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Dust Effect on The Performance of Optical Wireless Communication System

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Abstract

In this paper wireless optical communication system (FSO) is designed through the use of software (Optisystem) . The paper also study the effect of atmospheric dust on the performance of communication system (FSO), the effect of dust concentration on the visibility by taking a different concentrations of dust (9, 20, 40, 60, 80 100, 120) gm / month / m^2 . The effect of the visibility on the attenuation of dust concentration on each of these concentrations , and calculate attenuation of dust for the wavelengths (784 nm, 1550 nm). The Paper also deals with effect of the transmitted laser power on the transmitter range (propagation distance) where five different values of transmitted laser power (10mw, 20mw, 30mw, 40mw, 50mw) are taken and the study calculates the maximum transmitter range of each value of the transmitted power under the influence of attenuation atmospheric dust concentrations for each concentration of dust used and also for the two wavelengths (1550nm, 784nm).

key words : Free space Optical Communications System (FSO) , Dust, Atmosphere, Transmitted Laser Power , Concentration of Dust.

الخلاصه

في هذه الورقة تم تصميم منظومة اتصالات بصرية لاسلكية من خلال استخدام برنامج (اوبتيسستم)، ودراسة تأثير الغبار الجوي على ادائها ، وكذلك تم دراسة تأثير تركيز الغبار الجوي على الرؤية الجوية من خلال اخذ قيم مختلفة لتركيز الغبار (9 ، 20، 40، 60، 80، 100، 120)غرام اشهر ام^2 . ايضا" تم دراسة تأثير الرؤية الجوية على توهين الغبار الجوي ، حيث تم حساب توهين الغبار الجوي لهذه التراكيز ولطولين موجيين(1550,784) نانو متر . ودراسة تأثير قدرة الليزر المرسلة على مدى الارسال حيث تم اخذ خمس قيم لقدرة الليزر المرسلة (10، 20، 30، 40، 50) ملي واط وحساب اقصى مدى ارسال لكل قيمة من قيم قدرة الليزر المرسلة وايضا" لطولين موجيين هما (1550، 784) نانو متر.

الكلمات المفتاحية : منظومة اتصالات الفضاء الحر البصري ، الغبار ،الغلاف الجوي ، قدرة الليزر المرسلة .

1. Introduction:

The free-space communication is an effective technique with many special advantages There is no need for any physical connection between the transmitter and receiver, and it provides a wide range of frequencies which ensure the highest data rate (bit) up to a few hundred (Gbps) Kikabait per second. Some other advantages of this technology are there is no need to customize the scope of licensed and without any hesitation cost, it is easy to install and there is no dangers of radiation from radio frequency and electromagnetic interference immunity, and shows low power consumption and low (BER) (Alkholidi *et.al.*, 2014).

Free-space optical communication system works along the lines of the optical fiber in terms of speed and bandwidth but it uses infrared radiation transmitted through the atmosphere. It also eliminates free space optical communication system (FSO) (Suriza *et.al.*, 2011). Free-space optical communication system that uses (FSO) narrow laser beam which makes detection and jamming is very difficult. the system devices (FSO) are portable and rapidly deployable (the distribution). Although this system a lot of advantages, but it is sensitive to bad weather and to the obstruction of 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) as any rain and snow, fog and dust can weaken the quality of the transmitter system (FSO). So you make study about the weather is necessary before the final commissioning and installation of the system (FSO) to improve the final performance of it (Naimullah *et.al.*,2008) .

In addition, the choice of wavelength appropriate for the system (FSO) is important and essential 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 the range of (1550nm - 850nm) . Many communications systems in free space optical used beams of (850nm, 780nm) and beam of (1550nm) lately, as this wavelength produces a larger power and safer as compared with the eye wavelengths (850nm, 780nm) . Either wavelengths (1400nm) is allowed to light Al focusing human cornea. In contrast, the wavelength which is larger than (1400nm) is absorbed 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 (Naimullah *et.al.*,2008). Free-space optical communication is the only way that is transmitted the visible light or infrared is transmitted through the atmosphere (Mohammad,2014).

2. Free-space optical communication system (FSO):

Free space optical communication system (the FSO) could be stated in figure (1), which represents the sub-scheme of the main parts of the system. Data sent to the other side distant is modulated externally on the optical carrier and the optical carrier often is the laser, which is transmitted through the atmosphere. The other important aspects of the system are optical transmitter, the size, power, and the quality of the beam, which determine the intensity of the laser. The minimum of the different laser beam which can be obtained from the system. In the lasers are collected and detection but with some noise and distortion of the signal and the effect Ambient Light and also significant characteristics of the recipient (receiver), the receiver aperture 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) , frequency modulation (FM) , phase modulation (PM) (Kadhim *et.al.,* 2015). 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 (Pradhan *et.al.,* 2016). The optical receivers can be divided into two types of receivers: non - coherent receivers and coherent receiver, The receiver devices are non - coherent based devices which detect the received power at the receiver and they are often so-called direct detection receivers. They represent the most basic types of receivers implementation and can be used when there is a difference in the power of the received information (which gets a difference in the visual field) **.** The receivers coherent optical mixing, are found between the field of optical wave generated locally with the received optical field, and the combined wave which 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 main photo detectors used in receiver side are : Avalanche Photo Diodes (APD) or (PIN) diodes. The main photo detectors are used in receiver side such as Avalanche Photo Diodes (APDs) which is very sensitive and can work in reverse bias when needs to be 100 V - 200V to run in reverse bias also can reveal that the waves near-infrared if used silicon in industry (Sharma *et.al.,* 2015) .

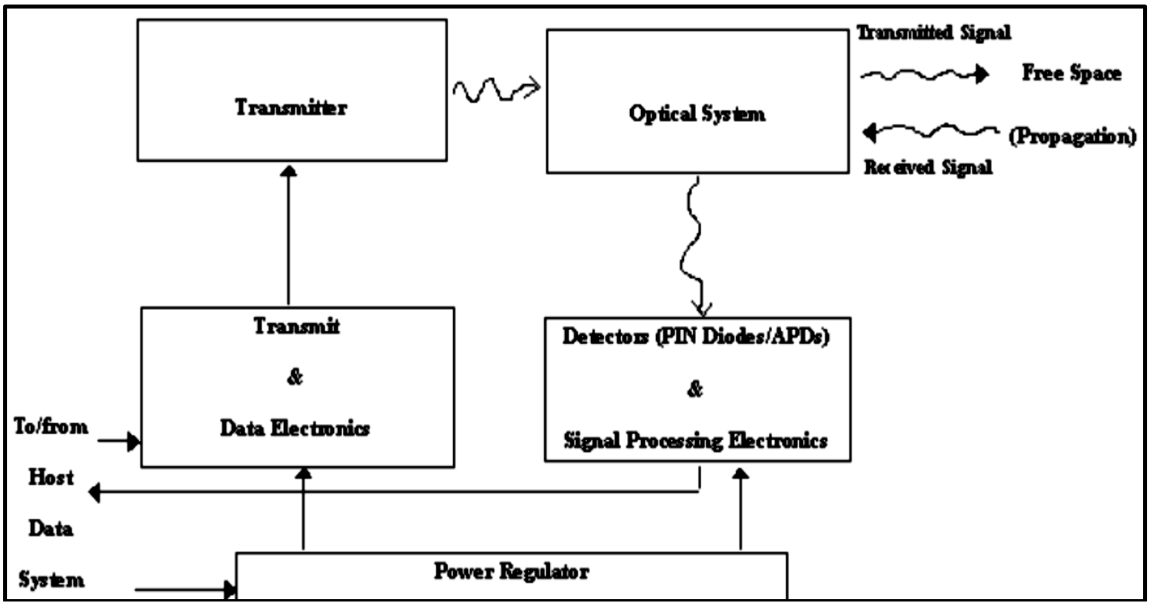


Figure (1) Block diagram of (FSO) communication system (Kadhim *et.al.*, 2015).

3. Atmospheric Optical Channel:

Atmosphere channel is link free-space optical called. This channel is 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 , the deviation of the light beam , sunlight (ambient light), dust , fog, rain and snow particles (Sharma *et.al.*, 2015). Optical received power is the amount of light energy transmitted through the system (FSO), It is possible to calculate how much power the optical signal received . The received power in the free-space optical communication system (FSO) is depended equation (1) (Bloom *et.al.,2003*):

$$P_{received} = P_{transmitted} \times \frac{d_2^2}{[\, d_1 + (D \times R)]^{\,2}} \times 10^{(-\alpha \times R/10)} \quad \ldots\ldots\ldots\ldots..(1)$$

Where :

$P_{received}$ = Received Power , $P_{transmitted}$ = Transmitted Power , 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 the received power directly is 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 . Variables that can be controlled is the ability of the transmitted optical signal, receiver aperture diameter, transmitter aperture diameter , 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 main instabilmente in the spread of free-space optical communication systems (FSO) is availability and it depends on a combination of factors including equipment and the design of the network, both are known and quantifiable, but the big unknown is the attenuation of the atmosphere (Bloom et.al., 2003) .

The sensitivity of the recipient: is the minimum energy that must be received by the free space optical communication system (FSO) for the specified error rate. They 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 and overfilling losses [Bloom, S., et al,2003] .

4. Dust Attenuation :

Dust defined as a set of outstanding in the center of Ghazi particles often have the air, or air plankton may be present in the form of airborne dust or spray sparse and smoke, and dust longer of circles effective attenuated all-important in the attenuation of beam of electromagnetic radiation processes (Thannon ,2009) . Attenuation due to atmospheric dust, or plankton air (aerosol) result from the scattering of the particles may depends on plankton flights. The electromagnetic absorption effect is relatively small compared with the may scattering , so the scattering coefficient can be calculated depending on the viewing distance and frequency of the beam incident, and the visibility is linked to concentration of dust through the equation (3) (Jassim *et.al.*,2013):

$V=7080\times C^{-0.8}$ ………………..(2)

Where : V = visibility (km) , C = concentration .

The scattering coefficient was calculated depending on visibility and the wavelength of the incident beam through the equation (4) [Thannon, M. A.,*2009*] :

$\alpha = \frac{3.19}{V} \times (\frac{\lambda}{8.55nm})^{-q}$…………………(3)

Where :

V = visibility (km) , λ = wave length

q = The size of the particles dispersed Coefficient . And it is calculated by the following models [Ethiraj , S . ,*et al,2013*].

$$q = \begin{cases} 1.6 \text{ if } V > 50km \\ 1.3 \text{ if } 6km > V > 50km \\ 0.16V + 0.34 \text{ if } 1km < V6km \\ V - 0.5 \text{ if } 0.5km < V < 1km \\ 0 \quad \text{if } V < 0.5\ km \end{cases}$$ Kim model – 1

$$q = \begin{cases} 1.6 \text{ if } V > 50km \\ 1.3 \text{ if } 6km > V > 50km \\ 0.585\ V^{\frac{1}{3}} \quad \text{if } V < 6km \end{cases}$$ Kruse model -2

5. Proposed system :

Optisystem package are used for the designed of free-space optical communication system (FSO).The characteristics and performance of the system are simulated. The program design allows simulation and the latter tests each type of links and optical wide spectrum of local optical networks and fiber optic .....etc .The program can also reduce the time requirements and 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 , a receiver system. Both of the transmitter and the receiver systems are composed of parts or other sub-systems.

The transmitter system is composed of four subsystems . The first subsystem is the Pseudo-Random Binary Sequence generator (PRBS) . The output data will be sent 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 its job is to encrypt information from the generator of random impulses (PRBS) by using the encoding technique (NRZ) which represents the pulse by symbols "1" and "0".The third Subsystem is the optical transmitter which is (laser) one of the semiconductor types here we used (InGaAa) which is either the Fabry-Perot laser (FPL) or

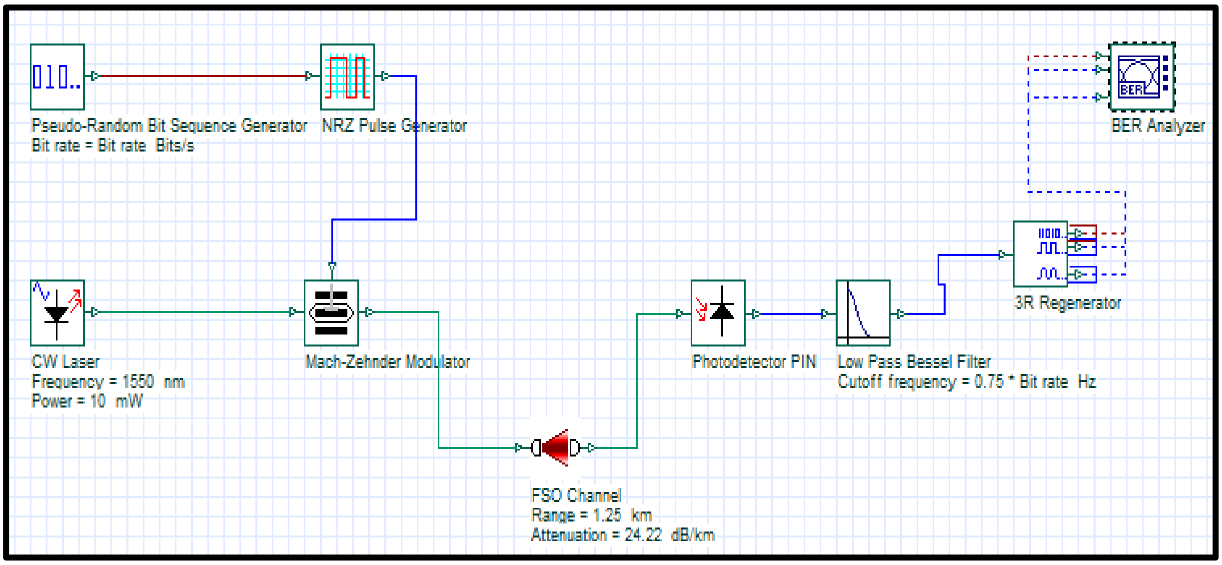
Distributed-Feedback lasers (DFB) or Vertical Cavity Surface Emitting Laser (VCSEL), which is working with wavelengths around 1550nm.

The fourth sub-system is the external modulator (Mach - Zehnder modulator) and the function of this system is to modulated the intensity 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 (FSO) represents the propagation medium through which the transmitted light (laser), and in the program (Optisystem), is a free-space optical (FSO) between the two apertures of the transmitter and receiver.

The receiver optical device converts the received optical signal to an electrical signal that can be used in light- diode semiconductor devices of the optical sensor. The optical receiver is Composed of an avalanche photodiode (APD) , optical amplifiers , the filter (Law Pass Bessel Filter) and 3R regenerator. A preamplifier is used (Trans- Impedance Amplifier) after the use of detector because it works to restore electrical transmitter as a way to compensate the lost optical signals and filter is used after the amplifier to filter the high frequency of unwanted signals.

Bessel filter (LPF) is used in the cutting of the frequency of the signal. As regenerator is another subsystem in the optical received system which is used to determine the electrical signal embedded, they are composed of 3R 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 is the main one.

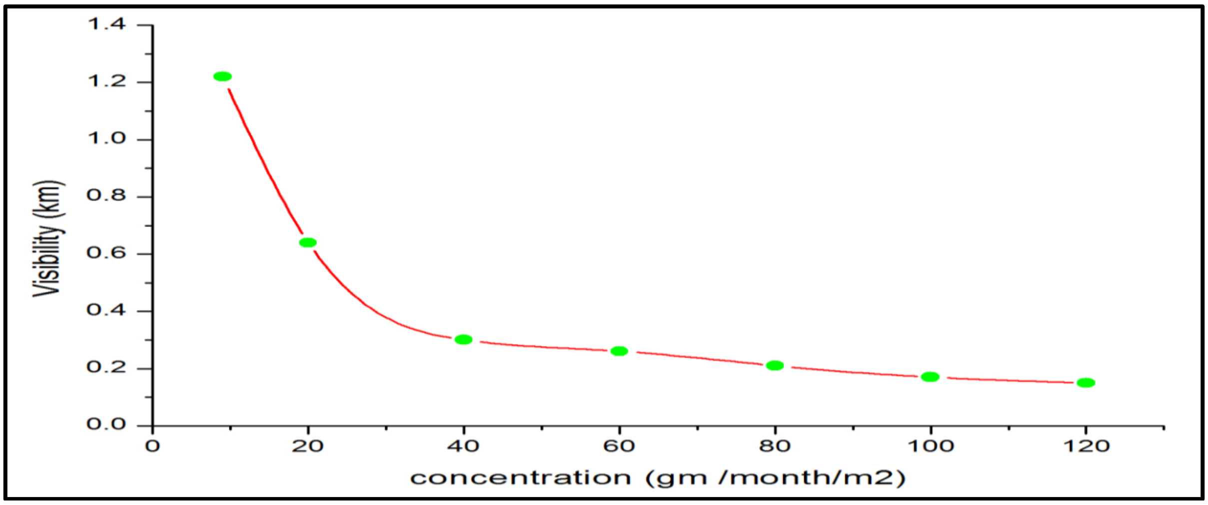


Figure(2) Shows the system (FSO) design.

6. Results:

The figure (3) shows that the visibility decreases with the increasing concentration of atmospheric dust and that the greatest value to the visibility occurs when the concentration dust is(9 gm / month / m^2), where the greatest value of the visibility is equal to (1.2km) . Figure(4) shows that the attenuation coefficient of dust increases with the increasing concentration of atmospheric dust, where the highest value occurs when atmospheric dust concentration is (120gm / month / m^2),where the highest value of the attenuation is equal to (4.22 dB / km) , and it also illustrates that dust attenuation coefficient at the wavelength (1550nm) is less than the dust attenuation coefficient when the wavelength is (784nm). Figure (5) shows that the atmospheric dust attenuation decreases with increasing visibility where the highest value for the attenuation of dust occurs is equal to (4.22dBlkm), when the visibility is (0.15km) , and the less valuable is (0.12dB / km) when visibility is equal to (1.22 km) . It is shown that when the dust attenuation wavelength (1550nm) is less than the attenuation of dust the wavelength is (784nm).

Figures (6) , (7) , (8) , (9) , (10) , (11) and (12) are taken when the dust concentrations are (9, 20, 40,60,80,100,120) gm / month / m^2, the transmitter range increases with the increase of the transmitted laser power and that this increase varies depending on the concentration of dust in the atmosphere, Since the transmitter range is reduced , the more atmospheric dust concentration due to the increased attenuation of atmospheric dust factor will be the extent of the transmitter when the transmitted laser power is (50mw) the concentrations above and the wavelength (784nm) is equal to(1.44km , 1.43km , 1.37km ,1.3km,1.34 km, 1.25km,1.21km) respectively. The transmitter range increases with the increase of the transmitted laser power and that this increase varies depending on the concentration of dust in the atmosphere, Since the transmitter range is reduced , the more atmospheric dust concentration due to the increased attenuation of atmospheric dust factor will be the extent of the transmitter when the transmitted laser power is (50mw) the concentrations above and the wavelength (1550nm) is equal to (1.45km, 1.44km, 1.38km, 1.36km, 1.33km, 1.28km, 1.25km) respectively .



Figure(3) the relationship between the dust concentration and visibility.

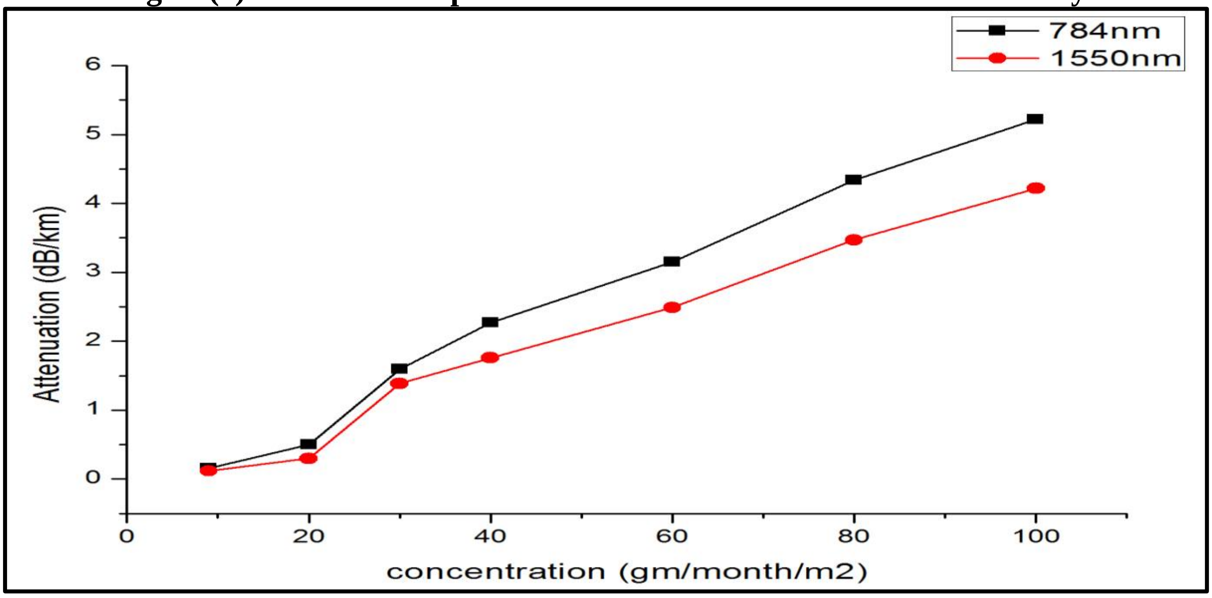
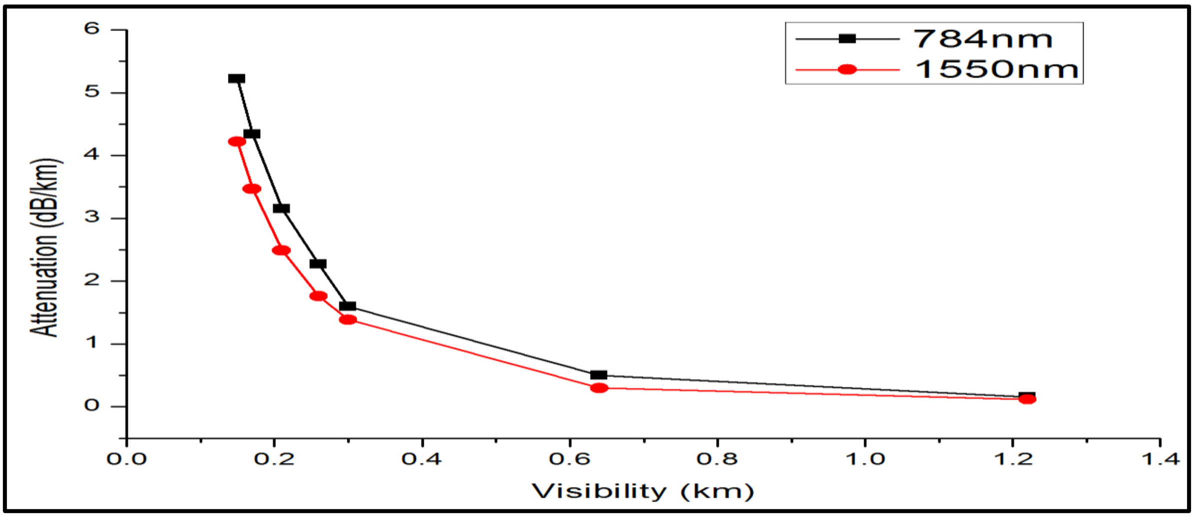


Figure (4) the relationship between the attenuation and the concentration of dust.



Figure(5) the relationship between the attenuation and the visibility.

C = 9 gm/month /m^2 .

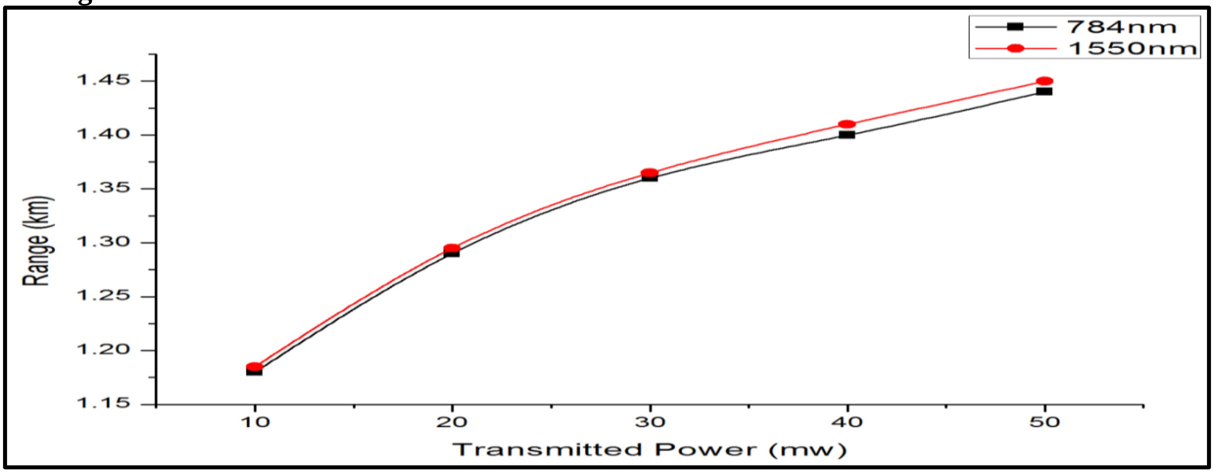


Figure (6) the relationship the Transmitted power and the Range transmitter.

C = 20 gm/month /m^2 .

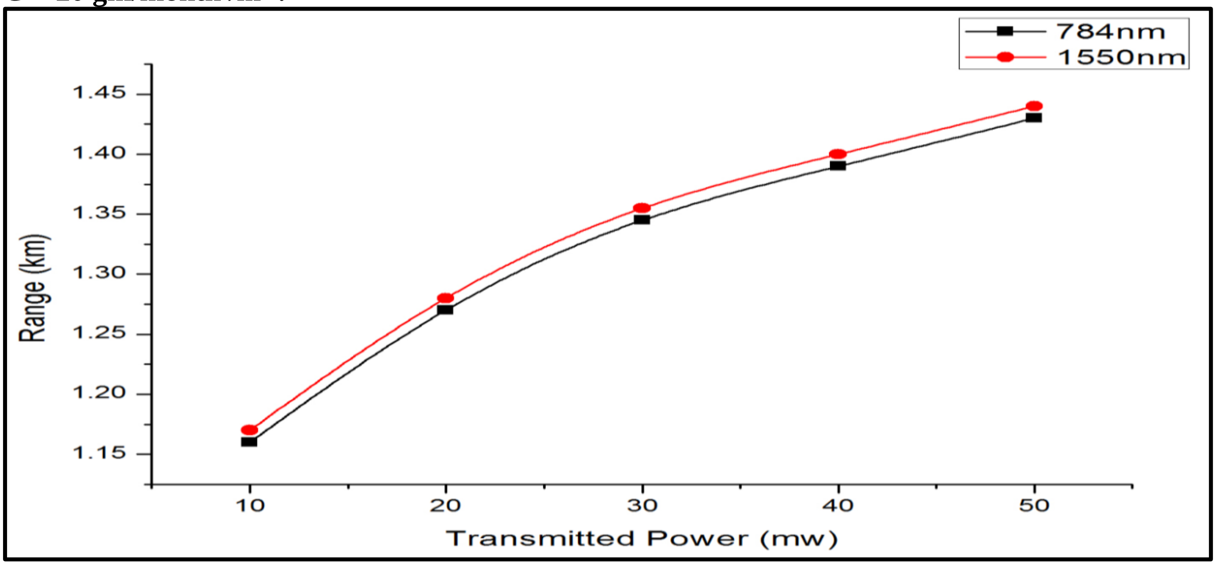


Figure (7) the relationship the Transmitted power and the Range transmitter.

C = 40 gm/month /m^2 .

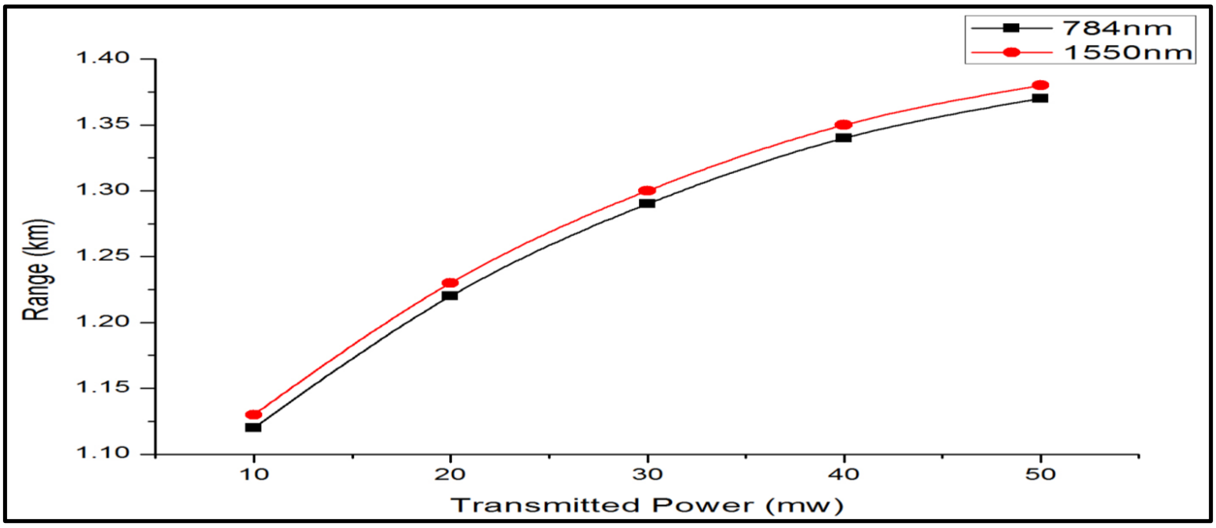


Figure (8) the relationship the Transmitted power and the Range transmitter.
C = 60 gm/month /m^2 .

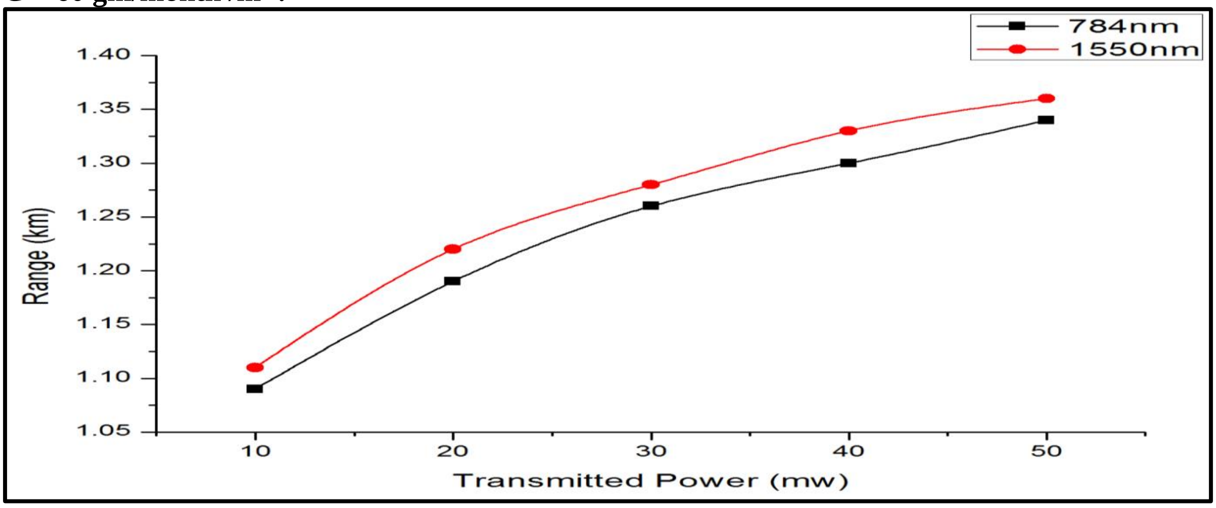


Figure (9) the relationship the Transmitted power and the Range transmitter.
C = 80 gm/month /m^2 .

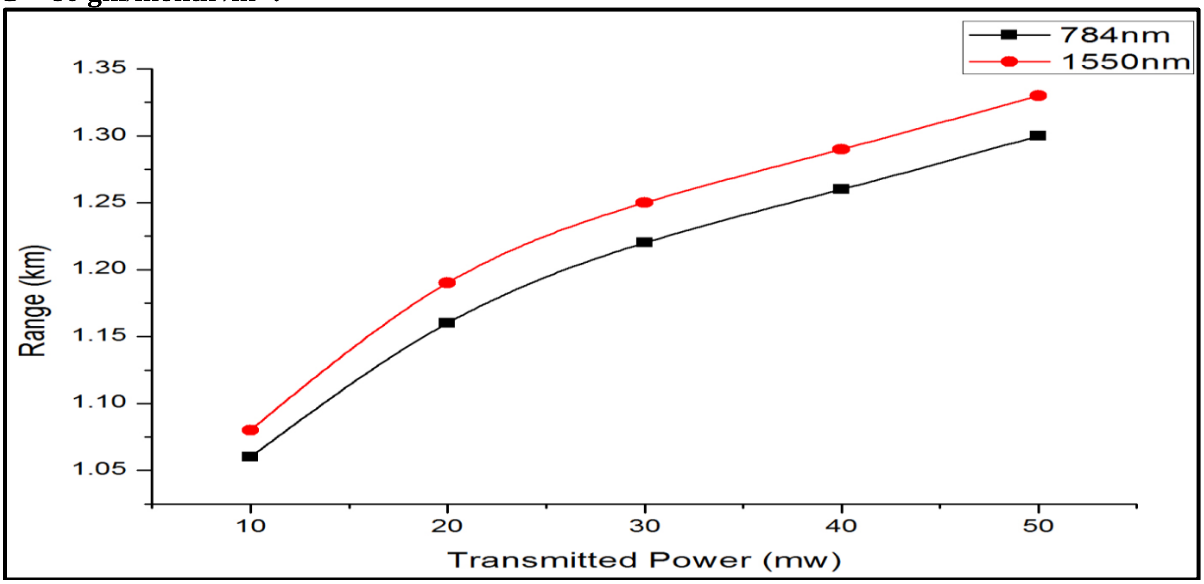


Figure (10) the relationship the Transmitted power and the Range transmitter.
C = 100 gm/month /m^2 .

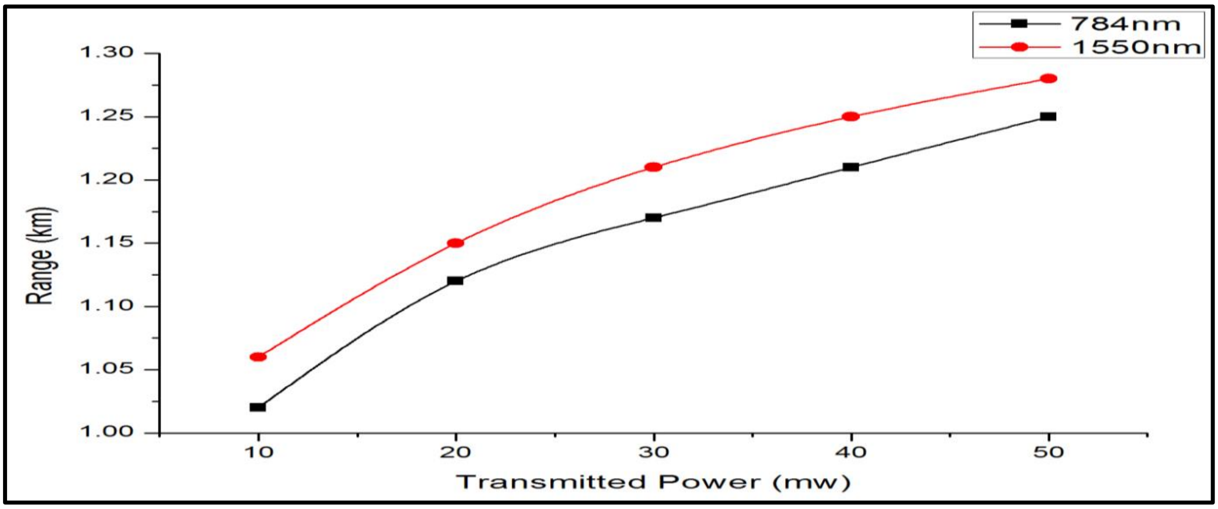


Figure (11) the relationship the Transmitted power and the Range transmitter.

C = 120 gm/month /m^2 .

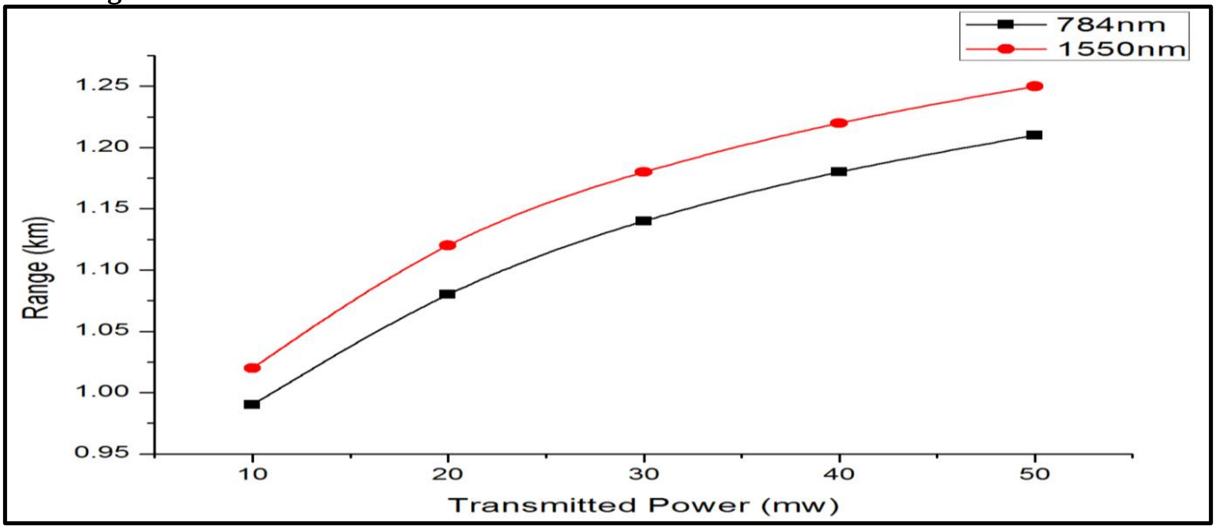


Figure (12) the relationship the Transmitted power and the Range transmitter.

7. Conclusion:

Both the study of the design of free space optical communication system (FSO) is done and the study of atmospheric dust effect on the performance of the system, lead to conclusion that the visibility decreases with the increase concentration of dust and that the increase in the concentration of dust increases the output attenuation due to dust. When the wavelength is (1550nm) , the dust attenuation will be lower than it is when the wavelength is (784nm). The attenuation due to dust affects the transmitted laser power through the atmosphere and thus will effect of the transmitter range and the performance of the system in general. It is found that, the increase of the transmitted laser power leads to the increase of the transmitter range to the maximum is when the dust concentration (120gm / month / m^2) and transmitted laser power is (50mw) when the wavelength is (1550nm) then the transmitter range is equals (1.25km) and when the wavelength is(784nm) when the transmitter range is equals (1.21km).

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