EXPERIMENTAL STUDY OF THE INFLUENCE OF AEROSOL PARTICLES ON LINK RANGE OF FREE SPACE LASER COMMUNICATION SYSTEM IN IRAQ

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Abstract

Attenuation due to aerosols restricts the distance of FSO communication systems and limits the availability for line-of-sight terrestrial link. This work is focused on the effect of aerosols on the FSO link. The attenuations was studied in the Hilla city in the aerosols phenomena for three selected wavelengths (532, 1064, and 10600 nm) for horizontal transmitting range (1-10) Km. The results show that system availability as a function of the range, and indicate that FSO systems can be deployed with reliability in Hilla city of Iraq.

Key words: Attenuation, Propagation, Atmospheric Transmittance, FSO.

1. INTRODUCTION

The propagation of electromagnetic (EM) wave in the atmosphere is subject to many effects, that happen when the interaction between the EM wave and the field environment in a complex mechanism which can be cover the propagation of EM wave in different ranges starting with x-ray and ending to radio wave. Laser as a from of EM wave unavoidable suffers all of these effects, which such as dense fog, haze, dust, rain, clouds, eddies and air molecules which are unavoidable effects on the laser beam [1].

The propagation of laser beam through atmospheric space can be classified in horizontal, vertical, or slant paths propagation which may provide an information on structure of the atmosphere [2].

2. ATMOSPHERIC ATTENUATION

The attenuation of laser power in the atmosphere is described By Beer's Lambert law [3].

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

where: $\tau(R)$ =transmittance at range R, P_r = laser power at R , P_t = laser power at the source, at zero range μ =Attenuation or total extinction coefficient (per unit length).

The attenuation coefficient has contributions from the absorption and scattering of laser photons by different aerosols and gaseous molecule in the atmosphere [4]. The attenuation coefficient is made up of four parts:

$$\mu = \alpha_g + \alpha_p + \gamma_g + \gamma_p \qquad (2)$$

where: α_g = molecular absorption coefficient, α_p = aerosol absorption coefficient, γ_g =molecular or Rayleigh scattering coefficient, and γ_P =aerosol or Mie scattering coefficient.

This relationship applies to both visible and IR wavelengths, in this expression, the factor $e^{-\mu R}$ represent the transmittance.

The total atmospheric transmittance can be factored as the product of the absorption and scattering transmittances

$$\tau(R) = \tau(\alpha)\tau(s) \qquad (3)$$

where: τ_α = the absorption transmittance, τ_s = the scattering transmittance [4].

3. ATTENUATION DUE TO DUST

Dust is a solid particle formed by disintegration processes such as crushing, grinding, blasting, and drilling. The particles are small replicas of the parent material, and their particle size may range from submicroscopic to microscopic. The attenuation from dust and atmospheric aerosols are resulting from Mie scattering particles, which dependent on the volume of the atmospheric aerosols, and the effects of absorption electromagnetic will be relatively small comparing with Mie scattering, therefore, the scattering coefficient can be computed form the visibility distance and wavelength of the incident beam [5-7]. The range of visibility is related with concentration of dust as:

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

where V - visibility distance ,
C- concentration of dusts (various with altitude) Therefore, there is a direct relation between concentrations of dust and scattering coefficient due to atmospheric aerosol is [8]:

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

where τ_S - transmittance resulting from scattering , λ - wavelength , q - positive constant proposed computed (the size distribution of the scattering particles) ,
R - propagation range .

4. RESULTS AND DISCUSSION

4.1. Calculation of the atmospheric transmittance for three different beams propagation in Hilla city

Figures (1),(2), and (3), which represent variations of atmospheric transmittance with range of 1 km, for wavelengths of (532, 1064, and 10600 nm), for state of clear weather, haze weather, and thick fog weather. In this figure its found that the wavelength of 10600 nm more capability to penetrate atmospheric effects on beam propagation beam than other wavelengths, because higher wavelength, and found that wavelength of 1064 nm is better than 532 nm.

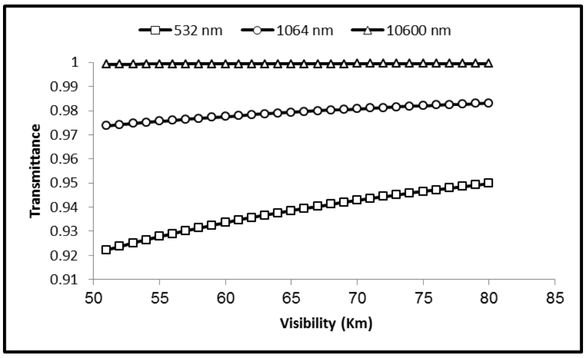

Figure 1. Atmospheric transmittance of wavelength (532, 1064, and 10600) nm dependent on visibility distance for very clear weather.

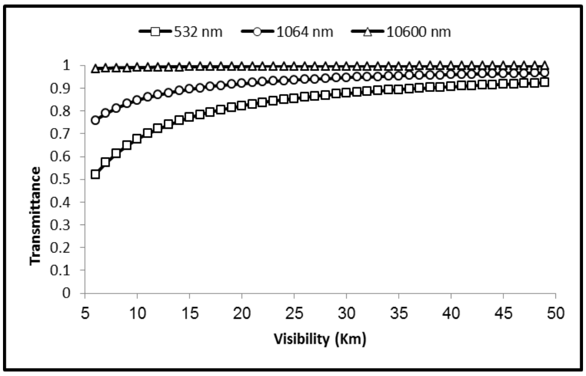

Figure 2. Atmospheric transmittance of wavelength (532, 1064, and 10600) nm dependent on visibility distance for haze weather.

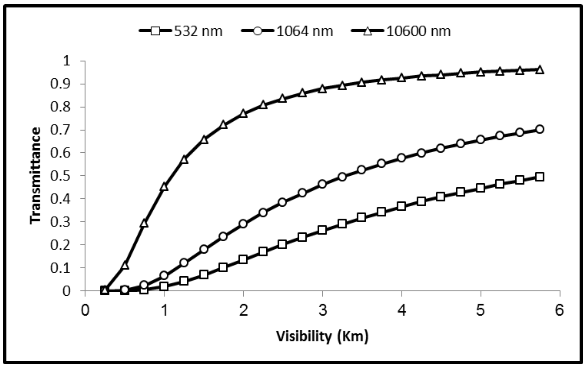

Figure 3. Atmospheric transmittance of wavelength (532, 1064, and 10600) nm dependent on visibility distance for bad weather.

4.2. Calculation of the beam attenuation due to dust in Hilla city

Figure (4) which represent variations of transmittance as a function of dust concentration with propagation distance of 10 km for a dust concentration (C=95.59 $\mu g / m^3$) and for the three wavelengths its shows that the wavelength of 10600 nm is capable to penetrate dust effect in the path length than the other two wavelengths (532, 1064 nm), and wavelength of 1064 nm has better capablty to overcome effect of dust than the wavelength of 532 nm.

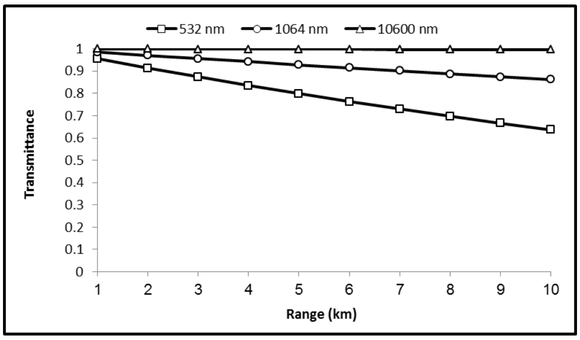

Figure 4. Variations of transmittance as a function of dust concentration, for (C= 95.59 $\mu g\ / m^3$) for the three wavelengths, for path length of 10 km.

Figure (5) represent variations of transmittance as a function of dust concentration with propagation distance of 10 km, concentration of dust (C= 343.71 $\mu g / m^3$), we saw twice time that wavelength of 10600 nm has high capability to overcome dust effect, the transmittance of 10600 nm at 10 km distance approach to 0.99 value, while the value of transmittance of wavelength 1064 nm approach to 0.81 value, and 532 nm approach to 0.55 at distance of 10 km.

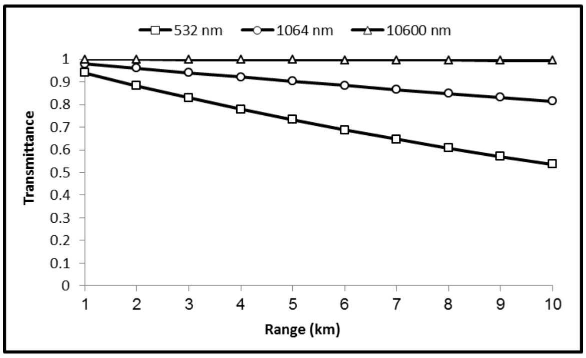

Figure 5. Variations of transmittance as a function of dust concentration, for (C= 343.71 $\mu g\ / m^3$), for the three wavelengths, for path length of 10 km.

Figure (6) represents variations of transmittance as a function of dust concentration with propagation distance of 10 km, concentration of dust (C= 450.95 $\mu g / m^3$), we saw that the transmittance of wavelength 10600 nm value of 0.99, while wavelengths of (1064, and 532) nm, values of (0.77 - 0.47) respectively at distance propagation of 10 km.

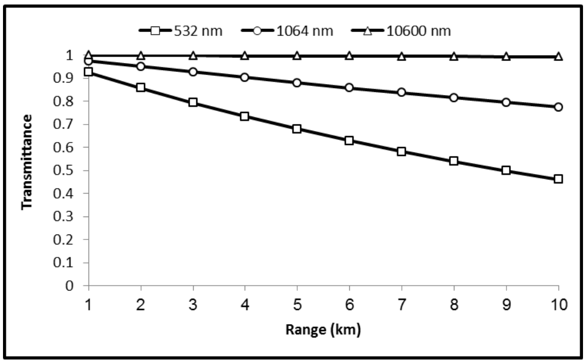

Figure 6. Variations of transmittance as a function of dust concentration, for (C= 450.95 $\mu g\ / m^3$), for the three wavelengths, for path length of 10 km.

Figure (7) represent variations of transmittance as a function of dust concentration with propagation distance of 10 km, concentration of dust (C= 50.762 $\mu g/m^3$), we saw that the transmittance of wavelength 10600 nm value more than 0.99 at distance of 10 km, while wavelengths 1064 nm, and 532 nm have transmittance of 0.96, and 0.88 respectively at propagation distance of 10 km, which lead to more capability of wavelength 10600 nm than the wavelengths of 1064 nm, and 532 nm of penetrating effects of dust.

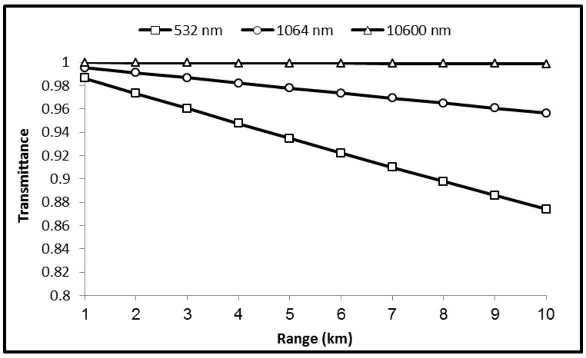

Figure 7. Variations of transmittance as a function of dust concentration, for (C= 50.762 $\mu g/m^3$), for the three wavelengths, for path length of 10 km.

Figure (8) represents variations of transmittance as a function of dust concentration with propagation distance of 10 km, concentration of dust (C= 707.79 $\mu g/m^3$), we saw that the transmittance of wavelength 10600 nm value of 0.99, while wavelengths of (1064, and 532) nm, values of (0.7 - 0.37) respectively at distance propagation of 10 km.

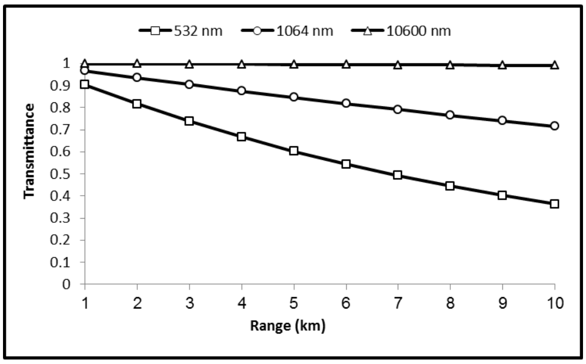

Figure 8. Variations of transmittance as a function of dust concentration, for (C= 707.79 $\mu g/m^3$), for the three wavelengths, for path length of 10 km.

Figure (9) represent variations of transmittance as a function of dust concentration with propagation distance of 10 km, concentration of dust (C= 937.05 $\mu g/m^3$), we saw wavelength of 10600 nm has high capability to overcome dust effect, the transmittance of 10600 nm at 10 km distance approach to 0.98 value, while the value of transmittance of wavelength 1064 nm approach to 0.55 value, and 532 nm approach to 0.22 at distance of 10 km.

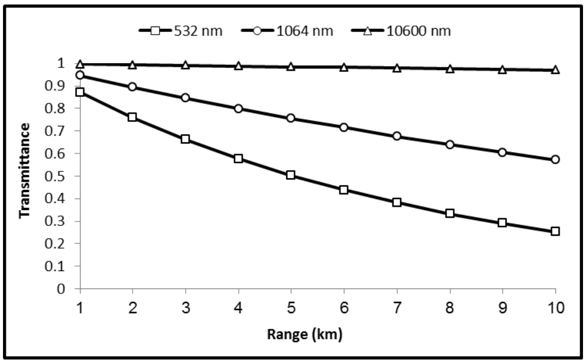

Figure 9. Variations of transmittance as a function of dust concentration, for (C= 937.05 $\mu g / m^3$), for the three wavelengths, for path length of 10 km.

From the figures, we saw that the wavelength of 10600 nm has more operative than wavelengths of 1064 nm, and 532 nm to overcome the effect of dust because their higher wavelength comparing with other wavelength.

5. CONCLUSIONS

1. In Iraq the effect of dust is approximately high effect because of there climate area in Iraq are semi desert area (desert climate).
2. Laser beam of wavelength (10600 nm) is more practical in laser communication than both the 532&1064 nm.
3. The best use of laser beam propagation is through clear weather especially in winter period, because of the decrease in temperature and the absence of any turbid phenomenon which reduces the visibility range to less than 10 km. scattering of laser beam is at most constant in clear weather.

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