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INVESTIGATING OF THE OPTIMUM WAVELENGTHS AND ATTENUATION OF OPTICAL SIGNAL POWERFOR FREE-SPACE OPTICAL (FSO) SYSTEM

INAS A.F.AL TAHAR, NABIL JALILAKLO, WATHEQ ABDULKAREEM NEAMAH, AND WATHIQ KAREEM.

Abstract

This paper use Free Space Optical systems (FSO) by depending the local weather condition in Iraq. FSO systems are effected to bad weather conditions like dust, fog,, rain, turbulence, high temperature and other factors, so to improve the performance of FSO system, we reduced the transmission range and select the optical wavelength to be 1650nm and a program had been developed for the calculation of the laser power required for a given distance and atmospheric parameters.

***Keywords: Free Space Optical Communication (FSO),propagation, transmission, wavelength*.**

1. INTRODUCTION

FSO is a new wireless access technology used to transmit information laser light optical and infrared, FSO formed from two identical receiving and transmitting stations, and it designed to provide point to point communication between objects located within the line of sight(LOS), with speeds from 2 to 622 Mbit/s,compared with the traditional fiber-optic technology it has the following advantages [1,2]:

1. High bandwidth communication channel.
2. Transparency to the networks because these devices are just physical transmission medium converters for higher levels of model OSI.
3. No need to license the frequency band also the optical range is not regulated.
4. Insensitivity to radiofrequency interference.
5. High secure channel communications from unauthorized access.

6. The low cost and rapidity of establishing a communications link.
7. Environmental safety.

FSO have a place among the information and communication systems because of its properties where it widely used for tasks such as [3]:

1. Connection of digital subscriber removal.
2. Connecting base stations.
3. Organization of communication in corporate networks.
4. Internet access is fast.

Briefly distinctive features of FSO can be summarized as follows: the transfer of so much of data over short distances (up to several kilometers). Consequently, data are widely used mainly in the enterprise and cellular networks. However, continuously rising demands on the features of the transmitted information draws attention to some of the specific problems of FSO, due to both the equipment and most importantly the peculiarities of the atmospheric channel which by their effect on the optical signal can be divided into two groups.

The first form processes that cause energy attenuation, in particular, the absorption of gases and vapor components of the atmosphere, absorption and scattering of aerosols and precipitation. This may also include lighting and backgrounds, worsening the signal to noise ratio (RSN) at the receiver input FSO.

The second group processes related to irregularities in the refractive index (turbulence) the air and create amplitude and phase fluctuations of optical waves. The most unfavorable to the FSO are the first group of processes that may lead to interruptions in the line among them stands now fall and fog. Recent cause weakening reach up to 100 dB / km or more. Any other meteorological events and result in reduced strength of the received signal and hence to increasing in the amount of errors.

The rest of the paper is organized as follow : Section (2) will explain the basic concept of work program to the maximum transparency (window) of the atmosphere for specific conditions of FSO in particular for areas of Iraq, section (3) will discuss the simulation and result , and finally section (4) is the conclusions.

2. CALCULATINGTHE OPTIMUM WAVELENGTHOF THE ATMOSPHERE

2.1. Working with the program

The work in this study use software developed by the staff members of the State Institute of Applied Optics. The "transparency" folder can be transferred to the selected computer disk. In order to open the working window of the program, run the file trans.exe.

After running the file trans.exe, the working window of the program opens, which has the form shown in Fig. 1.

2.2. Parameters of the program

The used program allow us to input the weather parameters, where the input parameters of the atmospheric unit are:

- Temperature C^0: the temperature of the surface air layer is set.
- Relative humidity% : the humidity of the surface air layer is set.

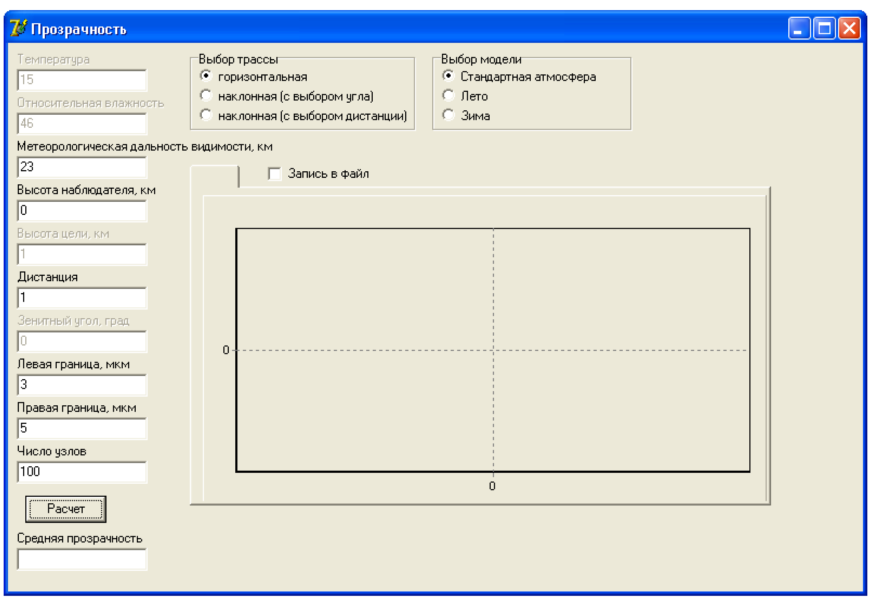

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Figure 1 - Working window of the program

- Meteorological visibility range, km - the meteorological visibility range is set.
- The input parameters for defining the trace are:

- The elevation of the observer, km – this mean the set (the parameter values should lie within range from 0 to 30 km);
- Target height, km (parameter values should within range from 0 to 30 km).
- Distance, km (the value of the parameter should not be less than the difference between the heights of the observer and the target).
- Zenith angledegree (the parameter valuesshould lie in the range from 0° to 90°);

The trans program implements two scenarios:

1. horizontal path: In this case the user sets the parameters "observer height" and "distance".

2. Inclined path: For the convenience of the user, the second scenario - an inclined path - can be founded in two ways: "with angle selection" and "with distance selection".

For the case of "inclined with angle selection", the orientation of the path is specified by the user with the parameters "observer's height", "target height" and "zenith angle".For the case of "inclined with distance selection", the orientation of the path is specified by the user with the parameters "observer height", "target height" and "distance".The spectral range is given by the parameters:

- The left border of the spectral range (from 0.26 μm).
- The right border of the spectral range (up to 15 μm).

Models of the atmosphere included the following: standard atmosphere, summer, winter.
For the "standard atmosphere" model, the program sets the average values for temperature and humidity:
Temperature is 15 ° C;
Relative humidity is 46%.
For the "summer" and "winter" models, we changethe values of the "temperature" and "relative humidity" parameters depending on the data base of the weather department.

2.3. Results of the program

After the calculationsis completed, the mean transparency value is given out, as well as a graph characterizing the spectral dependence of the atmospheric transparency.The average transparency is determined by the ratio of the transparency integral to the specified spectral range. The local weather conditions in Iraq is illustrated as below[5]:

Temperature : (5°C to 45°C).

The average ofrelative humidity: (10% to 85%).

Meteorological visibility of data from the Internet is about(2 - 23)km.

The elevation of the observer (per subscriber) :(10- 50)m.

Target height (the other party) :(10m- 1km).

The distance between the optical transmitter and receiver (range) is (1-5)km and Zenith angle: 0^0 to 90^0.The figures(1,2,3,4,5,6,7,8 and 9) shows the results of calculating average atmospheric transparency(window)for wavelengthsin therangeof from (1.5 -1.8)µm.

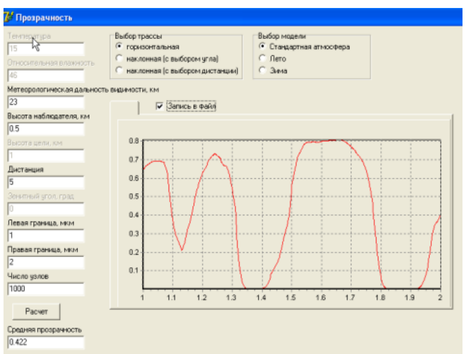

Figure1 Temp.=15ºC, Humidity=46%, distance between Tx and Rx=5kmfor the model of standard atmosphere and horizontal path

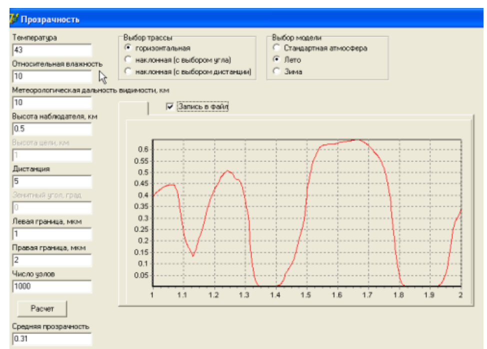

Fig.2.Temp.=43ºC, Humidity=10%, distance between Tx and Rx=5kmfor the summer and horizontal path

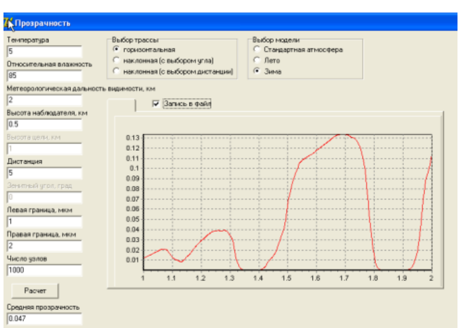

Fig.3.Temp.=5ºC, Humidity=85%, distance between Tx and Rx=5kmfor the winter and horizontal path

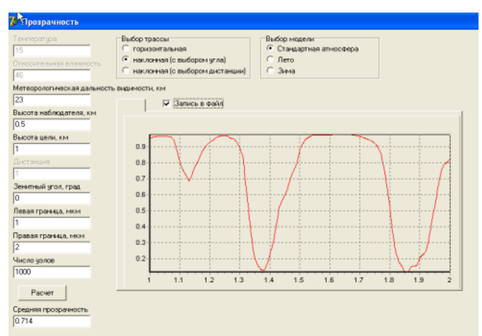

Fig.4.Temp.=15ºC, Humidity=45%, distance between Tx and Rx=1kmfor the model of standard atmosphere and for the case of "inclined with angle selection"

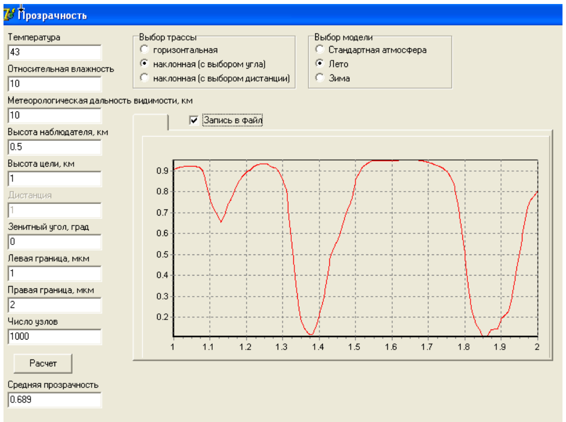

Fig.5.Temp.=43ºC, Humidity=10%, distance between Tx and Rx=1kmfor the summer and for the case of "inclined with angle selection"

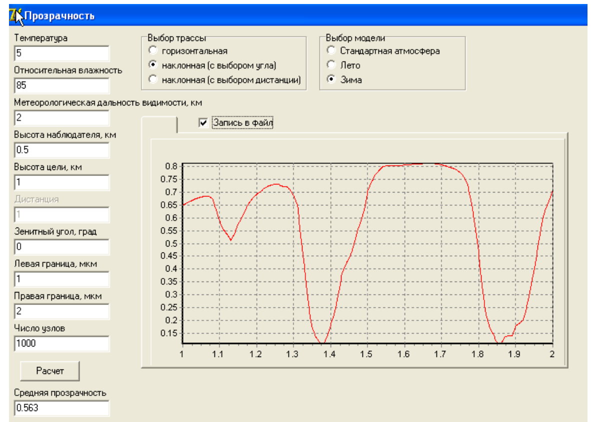

Fig.6.Temp.=5ºC, Humidity=85%, distance between Tx and Rx=1kmfor the winter and for the case of "inclined with angle selection"

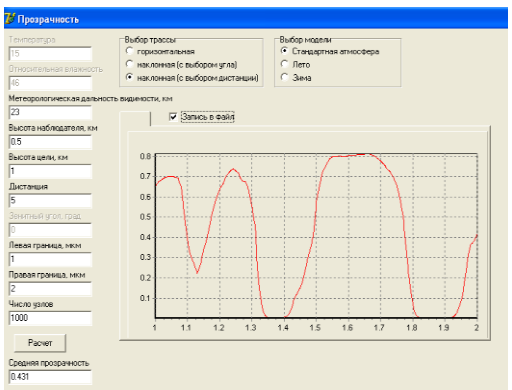

Fig.7.Temp.=15ºC, Humidity=46%, distance between Tx and Rx=1kmfor the model of standard atmosphere and for the case of inclined with distance selection

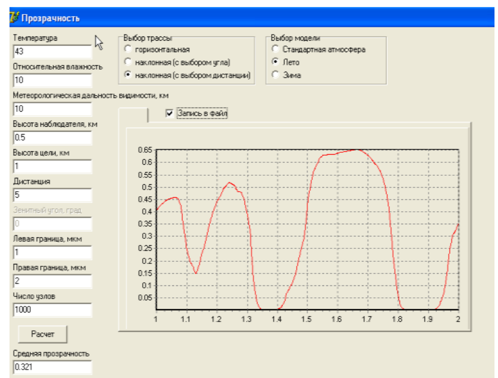

Fig.8.Temp.=43ºC, Humidity=10%, distance between Tx and Rx=1kmfor the summer and for the case of inclined with distance selection

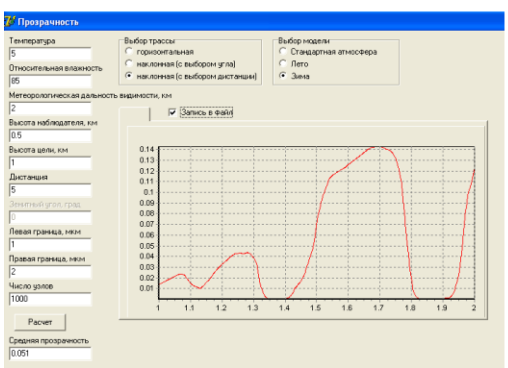

Fig.9.Temp.=5ºC, Humidity=85%, distance between Tx and Rx=5km for the winter and for the case of inclined with distance selection

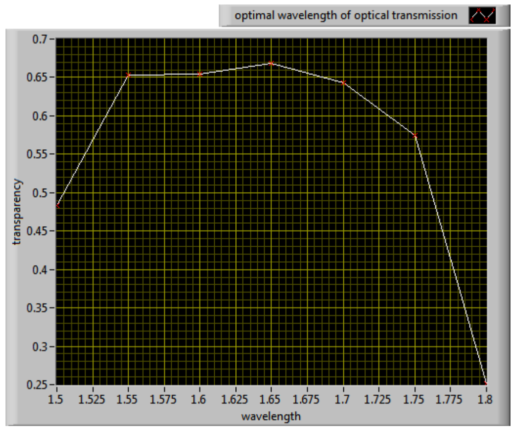

Fig.10 Optimal wavelength of the optical transmitter

Fig.10showthe calculating wavelength corresponding to the maximum transparency (window)of the atmosphere for specific conditions of FSO in particular for areas of Iraq. This figure shows that the optimum wavelength is radiation 1.65 µm where this radiation has the greatest atmosphere of transparency.

3. CALCULATION ATMOSPHERIC CHANNEL

This method of calculation is developed with reference to small and medium distances up to 1km. For longer distances, it may be necessary to take into account a larger number of factors affecting the propagation of the optical signal in the atmosphere. To simplify the calculations, we introduce a number of assumptions:

The calculation is carried out for systems for transmitting information through the atmospheric channel to radiating diodes.
The Rayleigh distance can be neglected.
Nonlinear propagation effects can be neglected.
Multiplicative interference of forward scattering can be ignored.
signal attenuation on an inclined path for heights of up to (10 km) is always less than on a horizontal path of the same length at an altitude of (0 km)above ground level. The following transparency windows suitable for the transmission of the optical signal can be distinguished:

400-1330nm excluding 1200nm,1520-1560nm,1590-2200nm,3000-3300nm,and 4100-4700nm.The best window is1500-1800nm of the visible and near infrared the moment created a sufficiently large number of working wavelength of the radiation source in the specified range.

3.1.The effect of weather conditions

The attenuation of the optical signal in the atmosphere introduced such a concept as a distance visibility υ (km) at which the visible radiation of the light source is reduced 50V relative to the initial value with sufficient precision for engineering calculations it is possible to use formula:

$S=17/\upsilon$ (1)

where:

S-attenuation dB / km;υ-range of visibility.

Table (1) shows a typical loss depending on weather conditions for the atmospheric communication channel in the infrared range.

Weather	The attenuation in dB / km
Clear weather	0-3
Light rain	3-6
Heavy rain	6-17
Snow	6 - 26
fog	20-30
Thick fog	50-100

Table 1. influence of weather conditions on the attenuation of the optical signal

and another factor of the registered signal in this case showing signal. This useful type of interference reduces the effectiveness information systems and changing the size and shape of the transmitted signal and an increase in the power of the optical signal does not lead to a linear increase in the signal-to-noise ratio. In addition to shot noise is caused by a change in intensity due to fluctuations in the number of received quanta of the optical signal.

The calculate of the optical noise level, it is possible to use formula:

$P_n=10^{-2}*S_p*\theta * \Delta\lambda$ (2)

where:

S_p: Receiver area (cm^2).

θ:The angle of the receiver (rad).

$\Delta\lambda$: Wavelength received by a photo detector (μm).

depending on of the optical modulation signal and varies the minimum allowable ratio / noise information is correctly. The minimum power of the optical signal will be:

$P_s = N_{min} * P_n$ (3)

where:N_{min}: the minimum possible signal-to-noise ratio for the selected type of optical signal modulation.

3.2. Optical System

The value of the total flux of light emitting element characteristic and cannot enlarge any optical system and operation these systems can only be reduced to e.g. redistribution light flux greater its concentration in some areas in this way it achieved an increase in light intensity in these areas decreasing description complies with its other directions, such as action of spotlights or signaling devices allow using sources having average spherical luminous intensity several hundred channels to create on-axis illuminator light intensity in candelas millions. The Demeter of the receiving antenna in this case is smaller than the diameter of the light spot of the optical signal produced by the source to estimate the power loss, one can use

$P_{lost} = 10 \log(\varphi *L/D)^2$ (4)

where:

φ: The divergence angle of the beam, rad.

L: Distance to the receiver, m.

D: The diameter of thereceiver, cm.

also be taken into account that the optical system also introduces damping of the optical signal take lens transmittance value of 0.95 (two lenses one another at the receiver at the transmitter) if the optical signal power should be increased further to 0.5dB.

3.3. Results of Case Study

Wavelength-1650nm;

Wavelength range received by a photodetector-1500-1800nm;

Divergence of angle -0.004rad;

Distance – 5km;

receiver radius-4cm;

angle of view of the receiver-0.17rad;

work is guaranteed by thick fog. attenuation no more than 60dB/km;

modulation-AM;

the minimum signal-to-noise ratio is 3 dB;

calculate the power of optical noise:

$P_n=10^{-2}*S_p*\theta * \Delta\lambda= 10^{-2}*1*0.17*0.3=0.51$

Calculate the losses due to weather conditions for a given range:

$P_{w\text{-}5km} = P_{spr} * L = 60*5km=300mW$

Calculate the loss of the optical signal due to the divergence of the beam:

$P_{lost} = 10 \log(\varphi *L/D)^2 = 10\log(0.004*5000/0.08)^2 = 48dB$

Find the value of the signal / noise (in dB) taking into account all losses:

$P_{s\text{-}n} = P_{s\text{-}min} + P_{w\text{-}5km} + P_{lost} + P_{opt} = 3+0.3+48+0.5=52$

The minimum power of the optical signal will be:

$P_s = 10^{Ps-n/10} * P_n = 10^{P_{s\text{-}n}/10} * P_n = 80mW$

Using theMATLABto results of simulation system for atmospheric channel ofshow Fig.11.

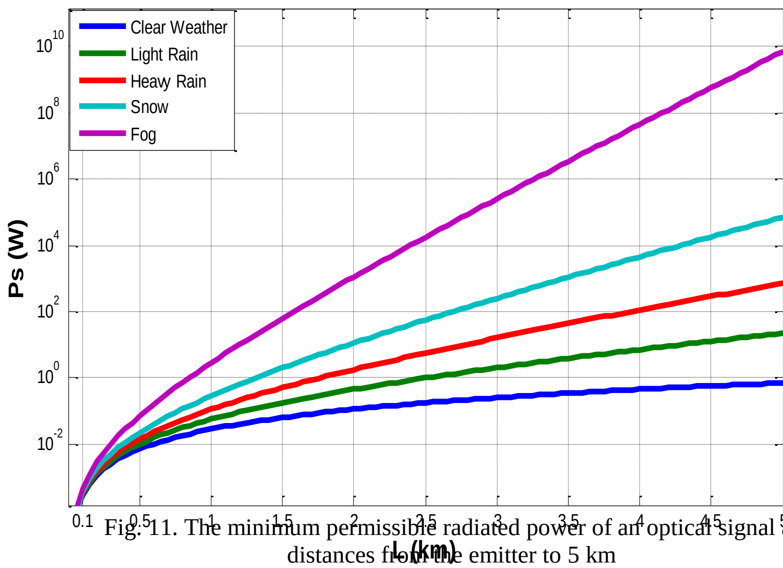

Fig. 11. The minimum permissible radiated power of an optical signal at distances from the emitter to 5 km

CONCLUSION

According to the results in this work the required laser power at a given distance and atmospheric parameters led to obtaining precise results and the reasons leading to the weakening of the power of the radiation passing through the atmosphere and the main reason is the molecular and aerosol scattering, however the strongest impact is dispersion in the fog. The maximum laser power required for a given distance and atmospheric parameters is300mw,where it regarded small power.

As a results, at rain, snow, and especially fog conditions, communication range is significantly reduced. We conclude that there is ability to improve the performance of transmission of FSO system at this bad weather conditions by using the optical wavelength (window) is 1650nm which give the best performance as compare to other window and short distance between transmitter and receiver also clear weather sure communication is possible at maximum power is300mw.

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