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Performance Analysis of Free Space Optical Communication Under the Effect of Rain in Arusha Region, Tanzania

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***Abstract*—Free Space Optical (FSO) is an optical communication technology that uses light propagating in free space to transmit data between two points. Arusha being a tourist city 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 proposing the use of FSO communication by presenting different parameters to be used in Arusha when transmitting data during the heavy rain period months, especially April and November. We designed a model of FSO system using OptiSystem to establish an FSO link by a range of 3, 7,11,15,18, and 20 km. In the FSO link we have used a Marshal & Palmer model as rain attenuation model, while transmitting the data on NRZ modulation scheme, and reported analysis of various parameters like transmission power, Bit Error rate (BER),and transmission length. The simulation results shows, for better transmission of data during the heavy rain seasons of the mentioned months above, the transmitting power of 30dBm should be used. This power can be implemented within 7 to 17km of the FSO links with an acceptable BER of less than 1. Also for the transmission links of less than 5km and less than 10km, a transmission power of 10dBm and 20dBm can be used respectively. 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.**

Keywords—FSO; NRZ; Rain Attenuation;BER

I. INTRODUCTION

Arusha is a city in northern part of Tanzania, which is surrounded by some of Africa's most famous landscapes and most of the national parks like Serengeti, Ngorongoro Crater, Lake Manyara, Olduvai Gorge, Tarangire National Park and The Arusha National Park on Mount Meru. Despite its proximity to the equator, Arusha's eleveation of 1400 metres on the southern slopes of Mount Meru keps temperatures relatively low and alleviates humidity. Apart from that, is a major international diplomatic hub, where by its hosts and regarded as the defacto capital of the East African Community. Due to presences of those landscapes and national parks, Arusha become the most visited city in Tanzania by many tourists. To rise attraction of many tourist, Arusha requires to have better means of communications, whereas transmission of information should be better even during rain seasons. To account for this, transmitting through Free Space Optics should be considered, because; 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. 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 the survey of existing optical fiber have been presented and the analysis of rain effect in the named region by using FSO-NRZ based on Mach-Zehnder modulation technique under Marshal & Palmer model to the proposed system have been done. We have used the rain fall data rate (mm/hour) of the year 2002-2012 for the months of April and November, which obtained from Tanzania Metrological Agency (TMA). In the simulation we have analyzed the effect of rain by altering the transmission distance and transmitting power under 17dBm optical attenuator, while observing received power, Q-factor and BER. The BER, Q factor and received power versus optical attenuation curves are plotted for clear analysis.

The remainder of the paper is arranged as follows: Section II describes Optic Fiber System. Proposed System model is dealt in section III. Section IV discusses the simulation results and discussion. Section V contains the concluding remarks.

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II. THE OPTIC FIBER SYSTEM

An Optical fiber is a flexible, transparent fiber made of extruded glass or plastic, slightly thicker than a human hair, it can function as a waveguide or light pipe to transmit light between the two ends of the fiber. Optical fibers are used extensively for data transmission systems because of their dielectric nature and their large information-carrying capacity [6]. Apart from having those advantages above an optical fiber have some drawbacks like actual loss of light as travels through the fiber, maximum limitation of the bandwidth of the signals that can be carried [7]. Also Optical fiber has high cost of digging roads, impractical physical connection between transmitters and receivers. On considering those factors

III. PROPOSED FSO SYSTEM MODEL

A. FSO-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 [8]. 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 [9]. The 1550nm band is attractive due to its compatibility with the third window and eye safety. Output of 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) [10]. 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.

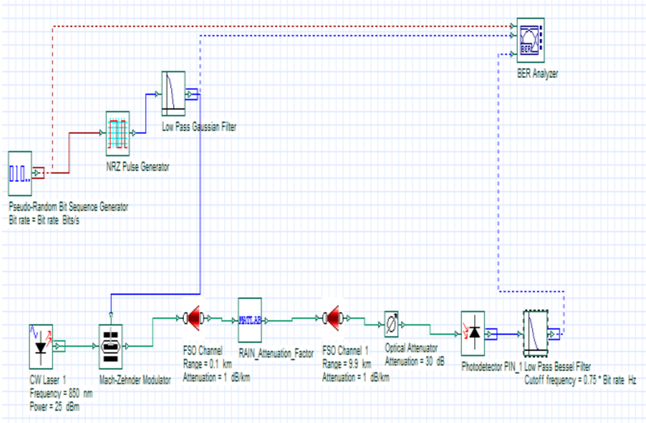

Fig. 1 Block Diagram of FSO-NRZ system simulation with rain effect

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 [11]. The most commonly used raindrop size distributions that have been proposed are Marshal and Palmer [12]. Marshal and Palmer distribution proposed renowned empirical expression by fitting their data and the Laws and Parsons data. The specific attenuation of wireless optical link for rain rate of R mm/hr is given by (1)

$$\gamma(\text{dB/km}) = a.R^{b}, \qquad (1)$$

Where a & b are power law parameters equal to 0.365, 0.63 respectively.

The power law parameters depend on frequency, rain drop size distribution and rain temperature. For the purpose of calculating the attenuation, it is adequate to assume that raindrops have spherical shape. This assumption makes a & b independent of polarization [6].

TABLE 1. RAINFALL RATE DATA OF ARUSHA FOR THE MONTHS, APRIL AND NOVEMBER FROM 2002 TO 2012 AS ACQUIRED FROM TMA.

	APRIL		NOVEMBER	
Year	Rainfall (mm)	RainRate (mm/hr)	Rainfall (mm)	RainRate (mm/hr)
2002	220.2	0.30583	36.8	0.05111
2003	39.4	0.05472	18.1	0.02514
2004	97.1	0.13486	29.3	0.04069
2005	130.1	0.18069	86.5	0.12014
2006	274.6	0.38139	281.5	0.39097
2007	112.3	0.15597	59.5	0.08264
2008	289.6	0.40222	91.8	0.12750
2009	123.8	0.17194	144.9	0.20125
2010	322.4	0.44778	98.9	0.13736
2011	51.1	0.07097	38.7	0.05375
2012	233.0	0.32361	211.2	0.29333

IV. SIMULATION RESULTS AND DISCUSSION

This section 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 Arusha region in Tanzanian during its heavy rain months, which are April and November from year 2002 to 2012, using Marshal & Palmer rain attenuation prediction model as shown in Table 1. It is observed that in Arusha, during heavy rain month of April, data can be transmitted with less BER over a maximum of 15km under the transmission power of 30dBm as shown in Fig. 2.

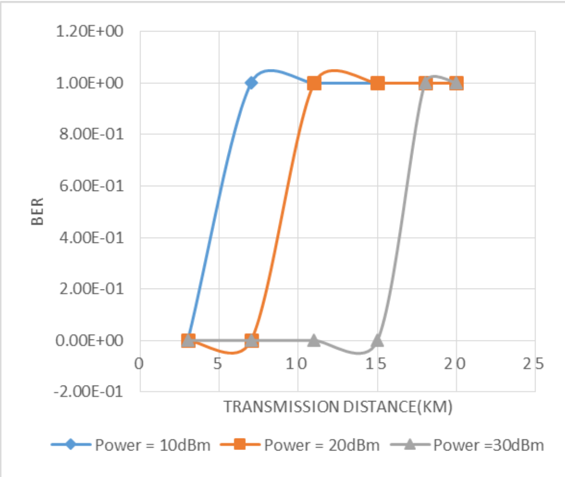

Fig. 2. Bit Error rate versus transmission distance under different transmission power of 10, 20 & 30dBm, April

In Fig. 3, the graph of Q-factor versus transmission distance, depict that in Arusha April, the data can be transmitted with a transmission power of 30 dBm and with a constant 0 Q-factor, over transmission distance of 15km. This implies that the BER becomes 1 as Q-factor is inversely proportional to BER. The received power is decreasing as the transmission distance increases, but is much less lost when transmitting using a power of 30dBm and above, as shown in Fig. 4.

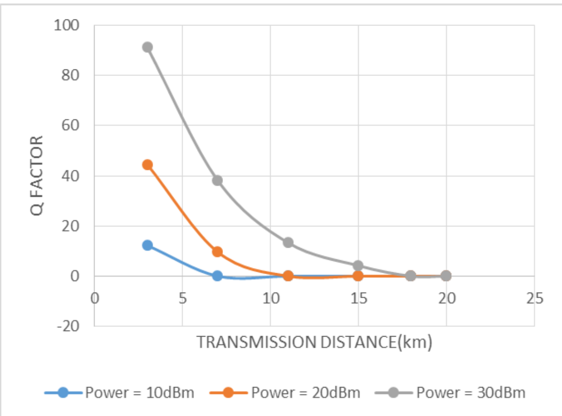

Fig. 3. Q-factor versus transmission distance under different transmission power of 10, 20 & 30dBm, April

Again in Arusha, November data can be transmitted with less BER over a maximum of 15km under the transmission power of 30dBm as shown in Fig. 5. Also the Q-factor versus transmission distance curve in Fig. 6 shows that, data can be transmitted with less than 1 BER under transmission distance less than 15km using transmission power of more than 30dBm. If the transmission power is less than 30dBm then data can be transmitted over 10km with a constant Q-factor of 0.

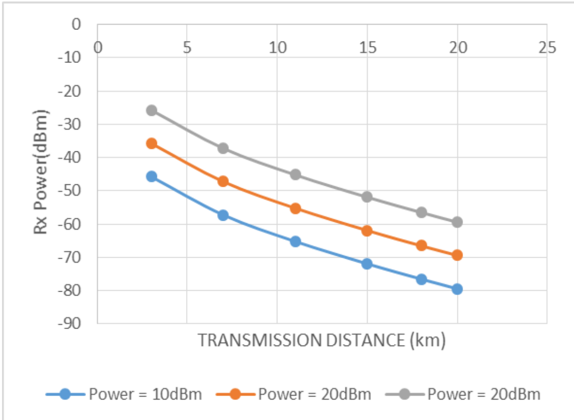

Fig. 4. Received power versus transmission distance under different transmission power of 10, 20 & 30dBm, April.

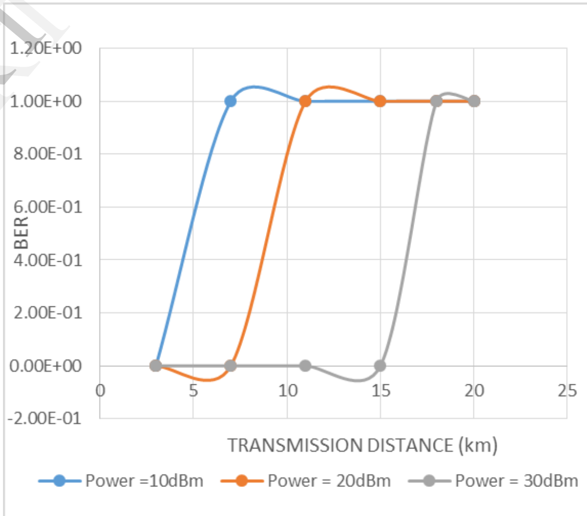

Fig. 5. Bit Error rate versus transmission distance under different transmission power of 10, 20 & 30dBm, November.

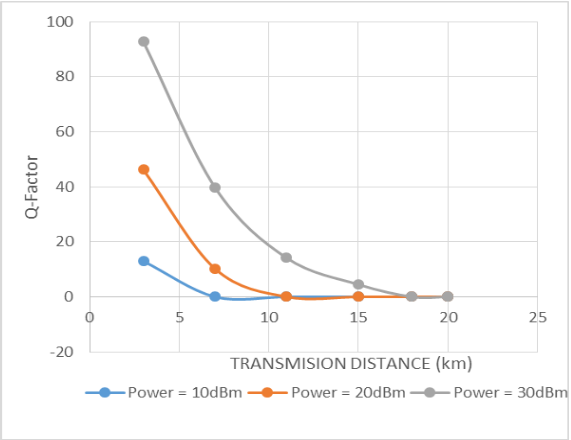

Fig. 6. Q-factor versus transmission distance under different transmission power of 10, 20 & 30dBm, November

In Arusha transmitting data during heavy rain seasons like month of November, their received power is decreasing as the transmission distance increases when transmitting with a power less than 30dBm, but with a transmitting power more than 30dBm, the transmitted data can be received with a power less than -60dBm when transmitting in the distance less than 20km, Fig. 7.

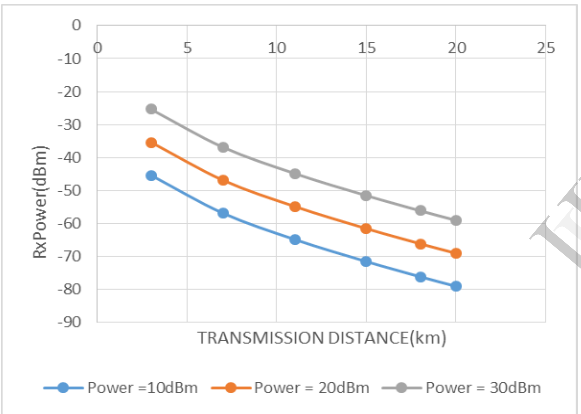

Fig. 7. Received power versus transmission distance under different transmission power of 10, 20 & 30dBm, November.

V. CONCLUSION

In Tanzania, the Arusha City communication is very important factor through all of its months a year, this cause a demanding for using FSO being 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 Marshal & Palmer Model as rain attenuation model, and 1550nm 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 over the transmission power of 30dBm and above, for April and November. Communication through FSO can be tolerable for the coverage of more than 15km in Arusha if the transmitting power is more than 30dBm whereas the BER will become 1 constantly and received power become -100dBm

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