



Faculty of Engineering

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

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

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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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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 5.91×10^{-11} as compared to conventional ASK only at 2.77×10^{-4} . This gives percentage improvement about 175%. Meanwhile in distance analysis, the DTBR manage to achieve BER approximately 5.51×10^{-17} while conventional only 4.89×10^{-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 5.91×10^{-11} berbanding ASK konvensional hanya pada 2.77×10^{-4} . Ini memberikan peratusan peningkatan kira-kira 175%. Manakala dalam analisis jarak jauh, DTBR berjaya mencapai BER kira-kira 5.51×10^{-17} manakala konvensional hanya 4.89×10^{-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*

TABLE OF CONTENTS

	PAGE
DECLARATION	i
ACKNOWLEDGEMENTS	ii
ABSTRACT	iii
<i>ABSTRAK</i>	iv
TABLE OF CONTENTS	vi
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xvii
CHAPTER 1: INTRODUCTION	1
1.1 Study Background	1
1.2 Problem Statement	2
1.3 Objectives	4
1.4 Scope Research	4
1.5 Thesis Organization	7
1.6 Research Significance	8
1.7 Research Gap	9
1.8 Summary	12
CHAPTER 2: LITERATURE REVIEW	13
2.1 Introduction	13
2.2 Overview	14

2.2.1	Fundamental of FSO System	16
2.2.2	Main Elements in FSO System	18
2.2.2.1	Transceiver	18
2.2.2.2	Receiver	21
2.2.3	FSO Current Technology	22
2.3	Atmospheric Attenuation	24
2.3.1	Absorption	24
2.3.2	Scattering	25
2.4	Eye and Skin Safety	27
2.5	Atmospheric Turbulence	30
2.5.1	Mitigate Effect 1: Adaptive Optics	32
2.5.2	Mitigate Effect 2: Forward Error Correction (FEC)	35
2.5.3	Mitigate Effect 3: Diversity Technique	36
2.5.4	Mitigate Effect 4: Modulation	38
2.5.4.1	Type Modulation 1: Pulse Modulation	39
2.5.4.2	Type Modulation 2: Subcarrier Intensity Modulation (SIM)	40
2.5.4.3	Type Modulation 3: On-Off Keying (OOK)	42
2.5.4.3.1	Direct Detection	44
2.5.4.3.2	Coherent Detection	47
2.5.5	Effect of Atmospheric Turbulence	48
2.6	Summary	50
CHAPTER 3:	METHODOLOGY	51
3.1	Introduction	51

3.2	Methodology	52
3.3	Measurement Elements Consideration	54
3.3.1	Signal to Noise Ratio (SNR)	56
3.3.2	Bit Error Rate (BER)	56
3.4	Simulation Analysis	57
3.4.1	Simulation Setup	58
3.5	Noise Detection Analysis	59
3.5.1	Shot Noise	60
3.5.2	Dark Current Noise	61
3.5.3	Background Noise	61
3.5.4	Thermal Noise	62
3.6	Scintillation Index	63
3.6.1	Flux Variance	63
3.7	Gaussian Analysis: Atmospheric Turbulence	66
3.8	Type of Turbulence (ToT)	67
3.8.1	ToT 1: Log Normal Distribution	69
3.8.2	ToT 2: Gamma-Gamma Distribution	70
3.8.3	ToT 3: The Exponential Distribution	71
3.9	Summary	71
CHAPTER 4: DEVELOPMENT OF DOUBLE TRANSMISSION BALANCE RECEIVER (DTBR) MODULATION TECHNIQUE		72
4.1	Introduction	72

4.2	Concept of DTBR System	72
4.2.1	Component 1: Light Source (LS)	75
4.2.1.1	LS Type 1: Light Emitting Diode (LED)	75
4.2.1.2	LS Type 2: light amplification by stimulated emission of radiation (LASER)	77
4.2.2	Component 2: Inverter Functionality	80
4.2.3	Component 3: Balance Receiver	82
4.2.4	Component 4: Photodetector	83
4.2.5	Component 5: Subtractor	85
4.3	Mathematical Derivation	87
4.3.1	Signal Power	87
4.3.1.1	Conventional ASK-OOK Scheme	89
4.3.1.2	Double Transmission Balance Receiver Scheme	89
4.3.2	Threshold Detection in DTBR Technique	90
4.3.3	SNR Without Presence of Turbulence	93
4.3.3.1	Conventional ASK-OOK Technique	93
4.3.3.2	Double Transmission Balance Receiver Modulation Technique	94
4.3.4	Bit Error Rate (BER)	94
4.3.4.1	Conventional ASK-OOK Scheme	95
4.3.4.2	Double Transmission Balance Receiver Scheme	97
4.4	Main Performance Analysis with Presence Turbulence Effect : Comparison evaluation DTBR Versus Conventional ASK-OOK	98

4.4.1	Signal to Noise Ratio (SNR)	98
4.4.2	Probability of Error, P_e	99
4.5	Summary	100
CHAPTER 5: PERFORMANCE ANALYSIS OF DOUBLE TRANSMISSION BALANCE RECEIVER (DTBR) IN FSO SYSTEM		101
5.1	Introduction	101
5.2	Theoretical Performance	101
5.2.1	Analysis 1: Power	103
5.2.2	Analysis 2: Bit Rate	107
5.2.3	Analysis 3: Distance Propagation	109
5.3	Simulation Performance	113
5.3.1	Analysis 1: Power	115
5.3.2	Analysis 2: Bit Rate	124
5.3.3	Analysis 3: Distance Propagation	126
5.4	Summary	128
CHAPTER 6: CONCLUSION AND FUTURE WORK		129
6.1	Introduction	129
6.2	Contribution of This Research	129
6.3	Conclusion	131
6.4	Recommendations for Future Work Research	133

REFERENCES	134
PUBLICATIONS	149
APPENDICES	150

LIST OF TABLES

	Page	
Table 1.1	Prior researcher related with research	9
Table 2.1	Comparison wavelength limit	28
Table 2.2	Standard for categorizing lasers, IEC 60825-1	29
Table 2.3	OOK scheme signaling status	46
Table 3.1	Main component setup	58
Table 3.2	Analyzer component setup	59
Table 3.3	Range turbulence regime	69
Table 4.1	Bit detection for DTBR technique at receiver	93
Table 4.2	Summary of DTBR derivation	100
Table 5.1	Parameters for DTBR technique performance under strong turbulence	102

LIST OF FIGURES

		Page
Figure 1.1	Scope of research	6
Figure 2.1	Flow of Literature Review	13
Figure 2.2	Element FSO communication	14
Figure 2.3	Absorption rate for H ₂ O	24
Figure 2.4	Absorption rate for CO ₂	25
Figure 2.5	Category of scattering	26
Figure 2.6	Effect of wavelength over human eye	28
Figure 2.7	Phenomenon laser beam wanders due to larger turbulence cells	31
Figure 2.8	Phenomenon scintillation at the receiver when turbulence cells are smaller than the beam diameter	31
Figure 2.9	Noise reduction using adaptive optics systems (Grave & Drenker, 2002)	33
Figure 2.10	Wavefront sensor (WFS) and wave front reconstruction in adaptive optics approach (Majumdar & Ricklin, 2007)	34
Figure 2.11	Blind optimization performance for wavefront distortion compensation (Majumdar & Ricklin, 2007)	35
Figure 2.12	Diagram of triple-aperture receiver (Qian et al. 2021)	37
Figure 2.13	Type digital modulation technique	38
Figure 2.14	Comparison time waveforms for NRZ, RZ and PPM OOK (Samir et al., 2021)	40
Figure 2.15	Signal process in direct detection approach (Samir et al, 2021)	45
Figure 2.16	On Off Keying detection process (Majumdar & Ricklins, 2007)	45

Figure 2.17	Miss detection and false alarm in signal processing (Andrews & Phillip, 2005)	46
Figure 2.18	Example of coherent detection in FSO communication system for (Qian et al., 2021)	47
Figure 3.1	Flow of Methodology	51
Figure 3.2	Overall flowchart of work process DTBR technique	53
Figure 4.1	Flow of development DTBR technique	72
Figure 4.2	Proposed setup for Double Transmission Balance Receiver modulation (DTBR) technique	73
Figure 4.3	Flowchart of a DTBR technique for FSO communication	74
Figure 4.4	Example LED output	77
Figure 4.5	CW laser setup	79
Figure 4.6	Example output LASER	80
Figure 4.7	Signal compliment using inverter for DTBR technique	81
Figure 4.8	Example output original data signal	81
Figure 4.9	Example compliment of original data signal due to inverter effect	82
Figure 4.10	Balance receiver 1 and 2 setup	82
Figure 4.11	Type for PIN and APD light detector	83
Figure 4.12	Subtraction process configuration	86
Figure 4.13	Example output after subtraction process	86
Figure 4.14	Fundamental Gaussian beam in free space transmission (A. Prokes, 2009)	88
Figure 4.15	Threshold detection concept at receiver for DTBR technique	91
Figure 5.1	Comparison DTBR and Conventional ASK for effective power received under weak turbulence	103

Figure 5.2	Comparison DTBR and Conventional ASK for effective power received under strong turbulence	104
Figure 5.3	Minimum power requirement at transmitter for minimum acceptable BER 10 ⁻⁹	105
Figure 5.4	Figure 5.4 (a) and (b): Effect of transmitter and receiver aperture size of DTBR over power received	106
Figure 5.5	Comparison performance received power BER at 10Gbps data rate	107
Figure 5.6	DTBR performance BER for different of STM level	108
Figure 5.7	Performance under strong turbulence condition	109
Figure 5.8	Comparison DTBR and Conventional ASK varying distance under strong turbulence	110
Figure 5.9	Comparison 780nm and 1550nm wavelength performance	111
Figure 5.10	Comparison DTBR performance for 1km, 2km and 3km range of transmission	112
Figure 5.11	Simulation setup DTBR system	114
Figure 5.12	Minimum power required to operate FSO system	115
Figure 5.13	Comparison performance of received power operate at low power 0 dBm	116
Figure 5.14	Comparison performance BER versus increment of attenuation (dB/km)	116
Figure 5.15	Comparison performance of noise power for both DTBR and conventional approach	118
Figure 5.16	Comparison received power at minimum acceptable BER 10 ⁻⁹	118
Figure 5.17	Figure 5.17 (a) and (b): Performance of eye diagram for noise (green) and signal power (blue) without presence of turbulence	120

Figure 5.18	Figure 5.18 (a) and (b): Performance of eye diagram for noise (green color line) and signal power (blue color line) with presence of turbulence at $C_n^2=1 \times 10^{-13} \text{ m}^{-2/3}$ (Moderate turbulence)	121
Figure 5.19	Figure 5.19 (a) and (b): Performance of eye diagram for noise (green color line) and signal power (blue color line) with presence of turbulence at $C_n^2=1 \times 10^{-12} \text{ m}^{-2/3}$ (Strong turbulence)	123
Figure 5.20	Performance of BER for varying data bit rate under strong turbulence effect	124
Figure 5.21	Comparison performance DTBR and conventional ASK for different STM level (STM1, STM4, STM16 & STM64)	125
Figure 5.22	Performance of BER for varying distance transmission under strong turbulence effect	126
Figure 5.23	Comparison BER versus attenuation for different range propagation	127
Figure 6.1	Flow of Conclusion	129

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 than 10 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.