Bend-Insensitive Fiber

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Introduction

The ever increasing demand for bandwidth in the residential sector has pushed fiber optics manufacturers and service providers to develop Fiber-to-the-Home (FTTH) technology. Fiber has the highest transmission capacity, 25Tbps, of all mediums, but it is not as rugged and forgiving as copper. Current fiber installations in homes and buildings experience loss in signal strength because fiber has to be routed around tight corners, making it complicated and expensive to install. Sometimes holes would have to be drilled through walls in order to avoid bending the fiber optic cable, making fiber installations visually unappealing. Service providers like Verizon and fiber optic manufacturers like Corning are working closely together to develop fiber that can handle the smaller bend radii encountered in single-family units (SFUs), multiple-dwelling units (MDUs), and in-home wiring. Currently, only 5 percent of all FTTH installations in the United States are in MDUs (Deutsch, October 2007).

What is Fiber and How Does It Work?

A fiber-optic cable is made up of four basic elements: optical fiber, buffer, strength element and outer jacket. The optical fiber is a thin, transparent, flexible strand made of glass or plastic. The optical fiber consists of a core surrounded by cladding, which is covered with a protective coating. Its function is to carry a light signal. The buffer protects the fiber from environmental damage. The strength element protects the fiber from mechanical stress that may be encountered during installation and operation. The outer jacket holds all these elements together and provides further protection from environmental damage (Mynbaev, 2001).

The optical fiber carries a light signal by using a cladding with a refractive index that is less than the core's refractive index. This configuration achieves total internal reflection at the core-cladding boundary, but total internal reflection is lost when the fiber is bent. This is called bending loss. Bending loss occurs when the light beam traveling along the fiber hits the core-cladding boundary of the bent portion of the fiber causing the critical propagation angle to become more than critical and therefore failing to achieve total internal reflection. There are two types of bending loss: macro-bending loss and micro-bending loss. Macro-bending loss is bending loss caused when the whole fiber axis is curved, such as around corners. Micro-bending loss occurs when there are imperfections in the geometry of the core-cladding interface (Mynbaev, 2001). Stapling fiber-optic cables to studs could cause micro-bending (Ross, August 2007).

Improving Bend Performance

Developments to improve the bend performance of optical fiber date back approximately twenty years. There are several ways to improve bend performance of a fiber. The core diameter can be reduced or the core's refractive index can be increased, or both. Another method is to reduce the refractive index of the cladding to less than that of silica glass by pressing the cladding fibers where a circular zone around the core is doped. This is called depressed clad fibers. A method called trench-assisted fibers can also be used. It is similar to depressed clad fibers but instead the doped circular zone is further away from the core. These methods have only produced small improvements. Other approaches were also developed to produce greater improvements in bend performance. The main approaches are known as hole-assisted fiber (HAF) and photonic band-gap fiber (PBGF). They provide greater improvement, but they are expensive to manufacture, difficult to connect, and are not backward compatible to existing standards defined by International Telecommunications Union Telecommunications Sector (ITU-T) recommendation G.652.D or current termination and field procedures (Deutsch, October 2007).

Standardization

The demand for better bend performance of fiber has led ITU-T to develop recommendation G.657 in 2006 to standardize the bend performance of these new types of fibers. Bend-improved fibers are defined by G.657.A, which limits improvement in bend loss to ensure backward compatibility with G.652.D, standard low-water-peak single-mode fiber. Bend-tolerant fibers are defined by G.657.B, where backward compatibility is not required so the focus is placed on improving bend loss (Deutsch, August 2007).

Recent Developments

Lucent, now Optical Fiber Solutions (OFS), was producing bend-insensitive fiber since the late 80s, but the first major breakthrough came in 2005 when, at the FTTH Council Europe meeting in Amsterdam, Nippon Telephone and Telegraph (NTT) introduced a fiber that could be tied in knots. The NTT fiber is known as HAF. The fiber can be tied in knots and maintain virtually zero loss because the cladding is manufactured with tunnels running parallel to the core, relieving stress on the cladding when the fiber is bent. NTT's fiber was fine for user-installed networks but it was not meant to be fastened to the structure of a building and it was difficult to manufacture, expensive, and required special connectors (Ross, August 2007).

In July of 2007, Corning Inc. announced the development of optical fiber that is as forgiving and rugged as copper while still providing the bandwidth of fiber with virtually no signal loss (July 2007). Corning achieves this using nanotechnology. Corning calls its new development nanostructures optical fiber design. This design coats the core with reflective, tube-like nanostructures that guide the light back into the core when the fiber is bent, maintaining total internal reflection. In standard low-water-peak single-mode fiber, total internal refection is lost when the fiber is bent. This causes some of the light to be absorbed by the cladding, resulting in some signal loss. This is unacceptable in an MDU installation, which requires the fiber optic cable to negotiate many tight turns.

This process is completely synthetic so no mechanical work has to be done on the fiber as in HAF. This makes the manufacturing of nanostructures optical fiber easier and more cost-effective for FTTH installations. This design is capable of achieving the bend radii of 5mm that is required to be comparable to copper cable. It is also compatible to current termination and field procedures, and backward compatible with G.652.D. This new technology will also enable the design of cables, hardware, and equipment, such as local convergence cabinets, that takes up less space, is lighter, more visually pleasing, and easier to get permits for (Deutsch, October 2007).

Concerns

There has been some concern expressed about how this new fiber will handle the abuse it will encounter in an actual construction environment where kinks can occur when a cable is pulled taut during installation. The fiber may initially work but these kinks could be a major problem over time. To minimize the chance of kinking, designers advise using ducts to run fiber through. There is also some concern as to how it will handle sag when it is horizontally installed, especially in garages and attics where there are extreme changes in temperature. There have been mechanical stress problems reported. When fiber is installed during the cooler season, the sag increases when summer comes around. Also, if installed during the hotter season, the cable goes taut when winter rolls around (Ross, August 2007).

Corning has reported that it has thoroughly tested the thermal and mechanical performance of its nanostructures fiber in their labs. Corning has also started testing its fiber in an actual building in mid-September, 2007. Corning introduced its nanostructures collection of optical fiber, cable, hardware and equipment at the FTTH Conference in Orlando on September 30, 2007. This collection is known as the Corning ClearCurve solution and they reported that the fiber would be ready for distribution towards the end of 2007 (July 2007).

Future Trends

Verizon has said that it will be ready to use Corning's nanostructures optical fiber when it becomes available. In "Corning Intros New Bend-Insensitive

Fiber Technology," the Corning president and chief operating officer, Peter F. Volanakis, said, "There are more than 680 million apartment homes worldwide, including more than 25 million in the United States. The high cost of installation and difficulty in delivering fiber to the home made this market unappealing to most providers. We have been working closely with these carriers to create a solution that will make this more economically viable for them and for their customers" (July 2007). Once Corning's nanostructures optical fiber is made available, I believe we will see a massive deployment of FTTH in this market in the coming years. We should also be seeing further development in end equipment to take further advantage of fiber's bandwidth capabilities.

Conclusion

It seems like not so long ago I was using dial-up. Technology changes so fast and seems to be able to overcome just about any obstacle in its path. With this new technology, the telecommunications industry should be able to satisfy society's hunger for bandwidth. This may help create more jobs to handle the deployment of FTTH in areas where it was previously impractical. It may even help improve the economy. In the pursuit of satisfying society's insatiable appetite, we must keep in mind that we want to be as environmentally friendly as possible. Only time will tell what the future may bring.

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