

Recent Trends and Advancements in Wireless Fiber Optic Communication

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Abstract:

Optical Communication using free space is a field of huge interest among researchers around the world, however, its implementation remains theoretical till date. This paper will discuss the recent trends in this technology and the results from our examination in propelling the demonstration and data hypothesis for space optical communication in scattering conditions.

Keywords: *Optical wireless communication, Discrete time Poisson, lased based communication.*

I. Introduction

With the advancements in the mobile telephony, we expect to establish broadband data connection or be able to make calls anyplace. However, there are various situations where radio Frequency Communication(RF) fails. Energy efficiency restrictions, attenuation offered by the propagating environment and interferences offered to the RF signals can make any radio communication system unreliable. Therefore, Optical wireless (OW) communication offers a cheap and reliable broadband communication channel because they are immune to RF interference. Moreover, they don't have any spectral licensing requirement. Furthermore, the algorithms designed for RF systems are hardly efficient for optical wireless links because of different propagation environments, types of optical transmitters and receivers used and the imposed limitations[1].

Table1:- Comparison of FSO with other Communication Techniques

Parameters	FSO	Optical fiber	Microwave radio	Coaxial cable
Installation	Moderate	Difficult	Difficult	Moderate
Data rate	Gbps	Independent	Mbps	Mbps
Security	Good	Very good	Poor	Good
Connectivity	P2P, P2MP short and long reach	P2P, P2MP short and long reach	P2MP long reach	Multidrop short reach
Maintenance	Long	Low	Low	Moderate
Spectrum license	Not required	Required	Required	Required

The Table1 enlists the various benefits of FSO communication technique compared to other communication techniques, providing data rates in Gbps and no spectrum licensing. Moreover, the maintenance cost is tremendously low as compared to the other techniques providing cheaper data rates.

This paper will review two key areas of research, the FSO (free space optical) communication and OW (optical wireless) systems. This paper will discuss laser based communication highlighting its advantages and the recent progress in modelling of such channels.

II. Free Space Optical Communication Links (FSO)

Laser transmission through optical strands communicate terabits of information consistently among users around the globe, but laying optical fibers on most of the Earth's Surface is unrealistic physically, therefore, space satellites provide a way to connect ground users and mobile platforms such as ships, aeroplanes and even other satellites. Although Radio frequency communication is reliable, it is much slower than optical fiber and has problems of power requirement, radio interference, antenna problems and limited spectrum, therefore laser based free space data transmission seems to be the only viable solution.

The free space optical links have inherited benefits as compared to RF links in terms of data rate because of vast amount of available bandwidth. Moreover, as compared to RF solutions, the FSO transmitters are low divergent and can provide large antenna gain. Furthermore, RF communication is a bottleneck for high speed data transmission in space and microwaves having centimetre long wavelengths (Ka band at 26 GHz) result in wide diffracting beam of hundreds of kilometres on Earth when transmitted from a satellite 39000 Km above ground in the geo stationary orbit. For achieving speeds above 1Gbps more concentrated beam is needed and using RF antenna means the transmitter antenna will be larger than a meter to narrow the beam width and higher energy transmission to transmit higher energy per bit [2].

There are many benefits of optical communication in free space, however, as the transmission medium is air for free space optical communication and the light goes through it, some ecological difficulties are inevitable. Troposphere region is where the majority of the interactions happen in the atmosphere. The impact of these confinements over the climate are shown in Figure 1.

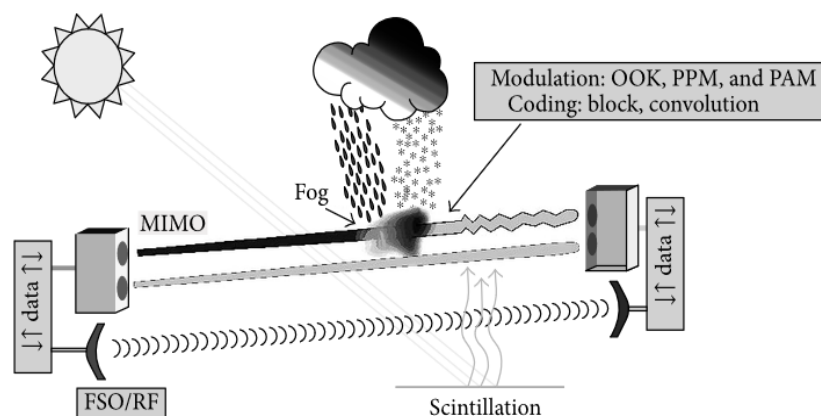


Figure1: Atmospheric effects on a FSO system

The temperature variations because of the heat rising among different man-made drives like heating ducts and the earth, can cause variations in signal's amplitude which causes "image dancing" at the FSO receivers end. Absorption by the suspended water molecules in the air can also cause attenuation of signals because of absorption of photons' energy.

Therefore, the power spectral density of an optical fiber is diminished and the accessibility of the transmission in an FSO framework is straightforwardly influenced by absorption.

Table 2: Radius ranges for various types of particles.

Type	Radius(μm)	Concentration (in cm^{-3})
Air molecules	10^{-4}	10^{19}
Aerosol	10^{-2} to 1	10 to 10^3
Fog	1 to 10	10 to 100
Clod	1 to 10	100 to 300
Raindrops	10^2 to 10^4	10^{-5} to 10^{-2}
Snow	10^3 to 5×10^3	N/A

For enhancing system's performance various techniques have been introduced like spectral direct decoding, Optical Tandem Side Band, Optical single sideband and Wavelength division multiplexing.

Table3: Comparison of various techniques for optical communication systems on wavelength of 1550 nm [2-4].

Technique		Weather Condition	Attenuation Level (dB/Km)	Data Rate	Link distance (km)
OFDM-FSO	SDD	Heavy rain	8.68	2.5 Gbps	1.1
		Clear sky	3	2.5 Gbps	1.3
	OFDM-OSTB-FSO	Clear	0.155	2 Gbps	10
				5 Gbps	6
		Mild clear	0.441	2 Gbps	9
				5 Gbps	5
		Low haze	1.537	2 Gbps	5.4
				5 Gbps	3.4
		Mild haze	4.285	2 Gbps	3.2
				5 Gbps	2.2
		Heavy haze	10.115	2 Gbps	1.8
				5 Gbps	1.15
	OFDM-OSSB-FSO	Clear	0.155	2 Gbps	10.2
				5 Gbps	6.2
		Mild clear	0.441	2 Gbps	8
				5 Gbps	5.2
		Low haze	1.537	2 Gbps	5
				5 Gbps	3.6
		Mild haze	4.285	2 Gbps	2.8
				5 Gbps	2.5
		Heavy haze	10.115	2 Gbps	1.7
				5 Gbps	1.4
	WDM-FSO	Very clear	0.065	2.5 Gbps	150
		Clear	0.233	2.5 Gbps	150
		Light haze	0.55	2.5 Gbps	150
		Heavy haze	2.37	155 Mbps	150
				155 Mbps	55

Discrete time Poisson are used for the modelling of Inter satellite optical wireless link in which discrete intervals represents variation of the transmitted power and the channel's output is a statistic in which number of photons are received on the time interval [3]. The data representation is done by modulating transmitted intensity on an optical transmitter a (photons/sec). On the receiver side, a detector counts the number of falling photons during a time interval, which outputs a measurement b (photons) and is Poisson distributed. It is noteworthy that the received signal is corrupted by dark current and background light of a photodetector, which is modelled at a rate λ (photons/sec). Thus, the DTP channel's law is

$$P_{b|a}(a, b) = \frac{(a+\lambda)^b}{b!} e^{-(a+\lambda)}, a \in R^+, b \in Z^+ \quad (1)$$

Due to practical implementation problem two fundamental constraints on the emitted energy are imposed.

$$E(X) \leq \varepsilon \text{ where } \varepsilon \text{ is fixed average optical power} \quad (2)$$

The first expression represents the Average power constraint which arises due to the limited energy storage, while the peak power restrictions represented by the arises due to LASER and driver circuit limitations represented by the below range.

$$0 < X < A \quad \text{where } A \text{ is peak power constraint (3)}$$

This study about the DTP channels is to research capacity-achieving distributions under average and top optical power limits. This methodology is particularly critical in that it allows us to apply theoretic data outcomes directly to signalling designs under various different amplitude restrictions[5].

The maximum mutual information is the capacity of a DTP channel over input distributions satisfying average and peak power limitations. The value λ represents the amount of dark current and background illumination when the light is falling on the Photo receiver and the dark current is not zero. Here two cases arise when $\lambda = 0$ and when $\lambda \neq 0$.

Case I: When $\lambda = 0$, This means when there is no background radiance on the receiver and the dark current is zero. This means that the receiver of the satellite has narrow band optical filters which is pointed away from the falling and is at low temperature. Therefore, the dark current is zero light[5-6].

Case II: When $\lambda > 0$ or large, this means noise or intense noise due to background illumination. The situation like this arises in inter-satellite communication when solar radiation causes high background intensity and thus causes large λ . Due to high λ the high intensity DTP approaches gaussian noise. Because of this reason, gaussian law plays a very vital role in wireless optical communication.

III. Scattering in FSO Channels

Scattering of an optical energy in FSO communication links is often considered as an impairment, but there are various classes of FSO channels in which scattering plays a vital role in the establishment of an optical communication link. For instance, the communication in solar blind band of 200-280nm region takes place through scattering by atmospheric particles for establish a wireless communication link between a transmitter and a receiver [7]. Moreover, the ozone layers help in reducing background illumination by attenuation of band emissions in this region. Non line of sight communication links are established through these channels. Therefore, this finds its application in military and disaster recovery.

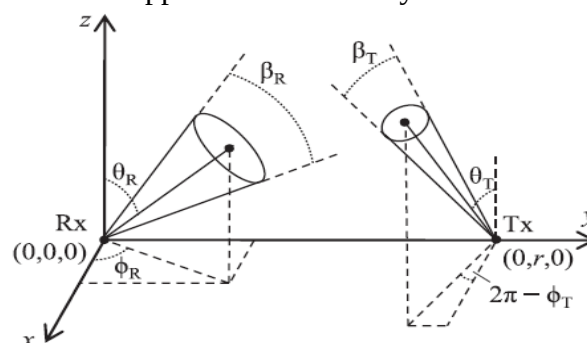


Fig1: UV NLOS communication between Tx and Rx

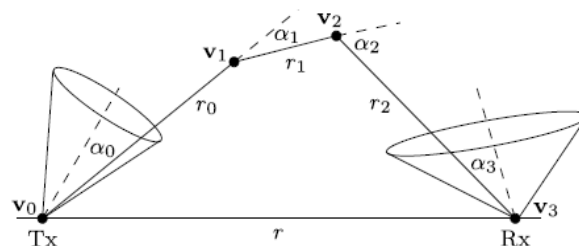


Fig2: Schematic of planer path propagation [7]

Figure1 represented a schematic where a transmitter (Tx) and receiver (Rx) is separated by some distance let it be d . The two cones represent transmitted beam a field of view (FOV). There are various drawbacks like Inter symbol interference because of high temporal disturbance but can be mitigated by spatial diversity techniques.

In Figure 2 for calculating propagation paths the conditional Probability density function of each path can be combined to find the PDF of the complete path. Moreover, by integrating this probability density function for the set of paths from the Tx to the Rx we can obtain an expression for the probability PD,n , that n scattering interactions with the atmosphere are experienced by a transmitted photon before being and is detected at the receiver[6]. The overall path loss will be given by

$$P_L = 10 \log_{10} \frac{1}{P_D}$$

Therefore, main challenges in evaluating the path loss is finding the conditional probabilities that will model the atmospheric effect on the transmitted photons and methods for evaluating multiple integrals[8-9].

IV. Conclusion

Even Though line of sight communication techniques are thoroughly studied and implemented, there are many open topics in free space optical communication and scattered FSO channels, yet to be studied and properly implemented. The approach is to study and investigate modelling and information theory of these channels which can serve as base for the future implementation of these technologies.

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