Faculty of Engineering

A New Modulation Technique Using Double Transmission In Free Space Optical Communication for Access Network

Simon Ang Kwang Thai

Doctor of Philosophy
2024

A New Modulation Technique Using Double Transmission In Free Space Optical Communication for Access Network

Simon Ang Kwang Thai

A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

(Optical Communication)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK

2024

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Signature

Name: Simon Ang Kwang Thai

Matric No.: 20010148

Faculty of Engineering

Universiti Malaysia Sarawak

Date : 10 July 2024

ACKNOWLEDGEMENT

First and foremost, thank God for giving me strength to finish my thesis. I am grateful to my supervisor, Ts. Dr. Abdul Rahman Bin Kram, who welcomed me as a student without hesitation and supported me in completing my project. Ir Dr. Khairul Fikri Bin Tamrin, my co-supervisor, thank you for your advise, support, and direction during my thesis.

My deepest gratitude to my parents, who pray for my success and support me always. My siblings also gave me moral support. Finally, thanks to the University Malaysia Sarawak for supporting my education.

Finally, I would like to thank the management of the Universiti Malaysia Sarawak for making it possible for me to complete my study here in Sarawak. Thank you all.

ABSTRACT

In FSO communication links, the atmospheric turbulence has a significant impact on the quality of a laser beam where turbulence results in intensity scintillation, which can severely impair the operation of target designation and FSO communications systems.This research proposed the Double Transmission Balance Receiver (DTBR), a new approach for modulation technique in free-space optical communication. By utilise the Gaussian atmospheric channel analysis is the first step method. This factor will determine the trajectory of the research study and will restrict this strategy to implementing the calculations-related research. The second method is a mathematical derivation development where the new modulation technique is compared to conventional modulation techniques. The performance evaluation will investigate signal strength, signal threshold, signal-to-noise ratio, and bit error rate. In the meantime, the third method simulates the DTBR method using the OptiSystem software. This allows for an analysis close to actual FSO conditions, which can be validated with the theoretical portion. From the result shows that analysis from effective power, in strong turbulence condition the DTBR can improve approximately 50% of power received. For bit rate analysis, it can operate at higher bit rate of 10 Gbps (STM64) with the BER is approximately at 5.91 x 10^{-11} as compared to conventional ASK only at 2.77x 10^{-4}. This gives percentage improvement about 175%. Meanwhile in distance analysis, the DTBR manage to achieve BER approximately 5.51 x 10^{-17} while conventional only 4.89 x 10^{-4}. Thus, contribute improvement of 13 magnitude of BER or equivalent of 325%. Therefore, via the presented analysis the new proposed is have the better performance as compare to conventional ASK technique with new threshold at level zero ‘0’.

Keywords: *Free space optical, modulation, conventional ASK, BER, signal noise*

Teknik Modulasi Baharu Menggunakan Penghantaran Berganda Dalam Komunikasi Optik Ruang Bebas untuk Rangkaian Capaian

ABSTRAK

Dalam komunikasi FSO, pergolakan atmosfera mempunyai kesan yang ketara ke atas kualiti pancaran laser di mana pergolakan menghasilkan kilauan intensiti, yang boleh menjejaskan operasi penetapan sasaran dan sistem komunikasi FSO dengan teruk. Penyelidikan ini mencadangkan Penerima Baki Penghantaran Berganda (DTBR), pendekatan baru untuk teknik modulasi dalam komunikasi optik ruang bebas. Dengan menggunakan analisis saluran atmosfera Gaussian adalah kaedah langkah pertama. Faktor ini akan menentukan trajektori kajian penyelidikan dan akan menyekat strategi ini untuk melaksanakan penyelidikan berkaitan pengiraan. Kaedah kedua ialah pembangunan terbitan matematik di mana teknik modulasi baru dibandingkan dengan teknik modulasi konvensional. Penilaian prestasi akan menyiasat kekuatan isyarat, ambang isyarat, nisbah isyarat kepada hingar, dan kadar ralat bit. Sementara itu, kaedah ketiga mensimulasikan kaedah DTBR menggunakan perisian OptiSystem. Ini membolehkan analisis hampir dengan keadaan FSO sebenar, yang boleh disahkan dengan bahagian teori. Daripada keputusan menunjukkan bahawa analisis daripada kuasa berkesan, dalam keadaan turbulensi yang kuat DTBR boleh meningkatkan kira-kira 50% kuasa yang diterima. Untuk analisis kadar bit, ia boleh beroperasi pada kadar bit yang lebih tinggi iaitu 10 Gbps (STM64) dengan BER adalah lebih kurang pada 5.91 x 10^{-11} *berbanding ASK konvensional hanya pada 2.77x* 10^{-4}*. Ini memberikan peratusan peningkatan kira-kira 175%. Manakala dalam analisis jarak jauh, DTBR berjaya mencapai BER kira-kira 5.51 x* 10^{-17} *manakala konvensional hanya 4.89 x 10-4. Oleh itu, menyumbang peningkatan sebanyak 13 magnitud BER atau bersamaan dengan 325%. Oleh itu, melalui analisis yang dibentangkan, cadangan baharu mempunyai* *prestasi yang lebih baik berbanding teknik ASK konvensional dengan ambang baharu pada tahap sifar ‘0’.*

Kata kunci: *Ruang bebas optik, modulasi, ASK konvensional, BER, bunyi isyarat*

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LIST OF ABBREVIATIONS

APD	Avalanche photodiode
ASK	Amplitude Shift Keying
BER	Bit Error Rate
DTBR	Double Transmission Balance Receiver
ERF	Error Function
FCC	Federal Communications Commission
FEC	Forward Error Control
FSO	Free Space Optic
Gpbs	Giga bit per seconds
LASER	Light Amplification by Stimulated Emission of Radiation
LED	Light Emitting Diode
Mbps	Megabits per seconds
OOK	On Off Keying
PIN	p-i-n diode
Rx	Receiver
SNR	Signal to Noise Ratio
Tx	Transmitter

CHAPTER 1

INTRODUCTION

1.1 Study Background

The Light Amplification by Stimulated Emission of Radiation technology was successfully created by scientists in the 1960s, and it was later used in the optical communication industry (Jahid et al., 2022). The term "Free Space Optics," or FSO for short, refers to an optical communication method that transmits data between two sites using light, which typically comes from a laser as its source, and which travels across free space (Free Space Optic, 2020). Alexander Graham Bell, who was the first person to discover it in the late nineteenth century with his experiment to convert voice sounds into telephone signals and transmit them between receivers through free air space along a beam of light for a distance of approximately 600 feet, is credited with making this discovery (Fu, 2019). This technology has the same characteristics as fibre optic communications, and the only difference is in the medium through which the signal is sent. Whereas the data in an optical fibre connection are sent via the cable using laser light that has been modified, the data in a FSO communication are sent as a narrow beam across the atmosphere. As a result of the fact that light travels through air at a quicker rate than it does through glass, it is reasonable to refer to FSO as optical communications that occur at the speed of light. The fog, haze, scintillation, and heat of the atmosphere all have a significant role in determining the quality of the connection as well as its degree of stability. The maximum range that terrestrial networks can provide is restricted (less than10 km). In today's world, the FSO communication systems are being looked at more and more as a potentially lucrative choice for the speedy provisioning of multi-gigabit per second networks (Carbonneau and Wisely, (1998), Harjeevan and Nitin, (2022), Nosov et al., (2022)).

During the last several years, there has been a meteoric rise in the usage of FSO technology, mainly for applications pertaining to the "last mile." This is due to the fact that FSO lines offer the transmission capacity necessary to circumvent information bottlenecks (Fei, 2019). This high-speed data application is able to convey audio, video conferencing, and real-time picture transmission, and it also makes communication more inexpensive for everyone and every area (Hamed, 2002). A FSO system may be used for a wide variety of applications in today's world, including high-bandwidth internet access in the last mile, temporary high-bandwidth data communications, mobile phone backhaul (3G), satellite links, and other applications in which optical fibres cannot be used. The communication skills make it possible not only for humans to communicate and make contact with one another but also for humans to engage with machines and machines to interact with one another. Our sight, hearing, and sense of touch will all be able to make contact with a virtual three-dimensional presence to the connection (Anuranjana, 2019).

1.2 Problem Statement

The purpose of the FSO's communication is to alleviate the effects of any meteorological events. Atmospheric attenuation and air turbulence are two main atmospheric phenomena that might impact the quality of the FSO signal, as documented in Laialy & Natan (2020). Atmospheric attenuation, as reported by Marko (2021) and Wang et al., (2021), may lead to signal scattering and absorption. It may be necessary to adjust the layout of a FSO system so that it can transfer more power without jeopardising user safety or shortening the propagation connection. Atmospheric scintillation is attributed to temperature inhomogeneity, as reported by Li et al. (2003) and Shreesh (2020). When the optical beam travels through the atmosphere, it encounters both constructive and destructive interference, which may weaken the signal (Shrouk, 2021). When the distance between transmitter and receiver is more than 1 km, scintillation may drastically reduce FSO connection availability and performance (Tomoko et al., 2021).

The typical ASK - OOK modulation method is a common basic modulation technique that is now employed in commercially available terrestrial FSO systems (Ebrahim & Bedir, 2020). Nevertheless, the main issue with traditional ASK - OOK is the threshold signal level. The decision circuitry's threshold level/point for distinguishing between bits zero and one is always positioned halfway between the predicted values of data bits one and zero (Won et al., 2021). This will result in the best possible error performance in non-fading channels. Nevertheless, when turbulence is present, the received signal level fluctuates, and the threshold detector must watch this variation in order to find the best decision point (Yamamoto & Ohtsuki, 2003). As a consequence, a considerable design challenge will be required, since channel noise and fading will need to be continuously monitored for the OOK in FSO to work ideally. Ignoring the signal fluctuation and allowing the OOK FSO system to function with a constant threshold level will result in an increase in detection inaccuracy (Lee & Chan, 2004).

Because of the background noise, dark current dominates the detection of weak signals in FSO transmission. FSO is encountering significant hurdles in limiting the presence of undesired signal noise in the receiver. This is because the laser beam is transmitted straight through the air, with varying contributions from atmospheric effects (Androutsos et al., 2021). As a result, the optimum receiver design must condense the presence of noise.

1.2 Objectives

The realisation of FSO technology's potential inspired the development of a brand-new DTBR method. Understanding the impact of air turbulence on signal transmission is essential to evolving this system into a robust communications technology. Because of this, the following are the study's primary aims:

a) To examine the restriction of traditional ASK in open space optical communication systems due to atmospheric effects.
b) To develop a new Double Transmission Balance Receiver (DTBR) technique using Optisystem.
c) To compare and validate the performance between conventional ASK-OOK and DTBR

1.3 Scope Research

The research effort is carried out under the terrestrial FSO, which may be divided into three basic problems. The impact of absorption and dispersion is the first issue (fog, aerosol, and smog). However, the effects of air turbulence and eye and skin safety are the second and third obstacles. The current primarily focuses on the atmospheric turbulence effects that are particular to the scintillation effect, which causes signal fading in the FSO. There are four approaches that may be used to reduce the scintillation effect. The first is adaptive optics, which does not need wavefront measurements, which are difficult to get under high scintillation circumstances, which are common in many communication situations. It works by directly optimising a performance quality parameter, such as communication signal strength. The second technique is forward error control (FEC), which seeks to keep bound error variability under predefined bounds in order to enhance connection dependability. The third approach is diversity, which is separated into two parts: a) spatial domain technique and b) temporal domain technique. The modulation strategy is used in the fourth method.