FREE SPACE OPTIC (FSO) ENHANCEMENT FOR FUTURE WIRELESS NETWORK

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Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer Universiti Teknikal Malaysia Melaka

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I would like to express my deepest dedicated to my beloved family, partner, lecture, friend and those people who have guided and inspired me throughout my journey of education.

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ABSTRACT

With the worldwide demand for larger bandwidth there is a rapid advancement in the area of broadband wireless communications. The high capacity and low loss of optical fiber has seen its exploding growth in the last few decades. This report will mainly cover on the effect of weather to Free Space Optics transmission line and its enhancement for future network. The major problem of FSO system is its effect to weather since its transmitted data through the air. Various weather conditions can affect the performance of FSO Link, most likely known weather phenomena are scattering and Turbulence which causes attenuation in the transmitted signal those results in high bit error rate or signal loss at the receiver end. To encounter these problems, a research has been done in order to calculate the Maximum Pointing Error and enhancement that has been done to the circuit in order to get a maximum result for minimum the effect of weather attenuation to the data transmitted. This research will be measured by using Optiwave Software to simulate the attenuation occur for four different types of weather conditions. Here, the attenuation data was obtained from the meteorology department web site and the journals that have been studied. From this report, technology of FSO has been acknowledged to be one of the efficient transmission systems that used half optical and half wireless network systems. Also, noticed that now the effect of attenuations can be reduced by adding an additional optical amplifier to the circuit. By reducing the attenuations that effect by the weather, the transmitting of the data will be more efficient and losses will be low. From this enhancement, the technology can be used widely in the future.

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ABSTRAK

Dengan permintaan yang semakin meluas terhadap jalur lebar terdapat peningkatan di dalam bidang komunikasi jalur lebar tanpa wayar. Dengan keupayaan yang tinggi dan kehilangan yang rendah, gentian optik berkembang dengan pesat dalam beberapa abad ini. Laporan ini menerangkan tentang kesan cuaca terhadap talian penghantaran Ruang Optik Bebas (Free Space Optic, FSO) dan penambahbaikkan untuk kegunaan masa hadapan. Masalah utama yang dihadapi oleh sistem ini ialah kesan terhadap cuaca memandangkan ia menggunakan ruang udara sebagai medium penghantaran. Pelbagai masalah cuaca boleh memberi kesan terhadap penghantaran talian FSO, antara fenomena cuaca yang paling dikenali adalah Penyelerakan dan Pergolakan yang menyebabkan kehilangan data dihujung talian penerima. Untuk mengatasi masalah ini, suatu kajian telah dijalankan untuk mengira Ralat Penunjuk Maximum dan penambahbaikkan yang telah dilakukan terhadap litar untuk mendapat keputusan yang maximum dengan mengurangkan kesan kehilangan pada data yang telah dihantar. Kajian ini akan menggunakan perisian Optiwave sebagai alat untuk mengukur dan mensimulasikan kehilangan yang disebabkan oleh empat keadaan cuaca yang berbeza. Disini, data kehilangan diperolehi daripada laman sesawang jabatan meteorologi dan juga daripada jurnal yang telah dikaji. Daripada laporan ini, FSO telah dikenalpasti sebagai salah satu penghantar data yang cekap dimana ianya menggunakan sistem rangkaian separuh optik dan separuh wayar. Juga, kehilangan yang disebabkan oleh kesan cuaca dapat dikurangkan dengan penambahan penguat optik pada litar yang disimulasi. Dengan mengurangkan kehilangan terhadap cuaca, penghantaran data akan bertambah cekap dan kehilangan akan berkurang. Dengan penambahbaikkan ini, teknologi ini dapat digunakan dengan lebih meluas dimasa akan datang.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In communication systems, we are familiar with fiber optic cable as a transmission medium. Its application as an effective transmission medium with fewer losses has become one of the most popular transmission medium that has been used. It works by sending pulses of light through an optical fiber transmitted it to one places to another. The light then forms an electromagnetic carrier wave that is modulated to carry information. Fiber optic communications transmit data through glass covered with plastics that will protect the data transmitted. An optical fiber cable is a cable containing one or more optical fibers that are used to carry light. The optical fiber elements are typically individually coated with plastic layers and contained in a protective tube suitable for the environment where the cable will be deployed. Different types of cable are used for different applications, for example long distance telecommunication, or providing a high-speed data connection between different parts of a building. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world. Optical fiber is used by many telecommunications companies to transmit telephone signals, Internet communication, and cable television signals. In the era where unlimited bandwidth and

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faster internet connectivity is required, Free Space Optics (FSO) has emerged as a promising solution. It is due the advantages of FSO. FSO is the best solution for last-mile bottleneck problem. It offers broader and unlimited bandwidth and license free compare to deployment of microwave link. FSO can be installed in a shorter time and lower cost compare to laying down fiber optic cable [1]. An FSO is an upgraded transmission medium from the fiber optics. For one transmission line, instead of sending the data in a closed glasses path, it is transmitted through the air. Also known as Free Space Photonics (FSP) or Optical Wireless, this transmission line used infrared (IR) beams through the atmosphere to obtain optical communications. FSO works on the same basic principle as Infrared television remote controls, wireless keyboards or wireless Palm devices.

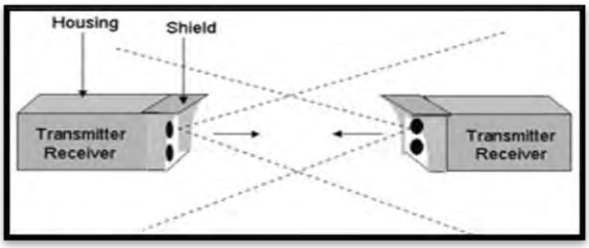

Figure 1.1: A pair of FSO with transceiver in each.

Even though it is still considered as a new technology compared to fiber optics transmission line, FSO technology is surprisingly simple. Its technology enables bandwidth transmission capabilities that are similar to fiber optics, by using similar optical transceiver and even enabling WDM-like technologies to operate through free space. FSO-based optical wireless units, has provide full-duplex (bi-directional) capability which each of it supplied a transceiver. Each optical wireless unit uses an optical source, plus a lens or telescope that transmits light through the atmosphere to another lens receiving the information. The receiving lens has a very high sensitivity due to atmospheric effect by using optical fiber. FSO has the potential to be a highly developed and highly used wireless system. The throughput is amazing for a wireless system. It could provide the much needed bandwidth for connecting the last mile or

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connecting buildings. Even though with its disadvantages, FSO could be one of the mainstream wireless systems that will be used in the future.

1.1.1 Comparison between Free Space Optic (FSO) and Fiber Optic Cable (FOC)

An optical fiber cable is a cable containing one or more optical fibers that are used to carry light. The optical fiber element are typically individually coated with plastic layers and contained in a proactive tube suitable for the environment where the cable will be deployed. Optical fiber consists of a core and cladding layer, selected for total internal reflection due to the different in the refractive index between the two. The light was transmitted between one ends to the other end. The loss of the cable was many due to the scattering inside the fiber cable. Even with the high in cost, fiber optic cable was quite a hit for its fast transmission.

Free space optics, refers to the transmission of modulated visible or infrared beams through the atmosphere to obtain optical communication. FSO systems can function over distances of several kilometers. FSO is a line-of-sight technology, which enables optical transmission up to 2.5 Gbps of data, voice and video communications, allowing optical connectivity without deploying fiber optic cable or securing spectrum licenses. Free space optics require light, which can be focused by using either light emitting diodes (LED) or LASERS (light amplification by stimulated emission of radiation). The use of lasers is a simple concept similar to optical transmissions using fiber-optic cables, the only difference being the medium. As long as there is a clear line of sight between the source and the destination and enough transmitter power, communication is possible virtually at the speed of light. Because light travels through air faster than it does through glass, so it is fair to classify FSO as optical communications at the speed of light. Below are the structure of FSO and FOC:

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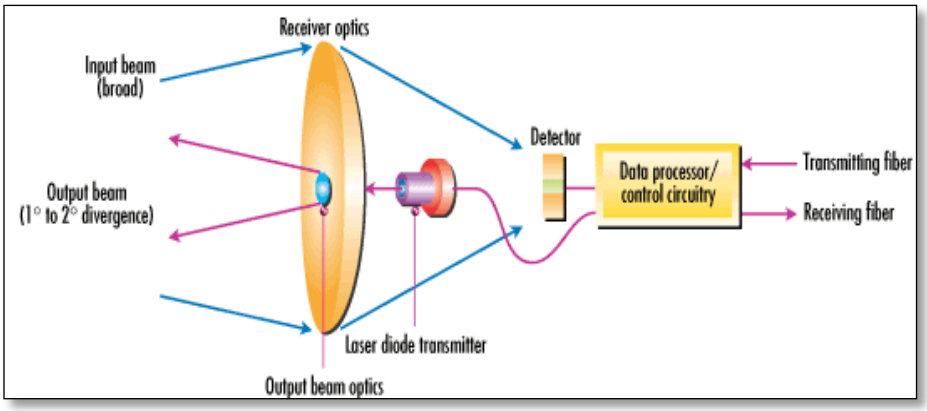

Figure 1.2(a): FSO structure

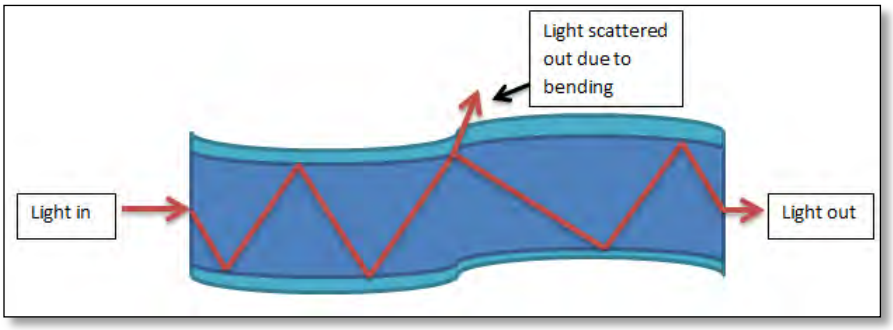

Figure 1.2(b): FOC structure

1.1.2 FSO History

According to the history, essentially all of the engineering of today‟s FSO or free space optical communication systems was done over the past 40 years or so mostly for defense applications. It is said that the first “FSO” system has been used in the 8th century by the Greek people. They used fire as the light source, the atmosphere as the transmission medium and human eye as receiver. Later in the late 19th century, the first real FSO has been invented by Alexander Graham Bell before he ever invented the telephone as the communication systems. Bells FSO experiment converted voice sounds to telephone signals and transmitted them between receivers through free air space along a beam of light for a distance of some 600 feet, this was later called photo-phone. Although Bells photo-phone never became a commercial reality, it demonstrated the basic principle of optical communications. Then three decade ago, the military and

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NASA build the system and has providing us with fast communication links in remote locations through various forms.

1.1.3 FSO Advantages, Disadvantages and Market

Telecommunication has seen massive expansion over the last few years. First was the tremendous growth of the optical fiber. Long-haul Wide Area Network (WAN) followed by more recent emphasis on Metropolitan Area Networks (MAN). Meanwhile LAN giga bit Ethernet ports are being deployed with a comparable growth rate. Even then there is pressing demand for speed and high bandwidth. In the United States 5 percent of buildings for the telecommunication industries are connected to OFC. Yet 75 percent are within one mile of fiber. Thus FSO offers to the service providers, a compelling alternative for optical connectivity and a complement to fiber optics. While in Malaysia, investors are not quite familiar with FSO systems. If telecommunication engineers could present the goodness of this system, it could be hits.

Every system has its advantages and disadvantages, including FSO. Below is some of it:

Table 1.1: Advantages and Disadvantages of FSO

Advantage	Disadvantage
1) Security system is high	1) Transmitter and receiver have to have line-of-sight to each other.
2) Optical technology and no spectrum licensing or frequency coordination with other users are required.	2) Blocking conditions such as trees, buildings, animals, and atmospheric conditions.
3) Also interference from or to other systems or equipment is not a concern.	3) Sway if installed in tall building.
4) Low cost	
5) Ability to operate at higher power levels.	

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6) High-speed modulation, small footprint and low power consumption.	

1.1.4 FSO Applications

Users demand for high bandwidth and differentiated data services has been one of the crisis thinking to the telecommunication engineer nowadays. An ideas need to be generated in order to maximize the applications of network system and in line with the demand. Network traffic doubles every 9-12 months forcing the bandwidth or data storing capacity to grow and keep pace with this increase. The right solution for the pressing demand is the untapped bandwidth potential of optical communications. Optical communications are in the process of evolving Giga bits/sec to terabits/sec and eventually to pentabits/sec. The explosion of internet and internet based applications has fuelled the bandwidth requirements. Business applications have grown out of the physical boundaries of the enterprise and gone wide area linking remote vendors, suppliers, and customers in a new web of business applications. Hence companies are looking for high bandwidth last mile options. The high initial cost and vast time required for installation in case of OFC speaks for a wireless technology for high bandwidth last mile connectivity there FSO finds its place.

The concept behind FSO is simple. Its uses a directed beam of light radiation between two ends points to transfer information whether it is data, voice or video. The systems were basically similar to the fiber optic cable (FOC) transmission networks, except that light pulses are sent through free air instead of FOC cores. Due to its fast transmission rate, FSO has become quite popular transmission line nowadays. Their application varies, including:

i. **Metro Area Network (MAN):** FSO network can close the gap between the last mile customers, thereby providing access to new customers to high speed MAN"s resulting to Metro Network extension.

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ii. **Last Mile Access:** End users can be connected to high speed links using FSO. It can also be used to bypass local loop systems to provide business with high speed connections.

iii. **Enterprise connectivity:** As FSO links can be installed with ease, they provide a natural method of interconnecting LAN segments that are housed in buildings separated by public streets or other right-of-way property.

iv. **Fiber backup:** FSO can also be deployed in redundant links to backup fiber in place of a second fiber link.

v. **Backhaul:** FSO can be used to carry cellular telephone traffic from antenna towers back to facilities wired into the public switched telephone network.

vi. **Service acceleration:** Instant services to the customers before fiber being laid.

1.1.5 FSO Working Systems

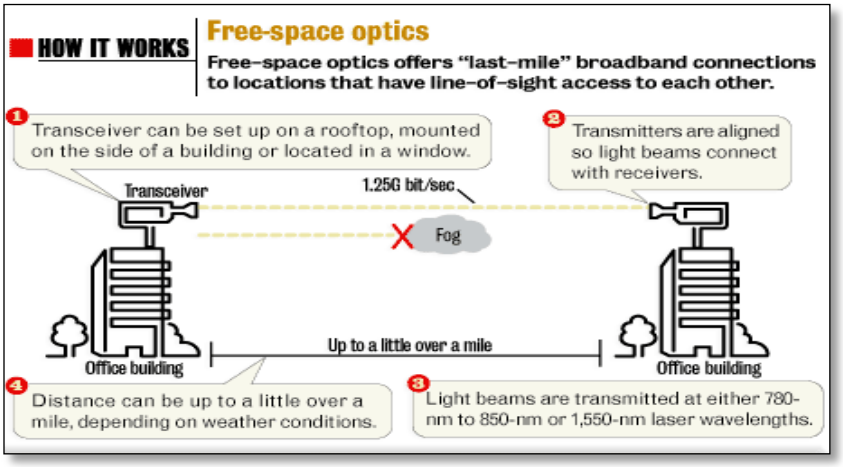

Figure1.3: How FSO system works

Optical systems work in the infrared or near infrared region of light. The infrared carrier used for transmitting the signal is generated either by a high power LED or a laser diode. Two parallel beams are used, one for transmission and one for reception,

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taking a standard data, voice or video signal, converting it to a digital format and transmitting it through free space. The beams are kept very narrow to ensure that it does not interfere with other FSO beams. The receive detectors are either PIN diodes or avalanche photodiodes. The FSO transmits invisible eye safe light beams from transmitter to the receiver using low power infrared lasers in the Tera hertz spectrum. FSO can function over kilometers.

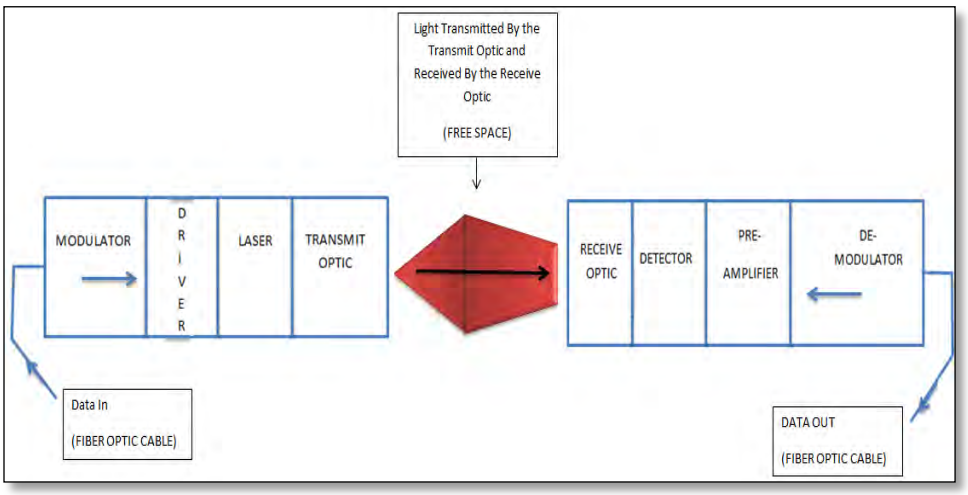

Figure 1.4(a): FSO subsystem

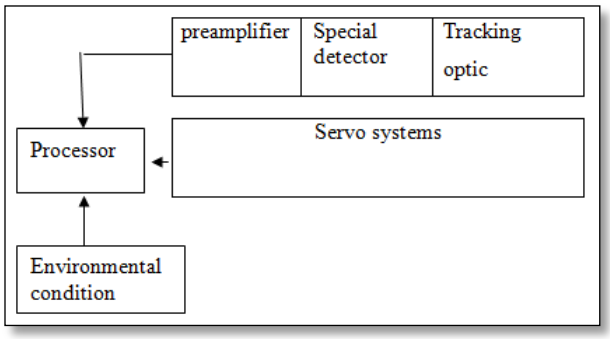

Figure 1.4(b): FSO subsystem (The Processor)

In the transmitting section, the data is given to the modulator for modulating signal and the driver to activate the laser. In the receiver section the optical signal is detected and it is converted to electrical signal, preamplifier is used to amplify the signal

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