the information to inform the specification. This approach often uncovers several dB of unrealized margin in an optical link. An LDV-based specification typically has different language associated with it because the parameter is statistically derived. It provides a statement of loss/km, and also provides a minimum length or number of cables needed for the specification to be valid. Example LDV specification wording follows: *“0.33/0.31/0.19 dB/km maximum end-to-end link attenuation over a concatenated span of cable, not including splice loss, assuming a minimum of a 8 cables comprising the link”.* The reason for this more precise wording is that LDV specifications are based on statistical analyses of the manufacturing distributions (lengths and loss levels) over long periods of time.

## Benefit in longer distance networks

The benefit from moving to LDV specifications can be substantial. The longer the network, the more substantial the impact is on the network. The impact on a 100 km network is shown in the table below (cable loss only, not including splices or connections):

| Long Distance Network – 100 km | | | | | | |
|---|---|---|---|---|---|---|
| | Expected loss using "maximum" design rules (1550 nm) – AllWave Fiber | | Expected loss using "maximum" design rules (1550 nm) – AllWave One Fiber | | Expected loss using "LDV" design rules (1550 nm) – AllWave One Fiber | |
| 100 km cable | Attn/km | For 100 km | Attn/km | For 100 km | Attn/km | For 100 km |
| | 0.25 dB/km | 25.00 dB | 0.22 dB/km | 22.00 dB | 0.19 dB/km | 19.00 dB |
| Reach added from typical method | Baseline case – typical method | | 3.00 dB of margin added | | 6.00 dB of margin added (longer reach, more possible splice/access points) | |

In the example above, up to 6 dB of margin is obtained by using the LDV specification method. This margin can be used to add additional distance to the network, use less expensive optics, or however the network designer sees fit.

The table below compares the different specification methods for common OFS fiber and cable types. In the case of discrepancies between values in this document versus data sheets, the fiber and cable datasheet values supersede the values below.

| Single-Mode Fiber | Fiber (S1) | Fiber (S2) | Fiber (SF) | Fiber Standards | Wavelengths (nm) | Typical LDV Attenuation (Loose tube) | Typical LDV Attenuation Flat ribbon) | Typical LDV Attenuation (Rollable ribbon) | Maximum Cable on Reel Attenuation (dB/km) |
|---|---|---|---|---|---|---|---|---|---|
| AllWave® ZWP Fiber | 3 | B | 3 | G.652.D | 1270/1310/1385/1550 | - | - | - | N/A/0.35/0.31/0.25 |
| AllWave®+ ZWP Fiber | 3 | C | E | G.652.D/G.657.A1 | 1270/1310/1385/1550 | - | - | 0.4/0.35/0.3/0.22 | N/A/0.35/0.31/0.25 |
| AllWave® FLEX ZWP Fiber | 5 | B | E | G.652.D/G.657.A1 | 1270/1310/1385/1550 | - | - | 0.4/0.35/0.3/0.22 | N/A/0.35/0.31/0.25 |
| AllWave® One ZWP Fiber | 3 | F | E | G.652.D/G.657.A1 | 1270/1310/1385/1550 | 0.4/0.33/0.31/0.19 | 0.4/0.33/0.31/0.19 | - | N/A/0.35/0.31/0.22 |
| TrueWave® RS LWP Fiber | 6 | 2 | 6 | G.655.C&D | 1550 | 0.21 | 0.21 | - | 0.25 |
| TeraWave® Fiber | 6 | 2 | R | G.654.B | 1550 | 0.19 | .20 | - | 0.25 |
| TeraWave® ULL Fiber | 6 | 9 | R | G.654.E | 1550 | 0.18 | - | - | 0.22 |

For more information, please contact your OFS sales representative.

Reference

**(1)** David Mazzarese, "Improved Accuracy For Estimating Attenuation of Installed Single-Mode Optical Cable Links", Proceedings of the IWCS, October 2014.