Performance Evaluation of Free Space Optical (FSO) Communication with Direct Detection in the Presence of Optical Jammer

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Submitted by

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DECLARATION

I, Parampreet Kaur, hereby certify that the work which is being presented in this dissertation entitled **"PERFORMANCE EVALUATION OF FREE SPACE OPTICAL (FSO) COMMUNICATION WITH DIRECT DETECTION IN THE PRESENCE OF OPTICAL JAMMER"** by me in partial fulfilment of the requirements for the award of degree of Masters of Engineering in wireless communication Engineering from Thapar University (Deemed University), Patiala is an authentic record of my own work carried out under the supervision of **Dr. Amit Kumar Kohli**.

The matter presented in this dissertation has not been submitted in any other university / Institute for the award of any other degree .

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ABSTRACT

Optical jammer, it is random noise in the form of fake noise and can be used to disgrace all type of signals operators often error it for receiver or atmospheric noise and fail to take appropriate actions. Random pulse type of interference ,of changing amplitude duration and rate are generated and transmitted. They used to interrupt radar and all types of data transmission systems. Unintentional interference may be caused by other radios, some other type of electronic or electric/ electromechanical equipment or atmospheric conditions. The battleground is so crowded with radios and other electronic equipment that some accidental interference is virtually available. Also, the static electricity shaped by atmospheric conditions can negatively have an effect on radio communications. Unintentional interference usually travels only a short distances may cause obvious variations in the strength of the noisy signal. These Variations normally point to unintentional interference.

A alteration of the alamouti code originaly proposed for RF wireless applications is described that allows it to be practical in scenarios such as free- space optical communication with direct detection where unipolar modulations like on-off Keying are traditionally used to express the information. The modification of the code and associated decision metric is such as to maintain all of the pleasing properties of the original scheme.

Therefore, we have made efforts to study Free Space Optical Communications is a cost – effective and high bandwidth technique which has been receiving growing attention with recent commercialization successes. A major mistakein FSO links presentation . Therefore to get better error rate performance, spatial diversity and possible spatial correlation in log-normal channels.

Simulation results are presented to demonstarate BER performance of OSTBCs and repetition codes for BER performance of OSTBCs and repetition codes for $N = 2, 3, 4$. OOK modulation and lognormal fading channel with standard deviation of $\sigma\chi = 0.3$ are assumed. the BER performance of ostbc and repetition coding in fso IM/DD link with jamming schemes for $\sigma\chi = 0.1$. Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively.

Keywords: Optical Jammer, OSTBCs, Repetition Coding, Free Space Optical Communication.

CONTENTS

LIST OF FIGURES

LIST OF ABBREVATIONS

AESA	Active Electronically Scanned Array
ASK	Amplitude shift keying Active
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
EGC	Equal gain combining
FOV	Field of View
FSO	Free Space Optics
IR	Infrared
IrDA	Infrared Data Association
IM/DD	Intensity-modulation/Direct-Detection
LOS	Line of Sight
LPI	Low Probability of Intercept
MISO	Multiple Input Single Output
MRC	Maximal Ratio Combining
NRZ	Non-Return Zero
OOK	On-Off Keying
OSTBCs	Orthogonal Space Time Block Codes
PDF	Probabilty Density Function
QAM	Quadrature Amplitude Modulation
SNR	Signal to Noise Ratio
STBC	Space Time Block Codes
STC	Space Time Codes
SISO	Single Input Single Output
UAV	Unmanned Aerial Vehicle

CHAPTER 1

Introduction

1.1 Free Space Optical Communication

Free-space optical communication (FSO) is an optical communication technology that uses light propagating in free space to wirelessly transmit data for telecommunications . "Free space" means air, outer space, vacuum, or something similar. This contrasts with using solids such as optical fibre cable or an optical transmission line. The technology is helpful where the physical connections are unrealistic due to high costs or other considerations.

Free Space Optics (FSO) communications, also called Free Space Photonics (FSP) or Optical Wireless, refers to the transmission of modulated visible or infrared (IR) beams through the atmosphere to obtain optical communications. Like fibre, Free Space Optics (FSO) uses lasers to transmit data, but instead of enclosing the data stream in a glass fibre, it is transmitted through the air. Free Space Optics (FSO) works on the same basic principle as Infrared television remote controls, wireless keyboards.

1.1.1 History

Optical communications, in a variety of forms, have been used for thousands of years. The Greeks polished their shields to send signals for the period of battle. In the modern era, semaphores and wireless solar telegraphs called heliographs were developed, using coded signals to communicate with their recipients. In 1880 Alexander Graham Bell and his assistant Charles Sumner Tainter created the Photophone, at Bell's newly established Volta Laboratory in Washington, DC. Bell consider it his most important invention. The device allowed for the transmission of sound on a beam of light. On June 3, 1880, Bell conducted the world's first wireless telephone communication between two buildings, some 213 meters apart [1] [2].

The invention of lasers in the 1960s revolutionized free space optics. Military organizations were particularly interested and boosted their growth. However the technology lost market momentum when the installation of optical fibre networks for civilian uses was at its peak. Many easy and inexpensive customer remote controls use low-speed communication using infrared (IR) light. This is recognized as consumer IR technologies.

1.1.2 Implementation and Uses of Free Space Optical Communication

Free-space point-to-point optical links can be implemented using infrared laser light, even though low-data-rate communication over short distances is probable with the help of LED. Infrared Data Association (IrDA) technology is a very easy form of free-space optical communications. Free-space optics are moreover used for communications between spacecraft. Maximum range for terrestrial links is of the order of 2 to 3 km , [3] but the steadiness and quality of the link is highly dependent on atmospheric factors such as rain, fog, dust and heat. A mature radio operators have achieved significantly farther distances using incoherent sources of light from high-intensity LEDs. One reported 173 miles (278 km) in 2007. [4] However, physical boundaries of the equipment used limited bandwidths to about 4 kHz.

The optical carrier can be modulated in its frequency , amplitude phase ,and polarization .The most usually used schemes because of their comparatively simple implementation are amplitude modulation with direct detection and phase modulation in combination with a(self)- homodyne or heterodyne receiver.

1.1.3 Modulation Scheme for Free Space Optical Communication (FSO)

The technically simplest digital modulation scheme is amplitude shift keying (ASK).In optical systems it is referred to as on-off keying (OOK).OOK is an intensity modulation scheme where the light source . (carrier) is turned on to a transmit a logic “one” and turned off to transmit a “zero”.

Its simplest form this modulation scheme is called NRZ(non-return to zero)-OOK.Besides NRZ also other codes exist. The most common one besides NRZ is RZ coding . The advantage of RZ compared to NRZ are its higher sensitivity and the fact that the clock frequency lies within the modulation spectrum unfortunately both NRZ and RZ can lead to loss of clock synchronization if long strings of ones or zeros are transmitted .This can be avoided with other coding systems such as Manchester coding ,which is related to RZ but amounts to state changes at the start or in the middle of clock cycle-pulse position modulation .with such a alternative of RZ the clock of the digital signal can easily be recovered. These advantages come at the cost of a condition of twice the bandwidth of NRZ in order to fulfil the Nyquist –Shannon theorem.

For OOK, the precise wavelength of the carrier and its place are inappropriate for the demodulation. The receiver just directly detects the at present incoming power and compares it next to a certain level. OOK is responsive to amplitude distortion (fading) and propagation through different routes, while the second one is negligible for clear-sky conditions. Atmospheric obscuration e.g. in clouds can lead to significant attenuation of the received signal but is less important for FSO systems operating under clear –sky conditions.

1.1.4 Advantages of Free Space Optical Communication (FSO)

The advantage of FSO result from the essential characteristics of laser beam, especially from its high frequency, coherency and low divergence, which leads to well-organized delivery of power to receiver and a high information carrying capacity.

The basic characteristics of a laser beam provide the following additional advantages of FSO links:

- A narrow beam guaranties high spatial selectivity so there is no interference with other links.
- The high accessible bit rate allows them to be applied in all types of networks.
- The optical band lies exterior the area of telecommunication regulation , therefore no license is essential for operation .
- The small size and small weight of optical terminals enables links to be easily integrate into mobile systems.

  however, challenges remains. The main problems of FSO links working outdoors in the atmosphere results from attenuation and fluctuation optical signal on a receiver .To get better reliability , a number of new methods are being applied .For example, a hybrid FSO/RF system increases link accessibility by overcoming attenuation effects RF transmissions is affected more in rain and optical transmission is affected more by fog further, error protection schemes able to deal with the slow fading usual for FSO links are currently below development.

  After in view of all its advantages and disadvantages it is clear that FSO has good prospects for widespread implementation. FSO technology is set for utilization as terestrial links, mobile links as well as satellite links.

1.1.5 Free Space Optics (FSO) Technology

Lasers are one of the most significant inventions of the 20th century - they can be found in several modern products, from CD players to fibre-optic networks. The word laser is actually an acronym for Light Amplification via Stimulated Emission of Radiation. Although stimulated emission was first predicted by Albert Einstein near the foundation of the 20th century, the first working laser was not established until 1960 when Theodore Maiman did so using a ruby. Maiman's laser was predated by the maser - another acronym, this time for Microwave Amplification through Stimulated Emission of Radiation. A maser is very similar to a laser apart from the photons generated by a maser are of a longer wavelength exterior the visible and/or infrared spectrum.

A laser generates light, either visible or infrared, throughout a process recognized as stimulated emission. To understand stimulated emission, understanding two necessary concepts is necessary. The first is absorption which occurs when an atom absorbs energy or photons. The second is discharge which occurs when an atom emits photons. Emission occurs when an atom is in an excited or high energy state and returns to a stable or ground state – when this occurs as expected it is called spontaneous emission because no outside trigger is necessary Stimulated emission occurs when an previously energized atom is bombarded by yet another photon causing it to let go that photon along with the photon which earlier excited it. Photons are particles, or more appropriately quanta, of light and a light beam is made up of what can be thought of as a stream of photons.

Free-space optical (FSO) links give line-of-sight (LOS) data links by modulating the immediate intensity of a laser and allowing it to spread through the atmosphere to a receiver. Such links are comparatively inexpensive and provide high data rates free of jamming and interference.

FSO links operate at $1 - 2$ Gbps over ranges of $1 - 3$ km, however, links of up to 80 Gbps over 3.4 km have been established [5]. Although most FSO links are inactive, they have also been considered for mobile applications. Applications such as ship-to-ship [6], ground-to-air and air to- air FSO communication systems have been considered [7], [8]. FSO links satisfy the needs of long-range deep-space communications [9] and have also been considered for military wireless communications [10]. In mobile FSO channels, the transmitter must path the motion of the receiver in order to continue a LOS link. Consider the ground-to-unmanned aerial vehicle (UAV) FSO link .where the speediness of the UAV can reach several hundred meters per second [11].

Free space optics (FSO), also known as wireless optics, is a commercial and high bandwidth access technique and receives growing awareness with recent commercialization success. With the possible high data-rate capacity, low cost, suitable reconfigurability and scalability, high-security and mainly wide bandwidth on unregulated spectrum (as opposed to the limited bandwidth radio frequency (RF) complement), FSO systems have emerged as an smart means for deep-space and inter satellite communication and other applications, e.g., search and rescue operations in remote areas. This work considers outdoor long-distance FSO systems, in which optical transceivers communicate straight through air.

Along point-to-point line-of-sight (LOS) FSO links. We first talk about the channel model under weak atmospheric turbulence, and then examine the capacity of this channel. While capacity calculation is useful in providing an final limit of the system performance, it should be noted that performance assessment is application specific.. For non-real-time data services, ergodic capacity was developed, which determines the maximum attainable information rate averaged over all fading states. On the other hand, delay-limited capacity (which specifies the attainable information rate subject to a given (decoding) delay independent of the fading association status) is useful for real-time data services, and outage capacity is useful for block fading (or quasi-static fading) channels. The ergodic capacity of turbulence-induced FSO link that is characterized by log-normal fading. What makes the problem exciting is that we consider on off keying (OOK). OOK is hardly ever used in wireless RF systems, and little work has been reported in terms of capacity and coding performance. With OOK, the received signal demonstrates different statistics depending on whether “1” (On signal) or “0” (Off signal) is transmitted, which makes the channel (or the output from the channel) appear asymmetric. It is worth mentioning that intensity-modulation/direct-detection(IM/DD)with OOK is the only practical modulation/detection method that has been deployed in commercial systems. Higher order modulation with heterodyne reception, such as phase shift keying (PSK) and Quadrature Amplitude Modulation (QAM), although attainable are rarely used in preparation due to technical difficulties and high cost. Hence, we OOK forward to our result to be helpful for current and instant future systems. In actuality, the turbulence-induced fading channel has channel gains correlated in time. Here we consider the capacity averaged over all time with the assumption that ideal interleaving is performed over an substantially long sequence. Thus, the channel is simplify to a memoryless, stationary and ergodic channel with autonomous and identically distributed (i.i.d.) channel gain.

Free Space optical communication using intensity modulation and direct detection (IM/DD) can make available high-speed links for a diversity of applications and are specially exciting to solve the "last mile" problem, above all in densely populated urban areas. However, atmospheric turbulence produces fluctuations in the irradiance of the transmitted optical beam, which is known as atmospheric scintillation, severely degrading the link performance [12], [13]. Space-time block coding (STBC) can be used over free-space optical (FSO) links to lessen turbulence-induced fading. error rate performance of space-time block-coded FSO links in action over atmospheric channels is investigated, where the turbulence-induced fading is described by the negative exponential distribution. Based on the modification of the Alamouti code presented by Simon and Vilnrotter in [14] by using the complement signal, a general approach is adopted to consider space-time coded on-off keying (OOK) formats with any pulse shape and compact duty cycle, allowing the increase of the peak-to-average optical power ratio (PAOPR) and, hence, a related improvement in bit error rate (BER) performance.

Free-space optical (FSO) communication is a commercial and high bandwidth access technique which has concerned significant attention recently for a variety of applications [15-17]. A major destruction in FSO links is the atmospheric turbulence-induced fading [18], which results in rapid fluctuations at the received signal and degrades the link performance strictly. Powerful fading-mitigation techniques necessitate to be deployed for FSO links particularly with communication range of one km or longer. Error control coding in conjunction with interleaving has been planned for FSO links [19], [20]. However, optical links with their communication rates of order of gigabits exhibit high sequential correlation. For most scenarios, this requires practically infeasible large-size interleavers to attain the promised coding gains. Based on the arithmetical properties of turbulence-induced fading, maximum likelihood sequence detection (MLSD) has been planned in [21] as another solution for fading lessening. However, MLSD requires complicated multidimensional integrations and suffers from extreme computational complexity. Some sub-optimal temporal-domain fading improvement techniques are further explored in [21], [22]. Spatial diversity techniques i.e., the employment of various transmit and/or receive apertures, present an attractive another approach for fading compensation. Further justification for the employment of various transmit apertures comes from boundaries in transmit power density and likelihood of irregular blockage, e.g., birds passing through the laser path. Such motivations have initiated an attention on applying MIMO (multiple-input multiple-output) techniques [23] to the FSO links. It is well known from the vast literature on wireless RF (radio-frequency) systems that simply sending the same signal from diverse antennas (i.e., repetition coding) does not realize any transmit diversity advantage. This is also the case for FSO links with heterodyne reception and it is definitely demonstrated in [24] that conventional space-time block codes(STBCs) considered for wireless RF systems to eliminate full diversity can be employed in heterodyne FSO links with quadrature amplitude modulation (QAM) or phase shift keying (PSK). Since heterodyne FSO communication, although probable, is rarely deployed in current systems due to technical inconvenience and high cost, practical interest lies in the design of MIMO FSO links with intensity modulation and direct detection (IM/DD). MIMO schemes with repetition coding have been considered in [25-26] assuming OOK and PPM over Gaussian and Poisson channels. It has been established that repetition code is able to take out spatial diversity advantages in a FSO IM/DD link unlike wireless RF communication systems. In [27], Simon and Vilnrotter have planned a modified version of Alamouti code [28] (i.e., STBC for two transmit antennas) for FSO IM/DD links. The basic assumption in the original Alamouti code as well as other orthogonal STBCs of is that the signal polarity (phase) could be detected at the receiver. This is apparently not possible with unipolar modulations such as OOK (on-off keying) and PPM (pulse position modulation) normally used in FSO IM/DD links. Simon and Vilnrotter [29] have overcome this problem modifying Alamouti code in a clever manner to avoid the essential of transmitting the negative of a modulation signal, thus allowing the use of unipolar modulation techniques. we first enlarge the idea in [29] for any number of transmit apertures based on the orthogonal STBCs of and then calculate their error rate performance over a lognormal atmospheric turbulence channel. We additional compare their performance to a MISO (multiple-input single-output) system with repetition coding and find out that the performance of STBC FSO system is lower to its counterpart with repetition code though both are able to give full diversity. Even a more impressive observation is that the performance gap increases as the number of transmit apertures increases. Our findings clearly point out that employment of space-time coding is not necessary for a FSO IM/DD link. Because of their growing technologies and their vast applications, free-space optical (FSO) communication systems are becoming widely accessible, particularly for use in high-capacity photonic switch and short range point-to-point and point-to-multipoint wireless networks. So, certainly FSO technology will be an important building block for future all optical networks .

Potentially these systems are implemented in order to create high-performance links between nodes where there is a line-of-sight path. FSO systems, for definite applications, offer important advantages over radio frequency (RF) systems. Rapid operation and not requiring spectrum certify to operate, besides the ability to focus power in extremely narrow beams, are the most significant and desirable features of such systems. The narrow beam width brings more safety to FSO systems when compared with RF systems. The information capacity of such systems in contrast with RF systems is increased due to the higher carrier frequency in the optical domain. likewise, the bandwidth in optical systems is outsized than in RF systems.

Free–space optics (FSO) communications . In recent times, it has been shown that the effects of fading in FSO systems can be significantly reduced by deploying multiple lasers at the transmitter and multiple photodetectors at the receiver . For FSO systems with intensity modulation and direct detection (IM/DD) heuristic space–time code (STC) designs such as repetition codes (RCs) and orthogonal space–time block codes (OSTBCs) have been planned. Furthermore, the concatenation of FSO STCs with forward error correcting codes has been considered . In it was shown that, apparently surprisingly, simple RCs always outperform OSTBCs. In addition, FSO STC design was discussed . Though, unlike in the RF case , performance bounds and systematic design guiding principle for general FSO STCs are not available. In particular, from , it is not clear whether FSO STCs that outperform RCs may exist. Assuming two lasers at the transmitter and an arbitrary number of photodetectors at the receiver we derive an asymptotically tight approximation for the pairwise error probability (PEP) of general FSO STCs in spatially independent Gamma–Gamma fading. The Gamma–Gamma fading model is adopted because of its excellent fit with dimension data over a wide range of turbulence conditions (weak to strong). We note that although the effects of spatial relationship the performance of FSO systems have been considered in the literature before, e.g. , the assumption of spatial independence seems defensible. For example, recent experiments reported in showed that for a wavelength of 1550 nm and a communication distance of 1500 m photodetectors with a separation distance of only 35 mm are practically autonomous.

1.1.6 Free Space Optics (FSO) Advantages

Free space optical (FSO) systems offers a flexible networking result that delivers on the promise of broadband. Free Space Optics (FSO) provides the necessary combination of qualities requisite to bring the traffic to the optical fibre backbone – practically unlimited bandwidth, low cost, ease and velocity of deployment. Freedom from licensing and regulation translates interested in ease, speed and low cost of deployment. While Free Space Optics (FSO) optical wireless transceivers know how to transmit and receive throughout windows, it is possible to build up Free Space Optics (FSO) systems inside buildings, reducing the necessitate to compete for roof space, simplifying wiring and cabling, and permitting the tools to operate in a very favorable environment. The just essential for Free Space Optics (FSO) is line of sight linking the two ends of the link.

- Freedom since licensing and regulation leads toward ease, speed and low cost of deployment.
- Since FSO units be able to receive and transmit all the way through windows it reduces the necessitate to compete for roof space, simplifying wiring as well as cabling.
- Only requirement is the line of sight among the two ends of the link.
- Providers take benefit of the reduced risk in installing FSO tools, which can even be re-deployed.
- Zero chances of network collapse.
- Virtually limitless bandwidth.

1.1.7 Free Space Optics (FSO) Security

Security is an necessary element of data communication, irrespective of the network topology. It is mainly important for military and corporate applications. Building a network on the SONA beam™ platform is one of the finest ways to ensure that data communication between any two points is totally secure. Its focused transmission beam foils jammers and eavesdroppers and enhances security. Moreover, SONA systems can employ any signal-scrambling technology that optical fibre can use.

- The general awareness of wireless is with the aim of it offers less security than wireline connections. In fact Free Space Optics (FSO) is far more secure than RF or prior wireless-based transmission technologies for quite a few reasons:
- Free Space Optics (FSO) laser beams cannot be there detected through spectrum analyzers or RF meters.

- Free Space Optics (FSO) laser transmissions are optical and travel down a line of sight path so as to cannot be intercepted effortlessly. It requires a matching Free Space Optics (FSO) transceiver cautiously associated to complete the transmission. Interception is very hard and exceptionally unlikely .
- The laser beams generated by Free Space Optics (FSO) systems are thin and hidden, making them harder to establish and even harder to intercept and crack . Data be able to transmitted over an encrypted association addition to the degree of security available in Free Space Optics (FSO) network transmissions.

1.1.8 Applications

- Metro network extensions – FSO is used to extend accessible metropolitan area fibreings in the direction of connecting original networks as of outside.
- Last mile access – FSO can be used inside high-speed relations to connect end users through ISPs.
- Enterprise connectivity - The ease within which FSO can be installed makes them a solution meant for interconnecting LAN segments, housed inside buildings divided by public streets.
- Fibre backup - FSO may exist deployed in redundant links toward backup fibre inside place of a second fibre link.
- Backhaul – Used to carry cellular telephone traffic starting antenna towers back to facilities into the public switched telephone networks.

1.1.9 Free Space Optics (FSO) Challenges

The advantages of free space optical wireless or Free Space Optics (FSO) do not approach without some cost. When light is transmitted throughout optical fibre, transmission integrity be quite predictable – barring unforseen events for example backhoes or animal interference. When beam is transmitted through the air, since with Free Space Optics (FSO) optical wireless systems, it have to contend with a a complex and not forever quantifiable subject - the atmosphere.

1.1.10 Fog and Free Space Optics (FSO)

Fog substantially attenuates visible radiation, as well as it has a similar affect on the near-infrared wavelengths so as to employed in Free Space Optics (FSO) systems. Note that the effect of fog on Free Space Optics (FSO) optical wireless radiation is entirely similar to the attenuation – and fades – suffered by RF wireless systems because of rainfall. Similar to the case of rain attenuation by means of RF wireless, fog attenuation is not a "show-stopper" intended for Free Space Optics (FSO) optical wireless, as the optical link can be engineered such that, In favour of a large fraction of the time, an acceptable power will be received even within the presence of heavy fog. Free Space Optics (FSO) optical wireless-based communication systems be able to enhanced to yield still greater availabilities.

1.1.11 Eye Safety

Laser beams through wavelengths in the range of 400 to 1400 nm emit light to passes through the cornea and lens and is focused on a tiny spot on the retina while wavelengths above 1400 nm are immersed by the cornea and lens, and do not focus on the retina. It is possible to design eye-safe laser transmitters at equally the 800 nm and 1550 nm wavelengths but the acceptable safe laser power is about fifty times higher on 1550 nm. This factor of fifty is significant as it provides up to 17 dB additional margin, allowing the system to propagate above longer distances, throughout heavier attenuation, in addition to to support higher data rates.

1.1.12 Atmospheric Attenuation

Carrier-class Free Space Optics (FSO) systems must be deliberate to accommodate heavy atmospheric attenuation, particularly by fog. Though longer wavelengths are favored in haze and light fog, Below conditions of very low visibility this long-wavelength benefit does not apply. However, the fact with the aim of 1550 nm-based systems are authorized to transmit up to 50 times more eye-safe power will decode into superior penetration of fog or any previous atmospheric attenuator.

1.1.13 Performance-Transmit Power & Receiver Senstivity

Free Space Optics (FSO) products performance can be characterized through four main parameters (for a given data rate).

- Transmitting beamwidth
- Receiving optics collecting area
- Receiver sensitivity
- Total transmitted power

1.1.14 Atmospheric Turbulence Channel

The irradiance is subject on the way to either atmospheric turbulence conditions and pointing error effects. In this case, it is consider to be a product of two independent random variables, i.e. $I = I(a)\ I(p)$, representing $I(a)$ and $I(p)$ the attenuation because of atmospheric turbulence and the attenuation owing to geometric spread and pointing errors, respectively, among transmitter and receiver. Though the effects of turbulence and pointing are not strictly independent, for smaller jitter principles they can be approximated as independent [34].

1.1.15 Atmospheric Turbulence-Induced Fading Channel Model for Space-to-Ground Laser Communications links

The fading channel replica for generating a random time-varying signal based going on the atmospheric turbulence spectrum used for space-to-ground laser links is discussed. The temporal frequency characteristics of the downlink are in theory derived based on the von Karman spectrum. The rms wind speed based going on the Bufton wind model is used as the transverse wind velocity, which makes the simulation easy. The time-varying signal is generated as functions of the receiver opening diameter and the rms wind speed. [35] The achievable information rate among the state of the art turbo coding and intensity modulation/direct detection meant for outdoor long-distance free-space optic (FSO) communications. The channel under weak atmospheric turbulence be modeled as a log-normal intensity fading channel where on-off keying makes it OOK asymmetric. While no attempt is made to spectrally match the code towards the asymmetry of the channel, the decoding strategy is optimally in synch to match to the channel response. Additionally to fixed rate turbo coding, a family of variable rate turbo codes are constructed and discussed. Shannon capacity is also briefly visit to denote the theoretic limit. It is exposed that under low turbulence a solo long turbo code is sufficient to get inside 1 dB from the capacity, but after the turbulence gets strong.

1.2 Space Time Coding Technique

Space–time block coding is a technique used in wireless communications to transmit various copies of a data stream transversely a number of antennas and to exploit the different received versions of the data to get better the reliability of data-transfer. The fact that the transmitted signal must navigate a potentially difficult environment with scattering, reflection, refraction and so on and may then be additional contaminated by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This unemployment results in a higher chance of being capable to use one or more of the received copies to precisely decode the received signal. In fact, space–time coding combines all the copies of the received signal in an optimal way to take out as much information from each of them as possible. Most work on wireless communications had determined on having an antenna array at only one end of the wireless link — usually at the receiver. Gerard J. Foschini and Michael J. Gans [27] Foschini [28] and Emre Telatar [29] enlarged the span of wireless communication possibilities by viewing that for the highly scattering environment substantial capability gains are enabled when antenna arrays are used at both ends of a link. An alternative approach to utilizing various antennas relies on having multiple transmit antennas and only optionally various receive antennas. Proposed by Vahid Tarokh, Nambi Seshadri and Robert Calderbank, these space–time codes [30] (STCs) achieve important error rate improvements over single-antenna systems. Their original system was based on trellis codes but the simpler block codes were utilised by Siavash Alamouti, [32] and later Vahid Tarokh, Hamid Jafarkhani and Robert Calderbank [33] to expand space–time block-codes (STBCs). STC involves the transmission of multiple redundant copies of data to compensate for fading and thermal noise in the hope that some of them may appear at the receiver in a better state than others. In the case of STBC in particular, the data stream to be transmitted is encoded in blocks, which are distributed between spaced antennas and across time. While it is necessary to have various transmit antennas, it is not essential to have multiple receive antennas, although to do so improves performance. This process of acceptance diverse copies of the data is known as diversity reception and is what was largely studied until Foschini's 1998 paper.

1.2.1 Orthogonality

STBCs as initially introduced, and as usually studied, are orthogonal. This means that the STBC is considered such that the vectors representing any pair of columns taken from the coding matrix is orthogonal. The outcome of this is simple, linear, optimal decoding at the receiver. Its most serious disadvantage is that all but one of the codes that satisfy this criterion must let go some proportion of their data rate (see Alamouti's code).

Furthermore, there be present quasi-orthogonal STBCs that achieve higher data rates at the cost of inter-symbol interference (ISI). then, their error-rate performance is lower bounded with the one of orthogonal rate 1 STBCs, to provide ISI free transmissions for the reason that of orthogonality

1.3 Introduction to Optical Jammer with OSTBC and Repetition Coding

Remedial techniques reduce the efficiency of enemy efforts to jam our radio nets. They apply only to opponent jamming efforts or any unidentified or accidental interference that disrupts our ability to communicate. There are no corrective techniques that apply to other actions the enemy might use to disturb or destroy our communications. We must stop enemy jamming and interference--after the opponent has gathered information about us, we cannot get it reverse.

1.3.1 Types of Jamming Signals

Jamming is an efficient way for the enemy to disturb our command, control, and communications on the battlefield. All the enemy needs to jam us is a transmitter tuned to our frequency with sufficient power to ignore friendly signals at our receivers. Jammers operate against receivers--not transmitters. There are two modes of jamming: spot and barrage. Spot jamming is concentrated power directed toward one channel or frequency. Barrage jamming is power spread over a number of frequencies or channels at the same time. Jamming can be difficult, if not possible to detect. For this reason, we must forever be aware of the possibility of jamming and be able to distinguish it. The two types of jamming most commonly encountered are obvious and subtle jamming.

A. Obvious Jamming. This is normally very simple to spot. The more commonly used jamming signals of this type are described under Do not try to remember them; just be aware that these and others survive. When experiencing a jamming event, it is more important to recognize and defeat the incident than to identify it formally.

(1) Random noise. This is fake radio noise. It is random in amplitude and frequency. It is analogous to normal background noise and can be used to disgrace all types of signals. Operators often error it for receiver or atmospheric noise and fail to take appropriate ECCM actions.

(2) Stepped tones. These are tones transmitted in increasing and decreasing pitch. They lOOK like the sound of bagpipes. Stepped tones are usually used against single-channel AM or FM voice circuits.

(3) Spark. The spark signal is easily produced and is one of the most efficient for jamming. Bursts are of short duration and high strength. They are repeated at a fast rate. This signal is useful in disrupting all types of radio communications.

(4) Gulls. The gull signal is generated by a quick rise and slow fall of a variable radio frequency and is alike to the cry of a sea gull. It produces a nuisance effect and is very effective in opposition to voice radio communications.

(5) Random pulse. In this type of interference, pulses of changing amplitude, duration, and rate are generated and transmitted. They are used to interrupt teletypewriter, radar, and all types of data transmission systems.

(6) Wobbler. The wobbler signal is a single frequency which is modulated by a low and slowly changing tone. The result is a crying sound that causes a nuisance effect on voice radio communications.

(7) Recorded sounds. Any capable of being heard sound, especially of a changeable nature, can be used to divert radio operators and disturb communications. Music, screams, applause, whistles, machinery noise, and laughter are examples.

(8) Preamble jamming. This type of jamming occurs when a quality resembling the synchronization opening of the speech security equipment is broadcast over the effective

frequency of secure radio sets. Preamble jamming results in all radios being protected in the receive mode. It is particularly effective when employed against radio nets using speech security devices.

B. Subtle Jamming. Subtle jamming is not understandable; no sound is heard from our receivers. They cannot receive an received friendly signal, even though the whole thing appears normal to the radio operative Subtle jamming takes benefit of design features of the AN/PRC-77 and AN/VRC-12 series radios. In order to turn on the receiver of an AN/PRC-77 in the SQUELCH mode or an AN/VRC-12 series radio in the NEW SQUELCH ON mode, a 150-hertz tone must be transmitted to them along with the carrier signal. In addition to this squelch feature, the AN/PRC-77 and AN/VRC-12 series radio receivers lock onto the strongest carrier signal received and eliminate the reception of all other signals. For example, if we have an AN/PRC-77 in the SQUELCH mode and an AN/VRC-12 series radio in the NEW SQUELCH ON mode and they understand a jamming signal without the 150-hertz tone, the receivers of these radios will not be activated by any signal on condition that the jamming signal is stronger than any previous signal being received. Effectively, the threat jammers block out these radios' capability to receive a friendly transmission exclusive of the operator being aware it is happening. This is called squelch capture along with is a subtle jamming technique. The radio operator can willingly detect jamming in all other function control modes and the other modes must be checked. Often, we suppose that our radios are malfunctioning as an alternative of recognizing subtle jamming for what it is.

1.3.2 Recognizing Jamming

A. Radio operators must be capable to recognize jamming. Again, this is not forever an easy task. Threat jammers may utilize obvious or subtle jamming techniques. Also, interference may be caused by sources having nothing to do with enemy jamming. Interfering may be caused by the following:

- Unintentionally by previous radios (friendly and enemy).
- former electronic or electric/electromechanical equipment.
- Atmospheric conditions.
- Breakdown of the radio.

- A combination of whichever of the above.

(1) Internal or external interference. The two sources of interference are internal and external. If the interference or suspected jamming can be eliminated or considerably reduced by grounding the radio equipment or disconnecting the receiver antenna, the source of the trouble is most likely external to the radio. If the interference or supposed jamming remains after grounding or disconnecting the antenna, the disturbance is most probable internal and is caused by a malfunction of the radio. Preservation personnel should be contacted to repair it. External interference must be checked further for enemy jamming or accidental interference.

(2) Jamming or unintentional interference. Unintentional interference may be caused by other radios, some other type of electronic or electric/ electromechanical equipment, or atmospheric conditions. The battleground is so crowded with radios and other electronic equipment that some accidental interference is virtually unavoidable. Also, the static electricity shaped by atmospheric conditions can negatively have an effect on radio communications. Unintentional interference usually travels only a short distance, and a search of the instant area may reveal the source of this type of nosiness. Moving the receiving antenna for short distances may cause obvious variations in the strength of the nosy signal. These variations normally point to unintentional interference. Conversely, small or no variation normally indicates opponent jamming. Regardless of the source, performance must be taken to decrease the effect of interference on our communications.

b. In all cases, supposed enemy jamming and any unidentified or accidental interference that disrupts our ability to communicate must be reported. This applies even if the radio operative is able to overcome the effects of the jamming or interfering. The format for reporting this information is the MIJI report. Commands for submitting a MIJI report and are usually listed in the SOI. As it applies to remedial techniques, the information provided to higher headquarters in the MIJI report can be used to obliterate the enemy jamming efforts or take other action to our advantage.

c. The opponent can use two types of jamming signals: influential unmodulated or noise-modulated signals. Unmodulated jamming signals are considered by a lack of noise. Noise-modulated jamming signals are considered by obvious interference noises. The following procedures will help radio operators conclude whether their radios are being threatened by enemy jamming.

(1) AN/PRC-77.

(a) Turn the function manage from the SQUELCH OFF to the ON place.

(b) Lack of noise may point to that the radio is being jammed by an unmodulated jamming signal. The operative should temporarily disconnect the antenna. If normal static noise returns when the antenna is disconnected, there is a high probability that the radio is being jammed by an unmodulated signal.

(c) A better than normal level of noise or an clearly modulated signal may point to that the radio is being stuck by a noise-modulated jamming signal. The operative should temporarily cut off the antenna. If normal static noise income when the antenna is disconnected, the radio most probable is being jammed by a noise-modulated signal.

(d) If the above tests indicate there is a high likelihood the radio is being jammed, the operator should go after the local SOP to reestablish communications and start a MIJI report informing higher headquarters of the incident.

(2) AN/VRC-12 series radio.

(a) Turn the squelch manage from the NEW SQUELCH ON to the NEW SQUELCH OFF mode.

(b) Lack of noise and an unlighted call light may indicate that the radio is being jammed by an unmodulated jamming signal. The operator should temporarily disconnect the antenna. If normal static noise returns and the call light goes off when the antenna is disconnected, the radio is most likely being jammed by an unmodulated signal.

(c) A greater than normal level of noise or an obviously modulated signal may indicate that the radio is being jammed by a noise-modulated jamming signal. The operator should temporarily disconnect the antenna. If normal static noise returns, and the call light goes off when the antenna is disconnected, there is a high probability that the radio is being jammed by a noise-modulated signal.

(d) If the above tests indicate that there is a high probability that the radio is being jammed, the operator should follow the local SOP to reestablish communications and initiate a MIJI report informing higher headquarters of the incident.

(3) Other unique organizational radios. Signal officers should coordinate with organic military intelligence units for assistance in developing appropriate tests for special capacity radios or radios that are unique to that specific organization. Examples of these are nonstandard issue, off-the-shelf commercial, intermediate high frequency radios (IHFR), or SINCGARS radios. Signal officers should ensure that their unit radio operators are trained to use these radios.

1.3.3 Overcoming Jamming

The enemy constantly strives to perfect and use new and more confusing forms of jamming. Our radio operators must be increasingly alert to the possibility of jamming. Training and experience are the most important tools operators have to determine when a particular signal is a jamming signal. Exposure to the effects of jamming in training or actual situations is invaluable. The ability to recognize jamming is important, because jamming is a problem that requires action. Once it is determined that jamming is being used against our radios, the following actions must be taken. If any of the actions taken alleviate the jamming problem, we simply continue normal operations and make a MIJI report to higher headquarters.

A. Continue to operate. Stop for a moment and consider what the enemy is doing during his typical jamming operation. Usually, enemy jamming involves a period of jamming followed by a brief listen period. He is attempting to decide how effective his jamming has been. What we are doing during this small period of time when he is listening will tell him how effectual his jamming has been. If the operation is progressing in a normal manner, as it was before the jamming began, the enemy will assume that his jamming has not been chiefly effective. On the other hand, if he finds us eagerly discussing our problem on the air or if we have shut down our process entirely, the enemy may very well take for granted that his jamming has been effective. Because the enemy jammer is monitoring our operation like this, we have a simple yet very important rule that apply when we are experiencing jamming. if not otherwise ordered, never shut down operation or in any other way reveal to the enemy that you are being unfavourably affected. This means normal operations should carry on even when tainted by jamming.

B. Improve the signal-to-jamming ratio. The signal-to-jamming ratio is the relative strength of the desired signal to the jamming signal at the receiver. Signal refers to the signal we are annoying to receive. Jamming refers to the hostile or unidentified interference being received. It is always best to have a signal-to-jamming ratio in which the desired signal is stronger than the jamming signal. In this situation, the desired signal cannot be significantly corrupted by the jamming signal. The following will get better the signal-to-jamming ratio to our benefit.

(1) Adjust the receiver. When jamming is knowledgeable, we should always check to ensure the receiver is tuned as precisely as possible to the wanted incoming signal. A slight readjustment of the receiver may provide an better signal-to-jamming ratio. Specific methods that apply to a exacting radio set are explained in the suitable operator's manual. Depending on the radio being used, some of these methods are--

- Correct the beat frequency oscillator (BFO).
- Alter the bandwidth.
- Adjust the gain or volume control.
- Well tune the frequency.

(2) Increase the transmitter power output. The mainly obvious way to improve the signal-to-jamming ratio is to increase the power production of the transmitter emitting the desired signal. In order to increase the power production at the time of jamming, the transmitter must be set on something less than full power when overcrowding begins. We must remember that using low power as a preventative ECCM technique depends on the enemy not being able to detect our radio transmissions. Once the enemy begins jamming our radios, the threat of being detected becomes academic. We should use the reserve power on our earthly line-of-sight radios to overrule the enemy's jamming signal. Tactical satellite communications terminals will not increase their transmit power.

(3) Adjust or change the antenna. Antenna adjustments can appreciably improve the signal-to-jamming ratio. When overcrowding is experienced, the radio operator should ensure the antenna is optimally adjusted to receive the desired incoming signal. Specific methods that apply to a particular radio set are in the appropriate operator's guide. Depending on the antenna being used, some of these methods are--

- Reorient the antenna.
- Alter the antenna polarization. (Must be done by all stations.)
- Set up an antenna with a longer range.

(4) Set up a retransmission station. A retransmission station can amplify the range and power of a signal between two or additional radio stations. Depending on the available resources and the situation, this may be a viable means to recover the signal-to-jamming ratio.

(5) Relocate the antenna. Frequently, the signal-to-jamming ratio may be enhanced by relocating the antenna and associated radio set affected by the jamming or nameless interference. This may mean moving a few meters or several hundred meters. It is best to relocate the antenna and related radio set so that there is a terrain feature between them and any supposed enemy jamming location.

c. Use an swap route for communications. In some instances, enemy jamming will stop us from communicating with a radio station with which we must communicate. If radio communications have been tainted between two radio stations that must communicate, there may be one more radio station or route of communications that can communicate with both of the radio stations. That radio station or route should be second-hand as a communicate between the two other radio stations.

d. Change frequencies. If a communications net cannot conquer enemy jamming using the above measures, the commander (or chosen representative) may direct the net to be switched to an swap or spare frequency. If practical, dummy stations can continue to operate on the frequency being stuck to mask the change to an alternate frequency. This action must be preplanted and well coordinated. During enemy jamming, it is very difficult to coordinate a change of frequency. All radio operators should know when and under what situations they are to switch to an swap or spare frequency. If this is not done smoothly, the enemy may find out what is happening and try to humiliate our communications on the new frequency.

e. Acquire another satellite. In many cases, a satellite communications terminal can see more than one satellite in a given theater. If one satellite is being stuck, then the operator should request authorization to contact another satellite until the jamming ceases or until the enemy jammer is neutralized.

Along with the wide increase of various wireless devices, especially with the arrival of user configurable intelligent devices, such as radios, the security threats of malicious jamming, detection, and interception is no longer limited to military communications. With the majority of today's transactions and communications relying heavily on wireless networks, security has turn into the key enabler for present and future high speed wireless networks. Patching or add-on security maybe effective in short term, but is far from adequate for addressing the requirements on wireless security and can deeply complicate the communication systems. In this dissertation, we focus on the free space optical communication for OSTBC and Repetition coding without optical jammer. optical jammer which will work as a noise (interference) ,we have used two techniques and has shown that the performance of repetition coding degrades on adding optical jammer. Presentation of free space optical communication for the above said two techniques has been discussed in this Thesis work. Probabilities of error are used to get the simulation results. Probability of error for OSTBC and possibility of error for repetition coding are used to get the results.

1.4 Problem Statement

This thesis report presents the following word

1. First, the OSTBC and Repetition coding techniques are investigated foe free space optical communication.
2. Next, the presentation of OSTBC is compared with repetition coding .
3. Subsequently, we have added optical jammer in the received signal to observe the performance .
4. further,the performance of OSTBC is compared with replication coding under similar conditions.

1.5 Organization of Report

This report is organized in six chapters.

- Chapter I summarize the basic problem statement of the research work and give the impression of FSO.
- In Chapter II, we review related work done in the area of free space optical communication by different techniques.
- Chapter III introduces two techniques OSTBC and Repetition coding with description of optical jammer.

- Chapter IV briefly discuss how OSTBC and repetition coding is implemented with optical jammer and bottomless mathematical description of OSTBC and repetition coding in FSO
- In Chapter V we showed simulation results of OSTBC and Repetition coding with optical jammer
- At last in Chapter VI we gave concluding remarks and future scope.

CHAPTER 2

Literature Survey

Garfield *et al.***,**describes in this paper A multiple input, multiple output (MIMO) diffuse optical communications connection is implemented and evaluated using a 2*2 Alamouti type space-time coding scheme to boost link performance beyond that of single input, single output (SISO) and multiple input, single output(MISO) systems. We present a delegate profile of received power versus distance, and comparative bit-error probability presentation

[36].

Jayassi Akella *et al.,*describes in this paper multi-channel systems for free-space optical (FSO) communications give outstanding bandwidth performance providing over a few 100 Gbps. In this paper, we considered two designs for the 2-dimensional arrays for analysis. An interesting future problem is to find an optimal design for the array that achieves highest ability for a given range, transmitter divergence, and the number of transmitters.126 Multiple hops using easily implemented in a LAN environment. For example, in an indoor access system or a campus-wide LAN scenario or in a mesh network, we can very increase the bandwidth by using 2-dimensional array. To use these arrays over very long distances outdoors, we would need very thin beams joined with auto-aligning mechanisms[37].

Majid Safari *et al.,*In this paper, has investigated spatial diversity techniques for free-space optical (FSO) associates with strength modulation and direct detection (IM/DD) in excess of log-normal atmospheric turbulence-induced fading channels. We restrict our become aware of to the use of orthogonal space-time block codes (OSTBCs) and repetition codes both of which have been just proposed for FSO links. Our presentation analysis demonstrates that, though both schemes are able to take out full diversity, repetition codes break OSTBCs. The performance gap increases with the increasing number of transmit apertures. Our findings clearly point out that use of OSTBCs is not necessary for a FSOIM/DD link.[38]

S.Mohammad Navidpour *et al.,*presented Free space optical (FSO) communications is a commercial and high bandwidth access technique, which has been receiving rising attention with recent commercialization successes. A major injury in FSO links is the turbulence induced fading which harshly degrades the link performance. To alleviate turbulence-induced fading and, therefore, to get better the error rate performance, spatial diversity can be second-hand over FSO links which involves the use of multiple laser transmitters/receivers. In this paper, we examine the bit error rate (BER) performance of FSO associates with spatial diversity over lognormal atmospheric turbulence fading channels, assume both independent and correlated channels in the middle of transmitter/receiver apertures. Our analytical derivations build upon an estimate to the sum of correlated log-normal random variables. The derived BER expressions quantify the result of spatial diversity and likely spatial correlations in a log-normal channel.[39]

Stephen G. *et al.,*has described in this paper about the use of numerous laser transmitters combined with multiple photodetectors (PDs) is studied for terrestrial, line-of-sight optical communication. The resultant multiple-input/multiple-output channel has the possible for combating fading belongings on turbulent optical channels. In this paper, the modulation format is repetition M-ary PPM across lasers, with strength modulation. Ideal PDs are assumed, with and without background emission. Both Rayleigh and log-normal fading models are treated. The focus is upon both symbol-/bit-error likelihood for uncoded transmission, and on forced channel capacity.[40]

Ehsan Bayaki *et al.,*has investigate about Atmospheric turbulence–induced fading is one of the main impairments moving free–space optics (FSO) communications. In this paper, we consider FSO systems with intensity modulation and direct detection (IM/DD) and derive a closed–form expression for the asymptotic pairwise error probability of common FSO space–time codes (STCs) for two lasers and an random number of photodetectors for channels suffering from Gamma–Gamma fading. Furthermore, we give a simple design criterion for FSO STCs which is used to set up the quasi–optimality of before proposed FSO repetition codes.We also show that STCs optimized for RF systems attain full diversity in FSO systems but are suboptimal as far as the coding gain is worried. Simulation results verify the analytical findings of this paper.[41]

Majid Safari *et al.,*In this paper, we inspect spatial diversity techniques for free-space optical (FSO) links with intensity modulation and direct detection (IM/DD) over log-normal atmospheric turbulence-induced fading channels. We consider the deployment of space-time block codes and repetition codes. Our performance analysis demonstrate that though both schemes are able to take out full diversity, repetition codes outperform their counterparts.The performance gap increases as the number of broadcast apertures increases. Our conclusion clearly point out that deployment of space-time coding is not essential for a FSO IM/DD link.[42]

Ratna Kalos Zakiah Sahbudin *et al.,* In this paper, the performance of free space optical (FSO) communication system employ the spectral amplitude coding optical code division multiple access (SAC OCDMA) method is presented. SAC OCDMA is one of the multiplexing schemes that have become a investigate area of interest in optical communication because of its elasticity in allocating channels, capability to operate asynchronously, improved privacy and increased network ability. It utilizes Khazani–Syed (KS) code with spectral direct decoding (SDD) technique. The SAC OCDMA-FSO communication system was compare with the FSO system employing intensity modulation/direct detection (IM/DD) technique. The marks of this study show that the performance of the future system is better than the system employing the IM/DD technique.[43]

Nazmus Saquib *et al.,* Bangladesh has just connected the SEA-ME-WE-4 submarine cable network consortium. The 10 Gbs bandwidth of this network is usual to serve Bangladesh's needs. Bangladesh having a submarine connectivity globally will open a new era of communications. Telecommunications communications requires both backbone network and the last-mile access for enabling a country to have well-organized telecom and Internet connectivity. There is a connectivity gap exists between the spine network and the last-mile access network. To bring the high-speed, last mile connectivity, we have future Free Space Optics (FSO) . Free Space Optics (FSO) is one of the most hopeful new access technologies where optical transceivers transmit laser beams in a straight line through the atmosphere to form point-to-point high-speed communications links. We have discuss and analyzed the details technical issues connected to FSO deployment in context of Bangladesh. [44]

Kenneth R. Baker *et al.,*We report on the presentation of a 1.047 wm wavelength semiconductor laser diode in a 50 Mbps free-space communications experimentation. This laser diode at 1.047 pm makes it likely to construct high-power master oscillator power amplifier (MOPA) transmitters for space communications. The MOPA system would consist of the diode and a Nd-doped crystal amplifier. We have established a 200 photons / bit sensitivity at a bit error rate of $10^{-6}$and have characterized the presentation parameters pertinent to the construction of a MOPA laser. To our knowledge, this is the maximum direct detection sensitivity at this wavelength report to date.[45]

Ha Duyen Trung *et al.,*In this paper, we in theory analyze pointing error effects on presentation of free-space optical (FSO)communication systems using subcarrier intensity quadrature amplitude modulation (SC-QAM) signals in excess of atmospheric turbulence channels. Unlike previous studies, we get into account both atmospheric turbulence channels and the pointing mistake effect. In order to replica atmospheric turbulence channels,we employ a log-normal division for weak-to-moderate turbulent condition and a gamma–gamma distribution for strong turbulent condition. Moreover, we study the pointing error effect by captivating into account the pressure of beamwidth, aperture size and jitter discrepancy. In addition, we use a mixture of these models to analyze the joint effect of atmospheric commotion and pointing error to FSO/SC-QAM systems. At last we derive analytical expressions to assess the average symbol error rate (ASER) performance of such systems. Numerical results present the impact of pointing error on the performance of FSO/SC-QAM systems and how we use correct values of aperture size and beamwidth to improve the presentation of such systems. In addition, simulation results of FSO/SC-QAM performance over well-built atmospheric turbulence and pointing errors demonstrate that the closed-form expression can provide a accuracy for evaluating ASER of such systems.[46]

Benshuang Yu *et al.,*Circular polarization shift keying (CPolSK) modulation method has many advantages such as excellent BER performance and freedom from the position of polarization coordinates of the transmitter and the receiver, etc., and it turns out to be a good choice to FSO system. In this paper, a FSO system using CPolSK modulation is studied by simulation; it is establish that the communication performance of the system is excellent in most weather condition. Additionally, three ways of optical signal strengthening are proposed,and contrastive examination on performance of corresponding optical magnification systems is carried out by investigative SNR BER and transmission distance with different specific reduction. The results show that the system by means of optical amplifier at the transmitter have the optimum presentation, and then the system with optical amplifier at the equally ends with the same total gain, it is most awful for the system with optical amplifier at the receiver. As well, the safety factor for high emission power induced by optical amplification is also considered in this paper for sensible application. The study above may be utilized in the system design for attractive performance.[47]

Lingyu Wan *et al.,* A process of on-ground simulation of optical links for free-space communications by Fourier-transform, image magnification and wavefront sampling with limited apertures was planned. An optical simulator for free-space laser links was planned, which has the range of alike links distances from 160,000km to 25 km. It can be used for the assessment of communication performances of optical links in space, mainly for measuring the bit error rate under a steady transmission distance or for testing the corresponding transmission distance under a steady bit error rate. System analysis indicate that the wavefront aberrations of Fourier-transform lens have the main influence on the dimension results. But these belongings can be corrected only if the RMS value of wavefront aberrations of Fourier- transform lens on the work opening is known. Simulation experiment additional shows that this method will be possible by providing excellent optical devices and fine calibration correctness and by overcoming the environmental disturbances.[48]

Hanling Wu *et al.,*High-speed free-space optical communication systems have just used fibre-optical components. The coupling effectiveness with which the received laser beam can be attached into a single-mode fibre is obviously limited by atmospheric turbulence because of the degradation of its spatial consistency. Fortunately, adaptive optics (AO) can ease this limitation by partially correcting the turbulence- distorted wavefront. The coupling efficiency development provided by Zernike modal AO alteration is numerically evaluated. It is establish that the first 3–20 corrected polynomials can significantly improve the fibre-coupling efficiency. The upgrading brought by AO is compared with that bring by a coherent fibre array. Finally, a mixture technique that integrates AO and a coherent fibre array is future. Results show that the hybrid technique outperforms each of the two above-mentioned techniques.[49]

Tao Shang *et al.,*Due to the noteworthy influence of atmospheric effects and the substance relative motion, attainment, pointing and tracking (APT) are the key technologies to set up the communication link in free space optical communication (FSO). In this paper, an all-way, cylinder-shaped optical antenna is proposed, and the theory and method of beam control are mainly studied. On situation that the communication terminals move arbitrarily and the antenna self-rotates in constant or changeable velocity, numerical simulations are carried out. In detail, some important parameters in practice are analyzed, like the communication time, actual bandwidth and broken up time, and compared with theoretical results. The consequence shows that the beam organize method is feasible, and this optical antenna can meet the demands of fast mobile FSO in a definite range of height.[50]

Jitender Singh *et al,.*In this article, dissimilar modulation format RZ, CRZ, CSRZ and NRZ on free space optical communication system has been investigated. It has been observed that external modulation gave us better performance in judgment to direct modulation because direct NRZ spectrum has a strong component compared to external modulated NRZ. Simulation marks show that RZ modulation format is best for long distance. Where NRZ is used for short distance and it is less complex, cheaper in contrast to RZ.[51]

Wei Liu *et al.,*Pointing errors caused by the atmospheric turbulence will disgrace the performance of free space optical (FSO) communication systems, particularly the bit error rate (BER). In this paper, we imaginatively analyze the relationship between BER and pointing errors by the probability density functions (PDFs) and strength displacement in focal plane under the On-Off Keying (OOK) modulation circumstances. The closed-loop experimental system is set up in laboratory, where the fast steering mirror (FSM) is real-time controlled by embedded manager with the parallel processing technology and the atmospheric turbulence is fake by a turbulence simulation box. The results of frequent experiments show that the means of pointing errors correction we proposed is efficient under the circumstances of atmospheric turbulence. By utilizing our method, the BER can decrease from nearly 10^{-3} to 10^{-9} nearly or even below , thus getting better the performance of FSO communication systems considerably.[52]

Mehmet Bilgi *et al.,*Wireless networking has predictably been realized via radio-frequency-based communication technologies. Free-space-optical (FSO) communication with an original multi-element node design leverages spatially-diverse optical wireless links; making it aviable solution to the well-known failing per-node throughput problem in large-scale RF networks. Though it has the advantage of high-speed modulation, preservation of line-of-sight between two FSO transceivers during a transmission is a confront since FSO transmitters are highly directional. In this paper, we present our simulation efforts to make high-level assessments on throughput characteristics of FSO-MANETs even as considering properties of FSO propagation and existence of numerous directional transceivers. We identify the irregular connectivity problem that is caused by the relation mobility of nodes with multiple directional transceivers. We suggest two cross-layer buffering schemes to remedy this problem and present their performance results. We conclude that sophisticated buffering mechanisms are necessary to properly buffer a packet during the misalignment period of two communicating nodes to keep away from negative effects of this intermittency on the transport layer.[53]

Linzi Zuo *et al.,*The bit-error-rate (BER) performance of rational free-space optical (FSO) links employing phase compensation techniques is investigated in weak non-Kolmogorov turbulence. Assuming that the amplitude fading and phase fluctuation follow lognormal model and Gaussian sharing respectively and using the expression of non-Kolmogorov turbulence in conditions of Zernike polynomials, the signal-to-noise ratio (SNR) at the coherent receiver is analyzed and as a special case, a new closed-form expression by chi-square distribution is obtained. Thus, the pressure of different compensation modes and normalized receiver diameter on BER performance is evaluate and an optimum normalized receiver diameter is optional to achieve the minimum BER. Moreover, the impact of outer scale and the supporter value α in non- Kolmogorov spectrum is deliberate with the optimum diameter, which reveals that the BER has an obvious reduce with larger values of α.[54]

Pierpaolo Boffi *et al.,*All-optical free-space architecture can find a lot of interesting applications in optical communications in case of packet-oriented data processing. An example of an all-optical system capable to perform data processing operations is described and experimented. Logic schemes characterized by high modularity and elasticity are reported. An optical implementation is planned by using an elementary switching unit realized with CdTe: In crystal. The unit is optically controlled and operates with beams at typical communication wavelengths. Initial experimentation in ns regime at 1550 nm is shown. q2000 Published by Elsevier Science B.V.[55]

Morio Toyoshima *et al.,*Bi-directional ground-to-satellite laser communication experiments were effectively performed between the optical ground station developed by the National Institute of Information and Communications Technology (NICT), located in Koganei City in suburban Tokyo, and a low down earth orbit (LEO) satellite, the ‘‘Kirari’’ Optical Inter-orbit Communications Engineering Test Satellite (OICETS). The experiments were conducted in support with the Japan Aerospace Exploration Agency (JAXA), and called the Kirari Optical communication Demonstration Experiments by means of the NICT optical ground station (or KODEN). The ground-to-OICETS laser communication experiment was the first in-orbit demonstration relating the LEO satellite. The laser communication experiment was conducted since March 2006. The polarization characteristics of an fake laser source in space, such as Stokes parameters, and the degree of polarization were calculated through space-to-ground atmospheric transmission paths, which results contribute to the link estimation for quantum key division via space and provide the potential for enhancements in quantum cryptography on a global scale in the future. The Phase-5 experiment, international laser communications experiments were also effectively conducted with four optical ground stations situated in the United States, Spain, Germany, and Japan from April 2009 to September 2009. The reason of the Phase-5 experiment was to establish OICETS-to-ground laser communication links from the different optical ground stations and the statistical analyses such as the normalized power, scintillation index, probability density function, auto-covariance function, and power spectral density were performed. Thus the applicability of the satellite laser communications was established aiming not only for geostationary earth orbit-LEO links but also for ground-to-LEO optical links. This paper presents the results of the KODEN experiments and mainly introduces the common analysis among the dissimilar optical ground stations.[56]

Abdullah Sevincer *et al.,*Free-Space-Optical (FSO) communication has the possible to achieve very high wireless communication rates at tens of GHz. Though it has the advantage of high-speed optical modulation, FSO communication is prone to mobility and it requires establishment and maintenance of line-of-sight (LOS) between FSO transceivers since FSO transceivers are highly directional. We consider FSO structures with multiple transceivers placed on a spherical form with angular diversity and tackle the difficulty of automatically detecting and maintaining LOS position among neighbour multi-transceiver FSO structures. We present a prototype functioning of such multi-transceiver electronically-steered communication structures. Our model uses a simple LOS detection and establishment protocol and assigns logical data streams to suitable physical links. We show that by using multiple directional transceivers and an auto-alignment mechanism, it is likely to maintain optical wireless links in a mobile setting by means of minimal disruptions and overhead.[57]

Dagang Jiang *et al.,*The LEO-Ground FSO link is a single link in the space-based satellite optical network, in which the capabilities are influenced by the various kinds of atmospheric effects. The atmospheric refraction and beam wander influence on the gaining are addressed in this research, especially under the scene of great zenith angle in the LEO-Ground link. The model is recognized and the numerical simulation is approved out in a cut down LEO-Ground link scenario basing on the profile model of force and temperature.The result shows that the atmospheric refraction and beam wander at large zenith angle will substantial increase required ambiguity cone and total scan time. In addition, the optimal acquisition opening zenith angle for the most data transmitting time is also approximate This research provides an uncertainty cone design method at large zenith angle and presents a suggestion for getting better transmitting time.[58]

Hector E. Nistazakis *et al.,*Optical wireless communication or free space optical systems have gained significant research and for profit attention in recent years due to their cost-effective and license-free high bandwidth admittance characteristics. However, by using the atmosphere as transmission media, the presentation of such a system depends on the atmospheric circumstances that exist between transmitter and receiver. Certainly, for an outdoor optical channel link, the survival of atmospheric turbulence may significantly degrade the performance of the linked communication system over distances longer than 1 or even 0.5 km. In order to expect this, particular attention has been given to diversity methods. In this work, we consider the use of wavelength and time diversity in wireless optical communication systems that function under weak to strong atmospheric turbulence conditions modeled by the gamma–gamma distribution, and we obtain closed form mathematical expressions for estimating the system's attainable outage probability and average bit error rate. Finally, numerical results referred to ordinary practical cases are also obtained in order to establish that wavelength and time diversity schemes enhances significantly these systems' availability and performance. [59]

Anshul Vats *et al.,* Free space optical (FSO) communication is an upgraded complement to the existing wireless technologies.FSO technology provides vast modulation bandwidth, unlicensed spectrum, cost effective consumption, low power consumption and less mass requirement. Today, researchers are preliminary determined to use the free space communication systems for inter satellites links. In this paper, the presentation analysis of FSO communication link in weak atmospheric commotion has been analyzed for different atmospheric transmission windows using OOK modulation. The study has been done using bit error rate as the performance metric. The outcome of attenuation on the link performance has been investigated by changing distance between transmitter and receiver for a given power and data rate. Further, BER performance analysis has been carried out for varying data rate and transmitted power. Also, the outcome of attenuation on received optical power has been studied. The work has been performed in Opt Sim environment.[60]

Taha Landolsi *et al.,* In this paper, we present an analytical study of the error presentation in optically preamplified, M-ary pulse position intonation, in free-space optical communication systems with finite extinction ratios. We obtain a theoretical expression for the probability of bit error and compute it numerically for diverse symbol sizes and extinction ratios. We also provide the power penalty due to a limited extinction ratio for both coded and uncoded systems. The study shows that, in certain cases and for a given extinction ratio, lower symbol sizes may yield an error presentation similar to that achieved by higher symbol sizes.[61]

Media Lario S.r.l. *et al.,*A simplified analytical model for the study of the performances of an adaptive optics system is described for application to direct discovery free-space optical communication in the atmosphere. The transfer function of the adaptive optics control loop is intended in the Zernike and Fourier domains for temporal and spatial dependence, respectively, and is used to decide the power spectrum of the corrected wavefront. To demonstrate the model, an adaptive optics system is calculated for the downlink channel of the free-space optical link operated by the European Space Agency between the ARTEMIS satellite and the Optical Ground Station in Tenerife Island, Spain.[62]

CHAPTER 3

Introduction of Two Techniques OSTBC and Repetition Coding with Description of Optical Jammer

3.1 Free Space Optical Communication with OSTBC and Repetition Coding

3.1.1 Alamouti-Type Space–Time Coding for Free-Space Optical Communication

Free Space Optical (FSO) communication is a communication pattern in which laser is used as the information carrier in atmosphere environment. FSO system has been widely practical in the fields of satellite communication and ground sight distance communication, with a promising application view and tremendous market potential. And space-time processing (using multiple antennas) is now documented as a key to achieving reliable high data rate wireless communications and is being included into the physical layer of many wireless standards. In this letter, error rate presentation for space-time block coding (STBC) in FSO communication systems with straight detection operating over strong atmospheric turbulence channels is analyzed.

Alteration of the Alamouti code originally proposed for RF wireless applications is described that allows it to be practical in scenarios such as free-space optical communication with direct finding where unipolar modulations like pulse-position modulation and on–off keying are traditionally used to express the information. The modification of the code and associated decision metric is such as to maintain all of the pleasing properties of the original scheme.

optical communication systems employing straight detection at the receiver, intensity modulations such as on–off keying (OOK) or pulse-position modulation (PPM) are commonly used to express the information. Consider the possibility of applying space–time coding in such a scenario by, for example, an Alamouti-type coding scheme [63]. Implicit in the Alamouti code is the fact that the intonation that defines the signal set is such that it is meaningful to transmit and detect both the signal and its negative. While modulations such as phase-shift keying (PSK) and quadrature amplitude modulation (QAM) obviously fall into this class, OOK and PPM do not since the signal polarity (phase) would not be detected at the receiver. a alteration of the Alamouti code to be used with such modulations that has the same desirable properties as the conservative Alamouti code but does not rely on the necessity of transmitting the negative of a signal.

Consider an optical communication system with two transmit antennas and one recieve antenna . This model inherently assumes that both transmitters are concurrently observed by the receiver, thus implying a large receiver field of view (FOV). This, in turn, implies a larger composed background radiation that could seriously disgrace system performance. Therefore, care must be exercised to limit background through the use of appropriate spatial filtering prior to detection. For example, if the link distance is R m, and the receiver FOV is rad, then the parting of the two transmitters cannot exceed approximately θRm (assuming small). Thus, if R=1 KM and $\theta = 10$ mrad, transmitters would have to be fewer than 10 m apart for the scheme to work. This model is applicable to urban "last-mile" links where multiple transmitters and receivers can be envisioned to alleviate link outage due to turbulence, scattering, and occasional blockage.

3.1.2 Modified Alamouti Code

The channel gain from antenna to the single receive antenna is denoted by $h_{ij\,,}$ 1, 2, and is supposed to be constant over a two-symbol duration. In the conventional Alamouti code, in the first bit gap, antenna 1 transmitsx_1 signal and antenna 2 transmitsx_2 where x_1 and x_2 each range over the signal set $\{s_{1\,,}s_2\}$. In the second bit interval, antenna 1 transmits $-x_2$whereas antenna 2 transmitsx_1. Note that here we are trading with real signals, and thus the complex conjugate notation that normally appears on transmitted in the second symbol interval is absent. A similar statement applies to the channel gains which, in the application under consideration, represent the alteration of the amplitude of the path from the optical source, e.g., a laser, to the photodetector—the phase lilt associated with the fading process disappears as a effect of the direct detection. Furthermore, the channel gains, which here stand for fading intensity, have statistical models equivalent tothe magnitude squared of the channel gains in the RF problem. We consider the channel model commonly working in ground-based free-space optical links where high signal energies allow the approximation of the Poisson photon as well as detection model by a much simpler continuous Gaussian limiting form. More specifically, we consider the case of binary communication in an additive white Gaussian noise (AWGN) background which occurs, for example, in a laser communication scenario

where the signal energy is so huge that the receiver signal-to-noise ratio (SNR) is limited by blast noise inherent to the photodetection process itself. System behaviour in such a scenario is referred to as photon-limited or shot-noise.
In the case of OOK, the signals are described by the waveforms

$$s_1 = 0 \text{ , } 0<t<T$$
$$s_2 = A \text{ , } 0<t<T \tag{3.1}$$

Where A is a positive constant linked to the intensity of the light source and T is the signal duration. In the case of binary PPM, the signals are described by the waveforms.

$$s_1 = \begin{cases} 0, & 0 < t < \frac{T}{2} \\ A, & \frac{T}{2} < t < T \end{cases}$$

$$s_2 = \begin{cases} A, & 0 < t < \frac{T}{2} \\ 0, & \frac{T}{2} < t < T \end{cases} \tag{3.2}$$

3.1.3 Free Space Optical Transmission with Spatial Diversity

Free space optical (FSO) communications is a cost-effective and high bandwidth contact technique, which has been receiving growing attention with recent commercialization successes. A major mistake in FSO links is the turbulence induced fading which severely degrades the link presentation. To alleviate turbulence-induced fading and, therefore, to get better the error rate performance, spatial diversity can be used over FSO links which involves the deployment of numerous laser transmitters/ receivers. In this paper, we investigate the bit error rate (BER) performance of FSO links with spatial variety over lognormal atmospheric turbulence fading channels, supposing both independent and correlated channels among transmitter/receiver apertures. Our analytical derivations build upon an approximation to the sum of correlated log-normal random variables. The derived BER expressions quantify the outcome of spatial diversity and possible spatial correlations in a log-normal channel.

We consider a FSO link with *M* transmit and *N* receive apertures. We assume high signal-to-noise ratio (SNR) regime where we can use Gaussian noise model [64]. supposing on-off keying (OOK), the received signal at the *n*th receive aperture is then given as

$$r_n = s_n \sum_{m=1}^{M} I_{mn} + V_n \tag{3.3}$$

where $s \in \{0, 1\}$ is the transmitted information bit, η is the optical-to-electrical conversion coefficient, and is V_n additive white Gaussian noise with zero significance and variance of $\sigma^2, v = N_0/2$. The fading channel coefficient which models n the channel from the *m*th transmit aperture to the *n*th receive aperture is specified by

$$I_{mn} = I_0 \exp(2X_{mn}) \tag{3.4}$$

where I_0 is the signal light intensity without turbulence and X_{mn} are identically (not necessarily independent) distributed normal casual variables with mean μ_x and variance σ_x^2. Therefore, I_{mn} follows a lognormal distribution

$$f(I_{mn}) = \frac{1}{2\, I_{mn}} \frac{1}{\sqrt{2\pi\sigma_x^2.}} \exp\left(\frac{-(\ln\left(\frac{I_{mn}}{I_0}\right) - 2\mu_x}{8\sigma_x^2.}\right) \tag{3.5}$$

To make sure that the fading does not attenuate or increase the average power, we normalize the fading coefficients such that $E[\frac{I_{mn}}{I_0}] = 1$.

3.2 Jamming

Radar jamming and deception is the intentional discharge of radio frequency signals to get in the way with the process of a radar by saturating its receiver with noise or false information. There are two types of radar jamming: Mechanical and Electronic jamming.

Mechanical jamming is caused by devices which reproduce or re-reflect radar energy back to the radar to produce false target returns on the operator's scope. Mechanical jamming devices include chaff, corner reflectors, and decoys.

- **Chaff** is made of different length metallic strips, which reproduce different frequencies, so as to create a large area of false returns in which a real contact would be difficult to detect. Modern chaff is usually aluminum coated glass fibres of various lengths. Their extremely small weight and small size allows them to form a dense, long lasting cloud of interference.

- **Corner reflectors** have the same effect as chaff but are physically very dissimilar. Corner reflectors are multiple-sided objects that re-radiate radar energy mostly back toward its starting place. An aircraft cannot hold as many corner reflectors as it can chaff.

- **Decoys** are flying objects that are proposed to deceive a radar operator into believing that they are really aircraft. They are especially dangerous because they can clutter up a radar with false targets creating it easier for an attacker to get within weapons range and neutralize the radar. Corner reflectors can be fixed on decoys to make them appear larger than they are, thus furthering the illusion that a decoy is a real aircraft. Some decoys have the capability to achieve electronic jamming or drop chaff. Decoys also have a deliberately sacrificial purpose i.e. defenders may fire guided missiles at the decoys, thereby depleting limited stocks of expensive weaponry which might otherwise have been used against genuine targets.

Electronic jamming is a type of Electronic warfare where jammers radiate interfering signals toward an enemy's radar, blocking the receiver with extremely concentrated energy signals. The two main technique styles are noise techniques and repeater techniques. The three types of noise jamming are spot, sweep, and barrage.

- **Spot jamming** occurs when a jammer focuses all of its power on a single frequency. While this would sternly degrade the ability to track on the jammed frequency, a frequency nimble radar would hardly be affected because the jammer can only jam one frequency. While multiple jammers could probably jam a range of frequencies, this would consume a great deal of resources to have any effect on a frequency-agile radar, and would probably still be unproductive.

- **Sweep jamming** is when a jammer's full power is shifted from one frequency to another. While this has the benefit of being able to jam multiple frequencies in quick succession, it does not affect them all at the same time, and thus limits the effectiveness of this type of jamming. Although, depending on the error examination in the device(s) this can render a wide range of devices effectively useless.

- **Barrage jamming** is the jamming of multiple frequencies at once by a single jammer. The benefit is that multiple frequencies can be jammed simultaneously; however, the jamming effect can be limited because this requires the jammer to extend its full power between these frequencies, as the number of frequencies enclosed increases the less effectively each is jammed.

- **Base jamming** is a new type of Barrage Jamming where one radar is jammed successfully at its source at all frequencies. However, all other radars continue working normally.

- **Pulse jamming** produces noise pulses with period depending on radar mast rotation speed thus creating blocked sectors from directions other than the jammer creating it harder to learn the jammer location.

- **Cover pulse jamming** creates a short noise pulse when radar signal is received thus concealing any aircraft airborne behind the EW craft with a block of noise.

- **Digital radio frequency memory , or DRFM jamming**, or **Repeater jamming** is a repeater technique that manipulates received radar energy and retransmits it to modify the return the radar sees. This technique can change the range the radar detects by changing the glitch in transmission of pulses, the velocity the radar detects by changing the doppler shift of the transmitted signal, or the angle to the plane by using AM techniques to convey into the sidelobes of the radar. Electronics, radio equipment, and antenna can cause DRFM jamming causing wrong targets, the signal must be timed after the received radar signal. By analysing received signal strength from side and backlobes and thus getting radar antennae radiation pattern false targets can be formed to directions other than one where the jammer is coming from. If each radar pulse is exclusively coded it is not possible to create targets in directions other than the direction of the jammer

- **Deceptive jamming** uses techniques like "range gate pull-off" to smash a radar lock.

In some cases, jamming of either type may be caused by friendly sources. Inadvertent mechanical jamming is quite common because it is indiscriminate and will affect any nearby radars, hostile or not. Electronic jamming can also be unintentionally caused by friendly sources, usually powerful EW platforms functioning within range of the affected radar. Unintentional electronic jamming is most easily prohibited by good planning and common sense, though sometimes it is inescapable.

- Constantly alternating the frequency that the radar operates on (frequency hopping) over a spread-spectrum will limit the efficiency of most jamming, making it easier to read through it. Modern jammers can track a expected frequency change, so the more random the frequency change, the more likely it is to counter the jammer.

- Cloaking the outgoing signal with random noise makes it more difficult for a jammer to discover the frequency that a radar is operating on.

- Limiting unsecure radio communication regarding the jamming and its effectiveness is also important. The jammer could be listening, and if they know that a optimistic technique is effective, they could direct more jamming assets to employ this method.

- The most important method to contradict radar jammers is operator training. Any system can be fooled with a jamming signal but a properly trained operator pays attention to the raw video signal and can sense abnormal patterns on the radar screen.

- The best indicator of jamming effectiveness to the jammer is countermeasures taken by the operator. The jammer does not know if their jamming is effective before operator starts changing radar transmission settings.

- Using EW countermeasures will give away radar capabilities thus on peacetime operations most military radars are used on fixed frequencies, at minimal power levels and with blocked Tx sectors toward possible listeners (country borders)

- Mobile fire control radars are usually kept passive when military operations are not ongoing to keep radar locations secret

- Active Electronically Scanned Array (AESA) radars are innately harder to jam and can operate in Low Probability of Intercept (LPI) modes to reduce the chance that the radar is detected.

  - While not usually caused by the enemy, interference can greatly impede the ability of an operator to track. Interference occurs when two radars in relatively close proximity (how close they need to be depends on the power of the radars) are operating on the same frequency. This will cause "running rabbits", a visual phenomenon that can severely clutter up a scope with useless data. Interference is not that common between ground radars, however, because they are not usually placed close enough together. It is more possible that some sort of airborne radar system is inadvertently causing the interference—particularly when two or more countries are involved.

- The interference among airborne radars referred to above can sometimes (usually) be eliminated by frequency-shifting the magnetron.
- The other interference frequently experienced is between the aircraft's possess electronic transmitters, i.e. transponders, being picked up by own radar. This interference is eliminated by suppressing the radar's reception for the period of the transponder's transmission. As an alternative of "bright-light" rabbits across the display, one would observe minuscule black dots. Because the external radar causing the transponder to respond is normally not synchronised with your own radar (i.e. different PRFs [pulse repetition frequency]), these black dots appear randomly across the display and the operator sees through and just about them. The returning image may be much larger than the "dot" or "hole", as it has become known, at any rate. Keeping the transponder's pulse widths very slender and mode of operation (single pulse rather than multi-pulse) becomes a decisive factor.
- The exterior radar could, in theory, come from an aircraft flying alongside your own, or from space. Another aspect often overlooked is to reduce the sensitivity of one's own transponder to external radars; i.e., make certain that the transponder's threshold is high. In this way it will only act in response to nearby radars—which, after all, should be friendly.
- One should also diminish the power output of the transponder in like manner.

3.3 Matrix Representation of OSTBC

We set up space–time block coding, a new paradigm for communication in excess of Rayleigh fading channels by means of multiple transmit antennas. Data is encoded using a space–time block code and the encoded data is tear into n streams which are simultaneously transmitted using n transmit antennas. The received signal at each receive antenna is a linear superposition of the n transmitted signals anxious by noise. Maximum probability decoding is achieve in a easy way through decoupling of the signals transmitted from different antennas rather than shared discovery This uses the orthogonal structure of the space–time block code and give a maximum-likelihood decoding algorithm which is based only on linear dispensation at the receiver. Space–time block codes are designed to achieve the maximum diversity command for a given number of transmit and receive antennas subject to the restriction of having a simple decoding algorithm .The traditional numerical framework of orthogonal design is applied to construct space–time block codes. It is shown that space–time block codes constructed in this way only exist for few irregular values of n. Subsequently, a simplification of orthogonal designs is shown to provide space–time block codes for both real and complex constellations for any number of transmit antennas. These codes achieve the maximum promising transmission rate for any number of transmit antennas using any random factual collection such as PAM. For an arbitrary complex constellation such as PSK and QAM, space–time block codes are designed that achieve 1=2 of the maximum possible transmission rate for any number of transmit antennas. For the specific cases of two, three, and four transmit antennas, space–time block codes are designed that achieve, respectively, all, 3=4, and 3=4 of maximum possible transmission rate by means of arbitrary complex constellations. The best deal mouldy between the decoding delay and the number of transmit antennas is also computed and it is shown that many of the codes accessible here are optimal in this wisdom as well.

3.3.1 A Real Orthogonal Design

A factual orthogonal design of size n is an n$\times n$ orthogonalmatrix with entry the in determinates .$\pm x_1$,$\pm x_2$ ……..$\pm x_n$.The subsistence problem for orthogonal designs is known as the Hurwitz–Radon problem in the mathematics literature [65], and was completely settled by Radon in another context at the commencement of this century. In fact, an orthogonal design exists if and only if n= 2,4…. . Given an orthogonal design O , one can counteract certain columns of O to turn up at another orthogonal design where all the entries of the first row have positive signs. By permuting the columns, we can make sure that the first row of O is,x_1,x_2 …. .x_n. Thus we may assume without beating of overview that has this property.

Examples of orthogonal designs are the 2$\times$ 2 design

$$\begin{pmatrix} x_1 & x_2 \\ -x_2 & x_1 \end{pmatrix} \tag{3.5}$$

The 4× 4 design

$$\begin{pmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2 & x_1 & -x_4 & x_3 \\ -x_3 & x_4 & x_1 & -x_2 \\ -x_4 & -x_3 & x_2 & x_1 \end{pmatrix} \tag{3.6}$$

The matrices (3.5) and (3.6) can be identified, respectively, with complex number $x_1 + x_2$i .

We have urbanized the theory of space–time block coding, a straightforward and pleasing to the eye method for transmission using multiple transmit antennas in a wireless Rayleigh/ Rician environment. These codes have a very trouble-free maximum-likelihood decoding algorithm which is only based on linear processing. Furthermore they make use of the full diversity known by transmit and receive antennas. For arbitrary real constellations such as PAM, we have construct space–time block codes that achieve the maximum possible transmission rate for any number n of transmit antennas. For any multipart constellation, we have constructed space–time block codes that achieve half of the maximum possible transmission tempo for any number of transmit antennas. For arbitrary complex constellations and for the specific cases n=2,3,…and,4 . we have provide space time block codes that achieve, respectively, all, ¾ , and ¾ of the maximum possible transmission rate. We deem that these discoveries only represent the incline of the iceberg.

3.4 Pros and Cons of Free Space Optical Communication (FSO)

- The free space optics reward and disadvantage are worth exploration . After all , at whatever time a new method of modern statement is developed it is important to consider all the positives and negatives that come along with it .

- There are many recompense to free space optics. Among these are the lower rate associated with the system . There are no fibre optic cables to lay no dear rooftop installations required and no refuge upgrades basic. In addition, the scheme upgrades are generally made rather easily and no RF license is required.

- Another lead of free space optical communication is that it is extremely fast. These systems can currently transmit a large quantity of data 1.25 GB per second . In the further it is
- expected that this will boost to a gigantic 10 GB per second.

- This swiftness is due to the fact that the signals can be transmitted through the signals can be transmitted through the air sooner than they can be transmitted through fibre optic cables . The signals are sent from one wireless unit to another in a straight line from side to side the atmosphere.

- Up till now another benefit of free space optics is that there is no meddling of the signal by radio frequencies .This means smaller amount disruptions to the in sequence flow.

- What time it comes to free space optics advantages and disadvantages , there are also a number of drawbacks, free space optical communication is focus to atmospheric turbulence and circumstances.

- Chunky fog is one of the most tricky forms of intrusion for wireless optical communication that is based on free space optics . This is because the moisture in the fog can reflect , soak up and disperse the signal.

- Assimilation and spreading can both occur whenever there is a group of damp in the air. Absorption of the signal causes a diminish in signal strength but somewhat causes the signal to be sent rancid in different directions. This is an issue chiefly over extensive distances.

- After it comes to free space optics advantages and disadvantages , bodily obstructions can also be problem . These are generally provisional and include birds, cranes , and even building swing that grades from earthquakes, scintillation, which is heat going up from the earth or a touch man-made, can also upset the signal.

- There have also been concern about the level of protection of free space optical announcement due to the use of laser. This is of concern predominantly when it comes to eye safety and to the high voltages required to power the systems. On the other hand, there have been stern set of laws put into effect to curtail the risks.

CHAPTER 4

Implementation of OSTBC and Repetition Coding with Optical Jammer and Mathematical Description of OSTBC and Repetition Coding

4.1 OSTBC and Repetition Coding with Optical Jammer

We judge a MISO FSO IM/DD system equipped with *N* transmit aperture and one receive aperture. We assume background noise classified receivers [66], [67] in which the shot noise caused by milieu radiation is overriding with respect to the other noise components, e.g., thermal, signal-dependent and dark noise. Assuming the intensity of light incident on the photo detector is sufficiently high, the Poisson photon counting detection model can be approximated such that the received noise is as an additive white Gaussian noise [68].Furthermore, we assume that the transmitter apertures are located far enough apart such that underlying channels are independent and the Airy patterns of the *N* different transmitter scan be determined at the detector [69], [70]. The receiver n integrates the detected photocurrent over the bit gap. There sulting electrical signal over a duration of *P* bit intervals is given by

$$r = \sqrt{E_b}\mathbf{C}h + n \quad (4.1)$$

where $Eb=\eta^2 I_0^2/N^2$ is the electrical energy 1 of the OOK intensity modulated pulse in the "on" state at each transmit aperture, η is the optical-to-electrical conversion coefficient[71], and I_0 is signal light intensity without turbulence at the input of detector. **N=**$[n_1, n_2, \ldots\ldots, n_p]^T$denotes the additivenoise vector and its entries n_i's are 46odelled as Gaussian random variables with zero mean and variance of $\sigma_n^2=N_0/2$.We assume a log-normal turbulence-induced fading channel which is commonly used to model weak turbulence conditions. Under this assumption, the entries of the channel irradiance vector **h** = $[h_1,\ h_2, \ldots\ldots, h_3]^T$in (4.1)are given by

$$hi = |\alpha_i| = e^{2x_i} \quad (4.2)$$

where is the channel fading coefficient from *i*th transmit aperture to the receiver. The fading log-amplitudes x_i's are as independent and identically distributed (i.i.d.) Gaussian random variables with mean μ_x and variance σ_x^2 Hence, the fading coefficients are i.i.d. random variables withlog-normal distribution. We normalize the fading coefficientssuch that $E[h_i]$ = 1 implying $\mu_x = -\sigma_x^2$.. This ensures thatthe fading does not attenuate or amplify the average power[37]. In (4.1), **C** stands for the codeword matrix which will be elaborated in the following.

4.2 Modified OSTBCs for FSO Communication with OOK

Our approach for modification of OSTBCs differs from that of [72] and builds upon a linear transformation of OSTBCs designed for real signal constellations such as BPSK (binaryphase shift keying). Note that, for real constellations, there exists full-rate STBCs for any number of transmit antennas. The reader may refer to [73] for the codeword matrices of full-rate OSTBCs for N = 1, 2, ...,8. The new OOK OSTBC based on the input symbol sequence **s** = $[s_1, s_2, \dots \dots, s_p]$,$s_i \epsilon \{0, 1\}$, is given by

$$\mathbf{C} = \frac{1_{P\times N}}{2} + \frac{1}{2}\, G \qquad (4.3)$$

entries, $xi \in \{-1, 1\}$, to encode the corresponding BPSK input symbol sequence, **x**=$[x_1, x_2, \dots \dots, x_p]$. Note that $P = N$ only for N = 2, 4, and8. In the above transformation, BPSK symbols are respectively mapped into the corresponding OOK symbols. For instance, the OOK version of the Alamouti code can be represented

$$\mathbf{C} = \frac{1_{2\times 2}}{2} + \begin{bmatrix} x_1 & x_2 \\ -x_2 & x_1 \end{bmatrix} \qquad (4.4)$$

$$= \begin{bmatrix} s_1 & s_2 \\ \sim s_2 & s_1 \end{bmatrix}$$

Where ~s (which is equivalent to $\bar{s}$ of [38]) denotes "bitwise not" or complement of s. where $1_{P\times N}$ is a P-by-N matrix with entries 1 and **G** is the delay-optimal (full-rate) orthogonal P-by-N STBC matrix with entries $\pm x_1, \pm x_2, \dots, \pm x_P$, $x_i \in \{-1, 1\}$, to encode the corresponding BPSK input symbol sequence, **x** =$[x_1, x_2, \dots, x_P]$. Note that $P = N$ only for N = 2, 4, and

8. In the above transformation, BPSK symbols are respectively mapped into the corresponding OOK symbols.

At the receiver side, the signal can be transferred back into the BPSK space by an amplitude shift, i.e.,

$$\tilde{r} = r - \sqrt{\frac{E_b}{2}} \sum_{i=1}^{N} h_i = \sqrt{\frac{E_b}{2}}\ Gh + n \quad (4.5)$$

where the resulting signal can be decoded linearly using the orthogonality of the BPSK OSTBCs. For this purpose, we first rewrite (4.5) as

$$\tilde{r} = \sqrt{\frac{E_b}{2}}\ Gh + n = \sqrt{\frac{E_b}{2}}\ Hx + n \quad (4.6)$$

where **H** is the channel matrix which can be defined by **Gh** = **Hx**. It can be readily verified that **H** maintains an orthogonal form. Under the assumption that channel irradiances are available at the receiver side ,we multiply r̃ by H^T which yields

$$\hat{r} = H^T \tilde{r} \quad (4.7a)$$

$$= \sqrt{E_b} \sum_{i=1}^{N} h_i^2 \frac{x}{2} + H^T n \quad (4.7b)$$

$$= \sqrt{E_b} \sum_{i=1}^{N} h_i^2\ s + H^T n \quad (4.7c)$$

which results in *P* decoupled streams. (4.7b) and (4.7c) are equivalent since the Euclidean distance between OOK symbols, si ∈ {0, 1}, is equal to that between half-amplitude BPSK symbols, xi/2 ∈ {−1/2, 1/2}.

4.3 Repetition Coding

Unlike wireless RF communication systems, transmit diversity can be realized in FSO communication through repetition coding. This comes from the fact that the intensity of the optical fields coming from sufficiently separated transmit apertures are orthogonally detected by direct detection receivers. The received signal over a duration of a bit interval is given by

$$r = \sqrt{E_b} \sum_{i=1}^{N} h_i s + n \quad (4.8)$$

where the same OOK signal is simultaneously transmitted from *N* apertures. Since h_i's (which are the magnitude square of the fading coefficients) are real and positive, the intensities received from independent transmitters add up. Considering that the signals from different channels are combined with the same weight, such a scheme can be seen equivalent to a SIMO (single-input multiple-output) FSO scheme with equal gain combining (EGC) [74] which achieves a diversity order of *N*. It should be also noted that this scheme combines the faded signals before any noise accumulation unlike a SIMO scheme which combines the noisy faded signals. Therefore, we expect that a transmit diversity scheme with repetition code should be able to outperform a SIMO scheme with EGC. Further noting the observation in [40] that EGC performs very close to maximal ratio combining (MRC) (e.g., within 0.5 dB for N = 2 apertures and $\sigma\chi$= 0.3), such a scheme can possibly exceed a SIMO scheme with MRC. In the next section, we prove that this in truth happens.

4.4 Comparison of STBC and Repetition Coding

The conditional bit error rate performance of STBC (conditioned on channel irradiance vector h) is given by

$$P_{e|h} = Q(\sqrt{\gamma OOK} = Q\left(\frac{\sqrt{E_b}\sum_{i=1}^{N} h_i^2}{\sqrt{2}\sum_{i=1}^{N} h_i^2\, N_0}\right) = Q\left(\sqrt{\frac{E_b}{2N_0}\sum_{i=1}^{N} h_i^2}\right) \tag{4.9}$$

where Q(x)= $(1/\sqrt{2\pi})\int_x^\infty \exp\left(-\frac{u^2}{2}\right)du$ and is the γook instantaneous electrical signal-to-noise ratio (SNR) for OOK symbols at the input of the maximum likelihood detector. The term $\sum_{i=1}^{N} h_i^2$ in (4.9) indicates the equivalency of the STBC to a SIMO scheme with MRC which guarantees the full diversity order of N. On the other hand, the conditional BER for repetition coding is given by

$$P_{e|h} = Q(\sqrt{\gamma OOK} = Q\left(\sqrt{\frac{E_b}{2N_0}\sum_{i=1}^{N} h_i}\right) \tag{4.10}$$

We note

$$\sum_{i=1}^{N} h_i > \sqrt{\sum_{i=1}^{N} h_i^2}$$

therefore, it can be readily verified that the argument of Q function in (4.9) is always greater than that of (4.8) indicating that repetition coding outperforms STBC.

4.5 Jamming as a Noise in (FSO)

The received signal over a duration of bit interval is given by

$$r=\sqrt{E_b}\sum_{i=1}^{N} h_i s+n+\sqrt{E_b}\sum_{j=1}^{N} h_j s_j \tag{4.11}$$

where the same OOK signal is simultaneously transmitted from *N* apertures. Since *hi*'s (which are the magnitude square of the fading coefficients) are real and positive, the intensities received from independent transmitters add up. Considering that the signals from different channels are combined with the same weight, such a scheme can be seen equivalent to a SIMO (single-input multiple-output) FSO scheme with equal gain combining (EGC) which achieves a diversity order of *N*. It should be also noted that this scheme combines the faded signals before any noise increase unlike a SIMO scheme which combines the noisy faded signals. Therefore, we expect that a transmit diversity scheme with repetition code should be able to outperform a SIMO scheme with EGC. Further noting the observation in that EGC performs very close to maximal ratio combining (MRC) (e.g., within 0.5 dB for *N* = 2, 3 apertures and σ_x= 0.1), such a scheme can possibly outperform a SIMO scheme with MRC. In the next section, we demonstrate that this indeed happens. h_j is jamming coefficient used to jam the signals hence graph will show alternate graphs.

4.5 Repetition Coding for FSO IM/DD Link without Jamming

Let γMISO denote the instantaneous electrical SNR for coded OOK symbols at the input of the maximum likelihood detector. For space-time encoding, it can be obtained

$$\gamma_{MISO}=\frac{E_b}{2N_0}\sum_{i=1}^{N} h_i^2 \tag{4.12}$$

which can be further related to instantaneous electrical SNR of the SISO scheme, i.e.,

$$\gamma_{MISO}=\frac{E_b}{2N_0}\sum_{i=1}^{N} \gamma_{SISO} \tag{4.13}$$

The conditional bit error rate performance of OSTBC (conditioned on channel irradiance vector **h**) is then given by

$$P_{e|h} = Q(\sqrt{\gamma_{MISO}}) = Q(\sqrt{\frac{E_b}{2N_0}\sum_{i=1}^{N} h_i^2}) \tag{4.14}$$

Where Q(x)= $(1/\sqrt{2\pi})\int_x^{\infty} \exp\left(-\frac{u^2}{2}\right) du$ The term $\sum_{i=1}^{N} h_i^2$in the argument of Q function in (4.14) indicates the equivalency of the OSTBC to a SIMO scheme with MRC which guarantees the full diversity order of *N*. On the other hand, the instantaneous received electrical SNR for repetition coding can be expressed

$$\gamma_{MISO}=\frac{E_b}{2N_0}\left(\sum_{i=1}^{N} h_i\right)^2 \tag{4.15}$$

Unconditional BER expressions can be obtained carrying out expectations of (4.13) with respect to log-normal **h**. This would yield expressions in terms of the frustration function. Since the resulting expressions would not provide additional insight into performance comparison, we did leave out them here. Instead, we present the numerical calculations of unconditional BER expressions .Fig. 5.1 illustrates the BER performance of OSTBCs and repetition codes for *N* = 2*,* 3*,* 4. OOK modulation and lognormal fading channel with standard deviation of σχ= 0.3 are assumed. The SISO scheme is also included as benchmark. It is observed that repetition coding outperforms OSTBC and the performance gap increases as the number of transmit apertures increases. Specifically, for *N* = 2, we observe gains of 5.8 dB and 10.3 dB at a target BER of 10^{-9} for OSTBC and repetition coding with respect to SISO scheme. The inferiority of OSTBC becomes more evident when repetition coding for *N* = 2 is able to even outperform its OSTBC counterpart with *N* = 3 within the SNR range of practical interest. Only after 40 dB, the extra diversity gain of the latter comes into play and makes OSTBC superior. For STBC with *N* = 4,this problem is even worse as its superiority with respect to repetition scheme with *N* = 3 is not even observed in the SNR range of the current figure .Fig. 5.2 illustrates the BER performance of OSTBC and repetition coding in FSO IM/DD link with jamming schemes for *σχ*= 0.1. Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, In Fig. 2 repetition coding performs poor on adding jamming and the signal is being observed at target BER of 10^{-20} for repetition coding which obviously degrade its performance from 10^{-25}. And for OSTBC its BER performance target 10^{-10} which means it has been degrade from 10^{-15} to 10^{-10} . Hence for *σχ*= 0.1 on adding jamming performance of repetition coding degrades.

Performance comparison of OSTBC and repetition coding in FSOIM/DD link for σχ= 0.1.*N* = 2*,* 3*,* 4 over SISO transmission at BER = 10^{-9} Since the turbulence is very weak, the diversity advantage is pronounced at even higher SNR values. Similar to the previous figure, STBC presents an inferior performance with respect to repetition code and is outperformed by its competitor irrespective of transmit aperture number. For the weak turbulence under consideration, STBC is even exceed by SISO scheme within the SNR range of practical interest. STBC provides a superior performance over SISO scheme only after 26 dB, 28dB, and 29 dB for N = 2 and 4, respectively. Unconditional BER expressions can be obtained carrying out expectations with respect to log-normal h. This would yield expressions in terms of frustration function. Since the resulting expressions would not provide additional insight into performance comparison, we did omit them here. Instead, we present the numerical calculations obtained averaging with respect to h. The BER performance of two competing schemes for N = 2,4 for σ_x= 0.3. The SISO (single-input single-output) transmission is also included as benchmark. It is observed that repetition coding outperforms STBC and the performance gap increases as the number of transmit apertures increases. Specifically, for N = 2, we observe gains of 5.8 dB and 10.3 dB at BER= 10^{-9} for STBC and repetition coding, respectively, in comparison to SISO scheme. The inferiority of STBC becomes more evident when repetition coding for N= 2 is able to even outperform its STBC counterpart with SNR range of practical interest. Only after 40 dB, the extra diversity gain of the latter comes into play and makes STBC superior. For STBC with N= 4, this problem becomes worse as its expected superiority with respect to repetition scheme is not even observed in the SNR range of the current figure. The BER performance of two competing schemes for σ_x= 0.1 Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, for N = 2,4 over SISO transmission at BER= 10^{-9} . Since the turbulence is very weak, the diversity advantage is pronounced at even higher SNR values. Similar to the previous figure, STBC presents an inferior performance with respect to repetition code and is outperformed by its competitor irrespective of transmit aperture number. For the weak turbulence under consideration, STBC is even outperformed by SISO scheme within the SNR range of practical interest. STBC provides a superior performance over SISO scheme only after 26dB, and 29dB for N = 2 and 4 , respectively.

CHAPTER 5

Simulation Results

5.1 Simulation Parameters

Simulation results shown in this chapter are verified in this chapter are verified using matrix laboratory v- 7.10.0.499. No. Of transmit antennas is 2 SNR in db 0 to 60 with difference of 5. Now we have to calculate simple SNR without db that

$$SNR = 10.\hat{}(SNR_{db}\ ./10)$$

For $\sigma\chi = 0.3$ and variance i.e. var is σ_x^2

For σχ = 0.1 and variance i.e varj is σ_j^2

We have calculated probability of error for both the OSTBC and Repetition analog with optical jammer coefficient Q function for both the cases is different when we calculate probability of error for OSTBC the coefficient h_j will be squared but in case of repetition coding h_i will remain in the equation no need of squaring and argument of Q function indicating repetition coding outperforms OSTBC. h_j is jamming coefficient used to jam signal. A alteration of the alamouti code originally proposed for RF wireless applications is described that allows it to be practical in scenarios such as free- space optical communication with direct detection where unipolar modulations like on-off Keying are traditionally used to express the information. The modification of the code and associated decision metric is such as to maintain all of the pleasing properties of the original scheme.

Therefore, we have made efforts to study Free Space Optical Communications is a cost – effective and high bandwidth technique which has been receiving growing attention with recent commercialization successes. A major mistake in FSO links presentation . Therefore to get better error rate performance, spatial diversity and possible spatial correlation in log-normal channels.

Performance comparison of OSTBC and repetition coding in FSOIM/DD link for σχ= 0.1.*N* = 2, 4 over SISO transmission at BER = 10^{-9} Since the turbulence is very weak, the diversity advantage is pronounced at even higher SNR values. Similar to the previous figure, STBC presents an inferior performance with respect to repetition code and is outperformed by its competitor irrespective of transmit aperture number. For the weak turbulence under consideration, STBC is even exceed by SISO scheme within the SNR range of practical interest. STBC provides a superior performance over SISO scheme only after 26 dB, 28dB, and 29 dB for N = 2, and 4, respectively. Unconditional BER expressions can be obtained carrying out expectations with respect to log-normal h. This would yield expressions in terms of frustration function. Since the resulting expressions would not provide additional insight into performance comparison, we did omit them here. Instead, we present the numerical calculations obtained averaging with respect to h. The BER performance of two competing schemes for N = 2,4 for σ_x= 0.3. The SISO (single-input single-output) transmission is also included as benchmark. It is observed that repetition coding outperforms STBC and the performance gap increases as the number of transmit apertures increases. Specifically, for N = 2, we observe gains of 5.8 dB and 10.3 dB at BER= 10^{-9} for STBC and repetition coding, respectively, in comparison to SISO scheme. The inferiority of STBC becomes more evident when repetition coding for N= 2 is able to even outperform its STBC counterpart with SNR range of practical interest. Only after 40 dB, the extra diversity gain of the latter comes into play and makes STBC superior. For STBC with N= 4, this problem becomes worse as its expected superiority with respect to repetition scheme is not even observed in the SNR range of the current figure. The BER performance of two competing schemes for σ_x= 0.1 Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, for N = 2,4 over SISO transmission at BER= 10^{-9} . Since the turbulence is very weak, the diversity advantage is pronounced at even higher SNR values. Similar to the previous figure, STBC presents an inferior performance with respect to repetition code and is outperformed by its competitor irrespective of transmit aperture number.

Simulation results are presented to demonstarate BER performance of OSTBCs and repetition codes for BER performance of OSTBCs and repetition codes for N = 2, 4. OOK modulation and lognormal fading channel with standard deviation of $\sigma\chi$= 0.3 are assumed. The BER performance of OSTBC and repetition coding in FSO IM/DD link with jamming schemes for $\sigma\chi$= 0.1. Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, In Fig. 5.2 repetition coding performs poor on adding jamming and the signal is being observed at target BER of 10^{-20} for repetition coding which obviously degrade its performance from 10^{-25}. And for OSTBC its BER performance target 10^{-10} which means it has been degrade from 10^{-15} to 10^{-10} . Hence for $\sigma\chi$= 0.1 on adding jamming performance of repetition coding degrades.

5.2 Comparison of Results with and without Jamming

Comparison of OSTBC and repetition coding is given by without jamming with $\sigma\chi = 0.3$

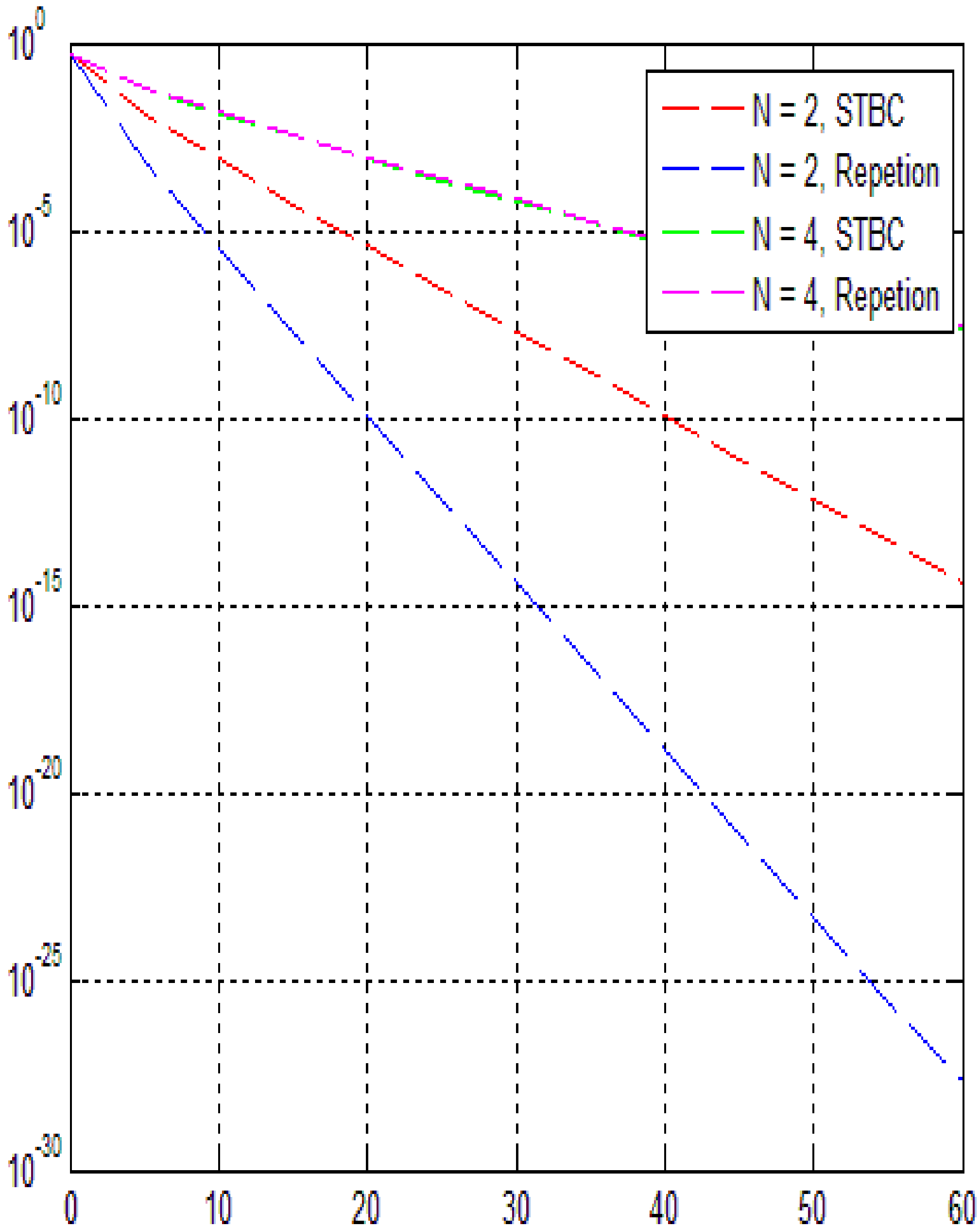

Fig. 5.1 Illustrates the BER performance of OSTBCs and repetition codes for *N* = 2, 4.

The SISO scheme is also included as benchmark. It is observed that repetition coding outperforms OSTBC and the performance gap increases as the number of transmit apertures increases. Specifically, for *N* = 2, we observe gains of 5.8 dB and 10.3 dB at a target BER of 10^{-9} for OSTBC and repetition coding with respect to SISO scheme. The inferiority of OSTBC becomes more evident when repetition coding for *N* = 2 is able to even outperform its OSTBC counterpart with *N* = 3 within the SNR range of practical interest. Only after 40 dB, the extra diversity gain of the latter comes into play and makes OSTBC superior. For STBC with *N* = 4,this problem is even worse as its superiority with respect to repetition scheme with *N* = 3 is not even observed in the SNR range of the current figure .Fig. 5.2 illustrates the BER performance of OSTBC and repetition coding in FSO IM/DD link with jamming schemes for $\sigma\chi$= 0.1. Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, In Fig5. 2 repetition coding performs poor on adding jamming and the signal is being observed at target BER of 10^{-20} for repetition coding which obviously degrade its performance from 10^{-25}. And for OSTBC its BER performance target 10^{-10} which means it has been degrade from 10^{-15} to 10^{-10} . Hence for $\sigma\chi$= 0.1 on adding jamming performance of repetition coding degrades.

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Comparison of OSTBC and repetition coding in FSO IM/DD link for $\sigma\chi = 0.1$ with jamming

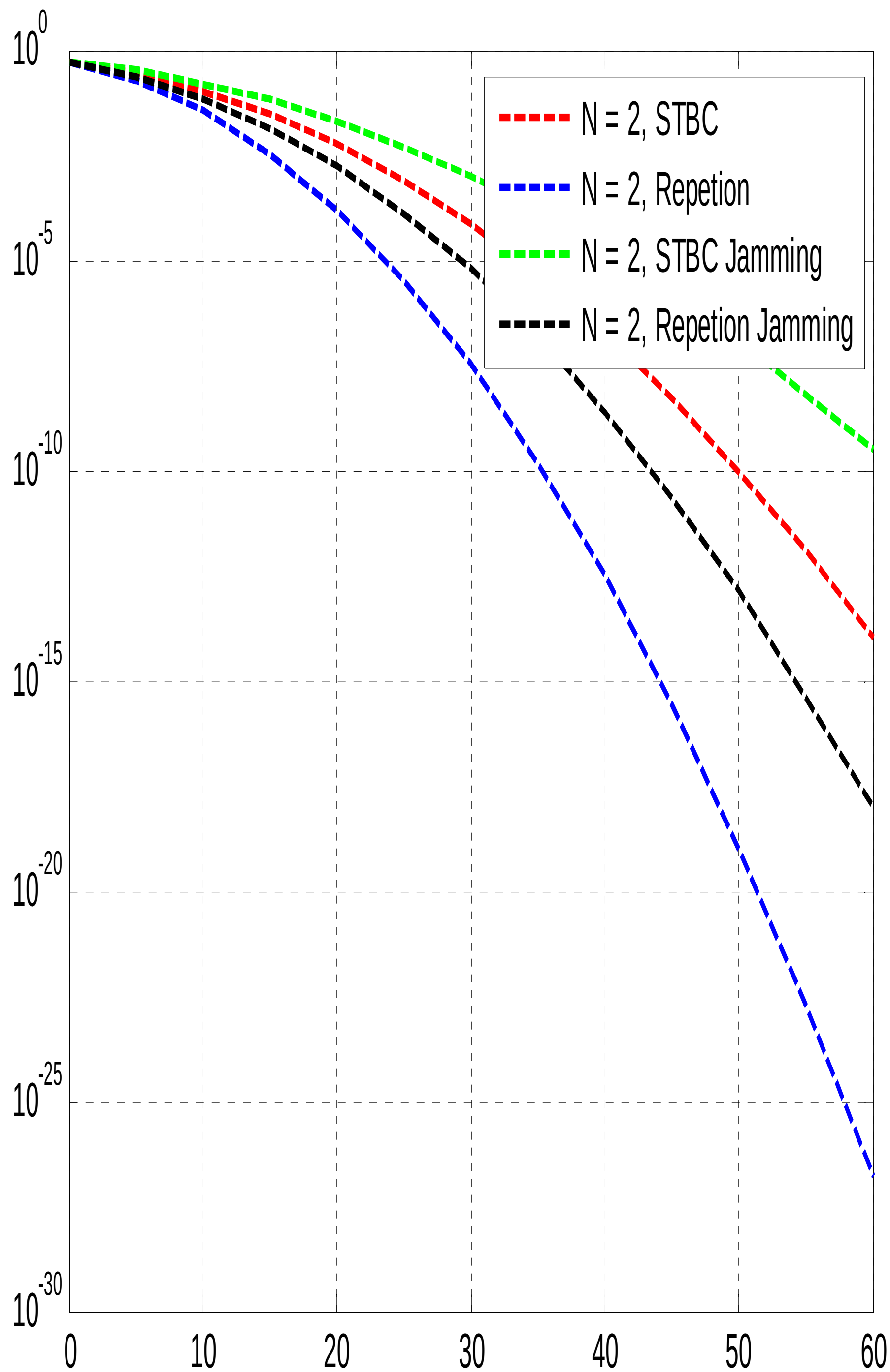

Fig 5. 2 Illustrates the BER performance of OSTBC and repetition coding in FSO IM/DD link with jamming schemes for $\sigma\chi$= 0.1.

The SISO scheme is also included as benchmark. It is observed that repetition coding outperforms OSTBC and the performance gap increases as the number of transmit apertures increases. Specifically, for *N* = 2, we observe gains of 5.8 dB and 10.3 dB at a target BER of 10^{-9} for OSTBC and repetition coding with respect to SISO scheme. The inferiority of OSTBC becomes more evident when repetition coding for *N* = 2 is able to even outperform its OSTBC counterpart with *N* = 3 within the SNR range of practical interest. Only after 40 dB, the extra diversity gain of the latter comes into play and makes OSTBC superior. For STBC with *N* = 4,this problem is even worse as its superiority with respect to repetition scheme with *N* = 3 is not even observed in the SNR range of the current figure .Fig. 5.2 illustrates the BER performance of OSTBC and repetition coding in FSO IM/DD link with jamming schemes for $\sigma\chi$= 0.1. Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, In Fig. 2 repetition coding performs poor on adding jamming and the signal is being observed at target BER of 10^{-20} for repetition coding which obviously degrade its performance from 10^{-25}. And for OSTBC its BER performance target 10^{-10} which means it has been degrade from 10^{-15} to 10^{-10} . Hence for $\sigma\chi$= 0.1 on adding jamming performance of repetition coding degrades.

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= 2, we observe gains of 5.8 dB and 10.3 dB at BER= 10^{-9} for STBC and repetition coding, respectively, in comparison to SISO scheme. The inferiority of STBC becomes more evident when repetition coding for N= 2 is able to even outperform its STBC counterpart with SNR range of practical interest. Only after 40 dB, the extra diversity gain of the latter comes into play and makes STBC superior. For STBC with N= 4, this problem becomes worse as its expected superiority with respect to repetition scheme is not even observed in the SNR range of the current figure. The BER performance of two competing schemes for σ_x= 0.1 Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, for N = 2,4 over SISO transmission at BER= 10^{-9} . Since the turbulence is very weak, the diversity advantage is pronounced at even higher SNR values. Similar to the previous figure, STBC presents an inferior performance with respect to repetition code and is outperformed by its competitor irrespective of transmit aperture number. For the weak turbulence under consideration, STBC is even outperformed by SISO scheme within the SNR range of practical interest. STBC provides a superior performance over SISO scheme only after 26dB, 28dB, and 29dB for N = 2 and 4 , respectively.

Repetition code brings performance improvements of 1.95 dB, 2.7 dB, 3.15 dB respectively, In Fig 5.2 repetition coding performs poor on adding jamming and the signal is being observed at target BER of 10^{-20} for repetition coding which obviously degrade its performance from 10^{-25}. And for OSTBC its BER performance target 10^{-10} which means it has been degrade from 10^{-15} to 10^{-10} . Hence for $\sigma\chi$= 0.1 on adding jamming performance of repetition coding degrades.

<u>**CHAPTER 6**</u>

Concluding Remarks and Future Scope

6.1 Concluding Remarks

Unconditional BER expressions can be obtained carrying out expectations of and with respect to log-normal **h**. This would yield expressions in terms of the frustration function . Since the resulting expressions would not provide additional insight into performance comparison, we did omit them here. Instead, we present the numerical calculations of unconditional BER expressions. Fig. illustrates the BER performance of OSTBCs and repetition codes for N = 2, 4. OOK modulation and lognormal fading channel with standard deviation of $\sigma\chi$ = 0.3 are assumed. The SISO scheme is also included as benchmark. It is observed that repetition coding outperforms OSTBC and the performance gap increases as the number of transmit apertures increases. Specifically, for N = 2, we observe gains of 5.8 dB and 10.3 dB at a target BER of for OSTBC and repetition coding with respect to SISO scheme. The inferiority of OSTBC becomes more evident when repetition coding for $N = 2$ is able to even outperform its OSTBC counterpart with N = 4 within the SNR range of practical interest. Only after 40 dB, the extra diversity gain of the latter comes into play and makes OSTBC superior.

We have investigated the performance of two transmit diversity techniques for FSO links over lognormal atmospheric turbulence channels. The first one is repetition coding where the same signal is simultaneously transmitted from different apertures. The second one is the modified version of OSTBCs originally proposed for wireless RF channels. The coding and decoding schemes have been presented for modified OSTBCs with OOK constellation. Our performance evaluation of the two approaches reveals that repetition codes outperform OSTBCs although both schemes are able to extract full diversity. OSTBCs are even outperformed by the SISO schemes under certain turbulence conditions. Our findings clearly point out that deployment of OSTBCs is not necessary, even detrimental in some cases, for a FSO IMIDD link.

We have investigated the performance of two transmit diversity techniques for FSO links over log-normal atmospheric turbulence channels. The first one is repetition coding where the same signal is simultaneously transmitted from different apertures. The second one is the modified version of OSTBCs originally proposed for wireless RF channels. The coding and decoding schemes have been presented for modified OSTBCs with OOK constellation. Our performance evaluation of the two approaches reveals that repetition codes outperform OSTBCs although both schemes are able to extract full diversity. OSTBCs are even outperformed by the SISO schemes under certain turbulence conditions. Our findings clearly point out that deployment of OSTBCs is not necessary, even detrimental in some cases, for a FSO IM/DD link. for practical SNR used N=2 OSTBC is better than N=2 repetition coding.Thus the proposed objective is to investigate the utility of orthogonal space time block coded system for free space optical links working over log normal atmospheric turbulence-induce fading channels. The main focus will be on rate compatible FSO links .The OOK signal is simultaneously transmitted from N apertures. Since h_i's (which are the magnitude square of the fading coefficients) are real and positive , the intensities received from independent transmitters add up. For case of jamming we have to add up noise in the received signal and the signal will be different with jamming performance of repetition coding degrades. Optical jammer will act as interference and hence drastic change in fig. 2 than fig. 1.and the conclusion of that particular , In Fig 5.2 repetition coding performs poor on adding jamming and the signal is being observed at target BER of 10^{-20} for repetition coding which obviously degrade its performance from 10^{-25}. And for OSTBC its BER performance target 10^{-10} which means it has been degrade from 10^{-15} to 10^{-10} . Hence for $\sigma\chi$= 0.1 on adding jamming performance of repetition coding degrades.

6.2 Future Scope

In this Desertation work we have compare performance of two techniques OSTBC and repetition coding for free space optical communication

The performance of repetition coding degrades on adding optical jammer as a interference hence on comparison even in case of repetition coding when we use some interference for example optical jammer the performance get worst than the when we found the results without optical jammer(interference or noise).

The investigation for the utility of orthogonal space time block coded system for free space optical links working over log normal atmospheric turbulence- induce fading channels. For the rate compatible FSO links can be the future work .

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