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Performance Evaluation of Digital Modulation Techniques for Next Generation FSO

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***Abstract*— Free space optics (FSO) is a fascinating optical wireless technology providing a license-free alternative to microwave communications. In this work, we evaluate the performance of digital modulation techniques such amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK) to send and receive signals over a distance of 5 Kms in the presence of turbulent atmospheric conditions such as rain and fog for the Hyderabad region of Pakistan. Simulations of next generation FSO link have been performed in Optisystem tool to estimate BER under different atmospheric conditions. The results show that frequency shift keying outperforms other modulation techniques providing better performance, signal quality and lower bit error rate.**

Keywords- Free space optics; next generation netwroks; rain; fog; digital modulation techniqus.

I. INTRODUCTION

Free space optical technology becomes more and more important in different areas such as wireless communications or remote sensing [1]–[3]. In communications, free space optical links provide a solution for high capacity data transmission through free atmosphere. The advantages of the free space optics (FSO) technology with respect to radio frequency systems are well known, significantly higher transmission capacity, no need for frequency allocation and licensing, easy deployment. The proliferation of wireless communications stands out as one of the most significant phenomena in the history of technology. Wireless devices and technologies have become pervasive much more rapidly than anyone could have imagined thirty years ago and they will continue to be a key element of modern society for the foreseeable future. Today, the term "wireless" is used almost synonymously with radio-frequency (RF) technologies as a result of the wide-scale deployment and utilization of wireless RF devices and systems. The RF band of the electromagnetic spectrum is however fundamentally limited in capacity and costly since most sub-bands are exclusively licensed. With the ever-growing popularity of data heavy wireless communications, the demand for RF spectrum is outstripping supply and the time has come to seriously consider other viable options for wireless communication using the upper parts of the electromagnetic spectrum.

Free space optical communication (FSO) refers to transmission in unguided propagation media (air) through the use of optical carriers, i.e., visible, infrared (IR) and ultraviolet (UV) band. Over the decades, the interest in FSO remained mainly limited to covert military applications [4], [5] and space applications including inter-satellite and deep-space links. FSO's mass market penetration has been so far limited with the exception of IrDA which became a highly successful wireless short-range transmission solution [6]. With the growing number of companies offering terrestrial OWC links in recent years and the emergence of visible light communication (VLC) products [7]–[13], the market has begun to show future promise [14], [15]. Development of novel and efficient wireless technologies for a range of transmission links is essential for building future heterogeneous communication networks to support a wide range of service types with various traffic patterns and to meet the ever-increasing demands for higher data rates.

FSO systems are used for high rate communication between two fixed points over distances up to several kilometers. In comparison to RF counterparts, the FSO link has a very high optical bandwidth available, allowing much higher data rates. Terrestrial OWC products with transmission rates of 10 Gbps are already in the market [38] and the speeds of recent experimental OWC systems are competing with fiber optic [14]–[18]. FSO systems use very narrow laser beams. This spatial confinement provides a high reuse factor, an inherent security, and robustness to electromagnetic interference. Furthermore, the frequency in use by the FSO technology is above 300 GHz which is unlicensed worldwide. Therefore, FSO systems do not require license fees [19]. FSO systems are also easily deployable and can be reinstalled without the cost of dedicated fiber optic connections.

The paper is structured as follows: section II discusses the block diagram of the next generation FSO channel and its simulation in optisystem software, section III provides detailed results of the FSO channel under different atmospheric conditions using digital modulation techniques, and then the paper ends with conclusion and future work given in sections IV and V, respectively.

II. NEXT GENERATION FSO CHANNEL SIMULATION

The optical power launched from the transmitter is affected by various factors before arriving at the receiver. These include system loss, geometric loss, misalignment loss, atmospheric loss, atmospheric turbulence induced fading, and ambient noise. In this paper, we consider rain and fog as the atmospheric conditions that impair our channel and attenuate the transmitted signal. Optisystem software version 16 has been used to perform simulations of FSO system. Wavelength division multiplexer and de-multiplexers have been used at transmitter and receiver ends to send and receive multiple data types over the channel. The type of data include text, image, voice and video. The block diagram of the next generation FSO system is shown in Figure 1.

Figure 1. Block diagram of next generation FSO system based on WDM technology

In optisystem software the FSO sytem shown in Figure 1 was simulated and is shown in Figure 2a. An 8-channel WDM multiplexer and de-multiplexer was realized with each channel containing unique data set. The transmitter of each channel (finger) at transmission end comprises of data generator, ASK/FSK/PSK modulator, a laser diode and an external modulator. The data from each finger of 8-channnel WDM is multiplexed over a single carrier with high bandwidth and transmitted over FSO channel. Similarly, at the receiver end, the data is de-multiplexed and demodulated using a photo-detector and then the signal is passed through Low-pass filter to remove unwanted high-frequency signals. The received signal is analyzed in frequency and time domain. The bit error rate (BER) analyzer compares the received and original transmitted signal to estimate the bit error rate and visualize it in eye diagram.

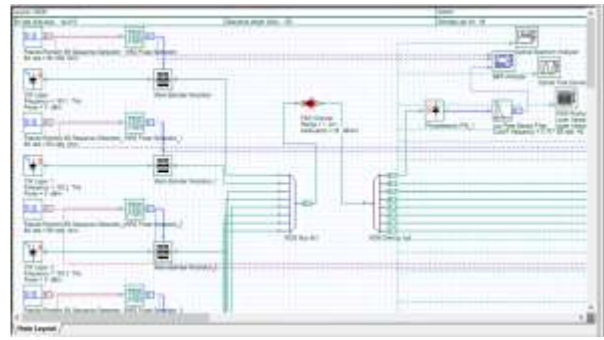

Figure 2. Next Generation FSO system model simulated in optisystem software free trial version 16.

III. RESULTS

In the work [20], authors have developed analytical model for estimation of the attenuation caused by rain on free space optics links. In the paper distance between the FSO transceivers was considered up to 5 Km and uses different drop size distribution according to Hyderabad weather conditions and measure the attenuations. It is concluded that rain rate (50 mm/h) for rain droplet shape size of 7mm can induce attenuation of 30 dB/Km at the wavelength of 1550 nm [20].

The researchers in the paper [21] discussed the impact of fog on FSO link performance. They argued that FSO links provide best alternative to RF/microwave links in clear weather. However, in the presence of fog, the performance of FSO communication deteriorates and can cause attenuation of 46 dB/Km at the operation wavelength of 1550 nm. Further they have used two techniques (charge coupled device CCD and laser diode) to experimentally measure the attenuation caused by fog [21].

In the research from authors given in [22], the multiple effects of weather on FSO link are studied with the help of Monte Carlo simulalions. The simulations have shown that the impact of fog on links is almost double than the rain, confirming the results acquired by [21].

In another paper [7], the effect of weather conditions on FSO links at different wavelengths in the near and far infrared spectral region (800 nm, 1600 nm and 10 um) was investigated. It was reported that longer wavelengths perform better during rain and dense fog conditions.

In a study [8], it is shown that FSO can be utilized for high speed, reliable and huge bandwidth Ethernet networks between the buildings within an organization.

A. *Amplitude Shift Keying*

In this section of the results, we demonstrate the use of amplitude shift keying (ASK) as digital modulation technique to modulate the digital bit stream over the optical signal emitted by CW laser diode. ASK technique modulates the amplitude of the carrier and transmits signal when bit 1 is sent and no signal when bit 0 is sent. When the attenuation of

30 dB/Km at the wavelength of 1550 nm due to rain from [20] is considered in the FSO channel of the optisystem software given in Figure 2, the BER given by ASK technique is worst as shown in the eye diagram of Figure 3.

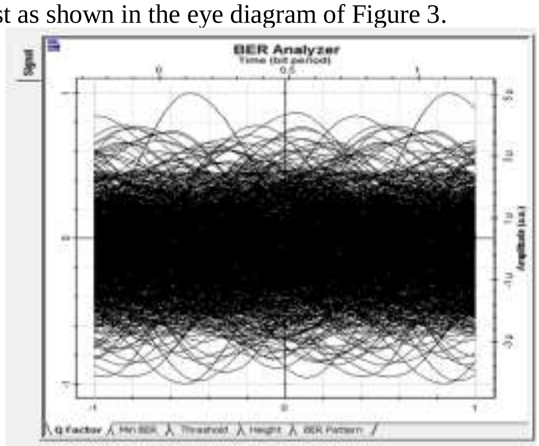

Figure 3. Performance of ASK technique in FSO link in the presence of rain.

When the attenuation of 46 dB/Km at the wavelength of 1550 nm due to fog from [21] is considered in the FSO channel of the optisystem software given in Figure 2, the BER given by ASK technique is again worst as shown in the eye diagram of Figure 4. ASK technique performed poorly in turbulent atmospheric conditions and is not considered suitable for FSO channel.

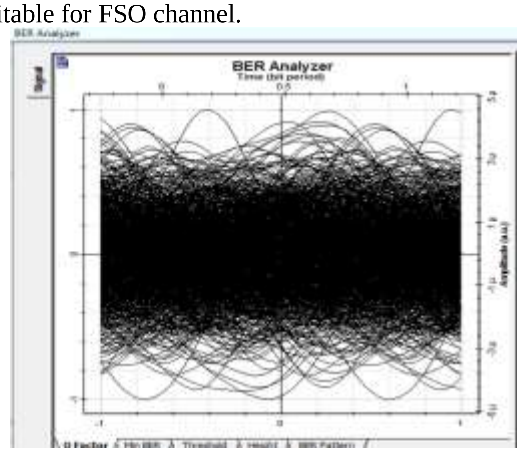

Figure 4. Performance of ASK technique in FSO link in the presence of rain.

B. *Phase Shift Keying*

In this section of the results, we demonstrate the use of phase shift keying (PSK) as a digital modulation technique to modulate the digital bit stream over the optical signal emitted by CW laser diode. PSK technique modulates the phase of the carrier by 180 degrees when a bit 1 or 0 is sent. When the attenuation of 30 dB/Km at the wavelength of 1550 nm due to rain from [20] is considered in the FSO channel of the optisystem software given in Figure 2, the BER given by PSK technique is better with a BER of 7 x 10^{-5} as shown in the eye diagram of Figure 5.

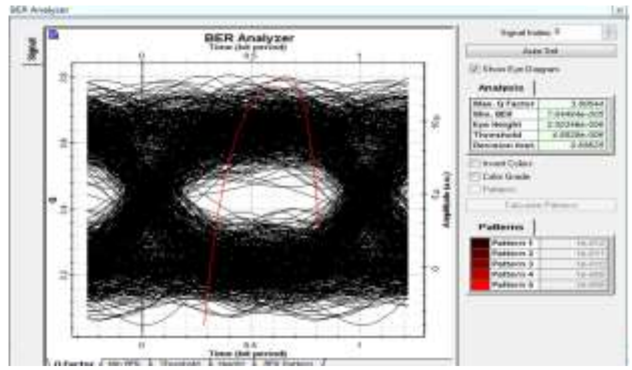

Figure 5. Performance of PSK technique in FSO link in the presence of rain.

When the attenuation of 46 dB/Km at the wavelength of 1550 nm due to fog from [21] is considered in the FSO channel of the optisystem software given in Figure 2, the BER given by PSK technique is 2.8 x 10^{-5} that is better compared to ASK results as shown in the eye diagram of Figure 6. PSK technique performed better than ASK in turbulent atmospheric conditions and is considered suitable for FSO channel.

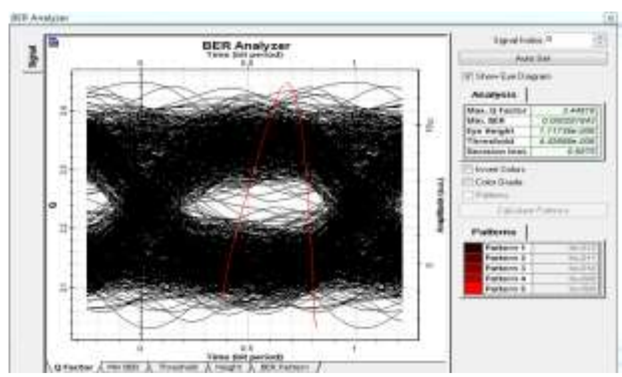

Figure 6. Performance of PSK technique in FSO link in the presence of rain.

C. *Frequency Shift Keying*

In this section of the results, we demonstrate the use of frequency shift keying (FSK) as a digital modulation technique to modulate the digital bit stream over the optical signal emitted by CW laser diode. FSK technique modulates the frequency of the carrier. It increases the frequency when a bit 1 is sent and decreases the frequency when a bit 0 is sent. When the attenuation of 30 dB/Km at the wavelength of 1550 nm due to rain from [20] is considered in the FSO channel of the optisystem software given in Figure 2, the BER given by FSK technique is best compared to ASK and PSK techniques. The obtained BER with FSK is 8 x 10^{-12} as shown in the eye diagram of Figure 7.

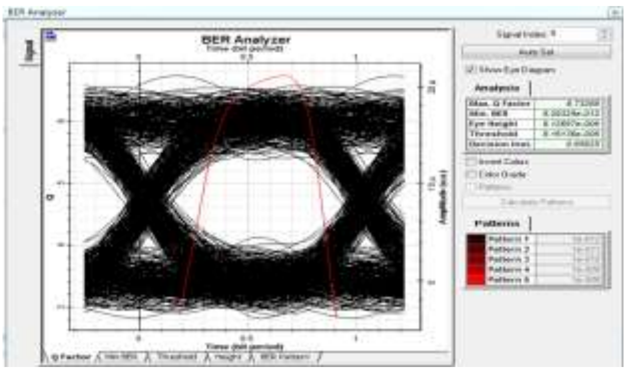

Figure 7. Performance of PSK technique in FSO link in the presence of rain.

When the attenuation of 46 dB/Km at the wavelength of 1550 nm due to fog from [21] is considered in the FSO channel of the optisystem software given in Figure 2, the BER given by FSK technique is 2 x 10^{-9} that is better compared to ASK and PSK results as shown in the eye diagram of Figure 8. PSK technique outperformed the ASK and PSK techniques in turbulent atmospheric conditions and is considered most suitable for FSO link.

IV. CONCLUSION

In this work, we have designed Next Generation FSO link for communication between two towers or buildings. The impact of atmospheric conditions such as rain and dense fog on FSO channel have been studied. The performance of digital modulation techniques including ASK, FSk and PSK have been evaluated.

The results show that frequency shift keying (FSK) performs better than ASK and PSK techniques. The better performance is attributed to the change in frequency of the carrier that is least affected by atmospheric conditions.

V. FUTURE WORK

Free space optics is likely to change the game of microwave communications as it provides the opportunity of huge bandwidth in the license free optical spectrum region. FSO is considered as the future of line-of-sight communications that will enable high-speed and high data rate communications.

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