SIMULATION OF A CODE DIVISION MULTIPLE ACCESS (CDMA) 2000 DOWNLINK SYSTEM

By

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FINAL YEAR PROJECT REPORT

Submitted to the Electrical & Electronic Engineering Department
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CERTIFICATION OF APPROVAL

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A project interim submitted to the
Electrical & Electronic Engineering Programme
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Approved:

Ms Norashikin Yahya
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Hilmy bin Md. Satibi

ABSTRACT

The topic chosen for this project is the simulation of a CDMA 2000 downlink system. CDMA 2000 is a 3G mobile telecommunications standard that uses CDMA to send voice, data and signaling data (such as a dialed telephone number) between mobile telephones and cell sites. The purpose of the simulation is to show that the design of the system can be implemented in actual application. The original codes and libraries are taken directly from the Matlab software for the purpose of the simulation. The simulation is set up by considering the data rate, the channel model and also the performance of the system in terms of bit error rate results and the frame quality indicator.

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In the name of Allah the Beneficent, the Merciful

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ABBREVIATIONS AND NOMENCLATURES

2G	Second Generation
3G	Third Generations
AWGN	Additive White Gaussian Noise
BER	Bit error rate
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CDMA 2000 1x	single carrier (1x)
CDMA 2000 1xRTT	single carrier (1x) radio transmission technology
CDMA 2000 1xEV	single carrier (1x) evolutionary
CDMA 2000 1xDV	single carrier (1x) data & voice
CDMA 2000 1xEV-DO	single carrier (1x) data only
CDMA 2000 1xEV-DV	single carrier (1x) evolutionary data & voice
CR	communication resource
CRC	cyclic redundancy code
DS-SS	Direct Spread Spectrum System
EVRC	Enhanced Variable Rate Codec
FDMA	frequency-division multiple access
FER	Frame-error rate
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
IMT-2000	International Telecommunication Union 2000
ITU	International Telecommunication Union
Kbps	Kilobits per second
LOS	line-of-sight
MAC	Medium Access Control
Mbps	Megabits per second
MHz	Megahertz
MS	Mobile Station

NLOS	non-line-of-sight
PC	Power Control
PCS	Personal Communication Services
PN	Pseudo-noise
RC	Resistor Capacitor
RF	Radio Frequency
SCH	Supplemental channels
SNR	signal-to-noise ratio
SS	Spread Spectrum
TD	Transmit Diversity
TDMA	time-division multiple access
FPiCh	Forward Pilot Channels
SyncCh	Forward Sync Channel
FPCh	Forward Paging Channels
BCCh	Broadcast Control Channel
QPCh	Quick Paging Channel
CPCCh	Common Power Control Channel
CACh	Common Assignment Channel
FCCCh	Forward Common Control Channel
FDCCh	Forward Dedicated Control Channel
FFCh	Forward Fundamental Channel
FSCh	Forward Supplemental Channel
FSCCh	Forward Supplemental Code Channel

CHAPTER 1: INTRODUCTION

The project objectives and the scope of study are highlighted at the beginning of this report. The theories that are involved and will be used are covered in the literature review or theory section. This report also covers the methodology used and tools required during this project. The last part is the findings which describes the advantage and great purpose derived from this project.

1.1 BACKGROUND OF STUDY

CDMA is a 3G standard for the next generation mobile services which provide better quality voice and high-speed Internet and multimedia services [1]. While there are many interpretations of what 3G represents, the only definition accepted universally is the one published by the International Telecommunication Union (ITU). ITU, working with industry bodies from around the world, defines and approves technical requirements and standards as well as the use of spectrum for 3G systems under the IMT-2000 (International Telecommunication Union-2000) program.

The ITU requires IMT-2000 (3G) networks to deliver improved system capacity and spectrum efficiency over the 2G systems. This is required in order to 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 ITU approved five radio interfaces for IMT-2000 standards as a part of the ITU-R M.1457 Recommendation.

CDMA2000 represents a family of technologies that includes CDMA2000 1X and CDMA2000 1xEV. CDMA2000 1X can double the voice capacity of cdmaOne networks and delivers peak packet data speeds of 307 kbps in mobile environments. There are two platforms involved in CDMA2000 1xEV. The first is CDMA2000 1xEV-DV which provides integrated voice and simultaneous high-speed packet data multimedia services at speeds of up to 3.09 Mbps [2]. Secondly, CDMA2000 1xEV-DO and CDMA2000 1xEV-DV are both backward compatible with CDMA2000 1X and cdmaOne. The terminologies associated with CDMA are listed in Table 2-1:

Table 2-1 Terminologies associated with CDMA 2000

Terminology	**Explanation**
CDMA2000	Common name for IMT-2000 CDMA Multi-Carrier.
CDMA2000 1X	3G technology which offers up to 2 times increase in voice capacity and provides data speeds up to 307 kbps on a single (1X) carrier in new or existing spectrum. CDMA2000 1X has been commercially available since October 2000.
CDMA2000 1xEV	Evolutionary steps of CDMA2000 1X that offer higher data rates and maximize performance.
CDMA2000 1xEV-DO	3G technology that uses a separate 1.25 MHz carrier for data and offers peak data rates of 2.4 Mbps. The first CDMA2000 1xEV-DO networks were launched in early 2002.
CDMA2000 1xEV-DV	3G technology that integrates voice & data on the same carrier. CDMA2000 1xEV-DV has been submitted to ITU for formal standardization approval.

1.2 PROBLEM STATEMENT

1.2.1. PROJECT DESCRIPTION

CDMA2000 is a 3G mobile telecommunications standard that uses CDMA to send voice, data and signaling data (such as a dialed telephone number) between mobile telephones and cell sites [3]. Code Division Multiple Access (CDMA) is a multiplexing technique where a number of users simultaneously access a channel by modulating and spread their baseband signals with pre-assigned sequences. CDMA has proved to provide higher capacity over conventional access techniques such as time-division multiple access (TDMA) and frequency-division multiple access (FDMA). This project will simulate CDMA2000 1xRTT Forward link (between Base Station and Mobile Station) based on the Matlab codes authored by Alex Rodriguez.

1.2.2. PROJECT SIGNIFICANCE

This simulation will ultimately be the backdrop of a real CDMA 2000 implementation physically if conducted on a Base Station and a Mobile Station. From this simulation, the performance of the system can be analyzed in terms of bit error rate (BER), frame quality indicator (FQI), and the scope output from the model.

1.3 OBJECTIVES

The objectives of this Final Year Project are:

- To understand and comprehend the use and technology of CDMA 2000
- To simulate CDMA 2000 downlink system using 1xRTT (single carrier (1x) radio transmission technology) Forward Link platform as the standard for implementation

1.4 SCOPE OF STUDY

For this project, the 2 semesters time frame allocated will be used to simulate the CDMA 2000 technique using Matlab. To further narrow down the scope, this project will be conducted based on the platform of 1xRTT third generation (3G) wireless technology. This project will focus on the Forward Link Channels between the Base Station and the Mobile Station by using the direct spread spectrum system (DS-SS) for the channel structure.

CHAPTER 2: BACKGROUND STUDY & LITERATURE REVIEW

The definition and the advantages of CDMA 2000 are described in more detail in this chapter. An introduction into cellular network is also contained in this chapter. The channel models used are briefly explained and the effects of fading were also inserted in this chapter.

2.1 CODE DIVISION MULTIPLE ACCESS (CDMA)

Code Division Multiple Access (CDMA) has a meaning which best describes according to each word. Multiple access refers to the sharing of a communications resource (CR). CR represents the time and bandwidth that are available for communication signaling associated with a given system [4]. It can be visually represented with a plane, where the abscissa represents time and the ordinate represents frequency. Planning out these resource allocations among system users can develop an efficient use of the communication system so that users can share the resource in an equitable manner without wasting the block of time/frequency allocated. It involves the remote sharing of a resource which means the amount of information transferred by the user can dynamically change according to the user's CR needs. Code division in itself means specified members of a set of orthogonal or nearly orthogonal spread spectrum codes (each using the full channel bandwidth) are allocated.

All these techniques allow the various signals to share a CR without creating unmanageable interference to each other in the detection process. The orthogonal signals on separate channels will avoid interference between users.

2.2 ADVANTAGES

CDMA 2000 is an application of spread spectrum (SS) techniques. It can be classified into two major categories: direct sequence and frequency hopping. Frequency hopping is the hybrid combination of the Frequency division multiple access (FDMA) and also Time division multiple access (TDMA). The advantages of CDMA 2000:

2.2.1. Increased voice capacity

CDMA 2000 1x supports 35 traffic channels per sector per RF (26 Erlangs/sector/RF) using the EVRC (Enhanced Variable Rate Codec) vocoder (voice coder), which became commercial in 1999. Voice capacity improvement in the forward link is attributed to faster power control, lower code rates (1/4 rate), and transmit diversity (for single path Rayleigh fading).

2.2.2. Higher data throughput

CDMA 2000 1x networks support a peak data rate of 153.6 kbps.

2.2.3. Frequency band flexibility

CDMA 2000 can be deployed in all cellular and PCS spectrum. The high spectral efficiency permits high traffic deployments in any 1.25 MHz channel of spectrum.

2.2.4. Increased battery life

CDMA 2000 significantly enhances battery performance which benefits quick paging channel operation, improved reverse link performance, new common channel structure and operation, reverse link gated transmission and new MAC states for efficient and ubiquitous idle time operation.

2.2.5. Synchronization

CDMA 2000 is synchronized with the Universal Coordinated Time (UCT). The forward link transmission timing of all CDMA 2000 base stations worldwide is synchronized within a few microseconds.

2.2.6. Power control

The basic frame length is 20 ms divided into 16 equal power control groups. CDMA 2000 defines a 5 ms frame structure, essentially to support signaling burst, as well as 40 and 80 ms frames which offer additional interleaving depth and diversity gains data services. CDMA 2000 channels can be power controlled at up to 800 Hz in both reverse and forward links.

2.2.7. Soft Hand-off

CDMA 2000 provides a framework to the terminal in support of the inter-frequency handover measurements consisting of identity and system parameters to be measured. The terminal performs required measurement as allowed by its hardware capabilities.

2.2.8. Transmit diversity

Transmit diversity consists of de-multiplexing and modulating data into two orthogonal signals, each of them transmitted from a different antenna at the same frequency. The receiver reconstructs the original signal using diversity signals, thus taking advantage of the additional space and/or frequency diversity.

2.2.9. Channels

CDMA 2000 forward traffic channel structure provides many physical channels. The traffic channel structure and frame format is very flexible. It defines a spreading rate and an associated set of frames for each configuration. The multichannel forward traffic structure is the flexibility to independently set up and tear down new services without any complicated multiplexing reconfiguration or code channel juggling. The structure also allows different hand-off configurations for different channels.

2.2.10. Turbo coding

CDMA 2000 provides an option of either using turbo coding or convolutional coding on the forward and reverse supplemental channels (SCH). The turbo coding can support at rate 1/2, 1/3, or 1/4. Turbo coding provides a very efficient scheme for data transmission and leads to better link performance and system capacity improvements.

Direct sequence spread spectrum in the other hand means a carrier wave is first modulated with a data signal then the data-modulated signal is again modulated with a high-speed (wideband spreading signal) [5]. It allows multiple users simultaneously occupy the same spectrum.

2.3 CELLULAR NETWORK

The cellular concept is a system-level idea which calls for replacing a single, high power transmitter (large cell) with many lower power transmitter (small cells), each providing coverage to only a small portion of the service area [6]. Each base station is allocated apportion of the total number of channels available to the entire system, and nearby base stations are assigned different groups of channels so that all the available channels are assigned to a relatively small number of neighboring base stations. Neighboring base stations are assigned different group channels so that interference between base stations (and the mobile users under their control) is minimized. By symmetrically spacing the base stations and their channel groups throughout a market, the available channels are distributed throughout the geographic region and may be reused as many times as necessary as long as the interference between co-channel stations is kept below acceptable levels.

Cellular radio systems rely on an intelligent allocation and reuse of channels throughout a coverage region. Each cellular base station is allocated a group of radio channels to be used within a small geographic area called a cell. Base stations in adjacent cells are assigned channel groups which contain completely different channels than neighboring cells. The base station antennas are designed to achieve the desired coverage within the particular cell. By limiting the coverage area to within the boundaries of a cell, the same group of channels may be used to cover different cells that are separated from one another by distances large enough to keep interference levels within tolerable limits. The design process of selecting and allocating channel groups for all of the cellular base stations within a system is called frequency reuse or frequency planning.

Mobile Stations (MS) are connected to the Base Transceiver Station (BTS) through the standardized air-interface [7]. One or more BTS may be located in the same place known as a site sharing the same infrastructure. A BTS may have one or multiple sectors. The typical number of sectors used in existing CDMA networks is three. BTS sectors are also known as sector cells or sectors (ST). A group of sectors forms the BTS or cell. Each sector can consist of multiple transceivers that have the same coverage but different frequencies. The multiple sectors within a BTS may be pointing their antennas toward different directions.

The pilot channel in the forward link establishes the maximum sector footprint because only MS that receive the pilot signal above a certain level can be connected to it. The use of this pilot provides synchronization for the receiver by indicating the start and end of each code, and improves detection capability (coherent detection). In coherent detection the alignment of the code is known and this makes the detection much more robust. The overhead due to the pilot is relatively low as the BTS hosts many user channels and its impact is shared among users.

Forward link traffic channels are power adjusted to meet the requirements of the target MS. The long Pseudo-noise (PN) code, offset by the channel user key, scrambles the information data allowing only the intended recipient to recover the information. Each channel is then identified and orthogonally spread by a Walsh code, to identify the signals from each sector and to provide alignment recovery capabilities for multipath situations.

For the Forward Link CDMA 2000 network, the BTS or Base Station can be configured to offer the following logical channels [8]:

1. Forward Pilot Channels (FPiCh)
2. Forward Sync Channel (SyncCh)
3. Forward Paging Channels (FPCh)
4. Broadcast Control Channel (BCCh)

5. Quick Paging Channel (QPCh)
6. Common Power Control Channel (CPCCh)
7. Common Assignment Channel (CACh)
8. Forward Common Control Channel (FCCCh)
9. Forward Dedicated Control Channel (FDCCh)
10. Forward Fundamental Channel (FFCh)
11. Forward Supplemental Channel (FSCh)
12. Forward Supplemental Code Channel (FSCCh)

2.4 CHANNEL MODEL

Small-scale fading or simply fading is used to describe the rapid fluctuations of the amplitudes, phases, or multi-path delays of a radio signal over a short period of time or travel distance, so that large-scale path loss effects may be ignored. Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times [9]. These waves, called multi-path waves, combine at the receiver antenna to give a resultant signal which can vary widely in amplitude and phase, depending on the distribution of the intensity and relative propagation time of the waves and the bandwidth of the transmitted signal.

Multi-path in the radio channel creates small-scale fading effects. The three most important effects are the rapid changes in signal strength over a small travel distance or time interval, random frequency modulation due to varying Doppler shifts on different multi-path signals, and time dispersion (echoes) caused by multi-path propagation delays.

Due to the relative motion between the mobile and the base station, each multi-path wave experiences an apparent shift in frequency. The shift in received signal frequency due to motion is called the Doppler shift, and is directly proportional to the velocity and direction of motion of the mobile with respect to the direction of arrival of the received multi-path wave.

2.5 FADING

Fading or a combination of mechanisms that causes the received signal levels to vary even when transmit signal levels are constant, can be divided into two types: fast (or multi-path) fading, and slow (or shadow) fading. In a fast fading channel, the channel impulse response changes rapidly within the symbol duration. That is, coherence time of the channel is smaller than the symbol period of the transmitted signal. This causes frequency dispersion (also called time selective fading) due to Doppler spreading, which leads to signal distortion. Viewed in the frequency domain, signal distortion due to fast fading increases with increasing Doppler spread relative to the bandwidth of the transmitted signal. Therefore, a signal undergoes fast fading if $T_S > T_C$ (symbol period greater than coherence time) and $B_S < B_D$ (symbol bandwidth smaller than Doppler spread). Fast fading only deals with the rate of change of the channel due to motion. In practice, fast fading only occurs for very low data rates.

From another viewpoint, this fading is caused by the reception of a signal coming from many different directions but transmitted from a single source. Each of the waves received has a different strength and a different phase. It is impractical to deterministically calculate all the multi-path components; therefore a statistical approach is used.

Three situations are possible when statistically analysing fading. First, there is no multi-path and the signal is received in a line-of-sight (LOS) situation with only environment noise present (AWGN channel). Second, there are only non-line-of-sight (NLOS) components and there is noise present (Rayleigh distribution). Third, there is a LOS component, NLOS components and noise (Rice distribution).

In the LOS scenario, a LOS signal is combined with many NLOS signals. The ratio between the LOS and NLOS signal components determines the type of fading. When the LOS is pre-dominant, fading has a Gaussian distribution; when the NLOS is pre-dominant, fading has a Rayleigh distribution; when there is a balance, fading follows a Ricean distribution. There is not a distinctive line separating the distributions and all three of them can be derived from a Rice distribution just by changing its parameters.

2.6 AWGN CHANNEL

AWGN or Additive White Gaussian Noise characterizes a channel when the signal reaches the receiver through a single path and noise is present in the environment.

2.7 RAYLEIGH DISTRIBUTION

In mobile radio channels, the Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multi-path component. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution.

For the purpose of this project, the channel models used for the simulation in Matlab will be upon the combination of the two fading channels, namely the AWGN and the Multi-path (Rayleigh) channels. In conjunction with this scope, the small-scale fading based on the Doppler spread will be concentrated upon fast fading which has the following properties; a high Doppler spread, coherence time smaller than symbol period, and channel variations faster than baseband signal variations.

CHAPTER 3: METHODOLOGY OF PROJECT WORK

The method used to proceed with the project is described here in this chapter.

3.1 PROCEDURE IDENTIFICATION

For the first semester of this Final Year project, the focus is mainly on the understanding and the theoretical literacy of each of the component of the system starting from the transmission of the signal at the Base Station to the reception of the signal at the Mobile Station. In the second semester, the focus is more on the implementation of the system in Matlab codes of each of the component in the system.

3.2 TOOLS / DELIVERABLES

Simulate the system using Matlab. Required product: Communications Toolbox, Communications Blockset, Signal Processing Blockset, Signal Processing Toolbox, Simulink

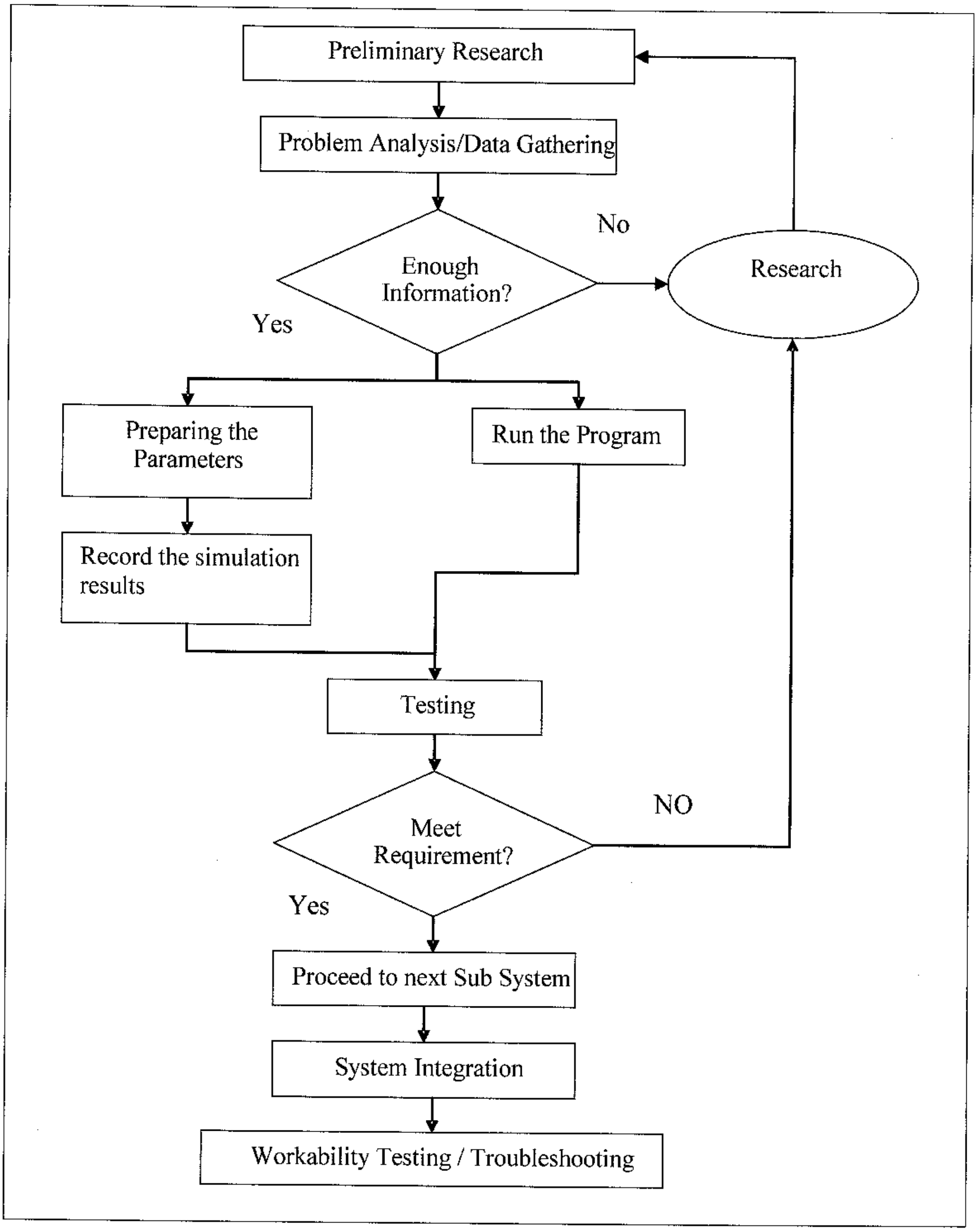


Figure 3-1 Flow of design step

CHAPTER 4: SIMULATION WORK

The block diagrams and parameters involve in the simulation of the system are described in this chapter. The overall concept and execution of the system can be understood here.

4.1 OBJECTIVES

The objectives of the final report were set and met in order to realize the project in actual implementation. Among them is to describe the concept of Code Division Multiple Access in particular the concept of Direct-Sequence Spread Spectrum (DS-SS). Other than that, it is to describe the forward link channels in CDMA 2000 standards. Besides that, it is to discuss and explain the concepts of small-scale fading encountered in CDMA 2000 particularly in Multi-path fast fading channels and its distribution (AWGN and Rayleigh). Based from that, it goes to discuss and explain the concepts and function of the Transmitter, Receiver, Encoding, and Decoding block diagram in a Multipath Fading channel, AWGN channel and the non-interference channel for the use in CDMA 2000.

4.2 SYSTEM FLOW

The system model as shown in Figure 4-1 starts off from the Data Source which uses the Bernoulli Binary which would generate the signals. It will pass through the Encoding block diagram which would encode the signal and modulate it for transmission. The Transmitter block diagram transmits the signal to the medium of choice. The Channel Model will simulate the proper conditions of the medium, namely the Multipath fading channel, the AWGN channel, and the non-interference channel. The Receiver block diagram will accept the signals from the medium using the Rake receiver. The Decoding block diagram will decode back the signal back to its original state and completes the process of the entire system. The bit error rate (BER) results before and after decoding were shown and analyzed to give a better description of the performance of the receiver and decoder. In general, the whole project can be viewed in terms of the system model in Figure 4-1.

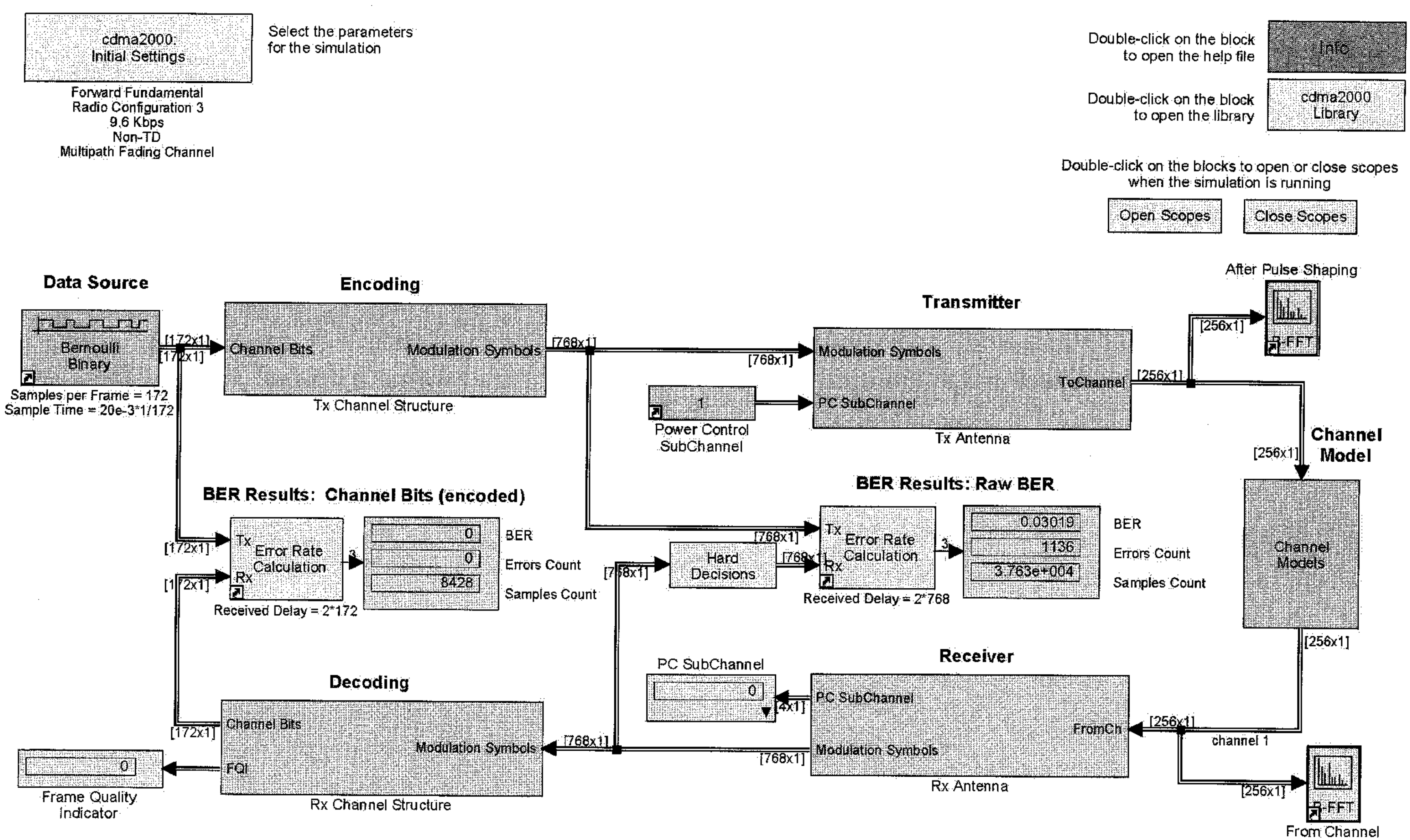


Figure 4-1: CDMA 2000 1 X RTT Physical Layer Radio Configuration 3 – Forward Fundamental Channel

4.3 BLOCK DIAGRAM

4.3.1. Transmitter block diagram

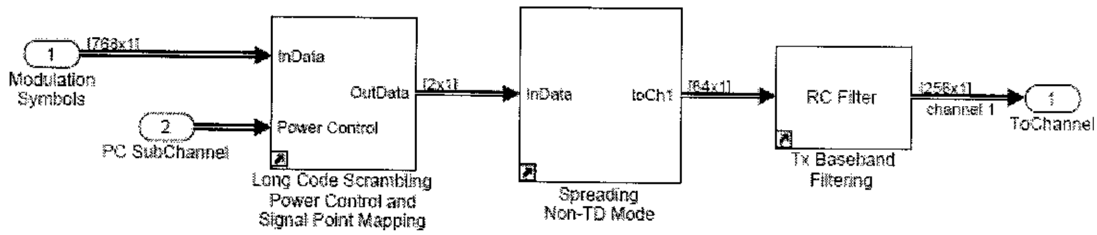


Figure 4-2 Transmitter block diagram

The simulation starts off from the Inport (Modulation Symbols, PC SubChannel, ToChannel) which creates an input port for a subsystem or an external input. Simultaneously, it performs Long Code Scrambling, Power Control and Signal Point Mapping for Forward Traffic Channel. Next, it goes to the Spreading Non-TD Mode, where it performs Orthogonal spreading using a real-valued Quasi-Orthogonal function and Quadrature spreading using a complex-valued PN sequence as described in 3.1.3.1.12 [10]. The Tx Baseband Filtering uses FIR Interpolation which up sample and filter the input signal.

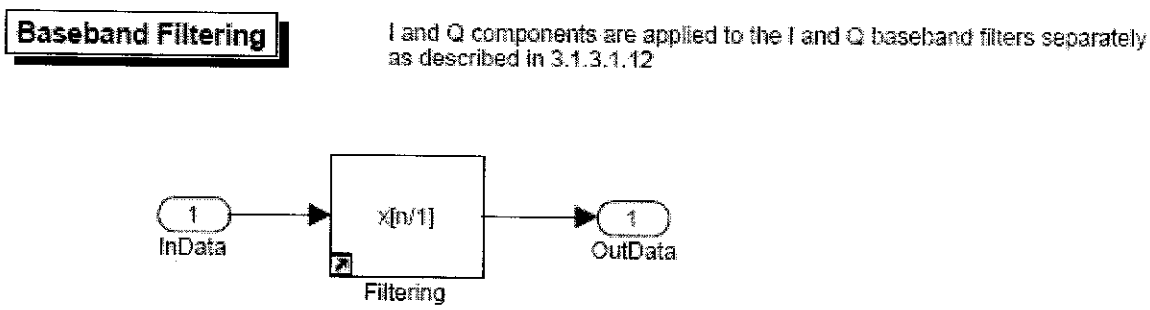


Figure 4-3 Baseband Filtering block diagram

4.3.2. Receiver block diagram

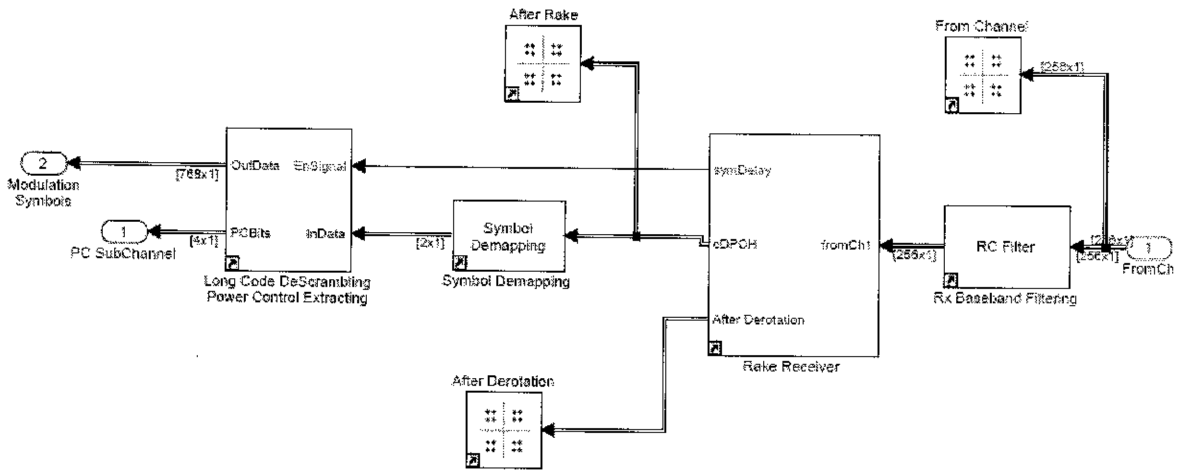


Figure 4-4 Receiver block diagram

The signal continues into the Rx Baseband Filtering where it does the Baseband filtering using the FIR interpolation. Baseband filtering basically filters the I and Q components separately using the typical RC filter.

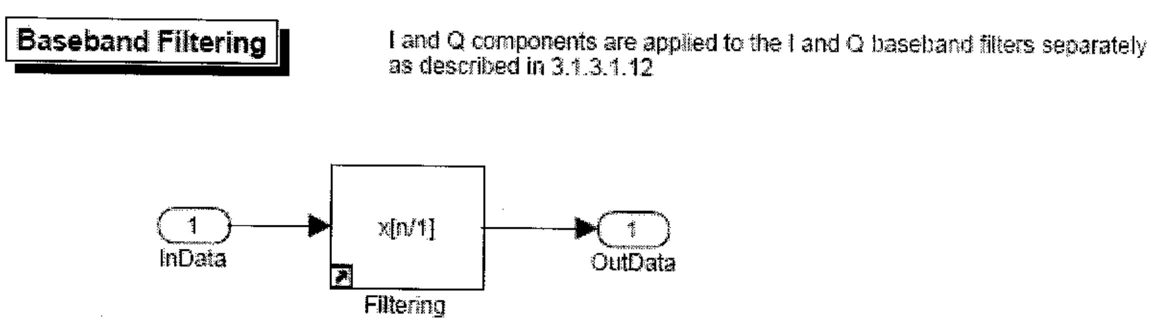


Figure 4-5 Baseband Filtering block diagram

Rake Receiver is made of 4 different fingers. Each finger downsamples and decorrelates pilot bits and data using the corresponding sequence. Pilot bits are then sent to the channel estimator whose output is then used to derotate the received data signal. The demodulated data processed by each rake finger is finally coherently combined.

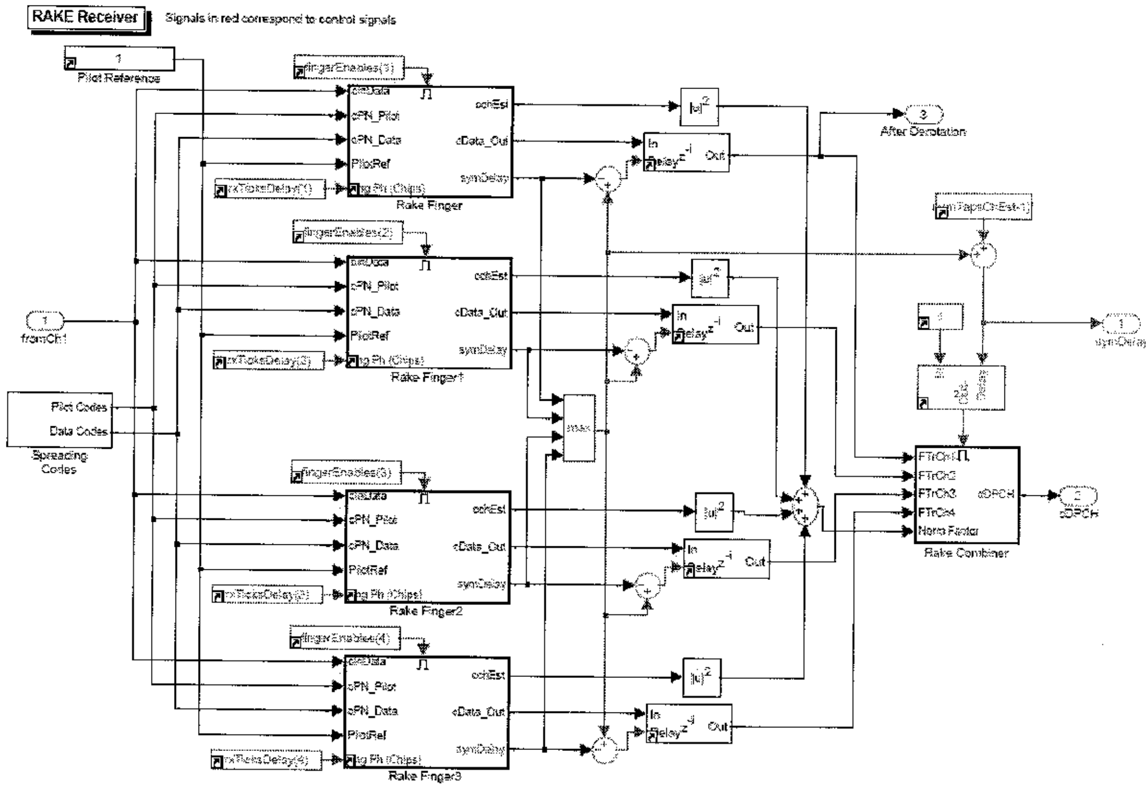


Figure 4-6 Rake Receiver block diagram

Symbol Demapping does the mathematical function of converting complex numbers into real and imaginary parts and also performs matrix concatenation. In this case, the block does the vertical concatenation.

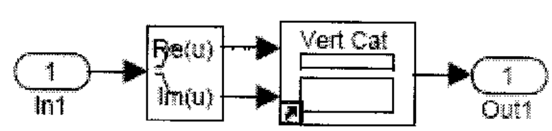


Figure 4-7 Symbol Demapping block diagram

The Long Code DeScrambling Power Control Extracting block then performs Long Code DeScrambling and Power Control Extraction for Forward Traffic Channel.

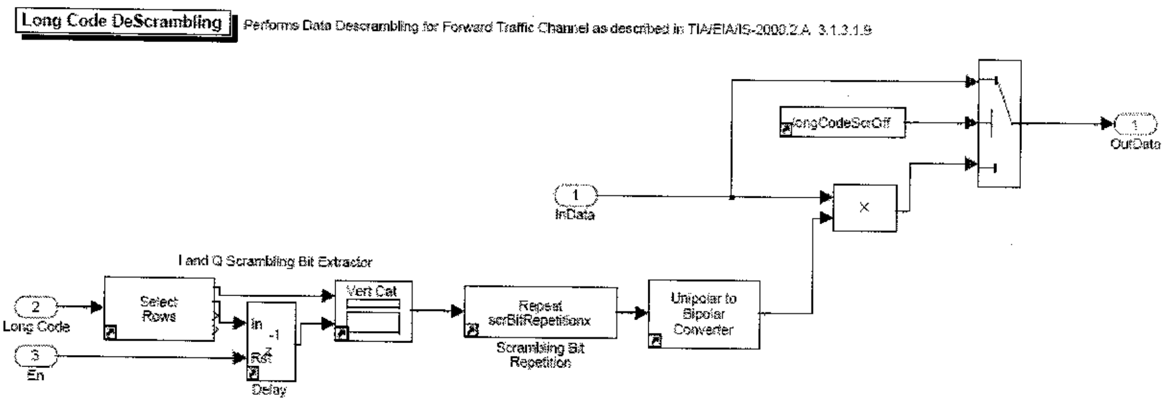


Figure 4-8 Long Code DeScrambling block diagram

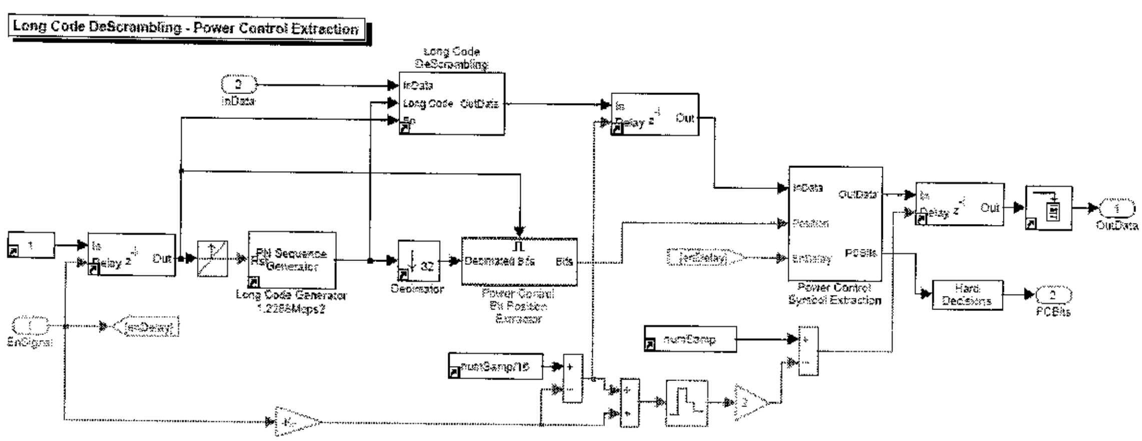


Figure 4-9 Long Code DeScrambling – Power Control Extraction block diagram

4.3.3. Encoding block diagram

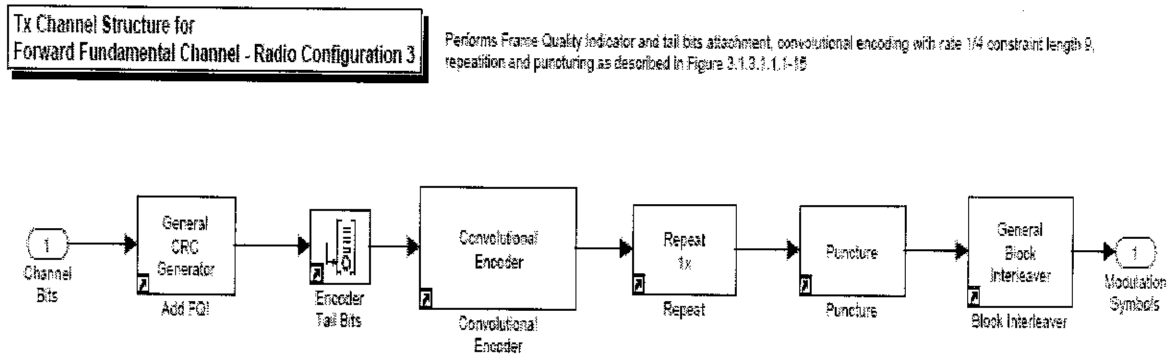


Figure 4-10 Encoding block diagram

The General CRC Generator generates cyclic redundancy code (CRC) bits according to the generator polynomial and appends them to the input data frames. The Encoder Tail Bits does the zero padding which alter the input dimensions by zero-padding (or truncating) rows and/or columns. The Convolutional Encoder creates a convolutional code from binary data. It basically encodes a sequence of binary input vectors to produce a sequence of binary output vectors. This block can process multiple symbols at a time. The Repeat block repeats input samples N times. In other words, it resamples an input at a higher rate by repeating values. The Puncture block output the elements which correspond to 1s in the binary Puncture vector. It creates an output vector by removing selected elements of the input vector and preserving others. The General Block Interleaver finally reorders the symbols in the input vector. In short, it rearranges the elements of its input vector without repeating or omitting any elements. The input can be real or complex.

4.3.4. Decoding block diagram

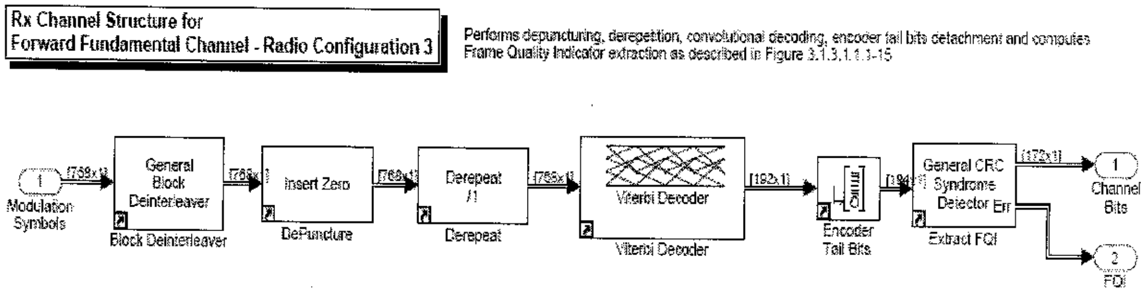


Figure 4-11 Decoding block diagram

The final stages of the simulation involve the Block Deinterleaver which restores ordering of the symbols in the input vector. It rearranges the elements of its input vector without repeating or omitting any elements. The Elements parameter must contain unique integers between 1 and N. The DePuncture block contains the Insert Zero block which distributes input elements in output vector. It constructs an output vector by inserting zeros among the elements of the input vector. The block determines where to place the zeros by using the Insert zero vector parameter. The Derepeat block reduces sampling rate by averaging consecutive samples. It basically resample the discrete input at a rate 1/N times the input sample rate by averaging N consecutive samples. The Viterbi Decoder decodes convolutionally encoded data using the Viterbi algorithm. In other words, it decodes input symbols to produce binary output symbols. This block can process several symbols at a time for faster performance. The Encoder Tail Bits contains the Zero Pad block which alters the input dimensions by zero-padding (or truncating) rows and/or columns. Finally, the Extract FQI block contains General CRC Syndrome Detector which detects errors in the input data frames according to the generator polynomial. It receives a message word and removes the checksum. The block then calculates a new checksum and compares the received checksum with the new checksum.

CHAPTER 5: RESULTS & DISCUSSION

The following results were taken from the simulation and were compared and analyzed in this chapter. The performance of the system can be deduced from these results and were explained also in this chapter.

5.1. MULTIPATH FADING CHANNEL

From the system above, there are 3 scopes that were used to evaluate the result from each of the output coming from different sources. First, there is the scope from the channel model itself which will be compared to the other 2 scopes which will receive the signal.

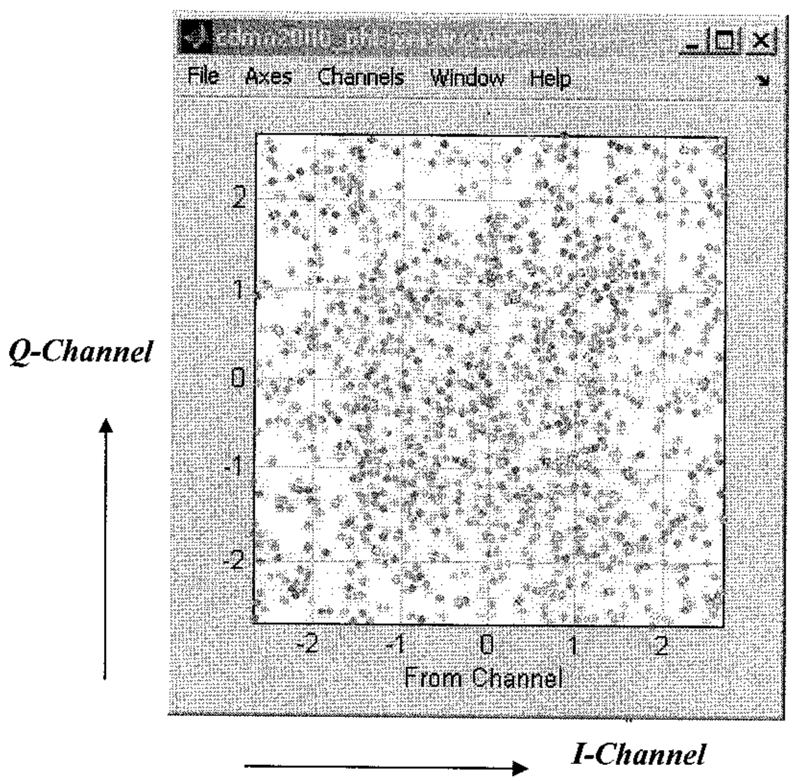


Figure 5-1 Scope from the Channel (Multipath Fading channel)

Figure 5-1 shows that the channel is well surrounded by extensive amount of noise which will degrade the quality of the signal and thus make it much harder to decode back to its original signal.

The inside structure of the transmitter provides 4 main blocks before sending to the decoder:

- Rx Baseband Filtering
- Rake Receiver
- Symbol Demapping
- Long Code DeScrambling Power Control Extracting

Rx Baseband Filtering does the Baseband filtering using the FIR interpolation. Baseband filtering basically filters the I and Q components separately using the typical RC filter.

Rake receiver is made of 4 different fingers. Each finger downsamples and decorrelates pilot bits and data using the corresponding sequence. Pilot bits are then sent to the channel estimator whose output is then used to derotate the received data signal. The demodulated data processed by each rake finger is finally coherently combined.

The output for these blocks is then sent through to the next step where the signal is then sent to the decoder block to decipher the signal. Regarding the Rake receiver, 2 of the scopes were put after derotation and also after the Rake receiver itself.

The output of the scope for the derotation is shown in Figure 5-2.

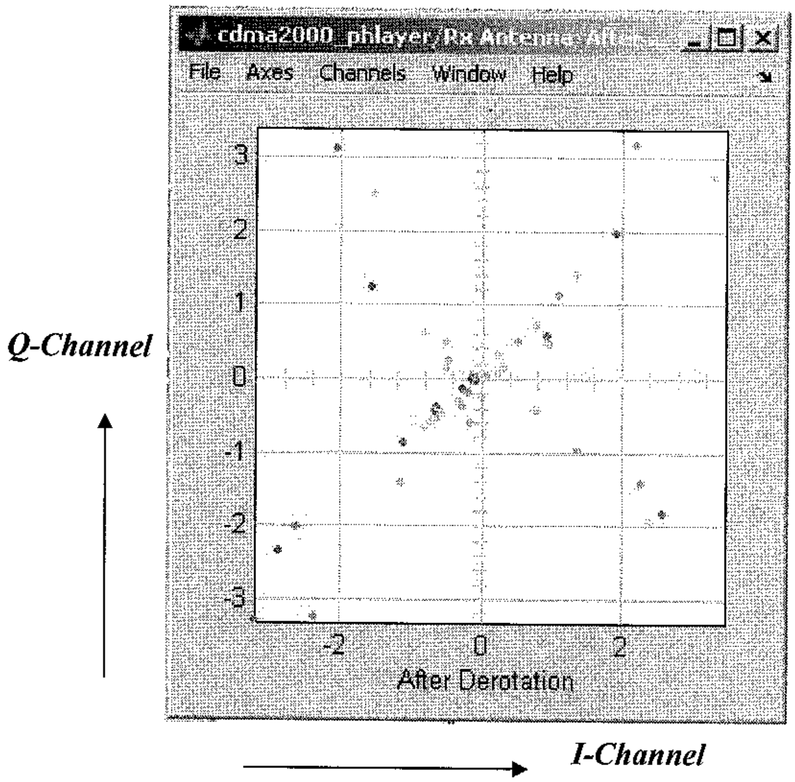


Figure 5-2 Scope from the After Derotation (Rake receiver)

The signals are being estimated at this point to determine the actual location of the signal. They will later coherently combine to make up for the original signal just like before being interfered by the channel model.

The output of the scope for the rake is shown in Figure 5-3.

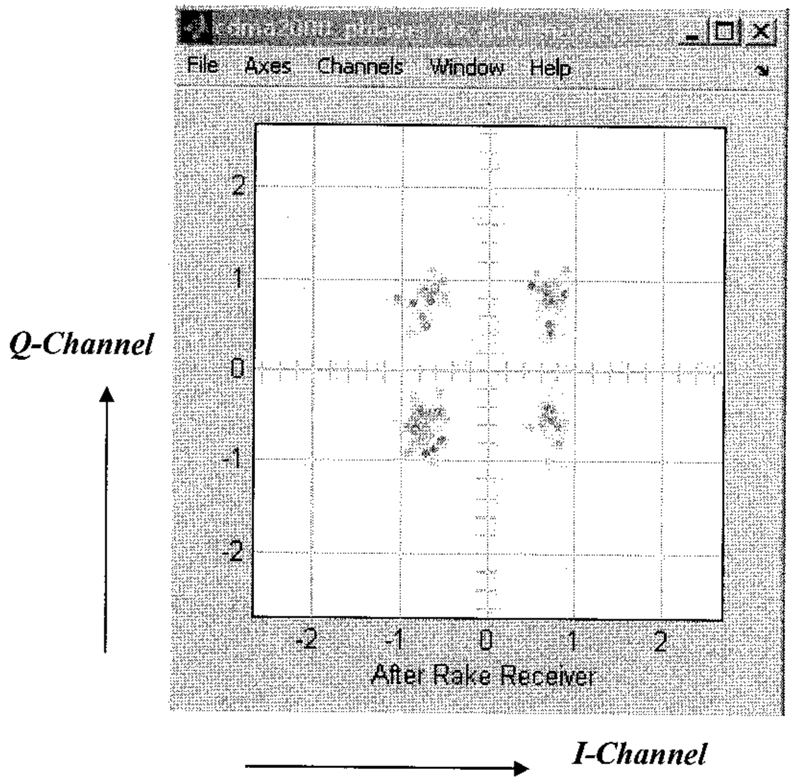


Figure 5-3 Scope from the After Rake Receiver (Rake receiver)

Basically, after Rake receiver, the signal is already coherently combined and the result is almost the same as the original signal from the transmitter. This goes to show the necessity of the Rake receiver in establishing the main function of the receiver in this CDMA 2000 downlink simulation.

5.2. AWGN CHANNEL

The main focus here will be the function of the Rake receiver which is the main block that is used for this receiver. The initial settings from the Channel Model were specified with the AWGN channel. This channel model gives lesser noise than the Multipath Fading channel which was investigated earlier.

From the system above, there are 3 scopes that were used to evaluate the result from each of the output coming from different sources. First, there is the scope from the channel model itself which will be compared to the other 2 scopes which will receive the signal. The output of the scope is shown in Figure 5-4.

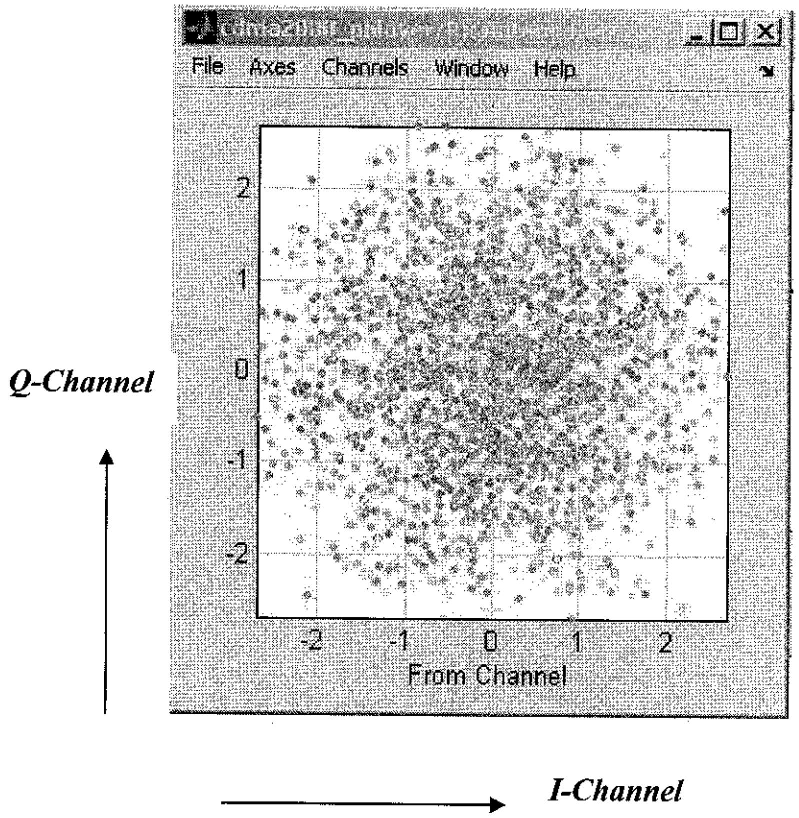
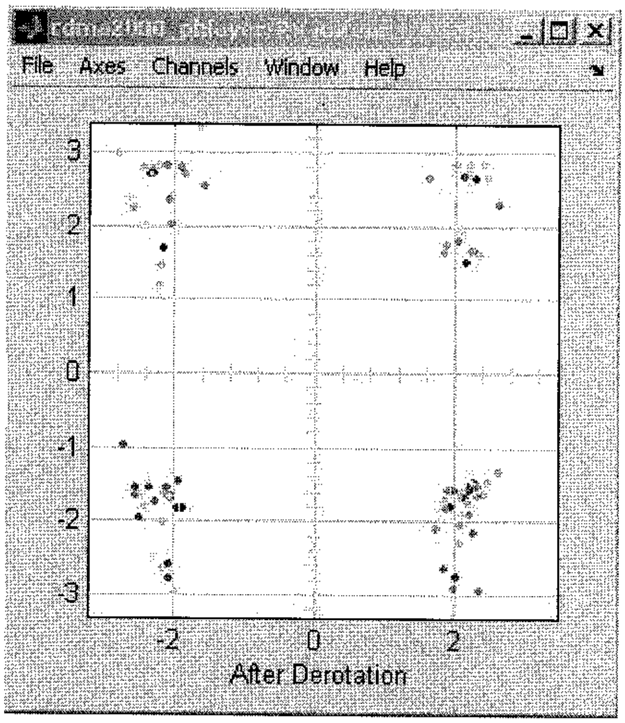


Figure 5-4 Scope from the Channel (AWGN channel)

The scope from the AWGN channel shows that the channel is well surrounded by extensive amount of noise which will degrade the quality of the signal and thus make it much harder to decode back to its original signal.

The output of the scope for the derotation is shown in Figure 5-5.

Q-Channel



I-Channel

Figure 5-5 Scope from the After Derotation (Rake receiver)

After derotation, the signal is estimated at this point to determine which location the signal actually positioned to. They will later coherently combine to make up for the original signal just like before being interfered by the channel model. The difference between the Multipath fading channel and the AWGN channel lies here after derotation. The scope shows the spreading modulation used which is the Offset Quadrature Phase-Shift Keying. It clearly shows that it is shifted 45 degrees out of phase in the signal constellation diagram.

The output of the scope for the rake is shown in Figure 5-6.

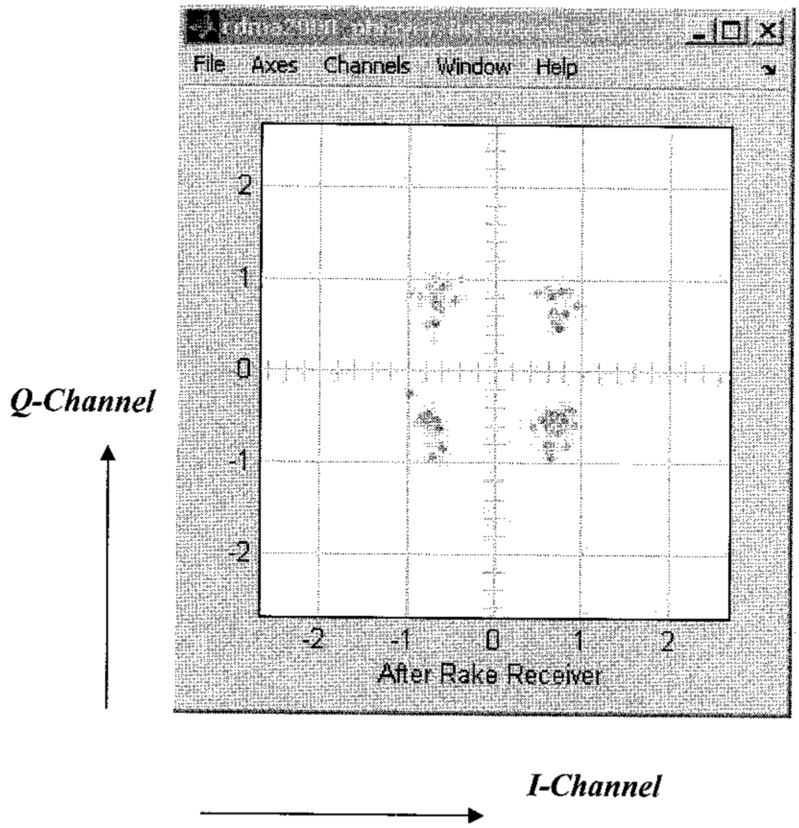


Figure 5-6 Scope from the After Rake Receiver (Rake receiver)

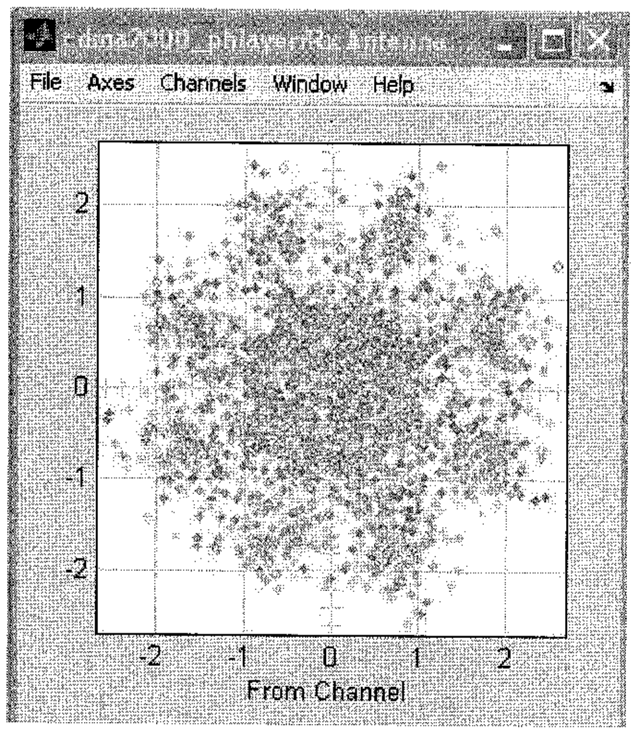
After passing through the Rake receiver, the signal is already coherently combined and the result is almost the same as the original signal from the transmitter. The Rake receiver uses multiple correlators to separately detect the strongest multipath components. It is then tries to synchronize the signals in the receiver to match that of the transmitted signal.

5.3. NO CHANNEL (NOISE FREE)

The initial settings from the Channel Model were specified with a non-interference channel. This channel model provides the system with an ideal condition for investigating the robustness and comprehensive functions of the block diagrams without having to be concerned about the effects of the channel.

From the system above, there are 3 scopes that were used to evaluate the result from each of the output coming from different sources. First, there is the scope from the channel model itself which will be compared to the other 2 scopes which will receive the signal. The output of the scope is shown in Figure 5-7.

Q-Channel



I-Channel

Figure 5-7 Scope from the Channel (No channel)

From this output, you can see that the signal from the channel is randomly received from the transmitter. But if you look more closely, the output showed a more visible pattern than the previous 2 conditions set at the initial conditions of the channel block diagram. This signal will in turn will make the decoding at the decoding block diagram much easier than the previous 2 channel models previously simulated.

The output of the scope for the derotation is shown in Figure 5-8.

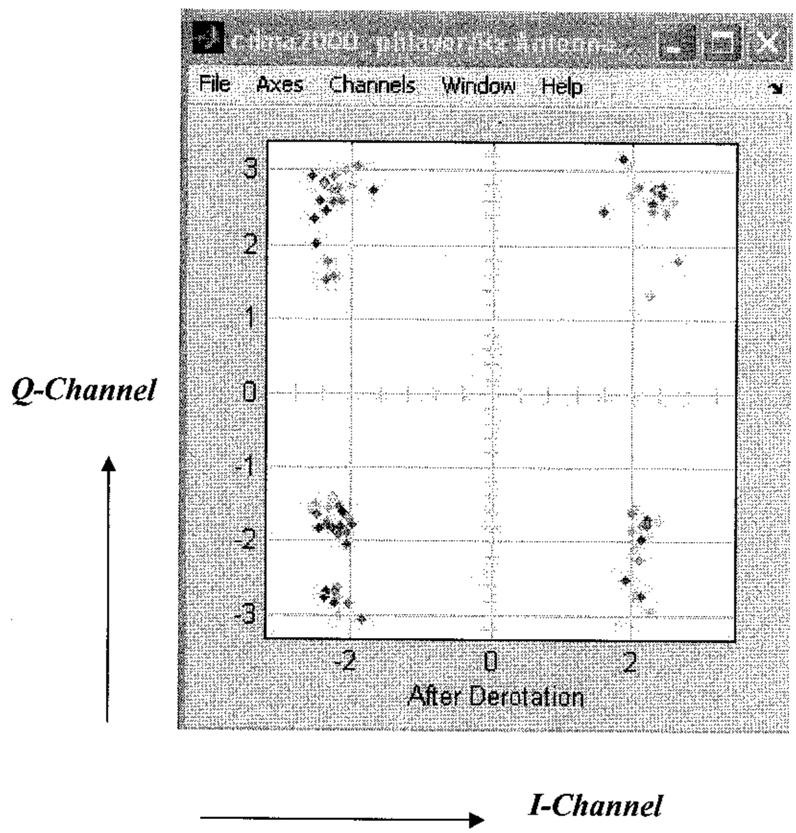


Figure 5-8 Scope from the After Derotation (Rake receiver)

The scope After Derotation shows that the signal is estimated at this point to determine which location the signal actually positioned to. They will later coherently combine to make up for the original signal just like before being interfered by the channel model. The output for this channel does not differ from the AWGN channel model after derotation since both models provide little significance in the noise level at the receiver. The scope shows the spreading modulation used which is the Offset Quadrature Phase-Shift Keying. It clearly shows that it is shifted 45 degrees out of phase in the signal constellation diagram.

The output of the scope for the rake is shown in Figure 5-9.

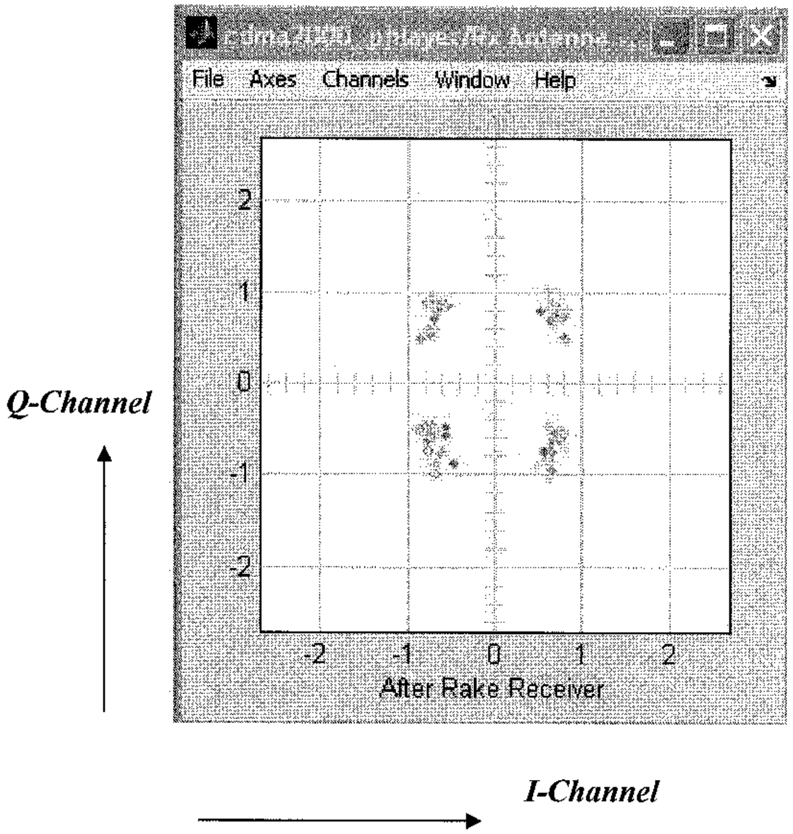


Figure 5-9 Scope from the After Rake Receiver (Rake receiver)

Lastly, after passing through the Rake receiver, the signal is already coherently combined and the result is almost the same as the original signal from the transmitter. The Rake receiver uses multiple correlators to separately detect the strongest multipath components. It is then tries to synchronize the signals in the receiver to match that of the transmitted signal.

From the 3 channels model simulated before, which were the Multipath Fading channel, AWGN channel, and the non-interference channel, there lie subtle differences between each channel models. The significance difference that can be shown throughout the 3 channel models were shown from the scope of the channel, where Multipath Fading channel can be seen to have the most amount of noise, AWGN channel have a moderate amount of noise and the non-interference channel neglects the noise altogether. For the After Derotation scope, only Multipath Fading channel seems to have a difficulty of decoding the signal back to its original state with a weak signal while the 2 models have provided the same output with a stronger signal. The end result for all the 3 channel models showed the same output signal as the original signal transmitted. It can be concluded that the system provides good signal detection even with the worst channel condition available.

5.4. BIT ERROR RATE (BER) RESULTS

The BER Results: Channel Bits block computes and shows the bit error rate between the transmitting base station and the mobile receiver.

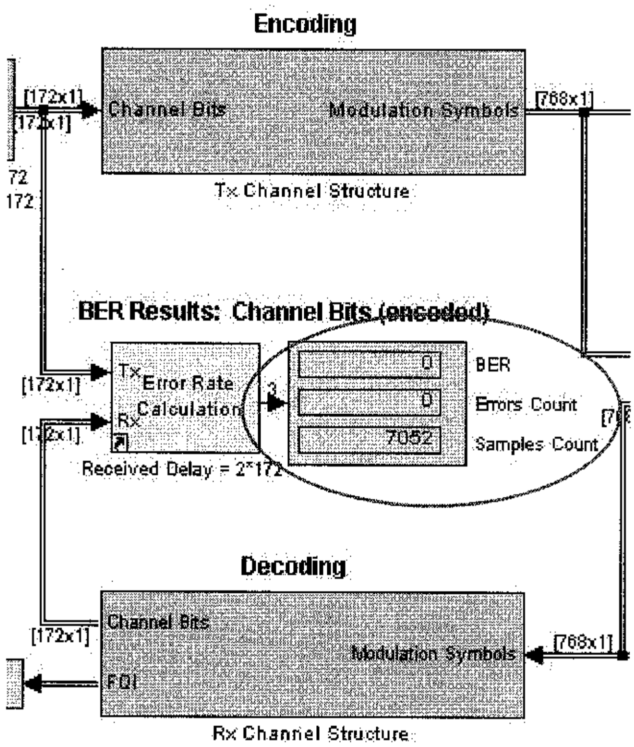


Figure 5-10 BER results for the encoded channel bits

Figure 5-11 Time taken to reach the sample count

From Figure 5-10 and Figure 5-11, after T=0.840, the BER is zero due to no error counts being made after encoding and decoding the samples with the sample count at 7052. The initial settings for this AWGN channel simulation was configured at 172 samples per frame with the sample time, $T = \frac{20e^{-3}}{172}$. The received delay for the error rate calculation is however twice the samples per frame. This parameter is the number of samples by which the received data lags behind the transmitted data. It also tells the block which samples correspond to each other and should be compared. The receive delay persists throughout the simulation.

The BER Results: Raw BER section computes and shows the bit error rate of the data between the transmitter input and the receiver output. This computation excludes the effects of interleaving and coding.

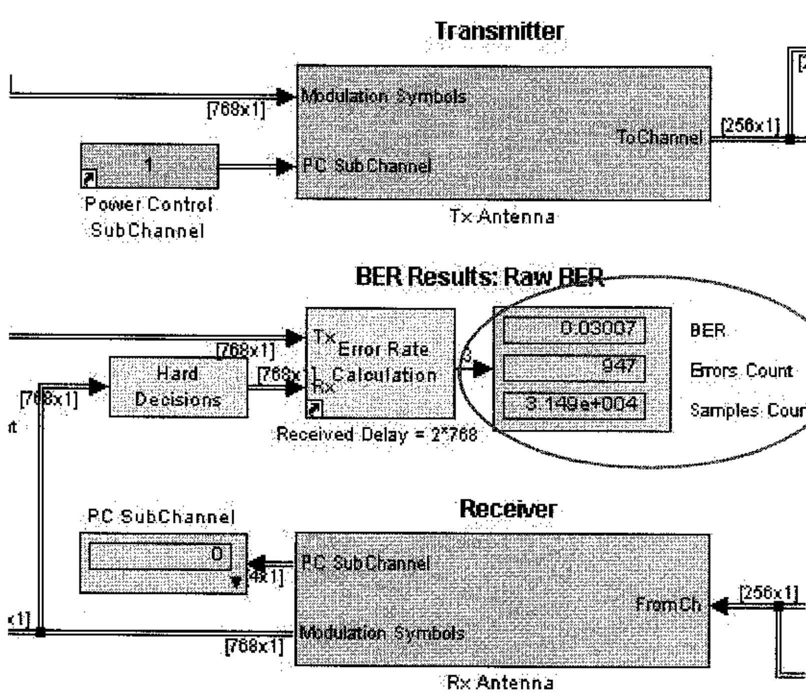


Figure 5-12 BER results for the raw channel bits

Comparing the Raw BER and the encoded Channel Bits, the results before encoding the signal shows an extensive amount of errors made by the channel, which in this case the AWGN channel gives 947 error counts with a BER of 0.03007 at T=0.840.

This goes to show that the encoding and decoding block diagram does a precision job of reducing the error rate to zero. In terms of performance in an AWGN channel, the end result is surprisingly good for the system to manage. The system shows a relatively good performance in both the Multipath Fading channel and the AWGN channel in both cases as the end result of the bit error rate after many samples shows no error which makes this system stable.

5.5. FAST FOURIER TRANSFORM SCOPES

The Fast Fourier Transform (FFT) scope output before transmission and after reception for all 3 channel models were investigated and discussed. The main focus here will be effects of the channel models by differentiating them using the scopes. The initial settings from the Channel Model were specified with the 3 channels models, namely the Multipath Fading channel, the AWGN channel, and the non-interference channel. The scope will show the amount of distortion made by the 3 channels and compared them before being transmitted.

The After Pulse Shaping scope shows the original FFT signal being transmitted by the system before going through the channel. This will be the base comparison with the From Channel scope which will show the effects of the channel after being passed through it.

The output of the After Pulse Shaping scope was shown in Figure 5-13.

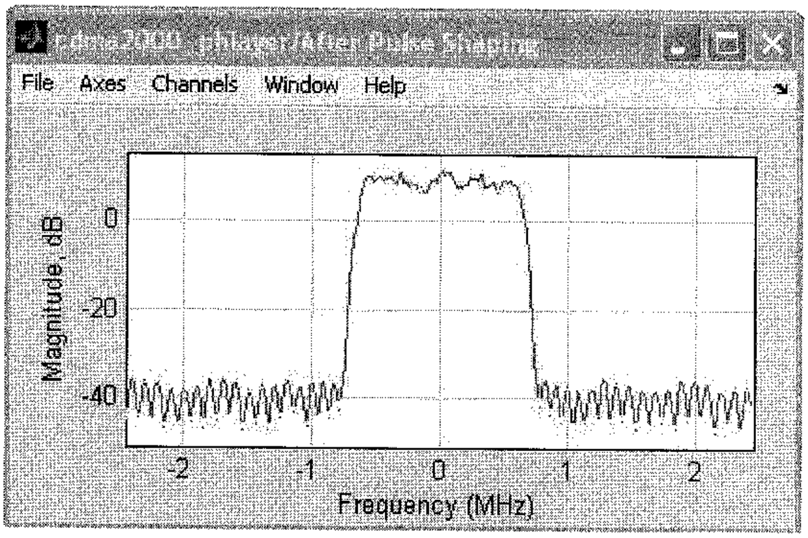


Figure 5-13 Scope output before transmission (After Pulse Shaping)

5.5.1. Multipath Fading channel

The output of the scope from the channel was shown in Figure 5-14.

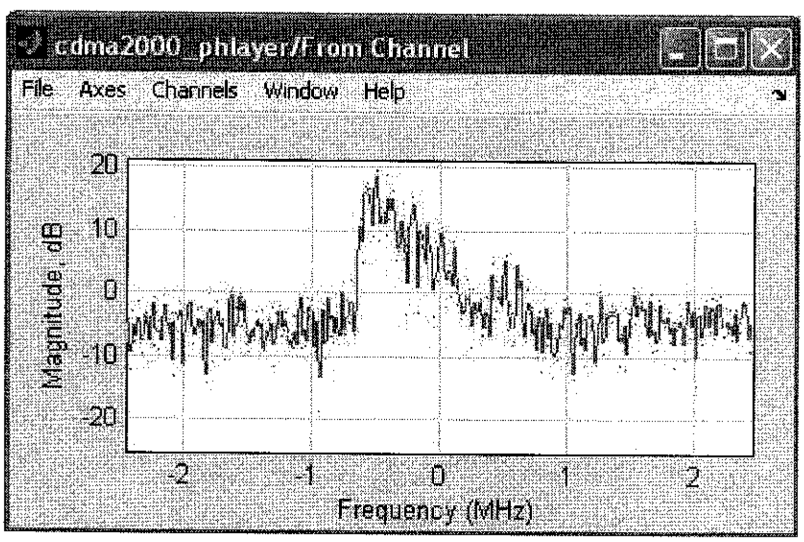


Figure 5-14 Scope output from the channel (From Channel)

From this output, you can see that the signal from the channel is tremendously distorted with the noise produced by this channel. This signal will in turn will make the reception and decoding at the receiver and decoding block diagram much harder than the 2 channel models previously mentioned.

5.5.2. AWGN channel

The output of the scope from the channel was shown in Figure 5-15.

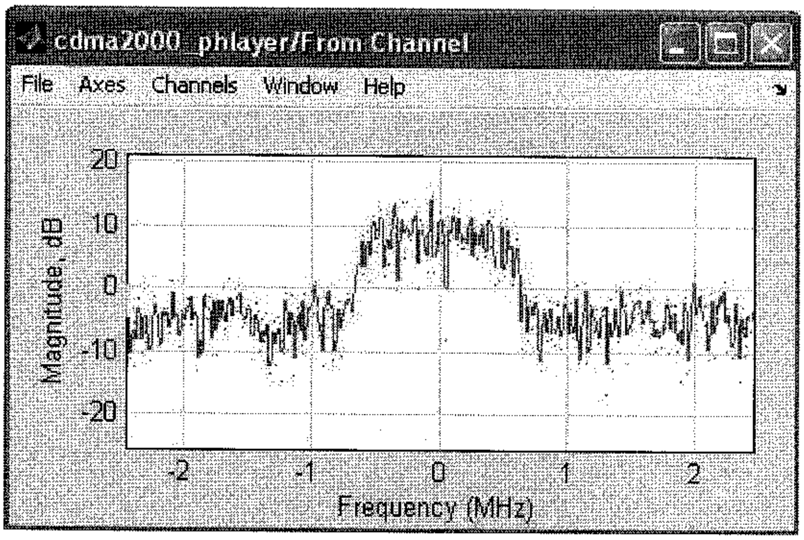


Figure 5-15 Scope output from the channel (From Channel)

From this output, you can see that the signal from the channel is heavily distorted with the noise produced by this channel, yet not as much as the Multipath Fading channel shown earlier. This signal will in turn will make the reception and decoding at the receiver and decoding block diagram much easier than the Multipath Fading channel previously simulated.

5.5.3. No channel

The output of the scope from the channel is shown in Figure 5-16

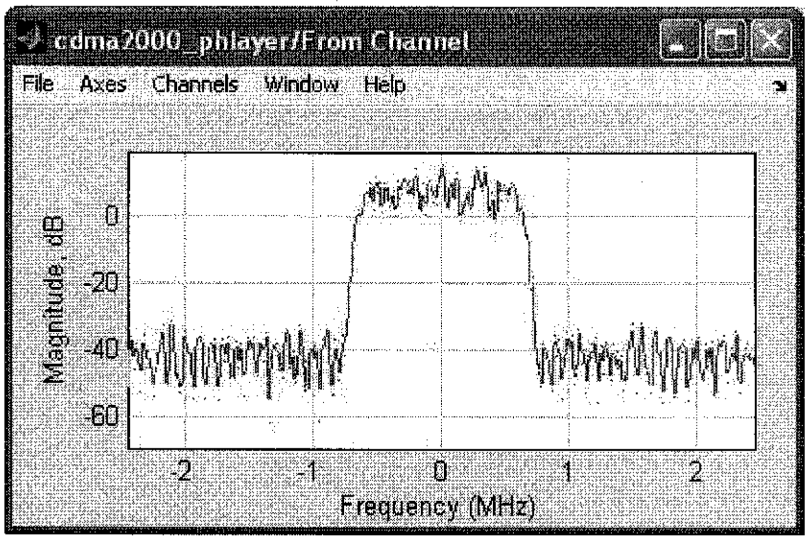


Figure 5-16 Scope output from the channel (From Channel)

From this output, you can see that the signal from the channel does have distortion with noise but produced by the system itself. Otherwise, the signal is excellent on it own. This signal will in turn will make the reception and decoding at the receiver and decoding block diagram so much easier than the 2 channel models previously simulated.

From the 3 channels model simulated before, which were the Multipath Fading channel, AWGN channel, and the non-interference channel, there lie subtle differences between each channel models. The significance difference that can be shown throughout the 3 channel models were shown from the scope of the channel, where Multipath Fading channel can be seen to have the most amount of noise, AWGN channel have a moderate amount of noise and the non-interference channel has only noise produced by system itself. The end result for all the 3 channel models showed the same output signal as the original signal transmitted. It can be concluded that the system provides good signal detection even with the worst channel condition available.

5.6. FRAME QUALITY INDICATOR AND PC SUBCHANNEL

The Power Control (PC) SubChannel and the Frame Quality Indicator block diagram was also investigated and discussed. The main objective of power control is to limit transmitted power on the forward link while maintaining link quality under all conditions. CDMA itself is an interference-limited system, since all mobile transmits at the same frequency, internal interference generated within the system plays a critical role in determining system capacity and voice quality. The transmit power from each mobile must be controlled to limit interference. However, the power level must be adequate for satisfactory voice quality. As the mobile moves around, the RF environment changes continuously due to fast and slow fading, shadowing, external interference, and other factors.

Power control is also needed in CDMA systems to resolve near-far problem. To minimize the near-far problem, the goal in a CDMA system is to assure that all mobiles achieve the same received power levels at the base station. The target value for the received power level must be the minimum level possible that allows the link to meet user-defined performance objectives. In order to implement such a strategy, the mobiles closer to the base station must transmit less power than those far away.

The inside structure of the Long Code Scrambling, Power Control and Signal Point Mapping subsystem located inside the Transmitter block diagram where the power control insertion is put to use, is shown in Figure 5-17.

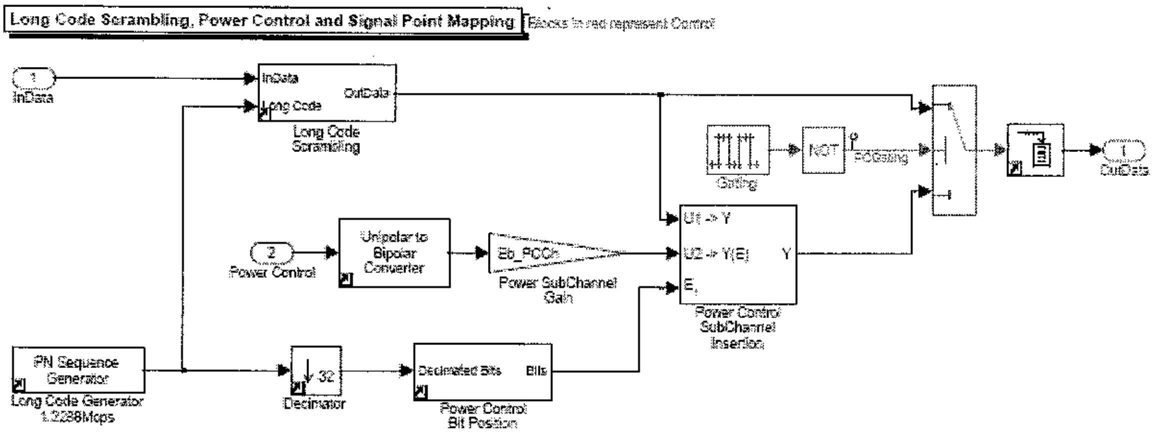


Figure 5-17 Inside structure of the Long Code Scrambling, Power Control and Signal Point Mapping subsystem

While power control relates to signal quality and measured in signal-to-noise (SNR) ratio, frame quality indicator relates to voice quality and measured in frame-error rate (FER). The FER also depends on vehicle speed, local propagation conditions, and distribution of other co-channel mobiles. The forward link power control attempts to set each traffic channel transmit power to the minimum require to maintain the desired FER at the mobile. The mobile continuously measures forward traffic channel FER. It reports this measurement to the base station on a periodic basis. After receiving the measurement report, the base station takes the appropriate action to increase or decrease power on the measured logical channel. The base station also restricts the power dynamic range so that the transmitter power never exceeds a maximum value that would cause excessive interference or so that it never falls below the minimum value required for adequate voice quality.

The insertion of the frame quality indicator lies in the Encoding block diagram, using the General CRC Generator S-function. The General CRC Generator itself is an error correction and detection method where the main purpose is to generate cyclic redundancy code (CRC) bits according to the generator polynomial and append them to the input data frames. In this case, the polynomial is represented as an integer row vector containing the powers of nonzero terms in the polynomial, in descending order, which the vector [12 11 10 9 8 4 1 0] represents the polynomial $x^{12}+x^{11}+x^{10}+x^{9}+x^{8}+x^{4}+x+1$.

The frame quality indicator insertion is shown in Figure 5-18.

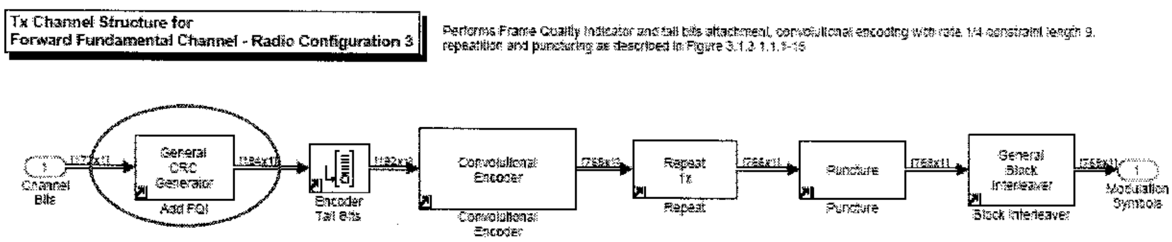


Figure 5-18 Frame quality indicator insertion

CHAPTER 6: CONCLUSION

The overall block diagram or rose model for the communication downlink between the Base Station and the Mobile Station using Matlab for the CDMA 2000 1XRTT Physical Layer Radio Configuration 3 Forward Fundamental Channel has been analyzed. The settings for the Transmitter block diagram were configured and tested. The output from the scope and the receiver block diagrams were able to be shown and investigated by using the 3 channel models, namely the Multipath fading channel, the AWGN channel, and the non-interference channel. The worst bit error rate result was the Multipath fading channel, followed by the AWGN channel, and last the non-interference channel. The resulting output can be seen at the Receiver block diagram which shows the plot for the Rake receiver from the channel which can be compared and analyzed. The plot after derotation from the receiver's antenna was also shown. The bit error rate (BER) results before and after decoding were shown and analyzed to give a better description of the performance of the receiver and decoder under these conditions. The frame quality indicator and also the Fast Fourier Transform (FFT) scope output for the transmission and reception of the system were tested out and shown. The overall result of the simulation were documented and evaluated.

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APPENDIX A: GANTT CHART

Suggested Milestone for the First Semester of 2 Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	▒													
	-Propose Topic														
	-Topic assigned to students														
2	Preliminary Research Work		▒	▒											
	-Introduction														
	-Objective														
	-List of references/literature														
	-Project planning														
3	Submission of Preliminary Report			●											
4	Project Work				▒	▒	▒	▒							
	-Reference/Literature														
	-Practical/Laboratory Work														
5	Submission of Progress Report								●						
6	Project work continue								▒	▒	▒	▒			
	-Practical/Laboratory Work														
7	Submission of Interim Report Final Draft												●		
8	Oral Presentation													●	
9	Submission of Interim Report														●

Suggested milestone ●

Process ▒

Suggested Milestone for the Second Semester of 2 Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue		▒	▒											
	-Practical/Laboratory Work														
2	Submission of Progress Report 1			●											
3	Project Work Continue				▒	▒	▒	▒							
	-Practical/Laboratory Work														
4	Submission of Progress Report 2								●						
5	Project work continue								▒	▒	▒	▒			
	-Practical/Laboratory Work														
6	Submission of Dissertation Final Draft												●		
7	Oral Presentation													●	
8	Submission of Project Dissertation														●

Suggested milestone ●

Process ▒

APPENDIX B: WEEKLY ACTIVITIES

DATE		BRIEF DESCRIPTION OF DAILY ACTIVITIES
FROM	TO	
8 August 2005	14 August 2005	1. Meeting with Supervisor regarding the general overview of the project and also discuss about the criteria's set for the project 2. Research from the internet and books about CDMA 2000 technology and its applications 3. Do a literature review based on the facts and concepts read from the resources available 4. Understand and try to visualize the overall perspective of the project 5. Skim through the MATLAB codes and try to link them with the theories and concepts
15 August 2005	21 August 2005	6. Prepare for preliminary report based on the title project. 7. Submit preliminary report to technician for date approval. 8. Learn about the theories and concept of direct spread spectrum 9. Try to relate the use of this technique to the actual implementation of the project

22 August 2005	28 August 2005	10. Discuss with Ms. Norashikin concerning the progress of the previous and forthcoming logbook 11. Submit logbook report to technician for date approval. 12. Investigate and relate the evolution of standards used in CDMA 2000 13. Find out the key components of the system and focus towards its implementation
29 August 2005	4 September 2005	14. Discuss with Ms. Norashikin concerning the progress of the previous and forthcoming logbook 15. Submit logbook report to technician for date approval. 16. Read about the different channel models used and focus on the details of the specific model for the project. 17. Find out the key components of the system and focus towards its implementation
5 September 2005	19 September 2005	18. Discuss with Ms. Norashikin concerning the progress of the previous and forthcoming logbook 19. Submit logbook report to technician for date approval. 20. Focus on the transmitter of the block diagram in Matlab and investigate and analyse its function and performance. 21. Find out the key components of the system and focus towards its implementation

20 September 2005	26 September 2005	22. Discuss with Ms. Norashikin concerning the progress of the previous and forthcoming logbook 23. Submit logbook report to technician for date approval. 24. Focus on the receiver of the block diagram in Matlab and investigate and analyse its function and performance. 25. Find out the key components of the system and focus towards its implementation
26 September 2005	3 October 2005	26. Discuss with Ms. Norashikin concerning the progress of the previous and forthcoming logbook 27. Submit logbook report to technician for date approval. 28. Focus on the encoding of the block diagram in Matlab and investigate and analyse its function and performance. 29. Find out the key components of the system and focus towards its implementation
4 October 2005	10 October 2005	30. Discuss with Ms. Norashikin concerning the progress of the previous and forthcoming logbook 31. Submit logbook report to technician for date approval. 32. Focus on the decoding of the block diagram in Matlab and investigate and analyse its function and performance. 33. Find out the key components of the system and focus towards its implementation

31 January 2006	6 February 2006	34. Submit logbook report to technician for date approval. 35. Focus on the transmitter block diagram and investigate and analyse its function and performance. 36. Find out the key components of the system and focus towards its implementation
7 February 2006	13 February 2006	37. Submit logbook report to technician for date approval. 38. Focus on the receiver block diagram and investigate and analyse its function and performance. 39. Find out the key components of the system and focus towards its implementation
14 February 2006	20 February 2006	40. Submit logbook report to technician for date approval. 41. Focus on the encoding and decoding block diagram and investigate and analyse its function and performance. 42. Find out the key components of the system and focus towards its implementation

21 February 2006	27 February 2006	43. Submit logbook report to technician for date approval. 44. Focus on the receiver block diagram and investigate and analyse its function and performance in an AWGN channel. 45. Find out the key components of the system and focus towards its implementation
28 February 2006	6 March 2006	46. Submit logbook report to technician for date approval. 47. Focus on the encoding and decoding block diagram and investigate and analyse its function and performance. 48. Find out the key components of the system and focus towards its implementation
14 March 2006	20 March 2006	49. Submit logbook report to technician for date approval. 50. Focus on the receiver block diagram and investigate and analyse its function and performance in a non-interference channel. 51. Find out the key components of the system and focus towards its implementation

21 March 2006	27 March 2006	52. Submit logbook report to technician for date approval. 53. Focus on the Fast Fourier Transform (FFT) scope output before transmission and after reception for all 3 channel models. 54. Find out the key components of the system and focus towards its implementation
28 March 2006	3 April 2006	55. Submit logbook report to technician for date approval. 56. Focus on the function of the frame quality indicator and pc subchannel used in CDMA 2000. 57. Find out the key components of the system and focus towards its implementation