International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
Available at http://inpressco.com/category/ijcet

Research Article

Determine the optical turbulence parameter (Cn^2) in Babylon City-Iraq

Jassim Mohammed Jassim†*, R. N. Ali† and Hawraa Hassaball Khribet†

†Babylon University - College of Science for Women, Iraq

Accepted 25 Jan 2015, Available online 01 Feb 2015, **Vol.5, No.1 (Feb 2015)**

Abstract

This research present to obtain optical turbulence structure and refractive index information a long a near horizontal (0.035 Km) free space path length. Measurement the optical turbulence structure (Cn2), refractive index (nr), Pressure and temperature for several case in winter, spring, summer and autumn. Optical measurements were investigated using three different wavelengths of laser sources (808, 632 and 1064 nm) .we found the change in refractive index is very small but the change in refractive index structure is very strong.

Keywords: *optical turbulence, turbulence, refractive index*

Introduction

Applications of laser communications, ranging, guidance, positioning, navigation, reconnaissance, and laser weapons are related to laser transmission in the atmosphere. Various interferences in the atmosphere are related to laser applications, especially the effect of optical turbulence. Some research reports (Jassim, 2013), (Wasiczko ,2004) . Optical turbulence is an important microphysical effect that acts on the propagation of light waves ,It is brought about by fluctuations in the refractive index in air, i.e., air density, which affects the speed at which light wave fronts propagate ,the local density of the air is constantly fluctuating because of temperature and pressure fluctuations, the temperature of air decreases rapidly with increasing altitude causing turbulence strength to decrease with altitude, therefore the optical turbulence can become very strong near the ground because of the heat transfer between ground and air (Tunick, 2005). These fluctuations in refractive index distort the phase front and vary the temporal intensity of an optical wave. this optical turbulence effects on an optical system can cause phenomena such as beam spreading, image dancing, beam wander, and scintillation (Puryear , 2011), (Jassim , 2013). Where we studied the optical turbulence by establishing the empirical meteorology data of weather Babylon city .

Theory

Physically, the refractive-index structure parameter, Cn2, is a measure of the strength of the fluctuations in the refractive index, and the refractive index is a function of pressure, temperature, and wavelength. At optical wavelengths, a good approximation, neglecting water vapor pressure, the index of refraction for the atmosphere can be written for visible and IR wavelengths as (Shapiro, 1974) .

$$n(\vec{r}) = 1 + 77.6\times10^{-6}\left(1 + 7.52\times10^{-3}\lambda^{-2}\right)\frac{p(\vec{r})}{T(\vec{r})} \quad (1)$$

where λ, the optical wavelength, is expressed in μm, P(**R**) is the pressure in millibars at a point in space, and T(**R**) is the temperature in Kelvin at a point in space. It is noticed that the wavelength dependence for optical frequencies is very small; equation 1 can then be rewritten.

$$n(R) \cong 1 + 79\times10^{-6}\frac{P(R)}{T(R)} \quad (2)$$

At point to point communication pressure fluctuations constant are usually negligible, the index of refraction exhibits an indirect relation with the random temperature fluctuations. Thus, we can deduce that the refractivity structure function Dn(r) also obeys the 2/3-squared law (Yuksel , 2005).

$$D_n(r) = C_n^2 r^{2/3} \quad (3)$$

where C_n^2 is the index-of-refraction structure parameter, l_0 is the inner scale of turbulence, and L_0 is the outer scale of turbulence. Figure 1 illustrates the inertial sub-range and the formation of the inner scale from the outer scale.

The structure parameter Cn2 is a measure of turbulence strength. Inner scale **lo** has a strong impact on scintillation.

Weak turbulence: Cn2 = 10-17 m-2/3 or less.
Strong turbulence: Cn2 = 10-13 m-2/3 or more.

*Corresponding author: **Jassim Mohammed Jassim**

For applications involving propagation along a horizontal path, assume Cn2 is constant. Propagation along a vertical or slant path, however, requires a Cn2 profile model as a function of altitude (h). Hufnagle-Valley Model: one most often used by researchers (Kareem , 2008) ,(Parry , 1981).

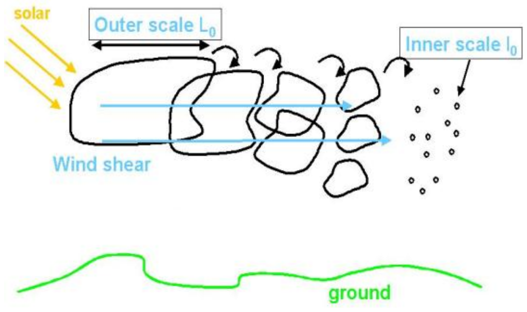


Figure 1 Outer scale breaking up into inner scale (Strobehn, 1978)

$$C_n^2 = 0.00594\left(\frac{w}{27}\right)^2 (10^{-5}h)^{10}\exp\left(\frac{-h}{1000}\right) + 2.7\times10^{-16}\exp\left(\frac{-h}{1500}\right) + A\exp\left(\frac{-h}{100}\right) \quad (4)$$

$A = C_n^2(0)$ is a ground-level value of C_n^2 , and w is root mean square (rms) wind speed which is defined as:

$$w^2 = \left(\frac{1}{15}\right)\int_{5\times10^3}^{20\times10^3} V^2(h)dh \quad (5)$$

$$V(h) = w_s h + w_g + 30\exp\left[-\left(\frac{h-9400}{4800}\right)^2\right] \quad (6)$$

$V(h)$ is the wind speed in meters per second is also given by the Bufton wind model.

$$w = \left[\frac{1}{15\times10^3}\int_{5\times10^3}^{20\times10^3}\left\{w_s h + w_g + 30\exp\left[-\left(\frac{h-9400}{4800}\right)^2\right]\right\}^2 dh\right]^{1/2} \quad (7)$$

where w_g is the ground wind speed, and w_s is the beam slew rate.

$$C_n^2 = 8.2\times10^{-16}w^2\left(\frac{h}{10}\right)^{10}\exp(-h) + 2.7\times10^{-16}\exp\left(\frac{-h}{1.5}\right) + A\exp\left(\frac{-h}{0.1}\right) \quad (8)$$

Results and Discussion

Atmospheric refractive index empirical measurement n(r)

The local meteorology data selected for twelve case studies. We chose the dates (from winter, spring, summer and autumn) somewhat randomly, two different days for each month. where they were taking statements weather forecasters for the temperature and pressure of the months of the year complete and during different times of the day from the Directorate of Environment in Babylon City Iraq.

Figure (2a) presents the time series of nr data collected on 1and15 February 2014. we see that change by a refractive index increases during the night and early morning hours and the minimum value at 10:00 and 6 pm.. Figure (2 b) presents the local meteorology data for this case. The temperature were sporadic at about (6-21⁰C) and pressure were (1100-1620 mb).

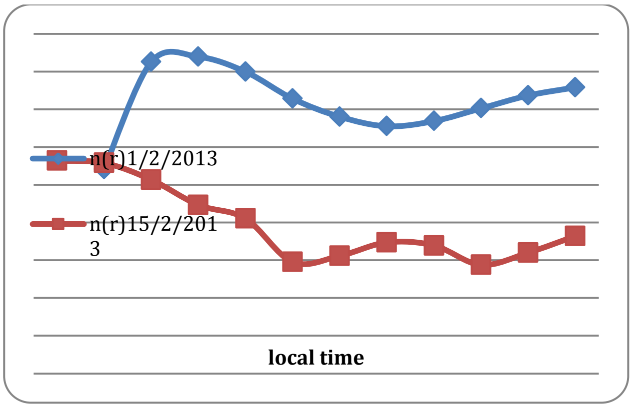


Fig (2a) Relation between the n(r) and local time on 1 and 15/2/2014

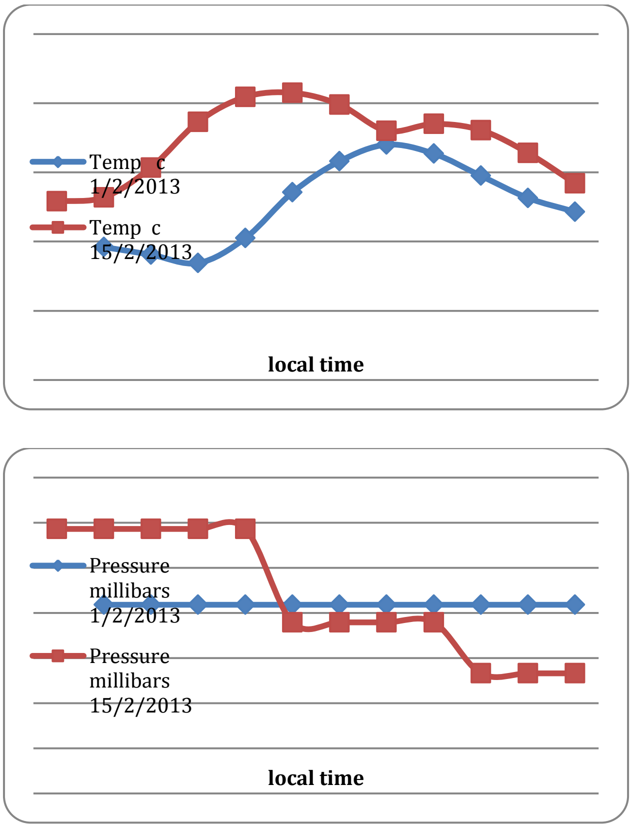


Fig (2b) Time series of local meteorological data collected on 1 and 15/2/2014

Figure (3 a) presents the time series of (nr) data collected on 1and 15 March 2014. On one Day the refractive index is highest during the night and fall to the lowest value at 16:00, and fifteen Day passes two term in which refractive index less than can be. Figure

(3 b) presents the local meteorology data for this case. The temperature were sporadic at about (15-35 ^{0}C) and pressure were (970-1700 mb

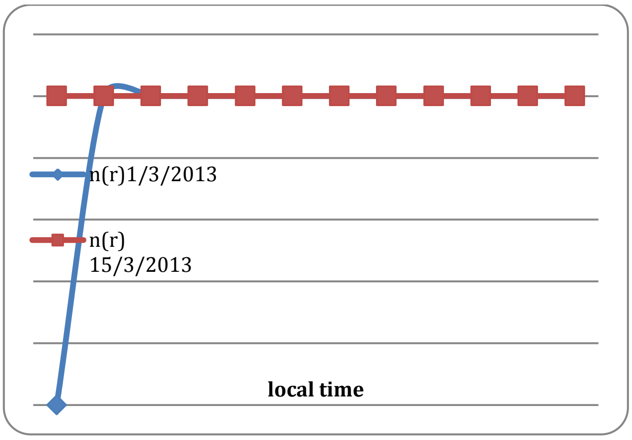


Fig (3a) Relation between the n(r) and local time on 1/3/2013 and 15/3/2013

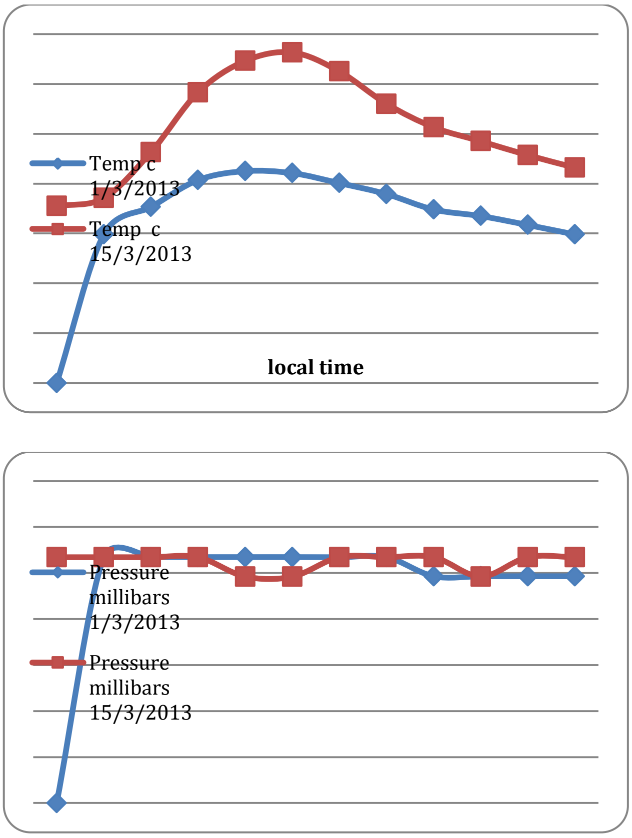


Fig (3b) Time series of local meteorological data collected on 1/3/2013 and 15/3/2013 .

Figure (4 a) presents the time series of (nr) data collected on 1and 15 April 2014. On one Day the change in refractive is very slight but in other days the increasing passes in two terms first in (3-8 AM) and second (2- over 10 PM). Figure (3 b) presents the local meteorology data for this case. The temperature were sporadic at about (20-35 ^{0}C) and pressure were (980-1700 mb).

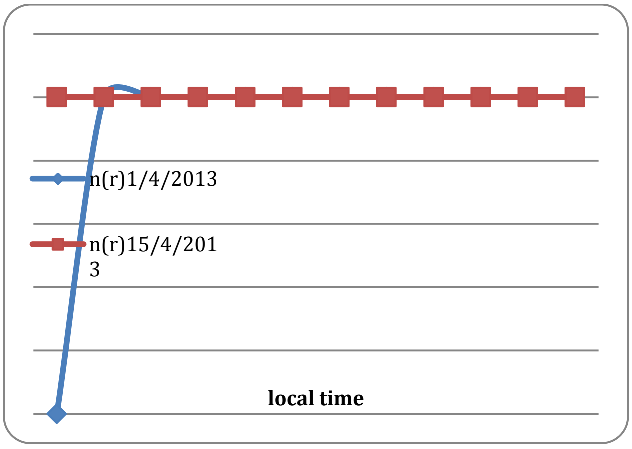


Fig (4a) Shows the relation between the n(r) and local time on 1 and 15/4/2014

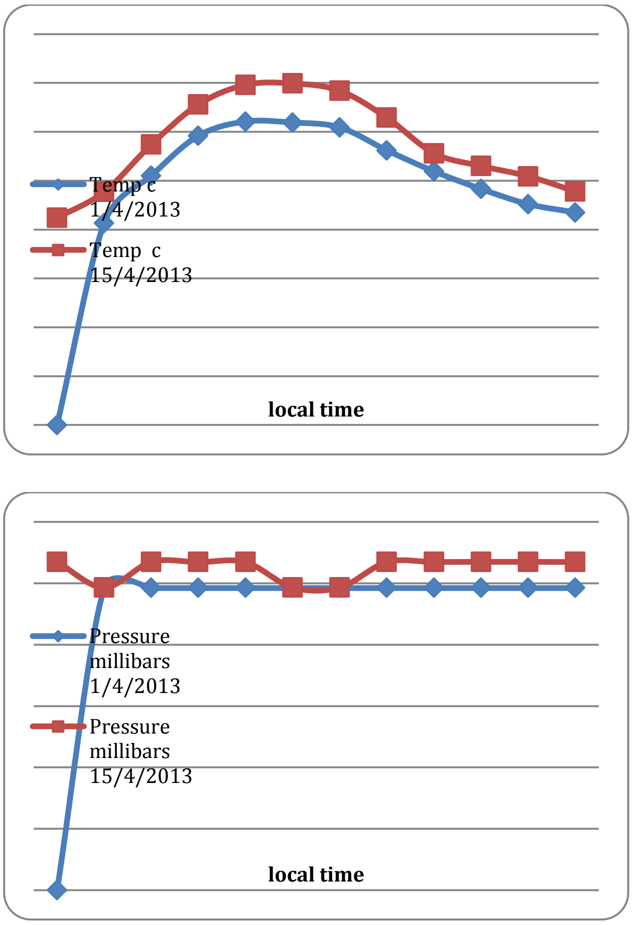


Fig (4b) Time series of local meteorological data collected on 1and 15/4/2014 .

Figure (5 a) presents the time series of (nr) data collected on 1and 15 May 2014. On one Day the change in refractive is very slight except (4 and 8 PM) it less than can be .On other day the change in refractive is slight too but different in interval time less than can be. Figure (5 b) presents the local meteorology data for this case. The temperature were sporadic at about (18-32 ^{0}C) and pressure were (980-1700 mb).

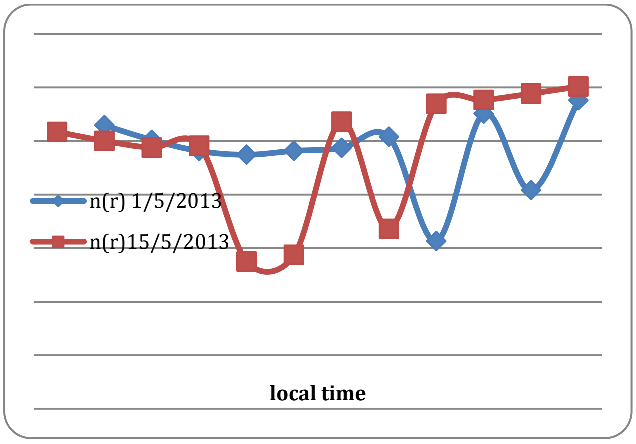


Fig (5 a) shows the relation between the n(r) and local time on 1 and 15/5/2014

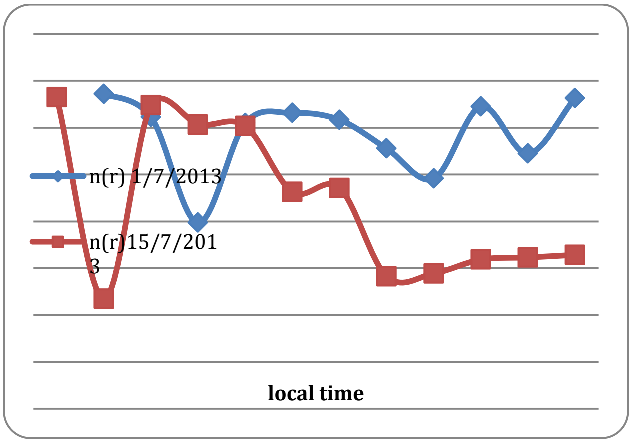
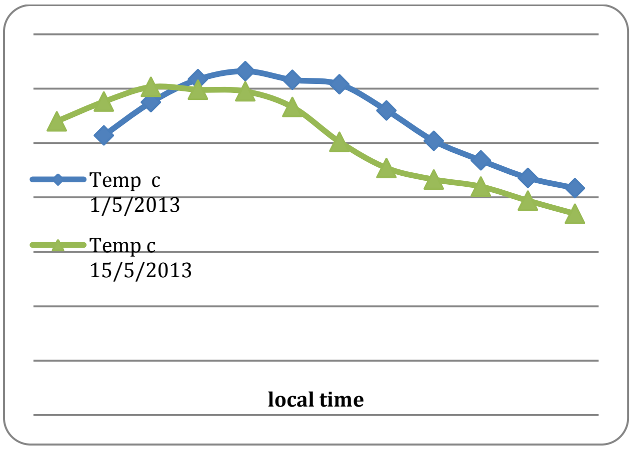


Fig (6 a) Shows the relation between the n(r) and local time on 1 and 15/7/2013



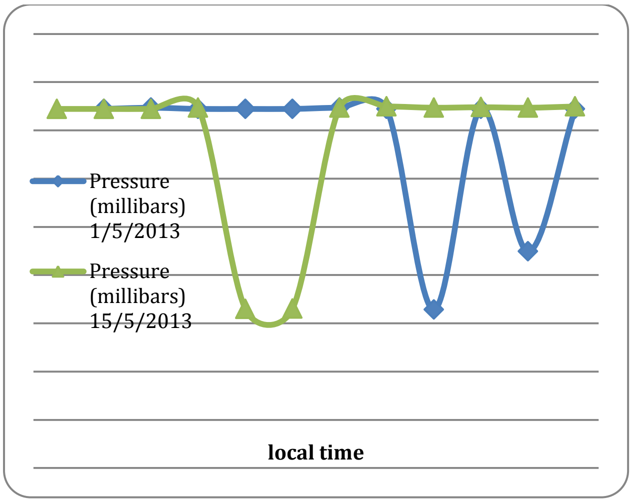
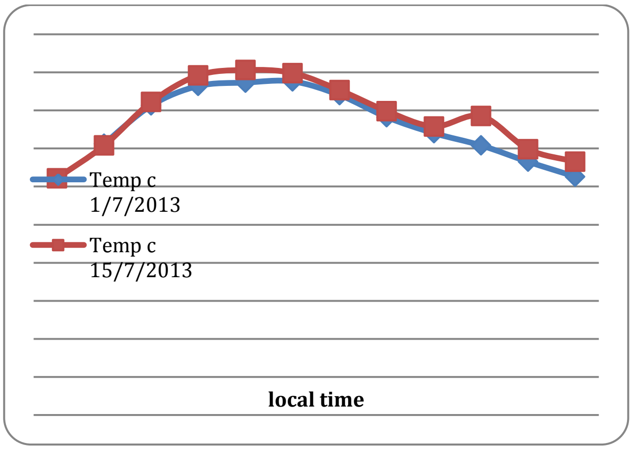


Fig (5b) Time series of local meteorological data collected 1 and 15/5/2014



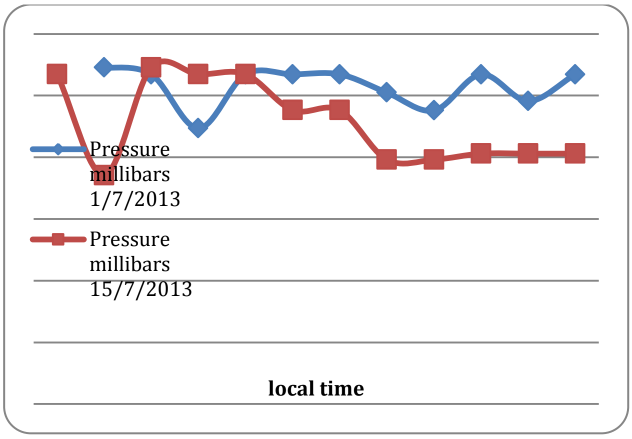


Fig (6b) Time series of local meteorological data collected on 1 15/7/2013 .

Figure (6 a) presents the time series of nr data collected on 1and15 July 2014. We see that a refractive index it much swing during two because the pressure it variation. Figure (6 b) presents the local meteorology data for this case. The temperature were sporadic at about (30-45^{0}C) and pressure were (700-1100 mb).

Figure (7 a) presents the time series of (nr) data collected on 1and 15 October 2014. On one Day the refractive is constant because the change in pressure and temperature it very slight but in other day the refractive index is highest during the night and in (5-10 AM) and fall in other time . Figure (7 b) presents the local meteorology data for this case. The temperature were sporadic at about (09-32 ^{0}C) and pressure were (600-1100 mb).

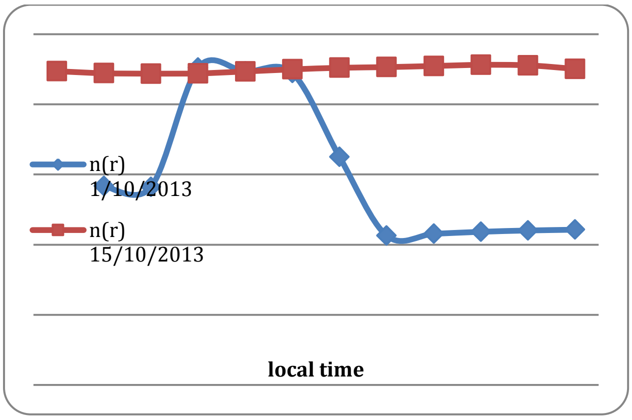
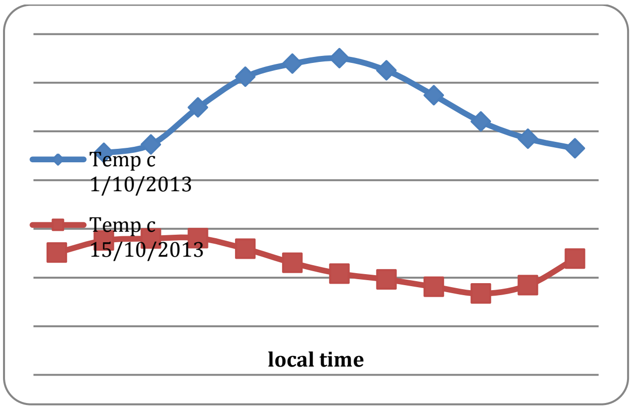


Fig (7 a) Relation between the n(r) and local time on 1 and 15/10/2013



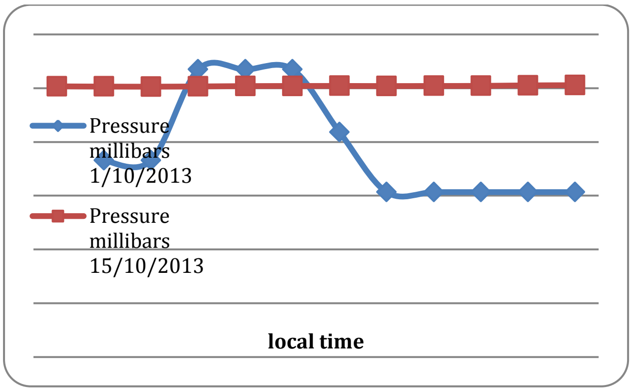


Fig (7b) Time series of local meteorological data collected on 1 and 15/10/2013

Relationship between refractive index n(r) and wavelengths optical beam

The spectral refractive index has been calculated for three different ratios of (P / T). The results are shown in the figure (9) by the equation (1-1) and we got the three curves are different for each lineage of these three ratios, we see from the figure (8) that the refractive index for the same wavelength changes with pressure and temperature ,for example wavelength of 0.407 micrometers, the refractive index is higher what can be the day 1 / 2/ 2013 because the pressure in this day higher than the two days 1 / 3 / 2013 and 01/04/2013 and temperature less days of 1 / 3 / 1 and 2013/3/2013, and so for the rest of wavelengths, that figure shows the refractive index is less wavelength 1.06 micrometers, where the greater the wavelength indicate the refractive index at least.

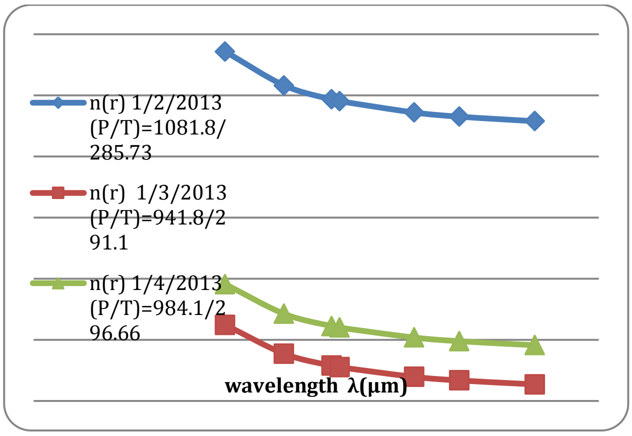


Fig 8 Variation of Refractive index with pressure and wavelengths optical beam

The relation between the n(r) and the temperature

Depending the metrological data for Babylon city (h= constant= 0.35 km/ , w = 5 Km/H, T= 270- 330 K) with different wavelength optical beam (0.633 , 0.810 and 1.06 µm). we found the refractive index about (1.00031) at minimum temperature (270K),shown in figure (9).

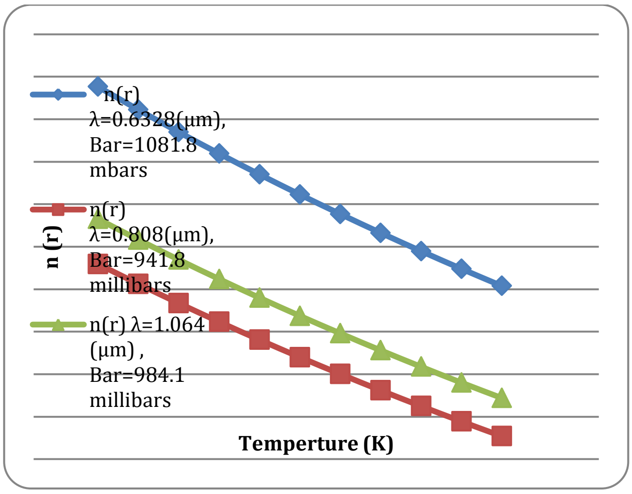


Fig 9: Variation of Refractive index with Temperature and wavelengths optical beam

Relationship between refractive index n(r) and the pressure

Figure (10) shows the relation between the refractive index n(r) for different three values of wavelengths optical beam and constant value of Temperature . the relation is a direct correlation linear, and the change is very limited .

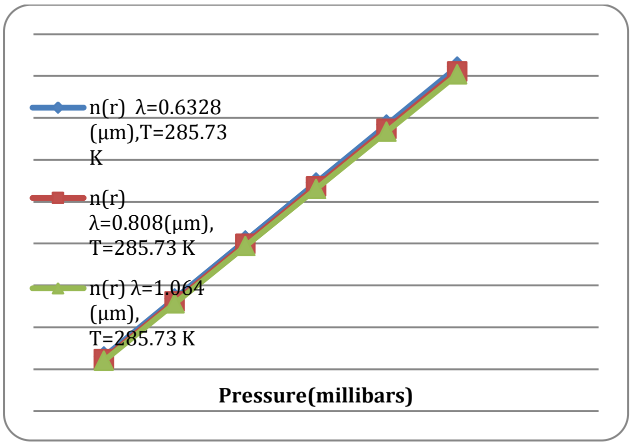


Fig 10 Variation of Refractive index with pressure

Empirical Calculation of Cn^2

Depending the metrological data for Babylon city (h= constant= 0.35 km/ and w = 5-30 Km/H) and using Hufnagle-Valley model ,we found the optical turbulence is varation between (1.7264×10^{-14} - 1.7×10^{-14} $m^{-2/3}$) , Because the inner scale of turbulence is varies from (1 mm) to (10 mm).

Conclusions

1- The refractive index is affected by the temperature and pressure difference but still it very small in Babylon city .
2- The Refractive index is affected by different wavelengths of laser sources
3- The optical turbulence in high (0.035Km) is limited variation and strong

References

Jassim M. J.,(2013),Experimental Study on the Atmospheric Attenuation Effective on Audio Signals In Free Space Laser Communication Links, International Journal of Engineering and Innovative Technology (IJEIT), Vol. 3, Issue 4, pp 53-57.

Jassim M. J. , Kodeary A. K., (2013),Experimental study of the influence of aerosol particles on link range of free space laser communication system in Iraq, Journal of Applied Electromagnetism , JAE , VOL. 15, NO.2, pp 28-33.

Kareem F.A.,(2008),Study the attenuation of the atmospheric effects on laser beam (785,850,1550)nm free space laser communication , Ph.D. theses Submitted Al-Mustansiriyah University.

Puryear A. L. ,(2011) ,Optical communication through the turbulence Atmosphere with Transmitter and receiver Diversity , wave front control , and coherent Detection ,Massachusetts Institute of Technology .

Parry G.,(1981), Measurement of atmospheric turbulence induced intensity fluctuation in a laser beam, Opt. Acta. **28**, 715-728 ..

Strobehn, J.W. ,(1978), Laser Beam Propagation in the Atmosphere. Topics in Applied Physics, Vol. 25, Springer-Verlag: New York.

Shapiro J.H., (1974) ,Normal-Mode Approach to Wave Propagation in the Turbulent Atmosphere, Applied Optics, vol. 13 (11) pp. 2614-2619.

Tunick A., (2005), Characterization of optical turbulence (Cn2) data measured at the ARL A_LOT facility , Army Research Laboratory .

Wasiczko L, M., (2004),Techniques to mitigate the effects of atmospheric turbulence on free space optical communication links , university of Maryland

Yuksel H. , (2005),Studies of the effects of atmospheric turbulence on free space optical communication , university of Maryland