Analysis of Rain Effect in Free Space Optical Communication under NRZ Modulation in Two Regions of Tanzania

Florence Upendo Rashidi, Senzota Kivaria Semakuwa

Abstract—Free Space Optical (FSO) is an optical communication technology that uses light propagating in free space to transmit data between two points. In Tanzania now days the demand for higher and unlimited bandwidth for communication channel is highly required. For this case the communication through FSO is the best alternative solution than optical fiber. In this paper we are presenting the effects of different parameters to be used in Dodoma and Dar-es -Salaam when transmitting during the rain period. We designed a model of FSO system using OptiSystem to establish an FSO link by a range of 3 to 5 km and 5 to 15 km in Dodoma and Dar-es-Salaam respectively. In the FSO link we have used a Carbonneau model as rain attenuation model, while transmitting the data on NRZ modulation scheme, and reported analysis of various parameters like Bit Error rate (BER), transmission power and transmission length. The simulation results shows, the received signal power decrease while bit error rate increase when increasing transmission length and optical attenuation but is becoming less than 1 and less than 100 dBm respectively when transmitting within the selected range above. The analysis also found that using FSO for communication is better than optical fiber because it can avoid some challenges such as high cost of digging roads, impractical physical connection between transmitters and receivers and insecure of data.

Index Terms— Rain Attenuation, Free Space Optical Communications, NRZ, BER.

I. INTRODUCTION

Free Space Optical (FSO) Communication nowadays is one of the major hot topics in the world of optical and wireless communications. This type of cable-less optical communications technology uses a highly directed narrow light beam to transmit data between two fixed points [1]. It can avoid some challenges facing optical fiber communications such as high cost of digging roads, impractical physical connection between transmitters and receivers. Also, it can be presented to be an alternative or an upgrade for long distance wireless communications systems (up to few kilometers) [2].Some advantages are: No need for licensed frequency band allocation, Easy to install, Absence of radiation hazards of radio frequency, Immunity to interference, High data rates [1, 3]. With the fact that FSO has more advantages, the main factor that limit the FSO link availability is a local weather condition [4]. Since the medium of transmission is free atmospheric attenuation can cost link to attenuate from a few decibels to hundreds of decibels per kilometer.

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In tropical regions with the absence of fog, heavy rain expected to attenuate and distort the signal in the FSO receiver system. [5]. In this paper we analyze the effect of rain in the named two regions by using FSO-NRZ based on Mach-Zehnder modulation technique under Carbonneau model. We have used the rain fall data rate (mm/hour) of the year 2012 for the months of April and December for Dodoma and Dar es Salaam respectively, which obtained from Tanzania Metrological Agency (TMA). In our simulation we have analyzed the effect of rain by altering the transmission distance and optical attenuation under 30dBm transmitting power, while observing received power and BER. The BER, Q factor and received power versus optical attenuation curves are plotted for the two regions. The remainder of the paper is arranged as follows: Section 2 describes FSO-NRZ system model. System model of rain attenuation is dealt in section 3. Section 4 discusses the simulation results and discussion. Section 5 contains the concluding remarks.

II. SYSTEM MODEL

A. NRZ System Model

FSO system basic design has simulated for performance characterization by using optisystem-7. Optisystem-7 is an innovative optical communication system simulation package that design, tests and optimize virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broad casting system to intercontinental backbones. It can minimize the time requirement and decreased overall cost related to design of optical system. The FSO design model is shown in Fig. 1.In our proposed design; FSO has subsystem Transmitter, Propagation channel and Receiver. Transmitter has subsystems data source, NRZ driver, CW laser, Mach-Zehnder modulator. The first subsystem is pseudo-random binary sequence (PRBS) generator, represents the information of data that wants to be transmitted. The output of a PRBS is a bit string consists of a sequence ‘1’ (ON) and ‘0’ (OFF) represents the binary pulses of a reproducible pattern. The output of a PRBS is given to second subsystem is that NRZ driver. This subsystem encodes the data using NRZ encoding technique in which ‘1’ is represented by a significant bit and ‘0’ is represented by another significant bit. The output of a NRZ driver is given to a subsystem Mach-Zehnder modulator which has two input ports, one is electrical input and another is optical input port. A CW laser is connected to optical input port of Mach-Zehnder modulator. The operating wavelength of CW laser is 1550 nm [6]. The 1550nm band is attractive due to its compatibility with the third window and eye safety. Output of

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Mach-Zehnder modulator is given to optical amplifier to increase the gain and traverse through FSO channel which is propagation medium and received at the receiver side. Between the two FSO channels there is Rain attenuation factor which is used to act as rain effect on the FSO system. The beam divergence angle is set to 2mrad. The optical receiver consists of PIN photo diode (PIN) followed by a low pass filter (LPF) [7]. A Bessel LPF is used with a cut-off frequency of 0.75*bit rate of signal. A LPF is used to remove the unwanted high frequency signal. Receiver is used to regenerate an electrical signal of the original bit sequence and bit error pattern is analyzed by using a BER analyzer

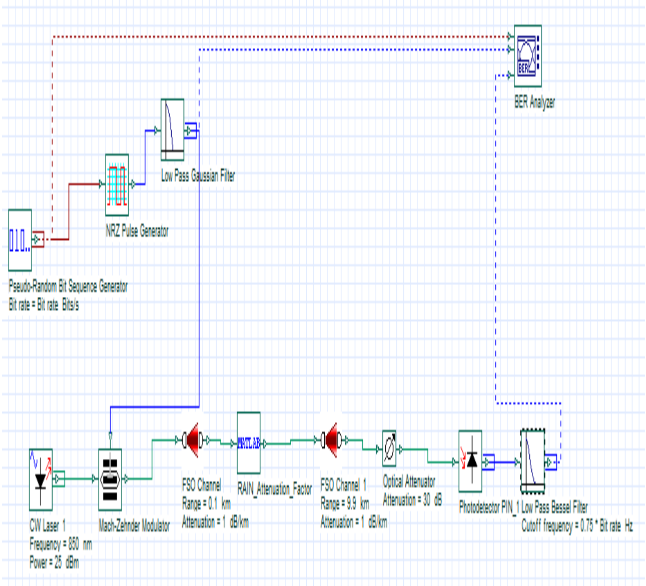

Fig. 1 Block Diagram of FSO-NRZ System Simulation with Rain Effect

B. Rain Attenuation Model

Rain attenuation prediction is normally referred as "specific attenuation" which means attenuation per unit length. In Terahertz wave system like FSO, rain attenuation is particularly severe and greatly dependent on various models of raindrop-size distribution [8]. Analysis on the effect of rain on FSO link can be done by knowing the rain attenuation on FSO links and corresponding rainfall intensity. In our simulation the modeling of rain attenuation prediction was done using Carbonneau model, which its model prediction is

γ (dB/km) = 1.076.R 0.67 (1)

Carbonneau's model proposed values to predict a & b based on measurement done in France [9]. However the measurement done was for high and moderate rain intensities.

III. Simulation Results and Discussion

This work discussed the results obtained from our proposed simulative setup consisting of random generated-NRZ analog data signals transmitted via FSO link under rain condition. The results are investigated over two Tanzanian regions during their heavy rain months, which are April and December for Dodoma and Dar es Salaam respectively using Carbonneau rain attenuation prediction model. It is observed that in Dar es Salaam during heavy rain season data can be transmitted with less BER over a maximum of 10km and being transmitted with a constant BER of 1 above 10km as shown in Fig. 2.

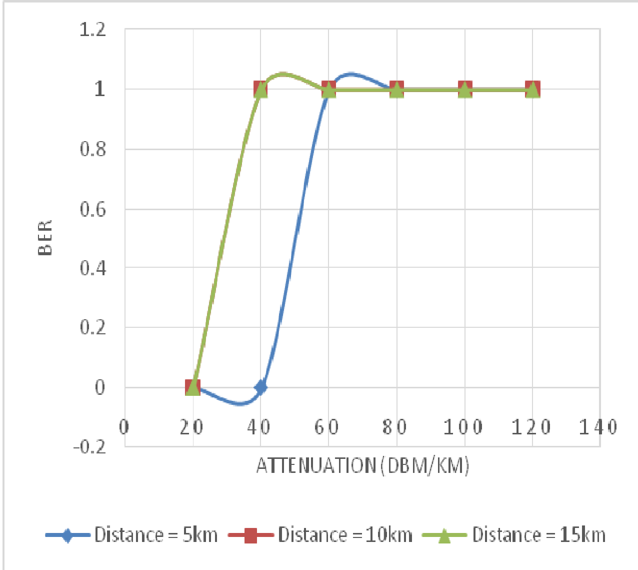

Fig. 2 Bit Error Rate Versus Optical Attenuation under Different Transmission Distance of 5, 10&15 km, Dar es Salaam

In Fig. 3, the graph of Q-factor versus Optical Attenuation, depict that in Dar es Salaam, the data can be transmitted with an Optical attenuation of 60 dBm/km and above, with a constant 0 Q-factor, over any transmission distance. This implies that the BER becomes 1. The received power is decreasing as the transmission distance and optical attenuation increases, but when the transmission distance is 10km, optical attenuation is 80dBm/km and above respectively, the received power is -100dBm as shown in Fig. 4.

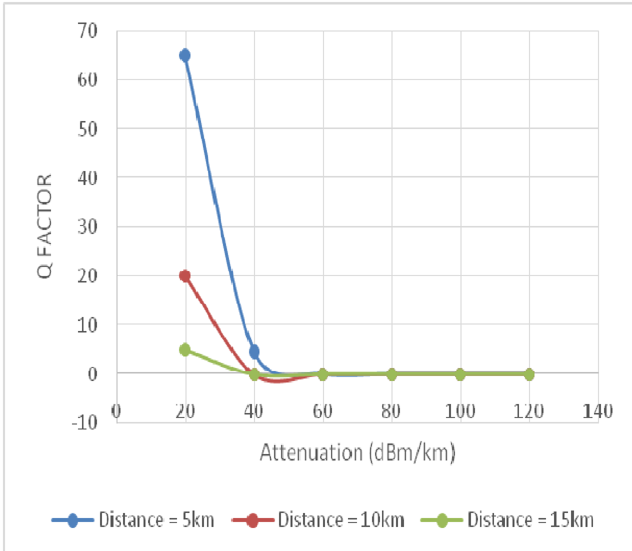

Fig. 3 Q Factor Versus Optical Attenuation under Different Transmission Distance of 5, 10 &15km, Dar es Salaam

On the other side, in Dodoma during heavy rain season data can be transmitted with less BER over a maximum of 5km and being transmitted with a constant BER of 1 above 5km as shown in Fig. 5. The Q-factor versus optical attenuation curve in Fig. 6 shows that, data can be transmitted with less than 1 BER under transmission distance less than 5km using optical attenuation less than 30dBm/km. If optical attenuation is greater than 25dBm/km, data can be transmitted over 10km with a constant Q-factor of 0.

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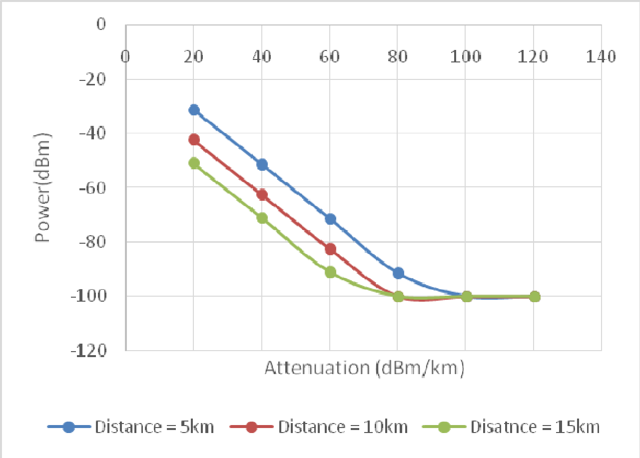

Fig. 4 Received Power Versus Optical Attenuation under Different Transmission Distance of 5, 10 &15km, Dar es Salaam

Fig. 5 Bit Error Rate Versus Optical Attenuation under Different Transmission Distance of 3, 5 &10 km, Dodoma

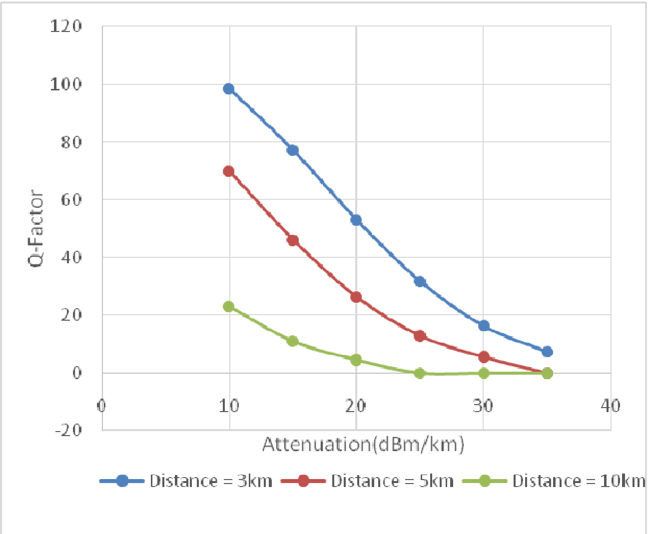

Fig.6 Q Factor Versus Optical Attenuation under Different Transmission Distance of 3, 5&10 km, Dodoma

In Dodoma, transmitting data during heavy rain seasons like month of April, their received power is decreasing as the transmission distance and optical attenuation increases, but with optical attenuation of less than 37dBm, the transmitted data can be received with a power less than -70dBm when transmitting in the distance less than 10km, Fig. 7.

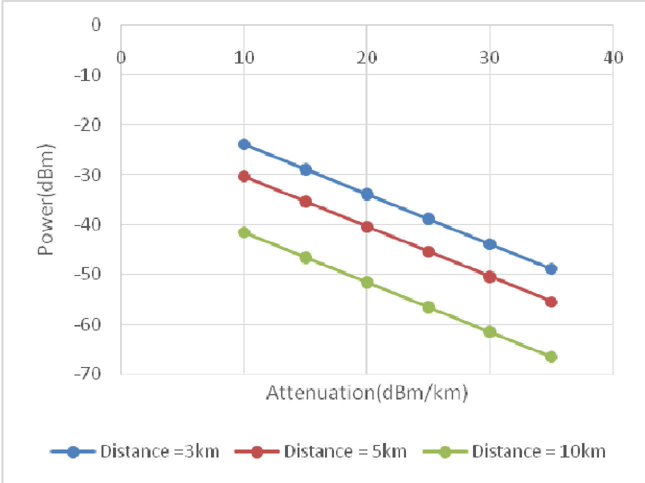

Fig.7 Received Power Versus Optical Attenuation under at Transmission Distance of 3, 5 & 15km, Dodoma

IV. CONCLUSION

In Tanzania, Dodoma during its heavy rain month of April, there is more communication that's why demanding for using FSO is higher. Moreover in Dar es Salaam, which is the biggest city, during December its month of heavy rainfall, communication also is higher. In considering those factors we have analyzed the effect of rain when transmitting over FSO, by simulating the Free Space Optical system under NRZ modulation scheme using Carbonneau Model as rain attenuation model, and 850nm as wavelength. Our study came out with the conclusion that, in order for data to be received with less BER, minimal power loss, they should be transmitted under the optical attenuation of less the 37dBm/km and 80dBm/km in Dodoma and Dar es Salaam respectively. Communication through FSO can be tolerable for the coverage of more than 10km in Dodoma if the transmitting power is more than 30dBm as well as more than 15km in Dar es Salaam, whereas the BER will become 1 constantly and received power become -100dBm.

V. ACKNOWLEDGMENT

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