Performance, Monitoring and Analysis of OWC Link at Different Atmospheric Conditions

Deman Kosale, Anita Khanna

***Abstract*—In this paper we present a new and gifted technology Optical wireless communication (OWC) systems. It undergoes from average optical signal power loss and random power fading due to the different atmospheric condition. For focused laser beams along direct line of sight propagation, the averages received optical signal power and Bit Error Rate (BER) as functions of the high data rates and are studied via large scale numerical simulations. In that case we evaluate the performance of OWC we consider a link of distance 500 meter, optical window 1550nm and three different atmospheric condition 10dB/Km, 40dB/Km and 60dB/Km. The VCSEL laser is used for direct line of sight communication and at the receiver side the APD is used for power reception. The NRZ – OOK modulation format is used for laser beam modulation.**

***Index Terms*—Optical Communication Link (OWC), VCSEL, APD, Bit Error Rates, Optical Received Power.**

I. INTRODUCTION

Optical Wireless Communication (OWC) systems are an exciting technology that establishes point-to-point communication links through the atmosphere. They provide high security, low cost, low power, and high rates due to the unregulated bandwidth [4]. Such links are suitable for 1–2 Gbps rates over distances in the range of 1–5 km. Optical signal propagation in free space is affected by atmospheric turbulence and pointing errors, which fade the signal at the receiver and deteriorate the link performance [5]. In this paper, we investigate the receiver power and bit error rate (BER) by using different attenuations. The average transmitted optical power Pt governs the eye safety and electrical power consumption of the transmitter. Hence, the most important criterion for evaluating modulation techniques is the average received optical power P required to achieve a desired BER. We will normalize these received average optical power requirements to those required to achieve the desired BER when transmitting the signal by using OOK modulation over an ideal channel [1].

A transmitter or source converts an electrical signal to an optical signal. The two most appropriate types of device are the light-emitting diode (LED) and semiconductor laser diode (LD). LEDs have a naturally wide transmission pattern, and so are suited to non directed links. Eye safety is much simpler to achieve for an LED than for a laser diode, which usually have very narrow transmit beams. The principal advantages of laser diodes are their high energy conversion efficiency, their high modulation bandwidth, and their relatively narrow spectral width. Although laser diodes offer several advantages over LEDs that could be exploited, most short-range commercial systems currently use LEDs [2].

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In this model we are using vertical cavity surface emitting laser (VCSEL) at a wavelength of 1550 nm. VCSEL Laser transmitting system consists of laser transmitter, laser driver and optical transmitting antenna. Comparing to the conventional semiconductor emitting laser(EEL), the vertical cavity semiconductor emitting laser(VCSEL), as the laser transmitter, its circle thin beam has the advantages of smaller far field angle of divergence and easier to couple into optical fiber. The average power, not the peak power, determines the link margin. Because of their high efficiency, power dissipation is typically not an issue for VCSELs, and active cooling is not required. In addition, VCSEL has the characteristics of low threshold current, high modulating frequency and operating of single longitudinal mode in broad range of temperature and current [6].The APD is used as a receiver with a dark current of 1μA. APD‟s are essentially p-i-n devices that are operated at very high reverse bias, so that photo generated carriers create secondary carriers by impact ionization, resulting in internal electrical gain. APD‟s are favored in direct detection optical receivers when there is little ambient-induced shot noise, because their internal gain helps overcome preamplifier thermal noise, increasing the receiver SNR. APD-based receivers can lead to impressive infrared link performance when ambient light is weak [1].

Atmospheric attenuators like fog, rain, snow, mist and haze severely degrade the system performance. Absorption and scattering of radiation from fog, clouds, dust, snow and smoke cause significant attenuation of a laser beam propagating through the atmosphere. Fog and clouds are typical dominating factors causing atmospheric attenuation over a considerable period of the time. However other factors like rain and snow are generally less significant. Turbulence induced atmospheric scintillation causes several fluctuation in received signal power. Scintillation effects, for Optical Wireless Communication links, can be mitigated by increasing transmission power, wavelength diversity, multiple transmit beam and multiple receiver [3].Turbulence in the atmosphere distorts the FSO signal and limits the data rate that can be transmitted over the link. The proposed link gives the performances at different atmospheric conditions. The main impairing factors for direct line of sight Optical telecommunication, Wireless Communication links are power and fog and thus the primary focus of this paper is to find the values of received power and BER over different attenuations.

II. SYSTEM DESIGN

A block diagram of an FSO communication link is presented in Figure 1. The transmitter modulates data onto the instantaneous intensity of an optical beam.

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In this paper, we consider intensity modulated direct detection channels using OOK modulation, which is widely employed in practical systems.

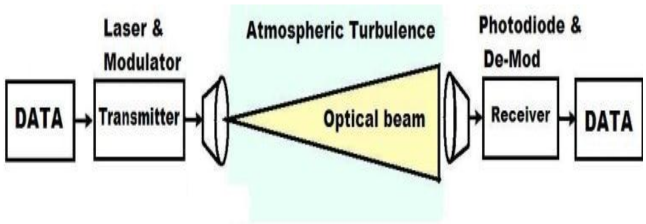

Fig.1 Model of Optical Wireless Communication Link

The technically simplest digital modulation scheme is amplitude-shift keying (2 ASK). In optical systems it is referred to as on-off keying (OOK). OOK is an intensity modulation scheme where the light source (carrier) is turned on to transmit a logic "one" and turned off to transmit a "zero". In its simplest form this modulation scheme is called NRZ (non-return-to-zero)-OOK. Besides NRZ also other codes exist. The most common one besides NRZ is RZ (return to- zero) coding. The advantages of RZ compared to NRZ are its higher sensitivity [7] and the fact that the clock frequency lies within the modulation spectrum. Unfortunately, both NRZ and RZ can lead to loss of clock synchronization if long strings of ones or zeros are transmitted. With such a variant of RZ the clock of the digital signal can easily be recovered. These advantages come at the cost of a requirement of twice the bandwidth of NRZ in order to fulfill the Nyquist–Shannon theorem. That RZ can also work when using the same bandwidth as for NRZ [7]. Table I shows the parameter and their specification taken in to consideration during the simulation.

TABLE1. Technical Specification for OWC Link

Parameter	**Description/ Values**
Transmitter type	VCSEL
Tx. Wavelength	1550 nm
Tx. Optical power	1.3 dBm
Tx. Aperture diameter	180 mm
Link Distance	500 meter
Pd_ APD Multiplier	1.0
APD ionization coefficient	1.0
APD Quantum Efficiency	0.8
Filter Type	LP Bessel
APD Dark Current	1µA
Sigma Add	1.9
Divergence Angle	3mrad
Modulation Type	NRZ
Bit Pattern Type	PRBS
Distribution	Gaussian

III. SIMULATION RESULTS

The signal attenuation in this model is based on the FSO range equation that combines attenuation and geometrical aspects to calculate the received optical power as function of range and receiver aperture size.

$$P_{RX} = \frac{A_{RX}}{\pi\left(\theta/2+L\right)^2} * 10^{-\alpha\frac{L}{10}} * P_{TX} + P_{BG} \ldots\ldots \quad (1)$$

Here P_{RX} is the received signal, P_{TX} - transmitted signal, A_{RX} is receiver aperture area, **θ** - beam divergence angle, T - combined transmitter receiver optical efficiency, P_{BG} - optical power of background radiation, L – link range (500meter), and α – environmental attenuation in dB/km. The first term in parenthesis is a geometrical attenuation due to beam spreading and is calculated for given parameters A_{RX}, **θ**, and L as a ratio of aperture to signal beam cross-section. The atmospheric attenuation α is a not a linear function of distance, it depends on many factors and changes randomly with time. Combining together optical efficiency and attenuation, we can re-write the above equation in the following form.

$$P_{RX} = 10^{\frac{\left[a_{geom} - a_{add}\right]}{10}} * P_{RX} + P_{BG} \ldots\ldots\ldots \quad (2)$$

Where αadd represents total additional attenuation in dB for given distance and is specified with a mean value and standard deviation. According to lognormal model the logarithm of signal intensity is a Gaussian random variable. Hence, the signal attenuation in dB units, αadd, is a Gaussian random variable as well [8].

The BER Bit Error Rate of a system is depends upon the several conditions like distance, bit rates, wavelength and atmospheric turbulences. In our model we have calculated the BER at different data rates (1.0 Gbps to 3.75 Gbps) over three different atmospheric attenuations 10dB/km, 40dB/Km and 60dB/Km. From the figure 2 we can see that the Bit Error Rate is different upto data rates of 1.75 Gbps but when we increase the data rate the BER is increasing rapidly and approaching to same values at 40dB/Km and 60dB/Km. The wavelength is used in this simulation is 1550nm and distance is 500 meters.

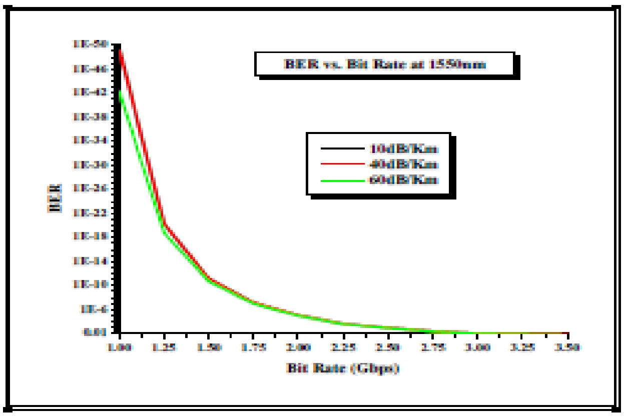

Fig.2 BER vs. Bit Rate at Different Attenuations

Results of receiver power versus bit rates with three atmospheric attenuations are shown in Fig 3, 4, and 5. From these figures we can see the higher is attenuation the received power at receiver side is very less which degrade the system performances.

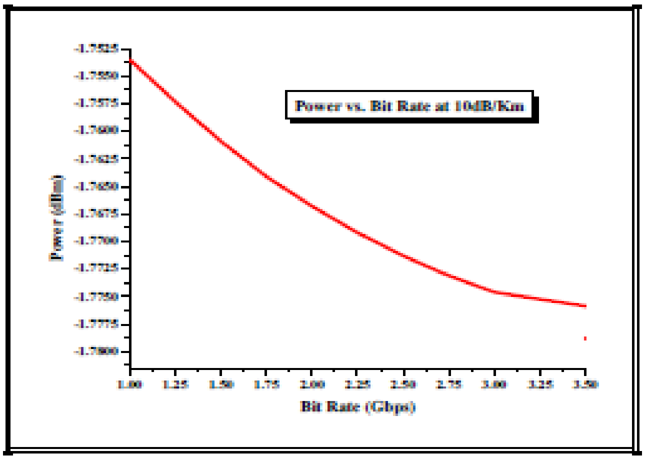

Fig.3 Power vs. Bit Rate at attenuation 10dB/Km.

When the attenuation is very low (10dB/Km) the received optical power is very high (-1.750dBm to 1.780dBm) But at attenuation 40dB/Km the received optical power is vary from -16.750 to -16.780dBm which is shown in fig. 4.

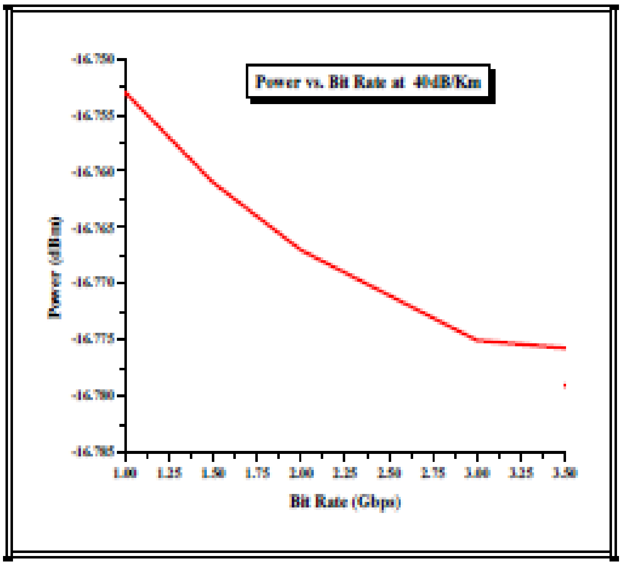

Fig.3 Power vs. Bit Rate at attenuation 40dB/Km

IV. CONCLUSION

This paper has studied the BER and Power performance of the free-space optical Link and experiencing that the Bit Error Rate and Power both are the function of the Data Rates over a defined window 1550nm. From figure 2 we can say that upto1.75 Gbps data rate the BER is less than 10^{-6} but it get higher for higher data rates, that is not acceptable. The figure 3, 4, and 5 shows the relation between received optical power and data rates. The power of all transmission using different attenuation we can easily analyse that after increasing the attenuation the Power at receiver is getting low and degrade system performances, which results that high data rates (more than 1.5Gbps) is also not permissible for the optical wireless communications.

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