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Performance Evaluation of High Speed Optical Wireless Communication System Based on Atmospheric Turbulence (Fog Effect)

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Abstract: ***In this paper the design and simulation of wireless optical communication system (FSO) through the use of software (Optisystem 7.0) and study the effect of fog on the performance of communication system (FSO), where the fog attenuation calculate wavelengths are (1550 nm, 784nm) and the types of fog (thin Fog and The dense fog and very dense fog). And also studied the effect of the attenuation of the fog on the transmitted Laser Power and transmitter range (propagation distance) where they were taking five different values of transmitted laser power They (50mw, 40mw, 30mw, 20mw, 10mw) and calculate the maximum send range each value of the values of the power transmitted under the effect of Fog attenuation of wavelength (1550nm, 784nm).***

Keywords: free space optical communication System (FSO), atmosphere, transmitted power

1. Introduction

The free-space communication is that it is an effective technique many special advantages and that there is no need for any physical connection between the transmitter and receiver, and it provides a wide range of frequencies ensures the highest data rate (bit) up to a few hundred (Gbps) Kikabait per second. and Some other advantages of this technology there is no need to customize the scope of licensed and without any hesitation cost, easy to install and the absence dangers of radiation from radio frequency and electromagnetic interference immunity and low power consumption and low (BER) [1]. And free-space optical communication system that works along the lines of the optical fiber in terms of speed and bandwidth but using infrared radiation transmitted through the atmosphere. Also it eliminates free space optical communication system (FSO) the need to purchase costly spectrum of radio frequencies, and that the atmosphere is a center-carrier for the transfer of optical signals in the system (FSO). And that the scattering the atmosphere is the main disadvantage compared with transferring light through optical fibers which is a attenuation a continuous along the fiber [2].Free-space optical communication system that uses (FSO) narrow laser beam which makes detection and jamming it very difficult. And system devices (FSO) is portable and a rapidly deployable (the distribution), and although there are a lot of advantages, but this system is sensitive to bad weather and obstructing the line of sight and the movement of building and gleams but the weather conditions were more influential factor "in the implementation of the system (FSO) any rain and snow, fog and dust can weaken the quality of the transmitter system (FSO). so should conducting a thorough study about the weather before the final commissioning and installation of the system (FSO) to improve the final performance of the system. In addition, the choice of wavelength appropriate for the system (FSO) is important and regard to eye safety and the skin from the effects of beam free space optical communication system (FSO), where the wavelength of the most widely used optical communications is the range (1550nm - 850nm) and that many communications systems in free space optical used beams (850nm, 780nm) and beam (1550nm) lately, as this wavelength produces a larger power and safer, "compared with the eye wavelengths (850nm, 780nm) either wavelength (1400nm) are allowed to light Al focusing human cornea.In contrast, the wavelength which is larger than the wavelength (1400nm) absorbs by the cornea and lens and therefore, the eye is more protective In addition, the optical beam highest wavelength is able to penetrate the fog, dust and smoke [3] .And free-space optical communication is the only way in which is transmitted the visible light or infrared be through the atmosphere [4].

2. Free-Space Optical Communication System (FSO)

That parts of free space optical communication system (the FSO) could be clarified through the figure (1-1), which represents the sub-scheme of the main parts of the system. Data sent to the other side distant modulated externally on the optical carrier and the optical carrier often is the laser, which is transmitted through the atmosphere. As for the other important aspects of the system are optical transmitter the size and power and the quality of the beam, which determines the intensity of the laser, Well asminimum of the different laser beam which can be obtained from the system. In the recipient (receiver) are collecting lasers (visual field) and detection but with some effects noise and distortion of the signal and the effect of background radiation and also significant characteristics of the recipient (receiver), the aperture receiver and the number that you specify the size of the light that is received by optical detector. the source data is included on optical carrier are three ways a capacitive modulation (AM) and frequency modulation (FM) and phase modulation (PM) [5].And also in the light waves are often" used to include another which intensity modulation (IM), where the intensity is the energy flow per unit area through the unit time and measured in (w / m^2) and commensurate with the domain amplitude square [6]. In addition, the optical receivers can be divided into two types: receivers non - coherent receivers coherent, as the receiver devices non - coherent based direct detects the received power at the receiver often so-called direct detection receivers, which is the most basic types of receivers implementation and can be used when there is a difference in the power of information received (which gets a difference in the visual field). Either receivers coherent optical mixing, they are between the field of optical wave generated locally with the received optical field, and the combined wave is photo detected. These receivers are used when information is included on optical carrier by using a modulated modes (AM) or (FM) or (PM).The mainly photo detectors are used in receiver side: Avalanche Photo Diodes (APD) or (PIN) diodes. The mainly photo detectors are used in receiver side Avalanche Photo Diodes (APDs) is a very sensitive and works the reverse being biased as needs to be 100 V - 200V to run in reverse bias and can reveal that the waves near-infrared if used silicon in industry [7].

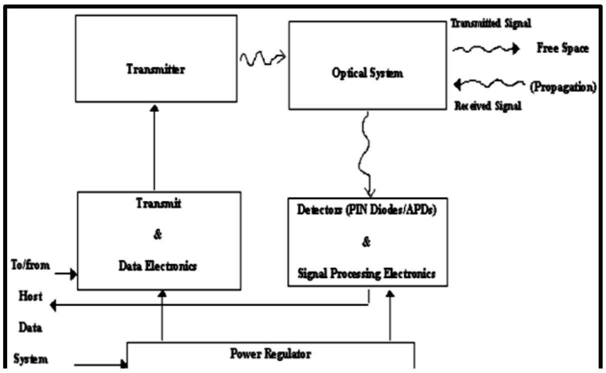

Figure (1-1): Block diagram of (FSO) communication system [5]

3. Atmospheric Optical Channel

Link free-space optical called Atmosphere channel. It is a channel open to a number of factors that affect the optical signal such as data rate and the length of the extent of the transmitter and the error rate.The main factors affecting the optical signal are absorption and scattering atmospheric turbulence and the deviation of the light beam and the other factor that affects the optical signal is sunlight (ambient light), and some dust, fog, rain and snow particles [7].Optical received power is the amount of light energy transmitted or transmitted through the system (FSO), can calculate how much power the optical signal received hyphen to the receiver through the channel of the atmosphere in the free-space optical communication system (FSO) by equation (1) [8]: $-P_{received} = P_{transmitted} \times \frac{d_2^2}{[d_1 + (D \quad R)]^2} \quad 10^{(-\alpha \times R/10)}$...(1)

Where:$P_{received}$=Received Power,$P_{transmitted}$ = TransmittedPower,d_1= Transmit aperture diameter (m),d_2 = Receive aperture diameter (m), D = Beam divergence (mrad), R=Range (distance propagation) (km),α= Atmospheric attenuation factor (dB/km).

In equation (1), we note that the amount of received power directly proportional to the amount of transmitted power and aperture receiver, but is inversely proportional with the resulting exponential coefficient of attenuation in the atmosphere (in units (1 / R)) square Range the link and divergence of the laser beam and transmitter aperture .And variables that can be controlled is the ability of the optical signal transmitted and diameter aperture receiver and transmitter and laser beam divergence and the Range of the link (propagation distance).The attenuation coefficient of the atmosphere cannot be controlled in the open-air environment, independent of wavelength attenuation in heavy conditions, the power is heavily dependent on the outcome of the attenuation coefficient and the range (distance propagation).The maininstabilmente in the spread of free-space optical communication systems (FSO) which is availability and that depend on a combination of factors including equipment and the design of the network, but this is known and quantifiable, but the big unknown is the attenuation of the atmosphere [8] .

The sensitivity of the recipient: are the minimum energy that must be received by the free space optical communication system (FSO) for the specified error rate. They are usually measure both peak or average of this energy in the transmitter or receiver or apertures detected. As the losses that occur during the passage of light energy through the system devices include dispersion and absorption, surface reflections, overfilling losses [8].

4. Fog Attenuation

Fog is formed when moist air is cooled to mass saturation point (dew point) and this cooling is the result of horizontal of movement warm air up the cold surfaces and this is called a thermal fog, and also consists of a radiologicaloperations and evaporation of rain. And the advantage of the fog several physical parameters such as water content and droplet size distribution (molecules or particles) and the temperature [9].Fog works onscattering the laser light and thus reduce the visibility near the earth's surface. When considering transmitter threshold (τ_{TH}) through a free-space optical equal to (2%), it can fog attenuation coefficient was calculated by Equation (2) [10]:

$$\alpha_{fog}(\lambda) \cong \beta(\lambda) \frac{\ln(\tau_{TH})}{V} \left(\frac{\lambda}{550\,nm}\right)^{-q} = \frac{3.912}{V} \left(\frac{\lambda}{550}\right)^{-q} \quad \ldots\ldots\ldots..(2)$$

Either when considering the transmitter threshold (τ_{TH}) equal to (5%), can be calculated attenuation coefficient by

Equation (3) [10]:

$$\alpha_{fog}(\lambda) \cong \beta(\lambda) = \frac{\ln(\tau_{TH})}{V} \left(\frac{\lambda}{550\,nm}\right)^{-q} = \frac{13}{V} \left(\frac{\lambda}{550}\right)^{-q} \ldots\ldots\ldots..(3)$$

Where :α_{fog} = Fog attenuation coefficient (dB/km),V = visibility(km),λ= wave length(nm),q = The size of the particles dispersed Coefficient .And it is calculated by the following models [11].

1. Kim model

$$q = \begin{cases} 1.6 \text{ if } V > 50km \\ 1.3 \text{ if } 6km > V > 50km \\ 0.16V + 0.34 \text{ if } 1km < V 6km \\ V - 0.5 \text{ if } 0.5km < V < 1km \\ 0 \text{ if } V < 0.5\ km \end{cases}$$

2. Kruse model

$$q = \begin{cases} 1.6 \text{ if } V > 50km \\ 1.3 \text{ if } 6km > V > 50km \\ 0.585\ V^{\frac{1}{3}} \text{if } V < 6km \end{cases}$$

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5. Experimental and Simulation

Through the use of the program (Optisystem 7.0) are designed for free-space optical communication system (FSO), as well as a simulation of the characteristics and performance of the system, where it can be through this program design and simulation test each type of links and optical wide spectrum of local optical networks and fiber optic .....etc. Also can reduce the time requirements and a lack cost of relevant design of optical systems and components of optical systems .The optical wireless communications system (FSO) is composed of three main parts, a transmitter system and communication channel and receiver system, and both the system of the transmitter and receiver system composed of parts or other sub-systems, Since the transmitter system composed of four subsystems the first subsystem isthe Pseudo-Random Binary Sequence generator (PRBS) It represents to be sent and that the output data from the pulse generator (PRBS) in the form of a stream (bit) of binary pulses and a series of "1" s "ON" or "0" s "OFF". The second sub-system is a generator pulse Electrical, a (Non-Return-to-Zero) (NRZ) and his job encrypt information from the generator of random impulses (PRBS) by using the encoding technique (NRZ) which are represented the pulse by symbols "1" and "0".Subsystem third is the transmitter optical and is laser and be one of the types of semiconductor lasers (InGaAa) shall be either the Fabry-Perot laser (FPL) or Distributed-Feedback lasers (DFB) or VerticalCavity Surface Emitting Laser (VCSEL), which is working with wavelengths around 1550nm.The fourth sub-system is the external modulator (Mach - Zehnder modulator) and function of this system the intensity modulated of the light source (laser) according to the output pulse generator, where this device is composed of two junctions of optical power input.

Communication channel between the transmitter and the receiver in the visual communication free space optical wireless system (the FSO) represents the propagation medium during which the transmitted light (laser) and in the program (Opti system 7.0) is a free-space optical (FSO) between the two apertures of the transmitter and receiver. The receiver optical device is a device that to convert the received optical signal to an electrical signal and use of light-diodesemiconductor devices of the optical sensor. The optical receiver Composed of an avalanche photodiode (APD) and optical amplifiers and the filter (Law Pass Bessel Filter) and 3Rregenerator. Where the preamplifier is used (Trans- Impedance Amplifier) (Tin) after the detector because it works to restore electrical transmitter as a way to compensate for the lost optical signals and uses filter after the amplifier to filter high frequency signals of unwanted. And is used filter Bessel (LPF) in the cut frequency of 0.75* bit rate)) of the signal. As regenerator is another subsystem in the optical received where it is used to determine the electrical signal embedded they are sent and composed of3R regenerator (Re-shaping, Re-time, Regenerating). There are a lot of different parameters to get the best performance of the system, but the spread of the laser distance through the channel (FSO) between the optical transmitter and receiver optical is the main parameter.

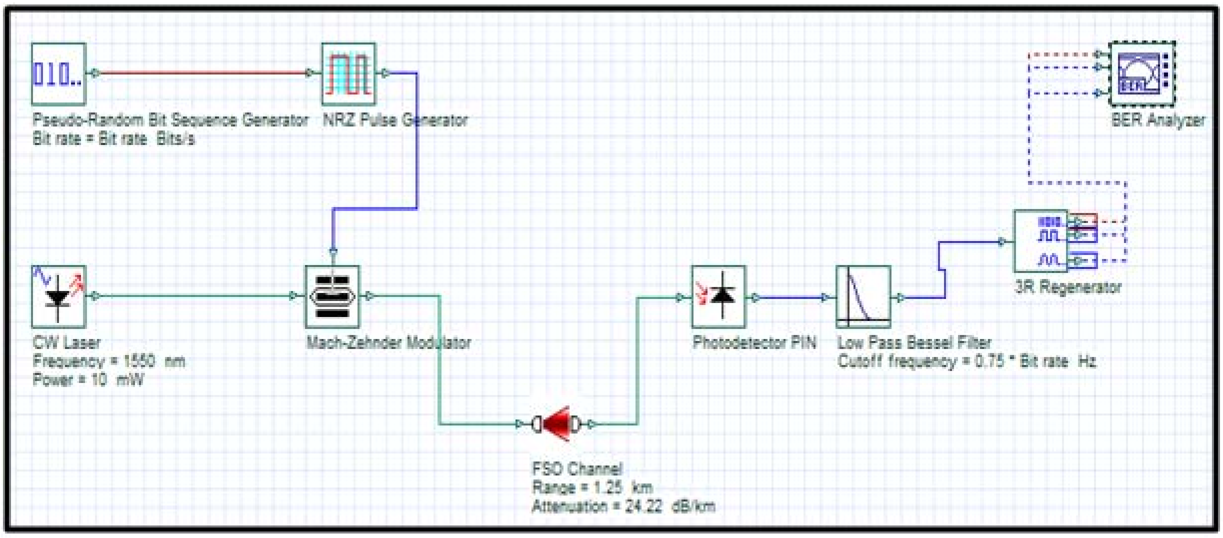

Figure (2-1): Shows the system (FSO) design

6. Results

The figure shows (3-1) that the attenuation coefficient of fog changes with visibility any greater the visibility least atmospheric attenuation coefficient of fog ,Vicu at its highest value when the visibility (0.1km) very dense fog "and less value for the coefficient of atmospheric attenuation fog when the visibility at its highest value (1.6km) thin fog, also shows that the atmospheric attenuation coefficient of fog when the wavelength (1550nm) less from the atmospheric attenuation coefficient of fog when the wavelength (784nm).And also showing graphic formats (4-1) and (5-1) and (6-1) for thin fog and dense fog is very dense fog respectively a transmitter range that increases with the transmitted Laser Power. And that this increase in the transmitter range according varies to the type of fog effective, where the highest value for the transmitter range when the wavelength (784 nm), and when the transmitted laser power (50mw) equal (1.35km) thin fog and (0.88 km) thick fog and (0.63 km) very dense fog , either when the wavelength (1550nm) shall be the highest value to the transmitter range when the transmitted power (50mw) is

(1.39km and 0.97km and 0.69 km) fog thin and thick and very dense. And also illustrates that transmitter range when the wavelength (1550nm) is greater than transmitter range when the wavelength (784nm).

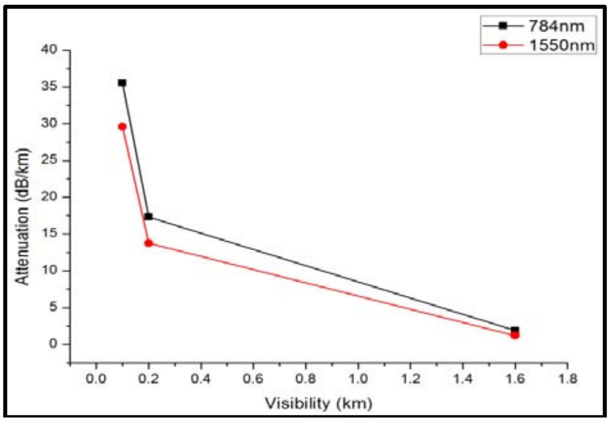

Figure (3-1): Shows the relationship between the fog attenuation and visibility

6.1 Thin Fog

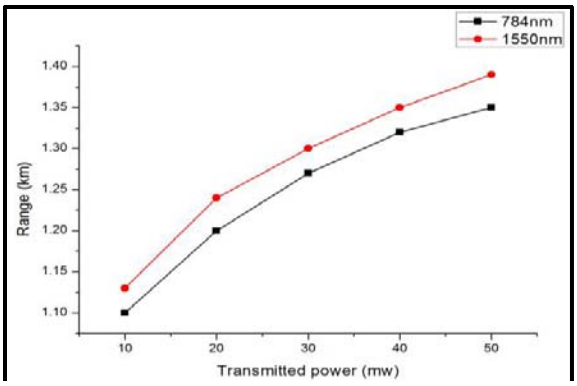

Figure (4-1): shows the relationship the Transmitted power and the Range transmitter

6.2. Thick Fog

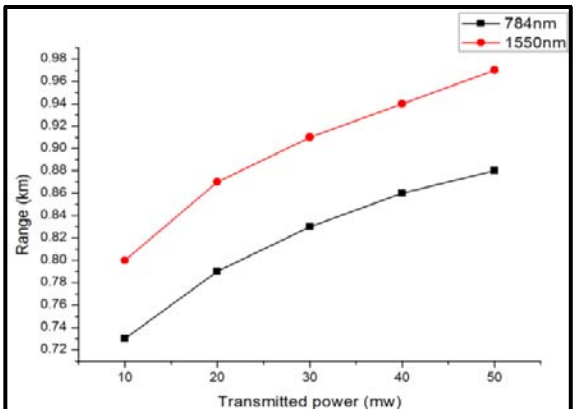

Figure (5-1): Shows the relationship the Transmitted power and the Range transmitter

6.3. Denise Fog

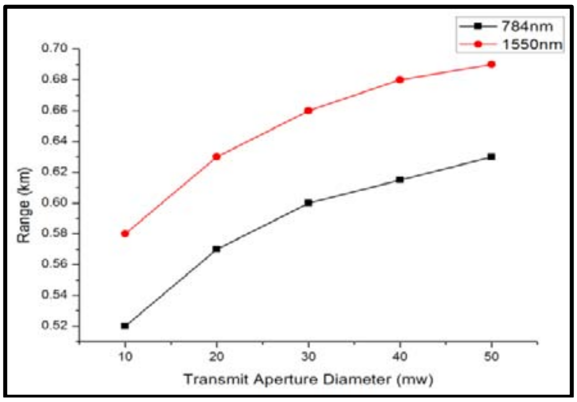

Figure (6-1): Shows the relationship the Transmitted power and the Range transmitter

7. Conclusion

When studying the design of communications free space optical communications system (FSO) and the effect of fog on the performance of the system, we concluded that the attenuation fog increases, the less visibility, and the attenuation of fog when the wavelength (1550nm) less than the attenuation fog when the wavelength (784nm), as well conclude that attenuation Fog effects on the transmitted Laser Power through the atmosphere and thus will affect the range of the transmitter and the performance of the system in general,Found that increasing the Laser Power transmitted lead to increase the range of the transmitter and increase the attenuation fog lead to minimize the range of the transmitter, where the maximum extent send when fog thin and thick and very dense, respectively, and when the laser power transmitter (50mw) equals (1.35km, 0.88km, 0.63km) at the wavelength of(784nm) and (1.39 km, 0.97km, 0.97km) at wavelength (1550 nm).

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