Improvement in Performance Parameters of FSO Link under Different Atmospheric Conditions in Spatial Diversity for Constant Power

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ABSTRACT

In this paper performance of free space optical communication system is evaluated for constant value of power (20 dBm) at 1550nm wavelengths in spatial diversity under different atmospheric conditions such as clear, haze and fog. Eye diagrams are constructed by simulating FSO system in OptiSystem tool to find out performance metrics such as Q-factor, bit error rate etc. Attenuation is taken as clear (0.43 dB/Km), haze (4.3 dB/Km) and fog (43 dB/Km). Various configurations (1x1, 2x2, 4x4, 8x8, 16x16) are analyzed. Configuration 2x2 means there are 2 transmitters and 2 receivers connected with FSO link.

Keyword: *- Mach-Zehnder interferometer, Attenuation, Non-Return-to-Zero, Bit Error Rate, Q Factor*

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1. INTRODUCTION

The propagation channel of each communication technology has some inappropriate effects on the transmission of signal. The propagation channel of FSO is known as atmosphere and the FSO links' reliability is generally dependent on the patterns of local weather. Optical absorption, optical scattering, and Index-of-Refractive Turbulence (IRT) are the fundamental atmospheric procedures that affect propagation of optical signal. The main problems of optical communication along the atmosphere are attenuation of optical power and variations in received optical signals. Our observation of distant objects is influenced by atmospheric conditions such as haze, fog, clouds, rain, dust particles and smoke. Optical wave propagation along the atmosphere is influenced by these atmospheric situations [3]. Optical waves are attenuated by the scattering, absorption and refraction of optical signals by gas molecules and aerosols like rain, haze, fog and snow. Fog is the most harmful attenuating factor with value of attenuation of 480dB/km under dense fog. Successful execution of FSO therefore needs detailed knowledge of the patterns of weather in the area of installation. The installation area must be explored to determine the level of attenuation caused by the weather patterns. Optical waves are still attenuated under clear-sky weather patterns by variations in the refractive index of the transmission medium. These originate fast fluctuations (scintillation) of the optical wave at the receiver end. The required margin should therefore be included in the installation budget to reimburse for such losses.

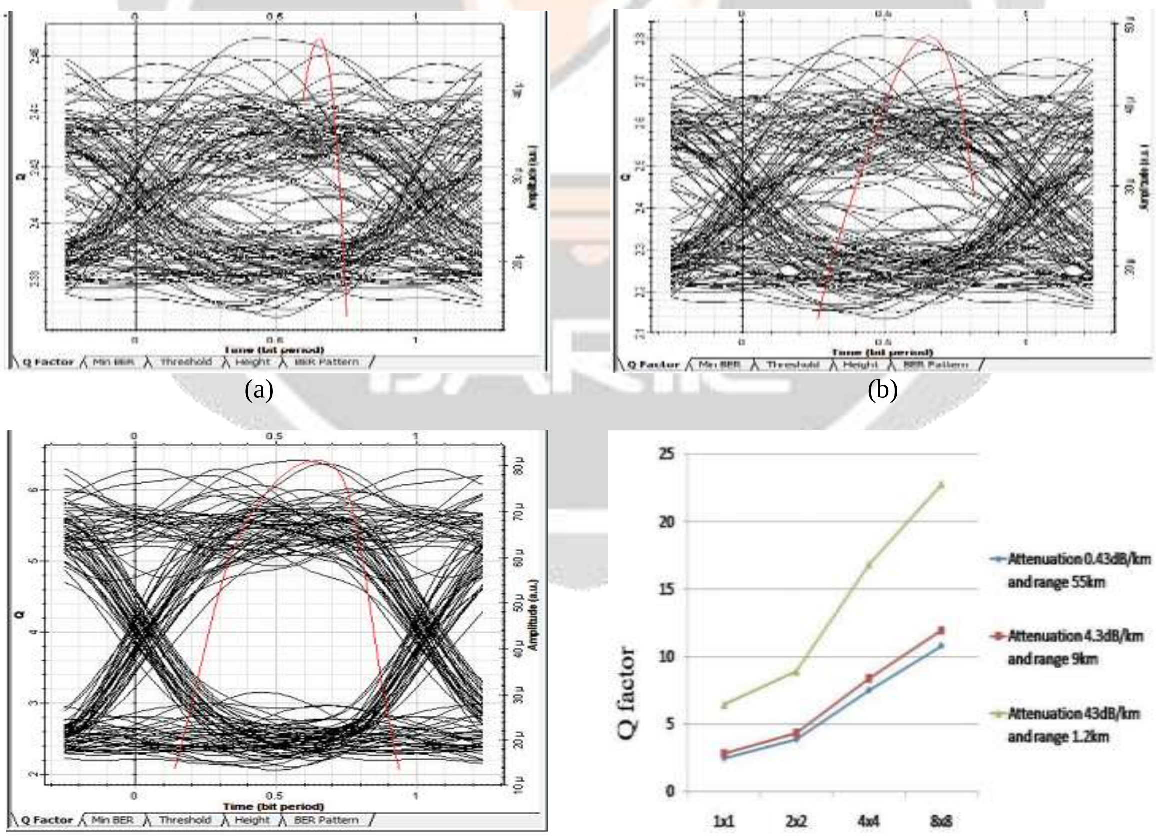
The transmitter is composed of the modulator, driver circuit, optical source (LED/ Laser) and the transmitter telescope. The modulator modulates the source signal onto the optical carrier. On-Off-Keying (OOK) modulation method is the most common utilized in FSO communications. The source message is modulated onto the irradiance of the optical source. This is obtained by modifying the driving current of the optical source depending upon the data to be transmitted or by an external modulator, like symmetric Mach-Zehnder interferometer.

Atmosphere is the transmission medium for FSO. The transmission of optical waves through free space is influenced by three main procedures such as scattering, absorption and Index-of-Refractive Turbulence (IRT). Optical radiation transmitted along the atmosphere is faded by scattering happened by gas particles and aerosols such as haze/fog, rainfall, snow and so on. This can be executed by the Rayleigh or Mie scattering coefficient. Atmospheric turbulence is another problem that must be noticed. Even in clear weather conditions, optical signals transmission is attenuated by atmospheric turbulence condition. When the earth receives sun's radiation, the surface of the earth absorbs some part of the radiation. This creates the heating up of the air mass of the earth's surface which increases and mixes turbulently with the cooler which is surrounding air mass.

The transmitted optical radiation is received by the receiver telescope and incident onto the photo detector. Aperture averaging can be utilized to decrease attenuations faced due to the spreading of beam. In aperture averaging process, the receiver telescope is formed relatively larger so that it can receive multiple uncorrelated optical signals, average them and incident their average onto the photo detector. It should however be noticed that a wide aperture also enhances the noise or background radiation as it receives other sources of light such as the solar radiation. The optical filter plays role of filtering the transmitted optical signal from other sources of light such as the sun radiations incident on the receiver aperture. This helps decrease the amount of background radiation. The photo detector receives the incident optical signal from the receiver telescope and transforms it back into electrical wave. P-I-N diode or Avalanche Photodiode (APD) is utilized to do the transformation.

2. PREVIOUS WORK

In 2017 authors Manisha Prajapat and Chetan Selwal analyzed different configurations (1x1, 2x2, 4x4, 8x8) of FSO system under three different conditions such as clear, haze and fog. Power is kept constant at 20 dBm. Q factor is determined for each configuration in Optisystem tool. Their results are mentioned below:



(a) (b) (c) (d)

Fig 1 Previous results (a) Range 55km, attenuation 0.43dB/km (b) Range 9km, attenuation 4.3dB/km (c) Range 1.2km, attenuation 43dB/km (d) Comparison graph

3. PROPOSED WORK

Different configurations of FSO system are analyzed under different atmospheric conditions for constant power. Some parameters such as Q factor, bit error rate and eye height are measured in this analysis. FSO system with 1x1 and 2x2 configurations are represented in Fig 2 and Fig 3 respectively.

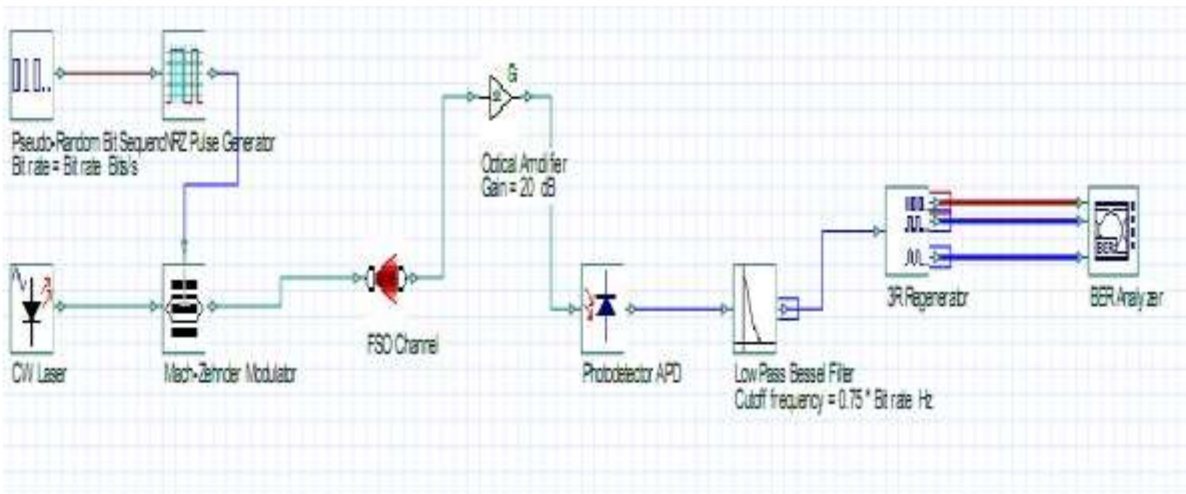


Fig 2 FSO system (1x1)

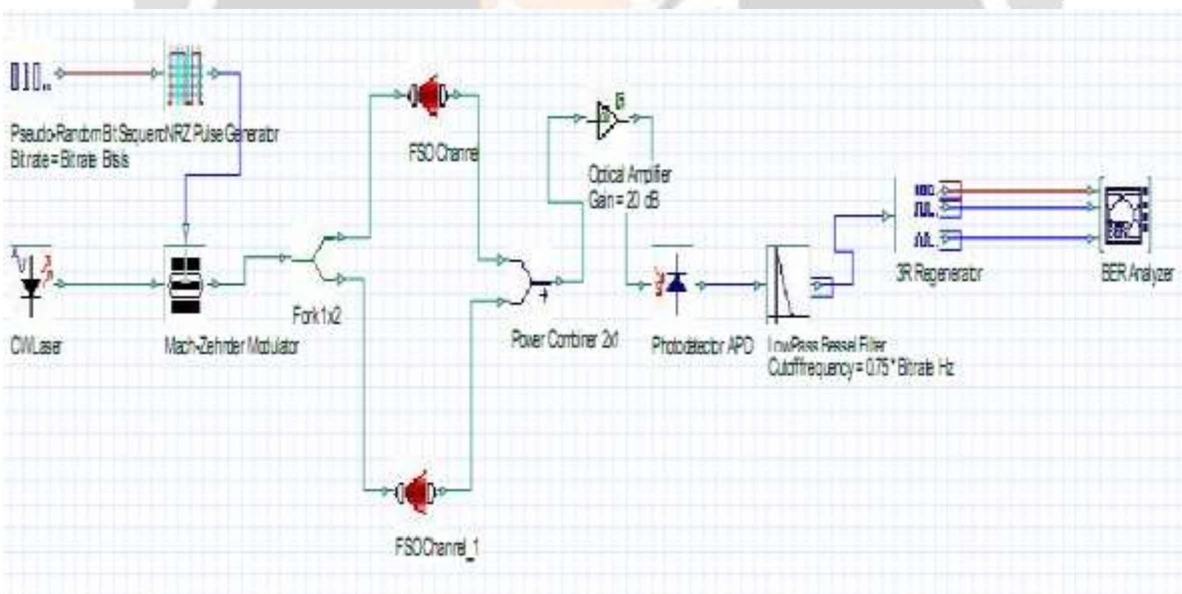


Fig 3 FSO system (2x2)

In this FSO system (2x2) bit sequence is generated by PRBS (Pseudo Random Bit Sequence) Generator component. Then this sequence is converted into NRZ (Non return to zero) pulse by NRZ Pulse Generator. Then this NRZ pulse is modulated with laser source by MZM (Mach-Zehnder modulator). This modulator converts the pulse into optical signal. Optical signal is then transmitted into atmosphere through FSO channel. This part of system completes the transmitter section of FSO system. Now at receiver optical signal is received and amplified through optical amplifier. Received optical signal is passed through Avalanche photodetector and gets converted into electrical signal. Now the electrical signal is passed through low pass Bessel filter to eliminate unwanted high frequency noise signals. Then the filtered signal is passed through 3R Regenerator to connect bit sequence and electrical signals to BER Analyzer. BER Analyzer is used to determine some properties like minimum bit error rate, Q-factor, eye height etc. Similarly other configurations are also analyzed.

4. EXPERIMENTAL RESULTS

Some parameters such as Q factor, bit error rate and eye height are measured from eye diagram in this analysis. Optisystem tool is used for simulation purpose. Proposed results are shown below:

Table 1 Simulation results for constant power at clear climate

Input power = 20 dBm, Range = 55 Km, Attenuation = 0.43 dB/Km			
Configuration	**Q-factor**	**Min. BER**	**Eye Height**
1x1	4.571	2.261×10^{-6}	1.346×10^{-5}
2x2	8.596	3.792×10^{-18}	5.281×10^{-5}
4x4	13.131	9.643×10^{-40}	12.552×10^{-5}
8x8	19.685	1.164×10^{-86}	27.522×10^{-5}
16x16	29.741	8.591×10^{-195}	57.97×10^{-5}

Table 2 Simulation results for constant power at haze climate

Input power = 20 dBm, Range = 9 Km, Attenuation = 4.3 dB/Km			
Configuration	**Q-factor**	**Min. BER**	**Eye Height**
1x1	5.271	6.446×10^{-8}	1.947×10^{-5}
2x2	8.654	2.188×10^{-18}	6.049×10^{-5}
4x4	13.894	2.941×10^{-44}	14.314×10^{-5}
8x8	21.253	1.229×10^{-100}	31.571×10^{-5}
16x16	32.327	1.156×10^{-229}	67.049×10^{-5}

Table 3 Simulation results for constant power at fog climate

Input power = 20 dBm, Range = 1.2 Km, Attenuation = 43 dB/Km			
Configuration	**Q-factor**	**Min.BER**	**Eye Height**
1x1	9.117	3.329×10^{-20}	7.861×10^{-5}
2x2	12.573	1.262×10^{-36}	11.648×10^{-5}
4x4	21.237	1.602×10^{-100}	39.929×10^{-5}
8x8	30.203	8.519×10^{-201}	84.304×10^{-5}
16x16	45.981	0	173.345×10^{-5}

5. COMPARISON WITH PREVIOUS RESULT

Table 4 Comparison of results with previous work for clear climate

Input power = 20 dBm, Range = 55 Km, Attenuation = 0.43 dB/Km		
Configuration	**Q Factor**	
	Proposed Work	**Ref [39]**
1x1	4.571	2.466
2x2	8.596	3.848
4x4	13.131	7.505
8x8	19.685	10.809
16x16	29.741	----

Table 5 Comparison of results with previous work for haze climate

Input power = 20 dBm, Range = 9 Km, Attenuation = 4.3 dB/Km		
Configuration	**Q Factor**	
	Proposed Work	**Ref [39]**
1x1	5.271	2.806
2x2	8.654	4.306
4x4	13.894	8.371
8x8	21.253	11.934
16x16	32.327	----

Table 6 Comparison of results with previous work for fog climate

Input power = 20 dBm, Range = 1.2 Km, Attenuation = 43 dB/Km		
Configuration	**Q Factor**	
	Proposed Work	**Ref [39]**
1x1	9.117	6.407
2x2	12.573	8.874
4x4	21.237	16.823
8x8	30.203	22.751
16x16	45.981	----

6. CONCLUSIONS

We have successfully performed analysis of FSO system under different values of attenuation for constant power. Three attenuation factors are considered such as 0.43 dB/Km for clear climate, 4.3 dB/Km for haze climate and 43 dB/Km for fog climate. Five configurations of FSO system have been considered such as 1x1 (1 transmitter and 1 receiver), 2x2 (2 transmitter and 2 receiver), 4x4 (4 transmitter and 4 receiver), 8x8 (8 transmitter and 8 receiver), 16x16 (16 transmitter and 16 receiver). One conclusion can be extracted that 16x16 FSO system provides 7, 6, 5 times better Q factor than 1x1 FSO system at clear climate, haze climate and fog climate respectively.

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