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PERFORMANCE ANALYSIS OF FSO WITH HAZE ATTENUATION CONSEQUENCE ACCLIMATIZE IN TROPICAL RAINFOREST ENVIRONMENT

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ABSTRACT

Free Space Optic (FSO) is an attractive link communication due to its outstanding capability to fulfil rapid demands in today's technology era. The bandwidth and speed FSO possess is similar to fiber optics. However, FSO is highly preferred than fiber optics. This can be seen in comparing the point of the deployment time frame and cost effectiveness. However, since the atmosphere is the transmission medium for FSO, the connection may be attenuated as atmosphere condition varies. The attenuation is due to climate vulnerability and it will distort the FSO link performance especially rains and haze since this type of weather occurring throughout the year in tropical temperate region. This paper is focused on the analysis of haze attenuation with real visibility data from meteorological departments for the mid-year 2012 until mid-year of 2013 and constructs the tropical haze attenuation model especially the maximum range of FSO system deployment. Here, low and moderate visibility was concentrated more in this research due to worst condition for FSO link. The data used is analysed with theoretical part and simulated using Optisystem software 6.0 version and validated with experimental part (lab scale). Observation performance is characterized through bit error rate (BER) synchronization and power received with related to the link range relationship.

Keywords: free space optics, communication, high data rate, attenuation, haze attenuation, optisystem, bit error rate.

INTRODUCTION

In today's increasing demand, especially on last mile problems which are based on microwave communications technology in a point of bandwidth limitations and security need to be highlighted. The need for transferring large amount of data was increased day by day (Boncho, 2013). Fiber optics was known as an outstanding solution to outcomes problems. However, there are several disadvantages that make fiber optics a second choice. This is due to the high cost of deployment and the time taken for installation. Hence, the alternative solution that is compatible to this issue is FSO system design (Nistazakis et al., 2009).

FSO communication provides point-to-point data rate transfer by adapting visible or infrared laser light transmission of broadband communication through free atmosphere or wireless communication (Suriza et al., 2011). It provides high data rates that relate to unregulated bandwidth provided by optical wireless communication channels. For example, light frequencies required very high bandwidths to make it possible in achieving very high data rates (Al-Ghailani et al., 2012). FSO is also suitable for the last mile solutions that give unlimited bandwidth and no need a licensed. However, FSO link quality in performance was difficult to achieve due to uncontrollable factors such as weather effect, since the FSO link was vulnerable to the atmosphere (Alma and Khateeb, 2008).

The FSO system channel was placed in the troposphere region, where the part of the most of atmospheric phenomena occurred (Oliver et al., 2006). The modulated signal transmission was enormously affected by atmospheric attenuation such as absorption, turbulence, and scattering. Scattering can be defined in three groups which are Rayleigh scattering, Mie scattering, and non-selective scattering (Prashant, 2008). This paper concentrates on Mie scattering conditions. Mie scattering takes place when there are some spherical molecules exists in the atmosphere with similar or greater diameter than the wavelength of radiation such as existing fog and also haze. The scatter wavelength is longer than Rayleigh scattering. All of the attenuation mentioned above was being the overall effects that contribute to the FSO performance degradation.

In this tropical temperate region, fog is negligible because obviously fog is not the main phenomena when comparing with haze. Haze Elements were formed by combination of tiny salt crystals and dusts with a diameter range from 0.02 μm to 2 μm. The existence of haze was related to visibility. Visibility refers to the possible maximum range that the normal eye can discern.

LASER BIT COMMUNICATION AND SYSTEM PARAMETERS

FSO system uses laser bit in signal transmission. The laser diode acts as a light source and transmits a signal to a photo detector or receptor diode. High power required in this system in order to across the atmospheric phenomena such as rain, haze and fog. Nonetheless, the usages of power need to be limited when considering the eye safety. Laser bit contributes high transmit power and it was high sensitivity so that the receiver has high capability to sense the delight emitted from the isolated area.

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Laser bit was reliable in terms of cost effectiveness since its transmission can have up to 2 Mbps to 1 Gbps in a clean atmosphere. This system also can be an added advantage for the factories or other industrial companies which required a connection in river crossing or other obstacles because no cables need to be installed. This laser bit FSO devices use transmission methods with no latency of the transparent and wire speed data. No frequency licenses required since the system only use infrared light in the transmission medium. In addition, radio magnetic interference and electromagnetic will not give any effect to the transmission. In order to be more robust and protected from sunlight, the housing was strapped with metal.

The system conditions will be the main issues which give an influence to the system transmission quality. The system characteristics depends on the parameters of laser transmission power, diameter of transmitter aperture, the diameter of receiver aperture, beam divergence, output wavelength, load resistor, and bandwidth. Table-1 summarized the equipment parameters and its characteristic at a certain distance used in this research.

Table-1. Equipment parameters.

Parameter	Characteristic
Laser Power Transmit, P	1 mW / 0 dBm
Transmitter Aperture Diameter, d_T	5 cm
Receiver Aperture Diameter, d_R	20 cm
Beam Divergence, θ	2 mrad
Output Wavelength, λ	1550 nm
Resistance of Conductor, R	1030 Ω
Bandwidth, Δf	622 Mbps

MATHEMATICAL MODEL AND SIMULATION DESIGN

The theoretical part was based on the mathematical model for a haze attenuation equation, received power, signal noise ratio (SNR) and BER whereby the simulation part presented in simulation design using software Optisystem with version of 6.0.

Mathematical model

Visible condition can be characterized in three main levels, which are low visibility, moderate visibility, and high visibility. Referring to meteorological department, low visibility was in the distance of less than 6 km, whereby the moderate visibility was in range of 6 km to 50 km visibility and higher than 50 km was defined for high visibility (Rahman, 2010).

The haze attenuation is given as equation (1) from (Rahman, 2010)

$$\tau(R) = 10 \log e^{\beta R} \qquad (1)$$

where β is scattering coefficient. Equation (2) determines the scattering coefficient (Rahman, 2010) in hazy days.

$$\beta = -\left(\frac{3.91}{V}\right)\left(\frac{\lambda}{550\,nm}\right)^{-q} \qquad (2)$$

Where $q = 1.6$ for high visibility (V>50 km)

$q = 1.3$ for moderate visibility (6 km<V<50 km)

$q = 0.585V^{\frac{1}{3}}$ for low visibility (V<6 km)

V = Visibility (km)

R = Link range/Distance (km)

λ = Wavelength (nm)

When atmospheric attenuation happens, there is an additional loss occurring which being the factor of power losses during transmission which is geometric losses which occurring due to the transmitted beam spread between the transmitter and the receiver. Geometric loss refers to the ratio of the surface area of the receiver aperture diameter to the surface area of the transmitter aperture beam divergence at the receiver. Geometric loss is depending on the divergence and range with formula stated as (Al-Khateeb et al, 2011).

$$GeometricLoss = \frac{d_R^2}{(d_T + \theta R)^2} \qquad (3)$$

Where d_R = Receiver aperture diameter (m)

d_T = Transmitter aperture diameter (m)

θ = Beam divergence (mrad)

R = Link range/Distance (km)

From attenuation and geometrical loss, the equation of power received can be constructed as in equation (4) (Alexander et al., 2012).

$$P_{Received} = P_{Transmitted}\left(\frac{d_R^2}{(d_T + \theta R)^2}\right)\left(10^{\beta R}\right) \qquad (4)$$

The received power usually large enough so that the signal current can control the dark current and also the background noise. Thus, the noise could consider typically shot noise and thermal noise. To measure the direct detection receiver performances, the SNR is outlined as the ratio of signal power to the noise power as in equation (5) (Sugianto, 2006).

$$SNR = \frac{(RP_R)^2}{2qi_s\Delta f + \frac{4kT\Delta f}{R}} \qquad (5)$$

In telecommunication transmission, the BER is a percentage of errors in bits to have a retransmission of packet data. In this paper, the analysis has been

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characterized through BER of 10^{-9} which means that out of 1,000,000,000 bits transmitted to the channel, there will be one error. The higher the BER may indicate the slower the data rate (Yaochau, 2005).

$$BER = \frac{1}{2} erfc\left(\frac{SNR}{2\sqrt{2}}\right) \quad (6)$$

FSO system simulation layout

Figure-1 shows the FSO system design for simulation layout. It consists of a transmitter with laser diode as a light source and Mach Zehnder Modulator, followed by FSO channel with 1 km link range and receiver part. Wavelength of laser diode was set up at 850 nm. Modulator in transmitter part was assigned to randomly transmit the bit through the channel to the receiver. This process will be conducted by pseudo random bit sequence (PRBS) generator. Positive Intrinsic Negative (PIN) photo detector used in this research as PIN has low dark current compared to Avalanche Photodiode (APD) (Azadeh, 2009; Ron et al., 2005). PIN also cheaper compared to APD and less sensitive to the temperature. A photo detector functioned as converting element from the received optical signal into an electrical signal. The signal then crosses the amplifier and filter. The unwanted signal will be filtered via 3R Regenerator and select the desired range of frequencies. At the end of the receiver part, the output of the signal sent to the BER analyzer to be analyzed and power meter measured the received power.

EXPERIMENTAL SETUP (LAB SCALE)

The equipment used in this FSO system experiment included laser diode, laser power, attenuator, receiver lens, and power meter. Figure-2 presents the complete equipment setup. The actual picture of each equipment was present in Figure-2(a), Figure-2(b).

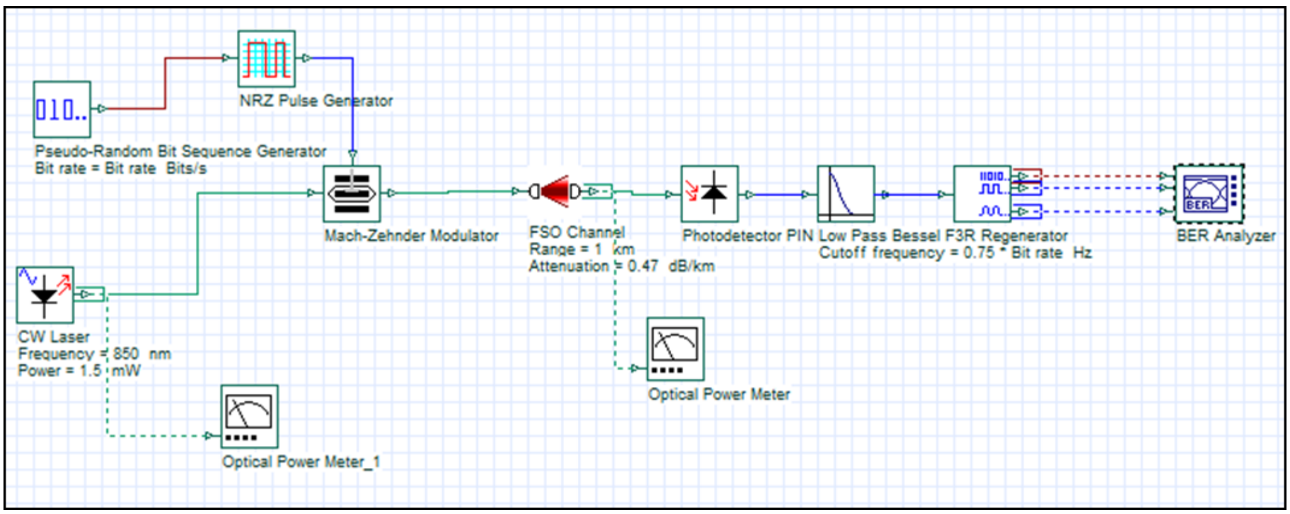

Figure-1. Simulation layout for FSO system design using Optisystem Software.

Figure-2. Full equipment setup.

Figure-2(a). Transmitter (Laser Diode) and receiver (receiver lens),

Laser light will be transmitted from the laser diode after turning on the laser power. Without attenuator, the emitting laser light will be set up directly to the center of the receiver lens to make sure the signal arrives to the receiver.

The haze attenuation will be customized using an attenuator as in Figure-2(b) which acts as atmospheric attenuation phenomena. Average attenuation for low and moderate visibility will be set using this equipment.

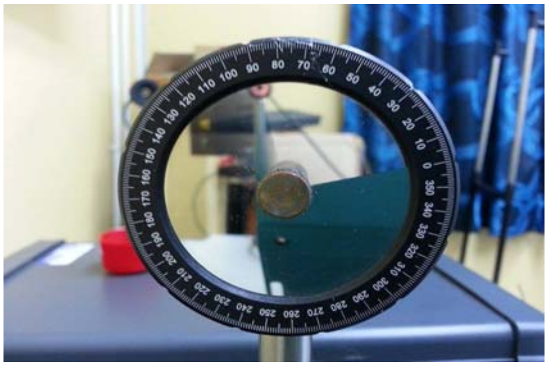

Figure-2(b). Attenuator

DATA ANALYSIS AND RESULTS

The data received from the meteorological department for mid-year of 2012 until mid-year 2013 for each month per hour has been analyzed to investigate the visibility range of mostly occurring in this year. Figure-3 shows that the visibility of 6 km was occurred frequently throughout the year with 105 hours. It means the visibility meter can give a reading of less than 10 km in a year. The haze visibility of less than 6 km is referred as low visibility (worst haze condition); and 6 km to 50 km considered as moderated visibility (Light Haze) [3]. The high visibility assumed neglected because it undoubtedly has no impact on FSO link as shown in Figure-4. It can be clearly seen in Figure-4 that the attenuation was rapidly decreasing with increasing visibility for low visibility (0 – 6 km) and remain steady for moderate visibility after 8 km visibility.

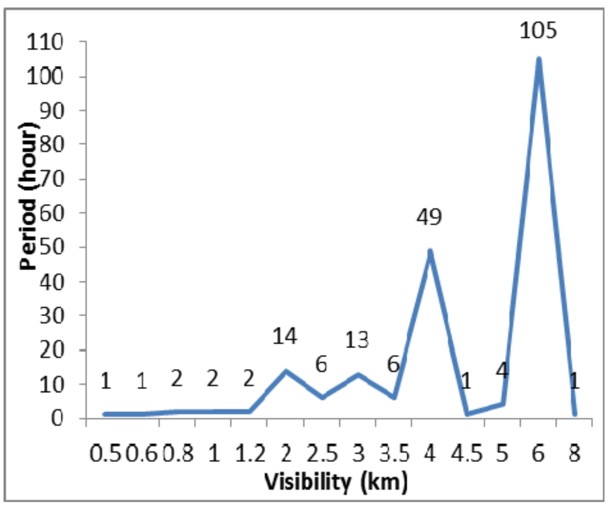

Figure-3. Haze frequency data analysis.

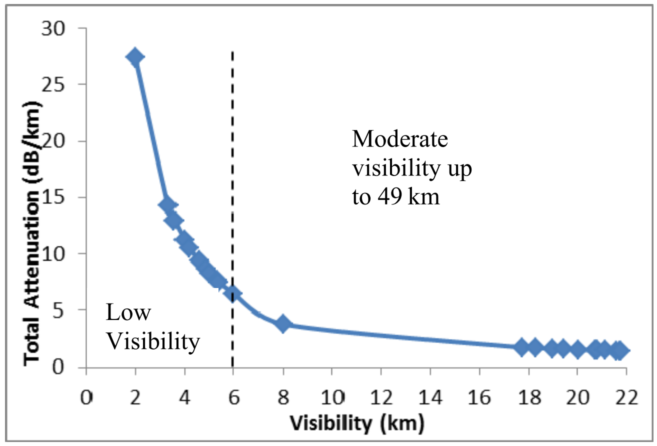

Figure-4. Margin for precipitation attenuation.

Figure-5 shows the BER against link range in kilometers. From this graph, the limitation range from the transmitter to the receiver can be estimated. If the haze value recorded 3 km visibility, the distance between transmitter and receiver should be placed with maximum 2 km. Meanwhile, the visibility of 4 km requiring the system to be deployed in maximum range value of 2.4 km. Whereby the maximum value for 6 km haze visibility in order to have a good performance and clear visibility is 2.9 km. Unfortunately, haze visibility of below than 2 km was assuming the worst condition and the FSO will not be able to occasionally have a good performance. In this situation, The maximum range of an FSO link only can be placed in the range of 1 km to have 0 BER. The review also can be easily observed from Table-2. In this research, the analysation has been made that the system of visibility below than 2.24 km will degrade the system performance.

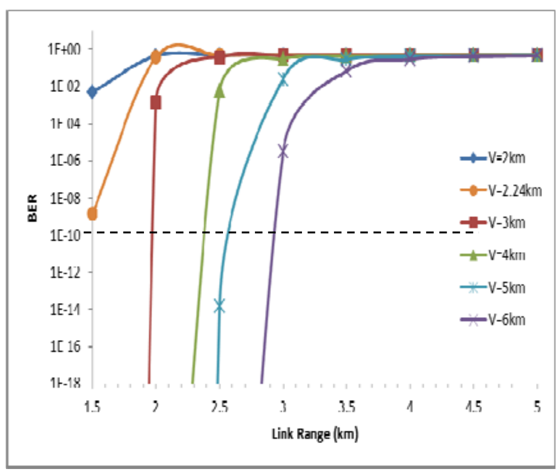

Figure-5. BER verses range (km).

Table-2. Analysis of maximum range verses haze visibility.

Visibility (km)	**Maximum range** (km)
1	0.5
2	1
2.24	1.5
3	2
4	2.4
5	2.6
6	2.9

Figure-6 demonstrates the relationship between BER and FSO link range with various bit rates. The possible maximum visibility that a system can achieve will be a better performance for FSO link system. In Figure-6, the characterization shows the maximum link range of the transmitter and receiver could be placed was 3.9 km which represents a bit rate of 155 Mbps. Bit rate of 10 Gbps did not appropriate for this link of transferring signal because the maximum distance only limited to 2 km. This means pattern in Malaysia shows that low bit rate resulted in better performance. High bit rate leads to high speed but high speed not suitable in this condition because the atmospheric phenomena were unpredictable. High bit rate with bad atmosphere phenomenon will make the system worse. The selection of bit rate also depending on the link range in order to maintain the performance. In a short distance, high bit rate was required while in long distance, need to decrease the bit rate.

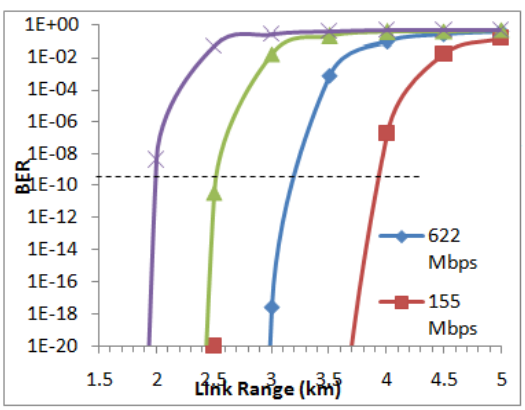

Figure-6. BER versus link range with various bit rates.

The analysis compared the theoretical, simulation and experimental part as shown in Figure-7 to show the difference in receiving power for such attenuation occurred. It has been clearly seen that the higher the attenuation, the lower the power received. It does not have significant changes in comparison of theoretical part and simulation part. It validates that this simulation can be used in this research, but it was rather differ in experimental parts. It may be the limitation of input setup and influence of light and humidity. In addition, the experimental part was only attenuated at the middle part of the transmitter and the receiver which not included the average of attenuation. In this comparison, the parameter was equalized. The power transmits used 1.5 mW, 850 nm frequency in a range of 1 km distance.

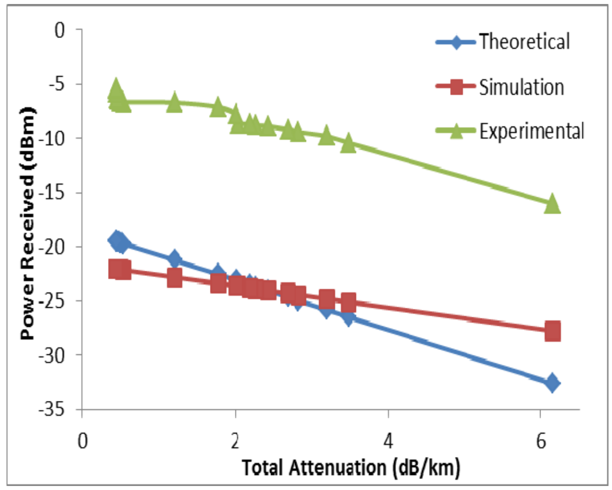

Figure-7. Power received versus total attenuation with comparison the analysis of theoretical, simulation and experimental.

CONCLUSIONS

Analysis of this research has been presented with a model for haze attenuation in tropical region. This study shows that the haze visibility of below than 2.24 km was the worst situation and this can be solved by placing the system in the range of 500 m. In addition, in order to get the optimum bit rate for this link, 622 Mbps was the most suitable bit rate in most cases which not too low and not too high.

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