PERFORMANCE ANALYSIS OF OPTICAL CDMA IN TRANSMISSION SYSTEMS

A Thesis
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of
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DECLARATION

I hereby declare that this thesis is based on the results found by myself. Materials of work found by other researcher are mentioned by reference. This theis, neither in whole nor in part, has been previously submitted for any degree.

Signature of
Supervisor

Signature of
Author

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We would also like to thanks to our family and friends for their support as this thesis could not be completed without their support and encouragement. We are very much thankful to them.

Abstract

Performance of an optical code division multiple access (OCDMA) system are evaluated to determine the impact of multi access interference for a given number of users. Analog clock include the effect of fiber non linearity such as cross phase modulation and the cross talk due to XPM. The expression for the signal MAI and cross talk are derived for a single mode fiber transmission link operating at gigabit per second. Performance results are evaluated 1 Gbps & 10 Gbps with different codes like M-system, gold sequence and pn-sequence to compare their relative performance. The optimum system design parameters are determined at a specific BER (bit error rate).

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CHAPTER- 1

Introduction

1.0. Introduction:

Communication may be broadly defined as the transfer of information from one point to another. When the information is to be conveyed over any distance a communications system is usually required. Within a communication system the information transfer is frequently achieved by the superimposing or modulating the information on to an electromagnetic wave which acts as a carrier for the information signal. This modulated carrier is then transmitted to the required destination where it is received and the original information signal is obtained by demodulation. Sophisticated techniques have been developed for this process using electromagnetic carrier waves operating at ratio frequencies as well as microwave and millimeter wave frequencies. However, communication may be also be achieved using an electromagnetic carrier which is selected from the optical range frequencies.

Modern world is standing on the progress of communication system. Now a day we can't think a day without communication system. We are totally depending on this system. Our concern is communication system based on electrical signal. Electrical communication is reliable and economical; communication technology is alleviating the energy crisis by trading information processing for more rational use of energy resources.

There are various types of electrical communication system. They are microwave communication, radio frequency communication, very high frequency communication, optical fiber communication.

Figure.1.0. Shows the components of a communication system are as follows: The source originates a message (such as human voice) it must be converted by an input transducer into an electrical waveform referred to as the message signal.

The transmitter modified the base band signal for efficient transmission.
The channel is a medium such as wire, coaxial cable, a waveguide an Optical fiber or a radio link-through which the transmitter output is same.
The receiver reprocesses the signal received from the channel by undoing the signal modification made at the transmitter and the channel.
The receiver output is fed to the output transducer which converts the electrical signal to its original form.

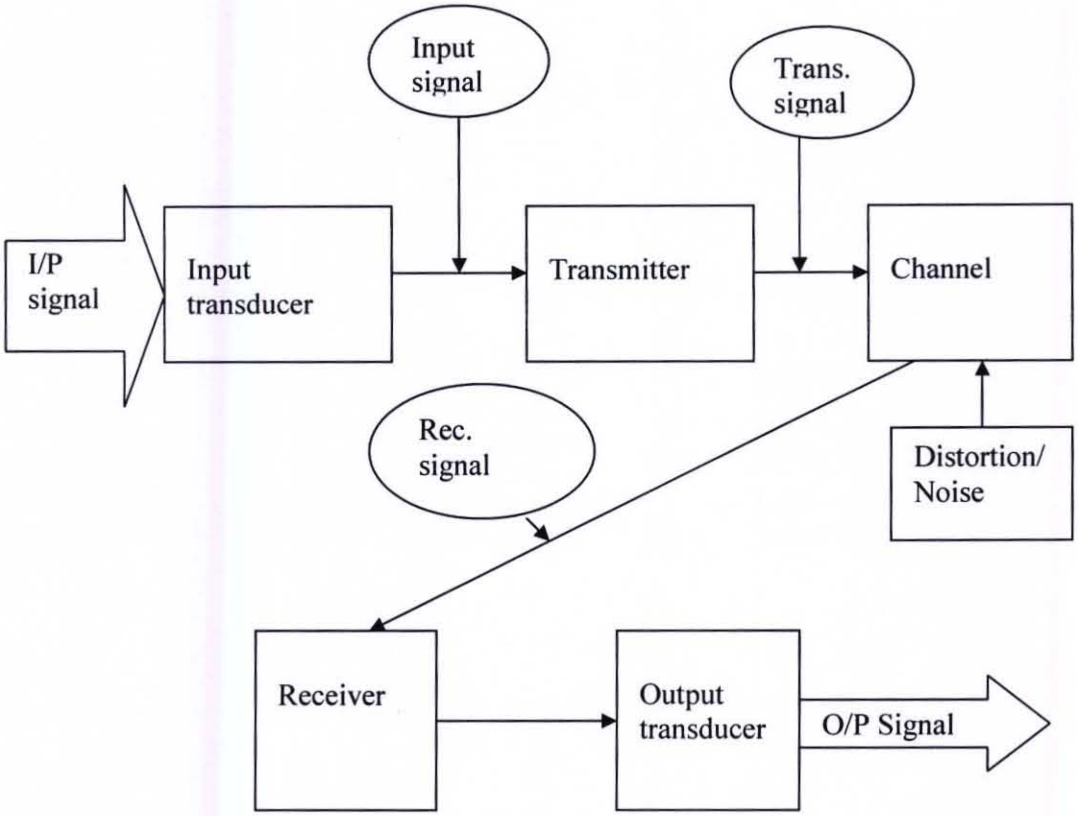

Fig: 1.0. Basic Block Diagram of communication system

The destination is the unique to which the message is communicated.
A channel acts partly as filter to attenuate the signal and distort this waveform. The signal attenuation increases with length of the channel, varying from a few percent for short distance to orders of magnitude for interplanetary communication. The waveform is distorted because of different amounts of attenuation and phase shift suffered by different frequency component of the signal. For example a square pulse is rounded or spread out during the

transmission. This type of distortion, called linear distortion, can be partly corrected by
the receiver by an equalizer. The channel may also cause nonlinear distortion through attenuation that varies with the signal amplitude.

The signal may also damage by noise which are random and unpredictable signals from causes external and internal. External noise includes interference from signals transmitted on nearby channels, human made noise generated by electrical equipment.
With proper care this noise can be minimized or even eliminated. Internal noise results from the thermal motions from electrons in conductors. Proper care can reduce the effect of internal noise but can be never eliminated.

The signal-to-noise ratio (SNR) is defined as the ratio of the signal power to noise power. Channel distorts the signal, and noise accumulates along the parts. Worse yet, the signal strength decreases while the noise level increases with distance from the transmitter. Thus the SNR is continuously decreasing along the length of the channel.

1.1. Different Types of communication system

1. **Radio frequency communication (RF)**
2. **Very high frequency(VHF)**
3. **Micro wave communication(MW)**
4. **Optical communication**

1.1.0 Radio frequency:

Radio frequency (RF) is a frequency or rate of oscillation within the range of about 3 Hz to 300 GHz. This range corresponds to frequency of alternating current electrical signals used to produce and detect radio waves. Since most of this range is beyond the vibration rate that most mechanical systems can respond to, RF usually refers to oscillations in electrical circuits.

A range of Radio frequencies that defines allowable or usable channels for specific radio transmission technologies. Radio Spectrum is typically Government regulated in most developed countries and in some cases sold or licensed to operators of private radio transmission systems. (E.g. Cellular telephone operators or Broadcast Television Stations). The range of allocated frequencies is often referred to by the provisioned use. (e.g. Cellular Telephone Spectrum or Broadcast Television Spectrum)

Radio spectrum is below or lowers in frequency than Infrared spectrum or visible frequencies, also known as light.

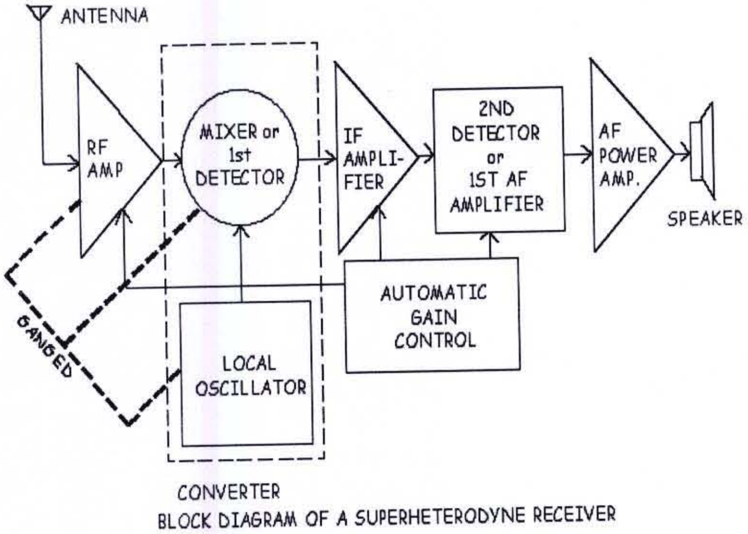

Fig: 1.1 Block diagram of radio frequency

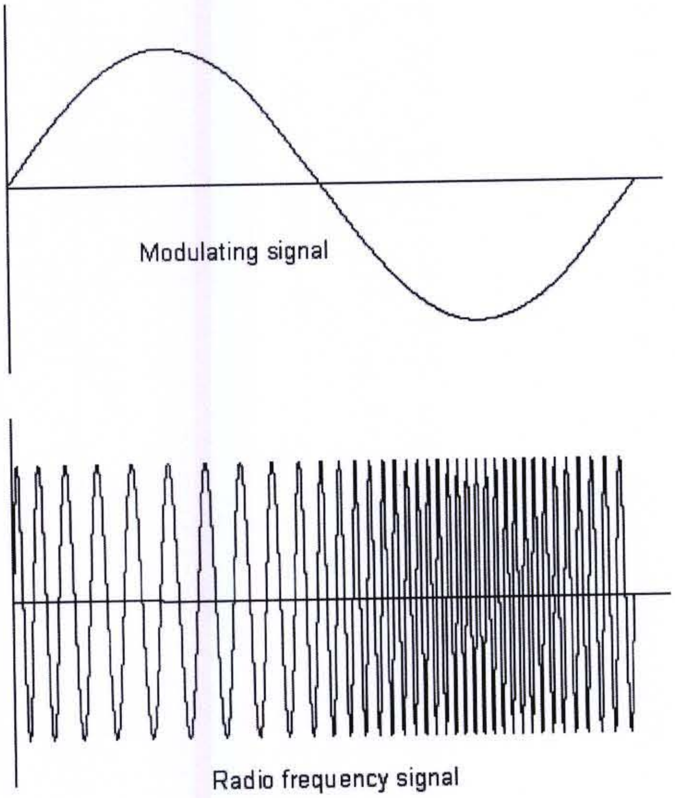

Fig.1.2. Waveform a modulating signal and the converted FM signal

1.1.1. Very high frequency:

VHF (Very high frequency) is the radio frequency range from 30 MHz to 300 MHz. Frequencies immediately below VHF are denoted High frequency (HF), and the next higher frequencies are known as Ultra high frequency (UHF). The wavelengths corresponding to these limit frequencies are 10 meters and 1 meter. The frequency allocation is done by ITU. Common uses for VHF are FM radio broadcast, television broadcast, land mobile stations (emergency, business, and military), Amateur Radio, marine communications, air traffic control communications and air navigation systems (e.g. VOR, DME & ILS).

In the VHF band, electromagnetic fields are affected by the earth's ionosphere and troposphere. Ionosphere propagation occurs regularly in the lower part of the VHF spectrum, mostly at frequencies below 70 MHz. In this mode, the communication range can sometimes extend over the entire surface of the earth. The troposphere can cause bending, ducting, and scattering, extending the range of communication significantly beyond the visual horizon. Auroral, meteor-scatter, and EME (earth-moon-earth, also called moon bounce) propagation take place on occasion, but these modes do not offer reliable communication and are of interest primarily to amateur radio operators.

The VHF band is popular for mobile two-way radio communication. A great deal of satellite communication and broadcasting is done at VHF. Wideband modulation is used by some services; the most common example is fast-scan television broadcasting. Channels and sub bands within the VHF portion of the radio spectrum are allocated by the International Telecommunication Union (ITU).

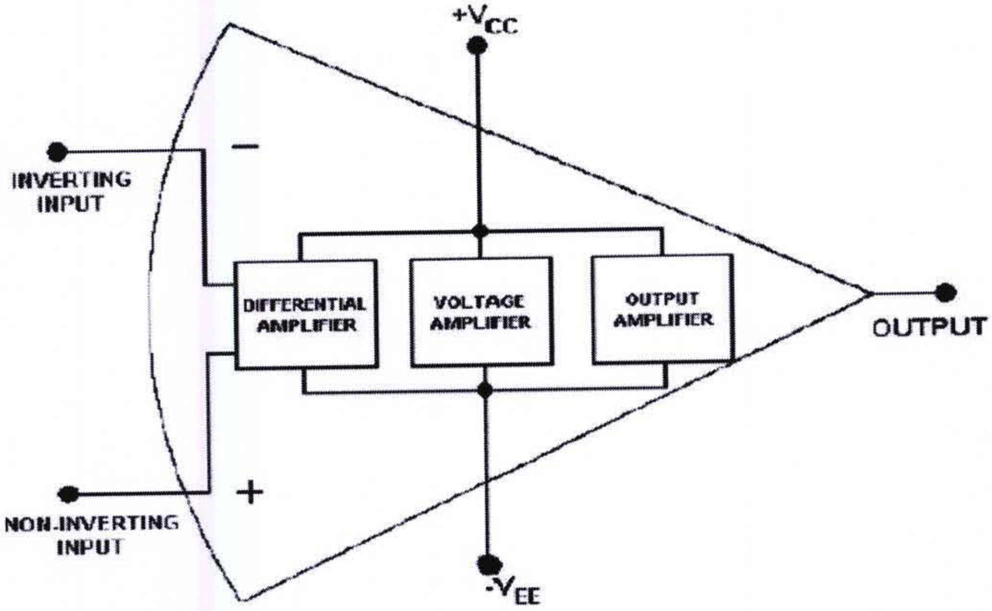

Fig: 1.3. Block diagram of VHF

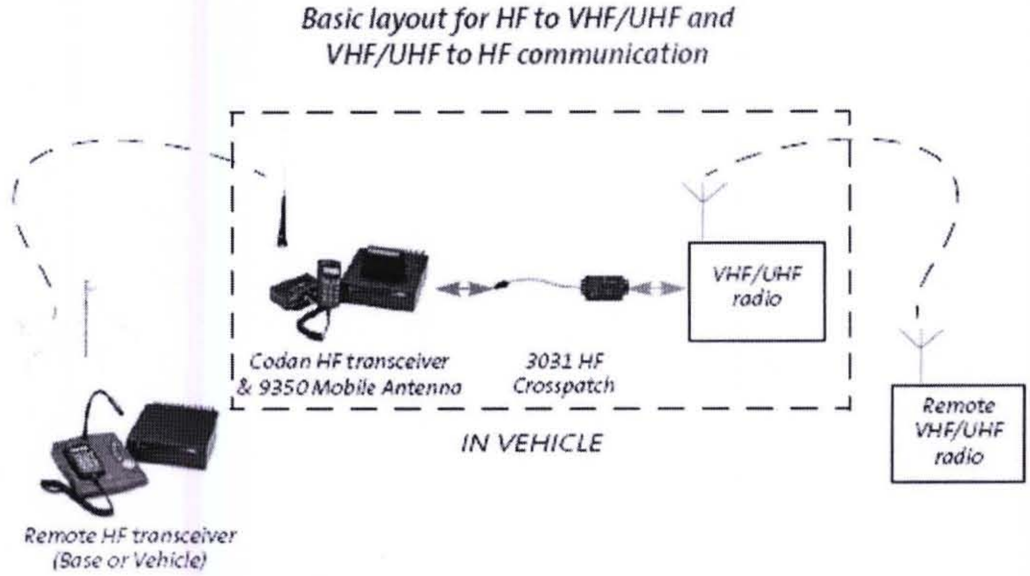

Fig: 1.4. Block diagram of a basic layout for HF to VF/UHF and VHF/UHF to HF communication.

1.1.2.0 Micro wave:

Microwaves are electromagnetic waves with wavelengths ranging from 1 m down to 1 mm, or equivalently, with frequencies between 0.3 GHz and 300 GHz.

Apparatus and techniques may be described qualitatively as "microwave" when the wavelengths of signals are roughly the same as the dimensions of the equipment, so that lumped-element circuit theory is inaccurate. As a consequence, practical microwave technique tends to move away from the discrete resistors, capacitors, and inductors used with lower frequency radio waves. Instead, distributed circuit elements and transmission-line theory are more useful methods for design and analysis. Open-wire and coaxial transmission lines give way to waveguides, and lumped-element tuned circuits are replaced by cavity resonators or resonant lines. Effects of reflection, polarization, scattering, diffraction and atmospheric absorption usually associated with visible light are of practical significance in the study of microwave propagation. The same equations of electromagnetic theory apply at all frequencies.

While the name may suggest a micrometer wavelength, it is better understood as indicating wavelengths very much smaller than those used in radio broadcasting. The boundaries between far infrared light, terahertz radiation, microwaves, and ultra-high-frequency radio waves are fairly arbitrary and are used variously between different fields of study. The term microwave generally refers to "alternating current signals with frequencies between 0.3 GHz (3×10^8 Hz) and 300 GHz (3×10^{11} Hz)."[1] Both IEC standard 60050 and IEEE standard 100 define "microwave" frequencies starting at 1 GHz (30 cm wavelength).

Electromagnetic waves longer (lower frequency) than microwaves are called "radio waves". Electromagnetic radiation with shorter wavelengths may be called "millimeter waves", terahertz radiation or even *T-rays*. Definitions differ for millimeter wave band, which the IEEE defines as 110 GHz to 300 GHz.

1.1.2.1. Frequency:

The microwave range includes ultra-high frequency (UHF) (0.3–3 GHz), super high frequency (SHF) (3–30 GHz), and extremely high frequency (EHF) (30–300 GHz) signals.

Above 300 GHz, the absorption of electromagnetic radiation by Earth's atmosphere is so great that it is effectively opaque, until the atmosphere becomes transparent again in the so-called infrared and optical window frequency ranges.

1.1.2.2. Uses:

1.1.2.2a. Communication

- Before the advent of fiber optic transmission, most long distance telephone calls were carried via microwave point-to-point links through sites like the AT&T Long Lines. Starting in the early 1950s, frequency division multiplex was used to send up to 5,400 telephone channels on each microwave radio channel, with as many as ten radio channels combined into one antenna for the *hop* to the next site, up to 70 km away.

- Wireless LAN protocols, such as Bluetooth and the IEEE 802.11 specifications, also use microwaves in the 2.4 GHz ISM band, although 802.11a uses ISM band and U-NII frequencies in the 5 GHz range. Licensed long-range (up to about 25 km) Wireless Internet Access services have been used for almost a decade in many countries in the 3.5–4.0 GHz range. The FCC recently carved out spectrum for carriers that wish to offer services in this range in the U.S.—with emphasis on 3.65 GHz. Dozens of service providers across the country are securing or have already received licenses from the FCC to operate in this band. The WIMAX service offerings that can be carried on the 3.65 GHz band will give business customers another option for connectivity.

- Metropolitan Area Networks: MAN protocols, such as WiMAX (Worldwide Interoperability for Microwave Access) based in the IEEE 802.16 specification. The IEEE 802.16 specification was designed to operate between 2 to 11 GHz. The commercial implementations are in the 2.3 GHz, 2.5 GHz, 3.5 GHz and 5.8 GHz ranges.

- Wide Area Mobile Broadband Wireless Access: MBWA protocols based on standards specifications such as IEEE 802.20 or ATIS/ANSI HC-SDMA (e.g. burst) are designed to operate between 1.6 and 2.3 GHz to give mobility and in-building penetration characteristics similar to mobile phones but with vastly greater spectral efficiency.

Cable TV and Internet access on coaxial cable as well as broadcast television use some of the lower microwave frequencies. Some mobile phone networks, like GSM, also use the lower microwave frequencies.

Microwave radio is used in broadcasting and telecommunication transmissions because, due to their short wavelength, highly directive antennas are smaller and therefore more practical than they would be at longer wavelengths (lower frequencies). There is also more bandwidth in the microwave spectrum than in the rest of the radio spectrum; the usable bandwidth below 300 MHz is less than 300 MHz while many GHz can be used above 300 MHz. Typically, microwaves are used in television news to transmit a signal from a remote location to a television station from a specially equipped van.

Most satellite communications systems operate in the C, X, Ka, or Ku Bands of the microwave spectrum. These frequencies allow large bandwidth while avoiding the crowded UHF frequencies and staying below the atmospheric absorption of EHF frequencies. Satellite TV either operates in the C band for the traditional large dish Fixed Satellite Service or Ku band for Direct Broadcast Satellite. Military communications run primarily over X or Ku Band links, with Ka band being used for Milstar.

1.1.2.2b. Remote sensing

Radar uses microwave radiation to detect the range, speed, and other characteristics of remote objects. Development of radar was accelerated during World War II due to its great military utility. Now radar is widely used for applications such as air traffic control, weather forecasting, navigation of ships, and speed limit enforcement.

A Gunn diode oscillator and waveguide are used as a motion detector for automatic door openers (although these are being replaced by ultrasonic devices).

Most radio astronomy uses microwave.

1.1.2.2c. Navigation

Global Navigation Satellite Systems (GNSS) including the Chinese Beidou, the American Global Positioning System (GPS) and the Russian GLONASS broadcast navigational signals in various bands between about 1.2 GHz and 1.6 GHz.

1.1.2.2d. Power

A microwave oven passes (non-ionizing) microwave radiation (at a frequency near 2.45 GHz) through food, causing dielectric heating by absorption of energy in the water, fats and sugar contained in the food. Microwave ovens became common kitchen appliances in Western countries in the late 1970s, following development of inexpensive cavity magnetrons.

Microwave heating is used in industrial processes for drying and curing products.

Many semiconductor processing techniques use microwaves to generate plasma for such purposes as reactive ion etching and plasma-enhanced chemical vapor deposition (PECVD).

Microwaves can be used to transmit power over long distances, and post-World War II research was done to examine possibilities. NASA worked in the 1970s and early 1980s to research the possibilities of using Solar power satellite (SPS) systems with large solar arrays that would beam power down to the Earth's surface via microwaves.

Less-than-lethal weaponry exists that uses millimeter waves to heat a thin layer of human skin to an intolerable temperature so as to make the targeted person move away. A two-second burst of the 95 GHz focused beam heats the skin to a temperature of 130 °F (54 °C) at a depth of 1/64th of an inch (0.4 mm). The United States Air Force and Marines are currently using this type of Active Denial System.[2]

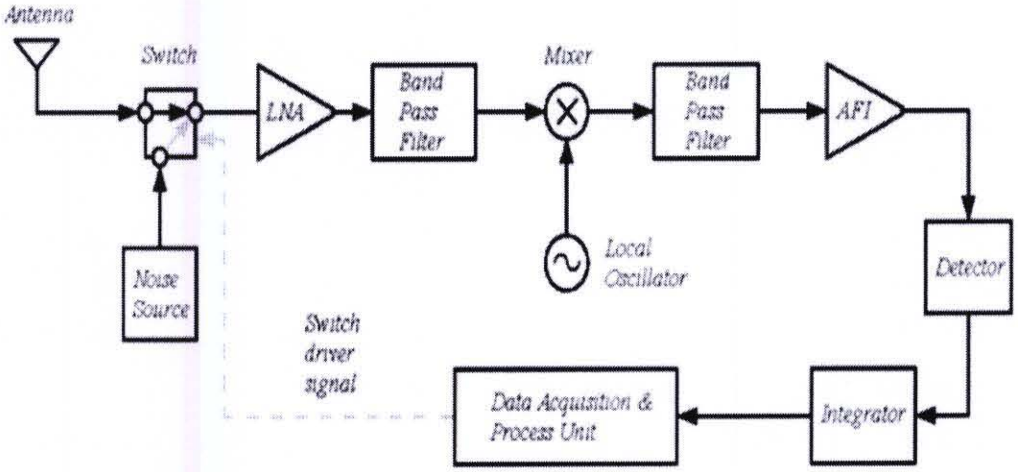

Fig: 1.5. Block diagram of microwave communication system

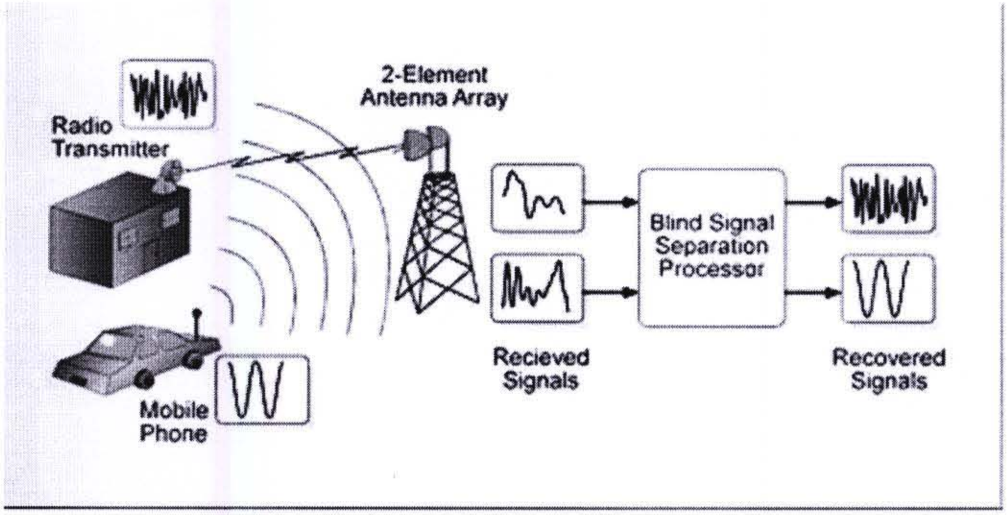

Fig: 1.6. Block diagram of microwave communication system

1.1.3. Optical communication:

Optical fiber can be used as a medium for telecommunication and networking because it is flexible and can be bundled as cables. It is especially advantageous for long-distance communications, because light propagates through the fiber with little attenuation compared to electrical cables. This allows long distances to be spanned with few repeaters. Additionally, the per-channel light signals propagating in the fiber can be modulated at rates as high as 111 gigabits per second, although 10 or 40 Gb/s is typical in deployed systems. Each fiber can carry many independent channels, each using a different wavelength of light (wavelength-division multiplexing (WDM)). The net data rate (data rate without overhead bytes) per fiber is the per-channel data rate reduced by the FEC overhead, multiplied by the number of channels (usually up to eighty in commercial dense WDM systems as of 2008).

Over short distances, such as networking within a building, fiber saves space in cable ducts because a single fiber can carry much more data than a single electrical cable. Fiber is also immune to electrical interference; there is no cross-talk between signals in different cables and no pickup of environmental noise. Non-armored fiber cables do not conduct electricity, which makes fiber a good solution for protecting communications equipment located in high voltage environments such as power generation facilities, or metal communication structures prone to lightning strikes. They can also be used in environments where explosive fumes are present, without danger of ignition. Wiretapping is more difficult compared to electrical connections, and there are concentric dual core fibers that are said to be tap-proof.

Although fibers can be made out of transparent plastic, glass, or a combination of the two, the fibers used in long-distance telecommunications applications are always glass, because of the lower optical attenuation. Both multi-mode and single-mode fibers are used in communications, with multi-mode fiber used mostly for short distances, up to 550 m (600 yards), and single-mode fiber used for longer distance links. Because of the tighter tolerances required to couple light into and between single-mode fibers (core diameter about 10 micrometers), single-mode transmitters, receivers, amplifiers and other components are generally more expensive than multi-mode components.

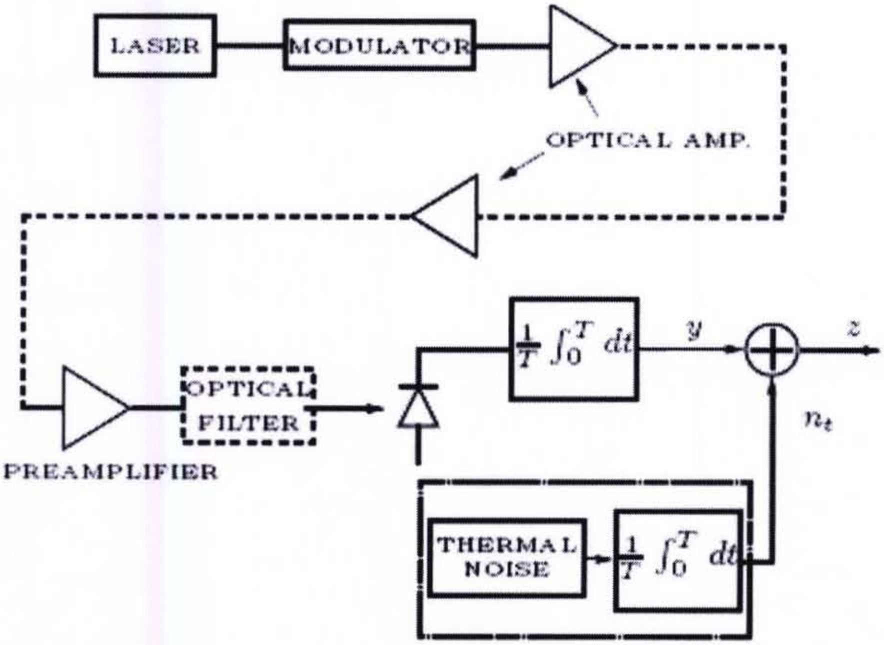

Fig: 1.7. Block diagram of an optical communication system

1.2. Basic for Optical CDMA:

Code division multiple access (CDMA) scheme has been an increasing interest for fiber optic network because it allows multiple users to access the network asynchronously and simultaneously. Optical code-division multiple-access (CDMA) is expected for further ultra-high speed and real-time computer communications where there is strong demand for the systems to support several kinds of data with different traffic requirements.

The conventional optical CDMA system can not support such kind of data because only one sequence code is assign to each user and thus the bit rate of each user is fixed. In addition it needs long length to accommodate many users and thus achieving high bit rate using this system, is not so easy.

Recently scientists propose multi code direct detection optical CDMA system is support several kinds of data in different bit rates coping with a multimedia network. In this system each user is assign a set of sequence code generated from time shifted version of optical orthogonal codes (OOC) to support several kinds of such data. In this way we can achieve our expected bit rate.

Fig. 1.8 is a schematic diagram of whole optical CDMA system. In the left there are data source which are analog (electrical) we need to convert them into optical light source. Optical encoders do this function. In the middle the transmission system named star coupler (In telecommunication, a star coupler is a passive optical coupler having a number of input and output ports, used in network applications) which transmit the data. In the right there optical decoder which decode the data from optical to analog (electrical).

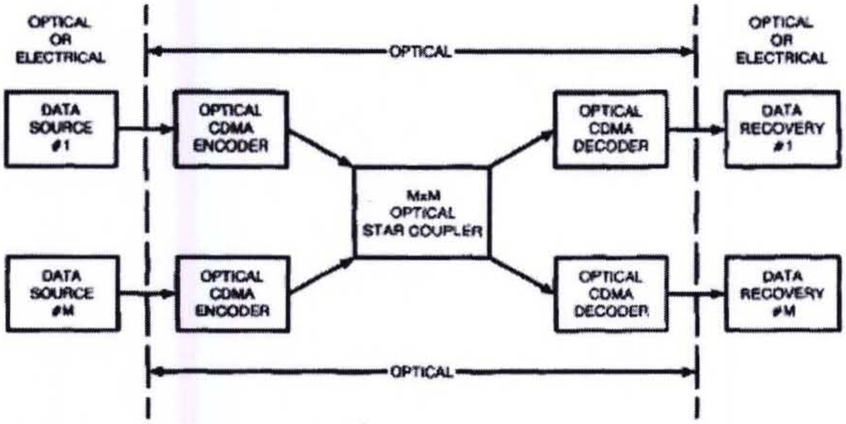

Fig. 1. A schematic diagram of an optical code division multiple-access communications system with an all-optical encoder and decoder.

Fig: 1.8. Schematic diagram of optical CDMA system

Fig 1.9 shows that ata are coming into the data conversation unit which converted the data in electrical form. This converted data is driving the laser driver. This laser light is passing through the optical fiber. Temperature controller controls the temperature of optical fiber.

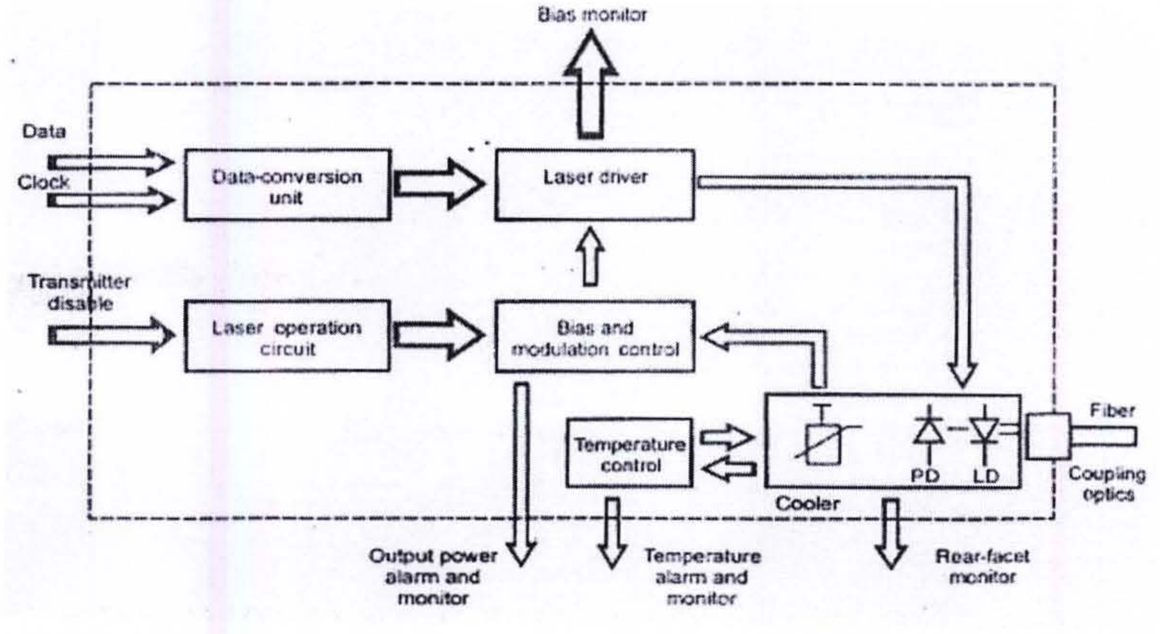

Fig 1.9. Block Diagram of an Optical Transmitter

Fig 1.10. Shows that signals are received in PD block, preamplifier amplify signal because it may be weaken during transmission time. Then it goes through filter it elements some noise. Finally we get the output from decision circuit.

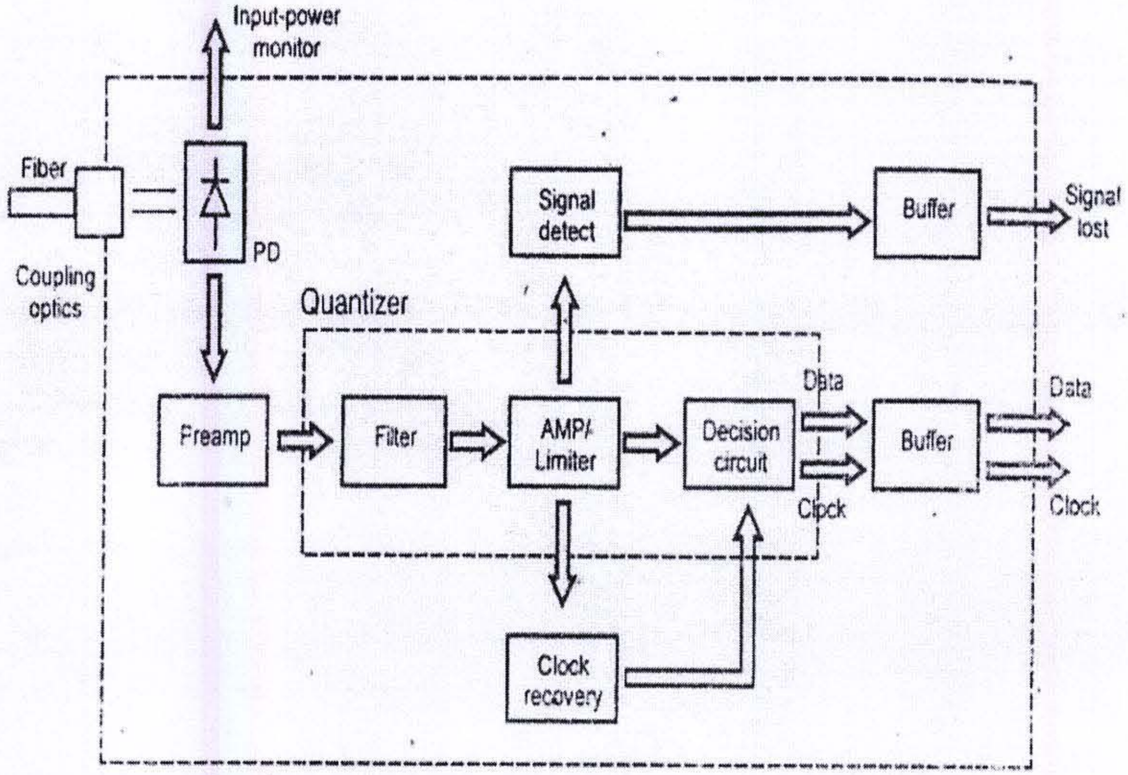

Fig: 1.10. Block Diagram of an optical receiver

1.3.0. Optical Fiber:

An **optical fiber** (or **fiber**) is a glass or plastic fiber that carries light along its length. **Fiber optics** is the overlap of applied science and engineering concerned with the design and application of optical fibers. Optical fibers are widely used in fiber-optic communications, which permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communications. Fibers are used instead of metal wires because signals travel along them with less loss, and they are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles so they can be used to carry images, thus allowing viewing in tight spaces. Specially designed fibers are used for a variety of other applications, including sensors and fiber lasers.

Light is kept in the core of the optical fiber by total internal reflection. This causes the fiber to act as a waveguide. Fibers which support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those which can only support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a larger core diameter, and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 550 meters (1,800 ft).

Joining lengths of optical fiber is more complex than joining electrical wire or cable. The ends of the fibers must be carefully cleaved, and then spliced together either mechanically or by fusing them together with an electric arc. Special connectors are used to make removable connections.

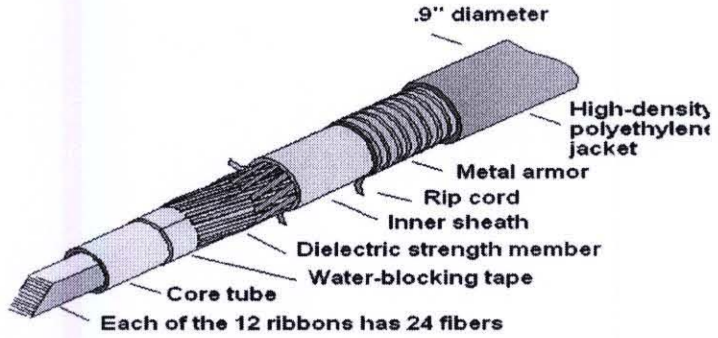

Fig: 1.11. An optical fiber

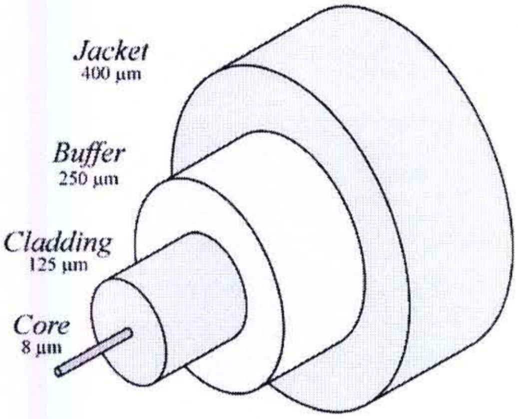

Fig: 1.12. Layer of an optical fiber

1.3.1 Classification of optical fiber:

Optical fibers are classified in various type based on there refractive index, material and modes of propagation:

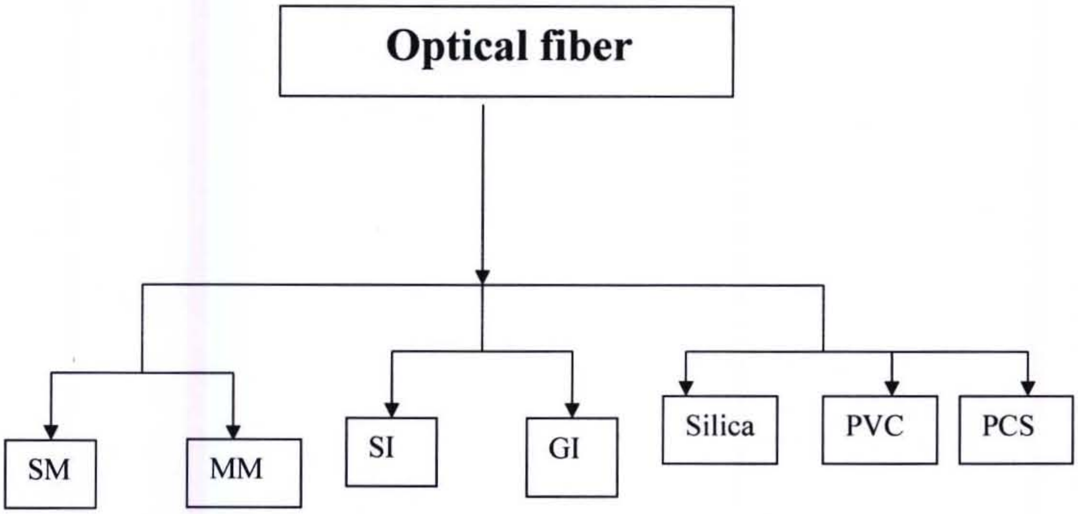

Fig: 1.13. Classification of optical fiber

1.3.2. Based on propagation mode:

Based on propagation mode optical fiber are two types:

1. Single mode fiber (SMF)
2. Multi mode fiber (MMF)

1.3.2a. Single mode fiber (SMF):

Fiber with a core diameter less than about ten times the wavelength of the propagating light cannot be modeled using geometric optics. Instead, it must be analyzed as an electromagnetic structure, by solution of Maxwell's equations as reduced to the electromagnetic wave equation. The electromagnetic analysis may also be required to understand behaviors such as speckle that occur when coherent light propagates in multi-mode fiber. As an optical waveguide, the fiber supports one or more confined transverse modes by which light can propagate along the fiber. Fiber supporting only one mode is called *single-mode* or *mono-mode fiber*. The behavior of larger-core multi-mode fiber can also be modeled using the wave equation, which shows that such fiber supports more than one mode of propagation (hence the name). The results of such modeling of multi-mode fiber approximately agree with the predictions of geometric optics, if the fiber core is large enough to support more than a few modes. SMF is faster than MMF. The speed is up to 10 Gbps.

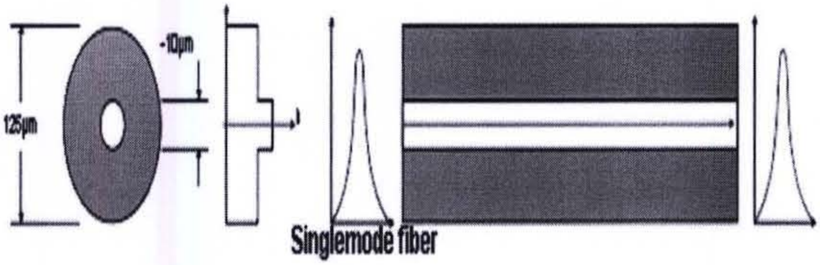

Fig: 1.14 Single mode fiber

1.3.3.2b. Multi mode fiber:

Fiber with large core diameter (greater than 10 micrometers) may be analyzed by geometric optics. Such fiber is called *multi-mode fiber*, from the electromagnetic analysis (see below). In a step-index multi-mode fiber, rays of light are guided along the fiber core by total internal reflection. Rays that meet the core-cladding boundary at a high angle (measured relative to a line normal to the boundary), greater than the critical angle for this boundary, are completely reflected. The critical angle (minimum angle for total internal reflection) is determined by the difference in index of refraction between the core and cladding materials. Rays that meet the boundary at a low angle are refracted from the core into the cladding, and do not convey light and hence information along the fiber. The critical angle determines the acceptance angle of the fiber, often reported as a numerical aperture. A high numerical aperture allows light to propagate down the fiber in rays both close to the axis and at various angles, allowing efficient coupling of light into the fiber. However, this high numerical aperture increases the amount of dispersion as rays at different angles have different path lengths and therefore take different times to traverse the fiber. A low numerical aperture may therefore be desirable.

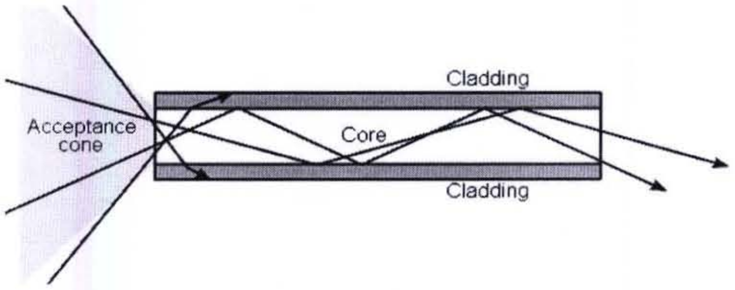

Fig: 1.15. Multi mode fiber

1.3.3. Based on refractive index:

Based on refractive index optical fiber are two types:

1. Step index fiber
2. Graded index fiber

1.3.3a. Step index fiber:

In this fiber refractive index profile is step function. So it is called step index fiber. Since index is constant so light reflects in straight line.

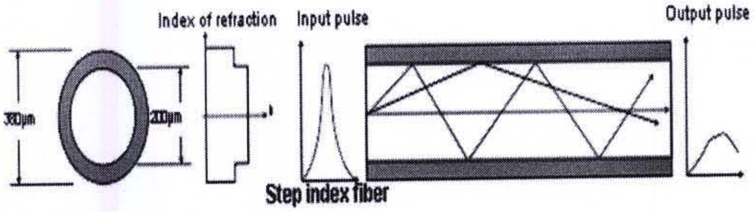

Fig: 1.16 Step index fibers

1.3.3b. Graded index fiber:

In graded-index fiber, the index of refraction in the core decreases continuously between the axis and the cladding. This causes light rays to bend smoothly as they approach the cladding, rather than reflecting abruptly from the core-cladding boundary. The resulting curved paths reduce multi-path dispersion because high angle rays pass more through the lower-index periphery of the core, rather than the high-index center. The index profile is chosen to minimize the difference in axial propagation speeds of the various rays in the fiber. This ideal index profile is very close to a parabolic relationship between the index and the distance from the axis.

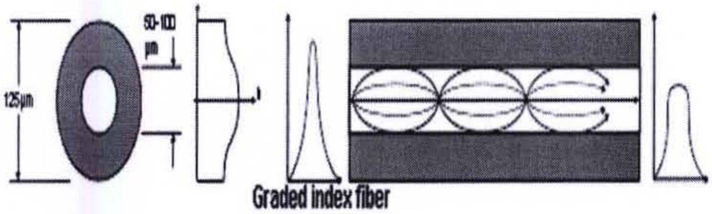

Fig: 1.17. Graded index fiber

1.4.0. Multiplexing techniques of Optical communication:

There are different types of multiplexing techniques used in optical communication system:

a. Optical frequency division multiplexing (OFDM)
b. Optical wavelength division multiplexing(WDM)
c. Optical code division multiple access(OCDMA)

1.4.1. Optical frequency division multiplexing:

A number of base band channels may be combined by frequency division multiplexing (FDM). In FDM the optical channel bandwidth is divided into a number of non over lapping frequency bands and each signal is assigned one of those bands of frequency.

The individual signals can be extracted from the combined FDM signal by appropriate electrical filtering at the receiver terminal. This system is suitable for cable TV distribution network and digital subscriber loop (ADSL, VDSL).

1.4.2. Optical wavelength division multiplexing (WDM):

Wavelength division multiplexing (WDM) involves the transmission of a number of different peak wavelength optical signals in parallel on a single optical fiber.

In fiber-optic communications, wavelength-division multiplexing (**WDM**) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths (colors) of laser light to carry different signals. This allows for a multiplication in capacity, in addition to enabling bidirectional communications over one strand of fiber. This is a form of frequency division multiplexing (FDM) but is commonly called wavelength division multiplexing.

A WDM system uses a multiplexer at the transmitter to join the signals together and a demultiplexer at the receiver to split them apart. With the right type of fiber it is possible to have a device that does both simultaneously, and can function as an optical add-drop multiplexer. The optical filtering devices used have traditionally been etalons, stable solid-state single-frequency Fabry-Perot interferometers in the form of thin-film-coated optical glass. WDM systems are popular with telecommunications companies because they allow them to expand the capacity of the network without laying more fiber. By using WDM and optical amplifiers, they can accommodate several generations of technology development in their optical infrastructure without having to overhaul the backbone network. Capacity of a given link can be expanded by simply upgrading the multiplexers and demultiplexers at each end.

This is often done by using optical-to-electrical-to-optical (O/E/O) translation at the very edge of the transport network, thus permitting interoperation with existing equipment with optical interfaces.

Most WDM systems operate on single mode fiber optical cables, which have a core diameter of 9 µm. Certain forms of WDM can also be used in multi-mode fiber cables (also known as premises cables) which have core diameters of 50 or 62.5 µm.

Early WDM systems were expensive and complicated to run. However, recent standardization and better understanding of the dynamics of WDM systems have made WDM less expensive to deploy.

Optical receivers, in contrast to laser sources, tend to be wideband devices. Therefore the demultiplexer must provide the wavelength selectivity of the receiver in the WDM system.

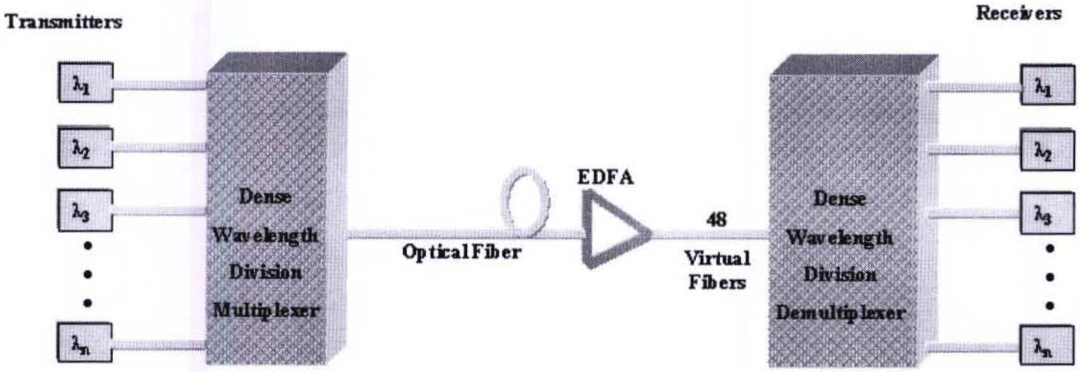

Fig: 1.18. Block diagram of WDM

1.4.3. Optical code division multiple accesses (OCDMA):

A desirable feature for future optical networks would be the ability to process information directly in the optical domain for purposes of multiplexing, demultiplexing, filtering, amplification, and correlation. Optical signal processing would be advantageous since it can potentially be much faster than electrical signal processing and the need for photon electron-photon conversion would be obviated. Code division multiple access (CDMA) is a multiple access protocol which is efficient with low traffic and has zero access delay. Especially, direct detection optical CDMA systems have been investigated widely to apply for high speed LAN, because they allow multiple users to access network simultaneously. In the case of data transfer where traffic tends to be bursty rather than continuous, CDMA can be used for contention-free, zero delay access. Optical CDMA has many advantages such as no need for the strict timing

Synchronization, no need for the centralized network control, and self-routing by code sequence. In optical CDMA, multiple user interference called multiple access interference (MAI) is dominant compared to photo detector shot noise, dark current and thermal noise. Thus, the elimination or suppression of MAI is the key issue in optical CDMA. Here, we summarize our recent results in optical CDMA, such as effective MAI suppression schemes and the embedded modulation schemes with error correcting codes.

OBJECTIVE

- To study OCDMA with different codes (orthogonal and nearly orthogonal).
- To determine the optimum system parameters for design of an optical CDMA system.
- To carry out the bit error rate including the effect of MAI.
- To evaluate performance result in terms of SNR, SIR, BER consider different codes and different number of users and code length.

CHAPTER 2

Performance Analysis of Optical CDMA System

2.0. Analysis of Optical CDMA system:

Throughout our thesis project we analysis the performance of Optical CDMA system. We analyze the performance in terms of SNR (signal-to-noise ratio) and BER (bit error rate). The equation we used for our analysis are derived below.

2.1. Equation derivation for SNR:

The balanced-detector output is derived as follows

$$I = \frac{\mathcal{R}}{4}\sum_{n=1}^{N} c(nT_c) \sum_{i=1}^{K}\left(S_i^0 + d_i(t)c_i(t - nT_c)S_i^1\right) + n(t) \ldots\ldots\ldots\ldots\ldots\ldots(A)$$

The modified differential output current equation considering the first user (#1) as the intended user as

$$I = \frac{\Re}{4}\sum_{n=1}^{N} S_1^0 c(nT_c) + \frac{\Re}{4}\sum_{i=2}^{K}\sum_{n=1}^{N} c(nT_c)c_i\,(t - nT_c)\,d_i(t)S_i^1 + n(t)\ \ldots\ldots\ldots.(1)$$

The first element in equation (1) is a dc current that needs estimation and removal in the balanced-detector. The second element assumes the interference (i.e., MAI) caused by other transmitters and the last one is the noise. Thus the system SNR can be expressed as

$$SNR = \frac{\left(\frac{\Re}{4}\sum_{n=1}^{N} c(nT_c)c_1(t-nT_c)\, d_1(t)S_1^1\right)^2}{\left(\frac{\Re}{4}\sum_{i=2}^{K}\sum_{n=1}^{N} c(nT_c)c_1(t-nT_c)d_1(t)S_i^1\right)^2 + \sigma_{n(t)}^2} \dots\dots\dots\dots\dots (2)$$

Now according to the DMPC properties we have,

$$\sum_{n=1}^{N} c(nT_c)c_1(t-nT_c) = P + 2 \dots\dots\dots\dots\dots .(3)$$

By defining the variable X_{li} as the DMPC Auto-Correlation value

$$X_{li} = \sum_{n=1}^{N} c_l(nT_c)c_i(t-nT_c) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (B)$$

Its probability density function (pdf) can be obtained from the independent values of random variable X_{li}. The in-phase cross correlation value is either zero or one depending on whether the codes are the same group or from the different groups. Obviously, the zero value does not cause the interference due to perfectly orthogonal sequences, while the one value causes the interference which is only among intended user and (P^2-P) users from the different groups (i.e., P^2 whole sequences and P sequences from the same group of intended user which are orthogonal). As the cross correlation values are uniformly distributed among interfering users, thus, the pdf of w realization of X_{li}, is

$$P(w = i) = \frac{i}{P^2 - P} \ldots\ldots\ldots\ldots\ldots\ldots\ldots .(4)$$

Where P(w=i) is the probability that w assumes the value i(the number of actively involved users in the transmission). Therefore, by substituting (3)and (4) into (2), the system SNR can be further simplified as

$$SNR(K) = \frac{1}{\left(\frac{(K+2)(K-1)}{2(P^2 - P)(P+2)}\right)^2 + \frac{16\sigma_n^2}{\Re^2 d_1^2 S_1^2 (P+2)^2}} \ldots\ldots\ldots\ldots\ldots .(5)$$

Where,

K=Number of Users

P=Code Length Parameter

$\sigma_n^2 = Total\ Noise = \sigma_{th}^2 + \sigma_{sh}^2$

$\Re = Load\ Resistence$

$S_1 = R_d\, P_r =\ signal\ current$

Note that,

$$SNR(1) = \mathcal{R}^2 d_1^2(t) * {S_1^1}^2 (P+2)^2 \Big/ 16\sigma_{n(t)}^2 = {}^{E_b}\!/_{N_0}$$

Where E_b is the energy of bit, N_0 is the noise PSD, denotes the single-user SNR.

Expression (5) is one of the main results of our thesis analysis as it represents the SNR of polarization-modulated OCDMA system.

2.2. Equation derivation for BER

We know bit error rate is the function of SNR. So BER=f(SNR).

$$\sigma_n^2 = Total\ Noise = \sigma_{th}^2 + \sigma_{sh}^2 \quad \dots\dots\dots\dots\dots\dots(6)$$

$$\sigma_{th}^2 = Thermal\ Noise = \frac{4KT}{R_L}B \quad \dots\dots\dots\dots\dots(6.a)$$

$$\sigma_{sh}^2 = Shot\ Noise = 2eBI_p \quad \dots\dots\dots\dots\dots\dots..(6.b)$$

Here,

K=Boltzmann constant

T=Temperature

B=Bandwidth=Bit Rate

$R_L = Load\ Resistance$

e=charge of a electron

$I_p = Output\ Power$

$I_s = R_d \times P_r$

P_r=Received power

I_s=Mean signal current

The probability equation of bit error rate is as bellow

$$P(i_1) = \frac{1}{\sqrt{2\pi\sigma_n^2}} e^{\frac{-(i_1 - I_s)^2}{2\sigma_n^2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(7)$$

$$\mathrm{P_r}(1/'0') = \mathrm{P_r}\left\{ \mathrm{i_0} > \mathrm{I_{th}}/_{'0'} \right\} = \int_{\mathrm{I_{th}}}^{\infty} \mathrm{P(i_0)d\,i_0} = \int_{\mathrm{I_{th}}}^{\infty} \frac{1}{\sqrt{2\pi\sigma_n^2}} \mathrm{e}^{-\frac{\mathrm{i_0^2}}{2\sigma_n^2}} \mathrm{di_0} \ldots\ldots(8)$$

$$\mathrm{P_r}(0/'1') = \mathrm{P_r}\left\{ \mathrm{i_1} < \mathrm{I_{th}}/_{'1'} \right\} = \int_{-\infty}^{\mathrm{I_{th}}} \mathrm{P(i_1)di_1} = \int_{-\infty}^{\mathrm{I_{th}}} \frac{1}{\sqrt{2\pi\sigma_n^2}} \mathrm{e}^{\frac{-(\mathrm{i_1} - \mathrm{I_s})^2}{2\sigma_n^2}} \mathrm{di_1} \ldots\ldots(9)$$

$$BER = P_r(1)P_r\left(^0/_1\right) + P_r(0)P_r\left(^1/_0\right) = \frac{1}{2}\left[P_r\left(^0/_1\right) + P_r\left(^1/_0\right)\right] \ldots\ldots\ldots(10)$$

$$BER = \frac{1}{2} erfc\left[\frac{I_s}{2\sqrt{2}\sigma_n}\right] = \frac{1}{2} erfc\left[\frac{Q}{2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(11)$$

$$\mathrm{SNR} = \mathrm{Q} = \left[\frac{\mathrm{I_s}}{\sqrt{2}\sigma_n}\right] = \left[\frac{\mathrm{P_{sig}}}{\mathrm{P_{noise}}}\right]^{1/2} = \left[\frac{\mathrm{I_s^2}/2}{\sigma_n^2}\right]^{1/2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(12)$$

$$BER = 0.5\, erfc\left[\frac{SNR}{\sqrt{2}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(13)$$

CHAPTER 3

Result and Graphical Analysis

3.0. Result and graphical analysis:

Using MATLAB, we evaluate the SNR and BER performance result of an Optical CDMA system with different system parameters.

Fig 3.1 shows the plot of SNR (dB) vs. Number of Users. In the figure we plot the number of user to the X-axis and the signal to noise ratio (SNR) to the Y-axis.

We see that the curve is downward slopping which means there is an inverse relation between SNR and the number of users. Initially we take the number of users ranges from 0-50. When less number of users communicates then SNR are higher. If we increase the number of user continuously then SNR is decreased. It occurs because of the decreasing of the signal power and increasing the noise power.

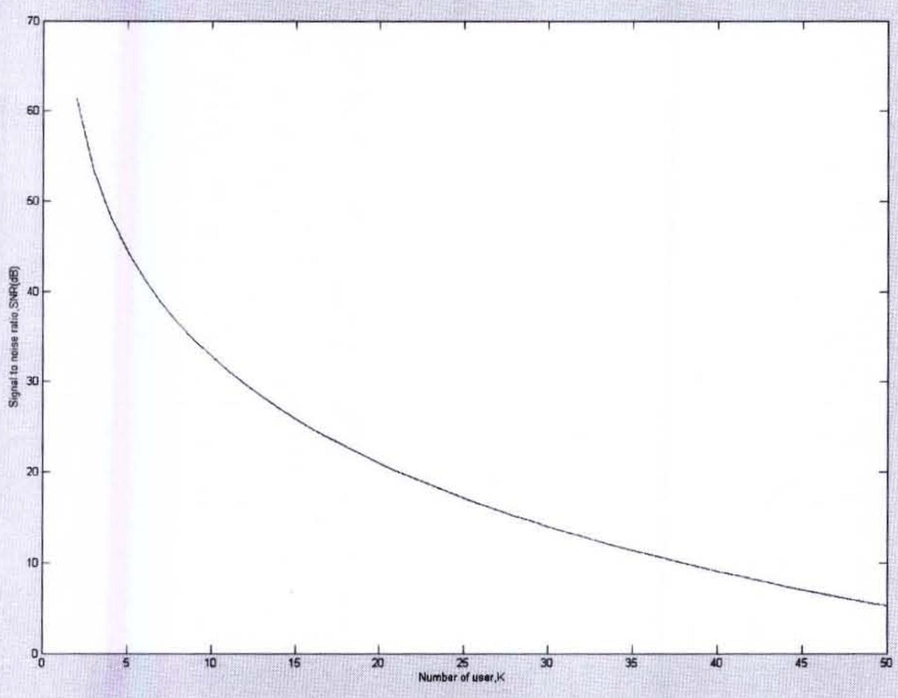

Fig: 3.1. Plot of SNR (dB) vs. Number of Users.

Fig 3.2. Shows the plot of bit error rate vs. number of users. We see in the graph the X axis mean the number of user and the Y axis mean bit error rate (BER). The curve is upward slopping that mean there is a positive relationship between numbers of user vs. bit error rate (BER). At the beginning when the number of user increased then bit error rate response highly but after a certain time when the number of user increased then BER changes slightly.

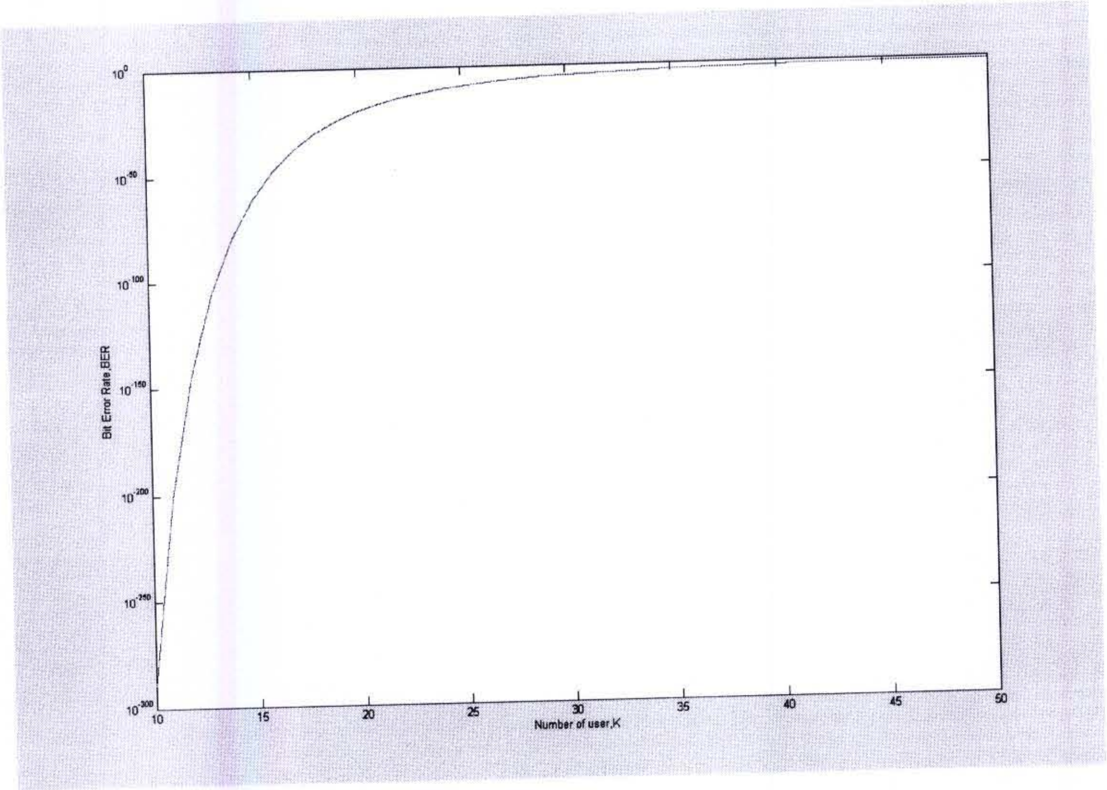

Fig: 3.2. Plot of Bit Error Rate vs. Number of User

Fig 3.3. Shows the plot of bit error rate vs. signal to noise ratio. We plotted SNR to the X-axis and BER to the Y-axis. From the graph we see that this graph is downward slopping. There is a negative relationship between SNR and BER. Low SNR gives the high BER and high SNR gives low BER. We observe here for thirty users.

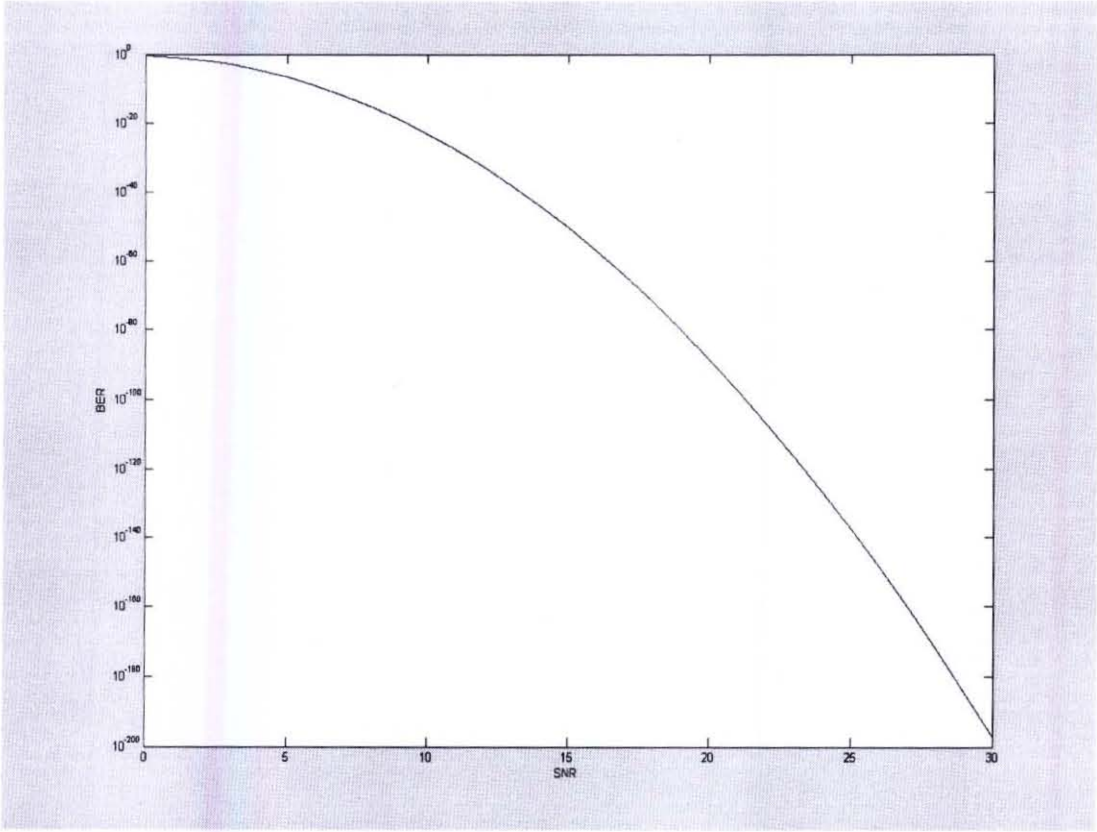

Fig: 3.3. Plot of BER vs. SNR

Fig 3.4. Shows the plot of signal to noise ratio vs. number of users for different values of code length parameter, P. The graph shows the relationship between the number of users K and the different values of SNR for different code length parameter P. We plot the graph here for fifty users and take the values of P(=7,13,16,19). The leftmost curve is for P=7 and then P=13,P=16 and the rightmost is for P=19.

Increasing the value of P(suppose from 7 to 13) will shift the graph to upward. Gradual increment of the values of P will shift the curve to upward gradually.

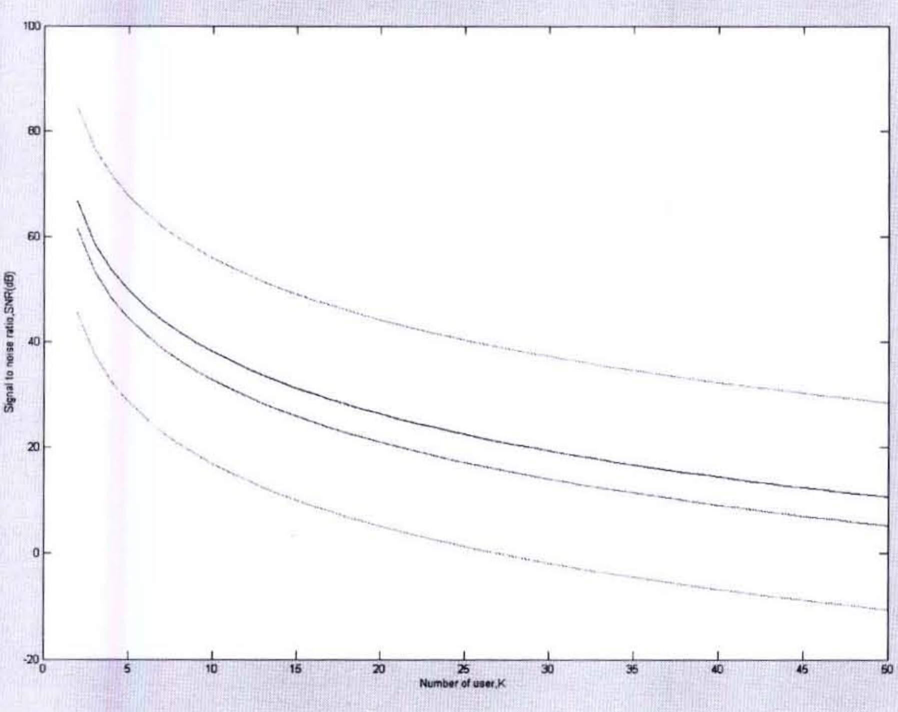

Fig: 3.4. Plot of SNR (dB) vs. Number of Users for different values of P (code length parameter).

Fig.3.5. Shows the relationship between the different values of BER and the number of users for different code length parameter P. From this graph we see when the number of user is increased gradually bit error rate also increased gradually due to growing interference. Here we consider another parameter which is code length parameter P. For different values of P we observe that the curve shift to rightward. So as the values of P are increased the values of bit error rate are decreased. Which means the relation between P and SNR is positive and the relation between P and BER is inverse.

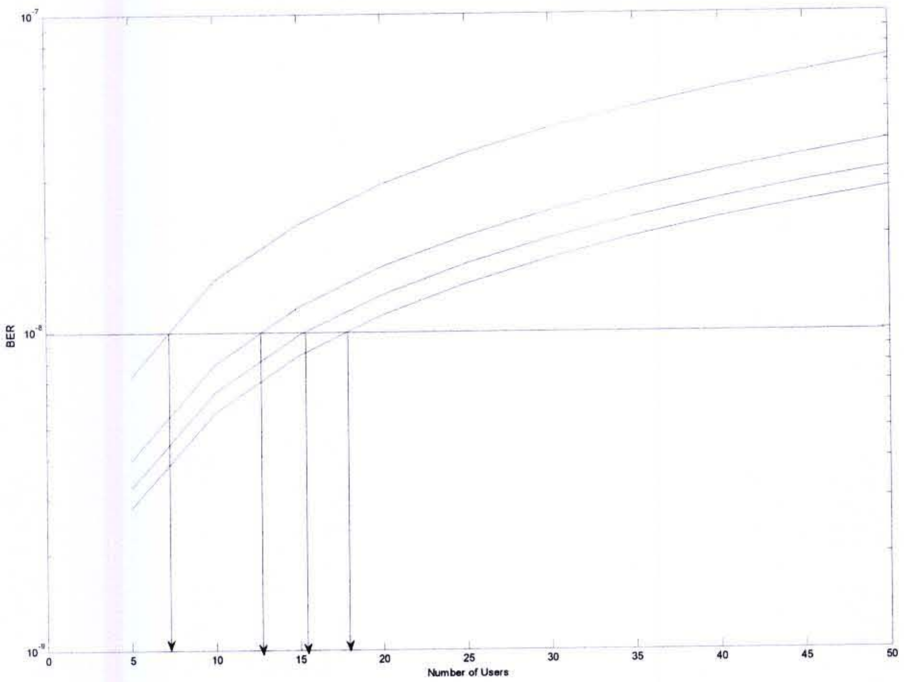

Fig: 3.5. Plot of Bit Error Rate vs. Number of User for different values of P.

Fig 3.6.Shows the relationship between the code length parameters P and the number of users K. We have plotted code length parameter to X-axis and number of user to the Y-axis. This graph shows a positive relationship between K and P. As it is seen that when we increase the value of p then it must increase the number of user. It's about a straight line.

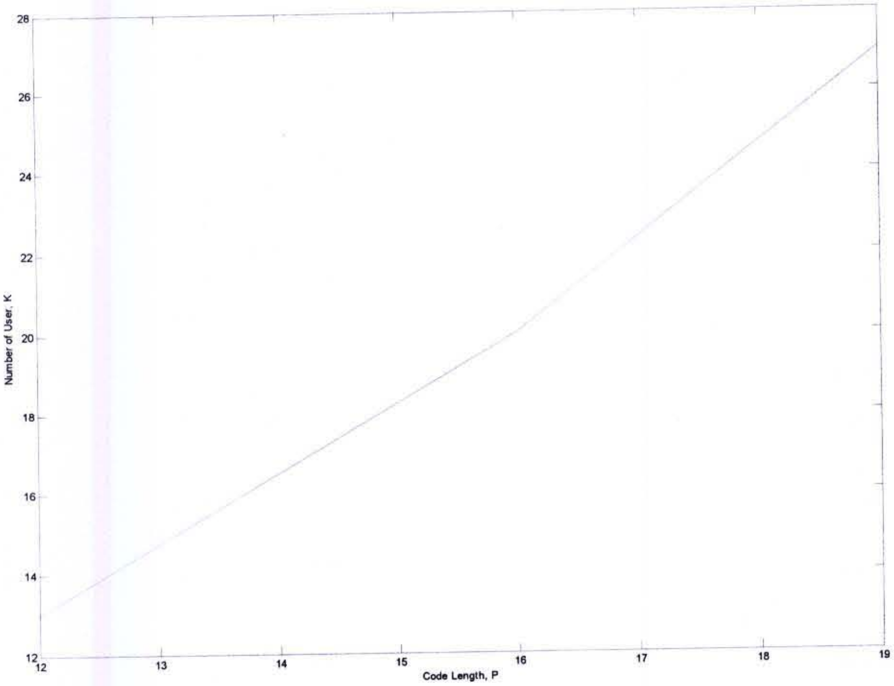

Fig:3.6. Plot of Number of user vs. code length parameter, P

Fig.3.7 shows the inverse relationship between bit error rate (BER) and received signal power P_r for different code length parameter P. Here we use the value of P equals 12, 16 and 19. The left most curve is for P=12 and middle one is for P=16 and the rightmost curve is for P=19. From the graph we can say that when receive power is lower then bit error rate is higher. That means high bit error rate gives low signaling power. If we increase the value of code length parameter then for a specific BER values, the received power is increased.

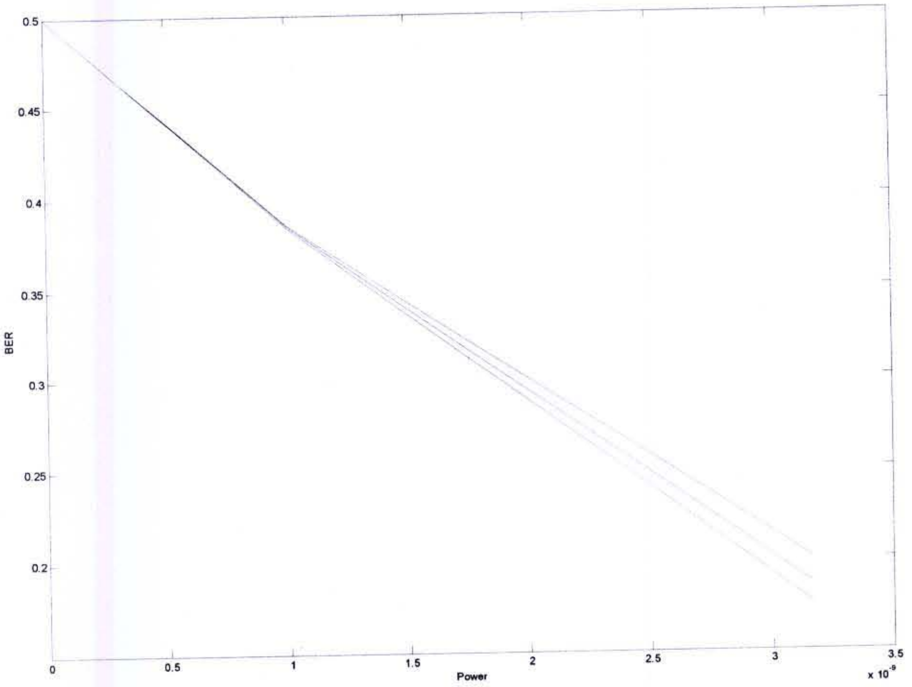

Fig. 3.7.Plot of BER vs. Power

Chapter 4

Conclusion and Future Work

4.0. Conclusion and Future Work:

Throughout the thesis project our goal was to analyze the performance of Optical CDMA in transmission system. We analyze the performance in terms of SNR (signal-to-noise ratio) and BER (bit error rate). We have also tried to find out the effect of Multiple Access Interference (MAI). We use several kinds of data (such as code length parameter, number of user) with different bit rates. In our analysis we used gold sequence to evaluate the performance.

Our results show that the Optical CDMA system can support several kinds of data with different bit rates in optical fiber network. Moreover we show that Optical CDMA system have better performance than conventional CDMA system.

In future we will analyze the performance of Optical CDMA system with different code sequence such as M-sequence, pn-sequence and we will try to compare among them.

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