Impact of Free Space Path (FSPL) Loss Suffered by FSO System under Different Transmission Distance at Different Wavelengths

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Abstract— In this paper impact of free space path loss (FSPL) on FSO channel has been investigated under different wavelengths (780nm, 800nm, 850nm, 1500nm, 1550nm & 1590nm) by varying transmission distance from 1km to 40km and 1m to 8800m. Since FSO systems operate between two wavelength ranges such as 750-850nm and 1500-1600nm. Results show that as transmission distance increases, FSPL also increases but when wavelength increases the value of the FSPL decreases. Further results show that maximum FSPL is observed at 750nm for both case clear weather (40Km) and haze weather (8800m) and minimum FSPL is observed at 1590nm for a transmission distance of 1m. So 1500 to 1590nm wavelength range is preferred for FSO communication systems. Thus Free space path loss has a very significant impact on FSO communication.

Key words: FSO, FSPL, Wavelength

I. INTRODUCTION

The increasing demand of bandwidth requires technology that leads beyond conventional copper wires and the technology that succeeded to meet demands of increased bandwidth, speed and wireless communication is called free space optics (FSO) technology. Free space optics is having the same capabilities as that of fiber optics, but at a very lower cost and very fast deployment speed [1]. It has advantages high speed, low cost, high bandwidth, quick installation high security and also license-free longer range spectrum [2]. But in fiber case have problem that is dispersion, nonlinear impacts in a transmission line but not in the FSO channel [3-5-6] and FSO system is also severely limited by the four wav mixing effect [4]. Mazin Ali et al [7] describes major difference between FOC (Fiber optical communication) and FSO. In FOC pulses of light through an optical or glass fiber carry information from one point to another whereas FSO system uses sources of visible light to transfer data through the clear air, space or atmospheric channel. FSO system operates in the near infrared wavelength between 750 to 850nm and between 1500 to 1600nm. FSO system is also severely affected by various parameters such as: atmospheric turbulence, scintillation, FSPL (free-space path loss) and weather conditions such as clear, rain, haze and fog etc. Free space path loss is a fabricated engineering quality that evolved from manipulating communication systems link budget equation, which include transmitting antenna gain, free space path loss and receiving antenna gain into a particular format.

In Telecommunication systems, (FSPL) is the loss in signal intensity that would appear in a line-of-sight path through free space with no obstructions nearby, to spring reflection or diffraction. [8]The equation for free space path loss (FSPL) and the effect of link length are given below:

$$\text{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 \qquad (1.1)$$

and because $$\lambda = \frac{c}{f} \qquad (1.2)$$

therefore $$\text{FSPL} = \left(\frac{4\pi f d}{c}\right)^2 \qquad (1.3)$$

Where: d= distance between transmitter and receiver (km)
λ = wavelength (nm)
f = frequency (Hz, THz)
c = velocity of light (m/s)

Mazin Ali et al. [7] analyzed data rate for FSO system and showed that the data rate decreases with increasing divergence angle and link distance. Jun He et al., (2014) discussed the survey on recent advances in optical communications. The FSO is used in various applications. In this paper investigate the overview of recent research in optical communications and focus on the topics of modulation, switching, add-drop multiplexer, coding schemes, detection schemes, orthogonal frequency-division multiplexing, system analysis, cross-layer design, control and management, free space optics, and optics in data center network. The author aim is provide the knowledge about the advances in optical communications. Hence from this survey conclude that optical communication plays important role in telecommunication and data center communications [9]. Jagjit Singh Malhotra et al., (2010) investigate the Performance analysis of NRZ, RZ, CRZ and CSRZ data formats in 10Gbps. In this paper investigate the performance of NRZ, RZ, CRZ and CSRZ data formats analyzed on the basis of bit error rate (BER), Q2 (dB), OSNR, eye opening performance metrics. The results show that CRZ and CSRZ modulation format is perform better as compared to NRZ and RZ. The CSRZ has optimal performance according to performance metrics [10-12].

In section II, Free Space Optical impairments are explained. Section III discusses the results and finally conclusions are in section IV.

II. FREE SPACE OPTICAL IMPAIRMENTS

FSO system is impact of attenuation under different weather conditions and influence of free space path loss (FSPL) on FSO channel under different wavelengths and some other optical impairments are discussed below such as scintillation, alignment, free space path loss (FSPL), etc.

1) Scintillations: Hot air rising from the ground or rooftops causes temperature among various air pockets . As a repercussion, the refractive index may alter in a time dependent and fortuitous manner along the line of sight of the link, giving rise to scintillations over the beam cross section. These scintillations emerge as a result of power variation in the receiver [8].
2) Alignment: Most significant key ultimatum for FSO communication to take place is that there should be clear line of sight between transmitter and receiver i.e. retaining excellent alignment among transceivers.[13, 14]

3) Free Space Path Loss (FSPL): In communication systems, free-space path loss (FSPL) is the loss in signal intensity. It does not depend upon factors such as antenna gain required at the transmitter and receiver ends and other losses concerned with system hardware imperfection.

III. Results and Discussions

In this paper impact of FSPL on FSO system has been investigated under different wavelengths (780nm, 800nm, 850nm, 1500nm, 1550nm and 1590nm) by varying transmission distance from 1km to 40km in clear weather and 1m to 8800m in haze weather in FSO system. Since FSO systems operate between two wavelength ranges such as 750-850nm and 1500-1600nm. So results are calculated by using equation (1.1) in the above mentioned wavelength ranges and are shown in Table 1, Table 2, Table 3 and Table 4 in clear weather and haze weather condition with transmission distance 40km and 8800m respectively.

Distance (km)	FSPL values under different wavelengths		
	750nm	800nm	850nm
1	20.664	18.228	16.146
5	518.37	455.786	403.739
10	2073.13	1823.143	1614.964
15	4665.34	4102.068	3633.676
20	8293.93	7292.558	6459.87
25	12959.28	11394.626	10093.5577
30	18661.43	16408.333	14534.7201
35	25400.26	22333.501	19782.7485
40	33175.31	29170.380	25839.0234

Table 1: FSPL values for 750-850nm wavelengths transmission distance 40km (clear)

Distance (km)	FSPL values under different wavelengths		
	1500nm	1550nm	1590nm
1	5.1858	4.85653	4.615113
5	129.6454	121.376	115.322
10	518.581	485.653	461.511
15	1166.809	1092.684	1038.41
20	2074.327	1942.467	1845.75
25	3241.13	3035.151	2884.611
30	4666.7943	4370.736	4153.675
35	6352.628	5949.369	5653.163
40	8297.015	7770.6075	7384.55

Table 2: FSPL values for 1500-1600nm wavelengths transmission distance 40km (clear)

Distance (m)	FSPL values under different wavelengths		
	750nm	800nm	850nm
1	0.00028	0.00024	0.00021
100	2.8096	2.4693	2.1874
1000	280.96	246.93	218.74
2000	1123.84	987.755	874.96
3000	2528.6	2222.448	1968.67
4000	4495.3	3951.020	3499.86
5000	7025.03	6173.469	5468.54
6000	10114.6	8889.79	7874.698
8800	21757.65	19122.93	16939.35

Table 3: FSPL values for 750-850nm wavelengths transmission distance 8800m (haze)

Distance (m)	FSPL values under different wavelengths		
	1500nm(199.8 THz)	**1550nm(193.4 THz)**	**1590nm(187.3 THz)**
1	0.000070	0.000065	0.000062
100	0.7024	0.6578	0.62513
1000	7.0240	65.787	62.513
2000	280.96	263.12	250.05
3000	632.16	592.03	562.62
4000	1123.84	1052.5	1000.21
5000	1756.00	1644.5	1562.84
6000	2528.65	2368.14	2250.49
8800	5439.413	5094.14	4841.05

Table 4: FSPL values for 1500-1600nm wavelengths transmission distance 8800m (haze)

Figure 1 shows graph for FSPL in clear weather with 40km transmission distance under different wavelengths and it is clearly shown that as distance increases, FSPL increases because distance is directly proportional to FSPL. Further, wavelength is inversely proportional to FSPL, therefore FSPL decreases as the wavelength increases. Thus, in 850nm wavelength range minimum FSPL is observed at 1590nm for 40km distance and maximum FSPL is observed at 750nm for 40km distance. Thus, in 1500-1600nm wavelength range minimum FSPL is observed at 1600nm for 1m distance and maximum FSPL is observed at 1500nm for 40km distance.

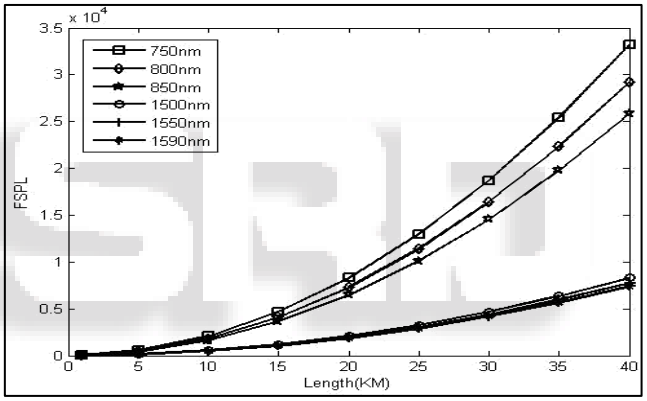

Fig. 1: FSPL v/s transmission distance for FSO system in clear weather at (a) 750, 800 & 850nm (b) 1500, 1550 & 1600nm wavelength

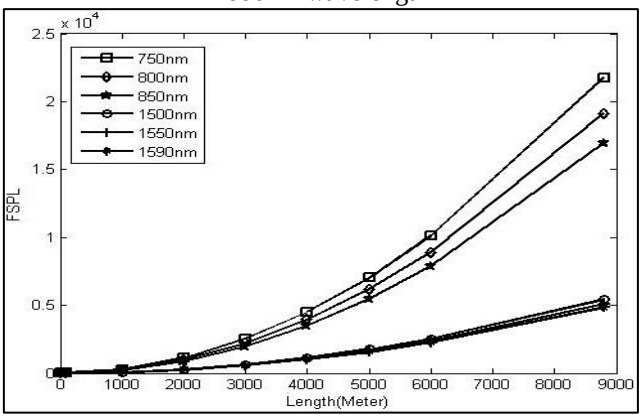

Fig. 2: FSPL v/s transmission distance for FSO system in haze weather at (a) 750, 800 & 850nm (b) 1500, 1550 & 1600nm wavelength

Figure 2 shows graph for FSPL in haze weather with 8800m transmission distance under different wavelengths and it is clearly shown that as distance increases, FSPL increases because distance is directly proportional to FSPL. Further, wavelength is inversely

proportional to FSPL; therefore FSPL decreases as the wavelength increases. Thus, in 850nm wavelength range minimum FSPL is observed at 1590nm for 8800m distance and maximum FSPL is observed at 750nm for 8800m distance. Thus, in 1500-1600nm wavelength range minimum FSPL is observed at 1600nm for 1m distance and maximum FSPL is observed at 1500nm for 8800m distance.

IV. CONCLUSION

Free space path has a very significant impact on FSO communication system because FSPL is increases as transmission distance increases, which degrade the performance of FSO system. FSPL decreases as wavelength increases, so 1500- 1600nm wavelength range is preferred for FSO communication systems.

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