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A model of optical fiber point-to-point communication system

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Abstract

The waveguide which is considered recently for transmission of radio frequency (RF) signals from one node to another node is the optic fiber technology. The reliance on fast transmission of information can be achieved with the implementation of fiber optic cable as a waveguide in a communication channel. Basically, optic fiber transmits information with the aid of light called laser at majorly two categories of wavelengths which are 1310 nm and 1550 nm. Propagation of signal over a long stretch of fiber is affected by attenuation due to scattering, fiber bend due to impurities and absorption between the core and the cladding when signal travels along the channel, but these loses are minimal between acceptable value. Optical fiber sensors called photodetector are used to detect the information at the receiving end with minimal losses along the fiber channel. Results obtained demonstrate that there are minimal losses in a fiber cable-based signal transmission.

Keywords: Attenuation; Fiber-to-the–Home (FTTH); Optical fiber; Point-to-point communication

1. Introduction

It is now more than 35 years that optical fiber communications have progressed, and the technology has imposed a significant revolution to the information technologically oriented society beyond the twenty-first century[1]. In recent times optical fiber cable is identified as an improved transmission technology in communications, due to its flexibility, capability to handle higher bandwidth, and ability to transmit signal over long distance with minimal attenuation as compared to electrical cables [4]. With the implementation of fiber optic technology, there is an increasing need for large transmission rate to transmit more information at faster speeds and at reduced costs as a result of this there is significant advancement in communications systems. Presently optic fiber channel supports up to 300 TeraHertz (THz) bandwidth. With advances to the implementation of fiber optic cable, there is increase in the ,bandwidth and throughput of the transmitting channel, this allows for transmission of data over long distances, presently optic fiber channel supports up to 300 THz bandwidth[2], this led to many users communicating simultaneously due to high bandwidth. The extension of fiber optic cables is a crucial component of a fiber optic communication system because it minimizes the losses caused by linking two distinct cables because it requires accurate fiber cleaving, joining lengths of optical fiber frequently proves to be more challenging than joining electrical wire or cable because it requires precise alignment of the fiber cores and careful splicing of these aligned fiber cores to prevent transmission losses.

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1.1 Related Studies

Without a doubt, the tremendous success of optical communications technology, which has significantly improved our quality of life over the past four decades, is due in large part to the use of low-loss optical transmission fibers. The success of technology based optical communications technology is undeniable which is largely due to the use of low loss optical transmission fibers. FTTH network which is widely implemented recently was based on the use of passive optical network, in the telecommunications industry through the extensive use of passive asymmetric splitters. Although FTTH didn't take place on a large scale until decades later. Optical fiber transmissions underwent a revolution when the fiber optic amplifier entered the market in the early 1990s. It was discovered that optical signals can travel more than hundreds of kilometers after being amplified without regeneration [3]. The performance of a communication system is determined by the channel capacity or data rate of the fiber link. With the implementation of wavelength division multiplexing (WDM) systems, optical network design flexibility and transmission capacity can both be markedly increased. Fiber can be broadly divided into two categories: Single-mode fiber and multimode fiber. However, because multimode fiber is a larger fiber, there is possibility of multiple light signal paths, this allows for more signal loss and signal distortion [1]. Future telecommunications networks will incorporate single-mode fiber-optic transmission media because of the financial benefits, developing technology, and high information capacity. Since single mode fiber experiences less signal attenuation than multimode, it can be used for longer deployments up to 100 km, whereas multimode fiber can be used for shorter deployments up to 6 km[6]. From the foregoing future optical networks for multiplexing, demultiplexing, filtering, amplification, and correlation purposes would benefit from having the capacity to process data directly in the optical domain. There are currently several new classes of optical networks emerging [5]. Generally, in this paper we will consider a simple point-to-point communication network implemented using fiber cable and test the loses at nodes (two nodes) using laser light source as the transmitting signal and power meter to measure the strength of the signal. Also use of splicer to join fiber cable was carried out.

2. Material and methods

Total internal reflection, which takes place at the boundary between the cladding and the core, if the carrier light wave's incident inside the core is greater than the critical angle within the core. Due to this reflection, the incident light will travel along the fiber after returning to the core, this allows the light used to carry the intended signal not pass through to the other medium. The reflection of the light at the interfaces of the core and cladding is determined by the angle of incidence and the refractive indexes of the core and cladding. Light will be guided through the fiber cable by the core section with the highest refractive index based on total internal reflection phenomena.

Fig. 1 illustrates the fundamental design of a single fiber optic cable. The optical fiber is made up of four parts: the core, cladding, buffer, and jacket.

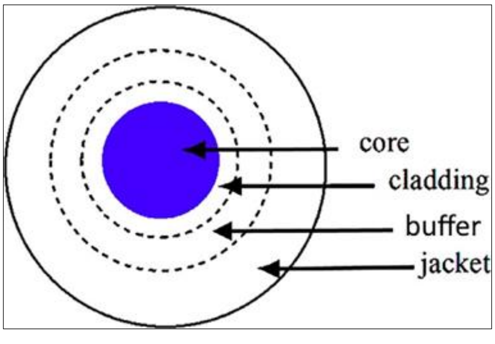

Figure 1 Structure optical fiber cable

2.1 Fiber Optic Point-to-Point Communication

Fiber-optic communication is a technique which uses light pulse to transmit information from one node to another. The light which is the electromagnetic carrier wave is undergoes modulation by the message signal to carry information. This method of communication can transmit information over short and long-distance communication networks, due to this benefit of fiber optic communications several telecommunications companies took the advantage of optical fiber technology to transmit data signals.

Fig. 2, provides an overview of a straightforward point-to-point communication model. While the receiving node (message output) is at point B, the message origin is at point A (input). This can also be reversed by transmitting from node B to node A.

Figure 2 A Simple Model of point-to-point System for Communication via Optical Fiber

2.2 Optical Detector

A detector at the receiving end picks up the information as it begins to be transmitted. In the fiber framework, a photodetector converts the optical wave into an electric current. The current flowing through the detector rises in proportion to the incident optical wave's power.. The transmitted data is contained in the detector output current. The constant bias is then removed from this detector output before it is amplified. One of the most important features of photodetectors is their small size, affordability, durability, minimal power consumption, very sensitivity to optical signals, and faster response time to sudden changes in optical power. Suitable filtering and amplification are part of signal processing which maximizes SNIR.

2.3 Jumper method

The design of fiber optic communication system is restricted by dispersion, and non-linearity of the fiber cable. The selection of operating wavelength becomes a significant design issue because the fiber properties are wavelength dependent. Many things can affect how well the data is transmitted as the optical signal pulse passes through the fiber. The likelihood that data will be received at the receiver end decreases as an optical pulse travels farther; however, the faster the pulse is transmitted, the more successfully the data will be recognized at the receiver side. In this article we are only interested in power meter and light source test which is called the jumper method, which is the most standard way to obtain the end-to-end attenuation in a fiber communication link. During this test a light source is sent from one end using light source probably laser while the power meter determines the light power level that comes out of the other end of the optical fiber. The power level difference offers a precise illustration of the optical fiber insertion loss. This results from the attenuation and dispersion of a light wave that is in motion. When a light wave travels down a fiber, the attenuation effect reduces the signal power, and the dispersion changes the pulse's shape. The three primary mechanisms that result in fiber signal attenuations are briefly discussed as follows:

2.3.1 Absorption Loss

A portion of the light energy can be blocked by any impurity, including hydroxyl ions and traces of metals left in the fiber after manufacturing.

2.3.2 Scattering Loss

Four kinds of scattering losses in optical fiber are: Rayleigh, Mie, Brillouin and Raman scattering. Due to changes in the refractive indices of the core and cladding materials, Rayleigh is the most significant scattering loss. These modifications are a result of issues with the manufacturing process. The problems with the manufacturing process led to these modifications. The following expression can be used to approximate the Rayleigh scattering loss in dB/km. The Scattering loss in dB/km based on Rayleigh fading can be approximated by the expression [6]*:*

$$L = 1.7 \left[\frac{0.85}{\lambda}\right]^4 \text{.......................................} (1)$$

Where; λ is the wavelength in μm.

For single component glass the scattering loss is given by [7],

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4}(n^2 - 1)^2 k_B T_f \beta_T \; nepers \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where; n = Refractive index
k_B = Boltzmann's constant
β_T = Isothermal compressibility of material
T_f = Temperature at which density fluctuations are frozen into the glass as it solidifies (fictive temperature)

The fourth power of the wavelength has an inverse relationship with the scattering loss. Rayleigh scattering thus severely limits the use of short wavelength in fiber optic communication.

3. Results and discussion

Based on the jumper method conducted in this paper, test was conducted using node A as the transmitter and node B as the receiver and vice versa. Eight core fiber cable was available to carry out the test but only four cores out of the eight were used. Tables 1 and 2 show the results obtained at two different signal wavelengths (1310 nm and 1550 nm).

Table 1 Power meter, light source test from point A to B

Fiber Cores	Insertion Loss (dB) at 1550 nm	Insertion Loss (dB) at 1310 nm
1	-0.13	0.01
2	-1.34	-1.37
3	-0.44	0.01
4	-0.24	0.04

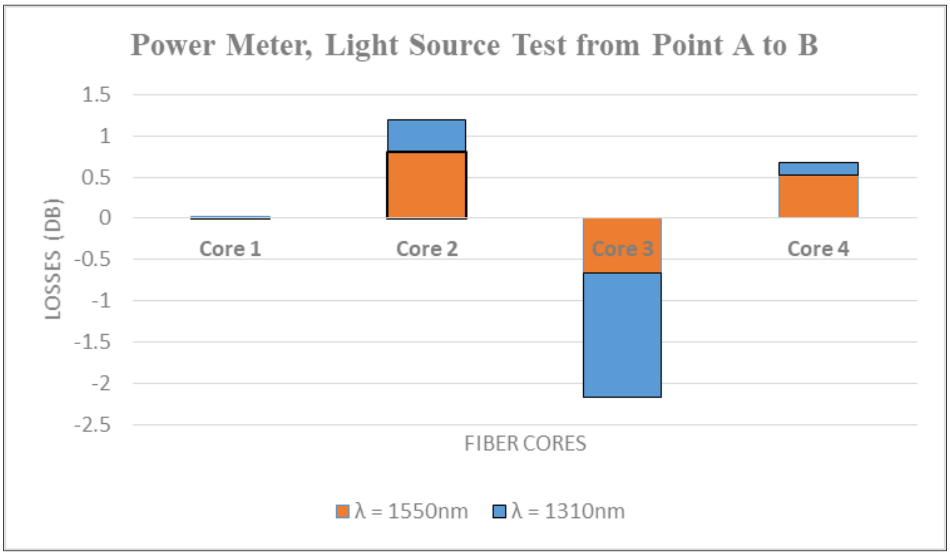

Figure 3 Losses along each core at 1310nm and 1550nm

Table 2 Power meter, light source test from point B to A

Fiber Cores	Insertion Loss (dB) at 1550nm	Insertion Loss (dB) at 1310nm
1	0.01	-0.01
2	0.81	0.39
3	-0.67	-1.5
4	0.53	0.15

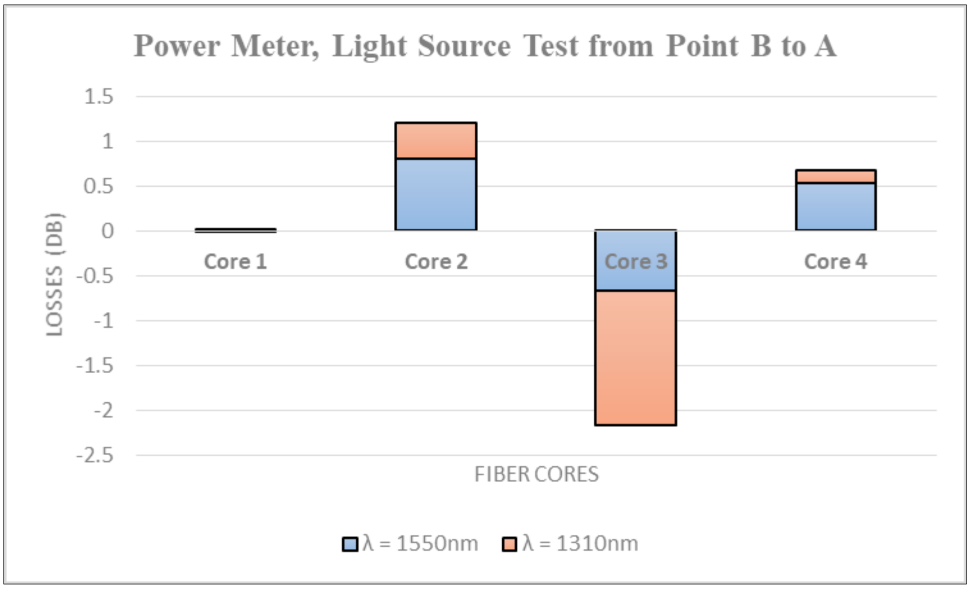

Figure 4 Losses along each core at 1310 nm and 1550 nm

It is to be observed from the graphs and tables above that

- The insertion losses measured sequentially from both ends varies most probably due to dust particles that contaminate end face can block optical signals and induce loss, misalignment of connectors and vibration of the optical fiber cable
- The insertion losses at 1550 nm wavelength is generally lower than those at 1310nm for the same fiber core.

4. Conclusion

It can be observed that fiber optic communication system has minimal signal loss as compared to coaxial or copper cables used in transmission of signals. Results obtained showed that the signal losses in dB in a fiber cable is appreciable as compared to losses in a copper or coaxial cable as seen in previous studies.

Compliance with ethical standards

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Disclosure of conflict of interest

The author(s) declare that they have no conflicts of interest

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