Practical and Theoretical Comparison and Testing Between Two Wave Length Applied to Single-Phase Optical Fiber Cable by using OTDR

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Abstract: ***Due to the development of optical fibers during the past decades, a rapid development that exceeded expectations, which made it the main element in the means of communication, where the goal became not only to provide communication, but also to transfer data with a large capacity, high speed and safety . Where the types of optical fibers were presented, with its advantages of each type, and its wavelength for each type operates on. As well as how to choose a cable to be used according to the specifications and environment in which the cable is to be installed. Then, the procedure for thermal welding of a cable was done in order to get highly accuracy results. After that, the calculation of losses in fiber optics through the link budget was discussed. A detailed study was conducted to analyze the system accounts using the OTDR device. Therefore, experiments were carried out on an optical fiber laboratory with a length of 8 km and a single-phase cable. Moreover, the test was done on two 1310nm and 1550nm wavelengths. Finally, a comparison was made with the practical result and shows that the optical fiber with Wavelength at 1550nm better than 1310 nm wavelength in terms of the loss and the possibility of its use in long distance. Besides the cable with wavelength 1550 nm is affected by bending over wavelength 1310 nm due to long distance.***

Keywords: OTDR, 1550mm, optical, fibers

1. Introduction

Since its invention in the early 1970s, the use of and demand for optical fiber have grown tremendously. The uses of optical fiber today are quite numerous. With the explosion of information traffic due to the Internet, electronic commerce, computer networks, multimedia, voice, data, and video, the need for a transmission medium with the bandwidth capabilities for handling such vast amounts of information is paramount. Fiber optics, with its comparatively infinite bandwidth, has proven to be the solution. Companies such as AT&T, MCI, and U. S. Sprint use optical fiber cable to carry plain old telephone service (POTS) across their nationwide networks [1]. Local telephone service providers use fiber to carry this same service between central office switches at more local levels, and sometimes as far as the neighborhood or individual home. Optical fiber is also used extensively for transmission of data signals. Large corporations, banks, universities, Wall Street firms, and others own private networks. These firms need secure reliable systems to transfer computer and monetary information between buildings, to the desktop terminal or computer, and around the world. The security inherent in optical fiber systems is a major benefit. Cable television or community antenna television (CATV) companies also find fiber useful for video services. The high information-carrying capacity, or bandwidth, of fiber makes it the perfect choice for transmitting signals to subscribers. The fibering of America began in the early 1980s. At that time, systems operated at 90 Mb/s. At this data rate, a single optical fiber could handle approximately 1300 simultaneous voice channels. Today, systems commonly operate at 10 Gb/s and beyond. This translates to over 130, 000 simultaneous voice channels [1]. Over the past five years, new technologies such as dense wavelength-division multiplexing (DWDM) and erbium-doped fiber amplifiers (EDFA) have been used successfully to further increase data rates to beyond a terabit per second (>1000 Gb/s) over distances in excess of 100 km. This is equivalent to transmitting 13 million simultaneous phone calls through a single hair-size glass fiber. At this speed, one can transmit 100, 000 books coast to coast in 1 second! The growth of the fiber optics industry over the past five years has been explosive. Analysts expect that this industry will continue to grow at a tremendous rate well into the next decade and beyond. Anyone with a vested interest in telecommunication would be all the wiser to learn more about the tremendous advantages of fiber optic communication [3]. In this paper practical test and comparison will be done on single – phase optical fiber cable in term of its wavelengths in order to evaluate which is more reliable for long distance for optical fiber communication system.

2. Background

It is understood that optical fibers have tremendous advantages over many communication transmission cables the advantages is previewed below:

2.1 Advantages of Fiber Optics

Optical fiber systems have many advantages over metallic-based communication systems. These advantages include:

1) **Long-distance signal transmission.**
The low attenuation and superior signal integrity found in optical systems allow much longer intervals of signal transmission than metallic-based systems. While single-line, voice-grade copper systems longer than a couple of kilometers (1.2 miles) require in-line signal for satisfactory performance, it is not unusual for optical systems to go over 100 kilometers (km), or about 62 miles, with no active or passive processing [3].
2) **Large bandwidth, light weight, and small diameter**
Today's applications require an ever-increasing amount of bandwidth. Consequently, it is important to consider the space constraints of many end users. It is commonplace to install new cabling within existing duct systems or conduit. The relatively small diameter and light weight of optical cable make such installations easy and practical, saving valuable conduit space in these environments [3].
3) **Non-conductivity.**
Another advantage of optical fibers is their dielectric nature. Since optical fiber has no metallic components, it can be installed in areas with electromagnetic interference (EMI), including radio frequency interference (RFI). Areas with high EMI include utility lines, power-carrying lines, and railroad tracks. All-dielectric cables are also ideal for areas of high lightning-strike incidence [3].
4) **Security.**
Unlike metallic-based systems, the dielectric nature of optical fiber makes it impossible to remotely detect the signal being transmitted within the cable. The only way to do so is by accessing the optical fiber. Accessing the fiber requires intervention that is easily detectable by security surveillance. These circumstances make fiber extremely attractive to governmental bodies, banks, and others with major security concerns [3].
5) **Designed for future applications needs.**
Fiber optics is affordable today, as electronics prices fall and optical cable pricing remains low. In many cases, fiber solutions are less costly than copper. As bandwidth demands increase rapidly with technological advances, fiber will continue to play a vital role in the long-term success of telecommunication [3].

2.2 Fiber Optic Principles Characteristics

Optical fibers allow data signals to propagate through them by ensuring that the light signal enters the fiber at an angle greater than the critical angle of the interface between two types of glass. The center core is composed of very pure glass with a refractive index of 1.5. Core dimensions are usually in the range of 8 to 62.5 µm. The surrounding glass, called cladding, is a slightly less pure glass with a refractive index of 1.45. The diameter of the core and cladding together is in the range of 125 to 440 µm. Surrounding the cladding is a coating, strengthening fibers, and a jacket [4].

When light is introduced into the end of an optical fiber, any ray of light that hits the end of the fiber at an angle greater than the critical angle will propagate through the fiber. Each time it hits the interface between the core and the cladding it is reflected back into the fiber. The angle of acceptance for the fiber is determined by the critical angle of the interface. If this angle is rotated, a cone is generated. Any light falling on the end of the fiber within this cone of acceptance will travel through the fiber. Once the light is inside the fiber, it "bounces" through the core, reflecting inward each time it hits the interface.

Figure 1. illustrates how light rays travel through the fiber, reflecting off the interface. If the physical dimensions of the core are relatively large, individual rays of light will enter at slightly different angles and will reflect at different angles. Because they travel different paths through the fiber, the distance they travel also varies. As a result, they arrive at the receiver at different times. A pulse signal sent through the fiber will emerge wider than it was sent, deteriorating the quality of the signal. This is called modal dispersion.

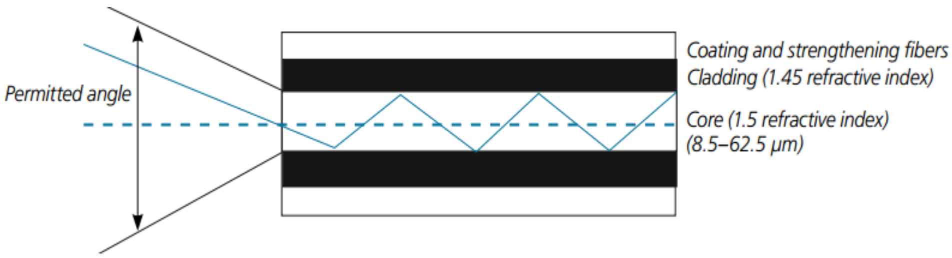

Figure 1: Light Traveling Through a Fiber.

Another effect that causes deterioration of the signal is chromatic dispersion. Chromatic dispersion is caused by light rays of different wavelengths traveling at different speeds through the fiber. When a series of pulses is sent through the fiber, modal and chromatic dispersion can eventually cause the pulse to merge into one long pulse and the data signal is lost [4].

2.3 Types Fiber Cables

There are many different environments in which optical fiber cable to be installed.

1) **Undersea Cable:**
Under sea cables must have the ultimate protection due to its hard environment that would be install in therefore must be

sported by armor protection and copper sheath in order to protect the fiber lines inside of the cable as figure 2 illustrates [3].

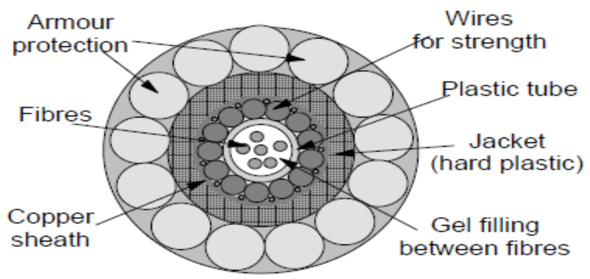

Figure 2: Typical Undersea Cable Design

2) Indoor Cabling

Indoor optical fiber cable are more cheaper and reliable in term of flexibility for indoor application due to its simplicity of its manufacturing as it illustrated in figure 3 [4].

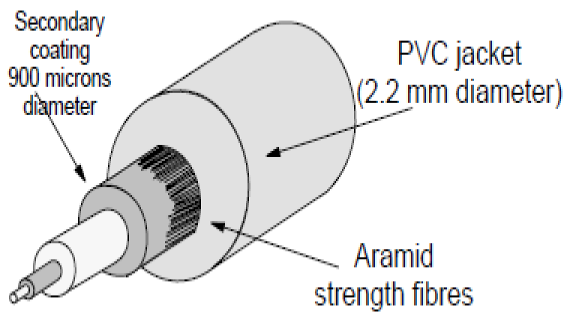

Figure 3: indoor Single-Core Optical Fiber Cable

2.4 basic fiber optic communication system

An optical fiber data link is made up of three elements module illustrated in figure 4 [3] which is consist of the list below:

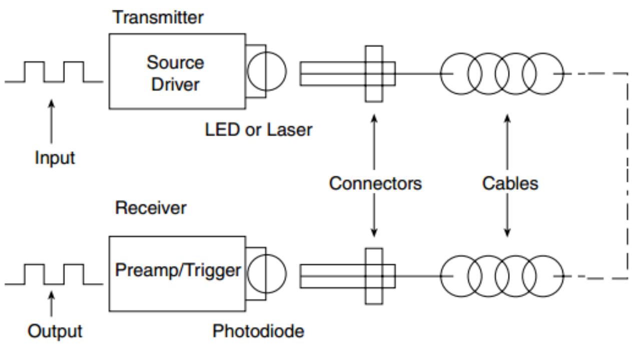

Figure 4: Basic fiber optic communication system

1) **A light source** at one end (laser or light-emitting diode [LED]), including a connector or other alignment mechanism to connect to the fiber. The light source will receive its signal from the support electronics to convert the electrical information to optical information.
2) **The fiber** (and its cable, connectors, or splices) from point to point. The fiber transports this light to its destination.
3) **The light detector** on the other end with a connector interface to the fiber. The detector converts the incoming light back to an electrical signal, producing a copy of the original electrical input. The support electronics will process that signal to perform its intended communications function. The source and detector with their necessary support electronics are called the transmitter and receiver, respectively

2.5 Transmission Windows

Optical fiber transmission uses wavelengths that are in the near-infrared portion of the spectrum, just above the visible, and thus undetectable to the unaided eye. Typical optical transmission wavelengths are 850 nm, 1310 nm, and 1550 nm. Both lasers and LEDs are used to transmit light through optical fiber. Lasers are usually used for 1310-or 1550-nm single-mode applications. LEDs are used for 850-or 1300-nm multimode applications. There are ranges of wavelengths at which the fiber operates best. Each range is known as an operating window. Each window is centered on the typical operational wavelength, as shown in Table 1. [6].

Table 1: Fiber Optic Transmission Windows.

Window	Operating Wavelength
800 – 900 nm	850 nm
1250 – 1350 nm	1310 nm
1500 – 1600 nm	1550 nm

2.5 Fiber Optic Losses Calculations

It is very important to calculate the power loss in optical fiber commendation system thus, the loss in a system can be expressed as the following:

$$\text{Loss} = P\ out / Pin \quad (1)$$

where P_{in} is the input power to the fiber and P_{out} is the power available at the output of the fiber. For convenience, fiber optic loss is typically expressed in terms of decibels (dB) and can be calculated using Equation 2 [3].

$$\text{Loss}_{dB} = 10\log (P_{out} / P_{in}) \quad (2)$$

2.6 Attenuation

As light pulses travel through the fiber, they lose some of their photons, which decreases their amplitude. This is know as attenuation, the other major factor that limits signal transmission (light output power) and consequently, reduces the length of the fiber [2]. Attenuation is usually specified in decibels per kilometer or per meter (dB/km or dB/m). Each type of fiber has a different attenuation versus wavelength curve, none of which is linear or exponential, but rather a complicated series of peaks and valleys. The attenuation of the light through a glass optical waveguide has been decreased over the last 25 years to less than 0.02 db/km and scientists are trying to decrease the attenuation even more. Attenuation of optical power in a fiber has three main causes: scattering, absorption, and bending. Attenuation varies over the light spectrum [7].

3. Data and Experimental Work

In order to meet with the experiment specification and its accuracy results of this Experiment, several calibrated tools and devise were used and, which it listed below:

1) Subscriber Connector (SC)
2) Biconic
3) Splicing Tool
4) Optical Time Domain Reflect Meters (OTDR)
5) Visual Fault Locator (VFL)
6) Light Source
7) Power Receiver

3.1 Experimental setup

In order to launch two single mode cable with 4 Km length which to make 8 Km connection the adapter was used in 10 dB attenuation set up as illustrated in figure 5.

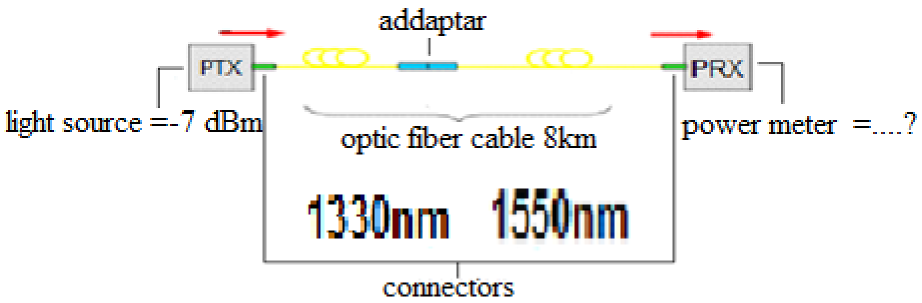

Figure 5: Experimental system connection setup

A light source was also used with-7 dBm output power, and 1310 nm, 1550 nm wave length. receiver power meter used in order to power the system with average power range (-70 dBm to 10 dBm), 1310nm, 1550 nm wave length. Shown lap figure 6.

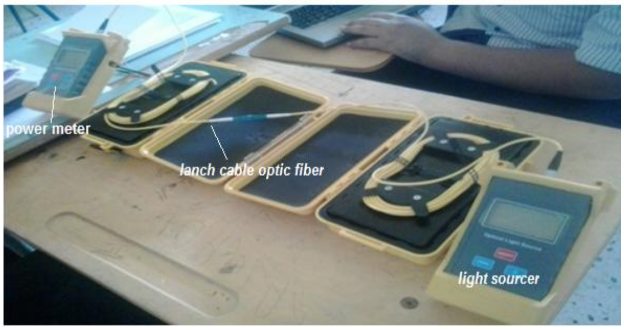

Figure 6: Experimental set up for lunching optical fiber

3.1.1 Calculate at wavelength 1310nm theoretically:

Equation 3 was used to calculate the total losses in the system and equation 4 was used in order to calculate the received power.

Calculate total losses and Power receiver at wavelength 1310 nm with attention of 0.35 dB/Km with Connector losses = 0.5dB

Total losses = Connector loss + Fiber attenuation losses + Adapter attenuation loss (3)
= (0.5*4) + (0.35*8) + 10
= 14.8 dB

Power receiver (PRX) = power transmitter (PTX) – Total losses (4)
= (-7) – (14.8):-=-21.8 dBm

3.1.2 The result of power received by the experiment in the lab

The result of the amount received in the power receiver was equal to -22dBm**.**

3.1.3 Calculate At wavelength 1550nm:

Calculate total losses and Power receiver at wavelength 1550 nm with attention of 0.2 dB/Km with Connector losses = 0.5dB
Total losses = Connector loss + Fiber attenuation losses + Adapter attenuation loss (3)
= (0.5*4) + (0.2*8) + 10
= 13.6 dB

Power receiver (PRX) = power transmitter (PTX) – Total losses (4)
= (- 7) – (13.):-=-20.6dBm

3.1.4 The Result of power received by the experiment in the lab

The result of the amount received in the power receiver was equal to-21.6 dBm**.**

3.2.1 OTDR Tasting

To find problems in the connector and splicing, device (OTDR) device was connected respectively with optic fiber and it is length 8km, with removing all sources of power (light source and power meter, and start to turn on the device with monitor the events on the screen, as it is shown figure 7, procedures were done to all two cable with the wavelength 1310 nm and 1550nm. and, figure 8 shows the module setup for OTDR testing.

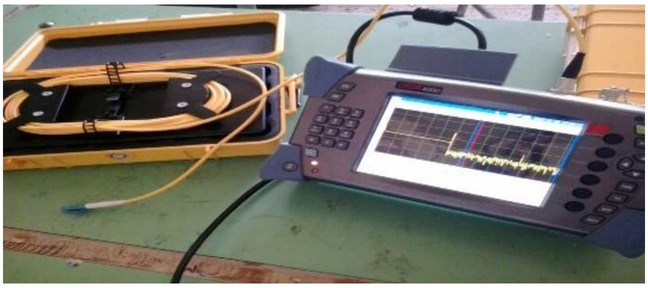

Figure 7: OTDR testing

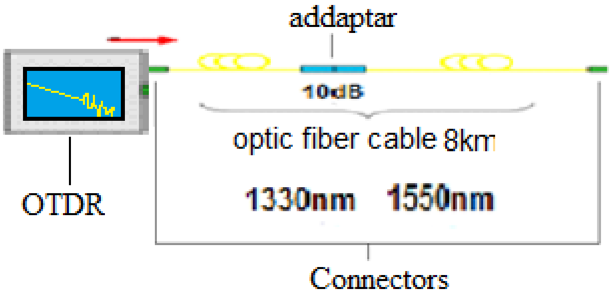

Figure 8: OTDR testing

3.2.2 Results of 1310nm OTDR test

The experiment result on 1310 nm wave length is showed in figure 9 and 10 by using OTDR.

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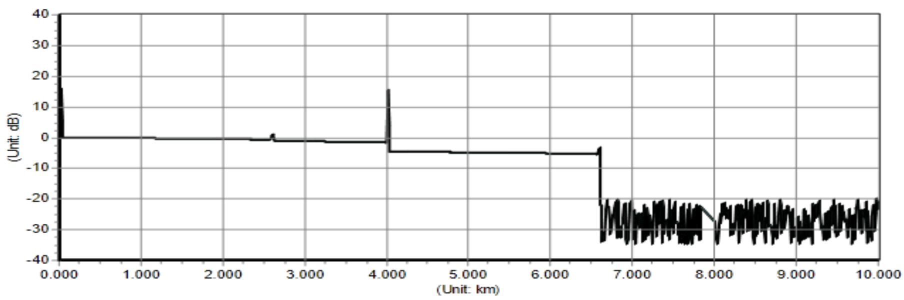
Test mode	AUTO	Range	010.0000(km)
Test item	Average	Pulse	320(ns)
Wave	1310(nm)	Event num	3
Attenuation	0.00(dB)	Total times	30
Rectify	1.00000		
Refraction	1.46502		
Threshold	0.00(dB)		

Figure 9: shows the record of OTDR for 1310 nm wavelength test



Type	No.	Dis(km)	Splice(dB)	Ref(dB)	Section(km)	Slope(dB/km)	Total(dB)
Ref	1	2.573(km)	0.42(dB)	2.30(dB)	2.573(km)	0.32	0.82
Ref	2	3.983(km)	3.00(dB)	19.30(dB)	1.410(km)	0.33	1.59
End	3	6.568(km)	0.00(dB)	2.30(dB)	2.585(km)	0.32	3.38

Figure 10: Result of 1310 nm test result by using OTRD

3.2.3 Results of 1550nm OTDR test

The experiment result on 1550 nm wave length is showed in figure 11 and 12 by using OTDR

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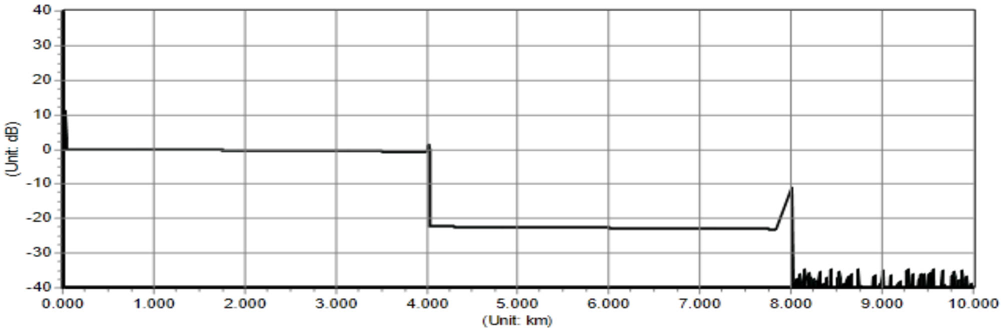
Test mode	AUTO	Range	010.0000(km)
Test item	Average	Pulse	320(ns)
Wave	1550(nm)	Event num	2
Attenuation	0.00(dB)	Total times	30
Rectify	1.00000		
Refraction	1.46502		
Threshold	0.00(dB)		

Figure 11: shows the record of OTDR for 1550 nm wavelength test



Type	No.	Dis(km)	Splice(dB)	Ref(dB)	Section(km)	Slope(dB/km)	Total(dB)
Ref	1	3.980(km)	21.66(dB)	2.40(dB)	3.980(km)	0.20	0.80
End	2	7.979(km)	0.00(dB)	13.58(dB)	3.998(km)	0.21	8.89

Figure 12: Result of 1550 nm test result by using OTDR

4. Discussion

The results approved that the optical fiber with Wavelength at 1550nm better than 1310 nm wavelength in terms of the loss and the possibility of its use in long distance, and the cable with wavelength 1550 nm is affected by bending over wavelength 1310 nm.

5. Conclusions

Optical fibers were studied in term of its types and advantages. Furthermore, Two mainly types of optical fiber were compared with each other in term of their wavelength and long distance transmission and that was done by using highly calibrated tools and devices with high accuracy in the experimental work. Finally, the used of 1550 nm wavelength turns out to be more reliable for long distance fiber optic communication modules however the 1550 nm wavelength has disadvantage in term of the bending application therefore, it is highly recommended to use 1310 nm wavelength for optical fiber communication systems that have many complication in building design in term of curving and wall angles.

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