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MSc Thesis

“Impact of Adjacent and Co-Channel Interference on AWGN and Rayleigh Channels Using Different Digital Modulation Techniques for Wireless Communication”

By

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بسم الله الرحمن الرحيم

((وعلمك ما لم تكن تعلم وكان فضل الله عليك عظيما))

صدق الله العظيم

سورة النساء ، الآية 113

Dedication

I dedicate my thesis *to my parents, husband, children and sisters as well as my* friends. *Without whom none of my success would be possible.*

ACKNOWLEDGEMENT

Praise and gratitude be to ALLAH almighty, without whose gracious help it would have been impossible to accomplish this work.

I wish words could express my gratitude and full appreciation to my supervisor ***Prof. Amer R. Zreek*** *for his efforts that helped me a lot during all the thesis and interesting discussion during this period. Also I would like thank* **Dr Amer M. Daeri** *for his assistance and advising while I doing my work .*

I am extremely grateful to my parents for their love, caring and for educating and preparing me for my future. I am very much thankful to my husband and children for their love, understanding, and continuing support to complete this research work, also I express my thanks to my sisters for their support .

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ABSTRACT

In wireless communication systems, the interference is predictable since many transmissions often take place instantaneously over a common communication channel. This is a phenomenon in communication systems have to live with. It is impossible to get rid of the interference effect but measures have to be taken to minimize their effect. In the cellular radio system, interference is a major limiting factor in their performance. It increases the number of dropped calls in the system as well as limit their capacity and it has a direct correlation to the quality of communication system. It is the main problem, and has to be taken into consideration when designing cellular wireless communication system. Sources of interference are additional mobile in the similar cell, a call in development in neighboring cell, and other base station working in the same frequency band. There are two main categories of interference, Co-Channel Interference (CCI), and Adjacent Channel Interference (ACI). To investigate the effect of these interferences on AWGN and Rayleigh channels for data communication. The Mary-PSK and Mary- QAM techniques are used. Because these schemes of modulation techniques have good performance in wireless communication systems.

In this work the effect of two interference signals on both AWGN and Rayleigh channels are investigated in terms of: bit error rate (BER) performances and power spectra density of the transmitted signals in an addition to that the constellation diagrams of the modulated and demodulated signals. The obtained results indicated that these interference signals have an effect on both modulation techniques. The severity of the effect depends on the modulation level i.e. the higher the level the more severe is the effect. The M-ary QAM proved to have better performance under these harsh environments.

الملخص

في أنظمة الاتصالات اللاسلكية ، يمكن التنبؤ بالتداخل نظرًا لأن العديد من عمليات الإرسال تحدث غالبًا على الفور عبر قناة اتصال مشتركة. هذه ظاهرة في أنظمة الاتصالات يجب أن تتعايش معها. من المستحيل التخلص من تأثير التداخل ولكن يجب اتخاذ تدابير لتقليل تأثيرها. في نظام الراديو الخلوي ، يعد التداخل عاملاً مقيدًا رئيسيًا في أدائها. يزيد من عدد المكالمات التي تم إسقاطها في النظام ويحد من سعتها وله ارتباط مباشر بجودة نظام الاتصال. إنها المشكلة الرئيسية ، ويجب أخذها في الاعتبار عند تصميم نظام الاتصالات اللاسلكية الخلوية. مصادر التداخل هي متنقلة إضافية في خلية مماثلة ، ومكالمة قيد التطوير في الخلية المجاورة ، ومحطة قاعدة أخرى تعمل في نفس نطاق التردد. هناك فئتان رئيسيتان من التداخل ، تداخل القناة المشتركة (CCI) ، وتداخل القناة المجاورة (ACI). للتحقيق في تأثير هذه التداخلات على قنوات التشويش و التوهين لتوصيل البيانات. يتم استخدام تقنيات تضمين ازاحة الطور والتضمين التربيعى متعدد المستويات (M- ary PSK و M- ary- QAM) لأن مخططات تقنيات التعديل هذه لها أداء جيد في أنظمة الاتصالات اللاسلكية.

في هدا العمل تم التحقق من تأثير اشارتي تداخل علي كل من قناتي التشويش و التوهين من حيت اداء معدل الخطأ في البتات (BER) و كثافة اطياف القدرة للإشارات المرسلة بالإضافة الي مخططات الكوكبة للإشارات المضمنة والمستخلصة . توضح النتائج التي تم الحصول عليها ان اشارات التداخل لها تأثير علي كلا تقنيات التضمين , شدة التأثير تعتمد علي مستوي التضمين بمعني انه كلما ارتفع المستوي **كان** التأثير اكثر شدة .واجمالا اثبتت التضمين التربيعى متعدد المستويات (M-ary QAM) ان ادائها افضل في ظل هده البيئات القياسية.

CONTENTS

List of Symbols and Abbreviations

Symbol	Description
ACI	Adjacent Channel Interference
ASK	Amplitude Shift Keying
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BW	Bandwidth
$BW\eta$	Bandwidth Efficiency
CCI	Co-Channel Interference
DVB-C	Digital Video Broadcasting -Cable
E_b	Energy per Bit
E_s	Energy Symbol
FSK	Frequency Shift Keying
f_b	Bit Rate
f_c	Carrier Frequency
GPS	Global Position System
LOS	Line Of Sight
LPF	Low Pass Filter
M	Number of Conditions, Levels
MIMO	Multi In Multi Out

MISO	Multi In Single Out
M-ary	Multi-Level
M- ary PSK	M- ary Phase Shift Keying
M- ary QAM	M-ary Quadrature Amplitude Modulation
n	Number of Bits
N_o	Noise Density
NLOS	Non Line Of Sight
OSTBC	Orthogonal Space-Time Block Code
PDAs	Personal Digital Assistants
PSK	Phase Shift Keying
P(e)	Probability of Error
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
Rx	Receiver
SIMO	Single In Multi Out
SISO	Single In Single Out
Tx	Transmitter

LIST OF FIGUERS

LIST OF TABLE

1.1 Introduction

Digital modulation offers many advantages over analog modulation and greatly improves the performance of the communication systems. Many types of digital modulation schemes are possible, and the choice of which one to use depends on spectral efficiency, power efficiency, and bit error rate performance[1]. There are two main types of carrier digital modulation schemes first scheme is a binary carrier digital modulation which include the Amplitude Shift Keying (ASK), , Phase Shift Keying (PSK) and Frequency Shift Keying (FSK) as well as a Quadrature Amplitude Modulation (QAM) [1] . Which is the combination of both ASK and PSK. The second scheme of digital modulation is an M-ary carrier digital modulation which include an M-ary FSK, M-ary PSK and M-ary QAM. In this work the M-ary PSK and M-ary QAM modulation schemes will be described in details in chapter three as well as these modulation schemes are used in the simulation model of communication system to investigate the effect of the Adjacent and Co-Channel Interferences on AWGN and Rayleigh channels [2,3].

The motivation behind M-ary PSK is to increase the bandwidth efficiency of the PSK modulation schemes. In BPSK, a data bit is represented by a symbol. In M-ary PSK, $n = \log_2 M$ data bits are represented by a symbol, thus the bandwidth efficiency is increased to n times. Among all M-ary PSK schemes, the lower level-PSK is the most-often-used scheme since it does not suffer from BER degradation while the bandwidth efficiency is increased. it will be seen in chapter three. Other M-ary PSK schemes increase band-width efficiency at the expense of BER performance.

M-ary QAM scheme is one of most efficient digital data transmission systems as it achieves better bandwidth efficiency than other modulation techniques and give higher data rate. In an M-ary signaling scheme, it may send one of M possible signals $s_1(t),s_2(t)\ldots s_m(t)$, during each signaling interval of duration T_s. For almost all applications, the number of possible signals: $M = 2^n$. Where n is an integer. The symbol duration $T_s= n\ T_b$, where T_b is the bit duration. In pass-band data transmission these signals are generated by changing the amplitude as in M-ary QAM.

Co-Channel Interference (CCI) is the most critical one ,it's limit the performances of wireless cellular systems. which occur in cellular radio, and it depends on the cellular traffic. the greatest possibility of appearing of co-channel interference is at the busy hours of a cellular system, while the interference between two adjacent channels of the adjacent cells is known as adjacent channel interference (ACI). Adjacent channel Interference refers to the interference arising from the signals which have the frequency close to the actual signal. The problem gets aggravated if two users in adjacent channels use very close frequency bands. The base station often face difficulty in discriminating the desired mobile from its counterpart using a close channel. This event is commonly known as near-far effect. ACI can be tackled by using efficient filters. An easy technique to achieve this is to assign every cell a set of channels, whose frequency are maximally separated [4].

1.2 Thesis Objectives

The main goal of this thesis are summarized in the following points:
General review on communication system and M-ary different types of carrier digital modulation techniques.

- Studying and Investigation the effect of Adjacent and Co-Channel Interference on AWGN and Rayleigh Channels using M-ary –PSK and M-ary QAM (for M=8, 16, 32 and 64) modulation for wireless communication.

- Modeling and simulation of the of communication system with two interference signals (Adjacent and Co-Channel Interference) Using M-ary PSK and M-ary QAM, for M=8,16, 32and 64 of both types of these modulation over AWGN and Rayleigh communication channels by Matlab with Simulink V. 2018a.
- Several tests will be carried out to evaluate the BER performance, constellation diagrams and power spectra density due to the effect of adjacent and co-channel interference over AWGN and Rayleigh communication channels using M-ary PSK and QAM modulation techniques for M=8, 16, 32 and 64 levels.

1.3 Thesis Structure

This thesis consists five chapters . The first chapter gives brief introduction and the outline of the thesis. The second presents brief explanation about the wired and wireless communication system, communication system with adjacent and co-channel interferences, Also deals with the communication channels schemes , multi input multi output system and carrier digital modulation schemes. While the third chapter gives brief description on both M-ary Phase Shift Keying Modulation (M-ary PSK) and M-ary Quadrature Amplitude Modulation M-ary QAM) from point of view; definition, mathematical representation, bandwidth, bandwidth efficiency, error of probability, bit rate, symbol error rate and as well as generation and detection. Also deals with the comparisons of these two types of modulation techniques. Where the fourth chapter describe the implementation and simulation of the of communication system model with two interference signals using M-ary PSK and M-ary QAM over AWGN and Rayleigh communication channels by software package known as Matlab with Simulink V. 2018a also this chapter deals with the achieved simulation result and their discussion. Finally the fifth chapter describe concluded of the achieved simulation results as well as proposes some points as a future work.

3.1 Introduction

Multi-level (M-ary) digital modulation is widely used to design a communication system that is more bandwidth efficient. With M-ary signaling, digital inputs with more than two modulation levels are allowed on the transmitter's input signals. The data is transmitted in the form of symbols, each symbol is represented by n bits, so there are $M=2^n$ different signal levels in M-ary modulation. The M-ary digital modulation techniques include three main types such as M-ary FSK, M-ary PSK and M-ary ASK. The combination of both M-ary PSK and M-ary ASK construct M- ary modulation called M-ary Quadrature Amplitude Modulation (M- ary QAM)) .

Although multi level (M-ary) PSK and M- ary –QAM are used in many applications including microwave digital radio, satellite communication, Digital Video Broadcasting-Cable (DVB-C) …etc. That two schemes of M- ary modulation will be described in details in this chapter from point of view definition, mathematical representation, parameters, generation and detection.

3.2 M-ary Phase Shift Keying

The justification behind M- ary PSK is to increase the bandwidth efficiency of the PSK modulation schemes. In M-ary PSK, $n = \log_2 M$ data bits are represented by a symbol, thus the bandwidth efficiency is increased to n times. Among all M- ary PSK schemes, QPSK (4-PSK) is the most-often-used scheme since it does not suffer from BER degradation while the bandwidth efficiency is increased. Other M-ary PSK schemes increase band-width efficiency at the expense of BER performance.

The 4- PSK is an M-ary encoding technique where M=4, in 4-PSK there are four phases are possible and one output amplitude , this allows for 4 combinations of 2 bits each. This means in one cycle it can transmit 2 bits to represent the 4 states. Where M=8 the M-ary encoding technique is 8-PSK which has eight levels of phase changes and one amplitude, this allows for 8 combinations of 3 bits each. This means in one cycle it can transmit 3 bits to represent the 8 states. for 16-PSK is an M-ary system where M=16 which has sixteen levels of phase changes and one amplitude, this allows for 16 combinations of 4bits each. This means in one cycle it can transmit 4 bits to represent the 16 states generally for M-PSK is an M-ary system which has M levels of phase changes and one amplitude, this allows for M combinations of n-bits each.

Therefore mathematical representation, parameters, generation and detection of an M- ary PSK are described briefly in the following subsections [19-24].

3.2.1 Mathematical Representation

Mathematical Representation of M -ary Phase Shift Keying is given by [21]

$$v_i(t) = A\cos(2\pi f_c t + \theta_i), \qquad 0 \le t \le T \quad i = 1, 2, 3, ...M \tag{3.1}$$

where $\theta_i = \frac{2(i-1)\pi}{M}$.

A is the amplitude of the M- ary PSK signal , T is the symbol duration and f_c is the carrier frequency.

3.2.2 M- ary PSK Parameters

There are several parameters of M- ary PSK in this work it will describe the bandwidth (BW) , bandwidth efficiency (BW_η) bit rate , baud rate and Probability of error P(e). only These parameters are described briefly in the following points. [21-23].

- **Bandwidth (BW)**

Generally the bandwidth is define as the frequency band needed to transmit the data signal or information over the communication channel, but it is also the frequency band occupied by the baseband binary signal to be transmitted.

The bandwidth required for M-ary PSK modulated signal is

$$BW = \frac{\mathbf{f_b}}{\mathbf{(\log_2 M)}}$$

For $n = \mathbf{\log_2 M}$

Then the BW is given by

$$BW = \frac{\mathbf{f_b}}{\mathbf{n}} \qquad (3.\ 2)$$

Where

f_b is the bit rate in bps

n = number of bits necessary

M = number of conditions, levels, or number of output level.

So the BW of 8, 16, 32 and 64 - PSK is given by

$$BW = \frac{f_b}{3}, \frac{f_b}{4}, \frac{f_b}{5} \text{ and } \frac{f_b}{6} \text{ for } 8, 16, 32 \text{ and } 64 - \text{psk respetively} \qquad (3.3)$$

- **Bite Rate and Baud Rate**

In digital modulation, the rate of change at the input of the modulator is called the bit rate and has the units of bits per second (bps).The measure of the rate of change at the output of the modulator is called baud rate and is equal to the reciprocal of the time of one output signaling element. In essence, baud is the line speed in symbols per second.

Where bit rate is: Data rate = $\frac{n(bits)}{T(\text{sec})} = \frac{log_2(m)}{T}\ bits/sec$ (3.4)

generally the relationship between bit and baud rates is given by

$\text{bit rate} = \text{baud}\log_2(\text{M}) = \text{baud}\log_2(2^{\text{n}}) = \text{n baud}$

i.e.

bit rate= n baud (3.5)

So the bit rate of 8, 16, 32 and 64 - PSK is given by

bit rate=3 baud, 4 baud, 5 baud, and 6 baud for 8, 16, 32 and 64 –PSK respectively (3.6)

- **Bandwidth Efficiency** (BW_η)

The Bandwidth efficiency (BW_η) is define as the ratio of transmitted data rate, f_b, to the required value of bandwidth (BW) the (BW_η) of an M-ary digital modulation is given by

$$BW_\eta = \frac{\text{Transmission bit rate (bps)}}{\text{Mimimum bandwidth (Hz)}} = \frac{\mathbf{f_b}}{\mathbf{BW}} = \mathbf{log_2 M} = \mathbf{n} \qquad (3.7)$$

For an M-ary PSK (M= 8, 16, 32 and 64) the bandwidth efficiency is given by

BW_η =3, 4, 5 and 6 for 8, 16, 32 and 64 –PSK respectively. (3.8)

Referring to the equation (3.8), it observes that the bandwidth efficiency of M-ary PSK increases as level M increases.

- **Probability of Error**

Probability of error P(e) is a function of the carrier-to-noise power ratio or, more specifically, the average energy per bit-to-noise power density ratio and the number of possible encoding conditions used M-ary.

In the M- ary PSK the probability of error mathematically is written as

$$\mathrm{p(e)} = \left(\frac{1}{log_2 M}\right)\mathrm{erf}(z) \tag{3.9}$$

Where erf is the error function

$$z = \sin\left(\frac{\pi}{M}\right)\sqrt{\log_2 M}\sqrt{\frac{E_b}{N_o}}$$

For an M-ary PSK (M= 8, 16, 32 and 64) the probability of error is given by

$$\mathrm{p(e)} = \left(\frac{1}{3}\right)\mathrm{erf}\left(sin\left(\frac{\pi}{8}\right)\sqrt{3}\sqrt{\frac{E_b}{N_o}}\right), \mathrm{p(e)} = \left(\frac{1}{4}\right)\mathrm{erf}\left(sin\left(\frac{\pi}{16}\right)\sqrt{4}\sqrt{\frac{E_b}{N_o}}\right)$$

$$\mathrm{p(e)} = \left(\frac{1}{5}\right)\mathrm{erf}\left(sin\left(\frac{\pi}{32}\right)\sqrt{5}\sqrt{\frac{E_b}{N_o}}\right), \mathrm{p(e)} = \left(\frac{1}{6}\right)\mathrm{erf}\left(sin\left(\frac{\pi}{64}\right)\sqrt{6}\sqrt{\frac{E_b}{N_o}}\right)$$

For 8, 16, 32 and 64 –PSK respectively. (3.10)

3.2.3 Generation of the M -ary Phase Shift Keying

For M ≥ 4, a quadrature modulator can implement the modulator because M-ary PSK signals are two-dimensional. The M-ary PSK modulator is shown in figure (3.1), each n inputted of bits is used to control the level generator. Where the level generator is the only difference for different values of M. Where the level generator (v_{i1}, v_{k2}) respectively provides the I and Q channels with the particular level and sign for a signal is horizontal and vertical coordinates [21].

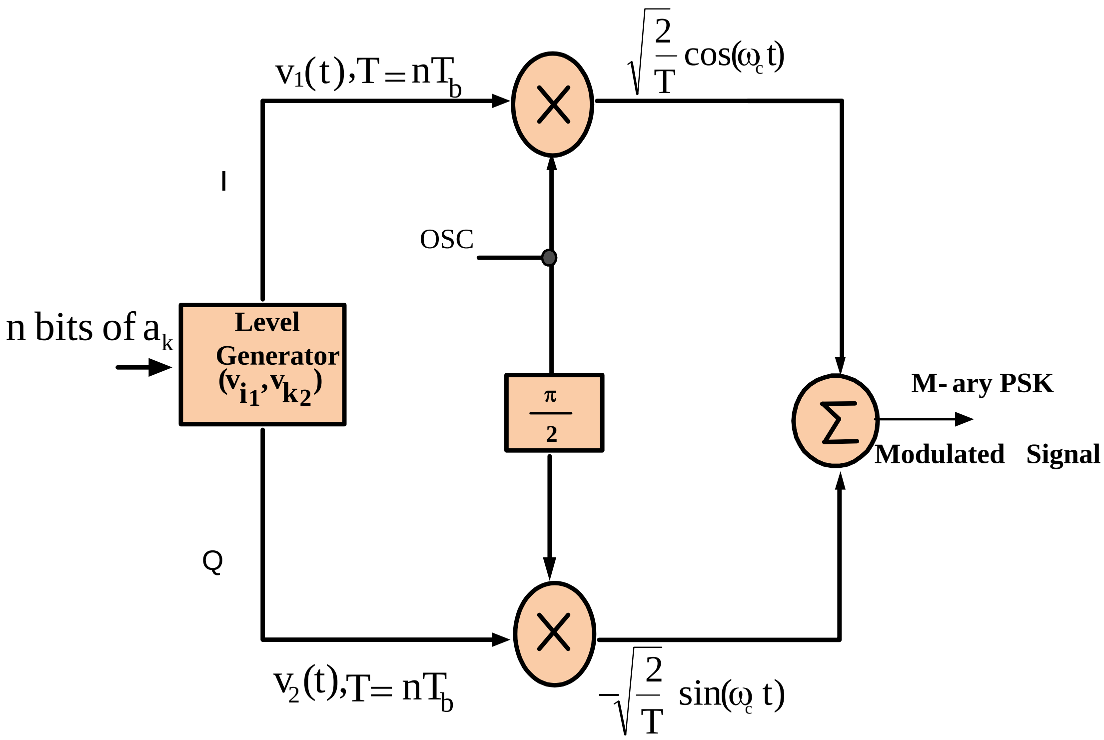


Figure (3.1) M-ay PSK generation

3.2.4 Detection of the M -ary Phase Shift Keying

The detection of M-ary PSK shown in figure (3.2) is used to recover the message signal out from the M-ary PSK modulated signal. One of the coherent detectors could implement that demodulator for M -ary signals. Since an M-ary PSK signal locate has only two basis functions, the simplest demodulator is the one that uses two correlates. Because the M-ary PSK signal has a special characteristic [21].

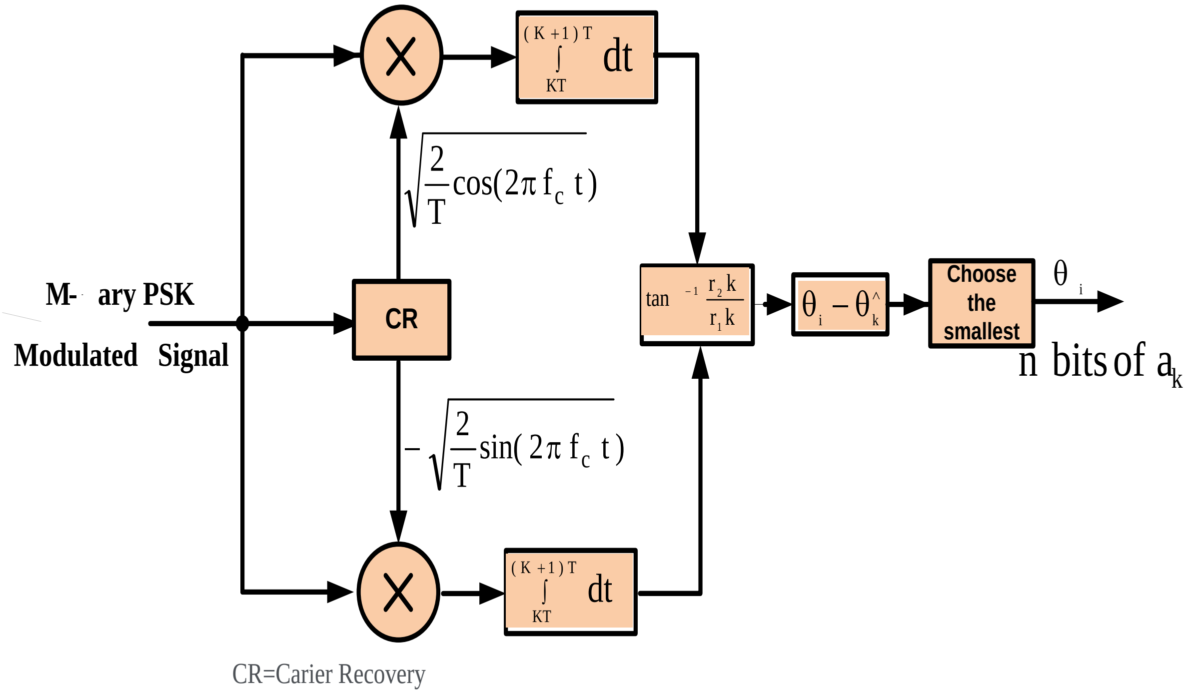


Figure (3.2): M-ary PSK detection

3.3 M-ary Quadrature Amplitude Modulation (M-QAM)

Quadrature amplitude modulation is the combination of phase shift keying and amplitude shift keying. More strictly, quadrature amplitude modulation is a system of modulation in which data is transferred by modulating the amplitude of two separate carrier waves, mostly sinusoidal, which are out of phase by 90° degrees (sine and cosine). Due to their phase difference, they are called quadrature carriers [23].

Although the QAM is an M-ary encoding technique where M=4, in 4-QAM there are four phases are possible and one output amplitudes, this allows for 4 combinations of 2 bits each. This means in one cycle it can transmit 2 bits to represent the 4 states. Where M=8 the M-ary encoding technique is 8-QAM which has four levels of phase changes and two levels of amplitude, this allows for 8 combinations of 3 bits each. This means in one cycle it can transmit 3 bits to represent the 8 states. For 16-QAM is an M-ary system where M=16 which has eight levels of phase changes and two levels of amplitude, this allows for 16 combinations of 4bits each. This means in one cycle it can transmit 4 bits to represent the 16 states. While 32-QAM is an which has eight phases are possible and four output amplitudes where M=32. The input data are acted in groups of five bits. This means in one cycle it can transmit 5 bits to represent the 32 states. And 64-QAM is an M-ary system where M=64 which has sixteen phases are possible and four output amplitudes. The input data are acted in groups of six bits. This means in one cycle it can transmit 6 bits to represent the 64 states. etc.

Hence mathematical representation, parameters, generation and detection of an M- ary QAM are described briefly in the following subsections [25, 26].

3.3.1 Mathematical Representation

The Mathematical representation of M-ary Quadrature Amplitude Modulation is given by

$$v_{ki}(t) = A_k \cos(2\pi f_c t + \theta_i) \qquad (3.11)$$

k=1, 2, 3… M_1 and i=1, 2, 3…M_2 [26]

Where

A_k is the signal amplitude, θ_i is the signal phase, M_1 is the number of possible amplitudes of the carrier, M_2 is the number of possible phases of the carrier and f_c is the carrier frequency.

3.3.2 M- ary QAM Parameters

M-ary QAM has several parameters but in this work it will illustrate only the bandwidth (BW) , bandwidth efficiency (BW_η) bit rate , baud rate and Probability of error P(e) .

- The bandwidth, bit rate and bandwidth efficiency of M-ary QAM are identical to the bandwidth , bit rate and bandwidth efficiency of M-ary PSK which are given in equations (3.3), (3.6)and (3.8) respectively [27,28].
- **Probability of Error**

In an M-ary. QAM probability of error mathematically is given by

$$P(e) = \frac{1}{Log_2 M}\left(\frac{M-1}{M}\right) erfc(x) \qquad (3.12)$$

Where $$x = \left(\frac{\sqrt{Log_2 M}}{M-1}\sqrt{\frac{E_b}{N_o}}\right)$$

erfc(z) is the complementary error function , while M is the number of levels

For an M-ary QAM (M= 8, 16, 32 and 64) the probability of error is given by

$$P(e)=\frac{7}{24}\operatorname{erfc}\left(\frac{\sqrt{3}}{7}\sqrt{\frac{E_b}{N_o}}\right),\ P(e)=\frac{15}{64}\operatorname{erfc}\left(\frac{2}{15}\sqrt{\frac{E_b}{N_o}}\right),$$

$$P(e)=\frac{31}{160}\operatorname{erfc}\left(\frac{\sqrt{5}}{31}\sqrt{\frac{E_b}{N_o}}\right)\ \text{and}\ P(e)=\frac{63}{384}\operatorname{erfc}\left(\frac{\sqrt{6}}{63}\sqrt{\frac{E_b}{N_o}}\right)$$

For 8, 16, 32 and 64 –PSK respectively. (3.13)

3.3.3 Generation of the M-ary Quadrature Amplitude Modulation

Figure (3.3) illustrated the M-ary QAM modulator. To obtain the M-ary QAM modulated signal a binary stream of data with bit rate ($\left(f_b = \frac{1}{T_b}\right)$

Is fed to the amplitude, phase selector, and evaluate different values of

A_{cm} and A_{sm}. The quadrature carrier signals $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$ are after that modulated by A_{cm} and A_{sm} respectively, where A_{cm} and A_{sm} are independent integers chosen in order of message point location. Both modulated signals are then added together to obtain a M-ary QAM (M=4, 8, 16, 32, 64 …etc.) modulated signal.

This method of modulation has the advantage of reducing or eliminating intermodulation interference caused by a continuous carrier near the modulation sidebands [29,30].

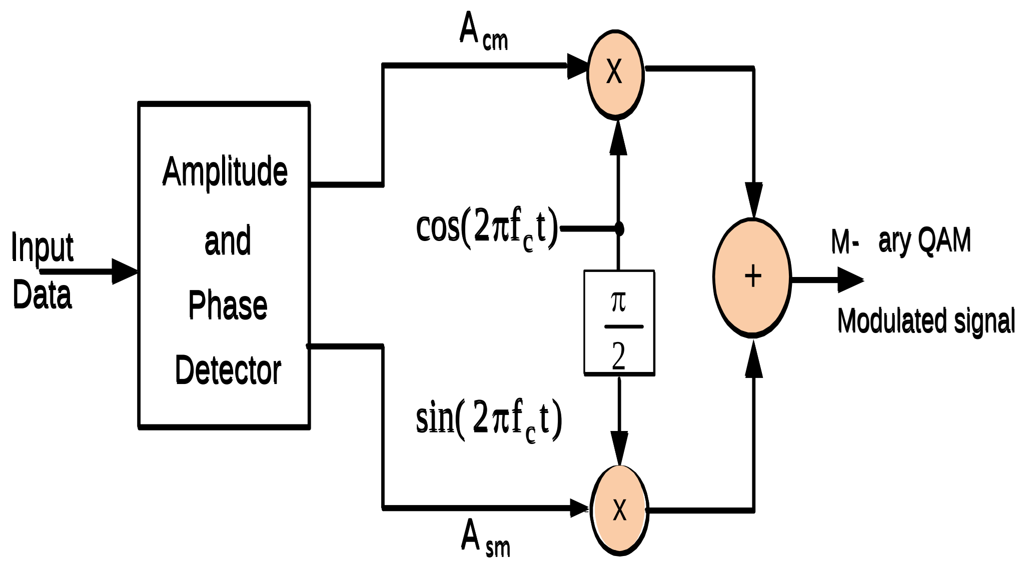


Figure (3.3): M- ary QAM generation block diagram

3.3.4 Detection of the M-ary Quadrature Amplitude Modulation

Block diagram shown in figure (3.4) is represented the M-ary QAM demodulator, the demodulated signals corrupted with a noise signal, n (t) is processed in cross correlator demodulators. That n (t) is taken white Gaussian zero mean with power spectral density is flat and equal $\frac{\eta}{2}$. With the effect of the noise a_{cm} and a_{sm} are corrupted values of A_{cm} and A_{sm}. The M- ary QAM demodulator calculates the distance between observed a_{cm} and a_{sm} values with different symbol points and then make a decisions in goodwill of minimum distance [31].

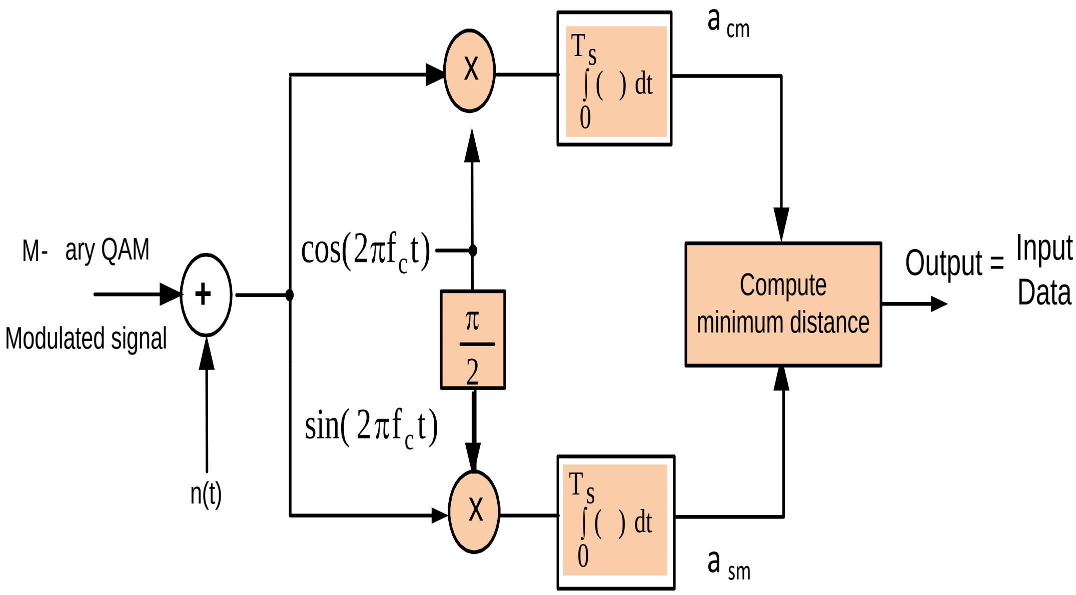


Figure (3.4) M- ary QAM detection block diagram

3.4 Comparisons Between the M-ary PSK and M-Ary QAM

The main comparison between the M-ary PSK and M-ary QAM modulation techniques are summarized in the following points: [1,32]

- M-ary PSK - is a modulation where data bits pick one of M phase shifted versions of the carrier to transmit the data. Thus, the M level possible waveforms all have the same amplitude and frequency but different phases. The signal constellations diagrams consist of M equally spaced points on a circle .While M-ary QAM - - is a modulation where data bits pick one of M combinations of both amplitude and phase shifts that are applied to the carrier. The M possible waveforms may be described by M constellation points.
- M-ary PSK use only the phase variations. while M-ary QAM utilizes both amplitude and phase variations to represent binary data.

- M- ary QAM is widely used in wireless communication system in terms of data carrying capacity, but M- ary QAM is more susceptible to noise compare to M-ary PSK.
- The power efficiency of QAM is superior to M-ary PSK
- The bandwidth efficiency of M- ary PSK is identical to M-ary QAM.
- Referring to the figure (3.5) which illustrated bit error rate vs. E_b/N_o theoretically performances for 8, 16, 32 and 64- PSK/QAM. It is quite clear that M-ary QAM has better BER performance then the M-ary PSK. As an example 32-PSK has more signal energy is needed to get a better BER than 32-QAM. Also when M-ary PSK used w.r.t the M-ary QAM more energy is needed when the level of modulation increases.

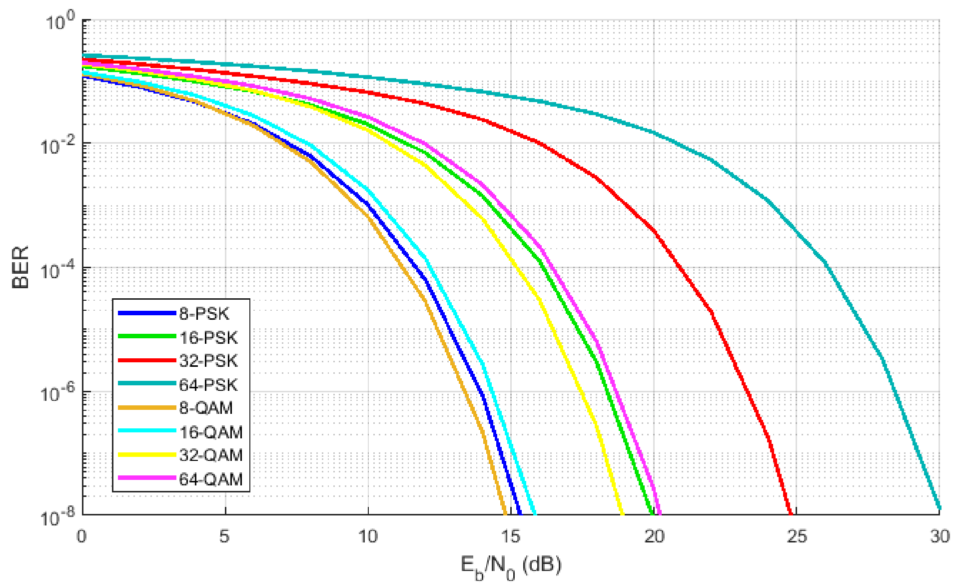


Figure (3.5) Bit Error Rate vs. E_b/N_o using M-ary PSK and M-ary QAM (for M=8, 16, 32 and 64)

4.1 Introduction

Simulation technique is a software package for modeling, simulating, and analyzing different systems. The main principle of using computer simulation is to assemble, analysis, and practice a model of a real system, in addition to that it's investigate their performance and studying behavior. There are several scientific computer packages available in the market that can be used to simulate the analogue or digital systems design, such as LabVIEW, Mathcad, Multisim, Matlab with Simulink, … etc. In this thesis Matlab with Simulink V.2018a is used to simulate and investigate the performances of the effect of the adjacent and co-channel interferences on AWGN and Rayleigh communication channels using two schemes of M- ary digital modulation techniques which are M- ary PSK and M- ary – QAM for M=8,16, 32 and 64).

4.2 Simulation Model of Communication System with Interference Using M- ary PSK Over AWGN and Rayleigh Channels

Referring to the basic block diagram shown in figure (2.4), which is implemented using Simulink as shown in figure (4.1). This simulation model includes the Transmitter, communication channel, receiver, interference 1 and interference 2 signals. These parts are described in the following points:

(a) Transmitter side

The transmitter side include the following blocks

- **Bernoulli Binary Generator block:** it generates random binary numbers using a Bernoulli distribution

M- PSK Modulator Baseband block: it modulates an input signal using M-ary phase shift keying (M- ary PSK) and returns a complex baseband output. The modulation order, M

(8,16,32 and 64), which is equivalent to the number of points in the signal constellation, is determined by the M-ary number parameter. The block accepts scalar or column vector input signal.

Raised Cosine Transmit Filter block: it up samples and filters the input signal using a normal raised cosine finite impulse response (FIR) filter or a square root raised cosine FIR filter.

(b) Interferences 1 and 2

These interferences include same blocks of transmitter in addition to the following blocks:

- **Constant block** : It generates a real or complex constant value. The block generates scalar, vector, or matrix output, depending on the dimensionality of the constant value parameter and the setting of the interpret vector parameters as 1-D parameter.
- **Slider Gain block** is used to modify a scalar gain during a simulation using a slider. The block accepts one input and generates one output.
- **Phase/Frequency Offset block**: it applies phase and frequency offsets to an incoming signal.
- **Product block**: it outputs the result of multiplying two inputs: two scalars, a scalar and a non-scalar, or two non-scalars that have the same dimensions.
- **dB Gain block:** this block multiple the input by the decibel values specified in the **Gain** parameter.
- **Manual Switch:** this switch block is a toggle switch that selects one of its two inputs to pass through to the output.

(c) Communication Channel

- The **Orthogonal Space-Time Block Code (OSTBC) Encoder block (Alamouti)**: It encodes an input symbol sequence using orthogonal space-time block code (OSTBC). The block maps the input symbols block-wise and concatenates the output codeword matrices in the time domain.

Multi Input Multi Output (MIMO) **Fading Channel block**: it filters an input signal using a multi-input/multi-output (MIMO) multipath fading channel. This block models both Rayleigh and Rician fading but in this work it uses the Rayleigh channel for two transmit antennas and three receive antenna.

- **AWGN channel block**: it adds white Gaussian noise to the input (modulated) signal. It inherits the sample time from the input signal. This block supports multichannel processing.
- **Squeeze block:** this block eliminates singleton dimensions from its multidimensional input signal. A singleton dimension is any dimension whose size is one. This squeeze block operates only on signals whose number of dimensions is greater than two.

OSTBC Combiner block: It combines the input signal from all of the receive antennas and the channel estimate signal to extract the soft information of the symbols that were encoded using an OSTBC.

(d) Receiver side

The Receiver side includes the following blocks

- **Raised Cosine Receive Filter block**: this block filters the input signal using a normal raised cosine FIR filter. It also down samples the filtered signal if it sets the output mode parameter to Down sampling**.**
- **Downsample block:** it decreases the sampling rate of the input by removing samples. When the block performs frame-based processing, it resamples the data in each column of the M_i-by-N input matrix independently. When the block performs sample-based processing, it treats each element of the input as a separate channel and resamples each channel of the input array across time.

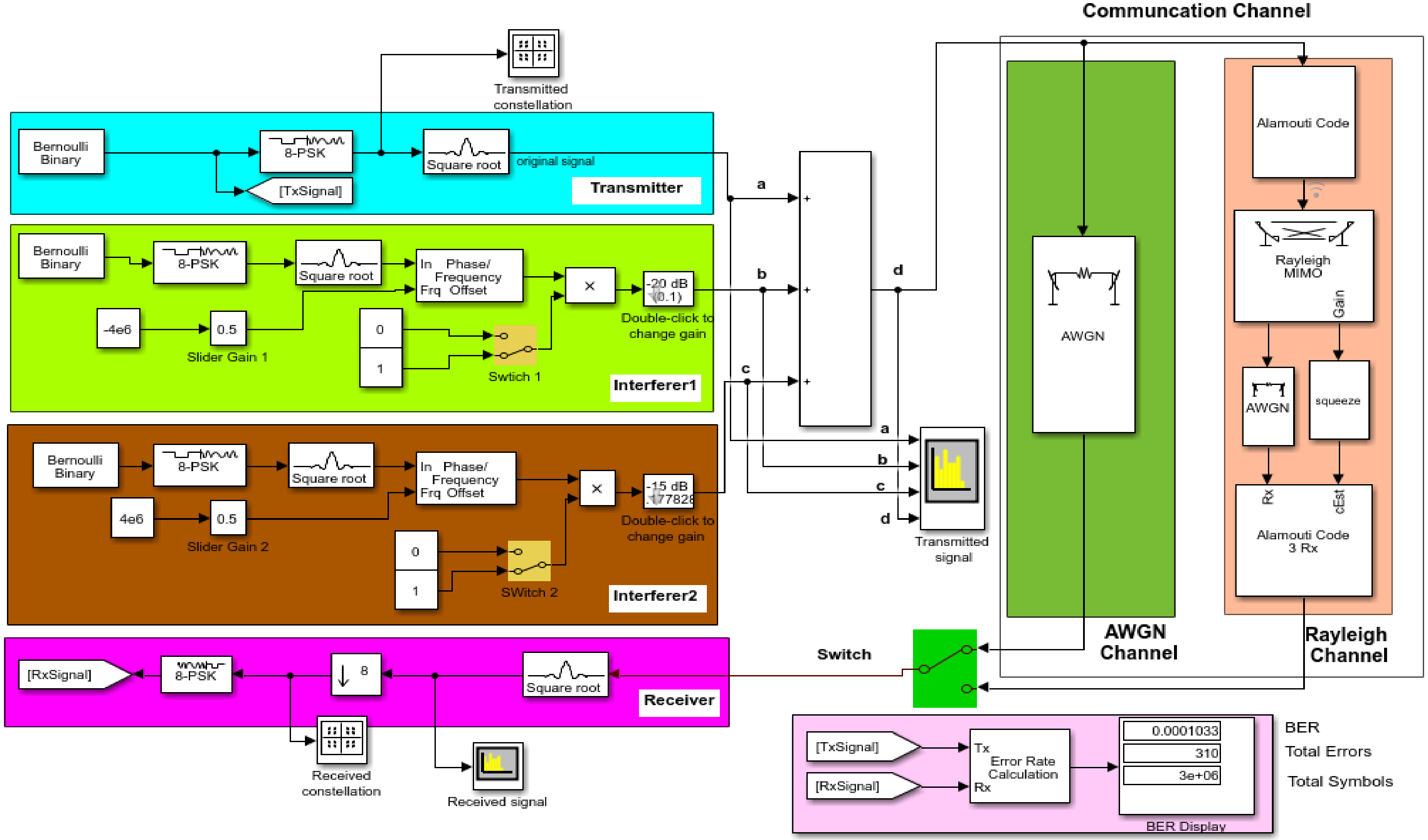


Figure (4.1) Simulation model of the communication system with two interferer using M-ary PSK (for M=8)

- **M- PSK Demodulator Baseband block:** it demodulates a baseband representation of a PSK-modulated signal. The modulation order, M (8,16, 32 and64), which is equivalent to the

number of points in the signal constellation, is determined by the M-ary number parameter. The block accepts scalar or column vector input signals.

An additionally to these parts of the system model it also includes another tools such as:

- Two **constellation diagrams** to plot the constellation diagrams of an 8,13,32 and 64 PSK modulated and the received signals.
- **Sum block:** this block performs addition of the three signals, original (transmitted), interfernce1 and interference 2 signals.
- **Goto block**: this block allows to pass a signal from one block to another without actually connecting them.
- The **from block** accepts a signal from a corresponding Goto block, then passes it as output. The data type of the output is the same as that of the input from the Goto block.
- Two **spectrum analyzer** to measure the spectra of the transmitted and received signals/
- **Error Rate Calculation block**: it compares input data from a transmitter with input data from a receiver. It computes the error rate as a running statistic, by dividing the total number of unequal pairs of data elements by the total number of input data elements from one source. and display block to show value of the BER, total errors and total symbols.

After implementing the communication model shown in figure (4.1). The random binary numbers are generated using Bernoulli Binary Generator block. The data is modulated by 8-PSK modulator; the transmitted constellation diagram is observed at the output of the 8- PSK modulator then modulated signal is filtered using raised cosine transmit filter. The filtered signal is mixed with the interferer 1 and interferer 2 signals respectively. The interferer 1 signal is obtained when the information binary data is mapped with 8-PSK modulator. The filtered signal is added with the phase and frequency offset to obtain the interferer signal 1 and interferer signal 2 is obtained by the similar way of the interferer signal 1. Although output of the sum is represented by the noisy signal. The original, interferer 1, interferer 2 and noisy signals in frequency domain are observed in spectrum analyzer. After that the noisy signal is transmitted through both AWGN and Rayleigh channels then is filtered by raised cosine receive filter which is observed in another spectrum analyzer. The raised cosine receive filter output is passed down sampled by sampler and received constellation diagram is observed at the output of the down sampler. The down sampled signal is demodulated by 8-PSK demodulator. That steps are repeated for 16, 32 and 64 – PSK.The overall simulation results will be represented in the next section.

4.3 Simulation Results of the Communication System Model with Two Interference Signals using M- ary PSK Over AWGN and Rayleigh Channels

After setting the simulation parameters of the communication model shown in figure (4.1) over two different channels, AWGN and Rayleigh which include two transmit antennas and three receive antennas (2x3 antennas). Several tests were carried out to investigate the communication system model with two interferer signals using 8, 16, 32 and 64 - PSK over AWGN and Rayleigh channels in terms of: bit error rate (BER) performances and power spectra density of the transmitted signals which include the original, interferer signals 1 and 2 as well as the noisy signal and receivered signals at the output of the raised cosine receive filter. In an addition to that the constellation diagrams of the modulated and demodulated signals. These tests are clarified in the following subsections.

4.3.1 Bit Error Rate Performances

BER performances without and with effect of the interferer signals over AWGN and Rayleigh channels of the communication system model shown in figure (4.1) using 8, 16, 32 and 64- PSK modulation techniques are illustrated in figures (4.2) to (4.7) respectively.

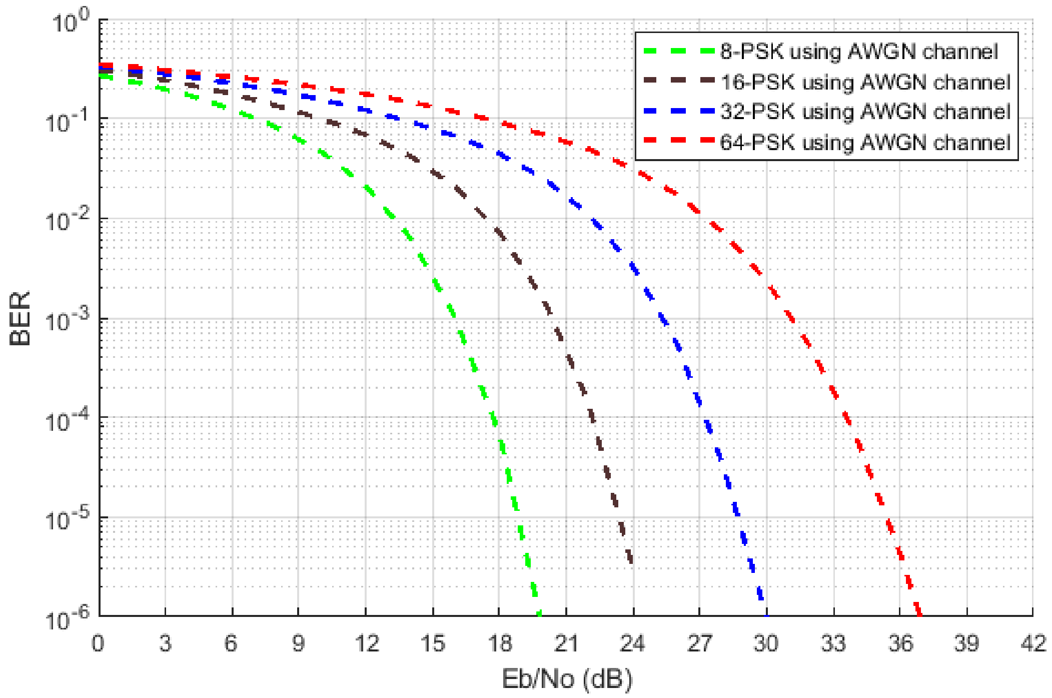


Figure (4.2) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – PSK over AWGN channel of the communication system model without interferer signals

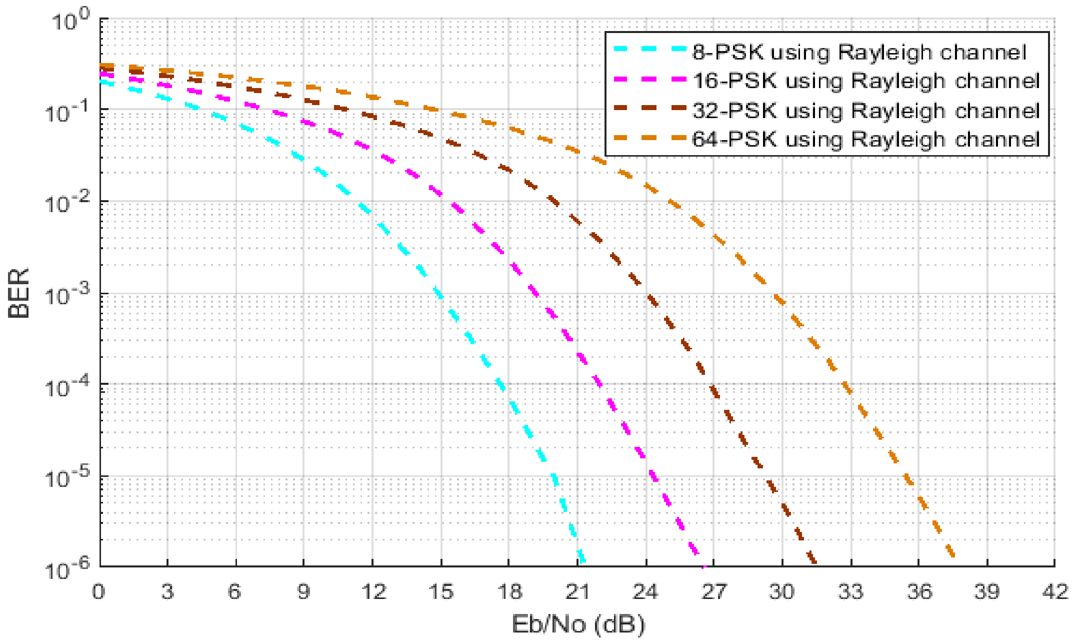


Figure (4.3) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – PSK over Rayleigh channel of the communication system model without interferer signals

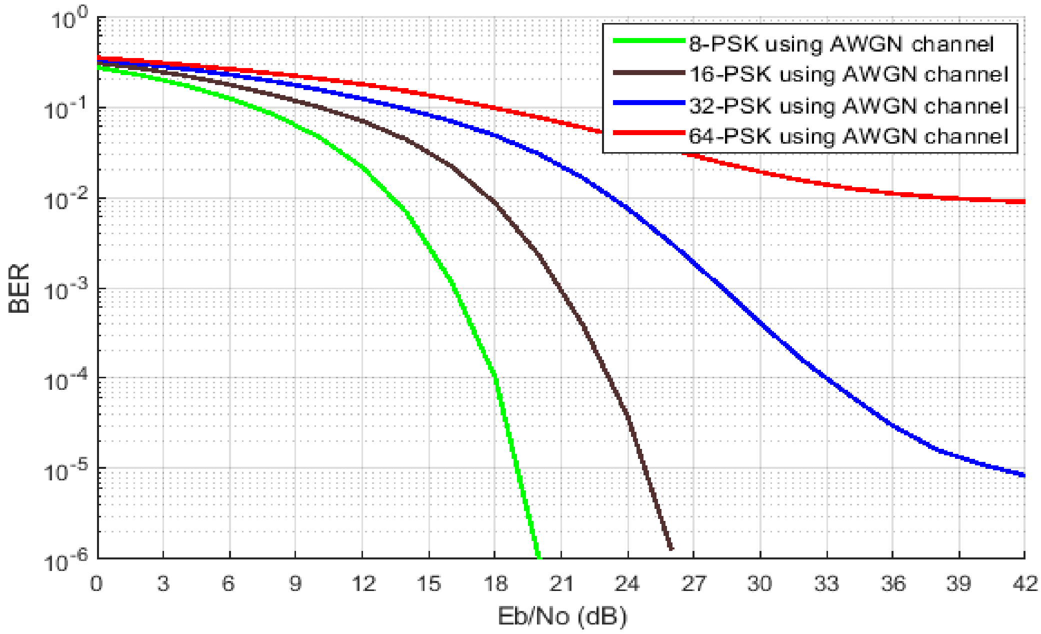


Figure (4.4) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – PSK over AWGN channel of the communication system model with two interferer signals

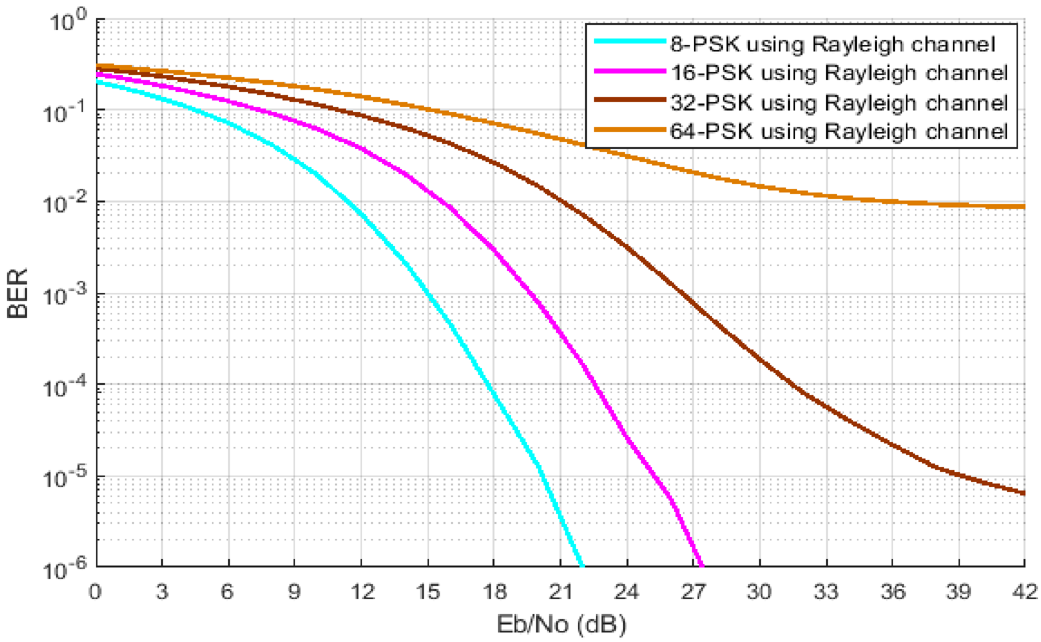


Figure (4.5) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – PSK over Rayleigh channel of the communication system model with two interferer signals

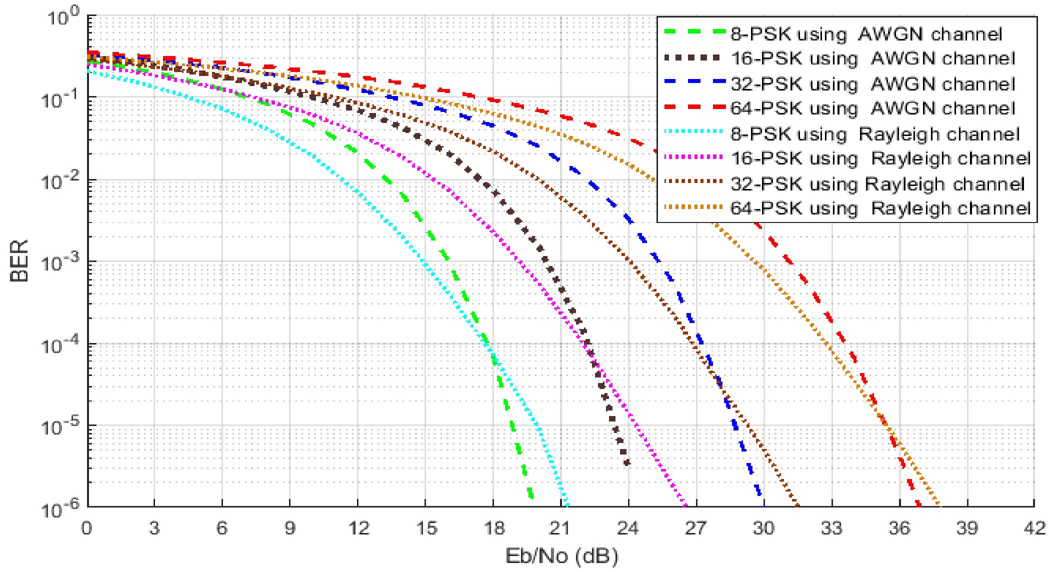


Figure (4.6) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – PSK over AWGN and Rayleigh channel of the communication system model without interferer signals

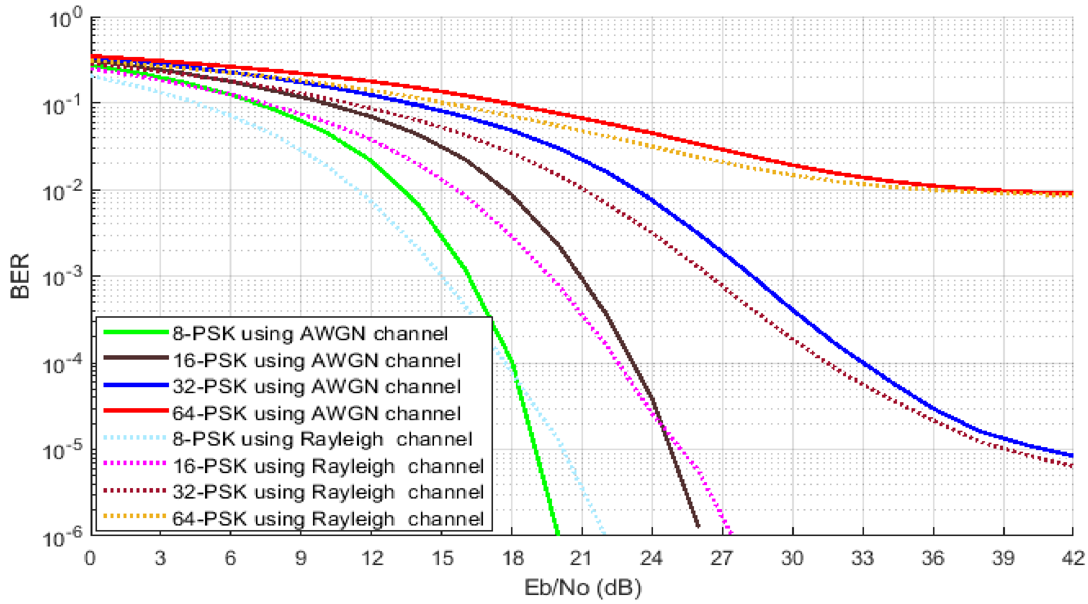


Figure (4.7) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – PSK over AWGN and Rayleigh channel of the communication system model with two interferer signals when examining the plots in figures (4.2) to (4. 7) BER performance for 8, 16, 32 and 64-PSK modulation, over fading effect i.e. under the fading model Rayleigh as well as an open space effect represented by AWGN channel it can be observed that:

- It is quite clear that as the level increases the BER increases i.e. more signal energy is needed to get a better BER that is true for all the schemes.
- It can be noted also that Rayleigh model has a better performance in terms of BER than the AWGN channel as confirmed by figures (4.6) and (4.7) and that can be clarified in that Rayleigh model combines both line of sight (LOS) and non-line of sight (NLOS) transmission components and because of that some of reflections that happens to the signal could have a positive effect and improves performance.
- Consequently, that the best value for BER is for the low level (8-PSK) modulation as can be clearly observed i.e. less signal energy is needed to obtain a better BER.

4.3.2 Constellation diagrams and Power Spectra of the Signals

Figure (4.8) illustrates the constellation diagrams transmitted and received signals of the communication system model shown in figure (4.1) with two interferer signals over AWGN and Rayleigh channels using PSK levels 8,16,32 and 64, where the E_b/N_o is chosen to be equal 18dB since this is the signal energy at which the BER is 10^{-4} dB.

Also the the power spectra density of the transmitted signal which include the original (8-PSK) modulated signal plus the two interferer signals and received signal at the output of the raised cosine receive filter, which are measured using Spectrum Analyzer as shown in figures (4.9) to (4.10) respectively for E_b/N_o of 18dB. The power spectra density of other PSK levels are very similar to the 8-PSK just very view differences in the case of without and with interferer signals.

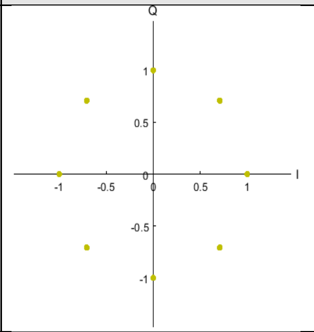
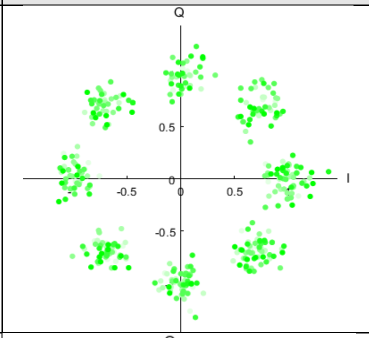
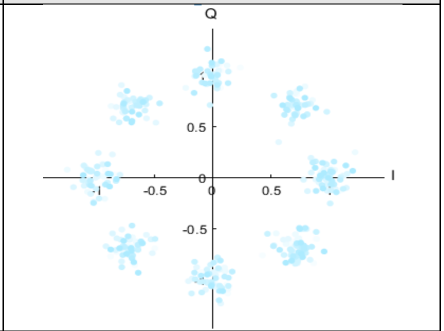
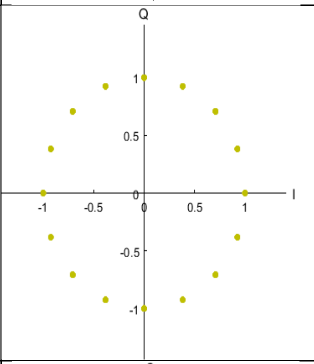
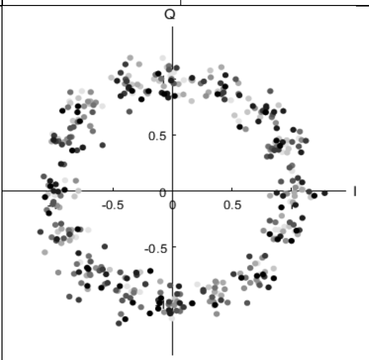
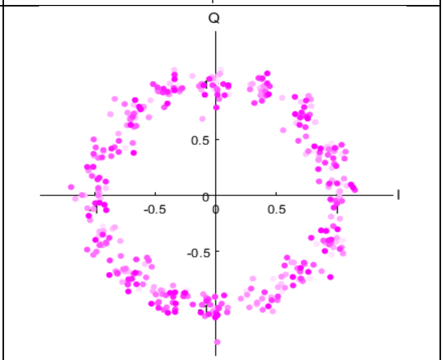
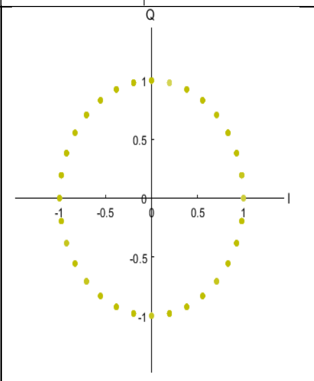
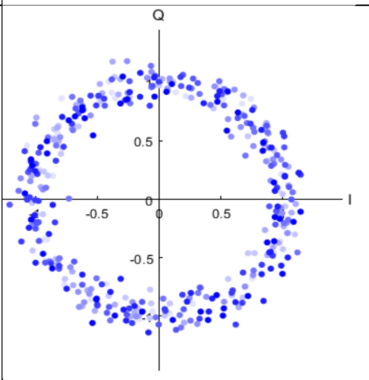
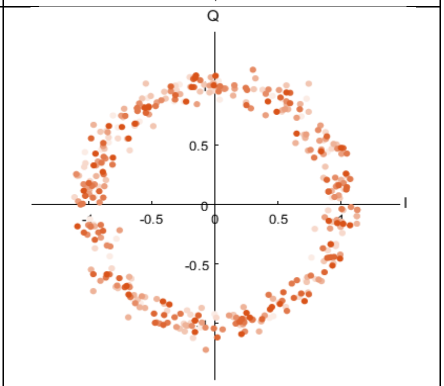
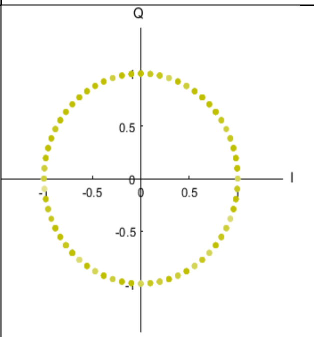
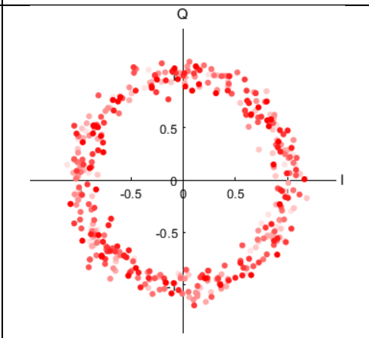
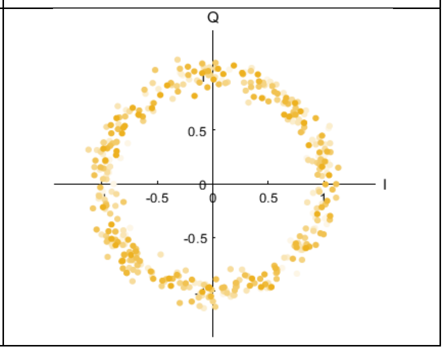
M-PSK Levels	Normal	Using AWGN Channel	Using Rayleigh Channel
8			
16			
32			
64			

Figure (4.8) Constellation diagrams of the communication system model with two interferer signals over AWGN and Rayleigh channels using 8, 16, 32 and 64 – PSK, E_b/N_o=18dB where I in-phase amplitude and Q is quadrature amplitude

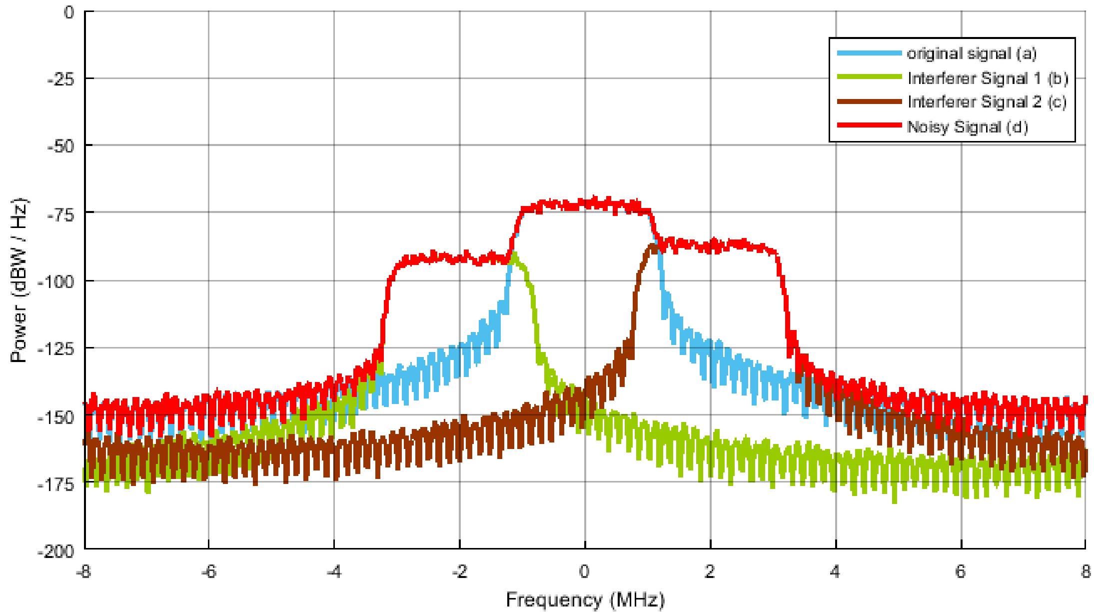


Figure (4.9) Power spectrum density of the original, interferer 1 &2 and noisy signals of the communication system model using 8– PSK. where Eb/No=18dB

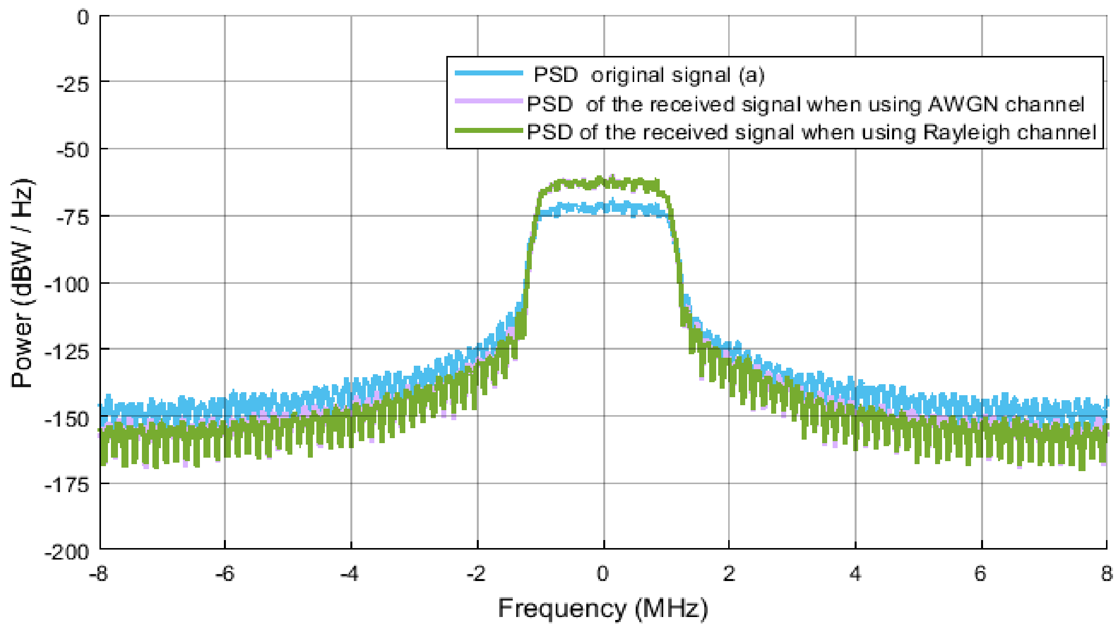


Figure (4.10) Power spectrum density of the received signals using 8,– PSK over AWGN and Rayleigh channels of the communication system model Where Eb/No=18dB.

From figures (4.8) to (4.10) it can be observed that the received constellation diagrams and power spectra density of the receiver filtered signals obtained respectively over the two communication channels confirm the BER achieved results shown in figures (4.2) to (47).

Although to o improve the performance of the communication system model with two interferer signals over AWGN and Rayleigh channels when using higher level PSK modulation, it is needed to increase Eb/No ratio, which implies more signal power is needed. Therefore, in fading environment condition it is better to use lower level PSK (8-PSK) modulation to improve their performance.

4.4 Simulation Model of Communication System with Interferences using M- ary QAM Over AWGN and Rayleigh Channels

Referring to the basic block diagram illustrated in figure (2.4) it is implemented using Simulink as shown in figure (4.11). This simulation model include the identical parts of the communication system model shown in figure (4.2) except that the 8-PSK modulator /demodulator replaced by the 8-QAM modulator/demodulator in the transmitter, and receiver sides.

M- QAM Modulator Baseband block: it modulates an input signal using M-ary Quadrature Amplitude modulation (M- ary QAM) (M=8, 16, 32 and 64) with a constellation on a rectangular lattice. The output is a baseband representation of the modulated signal. This block accepts a scalar or column vector input signal. For information about the data types each block port supports.

M- QAM Demodulator Baseband block: The M- ary Rectangular QAM Demodulator (M=8, 16, 32 and 64) Baseband block demodulates a signal that was modulated using M-ary QAM with a constellation on a rectangular lattice.

4.5 Simulation Results of the Communication System Model with Two Interference Signals using M- ary QAM Over AWGN and Rayleigh Channels

After setting the simulation parameters of the communication model shown in figure (4.11) over the AWGN and Rayleigh channels. That Rayleigh channel include two transmit antennas and three receive antennas (2x3 antennas). A number of tests were carried out to examine the communication system model with two interferer signals using M-QAM (M=8, 16, 32 and 64) over AWGN and Rayleigh channels in order to evaluate system performance in terms of : bit error rate (BER) and power spectra density of the transmitted signals which include the original, interferer signals 1 and 2 as well as the noisy signal which is the summation of the transmitted signals and also the power spectra density of the receivered signals at the output of the raised cosine receive filter. In an addition to that the constellation diagrams of the modulated and demodulated signals. These examinations are discussed in the following subsections

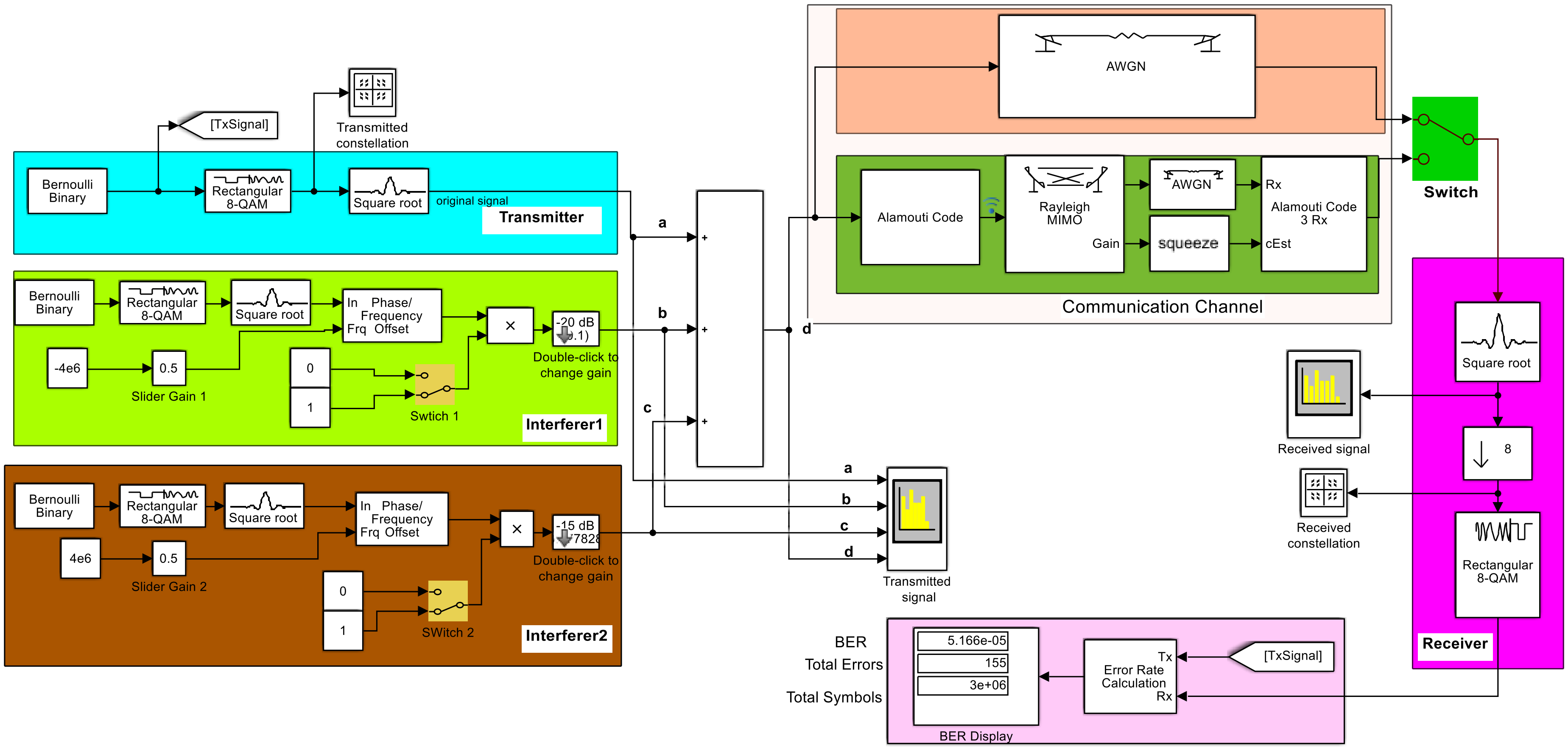


Figure (4.11) Simulation model of the communication system with two interferer using M-ary QAM (for M=8).

4.5.1 Bit Error Rate Performances

BER performances without and with effect of the interferer signals over AWGN and Rayleigh channels of the communication system model shown in figure (4.11) using M-ary QAM (M=, 16, 32 and 64) techniques are illustrated in figures (4.12) to (4.18).

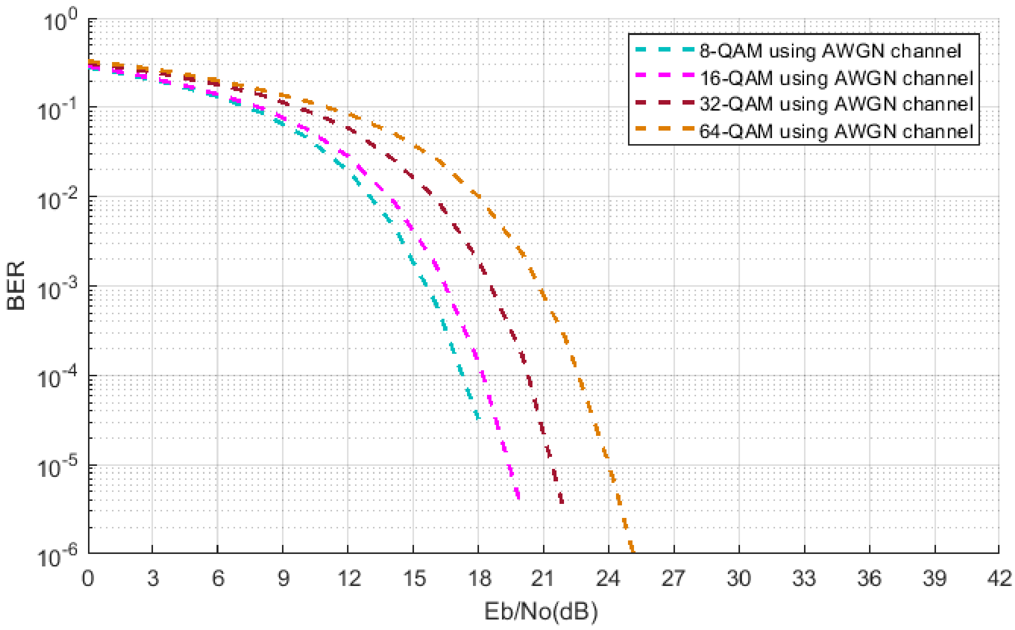


Figure (4.12) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – QAM over AWGN channel of the communication system model without interferer signals

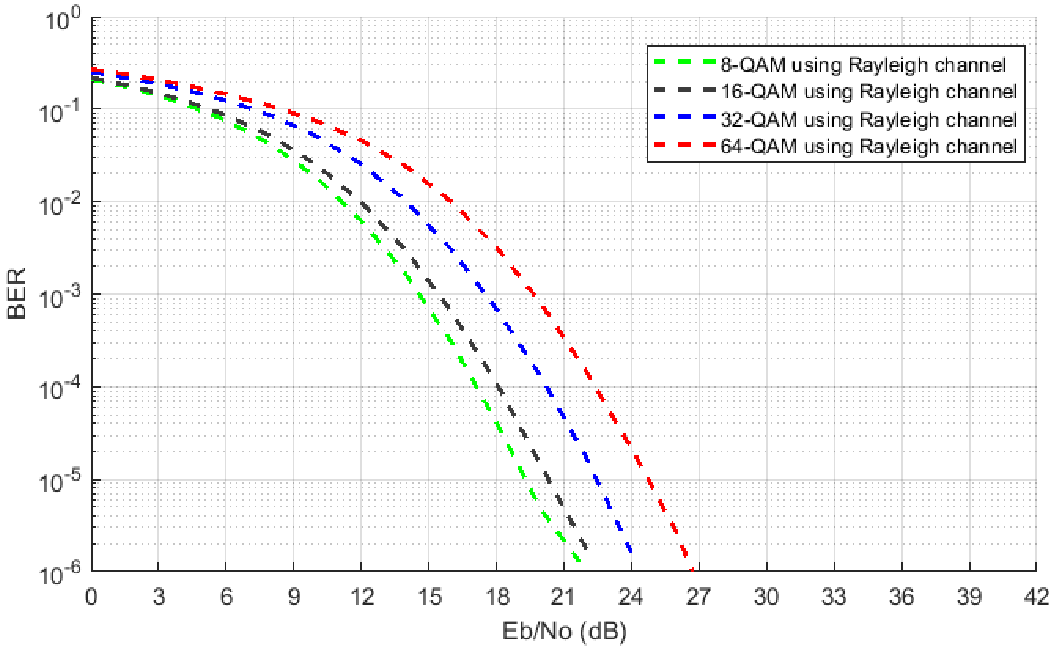


Figure (4.13) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – QAM over Rayleigh channel of the communication system model without interferer signals

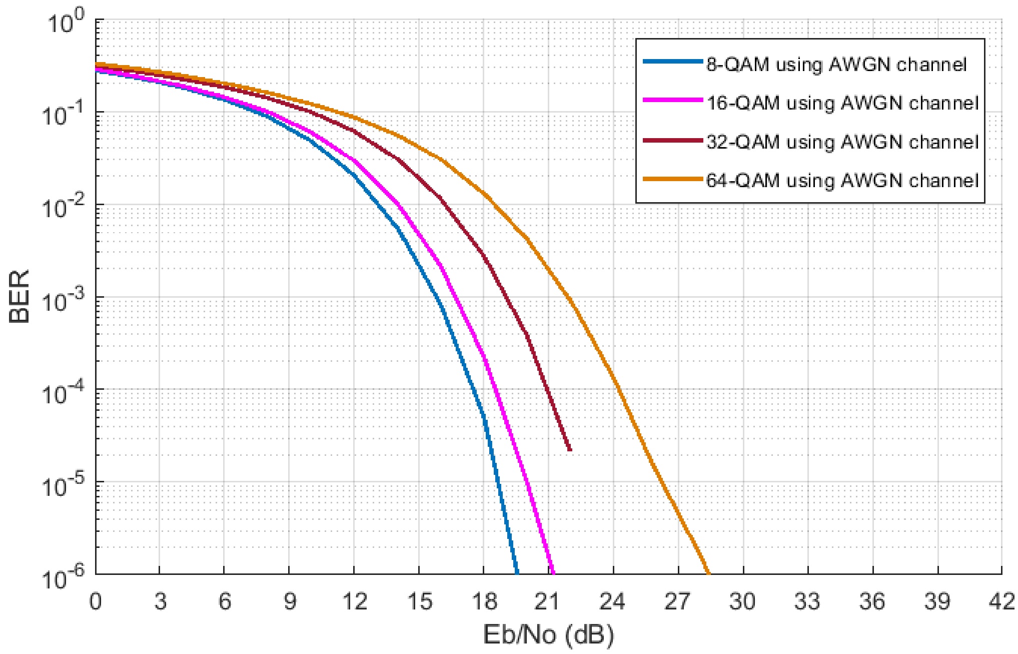


Figure (4.14) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – QAM over AWGN channel of the communication system model with two interferer signals

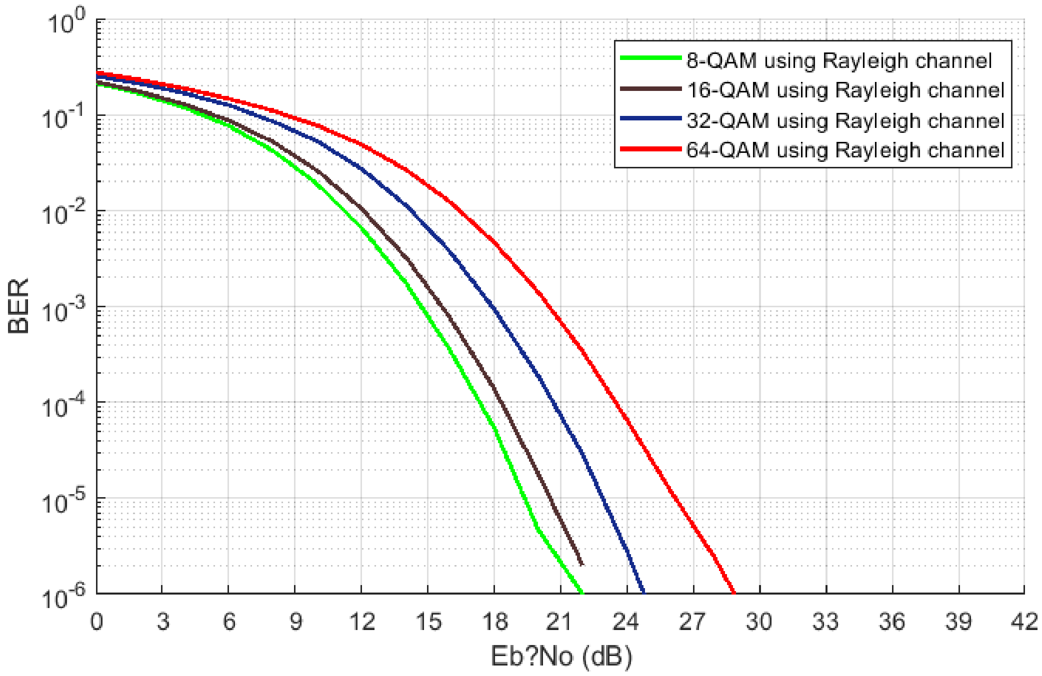


Figure (4.15) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – PSK over RayleighcChannel of the communication system model with two interferer signals

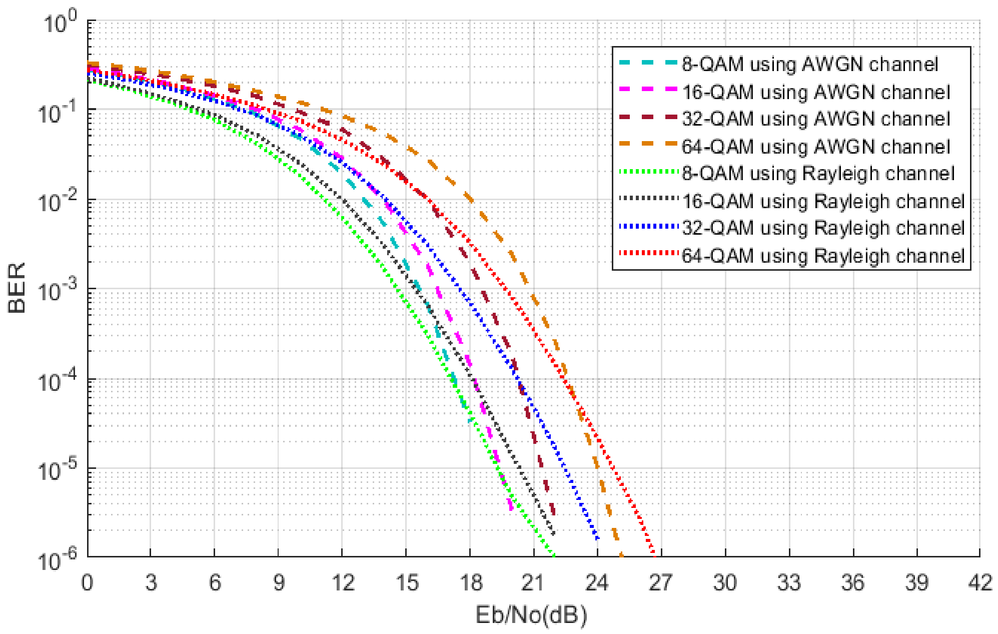


Figure (4.16) Bit rrror Rate vs. E_b/N_o using 8, 16, 32 and 64 – QAM over AWGN and Rayleigh channel of the communication system model without interferer signals

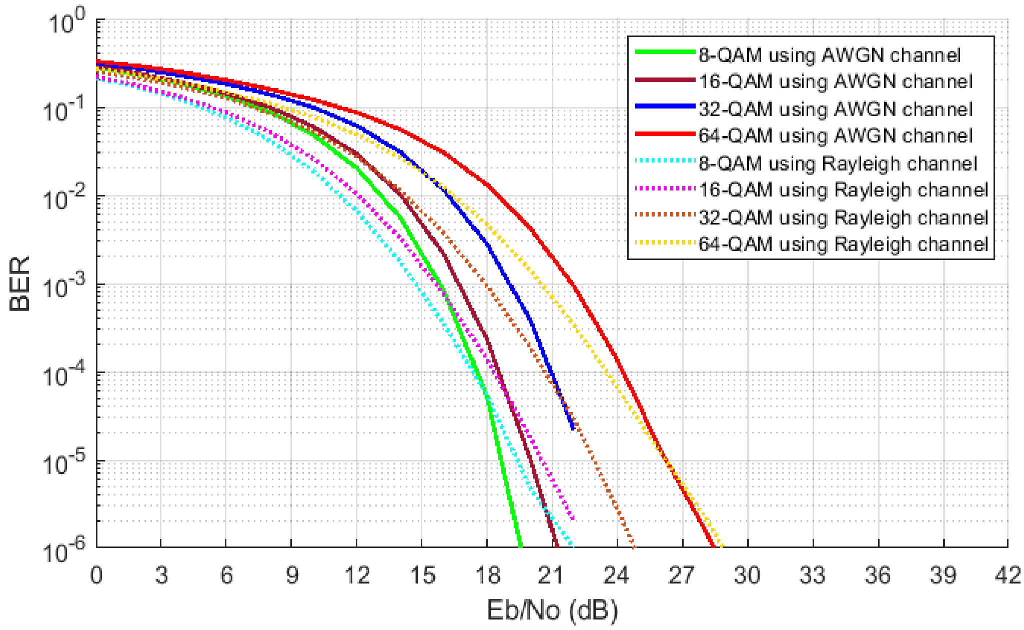


Figure (4.17) Bit error rate vs. E_b/N_o using 8, 16, 32 and 64 – QAM over AWGN and Rayleigh channel of the communication system model with interferer signals

when examining the plots in figures (4.12) to (4.17). BER performance for 8, 16, 32 and 64-QAM modulation, over AWGN and Rayleigh channels it can be observe that:

- It is quite apparent that as the level of the M-ary QAM system increases the BER increases i.e. an extra signal energy per bit to the power noise density (E_b/N_o) is required to obtain a better BER that is true for all the other schemes of modulation in use.
- The Rayleigh channel has a better BER performance than the AWGN channel as confirmed by figures (4.16) and (4.17) in the cases of without and with interferer signals and that can be clarified in that Rayleigh channel combines line of sight (LOS) and non-line of sight (NLOS) transmission components and because of that some of reflections that happens to the signal could have a positive reaction and improves performance.
- Consequently, that the best value for BER is for the low level (8-QAM) modulation as can be clearly observed i.e. less E_b/N_o is required to achieve a better BER.

4.5.2 Constellation diagrams and Power Spectra of the Signals

Figure (4.18) illustrates the constellation diagrams transmitted and received signals of the communication system model shown in figure (4.11) with two interferer signals over

AWGN and Rayleigh channels using M-ary QAM (M=8,16,32 and 64), where the Eb/N_o is selected 18 dB for the same reasoning mentioned in section 4.3.2

Moreover, the the power spectra density of the transmitted signal which include the original 8-QAM modulated signal plus the two interferer signals and also the power spectra density of the receivered signal at the output of the raised cosine receive filter are measured using Spectrum Analyzer as shown in figures (4.19) to (4.20) respectively for E_b/N_o. The power spectra density of using other M-ary QAM levels are very similar to the 8-QAM with very minor differences in the both cases of without and with interferer signals.

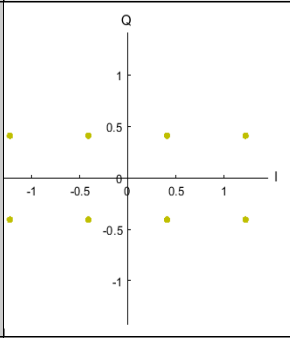
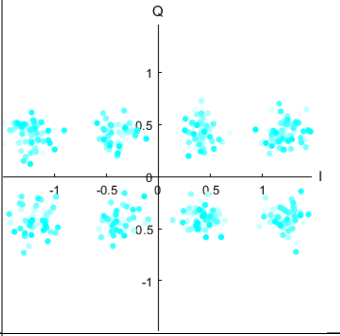
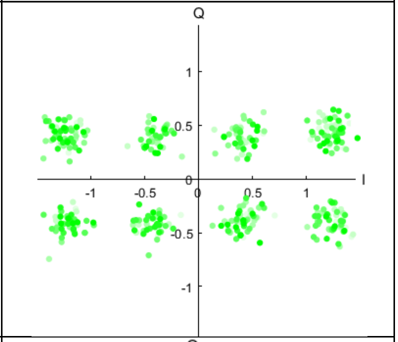
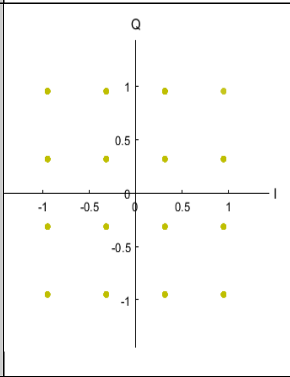
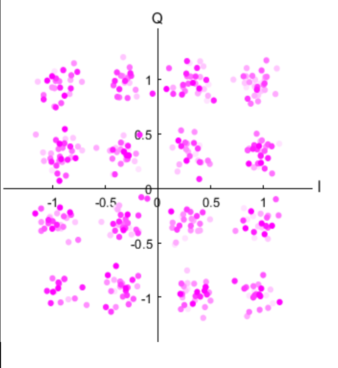
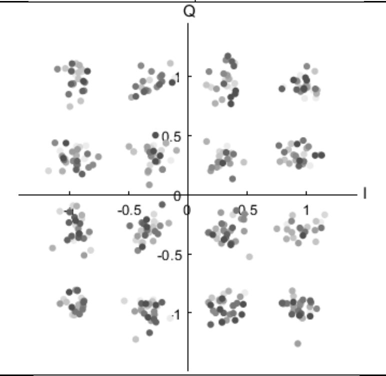
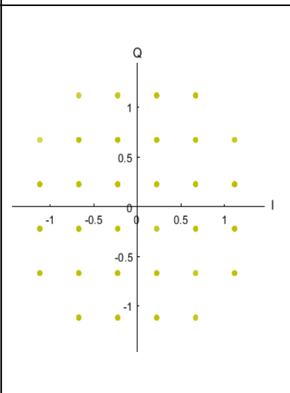
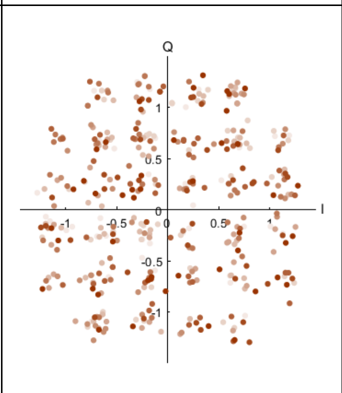
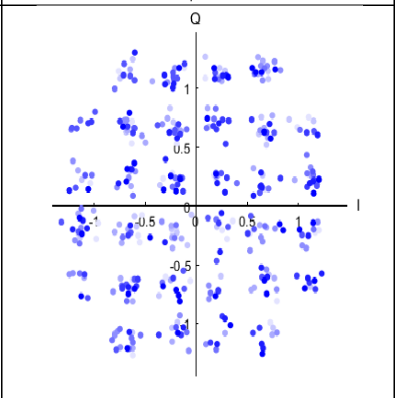
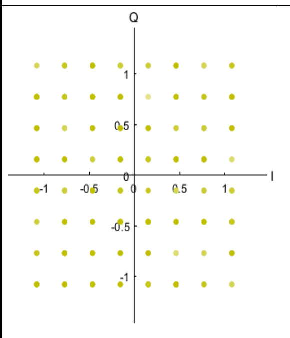
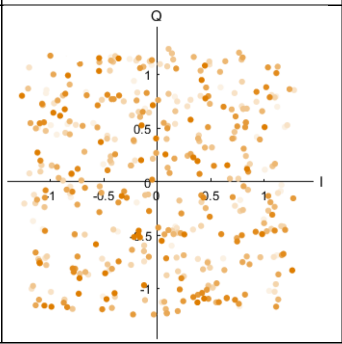
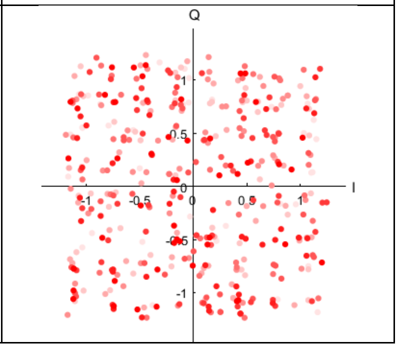
M-QAM Levels	Normal	Using AWGN Channel	Using Rayleigh Channel
8			
16			
32			
64			

Figure (4.18) Constellation diagrams of the communication system model with two interferer signals over AWGN and Rayleigh channels using 8, 16, 32 and 64 – QAM, E_b/N_o=18dBWhere I is in-phase Amplitude and Q is quadrature Amplitude

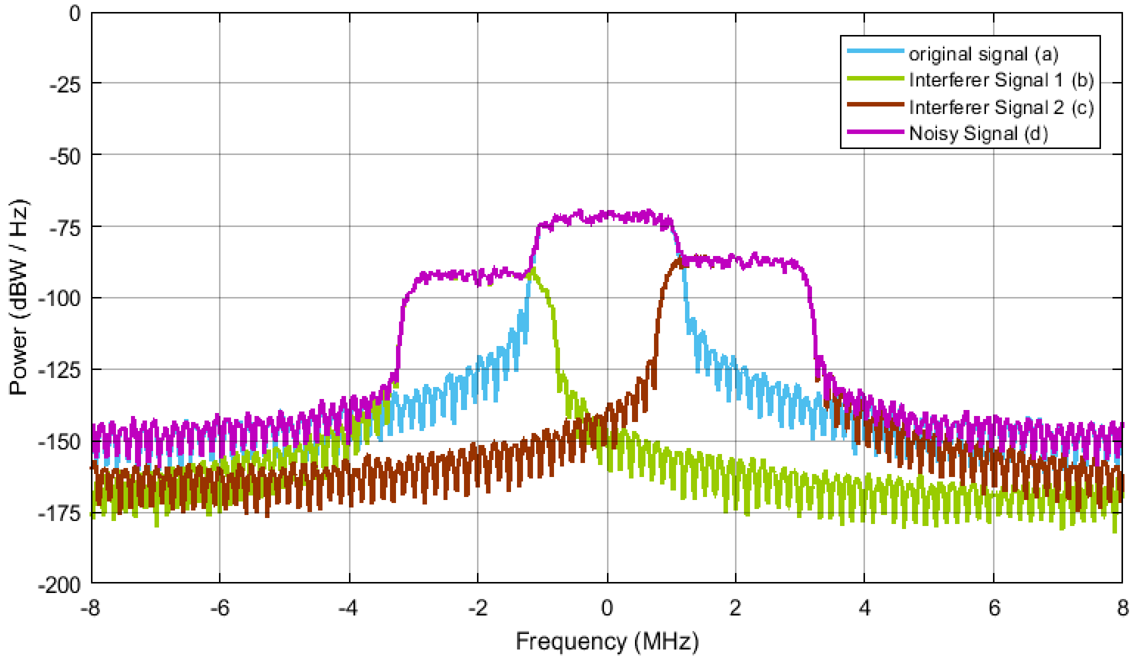


Figure (4.19) Power spectrum density of the original, interferer 1 &2 and noisy signals of the communication system model using 8– QAM. where Eb/No=18dB.

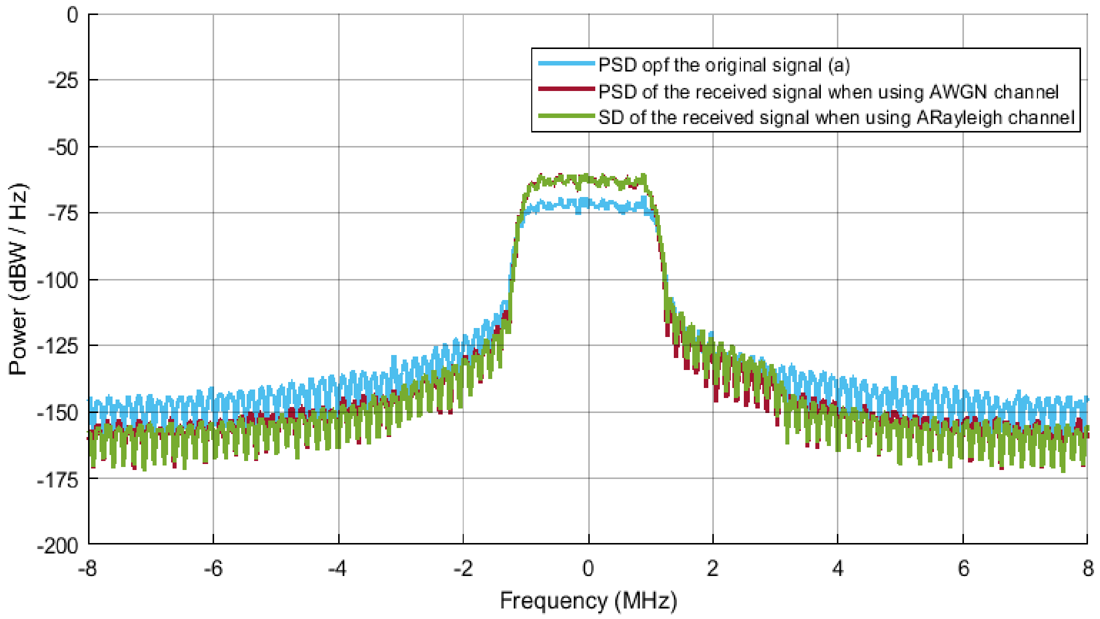


Figure (4.20) Power spectrum density of the received signals using 8,– QAM over AWGN and Rayleigh channels of the communication system model where Eb/No=18dB.

Referring to figures (4.18) to (4.20) it is observed that the received constellation diagrams and power spectra density of the receiver filtered signals achieved respectively over the AWGN and Rayleigh channels confirm the BER achieved results shown in figures (4.16) to (4.17).

Although to get better performance of the communication system model with two interferer signals over AWGN and Rayleigh channels when using higher level QAM modulation, it is needed to increase E_b/N_o ratio, which implies more signal power. AS a result, in fading environment situation it is better to use lower level QAM modulation to improve their performance.

4.6 Summery

Referring to the table (4.1) which outlines the comparison of BER performance results of both communication systems models with two interference signals using both of the M- ary PSK and QAM Over AWGN and Rayleigh Channels it can be deduced that:

1. For the 8 level PSK over the AWGN channel the difference in signal energy between the case with interference and without is 0.3 dB and over the Rayleigh channel is 0.2 dB. These values are quite close to the 8-QAM level.
2. For the 16 level case, the QAM scheme is better than the PSK scheme in terms of the difference in signal level between interference case and without interference for both AWGN and Rayleigh channels.
3. For the 32 and 64 level schemes the difference between the PSK and QAM gets very large.
4. In all cases the response over the Rayleigh channel is better than the AWGN channel and this is possibly because of what is known as a positive fading.
5. It is quite clear from the table that the QAM performance a lot better than PSK scheme even at high level in an interference environment and hence QAM is a better choice in such an environment over fading channel, since the largest difference in signal energy

in an environment with an interference (Adjacent and co-channel) and without is less than 1 dB. Hence QAM with very large bandwidth can be used in the harsh environment with an acceptable BER ratio, which in this case is 10^{-4} dB.

Table (4.1) Comparison between M-ary PSK and QAM used in the communication system model with two interferer signals over the AWGN and Rayleigh channels. where the BER=10^{-4}

Level (M)	**M-ary PSK**				**M-ary QAM**			
	AWGN Channel		Rayleigh Channel		AWGN Channel		Rayleigh Channel	
	Without Interference (dB) E_b/N_o	With Interference (dB) E_b/N_o	Without Interference (dB) E_b/N_o	With Interference (dB) E_b/N_o	Without Interference (dB) E_b/N_o	With Interference (dB) E_b/N_o	Without Interference (dB) E_b/N_o	With Interference (dB) E_b/N_o
8	17.70	18.0	17.50	17.70	17.25	17.50	17.10	17.34
16	22.20	23.17	22.0	22.50	18.20	18.50	18.10	18.33
32	27.18	32.95	26.80	31.40	20.25	20.90	20.25	20.70
64	33.0	$>> E_b/N_o$	32.70	$>> E_b/N_o$	22.60	24.60	22.40	23.50

5.1 Conclusion

Referring to the achieved simulation results it can be concluded that:

- The obtained results representing the BER performances for both 8, 16, 32 and 64- PSK and QAM modulations over AWGN and Rayleigh channels indicated that as the modulation level of implemented schemes increases the BER increases i.e. more E_b/N_o is needed to get a better BER. In addition to that Rayleigh model has a better performance in terms of BER than the AWGN channel as confirmed by constellation diagrams and power spectra density .
- For the 8 level PSK over the AWGN channel the difference in E_b/N_o value between the case with and without interference is 0.3 dB and over the Rayleigh channel is 0.2 dB. These values are fairly close to the 8-QAM level.
- For the 16 level case, the 16 -QAM system is better than the 16-PSK system in terms of the difference in signal level between with interference and without interference for both of communication channels.
- For the higher level of both PSK and QAM i. e. 32 and 64 the difference in signal energy level between these modulation schemes are very large.
- In all cases of using the two different M-ary modulation techniques the response over the Rayleigh channel is better than the AWGN channel and this is possibly because the Rayleigh model combines line of sight (LOS) and non-line of sight (NLOS) transmission components and hence some of reflections that happens to the signal could have a positive factor and improves performance.
- finally the best value for BER is for the low level PSK and QAM (M=8) modulation as can be clearly observed i.e. less E_b/N_o is required to get a better BER. In addition to that the M- ary QAM scheme performance is a lot better than

M- ary PSK scheme even at high level in an interference environment and hence QAM is a better choice in such an environment over fading channel.

5.2 Future Work

Some aspects are suggested in this thesis for future investigation as follows:

- Analysis and simulation of the effect of more than two Interference signals on AWGN , Rayleigh and Rician fading Channels using M-ary –PSK and M-ary QAM Modulation for wireless communication.
- Assessment, investigation and simulation of the effect of Adjacent and Co-Channel Interference on AWGN and Fading Channels using M-ary –PAM and M-ary DPSK Modulation for wireless communication.

References

[1] L. W. Couch, II, " Digital and Analog Communication Systems ", 8th Edition , 2013.

[2] Y. Duroc, "On the System Modeling of Antennas", Progress In Electromagnetics Research B, Vol. 21, 69{85, 2015.

[3] W. Tomasi, "Advanced Electronic Communications Systems", Pearson Education Limited, 6th Edition, 2014.

[4] L. Rangaiah, K. S. Rao and V. Thrimurthulu, "Reduction of Co-channel Interference in Cellular System, International Journal of Science and Technology, Vol. 1 Issue 1, November 2011.

[5] A. F. Molisch ,"Wireless Communications",2nd Edition, 2011.

[6] S. Guzelgon, H. Arslan, "A Wireless Communications Systems Laboratory Course", IEEE Transaction on Education. Vol. 53, No 4, November , 2010

[7] C. Campolo, A Molinaro , and A. Vinel ," Understanding Adjacent Channel Interference in Multi-Channel VANETs " , IEEE Vehicular Networking Conference(VNC). 2014.

[8] D. Altamirano, C. de Almeida"Evaluation of the Effects of Co-Channel Interference on the BER of Cellulr Networks" Revista Telecomnication, Vol. 13, No. 2 , Dec. 2011

[9] S. M. Usha and K.R. Nataraj "Analysis and Mitigation of Adjacent and Co-Channel Interference on AWGN Channel Using 8-PSK Modulation for Data Communication", IEEE WiSPNET 2016 conference, 2016.

[10] W. Stallings, "Wireless Communications and Networks", 2nd Edition, 2005.

[11] A. S. Babu and Dr. K.V Sambasiva Rao," Evaluation of BER for AWGN, Rayleigh and Rician Fading Channels under Various Modulation Schemes", International Journal of Computer Applications (0975 – 8887) Volume 26– No.9, July2011.

[12] V. Suresha ," Wireless Fundamentals & Key Enablers for LTE Features ", WC and LTE 4G module 1- 2019.

[13] N. Kovalevska, "Simulation of Adjacent Channel Interference Cancellation", M.sc Thesis, university of OSLO, 2008.

[14] A. W. Mustafa and K. G. Samarah, "Adjacent Channel Interference Reduction in OFDM Systems", Jordanian Journal of Computers and Information Technology (JJCIT), Vol. 3, No. 2, August 2017.

[15] O. S. Badarneh , Member, IEEE, and F. S. Almehmadi, Member, IEEE, " Performance of Multihop Wireless Networks in α-μ Fading Channels Perturbed by an Additive Generalized Gaussian Noise", IEEE Communications Letters, VOL. 20, NO. 5, MAY 2016.

[16] K.S. Ahn, "Performance Analysis of MIMO-MRC system in the Presence of Multiple Interference and Noise over Rayleigh Fading Channels", IEEE Transaction on Wireless Communication, Vol.8, No 7, July 2009.

[17] , I.A.Z. Qatawneh, "Multiple-Input Multiple-Output Transmission Over a Faded Channel", American Journal of Applied Sciences, 2013.

[18] D.D. Bohra , A. Bohra , "Bit Error Rate Analysis in Simulation of Digital Communication System with Different Modulation Schemes, IJISET – International Journal of Innovative Science, Engineering and Technology, Vol .I Issue 3,May 2014.

[19] G. Tesfay," Performance Analysis and Investigation of Digital Symbol Detection Techniques for Single and Multi-Carrier Modulations", M.sc Thesis, university of Addis Ababa University, Oct 2014.

[20] A,Mraz and L.Pap, "General Performance Analysis of M-PSK and M-QAM Wireless Communications Applied to OFDMA Interference", IEEE, 2010.

[21] H. Roelofs, R. Sirinivasan and W. van Etten ,"Performance Estimation of M-ary PSK in Co-channel Interference Using Fast Simulation", IEEE proc-commun, Vol. 150,No. 5, October 2003.

[22] S. Hong, "M-ARY Differential Phase Shift Keying with Non-Coherent Detection in Mobile Channels", M. Sc Thesis ,University of New South Wales, Australia July 1991.

[23] R.He and J.Xie, "BER Performance of MQAM and MPSK in Nakagami Fading Channel with STTD", The 14th IEEE 2003 International Symposium on Personal, lndoor and Mobile Radio Communication Proceedings,2003.

[24] P. K. Singya, P. Shaik, N. Kumar and V. Bhatia, Senior Member, IEEE," A Survey on Design and Performance of Higher-Order QAM Constellations", arXiv:2004.14708v1 [eess.SP] 30 April, 2020.

[25] S. M. Sadinov, "Simulation Study of M-ARY QAM Modulation Techniques using Matlab/Simulink", Opatija, Croatia , MIPRO 2017, May 22- 26, 2017.

[26] X.Li," Simulink-Based Simulation of Quadrature Amplitude Modulation(QAM) System ",proceeding of the IAJC-IJME international conference, 2008 .

[27] B.O. Omijeh , I.Eyo, "Comparative Study of Bit Error Rate of Different M-ary Modulation Techniques in AWGN Channel", American Journal of Networks and Communications, 2016.

[28] Ravisha and Saroj, " BER Performance for M-ARY Digital Communication", International Journal of Science and Research (IJSR), Volume 3 Issue 5, May 2014.

[29] B.A.Forouzan, Data Communications and Networking, 4th Edition, 2007.

[30] V.S. Acar, "Performance Evaluation of Different QAM Techniques Using Mathlab/Simulink, May 2015.

[31] S. W. Pallam, M. K. Luka and M. Aminu, " BER Evaluation of M-QAM Modulation in Wireless Transmission over AWGN Channel", International Journal of Scientific Research in Science, Engineering and Technology, Volume 1 | Issue 1, 2015.

[32] A.K.Singh and N.Singh, "Performance Evaluation of Digital M-ary Quadrature Amplitude Signalling Scheme", International Journal of Advanced Research in Electronics and Communication Engineering , Vol 6, Issue 10, October 2017.