STUDY OF ATMOSPHERIC EFFECT IN FREE SPACE OPTIC PROPAGATION

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STUDY OF ATMOSPHERIC EFFECT IN FREE SPACE OPTIC PROPAGATION

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In the name of God, Most Gracious, Most Merciful

Dedicated to

My beloved parent

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LIST OF ABBREVIATIONS

CLEC	-	Competitive Local Exchange Carrier
CO_2	-	Ground State Absorption
FCC	-	Federal Communications Commission
FIR	-	Far Infrared
FSO	-	Free Space Optic
GL	-	Geometric Loss
H_2O	-	Water
IEC	-	International Electrotechnical Commission
IR	-	Infrared
LASER	-	Light Amplified Spontaneous Emission
LAN	-	Local Area Network
LOS	-	Line Of Sight
MIR	-	Middle Infrared
MPE	-	Maximum Permissible Exposure
MST	-	Malaysian Station Time
NIR	-	Near Infrared
PCS	-	Personal Cellular Service
RF	-	Radio Frequency
SONET	-	Synchronous Optical Network
ST	-	Station Time
US	-	United State
WDM	-	Wavelength Division Multiplexing
XIR	-	Extreme Infrared

KAJIAN PENGARUH GANGGUAN UDARA DALAM PENYEBARAN RUANG BEBAS OPTIK

Sistem telekomunikasi Ruang Bebas Optik ialah sistem Lajur Pandangan yang merujuk kepada penyebaran nampak dan sinar infra merah yang melalui atmofera untuk mendapatkan komunikasi optikal. Sistem ini menggunakan laser untuk menghantar data di ruang bebas. Walaubagaimanapun sistem ini lemah kepada variasi pergolakan partikel udara yang berlaku di atmosfera. Tesis ini bertujuan untuk menyiasat kesan atenuasi ke atas perhubungan komunikasi Ruang Bebas Optik dari titik ke titik. Kajian dijalankan di bawah iklim hutan hujan tropika dan contoh data diambil di kawasan Perlis yang disediakan oleh Jabatan Meteorologi Malaysia (JMM). Terdapat dua jenis cuaca yang berpotensi untuk menggangu prestasi hubungan Ruang Bebas Optik. Pertama sekali ialah cuaca hujan di mana hujan yang turun dalam kawasan hutan hujan tropika berlaku hamper setiap hari dan mempunyai kadar kelebatan hujan yang tinggi. Keduanya ialah cuaca jerebu yang mana kebiasaannya di sumbangkan oleh asap yang terhasil daripada pembakaran terbuka oleh pertanian. Pembakaran yang berterusan dan di ruang kawasan yang besar telah menghasilkan kepadatan jerebu yang tinggi kepada persekitaran cuaca telah menyebabkan jarak penglihatan menjadi terhad. Kesannya jerebu dan hujan boleh menyumbang kepada atenuasi ganggua-gangguan udara yang tinggi. Dua pendekatan telah di gunakan dalam kajian ini. Pertama sekali ialah model atenuasi hujan dan jerebu untuk menyiasat corak cuaca di Perlis dalam menentukan sejauh mana atenuasi boleh berlaku dalam komunikasi perhubungan Ruang Bebas Optik. Model gangguan-ganguan atmosfera ini adalah di bina daripada persamaan serakan kofisien, atenuasi gangguan udara dan kehilangan geometric. Pendekatan yang kedua adalah menghasilkan sistem Ruang Bebas Optik dengan menggunakan software Optisys untuk mengamati kesan atenuasi ke atas sistem hubungan. Prestasi sistem Ruang Bebas Optik ini di selidiki di bawah perbezaan parameter-parameter jalur lebar, saiz lubang cahaya penghantar dan penerima, sudut sinar capahan dan kepekaan penerima. Keputusan daripada kajian ini menunjukkan bahawa kesan cuaca jerebu adalah lebih teruk berbanding hujan di mana maksima atenuasi jerebu dan hujan boleh mencapai 180 dB/km dan 96 dB/km masing-masing. Pada jarak sasaran 1km operasi untuk penyebaran Ruang Bebas Optik maksima jarak penglihatan jerebu ialah 0.5km dan kadar hujan ialah 70mm/hr. Sementara itu dalam analisis simulasi menunjukkan jalur lebar 1550nm adalah lebih baik berbanding 785nm. Reka bentuk 1 untuk saiz penerima lubang cahaya 0.25m dan saiz lubang cahaya penghantar 0.05m boleh mengurangkan kehilangan. Sudut sinar capahan yang kecil boleh mengurangkan penggunaan tenaga dan mengekalkan tenaga yang tinggi pada penerima dan juga diode cahaya APD adalah lebih baik berbanding p-i-n diode cahaya kerana mempunyai daya kepekaan yang tinggi untuk mengesan isyarat yang lemah.

STUDY OF ATMOSPHERIC EFFECT IN FREE SPACE OPTIC PROPAGATION

Free Space Optic (FSO) telecommunication system is Line of Sight (LOS) system which refer to transmission of visible and infrared beams that through to atmosphere to obtain the optical communication. This system uses laser to transmit the data in free space. However this system is vulnerable with variation of air turbulence particles that occurs in atmosphere. This thesis is aim to investigate the attenuation effect over the point-to-point FSO communication linkage. The study carried out under the tropical rainforest climate and the sample data is take at Perlis region that provide by Malaysia Meteorological Department (MMD). There two type of weather condition that capable to impair the FSO link performance. The first is rain weather where the rainfall occurs in tropical rainforest region almost everyday and has a high rain denseness rate. The second is haze weather which is usually contributed by smoke that produced from open burning of agriculture. The continuous burning and in wide area have produce the high density of haze to environment weather which create limited distance for visibility. Consequently, haze and rain can contribute to high atmospheric attenuation and predicted capable to impair the FSO link performance. Two approaches have been used in this research. The first is modeling the rain and haze attenuation to investigate the Perlis weather pattern in order to determine how strong the attenuation can occur in FSO communication linkage. This atmospheric model for haze and rain are constructed from scattering coefficients, atmospheric attenuation and geometric loss equation. The second approach is develop the FSO system using the OptiSystem to observe the effects attenuation over the link system. The performance of this FSO system is investigate under different parameters wavelength, size of aperture for transmitter and receiver, beam divergence angle and receiver sensitivity. The result from this research shows the haze weather effect is worst than rain where the maximum haze and rain attenuation can reach 180 dB/km and 96 dB/km respectively. At aim distance 1km operational for FSO deployment the prediction maximum visibility haze is 0.8km and rainfall rate is 70mm/hr. Meanwhile in simulation analysis shows that the longer wavelength 1550nm is much better than 785nm. The Design 1 for receiver aperture size 0.25m and transmitter aperture size 0.05m can reduce the loss. Narrow beam divergence angle can reduce the power consumption and maintain the high power at receiver and also the APD photodiode is much better than p-i-n photodiode due to have high sensitivity to detect weak signal.

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DECLARATION OF THESIS

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Academic Session : 2008/2009

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Free Space Optics (FSO) or optical wireless communications was first demonstrated by Alexander Graham Bell in the late nineteenth century where his experiment converted voice sounds into telephone signals and transmitted them between receivers through free air space along a beam of light for a distance of some 600 feet. The experiment device called as the 'photo-phone' which modulated sunlight for medium communication (fSONA, 2009). Then in the early 1960's, scientists have successfully developed Light Amplification by Stimulated Emission of Radiation (LASER) technology. Finally, optical communication was shortly discovered after the development of LASER technology (FSO, 2003 & Johnson, 2002).

In telecommunications technology, Free Space Optics (FSO) is an optical communication technology that uses light propagating in free space to transmit data between two points (FSO, 2009). The technology is useful where the physical connection by the means of fiber optic cables is impractical. It is similar to fiber optic communications in that data is transmitted by modulated laser light. Instead of containing the pulses of light within a glass fiber, they are transmitted in a narrow beam through the atmosphere. 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. The stability and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat. Maximum range for terrestrial links is limited (less than10 km). Nowadays, the FSO communication systems are being increasingly considered as an attractive option for the rapid provisioning of multi-gigabit per second links (Willebrand, 2002, Nykolak, 2001 & Carbonneau, 1998).

Various applications can be applies in FSO system today such as the last mile high bandwidth internet connectivity, the temporary high bandwidth data links, the mobile telephony backhaul (3G), satellite links as well as the various applications where the optical fibers cannot be used. There has been exponential growth in the use of FSO technology over the last few years, primarily for "last mile" applications, because FSO links provide the transmission capacity to overcome information bottlenecks (Dennis, 2002). This high data rates application can send voice, video conference and real-time image transmission, and also to achieve affordable communication for everyone, at anytime and place (Hamed Al-Raweshidy, 2002). The communication capabilities allow not only human to human communication and contact, but also human to machine and machine to machine interaction. The communication will allow our visual, audio, and touch sense, to be contacted as a virtual 3-D presence (Govind, 2001).

1.2 Background

The ever-increasing demand for more bandwidth of enterprise customers and services providers have given huge impact in development of telecommunication technologies with sophisticated equipment and various new invention. Today there are several options for data communication technology that exist in global market.

First is fiber optic cable technology which is the most obvious first choice. There are no doubt the fiber is the most reliable means of providing optical communications. The first generation of optical fiber communication system in the early 80's (Robert, 2004) has grow fast to achieve larger transmission and longer transmission distance for satisfy the increased demand of computer network. However the digging, delays, and associated costs to lay fiber often make it uneconomical. Moreover, in certain condition it can bring suffer loss when the request of customer to relocates or switches to a competing service provider making it extremely difficult to recover the investment in a reasonable timeframe.

Radio frequency (RF) technology is another option for data communication. The transmission of RF intensity modulated-signal over optical fiber is well-establish (Hakki, 2004 & William, 2002). RF is among the longer-range distance wireless communication technology compare to FSO. It is highly immune to interference from other sources of optical radiation (Hakki, 2003). However RF-based network require vast capital investment especially to require spectrum license. RF technologies also vulnerable when interference occurred and saturate in heavily congested RF environment. The speed of this technology cannot scale to gigabits which can emerge complication for certain high capacity customer. The current RF bandwidth ceiling is 622 Megabits. When compared to Free Space Optical, RF does not make economic sense for service providers looking to extend optical networks (Rockwell, 2001).

The third alternative is wire and copper based technologies and have a percentage higher than fiber technologies but still not a viable alternative for solving the “last mile” connectivity bottleneck. The biggest hurdle is bandwidth scalability. Copper technologies may ease some short-term pain, but the bandwidth limitation of 2 megabits to 3 megabits makes them a marginal solution, even on a good day. In term of loss, the copper cables will increase with the frequency, the more information carried in copper conductors the higher losses occurred.

The fourth and the most viable alternative is FSO technology. It offers the speed of fiber with the flexibility of wireless. FSO is also design in portable, bandwidth scalability, speed of deployment, quickly deployable and cost effective, costing on average one-fifth the cost of installing fiber optic cable (Willebrand, 2001). Further, its layer one transparency ensures interoperability with all major networking vendor switches, routers, and other equipment. The FSO communication has emerged as a promising candidate providing broadband, flexible, secure and low-cost communication links between stationary platforms. Application using FSO have proved it merits (Brian, 2006). In term of bandwidth, FSO provides higher bandwidth to the end user at a faster speed. Because of high bandwidth availability (currently capable of up to 2.5Gbps), a large amount of data can be transmitted through a narrow laser beam.

1.3 Problem Statement and Motivation

FSO are vulnerable with fluctuation atmosphere phenomena. Weather conditions such as rain, fog and haze are capable to attenuate the beam light and in certain circumstances able to hinder the light passage through the combination of absorption, scattering and reflection. As a result, interruption and disturbance that occurred in propagation light process will degrade the link performance.

A preliminary stage before the installation process of FSO at rooftop buildings is vital. It can be operated with investigate analysis of local weather patterns condition and prediction of worst scenario performance could be recognized. This period is important to ensure FSO will operate with sufficient transmission power and minimal losses, even during bad weather conditions.

The works covered in this research apply atmospheric model in FSO system which encircle propagation study on rain and haze attenuation effect in tropical rainforest region climate. The sample data was collected in Chuping Station Weather that provide by Malaysia Meteorology Department (MMD). The study focused on rain and haze effects upon the FSO system performance. The cause of increases atmospheric attenuation are such as the selection of divergence angle, receiver area, transmitter area and distance between transmitter and receiver will be examined to minimize attenuation effect on FSO. The research also carried out with simulation by using OptiSystem software to investigate BER, received power and eye patterns upon link performance. Detail explanation research will be elaborated later in this project.

1.4 Objectives

The implementing research project is cause of awareness of potential of FSO technology in future. In developing this system become strong telecommunication technology, need to examine the limitation in FSO to get proper understanding of weather effects on its signal propagation. The analysis based on weather statistics should be conducted at a specific location to estimate the link availability. Therefore the main objectives of this research are stated below:

a) To study the atmospheric model to perform the weather data using the scattering coefficient, atmospheric attenuation and total attenuation due to rain and haze condition.

b) To develop and to study the performance of FSO using OptiSystem software under different beam divergence, size of apertures, wavelength channel and receiver sensitivity.

1.5 Scope of Works

1.5.1 Model Description

In order to ensure successful of this project it is important to design scope model which can guide to implementing every phase of research. The scope of this project is illustrated in Figure 1.1. Generally, FSO system can be divided into two categories: indoor system and outdoor system. This research is focus to outdoor FSO communication system that usually placed at rooftop of building. The weather conditions that investigated in this research concentrate on rain and haze which under the tropical rainforest climate. The sample data was collected in Chuping Station Weather that provide by Malaysia Meteorological Department (MMD). The haze and rain weather data are throughout 2008. The research is divided into two main parts to achieve the objective research. The first is technical studies. In this part it focus on atmospheric attenuation that contribute to increasing of attenuation in FSO communication. Under this atmospheric attenuation the scattering coefficient, geometric loss and total attenuation will be studied. The attenuation that examined is due to scattering effect factor. The second main part is simulation with using the Optisystem software. This part will observe the effect of attenuation over the FSO system under the different parameters wavelength channels, beam divergences angle, receiver sensitivity, aperture size for transmitter and receiver.

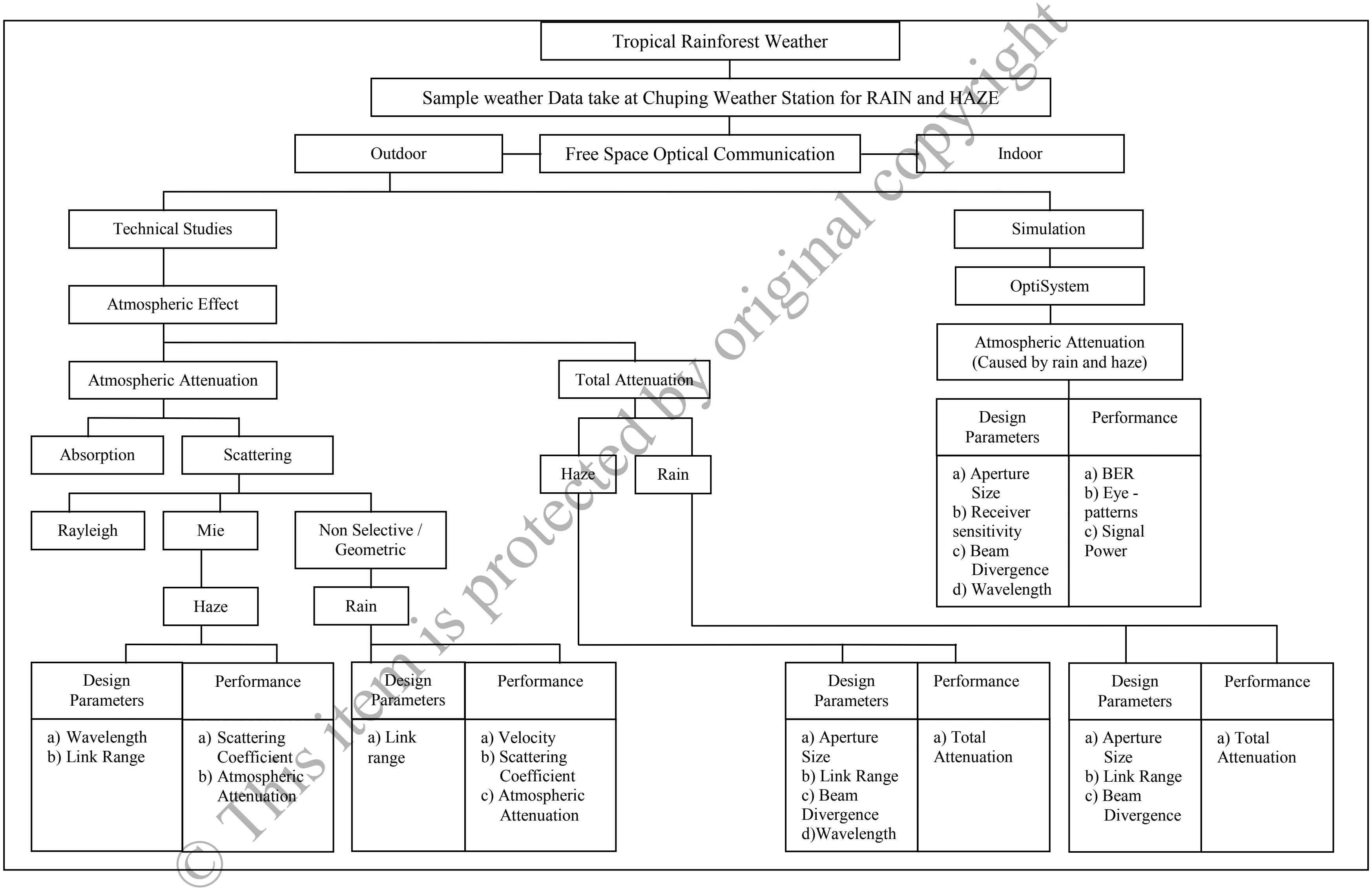

Figure 1.1: Model Showing the Scope of Study

1.5.2 Assumptions

In implementation this research, there are several assumption that have been made into consideration. Among the negligible condition involves are effect of aerosol absorption, Rayleigh scattering, scintillation effect and background noises. This based on several vital reasons such as wavelength transmission, beams selection, aperture diameter and optical receiver which elaborated in brief below.

One of important feature in transmit the laser signal is wavelength selection. The laser wavelengths of 780nm, 850nm and 1550nm are fall inside the transmission windows within the absorption spectra which the contributions of absorption to the total attenuation coefficient are very small. Therefore the absorption effect can be negligible (as shown in Figure 2.15. Since the FSO systems are operated in the longer wavelength near infrared wavelength range, the impact of Rayleigh scattering on the transmission signal also can be ignored (Chu, 2002).

In scintillation effect over FSO link it can be reduce using either multiple beams or larger receiver apertures. Through the previous researcher (Kim, 2001, Achour, 2001 & Bloom, 2003) state that the large receiver aperture approach is more effective for scintillation reduction compare to multiple smaller apertures. Moreover, at longer wavelength i.e 780nm, 850nm, 1550nm give small effects on scintillation. Therefore, usually at short ranges link (less than 1km) most FSO systems have enough dynamic range or margin to compensate for scintillation effects. In theory and simulation of this project utilize a larger receiver aperture, wavelength of 1550nm considered and link range is only 1km. Therefore effect of scintillation is ignored.

The background radiation from atmosphere has several components such as molecule scattering of sunlight, aerosol scattering of sunlight, thermal radiation of atmosphere and non-thermal radiation from atmosphere. Sunlight entering an optical receiver reduces background noise. The background noise effect will be too small and can be ignored. But direct sunshine is avoided into the receiver (avoid as far as possible the East to West path link). This is because the excess solar energy is able to saturate the receiver electronics. The other reason for ignoring background noise is because 1550nm wavelength is used. (Cablefree, 2001 & David A.Rockwell, 2001).

In term of beam of light, it assumed to be 1mrad. This is because the narrow beams have high speed compare to large beam. Besides that, it can provide additional security where the narrow beam divergence is inherently hard to intercept and jam. Moreover in nowadays, most of an auto-tracking had been added to the FSO system which able to compensate for building sways. An optical link with narrow beam and tracking has better performance when compared to one without tracking (Jeganathan, 2000).