The Performance of Dual Diffuser Modulation using Wavelength Filtrate Detection for Free Space Optics in the Presence of Rain Consequence

by

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ABSTRAK

Optik Ruang Bebas adalah salah satu langkah penyelesaian yang berkesan disebabkan oleh permintaan data berkelajuan tinggi yang semakin meningkat masa kini. Sistem ini bebas digunakan dan juga menawarkan jalur lebar berkelajuan tinggi tanpa had serta menyediakan keselamatan yang sangat baik. Kebiasaan sistem ini mempunyai masalah mengikut keadaan cuaca sekeliling dengan membuatkan isyarat yang di hantar menjadi lemah. Dikawasan tropika, punca utama kehilangan isyarat yang dihantar adalah disebabkan keadaan hujan. Kualiti isyarat akan menjadi rendah dan sekali gus akan menyebabkan sistem ini tidak dapat berfungsi dengan baik. Sistem modulasi sedia ada meningkatkan kadar peratusan kehilangan isyarat yang tinggi dan seterusnya menyebabkan isyarat yang diterima itu lemah. Oleh itu, untuk mengatasi masalah ini, penghasilan pengesan yang baru dikenali sebagai Pengesan Penapisan Gelombang telah diwujudkan untuk meningkatkan prestasi pada sistem komunikasi optik di ruang udara. Pengesan yang dicadangkan merujuk kepada fungsi Fibre Bragg Grating yang mampu mengoptimumkan penggunaan penapisan gelombang itu. Dalam kajian ini, data hujan yang disediakan oleh Jabatan Meteorologi Malaysia pada tahun 2015 meliputi kawasan Chuping Perlis telah dikumpulkan. Dari data ini, analisis penolakan hujan dianalisa menggunakan kaedah pengiraan matematik merujuk kepada rumus undang-undang kuasa. Dari pengiraan ini, nilai maksimum yang diperolehi adalah 13dB/km. Nilai ini dikategorikan sebagai situasi hujan yang lebat. Kemudian analisis diteruskan dengan melakukan perbandingan teknik modulasi sedia ada iaitu Kekunci Buka Tutup dan Modulasi Peresapan Dua Hala. Dua jenis analisis dilakukan iaitu dalam bentuk teori dan simulasi untuk membuktikan bahawa teknik Modulasi Peresapan Dua Hala ini dapat meningkatkan prestasi sistem optik ini pada keadaan cuaca yang buruk. Analisis ini diteruskan dengan melakukan perbandingan antara pengesan sedia ada dan juga pengesan yang dicadangkan. Teknik Modulasi Peresapan Dua Hala ini dipilih sebagai modulasi utama dalam penyelidikan ini disebabkan oleh kerana ia dapat menaik taraf penerimaan signal sejauh 0.12km dan meningkatkan kuasa isyarat yang diterima sebanyak 4dBm. Selain itu, dengan mengunakan jarak 0.5km, corak mata pada alat penganalisa menunjukkan teknik Modulasi Peresepan Dua Hala ini menghasilkan mata yang terbuka luas dengan kadar ralat bit yang baik iaitu 8.10×10^{-7} berbanding dengan teknik Kekunci Buka Tutup hanya memperolehi 6.51×10^{-4} disebabkan oleh kehilangan isyarat yang tinggi. Selain itu, teknik Modulasi Peresapan Dua Hala ini juga dapat menampung kadar data yang tinggi sehingga 10Gbps. Namun, terdapat masalah yang dihadapi pada Modulasi Peresepan Dua Hala ini di bahagian pengesan isyarat. Pengesan sedia ada perlu dinaiktaraf untuk mengelakkan banyak isyarat yang hilang. Untuk mengatasi masalah ini, pengesan yang telah dihasilkan iaitu Pengesan Penapisan Gelombang yang dapat meningkatkan prestasi kadar ralat bit sebanyak 21% serta dapat meningkatkan kuasa yang diterima sebanyak 6dBm. Kesimpulannya, gabungan teknik Modulasi Peresapan Dua Hala dan Pengesan Penapisan Gelombang dapat meningkatkan prestasi pada sistem komunikasi optik di ruangan udara dan mampu menghantar kapasiti data yang tinggi didalam situasi cuaca yang buruk.

The Performance of Dual Diffuser Modulation using Wavelength Filtrate Detection for Free Space Optics in the Presence of Rain Consequence

ABSTRACT

Free space optics (FSO) is one of the effective solutions to the ever growing needs of high speed data transfer. It offers unlicensed, higher speed with unlimited bandwidth as well as provides an excellent security. However, it is sensitive to local weather conditions which results to the inconsiderable loss of signal power over the communication path. To the fact, the quality of the FSO links are mainly affected by rain attenuation especially in a tropical environment. The conventional modulation of FSO system increases the error rate and produces low power received in situation of bad weather. Besides that, the existing detection degrades the received signal and not properly operated. Hence, in order to cater this problem, the proposed detection namely Wavelength Filtrate Detection has been developed to enhance the performance of FSO system. The proposed detection is based on the function of Fibre Bragg Grating which is capable to optimise the filter wavelength. In this research, the collection of rainfall data in year 2015 is provided by Malaysia Meteorological Department which covers region in Chuping, Perlis. From this data, a depth analysis of rain attenuation by using mathematical equation of power law has been carried out which results to the maximum rain attenuation of 13dB/km. This value is categorized under heavy rain condition. Then, the analysis is continued with the comparison between conventional modulation technique On Off Keying (OOK) and Dual Diffuser Modulation (DDM). Two types of analysis are done which are theoretical and simulation to prove that DDM technique enhances the performance of FSO system due to the adverse weather condition. The analysis continues with comparison between existing detection and Wavelength Filtrate Detection. The DDM technique is selected as the main modulation in this research because it supports 0.12km range of transceiver and improves signal received approximately 4dBm from the mathematical analysis. Also, the eye pattern in 0.5km range shows DDM technique is widely open with better BER 8.10×10^{-7} compares to OOK technique which is 6.51×10^{-4} and results to the higher loss of signal. Furthermore, this technique also supports high data rate up to 10Gbps. The problem occur in DDM technique is on the detection stage. The detection needs to be improved to avoid high signal losses when adverse weather condition occurs. To overcome this issue, Wavelength Filtrate Detection has been developed and it shows the improvement of 21% magnitude of BER as well as increase the power received up to 6dBm. As conclusion, the combination of DDM technique and Wavelength Filtrate Detection (WFD) have increase the performance of FSO system and capable to transmit high capacity of data in a situation of adverse weather condition.

CHAPTER 1 : INTRODUCTION

1.1 Introduction

The vigorous spreading of internet usage in this new era of technology requires the communication networks to have the best performance of system in terms of low power consumption with high data rate. The most suitable technology to meet the aforementioned requirement is known as Free Space Optics (FSO). This technology uses laser beam in order to communicate from one point to another which involves the transmission of optical data that is loaded through the atmospheric channel as stated by (Noor, N. H., Naji, A. W., & Al-khateeb, W., 2011). In addition, this technology is also part of several existing high-speed communication systems by means carries large capacity of data with high bandwidth in (Bouna, R. W. L., & Uranus, H. P., 2011). With these abilities, FSO system has achieved satisfaction in any type of users which is not only involving human to human interaction, but also human to machine and machine to machine in audio, video, and real-time image by (Soni, G., & Banga, V., K., 2014; Zabidi, S. A., Islam, M. R., Khateeb, W. Al, & Naji, A. W., 2011).

Most of the FSO applications are deployed in metropolitan area to avoid the data bottlenecks (Yahya, M., Salleh, K., & Awang, Z., 2011). A quick time is taken to deploy the system from the installation part between the link alignment and transmitter to the receiver. Redeployment to another location also could be easily done as mentioned in (Suriza, A. Z., Rafiqul, I. M., Wajdi, A. K., & Naji, A. W., 2012). For instance, this system could be applied in a disaster location as a temporary link to back up the communication breakdown before the original link is fully recovered as in (Fadhil, H. A., Al-Khafaji, H.

M. R., Abd, H. J., & Aljunid, S. A., 2012). The installation cost of FSO system is cheaper than fibre optics with a comparable data rate and could carry the same transmission capacity as optical fibre without the additional expense in (Suriza, A. Z., Wajdi, A. K., Rafiqul I, M., & Naji, A. W., 2011). Due to the eye safety and follow the laser standards in this FSO link, the license authority of Federal Communication Commission (FCC) is not needed to allocate this system (Vigneshwaran, S., Muthumani, I., & Raja, A. S., 2013).

However, the major problem that is faced by FSO system is atmospheric effect which could reduce and weaken the signal transmit. Atmospheric effect could be divided into two categories that are atmospheric turbulence and atmospheric attenuation. The atmospheric turbulence might cause the signal to face and refract the laser beam before reaching receiver station. Laser beam would bend when the size of turbulence cell is large and spread when the size of turbulence cell is small. In contrast, atmospheric attenuation is influenced by weather condition such as fog, haze, rain and snow. In tropical region, heavy rainfall is the major factor that disturbed the performance of FSO system by (Shahiduzzaman, K. M., Hassan, M., Karmaker, B. K., & Kumar Biswas, L., 2015).

Therefore, the existence of effective modulation technique in FSO system is crucially needed to avoid high signal losses due to atmospheric effect. The conventional technique of On Off Keying/Direct Detection is one of the popular modulations that is commercially available in current FSO system because of simple design and cheaper. Yet, this conventional technique is suffering from the threshold signal level. Generally, the threshold level for this modulation is half between bit one and zero. When bad atmospheric effect occurs, the signal would greatly loss due to the increasing of noise and the detector received weak power simultaneously in (Rahman, A. K. et al., 2015). Hence, the development of new modulation which is called as Dual Diffuser Modulation/Subtractor Detection technique from previous researcher is aimed to improve

the performance of the current modulation. This modulation could operate with high data rate 10Gbps which is suitable to be adopted in this modern technology nowadays.

The design technique of Dual Diffuser Modulation/Subtractor Detection employs two transmitters and receivers. The difference between first and second transmitter is that first transmitter would send the original data and second transmitter would send the invert of the original data. Both transmitters would be combined the power transmit with diffuser in order to increase the signal received. The improvement of this modulation has produces a new threshold level between one and negative one because it is using subtractor detection that act to combine the signal in (Rahman, A. K., Aljunid, S. A., Anuar, M. S., & Fadhil, H. A., 2015). Although this design could increase the performance of signal transmit, but it is also face a problem in signal detection. The usage of subtractor detection has causes the increment of signal error in situation of adverse weather condition. As a result, the signal would receive high error rate due to increment of noise. This detection method needs an improvement to support the performance of high data rate to achieve less bit error rate and high power received.

1.2 Problem Statement

The main factor that seriously capable to degrade the performance of FSO system is the existing of atmospheric attenuation specifically in rain condition. The impact of rain attenuation could disturb the signal transmit and reduce signal received. The distraction from rain attenuation would limit the reception of effective signal because the presence of noise in the system (Ong, J. T., Timothy, K. I., Chong, J. H., & Rao, S. V. B., 2003).

Also, selection of wrong modulation could degrade the system performance. It is because the transferring data depends on the performance of modulation. As discussed in Section 1.1, the conventional technique On Off Keying/Direct Detection is a cheaper modulation but the performance of this modulation could deteriorate signal received in situation of heavy rain conditions (Rahman, A. K., Aljunid, S. A., Anuar, M. S., & Fadhil, H. A., 2014).

The performance of the system is also measured in terms of power received which is influenced by the detection design. The erroneous detection would degrade the received signal and might not properly operate in high data rate 10Gbps due to the interference of high noise. Therefore, a good detection design plays a significant part in the performance of FSO system as in (Jasmine, S., Robinson, S., & Malaisamy, K., 2015).

1.3 Research Objectives

This research is aimed to enhance the performance of detection specifically in rain condition to improve the signal received of the system. The research is carried out using a simulator to compare the performance of existing detection and the proposed detection. Also, a suitable detection at the receiver is needed to reduce the impact of atmospheric interference. The results of analysis are measured in terms of power received and bit error rate (BER) that are required to achieve a desired level of performance based on certain parameters. A number of research objectives to achieve this analysis, have been outlined as follows:

1) To analyse the rain attenuation using an equation based on measurement and experimental.

2) To analyse the performance of Dual Diffuser Modulation technique in terms of bit error rate and effective power received using theoretical and simulation analysis in condition of rain attenuation.
3) To develop and validate a proposed detection based on Dual Diffuser Modulation technique using simulation in terms of power received and bit error rate.

1.4 Scope of Research Works

The overall research scope which focuses on the development of FSO detection in condition of rain attenuation are illustrated as in Figure 1.4. As shown in Figure 1.1, the analysis of rain attenuation is based on rainfall data that are provided by Malaysia Meteorological Department in year 2015 which covered area of Chuping Perlis, Malaysia. The Dual Diffuser Modulation technique has become the main part of modulation in this research will compare to the conventional modulation On Off Keying as shown in Figure 1.2. Figure 1.3 shows the performance of new proposed detection has been compared with former detection techniques such as subtractor detection, SDD detection, AND detection and Complimentary detection respectively. The analysis in terms of power received and bit error rate by tuning several parameters such as range, aperture diameter, power transmit, attenuation effect, and beam divergence have been done in this research. The research work is focused on simulation process using Optiwave Optisystem software.

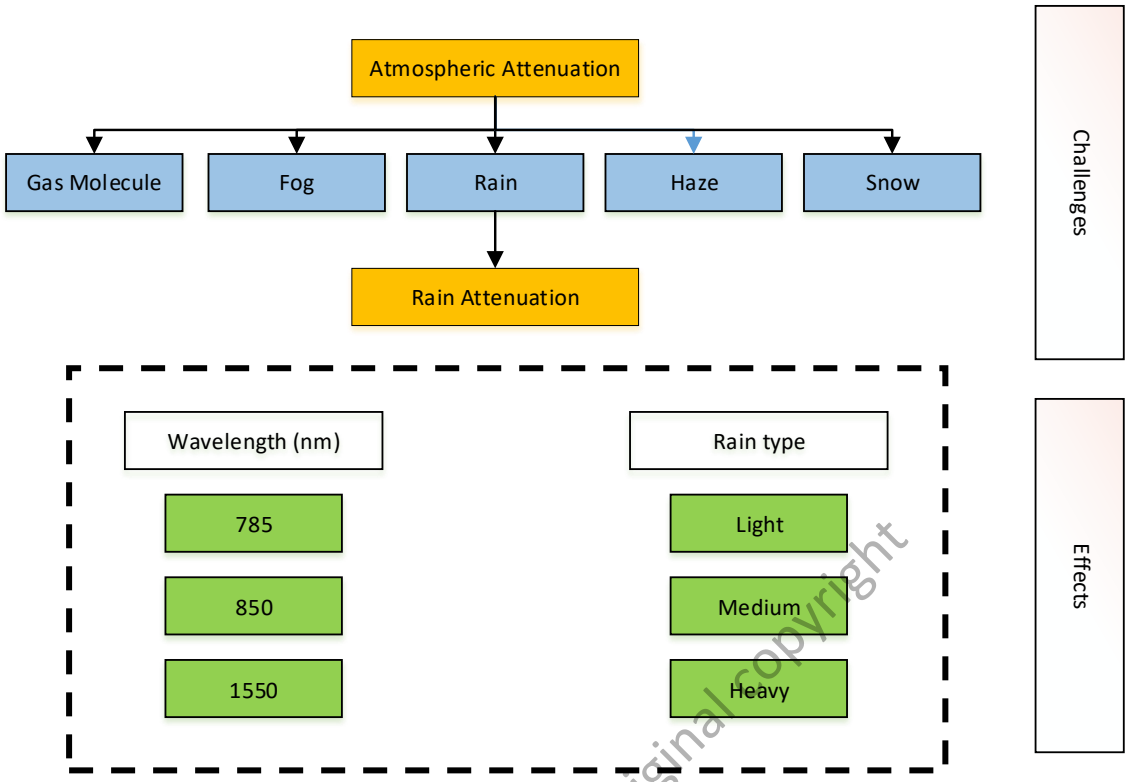

Figure 1.1: Rain attenuation chart

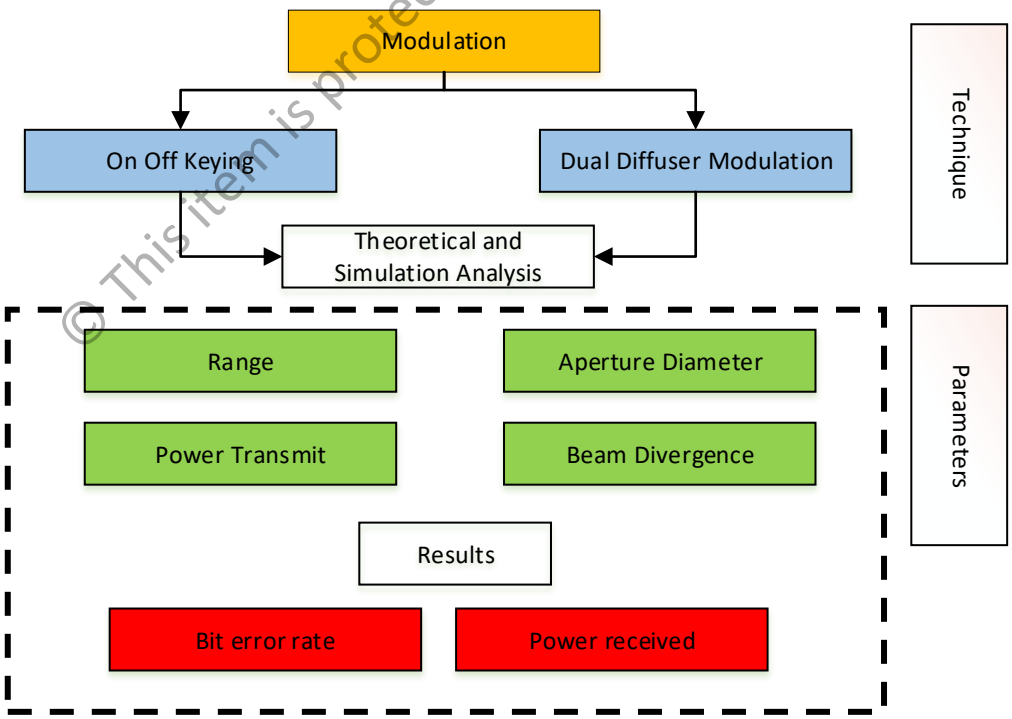

Figure 1.2: FSO modulation chart

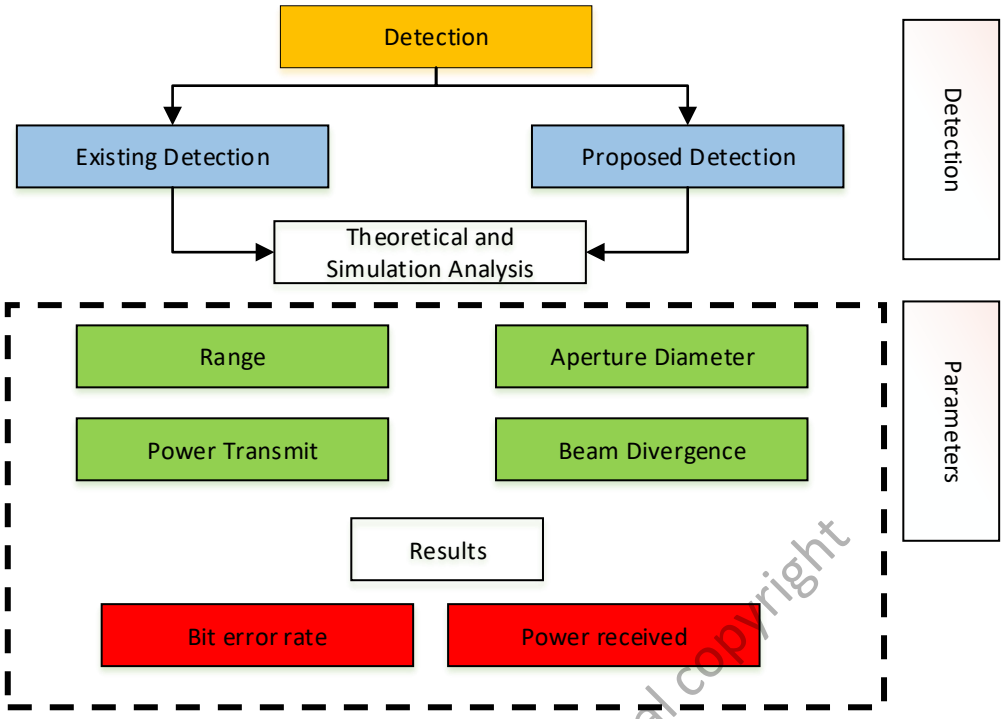

Figure 1.3: FSO detection chart

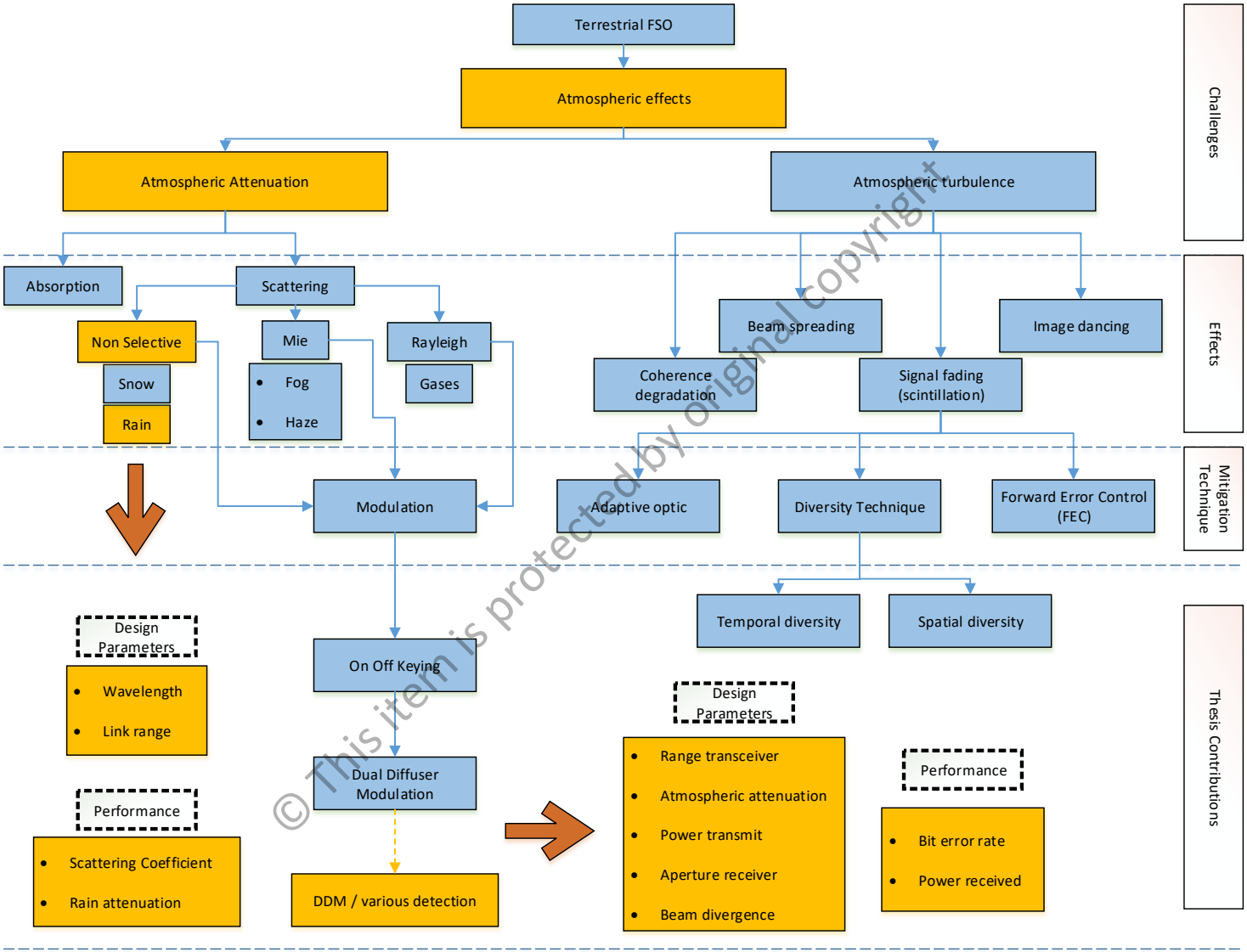

Figure 1.4: Overall scope of research

1.5 Research Contribution

The major contributions in this research is the development of a proposed detection called as Wavelength Filtrate Detection which blocked the particular wavelengths and only transmits the selective wavelength. Besides that, this new detection method could be used as an inline optical filter to block certain wavelengths other than 1550nm. This detection method could enhance the performance of power received and bit error rate. The implementation of this detection does not require going through a complex process. This analysis using Optisystem simulation tools to create a layout of design detection.

1.6 Thesis Organization

The thesis is organized as follows. Chapter 1 gives an introduction about the FSO system, problem statement, objectives, scope of works and research overview. Chapter 2 explains about the principles relating to effect of atmospheric turbulence, atmospheric attenuation and the research finding. This chapter focuses on the literature review about effect of atmospheric attenuation because of rain. The fundamental of detection and design are highlighted in the next chapter.

Chapter 3 describes the methodology of data analysis on rainfall rate that are provided by Malaysia Methodology Department specifically covering region of Chuping, Perlis, Malaysia. Also, the design model is briefly highlighted the elements of light source, inverter, photodetector and combination signal. This chapter also explains briefly about simulation design parameters using Optisystem software which is used to analyse the performance of BER and power received. The analysis of rain attenuation, theoretical

and simulation result are discussed in chapter 4. However, for simulation process, the effect of heavy rain become the major concern to compare and reveal the performance of proposed detection with the existing detection using Dual Diffuser Modulation technique as the main design. Finally, chapter 5 summarizes the research finding and proposed several recommendations for future work of FSO system to be implemented.

1.7 Conclusion

FSO system is exposed to the atmospheric effect which could reduce the performance of signal transmitted in the presence of atmospheric attenuation. This research is concerning on the improvement of detection which is based on Dual Diffuser Modulation technique in condition of heavy rain. The next chapter would discuss the literature review of this research.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter delivers the review of contemporary research and principles in FSO system project research. This chapter also discusses the overview of FSO system and the effects of atmospheric channel. In addition, the overall of background study is explained in this chapter.

2.2 Free Space Optical Communication System

Free space optical communication system is an alternative system that is needed in this new era toward facing the growth of high-speed data transfer in telecommunication sector. FSO system requires the best knowledge of atmospheric effects which create a major problem if the atmospheric effects occur in worst condition (Sharma, V., & Kaur, G., 2012). The system involves data transfer between two transceiver using sources of data transmit such as laser (Light Amplification by Stimulated Emission of Radiation) as the carrier signal through the atmosphere. The transceivers need to be directed to one another without any obstacles or signal blockage in order to have a successful data or information exchange. This system could only operate in several distance to maintain the signal condition and error losses (Ijaz, M. et al., 2013).

FSO system operates in outdoor situation that promises high data rates between Mbps to Gbps. The distance for this system is between hundred meters to few kilometres. FSO system bandwidth supports high capacity up to 2.5Gbps and nowadays covers