THE EFFECT OF ATMOSPHERE CONDITIONS ON PERFORMANCE OF FREE SPACE OPTICS IN MALAYSIA AT 1550NM

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Abstract- This paper presents the effect of atmosphere condition on performance of free space optics in Malaysia at 1550nm. The comparison of haze attenuations in FSO between September 2007 andJune2013 at Petaling Jaya region. The large-scale air quality disaster occur that effect widespread atmosphere visibility due to fires in Sumatra forest is the reason on choosing haze effect on June 2013. This paper also compared between the distance of FSO transmission for 300m and 500m distance in rain condition. The data for visibility for both years' data of rain intensity are obtained from Malaysia Metrological Department (MMD). This project uses LASER as a transmitter and PIN photodiode as a receiver with wavelength 1550nm. The results were found to be satisfactory. For haze condition, FSO transmission on June 2013 produces the worse signal performance than transmission on September 2007. For rain condition, the FSO transmission for 300m distance produce the better quality signal than transmission for 500m distance where at 500m distance, the BER value is 10^{-2} which produce the bad quality signals at receiver.

Keywords- Atmosphere Condition, Quality Disaster, Widespread Atmosphere.

I. INTRODUCTION

Free Space Optics (FSO) also known as Optical Wireless is one type of wireless technologies that refers to transmission of modulated visible/ infrared beams through atmosphere to obtain optical communication [2]. Like fiber, FSO use lasers or Light Emitting Diodes (LED) to transmit data (such as voice, data, video), but instead of enclosing data stream in glass fiber, it transmit through air in certain distance. The constrain of this type of transmission is it requires Line Of Sight of light propagation between transmitter and receiver which is it works on same basic principle as infrared television remote controls and wireless keyboard that required Line of Sight.

Nowadays, it can be used for last mile solution of metro network, within campus and for military system due to high security. It also can be applied for a new building which is very costly to lay the fiber. Consequently, US army is aggressively upgrading FSO systems that can support Gigabit Ethernet data rates. The advantages of FSO are its offers the abundance of unregulated bandwidth which is up to 200THz, high data rate which is up to Gbps, security, flexibility of installation and lower cost for equipment and deployment [2]. The system configurations of Free Space Optics is it can be for indoor or outdoor environment depending on the specific requirements of the system. In general, the topologies used for indoor optical wireless communication systems are classified according to two parameters. First is the existence of an unobstructed path between the transmitter and receiver (required LOS and N-LOS light propagations) and secondly is the degree of directionality of the transmitter, the receiver, or both [1]. But, in this project the focus will be more on propagations of lights for outdoor environment that more challenging because of an unpredictable of atmosphere conditions as a transmission medium.

II. DESIGN OF FSO

The FSO transmission link consist transmitter devices, atmosphere as medium of transmission and receiver devices [7]. As the medium of transmission, the occurrences on interferences are unpredictable [5]. Haze, fog, rain, snow is examples of weather conditions interference that lead to absorption and scattering of transmitted light. Affection from sun or scintillation also can affect the transmission on light and have to consider the building structure beneath the link that may cause additional thermal activity in the air above them that may then lead to scintillation on the received signal [13]. Besides that, the obstacles such as trees and bird flying through light transmission can cause blocking of the transmission signals.

A key parameter in the design FSO links is the consideration of the power budget. Link margin is to determine how far we can place transmitter and receiver while still maintaining enough margins for transmission availability. The link margin (dB), which is the power available above sensitivity of receiver, link margin is given by equation (2.1) [13];

$$M_{link} = P_e - S_r - A_{geo} - A_{atmo} - A_{scintillation} - A_{syst}$$

$A_{atmo}$are weather conditions such as rain, haze, fog and snow that cause the scattering effect while the present of molecules gaseous in clear air can cause the absorption effect. Margin allocated to compensate for fog or rain attenuations and also can compensate for scintillation effects [13].

Rain is water vapor contained in the atmosphere [3]. It consists of water droplets whose form and number are variable in time and space. The water droplets are depends on the size; usually the sizes can be up to 2000μm. When the size of irregularities due to precipitation becomes important compared to the

wavelength, the signal is attenuated by reflection and refraction. The rain attenuation can be defined using the equation (2.2) [13];

$$\gamma_{rain} = k \cdot R^{\alpha}$$

The parameters 'k' and 'α' depend on the rain characteristics, and some value determined from measurements. Table 2.2 shows k and α parameters values used for the estimation of the specific attenuation due to rain [13].

Haze or fog consists of fine water droplets suspended in the air. The haze attenuation can be defined using the equation (2.3) [13] as below;

$$\gamma_{fog}(\lambda) = \frac{3.91}{V}\left(\frac{\lambda}{550\ \text{nm}}\right)^{-q}$$

Where V is visibility (km), λ is wavelength (nm), q is a coefficient dependent on the size distribution of the scattering particles.

Visibility is the concept defined needs of meteorology. It characterized transparency of atmosphere estimation by human observer, visibility of human eye in kilometer [3]. The value of visibility should be high for less attenuation. The value of visibility is measured by transmissometer or diffusiometer, usually measured at airport by Meteorology Department. It gives mainly by the atmospheric extinction coefficient associated with solid liquid particles; this extinction primarily caused by scattering rather than absorption of the light.

The geometric attenuations or geometric loss refers to losses that occur due to divergence of the optical beam. For Free Space Optics propagation, the beam diverges by some amount over the path from transmitter to receiver. If the divergence value is high, the lights are never collected by receiver. Geometrical attenuation equation is as in equation 2.4 [13];

$$A_{geo}(\text{dB}) = 10\log_{10}\left(\frac{S_d}{S_{capture}}\right)$$

Where
$S_{capture}$: receiver capture surface (m_2)
S_d: surface area of transmit beam at range d, which is approximated by equation 2.5 [13];

d: emitter-receiv $S_d = \frac{\pi}{4}(d \cdot \theta)^2$
θ: beam diverger

III. METHODOLOGY

Basically methodology used in this research studies are divided into several sub area starts with data collections of visibility and rain intensity values, then refer to standard & procedure of ITU-R, after that FSO system design and technical specification selections and lastly is performance analysis of received signal.

Two types of data needed in this project which are visibility (km) and rain intensity (mm/hr). For haze conditions, the visibility was obtained from Malaysia Meteorological Department (MMD). Petaling Jaya (PJ) is the chosen location because considered as urban environment and another reason is one of observation MMD place is located at PJ [11]. The large-scale air quality disaster occur that effect widespread atmosphere visibility due to fires in Kalimantan forest is the reason on choosing haze effect on June 2013 and compared with haze attenuation on Sept 2007, considering free air quality disaster at that time.

The measurement for rain intensity was done at JalanSemarak, KL on 2010. JalanSemarak, Kuala Lumpur is a chosen location because of it is in urban area region as scope in this project. The local weather is equal to equator zone which the weather throughout year is damp and dries [16].

Designing the FSO system transmission link is the critical part in this project. The transmitter of the FSO system consist produce bit random sequence or PBRS, electrical signal generator, LASER as optical source and optical power normalizer before entered to atmosphere channel.

Atmosphere channel is a transmission medium of FSO system where unpredictable weather condition such as haze and rain that cause of attenuation occurs. The present of noise also may occur in this channel that can degrade the signal performance.

At receiver, it compound optical receiver consist PIN, amplifier to amplify the weak signal and filter to remove the unwanted signal or to select the desired range of frequencies. Figure 1 shows the FSO system transmission design using OPTsim software.

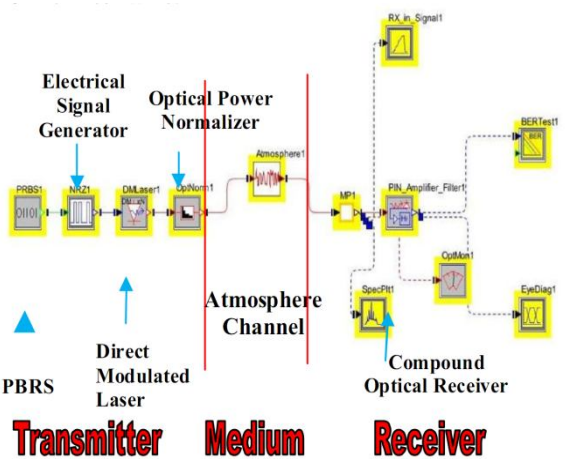


Figure 1: FSO system transmission design using OPTsim software

Table 1: The parameter use in design the FSO system transmission:-

Parameter	Value
Wavelength	1550nm
Bit Rate	1.25GHz
Tx_Power	15 dBm
Distance	300m & 500m
Beam_Divergence	0.17 rad
Capture_Area	180m^2
Attenuation_Add (Rain)	-12.25dB & -20.25dB
Attenuation_Add (Haze)	-17dB & -1dB
Sensitivity	10 dBm

IV. RESULTS AND DISCUSSION

A graph had been plotted in OPTsim software in order to show the effects of rain and haze conditions in FSO transmission system. The results can be divided by two which are analyses of rain conditions of distance affection and the comparison between haze attenuations for September 2007and June 2013. The analysis of received signal performance involves the analysis of eye diagram, optical signal analysis and optical spectrum analysis, BER and optical power analysis. In rain condition, the analyses of received signal performance are made by setting the distance as variable. The distance of 300m and 500m are selected and then the comparison between the performances of received signal for that two distances are made where each distance has the different of rain attenuation value. Based on the data collected for rain attenuation at JalanSemarak, Kuala Lumpur location in year 2010, the rain attenuation for 300m distance is -12.25dB while the rain attenuation for 500m distance is -20.25dB. The calculations are made by using equation 2.3. Figure 2 shows the BER versus rain attenuation (dB) for 300m and 500m distances. It shows that the higher distance results the higher rain attenuations and higher BER value that becomes the worse of signal performance. FSO transmission in 300m distance results lower rain attenuations and lower value of BER compared to 500m distance. For FSO transmission in 300m distance, with the value of rain attenuation -12.25dB, the value of BER is about 10^{-138} while the BER value for FSO transmission in 500m distance with rain attenuation value -20.25dB is 10^{-2}. From the graph, the link still can tolerate above -20dB of rain attenuation of 300m distance with about 10^{-25} of BER value while for 500m, it can tolerate above -18dB, $10e^{-12}$ of BER value in order to receive quality of signal.

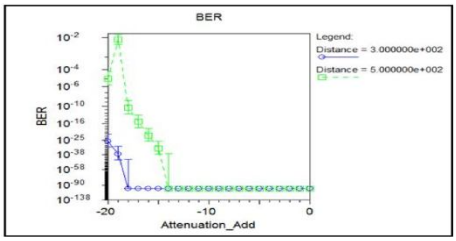


Figure 2 BER versus rain attenuation (dB) for 300m and 500m distances

Figure 3 shows the comparison of eye diagram between 300m distance and 500m distance in FSO transmission system. Eye diagram for 300m has wider eye opening compared to 500m distance because of the attenuation value of 500m higher than 300m which is -12.25dB compared to -20.25dB. The noise margin and sensitivity to timing error in eye diagram of 300m distance is larger than 500m distance. Besides that, the timing jitter of 300m distance also shows sharper than 500m distance.

From the graphs, the maximum amplitude of received signal for 300m distance is about 0.0108V while the maximum amplitude for 500m distance is about 0.00068V. The weakness of received signal in 500m distance because of the higher rain attenuation values compared to 300m distance.

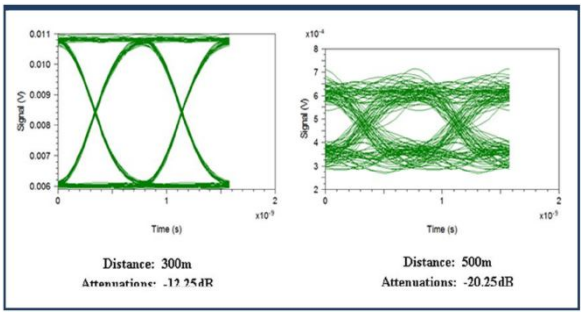


Figure 3 Comparison of eye diagram between 300m and 500m distances

Figure 4 shows the comparison of optical signal analysis between 300m and 500m distances. These optical signal pulses are measured after atmosphere block channel or before the signal enter to the compound optical receiver block that consists PIN, amplifier and filter.

More ripple produce in 500m distance of pulse signal compared to 300m distance in the graph because of the attenuation value in 500m distance is higher than in 300m distance.

The graph also shows that the maximum optical power received for FSO transmission in 500m is about -29dBm while for 300m distance is about -16dBm. The attenuations and noise at atmosphere

channel transmission influenced the degradation of the power received signal.

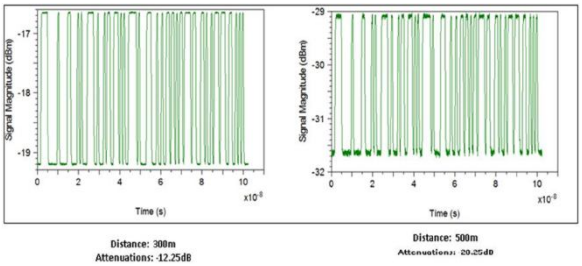


Figure 4 Comparison of optical signal analysis between 300m and 500m distance

For spectrum analysis, Figure 5 shows the optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission in 300m distance while Figure 6 shows the optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission in 500m distance.

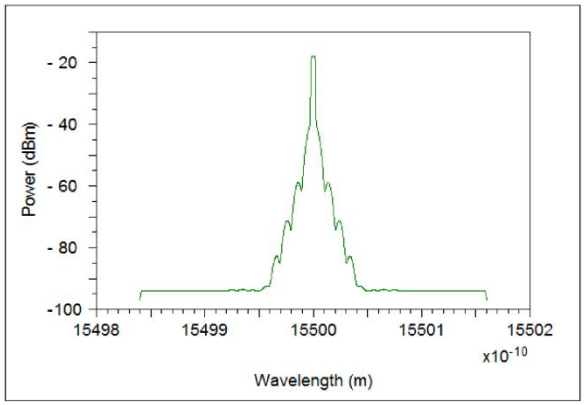


Figure 5 Optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission in 300m distance

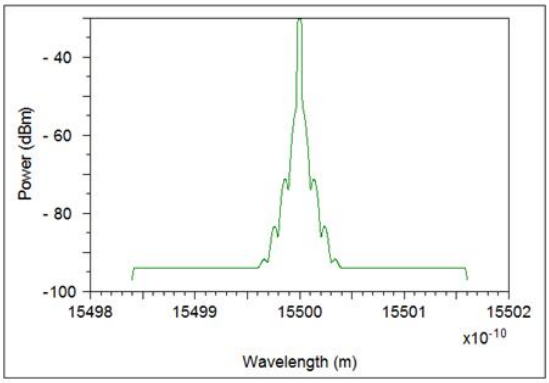


Figure 6 Optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission in 500m distance.

Link margin can be calculated to prove the power received with the spectrum graph as shown in calculation step below;

Power Transmit: 15dBm
Sensitivity: -10dBm
Rain Attenuations: -12.25dB (for 300m) and -20.25dB (for 500m),
Geometrical Loss as stated in equation (2.4) [13];

Beam Divergence: 0.17rad
Distance: 300m and 500m
Surface Receive Area: 180m^2

Therefore, Geometrical Loss: -10.55dB (for 300m distance) and -15dB (for 500m)
From equation 2.1 [13];

Link Margin = Power Transmit – Sensitivity – Atmosphere Attenuation (Rain) - Geometrical Loss [3.2]

Figure 7 shows the optical power at receiver (dBm) versus rain attenuations (dB) for transmission distances of 300m and 500m. The received optical power for 300m distance is higher compared to at 500m distance. For example, at rain attenuation value of 0dB, 300m distance received 0dBm compared to 500m receive about -10dBm.

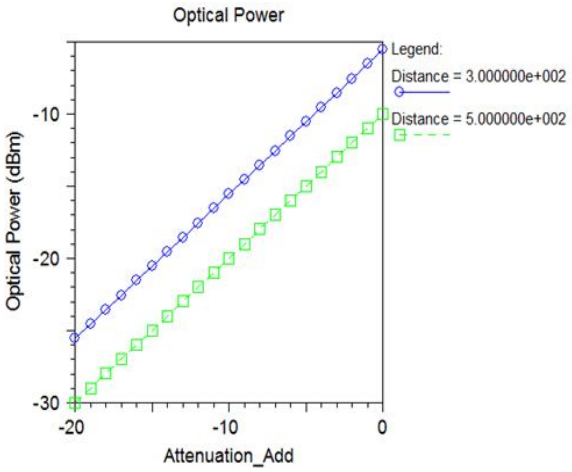


Figure 7 Optical power received (dBm) versus rain attenuations (dB) for transmission distances of 300m and 500m

In haze condition, the comparison of signal performance between FSO transmission on September 2007 and June 2013 are made because to analysis the affection of air quality disaster due to Sumatra forest in June 2013 in FSO transmission and compared with haze condition in September 2007, considering as free of air quality disaster. The analyses of signal performance comparison are made based on eye diagram, optical signal pulse analysis and spectrum signal analysis.

Figure 8 shows the comparison of eye diagram between haze condition for FSO transmission on June 2013 and September 2007 for 500m distance in FSO transmission system. Eye diagram for FSO transmission on September 2007 has wider eye opening compared to transmission on June 2013 because of the attenuation value on June 2013 is higher than on September 2007, -17dB compared to -1dB respectively. The weakness of received signal on

June 2013 compared to on September 2007 can be shown by looking the noise margin, sensitivity, timing jitter and amplitude between both eye diagrams. The noise margin and sensitivity to timing error in eye diagram for on September 2007 distance is larger than on June 2013. The timing jitter of eye diagram on September 2007 also shows sharper than on June 2013.

From the eye diagram, the maximum amplitude of received signal by transmission on September 2007 is about 0.052V while the maximum amplitude for June 2013 is about 0.0011V. It shows the degradation on performance of signal for transmission FSO on June 2013 compared to on September 2007 due to higher haze attenuation value on Jun 2013.

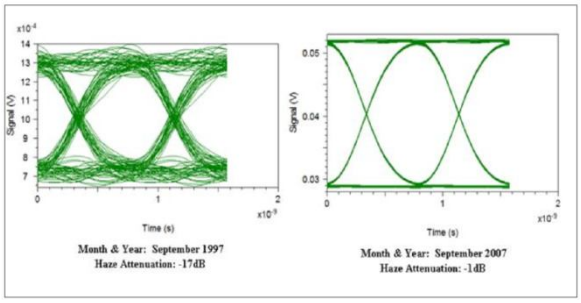


Figure 8 Comparison of eye diagram between the haze condition on June 2013 and September 2007 for 500m distance

The comparison of signal performance between haze condition on June 2013 and haze condition on September 2007 also can be done by the analysis the graphs of optical pulses. Figure 9 shows the comparison of optical signal analysis between haze condition on June 2013 and haze condition on September 2007. It shows that many ripple shown if transmit signal on June 2013 compare to if transmit the signals on September 2007 in FSO transmission system. The optical power received on June 2013 also lower compared to on September 2007 where the value of power optical received on June 2013 is about -26dBm while on September 2007 is -10dBm.

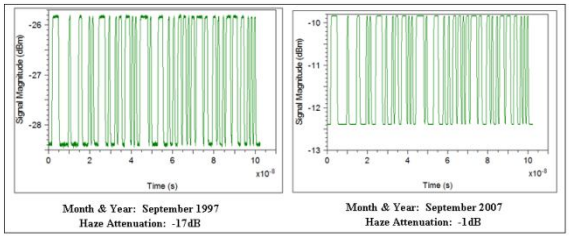


Figure 9 Comparison of Optical signal analysis between haze condition on June 2013 and haze condition on September 2007

For spectrum analysis, Figure 10 shows the optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission on June 2013 while Figure 11 shows the optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission on September 2007.

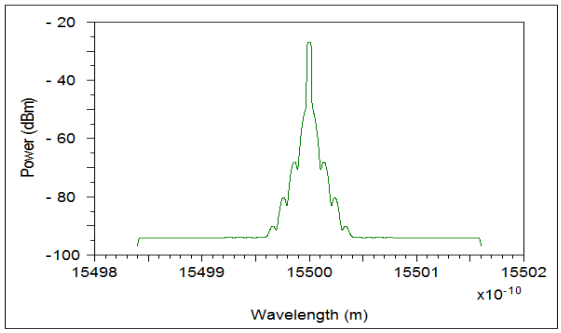


Figure 10 Optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission on June 2013

Link margin can be calculated to prove the power received with the spectrum graph

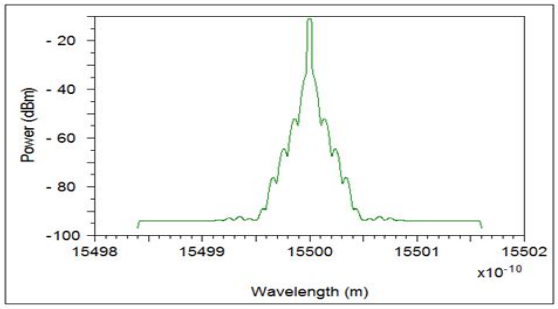


Figure 11 Optical power (dBm) versus wavelength (m) of spectrum analysis for FSO transmission on September 2007

CONCLUSION

It is shown that the performance of FSO system has been access in terms of degradation through haze and rain attenuation of weather conditions which considering transmission in short distance in urban area. From the information studies on weather conditions in Petaling Jaya region on June 2013 and September 2007, the air quality disaster on Jun 2013 influence the signal performance and produce higher haze attenuations. From eye diagram, optical signal pulse analysis and signal spectrum analysis between FSO transmission on June 2013 compared to transmission on September 2007 shows that the signal received by FSO transmission on June 2013 is worse than transmission on September 2007. It is found that the longer distance in rain conditions produce lower performance of quality signal. The transmission for 300m distance produces lower BER value than transmission for 500m distance. The BER value of rain condition for transmission in 500m distance in year 2010 is 10^{-2} where that high value can cause the low quality of received signal as shown from graph of eye diagram, optical signal analysis and signal spectrum analysis.

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