Analysis on Path Loss in SS-WDM FSO System for different weather scenario

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ABSTRACT:

In this paper, the SS-WDM is proposed for FSO communication in the different weather scenario. The study seeks to investigate the possibility of communication links suitable for wireless cameras in the campus effectively with minimum loss of data and path loss with 2.5Gbps data rate using 1550 wavelength window. A SS-WDM-FSO system has been realized and investigated for 4 channels. The purposed model system degradation due to turbulences where refractive index, wind velocity, rain, fog and height of the cameras in line of sight(LoS) majorly focused. The simulation result shows that the path loss for different weather condition mitigates by using 1550nm wavelength with 10dBm input transmitting power. Based on the above study, the result shows that the benefits of spectrum slicing wavelength division multiplexing (SS-WDM) have been worked up for the climatic conditions which enhance performance of system.

Moreover, the graphs plotted against bit error rate, attenuation (path loss) and distance makes the analysis better which effects to the wireless optical link performance. For this, link availability calculations were made based on the power budget analysis to FSO link. Overall path loss occurred in FSO link calculated using attenuation factor of different weather condition. Simulation has done using OPTISYSTEM Software version 16x64bit.

Keywords: spectrum slicing, WDM, FSO, BER, path loss, atmospheric turbulences.

I. INTRODUCTION

Free space optical communication has a remarkable hold in telecommunication industry, majorly because of its lowest cost transmission capacity. It's a growing technology to handle high data rate, high security, license free and full duplex operation. [2] FSO system sternly suffers from atmospheric turbulence due to random nature of the weather condition. The main impaired agents in establishing an optical link are absorption, scattering, diffraction, and atmospheric turbulences like, rain, fog, haze, rain etc.

These external agents increase the path loss analyzed in the form of BER and visibility range of a FSO link. On the other hand, geometric attenuation is the other factor to degrades the performance of the system which occur due to transmit beam spreading with increasing range. The spectrum slicing is the technique for improving the performance of the system over strong atmospheric turbulences. [5]

There are also several techniques to mitigate the effect of turbulence such as diversity technique, aperture averaging, forward error correction, different modulation and coding technique etc. The main motive of modulating the signal is to squeeze as much data as possible in the least amount of spectrum. [2,4] OOK, PPM, PAM, QPSK are the modulation techniques to enhance the performance of the system. 1550nm wavelength is less effected than 850nm and 785nm in atmospheric turbulences. With 10-15dB input power it safe for the eye retina than the other one. [3]

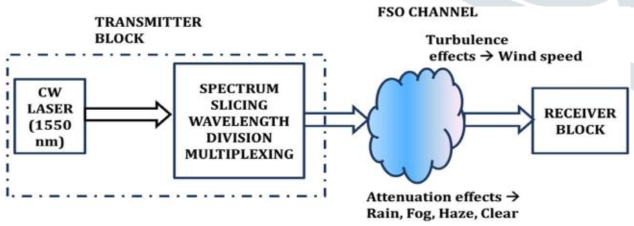


Fig. 1. Block diagram of SS-WDM-FSO communication system.

The concept of deploying WDM in FSO is that it permits enough budget and margin to support a higher capacity transmission with an extensive improvement of stability. [11] WDM-Demux is used to operate as slicing system with different transmission channels. This paper discussed in 6 major sections. The channel establishment of Demux, used to disperse power for the signal being transmitted in detail section 2. Section 3 describe the channel model used. In section 4, the average BER for SS-WDM are discussed. Section 5 i.e. simulation section describes the numerical results with graphical analysis. Finally concluding remarks are highlighted in section 6.

II. THE PROPOSED SYSTEM MODEL:

A FSO link is normally consists of a transmitter, a channel which is the medium of transmission and finally a receiver to reproduce that transmitted signal. The block diagram is shown in fig 1. Demux works as a spectrum slicer, this technology slices wide waveforms in lower speed slices and transmit each separate slice in parallel. It also improves optical system dispersion tolerance factor which obstructs the transmission of signals.

FSO link is a wireless connection for two points which are centered to line of sight (LoS) communication thereby involving the video, voice and data transmission considering air as a medium. [8]

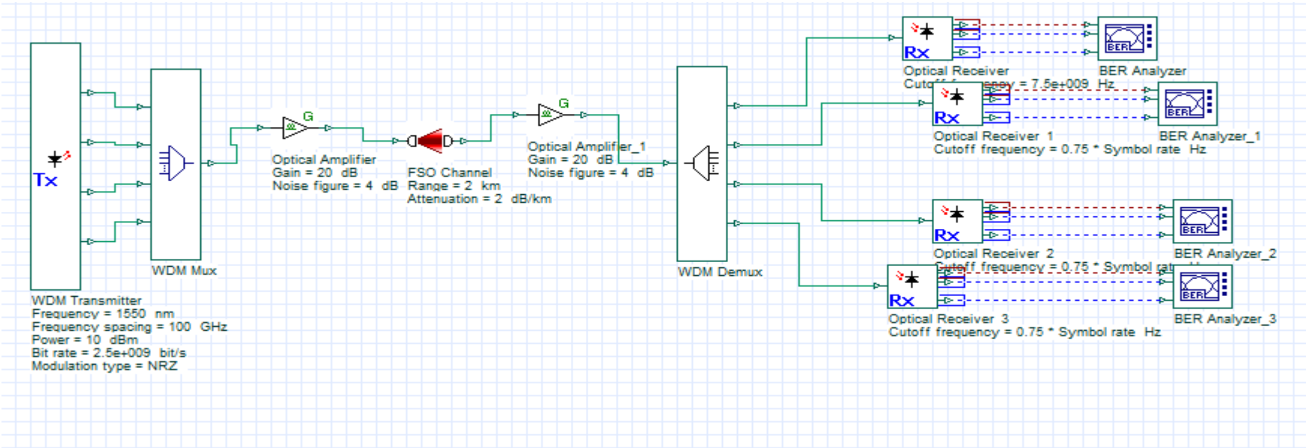


Fig. 2. Architecture of the 4 channel SS-WDM FSO system.

In this paper, SS-WDM system consist section wise components which have their own specific function. Transmitter consist NRZ modulation format which is feasible and simple for the system. A single CW laser is connected to Demux, transmits 1550nm window signal over the channel. 1550nm band is attractive because of reduced solar background/ scattering and its compatibility with WDM network. Also about 50-60 times higher power can be transmitted compare to 780-850nm, safe for the human eye. These higher wavelengths are better for transmission in fog as longer wavelengths are less affected by fog. [13] Each channel has different frequencies with channel spacing of 100GHz transmit to the point to multipoint(P2M).

The architecture of the proposed system is of 4 channel SS-WDM system shown in fig 2. The CW laser average input power is from 0dBm to 10dBm. The slices are modulated using NRZ and PRBS component with wavelength modulation technique. After channels are multiplexed by multiplexer the modulated is transmitted over FSO channel. The prorogation medium affects the signal because of weather turbulences like rain, fog, haze, etc. the signal received by PIN photo detector. The Bessel filter re-embarking the signals. BER analyzer is investigating the performance of each channel while power meter measured power penalty of the system.

III. FSO CHANNEL MODEL:

The main objective of this paper is to analyze path loss in FSO transmission medium. For this, first of all it has to evaluate the different turbulences parameters which introduce the attenuation in the signal. The wireless optical link impaired by absorption, scattering, diffraction and atmospheric turbulences. The random variation in both amplitude and phase of the transmitting beam which result in fading, beam spread and angular speed [6]. Following two types of attenuation in FSO system are….

III.A Geometrical Attenuation:

The optical beam should be collected at the receiver properly. If not, loss may occur because of misalignment of transmitter and receiver that create geometrical attenuation in the link. Geometric losses arise because of the dispersing of the transmitted optical beam between the transmitter and the receiver and due to the pointing and tracking errors at the receiver [13].

Geometric Losses can be given by the following equation as [13]

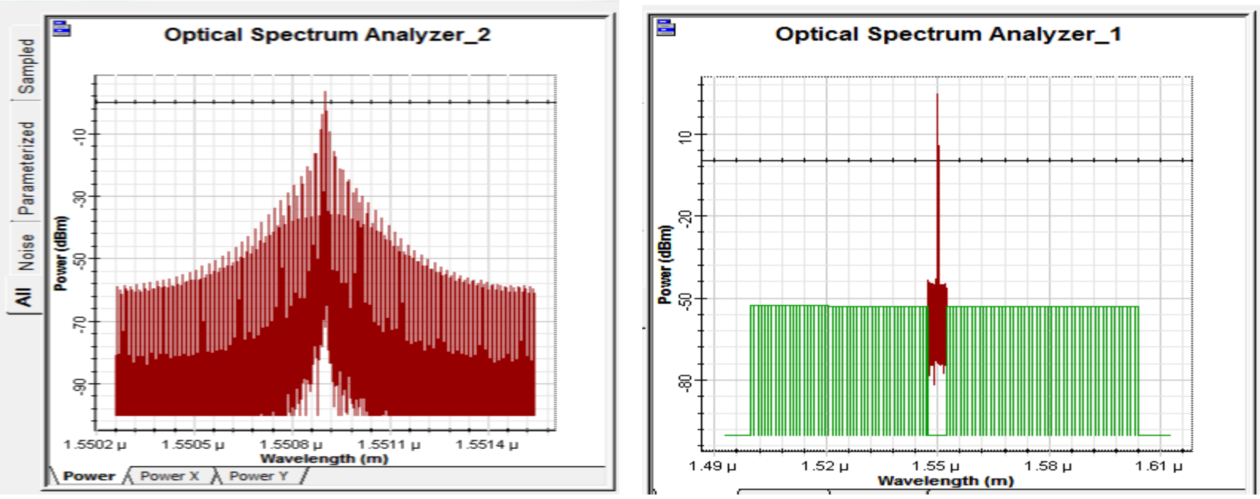
$$\text{Geometric Loss (dB)} = 10 \log \left\{ \frac{d_2^2}{(d_1 + D*L)^2} \right\}$$

where, d_1 = aperture diameter of transmitter (m), d_2 = aperture diameter of receiver (m),
D= beam divergence (mrad), L = range (km).

III.B. Atmospheric turbulences:

This is the main challenge of the FSO system due to bad weather condition like rain, fog, haze, etc. this makes the FSO suitable only for short distance communication. It describes in below…

1. Absorption occurs during the interaction between the photons propagating to the atmospheric molecules along its propagation path, is wavelength dependent. It depends on water vapor of the atmospheric channel, which in turn depends on humidity and altitude. Atmospheric scattering occurs due to interaction of an element of the light with the atoms and the molecules present in the transmission media [9,10]. It creates an angular redeployment of the component of the radiance with or maybe without alteration of the wavelength.



x **y**

Fig. 3. (x) the optical spectrum of CW laser. (y) the optical spectrum after transmission.

The atmospheric transmission of optical signals, τ_a is expressed by the following Beers law equation [9]

$$V_a = e^{-(\beta_{abs} + \beta_{scat})R}$$

where β_{abs} and β_{scat} are the absorption and scattering coefficients, respectively and R is the atmospheric path length. The attenuation coefficient τ_a is the sum of the absorption and the scattering coefficients from aerosols and molecular constituents of the atmosphere [10]. The attenuation coefficient is approximated by the following relation:

$$\beta(h) = \frac{(^{3.91})(\beta)^{-q}}{550V}$$

where, V= visibility in kilometers, λ= wavelength in nanometers and q= the size distribution of the scattering particles.

2. In fog the water elements are often dense enough to diffract the light pulse as well as extinct the signal. The beam propagating through the channel can be absorbed and scattered depending on the atmospheric condition [10]. Because of the two type of fog, attenuations are given below…

a. The attenuation by advection fog is given by the following relation [1]

$$\sigma_{advection} = \frac{0.11478\lambda + 3.8367}{V}$$

b. The attenuation by radiation fog is given by [10]

$$\sigma_{radiation} = \frac{0.18126\lambda^2 + 0.13709\lambda + 3.750}{V}$$

Where, V= visibility in kilometers, λ = wavelength in micrometers. However, the particles encountered in the atmosphere have complex shapes and orientations.

3. During rainfall, the water particles of rain cause distortion in the FSO link and the attenuation caused by it is variable in nature. The specific attenuation of free space optical link in dB/km due to rainfall rate of R mm/hr is given by [13]

$$A_{rain} = 1.076\ R^{0.67}$$

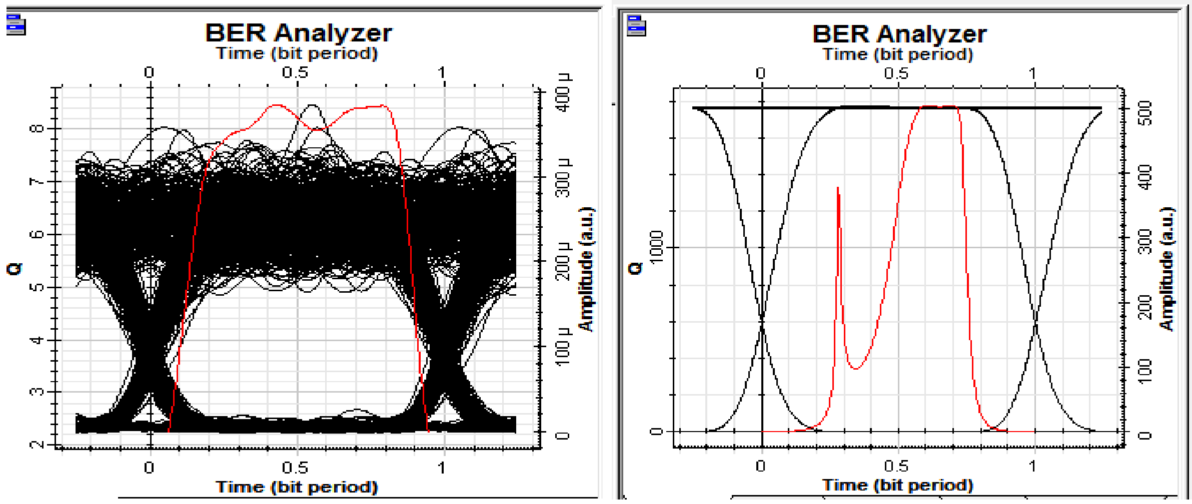
4. Wind turbulence causes drastic changes in atmosphere refractivity index which redistributes the optical beam of the FSO link. In order to investigate the wind influence on FSO certain wind parameters are taken into account due to optical energy re-distribution. The wind flows in every direction and releases turbulent energy which can determines the intensity of the velocity. This can be calculated by

$$E_t = 0.5 * 1/N \quad (u - \bar{u})^2 + (v - \bar{v})^2 + (w - \bar{w})^2$$

where u, v, w = the given wind speeds in a particular direction. $\bar{u}\bar{v}\bar{w}$ cumulative wind speed in any one direction. N = no. of samples E_t =Turbulent energy. The turbulent energy represents wind velocity standard deviation. The attenuation caused by the turbulence can be calculated by a regressive formula which is given as [7]

$$A = 70 - 73e^{-0.2867Et}$$

Since the wind speed affects the propagation of the signal, the height of the buildings also obstructs the signal transmission.



X Y

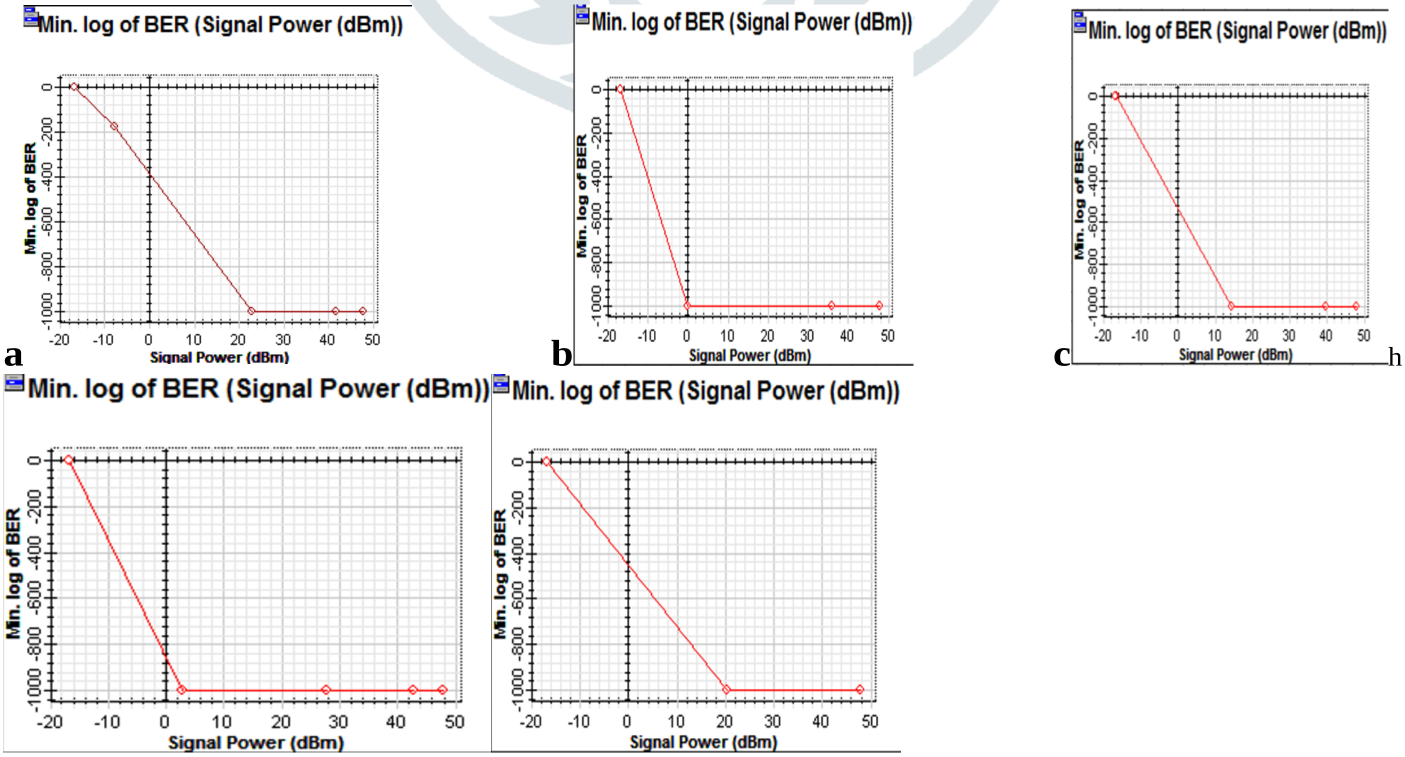
Fig. 4. Eye diagram in fog with geometrical loss(X) and very clear weather without geometrical loss(Y)

IV. SIMULATION:

In this paper, the simulation is carried out using Optisystem 16. The performance of the system is analyzed by using optical spectrum analyser and the BER analysers. The parameters of the system is shown in table 1.

Table1: Simulation parameter of FSO communication system:

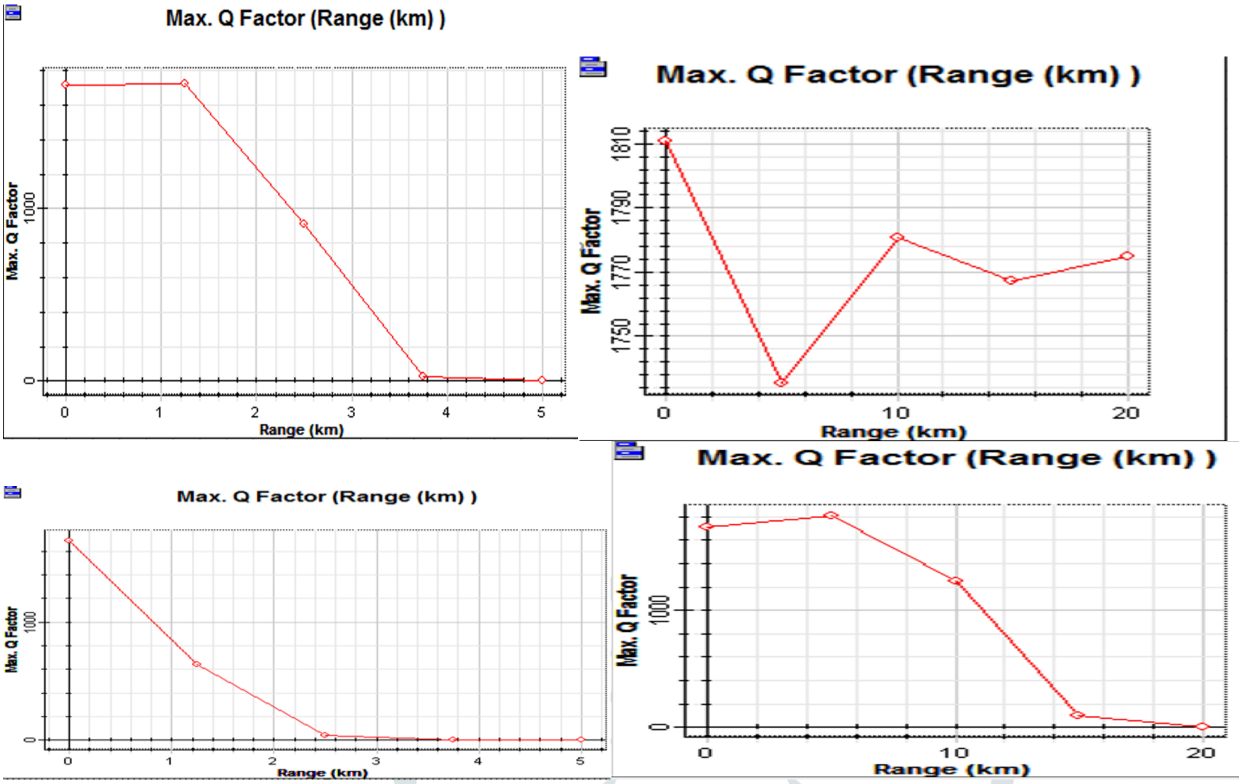
Parameters	Values
Data rate	2.5Gbps
Transmitted wavelength	1550nm
Power	10Db
Transmitter aperture	5cm
Receiver aperture	20cm
Responsivity	10A/W
Filter order	4
Dark current	10Na
Beam divergence	2mrad
Extinction ratio	30Db
Modulation type	NRZ



d e

Fig. 5. (a), (b), (c) and (d) diagram are showing min BER versus received signal power

A B



C D

Fig. 7. (A), (B), (C) and (D) diagram are showing max quality factor w.r.t. their transmission distance.

V. RESULT AND DISCUSSION:

The performance and characteristics of SS-WDM FSO system has been appraised and compared using quality factor versus distance and BER received power under different weather condition like rain, fog, haze and wind speed for the data rate 2.5Gbps. it is perceived that increase in BER, increase transmission distance as well as attenuation factor.

V.I. BER versus received optical power analysis

The received power analysis for diverse atmospheric condition has been analyzed and graphs have been plotted in fig. 6, there are the diagrams which reveals the BER versus received optical power at the PIN detector for different weather conditions. Fig.6a illustrates the BER versus power in fog at the attenuation factor of 22.4dB/km. It has been observed that SS-WDM 4 channel FSO system gets the value in BER analyzer in the form of log which is nearly -1000 at 20dBm received power on having a constant transmission distance i.e. 2km. BER performance of an FSO system is analyzed over rainy condition is illustrated in fig. 6e. In this work, the effect of rain is analyzed using rain attenuation factor. It is mainly austere and critically dependent on various models of raindrop-size distribution.

From fig. 6c, the BER of log (-1000) is achieved at the received power of 15dBm for haze with geometric loss. It visualizes the received power for hazy condition which impairs visibility in lower atmosphere with fine suspended particles.

V.II. Quality factor versus transmission distance

In Fig. 7C, the quality factor of 1825 is achieved at the transmission distance of 1.8km in haze. On increasing the range, it decreases linearly. At 1550nm quality factor is high with transmitting signal power of 10dBm. Because of the 5 iteration and linearly increment of wavelength from 1549.5nm to 1550.5nm it observed low with lower wavelength as well as at 5km of distance. It could be observed that without geometrical loss the factor fluctuates with in iteration points of measurement in haze shown in fig.7D. The attenuation factor is high in fog i.e. 22dB/km and the quality factor calculated as shown in fig.7A.

In Fig. 7B, the attenuation factor is too low (0.15 dB/km), so the quality factor of the SS-WDM system at this scenario goes high. The quality factor may increase with bit rate of the transmitter and extinction ratio. The NRZ modulation technique improve the quality factor at a better level of transmission. Hence its observed that when slicing is applied, a considerable increase in quality factor is recorded, which is a must for any system.

VI. CONCLUSION:

The paper infers that any FSO system suffers with many turbulences whether it is SS-WDM or DWDM system. Two major type of turbulences are discussed in detail. The geometric effect could mitigate by proper receiving of the signal through line of sight(LoS) transmission and proper design of the transceiver aperture. The performance of the SS-WDM FSO system have been analyzed for various atmospheric conditions namely wind, haze, rain and fog. The effect of turbulences on BER of the system in terms of received optical power are investigated. Furthermore, with slicing, loss of information is reduced and number of optical sources needed drops down to one. CW laser input power is used 10dBm because it is safe for the human eyes. Finally, it can be said that for low range of transmission the optical wireless cameras for the surveillance in such area where cable is not easy to lay under the ground, this technology may help for that purpose.

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