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# Comparison and Analysis of Atmospheric Turbulence in Free Space Optical Communication for Srinagar

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**ABSTRACT**
Traditional microwave communication systems can no longer support high bandwidth demand. Telecommunications companies in the country are therefore investing huge sums of money in laying underground fiber cables for their backbone network. The challenges these companies face in laying optical fiber cables include inaccessibility in the 4 major cities. These cities have already developed infrastructure (i.e. buildings and roads). Therefore digging and laying cables are very difficult if not impossible in some suburbs. In such areas, the companies are forced to depend on microwave links. Again, due to lack of already developed network infrastructure design in the country, underground fiber cables are destroyed during road constructions. An alternative to fiber cables in inaccessible areas could be the use of FSO installation. FSO can be used to provide backup links in the event of fiber cable destruction or as a backbone network. Free Space Optical (FSO) communication is the transmission of optical signals through the atmosphere. To the best of our knowledge, evaluation of FSO performance in the country has not been investigated to determine its feasibility. This paper seeks to investigate whether FSO communication implementation is feasible in Srinagar. However, turbulent atmospheric conditions have impacts on its performance and therefore hampered its wide spread deployment. In this paper, we investigate the feasibility of FSO in Srinagar. Atmospheric attenuation is estimated based on the atmospheric visibility data. Our results show atmospheric specific attenuation as high as 27.17dB/km in the 1550nm window, 29.315dB/km in 1300nm window and 35.20dB/km in the 850nm window. The probability of encountering different atmospheric attenuation conditions is estimated. Fading loss due to scintillation is investigated using the lognormal statistical model. It is shown that the margin to compensate for losses due to scintillation depends on the power scintillation index and the allowable system outage probability.

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***KEYWORDS:*** *FSO, Specific Attenuation, Fading Loss*

## INTRODUCTION

The field of wireless communication has been extensively researched in order to exploit the advantages it has over wired networks such as mobility and flexibility. The demand for bandwidth on wireless communication systems today is increasing at an exponential rate. Many bandwidth demanding applications (multimedia) are being developed these days. Thus traditional voice communication is not the only requirement of wireless communication in today's network. The main challenge is to design more adaptive and scalable networks that can provide high data rates to support the increasing demand for bandwidth. In view of this, several wireless networks have been developed to address the demand for high information carrying capacity. The amount of data that can be transmitted in any communication system is directly related to the bandwidth of the carrier which is directly related to the carrier frequency. Optical signals use a frequency range of 20THz - 375THz and could therefore guarantee very high data rates. Optical communication systems thus promise the highest possible information carrying capacity. The theoretical information carrying capacity of free space optical communication systems exceeds that of microwave systems. The information carrying capacity of microwave systems is the highest so far amongst the available wireless networks. Free Space Optical (FSO) communication is the transmission of high speed data over long distances using optical signals through free space. Free Space Optical (FSO) communication can be considered as a viable technology for next generation communication due to its wide range of applications [1, 2]. Some of its applications are links involving satellites (inter-satellite communication), High Altitude Platforms (HAPs), Unmanned Aerial Vehicles (UAVs), terrestrial communications, aircraft and ship-to-ship communication. FSO can be used to provide high data rates in areas where it is difficult or impossible to lay optical fiber cables. Again, it can be used in both military and civilian applications [3]. It can be used to provide temporal links in the event of disaster. FSO has more advantages over other traditional wireless technologies (i.e. Microwave systems). First, FSO can provide higher data rates (several gigabytes of data) than that provided by microwave systems. Secondly, it does not require licensing for its operation. This is a major cost advantage over microwave links. Again, FSO channels are highly immune to electromagnetic interference (EMI) and highly secure with low probability of interception and low probability of detection (LPI/LPD) properties [4]. However, FSO has some disadvantages which have hampered its wide deployment. It has low availability probability due to its susceptibility to atmospheric weather conditions [5]. The availability probability of a communication system is the percentage of time during which the communication link is operational. The availability probability requirement of wireless communication systems is 99.999% [6]. The primary atmospheric processes that affect optical signal propagation are atmospheric absorption, atmospheric scattering and index-of-refractive turbulence (Scintillation). For an optical radiation traversing the atmosphere, absorption occurs when some of the photons are extinguished by molecular constituents of the atmosphere and their energy converted into heat energy leading to loss of optical power.

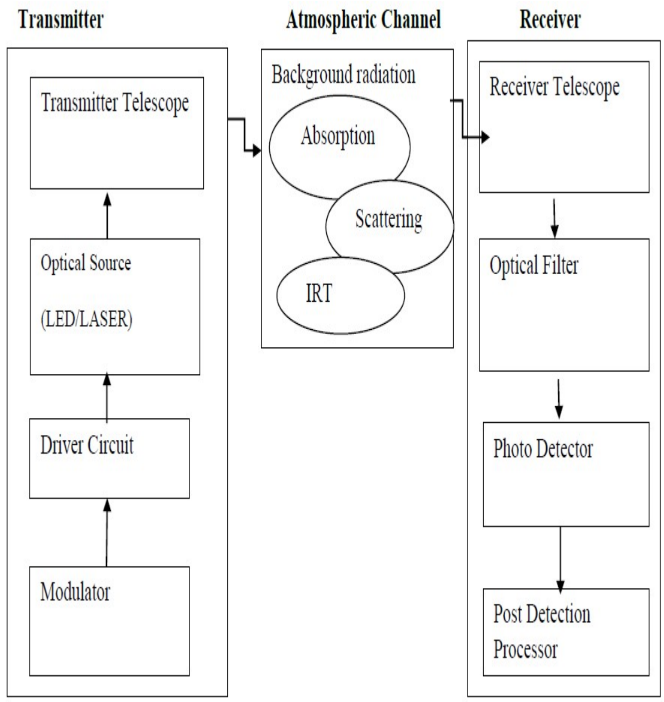


Figure 1.1 Block Diagram of FSO

**Model of Transmission of Optical Signals:**
The transmission of optical signals through the atmosphere can be modeled by the Beer-Lamberts law. The Beer Lamberts law can be stated as [3]:

$$\tau(\lambda, L) = \frac{Pt\ (\lambda,0)}{Pr\ (\lambda,L)} = \exp\left(-\gamma(\lambda)L\right)$$

The value of the atmospheric attenuation coefficient is dependent on the optical wavelength λ, $\gamma(\lambda)$ is composed of both atmospheric absorption and scattering terms and can be expressed as:

$$\gamma(\lambda) = \alpha m(\lambda) + \alpha a(\lambda) + \beta m(\lambda) + \beta a(\lambda)$$

The successful implementation of FSO systems depends largely on the local atmospheric conditions. Visibility measurement data for Srinagar were taken from the Indian Meteorological Agency for analysis [39]. Atmospheric visibility was measured every three hours in a day. Thus eight visibility measurements were collected daily for two years. For the two years (i.e. years 2018 and 2019), a total of 5840 visibility measurements were collected for Srinagar under research. Based on the visibility measurements, we will estimate the level of attenuation in Srinagar and estimate the probability of encountering such atmospheric attenuation conditions.

| Parameter | Typical Value |
|---|---|
| Transmit Power | 14dBm |
| Transmit Beam Divergence Angle | 2mrad |
| Wavelength | 850nm |
| Receiver Aperture Diameter | 8cm |
| Receiver Sensitivity | -30dBm |
| System Losses | 2dB |

Table 1.1 Typical FSO System Parameters

**Atmospheric Specific Attenuation Estimation of Srinagar:**
We have estimated the attenuation caused by the Srinagar atmosphere based on the visibility measurements using the Kruse model of equations. The graphs that follow show the attenuation coefficient, $\beta a(\lambda)$ of Srinagar in dB/km. The specific attenuation is estimated for three optical wavelengths typically used in commercial FSO systems (i.e. 850nm, 1300nm and 1550nm). On the X-axis, is the time of the year during which the visibility measurement was taken. On the Y-axis, is the attenuation (dB/km) estimated for each visibility measurement taken in the year.

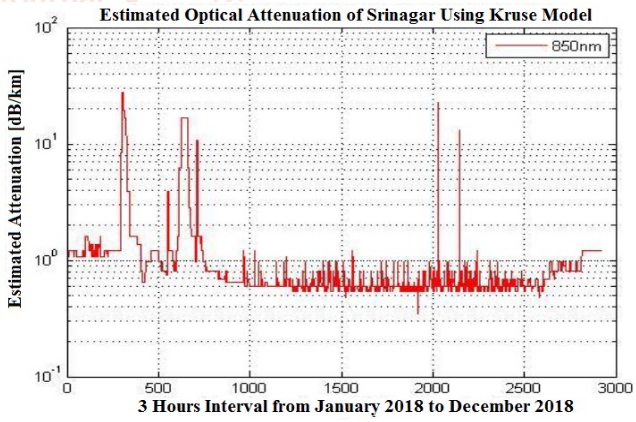


Fig1.2 Estd. Attenuation coeff for Srinagar at 850nm

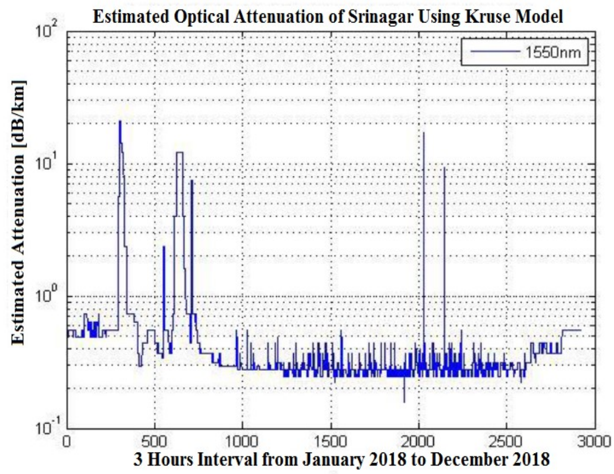


Fig1.3 Estd. Attenuation coeff for Srinagar at 1550nm

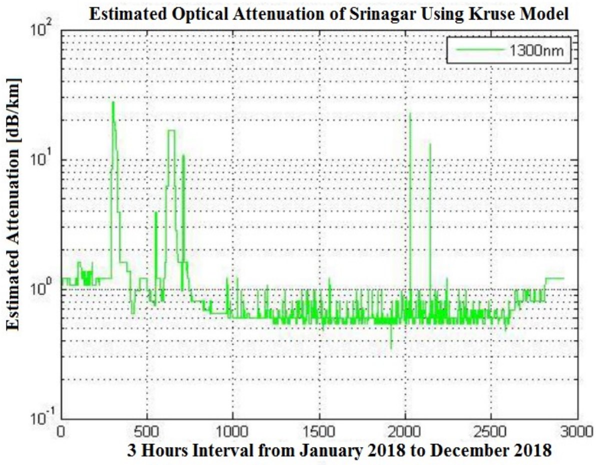


Fig1.4 Estd. Attenuation coeff for Srinagar at 1300nm

The estimated optical attenuation for Srinagar is shown in figures 1.2-1.4 for the year 2018. The highest attenuation estimated for the year 2018 was 21.0031dB/km on 1550nm wavelength, 22.7904dB/km on 1300nm wavelength and 27.7706dB/km on 850nm wavelength. The lowest estimated attenuation was 0.1578dB/km on 1550nm wavelength, 0.1983dB/km on 1300nm wavelength and 0.3446dB/km on 850nm wavelength. An annual average of 0.7092dB/km on 1550nm wavelength, 0.8374dB/km on 1300nm wavelength and 1.2725dB/km on 850nm were estimated.

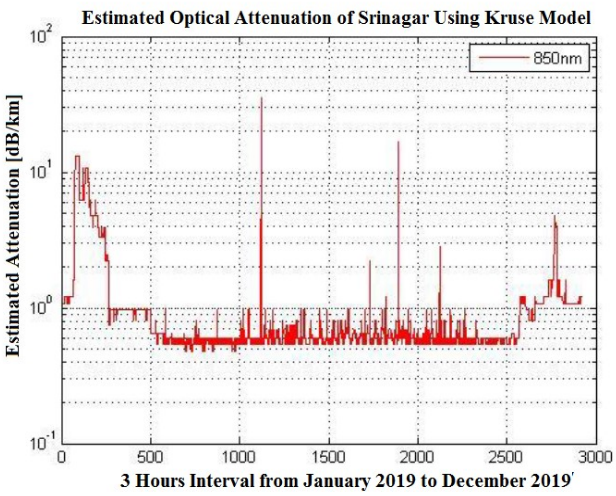


Fig1.5 Estd. Attenuation coeff for Srinagar at 850nm

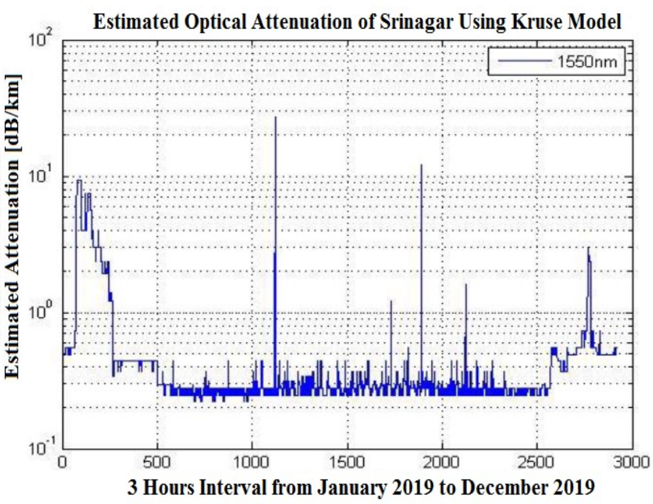


Fig1.6 Estd. Attenuation coeff for Srinagar at 1550nm

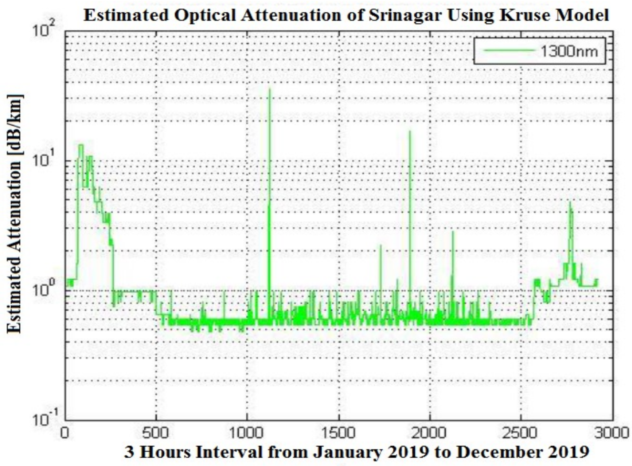


Fig1.7 Estd. Attenuation coeff for Srinagar at 1300nm

The estimated optical attenuation for Srinagar is shown in figures 4.6d-f for the year 2019. The highest attenuation estimated for the year 2019 was 27.1750dB/km on 1550nm wavelength, 29.3154dB/km on 1300nm wavelength and 35.2074dB/km on 850nm wavelength. The lowest estimated attenuation was 0.2209dB/km on 1550nm wavelength, 0.2777dB/km on 1300nm wavelength and 0.4824dB/km on 850nm wavelength. An annual average of 0.5598dB/km on 1550nm wavelength, 0.7165dB/km on 1300nm wavelength and 1.1143B/km on 850nm were estimated.

**Conclusion:**

In Srinagar, the highest attenuation estimated was 27.1750dB/km using 1550nm wavelength system, 29.3154dB/km on 1300nm wavelength system and 35.2074dB/km on 850nm wavelength system. The lowest attenuation estimated was 0.1578dB/km on 1550nm wavelength, 0.1983dB/km on 1300nm wavelength and 0.3446dB/km on 850nm wavelength. The average attenuation estimated was 0.6545dB/km on 1550nm wavelength, 0.7770dB/km on 1300nm wavelength and 1.1934dB/km on 850nm wavelength.

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