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Performance Analysis of FSO Channels with Various Modulation Technique over Atmospheric Turbulences

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Abstract

As free space optics (FSO) is unguided transmission media which is also named as optical wireless communication (OWC) and FSO links are operating near Infrared (IR) bands. And are widely used media to transmit information or signal as it provided wide range of bandwidth with effective modulation schemes. Free space optics works on line-of-sight (LOS) which leads to some major issues for transmitting signal at long range of distance due to weather changes, atmospheric disturbances, multi-storey buildings, etc. Over long ranges, received signal quality degraded due to random fluctuation during transmission. FSO provide high speed data rate transmission between transmitter and receiver over several kilometres of distance. Along with these applications it also provides different quantum key distribution protocols to provide secure transmission over the space.

Keywords: Free-space optical communication •All-optical relaying •Bit error rate •Amplify and forward •Decode and forward •Space shift keying •Optical wireless communication.

Introduction

A Free Space Optical (FSO) Communication system is an effective fall back for so many applications because it has plenty of benefits such as robustness to electromagnetic interference, wide range of bandwidth, licensed free transmission, especially for the applications which require high date rate transmission over long distance [1, 2]. But due to atmospheric disturbances its reliability become limited, which become major issue for FSO system. And also the loss of power due to atmospheric conditions (like water droplets, fog, rain and dust particles etc.), geometric beam spread in long-haul which degrade the performance at the receivers end which causes increase in bit error rate (BER) and thus lost the link range over the space [3].

A technique name relaying assisted transmission was proposed to enhance or increase the range of link and to reduce the bit error rate of the FSO system in atmospheric conditions. The basic purpose of this technique is to first process and then forwards the optical signal at intermediate terminals between receiver and transmitter, generally called as relaying nodes. The processing of optical signal can be done by amplify and forward (AF) or decode and forward (DF) [4]. This approach utilizes the conversion of electric to optical (E/O) or optical to electric (O/E), due to which relaying nodes become complex and expensive, except that the electrical processors bandwidth limits the data rate of relaying. While in AF relaying, the optical signals still need O/E and E/O conversion, though decoding and recording processes are eliminated, which eventually minimize the demand of electro-optic devices and high speed electronic devices [5].

Literature Review

All-optical FSO system with triple-hop relay-based forward and amplify technique

In, Jan bohata had implemented the novel experiment of 10Gbps triple hop all-optical free space optical (FSO) system with relay-based technique which utilize the amplify and forward relaying method [6]. The researcher also provides the framework for signal to noise (SNR) and the bit-error rate mathematically along with the analytical results at relatively high SNR.

The analyzed performance of bit error rate (BER) with different atmospheric conditions which was modeled by Gamma-Gamma distribution shows the significant improvement in performance for weak to strong turbulences in atmosphere of relay assisted FSO system. More precise results given as, a BER of 10-5 the proposed technique offers ~5 dB and ~4 dB of SNR gains compared to the direct transmission for turbulence strengths $\boldsymbol{C_n^2}$ of $\mathbf{3.8 \times 10^{-10}}$ m-2/3 and $\mathbf{5.4 \times 10^{-12}}$ m-2/3, respectively.

Free-space optical systems using avalanche photodiode (APD) over atmospheric turbulence channels

In Basically researcher proposed amplify and forward relaying based free space optical (FSO) system using avalanche photodiode over atmospheric turbulence channels [7]. They implement both serial and parallel configuration using sub-carrier binary phase shift keying (SC-BPSK) signalling. Also provide the bit error rate of proposed system analytically at both relay node and receiver node. The proposed system uses avalanche photodiode as amplification device at relay node which makes it much simpler as compared to electrical AF relaying node as it require separate electrical amplifier at the node.

To reduce the complexity of the proposed system, author limit the case to single-relay dual-hop AF system(i.e. between source and destination only one relay node is presented) and the turbulence channel has been characterized by log-normal distribution, which is generally used to implement low to moderate turbulence conditions.

For the purpose of simplicity, the author assumes that all the nodes are same and optical power is allocating to the source can be written as,

$$P_S = \frac{Pt}{Nr} \begin{cases} \frac{P_t}{N+1} & Serial\ Configuration \\ \frac{P_t}{2N} & Parallel\ Configuration \end{cases}$$

Where Pt is the total power transmitted of the whole system and Nr is the number of relay hops, which is N+1 for serial configuration and 2N for parallel configuration.

Approximation of K distribution for strong turbulence to depict the closed BER of optical wireless communication (OWC)

In the researcher proposed the closed form of K distribution as its has advantage to examine the expression of bit error rate close form easily [9]. As random fluctuations degrade the quality of received signal severely over mile ranges, the K distribution is significant in modelling turbulence [10]. The K distribution provide excellent compliance between theoretical and experimental data which makes it more suitable for strong turbulence channel [11,12]. The confined range of normalized scintillation index (SI) is between 2 < SI< 3, or when adequate propagation ranges are encountered, K distribution will come out to be better model [13].

On the basis of differential phase shift keying (DPSK) scheme, a closed form bit error rate (BER) expression has been derived to get the accurate approximated strong turbulence models over free space [14]. To analyse the approximated proposed model BER is the most important parameter to be considered [9]. As DPSK scheme is employed in which shot noise limited heterodyne detection is considered so Bit error rate of a signal is given by,

$$P_{e\,(X)} = \frac{1}{2} e^{-SNR}(x)$$

Where SNR(x) is signal dependent SNR and is given as,

The space shift keying is a optimistic modulation scheme for FSO system

In Anshul jaiswal evaluate the performance of a recently proposed spatial modulation scheme for optical wireless communication under both indoor and outdoor atmospheric conditions. Here he took both the condition separately, for outdoor condition, it takes Nt number of transmitters and calculate the optimize bit error rate (BER) using gamma-gamma distribution [15,16]. To define the system model let Nt X 1 FSO-SSK system with Nt optical signal sources and a single Rx at receiver end as shown below Figure1.

A relaying technique with EDFA amplifier combined with optical hard limiter in FSO system

In the proposed technique is introduced to improve the bit error rate and the high speed all optical systems in which optical hard limiter has combined with EDFA (Erbium doped fiber amplifier) amplifier. This scheme is basically include with all-optical relaying with amplify and forward (AF) technique [17]. Basically, this scheme is beneficial because use of optical hard limiter allows EDFA amplifier to prevent the accumulation of amplifier noise occurred in background which significantly degrade the performance of FSO system [18,19]. The EDFA amplifier is consider for the relaying technique while ignoring the issue of gain saturation impact of the device and receiver noise effect which can affect the overall system outcome [11,12].

Realizing the efficiency of modulation technique in relay based amplify and forward FSO system

In the researcher was working on to enhance the performance of relay based amplify and forward FSO system over long-haul transmission of optical data [20,21]. As modulation techniques play significant role in transmission of data, the researchers basically compare the parameter called receiving sensitivity loss (RSL) in which they took BER as 10-7 as reference value.

At transmission end, the OOK and DPSK used laser source and Mach-zehnder modulator (MZM). The optical power loss is one the factor on which researcher has been focused and is caused by atmospheric

turbulence during transmission of data [22-26].

Detection of OOK signal with the help of Source Information Transformation

In the author proposed a system to detect OOK signal in which source information transformation technique detect signal without knowledge of instantaneous channel state information and also turbulence model probability density function (PDF) [27]. Many authors introduce pivot system just to reduce the turbulence fading and to enhance the system performance [28]. The proposed system performance is near to idealized adaptive detection system, which also reduce the complexity to implement and SNR noise performance loss of only 1.8dB at BER of 10-9.

All-optical relay based FSO system by considering all background noise and effect of degree of freedom (DoF)

The proposed system in is basically utilize the most useful technique called amplify and forward relaying technique along with considering all background noises like thermal noise and amplified emission noise (ASE) and also taken into account the effect of optical degree of freedom [29]. And derive closed form expression for some quantities like ergodic capacity, outage probability and outage capacity expression [30-32]. Here transmission of source is done by all-optical AF relay which means each stage will be taken in optical domain. And EDFA amplifier is very much efficient for long-haul FSO links to enhance system performance [33].

With Gamma-Gamma FSO channel, a hybrid QAM-MPPM technique has analyzed over various turbulence levels.

In the researcher has investigated a new hybrid QAM-MPPM technique which provides more reliable and efficient FSO channel [34]. They compared the proposed hybrid technique with traditional QAM and MPPM techniques, as these techniques are power-efficient and MPPM provide a way better bandwidth efficient system [35-37]. Further, they showed that how FSO channel is adopting the proposed hybrid scheme under various atmospheric turbulence levels. When OOK and hybrid techniques had compared, it shows that both have same error rate and BER performance but hybrid technique have some advantage over OOK technique, which made this scheme more efficient.

FSO system with information-assisted amplify and forward relaying technique under pointing error effect

In this paper, author has proposed a new AF-LOS communal protocol which has given maximum ratio combination at receiving end. Basic technique used was amplify and forward (AF) technique which has been utilized for several years and has considered by most of the authors [38-41]. The basic idea behind this proposed strategy is that, the transmitter will transmit signal to receiving end as well as to relay node. And this relay node will amplify the signal and then transmit at receiving end for combining both the signals.

Performance analysis of subcarrier intensity-modulated (SIM) amplify-and-forward (AF) relaying system over free-space optics channel

The researcher discovered a two-way relay based amplify and forward technique in which subcarrier intensity modulated is being utilized [42]. The amplify and forward relaying technique takes very less power and is less complex and also can overcome the non-line of sight environment [43-44]. Basically this technique

had utilized binary phase shift keying (BPSK) modulation which provide about 30 dB SNR in weak turbulence condition but it also shown that pointing error degrade the performance of this technique.

Conclusion

In this paper, a brief literature review has been discussed as different modulation technique used in FSO system to enhance the performance at the receiving end. From this study we conclude that there are so many parameters which we need to analyse for optical communication but bit error rate, signal to noise ratio and pointing error are some of important parameters which can degrade the system performance and required to sustain. So, we can enhance our system performance by using amplify and forward relay technique along with avalanche photodiode at receiving end and quadrature amplitude modulation (QAM) can improve channel complications.