IRO Journal on Sustainable Wireless Systems (ISSN: 2582-3167)
www.irojournals.com/irosws/

An Overview of Free Space Optics Communication System

S. Kavitha

Professor, Department of ECE, Hindusthan Institute of Technology, Coimbatore

E-mail: kavithamani2003@gmail.com

Abstract

Free space optics is a kind of broadband communication technique that transmits the signals, in the atmosphere through laser beams. In some cases, the laser beams are replaced with infrared and modified beams. Free Space Optics (FSO) is also referred as Free Space Photonics that works same as the principle of fiber optic communication where the source beams are transferred through air medium. In the traditional fiber optic communication, the optical fibers were used for transferring the beam signals. The FSO methodology is widely employed in various ubiquitous applications for their cost and deployment effectiveness. The motive of the work is to explore the concepts and theories behind the operation of different FSO models with their recent progress.

Keywords: Free space communication, hybrid modulation schemes, channel estimation, satellite communication, bandwidth

1. Introduction

Line of sight is a technological concept used in FSO to make a bandwidth communication between the source and destination. It transfers the signals through wireless medium like air, space and vacuum. The FSO have the ability to transfer GBs of data efficiently without a spectrum license or a fiber optic cable. The data sharing speed and reliability of an FSO is high when there are no disturbances in their communication space. The FSO are also used for transferring the data like numerical values, recorded voices and videos. The FSO links are operated with 780 – 1600 nm wavelength of beams that uses laser or LEDs for focusing. The data transmission speed of FSO is comparatively high over the optical fiber networks as air or vacuum is utilized here for connecting medium. Moreover, the transfer speed almost equals to the speed of light as it uses light as a signal for transmission [1, 2]. The FSO are designed to overcome the limitations of the radio relay link line of sight communication methods. An architectural overview of an FSO system is shown in figure 1.

DOI: https://doi.org/10.36548/jsws.2022.4.001
Received: 08.09.2022, received in revised form: 14.10.2022, accepted: 01.11.2022, published: 10.11.2022

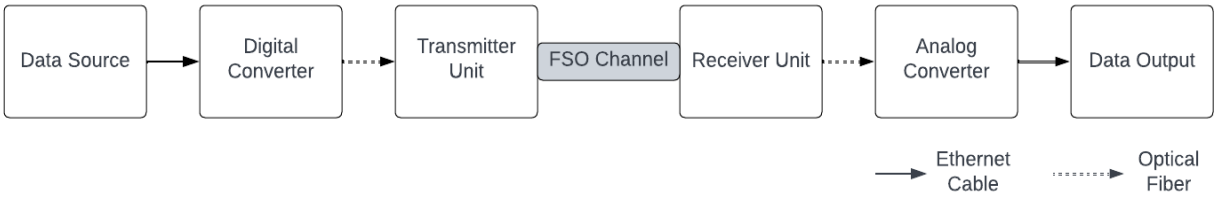

Figure 1. Architecture of FSO system

The data source on the architecture represents a computer system that is connected with a digital converter through an Ethernet cable for converting the raw inputs into digital format. The data that are converted into digital form is further forwarded to the transmitter unit for accessing the FSO channel. The transmitter unit represents a high power laser converter that develops laser pulses with respect to the received digital signal of source data. The generated laser beams are forwarded to the destination through a customized lens. The receiver lens captures the transmitted beam and converts it into digital data by the help of high sensitivity photo detector. Therefore an optical communication is enabled in the FSO without a fiber cable [3, 4]. The FSO communications are employed to the following applications as they have the possibility to send a wide range of data in meters to certain kilometers.

- Device to device communications
- Building to building communications
- Airborne and deep space communications

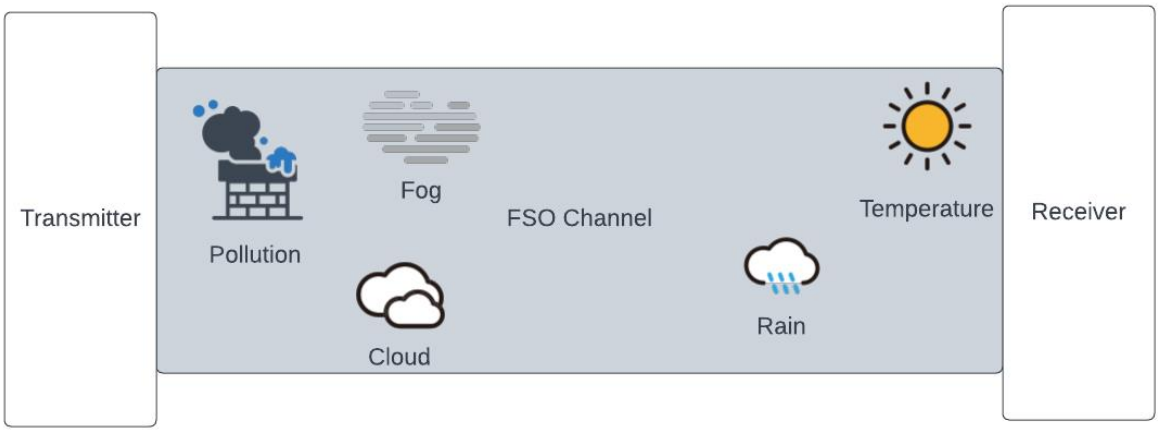

Figure 2. FSO performance degrading factors

Figure 2 represents the list of factors that affect the performances of FSO as they use atmosphere as their connecting medium.

2. Related Work

2.1 Security in FSO

The FSO signals are comparatively better in terms of security than the regular Radio Frequency (RF) and other wireless systems as its wireless signals cannot be observed with spectrum analyzers and meters. Similarly, the FSO signals are optical in nature and follow its own sight path that is not intercepted with any other receiver, since it requires a matching transceiver. The FSO laser beam signals cannot be cracked since they are generated as a narrow beam. In some cases, the signals are transferred through an encrypted connection [5].

2.2 Fog attenuation in FSO

Fog has the property to reduce the quality of a visible radiation. Therefore, the performance of the FSO comes almost same as of the RF signal in this case. In the same way, the FSO signal may also get faded to the presence of rainfall in its way. However, the power of optical link can be improved to certain range for maintaining its efficiency on communication even in the presence of fog. Hence the performances of FSO are comparatively better over the RF signals [6].

2.3 Physical disruption of FSO

The physical disruption of FSO can happen when some birds are crossing over the invisible FSO beams. In general, the FSO signals are very strong and the presence of a bird for a second will not affect the quality of the transmitted signal [7].

2.4 FSO stability

The FSO signal is more stabilized when its signal beams are transmitted in a wider way. The performances of a narrow beam FSO may not satisfy the user when its path is disturbed by the deployment of a new building. In such cases, a re-alignment of transmitter and receiver angle is required along with regular verification [8].

2.5 FSO and solar interference

The narrowband and spatial filters are widely employed at the receiving side of the FSO transmission that can handle the solar interference by filtering beam wavelength of the received signal. An automatic gain control block is also used in some modules for eliminating the effects of atmospheric jitter and scintillation [7].

2.6 Reliability

Automatic Transmit Power Control (ATPC) is a system employed in FSO transmission for handling the weather disturbance to the FSO signals. It is used to regulate the power requirement of the laser beams on different scenarios. The environmental conditions are observed by the ATPC module by the help of sensors, and the control architecture placed over the system reduces the beam power when the atmosphere is clear. Similarly, the power is increased to a certain limit for making a continuous optical link. A temperature monitoring system is also included in the FSO to observe the temperature changes in the laser beam diodes for increasing the lifetime and operational quality of the module [2].

3. Literature Survey

The following table represents the different types of modulation techniques that are widely employed to the transmission of FSO signals.

Table 1. Survey on FSO modulation methods

Reference	Modulation method	Outcome
[9]	On-Off Keying (OOK)	Better power to noise ratio on different thresholds
[10]	OOK with digital pulse modulation	Consumes 0.2–3 dB lower power than the regular OOK
[11]	Amplitude/frequency shift keying modulation	Good data rate for FSO channel length of 10kms
[12]	Orthogonal Frequency-Division Multiple Access (OFDMA)	Excellent bit error rate of 10Gbps/10GHz transmission
[13]	Mode-Division Multiplexing (MDM) with OFDMA	Better data transmission of 20Gb/s at 10 to 50kms
[14]	Quadrature Amplitude Modulation (QAM)	Free to atmospheric turbulence
[15]	QAM in turbulent environments	Observed low error rate with high transmission rate
[16]	Sequence Inverse Keying (SIK)	Performance degrade found above 3000m link distance
[17]	Optical domain encoder and SIK	Outcome is directly proportional to the pointing error of laser beams

[18]	Quadrature Phase Shift Keying (QPSK)	Accepts up to 7 cm of boresight displacement
[19]	Multi-Level Pulse Amplitude Modulation (MPAM)	Suitable for medium to weak turbulence
[20]	Comparison of OOK and PAM	OOK is more vulnerable and PAM gives better error rate

The literature analysis indicates that the FSO systems are widely operated with OOK, OFDMA and QAM modulation techniques where the module consumes low power for long range communications. The QAM based methods exhibit a good outcome in handling the atmospheric turbulence. The transmission range of OFDM techniques is comparatively high along with a good transmission rate.

4. Discussion

The communication systems are moving towards the light -based communication techniques for their betterment on interference handling than the regular RF methods. The light -based communication systems like FSO, Light Fidelity (LiFi) and Visible Light Communication (VLC) are looking better in terms of communication speed and security, compared to the RF methods. As the light based techniques are transferring information through diodes, it requires only minimum amount of power consumption for the communication. The following table explores the primary difference among the available light communication techniques on different parameters.

Table 2. Comparison of various light communication techniques

Features	**FSO**	**LiFi**	**VLC**
Source	Laser Diode	LED/ Laser Diode	LED/ Laser Diode
Receiver	LED/ Laser Diode	Photo Detector	Photo Detector
Modulation Methods	OOK, SIK, QAM, OFDM	OOK,CDMA, OFDM	OOK,CDMA, OFDM
Coverage Range	Upto 1000kms	10m	20m
Bit Rate	40Gb/s	100Gb/s	100Gb/s
Path Loss	High	Medium	Medium

Communication Topology	Bidirectional	Bidirectional	Unidirectional and bidirectional
Merits	High security		
Application	Satellite, defense and mobile backhaul	Healthcare and consumer electronics	Underwater and V2V communication
Limitations	Environmental issue affects the performance	Not suitable for long range communication	Comparatively higher interference

5. Conclusion

The FSO communication methods are attracting the recent year researchers for their betterment on high speed communication with large capacity of data transmission. The FSO technique requires a transmitter and receiver unit along with a modulator module for enabling a secure transmission between a source and destination. This paper has analysed the outcome of different modulation techniques that are used on FSO algorithm and found that there is still space for a new modulation scheme for providing a good communication rate with longer distance. An analysis among the different kinds of light-based communication techniques has also been studied in the article to explore the nature of an FSO method.

References

[1] Trichili, Abderrahmen, Mitchell A. Cox, Boon S. Ooi, and Mohamed-Slim Alouini. "Roadmap to free space optics." JOSA B 37, no. 11 (2020): A184-A201.

[2] Chaudhry, Aizaz U., and Halim Yanikomeroglu. "Free space optics for next-generation satellite networks." IEEE Consumer Electronics Magazine 10, no. 6 (2020): 21-31.

[3] Kaur, Sanmukh, and Amayika Kakati. "Analysis of free space optics link performance considering the effect of different weather conditions and modulation formats for terrestrial communication." Journal of Optical Communications 41, no. 4 (2020): 463-468.

[4] Malik, Suman, and Prasant Kumar Sahu. "Free space optics/millimeter-wave based vertical and horizontal terrestrial backhaul network for 5G." Optics Communications 459 (2020): 125010.

[5] Trinh, Phuc V., Thanh V. Pham, Ngoc T. Dang, Hung Viet Nguyen, Soon Xin Ng, and Anh T. Pham. "Design and security analysis of quantum key distribution protocol over

free-space optics using dual-threshold direct-detection receiver." IEEE Access 6 (2018): 4159-4175.

[6] Korai, Umair Ahmed, Lorenzo Luini, and Roberto Nebuloni. "Model for the prediction of rain attenuation affecting free space optical links." Electronics 7, no. 12 (2018): 407.

[7] Garlinska, Magdalena, Agnieszka Pregowska, Karol Masztalerz, and Magdalena Osial. "From mirrors to free-space optical communication—historical aspects in data transmission." Future Internet 12, no. 11 (2020): 179.

[8] Gozzard, D. R., S. W. Schediwy, Benjamin Stone, Michael Messineo, and Michael Tobar. "Stabilized free-space optical frequency transfer." Physical Review Applied 10, no. 2 (2018): 024046.

[9] Khalid, Hira, Hector E. Nistazakis, Sajid S. Muhammad, and Allah D. Raza. "Outage Performance Estimation of a MISO FSO System with OOK Signaling and Alamouti Type Space-Time Coding." Electronics 11, no. 14 (2022): 2220.

[10] Elsayed, Ebrahim E., Dhiman Kakati, Mehtab Singh, Amit Grover, and Gagan Anand. "Design and analysis of a dense wavelength-division multiplexed integrated PON-FSO system using modified OOK/DPPM modulation schemes over atmospheric turbulences." Optical and Quantum Electronics 54, no. 11 (2022): 1-27.

[11] Eid, Mahmoud MA, Vishal Sorathiya, Sunil Lavadiya, Ismail A. Abd El-Aziz, and Ahmed Nabih Zaki Rashed. "Free space optics communication channel with amplitude/frequency shift keying modulation technique based raised cosine line coding." Journal of Optical Communications (2021).

[12] Mallick, Khaleda, Paulomi Mandal, Gour Chandra Mandal, Rahul Mukherjee, Binoy Das, and Ardhendu Sekhar Patra. "Hybrid MMW-over fiber/OFDM-FSO transmission system based on doublet lens scheme and POLMUX technique." Optical Fiber Technology 52 (2019): 101942.

[13] Singh, Mehtab, and Jyoteesh Malhotra. "Long-reach high-capacity hybrid MDM-OFDM-FSO transmission link under the effect of atmospheric turbulence." Wireless Personal Communications 107, no. 4 (2019): 1549-1571.

[14] Singya, Praveen Kumar, Nagendra Kumar, Vimal Bhatia, and Mohamed-Slim Alouini. "On the performance analysis of higher order QAM schemes over mixed RF/FSO systems." IEEE Transactions on Vehicular Technology 69, no. 7 (2020): 7366-7378.

[15] Jiao, Wan, Hongzhan Liu, Jianjun Yin, Zhongchao Wei, Aiping Luo, and Dongmei Deng. "Performance of a QAM/FSO communication system employing spatial diversity in weak and saturation turbulence channels." Journal of Modern Optics 66, no. 9 (2019): 965-975.

[16] Islam, AKM Nazrul, and S. P. Majumder. "Effect of atmospheric turbulence on the BER performance of an optical CDMA FSO link with SIK receiver." Optik 179 (2019): 867-874.

[17] Islam, AKM Nazrul, and S. P. Majumder. "Effect of pointing error on BER performance of a multi-wavelength OCDMA FSO system with SIK dual detector receiver." Journal of Optical Communications 40, no. 3 (2019): 247-253.

[18] Alshaer, Nancy, and Tawfik Ismail. "Performance Evaluation and Security Analysis of UAV-Based FSO/CV-QKD System Employing DP-QPSK/CD." IEEE Photonics Journal 14, no. 3 (2022): 1-11.

[19] Yao, Haifeng, Xiaolong Ni, Chunyi Chen, Bo Li, Xinmeng Zhang, Yi Liu, Shoufeng Tong, Zhi Liu, and Huilin Jiang. "Performance of M-PAM FSO communication systems in atmospheric turbulence based on APD detector." Optics express 26, no. 18 (2018): 23819-23830.

[20] Gripeos, P. J., H. E. Nistazakis, G. D. Roumelas, V. Christofilakis, A. D. Tsigopoulos, and G. S. Tombras. "DF Relayed OOK and PAM FSO Links with Turbulence and Time Jitter." In 2020 International Conference on Broadband Communications for Next Generation Networks and Multimedia Applications (CoBCom), pp. 1-7. IEEE, 2020.

Author's biography

S. Kavitha works as a Professor in the Department of ECE at Hindusthan Institute of Technology, Coimbatore, India. Her research are includes WSN, mobile networks, optimization techniques, automation systems, artificial intelligence, computer vision, network security and cloud computing.