A PROJECT

ON

"DESIGN ISSUES OF OPTICAL CODE DIVISION MULTIPLE ACCESS SYSTEM"

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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PAURI, UTTRAKHAND, INDIA

August-2021

DECLARATION

We here by declare that the project titled "**Design issues of optical code division multiple access system**" submitted to the Department of Electronics & Communication Engineering, G. B. Pant Institute of Engineering and Technology,Pauri, Uttarakhand for the award of Bachelor of Technology degree in Electronics and Communication Engineering is a bonafide work carried out by us under the guidance of **Dr. Kamaljit Singh Bhatia** and that it has not been submitted anywhere for any other award of degree or diploma. Where other sources of information have been used ,they have been acknowledged.

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CERTIFICATE

This is to certify that the projectentitled as "**Design issues of optical code division multiple access system** " which is being submitted by **Bhawna Paliwal ,Chandresh Pandey, Divya Pant** in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Electronics and Communication Engineering to the Department of Electronics and Communication Engineering, G. B. Pant Institute of Engineering and Technology, Pauri Garhwal, Uttarakhand is a bonafide work carried out by them under my guidance andsupervision.

To the best of my knowledge, the matter embodied in the project has not been submitted for the award of any other degree or diploma.

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ACKNOWLEDGEMENT

It is our proud privilege and duty to acknowledge the kind of help and guidance received from several people in preparation of this project. It would not have been possible for us without their valuable help, cooperation and guidance.

First and foremost, we wish to record our sincere gratitude to our mentor **DR. KAMALJIT SINGH BHATIA** and to the Head of the Department **DR. ANIL KUMAR GAUTAM** and respected director of GBPIET **DR . Y SINGH** for his constant support and encouragement in preparation of this report and for making available library and laboratory facilities needed to prepare this report.

Secondly, we would like to thank our parents who patiently helped us as we went through our work and helped to modify and eliminate some of the irrelevant or unnecessary stuffs. We would also like to thank our friends who helped us to make our work more organized and well- stacked till the end.

At last we would like to thank God for his grace upon us.

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ABSTRACT

The Optical code division multiple access system plays a key role in long haul and high speed communication networks like LAN and MAN. These systems have advantage of high speed, large capacity and wide bandwidth. Code division multiple access is a spread spectrum technology that allows users to occupy the same bandwidth at the same time. In CDMA, all users assign an own code to all users to differentiate it from other users in a spread spectrum. The optical fiber communications have wide bandwidth, huge capacity and large reliability by the use of the broadband of optical fiber. To take the full benefits of these techniques, CDMA and optical fiber communication is the main idea to allow many users to transmit data simultaneouslyover the same frequency band at the same time. In OCDMA, types of code play a vital role that influencing its performance. The objective of the thesis is to analyze the different design issues for an OCDMA system.

Firstly, the design, implementation and performance analysis of OCDMA system with pseudo orthogonal coding. It has been observed that in the bit error rate performance curve the error is decreased when the number of subscriber is increased side by side the optical power is reduced

when the users is added. The performance evaluation of OCDMA system based on pseudo orthogonal coding has been analyzed by measuring the values of bit error rate and eye diagrams for different number of active users. We investigate the performance of multi-user OCDMA system to achieve data rate more than 1 Tb/sec.

Secondly, we have discussed the performance analysis of an optical code division multiple access schemes based on Spectral amplitude coding. In this, we have varied power with different length of fibers. The performance of the system is also analyzed on BER and EYE diagram under the influence of number of simultaneous users with different received power. The comparison on the basis of measured bit error rate (BER), Q-value, and eye diagrams has been taken and presented. Thirdly, we have proposed the hybrid RoF-OCDMA system. In this, OCDMA-ROF system incorporating Pseudo-orthogonal coding at data rate of Tb/s is presented. The effect of narrow band interference in the OCDMA spectrum is investigated through simulation and simulation results are experimentally confirmed. It also provides features like high data security, cost effectiveness of remote BSs and also enhance the performance.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

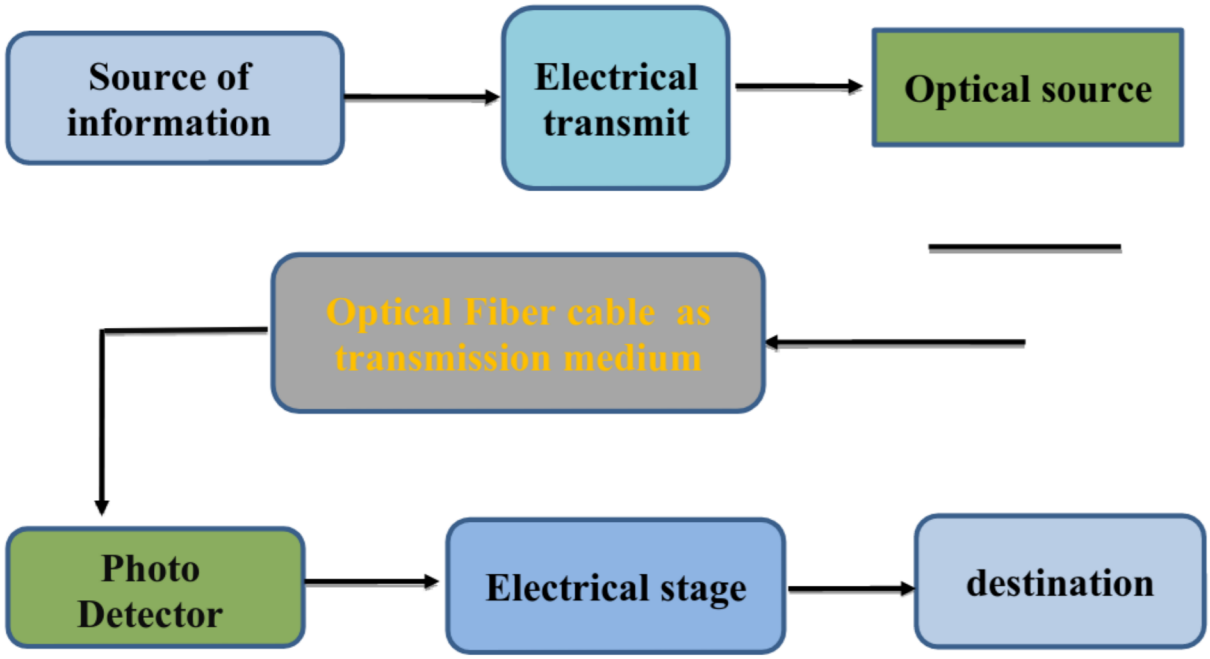
Optical fibers have been used for point to point communication at a very high speed. Optical fiber communication plays important role in the development of high quality and high speed telecommunication transmission. Fiber optic communication is the idea of allowing several users to transmit data simultaneously over the communication channel. Often the optical fiber offers much higher speed than the speed of electronic signal processing at both ends of the fiber. Because of this, the use of optical fiber has largely replaced copper wire in the communication. Fiber-optic communication systems have revolutionized the telecommunications industry and have played a major role in the advent of the Information Age. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world. The process of communicating using fiber-optics involves the following basic steps: Creating the optical signal involving the use of a transmitter, relaying the signal along the fiber, ensuring that the signal does not become too distorted or weak, receiving the optical signal, and converting it into an electrical signal.

1.2 History of optical fiber communication

The development of optic fiber communication has gone through four generations.

Optical fiber was successfully developed in 1970 with attenuation low enough for communication purposes and at the same time GaAs semiconductor lasers were developed 1 that were compact and therefore suitable for transmitting light through fiber optic cables for long distances. This first-generation system operated at a bit rate of 45 Mbps with repeater spacing of up to 10 km and at a wavelength around 0.8 μm and used GaAs semiconductor lasers2. In the early 1980s, for commercial use the second generation of fiber-optic communication was developed, operated at 1.3 μm, and used InGaAsP semiconductor lasers 3. These early systems were firstly used for multi-mode fiber dispersion, and in 1981 the single-mode fiber was used to greatly improve system performance.By 1987, these systems were operating at bit rates of up to

1.7Gb/s with repeater spacing upto 50km4.The third generation optical fiber communication used dispersion shifted single-mode fibers with wavelength of 1.55μm; with loss reduced to 0.2 dB/Km. They can be used in long-haul telecommunications or submarine long-span telecommunications with a high bit rate of 2.5Gbps and lnGaAsP LD light source 5.The fourth generation of fiber-optic communication systems used optical amplification to reduce the need for repeaters and wavelength-division multiplexing to increase data capacity. These two improvements caused a revolution that resulted in the system having a bit rate of 10 Tb/s. In 2006 a bit-rate of 14 Tbit/s was reached over a single 160 km line using optical amplifiers 6. The research on the next generation of optical fiber communication system is still going on. Its trends are to boost the bit rate of a single wavelength channel further to increase the transmission capacity of the system, to extend the transmission distance, and to develop ultra large capacity, ultra long distance and optical fiber networking.



1.1 Optical Fiber Communication System

The block diagram for optical communication is shown in figure 1.1. In this case the information source provides an electrical signal to a transmitter comprising an electrical stage, which drives an optical source to give modulation of light wave carrier. The optical source which provides the electrical optical conversion may be either a semiconductor laser or the Light Emitting Diode (LED). The transmission medium consists of an optical fiber cable or the receiver consists of an optical detector, which drives a further electrical stage and hence provides demodulation of the optical carrier. Photodiodes (P-N, P-i-N or Avalanche) and in some instances, phototransistor and photoconductors are utilized for the detection of the optical signal and optical electrical conversion. Thus there is a requirement for electrical interfacing at either end of optical link and at present the signal processing is usually performed electrically.

1.3Nonlinear OpticalEffects

Silica-glass fibers has two kinds of optical nonlinear effects – third-order non-linearity, which includes the fiber Kerr nonlinearities, and nonlinear inelastic scattering, which includes stimulated Raman and Brillouin scattering. The optical intensity sufficiently high for these nonlinear interactions to occur, when single mode fiber has small cross sectional area by which optical pulses transmitted through, causing a number of deleterious effects that damage the signal integrity in communication systems.

Self-phasemodulation (SPM) is a form of dispersion caused by the optical Kerr nonlinear effect(the slight dependence of the refractive index, and hence the phase velocity, on the optical intensity). Since different phases of the optical pulse travel at different velocities, pulse spreading ensues. The optical Kerr effect may also result in crosstalk between different waves in two-way communication systems.

Cross-phase modulation (XPM) results from nonlinear wave mixing wherein the phase velocity of a signal at one wavelength depends upon the intensities of waves at different wavelengths traveling simultaneously in the same fiber. In wavelength-division multiplexing (WDM) systems, XPM can cause serious crosstalk between the different

waves and channels.

Four-wave mixing (FWM) is also related with third-order nonlinear effects like optical Kerr nonlinear effects. It causes crosstalk and noise between four waves of different wavelengths traveling simultaneously in the same fiber since the waves may exchange energy. This introduces an intensity-dependent gain/loss into channels of a WDM system.

Stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS) are inelastic scattering associated with the nonlinear effects involving interactions between light and molecular through vibrations of the medium. In these processes, two optical waves of different wavelengths associated with each other through a molecular vibration mode (SRS) or an acousticwave (SBS). Such interactations also lead to undesirable noise between channels of a WDM system.

1.4Dispersion in optical communication system

Dispersion is the spreading of light pulse as its travels down the length of an optical fiber. Dispersion limits the bandwidth or information carrying capacity of a fiber. The bit-rates must be low enough to ensure that pulses are farther apart and therefore the greater dispersion can be tolerated.

There are three main types of dispersion in a fiber:

- Modal Dispersion
- Material dispersion
- Waveguide dispersion

1.4.1 Modal dispersion

Modal dispersion occurs only in Multimode fibers. It arises because rays follow different paths through the fiber and consequently arrive at the other end of the fiber at different times. Mode is a mathematical and physical concept describing the propagation of electromagnetic waves through media. In case of fiber, a mode is simply a path that a light ray can follow in travelling down a fiber. The number of modes supported by a fiber ranges from 1 to over 100,000. Thus a fiber provides a path of travels for one or thousands of light rays depending on its size and properties. Since light reflects at different angles for different paths (or modes), the path lengths of different modes are different.

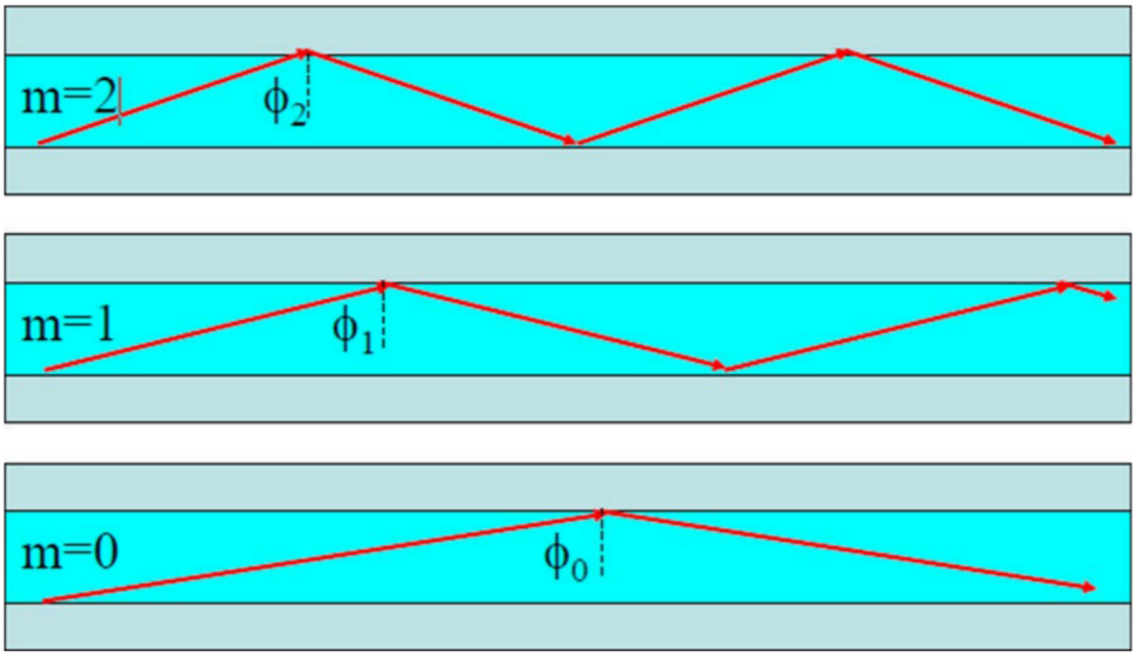


Figure 1.2 Modal dispersion in multimode waveguides

In Fig 1.2.The carrier wave can propagate along all these different "zig-zag" ray paths of different path lengths. Thus different rays take a shorter or longer time to travel the length of the fiber. The ray that goes straight down the center of the core without reflecting, arrives at the other end first, other rays arrive later. Thus light entering the fiber at the same time exit the other end at different times. The light has spread out in time.

The spreading of light is called modal dispersion. Modal dispersion is that type of dispersion that results from the varying modal path lengths in the fiber. Typical modal dispersion figures for the step index fiber are 15 to 30 ns/ km. This means that for light entering a fiber at the same time, the ray following the longest path will arrive at the other end of 1 km long fiber 15 to 30 ns after the ray, following the shortest path.

1.4.2 Material dispersion

Different wavelengths also travel at different velocities through a fiber, in the same mode, as

$n = c/v$.

Where n is index of refraction, c is the speed of light in vacuum and v is the speed of the same Wavelength in the material. The value of v in the equation changes for each wavelength, Thus Index of refraction changes according to the wavelength. Dispersion from this phenomenon is called material dispersion, since it arises from material properties of the fiber. Each wave

changes speed differently, each is refracted differently. White light entering the prism contains all colors. The prism refracts the light and its changes speed as it enters the prism. Red light deviates the least and travels the fastest. The violet light deviates the most and travels the slowest.

1.4.3 Waveguide dispersion

Waveguide dispersion, most significant in a single- mode fiber, occurs because optical energy travels in both the core and cladding, which have slightly different refractive indices. The energy travels at slightly different velocities in the core and cladding because of the slightly different refractive indices of the materials. Altering the internal structures of the fiber, allows waveguide dispersion to be substantially changed, thus changing the specified overall dispersion of the fiber.

1.5 Multiple access techniques

The major multiple access protocols are

Wavelength Division Multiple Access (WDMA)

Time Division Multiple Access (TDMA)

Code Division Multiple Access (CDMA)

1.5.1 Wavelength Division Multiple Access

In WDMA, each subscriber is assigned a wavelength channel as shown in figure1.3. Bandwidth is divided into number of channels and each channel occupies a narrow optical bandwidth around a center wavelength or frequency7. The channels are assigned only when demanded by the users. Therefore when a channel is not in use it becomes a wasted resource. Because each channel is transmitted at a different wavelength, they can be selected using an optical filter. In this, each user is assigned a fixed slot of wavelength all the time which makes it simple to implement and use.

1.5.2 Time Division Multiple Access

In TDMA, each subscriber to the system is assigned a time slot as shown in figure1.3. Each user must wait for its slot to transmit or receive data 8. As the number of subscribers increases, the number of time dots a particular user needs to wait increases, resulting in high latency. Since only a fraction of the subscribers are active at a given time on a LAN, many time slots are not used and bandwidth is wasted.

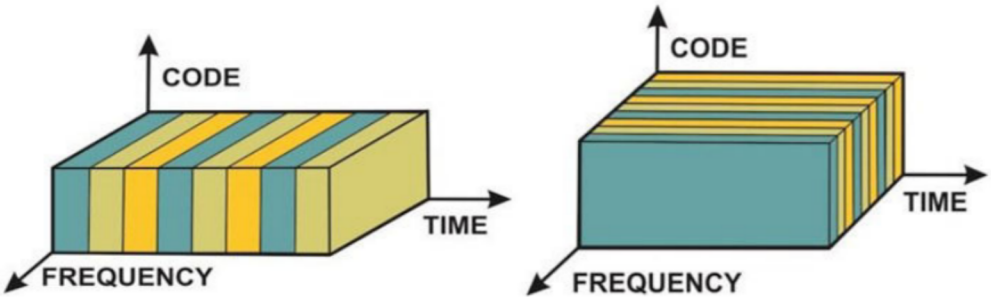


Figure 1.3 Schematic illustration of bandwidth allocation in TDM and WDM

1.5.3 Code Division Multiple Access

Unlike in TDMA or WDMA, CDMA does not assign to each subscriber a specific time slot or wavelength channel as shown in figure1.4. In CDMA, a unique code is assigned to each subscriber. These codes are designed to allow al1 users to transmit data simultaneously and asynchronously 9. The graceful degradation of the system bit error rate in a CDMA system enables various numbers of active users to transmit data regardless of the activities of other subscribers. CDMA is particularly suited to the bursty multiple access environment of the LAN.

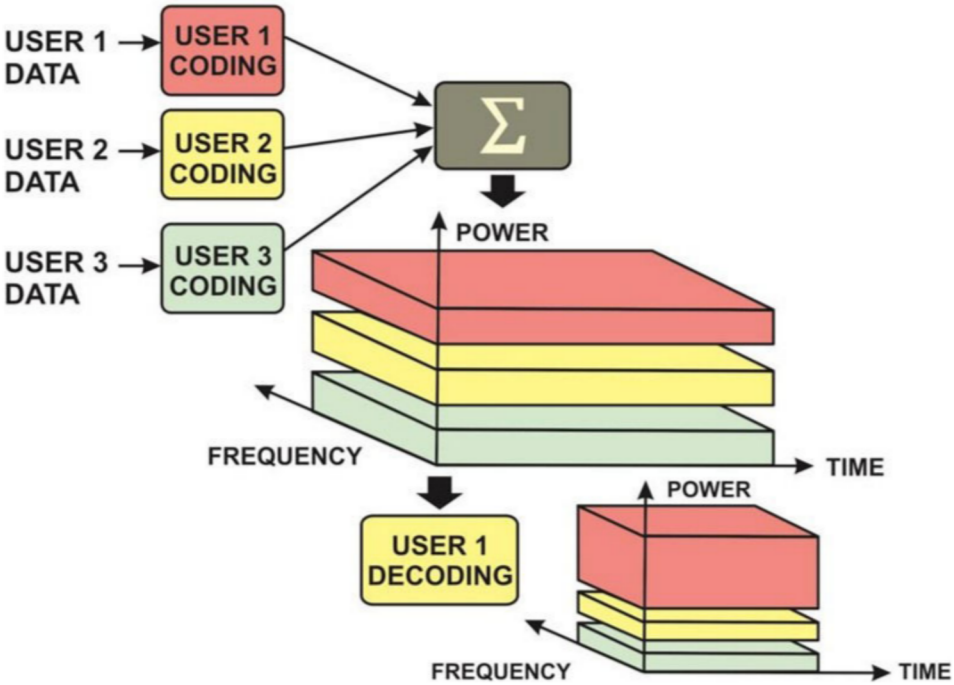


Figure 1.4 CDMA spreading

Spread spectrum code division multiple access (CDMA) allows asynchronous multiple access to a Local Area Network (LAN) with no waiting. The additional bandwidth required by spread spectrum can be accommodated by using a fiber-optic channel and incoherent optical signal processing. Optical CDMA is a scheme which is used for multiplexing optical communication channels that is based on the method of direct-sequence spread spectrum.

1.6 Introduction to OCDMA

CDMA (Code Division Multiple Access) has been extensively studied in the context of microwave communications as it allows users to access any shred channel randomly at any arbitrary time. Its use in optical fiber networks has attracted considerable attention since 1985. In long-haul optical fiber transmission links and networks, the information consists of a multiplexed

aggregate data stream originating from many individual subscribers and normally is sent in a well-timed synchronous format. O-CDMA (Optical CDMA) communication systems do not require any time or frequency management. It can operate asynchronously without centralized control and it does not suffer from packet collisions. As a result, O-CDMA systems have lower latencies than TDMA or In a O-CDMA system each bit is divided up into N time periods, called chips. By sending short optical pulse during some chip intervals, but no others, an optical signature sequence or codeword can be created. Each user on the O-CDMA system has a unique signature sequence. The encoder of the each transmitter represents each 1bit by sending signature sequence, however a binary o bit is not encoded and is represented using all-zero sequence. Since each bit is represented by a pattern of lit and unlit chips, the bandwidth of the data stream is increased. The O-CDMA is encoded data is then send to an 'N x N' known as star coupler (in local area network) or '1xN' coupler(in an access network) and broadcast to all nodes. The crosstalk between different users sharing the common fiber channel, known as MAI (Multiple Access Interface) is usually the dominant source of bit errors in an O-CDMA system. The main difference of O-CDMA systems from wireless CDMA is the code structure. Optical systems are mainly intensity modulated and hence the chips in the O-CDMA system are alternating '1' s and '0' s instead of '-1' s and '+1' s. In O-CDMA the overlap of optical pulses results in the addition of optical power. Optimum CDMA codes have been found assuming bipolar signals which can take on positive and negative values, though optical signal can also be processed coherently to provide bipolar signals. Recently practical optical -fiber systems use direct detection and cantherefore process only unipolar signals consisting of "1" s and "0" s. CDMA codes consisting entirely of '1' s and '0' s are referred to as optical codes and several

variants have been recently proposed in many literature.

An important class of CDMA optical codes is so called set of OOCs (Orthogonal Optical Codes). OOC is a family of (0,1) sequences with good auto and cross correlation properties. The (1,0) sequences of OOC are called its code words. In other words, the cross -correlation of two distinct CDMA codes must take a value as low as possible. Future optical network need to support multimedia service. Codes needed to provide multimedia services have been investigated in much literature. Researchers are still going on to develop a better O-CDMA code which will support the multimedia services. In O-CDMA, Bandwidth is shared; it is optical power from other users on the same wavelength channels that lead to the beat and short noise. There are also cost barriers. The encoding broad band and decoding hardware is expensive for O-CDMA. For generation a large number of wavelengths the broadband LED is the cheapest option, but the light generated may not have a high enough intensity for O-CDMA applications both the laser diode array and the EDFA options have the required power but are currently expensive. Performance of O-CDMA communications is clearly dependent on the MUI (Multiple User Interface) the type of modulation used and the receiver topology. The number of users is dependent on the code length and weight but these parameters should be carefully chosen since sometimes the system performance worst if we increase any of them.

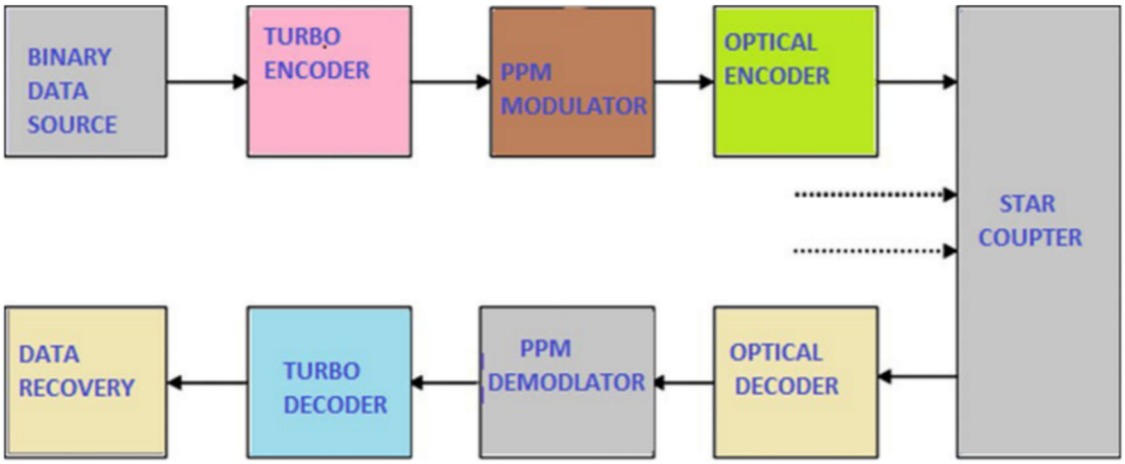


Figure1.5 Typical OCDMA System Schematic

The Fig 1.5 shows an OCDMA transmitter and receiver. Fiber optical code division multiple access is one technique which allows several users to transmit simultaneously over the same optical fiber. An OCDMA can, for each user, be described by data source, containing the data that will be sent, followed by an encoder and then a laser that maps the signal from electrical signal to an optical pulse sequence by using a modulator. At the receiver, the optical correlator is used to extract the encoded data.

1.7Classification of OCDMA system

Optical CDMA systems can be divided into two broad categories based on the way in which a particular user's code is applied to the optical signal. These classifications include:

1)Coherent optical CDMA

2)Incoherent optical CDMA

In a coherent OCDMA system, a given user's code is generally applied via phase coding of the optical signal field, which is often derived from a highly coherent wideband source, such as a mode-locked laser. The receiver for a coherent OCDMA system relies on a coherent reconstruction of the signal field to recover the decoded user's data. In this the signals are bipolar in nature. Coherent systems achieve higher performance than the incoherent ones but require high-precision control of the optical path within the encoder and decoder In contrast an incoherent OCDMA system typically relies on amplitude-modulated codes rather than directly manipulating the optical phase. Also, the receiver is based upon an incoherent decoding and recovery process. A number of incoherent OCDMA system architectures utilize wideband incoherent sources, such as a broadband amplified spontaneous emission source, while other incoherent architectures utilize coherent laser sources as part of their implementation. In most incoherent OCDMA systems, each user is assigned a specific code sequence: a coded transmission is sent to represent a data bit "1," and a null is used to represent a bit "0." Due to the incoherent nature of the system, there are no negative signal components and the signals are unipolar. To avoid loss of code confidentiality using simple energy level detectors, these schemes can be modified to assign two codes per user a 1 being represented by a code and a 0 being represented by another .Incoherent systems are regarded as more practical because the light sources and encoding and decoding techniques have low complexity and are cost effective.

1.8 Characteristics of OCDMA

OCDMA has become a promising technology to implement truly all optical communication and networking that uses optical signal processing directly, combining the advantage of electrical CDMA with the bandwidth predominance of fiber-optic and optical signal processing devices. The Passive optical access network, LAN and WAN, can be built up by using OCDMA technology The combination of OCDMA with WDM or TDM can enhance signal multiplexing and label switching through the combination of OCDMA with WDM or/and IP over WAN so that transmission and switching capacity of network can be enhanced and performance of the communication network can be heightened. OCDMA can implement high-speed transmission, switching and add/drop of data through using all-optical signal processing and thus it can realize all-optical communication and all-optical networking and overcome the effect of electronic bottleneck, which exists in the electronic node in the traditional network.

1.Subscribers can access the network at random and the network has soft capacity. Meanwhile, the pattern of networking is very flexible.

2.OCDMA does not need buffering in queue because it uses the tell-to-go protocol.

3.OCDMA network can assign the bandwidth dynamically and implement the bandwidth assignment with different granularities deftly, and used optical network bandwidth effectively.

4.An OCDMA network is somewhat secure and cryptic for the transmission information.

5.An OCDMA network needs fewer devices than a WDM network and its equipment is simple, and implementing cost of OCDMA network is low. A DWDM network needs accurate wavelength control and conversion. Furthermore, OCDMA is highly compatible with DWDM and TDM.

6.OCDMA networks employ distributed management, which is simple and it is convenient to locate network failure and protect and recover. Because of the advantages mentioned above, OCDMA can support multimedia including voice, data, video, including IP traffic, video-on-demand, streaming media.

1.9Comparison of OCDMA with other techniques

In theory, CDMA, TDMA and FDMA have exactly the same spectral efficiency but practically, each has its own challenges – power control in the case of CDMA, timing in the case of TDMA, and frequency generation/filtering in the case of FDMA.

TDMA systems must carefully synchronize the transmission times of all the users to ensure that they are received in the correct time slot and do not cause interference. Since this cannot be perfectly controlled in a mobile environment, each time slot must have a guard-time, which reduces the probability that users will interfere, but decreases the spectral efficiency. Similarly, FDMA systems must use a guard-band between adjacent channels, due to the unpredictable doppler shift of the signal spectrum because of user mobility. The guard-bands will reduce the probability that adjacent channels will interfere, but decrease the utilization of the spectrum.

1.10Advantages of Optical CDMA System

i.All-optical Communications: OCDMA system encodes and decodes signals (data) from different users optically; the messages are converted to optical signals at the source end and are retrieved as electronic signals after transmission has completed.

ii.Security Performance: The signal transmitting in OCDMA networks is multiplexed signal of various users, the spread spectrum technology guarantees the received signal at any receiving end is multiplexed and can only be de-multiplexed when the address sequences are strictly matched.

iii.Anti-interference Ability: The bandwidth of transmitting signal is increased with the use of spread spectrum technology at encoding. Therefore OCDMA is not sensitive to wavelength drifting and the anti-interference ability is enhanced.

iv.Asynchronous Access: OCDMA system allows various users to access the same channel asynchronously. The signal of a new user adds directly onto the multiplexed signal vector, no synchronization between different users and wavelength adjustability needed.

v.Low Cost: OCDMA system adopts wideband optical source, the wavelength has not to be precisely manipulated. In addition, there is no particular requirement of optical fiber and fewer devices are used in constructing networks. Thus the overall cost is reduced, network management is simplified and the reliability is enhanced.

vi.Integrated Transmission Services: OCDMA can actually support multi-rate transmissions and various transmission services such as IP transmission, ATM (Asynchronous Transfer Mode) and SONET (Synchronous Optical Network) transmissions simultaneously.

vii.Easily Managed: OCDMA does not require precise synchronization management in time as well as in wavelength, instead OCDMA employs different address sequences to distinguish

different users, therefore the network management is simplified.

1.11Multiple Access Interference (MAI) in OCDMA

The co-channel interference from other users, who are using the same frequency allocation at the same time, is known as Multiple Access Interference (MAI).The optical CDMA systems suffer from other simultaneous users. As the number of simultaneous users increases, the bit error rate (BER) degrades because the effect of MAIs increases. In addition, even if the received optical power is large enough i.e. if the effect of noise is small, the effect of noise is small, the effect of MAIs is constant because the power of the transmitted pulse is equal among all users. Light pulses transmitted by different users may overlap. As the light source in each transmitter is assumed to be incoherent, total intensity at a chip is the sum of the intensities of the individual light pulses existing in that chip. The codes are designed to be sufficient different that the probability of mistaking one code for another is very low. However, when many users are transmitting simultaneously, many overlaps may occur. A receiver may then conclude that its target code was sent. This phenomenon is known as an error due to multiple access interference (MAI).As more users share the channel simultaneously; the effect of MAI becomes more significant. MAI increases the level of a pulse by integer multiple of the original pulse level. When pulse power is high and the photo detectors are of low noise, MAI is the dominant cause of performance degradation in OCDMA systems.

1.12 Applications of Optical CDMA

1.12.1 Wireless Optical CDMA LAN

Wireless optical LANs is importance because it provides great security and obtaining radio frequency band would not be economical. Wireless local area networks have acquired attraction due to its feasibility, wide range of applications, market needs and consumer's considerable demands. Wireless LANs are of immense interest in places such as hospitals and inside planes where electromagnetic interference is of great concern. With progress in optical devices, technologies, considerable improvement in quality of service for such networks is achieved.WDM and TDM systems imposes higher cost and complexity in LAN, therefore CDMA find its place as it allows very flexible access of the large communication bandwidth available in optical fiber networks with a capability to conceal the data content in LAN. So, OCDMA is an attractive candidate for LAN application.

1.12.2 Radio Over Fiber network based on OCDMA

Microcellular systems have difficulties such as radio signals transfer. To solve these radio-over fiber(ROF)systems are proposed, where microcells in wide area are connected by optical fibers and radio signals are transmitted over fiber links. Optical code-division multiple access (OCDMA) is one of the candidate multiple access method for ROF systems because it has asynchronous access property and guarantees the high process gain by using the broad bandwidth of optical devices. Radio-over-fiber networks provides high bandwidth and introducing it with optical code division multiple access we can effectively utilized available bandwidth and transmitted data security can also be increased. In optical CDMA methods, there are time spreading CDMA, coherent coding CDMA, two dimensional (2-D)CDMA, spectral encoding CDMA and so on. However these coherent coding are complicated for radio signal transmission .And this time spreading CDMA for ROF systems might need or carrier synchronization and the band pass sampling technique with an aliasing canceller has been introduced for improving the carrier-to-interference ratio (CIR).

On the other hand, the spectral encoding CDMA can regenerate the information data without any synchronization. Furthermore, the proposed spectral encoding CDMA with the bipolar capacity can receive radio signals without any sampling techniques. The bipolar capacity can be obtained by pseudorandom noise (PN) codes in time spreading CDMA and spectral encoding CDMA. In the general optical CDMA by using PN codes ,the difference between the number of “1”and the number of “0”causes the channel interference or multiple access interference (MAI).The modified PN codes to reduce the channel interference have the same number of “1” and “0”.

1.12.3 Multimedia Transmission employing OCDMA

Multimedia communication has been expected in high speed optical networks due to the growing applications of multimedia. In optical communication systems, there has been increasing interest in optical code-division multiple access (OCDMA) system due to its many attractive features such as vast bandwidth, high speed signal processing and accommodating large number of simultaneous users.

CHAPTER 2

LITERATURE REVIEW

2.1 Work done in India/Abroad

The history of OCDMA dates back to the 1970s and as literatures from various sources is discussed in brief as below.

Optical code division multiple access method (OCDMA) has been widely used for optical networks and it is best solution for secure transmission 1011.Optical code division multiple access method used to transmit the data simultaneously by using same channel12 . Comparison of OCDMA with different techniques and it has many advantages over TDMA and WDMA 13.In 14, discussed comparison between coherent and incoherent detection techniques in OCDMA. Coherent detection has phase information of carriers but incoherent detection has no such type of information. Coherent detection performed in bipolar approach but on the other hand incoherent detection performed in unipolar approach. OCDMA serial interference cancellation (SIC) receivers is useful in terms of performance based on optical code division multiple access as compared to OCDMA correlation conventional receiver (CCR).SIC receivers helps to reduce the error probability and increases the number or simultaneous user15.By increasing simultaneous users, the performance of OCDMA decreases due to increase in MUI so orthogonal code sets used to increase the performance of OC161718.Multicode modulation signalling is the phenomenon which reduced the dispersion effects in multiwavelength code division multiple access system and effects of multiple-access interference(MAI) and optical-beating interference(OBI) can be mitigated in this system. This proposed system also supports high data rate and number of use19.To enhance the spectral efficiency, a scheme M-ary OCDMA over binary OCDMA have been investigated 20.For scaling purpose, optical code division multiple access has given best result as compared to optical time division multiple access system which increased the performance in terms of splitting losses, transmission loss over the demonstrated distance21. The technique combining fibre radio networks and spectral-amplitude-coding (SAC) optical code-division multiple access(OCDMA) using hybrid star/ring topology was shown to improve the power efficiency and carrier-to-noise ratio at the decoder of the proposed scheme22. For the implementation ofcoherent direct sequence (CDS)-OCDMA systems, Super structured fiber bragg gratings (SSFBGs) have been used because they are compact in-fiber devices with low loss, potentially low costs and have the capacity of implementing long codes with very high chip rate23.

In spite of these qualities, proposed system have two limitations. First, the power imbalance or added power penalty reduces the useable number of bands. The second limitation is the difficulty of closed spectral concatenation of multiple responses with optimum spectral utilization 24. A rectangular flat-top global envelope SSFBGs used for the CDS-OCDMA en/decoding of multiple WDM sub-bands with balanced insertion loss and sharp edges .The fabricated devices present a perfectly flat top spectrum with less than 0.6 dB of insertion loss imbalance per channel and an extinction ratio greater than 25 dB between lateral sub-bands and the out-band spectrum25. The appearance of equal-energy OCDMA was first discussed26by obtaining an approximate upper bound for the error- probability with 1-D MLVW-OOCs. Then 1-D and 2-D codes have been used to improve this error-probability upper bound with the proposed system 27.Moreover,1-D and 2-D codes with cross-correlation functions of at most one has been derived 28.Then, To overcome the problem of designing multilevel OCDMA systems under the same-bit-energy assumption,1-D and 2-D codes with cross-correlation functions of at most three. Additionly, the system is also essential for power-sensitive applications, such as service monitoring and fiber-fault surveillance in optical networks and sensor identification in fiber-sensor systems 2930. In 31, performance analysed of subcarrier multiplexed spectral- amplitude-coding optical code division multiple access (SCM SAC-OCDMA) system based on two techniques i.e. AND subtraction technique and complementary subtraction technique. Also discussed that AND subtraction technique provides better performance because this technique requires less no. of filters in the decoder. Multiple rates and/or QoS is the main factor to support multiple service-classes in OCDMA networks and utilization of multi-length codes is a simple solution for the provision of multi rate services32.However multi-length coding produces interference so then another solution is the optical fast-frequency technique which needs multi-wavelength transceivers with high sensitivity on power control33.After the fast-frequency technique, another technique has been discussed i.e. parallel mapping technique to provide the differential QoS and to control the BER at the receive34. Comparison of OCDMA and WDMPON and discussed OCDMA is better solution for symmetric traffic in PON35.Even though OCDMA-WDM-PON best for NG-OAN but complexity and cost effected the system. Also compare with WDM-PON on the basis of performance of noise and spectral efficiency 36 In 37,Constructed the system of WDM-OCDMA-PON which allows to achieve asynchronous transmission speed .Encoder/Decoder (E/D) used to generate codes at the rate of 2.56Tbps over 50km fiber .For the call-level performance of a hybrid WDM-OCDMA PON, that are based on a teletraffic model for the performance modelling of Wireless CDMA networks38. In 39, a performance analysis is performed on OCDMA PONs, which supports multiple service-classes

with infinite traffic-source population. In 40 a new multi-rate loss model has been proposed for the calculation of blocking probabilities in an OCDMA-PON which supports bursty traffic of multi service-classes with finite traffic source population and analysed the performance at different parameters such as different additive noise distributions and the user activity with different service times for active and passive periods. Comparison between complementary subtraction techniques with NAND detection technique for SAC-OCDMA system performance using Modified Double Weight (MDW) code has discussed, From results it concluded that NAND detection technique gives suitable results in terms of various noises and Multiple-Access Interference (MAI) effect. It is also concluded that NAND detection technique support more number of users and improved BER performance as compared to the complementary subtraction technique 41. There are various methods to secure data transmission through cryptography,Channel Scrambling method is discussed for secure optical transmissions at high data rates (> 10 Gb/s) so it helps to maintain the quality of transmission. The main advantage of this technique is that it can be implemented easily in current WDM systems 42. Multiple access interference (MAI) was the main limiting factor for the performance of incoherent optical code-division multiple access systems. For the purpose of eliminate the multiple access interference, one novel encoding/decoding method using ternary orthogonal sequences has been proposed and the number of code families in the SAC OCDMA networks is dramatically increased43. OCDMA on a passive optical network (PON) is considered to be an attractive, cost-effective, and complementary technology. In 44, integrated, incoherent spectral amplitude encoded (SAE) OCDMA technique used to reduce the operational expenditures. Integrated spectral optical code-division multiple-access technique has a comparable performance with respect to coherent OCDMA techniques based on a crosstalk analysis including coupler imbalance. A novelMultiple-access interference (MAI) cancellation technique using a reference signal has discussed which has no data of the desired signal that simplifies the receiver architecture in synchronous incoherent M-ary frequency-shift keying optical code-division multiple-access (FSK-OCDMA) network has been proposed45. Comparison between asynchronous coherent time-spreading optical code-division multiple-access (OCDMA) systems with spectral coding OCDMA systems using ultra short pulses has been analyzed and the results has analyzed in terms of multi-access interference46. OCDMA system architecture using the partial modified prime (PMP) codes and error-correction codes is proposed. PMP codes used to eliminate multiple-user interference and suppress phase-induced intensity noise due to the zero cross-correlation property 47.A novel incoherent transceiver architecture for the optical modulation scheme using polarization shift keying (Pol-SK) combined with optical code-division multiple-

access (OCDMA) has been discussed. The results has been accurately analyzed in terms of optical amplifier spontaneous emission (ASE) noise, electronic receiver noise, photodiode shot-noise and also multiple access interference (MAI)48.A novel architecture of an optical code division multiple access using self-heterodyne filtering (SHF) has been proposed. This method used to allow the multiple channel access with low-cost passive optical components, and standard on–off keying modulation 49. The novel address code based on the prime code (PC) families, referred to as "Enhanced-Modified PC" has been proposed for incoherent synchronous optical code-division multiple-access (OCDMA) network and evaluated in the communication systems in terms of BER. From the results it is concluded that the proposed code set is used to enhance the network capacity and power efficiency 50.A novel architecture of enhanced algorithm media access control (MAC) is used to provide quality of service in OCDMA networks. The proposed system used signalling method to provide different QoS for different users 51.The system composed novel family of codes for SAC OCDMA has been proposed .By using these codes, number of users can be increased without any essential change in the system 5253. In54 , demonstrated a 16- channel OCDMA/DWDM system 55based on new SSFBG-based coding/decoding techniques. We have evaluated that error-free performance was achieved for all 16 channels. It is also clear that DS-OCDMA based on SSFBG coding techniques is fully compatible with WDM technologies.56 A new family of three-dimensional (3-D) wavelength/ time/space codes for asynchronous optical code-division multiple access (OCDMA) systems have been proposed for improved BER performance and spectral efficiency 57. In 5859, calculated the BER performance of asynchronous coherent time-spreading OCDMA. Also compared the performance of TS- OCDMA and SC-OCDMA systems and clear that their fundamental MAI-limited performance is identical, while the considerations for receiver noise favour SC-OCDMA.60.

2.2 Gaps in optical CDMA

After the survey of literature review it is concluded that there is still some work left in design issues of optical code division multiple access. There are many design issues problems in OCDMA. Multiple access interference is a main limiting factor which degrades the performance of the system. In this thesis work, for various design issues of OCDMA system by using different type of coding techniques, MAI has been reduced. There is also gap left in hybrid Rof-OCDMA system like coding performance was not satisfactory. So, we have proposed hybrid Rof-Optical CDMA by using pseudo orthogonal coding to minimize the multiple access interference.

2.3 Motivation

The use of optical fiber communication enables transmission of data at very high rates in terms of terabits per second and beyond over distances of thousands of kilometers. Recently, there has been a lot of interest in applying the concepts of CDMA to optical fiber communication systems. According to the literature survey it has been observed that there is a lot of research has beendone on OCDMA, Researchers are still going on to develop a better O-CDMA code which will support the multimedia services .In thesis work, we have focus on optical code division multiple access system by using pseudo orthogonal coding which helps to reduce the need of bandwidth expansion and improve spectral efficiency. In this, we have also done work on SAC-OCDMA and hybrid ROF-OCDMA. Spectral amplitude coding scheme attracts increasing interest because multiple access interference (MAI) can be eliminated and preserve the orthogonality between users in the system Codes that can support various traffic demands in terms of bandwidth and Bit Error Rate (BER) performance. Moreover, it is logical to search for new OCDMA implementations that can meet the expected performance requirements in a simple and cost effective way.

2.4 Problem statement

Our problem is to design Optical Code Division Multiple Access system using pseudo orthogonal coding which helps to reduce the need of bandwidth expansion and improve spectral efficiency and we analyze the performance with high data rate and enhance the performance of multiuser-OCDMA system.

2.5 Objectives

Based on the gaps available in the literature we proposed following objectives:

- To design optical CDMA system using pseudo orthogonal coding which help to reduce the bandwidth expansion and enhance the performance of multi user OCDMA system.

2.6Methodologys

The very first step of any project work is to study about the area which is related to project topic. After the survey of literature review, it is found that how optical fiber communication and optical code division multiple access give benefits for high quality transmission. From study of basic domain we come to know that what work has been done in India and Abroad. For high transmission, it is necessary to encode and decode the data under different coding techniques.

CHAPTER 3

Performance system Analysis of Optical Code Division Multiplex

3.1 General

This chapter presents the Pseudo-Orthogonal Code generator for Optical Code Division Multiple Access (OCDMA) system which helps to reduce the need of bandwidth expansion and improve spectral efficiency. In this chapter, we investigate the performance of multi-user OCDMA system to achieve data rate more than 1 Tb/sec.

3.2 Introduction

OCDMA is technique to support large no of users using available frequency with no time delay [60] .Comparison of OCDMA with different techniques. OCDMA have many advantages over TDMA and WDMA61Compare coherent and incoherent detection techniques in OCDMA. Coherent detection has phase information of carriers but incoherent detection has no such type of information. Coherent detection performed in bipolar approach but on the other hand incoherent detection performed in unipolar approach . 62Spectral-Amplitude-Coding (SAC) technique used to remove the effect of MAI (multi-access-interference).The SAC-OCDMA technique enhance the physical bandwidth of the channel.63.Different detection techniques of SAC-OCDMA used to overcome the effect of MAI (multi-access-interference). Generally Coherent and Incoherent detection technique used to reduce the effect of MAI 64. Comparison of OCDMA and WDM PON and discussed OCDMA is better solution for symmetric traffic in PON 65. Even though OCDMA-WDM-PON best for NG-OAN but complexity and cost effected the system. Also compare with WDM-PON on the basis of performance of noise and spectral efficiency 66.This paper presents the trends and features of OCDMA techniques in communication systems. Also explained different OCDMA techniques such as 1d, 2d and spectrally-encoded ultrashort light pulse CDMA 67. In this performance of subcarrier multiplexed spectral-amplitude-coding optical code division multiple access (SCM SAC-OCDMA) system based on two techniques i.e. AND subtraction technique and complementary subtraction technique. Also discussed that AND subtraction technique provides better performance because this technique requires less no. of filters in the decoder 68. The main problem in OCDMA is OCDMA suffers from multi-access-interference (MAI) and fiber dispersion 69.This paper focus on the hybrid OCDMA system

which allows high user capacity means supports 16000 to 32000 users. Chaotic optical codes used to reduce the interference

between parallel transmission 70.Construction and architecture of WDM-OCDMA-PON which allows to achieve asynchronous transmission speed .Encoder/Decoder (E/D) used to generate codes at the rate of 2.56Tbps over 50km fiber 71. Construction and architecture of wavelength division multiplexing-passive optical networks (XDMA-WDM-PON) which has three solutions TDMA, OCDMA and OFDMA which is essential for optical access networks of the future. Also discussed OFDMA-WDM-PON architecture is best for optical access networks of the future.Then analyzed the performance of SAC-OCDMA system using Modified Double Weight (MDW) code with NAND detection and complementary subtraction techniques. The result shows that NAND detection technique with MDW code provides better performance and also supports more users 72. We have already achieved good results within MIMO-OFDM system with OADM recently for optical-OFDM system and Monitoring and Compensation of Optical Telecommunication Channels 73

3.3 Fundamentals of OCDMA

The basic principle of coding and decoding of OCDMA is defined. In coding operation, the spectrum of data signal is broadened as spread spectrum designation. Each user has been assigned a code sequences to share the same bandwidth using power splitters or combiners. This operation can be performed in the optical-domain. Decoders at the receiver recognize a target code by employing match filtering. It is important to produce high auto-correlations of desired codes, while undesired codes produce cross correlation with low-level power. An excellent code design has a relatively high code length with high auto-correlation for many users. This operation can be performed in the electrical-domain to recover the original data.

3.4 System Setup

In this system we have 10 users for encoder but for simplicity we have taken only 3 users out of 10users as shown in fig 3.1. Four wavelengths used for this system i.e.1.55e-06, 1.5504e-06, 1.5508e-06 and 1.5512e-06.In this system we are taking four lasers to produce dense WDM light source, Delay and Inverse delay are used in Encoders and decoders .In this system, ten users stransmitting data at high data rate i.e.9.95Gbps. The encoded data from these 3users get multiplexed and then passed through the 60-km span of standard single mode fiber. The output from standard fiber gets de multiplexed and then output passed to user's decoder. This decoded signal then arrives at receiver and BER tester. In this paper we consider 10 users for encoder,

encoder output from 10 users multiplexed. Losses occur in the encoded output because of more number of users at high data rate. After receiving output, we can observe the results in the presence of MAI and without presence of MAI. MAI is directly affected by number of users if number of users increase then it will enhance the MAI.

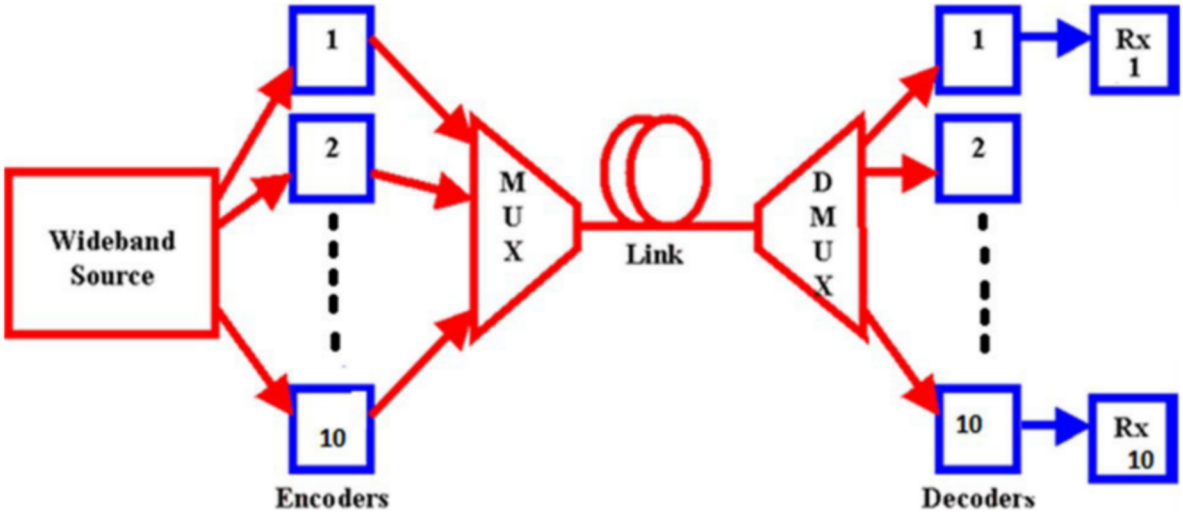


Figure 3.1 Block Diagram of OCDMA for 10 users

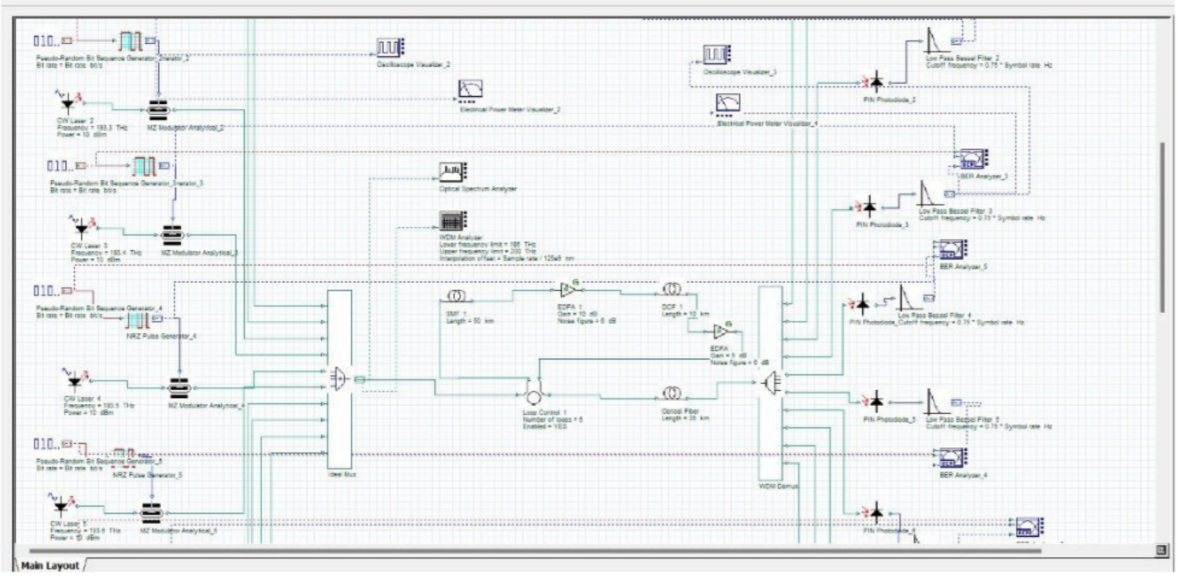


Figure 3.2 Simulation Setup

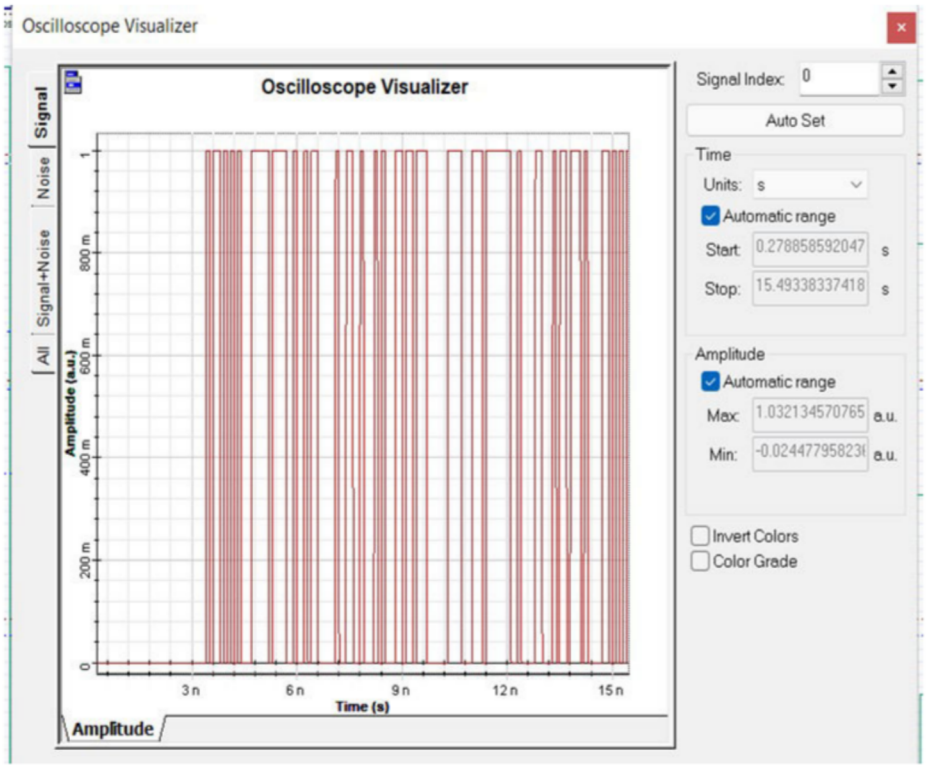


Figure 3.3 oscilloscope visualizer

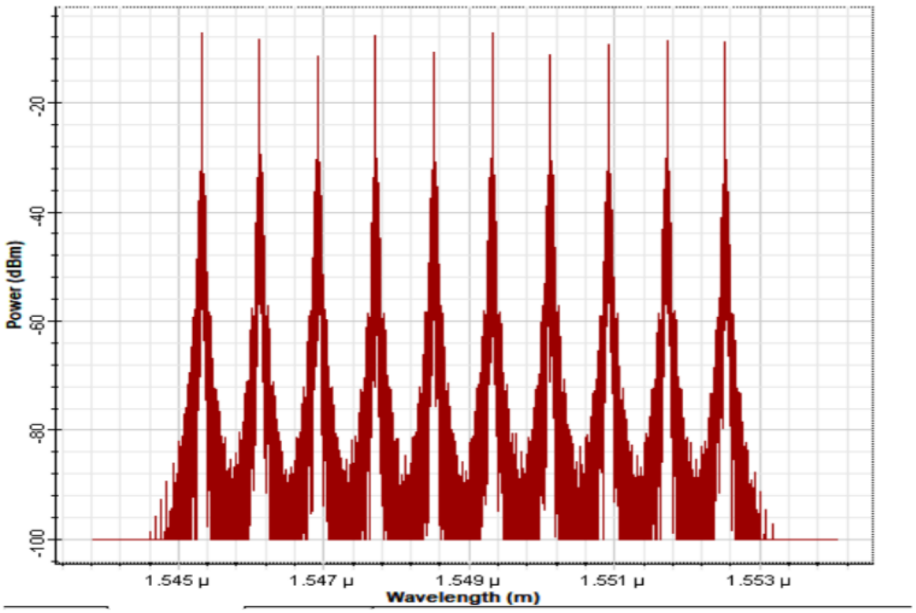


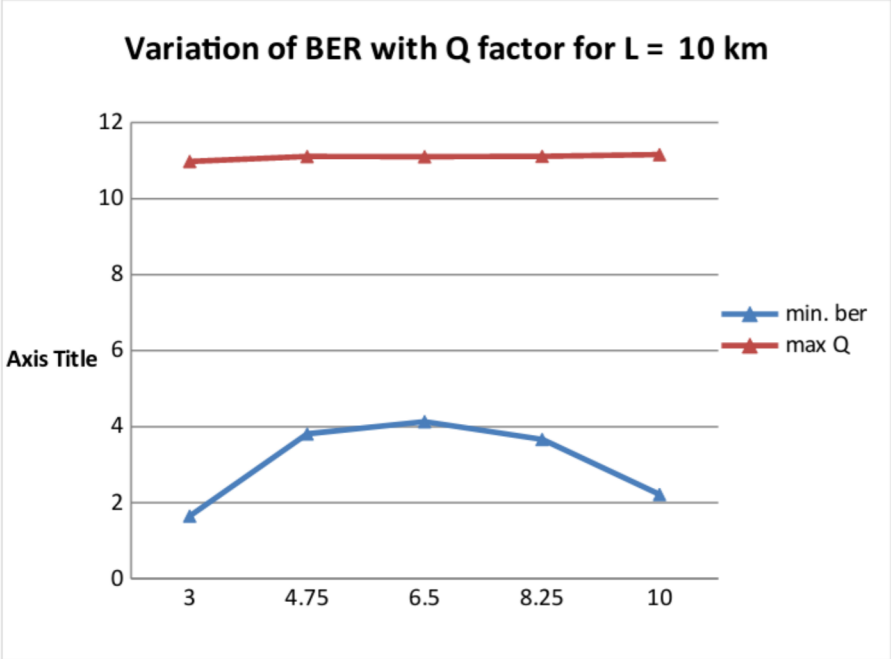
Figure3.4 Spectrum before encoding at user

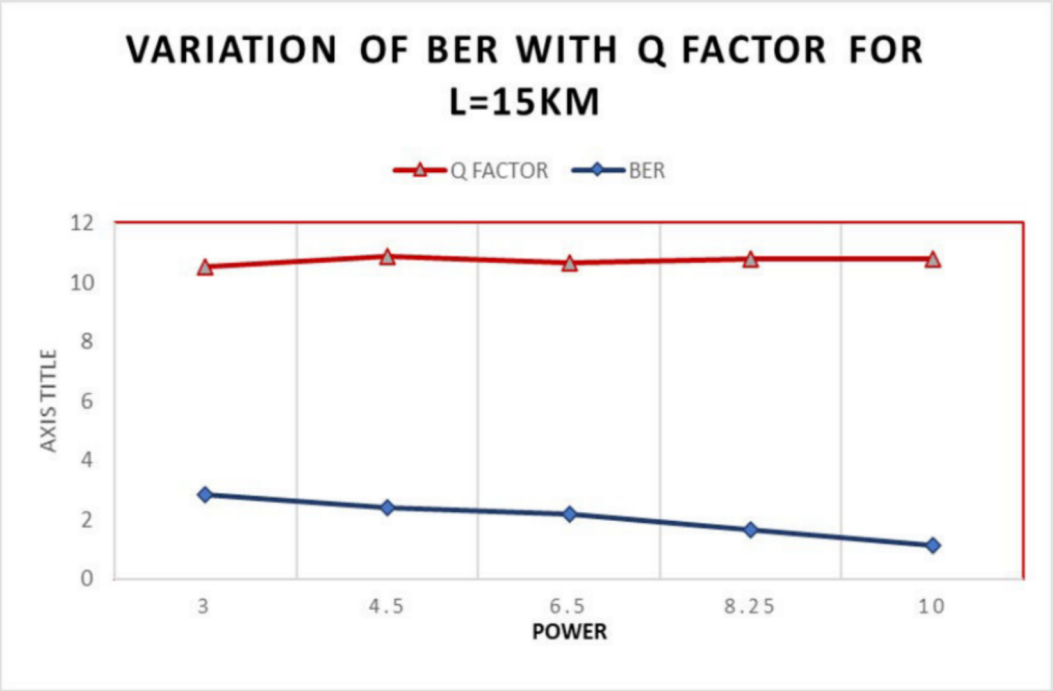
3.5 Results and discussions

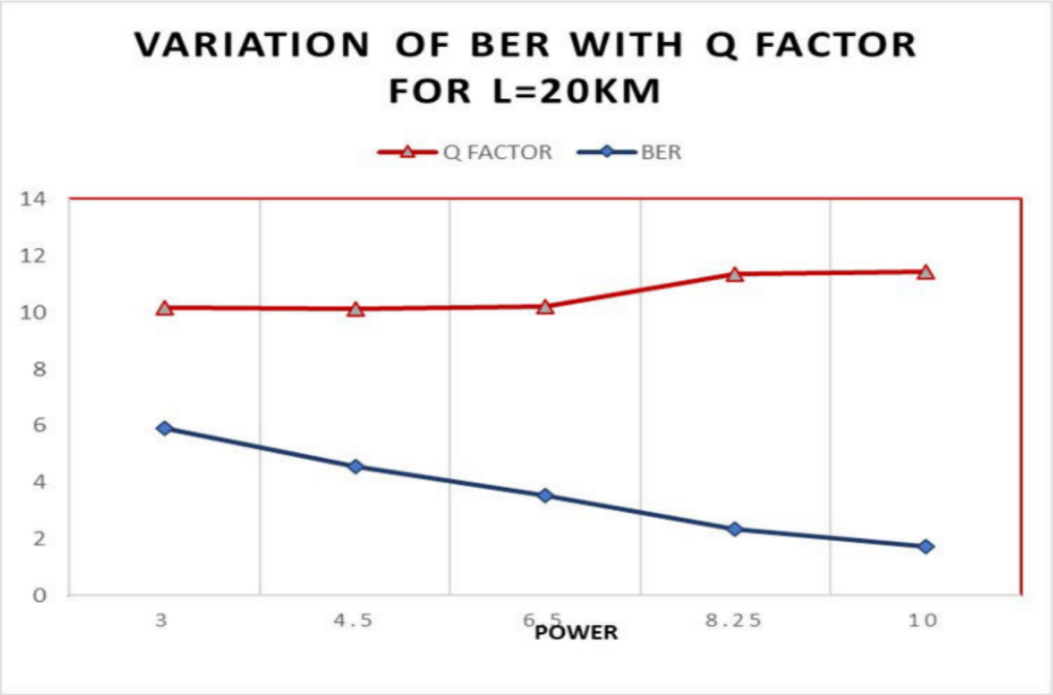
Table 3.5 shows the value of power is varied with the value of BER for L=10 Km to L=50Km.We also noticed Q factor for three users at different lengths.

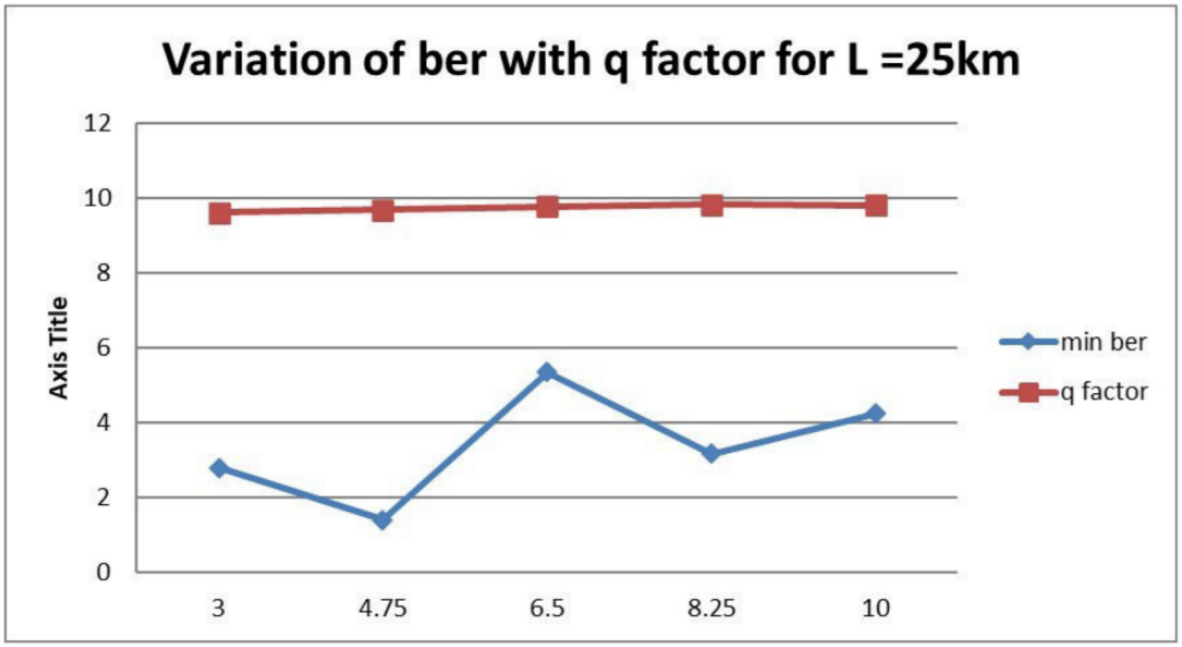
Table 3.5 Variation of BER with Power for Different Lengths

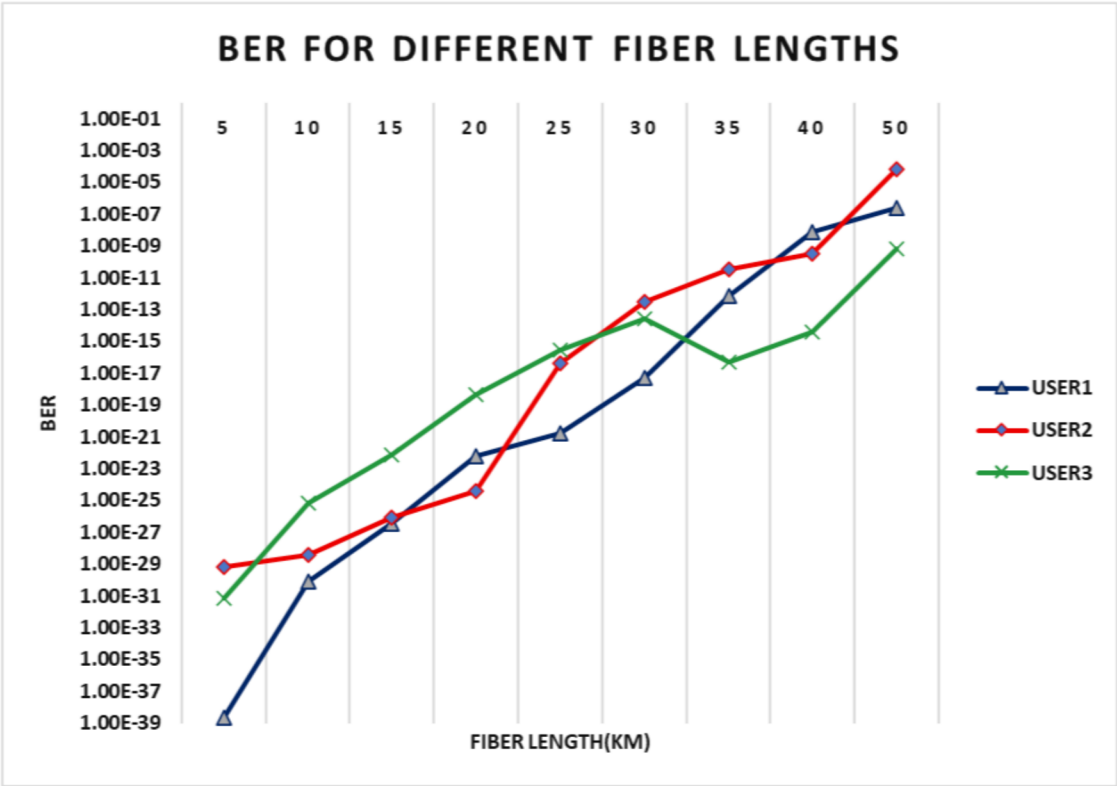
POWER (dbm)	5km		10KM		15KM		20KM		25KM	
	Q factor	BER	Q factor	BER	Q factor	BER	Q factor	BER	Q factor	BER
3	11.3728	1.911526e-031	10.9784	1.64839e-028	10.5485	1.82532e-026	10.1679	9.91305e-025	9.60718	2.78738e-022
4.75	11.3318	3.05355e-030	11.1108	3.8102e-029	10.8938	4.4122e-028	10.123	1.56754e-024	9.67659	1.4092e-022
6.5	11.4749	5.93146e-031	11.103	4.12995e-029	10.6773	4.56391e-027	10.2087	6.55933e-025	9.77613	5.34393e-023
8.25	11.3385	2.85605e-030	11.1148	3.66563e-029	10.7718	1.65066e-027	10.3616	1.33478e-025	9.82725	3.17117e-023
10	11.37781	1.80419e-030	11.1589	2.21732e-029	10.8075	1.11988e-027	10.442	5.75276e-026	9.79802	4.24421e-023




VARIATION OF BER WITH Q FACTOR FOR L=15KM
Q FACTOR
BER
AXIS TITLE
12
10
8
6
4
2
0
3
4.5
6.5
8.25
10
POWER


VARIATION OF BER WITH Q FACTOR FOR L=20KM
Q FACTOR
BER
14
12
10
8
6
4
2
0
3
4.5
6.5
8.25
10
POWER





To observe the eye diagram first we connect user 1 for encoder to multiplexer and run simulation to analyze the result at decoder .The eye diagram without presence of MAI with 1user ..In this

case User 1 decoder has no MAI(multi access interference) at the receiver end. This figure shows 1 user 4 slots for user 1.From this eye diagram it is clear that it has no multi access interference .The corresponding Q factor and BER is Q=21.3dB and BER=2.2e-31. Next, we can connect encoder for User 2 to the multiplexer and re-run simulation to observe at Decoder for User 2. The eye diagram degradation in the presence of MAI with 2 users.

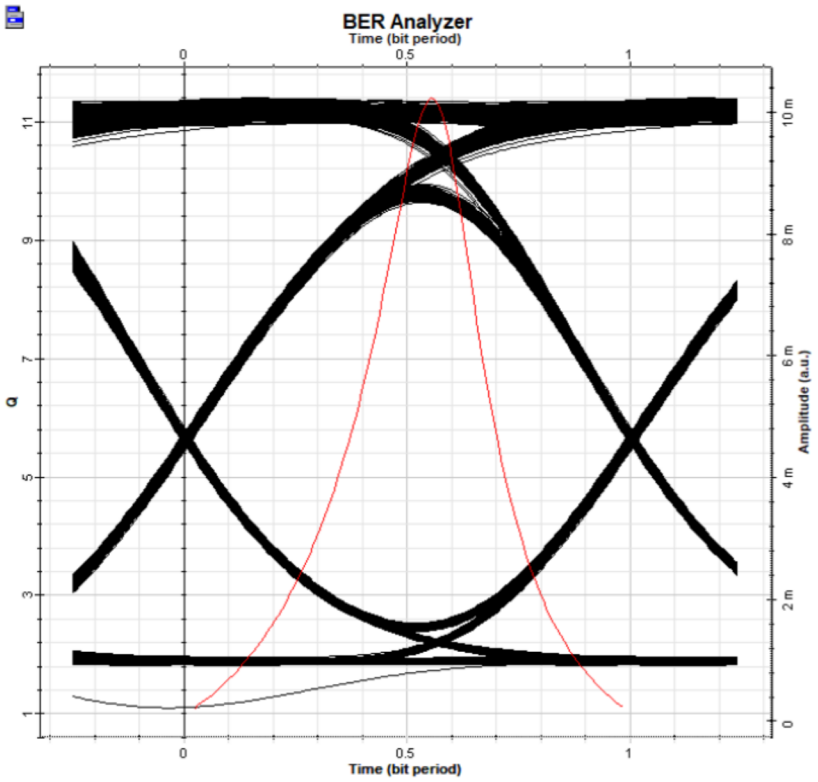


Figure 3.6 Received eye diagram at 10dBm

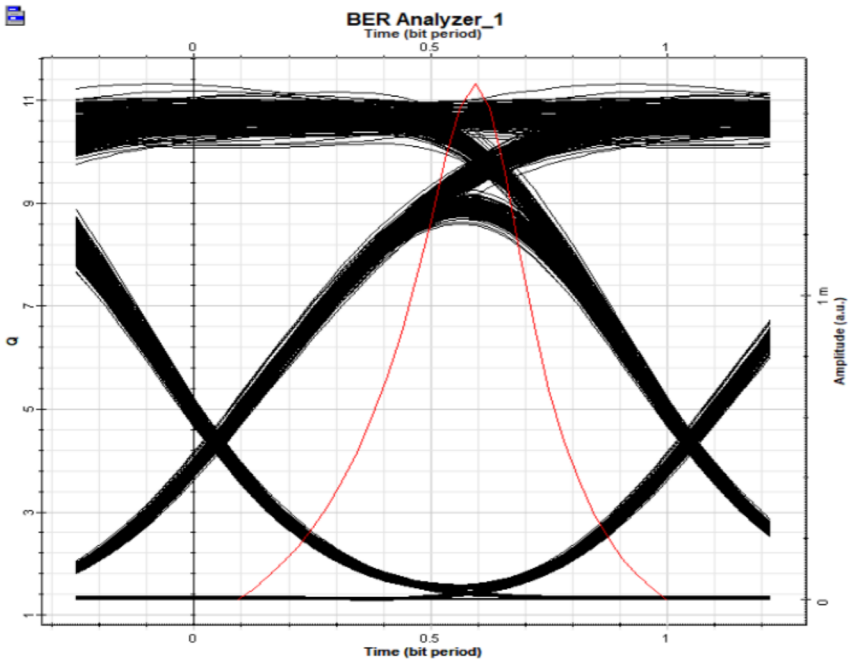


Figure3.7 Received eye diagram at 3dBm

This figure shows that the eye diagram at user 2.In this case 1 user 4 slots for user 2.This spectrum shows eye diagram in the presence of MAI(multi access interference).This shows eye diagram degradation in the presence of MAI. The corresponding Q factor and BER is Q=11.6164dB and BER=1.14294e-031.In this case we can observe the result in the presence of multi access interference (MAI), we have sufficient value of Q and BER. These figures show the results for the OCDMA with optical fiber length of 50km using Pseudo-Orthogonal Coding technique. The eye patterns show that the user 1 for encoder without interference gave a better performance. The BER for user 1 and user 2 is 2.2e-31 and5.5e-25, respectively. Hence we can visualize the performance degradation in the presence of multiple users due to MAI and we can add more users and analyze the result of eye diagrams in the presence of MAI.

3.6 Conclusion

The performance of the OCDMA system with the Pseudo-Orthogonal Code technique using high data rate has been presented. The results of the experimental simulation have proved that the OCDMA provides a better performance even when we are using multi users. Also discussed the effect of MAI (multi access interference), as we are increasing number of users, the influence of MAIAlso.

CHAPTER 4

Conclusions and Future Scopes

4.1 Conclusions

Firstly, The Optical CDMA system has been designed using pseudo orthogonal coding which helps to reduce the need of bandwidth expansion and improve spectral efficiency and we analyze the performance with high data rate and enhance the performance of multiuser-OCDMA system. Optsim software was used to access the propagation of these codes at high data rates over a long span fiber. The optical CDMA system has been designed for multi-user OCDMA system to achieve data rate more than 1 Tb/sec. It has been observed that in the bit error rate performance curve the error is decreased when the number of subscriber is increased side by side the optical power is reduced when the users is added. Various graphs have been taken to evaluate the bit-error-rate (BER) and the Q factor. Eye diagrams have been taken at different stages in OCDMA system in order to study the effect of multiuser. Received signal is also measured in all the cases.

4.2 Future Scopes

In this Thesis, the work is limited to coding techniques like Pseudo orthogonal coding and Spectral amplitude coding. Their various aspects like modulation formats and security have been considered. One important technique OFDM (Orthogonal Frequency Division Multiplexing) is not considered in this work. The present work can be enhanced by combining these OCDMA systems with Orthogonal Frequency Division Multiplexing. Moreover, multiple access interference is the main limiting factor of the OCDMA systems. It increases with the increases in number of users. Further work can be done to reduce the MAI. The timing jitter can also be studied with different modulation formats .

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