TECHNOLOGY FOR BUILDERS AND DEVELOPERS

Bending: The Truth About MDUs

Reliable, cost-effective fiber installations in multiple dwelling unit structures need bend-insensitive fiber. Here's how to calculate the signal-loss budget.

By Mark Turner ■ *Corning Cable Systems*

Are broadband requirements really any different for a customer in a 1200-square-foot condominium than for one in the 2500-square-foot house just across the street?

It's hard to answer "yes" knowing that broadband customers, regardless of where they live, want the same compelling TV channel lineup, ultra-high-speed connection to and from the Internet, and reliable phone service.

Physically, though, it is clear that fiber bending is an issue where fiber drop cables are placed indoors, so from that perspective a "yes" answer is the right one. The simple truth is that fiber bending matters if you want to reach those MDU customers without incurring excessive construction costs. This article discusses the fiber-to-the-home (FTTH) network design considerations for broadband customers living in multiple dwelling unit buildings (MDUs).

MDUS VERSUS SFUS

The key difference between MDU and single-family unit (SFU) networks is in the FTTH physical layer. SFU customers are fed with outside plant (OSP)-rated fiber cables and fiber hardware, while MDU customers can be fed with a combination of OSP-rated and indoor-rated fiber cable and fiber hardware.

Figure 1 shows a typical scenario where a single local convergence point (LCP) splitter cabinet serves customers living in SFUs or MDUs.

CONTRIBUTORS TO CHANNEL LOSS

An important consideration is channel loss and the need for the amount of optical power available to design the LCP serving area to be transparent for both SFU and MDU customers.

For example, GPON transmission equipment for FTTH networks is typically designed with 28 dB of optical power available between the optical line terminal (OLT) in the operator's central office or headend and the optical network terminals (ONTs) inside each customer's network interface (NID).

A single GPON OLT reliably delivers 2.4 Gbps down the network to the splitters near the customers and 1.2 Gbps back up the network from the splitters. All of the customers in a dwelling unit sharing that bandwidth (typically 32 of them) share the reliability as well, as long as the light level at each ONT is no less than 28 dB below the amount of "light power" that was injected into the fiber by the OLT at the central office.

Also, if other broadband services are provided out-of-band, those light budgets must also be respected. Physically, the light level decreases uniformly as it propagates away from the laser source (at either the OLT or ONT end) as long as the fiber is not bent excessively.

The fiber structure, also known as the refractive-index profile, and the operating wavelength(s) of the laser source and launch conditions (how well the laser signal is coupled to the fiber) influence how much power is lost when a fiber is bent. If a fiber is bent excessively, an additional drop in power at that specific bending point will occur. This is known as a "macro-bend" loss.

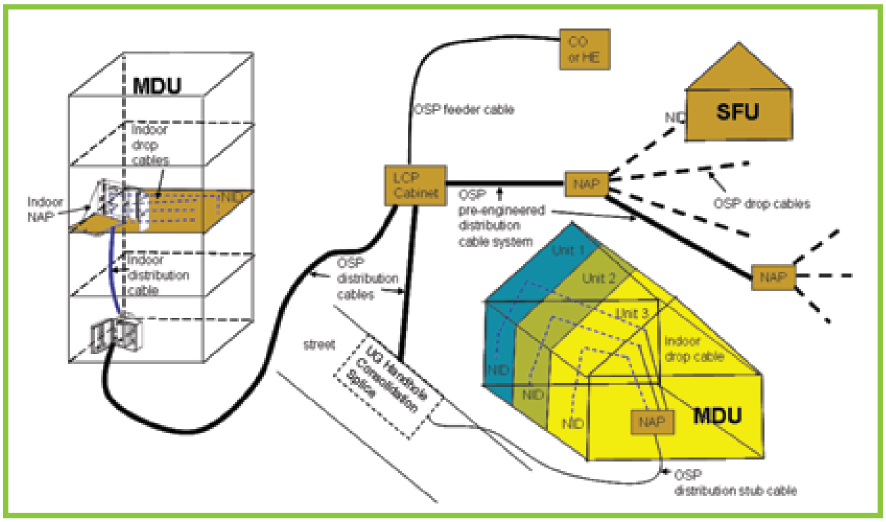

Figure 1. FTTH network with both MDU and SFU customers. MDUs can be high-rise (left) or garden-style (lower right).

Therefore, a key parameter of any fiber is its minimum bend radius during operation, which is the point at which it starts to lose its rated light-retention capability.

One complication for designers arises because the access network is actually composed of three distinct fiber cable segments:

- Feeder cables, from the central office or headend to the LCP.
- Distribution cables, from that LCP to the network access point (NAP).
- Drop cables, from the NAP on to the NID at each dwelling unit.

> ***This article discusses the fiber-to-the-home network design considerations for broadband customers living in multiple dwelling unit buildings.***

> ***Single-family-unit customers are fed with outside plant-rated fiber cables and fiber hardware, while MDU customers can be fed with a combination of OSP-rated and indoor-rated fiber cable and fiber hardware.***

These cables can be quickly joined together with fiber optic interconnection hardware such as LCP splitter cabinets and NAP fiber terminals with ports to interconnect the drop cable to the distribution cable. These interconnections typically reduce the light level only a tiny amount – between 0.15 dB and 0.5 dB during operation.

Let's look at an example that shows these different contributors to optical power channel loss. Figure 2 depicts a serving area where the customers in a multistory MDU are interconnected to the LCP splitter cabinet via indoor-rated optical drop and riser cables and outdoor-rated cables.

CHANNEL LOSS AND FIBER BENDING

As the PON schematic in Figure 2 shows, the ITU-T PON physical layer power limit is 20 km from OLT to ONT. That is, the light can travel a distance of up to 20 km (13 miles) with little enough signal loss and noise to maintain reliable service.

Assume the feeder fiber cable length is 13 km from the CO to the LCP splitter cabinet, and that the distribution length from the LCP cabinet to NAP fiber distribution terminal is another 2 km.

Let's also assume that the last crucial link, the fiber drop cable, is a mere 100 ft to the farthest dwelling unit. So, 13 + 2 + 0.03 km equals about 15.03 km from the OLT to ONT.

Assuming a maximum intrinsic fiber attenuation of 0.4 dB/km for 1310 nm and 0.3 dB/km for 1550 nm, then the optical channel length amounts to about 6.0 dB at 1310nm and 4.5 dB at 1550 nm (the two typical wavelengths a PON network uses) for fiber loss alone if standard single-mode fiber, which is ITU-T G.652.D compliant, is employed.

The calculation holds *if* the bend radius of the G.652.D standard is respected at the operational wavelengths.

The 1550 nm band wavelength, while it loses less signal over long fiber lengths, is affected more by tight bends. In that short 100 ft (0.03 km) from the MDU NAP to the MDU customer, eight 90-degree bends (equivalent to about two 360-degree rotations around a 5 mm radius mandrel) are in the path from NAP to customer NID.

This sort of drop configuration is normally not encountered for the SFU customer because single-family dwelling units typically use all OSP-rated fiber cables that do not encounter tight bends in the overhead and in-ground cable pathways.

At 1550 nm operation, eight 90-degree bends on standard G.652.D indoor fiber can amount to over 200 dB of loss. But the loss is far less – 21.5 dB – on

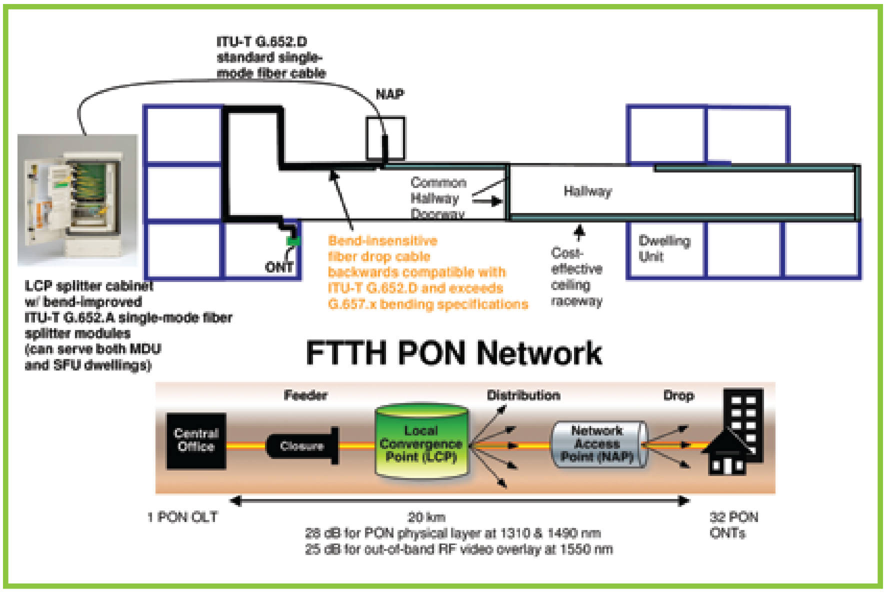

Figure 2. Typical bending of fiber drop cables (one per dwelling unit) in MDUs.

A key parameter of any fiber is its minimum bend radius during operation, which is the point at which it starts to lose its rated light-retention capability.

G.657.A bend-improved fiber. And it is only 4 dB on bend-tolerant G.657.B fiber. The new bend-insensitive fiber technologies suffer a loss of only 0.2 dB.

Additionally, between the OLT and ONTs there are other sources of insertion loss. The splitter module can attenuate the signal by as much as 17.5 dB on any given output lead and the six fiber optic connections in the channel also drop the optical power. Currently, the typical insertion loss for a field connection is 0.15 dB, and a fusion splice is about 0.1 dB. However, a mode-field diameter mismatch could also cause more loss if the extreme-bend drop fiber is not fully backward-compatible with industry-standard G.652.D single-mode fiber.

It is essential then to use a fiber that is known to be fully backward-compatible with G.652.D to minimize coupling loss from fiber to fiber. Therefore, the splitter, connections and fusion splices typically add another 17.8 dB of channel insertion loss. The calculation is:

$$16.5 + (0.15 * 6) + (0.1 * 4)$$

Bend-insensitive single-mode fiber is the only fiber that enables an FTTH designer to ignore costly cable pathway creation and simply design the MDU portion of the PON the same way as the SFU portion.

And the WDM combiner (to mix the PON and RF video signals onto a single fiber) in the central office or head-end can attenuate the power as much as 3 dB.

Assuming the link loss budget for RF video overlay operating in the 1550 nm band is 25 dB, the only fiber that will operate in the typical MDU configuration requiring many 90-degree bends is bend-insensitive.

Stated another way, bend-insensitive single-mode fiber is the only fiber that enables an FTTH designer to ignore costly cable pathway creation and simply design the MDU portion of the PON the same way as the SFU portion.

Table 1 summarizes this information from the configuration shown in Figure 2. Note that maximum cabled fiber loss (intrinsic) is calculated to build in some headroom with respect to the link loss budget of 25 dB.

SUMMARY

An FTTH designer is now free to design MDUs just like SFUs because bend-insensitive fiber enables the optical power to pass through many tight bends down to a 5 mm radius (such as 90-degree bends around wall corners and at the wall-ceiling transition) with very low loss.

This is extremely important because without this new fiber technology, very costly cable pathways would otherwise be needed in order to get enough optical power to the MDU customer's ONT.

Also, its backwards compatibility with industry standard ITU-T G.652.D single-mode fiber assures that mode-field diameter mismatch does not cause additional loss at fiber interconnections and splices. **BBP**

About the Author

Mark Turner is Market Development Manager at Corning Cable Systems.

Single-mode fiber type	Typical WDM combiner (dB)	OSP feeder (dB)	OSP distribution (dB)	Indoor MDU drop (dB) – 8 90° bends	Typical splitter lead loss (dB)	Fiber joining point loss	OLT to ONT channel loss (dB)
G.652.D	n/a	**3.9**	**0.6**	**200**	bend-limited	**1.3**	**224.8**
G.657.A	**2.5**	not required	not required	**21.5**	**16.5**	**1.3**	**46.3**
G.657.B	n/a	not required	not required	**4**	not needed	**≥ 1.3**	**≥ 28.8**
Bend-insensitive (G.652.A and .B capable)	n/a	not required	not required	**0.2**	not used currently	**1.3**	**25.0**

Table 1. RF video overlay channel loss (1550 nm) from OLT to MDU ONT, in the installation shown in Figure 2.