W-CDMA System Simulation Using MATLAB SIMULINK

NITIN KUMAR 071084

Under the supervision of
Mr. Bhasker Gupta

MAY 2011

Submitted in partial fulfillment of the Degree of
Bachelor of Technology

DEPARTMENT OF ELECTRONICS AND
COMMUNICATION ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION
TECHNOLOGY,
WAKNAGHAT

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT

CERTIFICATE

This is to certify that project report **entitled "WCDMA SYSTEM SIMULATON USING MATLAB SIMULINK", submitted by NITIN KUMAR** in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and Communication Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision. This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

Signature of the Supervisor: ....

Name of the Supervisor: **Mr.BHASKAR GUPTA**

Designation: Sr.Lecturer

Date: 23/5/11

ACKNOWLEDGEMENT

Apart from the efforts, the success of any project depends largely on the encouragement and guidelines of many others. Therefore we take the opportunity to express our gratitude to the people who have been instrumental in the successful completion of this project.

We would also like to show our appreciation to our project guide **Mr. Bhasker Gupta,Senior Lecturer Department of Electronics and Communication**. Without his able guidance, tremendous support ant continuous motivation the project work would not be carried out satisfactory. His kind behavior and motivation provided us the required courage to complete our project.

Special thanks to our project panel because it was their regular concern and appreciation that made this project carried out easily and satisfactory.

NITIN KUMAR

071084

Date: 23/05/11

SUMMARY

WCDMA (Wideband Codes Division Multiple Access) is an UMTS (Universal Mobile Telecommunication System) system which belongs to third generation (3G) technology The objective of this research is to present the wideband CDMA air interface scheme that is currently being developed by the standardization organizations in Europe, Japan, the United States, and Korea for third-generation communication systems. We will discuss the main technical approaches of W-CDMA and present key technical features of the system.

The main aim of next generation of mobile communications system is to provide uninterruptable services to anybody, anywhere and at anytime. The targeted services for next generation mobile phone users include services like transmitting high speed data, video and multimedia traffic as well as voice signals.

W-CDMA matches with high demands of the market. Demands include high-speed transmission, supported by multi-media services on the handsets. This report investigates multiuser effect and study of 3G mobile systems using Simulink MATLAB 7.5. The model for the system is constructed using block diagrams in Simulink library of MATLAB 7.5 that fulfills the characteristics of the system.

Furthermore, the air interface has flexible support of mixed services, variable-rate services, and an efficient packet mode. Key W-CDMA features also include improved basic capacity/coverage performance compared to second-generation systems,

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1
WIRELESS COMMUNICATION

1.1 First Generation (1G)

1G (or 1-G) refers to the first-generation [1] of wireless telephone technology, mobile telecommunications. These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The main difference between two succeeding mobile telephone systems, 1G and 2G, is that the radio signals that 1G networks use are analog, while 2G networks are digital

Although both systems use digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system, the voice itself during a call is encoded to digital signals in 2G whereas 1G is only modulated to higher frequency, typically 150 MHz and up.

One such standard is NMT (Nordic Mobile Telephone), used in Nordic countries, Switzerland, Netherlands, Eastern Europe and Russia. Others include AMPS (Advanced Mobile Phone System) used in the North America and Australia,[1] TACS (Total Access Communications System) in the United Kingdom, C-450 in West Germany, Portugal and South Africa, Radiocom 2000[2] in France, and RTMI in Italy. In Japan there were multiple systems. Three standards, TZ-801, TZ-802, and TZ-803 were developed by NTT, while a competing system operated by DDI used the JTACS (Japan Total Access Communications System) standard.

The first commercially automated cellular network (the 1G generations) was launched in Japan by NTT in 1979, initially in the metropolitan area of Tokyo. Within five years, the NTT network had been expanded to cover the whole population of Japan and became the first nationwide 1G network.

In 1981, this was followed by the simultaneous launch of the Nordic Mobile Telephone (NMT) system in Denmark, Finland, Norway and Sweden. NMT was the first mobile phone network featuring international roaming. The first 1G network launched in the

USA was Chicago-based Ameritech in 1983 using the Motorola Dynastic mobile phone. Several countries then followed in the early-to-mid 1980s including the UK, Mexico and Canada.

1.2 Second Generation (2G)

2G (or 2-G) is short for second-generation wireless telephone technology. Second generation 2G cellular telecom networks were commercially launched on the GSM [2] standard in Finland by Radiolinja (now part of Elisa Oyj) in 1991. Three primary benefits of 2G networks over their predecessors were that phone conversations were digitally encrypted; 2G systems were significantly more efficient on the spectrum allowing for far greater mobile phone penetration levels; and 2G introduced data services for mobile, starting with SMS text messages.

After 2G was launched, the previous mobile telephone systems were retrospectively dubbed 1G. While radio signals on 1G networks are analog, radio signals on 2G networks are digital. Both systems use digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system.

2G technologies can be divided into TDMA-based and CDMA-based standards depending on the type of multiplexing used. The main 2G standards are:

- GSM (TDMA-based), originally from Europe but used in almost all countries on all six inhabited continents. Today accounts for over 80% of all subscribers around the world. Over 60 GSM operators are also using CDMA2000 in the 450 MHz frequency band (CDMA450).[2]

- IS-95 aka cdmaOne (CDMA-based, commonly referred as simply CDMA in the US), used in the Americas and parts of Asia. Today accounts for about 17% of all subscribers globally. Over a dozen CDMA operators have migrated to GSM including operators in Mexico, India, Australia and South Korea.

- PDC (TDMA-based), used exclusively in Japan

- iDEN (TDMA-based), proprietary network used by Nextel in the United States and Telus Mobility in Canada
- IS-136 aka D-AMPS (TDMA-based, commonly referred as simply 'TDMA' in the US), was once prevalent in the Americas but most have migrated to GSM.

2G services are frequently referred as Personal Communications Service, or PCS, in the United States.

1.2.1. Capacity

- Using digital signals between the handsets and the towers increases system capacity in two key ways:
- Digital voice data can be compressed and multiplexed much more effectively than analog voice encodings through the use of various codec's, allowing more calls to be packed into the same amount of radio bandwidth.
- The digital systems were designed to emit less radio power from the handsets. This meant that cells could be smaller, so more cells could be placed in the same amount of space. This was also made possible by cell towers and related equipment getting less expensive

1.2.2. Advantages

- The lower power emissions helped address health concerns.
- Going all-digital allowed for the introduction of digital data services, such as SMS and email.
- Greatly reduced fraud. With analog systems it was possible to have two or more "cloned" handsets that had the same phone number.
- Enhanced privacy. A key digital advantage not often mentioned is that digital cellular calls are much harder to eavesdrop on by use of radio scanners. While the security algorithms used have proved not to be as secure as initially advertised, 2G phones are

immensely more private than 1G phone, which have no protection against eavesdropping.

1.2.3. Disadvantages

- In less populous areas, the weaker digital signal may not be sufficient to reach a cell tower. This tends to be a particular problem on 2G systems deployed on higher frequencies, but is mostly not a problem on 2G systems deployed on lower frequencies. National regulations differ greatly among countries which dictate where 2G can be deployed.
- Analog has a smooth decay curve, digital a jagged steppy one. This can be both an advantage and a disadvantage. Under good conditions, digital will sound better. Under slightly worse conditions, analog will experience static, while digital has occasional dropouts. As conditions worsen, though, digital will start to completely fail, by dropping calls or being unintelligible, while analog slowly gets worse, generally holding a call longer and allowing at least a few words to get through.
- While digital calls tend to be free of static and background noise, the lossy compression used by the codecs takes a toll; the range of sound that they convey is reduced. You'll hear less of the tonality of someone's voice talking on a digital cellphone, but you will hear it more clearly.

1.2.4. Evolution

- 2G networks were built mainly for voice services and slow data transmission.
- Some protocols, such as EDGE for GSM and 1x-RTT for CDMA2000, are defined as "3G" services (because they are defined in IMT-2000 specification documents), but are considered by the general public to be 2.5G services (or 2.75G which sounds even more sophisticated) because they are several times slower than present-day 3G services.

1.3. GPRS (2.5G)

2.5G is a stepping stone between 2G and 3G cellular wireless technologies. The term "second and a half generation" is used to describe 2G-systems that have implemented a packet-switched domain in addition to the circuit-switched domain. It does not necessarily provide faster services because bundling of timeslots is used for circuit-switched data services (HSCSD) as well.

- The first major step in the evolution of GSM networks to 3G occurred with the introduction of General Packet Radio Service (GPRS) [3]. CDMA2000 networks similarly evolved through the introduction of 1xRTT. The combination of these capabilities came to be known as 2.5G.
- GPRS could provide data rates from 56 Kbit/s up to 115 Kbit/s. It can be used for services such as Wireless Application Protocol (WAP) access, Multimedia Messaging Service (MMS), and for Internet communication services such as email and World Wide Web access. GPRS data transfer is typically charged per megabyte of traffic transferred, while data communication via traditional circuit switching is billed per minute of connection time, independent of whether the user actually is utilizing the capacity or is in an idle state.
- 1xRTT supports bi-directional (up and downlink) peak data rates up to 153.6 Kbit/s, delivering an average user data throughput of 80-100 Kbit/s in commercial networks.It can also be used for WAP, SMS & MMS services, as well as Internet access.

1.3.1. Services Offered

GPRS extends the GSM Packet circuit switched data capabilities and makes the following services possible:

- "Always on" internet access
- Multimedia messaging service (MMS)

- Push to talk over cellular (PoC).
- Instant messaging and presence—wireless village.
- Internet applications for smart devices through wireless application protocol (WAP).
- Point-to-point (P2P) service: inter-networking with the Internet (IP).
- Point-to-Multipoint (P2M) service: point-to-multipoint multicast and point-to-multipoint group calls.

If SMS over GPRS is used, an SMS transmission speed of about 30 SMS messages per minute may be achieved. This is much faster than using the ordinary SMS over GSM, whose SMS transmission speed is about 6 to 10 SMS messages per minute.

1.3.2. Multiple access schemes

- The multiple access methods used in GSM with GPRS are based on frequency division duplex (FDD) and TDMA [4]. During a session, a user is assigned to one pair of up-link and down-link frequency channels. This is combined with time domain statistical multiplexing; i.e., packet mode communication, which makes it possible for several users to share the same frequency channel. The packets have constant length, corresponding to a GSM time slot. The down-link uses first-come first-served packet scheduling, while the up-link uses a scheme very similar to reservation ALOHA (R-ALOHA).

1.4. EDGE

- Enhanced Data rates for GSM Evolution (EDGE) (also known as Enhanced GPRS (EGPRS) [1], or IMT Single Carrier (IMT-SC), or Enhanced Data rates for Global Evolution) is a digital mobile phone technology that allows improved data transmission rates as a backward-compatible extension of GSM. EDGE is considered a pre-3G radio technology and is part of ITU's 3G definition.EDGE was deployed on GSM networks beginning in 2003 — initially by Cingular (now AT&T) in the United States.
- EDGE is standardized by 3GPP as part of the GSM family.
- Through the introduction of sophisticated methods of coding and transmitting data, EDGE delivers higher bit-rates per radio channel, resulting in a threefold increase in capacity and performance compared with an ordinary GSM/GPRS connection.
- EDGE can be used for any packet switched application, such as an Internet connection.
- Evolved EDGE continues in Release 7 of the 3GPP standard providing reduced latency and more than doubled performance e.g. to complement High-Speed Packet Access (HSPA). Peak bit-rates of up to 1Mbit/s and typical bit-rates of 400kbit/s can be expected.
- EDGE/EGPRS is implemented as a bolt-on enhancement for 2.5G GSM/GPRS networks, making it easier for existing GSM carriers to upgrade to it. EDGE is a superset to GPRS and can function on any network with GPRS deployed on it, provided the carrier implements the necessary upgrade.
- EDGE requires no hardware or software changes to be made in GSM core networks.
- EDGE-compatible transceiver units must be installed and the base station subsystem needs to be upgraded to support EDGE. If the operator already has this in place, which is often the case today, the network can be upgraded to EDGE by activating an optional software feature. Today EDGE is supported by all major chip vendors for both GSM and WCDMA/HSPA.

1.4.1. Transmission techniques

- In addition to Gaussian minimum-shift keying (GMSK), EDGE uses higher-order PSK/8 phase shift keying (8PSK) for the upper five of its nine modulation and coding schemes. EDGE produces a 3-bit word for every change in carrier phase. This effectively triples the gross data rate offered by GSM. EDGE, like GPRS, uses a rate adaptation algorithm that adapts the modulation and coding scheme (MCS) according to the quality of the radio channel, and thus the bit rate and robustness of data transmission. It introduces a new technology not found in GPRS, Incremental Redundancy, which, instead of retransmitting disturbed packets, sends more redundancy information to be combined in the receiver. This increases the probability of correct decoding.

- EDGE can carry a bandwidth up to 236.8 Kbit/s (with end-to-end latency of less than 150 ms) for 4 timeslots (theoretical maximum is 473.6 Kbit/s for 8 timeslots) in packet mode. This means it can handle four times as much traffic as standard GPRS. EDGE meets the International Telecommunications Union's requirement for a 3G network, and has been accepted by the ITU as part of the IMT-2000 family of 3G standards. It also enhances the circuit data mode called HSCSD, increasing the data rate of this service. EDGE is part of ITU's 3G definition and is considered a 3G radio technology.

1.5. Comparison of Mobile Generations

- First, about cellular generations. Having worked in the industry for a while, I have a narrower view what 1G, 2G, 3G, 4G, etc. mean. First 1G service was based on a TDM voice infrastructure -- built around class x switches and 64 kbps slots. It had data, but circuit switched over a 64Kpbs voice bearer.
- Second, 2G service had the same switched TDM backbone, but added a true Data Bearer and a digital voice bearer. Data rates were still limited to the max 64kbps of a single time slot.
- 2.5G added a packet bearer to the mix, still limited to 64kbps slots.
- Third generation (3G) changed the backbone slightly to allow a full T1 or E1 or J1 to be consumed by a data sub-scriber, but is still based on an ISDN style backbone. Sure you have packet switched data, but its carried over a traditional TDM backbone. There still a circuit voice backbone and while the data rates are high enough for VoIP, the latency of the data service is to great to base all of the "bearer services" on it, so you still have circuit voice, circuit data and packet data bearers.
- Finally, 4G systems will utilize a packet infrastructure rather than traditional telephone architecture. Services will be horizontally layered on top of a proper low latency, QoS enabled packet switch (read IP) infrastructure. Gone will be the circuit voice and circuit data bearers.
- So "G" has more to do with the infra-structure and less to do with the data rates. The data rates over the air are driven by the organization of the infrastructure and other than that have little to do with what generation they are.
- 1G is the first generation cellular network that existed in 1980s. It transfer data (only voice) in analog wave, it has limitation because there are no encryption, the sound quality is poor and the speed of transfer is only at 9.6kbps.

- 2G is the second one, improved by introducing the concept of digital modulation, which means converting the voice (only) into digital code (in your phone) and then into analog signals (imagine that it flies in the air). Being digital, they overcame some of the limitations of 1G, such as it omits the radio power from handsets making life healthier, and it has enhanced privacy.
- 2.5G is a transition of 2G and 3G. In 2.5G, the most popular services like SMS (short messaging service), GPRS, EDGE, High Speed Circuit switched data, and more had been introduced.
- 3G is the current generation of mobile telecommunication standards. It allows simultaneous use of speech and data services and offers data rates of up to 2 Mbps, which provide services like video calls, mobile TV, mobile Internet and downloading. There are a bunch of technologies that fall under 3G, like WCDMA, EV-DO, and HSPA and others.
- In telecommunications, 4G is the fourth generation of cellular wireless standards. It is a successor to the 3G and 2G families of standards. In 2008, the ITU-R organization specified the IMT-Advanced (International Mobile Telecommunications Advanced) requirements for 4G standards, setting peak speed requirements for 4G service at 100 Mbit/s for high mobility communication (such as from trains and cars) and 1 Gbit/s for low mobility communication (such as pedestrians and stationary users)
- A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smart phones, and other mobile devices. Facilities such as ultra-broadband Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users.
- PRE-4G technologies such as mobile WiMAX and Long term evolution (LTE) have been on the market since 2006 and 2009 respectively, and are often branded as 4G. The current versions of these technologies did not fulfill the original ITU-R requirements of data rates approximately up to 1 Gbit/s for 4G systems. Marketing materials use 4G as a description for LTE and Mobile-WiMAX in their current forms.

CHAPTER 2

Global System for Mobile Communication (GSM)

GSM [1] (Global System for Mobile Communications, originally Group Special Mobile), is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for second generation (or "2G") digital cellular networks. Developed as a replacement for first generation analog cellular networks, the GSM standard originally described a digital, circuit switched network optimized for full duplex voice telephony. The standard was expanded over time to include first circuit switched data transport, then packet data transport via GPRS. Packet data transmission speeds were later increased via EDGE. The GSM standard is succeeded by the third generation (or "3G") UMTS standard developed by the 3GPP. GSM networks will evolve further as they begin to incorporate fourth generation (or "4G") LTE Advanced standards. "GSM" is a trademark owned by the GSM Association.

The GSM Association estimates that technologies defined in the GSM standard serve 80% of the global mobile market, encompassing more than 1.5 billion people across more than 212 countries and territories, making GSM the most ubiquitous of the many standards for cellular networks.

2.1. GSM Network Structure

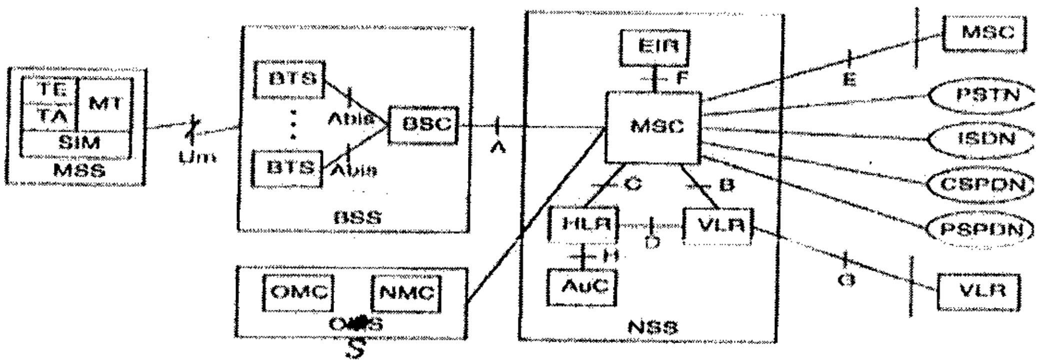


Fig 2.1 GSM architecture

2.1.1 Mobile Station (MS)

- Portable, vehicle mounted, hand held device.
- Uniquely identified by an IMEI (International Mobile Equipment Identity).
- Voice and data transmission.
- Monitoring power and signal quality of.
- Surrounding cells for optimum handover.
- Power level: 0.8W □ 20 W.
- 160 character long SMS.

2.1.2 Base Transceiver Station (BTS)

- Provides an entry point to the network for the subscribers who are present in the cell.
- It can handle up to 8 simultaneous communication by a single antenna used in BTS.

2.1.3 Base Station Controller (BSC)

It manages the radio interface between MS and all other subsystem of GSM.

Monitoring BTS Controls:

- Wireless link distribution between MS and BTS Communication connection and disconnection MS location, handover and paging.

2.1.4 Mobile Service Switching Centre (MSC)

- Holds all the switching functions manages the necessary radio resources, updating the location registration
- Inter-working with other networks.

2.1.5 Home Location Register (HLR)

Manages the mobile subscribers database

- Subscriber information
- Part of the mobile location information
- 3 identities essential
- The International Mobile subscriber Identity
- The Mobile station ISDN Number
- The VLR address

2.1.6 Visitor Location Register (VLR)

- Dynamically stores subscriber information needed to handle Incoming/outgoing calls.
- Mobile Station Roaming Number
- When a roaming mobile enters an MSC area. This MSC warns the associated VLR of this situation; the mobile enters a registration procedure through which it is assigned a mobile subscriber roaming number (MSRN).
- The location area in which the mobile has been registered.

2.2. GSM carrier frequencies

GSM networks operate in a number of different carrier frequency ranges (separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G), with most 2G GSM networks operating in the 900 MHz or 1800 MHz bands. Where these bands were already allocated, the 850 MHz and 1900 MHz bands were used instead (for example in Canada and the United States). In rare cases the 400 and 450 MHz frequency bands are assigned in some countries because they were previously used for first-generation systems.

Most 3G networks in Europe operate in the 2100 MHz frequency band.

Regardless of the frequency selected by an operator, it is divided into timeslots for individual phones to use. This allows eight full-rate or sixteen half-rate speech channels per radio frequency. These eight radio timeslots (or eight burst periods) are grouped into a TDMA frame. Half rate channels use alternate frames in the same timeslot. The channel data rate for all 8 channels is 270.833 Kbit/s, and the frame duration is 4.615 ms.

The transmission power in the handset is limited to a maximum of 2 watts in GSM850/900 and 1 watt in GSM1800/1900.

2.3. Subscriber Identity Module (SIM)

One of the key features of GSM is the Subscriber Identity Module, commonly known as a SIM card. The SIM is a detachable smart card containing the user's subscription information and phone book. This allows the user to retain his or her information after switching handsets. Alternatively, the user can also change operators while retaining the handset simply by changing the SIM. Some operators will block this by allowing the phone to use only a single SIM, or only a SIM issued by them; this practice is known as SIM locking.

2.4. Phone locking

Sometimes mobile network operators restrict handsets that they sell for use with their own network. This is called locking and is implemented by a software feature of the phone. Because the purchase price of the mobile phone to the consumer is typically subsidized with revenue from subscriptions, operators must recoup this investment before a subscriber terminates service. A subscriber may usually contact the provider to remove the lock for a fee, utilize private services to remove the lock, or make use of free or fee-based software and websites to unlock the handset themselves.

In some territories (e.g., Bangladesh, Hong Kong, India, Malaysia, Pakistan, Singapore) all phones are sold unlocked. In others (e.g., Finland, Singapore) it is unlawful for operators to offer any form of subsidy on a phone's price.

2.5. GSM open-source software

- Several open source software projects exist that provide certain GSM features:
- Gsmd daemon by Openmoko
- Open BTS develops a Base transceiver station
- Open BSC is developing a minimalistic, self-contained GSM network.
- The GSM Software Project aims to build a GSM analyzer for less than $1000.
- Osmocom BB developers intend to replace the proprietary baseband GSM stack with a free software implementation.

CHAPTER 3

Wideband-Code Division Multiple Access (W-CDMA)

3.1. Introduction to W-CDMA

W-CDMA [5] (Wideband Code Division Multiple Access), UMTS-FDD, UTRA-FDD, or IMT-2000 CDMA Direct Spread is an air interface standard found in 3G mobile telecommunications networks. It is the basis of Japan's NTT Do Como's FOMA service and the most-commonly used member of the UMTS family and sometimes used as a synonym for UMTS. It utilizes the DS-CDMA channel access method and the FDD duplexing method to achieve higher speeds and support more users compared to most time division multiple access (TDMA) schemes used today.

3.2. W-CDMA Block Diagram [6]

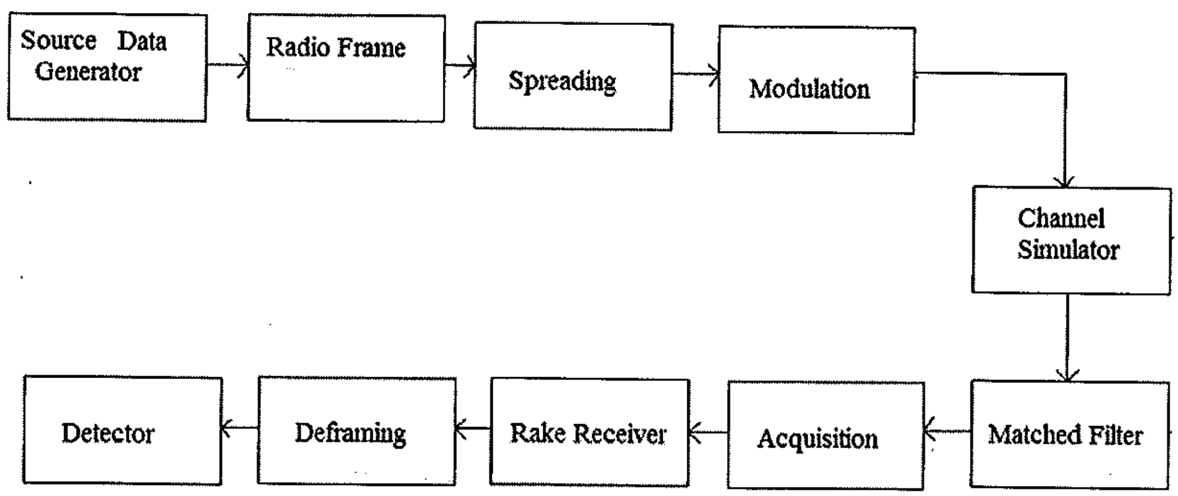


Fig 3.1: W-CDMA Block Diagram

3.3. Technical features [7]

Channel bandwidth	5 MHz
Duplex mode	FDD and TDD
Downlink RF channel	Direct Spread
Chip rate	3.84 Mcps
Frame length	10 ms
Spreading modulation	Balanced QPSK (downlink) Dual-channel QPSK (uplink) Complex spreading circuit
Data modulation	QPSK (downlink) BPSK (uplink)
Channel coding	Convolutional and turbo codes
Coherent detection	User dedicated time multiplexed pilot (downlink and uplink), common pilot in the downlink
Channel multiplexing in downlink	Data and control channels time multiplexed
Channel multiplexing in uplink	Control and pilot channel time multiplexed I&Q multiplexing for data and control channel
Multirate	Variable spreading and multi-code
Spreading factors	4–256 (uplink), 4–512 (downlink)
Power control	Open and fast closed loop (1.6 KHz)
Spreading (downlink)	OVSF sequences for channel separation Gold sequences 218-1 for cell and user separation (truncated cycle 10 ms)
Spreading (uplink)	OVSF sequences, Gold sequence 241 for user separation (different time shifts in I and Q channel, truncated cycle 10 ms)
Handover	Soft handover Interfrequency handover

3.4. Uplink frame structure

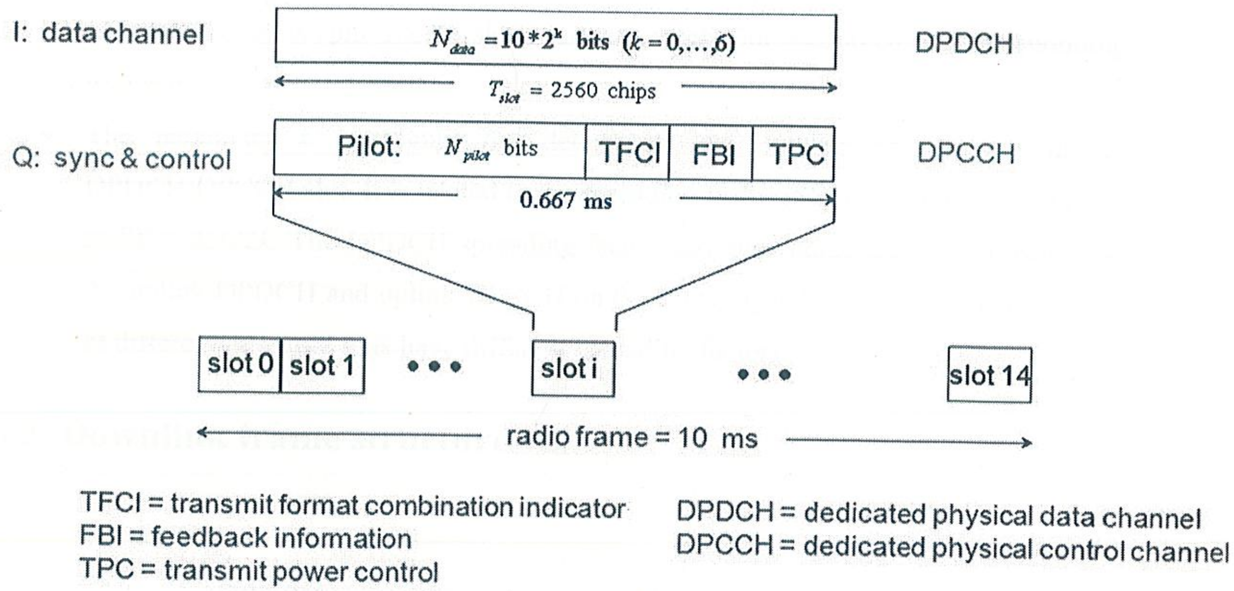


Fig 3.2 W-CDMA uplink Frame structure

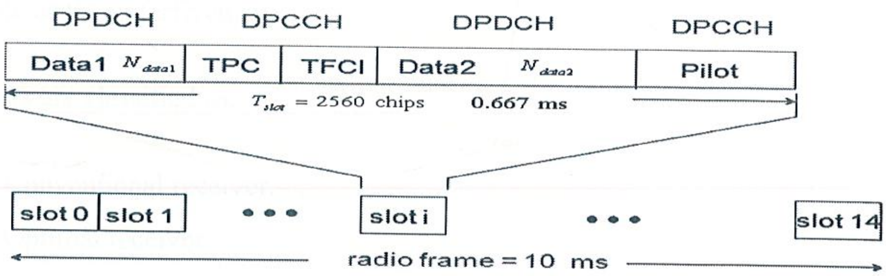
There are two uplink dedicated physical and two common physical channels:

- The uplink dedicated physical data channel (uplink DPDCH) and the uplink dedicated physical control channel (uplink DPCCH).
- The physical random access channel (PRACH) and physical common packet channel (PCPCH).
- The uplink DPDCH is used to carry dedicated data generated at layer 2 and above (i.e., the dedicated transport channel (DCH)). There may be zero, one, or several uplink DPDCHs on each layer 1 connection.
- The uplink DPCCH is used to carry control information generated at layer 1.
- Control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control (TPC) commands, feedback information (FBI), and an optional transport-format combination indicator (TFCI).
- The transport-format combination indicator informs the receiver about the instantaneous parameters of the different transport channels multiplexed on the uplink

DPDCH, and corresponds to the data transmitted in the same frame. For each layer 1 connection there is only one uplink DPCCH.

- The principle frame structure of the uplink dedicated physical channels. Each frame of length 10 ms is split into 15 slots, each of length Slot = 2560 chips, corresponding to one power-control period.
- The parameter k in Figure 6.5 determines the number of bits per uplink DPDCH/DPCCH slot. It is related to the spreading factor (SF) of the physical channel as SF = 256/2k. The DPDCH spreading factor may thus range from 256 down to 4. An uplink DPDCH and uplink DPCCH on the same layer 1 connection generally are of different rates and thus have different spreading factors.

3.5. Downlink frame structure



$$N_{data2} + N_{data2} = 10 * 2^k \text{ bits } (k = 0,\ldots,7)$$

Fig 3.3 W-CDMA Downlink Frame structure

There is one downlink dedicated physical channel, one shared and five common control channels:

- Downlink dedicated physical channel (DPCH);
- Physical downlink shared channel (DSCH);
- Primary and secondary common pilot channels (CPICH);
- Primary and secondary common control physical channels (CCPCH);
- Synchronization channel (SCH).

- The frame structure of the DPCH [8, 9]. On the DPCH, the dedicated transport channel is transmitted time multiplexed with control information generated at layer 1 (known pilot bits, power-control commands, and an optional transport-format combination indicator). DPCH can contain several simultaneous services when TFCI is transmitted or a fixed rate service when TFCI is not transmitted.
- The network determines if a TFCI should be transmitted. When the total bit rate to be transmitted exceeds the maximum bit rate for a downlink physical channel, multimode transmission is employed (i.e., several parallel downlink DPCHs are transmitted using the same spreading factor). In this case, the layer 1 control information is put on only the first downlink DPCH.

3.6. WCDMA Receiver

Receiver [10] is designed to extract information which is corrupted with ISI & MAI (multiple access interference).

Receivers are classified as:

- Conventional receiver.
- Optimal receiver.
- Sub-optimal receiver.

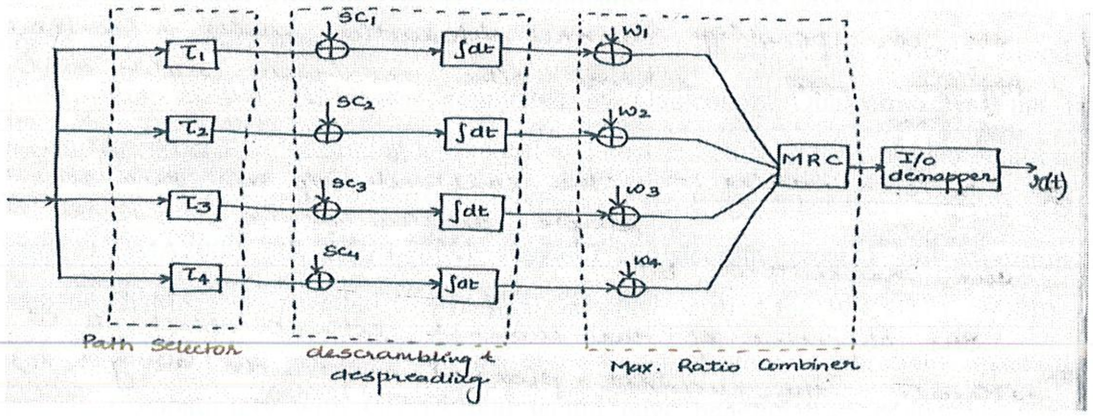


Fig 3.4 W-CDMA Four Finger Rake Receiver

- U(t) transmitted signal
- R(t) received signal
- Ak complex transmitted symbol
- Pk complex spreading & scrambling code combined.
- N spreading factor
- f(t) pulse shaping filter
- T chip duration.

3.7. Development

In the late 1990s, W-CDMA was developed by NTT Do Como as the air interface for their 3G network FOMA. Later NTT Do Como submitted the specification to the International Telecommunication Union (ITU) [11, 12, 13] as a candidate for the international 3G standard known as IMT-2000. The ITU eventually accepted W-CDMA as part of the IMT-2000 family of 3G standards, as an alternative to CDMA2000, EDGE, and the short range DECT system. Later, W-CDMA was selected as an air interface for UMTS.

As NTT Do Como did not wait for the finalization of the 3G Release 99 specification, their network was initially incompatible with UMTS.However; this has been resolved by NTT Do Como updating their network.

Code Division Multiple Access communication networks have been developed by a number of companies over the years, but development of cell-phone networks based on CDMA (prior to W-CDMA) was dominated by Qualcomm. Qualcomm was the first company to succeed in developing a practical and cost-effective CDMA implementation for consumer cell phones: its early IS-95 air interface standard, which has since evolved into the current CDMA2000 (IS-856/IS-2000) standard. Qualcomm created an experimental wideband CDMA system called CDMA2000 3x which unified the W-CDMA (3GPP) and CDMA2000 (3GPP2) network technologies into a single design for a worldwide standard air interface. Compatibility with CDMA2000 would have beneficially enabled roaming on existing networks beyond Japan, since Qualcomm CDMA2000 networks are widely deployed, especially in the Americas, with coverage in 58 countries as of 2006[update].

However, divergent requirements resulted in the W-CDMA standard being retained and deployed.

3.8. Rationale for WCDMA

W-CDMA transmits on a pair of 5 MHz-wide radio channels, while CDMA2000 transmits on one or several pairs of 1.25 MHz radio channels. Though W-CDMA does use a direct sequence CDMA transmission technique like CDMA2000, W-CDMA is not simply a wideband version of CDMA2000. The W-CDMA system is a new design by NTT Do Como, and it differs in many aspects from CDMA2000. From an engineering point of view, W-CDMA provides a different balance of trade-offs between cost, capacity, performance, and density; it also promises to achieve a benefit of reduced cost for video phone handsets. W-CDMA may also be better suited for deployment in the very dense cities of Europe and Asia. However, hurdles remain, and cross-licensing of patents between Qualcomm and W-CDMA vendors has not eliminated possible patent issues due to the features of W-CDMA which remain covered by Qualcomm patents.[5]

W-CDMA has been developed into a complete set of specifications, a detailed protocol that defines how a mobile phone communicates with the tower, how signals are modulated, how datagram's are structured, and system interfaces are specified allowing free competition on technology elements.

3.9. WCDMA versus GSM

- WCDMA (Wideband Code Division Multiplexing Access) and GSM are two technologies that are used in mobile telecommunications. The difference between these two is that GSM is a 2G technology and WCDMA is a part of the newer 3G group of technologies. Being newer and more advanced, WCDMA is now the technology that people want and it is slowly being deployed in a lot of areas that are already being occupied by GSM. Sooner or later, the WCDMA network would equal the coverage of GSM, making the GSM network redundant. With this said, it is clear that the GSM network is slowly being phased out and replaced with the newer and better WCDMA. But for now, GSM is still the most widespread technology that is used in the whole world. Surpassing all other 2G and 3G alternatives.

- The primary reason why telecommunications companies are having problems with rapidly deploying is the difference in the frequency bands they use. Because of this, GSM only phones, cannot communicate with WCDMA only networks and vice versa. In order to circumvent this, it has become common for most phone manufacturers to include multiple frequency bands for both 2G networks and 3G networks. This ensures that their mobile phones can be used in almost any network and any location in the world. Telecommunications companies need to deploy a WCDMA network over their existing GSM network to provide 3G services while still maintaining compatibility with older mobile phones that are not compatible with WCDMA.

- Although WCDMA support has become quite common in most mobile phones, there are still some models that do not support it. When you are buying a mobile phone, you should look at its specifications in order to make sure that it supports WCDMA and the frequencies available in your area. This is to ensure that you can use it in your country's networks. Even non-GSM networks are choosing to add WCDMA support as it is the most popular 3G technology. Sooner or later older and competing network standards, namely GSM, CDMA, and EV-DO, would probably be phased out and replaced with WCDMA

Difference between WCDMA and GSM.

	WCDMA	GSM
Carrier spacing	5 MHz	200 kHz
Frequency reuse factor	1	1–18
Power control frequency	1500 Hz	2 Hz or lower
Quality control	Radio resource management algorithms	Network planning (frequency planning)
Frequency diversity	5 MHz bandwidth gives multipath diversity with Rake receiver	Frequency hopping
Packet data	Load-based packet scheduling	Time slot based scheduling with GPRS
Downlink transmit diversity	Supported for improving downlink capacity	Not supported by the standard, but can be applied

Summary:

- WCDMA is a 3G technology while GSM is a 2G technology.
- GSM is slowly being phased out in favor of CDMA.
- GSM is still more widespread than CDMA.
- WCDMA and GSM use different frequency bands.
- WCDMA offers much faster data speeds than GSM.

CHAPTER 4

WCDMA Simulation

4.1. Development Tool

Simulink is a graphical extension to MATLAB for modeling and simulation of systems. In Simulink, systems are drawn on screen as block diagrams. Many Elements of block diagrams are available, such as transfer functions, summing Junctions, as well as virtual input and output devices such as function generators and oscilloscopes.

Simulink is integrated with MATLAB and data can be easily transfers between the programs. Simulink is supported on UNIX, Macintosh, and Windows environments; and is included in the student version of MATLAB for personal computer. Besides that, Mat lab Simulink 7.0 version ships with its own release of the WCDMA library, an essential reference for this project.

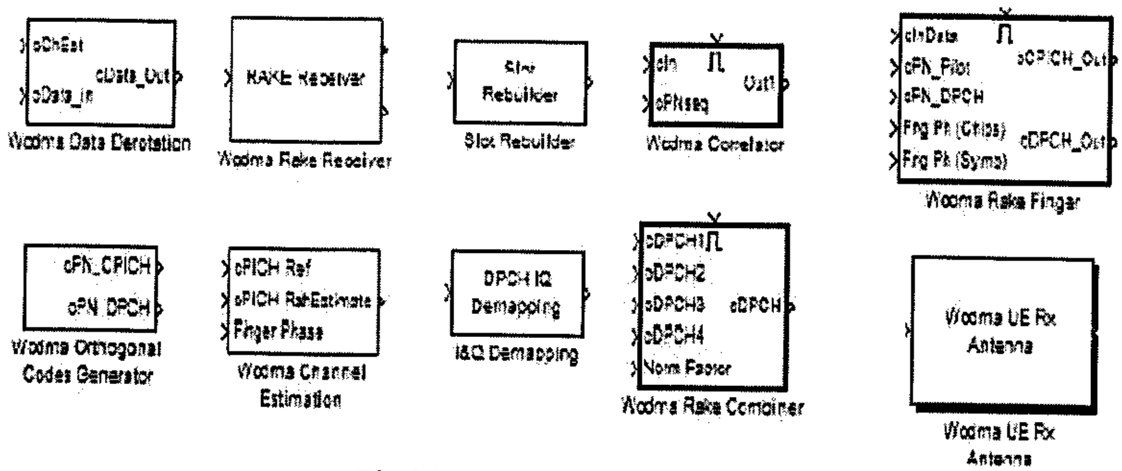


Fig 4.1 W-CDMA UE Receiver

4.2. Starting with Simulink

To get start with simulink, we have modeled a simple communication end-to-end system using:-

1. BPSK Modulation.
2. QPSK Modulation.

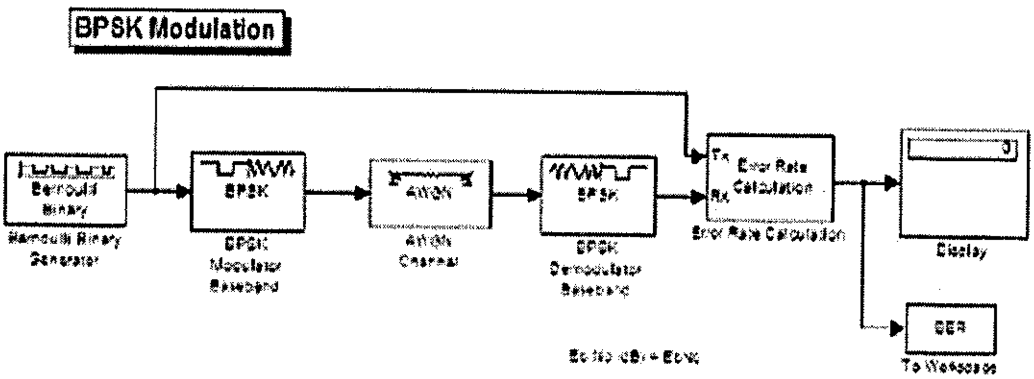


Fig 4.2 System Using BPSK Modulation

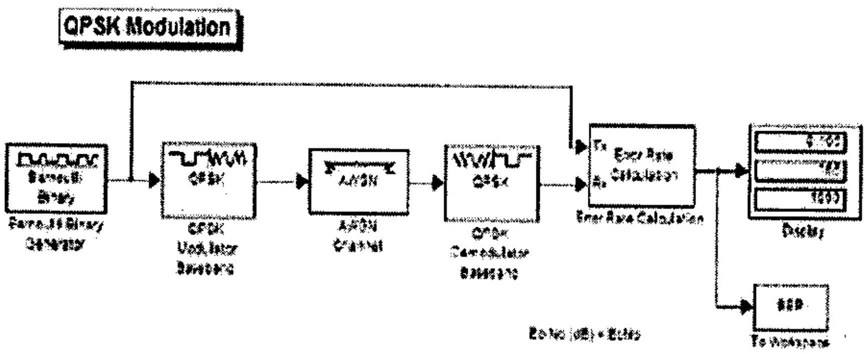


Fig4.3 System Using QPSK Modulation

4.3 WCDMA-Transmitter

Now, after getting a touch of Simulink, we started our project, completed End-to-End simulink model of WCDMA transmitter [14, 15].

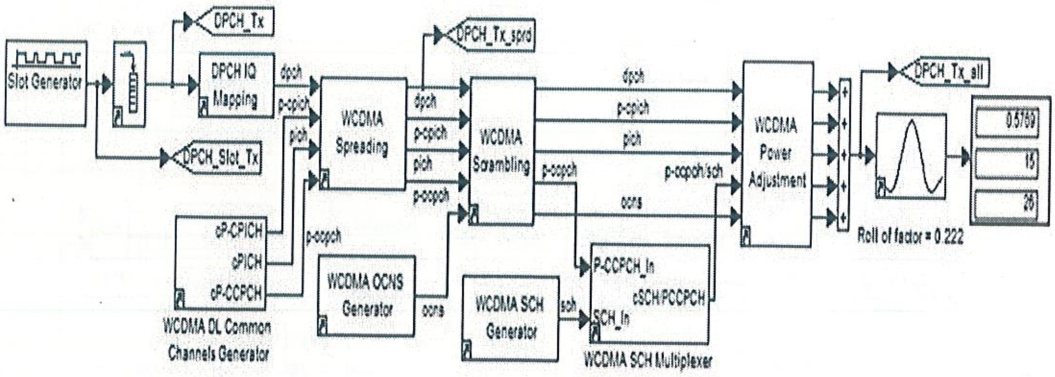


Fig 4.4 W-CDMA Transmitter

- Dedicated Channel:
- DPCH → Dedicated Physical Channel Common Channels:
- P-CPICH → Primary Common Pilot Channel

  Could be used at the receiver end for channel estimation, tracking
- P-CCPCH → Primary Common Control Physical Channel
- SCH → Synchronization Channel.Not multiplied by orthogonal code.

  Used mainly for cell search: slot and frame timing acquisition.
- PICH → Paging Indicator Channel
- OCNS → Orthogonal Channel Noise Simulator.Simulates interference caused by other users or signals

CHAPTER 5

Simulated W-CDMA System

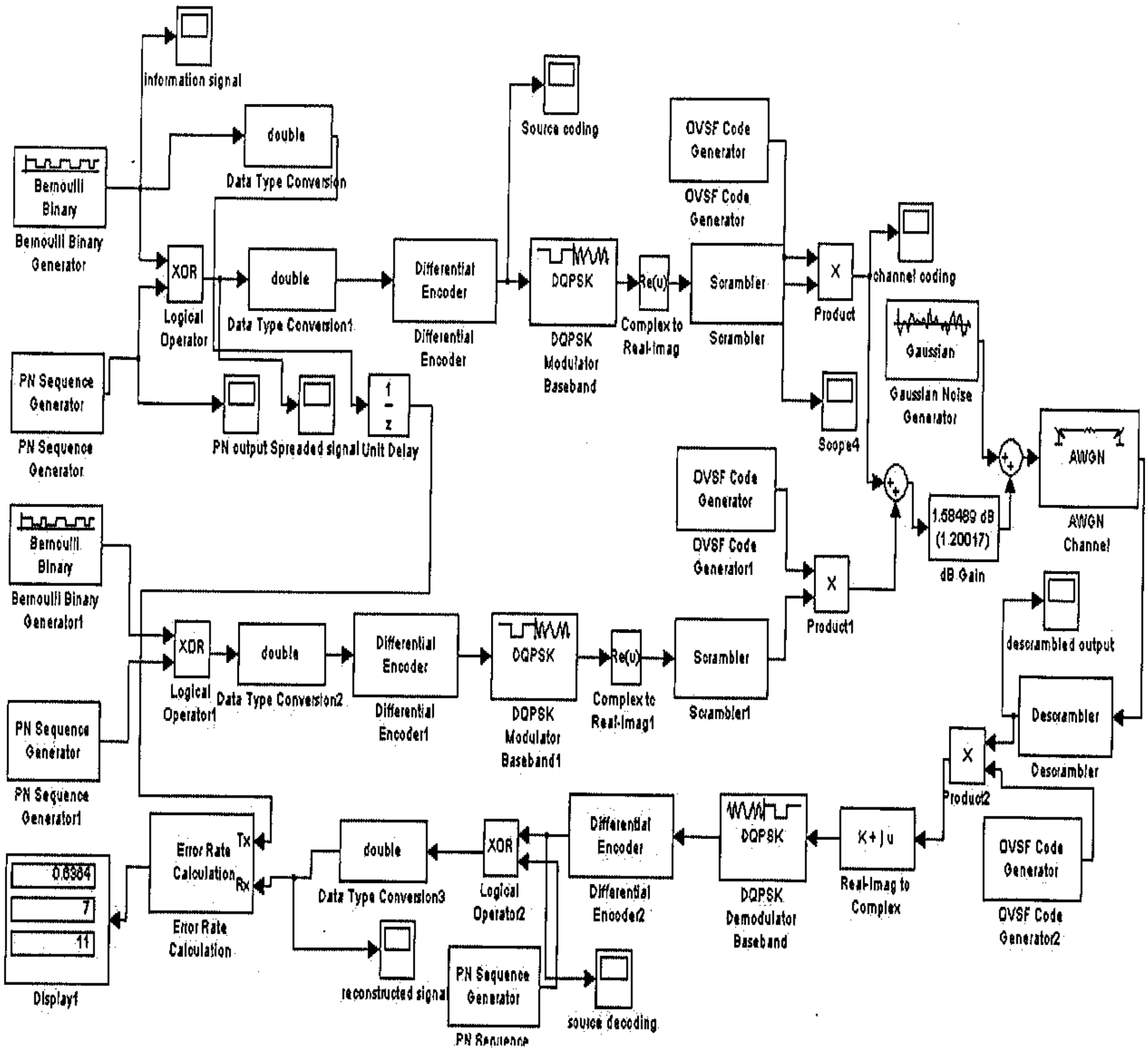


Fig 5.1.W-CDMA Simulated System [16, 17]

5.1. Bernoulli binary generator:

The Bernoulli Binary Generator block generates random binary numbers using a Bernoulli distribution.

- The Bernoulli distribution with parameter p produces zero with probability p and one with probability 1-p.
- The Bernoulli distribution has mean value 1-p and variance p(1-p).
- The Probability of a zero parameter specifies p, and can be any real number between zero and one.

5.2. PN Sequence generator:

Generate a pseudo noise sequence.

- The PN Sequence Generator block generates a sequence of pseudorandom binary numbers. A pseudo noise sequence can be used in a pseudorandom scrambler and descrambler. It can also be used in a direct-sequence spread-spectrum system.

5.3. OVSF Code Generator:

Generate orthogonal variable spreading factor (OVSF) code from set of orthogonal codes.

- The OVSF Code Generator block generates an OVSF code from a set of orthogonal codes. OVSF codes were first introduced for 3G communication systems. OVSF codes are primarily used to preserve orthogonality between different channels in a communication system.
- OVSF codes are defined as the rows of an N-by-N matrix, C_N, which is defined recursively as follows. First, define $C_1 = [1]$. Next, assume that C_N is defined and let $C_N(k)$ denote the kith row of C_N. Define C_{2N} by

$$C_{2N} = \begin{bmatrix} C_N(0) & C_N(0) \\ C_N(0) & -C_N(0) \\ C_N(1) & C_N(1) \\ C_N(1) & -C_N(1) \\ \dots & \dots \\ C_N(N-1) & C_N(N-1) \\ C_N(N-1) & -C_N(N-1) \end{bmatrix}$$

Fig 5.2 C2N C_N is only defined for N a power of 2

- It follows by induction that the rows of C_N are orthogonal.
- The OVSF codes can also be defined recursively by a tree structure, as shown in the following figure.

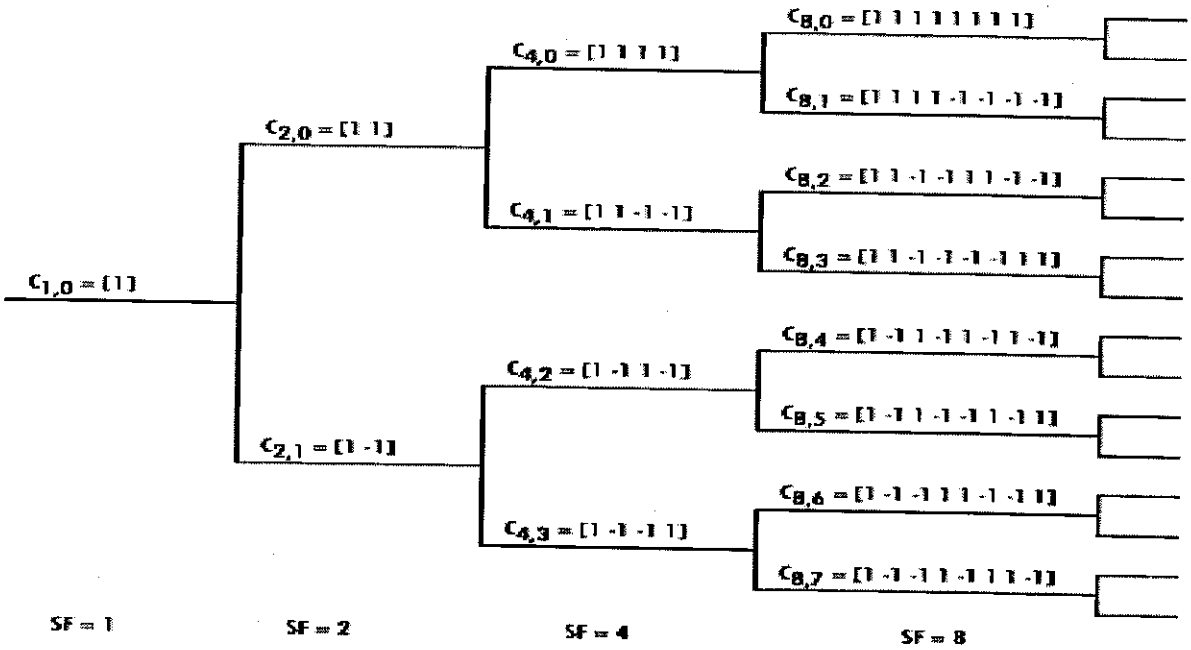


Fig 5.3 OVSF Code for SF=8 [18]

- If [C] is a code length 2^r at depth r in the tree, where the root has depth 0, the two branches leading out of C are labeled by the sequences [C C] and [C -C], which have length 2^{r+1}. The codes at depth r in the tree are the rows of the matrix C_N, where $N = 2^r$.

- Note that two OVSF codes are orthogonal if and only if neither code lies on the path from the other code to the root. Since codes assigned to different users in the same cell must be orthogonal, this restricts the number of available codes for a given cell. For example, if the code C_{41} in the tree is assigned to a user, the codes C_{10}, C_{20}, C_{82}, C_{83}, and so on, cannot be assigned to any other user in the same cell.

5.4. Spreading

- In WCDMA air interface enables multiple access based on a spread spectrum sequence.
- The transmitted data sequence is spread across the spectrum after being encoded by spreading codes, each of which is assigned uniquely to each user at a higher rate then the symbol rate of each data.
- The destination phone uses the same spreading code as the one used for spreading at the transmitter side to perform correlation detection, in order to recover transmitted data sequence.
- Spreading means increasing the signal bandwidth.
- Strictly speaking, spreading includes two operations:
    - Channelization (increases signal bandwidth) - using orthogonal codes.
    - Scrambling (does not affect the signal bandwidth) - using pseudo noise codes.

5.5. Scrambling

- In the scrambling process the code sequence is multiplied with a Pseudorandom scrambling code.
- The scrambling code can be a long code (a Gold code with 10 ms period) or a short code (S (2) code).
- In the downlink scrambling codes are used to reduce the inter-base station interference. Typically, each Node B has only one scrambling code for UEs to separate base stations. Since a code tree under one scrambling code is used by all

users in its cell, proper code management is needed. In the uplink scrambling codes are used to separate the terminals.

5.6. QPSK Modulator Baseband.

Modulate input signal using the quaternary phase shift keying method.

- The inputs can be either bits or integer. In case of sample – based bit input, the input width must be two. In case of frame based bit input, the input width must be an integer multiple of two. The bits can be either binary mapped or gray mapped into symbols.
- For sample based integer input, the input must be a scalar. For frame based integer input, the input must be a column vector.
- In case of frame based integer input, the width of output frame equals the product of the number of symbols and samples per value.
- In case of sample based input, the output sample time equals the symbol period divided by the samples per symbol value.

5.7. Gaussian Noise Generator

- The Gaussian Noise Generator block generates discrete-time white Gaussian noise. You must specify the Initial seed vector in the simulation.
- The Mean Value and the Variance can be either scalars or vectors. If either of these is a scalar, then the block applies the same value to each element of a sample-based output or each column of a frame-based output. Individual elements or columns, respectively, are uncorrelated with each other.
- When the Variance is a vector, its length must be the same as that of the Initial seed vector. In this case, the covariance matrix is a diagonal matrix whose diagonal elements come from the Variance vector. Since the off-diagonal elements are zero, the output Gaussian random variables are uncorrelated.

- When the Variance is a square matrix, it represents the covariance matrix. Its off-diagonal elements are the correlations between pairs of output Gaussian random variables. In this case, Variance matrix must be positive definite and it must be N-by-N, where N is the length of the Initial seed.

5.8. AWGN Channel

- The AWGN Channel block adds white Gaussian noise to a real or complex input signal. When the input signal is real, this block adds real Gaussian noise and produces a real output signal. When the input signal is complex, this block adds complex Gaussian noise and produces a complex output signal. This block inherits its sample time from the input signal.
- This block uses the DSP Block set's Random Source block to generate the noise. The Initial seed parameter in this block initializes the noise generator. Initial seed can be either a scalar or a vector whose length matches the number of channels in the input signal.
- This block can process multichannel signals that are frame-based or sample-based. The guidelines below indicate how the block interprets your data, depending on the data's shape and frame status:
- If your input is a sample-based scalar, then the block adds scalar Gaussian noise to your signal.
- If your input is a sample-based vector or a frame-based row vector, then the block adds independent Gaussian noise to each channel.
- If your input is a frame-based column vector, then the block adds a frame of Gaussian noise to your single-channel signal.
- If your input is a frame-based m-by-n matrix, then the block adds a length-m frame of Gaussian noise independently to each of the n channels.

5.9. QPSK Demodulator Baseband

- The QPSK Demodulator Baseband block demodulates a signal that was modulated using the quaternary phase shift keying method. The input is a baseband representation of the modulated signal.
- The input must be a discrete-time complex signal. The input can be either a scalar or a frame-based column vector. The block accepts the data type's double, single, and signed fixed-point (in hard-decision modes only).

5.10. Descrambler

- Descramble the input scalar or frame based column data using a linear feedback shift register whose configuration is specified by the scramble polynomial parameter.
- The scramble polynomial parameter represents the shift register connections. Enter these values as either a binary vector or a descending ordered polynomial to indicate the connection points.
- Descramble the input scalar or frame based column data using a linear feedback shift register whose configuration is specified by the scramble polynomial parameter.
- The scramble polynomial parameter represents the shift register connections. Enter these values as either a binary vector or a descending ordered polynomial to indicate the connection points.

5.11. Information signal

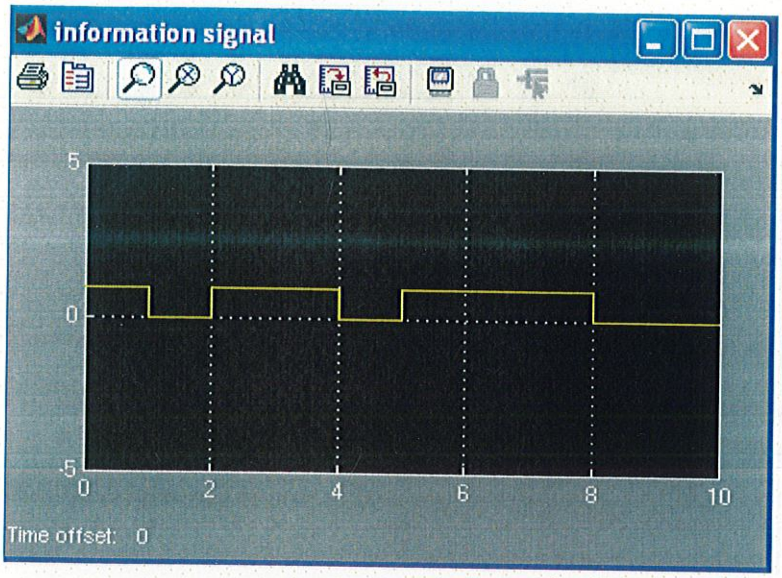


Fig 5.4 Information signal

5.12. PN output

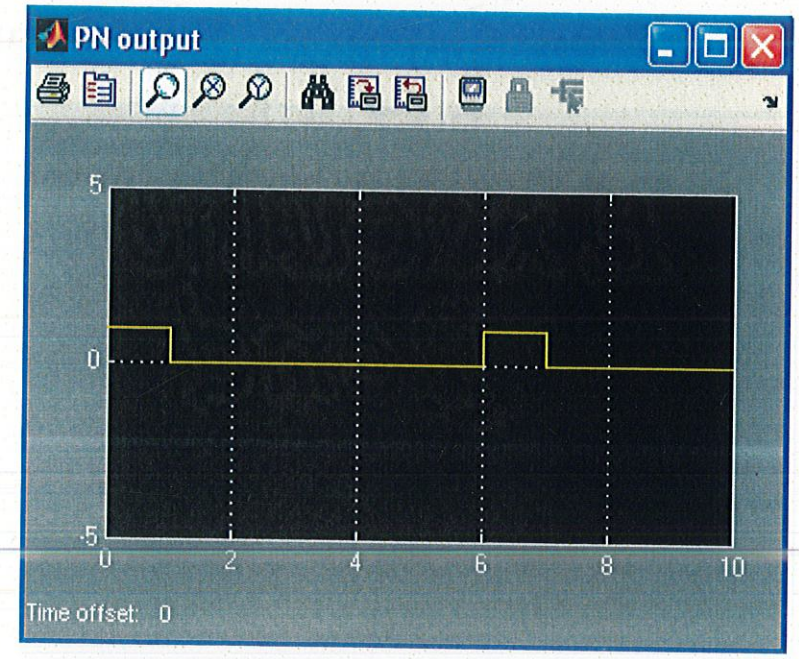


Fig 5.5 PN output

5.13. Spreader signal

Fig 5.6 Spreader signal

5.14. Source coding

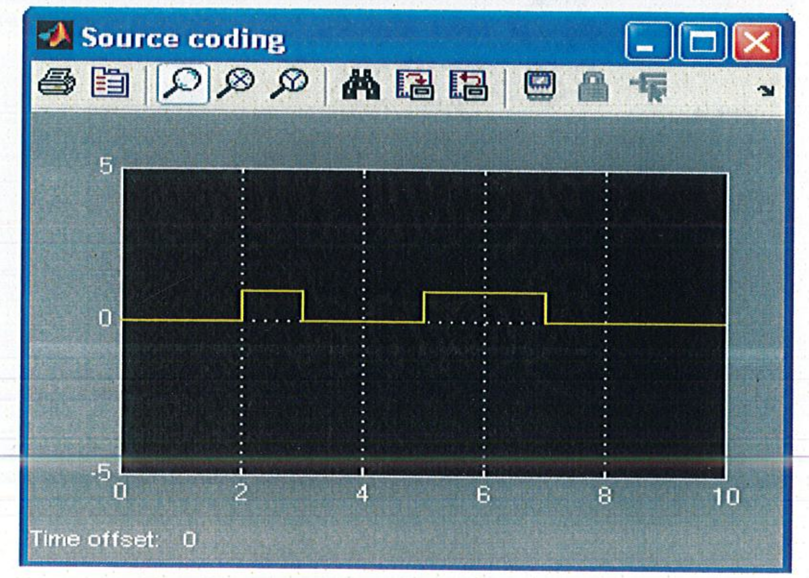


Fig 5.7 Source coding

5.15. Channel coding

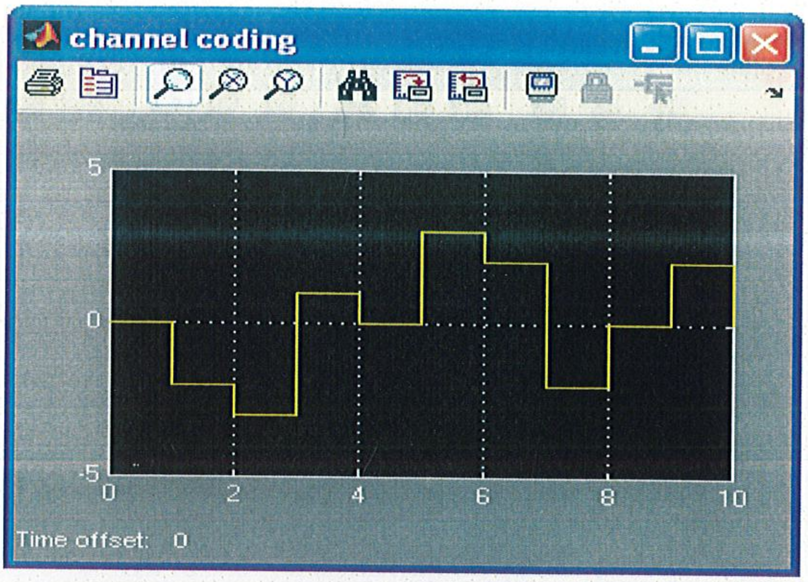


Fig 5.8 Channel coding

5.16. Scrambled Output

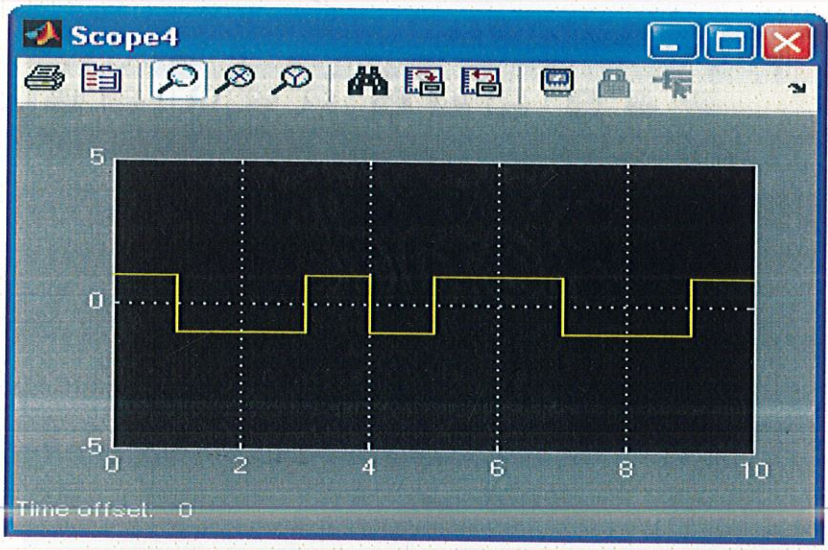


Fig 5.9 Scrambled Output

5.17. Descrambled output

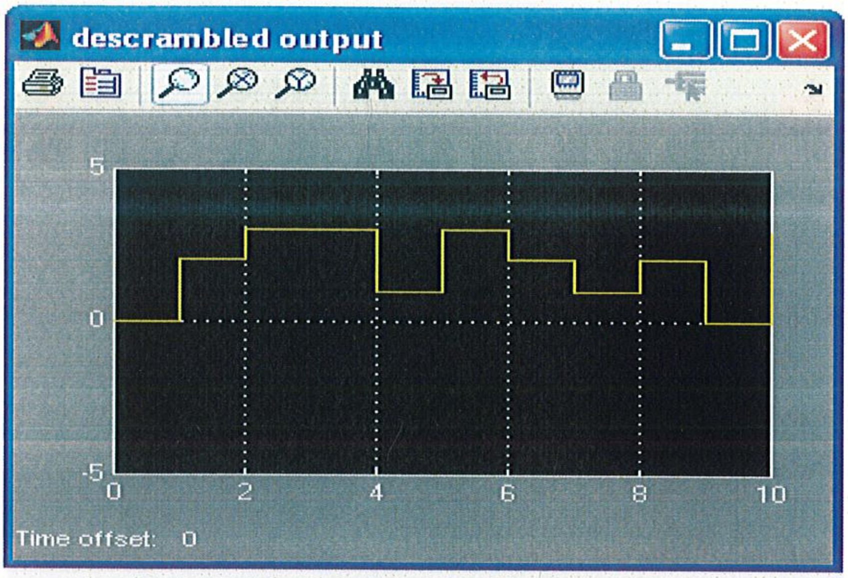


Fig 5.10 Descrambled output

5.18. Source decoding

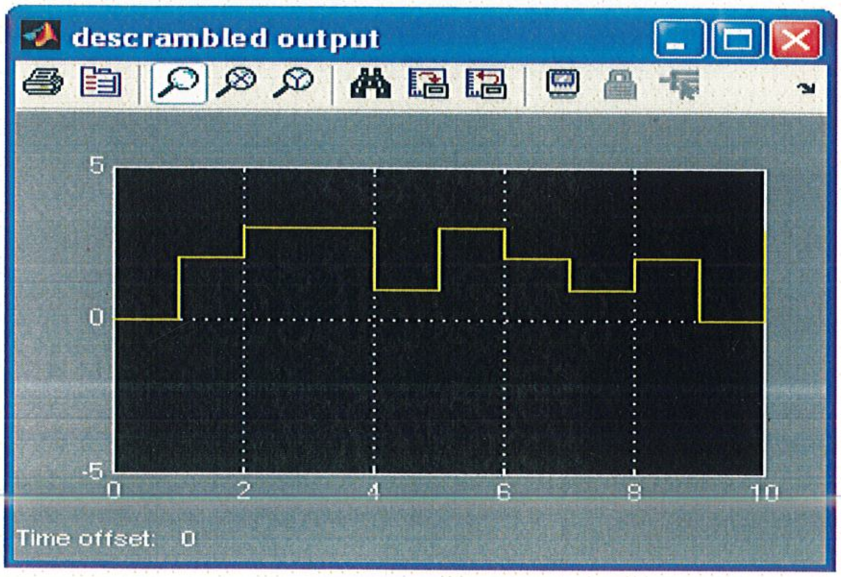


Fig 5.11 Source decoding

5.19. Reconstructed signal

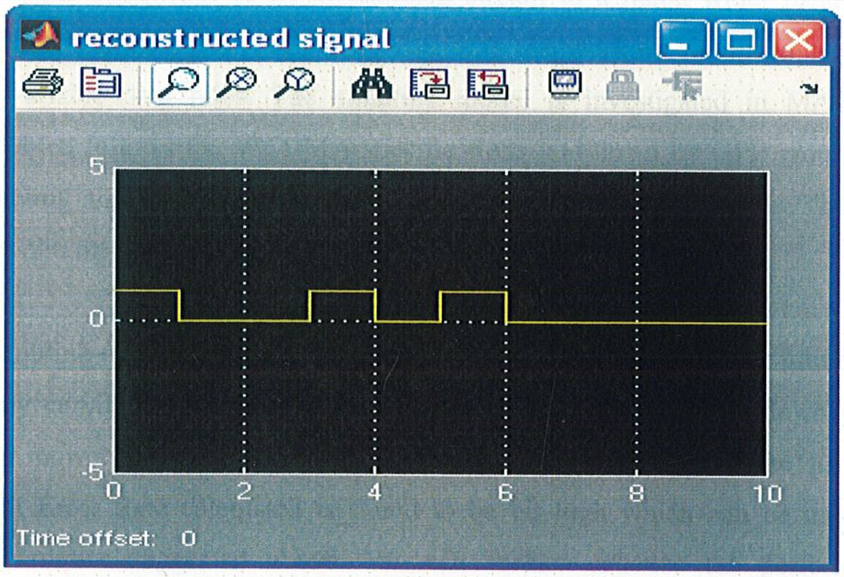


Fig 5.12 Reconstructed signal

CONCLUSION & FUTURE SCOPE

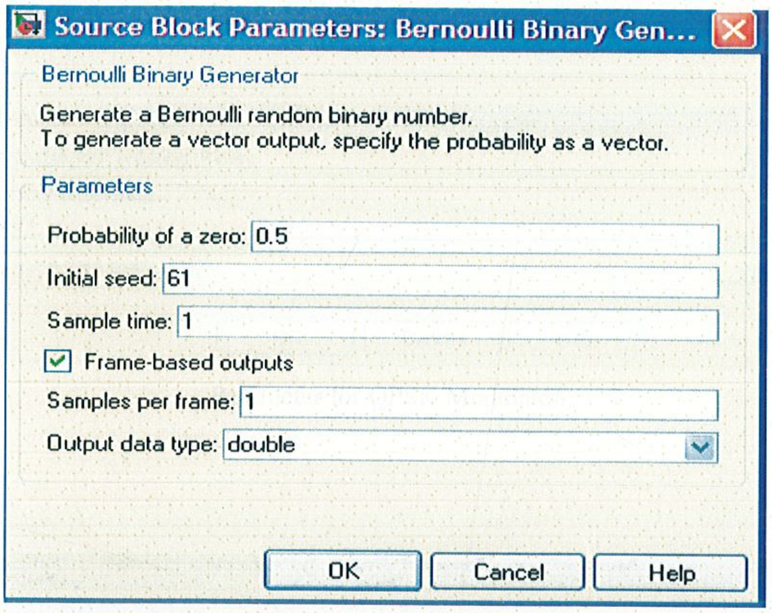
Wideband CDMA is a direct sequence spread spectrum (DSSS) system. W-CDMA systems spread the bandwidth of an information stream to a much wider bandwidth and lower the power spectral density (PSD) accordingly. In this work we simulated the WCDMA system with variable data rates. The simulink model is investigated in MATLAB 7.5 environment which follows the WCDMA specifications laid down by GPP group. Channel coding, scrambling and source coding is introduced to mitigate error effects. The simulink waveforms are obtained and analyzed.

The Simulink works with one constraint that chip rate is constant. For future, analysis can be done by varying chip rates and data rates up to 2Mbit/sec as lay down by GPPP. Provisions for power control can also be added to further enhance the performance parameters. Bit Error Rate calculated is found to be bit high which can be improved by employing techniques suggested above. We can further enhance the performance by deploying interference cancellation techniques at physical channel level.

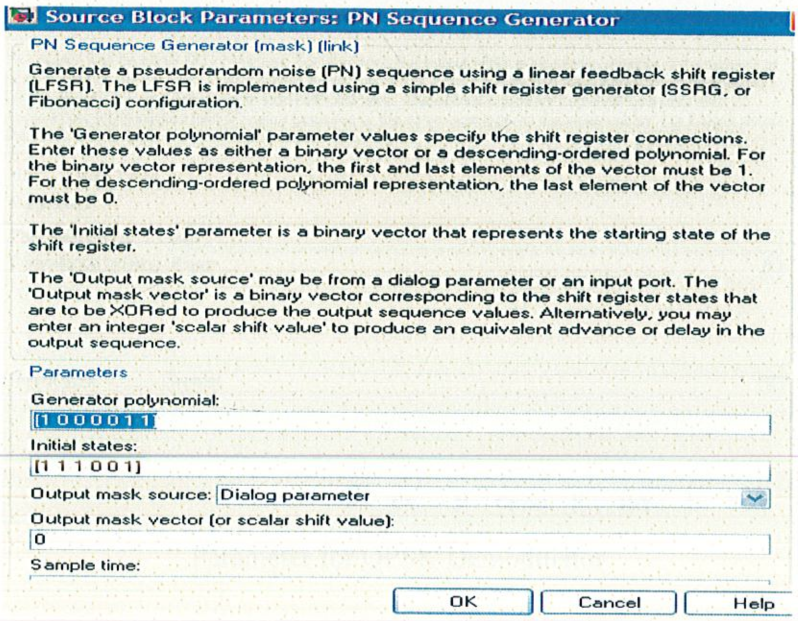
Appendix A

Simulation Parameters

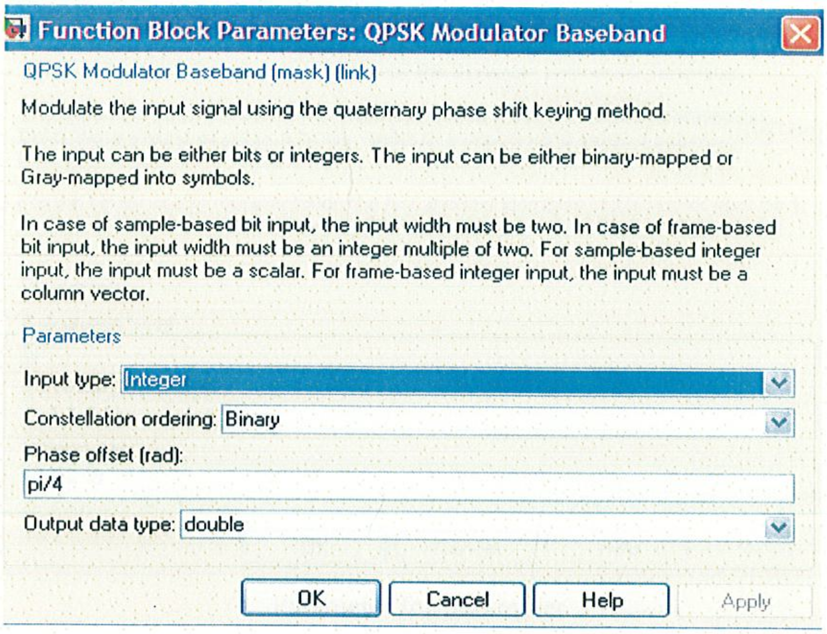
In this section various simulation parameters are shown which are used for simulation purpose and are in accordance with WCDMA specifications



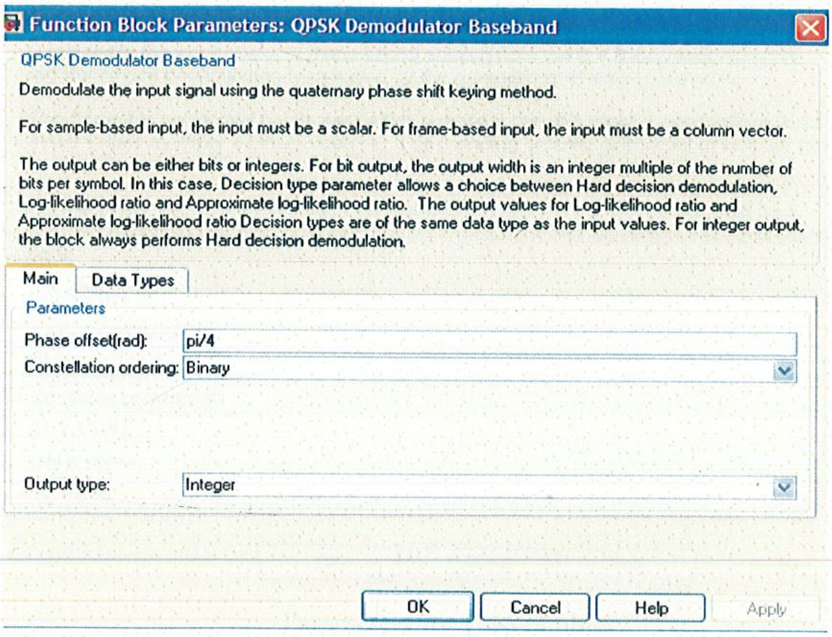
Parameters for Bernoulli Generator



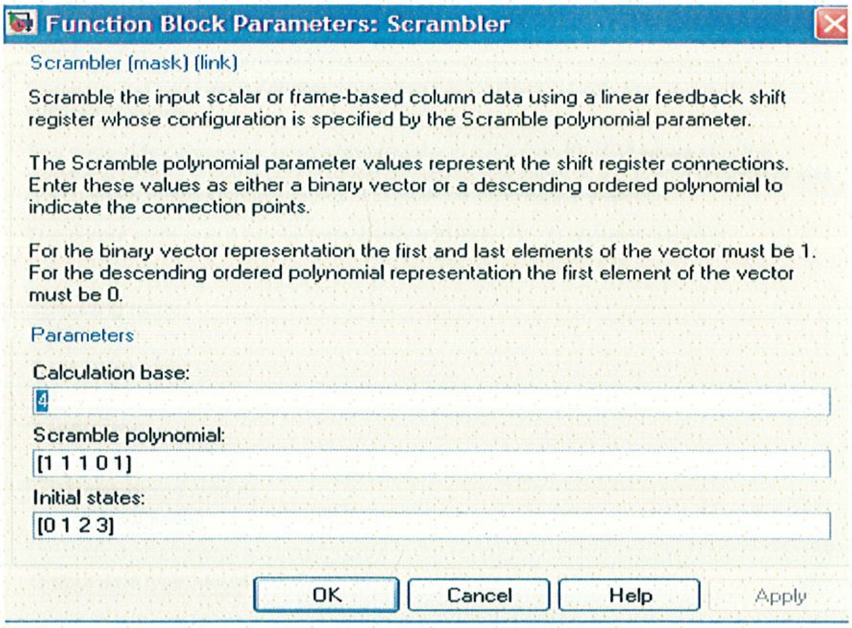
Parameter for PN sequence



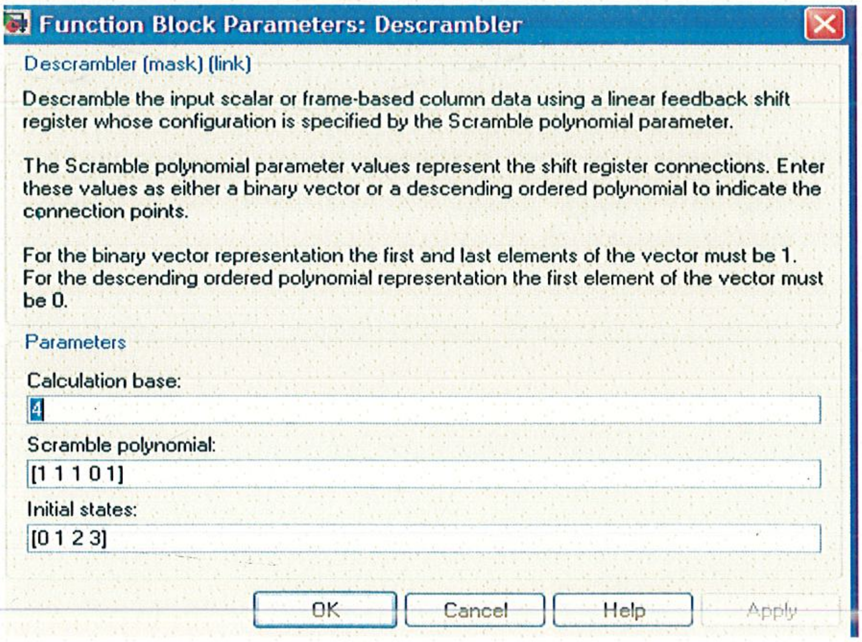
Parameter for QPSK Modulator



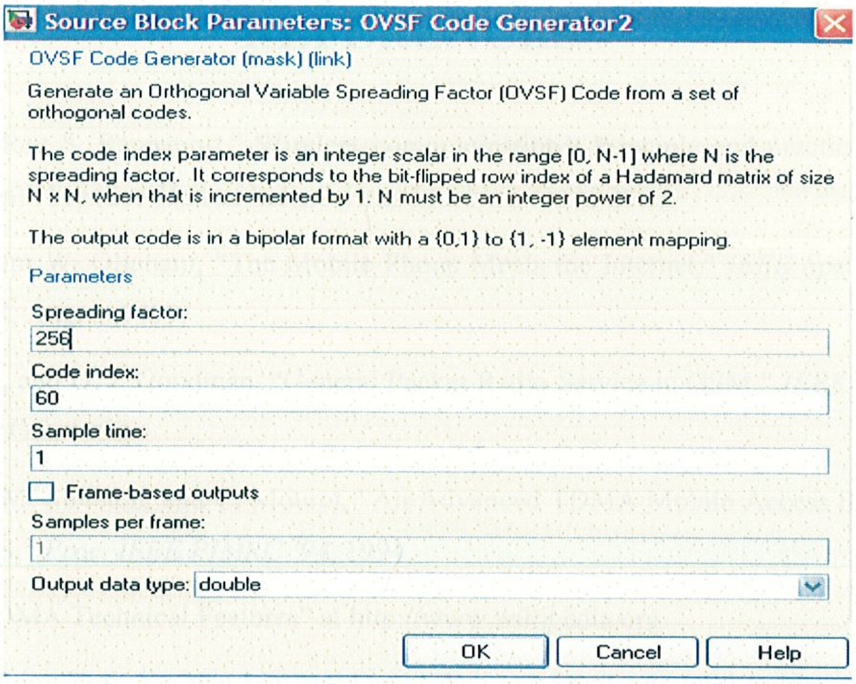
Parameter for QPSK Demodulator



Parameter for Scrambler



Parameters for Descrambler



Parameters for OVSF Code Generator

REFERENCES

[1] Theodore S. Rappaport," Wireless communications: Principle and practice (Second edition)" Prentice-Hall of India Private Ltd, New Delhi 2006.

[2] Malcom W. Oliphant, "The Mobile Phone Meets the Internet," *IEEE Spectrum*, pp. 20- 28, August 1999.

[3] J. Cai, and D. J. Goodman, "General Packet Radio Service in GSM," *IEEE Commun. Mag.*, Oct. 1997

[4] Urie, M. Streeton, and C. Mourot, "An Advanced TDMA Mobile Access System for UMTS," *Proc. IEEE PIMRC '94*, 1994.

[5] "WCDMA Technical Features" at http://www.wikipedia.org

[6] Song-Ling Tsai, Yu-Nan Lin, and David W. Lin," Study and DSP Implementation of 3GPPWideband-CDMA Transmission Signal Processing and Wireless Channel Simulation"

[7] 3GPP, Technical Specification Group Radio Access Network,"Spreading and Modulation (FDD)" Doc .No. 3G TS 25.213 version 4.1.0 June 2001

[8] P. O. Andresson *et al.*, "FRAMES Multiple Access — A Concept for the UMTS Radio Interface" *Proc. ACTS Mobile Commun, Summit '97*, vol. 1, Aalborg, Denmark, 1997.

[9] ETSI UMTS 30.06, "UMTS Terrestrial Radio Access (UTRA) Concept Evaluation," 1998.

[10] Hamizi Bin Zamzuri and Muhammad Bin Ibrahim, "Simulation On WCDMA For 3G Mobile Systems" proc of 4th National Conference on Telecommunication Technology, Shah Alam Malaysia, pp 244-249, 2003

[11] M. Rahman, F.A.M. Mirt," Fourth Generation (4G) Mobile Networks - Features, Technologies & Issues"

[12] Erik Dahlman, Bjorn Gudmundson, Matts Nilsson, and Johan Skold, " UMTS/IMT-2000 Based on Wideband CDMA," *IEEE Communications Magazine*, vol. 36, pp. 70-80, September 1998.

[13] Erik Dahlman, Per Beming, Jens Knutsson, Fredrik Ovesjo, Magnus Persson, and Christiaan Roobo, "CDMA- The Radio Interface for Future Mobile Multimedia Communications," *IEEE Transactions on Vehicular Technology*, vol. 47, No. 4, pp. 1105-1118, November 1998.

[14] "Simulation of Third Generation CDMA Systems" by Fakhrul Alam, Virginia Polytechnic Institute.

[15] Baier *et al.*, "Design Study for a CDMA-Based Third Generation Mobile Radio System," *IEEE JSAC*, vol. 12, May 1994.

[16] M. Ewerbring, J. Farjh, and W. Granzow, "Performance Evaluation of a Wideband Testbed Based on CDMA," *Proc. VTC '97*, Phoenix, AZ, May 1997.

[17] M. Sundelin, W. Granzow, and H. Olofsson, "A Test System for Evaluation of the W-CDMA technology," *Proc. VTC '98*, Ottawa, Canada, May 1998.

[18] F. Adachi, M. Sawahashi, and K. Okawa, "Tree-structured generation of orthogonal spreading codes with different lengths for forward link of DS-CDMA mobile radio," *Elect. Lett.*, vol. 33, Jan. 1997.

BIBLOGRAPHY

- www.wikipedia.org
- www.utdallas.edu
- Harri Holma,"WCDMA for UMTS: radio access for third generation mobile communications"

  ISBN 0470870966, 2004
- Tero Ojanpera ,"WCDMA: towards the IP Mobility and mobile internet "

  ISBN: 1580531806, 2000
- Keiji Tachikawa ,"W-CDMA: mobile communications system "

  ISBN: 0470847611, 2002.