

PERFORMANCE ANALYSES OF
MULTI-CARRIER DS-CDMA
WIRELESS COMMUNICATION SYSTEMS

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Abstract:

In this thesis, performance analyses of DS-CDMA, MT-CDMA, MC-CDMA and MC-DS-CDMA transmission systems are carried out in a mobile radio environment. The analysis is conducted to find the carrier to Multi-Access Interference (MAI) with a Rake receiver. The expression of Bit Error Rate (BER) is found with respect to number of users and SNIR. Also, BER performance results are evaluated numerically. Maximum number of users is estimated at a given BER with a fixed number of code length. The required SNIR is also found out for that maximum number of users. Results are evaluated in terms of BER with different user codes such as PN sequence, M-sequence, Gold sequence, Hadamard Walsh code sequence for the above schemes.

CHAPTER I: INTRODUCTION

1.1 Introduction to communication system:

Communication is a way of conveying information, Technology changes, but communication lasts; the availability of communication technologies has made a great impact on human lives. When we communicate, we are sharing information. This sharing can be local or remote. While remote communication takes place over distance, the term “telecommunication” includes telephony and television, means communication at a distance (tele is Greek for “far”)

Tele-Communications can therefore be basically grouped into two - voice & data.

Three basic components that comprise a full communication channel:

1. The Sender – A transmitter encodes the message in a language that can be understood by the receiver.
2. The Receiver –decodes the message.
3. The Medium – Air, copper wires, optical fiber. These carry the message across from the sender to the receiver.

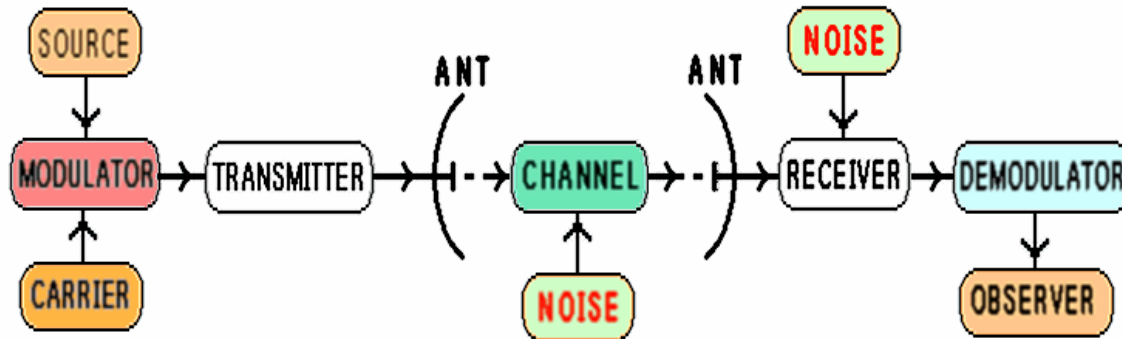


Fig: 1. Communication system

Telecommunication systems have now made it possible to communicate with virtually anyone at any time. Early telegraph and telephone system used copper wire to carry signal over the earth's surface and across oceans and high frequency (HF) radio, also commonly called shortwave radio, made possible inter-continental telephone links.

But now there is different type's communication system. They are following

- Telephone System
- Cellular Systems
- Packet Data Systems
- Satellite Systems
- Microwave Systems
- Fiber Optic Systems

Every communication system has its own frequency range, system, capacity, application implementation cost.

On the basis of transmission system there are two types of communication system

- Wired communication system
- Wireless communication system

Wireless Communication:

Wireless communication is the transfer of information over a distance without the use of electrical conductors or "wires" The distances involved may be short means few meters as in television remote control or long like thousands or millions of kilometers for radio communications. When the context is clear, the term is often shortened to "wireless". Wireless communication is generally considered to be a branch of telecommunications. The term "wireless" has become a generic and all-encompassing word used to describe communications in which electromagnetic waves or RF (rather than some form of wire) carries a signal over part or the entire communication path.

Early Wireless work:

Jagdish Chandra Bose has been credited with the invention of the first wireless detection device and the discovery of millimeter length electromagnetic waves. David E. Hughes, eight years before Hertz's experiments, induced electromagnetic waves in a signaling system. Hughes transmitted Morse code by an induction apparatus. In 1878, Hughes's induction transmission method utilized a "clockwork transmitter" to transmit signals. In 1885, T. A. Edison used a vibrator magnet for induction transmission. In 1888, Edison deploys a system of signaling on the Lehigh Valley Railroad. In the history of wireless technology, the demonstration of the theory of electromagnetic waves by Heinrich Rudolf Hertz in 1888 was important. The theories of electromagnetic waves were predicted from the research of James Clerk Maxwell and Michael Faraday. Hertz demonstrated that electromagnetic waves could be transmitted and caused to travel through space at straight lines and that they were able to be received by an experimental apparatus. The experiments were not followed up by Hertz. The practical applications of the wireless communication and remote control technology were implemented by Nikola Tesla. [5]

1.2 Limitation of communication system on perspective of Bandwidth, Noise and Fading:

Communication system has some limitation. Bandwidth and Noise limitation is part of communication system

Bandwidth is simply a measure of frequency range. It is easy to see that the bandwidth we define here is closely related to the amount of data you can transmit within it - the more room in frequency space, the more data you can fit in at a given moment.

In a communications system lack of bandwidth means lack of throughput of intelligible data. So that Bandwidth limitation means restricting the quantity of information transmitted from sender to receiver per second. This either means the information arrives slower, or the information contains less detail.

Noise will also affect intelligibility. In an electronic device such as an operational amplifier then there is such a thing known as gain bandwidth product in other words how fast can the output respond to the input and how much crud (noise) is added in the process. Thermal noise is also an issue and Boltzmann's constant k finds its way into the various equations. Noise is so important, a variety of measures have been developed to quantify the effect of noise on a communications system

There is another limitation of communication is fading. Fading effect is nothing but the fluctuation in received signal strength at the receiver that is, any random variation in the received signal can be termed as fading. While the microwave signal travel in the medium due to different parameters there is reduction in signal strength, according to that signal fading is divided into seven types

1.3 Multiple Access Technique:

A limited amount of bandwidth is allocated for wireless services. A wireless system is required to accommodate as many users as possible by effectively sharing the limited bandwidth. Therefore, in the field of communications, the term multiple access could be defined as a means of allowing multiple users to simultaneously share the finite bandwidth with least possible degradation in the performance of the system. There are several techniques how multiple accessing can be achieved. There are four basic schemes

1. Frequency Division Multiple Access (FDMA)
2. Time Division Multiple Access (TDMA)
3. Code Division Multiple Access (CDMA)
4. Space Division Multiple Access (SDMA)

These techniques can be grouped as narrowband and wideband systems, depending upon how the available bandwidth is allocated to the users. The duplexing technique of a multiple access system is usually described along with the particular multiple access scheme, as shown in the examples that follow.

Narrowband Systems: The term narrowband is used to relate the bandwidth of a single channel to the expected coherence bandwidth of the channel. In a narrowband multiple access system, the available radio spectrum is divided into a large number of narrowband channels. The channels are usually operated using FDD. To minimize interference between forward and reverse links on each channel, the frequency separation is made as great as possible within the frequency spectrum, while still allowing inexpensive duplexers and a common transceiver antenna to be used in each subscriber end.

Wideband Systems: In wideband systems, the transmission bandwidth of a single channel is much larger than the coherence bandwidth of the channel. Thus, multi-path fading does not greatly vary the received signal power within a wideband channel, and frequency selective fades occur in only a small fraction of the signal bandwidth at any instance of time. In wideband multiple access systems a large number of transmitters are allowed to transmit on the same channel.

Frequency Division Multiple Accesses (FDMA):

FDMA is one of the earliest multiple-access techniques for cellular systems when continuous transmission is required for analog services. In this technique the bandwidth is divided into a number of channels and distributed among users with a finite portion of bandwidth for permanent use as illustrated in figure 2. The vertical axis that represents the code is shown here just to make a clear comparison with CDMA (discussed later in this chapter). The channels are assigned only when demanded by the users. Therefore when a channel is not in use it becomes a wasted resource.

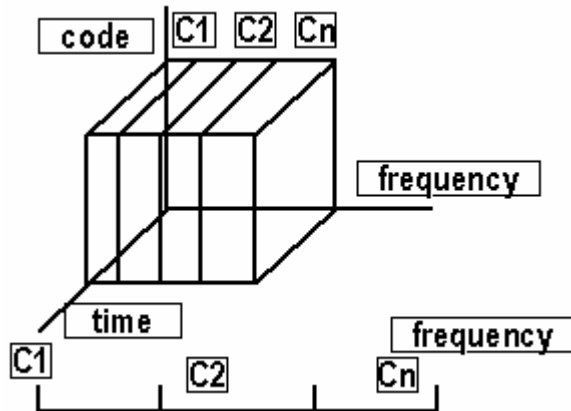


Fig: 2. Channel usage by FDMA

FDMA channels have narrow bandwidth (30 KHz) and therefore they are usually implemented in narrowband systems. Since the user has his portion of the bandwidth all the time, FDMA does not require synchronization or timing control, which makes it algorithmically simple. Even though no two users use the same frequency band at the same time, guard bands are introduced between frequency bands to minimize adjacent channel interference. Guard bands are unused frequency slots that separate neighboring channels. This leads to a waste of bandwidth. When continuous transmission is not required, bandwidth goes wasted since it is not being utilized for a portion of the time. In wireless communications, FDMA achieves simultaneous transmission and reception by using Frequency division duplexing (FDM). In order for both the transmitter and the receiver to operate at the same time, FDD requires duplexers. The requirement of duplexers in the FDMA system makes it expensive.

Time Division Multiple Access (TDMA):

In digital systems, continuous transmission is not required because users do not use the allotted bandwidth all the time. In such systems, TDMA is a complimentary access technique to FDMA. Global Systems for Mobile communications (GSM) uses the TDMA technique. In TDMA, the entire bandwidth is available to the user but only for a finite period of time. In most cases the available bandwidth is divided into fewer channels compared to FDMA and the users are allotted time slots during which they have the entire channel bandwidth at their disposal. This is illustrated in figure 3.

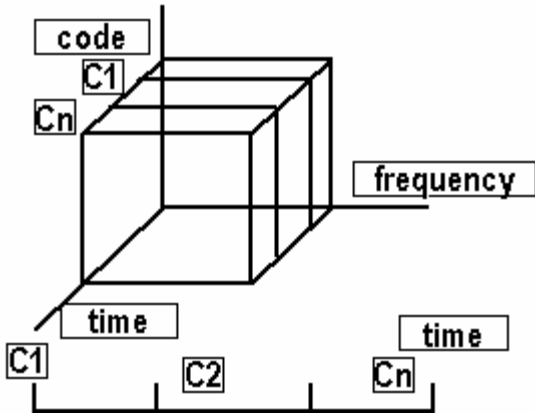


Fig: 3. Channel usages by TDMA

TDMA requires careful time synchronization since users share the bandwidth in the frequency domain. Since the number of channels are less, inter channel interference is almost negligible, hence the guard time between the channels is considerably smaller. Guard time is spacing in time between the TDMA bursts. In cellular communications, when a user moves from one cell to another there is a chance that user could experience a call loss if there are no free time slots available. TDMA uses different time slots for transmission and reception. This type of duplexing is referred to as Time division duplexing (TDD). TDD does not require duplexers.

Code Division Multiple Access:

In CDMA, all the users occupy the same bandwidth; however they are all assigned separate codes, which differentiate them from each other as shown in figure 4a. Figure 4b shows typical Walsh codes used for this purpose. CDMA systems utilize a spread spectrum technique in which a spreading signal, which is uncorrelated to the signal and has a large bandwidth, is used to spread the narrow band message signal. Direct Sequence Spread Spectrum (DS-SS) is most commonly used for CDMA. In DS-SS, the message signal is multiplied by a Pseudo Random Noise Code (PN code), which has noise-like properties. Each user has his own codeword which is orthogonal to the codes of other users. In order to detect the user, the receiver is required to know the codeword used by the transmitter. Unlike TDMA, CDMA does not require time synchronization between the users.

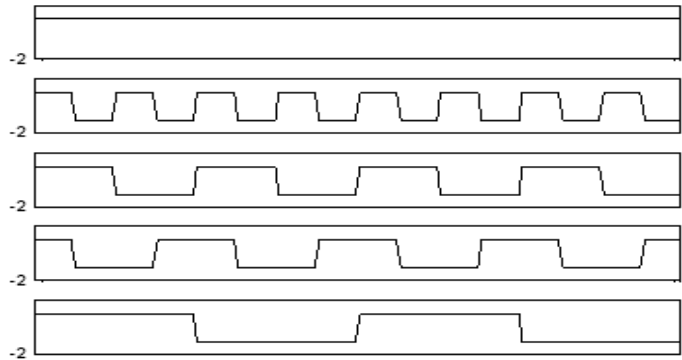
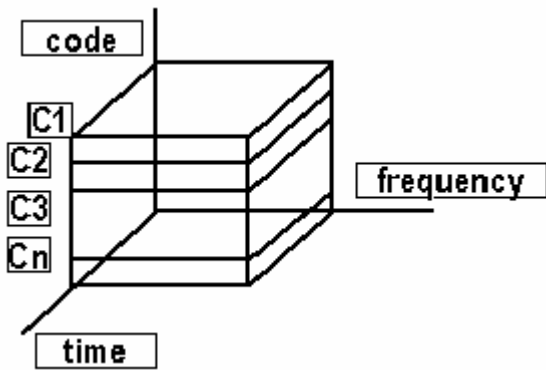


Fig: 4. a) Channel usage by CDMA

b) Walsh Codes

A CDMA system experiences a problem called self-jamming which arises when the spreading codes used for different users are not exactly orthogonal. This leads to a significant contribution from other users to the receiver decision statistic, while despreading. If the power of the multiple users in a CDMA system is unequal, then the user with the strongest signal power will be demodulated at the receiver. The strength of the received signal raises the noise floor for the weaker signals at the demodulators. This reduces the probability that weaker signals will be received. This problem, known as the near-far problem can be taken care of by using power control.

Space Division Multiple Access (SDMA):

SDMA utilizes the spatial separation of the users in order to optimize the use of the frequency spectrum. A primitive form of SDMA is when the same frequency is re-used in different cells in a cellular wireless network. However for limited co-channel interference it is required that the cells are sufficiently separated. This limits the number of cells a region can be divided into and hence limits the frequency re-use factor. A more advanced approach can further increase the capacity of the network. This technique would enable frequency re-use within the cell. It uses a Smart Antenna technique that employs antenna arrays backed by some intelligent signal processing to steer the antenna pattern in the direction of the desired user and places nulls in the direction of the interfering signals. Since these arrays can produce narrow spot beams, the frequency can be re-used within the cell as long as the spatial separation between the users is sufficient. Figure 5 shows three users served by SDMA using the same channel within the cell. In a practical cellular environment it is improbable to have just one transmitter fall within the receiver beam width. Therefore it becomes imperative to use other multiple access techniques in conjunction with SDMA. When different areas are covered by the antenna beam, frequency can be re-used.

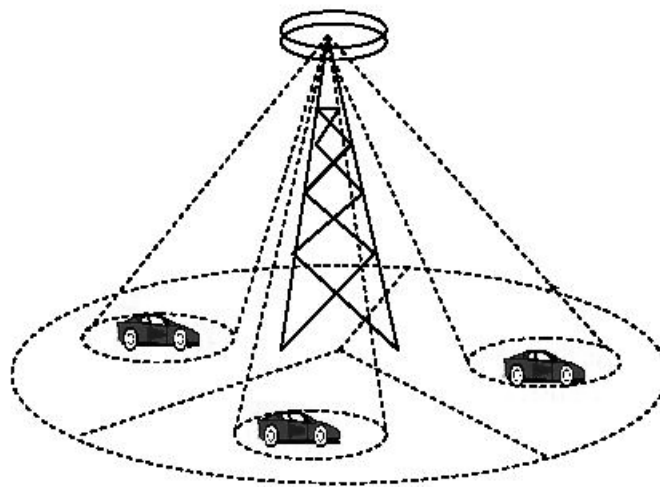


Fig: 5. Intra-cell SDMA

1.4 Review of Wireless Communication:

The generations in mobile networks were classified on Range of its signal strength. International Telecom Union (ITU) give this standard of wireless communication. 1G was the primitive step of wireless mobile networking and 2G is some what better in terms data transmission and widely distributed. Now 3G is the new form with relatively high capacity of signal and data transfer rate.

First Generation (1G):

Mobile communications as we know it today really started in the late 1970s, with the implementation of a trial system in Chicago in 1978. The system used a technology known as Advanced Mobile Phone Service (AMPS), operating in the 800-MHz band. For numerous reasons, however, including the break-up of AT&T, it took a few years before a commercial system was launched in the United States. That launch occurred in Chicago in 1983, with other cities following rapidly. Meanwhile, however, other countries were making progress, and a commercial AMPS system was launched in Japan in 1979. The Europeans also were active in mobile communications technology, and the first European system was launched in 1981 in Sweden, Norway, Denmark, and Finland. The European system used a technology known as Nordic Mobile Telephony (NMT), operating in the 450-MHz band. Later, a version of NMT was developed to operate in the 900-MHz band and was known (not surprisingly) as NMT900. Not to be left out, the British introduced yet another technology in 1985. This technology is known as the Total Access Communications System (TACS) and operates in the 900-MHz band. TACS is basically a modified version of AMPS. Many other countries followed along, and soon mobile communications services spread across the globe. Although several other technologies were developed, particularly in Europe, AMPS, NMT (both variants), and TACS were certainly the most successful technologies. These are the main first generation systems and they are still in service today. First-generation systems experienced success far greater than anyone had expected. In fact, this success exposed one of the weaknesses in the technologies—limited capacity. Of course, the systems were able to handle large numbers of subscribers, but when the subscribers started to number in the millions, cracks started to appear, particularly since subscribers tend to be densely clustered in metropolitan areas. Limited capacity was not the only problem, however, and other problems such as fraud became a major concern. [1]

Second Generation (2G):

Unlike first-generation systems, which are analog, second-generation systems are digital. The use of digital technology has a number of advantages, including increased capacity, greater security against fraud, and more advanced services. Like first-generation systems, various types of second-generation technology have been developed. The three most successful variants of second generation technology are Interim Standard 136 (IS-136) TDMA, IS-95CDMA, and the Global System for Mobile communications (GSM). Each of these came about in very different ways. [1]

Third Generation (3G):

The third generation phase began between the years 2003 and 2005. 3G include capabilities and features are

- Enhanced multimedia (voice, data, video, and remote control)
- Usability on all popular modes (cellular telephone, e-mail, paging, fax, video conferencing and web browsing.
- Broad bandwidth and high speed (upwards of 2 Mbps)
- Routing flexibility (repeater, satellite, LAN)
- Operation at approximately 2 GHz transmit and receive frequencies
- Roaming capability throughout Europe, Japan, and North America [2]

Wireless Communication based on FDMA:

FDMA is a basic technology in the analog Advanced Mobile Phone Service (AMPS), the most widely-installed cellular phone system installed in North America. With FDMA, each channel can be assigned to only one user at a time. FDMA is also used in the Total Access Communication System (TACS).

The Digital-Advanced Mobile Phone Service (D-AMPS) also uses FDMA but adds time division multiple access (TDMA) to get three channels for each FDMA channel, tripling the number of calls that can be handled on a channel.

In FDMA, each transmitter is assigned a distinct frequency channel so that receivers can discriminate among them by tuning to the desired channel. TDMA and CDMA are always used in combination with FDMA In 1989; the Cellular Telecommunications Industry Association (CTIA) chose TDMA over Motorola's frequency division multiple accesses (FDMA) (today known as narrowband analog mobile-phone service [NAMPS]) narrowband standard as the technology of choice for existing 800 MHz cellular markets and for emerging 1.9-GHz markets.[6]

<u>Standard</u>	<u>Type</u>	<u>Year Intro</u>	<u>Multiple Access</u>	<u>Frequency Band (MHz)</u>	<u>Modulation</u>	<u>Channel BW (KHz)</u>
<u>AMPS</u>	Cellular	1983	FDMA	824-894	FM	30
<u>PACS</u>	Cordless/PCS	1994	TDMA/FDMA	1850-1990	DQPSK	300
<u>ETACS</u>	Cellular	1985	FDMA	900	FM	25
<u>NMT-900</u>	Cellular	1986	FDMA	890-960	FM	12.5
<u>C-450</u>	Cellular	1985	FDMA	450-465	FM	20-10
<u>ERMES</u>	Paging	1993	FDMA4	Several	4-FSK	25
<u>CT2</u>	Cordless	1989	FDMA	864-868	GFSK	100

Table 1: Worldwide wireless communication standard based on FDMA Technique

Wireless Communication based on TDMA:

To increase the efficiency of transmission, TDMA offers a number of other advantages over standard wireless cellular technologies. Fast and foremost, it can be easily adapted to the transmission of data as well as voice communication. TDMA offers the ability to carry data rates to 64 Kbps to 120 Mbps. This enable operators to offer personal communication like services including fax, voice band data, and short message services(SMSs) as well as bandwidth-intensive application such as multimedia and video conferencing. TDMA's technology separates users in time, ensures that they will not experience interference from other simultaneous transmissions. TDMA is the most cost effective technology for upgrading a current analog system to digital. Because of its inherent compatibility with FDMA analog systems, TDMA allows service compatibility with the use of dual-mode handsets. [7]

Standard	Type	Year Intro	Multiple Access	Frequency Band (MHz)	Modulation	Channel BW (KHz)
USDC	Cellular	1991	TDMA	824-894	DQPSK	30
DCS-1900 (GSM)	PCS	1994	TDMA	1850-1990	GMSK	200
PACS	Cordless/PCS	1994	TDMA/FDMA	1850-1990	DQPSK	300
GSM	Cellular/PCS	1990	TDMA	890-960	GMSK	200KHz
DECT	Cordless	1993	TDMA	1880-1900	GFSK	1728
DCS-1800	Cordless/PCS	1993	TDMA	1710-1880	GMSK	200

Table 2: Worldwide wireless communication standard based on TDMA Technique

Wireless Communication based on CDMA:

The world is demanding more from wireless communication technologies than ever before as more people around the world are subscribing to wireless. Add in exciting Third-Generation (3G) wireless data services and applications - such as wireless email, web, digital picture taking/sending, assisted-GPS position location applications, video and audio streaming and TV broadcasting - and wireless networks are doing much more than just a few years ago. This is where CDMA technology fits in. CDMA consistently provides better capacity for voice and data communications than other commercial mobile technologies, allowing more subscribers to connect at any given time, and it is the common platform on which 3G technologies are built.

CDMA is a "spread spectrum" technology, allowing many users to occupy the same time and frequency allocations in a given band/space. As its name implies, CDMA (Code Division Multiple Access) assigns unique codes to each communication to differentiate it from others in the same spectrum. In a world of finite spectrum resources, CDMA enables many more people to share the airwaves at the same time than do alternative technologies.

CDMA Deployments:

CDMA is the fastest growing wireless technology and it will continue to grow at a faster pace than any other technology. It is the platform on which 2G and 3G advanced services are built.

Standard	Type	Year Intro	Multiple Access	Frequency Band (MHz)	Modulation	Channel BW (KHz)
IS-95	Cellular/PCS	1993	CDMA	824-894 1800-2000	QPSK/BPSK	1250
Cdma2000	Cellular	2000	CDMA	450, 800, 1700,1900,2100	QPSK	2000

Table 3: Worldwide wireless communication standard based on CDMA Technique

The CDMA air interface is used in both 2G and 3G networks. 2G CDMA standards are branded CDMA One and include IS-95A and IS-95B. CDMA is the foundation for 3G services: the two dominant IMT-2000 standards, CDMA2000 and WCDMA, are based on CDMA. [8]

CDMA One: The Family of IS-95 CDMA Technologies:

CDMA One describes a complete wireless system based on the TIA/EIA IS-95 CDMA standard, including IS-95A and IS-95B revisions. It represents the end-to-end wireless system and all the necessary specifications that govern its operation. CDMA One provides a family of related services including cellular, PCS and fixed wireless (wireless local loop).

2G-CDMA One: The Family of IS-95 CDMA Technologies:

CDMA One describes a complete wireless system based on the TIA/EIA IS-95 CDMA standard, including IS-95A and IS-95B revisions. It represents the end-to-end wireless system and all the necessary specifications that govern its operation. CDMA one provides a family of related services including cellular, PCS and fixed wireless (wireless local loop).

IS-95A: The first CDMA cellular standard:

TIA/EIA IS-95 (Telecommunications Industry Association / Electronic Industries Association Interim Standard - 95) was first published in July 1993. The IS-95A revision was published in May 1995 and is the basis for many of the commercial 2G CDMA systems around the world. IS-95A describes the structure of the wideband 1.25 MHz CDMA channels, power control, call processing, hand-offs, and registration techniques for system operation. In addition to voice services, many IS-95A operators provide circuit-switched data connections at 14.4 kbps. IS-95A was first deployed in September 1995 by Hutchison (HK).

IS-95B: 2.5G:

The IS-95B revision also termed TIA/EIA-95, combines IS-95A, ANSI-J-STD-008 and TSB-74 into a single document. TSB-74 describes interaction between IS-95A and CDMA PCS systems that conform to ANSI-J-STD-008. Many operators that have commercialized IS-95B systems offer 64 kbps packet-switched data, in addition to voice services. Due to the data speeds IS-95B is capable of reaching; it is categorized as a 2.5G technology. CDMA One IS-95B was first deployed in September 1999 in Korea and has since been adopted by operators in Japan and Peru.

2G – CDMA One Advantages:

when implemented in a cellular network, CDMA One technology offers numerous benefits to the cellular operators and their subscribers:

1. Capacity increases of 8 to 10 times that of an AMPS analog system and 4 to 5 times that of a GSM system
2. Improved call quality, with better and more consistent sound as compared to AMPS systems
3. Simplified system planning through the use of the same frequency in every sector of every cell
4. Enhanced privacy
5. Improved coverage characteristics, allowing for the possibility of fewer cell sites
6. Increased talk time for portables
7. Bandwidth on demand

3G CDMA2000:

Third Generation (3G) is the term used to describe the latest generation of mobile services which provide advanced voice communications and high-speed data connectivity, including access to the Internet, mobile data applications and multimedia content. The International Telecommunication Union (ITU), working with industry standards bodies from around the world, has defined the technical requirements and standards as well as the use of spectrum for 3G systems under the IMT-2000 (International Mobile Telecommunications-2000) program.

The ITU requires that IMT-2000 (3G) networks, among other capabilities, deliver improved system capacity and spectrum efficiency over 2G systems and that they support data services at minimum transmission rates of 144 kbps in mobile (outdoor) and 2 Mbps in fixed (indoor) environments.

Based on these requirements, in 1999 the ITU approved five radio interface modes for IMT-2000 standards (Recommendation 1457). Three of the five approved standards (CDMA2000[®], TD-SCDMA and WCDMA) are based on CDMA. CDMA2000 is also known by its ITU name, IMT-2000 CDMA Multi-Carrier (MC).

CDMA2000 Technologies:

CDMA2000 represents a family of standards and includes:

- CDMA2000 1X
- CDMA2000 1xEV-DO Technologies
 - CDMA2000 1xEV-DO Rel 0
 - CDMA2000 1xEV-DO Rev A
 - CDMA2000 1xEV-DO Rev B

CDMA2000 builds on the inherent advantages of CDMA technologies and introduces other enhancements, such as Orthogonal Frequency Division Multiplexing (OFDM and OFDMA), advanced control and signaling mechanisms, improved interference management techniques, end-to-end Quality of Service (QoS), and new antenna techniques such as Multiple Inputs Multiple Outputs (MIMO) and Space Division Multiple Access (SDMA) to increase data throughput rates and quality of service, while significantly improving network capacity and reducing delivery cost.

Key features of CDMA2000 are:

- a) **Leading performance:** CDMA2000 performance in terms of data-speeds, voice capacity and latencies continue to outperform in commercial deployments other comparable technologies
- b) **Efficient use of spectrum:** CDMA2000 technologies offer the highest voice capacity and data throughput using the least amount of spectrum, lowering the cost of delivery for operators and delivering superior customer experience for the end users.
- c) **Support for advanced mobile services:** CDMA2000 1xEV-DO enables the delivery of a broad range of advanced services, such as high-performance VoIP, push-to-talk, video telephony, multimedia messaging, multicasting and multi-playing online gaming with richly rendered 3D graphics
- d) **Devices selection:** CDMA2000 offers the broadest selection of devices and has a significant cost advantage compared to other 3G technologies to meet the diverse market needs around the world
- e) **Seamless evolution path:** CDMA2000 has a solid and long-term evolution path which is built on the principle of backward and forward compatibility, in-band migration, and support of hybrid network configurations
- f) **Flexibility:** CDMA2000 systems have been designed for urban as well as remote rural areas for fixed wireless, wireless local loop (WLL), limited mobility and full mobility applications in multiple spectrum bands, including 450 MHz, 800 MHz, 1700 MHz, 1900 MHz and 2100 MHz

CDMA2000 Advantages:

- Superior Voice Clarity
- High-Speed Broadband Data Connectivity
- Low End-to-End Latency
- Increased Voice and Data Throughput Capacity
- Differentiated Value-Added Services such as VoIP, PTT, Multicasting, Position Location, etc.
- Flexible Network Architecture with connectivity to ANSI-41, GSM-MAP and IP-based Networks and flexible Backhaul Connectivity (see the text at the end – we can do that later)
- Application, User and Flow-based Quality of Service (QoS)
- Flexible Spectrum Allocations with Excellent Propagation Characteristics
- Robust Link Budget for Extended Coverage and Increased Data Throughputs at the Cell Edge
- Multi-mode, Multi-band, Global Roaming
- Improved Security and Privacy
- Lower Total Cost of Ownership (TCO) [8]

UMTS:

The 3G standard proposed by the European Telecommunications Standards Institute (ETSI) with much joint work with Japanese standardization bodies is referred to as the universal mobile telecommunications system (UMTS). UMTS is one of a number of standards ratified by the International Telecommunications Union–Telecommunication Standardization Sector (ITU-T) under the umbrella of International Mobile Telephony 2000 (IMT2000), as discussed in the next section. It is currently the dominant standard, with the US CDMA2000 standard gaining ground, particularly with operators that have deployed CDMA One as their 2G technology. At the time of writing, Japan is the most advanced in terms of 3G network deployment. The three incumbent operators there have implemented three different technologies: J-Phone is using UMTS, KDDI has a CDMA2000 network, and the largest operator NTT DoCoMo is using a system branded as FOMA (Freedom of Multimedia Access). FOMA is based around the original UMTS proposal, prior to its harmonization and standardization.

The UMTS standard is specified as a migration from the 2G GSM standard to UMTS via the general packet radio service (GPRS) and enhanced data rates for global evolution (EDGE). The goal of 3G is to provide a network infrastructure that can support a much broader range of services than existing systems so the changes to the network should reflect this. However, many of the mechanisms in the existing networks are equally applicable to supporting new service models, for example mobility management. For a successful migration, the manufacturers and suppliers of new 3G equipment understand that most licenses granted for 3G network operations will be to existing 2G operators and thus the next step must be an evolution rather than a revolution. Operators in the main are expected to introduce GPRS functionality before taking the step to 3G. The first release (Release 99) specification for UMTS networks is focused on changes to the Radio Access Network. The handover between UMTS and GSM offering worldwide coverage has been one of the main design criteria for the 3G system.[2]

IMTS 2000:

The IMT2000 is a global process, coordinated by the ITU-T to develop next generation mobile networks, and covers both the technical specifications and the frequency allocations. It was started in 1995 under the original heading of Future Plans for Land Mobile Telecommunications System (FPLMTS). IMT2000 is not a particular technology, but rather a system which should allow seamless, ubiquitous user access to services. The task is to develop a next generation network fulfilling criteria of ubiquitous support for broadband real-time and non-real-time services. The key criteria are

- High transmission rates for both indoor and outdoor operational environments;
- Symmetric and asymmetric transmission of data;
- support for circuit and packet switched services;
- increased capacity and spectral efficiency;
- Voice quality comparable to the fixed line network;
- Global, providing roaming between different operational environments;
- Support for multiple simultaneous services to end users. [2]

1.5 Limitation of a Wireless Communication System with CDMA technique

In this chapter, we address the issues related to the technical limitations of traditional CDMA technology. The discussions carried out here will pave the way for the definition and proposal of next generation CDMA technology, which should be built up based on a thorough understanding of the problems associated with traditional CDMA systems. The currently available CDMA technology was proposed basically for slow-speed voice-centric applications, and thus bears many features pertaining to second generation mobile cellular systems, in particular the IS-95 standard. On the other hand, the birth of all CDMA-based 3G mobile cellular standards, such as WCDMA, cdma2000, and TD-SCDMA, was driven primarily by the competition between Japan and Korea for development of CDMA-based mobile cellular technologies, and thus sacrificing some great opportunities to bring sufficient technological innovations to the CDMA-based 3G mobile cellular standards.

Fading Limitation:

Frequency Selective Fading:

Frequency-selective fading is caused by multi-path propagation of the channel due to the fact that the frequency response function of the channel exhibits uneven gains in different frequencies, hence the name 'frequency-selective fading'. Therefore, frequency-selective fading can be simply interpreted as uneven gains at different frequencies.

Time Selective Fading:

Time-selective fading is caused by the Doppler Effect in the mobile communication channel, where terminals are in motion at a certain speed relative to the base station which is the receiver of the signals from the mobile terminals. Therefore, time-selective fading occurs due to the time-variant properties of a mobile channel. In this respect, we can also describe time-selective fading as the effect that uneven gains occur at different times.

Multi-path interference:

Multi-path propagation is a serious impairment factor which can cause serious damage to the signal detection process of a receiver in a mobile cellular or wireless communication system. The cause of multi-path propagation is related to the carrier frequency used in most mobile cellular and wireless network standards. Most of these wireless applications operate at the 800–900 MHz, 2 GHz, and 5 GHz spectrum sectors, in which the RF signal transmissions become much more like a light ray than a wave, which can circumambulate buildings and other objects on the earth when the signal impinges on it. Therefore, the reflections from different objects on the propagation path will arrive at the same receiver with different multi-path returns, which have different delays. If the delays are longer than symbol duration, inter symbol interference (ISI) will occur and can cause severe damage to the signal detection efficiency. The major causes of multi-path interference also include atmospheric ducting, ionospheric reflection and refraction, and reflection from terrestrial objects, such as mountains and buildings, etc. The effects of multi-path interference include constructive and destructive interference, and phase shifting of the signal. This causes Rayleigh fading, named after Lord Rayleigh. The standard statistical model of this gives a distribution known as the Rayleigh distribution. Rayleigh fading with strong line of sight content is said to have a Rician distribution, or to be Rician fading.

1.6 Objective of the thesis:

Future generations of wireless communication systems will be designed with the aim of making the best possible use of the limited radio spectrum in order to further increase throughput as well as user-capacity, less required SNIR, Security, non frequency selective fading channel. In Our thesis, the performances of different CDMA systems within mobile communication systems are discussed. Before our thesis, Performance of CDMA systems by using PN sequence code analyzed by other so far. In our thesis we give overview of the DS-CDMA, MT-CDMA, MC-CDMA, MC-DS-CDMA system. Also showing performance of those system and comparison between them by using different code like PN-Sequence, M-sequence, Gold sequence and Hadamard walsh code. The multi-carrier CDMA system is described in detail, including its relationship with OFDM (orthogonal frequency division. By doing analyses we show that MT-CDMA is most secure system, MC-DS-CDMA is maximum user supportable system among all CDMA system. DS-CDMA. Provide less required SNIR and MC-CDMA provide non frequency selective fading channel.

Chapter II: SYSTEM MODEL AND THEORITICAL ANALYSIS

2.1 System Model:

The system models considered for analysis are shown in fig. 1, 2, 3 and 4 for different schemes such as DS-CDMA, MT-CDMA, MC-CDMA and MC-DS-CDMA respectively.

2.1.1 DS-CDMA System Model:

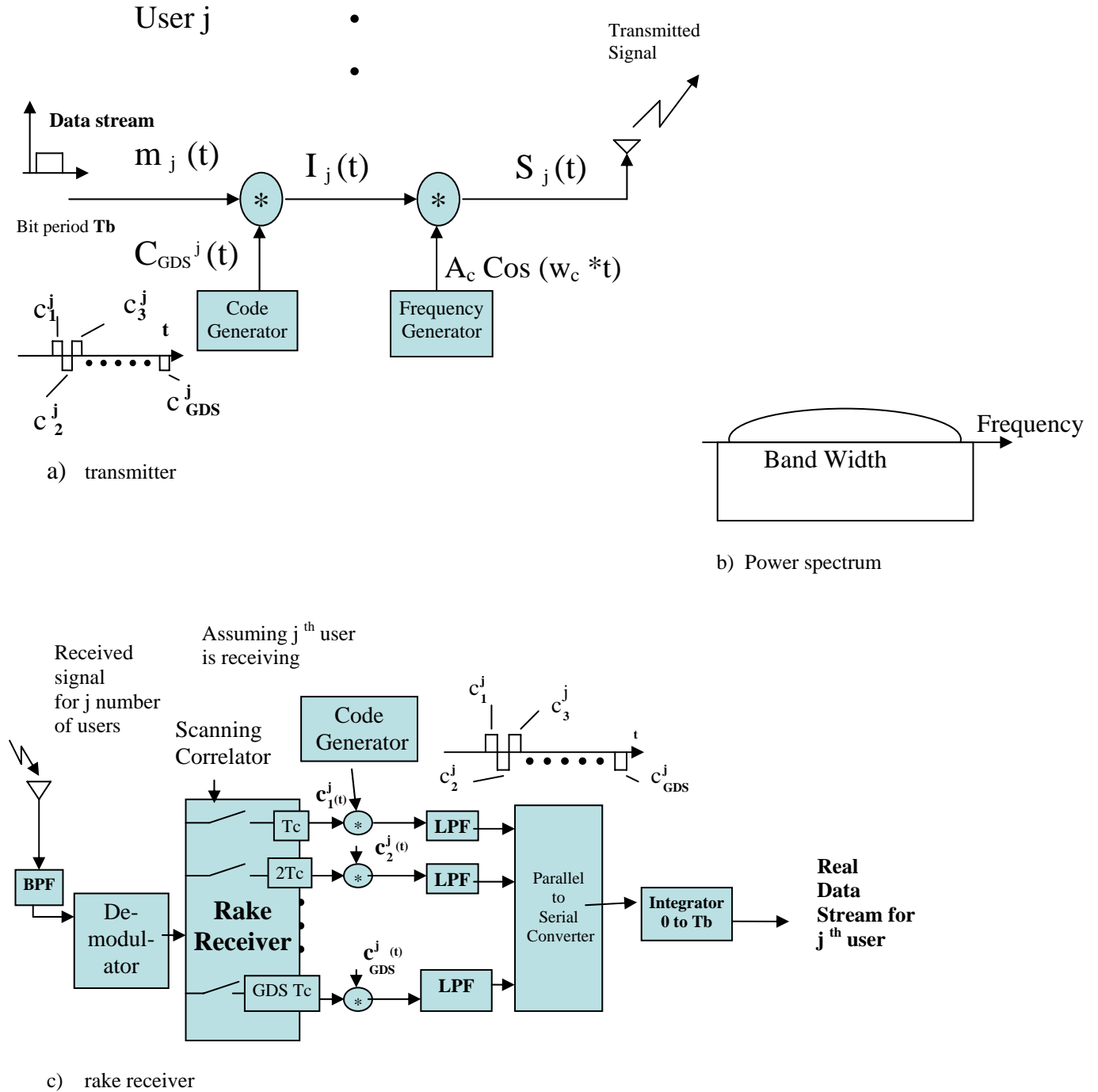


Fig: 6. DS-CDMA scheme: a) transmitter; b) power spectrum of its transmitted signal; c) receiver.

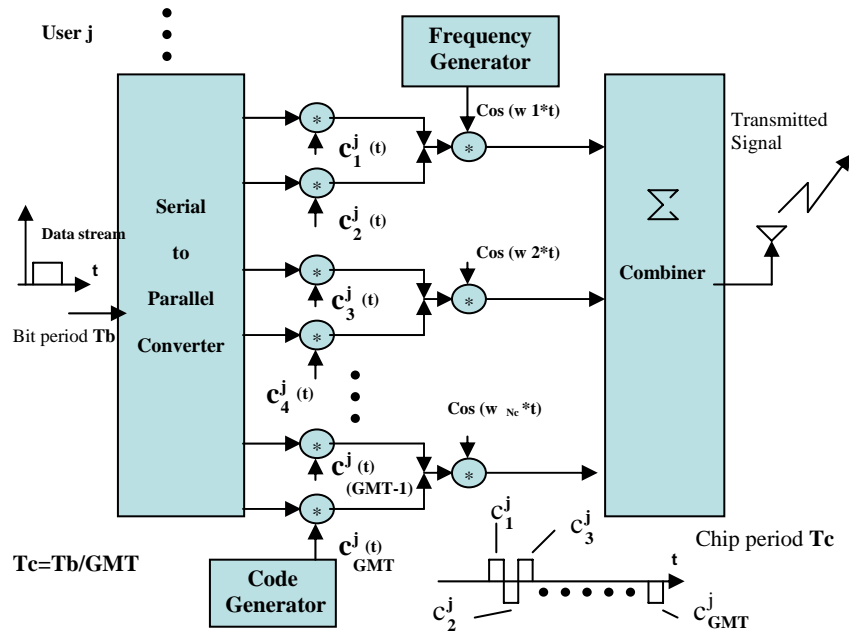
In CDMA, multiple accesses is achieved by assigning each user a pseudo random code with good auto and cross-correlation properties. This code is used to transform a user's signal into a wideband spread spectrum signal. A receiver then transforms this wideband signal into the original signal bandwidth using the same pseudo random code. The wideband signals of other users remain wideband signals [18].

Fig. 6(a) is the transmitter of j^{th} user in DS-CDMA scheme. In this fig. 6(a), the DS-CDMA transmitter spreads the original data stream using a given spreading code in the time domain. There are j numbers of transmitter for j number of users with the modulation technique of phase shift keying (PSK). Here, t is time, $m_j(t)$ is the j^{th} user digital data stream, $C^j(t)$ is specific code for j^{th} user, $I_j(t)$ is j^{th} user data stream after spreading, $S_j(t)$ is j^{th} user data signal after PSK modulation. The transmitter generates unique code for each user over one bit period; T_b by the Code Generator. T_b is equal to the bit rate R_b (here, it is taken as 500 Kbps for numerical calculation). Each unique code has a fixed number of chips per bit. Total number of chips over one bit period (T_b) is called code length (L) or processing gain (GDS). Let assume j^{th} user is transmitting. Then the specific code for the j^{th} user will be $C^j(t)$, which is equal to $[C_1^j, C_2^j, \dots, C_{GDS}^j]$. This code length is very important factor in all CDMA systems. Then again, the Frequency Generator generates one carrier for each specific user for PSK modulation technique. The generated carrier by the frequency generator is $\{A_c \cos(w_c * t)\}$, here A_c is the magnitude of the single carrier (here considered as 1) and w_c is the angular frequency, which is equal to $2\pi f_c$, f_c is the explicit frequency for j^{th} user given by the frequency generator. After the spreading and modulation of digital data, it is transmitted by the CDMA antenna over the wireless media (air). The power spectrum of transmitted signal is shown in figure 6(b).

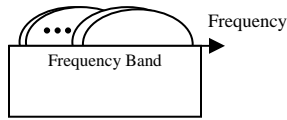
Fig. 6(c) is the receiver of j^{th} user in DS-CDMA scheme, assuming j^{th} user is receiving. In this figure, DS-CDMA receiver receives the transmitted signal as a summation of j number of users. Then it will face the MAI for user 1 to user ($j-1$). First the transmitted signal is received by a CDMA antenna and passed to a band pass filter (BPF). BPF allows a certain band of frequency of transmitted signal. Demodulator demodulates the signal with f_c carrier, which is same as the carrier frequency provided by the transmitter. Then, there is a special kind of receiver named rake receiver. It allows the appropriate signal to the code generator so that the despreading process is done correctly. It takes signals in time domain and scans signal with respect to $T_c, 2T_c, \dots, GDS T_c$. According to the number of chip, it select signals path. Finally it provides the proper signals to the code generator in time domain for despreading. Receiver code generator also generates the same code which was given by the transmitter code generator, for each user to recover the real user digital data. The low pass filter (LPF) restricts the high frequency portion of data signals. Then the parallel to serial (P/S) converter converts parallel data signal to serial data signal. At last, the integrator provides the real j^{th} user digital data. The multi-access interference (MAI) term can be reduced by the integrator. The integrator uses the cross-correlation characteristic of the spreading codes to suppress the MAI. It also uses the auto-correlation characteristic of the spreading codes to distinguish one component from other components in the composite received [12].

Original data is modulated with only one carrier over a huge Bandwidth in DS-CDMA scheme. As a result, a frequency selective fading channel is characterized by the superimposition of several signals with different delays in the time domain. However, it can be concluded that it is difficult for the DS-CDMA receivers to receive all the transmitted signal energy scattered in the time domain [14].

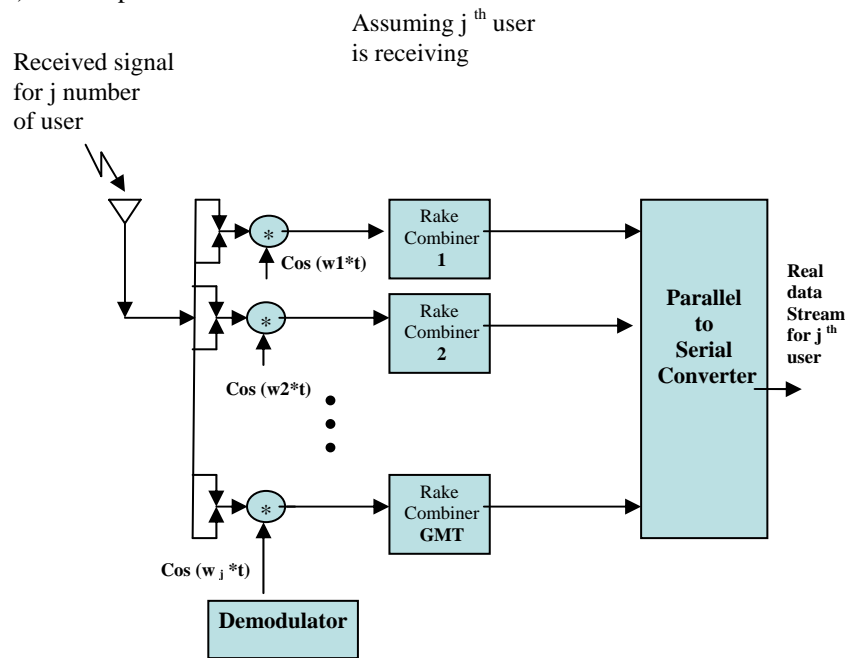
2.1.2 MT-CDMA System Model



a) transmitter



b) Power spectrum



c) Receiver

Fig: 7. MT-CDMA scheme: a) transmitter; b) power spectrum of its transmitted signal; c) receiver.

Multi-tone (MT) CDMA technique that combines orthogonal frequency division multiplex (OFDM) and direct-sequence spread-spectrum (DSSS) modulation has been recently proposed in. By using more sub-carriers, one can increase the processing gain of the system substantially [19].

Fig.7 (a) is the transmitter of j^{th} user in MT-CDMA scheme, assuming j^{th} user is transmitting. In this figure, The MT-CDMA transmitter spreads the serial to parallel (S/P) Converted data streams using a given spreading code in the time domain [16]. Code Generator produces unique codes for each user. After that, it modulates the data signal with different sub-carriers. Here, the modulation technique is Quadrature Phase Shift Keying (QPSK) and the sub-carriers are spawned by the transmitter frequency generator. The MT-CDMA scheme uses longer spreading codes in proportion to the number of sub carrier ($N_c =$ number of sub carrier), as compared with a normal (single carrier) DS-CDMA scheme. Consecutively each two chips are given separate sub-carriers in this analysis (at fig. 7 (a)). Then a Combiner merges the modulated signals and a CDMA antenna transmits the signals over wireless media. Here, code length $(L)/\text{GMT} > N_c$. The power spectrum of transmitted signal is shown in fig. 7 (b).

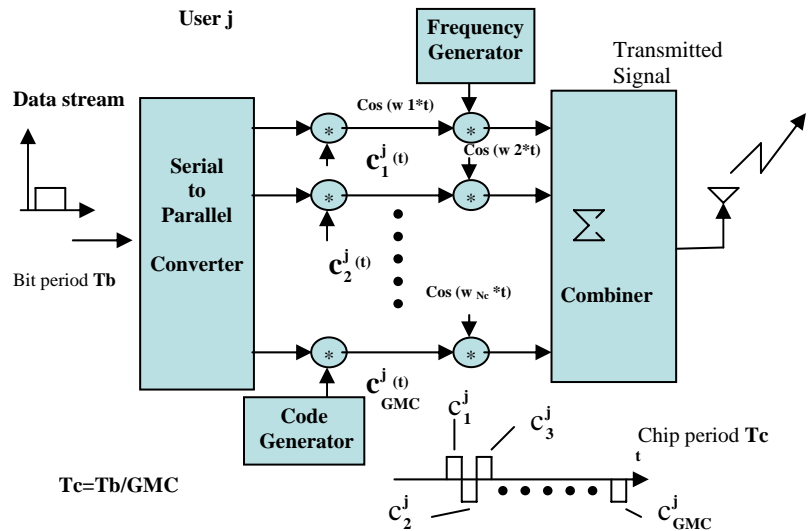
Fig. 7 (c) is the receiver of j^{th} user in MT-CDMA scheme, assuming j^{th} user is receiving. In this figure, MT-CDMA receiver receives the transmitted signal as a summation of j number of users. First, the CDMA antenna receives the signals. Then, the demodulator demodulates the received signals with N_c number of sub-carriers. After that, the data signal is routed with GMT number of rake combiners. The rake combiners acquire the signals in time domain. Rake combiner examines the data signals according to $T_c, 2T_c, \dots, \text{GMT } T_c$ and picks appropriate paths for data signals. The rake combiner block has a code generator inside it (in fig. 7(c)). The code generator generates specific code for j^{th} user for despreading. The code is same as it was given by the transmitter code generator. Otherwise the original user digital data signal can not be retrieved. The rake combiner block also has low pass filters inside it, in fig. 7(c), which restricts the high frequency portion of the data signal. It also has GMT number of integrators to minimize the multi-access interference (MAI) term using the cross-correlation characteristic. Afterward a P/S converter provides the original digital data for j^{th} user.

Since each consecutive two chips are given different sub-carrier, the effect of frequency selective multi-path fading in MT-CDMA is less compared to in DS-CDMA, but still remains some portion of it. Therefore, the system can accommodate more users than the DS-CDMA scheme.

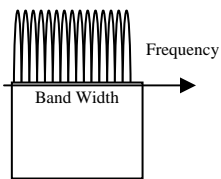
The MT-CDMA scheme suffers from inter-carrier interference (ICI), while the capability to use longer spreading codes results in the reduction of the ISI (inter-symbol interference) and MAI (multi-access interference), as compared with the spreading codes assigned to a normal DS-CDMA scheme [14]. MT-CDMA is found the most secure communication system among the other systems as it modulates different sub-carriers to specific number of chips at both transmitter and receiver. Security can be maintained by making undisclosed of the order of modulated chips. Then, that secret order of activating group chips can only be maintained by the proper destination receiver.

Serial to Parallel converter (S/P) and Parallel to Serial converter (P/S) are used for lower data rate streams at sub-carrier level and further reduction of frequency-selective fading.

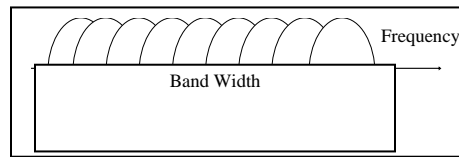
2.1.3 MC-CDMA System Model



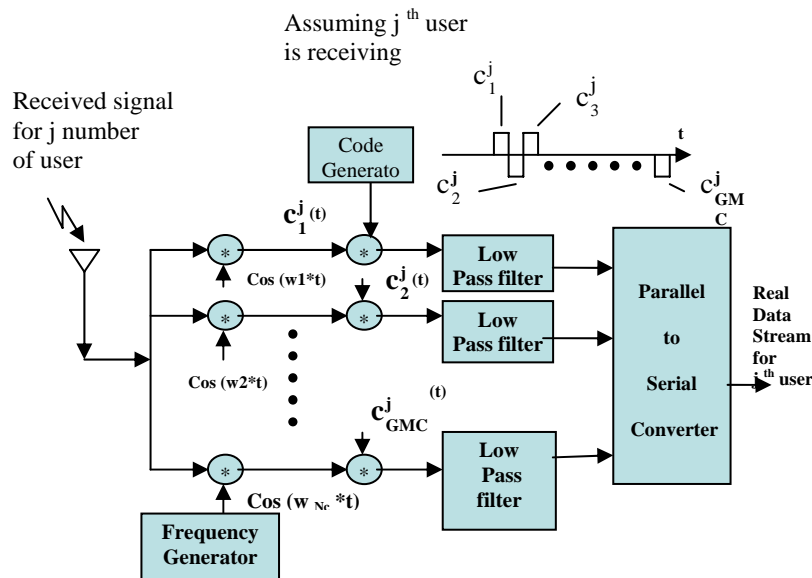
a) Transmitter



b) Power spectrum



c) Power spectrum of orthogonal sub-carriers



d) Receiver

Fig: 8. MC-CDMA scheme: a) transmitter; b) power spectrum of its transmitted signal; c) power spectrum of orthogonal sub-carriers; d) receiver.

Fig. 8(a) represents the transmitter of j^{th} user in MC-CDMA scheme, assuming j^{th} user is transmitting. In fig. 8(a), the MC-CDMA transmitter spreads the original S/P data stream using a given spreading code in the frequency domain [15-17]. Code Generator constructs unique codes for each user as well. Then QPSK modulation is done by the frequency generator. Here each chip is given one dissimilar and orthogonal sub-carrier that means code length $L/GMC=N_c$. Then a combiner combines the signals and a CDMA antenna transmits the signals over the wireless media. The power spectrum of transmitted signal is shown in fig. 8 (b).

Fig. 8(d) shows the receiver of MC-CDMA scheme, assuming j^{th} user is receiving. In fig. 8(d), MC-CDMA receiver also receives the transmitted signal as a summation of j number of users. It first demodulates the received signal and then dispread the signals with the specific codes given by the receiver code generator. Here, also the code for j^{th} user has to be same both in transmitter and receiver. After that low pass filter restricts the high frequencies portion of the signal. Finally, the P/S converter presents the actual digital data signal.

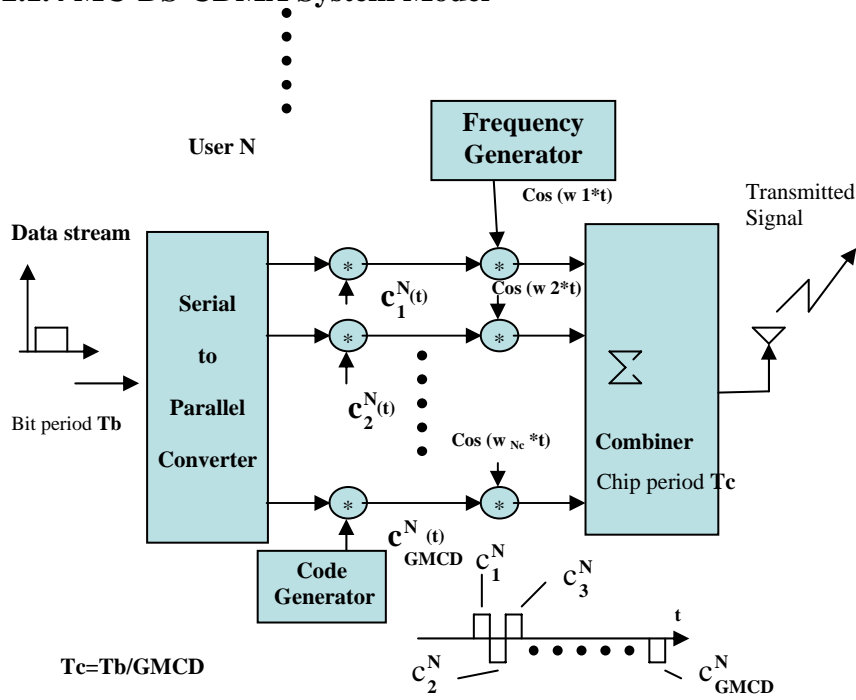
Since each chip is given different orthogonal frequency, this system can support more users with better performance compared to DS-CDMA and MT-CDMA. Multi Access Interference (MAI) and Inter-carrier Interference (ICI) can be minimized by using orthogonal code and orthogonal sub-carriers respectively. In accumulation, the system provides non-frequency selective fading channel.

Orthogonal Frequency Division Multiplexing (OFDM):

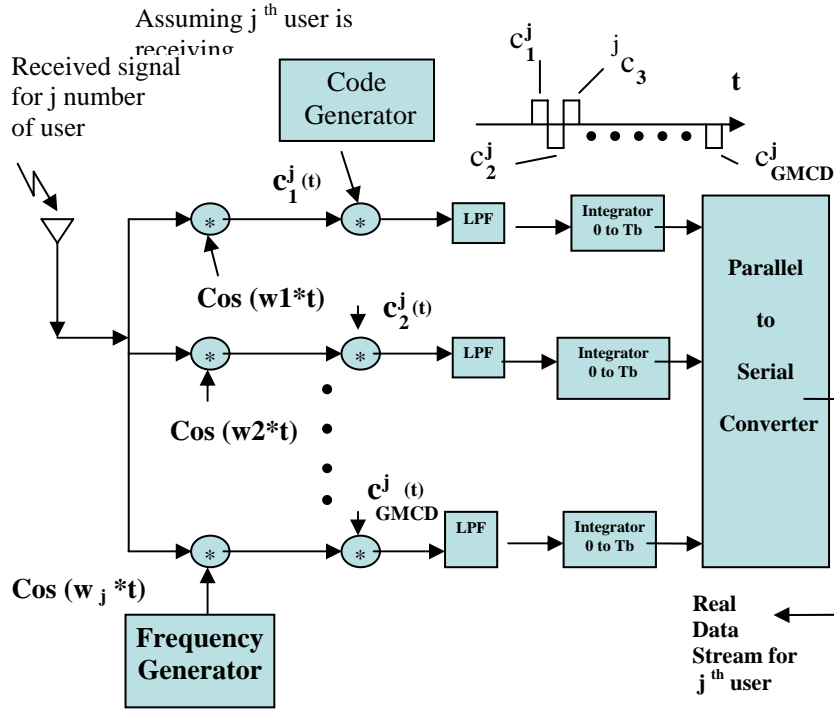
Each sub-carrier is orthogonal to each other in OFDM. That means, if one carrier has high power at any frequency, then all other have null at that frequency. Orthogonal sub-carrier is used both in MC-CDMA and MC-DS-CDMA. The ICI can be reduced to almost zero by using orthogonal sub-carriers. The power spectrum of orthogonal sub-carriers is publicized in fig. 8(c)

We can also use the Hadamard Walsh codes as an optimum orthogonal set, because we do not have to pay attention to the auto-correlation characteristic of the spreading codes [14].

2.1.4 MC-DS-CDMA System Model



a) Transmitter



b) Receiver

Fig: 9. MC-DS-CDMA scheme: a) transmitter; b) Receiver.

Fig. 9(a) symbolizes the transmitter of MC-DS-CDMA scheme for j^{th} user. In fig. 9(a), The MC-DS-CDMA transmitter functions in the similar way of the MC-CDMA transmitter.

Fig. 9(b) shows the receiver of MC-DS-CDMA system, assuming j^{th} user is receiving. In fig. 9(b), MC-DS-CDMA receiver is almost same as the MC-CDMA receiver but with the modification of integrators after the low pass filters (shown at figure 9 (b)). As a result the MAI reduced more and the performance of the system becomes the best among the DS-CDMA, MT-CDMA and MC-CDMA systems. Also MC-DS-CDMA can support highest number of users comparing to other schemes.

2.2 Theoretical Analysis

2.2.1 DS-CDMA

According to the figure 1 (a), the j^{th} user digital data stream $m_j(t)$ is defined by the following equation [1].

$$m_j(t) = \sum_{-\infty}^{+\infty} a_k(t) \dots \dots (1)$$

here, $a_k = \pm 1$.

After spreading, the digital signal is represented by $I_j(t)$, which can be defined as subsequent,

$$I_j(t) = m_j(t) \times \sum_{L=1}^{GDS} C_L^j(t) \dots \dots (2)$$

Then, after PSK modulation, the j^{th} user signal is $S_j(t)$, which is transmitted over the wireless medium.

$$s_j(t) = I_j(t) \times A_c \text{Cos} 2\pi f_c t \dots \dots (3)$$

In fig. 1(c), j^{th} user is receiving. After the BPF, the received signal for j number of users is $S_r(t)$ (assumed).

$$S_r(t) = \sum_{n=1}^j S_n(t) + No_n \dots \dots (4)$$

After demodulation, equation [4] can be characterized by the following,

$$\begin{aligned} S_{out}(t) &= S_r(t) \times A_c \text{Cos} 2\pi f_c t \\ &= \left[\sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GDS} C_L^n(t) \times A_c \text{Cos} 2\pi f_c t + No_n \right] \times A_c \text{Cos} 2\pi f_c \quad \text{[Putting the values from} \\ &\text{equations [1-4]]} \end{aligned}$$

$$\begin{aligned}
&= \frac{A_c^2}{2} \times [1 + \text{Cos}(2 \times 2\pi f_c t)] \times \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GDS} C_L^n(t) + No_n \text{ [After simplification]} \\
&= \frac{A_c^2}{2} \times [1 + \text{Cos}(2 \times 2\pi f_c t)] \times \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GDS} [C_L^n(t) \times C_L^j(t)] + No_n \text{ [After the receiver} \\
&\text{code generator]}
\end{aligned}$$

$$= \frac{A_c^2}{2} \times \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GDS} [C_L^n(t) \times C_L^j(t)] + No_n \text{ [After low pass filters]}$$

So, we get,

$$S_{out}(t) = \frac{A_c^2}{2} \times \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GDS} [C_L^n(t) \times C_L^j(t)] + No_n \dots \dots [5]$$

After the integrator, the depiction of the signal is following,

$$\begin{aligned}
Y_{out} &= \frac{1}{T_b} \times \int_0^{T_b} S_{out}(t) dt \\
&= \frac{1}{T_b} \times \int_0^{T_b} \left\{ \frac{A_c^2}{2} \times \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GDS} [C_L^n(t) \times C_L^j(t)] + No_n \right\} dt \\
Y_{out} &= \frac{A_c^2}{2T_b} \times \int_0^{T_b} \left\{ \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GDS} [C_L^n(t) \times C_L^j(t)] + No_n \right\} dt \dots \dots [6]
\end{aligned}$$

Since, j^{th} user is receiving, separating the j^{th} user part from the summation term of equation [6], we get,

$$\begin{aligned}
Y_{out} &= \frac{A_c^2}{2T_b} \int_0^{T_b} [m_j(t) \times \sum_{L=1}^{GDS} \{C_L^j(t) \times C_L^j(t)\} + No_j] dt + \frac{A_c^2}{2T_b} \int_0^{T_b} [\sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GDS} \{C_L^n(t) \times C_L^j(t)\} + No_n] dt \\
Y_{out} &= \frac{A_c^2}{2T_b} \times [m_j(t) \times 1 + No_j] \times T_b + \frac{A_c^2}{2T_b} \int_0^{T_b} [\sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GDS} \{C_L^n(t) \times C_L^j(t)\} + No_n] dt \dots \dots [7]
\end{aligned}$$

[For orthogonal codes, $\sum_{L=1}^{GDS} \{C_L^j(t) \times C_L^j(t)\} = 1$]

The expression $\frac{A_c^2}{2T_b} \int_0^{T_b} [\sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GDS} \{C_L^n(t) \times C_L^j(t)\} + No_n] dt$ (from equation [7]) is known as

Multi-access interference (MAI) with Noise. This property is called the auto-correlation characteristics of orthogonal codes. Entirely orthogonal code such as Hadamard Walsh code makes this interference exactly zero. Finally, the formula for signal to interference and noise ratio for j^{th} user in DS-CDMA scheme, is

$$SNIR = \frac{1}{\int_0^{Tb} \left[\sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GDS} \{C_L^n(t) \times C_L^j(t)\} \right] dt + No_n} \dots \dots [8]$$

where, $No(t)$ is equal to KTB (Thermal Noise), K is a constant, T is the Noise temperature and B is equal to Noise band width.

2.2.2 MT-CDMA

According to the figure 2 (a), the j^{th} user digital data stream is $m_j(t) = \sum_{-\infty}^{+\infty} a_K(t)$ (from equation (1)). For dispreading, the expression is $m_j(t) \times \sum_{L=1}^{GMT} C_L^j(t)$. Then, the frequency generator generates N_c number of sub-carriers for each two chips for QPSK modulation. For QPSK modulation the expression is

$$S_j(t) = m_j(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times \sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t \dots \dots [9]$$

here, $GMT > N_c$ and f_{c_i} is the frequency of different sub-carrier, for example, f_{c_1} is equal to $f_{c_0} + \Delta f_c$, f_{c_0} is the initial frequency segment of different carriers, Δf_c is equal to $f_{c_1} - f_{c_0}$. So the orthogonal sub-carriers can be defined as following,

$$\begin{aligned} f_{c_1} &= f_{c_0} + \Delta f_c \\ f_{c_2} &= f_{c_0} + 2\Delta f_c \\ &\vdots \\ &\vdots \\ &\vdots \\ f_{c_{N_c}} &= f_{c_0} + N_c \Delta f_c \end{aligned}$$

After modulation, the j^{th} user signal is transmitted by the antenna.

In fig. 2(c), j^{th} user is receiving. The receiver receives the signal as a summation of j number of users with some Noise. First the received signal is demodulated and the expression is

$$\begin{aligned} S_r(t) &= \sum_{n=1}^j (m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t + No_n) \times \sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t \times (\sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t) + No_n \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times (\sum_{i=1}^{N_c} A_c^2 \text{Cos}^2 2\pi f_{c_i} t + \sum_{i=1}^{N_c} A_c^2 \text{Cos} 2\pi f_{c_i} t \times \text{Cos} 2\pi f_{c_{i+1}} t) + No_n \\ &\hspace{20em} [\text{Assuming } f_{c_{N_c+1}} = f_{c_1}] \end{aligned}$$

$$= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \left(\sum_{i=1}^{N_c} \frac{A_c^2}{2} (1 + \text{Cos}^2 4\pi f_{c_i} t) + \sum_{i=1}^{N_c} \frac{A_c^2}{2} (\text{Cos} 2\pi(f_{c_i} + f_{c_{i+1}})t + \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t) \right) + N o_n$$

[After simplification]

$$= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times \left(\sum_{i=1}^{N_c} \frac{A_c^2}{2} (1 + \text{Cos}^2 4\pi f_{c_i} t) + \sum_{i=1}^{N_c} \frac{A_c^2}{2} (\text{Cos} 2\pi(f_{c_i} + f_{c_{i+1}})t + \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t) \right) + N o_n$$

[After the receiver code generator]

$$= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times \left(\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t \right) + N o_n \quad \text{[After low pass filters]}$$

$$= [m_j(t) \times C_L^j(t) \times C_L^j(t) \times \left(\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t \right) + N o_j] +$$

$$\sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times \left(\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t \right) + N o_n$$

[Separating the j^{th} user part from the summation term]

$$= \frac{1}{T_b} \left[\int_0^{T_b} [m_j(t) \times C_L^j(t) \times C_L^j(t) \times \left(\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t \right) + N o_j] dt \right. \\ \left. + \int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times \left(\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t \right) + N o_n dt \right]$$

[After integrators]

$$= \frac{1}{T_b} [m_j(t) \times C_L^j(t) \times C_L^j(t) \times (\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t) + No_j] \times T_b +$$

$$\int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times (\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t) + No_n$$

[After doing the integration]

So, we achieve

$$S_r(t) = [m_j(t) \times (\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t) + No_j] + \frac{1}{T_b}$$

$$\int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times (\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t) + No_n$$

. . . . [10]

[After using the auto-correlation and simplification]

The term $\frac{1}{T_b} \int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMT} C_L^n(t) \times \sum_{L=1}^{GMT} C_L^j(t) \times (\sum_{i=1}^{N_c} \frac{A_c^2}{2} + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t) + No_n$

(from equation [10]) is known as Multi-access interference (MAI) with Noise for MT-CDMA scheme. Now, the formula for signal to interference and noise ratio for j^{th} user in MT-CDMA system can be symbolized by equation [11].

$$SNIR = \frac{\sum_1^{N_c} \frac{A_c^2}{2}}{\sum_1^{N_c} \frac{A_c^2}{2} \times \frac{1}{T_b} \int_0^{T_b} [\sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMT} (C_L^n(t) \times C_L^j(t)) \times (1 + \text{Cos} 2\pi(f_{c_i} - f_{c_{i+1}})t)] + No_n}$$

. . . . [11]

where, A_c is magnitude of the sub carrier

2.2.3 MC-CDMA

According to the figure 3 (a), the j^{th} user digital data stream is $m_j(t) = \sum_{-\infty}^{+\infty} a_k(t)$ (from equation (1)). For spreading, the expression is $m_j(t) \times \sum_{L=1}^{GMC} C_L^j(t)$. Then, the frequency generator generates N_c number of sub-carriers for each chip for QPSK modulation. For QPSK modulation the expression is

$$S_j(t) = m_j(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t \dots [12]$$

here, $GMC=N_c$ and f_{c_i} is the frequency of different sub-carrier.

After modulation, the j^{th} user signal is transmitted by the antenna.

In fig. 3(c), j^{th} user is receiving. The receiver receives the signal as a summation of j number of users with some Noise. First the received signal is demodulated and the expression is

$$\begin{aligned} S_r(t) &= \sum_{n=1}^j [m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t + No_n] \times \sum_{i=1}^{N_c} A_c \text{Cos} 2\pi f_{c_i} t \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{i=1}^{N_c} (A_c \text{Cos} 2\pi f_{c_i} t \times A_c \text{Cos} 2\pi f_{c_i} t) + No_n \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{i=1}^{N_c} \frac{A_c^2}{2} (1 + \text{Cos}^2 2\pi f_{c_i} t) + No_n \quad [\text{After simplification}] \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{i=1}^{N_c} \frac{A_c^2}{2} (1 + \text{Cos}^2 2\pi f_{c_i} t) + No_n \quad [\text{After despreading by} \\ &\quad \text{the receiver code generator}] \end{aligned}$$

$$\begin{aligned} &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{i=1}^{N_c} \frac{A_c^2}{2} + No_n \quad [\text{After low pass filters}] \\ &= \left[\sum_{i=1}^{N_c} \frac{A_c^2}{2} m_j(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_j \right] + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n \end{aligned}$$

[Separating the j^{th} user component from the summation term]

So, we obtain,

$$S_r(t) = \left[\sum_{i=1}^{N_c} \frac{A_c^2}{2} m_j(t) + No_j \right] + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n \dots [13]$$

[After applying the auto-correlation characteristic]

The term $\sum_{i=1}^{N_c} \frac{A_c^2}{2} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n$ (from equation [13]) is known as Multi-access interference (MAI) with Noise for MC-CDMA scheme. Now, the formula for signal to interference and noise ratio for j^{th} user in MC-CDMA system can be signified by equation [14].

$$SNIR = \frac{\sum_1^{N_c} \frac{A_c^2}{2}}{\sum_{i=1}^{N_c} \frac{A_c^2}{2} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n} \dots \dots [14]$$

2.2.4 MC-DS-CDMA

According to the figure 4 (a), the j^{th} user digital data stream is $m_j(t) = \sum_{-\infty}^{+\infty} a_K(t)$ (from equation (1)). For dispreading, the expression is $m_j(t) \times \sum_{L=1}^{GMC} C_L^j(t)$. Then, the frequency generator generates N_c number of sub-carriers for each chip with QPSK modulation technique. For QPSK modulation, the expression is

$$S_j(t) = m_j(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{i=1}^{N_c} A_c \text{Cos } 2\pi f_{c_i} t \dots \dots [15]$$

here, $GMC=N_c$ and f_{c_i} is the frequency of different sub-carrier.

After modulation, the j^{th} user signal is transmitted by the antenna.

In fig. 4(b), j^{th} user is receiving. The receiver receives the signal as a summation of j number of users with some Noise. First the received signal is demodulated and the expression is

$$\begin{aligned} S_r(t) &= \sum_{n=1}^j [m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{i=1}^{N_c} A_c \text{Cos } 2\pi f_{c_i} t + No_n] \times \sum_{i=1}^{N_c} A_c \text{Cos } 2\pi f_{c_i} t \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{i=1}^{N_c} (A_c \text{Cos } 2\pi f_{c_i} t \times A_c \text{Cos } 2\pi f_{c_i} t) + No_n \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{i=1}^{N_c} \frac{A_c^2}{2} (1 + \text{Cos}^2 2\pi f_{c_i} t) + No_n \quad \text{[After simplification]} \\ &= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{i=1}^{N_c} \frac{A_c^2}{2} (1 + \text{Cos}^2 2\pi f_{c_i} t) + No_n \\ &\quad \text{[After dispreading by the receiver code generator]} \end{aligned}$$

$$= \sum_{n=1}^j m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{i=1}^{N_c} \frac{A_c^2}{2} + No_n \quad [\text{After low pass filters}]$$

$$= \left[\sum_{i=1}^{N_c} \frac{A_c^2}{2} m_j(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_j \right] + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n$$

[Separating the j^{th} user component from the summation term]

$$= \left[\frac{1}{T_b} \int_0^{T_b} \sum_{i=1}^{N_c} \frac{A_c^2}{2} m_j(t) \times \sum_{L=1}^{GMC} C_L^j(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_j \right] + \frac{1}{T_b} \int_0^{T_b} \sum_{i=1}^{N_c} \frac{A_c^2}{2} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n$$

[After the integrators shown in fig. 4(b)]

$$= \left[\frac{1}{T_b} \times \sum_{i=1}^{N_c} \frac{A_c^2}{2} m_j(t) \times T_b + No_j \right] + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \times \frac{1}{T_b} \int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n$$

[After doing the integration and applying the auto-correlation characteristic]

So, we obtain,

$$S_r(t) = \left[\sum_{i=1}^{N_c} \frac{A_c^2}{2} m_j(t) + No_j \right] + \sum_{i=1}^{N_c} \frac{A_c^2}{2} \times \frac{1}{T_b} \int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n \quad \dots \dots [16]$$

The term $\sum_{i=1}^{N_c} \frac{A_c^2}{2} \times \frac{1}{T_b} \int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n$ (from equation [16]) is known as

Multi-access interference (MAI) with Noise for MC-CDMA scheme. Now, the formula for signal to interference and noise ratio for j^{th} user in MC-CDMA system can be signified by equation [14].

$$SNIR = \frac{1}{\frac{1}{T_b} \int_0^{T_b} \sum_{n=1}^{j-1} m_n(t) \times \sum_{L=1}^{GMC} C_L^n(t) \times \sum_{L=1}^{GMC} C_L^j(t) + No_n} \quad \dots \dots [17]$$

2.3 Bit Error Rate:

The formula for Bit Error Rate in PSK and QPSK modulation is,

$$BER = \frac{1}{2} \operatorname{erfc} \left(\frac{SNIR}{\sqrt{2}} \right) \dots [18]$$

where, erfc is the complement of erf function. erf is known as error function.

We use PSK modulation for DS-CDMA; QPSK is used for MT-CDMA, MC-CDMA and MC-DS-CDMA. The BER equation is the same for all. This equation is used later in this analysis to find out the BER relationship with different parameters for the four different schemes.

Chapter III: RESULT AND SUMMARY

Result and Discussion:

Following the theoretical analysis's described in chapter 2.2 and 2.3; we evaluated the performance results of different CDMA systems and are shown in following figures.

3.1 DS-CDMA

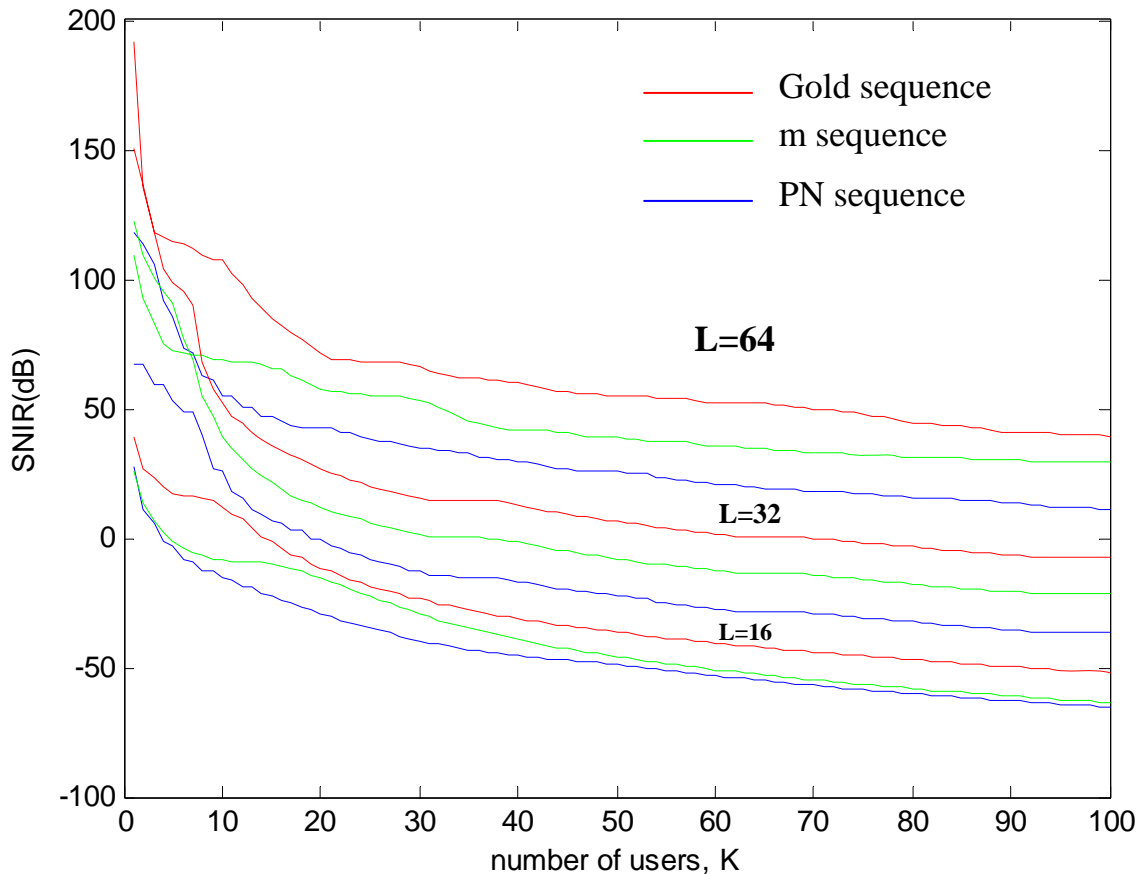


Fig: 10. Plots of SNIR versus number of users in DS-CDMA system with number of chips per bit as a parameter using PN sequence ($2^{10}-1$), m sequence (2^5-1), Gold sequence ($2^{10}-1$).

Fig. 10 shows the plots of SNIR versus number of users in DS-CDMA system with number of chips per bit as a parameter for PN, Gold and m sequence codes. It is drawn from equation (8). It is noticed that there is simplified reduction in SNIR with inverse in the number of user. However m sequence provides better performance over PN sequence and Gold sequence provides best performance over the m sequence. For each different code lengths, three different sequences are used. It is found that greater number of chips per bit gives the best SNIR with Gold sequence. Since Gold sequence gives better SNIR among PN and m sequence, it is used for the MT-CDMA, MC-CDMA and MC-DS-CDMA. PN sequence is used for DS-CDMA scheme.

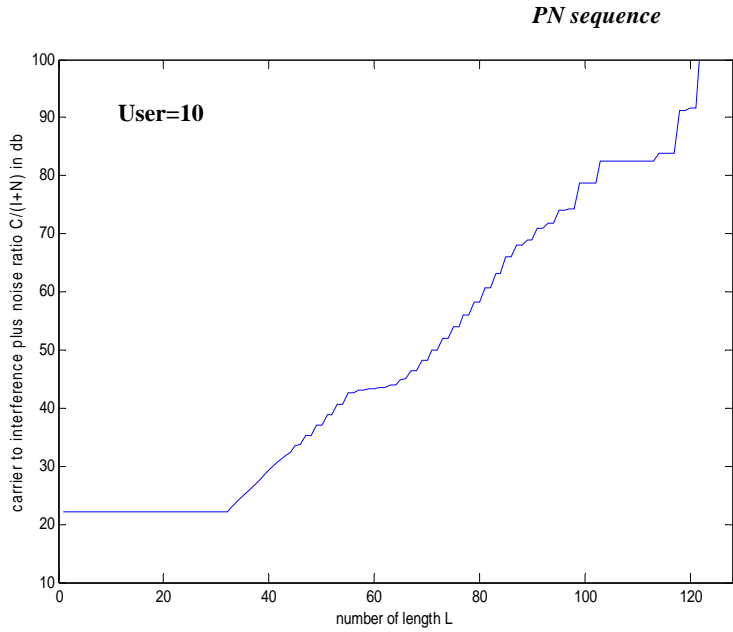


Fig: 11. Plots of SNIR versus number of chips per bit in DS-CDMA system using PN sequence codes ($2^{10}-1$).

Fig. 11 examines the plots of SNIR versus number of chips per bit in DS-CDMA system using PN sequence codes. It is observed that the SNIR is gradually rising with the number of chips per bit with a fixed number of 10 users. So, it is proved that greater code length gives better performance in DS-CDMA system. Code length is a significant factor in wireless communication with CDMA system.

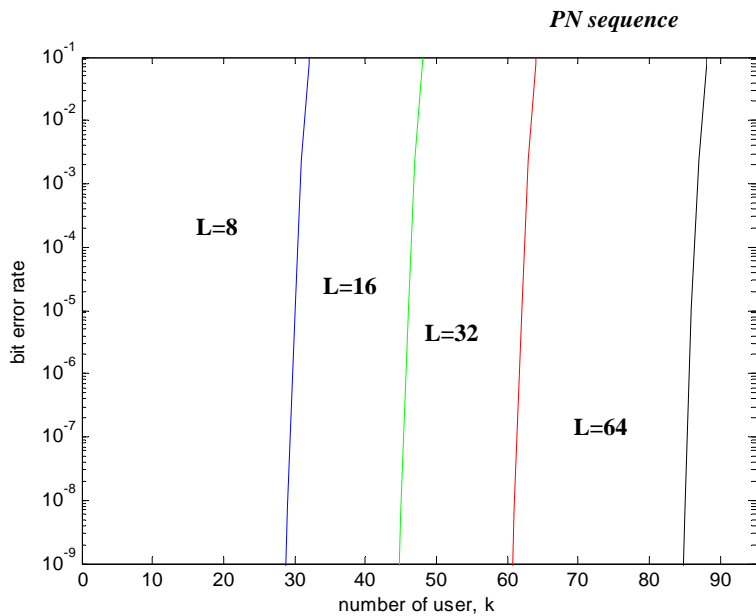


Fig: 12. Plots of bit error rate versus number of users in DS-CDMA system with number of chips per bit as a parameter using PN sequence codes ($2^{10}-1$).

Fig: 12. Plots of bit error rate versus number of users in DS-CDMA system with number of chips per bit at 8, 16, 32 and 64 using PN sequence codes. It is observed that as the number of user increases, the BER is also increases and that is obvious. Since greater BER is not supportive for a wireless communication system, so it is needed to be reduced and that is easily done by increasing the number of chips per bit. The more code length increases, the more BER decreases again with the more number of users sustain.

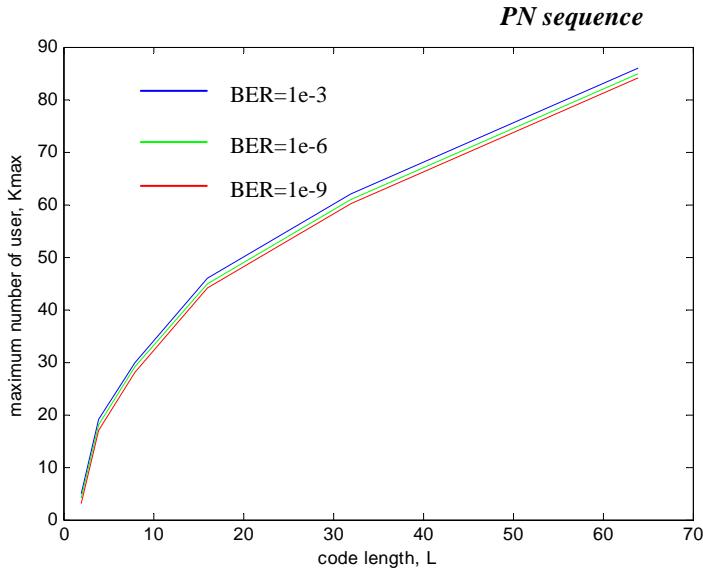


Fig: 13. Plots of maximum number of users versus number of chips per bit in DS-CDMA system with bit error rate as a parameter using PN sequence codes ($2^{10}-1$).

Fig. 13 is the plots of maximum number of users versus number of chips per bit in DS-CDMA system with bit error rate $1e-3$, $1e-6$ and $1e-9$ using PN sequence codes. In general, maximum number of users is increasing with the number of chips per bit. It is seen that maximum number of users at BER $1e-9$ are greater than the maximum number of users at BER $1e-3$. Again, a system can support the for the most part of maximum number of users with BER $1e-9$ compared to BER $1e-3$ and BER $1e-6$. So, we can summarize that the support of maximum number of users for a particular code length is maximum when the BER is minimum.

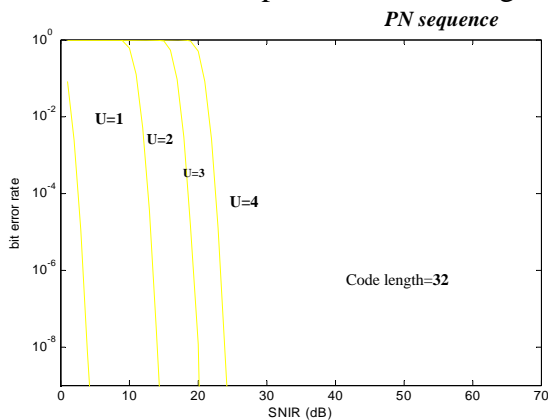


Fig: 14. Plots of bit error rate versus SNIR in DS-CDMA system with number of users as a parameter using PN sequence codes ($2^{10}-1$).

Fig. 14 describes the plots of bit error rate versus SNIR in DS-CDMA system with number of

users as a parameter using PN sequence codes. It is found that usually the BER decreases with respect to SNIR for a fixed number of users. Then again, if the number of users enhances the BER also increases.

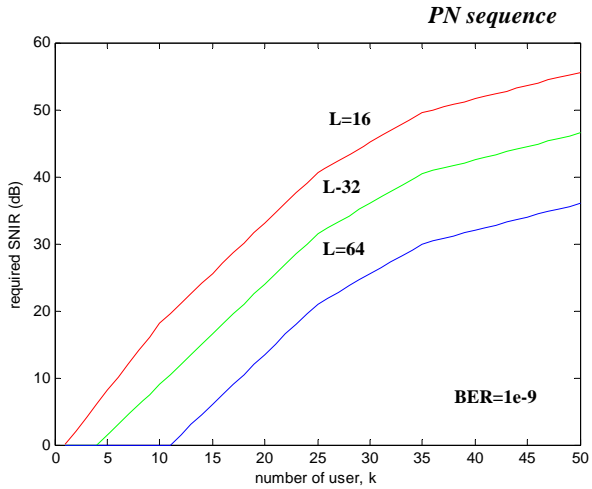


Fig: 15. Plots of required SNIR versus number of users in DS-CDMA system with number of chips per bit as a parameter using PN sequence codes ($2^{10}-1$).

Fig. 15 examines the plots of required SNIR versus number of users in DS-CDMA system with number of chips per bit at 16, 32 and 64 using PN sequence codes. Fig.15 is drawn from fig.14 by fixing the BER at 1×10^{-9} . It is observed that greater number of users needs greater required SNIR with fixed code length for a system. For example, at SNIR 30 dB with code length 16, a DS-CDMA system can support 15 users (taking a point from fig.15). Now with the increased code length 32, a system can support more users that are 25 with the same SNIR 30. Again, with the greatest code length 64, system can hold maximum number of users that are 35 with the same SNIR 30 dB. This is the main beauty of DS-CDMA.

3.2 MT-CDMA

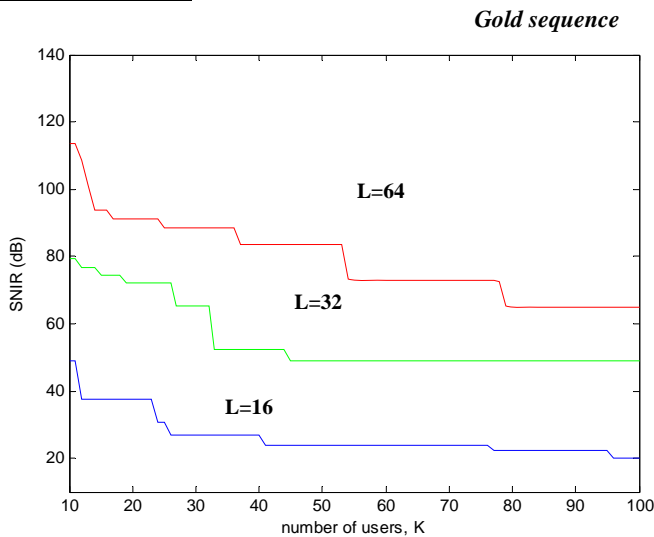


Fig: 16. Plots of SNIR versus number of users in MT-CDMA system with number of chips per bit as a parameters using Gold sequence ($2^{10}-1$).

Fig. 16 shows the plots of SNIR versus number of users in MT-CDMA system with number of chips per bit as a parameter using Gold sequence codes. It is drawn from equation (11). It is noticed that there is simplified reduction in SNIR with inverse in the number of user. Here, number of chips per bit is taken as 16, 32 and 64. It is found that greater number of chips per bit gives the best SNIR with Gold sequence.

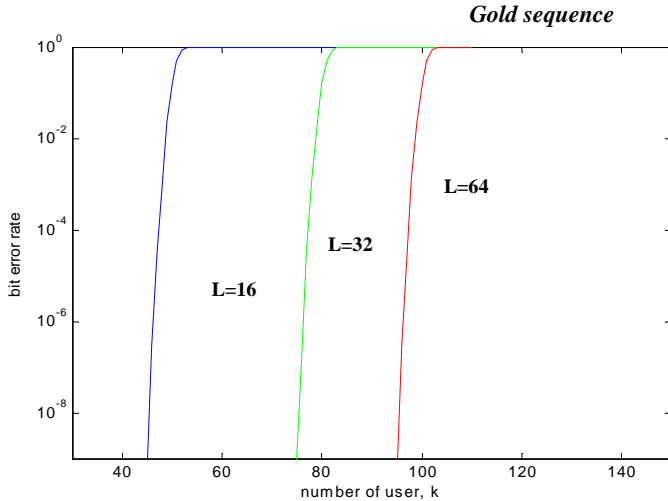


Fig: 17. Plots of bit error rate versus number of users in MT-CDMA system with number of chips per bit as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 17 Plots of bit error rate versus number of users in MT-CDMA system with number of chips per bit at 16, 32 and 64 using Gold sequence codes. It is observed that as the number of user increases, the BER is also increases and that is obvious. Since greater BER is not supportive for a wireless communication system, so it is needed to be reduced and that is easily done by increasing the number of chips per bit. The more code length increases, the more BER decreases again with the more number of users sustain.

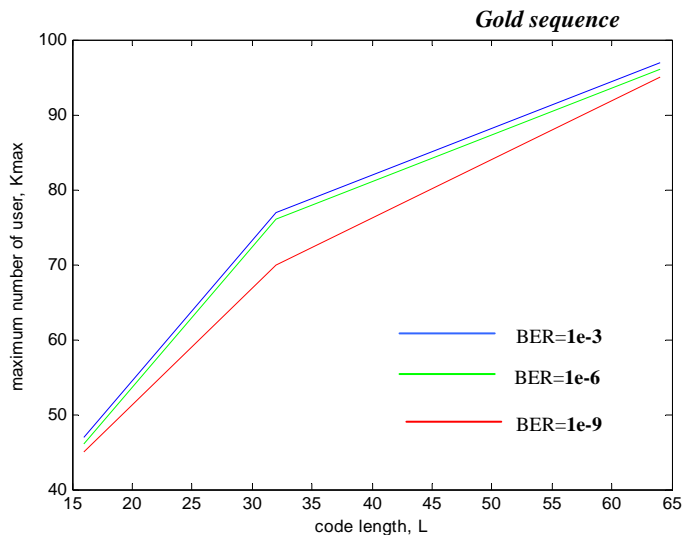


Fig: 18. Plots of maximum number of users versus number of chips per bit in MT-CDMA system with bit error rate as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 18 is the plots of maximum number of users versus number of chips per bit in MT-CDMA

system with bit error rate $1e-3$, $1e-6$ and $1e-9$ using Gold sequence codes. In general, maximum number of users is increasing with the number of chips per bit. It is seen that maximum number of users at BER $1e-6$ are greater than the maximum number of users at BER $1e-3$. Again, a system can support the largest part maximum number of users with BER $1e-9$ compared to BER $1e-3$ and BER $1e-6$. So, we can abridge that the support of maximum number of users for a meticulous code length is maximum when the BER is bare minimum.

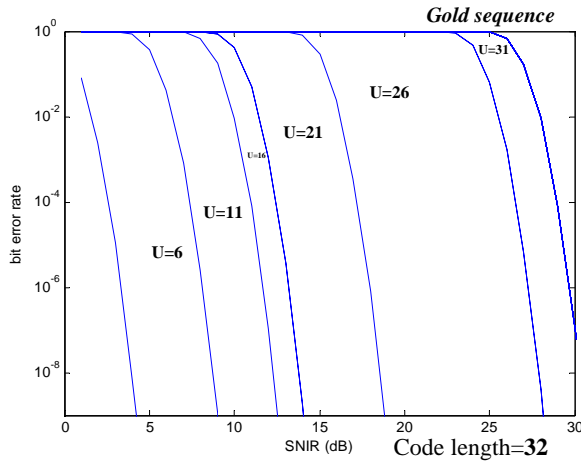


Fig: 19. Plots of bit error rate versus SNIR in MT-CDMA system with number of users as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 19 describes the plots of bit error rate versus SNIR in MT-CDMA system with number of users as a parameter using PN sequence codes. It is found that usually the BER decreases with respect to SNIR for a fixed number of users. Then again, if the number of users enhances the BER also increases.

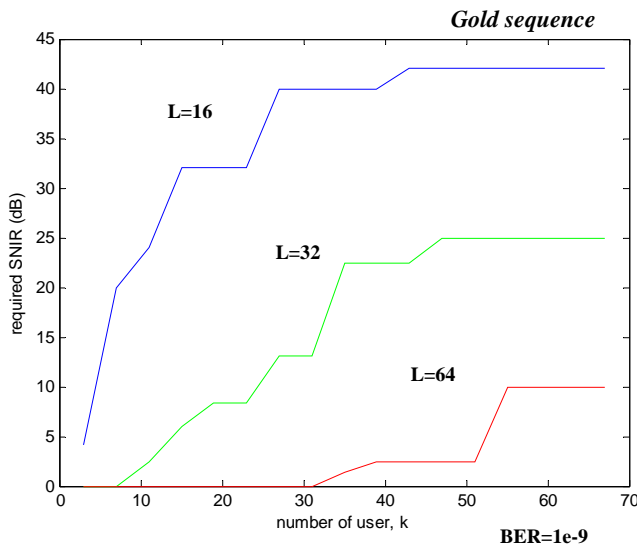


Fig: 20. Plots of required SNIR versus number of users in MT-CDMA system with number of chips per bit as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 20 examines the plots of required SNIR versus number of users in MT-CDMA system with number of chips per bit at 16, 32 and 64 using Gold sequence codes. Fig.20 is drawn from fig.19

by fixing the BER at 1×10^{-9} . It is observed that greater number of users needs greater required SNIR with fixed. For example, at SNIR 10 dB with code length 16, a MT-CDMA system can support 5 users (taking a point from fig.20). Now with the increased code length 32, a system can support more users that are 25 with the same SNIR 10. Again, with the greatest code length 64, system can hold maximum number of users that are 55 with the same SNIR 10 dB. This is the main beauty of MT-CDMA.

3.3 MC-CDMA

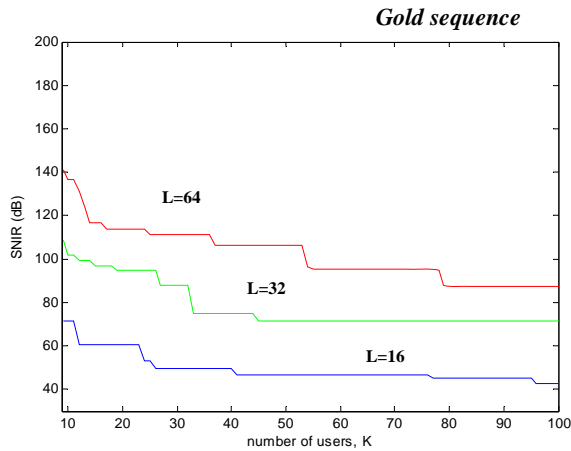


Fig: 21. Plots of SNIR versus number of users in MC-CDMA system with number of chips per bit as a parameters using Gold sequence ($2^{10}-1$).

Fig. 21 shows the plots of SNIR versus number of users in MC-CDMA system with number of chips per bit as a parameter using Gold sequence codes. It is drawn from equation (14). It is noticed that there is simplified reduction in SNIR with inverse in the number of user. Here, number of chips per bit is taken as 16, 32 and 64. It is found that greater number of chips per bit gives the best SNIR with Gold sequence.

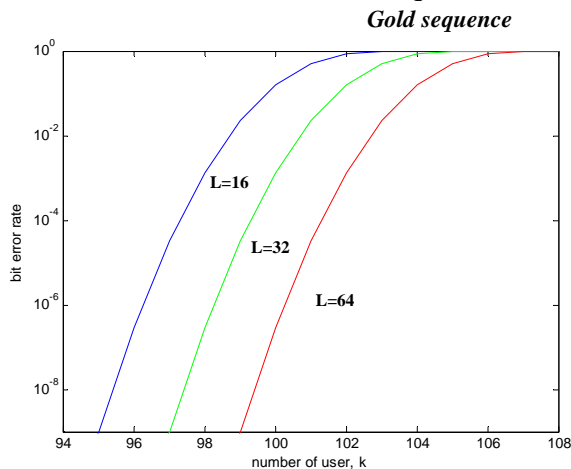


Fig: 22. Plots of bit error rate versus number of users in MC-CDMA system with number of chips per bit as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 22 Plots of bit error rate versus number of users in MC-CDMA system with number of chips per bit at 16, 32 and 64 using Gold sequence codes. It is observed that as the number of user increases, the BER is also increases and that is obvious. Since greater BER is not supportive for a wireless communication system, so it is needed to be reduced and that is easily done by increasing the number of chips per bit. The more code length increases, the more BER decreases again with the more number of users sustain.

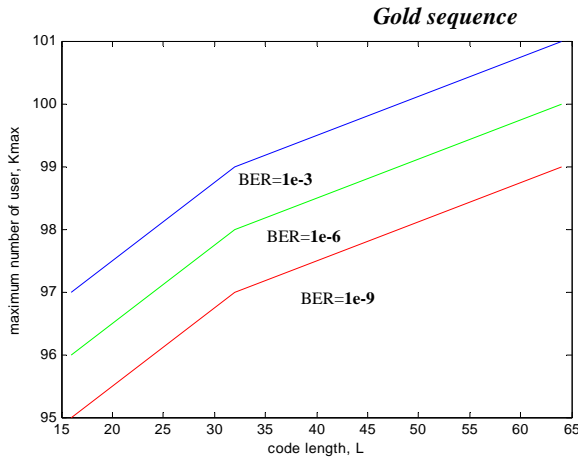


Fig: 23. Plots of maximum number of users versus number of chips per bit in MC-CDMA system with bit error rate as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 23 is the plots of maximum number of users versus number of chips per bit in MC-CDMA system with bit error rate 1×10^{-3} , 1×10^{-6} and 1×10^{-9} using Gold sequence codes. In all-purpose, maximum number of users is increasing with the number of chips per bit. It is illustrated that maximum numbers of users at BER 1×10^{-6} are greater than the maximum numbers of users at BER 1×10^{-3} . Again, a system can support the majority of maximum number of users with BER 1×10^{-9} compared to BER 1×10^{-3} and BER 1×10^{-6} . So, we can conclude that the support of maximum number of users for a particular code length is greatest when the BER is less.

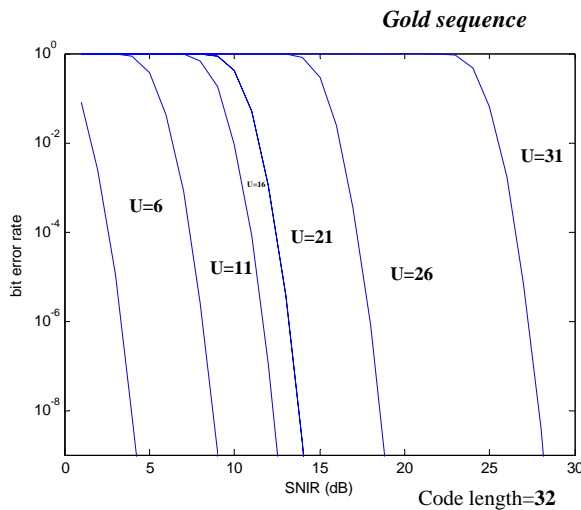


Fig: 24. Plots of bit error rate versus SNIR in MC-CDMA system with number of users as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 24 describes the plots of bit error rate versus SNIR in MC-CDMA system with number of users as a parameter using PN sequence codes. It is found that usually the BER decreases with respect to SNIR for a fixed number of users. Then again, if the number of users enhances the BER also increases.

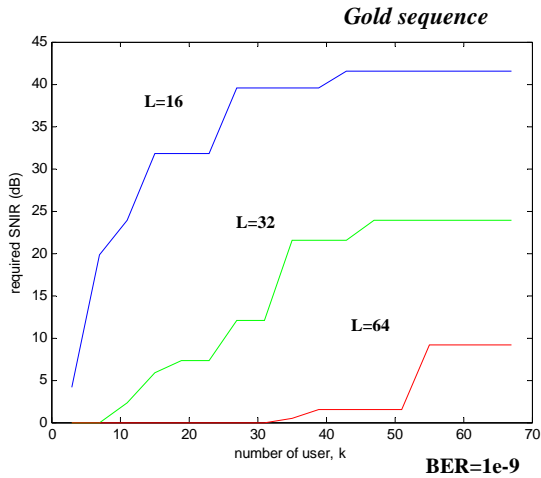


Fig: 25. Plots of required SNIR versus number of users in MC-CDMA system with number of chips per bit as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 25 scrutinizes the plots of required SNIR versus number of users in MC-CDMA system with numbers of chips per bit at 16, 32 and 64 using Gold sequence codes. It is found that greater number of users needs greater required SNIR with fixed code length for a system. For example, at SNIR 8 dB with code length 16, a MC-CDMA system can support 5 users (taking a point from fig.25). Now with the increased code length 32, a system can support more users that are 25 with the same SNIR 8. Again, with the greatest code length 64, system can support maximum number of users that are 55 with the same SNIR 5 dB. Here, one more observable thing is for code length 64, the system can support more number of users than DS-CDMA. That is the magnetism of MC-CDMA.

3.4 MC-DS-CDMA

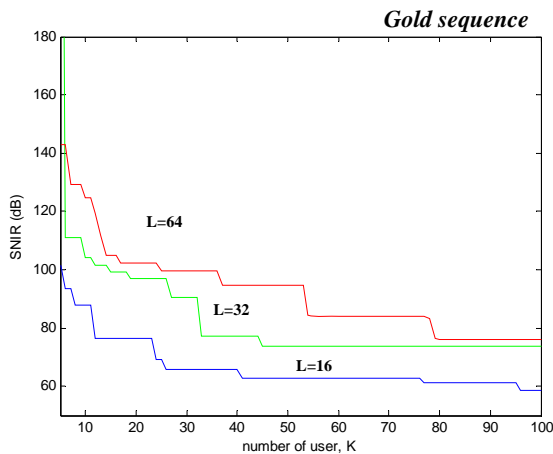


Fig: 26. Plots of SNIR versus number of users in MC-DS-CDMA system with number of chips per bit as a

parameters using Gold sequence ($2^{10}-1$).

Fig. 26 shows the plots of SNIR versus number of users in MC-DS-CDMA system with number of chips per bit as a parameter Gold sequence codes. It is drawn from equation (17). It is noticed that there is simplified reduction in SNIR with inverse in the number of user. Here, number of chips per bit is taken as 16, 32 and 64. It is found that greater number of chips per bit gives the best SNIR with Gold sequence.

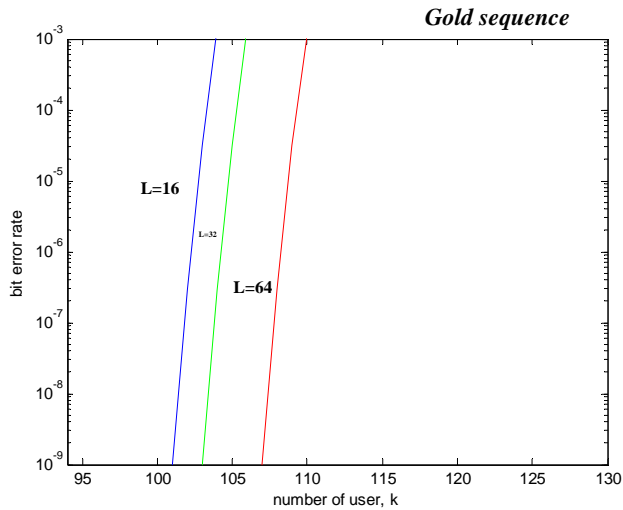


Fig: 27. Plots of bit error rate versus number of users in MC-DS-CDMA system with number of chips per bit as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 27 Plots of bit error rate versus number of users in MC-DS-CDMA system with number of chips per bit at 16, 32 and 64 using Gold sequence codes. It is observed that as the number of user increases, the BER is also increases and that is obvious. Since greater BER is not supportive for a wireless communication system, so it is needed to be reduced and that is easily done by increasing the number of chips per bit. The more code length increases, the more BER decreases again with the more number of users sustain.

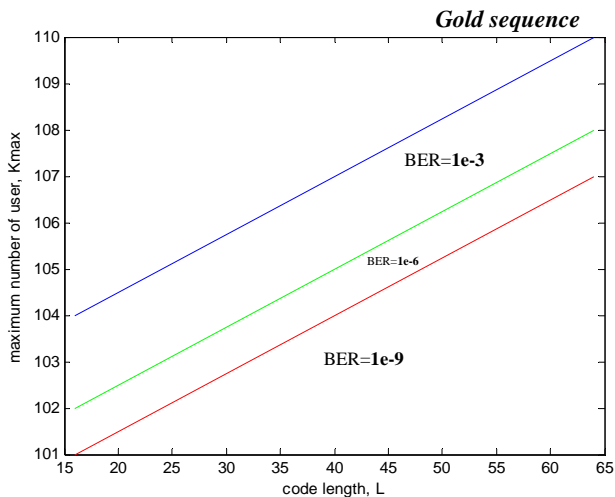


Fig: 28. Plots of maximum number of users versus number of chips per bit in MC-DS-CDMA system with bit error rate as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 28 is the plots of maximum number of users versus number of chips per bit in MC-DS-CDMA system with bit error rate at 1×10^{-3} , 1×10^{-6} and 1×10^{-9} using Gold sequence codes. In common, maximum number of users is increasing with the number of chips per bit. It is demonstrated that maximum numbers of users at BER 1×10^{-6} are greater than the maximum numbers of users at BER 1×10^{-3} . Again, a system can support the majority of maximum number of users with BER 1×10^{-9} compared to BER 1×10^{-3} and BER 1×10^{-6} . So, we can conclude that the support of maximum number of users for a particular code length is greatest when the BER is less.

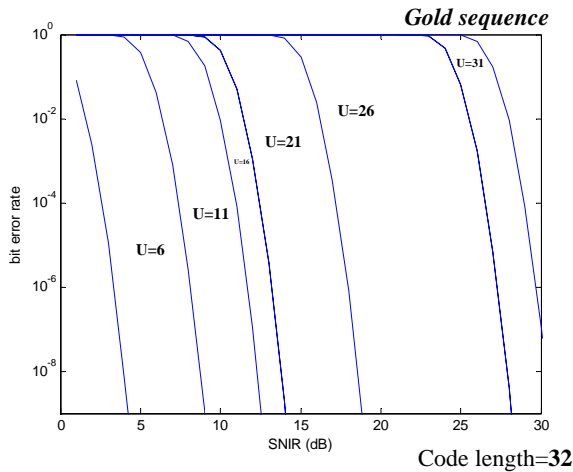


Fig: 29. Plots of bit error rate versus SNIR in MC-DS-CDMA system with number of users as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 29 describes the plots of bit error rate versus SNIR in MC-DS-CDMA system with number of users as a parameter using PN sequence codes. It is found that usually the BER decreases with respect to SNIR for a fixed number of users. Then again, if the number of users enhances the BER also increases.

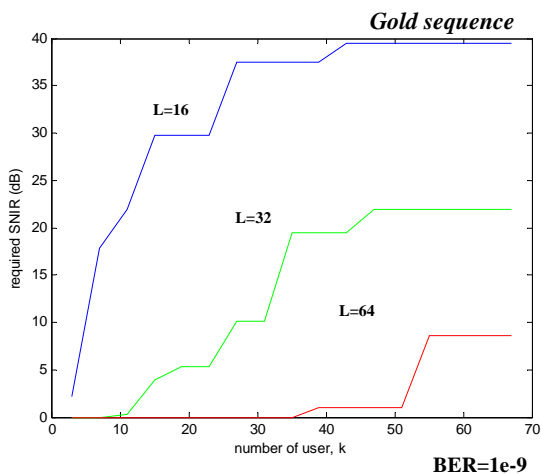


Fig: 30. Plots of required SNIR versus number of users in MC-DS-CDMA system with number of chips per bit as a parameter using Gold sequence codes ($2^{10}-1$).

Fig. 30 explains the plots of required SNIR versus number of users in MC-DS-CDMA system

with number of chips per bit at 16, 32 and 64 using Gold sequence codes. It is observed that greater number of users needs greater required SNIR with fixed code length and BER (here 1×10^{-9}) for a system. For example, at SNIR 5 dB with code length 16 a MC-DS-CDMA system can support 15 users (taking a point from fig.30). Now with the increased code length 32, a system can support more users that are 23 with the same SNIR 5. Again, with the greatest code length 64, system can support maximum number of users that is 53 with the same SNIR 5 dB. That is the wizardry of MC-DS-CDMA.

3.5 COMPARISON OF THE FOUR SCHEMES

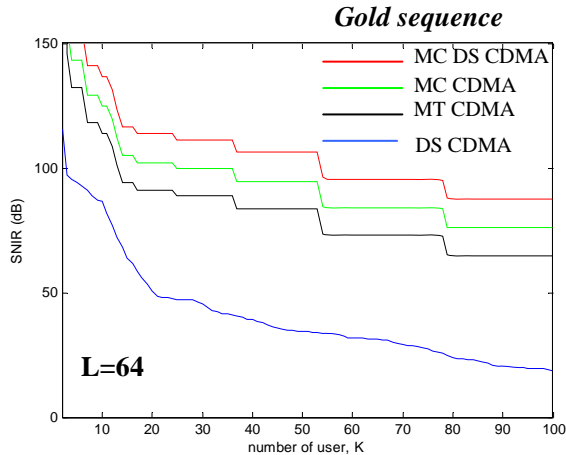


Fig: 31. Plots of SNIR versus number of users for MC-DS-CDMA, MC-CDMA, MT-CDMA and DS-CDMA systems at code length 64 using Gold sequence ($2^{10}-1$).

Fig. 31 shows the plots of SNIR versus number of users for four different schemes at code length 64 using Gold sequence. It is noticed that at a given number of code length (here 64), MC-DS-CDMA has the highest Signal to Noise and Interference Ratio (SNIR). As a result, this system countenances a reduced amount of interference compared to the other systems. MC-CDMA is instituted better-quality over MT-CDMA. DS-CDMA suffers with the majority interference among all the others.

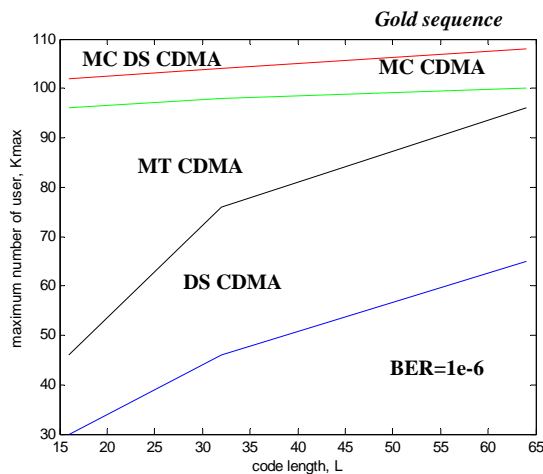


Fig: 32. Plots of maximum number of users versus number of chips per bit at bit error rate 1×10^{-6} for MC-DS-CDMA, MC-CDMA, MT-CDMA and DS-CDMA systems using Gold sequence codes ($2^{10}-1$).

Fig. 32 is the plots of maximum number of users versus number of chips per bit with bit error rate $1e-6$ for the four different schemes using Gold sequence codes. It is observed that for a particular number of code length, MC-DS-CDMA has the flotation of maximum number of users. Then, MC-CDMA is found supercilious over MT-CDMA. DS-CDMA has very diminished support of number of users compared all other schemes. To compare more specifically, let take a point from the fig. 32. Here K_{max} is the, maximum number of users. Suppose, code length is 32, then $K_{max}=48$ (DS-CDMA), $K_{max}=78$ (MT-CDMA), $K_{max}=98$ (MC-CDMA), $K_{max}=102$ (MC-DS-CDMA). So MC-DS-CDMA can support more users with higher code length.

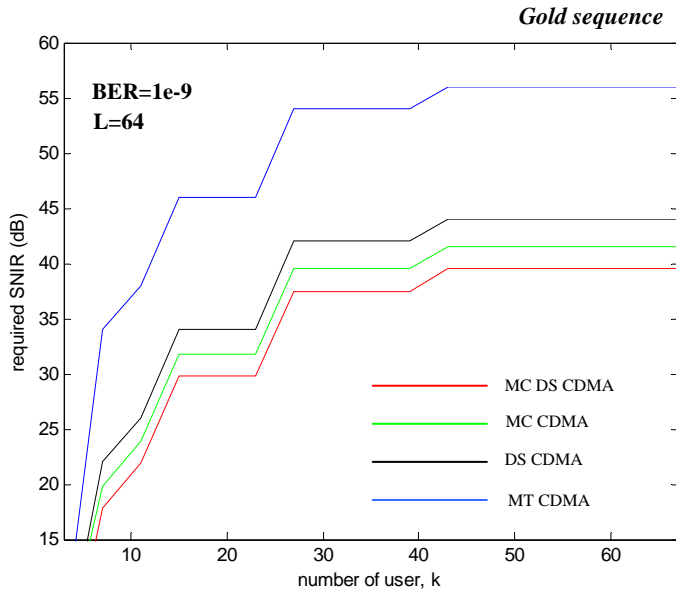


Fig: 33. Plots of required SNIR versus number of users at number of chips per bit 64 for the four systems using Gold sequence codes ($2^{10}-1$).

Fig. 33 is the plots of required SNIR versus number of users with number of chips per bit 64 and BER at 1×10^{-9} using Gold sequence codes for the four different systems. If maximum number of users supported by a system is 30 (taking a point from fig. 33), then required SNIR is 38 for MC-DS-CDMA, required SNIR is 40 for MC-CDMA, required SNIR is 47 for MT-CDMA, required SNIR is 55 for DS-CDMA. So, it is evidently inaugurated that at a minimum required SNIR MC-DS-CDMA system can support more number of users correlated to any other schemes.

Chapter IV: CONCLUSION AND FUTURE WORK

Conclusion:

We conspicuously describe the four systems of CDMA; DS-CDMA, MT-CDMA, MC-CDMA, MC-DS-CDMA. We perceive signal to interference and noise ratio with respect to the user, then the Bit error rate with respect to users for the four different schemes for PSK and QPSK modulations according to the SNIR, again the Bit error rate with respect to SNIR. Finally, we evaluate the maximum number of users for different code length and required SNIR for that maximum number of users for the four different systems, which are very extensive for wireless communication with CDMA technique. Then the four systems are compared in the above revealed categories.

<u>Applications</u>	<u>Schemes</u>
1. Maximum user supportable system among CDMA system	<input type="checkbox"/> MC-DS-CDMA
2. Non-frequency selective system with Less SNIR	<input type="checkbox"/> MC-CDMA
3. Most secured system	<input type="checkbox"/> MT-CDMA
4. Less required SNIR system	<input type="checkbox"/> DS-CDMA

Table: 4. Proposal of multi-carrier CDMA systems for future Wireless Communication Environment

As a final point, it can be concluded (from table: 4) that MC-DS-CDMA can support highest number of users with less required SNIR compared to others, MC-CDMA provides non frequency selective fading channel, MT-CDMA is the most secure system among all the four systems. According to the result, we proposed MC-DS-CDMA scheme for a wireless communication which required excessive number of users, MT-CDMA scheme for a system which requires more security such as military communications and any other security forces.

Future Work:

Future work will be carried out by the performance analyses of Multi-carrier DS-CDMA systems with multiple inputs and multiple outputs (MIMO) system using a rake receiver.

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