Simulation and Analysis Performance of 4-QAM and 8-PSK in WCDMA by Using Reed Solomon Codes in WCDMA Environment

Siti Suliza Binti Shuib
Faculty of Electrical Engineering
University Teknologi Mara Malaysia (UiTM)
Shah Alam, 40450 Selangor
Malaysia
sulizashuib@gmail.com

Abstract— **This project illustrates the simulation and performance of 4-QAM and 8-PSK in WCDMA. This model consists of transmission channel, transmitter and receiver. This simulation is dealing with two channels. Channel one is using 4-QAM and channel two is using 8-PSK. Reed Solomon codes is use to encode and decode the signal of the two channels before modulation and after demodulation process. The main objective of this project is to compare and identify which channel is better by analyzing the performance of both channels in term of bit error rate (BER). This project is simulated by using Matlab Version 7.6.**

Keywords – Additive White Gaussian Noise (AWGN), Rayleigh fading, Wideband Code Division Multiple Access (WCDMA), 4 Quadrature Amplitude Modulation (4-QAM), 8 Phase Shift Keying (8-PSK).

I. INTRODUCTION

A. *Digital Communication System*

Digital communication is widely used nowadays. Digital communication is the system where high frequency analog carriers are modulated by a low frequency of digital information signal. Digital communication systems consist of transmitting station (source), channel as a connecting medium and receiving station (destination) [1]. Compared to analog, digital communication system is more robust. Digital system is immune to noise. It is less susceptible to interference compared to analog and has better suited for processing and combination of signal in term of multiplexing technique. Besides, it is more resistance due to signal regeneration [2]. Digital communication system has higher data rate transmission, more power and better quality and coverage.

B. *Modulation Technique*

Modulation is the process of impressing low frequency information onto a high-frequency carrier signal. It is also known as the process by which some characteristics of a carrier are varied in accordance with a modulating wave to convey a message [3]. There are several types of digital modulation techniques which are Phase-Shift Keying (PSK), Frequency-Shift Keying (FSK), Amplitude-Shift Keying (ASK) and Quadrature Amplitude Modulation (QAM). For this project, 8-PSK and 4-QAM is used to modulate a signal.

C. *Wideband Code Division Multiple Access (WCDMA)*

Early on this century, Code Division Multiple Access (CDMA) is widely used in digital communication system. At that time, CDMA is the most excellent multiple access. As the time goes by, WCDMA is implemented. WCDMA is an enhancement of CDMA which will produce much more benefits. It is a direct spread technology to satisfy ever-increasing demands for higher data rates [4]. It will spread its transmissions over a wide, 5MHz carrier. Using WCDMA, user's information bits are spread over wider bandwidth compared to CDMA [5]. In reality, WCDMA networks are true multiservice network whose capabilities are unmatched by any other technology. It will permit very high-speed multimedia services such as full-motion video, Internet access and video- conferencing [6]. The project is going to be done to determine whether 4-QAM or 8-PSK modulation type can perform well in WCDMA. WCDMA is used as a multiple access for both modulation types.

D. *Reed Solomon Codes*

Reed-Solomon codes are non-binary cyclic codes with symbols made up of m-bit sequences, where m is any positive integer having a value greater than 2 [7]. It is conceptually simple and can work with any n and m. Where m is storage devices holding checksums and n is storage device holding data. The checksums are computed from the data [8]. Here are the parameters for Reed Solomon Codes: m is the number of bit/symbol, n is the number of symbol/codeword, k is the number of symbol/message and t is the error-correction capability of the code. In this project, all the parameters are assigned with a considered value. Where m=3, n=7, k=3.

E. Matlab Simulation

Matlab is a high-performance language for technical computing. It is a software package of simulation, analyzing and modeled in continuous time, sampled time or hybrid [9]. Using Matlab, a comprehensive communication model via WCDMA with Reed Solomon Codes and Rician channel can be built up to evaluate the performance of 4-QAM and 8-PSK by comparing the Bit Error Rate (BER) for both channels.

F. Rayleigh Fading and AdditiveWhite Gaussian Noise (AWGN)

AWGN is a thermal noise where Rayleigh fading describes the condition where the transmitted base station (BS) signal is reflected by obstacles that create multiple signal paths between user and BS [10]. In this project, both AWGN and Rayleigh fading are combined to be the additive noise at air interface.

II. Scope of Work

This project focused on the study of identifying the performance and development of 4-QAM and 8-PSK in WCDMA environment. Before the implementation this project, several important works must be completed to make sure it is functioning. Theory of communication must be well acknowledged by doing some literature review on digital communication especially for 8-PSK and 4-QAM modulation technique using Reed Solomon codes. The success of this project can be determined by comparing the theoretical and simulated results. Adding to this, it is important to be knowledgeable in Matlab programming. The main objective of this project is to make observation and analyzing the performance of 4-QAM and 8-PSK in WCDMA by using Reed Solomon codes in AWGN and Rayleigh fading channel. By comparing these two channels, a better modulation and evaluation of performance in term of Bit Error Rate (BER) through simulation in Matlab can be determined.

III. Methodoogy

A. Block Diagram and Flow Chart

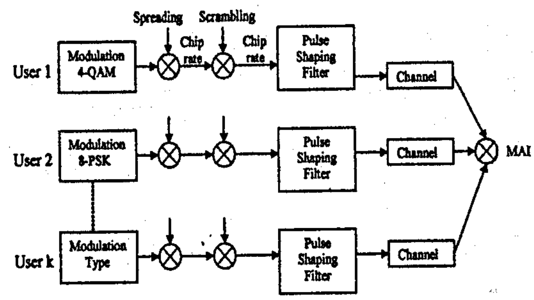

Figure 1: Transmitter of WCDMA Channel Model

In this project, WCDMA model is constructed for simulation using Matlab 7.6. Transmitter of WCDMA channel with k users is shown in Figure 1. User 1 (Channel 1) is for 4-QAM modulation technique and User 2 (Channel 2) is for 8-PSK modulation techniques. In WCDMA, more messages can be transmitted at the same time. Each message is differ by each scrambling code. Both channels will generate spread spectrum by multiplying each modulated signals with scrambling code to provide randomization so that interference would be uniform before it is going to be transmitted. In this project, Pseudorandom codes (PN) is used as scrambling code [11]. Then, signals will be composed at the summing point (MAI) and ready to be transmitted. At the receiver side, the process is vice versa. Hence, the results of the process will be analyzed.

	Channel	Input message (k)	Codeword (n)
4-QAM	1	3	7
8-PSK	2	3	7

Table 1: Parameters for Reed Solomon coding system in 4-QAM and 8-PSK modulation scheme

Table 1 shows the parameters used for Reed Solomon coding system.

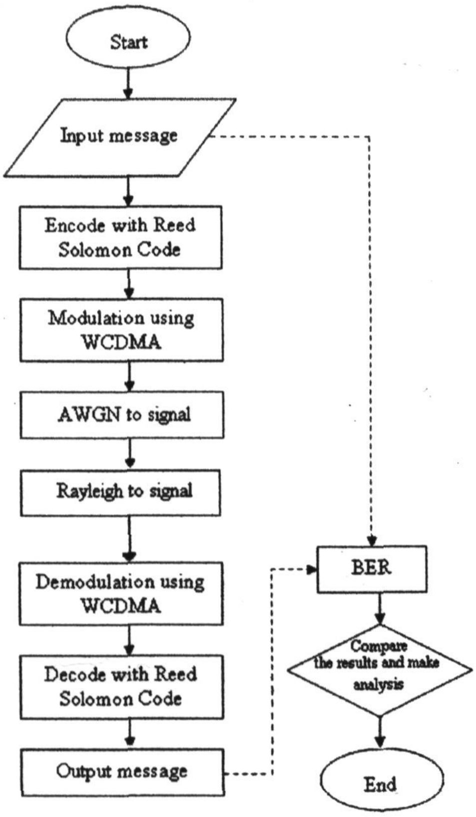

Figure 2: Program flow chart for simulation

Figure 2 shows the program flow for simulation. Simulation is started by generating input random signal for channel 1 and 2 with input message k=3 and codeword n=7. The input signal is set to be random for the reason to generate more messages to compare the performance between both modulation techniques. Reed Solomon code is used to perform encoding and decoding process. Input message length will change from 3 bits to 7 bits after encoded. Then, both signals will be modulated in WCDMA. WCDMA will take part to convert digital signal to analog signal before transmitting. At the air interface, signals will be added with AWGN and Rayleigh fading. At receiver end, demodulation process will convert back the analog signal to digital signal by interpreting it into codeword. Forward error correction (FEC) will be conducted to check the codeword. The corrected codeword will be decoded to get the output. Hence, to get BER, output message will be compared to the original message.

IV. Result and Analysis

A. *Simulation Results*

Results from simulation were attached in APPENDIX (Figure 3 – Figure 19).

B. *Analysis of Results*

After completing the simulation, the plotted graph can be observed in appendix. Figure 5 and 6 shows that the three bits input signal in Figure 3 and 4 were encoded to a corresponding codeword with vector length of 7 respectively. Referring to Figure 9 and 10, it shows that spread spectrum can transmit a lot of signals at the same time. To realize the simulation as in real world, additive noise (AWGN) and Rayleigh fading were added during simulation where the effect can be seen in Figure 12 and 13. By comparing Figure 11 and 12, it can be observed that while AWGN is added in the simulation (Figure 12), the amplitude of the plotted signal is slightly higher compared to signal without additive noise (Figure 11). While injecting Rayleigh fading (Figure 13), the plotted graph shows that there was a significant decrease in amplitude of signal. It clearly shows the effect of Rayleigh fading. At receiver side, assumption of additive noise and fading is removed had been made. At the end of simulation, the original signals (Figure 18 and 19) were observed.

C. *Performance Result*

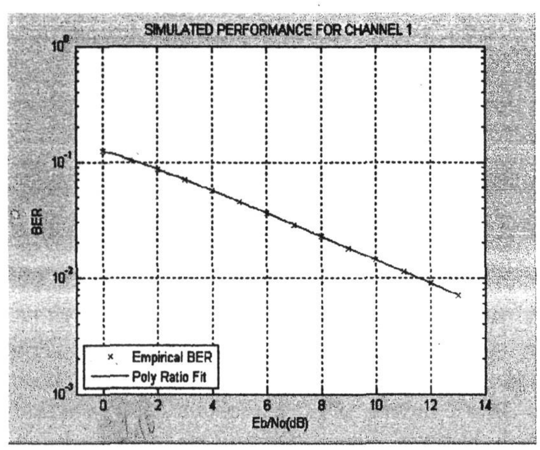

Figure 20: Simulated performance for channel 1

Figure above shows that the simulated performance of 4-QAM in channel 1. BER for 4-QAM in this simulation is much bigger compared to theoretical BER in Figure 22.

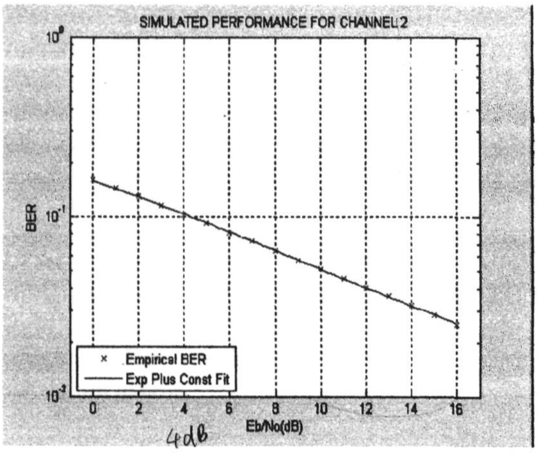

Figure 21: Simulated performance for channel 2

Figure 21 shows the simulated performance of 8-PSK in channel 2. There is slightly different when comparing with theoretical BER in Figure 22.

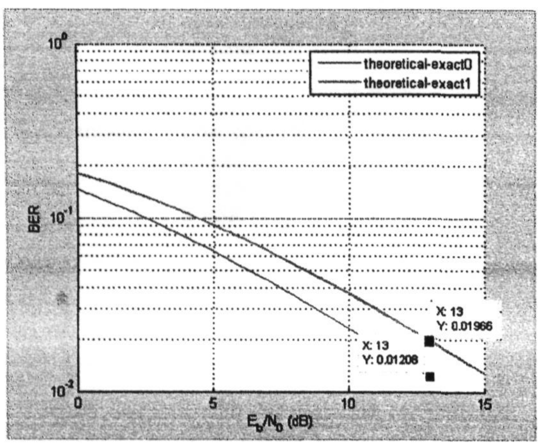

Figure 22: Theoretical BER plot of Rayleigh fading channel for 4-QAM (blue) and 8-PSK (green)

Performance between 4-QAM and 8-PSK can be observed by analyzing plotted BER in Figure 20 and Figure 21. Referring at BER equal to 10^{-1} in both Figure 20 and 21, 4-QAM shows 1dB for the value of Eb/No while 8-PSK shows 4dB. Thus, the performance of 8-PSK is 3dB better compared to 4-QAM. Then, refer to other BER value of 10^{-2}, 4-QAM shows 12dB for Eb/No while 8-PSK shows that the value is bigger than 16dB. Hence show that 8-PSK has better performance than 4-QAM.

D. *Tabulated Result*

Modulation Technique	4-QAM			8-PSK		
Eb/No (dB)	5	10	13	5	10	13
Theoretical BER	0.06301	0.02243	0.01208	0.09160	0.03818	0.01966
Simulation BER	0.09451	0.01521	0.00890	0.09153	0.05260	0.04050

Table 2: Comparison of BER for both channel with theoretical value

Table 2 shows the tabulated result for BER in simulation and in theory for both 4-QAM and 8-PSK modulation technique.

V. DISCUSSION

From the observation and analysis of this project, 8-PSK gives better performance than 4-QAM. 4-QAM is also referred as QPSK or 4-PSK transmits two bits on each carrier rather than 8-PSK which transmit three bits on each carrier [12]. Using 8-PSK, more output phases are possible and it can undergo almost ±22.5° phase shift during transmission and can still retain its integrity.

VI. CONCLUSION

The objective of this project is achieved. The performance for both modulation schemes had been analyzed. Using Matlab all the simulation process was conducted effectively. From the simulation and performance result, it shows that 8-PSK is more robust compared to 4-QAM or QPSK. Both QPSK and 8-PSK are widely used in wireless communication system. For example in satellite broadcast application. In PSK, the carrier amplitude is not modulated with information signal, hence the amplitude distortion in satellite channel is not a problem for both scheme.

However, 8-PSK give better performance since the spectral efficiency for QPSK is low [13]. The purpose of spread spectrum in WCDMA is to overcome issue regarding noise and interference in the channel. It is used as a multiple access for both 4-QAM and 8-PSK. Using WCDMA, more data can be transmitted at the same time since the bandwidth offered is larger (5MHz) compared to CDMA which offer 1.25MHz. In modern communication, WCDMA is very affective to fulfill the needs of higher data transfer rate. It offers 7.2Mbps for downlink access and 3.5Mbps for uplink access.

	QPSK	8-PSK
Advantage	QPSK has high bandwidth efficiency in wireless communications systems [15].	More bits can be transmitted on each carrier [12].
Disadvantage	Low spectral efficiency compared to 8-PSK [13].	8-PSK has higher incidence of symbol errors compared to QPSK for the same SNR [14].

Table 3: Advantage and disadvantage of QPSK and 8-PSK

Table 3 shows the advantage and disadvantages of QPSK and 8-PSK.

VII. Future Work

This project is applied the fundamental concepts of digital communication system. This project can be further explored as follow:

1) Used higher M-ary QAM since it is more robust compared to 8-PSK. For example, 8-QAM has higher peak-to-peak power ratio than 8-PSK and it is more immune to the effect of phase noise.
2) Advance the project using Orthogonal Frequency-Division Multiplexing (OFDM) since it has the ability to cope with channel conditions without complex equalization filters. For example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath.

References

[1] Michale B. Pursley, *Introduction to Digital Communication,* Pearson Prentice Hall, 2005.

[2] G. Maral and M. Bousquet, *Satellite Communication System (System),*4th Edition, John Willey & Sons, 2002.

[3] Wayne Tomasi, *Electronic Communications Systems, 5th Edition,* Pearson Prentice Hall, 2004.

[4] Laurence B. Milstein, *Fellow, IEEE, Wideband Code Division Multiple Access.*

[5] Malcolm W. Oliphant, *Radio Interfaces Make the Difference in 3G Cellular Systems.*

[6] Andrei Dulski, Hans Beijner and Hans Herbertsson, *Rural WCDMA –Aiming For Nationwide Coverage With One Network, One Technology, and One Service Offering.*

[7] Bernard Sklar, *Reed-Solomon Codes.*

[8] Ohad Rodeh, *Reed-Solomon Error Correcting Codes.*

[9] William J Palm III, *Basic Engineering Series and Tools, Introduction to Matlab 7 for Engineer.*

[10] Paul Bedell, *Wireless Crash Course, Technology and Engineering,* -2005

[11] QUALCOMM Incorporated October 2006.

[12] Philip A. Chou and Minaela Van der Schaar, *Multimedia Over IP and Wireless Network.*

[13] Tadashi Shiomi and Misutoshi, *Wave Summit Course Digital Broadcasting.*

[14] Ron Howell, *Make a seamless transition to high performance.*

[15] Cecil Deisch, *Low-Power Approach Provides QPSK Modulation* – May 2006

APPENDIX

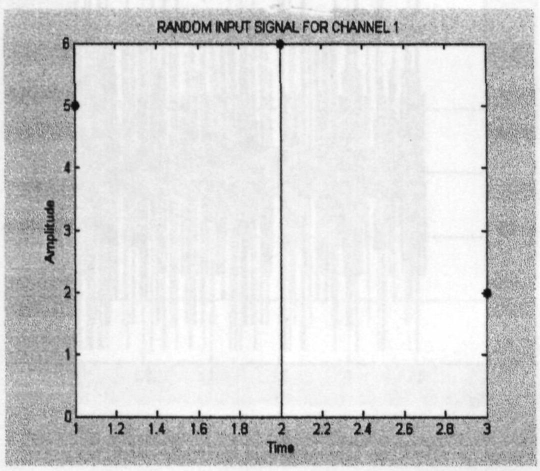

Figure 3: Input signal for channel 1

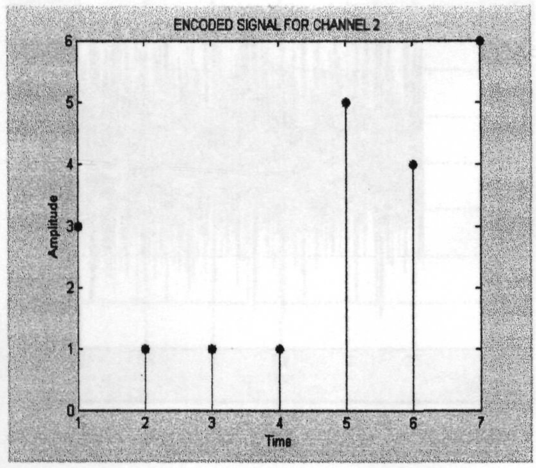

Figure 6: Encoded signal for channel 2

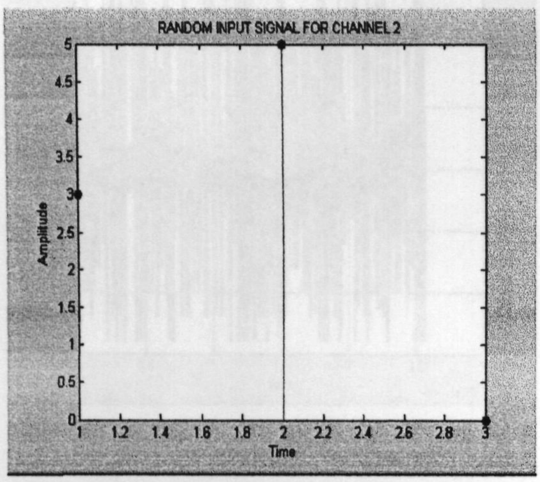

Figure 4: Input signal for channel 2

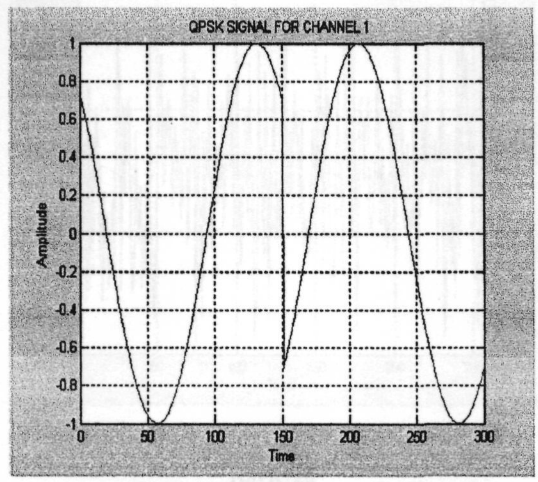

Figure 7: QPSK signal for channel 1

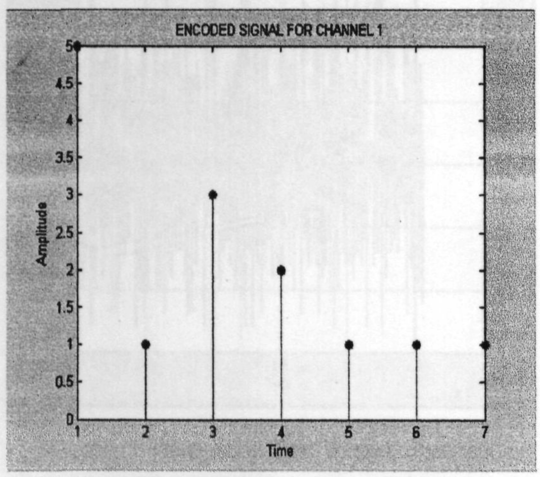

Figure 5: Encoded signal for channel 1

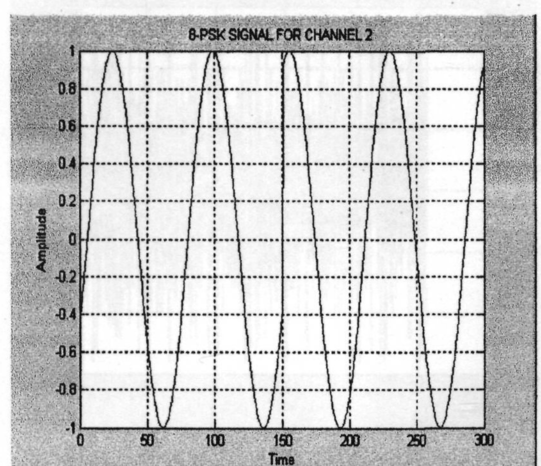

Figure 8: 8-PSK signal for channel 2

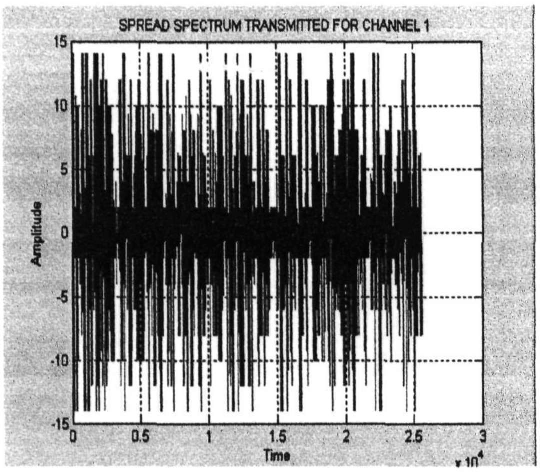

Figure 9: Spread spectrum for channel 1

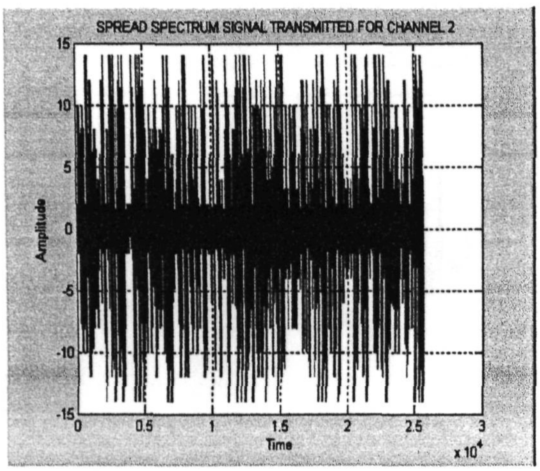

Figure 10: Spread spectrum for channel 2

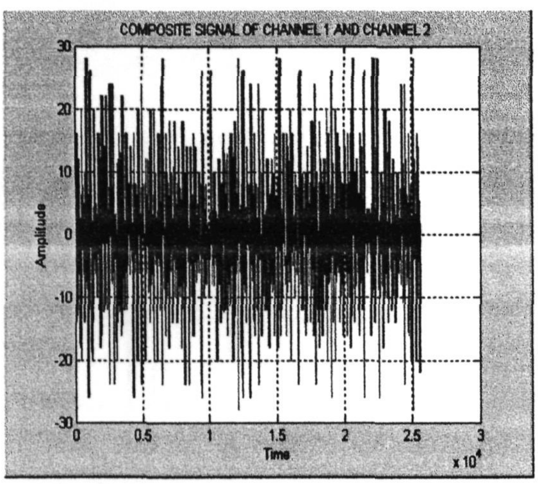

Figure 11: Composite signal for both channels

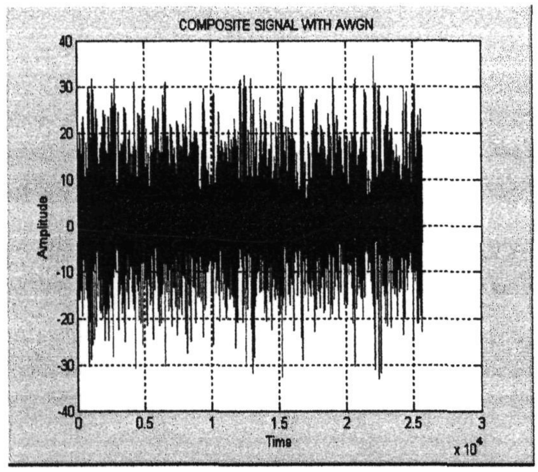

Figure 12: Composite signal with noise (AWGN)

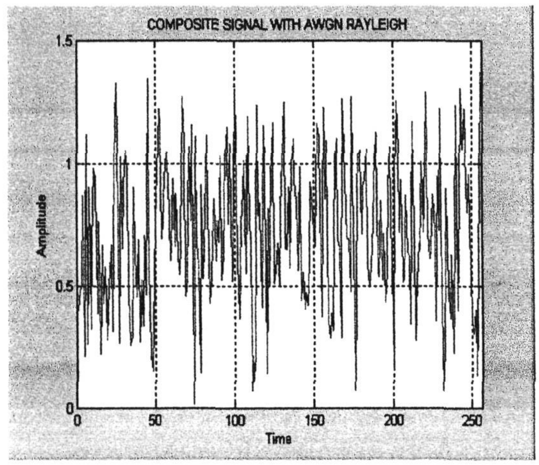

Figure 13: Composite signal with AWGN and Rayleigh

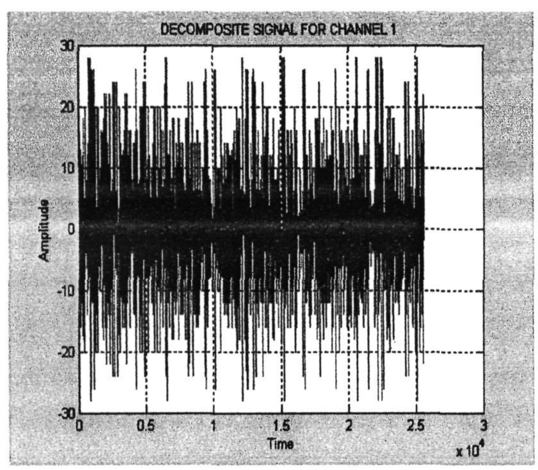

Figure 14: Decomposed signal for channel 1

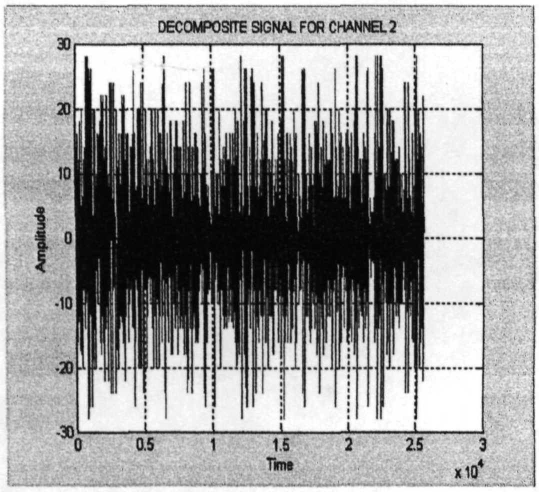

Figure 15: Decomposed signal for channel 2

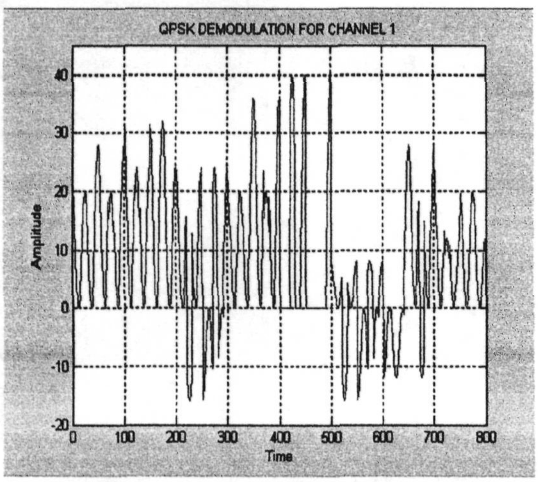

Figure 16: Demodulated signal for channel 1

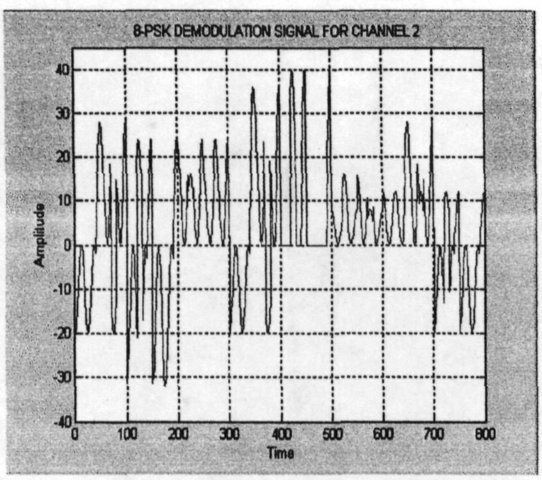

Figure 17: Demodulated signal for channel 2

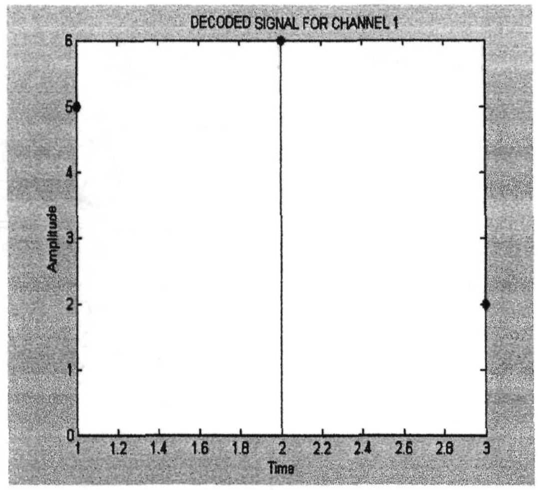

Figure 18: Output signal for channel 1

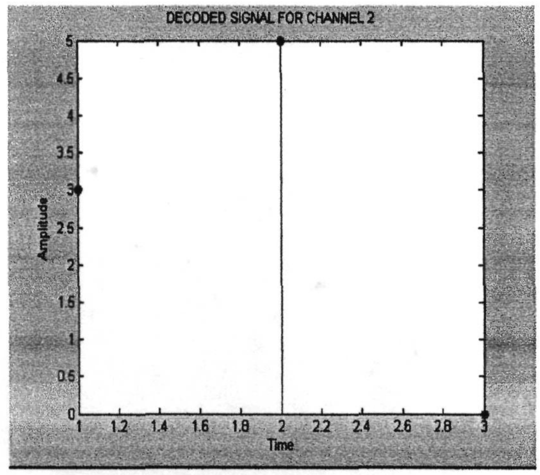

Figure 19: Output signal for channel 2