Performance Investigation of FSO Link at Different Optical Wavelength Windows

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Abstract— Free-space optics, as the name implies, means the transmission of optical signals through free space or air. Such propagation of optical capacity through air requires the use of light. Light sources can be either LEDs or lasers (light amplification by stimulated emission of radiation). FSO is a simple concept that is similar to optical transmission using fiber-optic cables. The only difference is the medium. Interestingly enough light travels faster through air (approximately 300,000 km/s) than it does through glass (approximately 200,000 km/s), so free-space optical communications could be classified as optical communications at the speed of light. In this paper we will study the FSO System. The paper explains all the necessary details of free space optics link design and discusses the core blocks and parameters associated with FSO system.

Key words: Free Space Optics (FSO), Optics Channel, Rain Attenuation, Rain Rates, Visible Light Communication

I. Introduction

Figure 1 shows the block diagram of an optical communication system through the atmosphere.

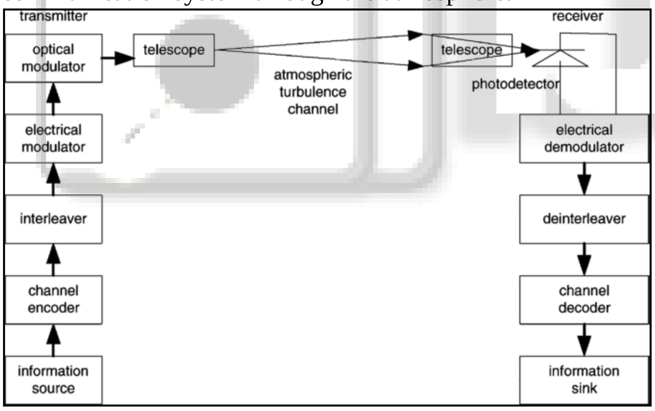

Fig. 1: Block diagram of optical communication system through atmospheric turbulence channel

The information generated by a source is encoded by an encoder, interleaved, and modulated into an electrical waveform by an electrical modulator. In the optical modulator, the intensity of a light source is modulated by the output signal of the electrical modulator. The light source can be a laser or LED, characterized by its wavelength, power, and beam divergence angle. There is a collimator or telescope in the transmitter to determine the direction and the size of the light beam. The receiver consists of an optical front end, a photo detector, a demodulator, a deinterleaver, and a decoder. The optical front end contains lenses focusing the received optical field onto a photo detector. The photo detector converts the received optical field to an electronic signal, which is demodulated. The demodulator output signal is deinterleaved and decoded. The decoded bits are fed into an information sink. In an optical communication system through the turbulent atmosphere, the intensity $P(u, t)$ of the received optical signal can be written as [9]

$$P(u,t) = A(u,t)P_s(t) \quad (1)$$

Where A(u, t) is a stationary random process for the signal scintillation caused by the atmospheric turbulence, u is an event in the sample space, and $P_s(t)$ is the received optical intensity in the absence of turbulence. Let RA(τ) be the autocorrelation function of A(u, t). Assume that $R_A(0)$ is normalized to unity so that the average power of the converted electrical signal is normalized for analysis. When $R_A(0)$ is normalized, the probability distribution of a sample at any time instant is determined by one parameter defined as the scintillation level σ. The bandwidth of the measured power spectral density was less than 1 kHz. The random process A(u, t) in (1) is well known as a log-normal process[6]. Let x(u, t) be a stationary Gaussian random process with the autocorrelation function $R_x(\tau)$, $R_x(0) = \sigma^2$. Then A(u,t) can be Defined as

$$A(u,t) = Ke^{x(u,t)}, k > 0 \quad (2)$$

Which is a log-normal random process. The sample $A(u, t = t_0)$ at any time instant $t = t_0$ is a random variable and has the probability density function (pdf). Observing power at the receiver and calculating the link margin, one can determine factors that affect quality of the link. Link Margin (LM), [1] usually expressed in decibels, is a ratio of the received power P_R and receiver threshold (s), or amount of power received above minimum detectable power:

$$LM = 10Log\frac{P_R}{S} \quad (3)$$

In order for signal to be recovered at the receiver's side, its power must be higher than receiver sensibility or receiver threshold. Receiver threshold is usually given by manufacturer and it ranges from -20 to -40 dBm. Power at the receiver [11] ,[8] can be expressed as:

$$P_R = P_T * \frac{A_{RX}}{(\theta L)^2} * e^{-\alpha L} \quad (4)$$

Where: P_R and P_T are power at the receiver and transmitter respectively, A_{RX} is receiver aperture area, θ divergence angle, α atmospheric attenuation and L distance between transmitter and receiver. [8] Power at the receiver is directly proportional to the transmit power and receiver aperture area, but inversely proportional to the link range and divergence angle.

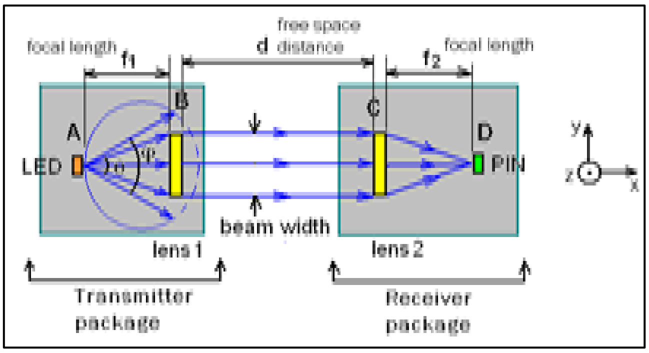

Fig. 2: Optical Link geometry

Exponential part of the equation is related to atmospheric attenuation and it has the strongest influence on the link quality. Another factor that adds to attenuation of the signal is beam divergence. Let us discuss the core blocks of wireless optical communication system in detail.

II. SIMULATION SETUP & RESULTS AND DISCUSSIONS

For designing of Free space optical link a simulation software used is optisystem 7.0. Table 1 given below shows the simulation parameters for 1550nm, 850nm, wavelengths.

Parameters	Values
Laser	CW
Transmitted Power	5mW
Modulation	NRZ
Modulator	MZM
Link Range	500m -1km
Attenuation	16-18dB/km

Table 1: Simulation Parameters for 1550nm, 850nm Wavelengths

Table 2 shows the link performance analysis of the link at 1550nm, 850nm wavelengths.

Wave length(nm)	BER	Q-Factor
1550	10^{-9}	5.6
850	10^{-8}	5.4

Table 2: performance analysis of the link at 1550nm, 850nm wavelengths

The figure 3 shows BER results of the optimized link at 1550nm which confirms that the minimum BER of 10^{-9} and Q Factor is 5.6 of the FSO Link. The figure 4 shows results of eye diagram of the optimized FSO link which confirms that the minimum BER of 10^{-8} and Q Factor is 5.4 of the FSO Link with maximum range of 500-1000 meters.

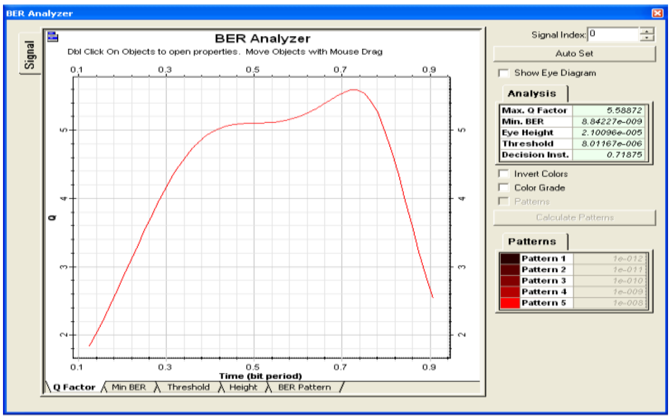

Fig. 3: BER of FSO at 1550nm link

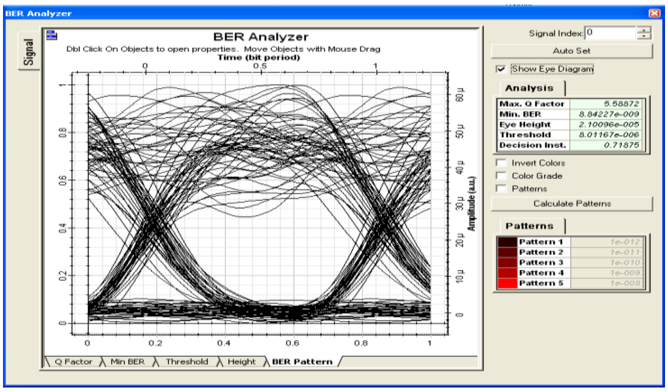

Fig. 4: Eye Diagram of FSO at 1550nm link

III. CONCLUSION

In this paper the characteristics and properties of several important design parameters in FSO communication systems are discussed and the performance degradation by the scintillation. In addition to free space loss, the atmosphere also introduces attenuation caused by either molecular absorption or scattering, and fading caused by optical turbulence. Atmospheric turbulence can cause fluctuations in the received signal level, which increase the bit errors in a digital communication link. In order to quantify the performance limitations, a better understanding of the effect of the intensity fluctuations on the received signal at all turbulence levels is needed. FSO link shows better performance at1550 nm as compared to 850 nm.

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