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Dust Particle Influence on the Range of the FSO Communication Systems

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Abstract

This study is aiming to study the spectrum attenuation on the free space optical communication systems under the condition of dust weather. In this work, an FSO system that operated in near infrared (NIR) and visible wavelengths of (650, 850 and 1550) nm has been used to and test their attenuation for range from (1 to 12) Km under. The dust has been generated homogeneously with controls in an atmospheric chamber with dimensions of (93 × 63 × 60) cm. The experimental results show that the attenuation by an aerosol is restricted the distance of FSO systems and will limits the availability for line-of-sight terrestrial link.

Keywords: FSO, free space optical communication systems, Kim Model, visibility attenuation, dust.

تأثير دقائق الغبار على مدى أنظمة الاتصالات البصرية في الفضاء الحر

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الخلاصة

تم في هذا البحث عمل تجربه مختبرية لدراسة التوهين الطيفي لأنظمة الاتصالات البصرية في الفضاء الحر التي تعمل في الطول الموجي المنظور والقريب من تحت الحمراء (650 نانوميتر، 850 نانوميتر و1550 نانوميتر) ولمديات (من 1 الى 12 كيلومتر) تحت تأثير عوامل الغبار. تم توليد غبار والسيطرة عليه بشكل متجانس في حجرة محاكاة التأثيرات الجوية والتي كانت بأبعاد (60*63*93) سنتمتر. أظهرت النتائج العملية ان التوهين الناتج من الهباء الجوي يؤثر على المسافة لأنظمة الاتصالات البصرية في الفضاء الحر ويقيد قابليتها على الاتصال في مدى الخط البصري.

1. Introduction

The FSO technique that utilized a slight propagating in free space to transfer data for computer networking or telecommunications. The Free space transmission means that the optical signal can transmit over air, vacuum, or outer space in wireless method. The FSO technology is advantageous where the physical connections are not practical because of higher costs or other aspects. FSO point-to-point links could be implemented by used infrared laser light (IR), even though low-data rate communication through short distances can be achieved by using LEDs. The IrDA technology (Infrared Data Association) is a so simple form of FSO communications [1].

The FSO is also utilized for communication between spacecraft. The terrestrial links maximum range is about 2 km to 3 km, but the quality and the stability of the link is greatly dependent on several atmospheric factors like as heat, dust, fog and rain [2].

2. Related Works

Hennes and Otakar (2010) [3], provides an overview for the challenges that should take in consideration by the system designer when implementing an FSO system. Losses in data and signal gains when the optical signal passes through the path from the transmitter over the medium to the receiver has been introduced in there works. They also discussed the different coding and modulation techniques for the FSO.

Ahmed (2015) [4], studied the aerosols effect on the FSO link. They studied attenuations of FSO by aerosols phenomena in the Babylon city for three wavelengths (450nm, 810nm, and 1550nm) for transmitting in horizontal range from 10m to 3km. The experimental results show that there is an increased in the annual average deposits of dust in the period of the study, which appears that the average dust deposit in Iraq is several times greater than amount recommended by the (WHO) standards that should not exceed (9 g/m2/month). Also, the results showed that the maximum dust deposits are in the industrial centre of Hilla, while the minimum concentration has been found in the agricultural centre of Hilla.

Fadel et. al (2018) [5], designed an FSO communication system by used a software called (Optisystem). They study the effects of atmospheric dust on the performance of FSO system. They study the dust concentration effect on the visibility via taking a several concentrations of dust and computed the attenuation of dust for the wavelengths (784nm, 1550nm). There work is also considering the effect of the power of laser that transmitted over the propagation distance (transmitter range) for the two wavelengths (1550nm, 784nm) under the attenuation influence caused by dust concentration. Their study 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 / m2) and transmitted laser power is (50mw) when the wavelength is (1550nm) then

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the transmitter range is equals (1.25km) and when the wavelength is(784nm) when the transmitter range is equals (1.21km).

3. Background Theory

The laser power attenuation in the atmosphere can be calculated from Beer's Lambert law [6].

$$\tau(R) = \frac{P_r}{P_t} = e^{-\mu R} \quad (1)$$

Where: τ(R), represent the transmittance at the range R, Pt, is the laser power at source Pr - laser power at propagation range (R), and the μ, is the total extinction or attenuation coefficient which can be calculated by following equation [7]:

$$\mu = ag + ap + \gamma_g + \gamma_p \quad (2)$$

where: αg, is the molecular absorption coefficient, αp, is the aerosol absorption coefficient, g^{γ}, is the Rayleigh or molecular scattering coefficient, and γp, is the Mie or aerosol scattering coefficient.

The total atmospheric transmittance τ(R) is factored by absorption and scattering transmissivities [8].

$$\tau(R)=\tau(\alpha)\, \tau(S) \quad (3)$$

where: τ(S), is the scattering transmittance and τ(α), is the absorption transmittance,

The dust particles are small when compared with the parent material. The size of dust particle is ranged from submicroscopic to microscopic. The attenuation caused by atmospheric aerosols and dust related to Mie scattering particles that depends on the atmospheric aerosols volume, and the absorption electromagnetic effects are relatively small when compared with Mie scattering, thus, the scattering coefficient is computing form the wavelength and the visibility distance of the incident beam. The visibility range is related with concentration of dust as [9, 10]:

$$V = 7080C^{-0.8} \quad (4)$$

Where V, is the visibility distance, C, is the dusts concentration (which is changes with altitude) .

Thus, there is a relation direct between scattering coefficient and the dust concentrations because of atmospheric Aerosol [11]:

$$\tau_S = exp\left[\left(\frac{-3.91}{7080\times C^{-0.8}}\right)\left(\frac{\lambda}{0.55}\right)^{-q} \times R\right] \quad (5)$$

Where: τ_S, is the scattering transmittance, λ, is the wavelength, q, is the size distribution of scatters particles), R, is the propagation range [12]

4. Proposed System Setting

This study is depending on advanced computer software that allows to perform the FSO system description and can implemented the measurement under of turbulences condition. The attenuations of light caused by dust based on Mie Scattering can be implemented by using Kim and Kruse, were we utilized and implemented in this experiment [13]. Kim model at very high attenuations is better model. The dust effects on FSO communication. The main concern of this study is the dust gales and the growing pollution. The dust influence on FSO has also presented. The dense dust has been generated within atmospheric chamber that prepared from earth soil. The transmitter will be on one side of chamber while their receiver in other side in such way that light should be passing through chamber and it subjected to atmospheric condition.

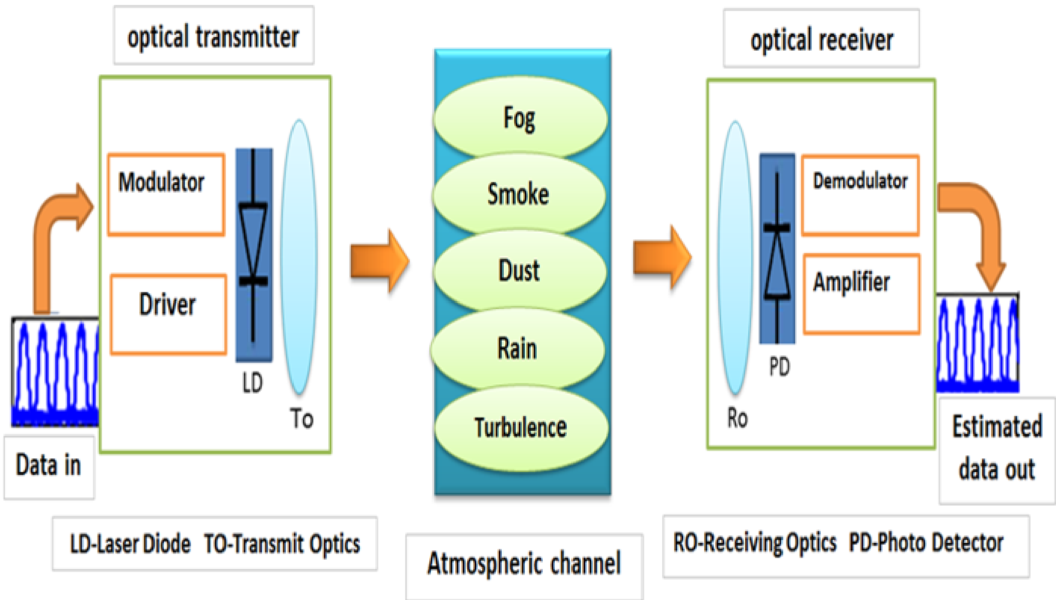

Figure 1: Proposed system structure

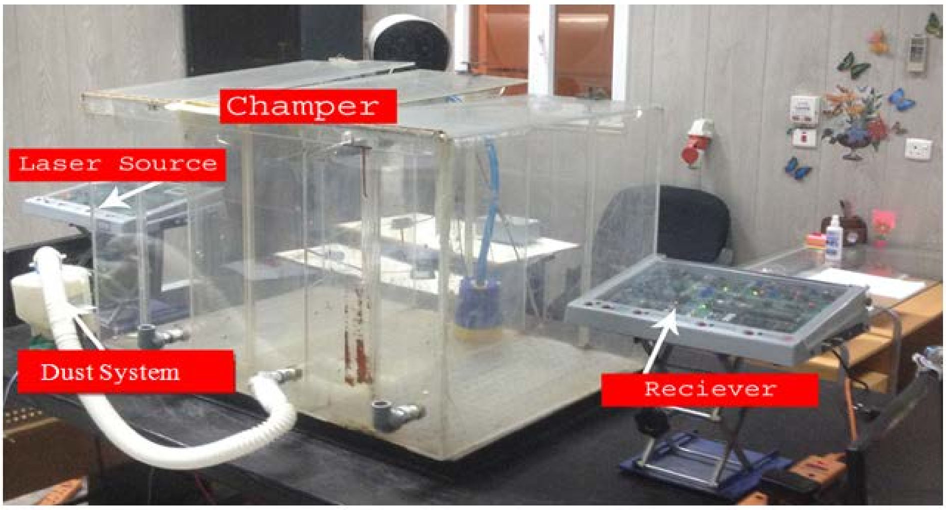

Figure 2: Experimental setup

5. Results

The dust system has first generated storm in the chamber, then the FSO system had transmitted IR laser through it to be received in other side by receiver and records the signal accuracy. To test visibility data, the atmospheric conditions calculations has been made for several dust conditions cases.

From experimental results, the dust is the higher attenuation for optical signal among all the other effects, although the dust hasn't affected on the intensity of FSO adversely but it the dust storms values and the increasing pollution are highly enough to effect on the FSO communication link. The dust attenuation vs the visibility for different wavelengths for lab-controlled FSO link are shown in figure 3, 4.

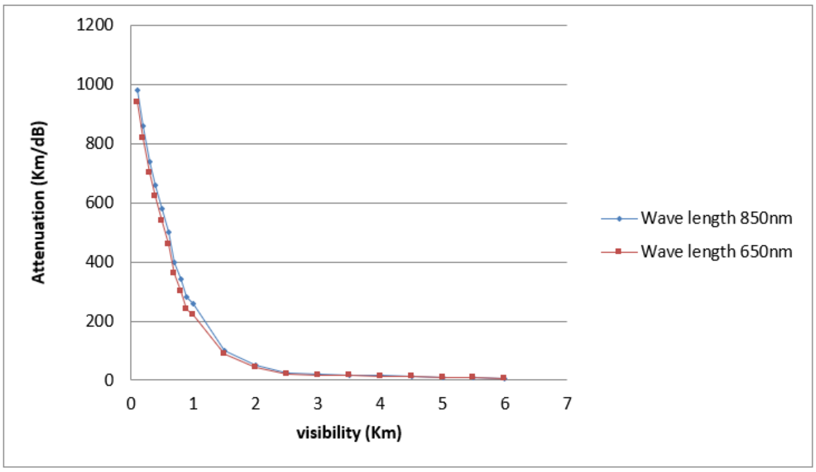

Figure 3: Dust attenuation verses visibility for different wavelengths for lab-controlled FSO link.

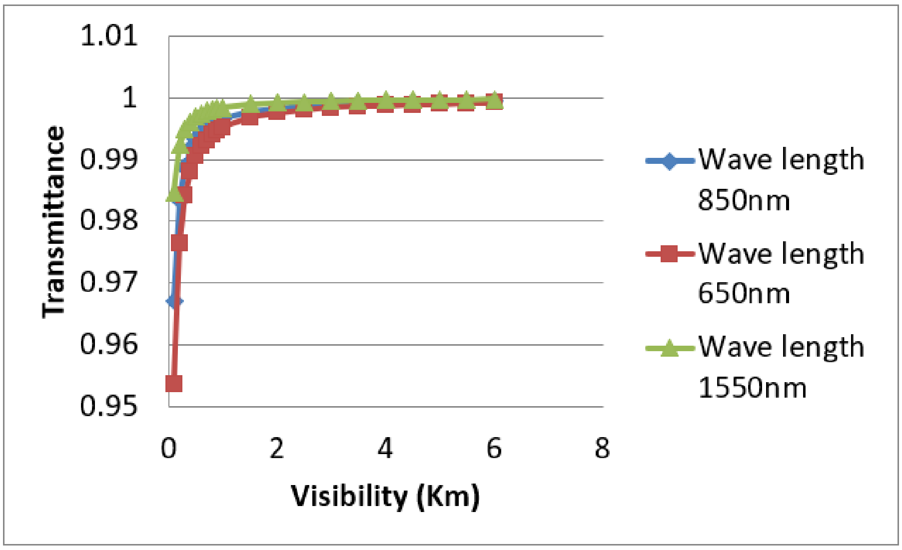

Figure 4: Atmospheric transmittance of wavelength (650, 850, and 1550) nm dependent on visibility distance.

We also study the relationship between the transmittance and the concentration and also the relationship between the visibility and concentration, and the results are illustrated in figures 5 and 6

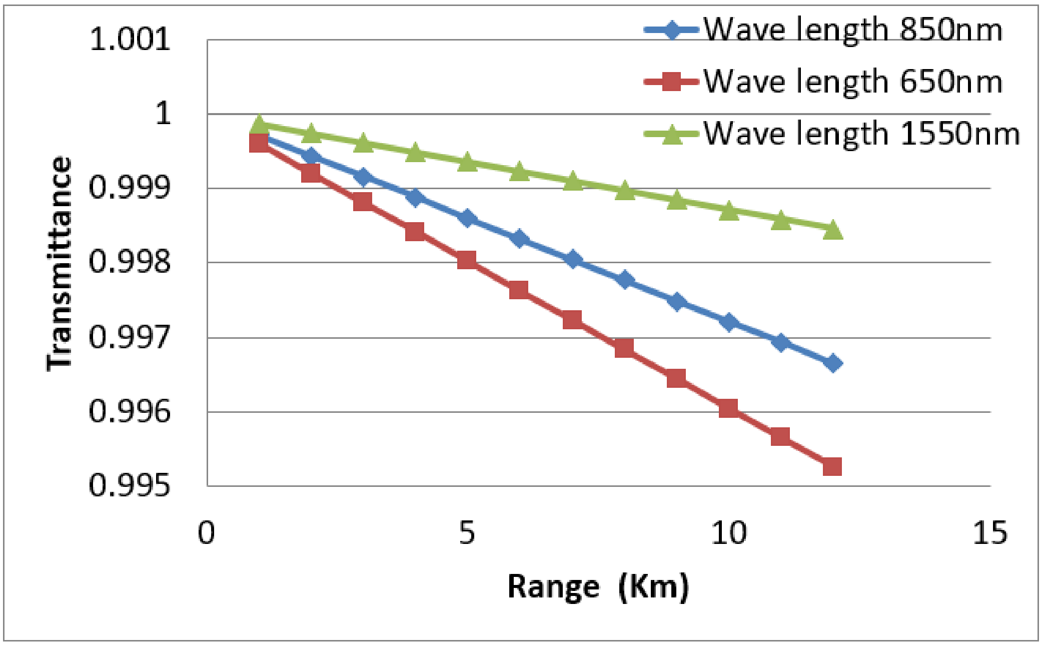

Figure 5: Variations of transmittance as a function of dust concentration, for the three wavelengths, for path length.

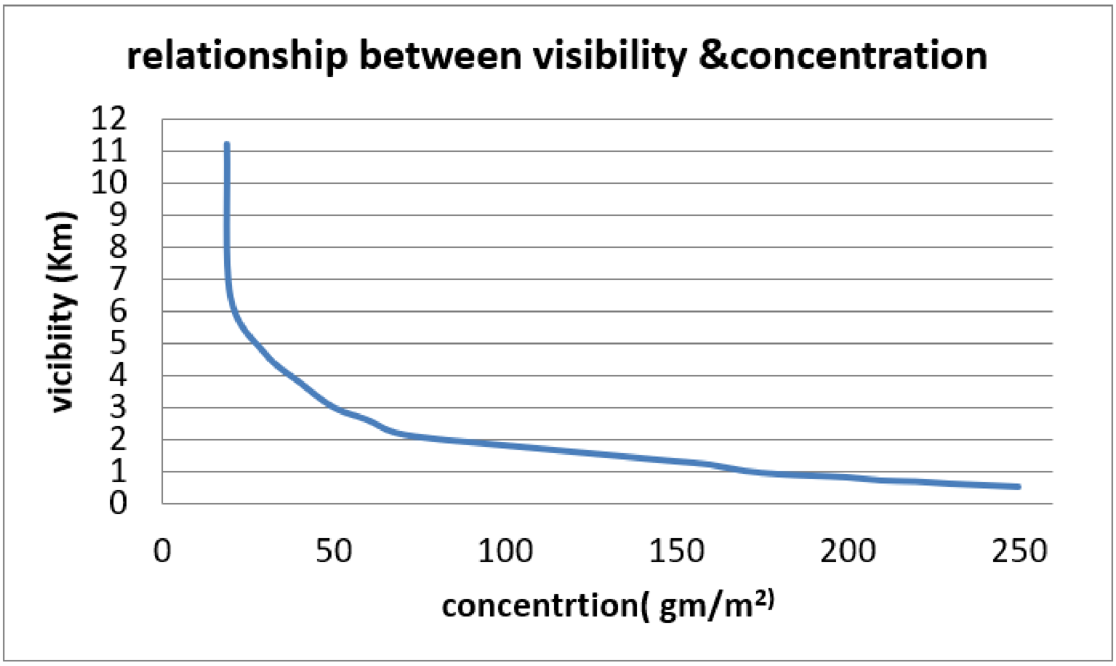

Figure 6: Variations of Visibility Range as Functions of Dust Concentration

From results its appears that he relationship between attenuation and visibility with the dust particles concentration is exponentially inverse, while for concentration and attention of dust particles is inverse linearly.

6. Conclusions

The 1550nm wavelength for Laser beam of is much suitable to overcoming many of atmospheric effects which is more than other lasers of wavelengths (650nm, and 850nm) that is commonly used in laser communication. The result shows that the effect of FSO of any wavelength is dependent on the dust attenuation even when the V is below 0.5 km. Additionally, the visibility distance reduced as the particles concentrations are increased, which can reduce the visibility distance.

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