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Analyzing the Quality of Laser Beam Transmission through Atmospheric turbulence

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ABSTRACT

The quality of laser beam in free – space optical communication is affective by the atmospheric turbulence, this quality of beam is describing by two important parameters signal –to- nose ratio (SNR) and bit error rate (BER) .In this paper using Laboratory simulation turbulence cell to analyzing the effective atmospheric turbulence on beam winder and Beam fluctuating power in different turbulence conditions, also effective at same conditions on BER and SNR

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Atmosheric Turblence:

Atmospheric turbulence affects the propagation of a beam of light within the channel in three ways (Zhu *et al*., 2002). Firstly, the wave front is distorted by the variation due to scintillation index, thus creating the fluctuations in the intensity of the optical signal. Secondly, the beam wandering takes place due to the diffraction of the laser beam, when the diameter of the beam is smaller equal to the size of the eddies. Thirdly, the atmospheric turbulence makes the laser beam to spread beyond the diffraction limit. Scintillation is a severe problem and can result in a significant deterioration of the link BER performance .

Basic Models:

The Rytov Approximation its better method to determined the atmospheric turbulence attenuation of laser beam (Jassim *et al*., 2015), (Uysal M., 2003) . For a plane wave, when the turbulence is weak, and assuming that the refractive index structure coefficient Cn^2 is symmetrical along the beam path, Rytov suggested a variance for the log intensity fluctuations given as (Popoola., 2008).

$$\sigma_X{}^2 = 23.17 C_n{}^2 k^{7/6} L^{11/6} \quad (1)$$

where $k=2\pi/\lambda$, L is the propagation length .

The relation for calculation the turbulence attenuation (αRY) according to the *Rytov* 's approximation method expressed by (Berman.G.P, 2007) :

$$\alpha_{RY} = 2\left(23.17 C_n{}^2 k^{7/6} L^{11/6} \right)^{1/5} \quad (2)$$

SNR and BER are used to evaluate the quality of communicating system. The average received power , receiver noise and scintillation strength restricts the performance of BER. Not only increased received optical power but also reduced effect of scintillation can be obtained by suitable design of aperture. For FSO links with on-off keying (OOK) modulation scheme the SNR can be written as (Larry *et al*., 1998).

$$SNR = \left(0.3 C_n{}^2 k^{7/6} L^{11/6} \right)^{-1} \quad (3)$$

With on-off keying (OOK) modulation the approximation BER can be written as(Jassim *et al*., 2013) :

$$BER = \frac{\exp\left(\frac{-SNR}{2} \right)}{\left(2\pi SNR \right)^{0.5}} \quad (4)$$

Laboratory simulation of turbulence:

In order to create a turbulence environment ,under control ,in the laboratory, a simple simulation system is constructed consisting of (He-Ne laser , turbulence cell ,CCD camera ,optical detector and many electrical parts shows in figure (1).

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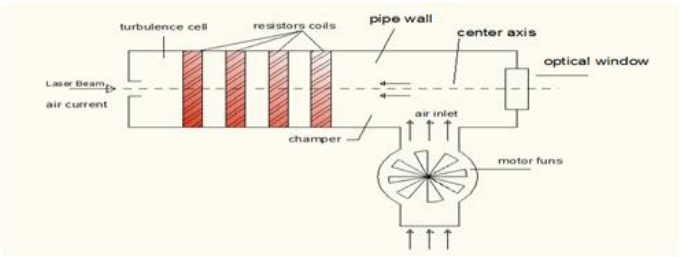

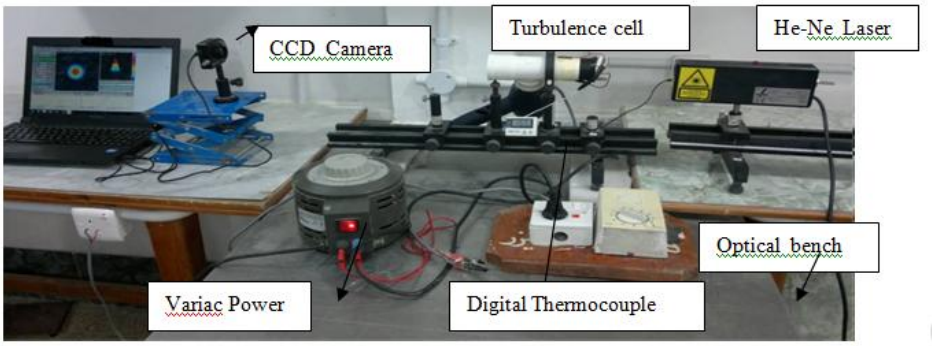

Fig. 1: Turbulence cell.

Effective atmospheric turbulence on Beam wander:

The experimental results for effective atmospheric turbulence on passing optical beam through turbulence cell used with parameters , propagation distance (150 cm), temperature varies between (23 ^{0}c to 55 ^{0}c), wind speed (5 m/s) and spot size of Laser beam is (1 mm) . Figures (2a , 3a ,4a ,5a and 6a) show the evaluation of the position Laser beam respective to the center of the optical detector , clear absorved the strong turbulence (increase Temperature) is effective in the position of beam in x and y directions . The charge in x-direction between (30-350)pixels with increase temperature also the change in y-direction about (30-450) pixels at same increase temperature . The change in refractive index related the change of atmosphere temperature lead to the beam of Laser arrived detector at different path .Figures (2b , 3b ,4b ,5b and 6b) show the optical beam profile with different turbulence (temperature), observation the distribution of light beam intensity on cross-section surface drift decrease in the temperature (35 ^{0}c) and drift increase with increase temperature about (55 ^{0}c) , almost the drift change is small because the propagation distance is very small around (150 cm).

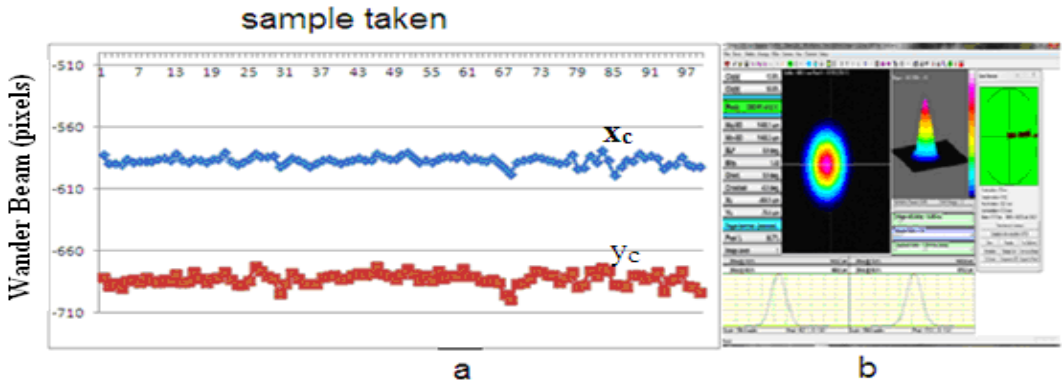

Fig. 2: Position and profile of Laser beam varies with temperature (room Temp).

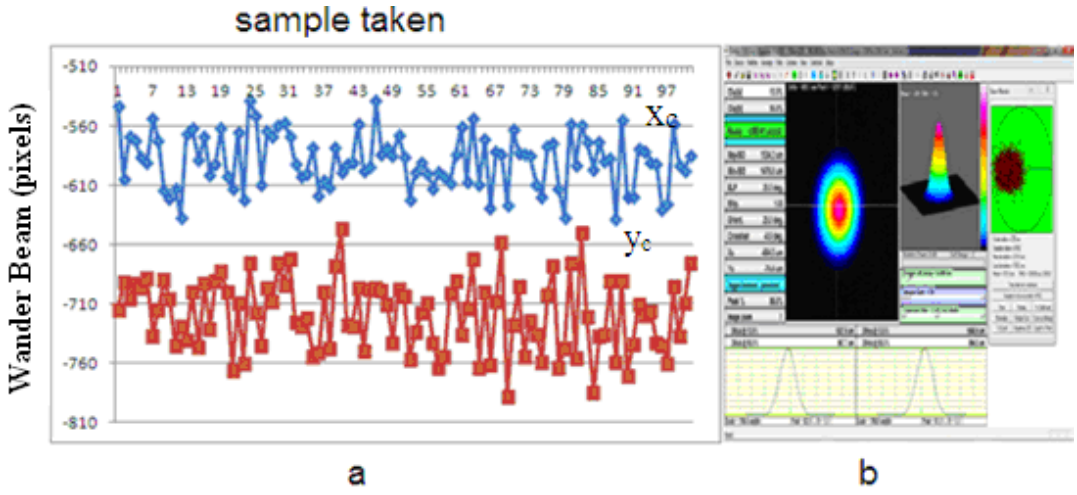

Fig. 3: position and profile of Laser beam varies with temperature (36 ^{0}c Temp).

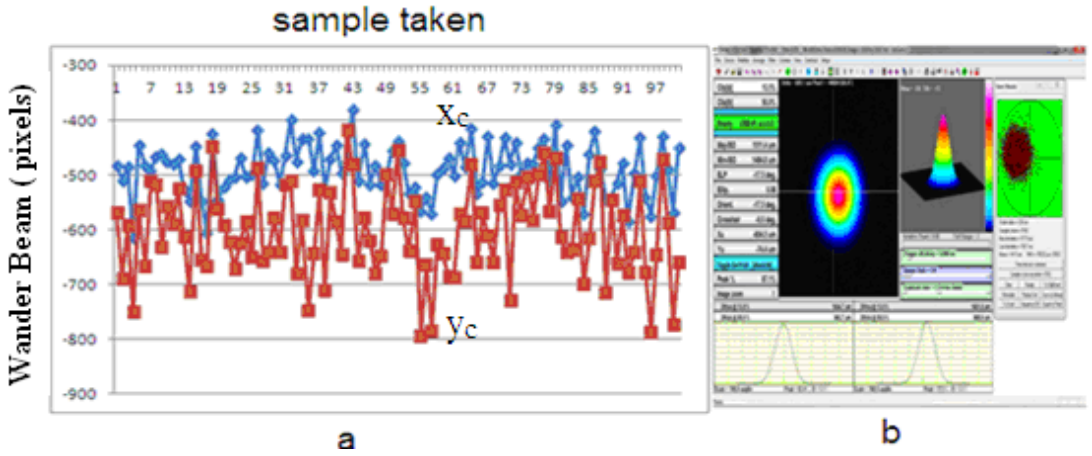

Fig. 4: Position and profile of Laser beam varies with temperature (45.6 ^{0}c Temp).

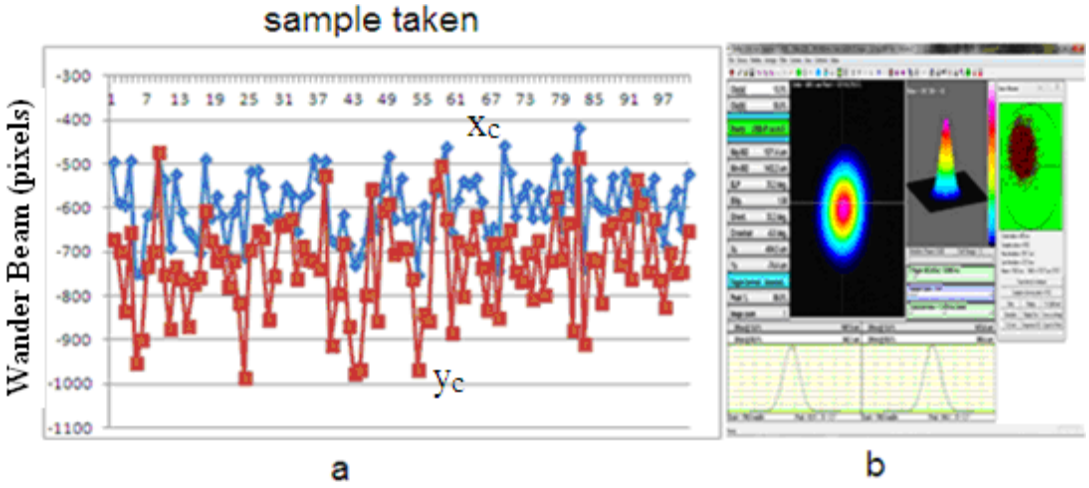

Fig. 5: Position and profile of Laser beam varies with temperature (51^{0}c Temp).

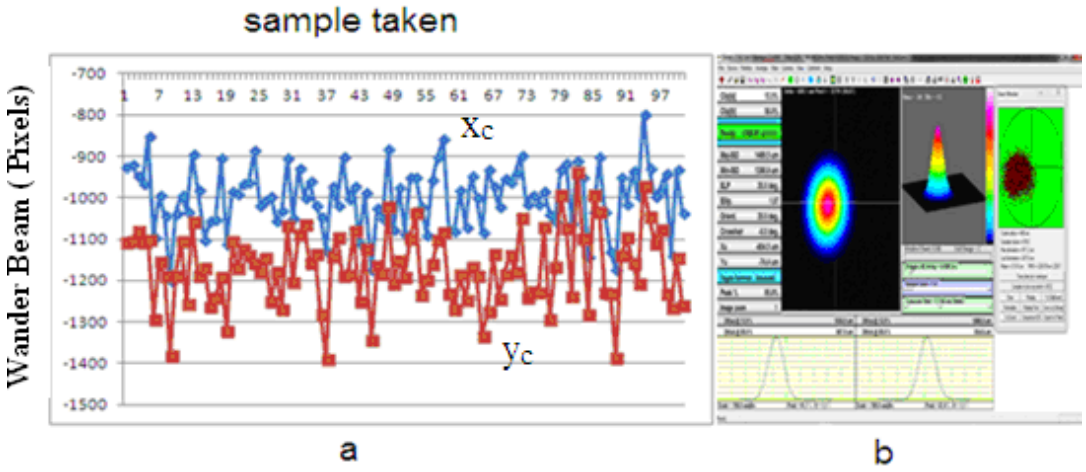

Fig. 6: Position and profile of Laser beam varies with temperature (55 ^{0}c Temp).

Effective atmospheric turbulence on Beam fluctuating power:

The experimental results for effective atmospheric turbulence on power of beam passing through turbulence cell, when the cold and warm air meets in turbulence cell generation turbulence , this causes variation in power of Laser beam Figure (7)(a, b, and c) show that result measurement of the variation power , it can be seen that most of the variation intensity below (80 mV), which mean that the value of (S/N) is large in high turbulence and cause limitation of the propagation distance . Clear observation the value of variation intensity its linear with variation turbulence (temperature).

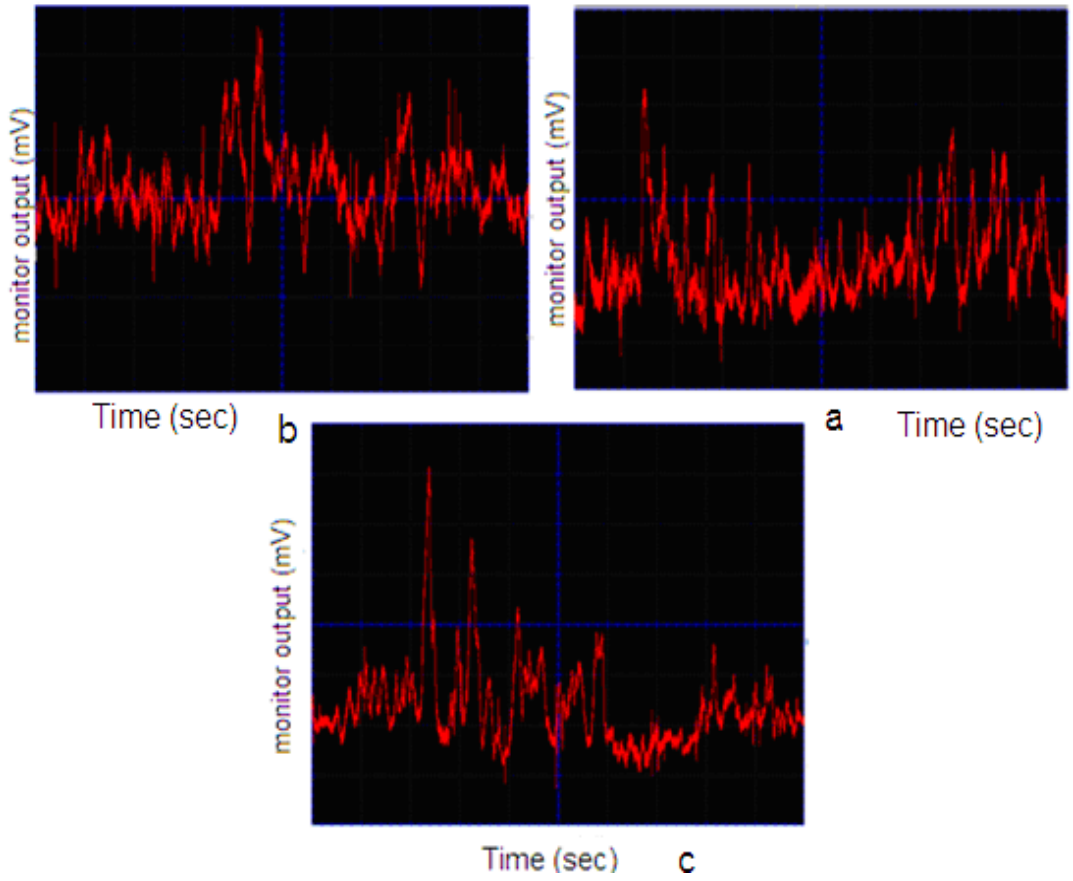

Fig. 7: The time change of received power at different turbulence [Temp= 20 , 30 , 45) ^{o}C Respectively.

***Calculate turbulence attenuation on Laser beam*:**

In this section calculating the turbulence attenuation on Laser beam for the turbulence parameter Cn^2= (10^{-16} , 10^{-15} and 10^{-14}) m-2/3,propagation distance (500- 5000)m , the wavelength used is 632nm rather than 532 ,355,407 and 810 nm . Fig.8 (a,b and c) shows the turbulance attenuation against the distance with different three value wavelengths and turbulence. The acceptable value of turbulence attenuation is (0.4 dB) at wavelength (632)nm , low turbulence and propagation distance lower (2000)m.

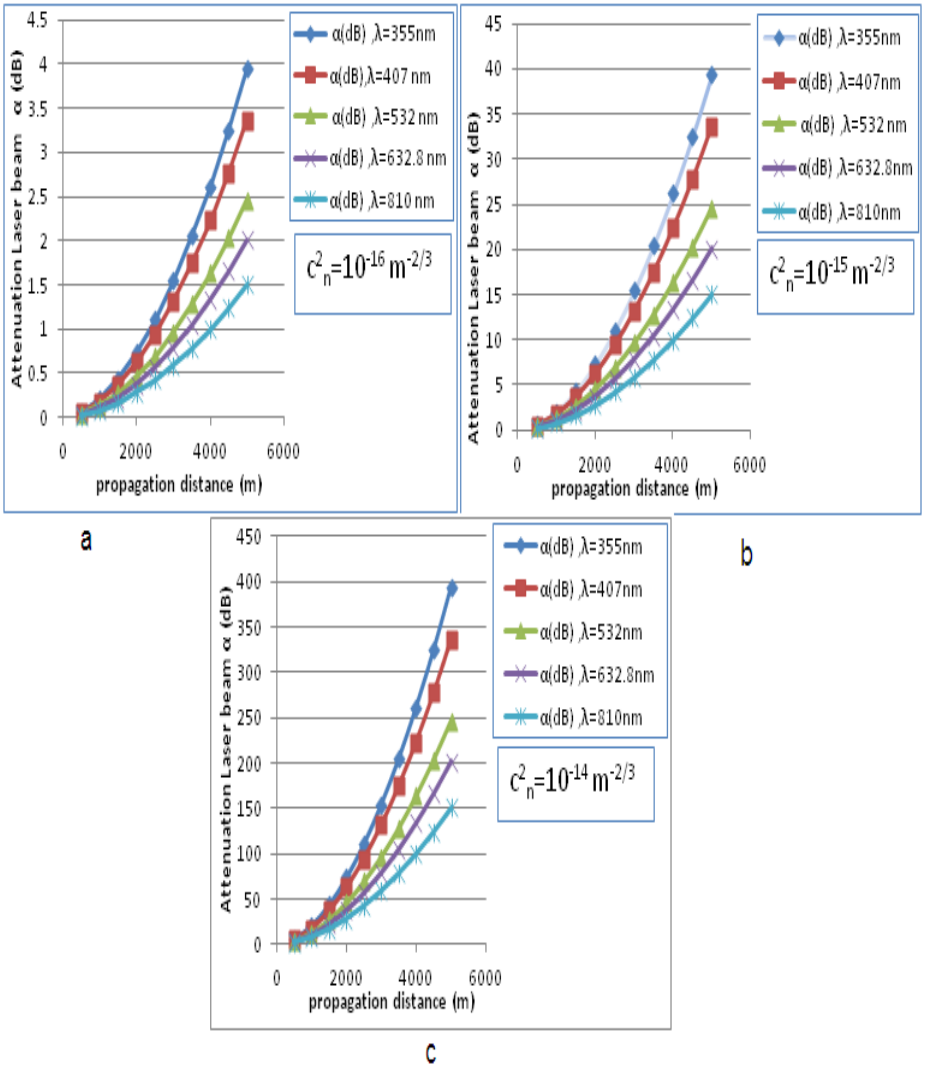

Fig. 8: The Attenuation turbulence is varies the propagation distance for different value of wavelengths and structure function

Calculate the SNR and BER:

In this section calculating the SNR and BER for the turbulence parameter Cn^2= (10^{-16} , 10^{-15} and 10^{-14}) m-2/3,propagation distance (500- 5000)m , the wavelength used is 632nm rather than 532 and 810 nm . Fig.9 (a,b and c) shows the SNR against the distance with different three value wavelengths and turbulence. The acceptable value of SNR is (2500) at wavelength (810)nm , low turbulence and propagation distance lower (500)m. Fig.10 (a,b and c) shows the BER against the distance with different three value wavelengths and turbulence. The acceptable value of BER (1×10^{-19}) at wavelength (632)nm , low turbulence and propagation distance lower than (500)m.

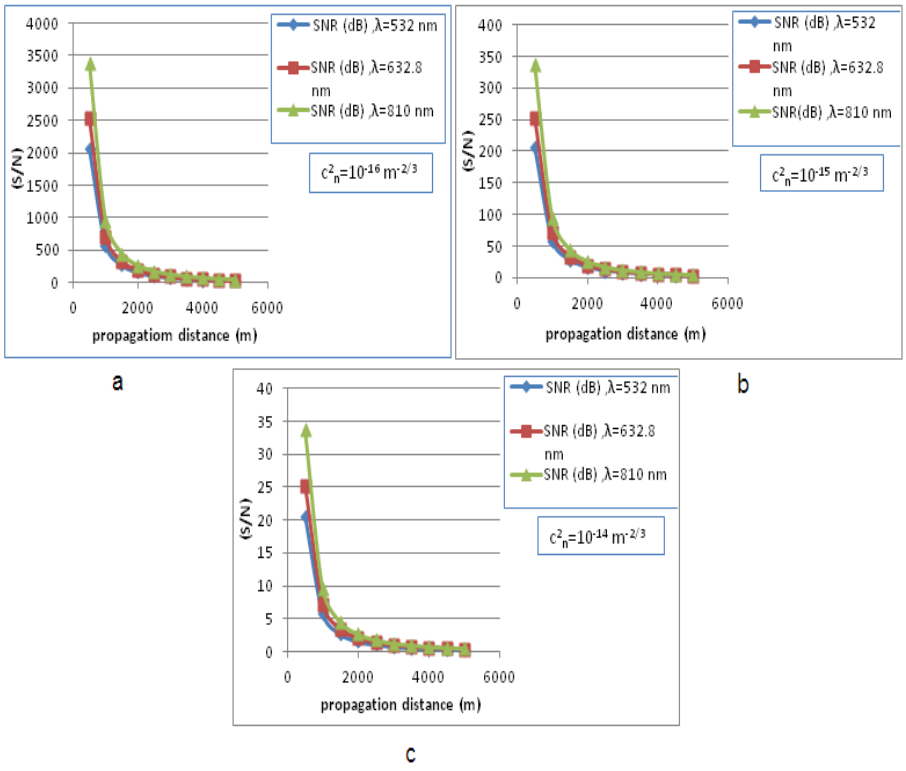

Fig. 9: The SNR is varies the propagation distance for different value of wavelengths and structure function.

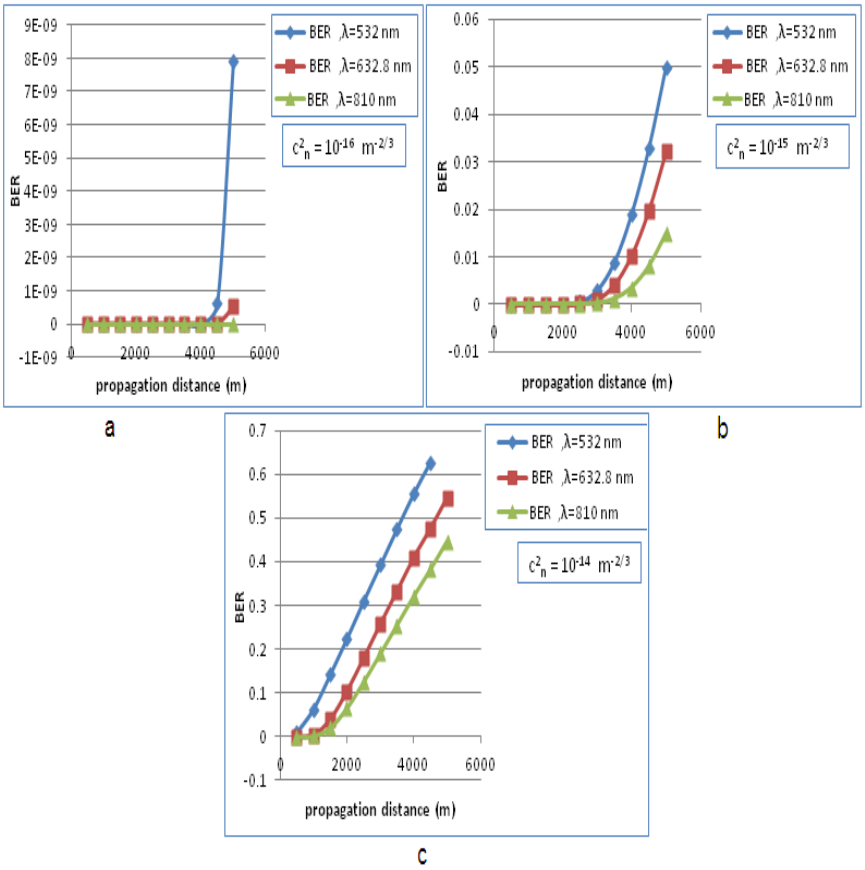

Fig. 10: The BER is varies the propagation distance for different value of wavelengths and structure function.

Conclusion:

The error in space optical communication caused by beam wander, fluctuating power, propagation distance and wavelength of laser beam. This result will be useful for the analysis of atmospheric turbulence on optical communication link in this geographical region.

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