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Performance Analysis and System Design of the Performance Characterization of Data Transmission on Free Space Optics (FSO) by using Optic System 14.0

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Abstract

In Broadband wireless communication, the free space optical (FSO) communication has emerged as a viable technology and having potential of high bandwidth capacity over numerous optical wavelengths. Our research is based on the FSO system design and simulation study using mathematical and computer program which based on mathematical relationship of weather factors and their impact on the motion of beam to observe the performance of FSO communication systems by studying the result of weather factors affecting the transmission of laser beam carries the information within different ranges. The obtained results and data were identical to scientific publications and were adopted as a inputs for preparation of advanced computer course where output have compared with a software (Optisystem 14.0) which is a program for optical communication system design and used for evaluation and design analysis. This research will help for opening new dimension of electro-optical and optical design.

Keywords*: System design, Data transmission, Free space optics.*

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1. Introduction

Free Space Optical (FSO) communication or Optical wireless communication (OWC) has emerged as a viable technology for next generation broadband wireless applications in different areas of the long and short haul communications space from links of inter satellite to links of inter building. In applying wireless infrared communication, non-directed links, which do not require precise alignment between transmitter and receiver, are desirable. They can be categorized as either line-of-sight (LOS) or diffuse links. LOS links require an unobstructed path for reliable communication, whereas diffuse links rely on multiple optical paths from surface reflections. On the other hand, FSO communication usually involves directed LOS and point-to-point laser links from transmitter to receiver through the atmosphere. FSO communication over few kilometer distances has been demonstrated at multi-Gbps data rates [2]. FSO technology offers the potential of broadband communication capacity using unlicensed optical wavelengths. However, in-homogeneities in the temperature and pressure of the atmosphere lead to refractive index variations along the transmission path. These refractive index variations lead to spatial and temporal variations in the optical intensity incident on a receiver, resulted in the fading. In FSO communication, faded links caused by such atmospheric effects can cause performance degradation manifested by increased bit error rate (BER) and transmission delays [3].

2. Free Space Optical Communication Systems

The major subsystems in an FSO communication system are illustrated in figure 1. A source producing data input is to be transmitted to a remote destination. This source has its output modulated onto an optical carrier; typically laser, which is then transmitted as an optical field through the atmospheric channel. The important aspects of the optical transmitter system are size, power, and beam quality, which determine laser intensity and minimum divergence obtainable from the system. At the receiver, the field is optically collected and detected, generally in the presence of noise interference, signal distortion, and background radiation. On the receiver side, important features are the aperture size and the f/-number, which determine the amount of the collected light and the detector field-of-view (FOV). The modulation of the source data onto the electromagnetic wave carrier generally takes place in three different ways: amplitude modulation (AM), frequency modulation (FM), or phase modulation (PM), each of which can be theoretically implemented at any frequency. For an optical wave, another modulation scheme is also often used, namely intensity modulation (IM). Intensity is defined as flow energy per unit area per unit time expressed in W/m2, and is proportional to the square of the field's amplitude. The light fields from laser sources then pass beam forming optics to produce a collimated beam. This practice is equivalent to providing antenna gain in RF systems [5].

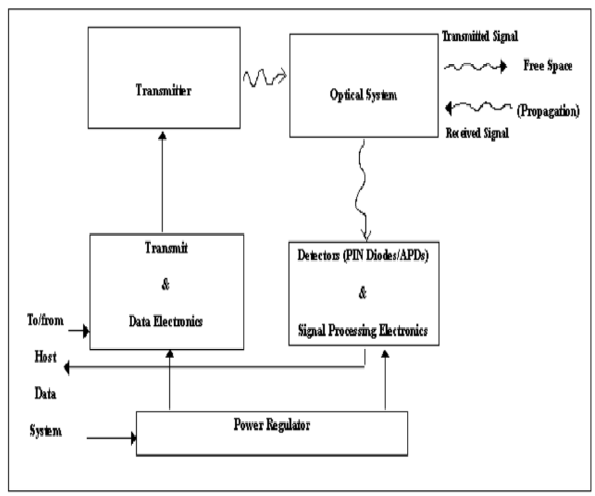

Fig. 1: Block diagram of FSO communication system

There are two basic types of optical receivers: non-coherent receivers and coherent receivers. Non-coherent receivers directly detect the instantaneous power of the collected optical field as it arrives at the receivers, thus are often called direct or power detection receivers. These receivers represent the simplest type of implementation and can be used whenever the transmitted information occurs in the power variation (i.e. IM) of the optical field. Coherent receivers, better known as heterodyne receivers, optically mix a locally generated light wave field with the received field, and the combined wave is photo detected. These receivers are used when information is modulated onto the optical carrier using AM, FM, or PM, and are essential for FM or PM detection. The detection of optical fields is effected by various noise sources present at the receiver. The three dominant sources in FSO communications are: background ambient light, photo detector induced noise, and electronic thermal noise in circuits. Although background radiation may be reduced by the use of optical filtering, it still provides significant interference in the detection process. The detector quantum noise originates from the randomness of the photon counting process at the photo detector. The thermal noise can be modeled as additive white Gaussian noise (AWGN), whose spectral level is directly proportional to the receiver temperature [6].

3. Atmospheric Optical Channel

When turbulence effects are included, the effects of the atmosphere are in a sense more subtle. This optical turbulence is caused almost exclusively by temperature variations in the atmosphere, resulting in random variations of refractive index. An optical wave propagating through the atmospheric turbulence will experience random amplitude and phase fluctuations, which will generate a number of effects: breakup of the beam into distinct patches of fluctuating illumination, the wonder of the centroid of the beam, and increase in the beam width over the expected diffraction limit. For long links, the problems presented by atmospheric turbulence are quite severe, since the average power received at the FSO receiver will decrease even more [8]. Besides power loss, the atmosphere may also distort the optical wave shape during propagation through dense clouds. This is particularly true for transmission of high power, narrow optical pulses, in which the atmospheric scattering can cause pulse broadening through multipath effects. Scattered pulse fields may be reflected toward the receiver and still have appreciable energy to produce a distorted optical pulse shape. If an optical pulse is transmitted from the source, the pulse signals along the scattered paths arrive with delays relative to the direct path and combine to yield a wider, broadened optical field pulse from that transmitted.

4. Atmosphere Turbulence Model

The atmosphere is not an ideal communication channel. Atmospheric turbulence can cause fluctuation in the received signal level, which increases the bit errors in a digital communication link. In order to quantify the performance limitation, a better understanding of the effect of the intensity fluctuations on the received signal, all turbulence levels are needed. When a laser beam propagates through the atmospheric turbulence it causes a number of effects including scintillation. Scintillation can be described as the destructive and constructive interference of optical waves caused by the fluctuations in the index of refraction along the optical path [9].

5. Experimental and Simulation Concept

The FSO system basic design was modeled and simulated for performance of characterization by using OptiSystem 14.0 which is a powerful software design tool that enables to plan, test and simulate almost every type of optical link in the transmission layer of a broad spectrum of optical networks from LAN etc. It can minimize time requirement and decrease cost related to the design of optical systems, links and even components. There are several parameters of the system varied to obtain the optimum system performance. The main parameter that was considered is the laser propagation distance between the specific FSO channels. The FSO design model is illustrated in fig. 2. The optical transmitter consists of four subsystems. The first subsystem is the Pseudo-Random Binary Sequence (PRBS) generator. This subsystem is to represent the information or data that wants to be transmitted. The output from a PRBS generator is a bit stream of binary pulses; a sequence of “1”s (ON) or “0”s (OFF), of a known and reproducible pattern. The 2nd subsystem is the Non-Return-to-Zero (NRZ) electrical pulse generator. This subsystem encodes the data from the PRBS generator by using the NRZ encoding technique. A NRZ line code is a binary code in which 1's are represented by one significant condition and 0's are represented by some other significant condition. The 3rd subsystem in the optical transmitter is the Fabry-Perot and Distributed-Feedback lasers. FP and DFB lasers based on InGaAs semiconductor technology with operating wavelengths around 1550 nm were developed specifically for fiber optic communications systems because of the low attenuation characteristics of optical fiber in this wavelength range. The last subsystem is the Mach-Zehnder modulator. It is an optical modulator that the function is to vary intensity of the light source from the laser according to the output of the NRZ pulse generator. The device comprises of two Y junctions which give an equal division of the input optical power. The free space between transmitters-receiver is considered as FSO channel which is propagation medium for the transmitted light. In the OptiSystem 14.0, the FSO channel is between an optical transmitter and optical receiver with aperture diameter of 5cm and 8cm at each end respectively. Meanwhile, the beam divergence is set to 2 mrad. The optical receiver consist of an avalanche photodiode (APD) followed by a front-end amplifier, a low pass filter and a 3R regenerator. The InGaAs APD must be capable of matching the system bandwidth. Therefore, a Trans-Impedence Amplifier (TIA) is used after the detector because it is preferred for use in wideband optical communication receivers. A Low Pass Filter (LPF) after the front-end amplifier is used to filter out the unwanted higher frequency signals. Bessel LPF is used in a cut-off frequency of 0.75 x bit rate of the signal. The 3R (Re-shaping, Re-timing, Regenerating) regenerator is the last subsystem in the optical receiver. The 3R function is used to regenerate electrical signal of the original bit sequence, and the modulated electrical signal as in the optical transmitter to be used for BER analysis. In other words, it normalized the signal waveform with Gigabit class transmission. This is in order to allow relay transmissions without deterioration of signal quality between buildings that are more than 1 km apart or that do not provide a good LOS.

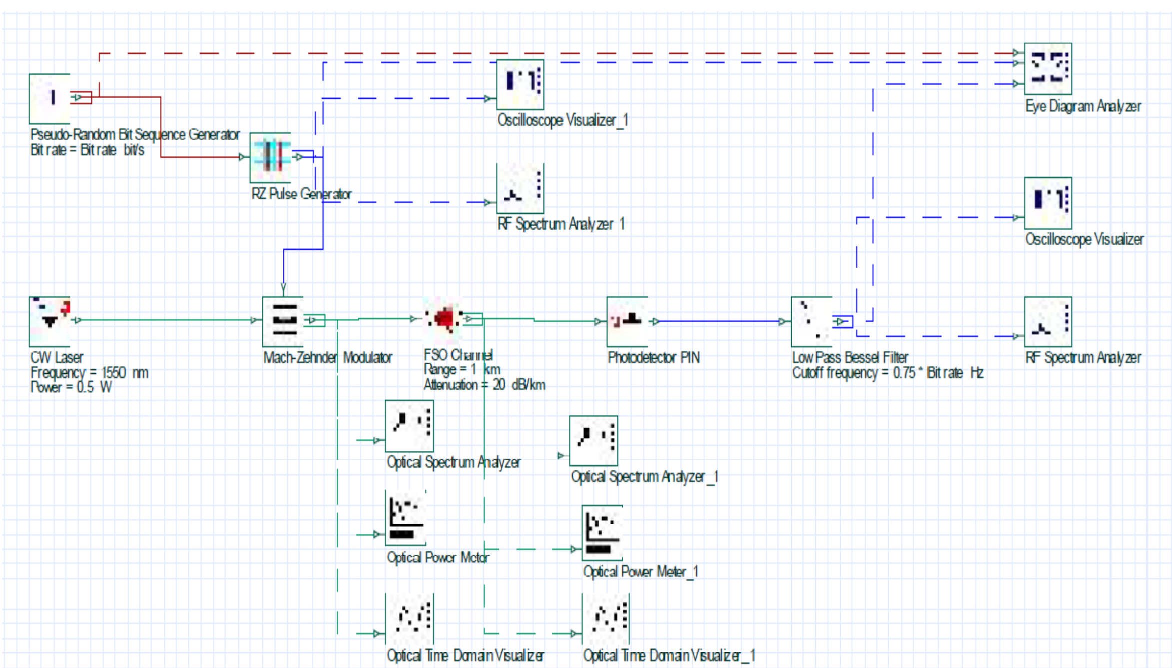

Fig. 2: FSO Design

6. Result

The result is displayed in figure 3.

7. Conclusion

FSO communication system were modeled and simulated as the system performances were analyzed when several parameters of the system were varied. The selection of wavelength is important for particular applications. From the results analysis, FSO wavelength with 1550 nm produces less error due to higher value of the Q factor as compared to other wavelength. Such wavelength requires active heating and cooling to maintain intensity. The contribution of the absorption coefficient for the total attenuation is very special for laser beam. In the fog condition where the visibility is less than 0.5 km while the atmospheric attenuation take the same value for different laser wavelength, therefore the atmospheric attenuation is independent to the wavelength. By using this theoretical model the atmospheric attenuation caused by scattering can calculated for different laser wavelength with different visibility and we can calculates the atmospheric transmission for different estimated ranges.

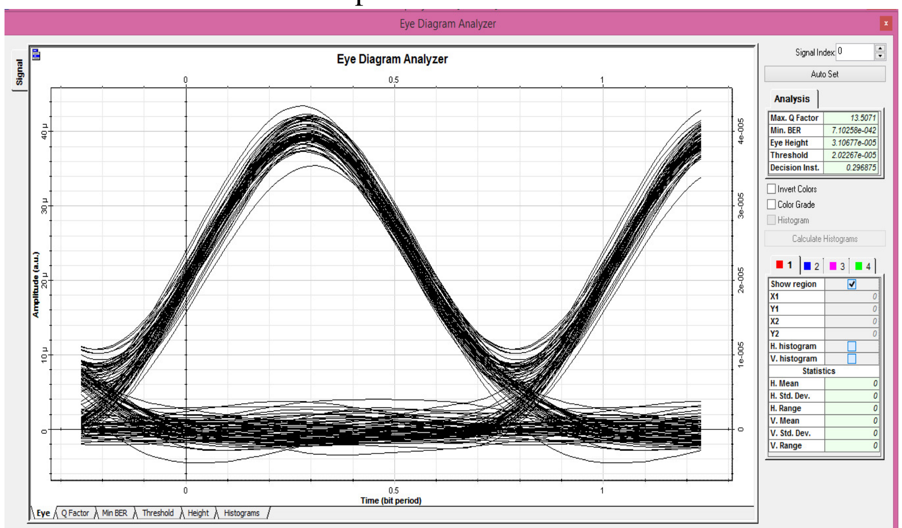

Fig. 3

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