"PERFORMANCE of 2:1 MISO SYSTEM in MOBILE COMMUNICATIONS"

The Thesis submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ENGINEERING
IN
ELECTRONICS AND COMMUNICATION ENGINEERING

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YEAR 2006

CERTIFICATE

I, SAHIL GARG hereby certify that the work which is being presented in this thesis entitled "**PERFORMANCE of 2:1 MISO SYSTEM in MOBILE COMMUNICATIONS**" by me in partial fulfillment of requirements for the award of degree of Master of Engineering in Electronics and Communication from THAPAR INSTITUTE OF ENGG & TECH (Deemed University), PATIALA, is an authentic record of my own work carried under the supervision of Mr. RAJESH KHANNA and Mrs. YUGNANDA PURI at TIET, PATIALA.

The matter presented in this thesis has not been submitted in any other University or Institute for the award of Master of Engineering.

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ABSTRACT

Wireless access to data networks is expected to be an area of rapid growth for both fixed and mobile communications. In this thesis, the major challenges provided by narrowband and broadband wireless channels and effective ways to mitigate those challenges through the use of techniques that take advantage of the spatial dimension are described. These techniques range from space-time processing, such as diversity combining, to spatial multiplexing and space-time coding, the discussion of which will be the main focus of the present thesis. In this thesis, the BER of 2:1 antenna systems using different modulation techniques in mobile environments such as Quadrature Phase Shift Keying (QPSK), Binary Phase Shift Keying (BPSK), 8-PSK and Quadrature amplitude modulation (M-QAM) are discussed. In addition to the above, it is proposed to compare the performances of various modulation techniques of 2:1 antenna systems under different fading environments such as Rayleigh, Rician and Nakagami fading. It is concluded that the BIT ERROR RATE (BER) and SYMBOL ERROR RATE (SER) is least in case of QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK for different fading environments i.e.: RAYLEIGH, RICIAN and NAKAGAMI. In case of all the modulation techniques, for a particular value of error rate, NAKAGAMI fading gives approximately 3db more gain as compared to RAYLEIGH fading. The performance of RICIAN fading lies in between NAKAGAMI and RAYLEIGH fading. So the performance of the system is better in case of NAKAGAMI fading environment.

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CHAPTER 1

1.1 INTRODUCTION

"If you can dream it, you can do it", according to this we can leap 3G to 4G along its features and future trends in mobile technology. In wireless communication, mobile technology is advanced and in this system 4G is the latest at present. 4G mobile, aims to provide an effective solution for the next generation mobile services. Progressing from previous three generations, 4G mobile systems have been significantly improving in terms of interactive multimedia services.

1.2 EVOLUTION OF MOBILE TECHNOLOGIES

The first radio telephone service was introduced in the US at the end of the 1940s, and was meant to connect mobile users in cars to the public fixed network [1]. In the 1960s, a new system launched by Bell Systems, called Improved Mobile Telephone Service" (IMTS), brought many improvements like direct dialing and higher bandwidth. The first analog cellular systems were based on IMTS and developed in the late 1960s and early 1970s. The systems were "cellular" because coverage areas were split into smaller areas or "cells", each of which is served by a low power transmitter and receiver. 1G analog system for mobile communications saw two key improvements during the 1970s: the invention of the microprocessor and the digitization of the control link between the mobile phone and the cell site. AMPS (Advance mobile phone system) were first launched by US which are 1G mobile system. It is best on FDMA technology which allows users to make voice calls within one country. Frequency Division Multiple Access (FDMA) is the most common analog system [2]. It is a technique whereby spectrum is divided up into frequencies and then assigned to users. With FDMA, only one subscriber at any given time is assigned to a channel. The channel therefore is closed to other conversations until the initial call is finished, or until it is handed-off to a different channel. A "full-duplex" FDMA transmission requires two channels, one for transmitting and the other for receiving. FDMA has been used for first generation analog systems. 2G digital cellular systems were first developed at the end of the 1980s. These systems digitized not only the control link but also the voice signal. The new system provided better quality and higher capacity at lower cost to consumers. GSM (Global system for mobile communication) was the first commercially operated digital cellular system which is based on TDMA. Time Division Multiple Access (TDMA) improves spectrum capacity by splitting each frequency into time slots. TDMA allows each user to access the entire radio frequency channel for the short period of a call. Other users share this same frequency channel at different time slots. The base station continually switches from user to user on the channel. TDMA is the dominant technology for the second generation mobile cellular networks.

3G systems promise faster communications services, including voice, fax and Internet, anytime and anywhere with seamless global roaming. ITU's IMT-2000 global standard for 3G has opened the way to enabling innovative applications and services (e.g. multimedia entertainment, infotainment and location-based services, among others). The first 3G network was deployed in Japan in 2001. 2.5G networks, such as GPRS (Global Packet Radio Service) are already available in some parts of Europe.3G technology supports 144 Kbps bandwidth, with high speed movement (e.g. vehicles), 384 Kbps (e.g. on campus) & 2 Mbps for stationary (e.g. in building).

At present the download speed for mode data is limited to 9.6kbit/sec which is about 6 times slower than an ISDN (Integrated services digital network) fixed line connection. Recently, with 504i handsets the download data rate was increased 3-fold to 28.8kbps. However, in actual use the data rates are usually slower, especially in crowded areas, or when the network is "congested". For third generation mobile (3G, FOMA) data rates are 384 kbps (download) maximum, typically around 200kbps, and 64kbps upload since spring 2001. Fourth generation (4G) mobile communications will have higher data transmission rates than 3G. 4G mobile data transmission rates are planned to be up to 20 megabits per second. 3G initiative came from device manufactures, not from operators. In 1996 the development was initiated by Nippon Telephone & Telegraph (NTT) and Ericsson; in 1997 the Telecommunications Industry Association (TIA) in the USA chose CDMA as a technology for 3G; in 1998 the European Telecommunications Standards Institute (ETSI) did the same thing. Code Division Multiple Access is based on "spread" spectrum technology [2]. Since it is suitable for encrypted transmissions, it has long been used for military purposes. CDMA increases spectrum capacity by allowing all users to occupy all channels at the same time. Transmissions are spread over the whole radio band, and each voice or data call are assigned a unique code to differentiate from the other calls carried over the same spectrum. CDMA allows for a “soft hand-off”, which means that terminals can communicate with several base stations at the same time. In 1998 wideband CDMA (W-CDMA) and cdma2000 were adopted for the Universal Mobile Telecommunications System (UMTS).WCDMA and CDMA 2000 are two major proposals for 3G. In this CDMA the information bearing signal is multiplied with another faster rate, wider bandwidth digital signal that may carry a unique orthogonal code. W-CDMA uses dedicated time division multiplexing (TDM) whereby channel estimation information is collected from another signal stream. CDMA 2000 uses common code division multiplexing (CDM) whereby channel estimation information can be collected with the signal stream.

The study of 4G mobile communication services is very important as it provides wider bandwidths, higher bit rates, data rates greater than 2 Mbps, global mobility and service portability, broadband and large capacity, support interactive multimedia services such as teleconferencing, wireless Internet, providing users with high quality color video images, 3D graphic animation games, and audio services in 5.1 channels and low cost.

1.3 PROBLEMS IN 3G SYSTEMS

In the field of mobile communication services, the 4G mobile services are the advanced version of the 3G mobile communication services. The various problems that 3G systems faced are as under:

- Lesser bandwidths.
- Low data rates (2 Mbps for indoor communications).
- Global mobility and service portability not present.
- High cost.
- Less power efficiency.
- Less system capacity.

The WWRF (World Wide Research Forum) has suggested following techniques to overcome the problems of 3G.

- Multiple Input Multiple Outputs (MIMO).
- Space Time Processing (STP).
- Space Time Coding (STC).
- Advanced Signal Processing Techniques.
- Realistic Modeling of Fading Environment.
- Adaptive Antennas.

In this thesis the 2:1 MISO systems which are subset of MIMO systems are taken up for further study. A brief introduction of MIMO systems is given next.

1.4 MULTIPLE INPUTS MULTIPLE OUTPUTS (MIMO)

Multiple-input multiple-output (MIMO) is a promising technology for next generation wireless systems to enhance capacity and robustness of the link. MIMO technology is enabled by the presence of multiple transmit antennas and multiple receive antennas in the communication link and is being investigated for cellular communication, broadband wireless access, as well as for wireless local area networks (WLANs). The benefits of MIMO communication are obtained through a combination of antenna arrays that provide spatial diversity from the propagation channel. Achieving the highest performance in MIMO communication systems generally requires spacing the antennas far apart (typically at multiples of the wavelength) yet small user terminals such as notebook computers or cell phones necessitate placing the antennas close together.

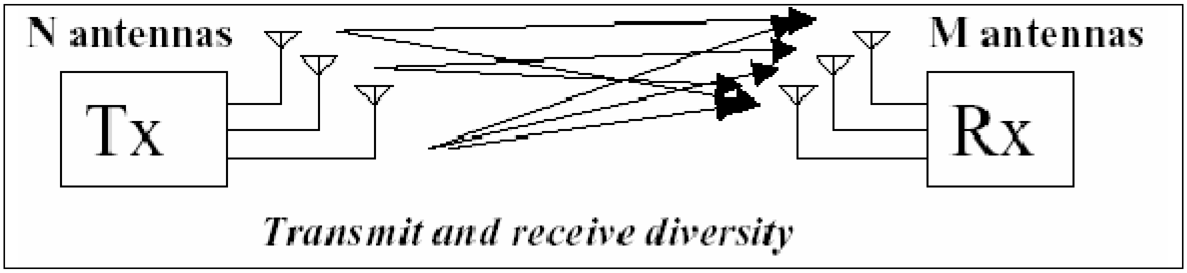

Figure-1.1: Multiple Input Multiple Out

These systems can be compared in terms of the Maximum Diversity Gain and Maximum Array Gain available.

1.5 SPACE TIME PROCESSING (STP)

Space-time processing refers to manipulating signals that are received at or transmitted from an antenna array so as to improve performance. Cellular radio signals processing functions include modulation/demodulation, channel coding/decoding, equalization and diversity combining. These functions are performed by the radio modem. Current cellular radio modems do not, however, efficiently exploit the spatial dimension offered by multiple antennas. The spatial domain can be used to reduce co-channel interference (CCI), increase diversity gain, improve array gain, and combat inter-symbol interference (ISI). These improvements can have significant impact on the overall performance of a wireless network. Modems that operate with multiple antennas in receive and transmit can exploit the spatial domain by performing space-time processing (STP). Receive STP improves signal to interference ratio through CCI cancellation, mitigates fading through improved receive diversity, offers higher signal-to-noise ratio through array gain and reduces ISI through spatial equalization. Likewise, transmit STP reduces CCI generation, improves transmit diversity and in some cases also reduces ISI generation.

1.6 SPACE TIME CODING

Space-time coding is an effective technique to combat fading in wireless communications. Space-time codes are a highly bandwidth-efficient approach to signaling within wireless communication that takes advantage of the spatial dimension by transmitting a number of data streams using multiple co-located antennas. There are various approaches to the coding structures, including space-time trellis codes and space-time turbo codes. The central issue in all these various coding structures is the exploitation of multipath effects in order to achieve very high spectral efficiencies. The spectral efficiencies of traditional wireless systems range between 1-5bps/sec/Hz but by using space-time techniques spectral efficiencies of 20-40bps/sec/Hz have been possible. Hence, space-time coding enables an increase in capacity by an order of magnitude.

1.7 STATEMENT OF PROBLEM

S.M.Alamouti presented a simple two-branch transmit diversity scheme. Using two transmit antennas and one receive antenna the scheme provides the same diversity order as maximal-ratio receiver combining (MRRC) with one transmit antenna, and two receive antennas. It was also shown that the scheme may easily be generalized to two transmit antennas and M receive antennas to provide a diversity order of 2M [3].Alamouti studied the 2:1 MISO system and gave results for Rayleigh faded channel using BPSK modulation. In this thesis the work is extended further to study the Alamouti scheme for various other modulation techniques under different fading environments.

1.8 OBJECTIVES OF THESIS

- To study the Alamouti scheme for Rayleigh faded channel using BPSK modulation.
- To study the performance of 2:1 system for BPSK in different fading environments.
- To study the performance of 2:1 system for QPSK in different fading environments.

- To study the performance of 2:1 system for 8-PSK in different fading environments.
- To study the performance of 2:1 system for 8-QAM in different fading environments.
- Compare the performances of 2:1 system under different fading environments i.e.: Rayleigh, Rician and Nakagami for different modulation techniques.

1.9 THESIS ORGANISATION

- Chapter 2 includes the literature survey about spatial diversity under two conditions i.e. channel unknown to the transmitter: MISO and channel known to the transmitter: MIMO. It also includes description about space time coding (STC) and its coding and interleaving architecture. Further it tells us about the space time trellis codes (STTC), space time block codes (STBC) and transmission data rate.
- Chapter 3 includes performance of 2:1 MISO system for different modulation schemes in RAYLEIGH fading channel. It discusses about the basic communication system model and RAYLEIGH fading channel. The various modulation techniques such as BPSK, QPSK, 8PSK, M-QAM are also discussed. It also includes the MONTE CARLO SIMULATION basics for various modulations. The simulation results of BER/SER for RAYLEIGH fading along with comparison of various modulations under the same channel is mentioned.
- Chapter 4 includes performance of 2:1 MISO system for different modulation schemes in RICIAN fading channel. It discusses about the RICIAN fading channel and simulation results of BER/SER for RICIAN fading along with comparison of various modulations under the same channel.
- Chapter 5 contains performance of 2:1 MISO system for different modulation schemes in NAKAGAMI fading channel. It includes description about NAKAGAMI fading channel and simulation results of BER/SER for NAKAGAMI fading along with comparison of various modulations under the same channel.
- Chapter 6 includes conclusions and future scopes.

CHAPTER 2

2.1 LITERATURE SURVEY

The mobile communication channel is susceptible to multipath fades due to a large number of scatterers and reflectors. Diversity techniques are used to mitigate the effects of the multipath phenomenon. For a communication system to exhibit acceptable performance, a certain minimum signal level is needed at the receiver. When the signal level is less than this minimum threshold, the system is in a fade .To make the system more reliable, the length of time that these fades occur must be decreased. Due to multipath reflections, the channel impulse response looks like a series of impulses with different amplitudes. It is desirable to minimize the amount of time the received signal is in a fade. If the receiver is supplied with L independent copies of the transmitted signal, then the probability that all L paths fade is p^L , where p is the probability that any one signal is in a fade.

Diversity is the method by which these L independent versions are received [4]. This technique is known as receive diversity. There are various methods to provide receive diversity in communication systems. Frequency diversity transmits the message on multiple carrier frequencies spaced sufficiently far apart so as to provide independent fading versions of the channel. Time diversity transmits the message in different time slots, providing signal repetition. The other receive diversity techniques are antenna diversity, bandwidth expansion and coding and interleaving. All these methods are wasteful in that they use up excessive channel bandwidth. Another method to mitigate the effects of multipath is transmit diversity. With transmit diversity, multiple receiving antennas are spaced at least half a wavelength of the carrier frequency apart to ensure that the signals reaching them are statistically independent [5]. The advantage of transmit diversity over frequency and time diversity is that the message carrying signal does not have to be rebroadcast. The diversity is achieved by employing multiple antennas on the transmitter side, which is illustrated in Figure-2.1.

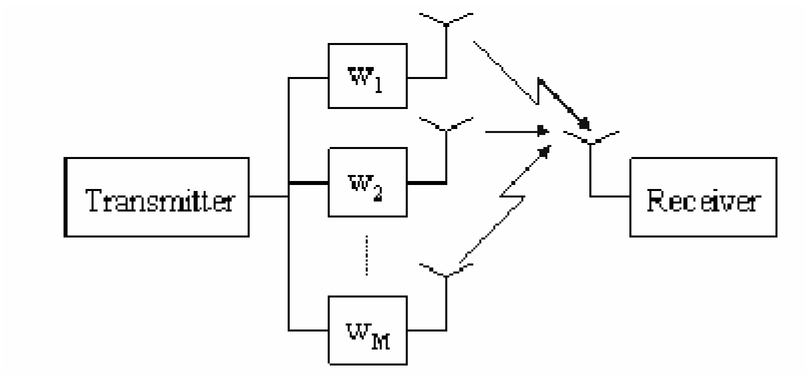

Figure-2.1.: Transmit Diversity

But merely by transmitting the same signal from different positions in space produces no gains. With receive diversity in the receiver, the signals arriving at the different receive antennas can be combined in the receiver. But no such option exists with transmit diversity, since the different branches inevitably add up in space before they reach the receiver, the same way as the multipath phenomenon appears. This means that with identical transmitted signals from any number of antennas, no diversity gain will be produced. The transmit diversity may be leveraged in both the presence and absence of channel knowledge at the transmitter for MISO and MIMO systems.

2.2 MISO systems: Channel unknown to the transmitter

Consider a simple but ingenious transmit diversity technique-the Alamouti scheme. In this technique, two different symbols s_1 and s_2 are transmitted simultaneously from antennas 1 and 2 respectively during the first symbol period, followed by signals $-s_2^*$ and s_1^* from antennas 1 and 2 respectively during the next symbol period [6]. Assuming that the channel remains constant over the two symbol periods and it is frequency flat. Therefore, $h = [h_1 \quad h_2]$ and the signals y_1 and y_2 received over the two symbol periods are given by

$$y_1 = \sqrt{\frac{E_s}{2}} h_1 s_1 + \sqrt{\frac{E_s}{2}} h_2 s_2 + n_1 \qquad 2.2.1$$

$$y_2 = -\sqrt{\frac{E_s}{2}} h_1 s_2^* + \sqrt{\frac{E_s}{2}} h_2 s_1^* + n_2 \qquad 2.2.2$$

Where n_1 and n_2 are noise with $\varepsilon\{|n_1|^2\} = \varepsilon\{|n_2|^2\} = N_0$ and $\frac{E_s}{2}$ is the average energy per symbol period per antenna. The receiver forms a rearranged signal vector y as follows:

$$\begin{aligned} \begin{bmatrix} y_1 \\ y_2^* \end{bmatrix} &= \sqrt{\frac{E_s}{2}} \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix} \\ &= \sqrt{\frac{E_s}{2}} H_{eff} s + n \end{aligned} \qquad 2.2.3$$

The average received SNR, η, per symbol is given by

$$\eta = \frac{\|h\|_F^2 \rho}{2} \qquad 2.2.4$$

The Alamouti scheme extracts a diversity order of 2 (full M_T diversity), even in the absence of channel knowledge at the transmitter. A somewhat similar approach has been proposed for wideband CDMA systems and is now part of the CDMA 2000 standard. Since $\varepsilon\{\|h\|_F^2\} = 2$ for $h=h_w$, the average SNR at the receiver $\bar{\eta} = \rho$. Therefore, the absence of channel knowledge at the transmitter does not allow array gain. Transmit diversity techniques in the absence of channel knowledge at the transmitter may be designed to extract spatial diversity in systems with more than two transmit antennas.

2.3 MISO systems: Channel known to the transmitter

Consider a MISO system with MT transmit antennas and a frequency flat fading channel. The vector channel h is given by

$$h = \lfloor h_1 \; h_2 \; \ldots\ldots.. h_{M_T} \rfloor$$

to exploit spatial diversity, the signal is transmitted from each transmit antenna after being weighted appropriately, so that the signals arrive in phase at the receive antenna and add coherently. The signal at the receiver is given by

$$y = \sqrt{\frac{E_s}{M_T}} hws + n \qquad 2.3.1$$

Where y is the received signal, w is a weight vector of dimension $M_T \times 1$ and n is noise. The weight vector must be chosen subject to $\|w\|_F^2 = M_T$ to ensure that the average total power of the transmitted signal is Es. This scheme is known as transmit-maximal ratio combining. The SNR at the receiver η is given by

$$\eta = \|h\|_F^2 \rho \qquad 2.3.2$$

Hence, if perfect channel knowledge is available to the transmitter, transmit-MRC will deliver array gain and diversity gain. So in order to utilize the potential diversity gains associated with independently propagating signals, the signal is first coded then transmitted and these coding schemes are called Space Time Coding Schemes.

2.4 SPACE TIME CODING

Space-time coding is a specific method to make use of multiple antennas from a diversity point of view improving link reliability and power efficiency [6]. In general, space-time codes are able to obtain a full diversity order of with Rate=1.From an “error rate performance view", space-time coding brings diversity advantage (i.e. slope of the performance curve) and coding advantages (i.e. horizontal shift in the curve).

2.5 CODING AND INTERLEAVING ARCHITECTURE

A general coding architecture for transmission over multiple antennas is described as under. Consider figure 2.3 in which a block of qk bits is input to a block that performs the functions of temporal coding, interleaving and symbol mapping. In the process q (N-K) parity bits are added and N symbols are output.2q is the modulation order. The N symbols are now input to a ST coder that adds an additional MTT-N parity symbols are now input to a ST coder that adds an additional MTT-N parity symbols and packs the resulting MTT symbols into an MT*T frame of length T. The block/frame is then transmitted over T symbol periods and is referred to as ST Codeword. The signaling (data) rate on the channel is qK/T bits/transmission and should not exceed the channel capacity if we wish to signal with zero error. Signaling rate is given by,

$$\frac{qK}{T} = q\left(\frac{qK}{qN}\right)\left(\frac{N}{T}\right) \qquad 2.5.1$$

$$= q\, r_t\, r_s \qquad 2.5.2$$

Where r_t=qK/qN is the temporal code rate of the outer encoder and r_s=N/T is the spatial code rate defined as the average number of independent symbols (constructed from the input symbols) transmitted from the M_T antennas over T symbols periods. When all transmit antennas send one symbol per symbol period we get r_s=1.On the other hand, in spatial multiplexing, M_T independent symbols per symbol period are sending to get $r_s=M_T$. Depending on the choice of ST coding, the spatial rate r_s varies between 0 to M_T.

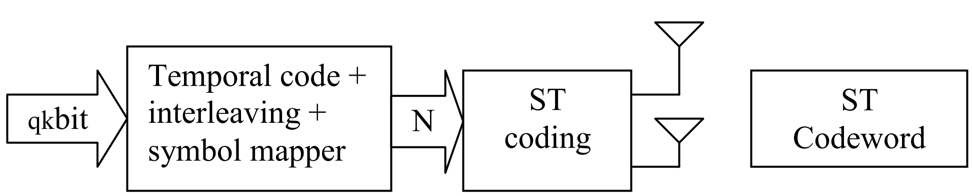

Figure-2.2: Coding architecture [6]

There are two main classes of space time codes:

2.6 SPACE TIME TRELLIS CODES (STTC)

STTC is a system where code, modulation and array processing techniques are jointly designed so that the temporal orthogonality criterion may be relaxed. Traditional error correction codes involve adding redundant bits to the bit stream, thus decreasing the bandwidth efficiency of the transmission. In STTC, redundant information is distributed over the space and the time domain, leading to an increased bandwidth efficiency and improved performance for the same transmission rate [7]. The time multiplexing approach used in the delay diversity scheme was a precursor to such a system. In this scheme, delayed replicas of the same symbol are transmitted via different antenna elements so that the flat fading channel becomes a frequency selective fading channel. Tarokh and Calderbank used principles from trellis coded modulation to create STTC. STTC achieves both diversity and coding gain, but suffers from high receiver complexity. The complexity is due to the fact that the space-time maximum likelihood sequence estimator is often implemented as a vector-Viterbi Algorithm. Since this code is in fact a trellis implementation, at the receiver, the trellis path with the minimum distance is chosen.

2.7 SPACE TIME BLOCK CODES (STBC)

The concept was generalized for more than transmit antennas by Tarokh et.al. and named as “Space-Time Block Codes”. Space-time block code (STBC), which possesses the advantage of possible diversity both spatially and temporally has been given enormous attention in the past few years. Extensive efforts have been made in designing STBC to achieve full rate and full diversity because of its relative simplicity of implementation. However, this is sometimes realized at the expense of channel capacity. STBC involves block encoding an incoming stream of data and simultaneously transmitting the symbols over n_T transmit antenna elements. This technique was first proposed by Alamouti for $n_T = 2$ and $n_R = 1$, where n_R is the number of receive antenna elements. Alamouti’s scheme is a simple transmit diversity scheme which improves the signal quality at the receiver on one side of the link by simple processing across two transmit antennas on the opposite side.

2.8 TRANSMISSION DATA RATE

Generally, there are two ways of considering transmission data rate, i.e., symbol rate R_S and bit rate R_B. If we let L denote the number of symbols transmitted during T time slots in the system, then the transmission symbol rate is given by $R_S = \frac{L}{T}$ symbols per channel use (pcu). Further, suppose the transmitted signals are selected from a certain constellation set, and let τ denote the constellation size, e.g., $\tau = 4$ for Q- PSK signals and $\tau = 16$ for 16-QAM. Then the number of bits contained in one symbol equals log2 r. Therefore, we define the transmission bit rate as $R_B = \frac{L}{T}\log_2 \tau$ bits pcu. Here, the data rate to be maximized refers to the transmission symbol rate, and for a given MIMO system, there exist an upper bound for the maximum number of symbols that can be safely transmitted. Therefore, maximization of the transmission data rate becomes an important criterion for the code design in a MIMO system.

CHAPTER 3

PERFORMANCE OF 2:1 MISO SYSTEM FOR DIFFERENT MODULATION SCHEMES IN RAYLEIGH FADING CHANNEL

3.1 BASIC COMMUNICATION SYSTEM MODEL

Consider a wireless communication system with 2 antennas at the base station and 1 antenna at the receiver (decoder). At each time instant t, signals are transmitted simultaneously from the 2 transmit antennas [8]. The channel is assumed to be a flat fading channel and it can be relaxed without any change to the method of encoding and decoding. At the receiver 1 antenna is present where decoding process is carried out as shown in figure-3.1.

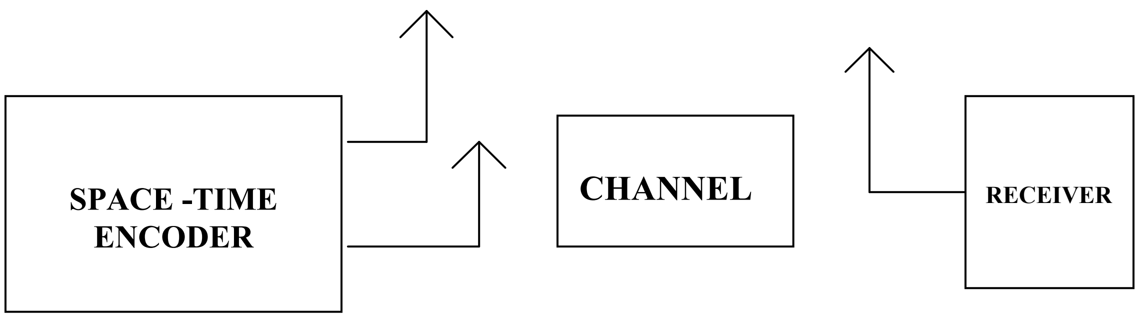

Figure-3.1: System Model

Figure-3.2 shows the baseband representation of the new two branch transmit diversity scheme. The scheme uses two transmit antennas and one receive antenna and is called as Alamouti's code which is the first open-loop transmit diversity technique which provides full diversity with linear processing at the receiver complexity[3]. The new transmit diversity scheme can improve the error performance, data rate and capacity of wireless communications systems. The decreased sensitivity to fading may allow the use of higher level modulation schemes to increase the effective data rate, or smaller reuse factors in a multi cell environment to increase system capacity. The scheme may also be used to increase the range or the coverage area of wireless systems. In other words, the new scheme is effective in all of the applications where system capacity is limited by multipath fading and, hence, may be a simple and cost-effective way to address the market demands for quality and efficiency without a complete redesign of existing systems. Furthermore, the scheme seems to be a superb candidate for next-generation wireless systems as it effectively reduces the effect of fading at the remote units using multiple transmit antennas at the base stations. It may be defined by the following three functions:

- The encoding and transmission sequence of information symbols at the transmitter;
- The combining scheme at the receiver;
- The decision rule for maximum likelihood detection.

a) The Encoding and Transmission Sequence*:* At a given symbol period, two signals are simultaneously transmitted from the two antennas. The signal transmitted from antenna zero is denoted by s_0 and from antenna one by s_1. During the next symbol period signal ($-s_1$*) is transmitted from antenna zero, and signal s_0* is transmitted from antenna one where * shows the complex conjugate operation. This sequence is shown in table 3.1. In table 3.1, the encoding is done in space and time (space–time coding). The encoding, however, may also be done in space and frequency. Instead of two adjacent symbol periods, two adjacent carriers may be used (space–frequency coding).

Table-3.1: Encoding and transmission sequence for the two branch transmit diversity scheme

Time ↓	**Space** ⟶	**Antenna 0**	**Antenna 1**
Time t		S_0	s_1
Time t +T		$(-s_1^*)$	s_0^*

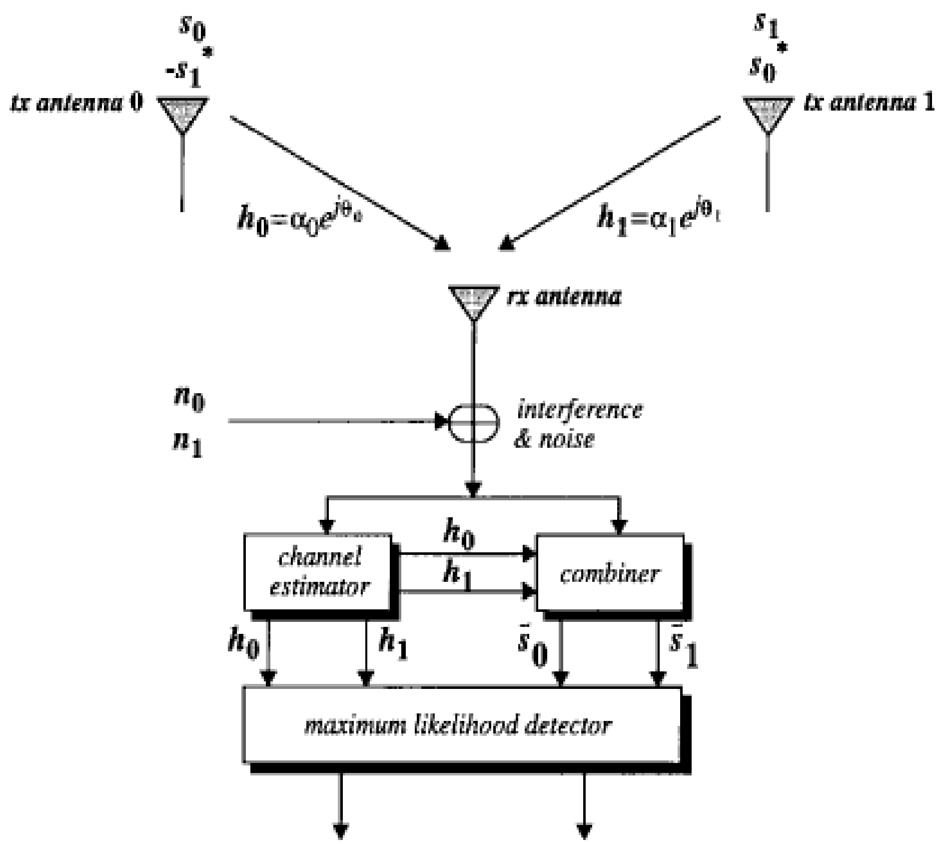

Figure-3.2: The new two-branch transmit diversity scheme with one receiver.

The channel at time may be modeled by a complex multiplicative distortion $h_0(t)$ for transmit antenna zero and $h_1(t)$ for transmit antenna one. Assuming that fading is constant across two consecutive symbols, we can write

$$h_0(t) = h_0(t+T) = h_0 = a_0 e^{j\theta_0}$$
$$h_1(t) = h_1(t+T) = h_1 = a_1 e^{j\theta_1} \qquad 3.1.1$$

where T is the symbol duration. The received signals can then be expressed as

$$r_0(t) = r(t) = h_0 s_0 + h_1 s_1 + n_0$$
$$r_1 = r_1(t+T) = -h_0 s_1^* + h_1 s_0^* + n_1 \qquad 3.1.2$$

where r_0 and r_1 are the received signals at time t and (t+T) and n_0 and n_1 are complex random variables representing receiver noise and interference.

b) The Combining Scheme: The combiner shown in Figure-3.2 builds the following two combined signals that are sent to the maximum likelihood detector:

$$\tilde{s}_0 = h_0^* r_0 + h_1 r_1^*$$
$$\tilde{s}_1 = h_1^* r_0 - h_0 r_1^* \qquad 3.1.3$$

Substituting (3.1.1) and (3.1.2) into (3.1.3) we get

$$\tilde{s}_0 = \left(\alpha_0^2 + \alpha_1^2\right)s_0 + h_0^* n_0 + h_1 n_1^*$$
$$\tilde{s}_1 = \left(\alpha_0^2 + \alpha_1^2\right)s_1 - h_0 n_1^* + h_1^* n_0 \qquad 3.1.4$$

c) The Maximum Likelihood Decision Rule: These combined signals are then sent to the maximum likelihood detector which, for each of the signals and, uses the decision rule expressed for PSK signals. The resulting combined signals in (3.1.4) are equivalent to that obtained from two-branch MRRC. The only difference is phase rotations on the noise components which do not degrade the effective SNR. Therefore, the resulting diversity order from the new two-branch transmit diversity scheme with one receiver is equal to that of two-branch MRRC.

Two-Branch Transmit Diversity with M Receivers

There may be applications where a higher order of diversity is needed and multiple receive antennas at the remote units are feasible. In such cases, it is possible to provide a diversity order of 2 with two transmit and receive antennas. The generalization to receive antennas is trivial. Figure-3.2 shows the baseband representations of the new scheme with two transmit and two receive antennas. The encoding and transmission sequence of the information symbols for this configuration is identical to the case of a single receiver, shown in table 3.1. Table 3.2 defines the channels between the transmit and receive antennas, and table 3.3 defines the notation for the received signal at the two receive antennas.

Where

$$r_0 = h_0 s_0 + h_1 s_1 + n_0$$
$$r_1 = -h_0 s_1^* + h_1 s_0^* + n_1$$
$$r_2 = h_2 s_0 + h_3 s_1 + n_2$$
$$r_3 = -h_2 s_1^* + h_3 s_0^* + n_3 \qquad 3.1.5$$

n_o, n_1, n_2 and n_3 are complex random variables representing receiver thermal noise and interference. The combiner in Figure-3.3 builds the following two signals that are sent to the maximum likelihood detector

$$\tilde{s}_0 = h_0^* r_0 + h_1 r_1^* + h_2^* r_2 + h_3 r_3^*$$
$$\tilde{s}_1 = h_1^* r_0 - h_0 r_1^* + h_3^* r_2 - h_2 r_3^* \qquad 3.1.6$$

Substituting the appropriate equations we have

$$\tilde{s}_0 = \left(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2\right)s_0 + h_0^* n_0 + h_1 n_1^* + h_2^* n_2 + h_3 n_3^*$$
$$\tilde{s}_1 = \left(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2\right)s_1 - h_0 n_1^* + h_1^* n_0 - h_2 n_3^* + h_3^* n_2 \qquad 3.1.7$$

These combined signals are then sent to the maximum likelihood decoder which for signal uses the decision criteria expressed in (3.1.8) or (3.1.9) for PSK signals.

Choose iff

$$\left(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1\right)\left|s_i\right|^2 + d^2\left(\tilde{s}_0, s_i\right) \le \left(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1\right)\left|s_k\right|^2 + d^2\left(\tilde{s}_0, s_k\right)$$

3.1.8

Choose iff

$$d^2\left(\tilde{s}_0, s_i\right) \le d^2\left(\tilde{s}_0, s_k\right) \qquad \forall i \ne k \qquad 3.1.9$$

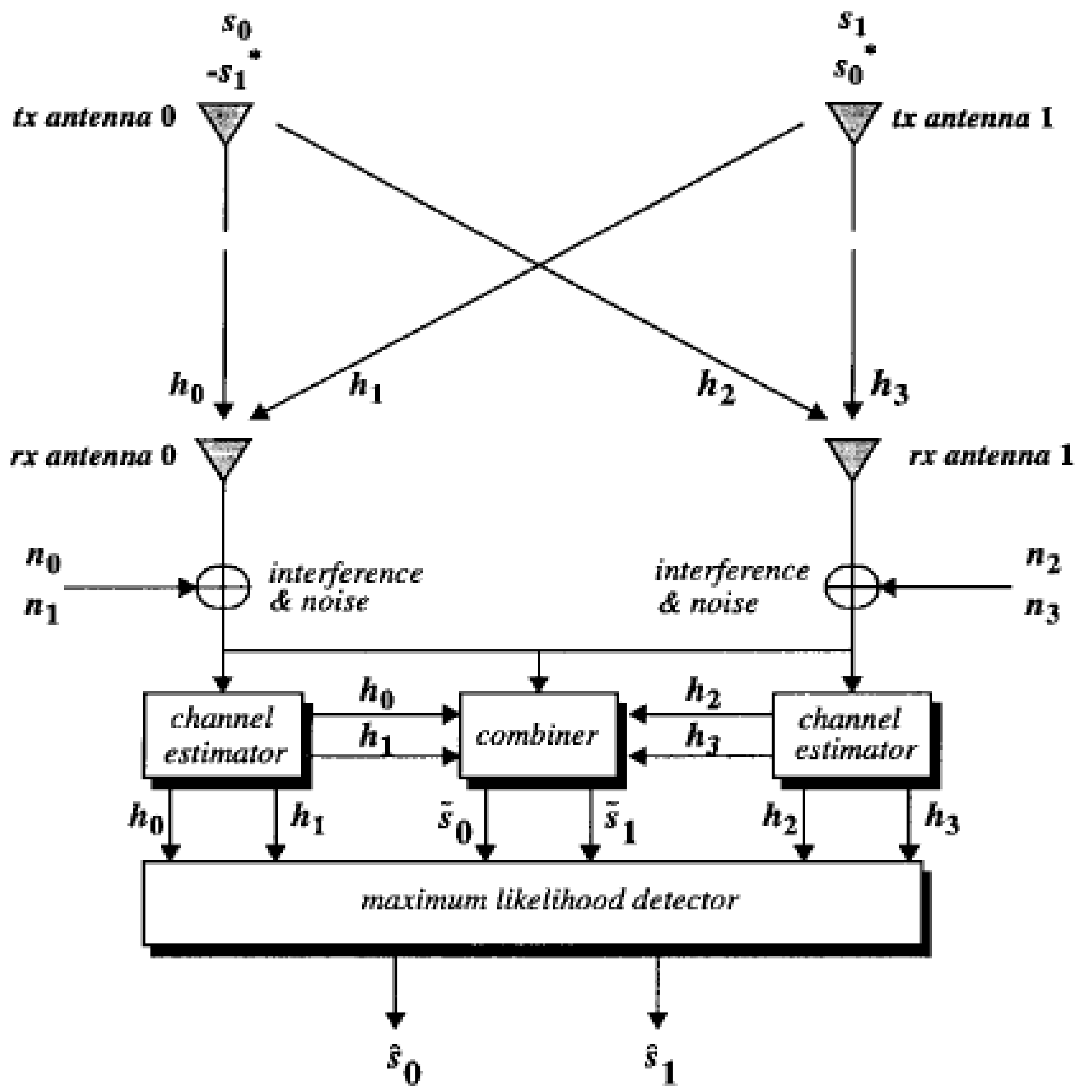

Figure-3.3: The new two-branch transmit diversity scheme with two receivers.

Similarly, for s_1 using the decision rule is to choose signal s_i iff

$$\left(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1\right)\left|s_i\right|^2 + d^2\left(\tilde{s}_1, s_i\right) \le \left(\alpha_0^2 + \alpha_1^2 + \alpha_2^2 + \alpha_3^2 - 1\right)\left|s_k\right|^2 + d^2\left(\tilde{s}_1, s_k\right)$$

3.1.10

Or, for PSK signals,

Choose iff

$$d^2\left(\tilde{s}_1, s_i\right) \le d^2\left(\tilde{s}_1, s_k\right) \qquad \forall i \ne k \qquad 3.1.11$$

Table-3.2: Definition of channel between the transmit and receive antennas

Time ↓	Space →	RX Antenna 0	RX Antenna 1
TX antenna 0		H_0	h_2
TX antenna 1		h_1	h_3

Table-3.3: Notation for the received signals at the two receive antennas

Time ↓	Space →	RX Antenna 0	RX Antenna 1
Time t		R_0	r_2
Time t+T		r_1	r_3

Therefore, the resulting diversity order from the new two-branch transmit diversity scheme with two receivers is equal to that of the four-branch MRRC scheme. It is interesting to note that the combined signals from the two receive antennas are the simple addition of the combined signals from each receive antenna, i.e., the combining scheme is identical to the case with a single receive antenna. We may hence conclude that, using two transmit and receive antennas, we can use the combiner for each receive antenna and then simply add the combined signals from all the receive antennas to obtain the same diversity order as –branch MRRC. In other words, using two antennas at the transmitter, the scheme doubles the diversity order of systems with one transmit and multiple receive antennas. An interesting configuration may be to employ two antennas at each side of the link, with a transmitter and receiver chain connected to each antenna to obtain a diversity order of four at both sides of the link.

3.2 CHANNEL MODELS

Multipath fading is due to the constructive and destructive combination of randomly delayed, reflected, scattered and diffracted signal components. This type of fading is relatively fast and is therefore responsible for the short-term signal variations. Depending on the nature of the radio propagation environment, there are different models describing the statistical behavior of the multipath-fading envelope. The Rayleigh, Rician and Nakagami are the most commonly used statistical models to represent small-scale fading phenomenon.

3.2.1 Rayleigh Fading Channel

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 multipath component [9]. In the Rayleigh flat fading channel model, it is assumed that the channel induces amplitude, which varies in time according to the Rayleigh distribution. When the channel impulse response is modeled as a zero-mean complex-valued Gaussian process, the envelope at any instant is Rayleigh-distributed. The Rayleigh distribution of a received complex envelope of a signal $z(t) = |r(t)|$ at any time t is given as

$$p_z(x) \frac{x}{\sigma^2} e^{\left(\frac{-x^2}{2\sigma^2}\right)} \qquad (x \geq 0) \qquad 3.2.1$$

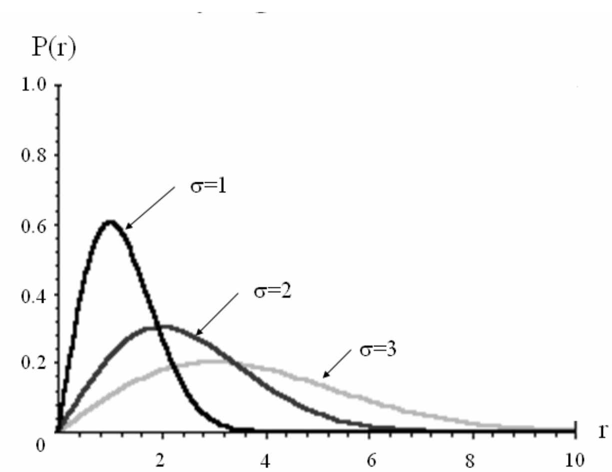

Figure-3.4: PDF of the envelope variation

where σ is the root man square value of the received voltage signal before envelope detection, and σ2 is the time-average power of the received signal before envelope detection. It is well known that the envelope of the sum of two quadrature Gaussian noise signals obeys a Rayleigh distribution. This fading distribution could be applied to any scenario where there is no LOS path between transmitter and receiver antennas.

3.3 MODULATION TECHNIQUES

A modulation scheme is needed to transmit information over a communication channel. Among the various modulation methods are; amplitude modulation (data encoded by changing the amplitude of the signal), frequency modulation (data encoded by changing the frequency of the signal), and phase modulation (data encoded by changing the phase of the signal).

The modulation methods chosen for this thesis are: Binary phase shift keying (BPSK), Quadrature phase shift keying (QPSK), M-ary phase shift keying (8PSK) and M-Quadrature amplitude modulation (M-QAM).

3.3.1 BPSK (shifting the phase by 180°)

As the word binary implies, BPSK can be used to encode one of two values. BPSK encodes data onto a carrier by changing the phase of the signal by 180 degrees to indicate either a data value of one or a data value of zero. BPSK is simplest form of PSK. It uses two phases which are separated by 180 and so can termed as 2-psk.it does not particularly matter exactly where the constellation points are positioned .This modulation is the most robust of all the PSK'S.

BPSK Constellation diagram

A constellation display provides a qualitative analysis. It is the two-dimensional display of the baseband amplitude and phase values of the receive symbols taken at a particular time. These points are a summation of plots. The vector from the center of the diagram to a specific constellation point is representative of the amplitude.

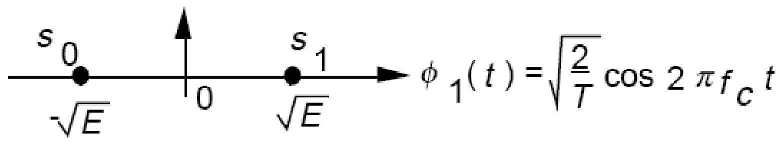

Figure-3.5: BPSK constellation diagram

Binary data is often conveyed with the following signals:-

$$s_0(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t) \quad \text{for binary "0"} \qquad 3.3.1.1$$

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi) = -\sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t) \quad \text{For binary "1"} \qquad 3.3.1.2$$

Where f_c is the frequency of the carrier wave.
Hence, the signal space can be represented by the single basis function

$$\phi(t) = \sqrt{\frac{2}{T_b}} \cos(2\pi f_c t) \qquad 3.3.1.3$$

Where 0 is represented by $\sqrt{E_b}\phi(t)$ and 1 is represented by - $\sqrt{E_b}\phi(t)$ where this assignment is arbitrary.

3.3.2 QPSK (shifting the phase by 90°)

QPSK (Quadrature Phase Shift Keying) is a phase modulation algorithm. Phase modulation is a version of frequency modulation where the phase of the carrier wave is modulated to encode bits of digital information in each phase change. The "PSK" in QPSK refers to the use of Phased Shift Keying. Phased Shift Keying is a form of phase modulation which is accomplished by the use of a discrete number of states. QPSK refers to PSK with 4 states. The "Quad" in QPSK refers to four phases in which a carrier is sent in QPSK: 45, 135, 225, and 315 degrees. Because QPSK has 4 possible states, QPSK is able to encode two bits per symbol.

Table-3.4: QPSK phase vs data

Phase	Data
45 degrees	Binary 00
135 degrees	Binary 01
225 degrees	Binary 11
315 degrees	Binary 10

QPSK Constellation diagram

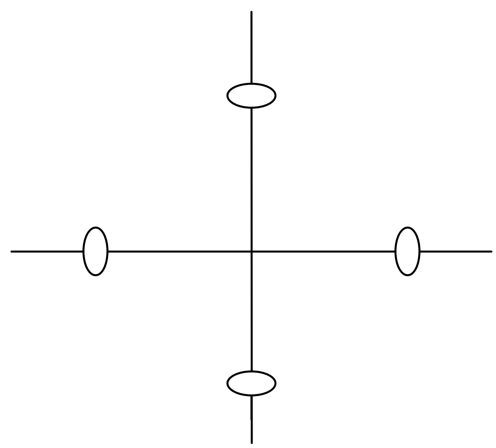

Figure-3.6: QPSK constellation diagram

3.3.3 MPSK (8-PSK)

The two basis functions represent a 2-dimensional signal space and are given below

$$\psi 1(t) = \left\{ \sqrt{\frac{2}{T}} \cos(\omega_c t) \right\} \qquad 3.3.3.1$$

$$\psi 2(t) = \left\{ \sqrt{\frac{2}{T}} \sin(\omega_c t) \right\} \qquad 3.3.3.2$$

The transmitted signal can also be represented by

$$Si(t) = \left\{ \sqrt{\frac{2}{T}} \cos[\omega_c t + (i-1)\frac{\pi}{2}] \right\} \qquad 0 \le t \le T$$

$$i = 1,2,3,\ldots,8. \qquad 3.3.3.3$$

Equation (3.3.3.3) explicitly shows that the phase of the transmitted signal is varied in accordance with the symbol to be transmitted when using PSK.

8-PSK Constellation diagram

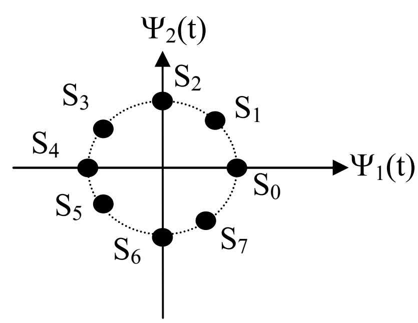

Figure-3.7: 8PSK Constellation

When an information signal is being transmitted with the help of a particular modulation technique over a communication channel the effect of fading and noise are very important to be considered.

3.3.4 M-QAM (8-QAM)

Quadrature amplitude modulation (QAM) is a modulation scheme in which two sinusoidal carriers, one exactly 90 degrees out of phase with respect to the other, are used to transmit data over a given physical channel. Because the orthogonal carriers occupy the same frequency band and differ by a 90 degree phase shift, each can be modulated independently, transmitted over the same frequency band, and separated by demodulation at the receiver. For a given available bandwidth, QAM enables data transmission at twice the rate of standard pulse amplitude modulation (PAM) without any degradation in the bit error rate (BER). QAM and its derivatives are used in both mobile radio and satellite communication systems.

8-QAM constellation diagram

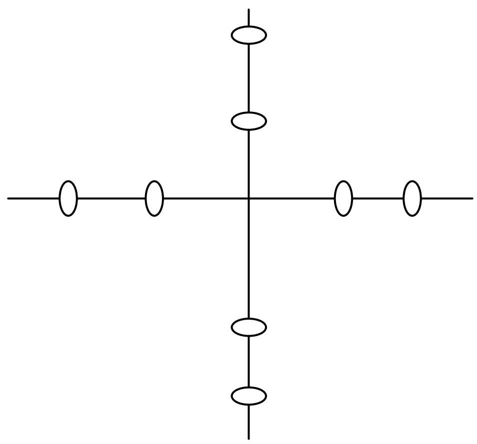

Figure-3.8: 8-QAM Constellation diagram

3.4 Monte Carlo (MC) Simulation Basics for various modulations

Monte Carlo simulation is a common computational tool to imitate the behavior of complex real-life systems. MC simulation was named after the city Monte Carlo, famous with its casinos containing games of chance.

Components of a generic MC Simulation:

• **Probability density function:** The physical/mathematical model under consideration must be described statistically.

• **A random number generator:** Most mathematical software packages/programming languages have uniform random generators.

• **Sampling rule:** Generation of samples with desired pdf.

• **Scoring (tallying):** Counting the number of occurrences of events of interest

• **Error estimation:** Estimation of error as a function of the number of trials in order to set the number of trials respectively.

Consider the simple communication system model that includes a modulator-demodulator pair.

• Randomly generate a stream of data bits. For e.g.: in case of 8-QAM table-5 gives the stream of data bits.

Table-3.5: 8-QAM data bits

Bit value	Amplitude	Phase shift
000	1	None
001	2	None
010	1	1/4
011	2	1/4
100	1	1/2
101	2	1/2
110	1	3/4
111	2	3/4

• Generate the transmitted signal corresponding to the data stream.

• Apply the transmitted signal to the filter which models the channel under consideration.

• Randomly generate noise values and add to the filter output.

• Feed the received signal into demodulator.

• Count the number of bits that are in error and compute bit-error-probability.

3.5 SIMULATION RESULTS OF BER for RAYLEIGH FADING WITH DIFFERENT MODULATION TECHNIQUES

MODULATION TECHNIQUE: BPSK

FADING: RAYLEIGH

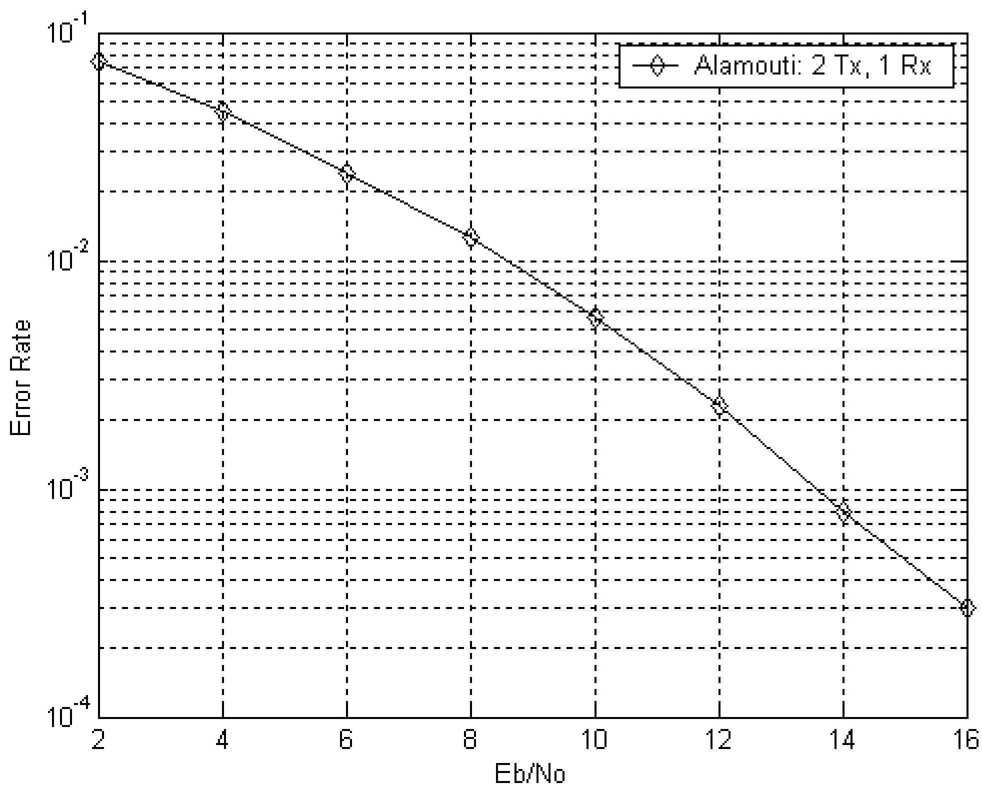

Figure-3.9: BER error performance of BPSK for RAYLEIGH fading

MODULATION TECHNIQUE: QPSK

FADING: RAYLEIGH

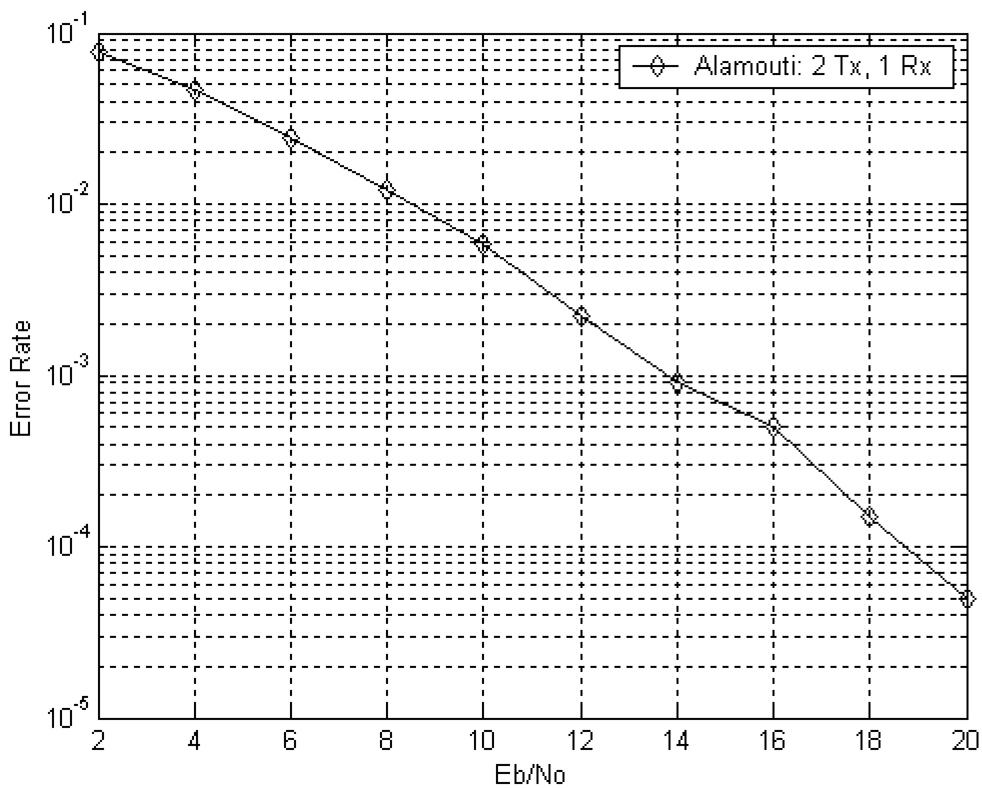

Figure-3.10: BER error performance of QPSK for RAYLEIGH fading

MODULATION TECHNIQUE: 8-PSK

FADING: RAYLEIGH

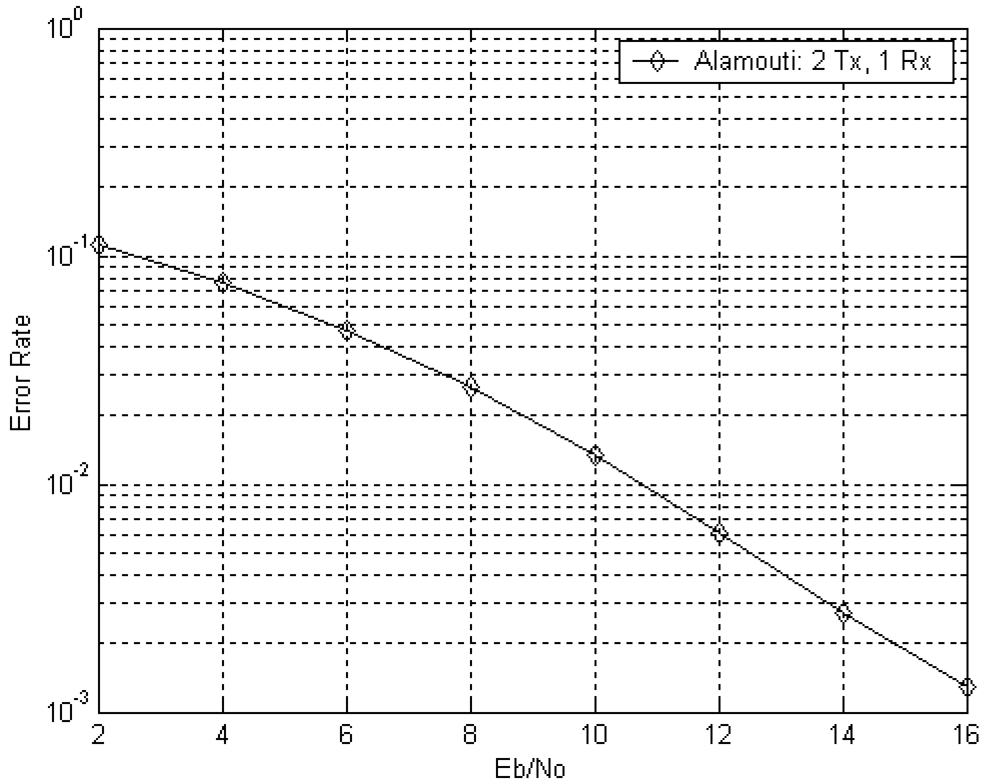

Figure-3.11: BER error performance of 8-PSK for RAYLEIGH fading

MODULATION TECHNIQUE: 8-QAM

FADING: RAYLEIGH

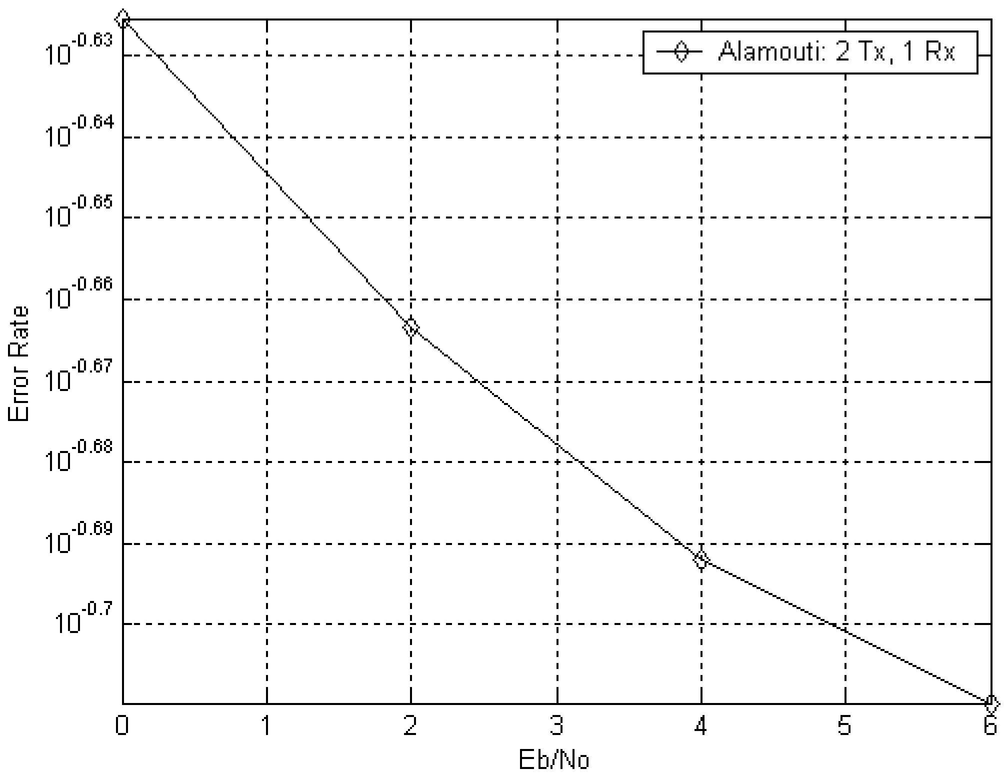

Figure-3.12: BER error performance of 8-QAM for RAYLEIGH fading

The Figure 3.9-3.12 show that in case of RAYLEIGH fading the bit error rate (BER) is least for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK . Hence the performance of the Quadrature Amplitude Modulation is best when RAYLEIGH fading in present in 2:1 MISO system.

3.6 SIMULATION RESULTS OF SER for RAYLEIGH FADING WITH DIFFERENT MODULATION TECHNIQUES

MODULATION TECHNIQUE: BPSK

FADING: RAYLEIGH

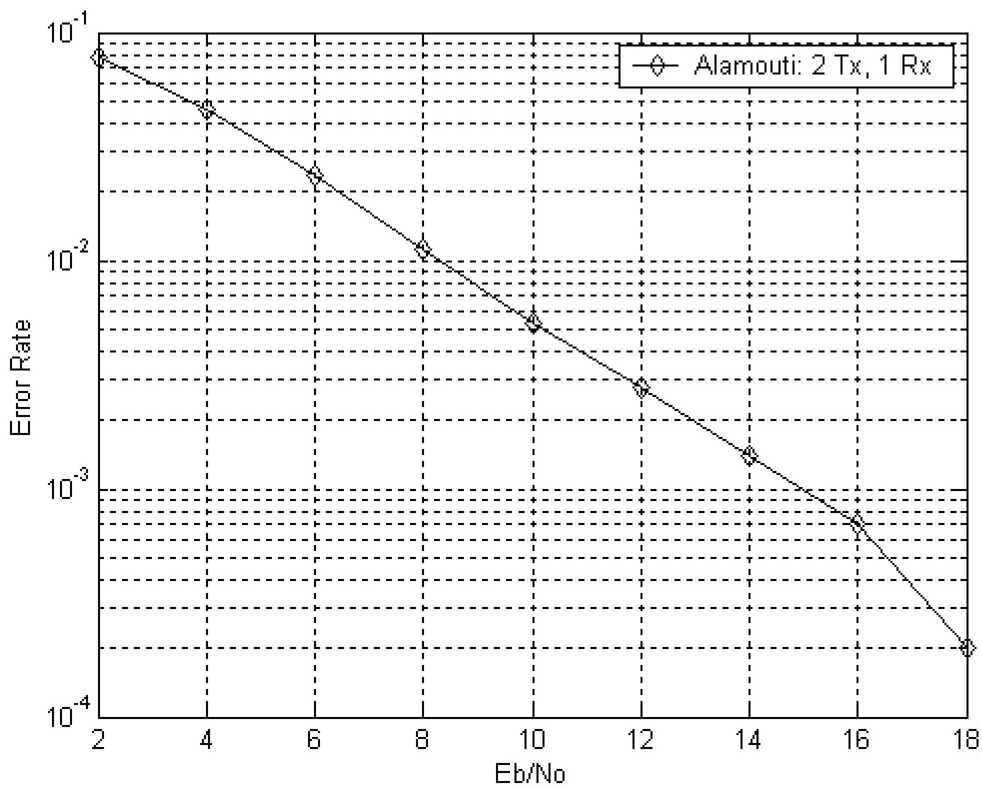

Figure-3.13: SER error performance of BPSK for RAYLEIGH fading

MODULATION TECHNIQUE: QPSK

FADING: RAYLEIGH

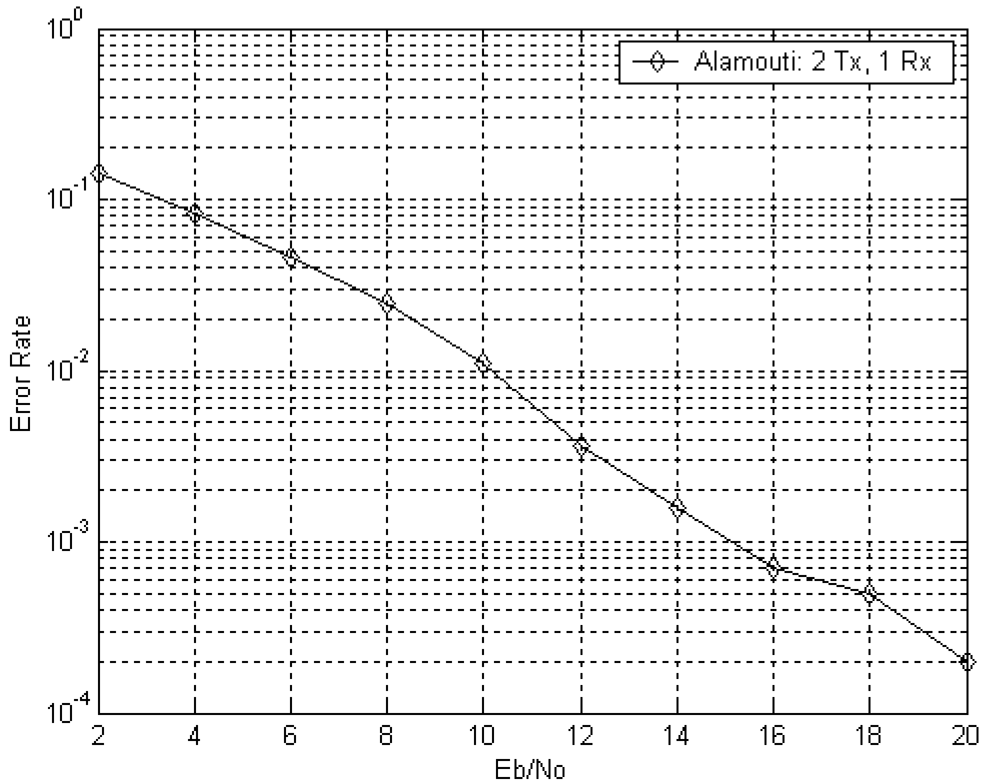

Figure-3.14: SER error performance of QPSK for RAYLEIGH fading

MODULATION TECHNIQUE: 8-PSK

FADING: RAYLEIGH

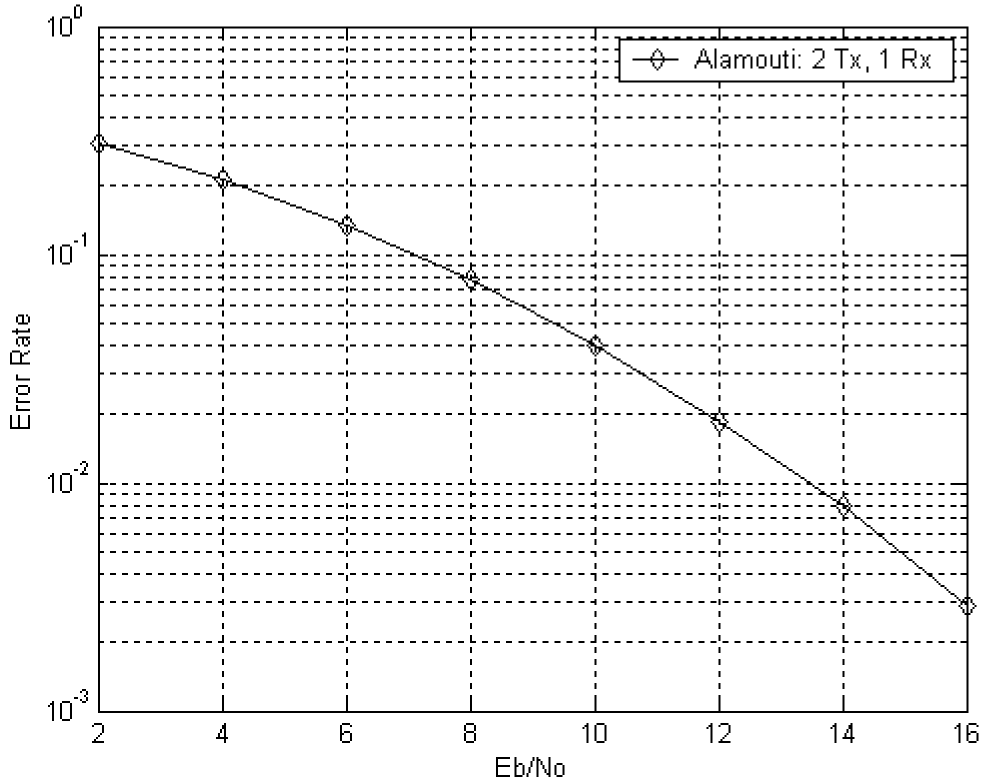

Figure-3.15: SER error performance of 8-PSK for RAYLEIGH fading

MODULATION TECHNIQUE: 8-QAM

FADING: RAYLEIGH

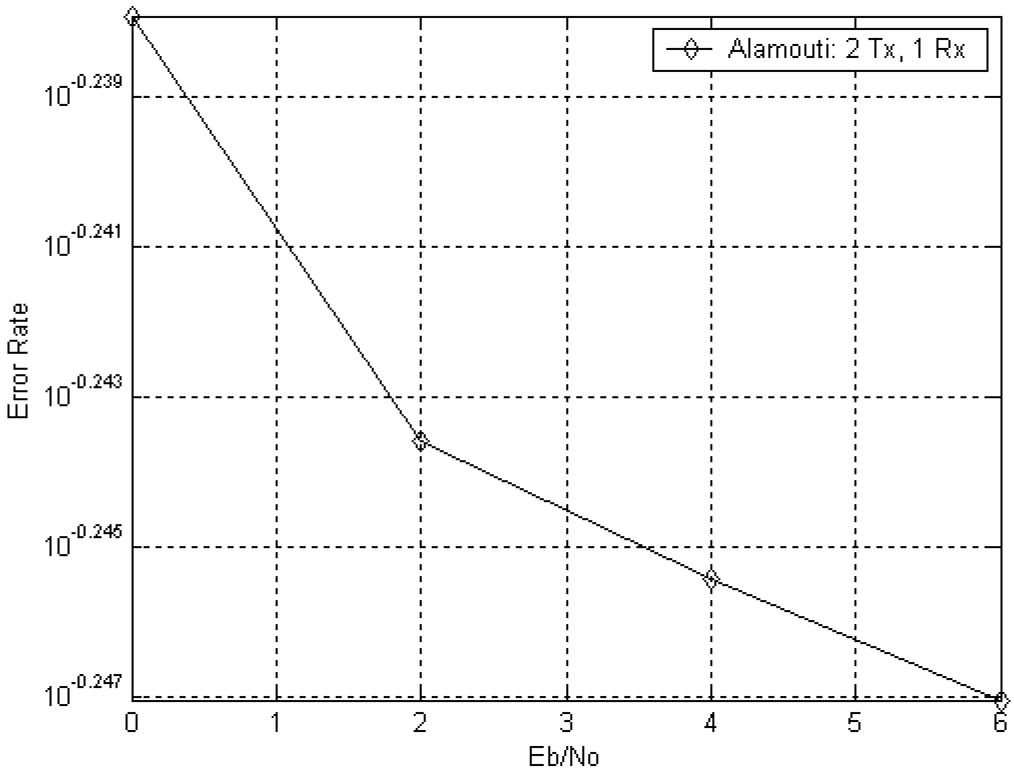

Figure-3.16: SER error performance of 8-QAM for RAYLEIGH fading

The Figure 3.13-3.16 show that in case of RAYLEIGH fading the symbol error rate(SER) is least for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK . Hence the performance of the Quadrature Amplitude Modulation is best when RAYLEIGH fading in present in 2:1 MISO system.

3.7 Performance of rate 1 code under RAYLEIGH fading using different modulation techniques.

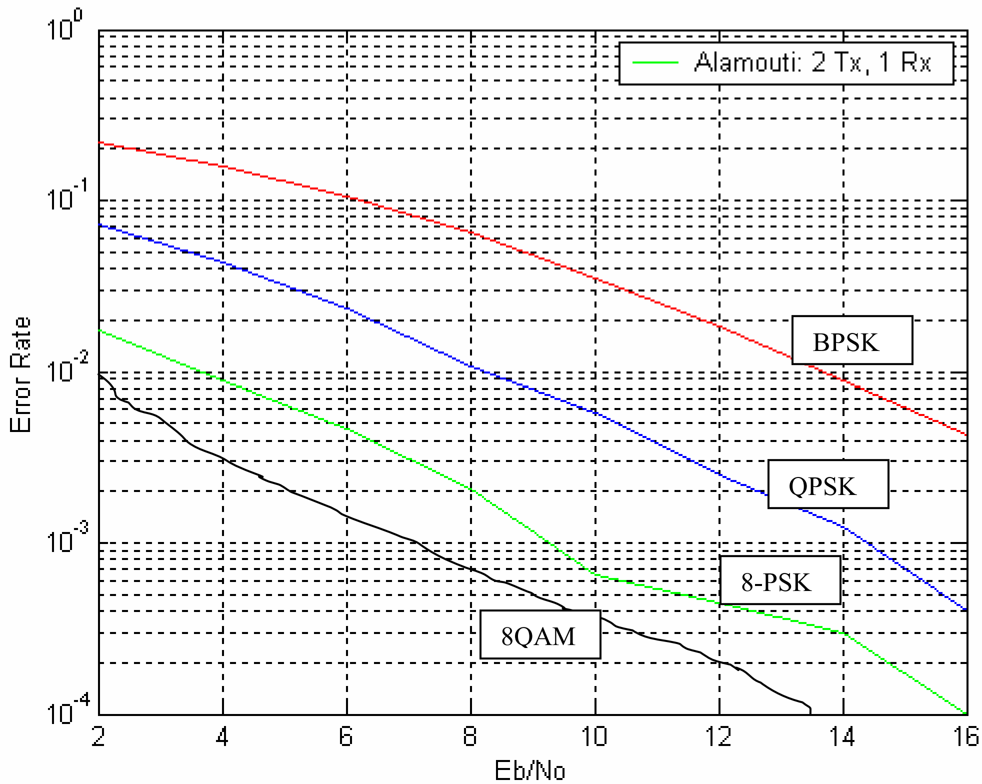

Figure-3.17: BER performance of rate 1 code in RAYLEIGH fading using different modulation techniques.

The figure-3.17 above shows that for rate 1 scheme under RAYLEIGH fading environment 8-QAM modulation technique has the lowest BER as compared to the other three modulations i.e.: BPSK, QPSK and 8-PSK. So the performance of 8-QAM modulation technique is best under these conditions.

3.7.1 COMPARISON OF VARIOUS MODULATIONS UNDER RAYLEIGH FADING.

Table-3.6: BER performance under RAYLEIGH fading at SNR of 8db

Modulation Technique	Bit Error Rate
BPSK	0.031
QPSK	0.01
8-PSK	0.0012
8-QAM	0.0010

Table-3.6 shows that in case of 8-QAM modulation technique the value of bit error rate is least i.e.:0.001 under RAYLEIGH fading environment as compared to other modulations. So, the performance of 8-QAM modulation technique is better in comparison to BPSK, QPSK and 8-PSK.

Table-3.7: SER performance under RAYLEIGH fading at SNR of 6db

Modulation Technique	Symbol Error Rate(SER)
BPSK	0.015
QPSK	0.014
8-PSK	0.002
8-QAM	0.001

Table-3.7 shows that in case of 8-QAM modulation technique the value of symbol error rate (SER) is least i.e.:0.001 under RAYLEIGH fading environment as compared to other modulations. So, the performance of 8-QAM modulation technique is better in comparison to BPSK, QPSK and 8-PSK.

CHAPTER 4

PERFORMANCE OF 2:1 MISO SYSTEM FOR DIFFERENT MODULATION SCHEMES IN RICIAN FADING CHANNEL

The basic wireless communication system model consisting of encoder, channel and the receiver discussed in section 3.1 is used for RICIAN fading also. Here also the space time encoder, encodes the incoming data bit stream and with the help of transmitting antennas transmits the signal. At the receiver, signal is decoded.

The only difference is in nature of the channel which is RICIAN in this case. Depending on the nature of the radio propagation environment, there are different channel models describing the statistical behavior of the multipath-fading envelope.

4.1 Rician Fading Channel

When there is a dominant stationary (non-fading) signal component present, such as LOS propagation path, the small-scale fading envelope distribution is Rician. In such a situation, random multipath components arriving at different angles are superimposed on a stationary dominant signal [10]. At the output of an envelope detector, this has the effect of adding a dc component to the random multipath. The effect of a dominant signal arriving with many weaker multipath signals gives rise to the Rician distribution. As the dominant signal becomes weaker, the composite signal resembles a noise signal, which has an envelope that is Rayleigh. Thus, the Rician distribution degenerates to a Rayleigh distribution when the dominant component fades away.

With fixed scatterers or signal reflectors in the medium, in addition to randomly moving scatterers, the channel impulse response will have a non-zero mean value and its envelope will have a Rice distribution. This channel is said to be a Rician Fading Channel. For a multipath fading channel containing a specular or LOS component, the complex envelope of the received signal can be given by the Rician distribution,

$$p(r) = \begin{cases} \frac{r}{\sigma^2} e^{-\frac{(r^2+A^2)}{2\sigma^2}} I_0\left(\frac{Ar}{\sigma^2}\right) & \text{for } (A \geq 0, r \geq 0) \\ 0 & \text{for } (r < 0) \end{cases} \quad 4.1.1$$

where *A* denotes the peak amplitude of the dominant or LOS signal and I0(.) is the zeroth order modified Bessel function of the first kind. The Rician distribution is often described in terms of a parameter *K* called Rician factor, which is defined as the ratio between the deterministic signal power and the variance of the multipath.

The method of filtered noise is used to generate channel coefficients with the specified distribution and spectral power density. For each tap a set of complex zero-mean Gaussian distributed numbers is generated with a variance of 0.5 for the real and imaginary part, so that the total average power of this distribution is 1.

This yields a normalized Rayleigh distribution (equivalent to Rice with *K*=0) for the magnitude of the complex coefficients. If a Rician distribution (*K*>0 implied) is needed, a constant path component $|m|$ has to be added to the Rayleigh set of coefficients. The ratio of powers between this constant part and the Rayleigh (variable) part is specified by the *K*-factor. For this general case, we show how to distribute the power correctly by first stating the total power *P* of each tap:

$$P = |m|^2 + \sigma^2 \quad 4.1.2$$

where m is the complex constant and σ2 the variance of the complex Gaussian set. Second, the ratio of powers is

$$K = \frac{|m|^2}{\sigma^2} \quad 4.1.3$$

From these equations, we can find the power of the complex Gaussian and the power of the constant part as

$$\sigma^2 = P\frac{1}{K+1}; \quad \text{and} \quad |\mathrm{m}|^2 = P\frac{K}{K+1} \quad 4.1.4$$

Now, with the help of the specified powers, Rician channel coefficients can be calculated.

K-Factor — the fading signal magnitude follows a Rice distribution, which can be characterized by two parameters: the power Pc of constant channel components and the power Ps from scatter channel components. The ratio of these two (Pc/Ps) is called the Rician K-factor. The worst-case fading occurs when Pc = 0 and the distribution is regarded as Rayleigh distribution (K = 0). The K-factor is an important parameter in system design since it relates to the probability of a fade of certain depth. Both fixed and mobile communications systems have to be designed for the most severe fading conditions for reliable operation (i.e., Rayleigh fading).

The description for various modulation techniques i.e.: BPSK, QPSK, 8PSK and M-QAM, their corresponding constellation diagrams remain the same as discussed in section 3.3. Also the MONTE CARLO SIMULATION STEPS for RAYLEIGH fading are similar for RICIAN fading too.

4.2 SIMULATION RESULTS OF BER for RICIAN FADING WITH DIFFERENT MODULATION TECHNIQUES

MODULATION TECHNIQUE: BPSK

FADING: RICIAN

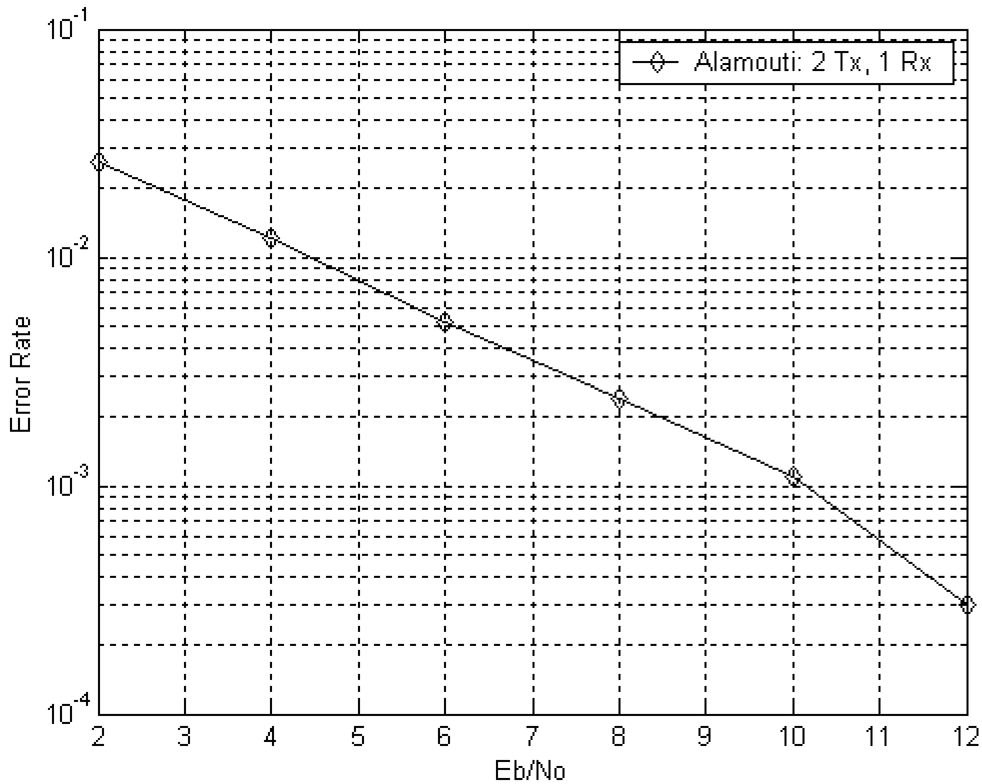

Figure-4.1: BER error performance of BPSK for RICIAN fading

MODULATION TECHNIQUE: QPSK

FADING: RICIAN

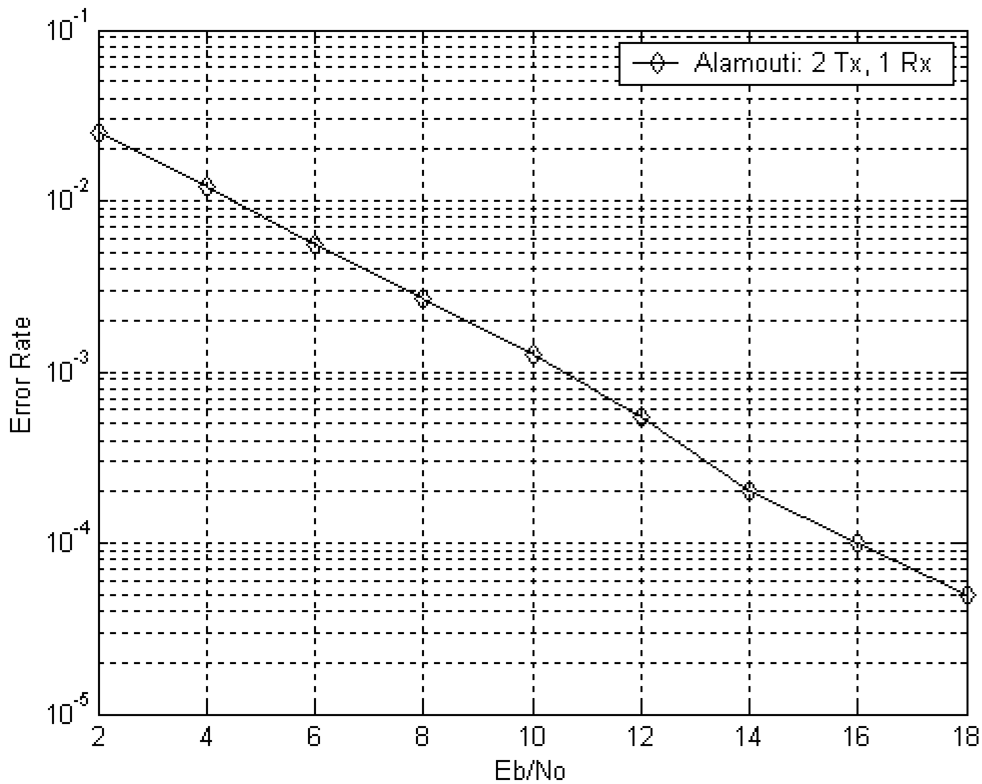

Figure-4.2: BER error performance of QPSK for RICIAN fading

MODULATION TECHNIQUE: 8-PSK

FADING: RICIAN

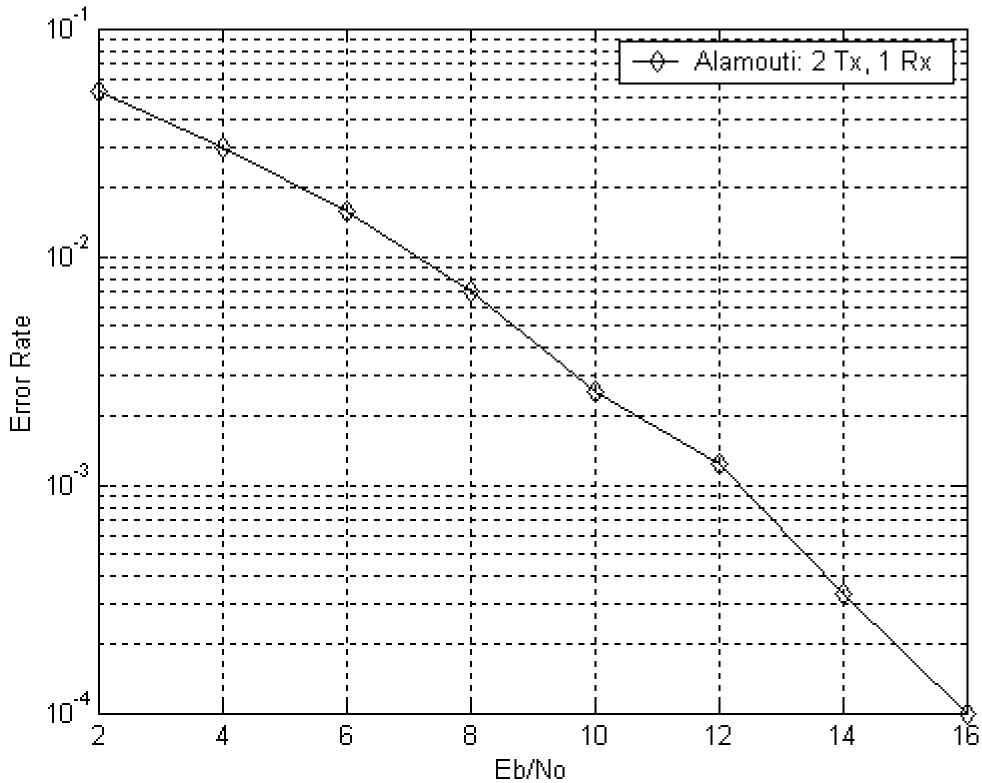

Figure-4.3: BER error performance of 8-PSK for RICIAN fading

MODULATION TECHNIQUE: 8-QAM

FADING: RICIAN

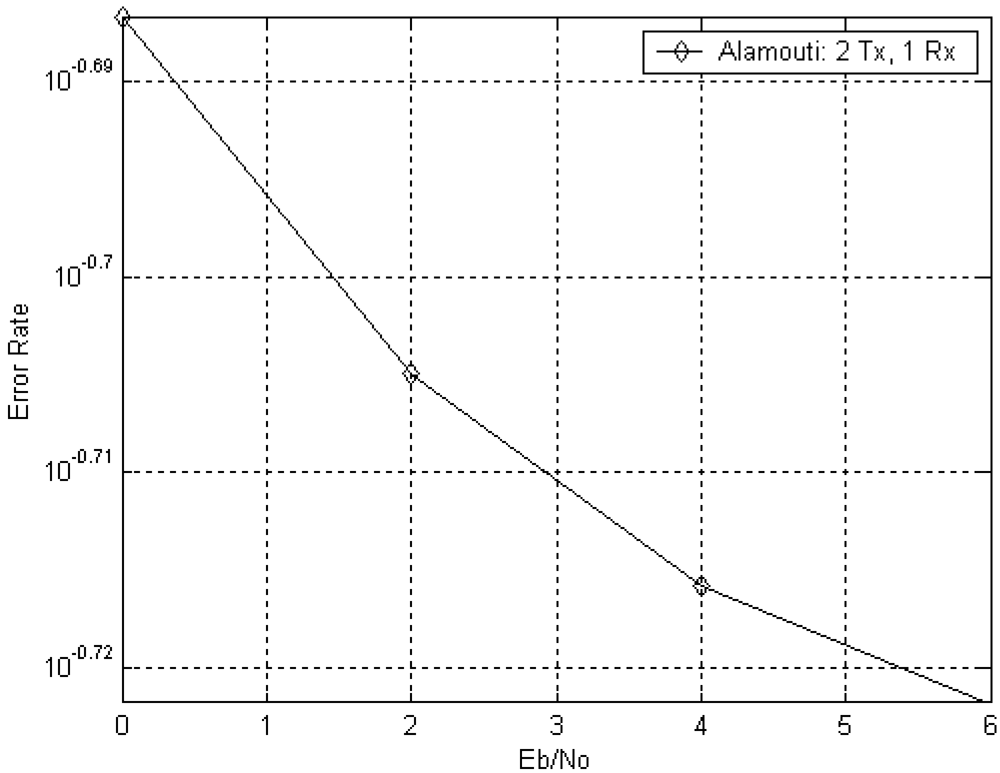

Figure-4.4: BER error performance of 8-QAM for RICIAN fading

The Figure 4.1-4.4 show that in case of RICIAN fading the bit error rate (BER) is least for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK . Hence the performance of the Quadrature Amplitude Modulation is best when RICIAN fading in present in 2:1 MISO systems.

4.3 SIMULATION RESULTS OF SER for RICIAN FADING WITH DIFFERENT MODULATION TECHNIQUES

MODULATION TECHNIQUE: BPSK

FADING: RICIAN

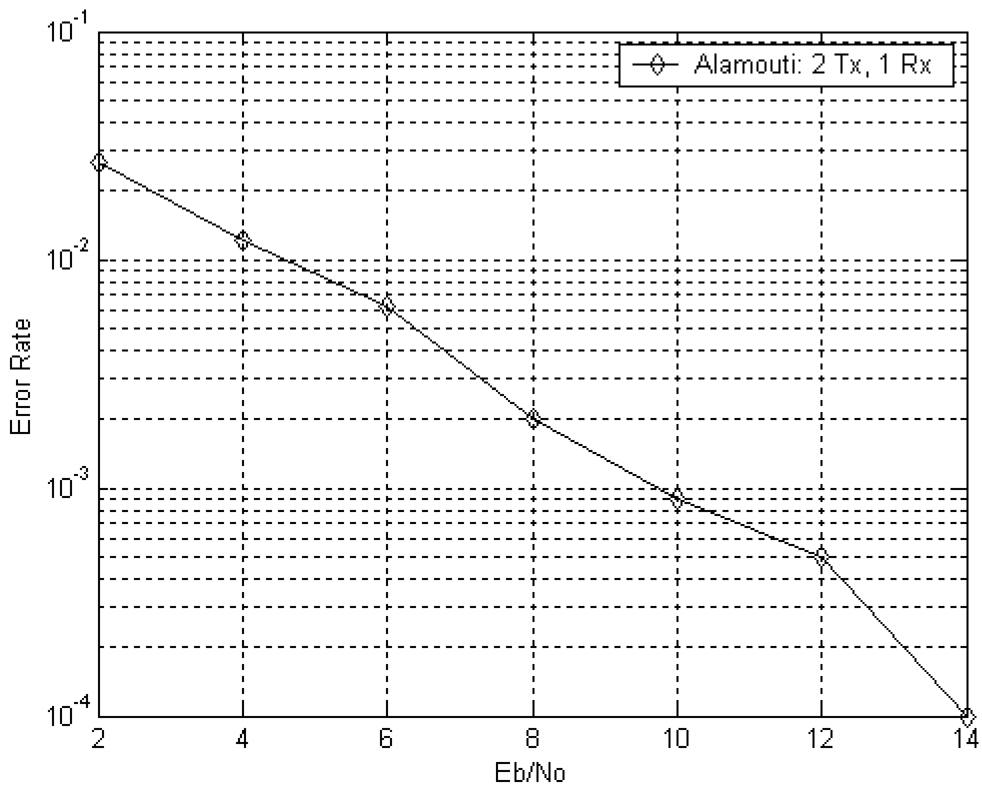

Figure-4.5: SER error performance of BPSK for RICIAN fading

MODULATION TECHNIQUE: QPSK

FADING: RICIAN

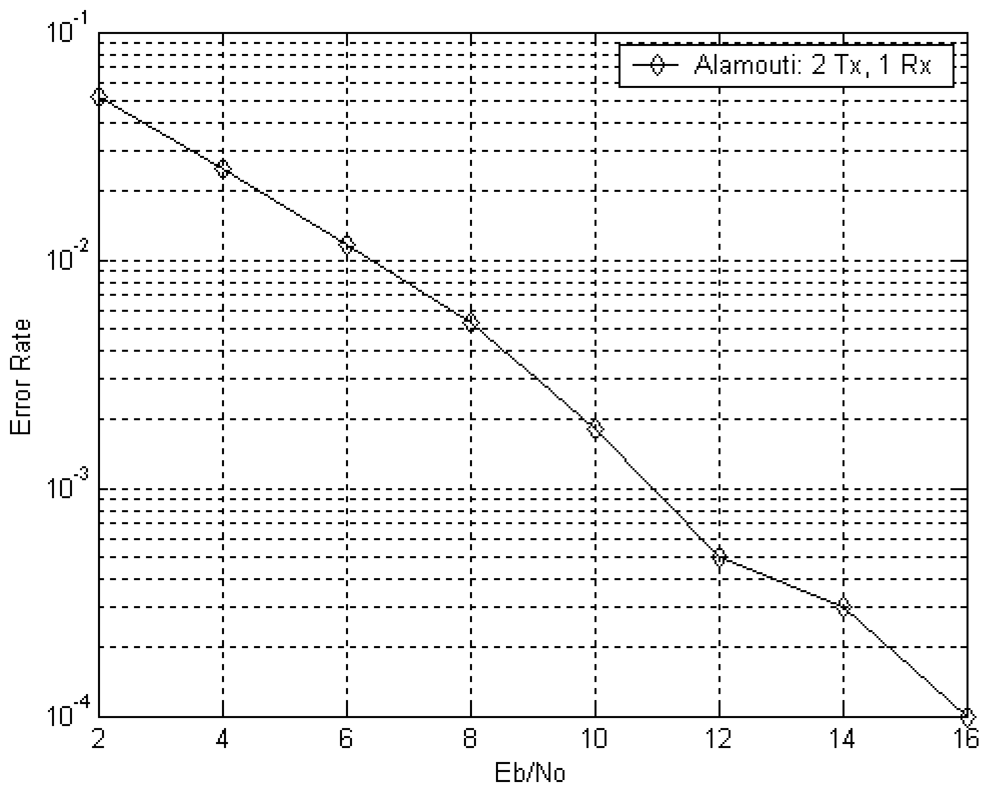

Figure-4.6: SER error performance of QPSK for RICIAN fading

MODULATION TECHNIQUE: 8-PSK

FADING: RICIAN

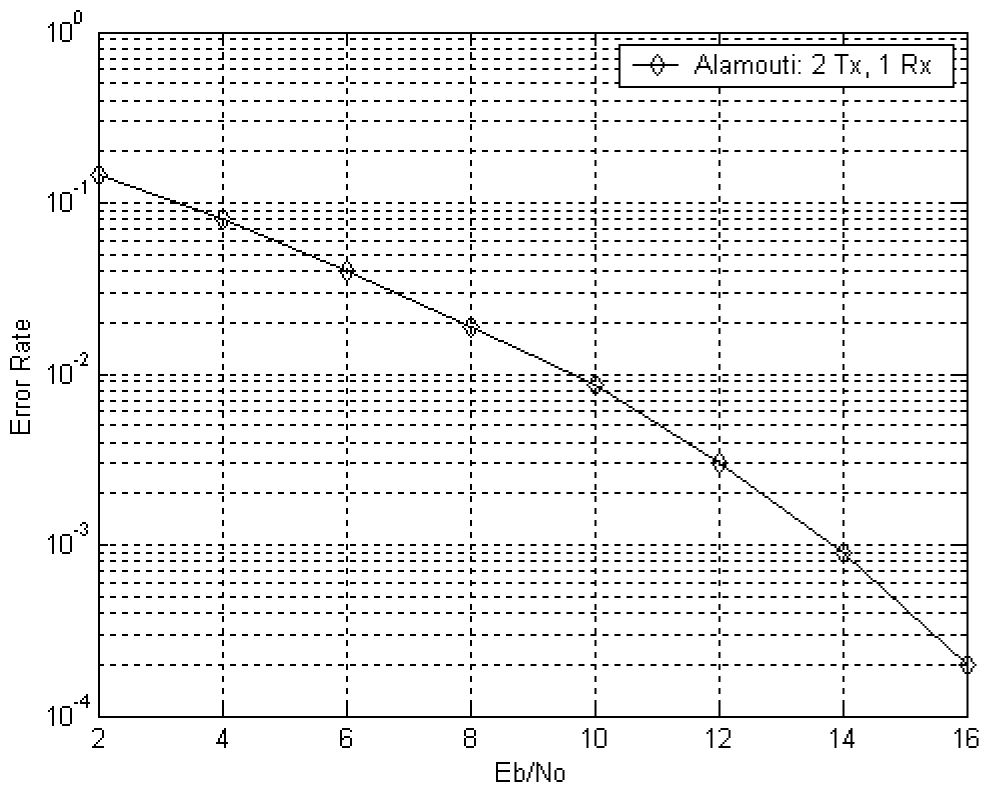

Figure-4.7: SER error performance of 8-PSK for RICIAN fading

MODULATION TECHNIQUE: 8-QAM

FADING: RICIAN

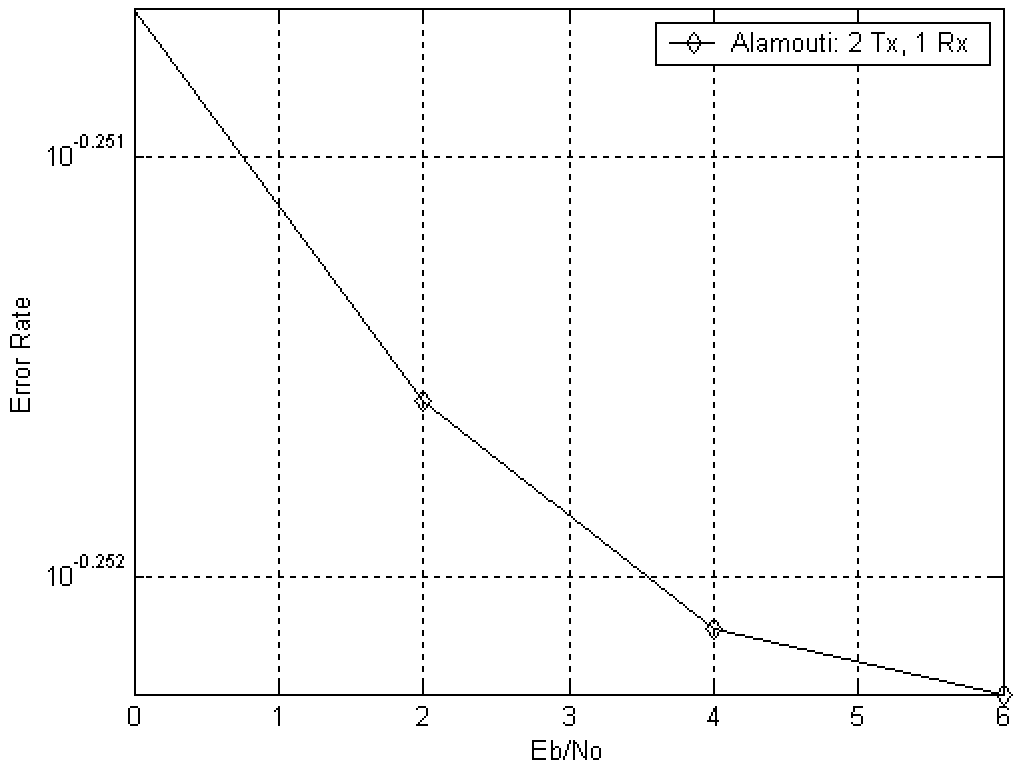

Figure-4.8: SER error performance of 8-QAM for RICIAN fading

The Figure 4.5-4.8 show that in case of RICIAN fading the symbol error rate (SER) is least for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK . Hence the performance of the Quadrature Amplitude Modulation is best when RICIAN fading in present in 2:1 MISO systems.

4.4 Performance of rate 1 code under RICIAN fading using different modulation techniques.

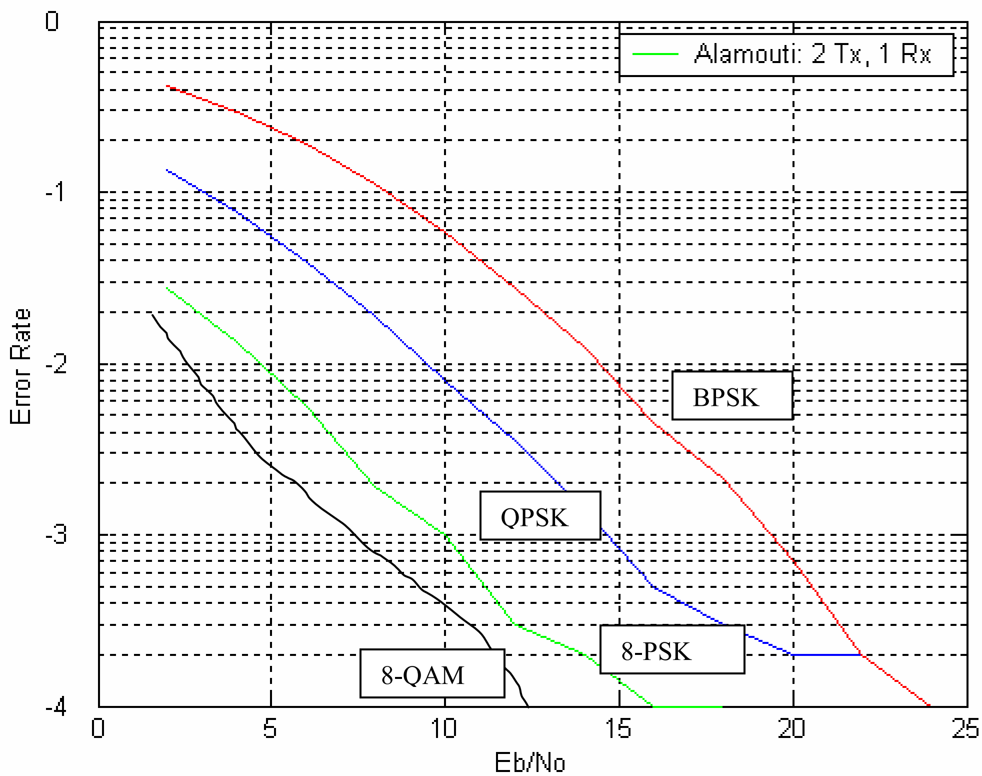

Figure-4.9: BER performance of rate 1 code in RICIAN fading using different modulation techniques.

The figure-4.9 above shows that for rate 1 scheme under RICIAN fading environment 8-QAM modulation technique has the lowest BER as compared to the other three modulations i.e.: BPSK, QPSK and 8-PSK. So the performance of 8-QAM modulation technique is best under these conditions.

4.4.1 COMPARISON OF VARIOUS MODULATIONS UNDER RICIAN FADING.

Table-4.1: BER performance under RICIAN fading at SNR of 10db.

Modulation Technique	Bit Error Rate
BPSK	0.0398
QPSK	0.006
8-PSK	0.0011
8-QAM	0.0010

Table-4.1 shows that in case of 8-QAM modulation technique the value of bit error rate is least i.e.:0.0010 under RICIAN fading environment as compared to other modulations. So, the performance of 8-QAM modulation technique is better in comparison to BPSK, QPSK and 8-PSK.

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Table-4.2: SER performance under RICIAN fading at SNR of 6db

Modulation Technique	Symbol Error Rate(SER)
BPSK	0.0102
QPSK	0.010
8-PSK	0.002
8-QAM	0.001

Table-4.2 shows that in case of 8-QAM modulation technique the value of symbol error rate (SER) is least i.e.:0.001 under RICIAN fading environment as compared to other modulations. So, the performance of 8-QAM modulation technique is better in comparison to BPSK, QPSK and 8-PSK.

CHAPTER 5

PERFORMANCE OF 2:1 MISO SYSTEM FOR DIFFERENT MODULATION TECHNIQUES UNDER NAKAGAMI FADING

The communication system model for 2:1 MISO system under NAKAGAMI fading also consists of space time encoder, channel involved and the receiver as discussed in chapter 3 and chapter 4.The basic functioning of the encoder and the receiver is the same. The only difference is in the nature of channel involved which NAKAGAMI is in this case.

5.1 Nakagami Fading Channel

The Nakagami distribution is selected to fit empirical data and is known to provide a close match to some experimental data than the Rayleigh, Rician or log-normal distributions. The Nakagami distribution is often used to model multipath fading as it can model fading conditions that are either more or less severe than Rayleigh fading. When m=1, Nakagami distribution becomes the Rayleigh distribution, when m=1/2 it becomes a one-sided Gaussian distribution and when $m \to \infty$ the distribution becomes an impulse (no fading). Even Rice distribution can be closely approximated using Nakagami parameter *m* via the relationship $m = (K+1)^2 / (2K+1)$.

Considering a receiver with M diversity branches, let the received instantaneous signal A_k at the k_{th} branch be characterized by the Nakagami distribution. The Nakagami distribution describes the received envelope $z(t) = r(t)$ by a central chi-square distribution with *m* degrees of freedom,

$$p(A_k) = \frac{2}{\Gamma(m_k)} \cdot \left(\frac{m_k}{\Omega_k}\right)^{m_k} \cdot A_k^{2m_k - 1} . e^{-\frac{m_k}{\Omega_k} A_k^2} , \quad k = 1,2,....M \qquad 3.12.3.1$$

Where $\Gamma(.)$ is the Gamma function, $\Omega_k = \overline{A_k^2}$ is the average power on k_{th} branch, m_k is the fading parameter. In joint domain processing, the samples in both the spatial domain and the temporal domain are processed simultaneously. The processor in this case computes the overall combiner coefficients/weight vectors by processing signals jointly in both the spatial and the temporal domains.

The description of various modulations i.e.: BPSK, QPSK, 8-PSK and 8-QAM are similar to the one discussed in section 3.3. The MONTE CARLO SIMULATIONS STEPS for NAKAGAMI fading are similar to the one for RAYLEIGH fading given in section 3.4.

5.2 SIMULATION RESULTS OF BER for NAKAGAMI FADING WITH DIFFERENT MODULATION TECHNIQUES

MODULATION TECHNIQUE: BPSK

FADING: NAKAGAMI

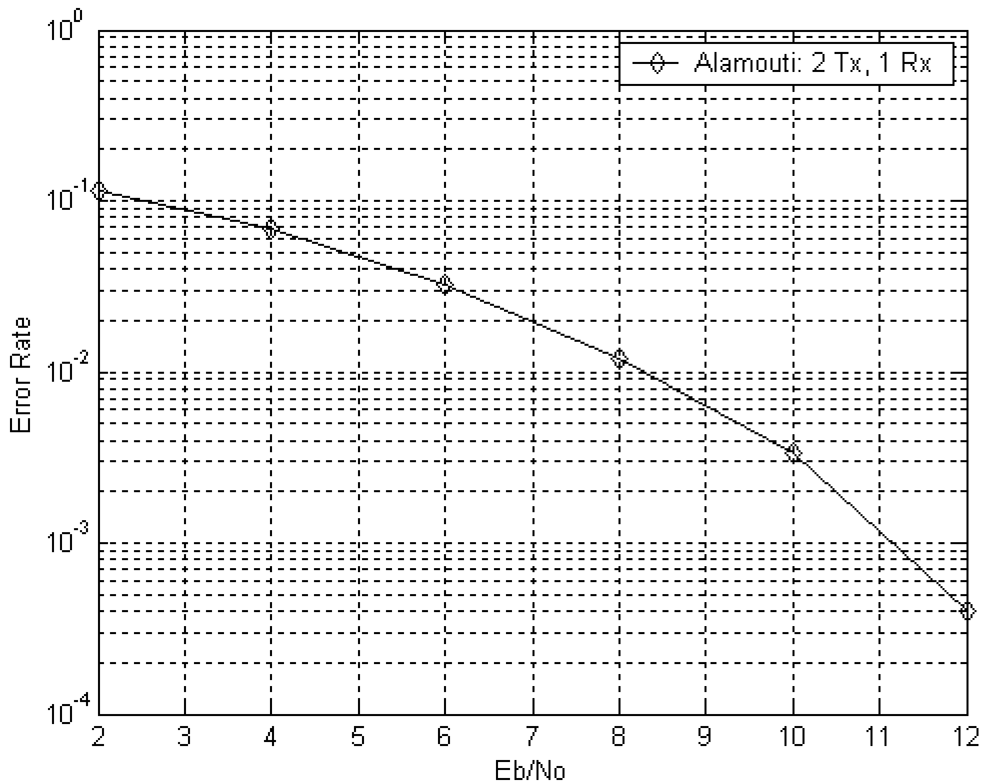

Figure-5.1: BER error performance of BPSK for NAKAGAMI fading

MODULATION TECHNIQUE: QPSK

FADING: NAKAGAMI

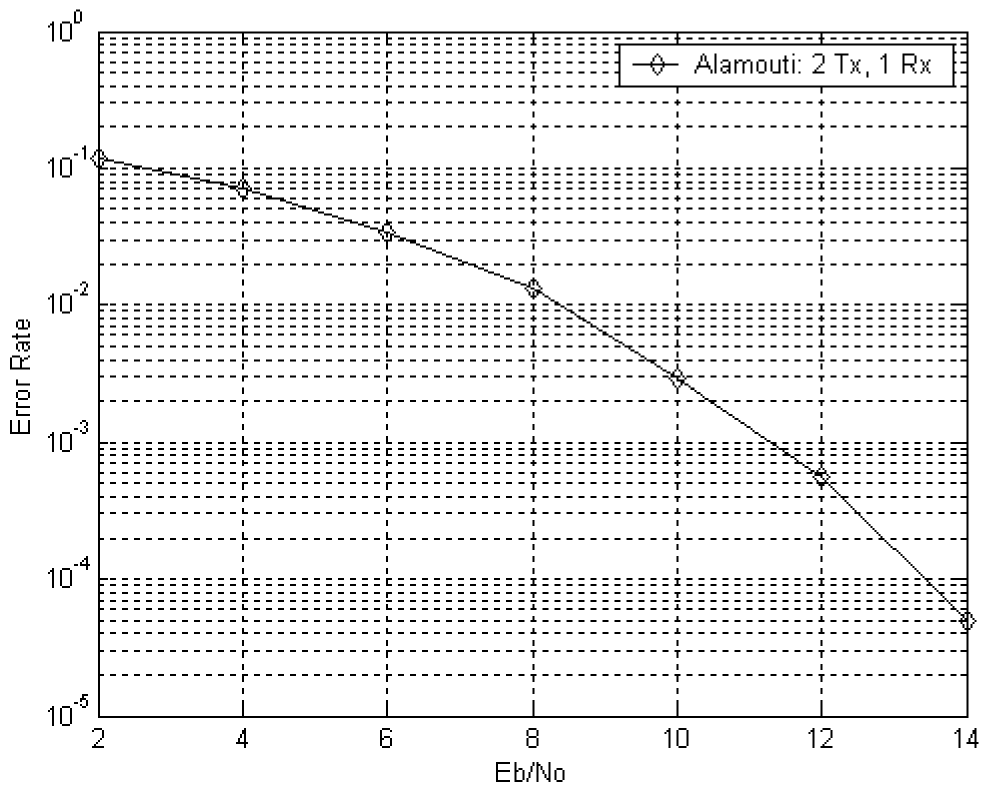

Figure-5.2: BER error performance of QPSK for NAKAGAMI fading

MODULATION TECHNIQUE: 8-PSK

FADING: NAKAGAMI

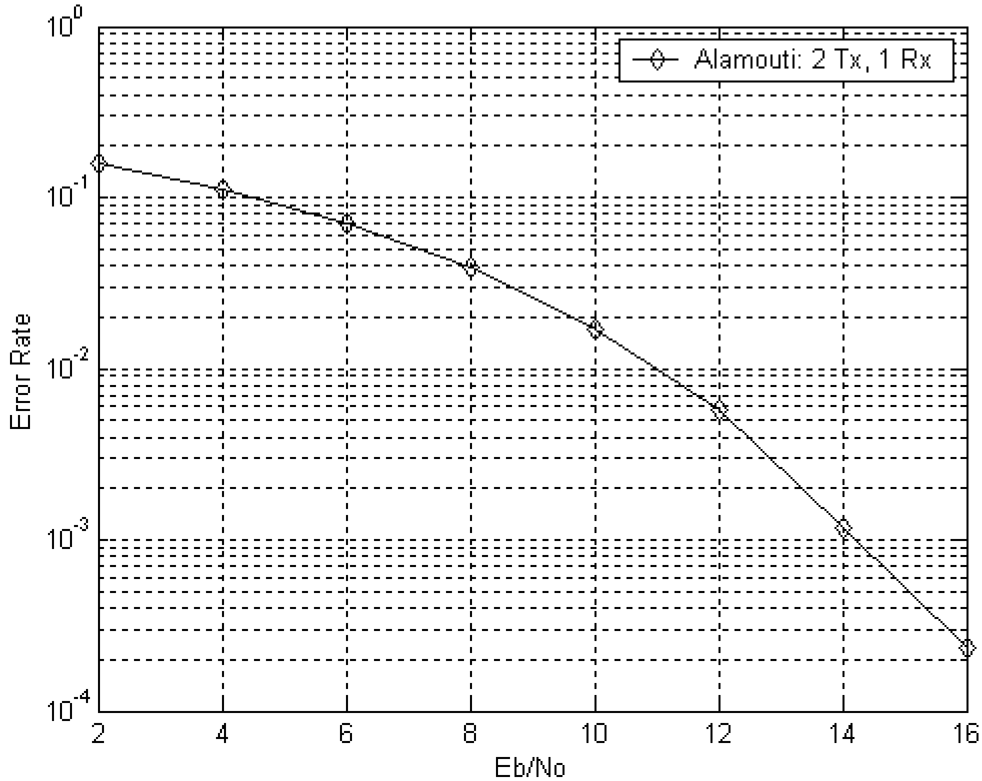

Figure-5.3: BER error performance of 8-PSK for NAKAGAMI fading

MODULATION TECHNIQUE: 8-QAM

FADING: NAKAGAMI

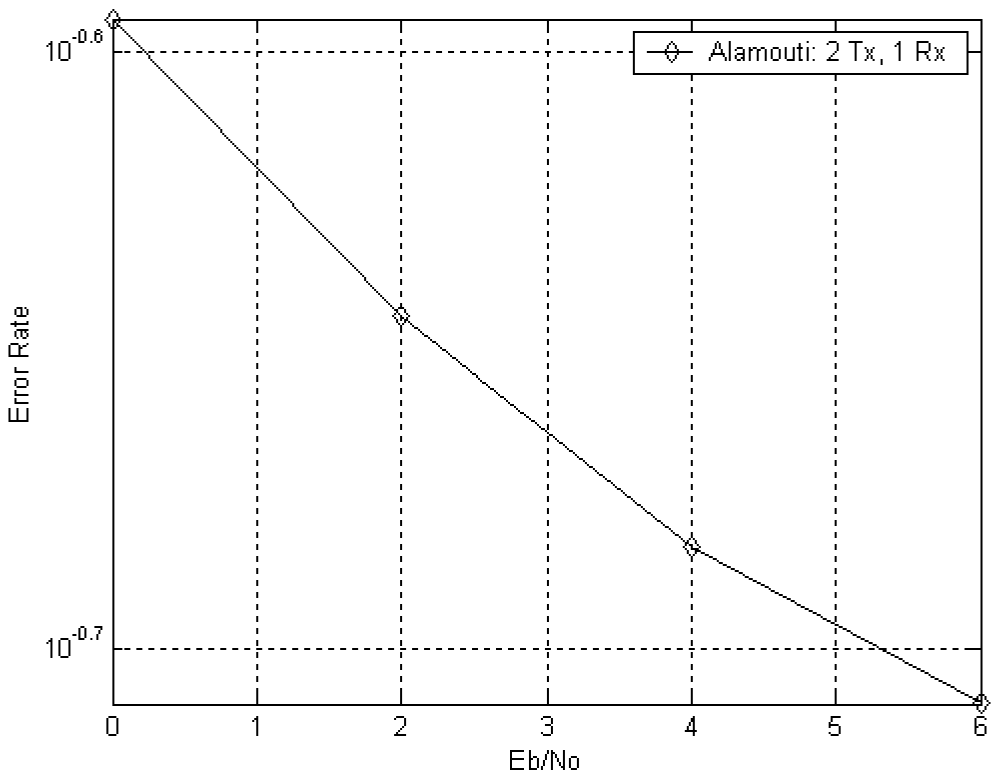

Figure-5.4: BER error performance of 8-QAM for NAKAGAMI fading

The Figure 5.1-5.4 show that in case of NAKAGAMI fading the bit error rate (BER) is least for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK . Hence the performance of the Quadrature Amplitude Modulation is best when NAKAGAMI fading in present in 2:1 MISO systems.

5.3 SIMULATION RESULTS OF SER for NAKAGAMI FADING WITH DIFFERENT MODULATION TECHNIQUES

MODULATION TECHNIQUE: BPSK

FADING: NAKAGAMI

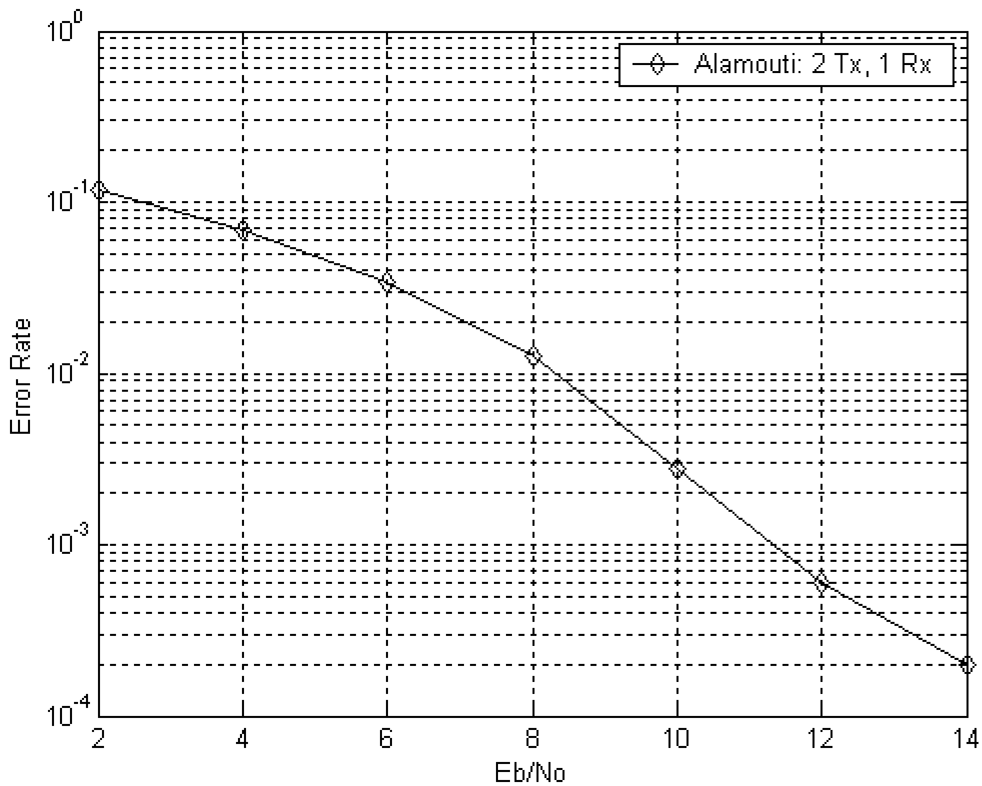

Figure-5.5: SER error performance of BPSK for NAKAGAMI fading

MODULATION TECHNIQUE: QPSK

FADING: NAKAGAMI

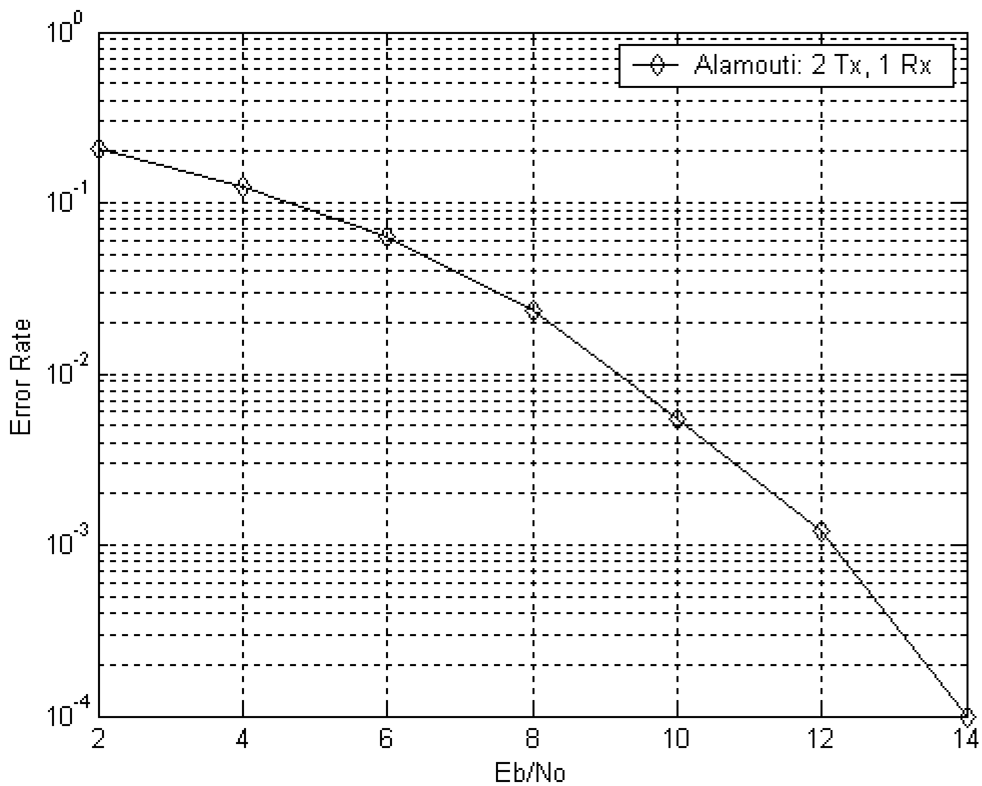

Figure-5.6: SER error performance of QPSK for NAKAGAMI fading

MODULATION TECHNIQUE: 8PSK

FADING: NAKAGAMI

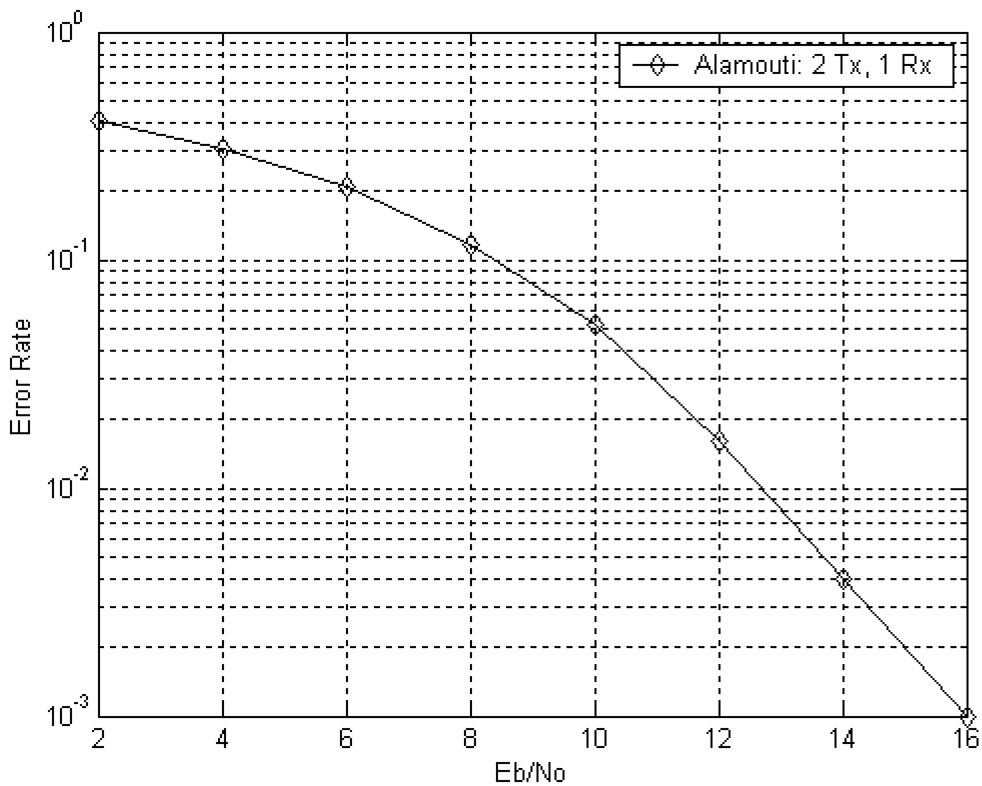

Figure-5.7: SER error performance of 8-PSK for NAKAGAMI fading

MODULATION TECHNIQUE: 8-QAM

FADING: NAKAGAMI

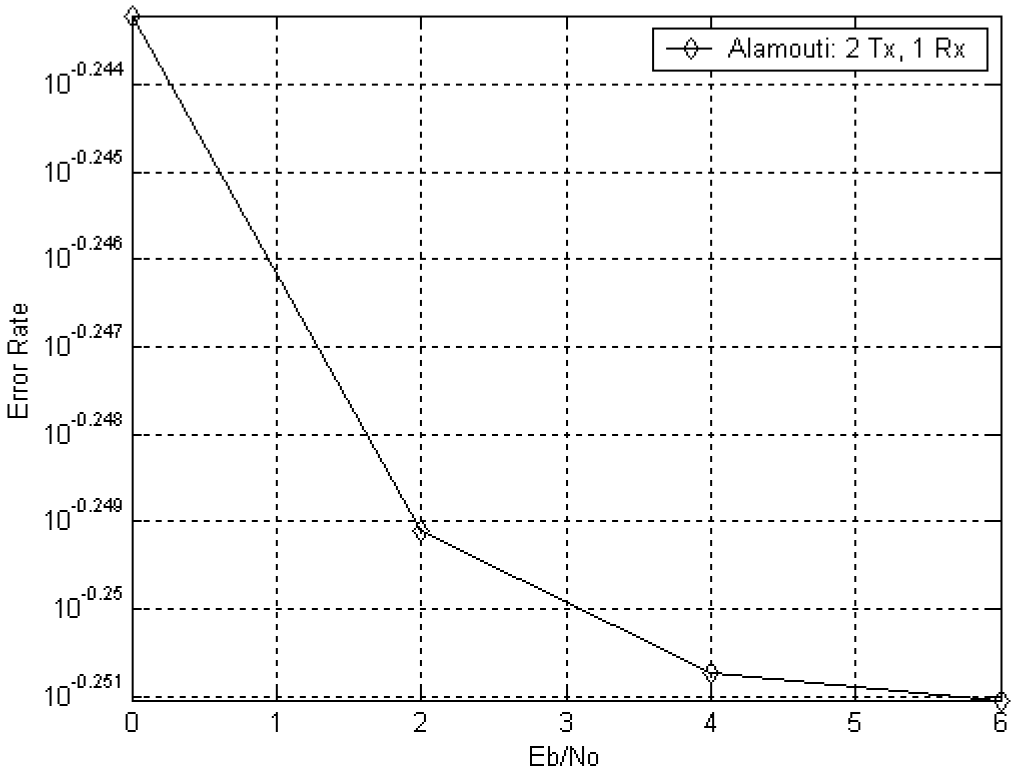

Figure-5.8: SER error performance of 8-QAM for NAKAGAMI fading

The Figure 5.5-5.8 show that in case of NAKAGAMI fading the symbol error rate(SER) is least for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK . Hence the performance of the Quadrature Amplitude Modulation is best when NAKAGAMI fading in present in 2:1 MISO system.

5.4 Performance of rate 1 code under NAKAGAMI fading using different modulation techniques.

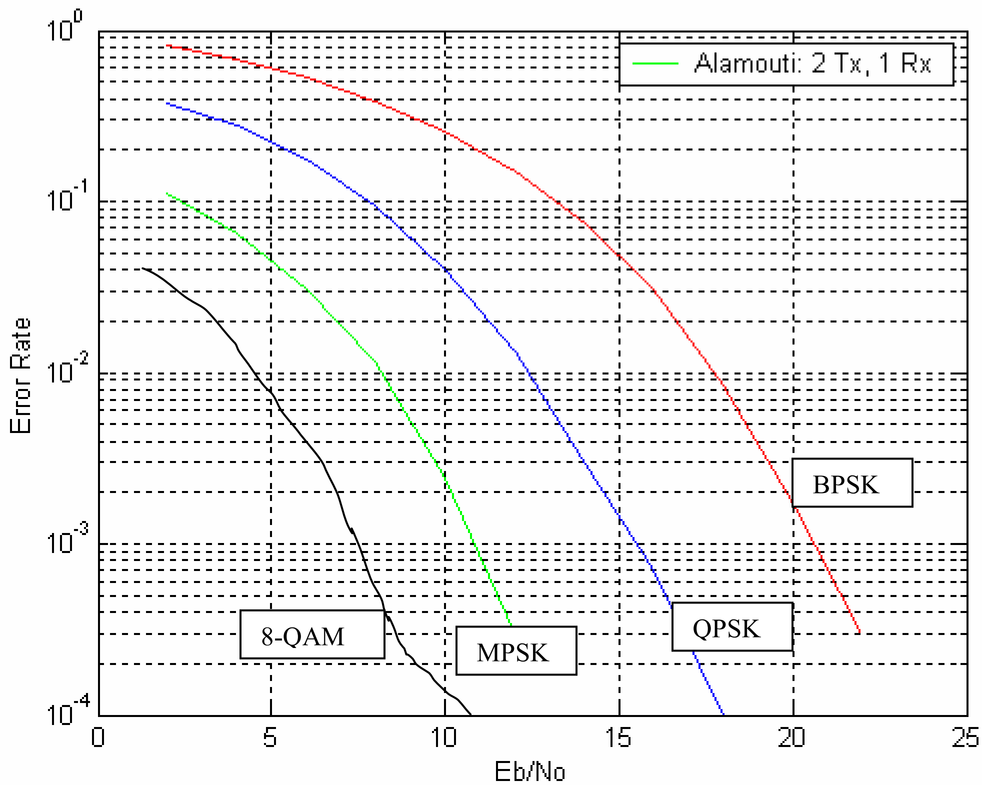

Figure-5.9: BER performance of rate 1 code in NAKAGAMI fading using different modulation techniques

The figure-5.9 above shows that for rate 1 scheme under NAKAGAMI fading environment 8-QAM modulation technique has the lowest BER as compared to the other three modulations i.e.: BPSK, QPSK and 8-PSK. So the performance of 8-QAM modulation technique is best under these conditions.

5.4.1 COMPARISON OF VARIOUS MODULATIONS UNDER NAKAGAMI FADING.

Table-5.1: BER performance under NAKAGAMI fading at SNR of 10db.

Modulation Technique	Bit Error Rate
BPSK	0.1412
QPSK	0.0251
8-PSK	0.0012
8-QAM	0.0010

Table-5.1 shows that in case of 8-QAM modulation technique the value of bit error rate is least i.e.:0.0010 under NAKAGAMI fading environment as compared to other modulations. So, the performance of 8-QAM modulation technique is better in comparison to BPSK, QPSK and 8-PSK.

.

Table-5.2: SER performance under NAKAGAMI fading at SNR of 6db

Modulation Technique	Symbol Error Rate(SER)
BPSK	0.0501
QPSK	0.0251
8-PSK	0.0130
8-QAM	0.002

Table-5.2 shows that in case of 8-QAM modulation technique the value of symbol error rate (SER) is least i.e.:0.002 under NAKAGAMI fading environment as compared to other modulations. So, the performance of 8-QAM modulation technique is better in comparison to BPSK, QPSK and 8-PSK.

CHAPTER 6

6.1 CONCLUSIONS AND FUTURE SCOPES

In this thesis a comparative study of different modulation techniques with 2:1 MISO system under different fading environments is done. The study of ALAMOUTI SCHEME is also carried out. The figures 3.9-3.12 show that in case of RAYLEIGH fading channel the bit error rate (BER) is least i.e.: 0.001 for 8-QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK. Hence the performance of the Quadrature Amplitude Modulation is best when RAYLEIGH fading in present in 2:1 MISO system. It is also found that in case of RAYLEIGH fading the symbol error rate (SER) is least i.e.:0.001 for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK. [Figure 3.13-3.16]. So, the performance of 8-QAM modulation technique is better in comparison to BPSK, QPSK and 8-PSK in terms of SER also.

The figures 4.1-4.8 show that in case of RICIAN fading the bit error rate (BER) and symbol error rate(SER) is again least for QAM modulation technique as compared to the other three modulation techniques i.e.: BPSK, QPSK, 8PSK . Hence the performance of the Quadrature Amplitude Modulation is best when RICIAN fading in present in 2:1 MISO systems.

It is also seen that in case of all the modulation techniques, for a bit error rate of 10^{-2}, 2:1 system with NAKAGAMI fading requires approximately 3db less power as compared to the system with RAYLEIGH fading. The performance of RICIAN fading lies in between NAKAGAMI and RAYLEIGH fading. The following figures show the comparison of various fading environments for a particular modulation technique.

FOR BPSK COMBINED.

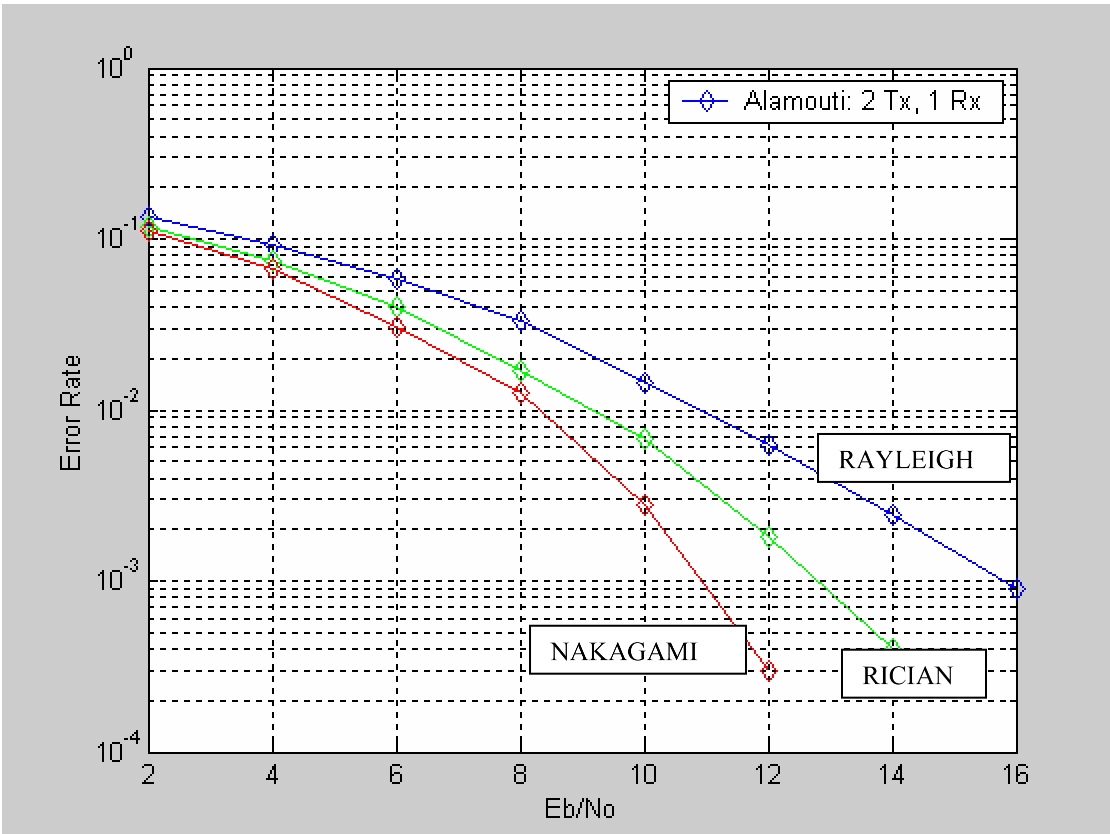

Figure-6.1: BER performance of BPSK under different modulation techniques

The figure-6.1 shows that in case of BPSK modulation scheme, for an error rate of 10^{-2}, NAKAGAMI fading requires approximately 3db less power as compared to RAYLEIGH fading. For the same error rate RICIAN fading requires approximately 2db less power as compared to RAYLEIGH fading. So, the performance of RICIAN fading lies in between NAKAGAMI and RAYLEIGH fading. Hence the performance of the system is better in case of NAKAGAMI fading environment.

FOR QPSK COMBINED

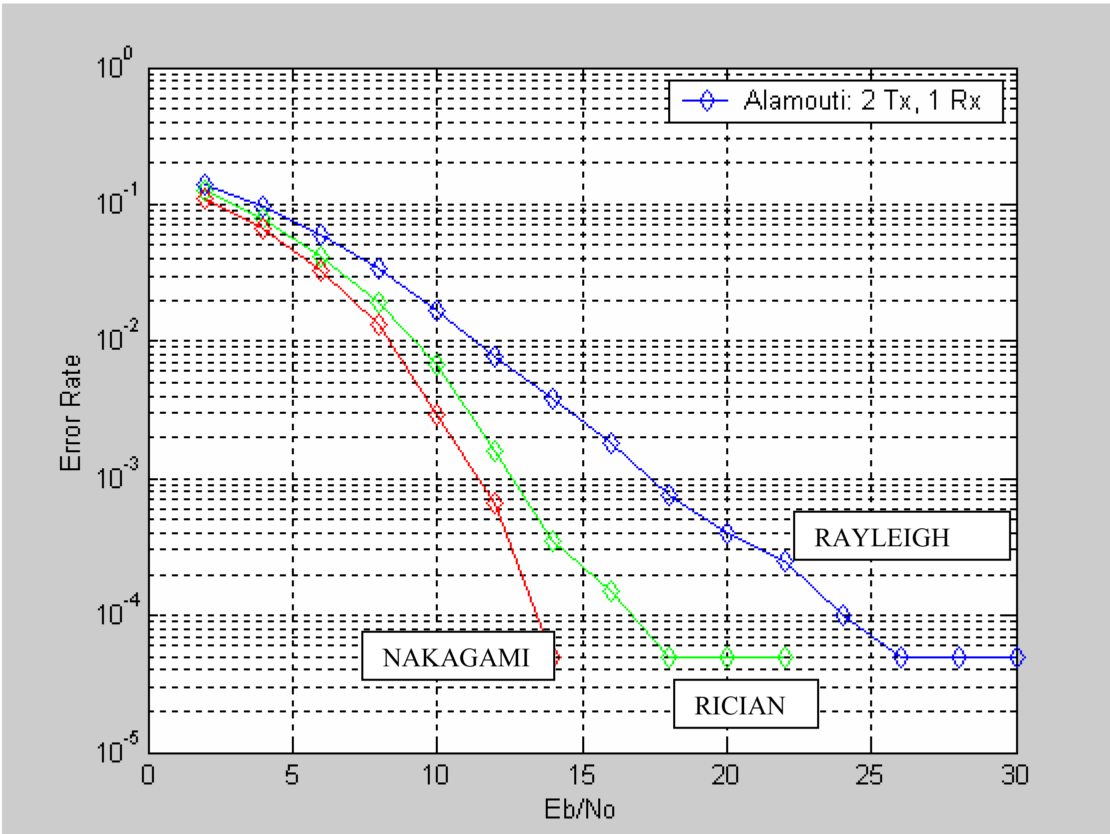

Figure-6.2: BER performance of QPSK under different modulation techniques

The figure-6.2 shows that in case of QPSK modulation scheme, for an error rate of 10^{-2}, NAKAGAMI fading requires approximately 4db less power as compared to RAYLEIGH fading. For the same error rate RICIAN fading requires approximately 3db less power as compared to RAYLEIGH fading. So, the performance of RICIAN fading lies in between NAKAGAMI and RAYLEIGH fading. Hence the performance of the system is better in case of NAKAGAMI fading environment.

FOR 8-PSK COMBINED

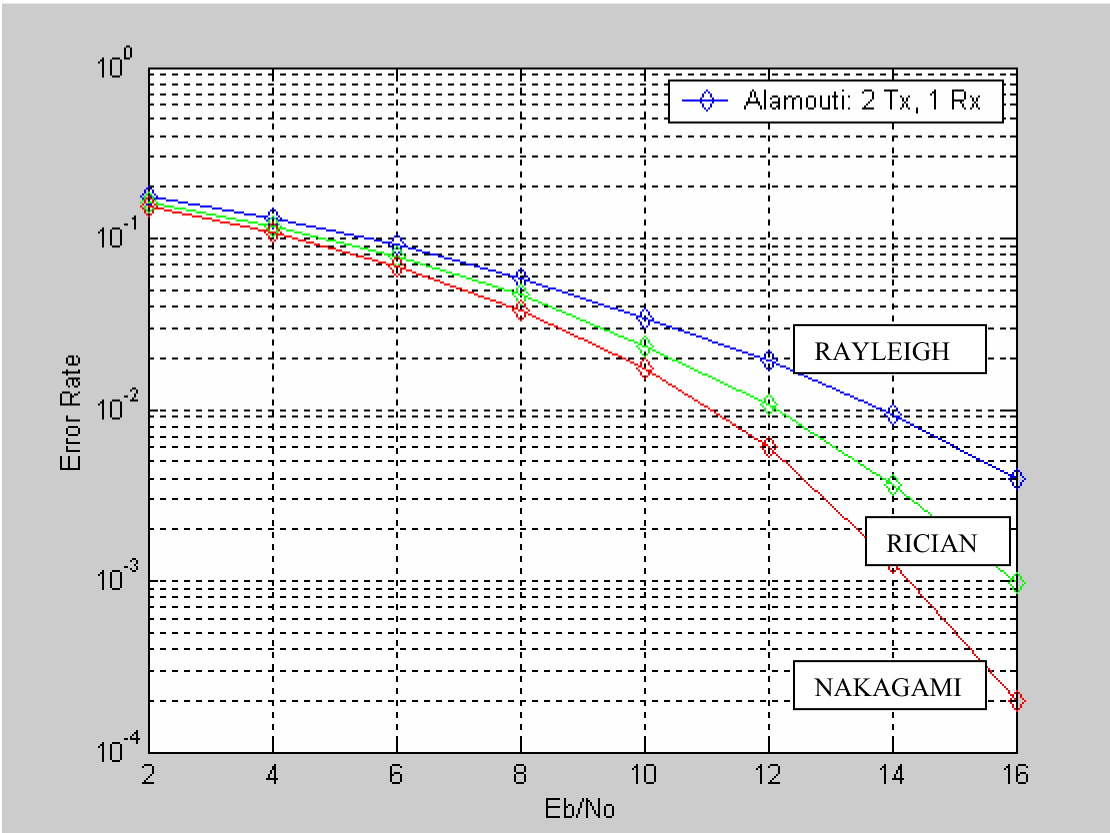

Figure-6.3: BER performance of 8-PSK under different modulation techniques

The figure-6.3 shows that in case of 8PSK modulation scheme, for an error rate of 10^{-2}, NAKAGAMI fading requires approximately 3.5db less power as compared to RAYLEIGH fading. For the same error rate RICIAN fading requires approximately 2db less power as compared to RAYLEIGH fading. So, the performance of RICIAN fading lies in between NAKAGAMI and RAYLEIGH fading. Hence the performance of the system is better in case of NAKAGAMI fading environment.

FOR 8-QAM COMBINED

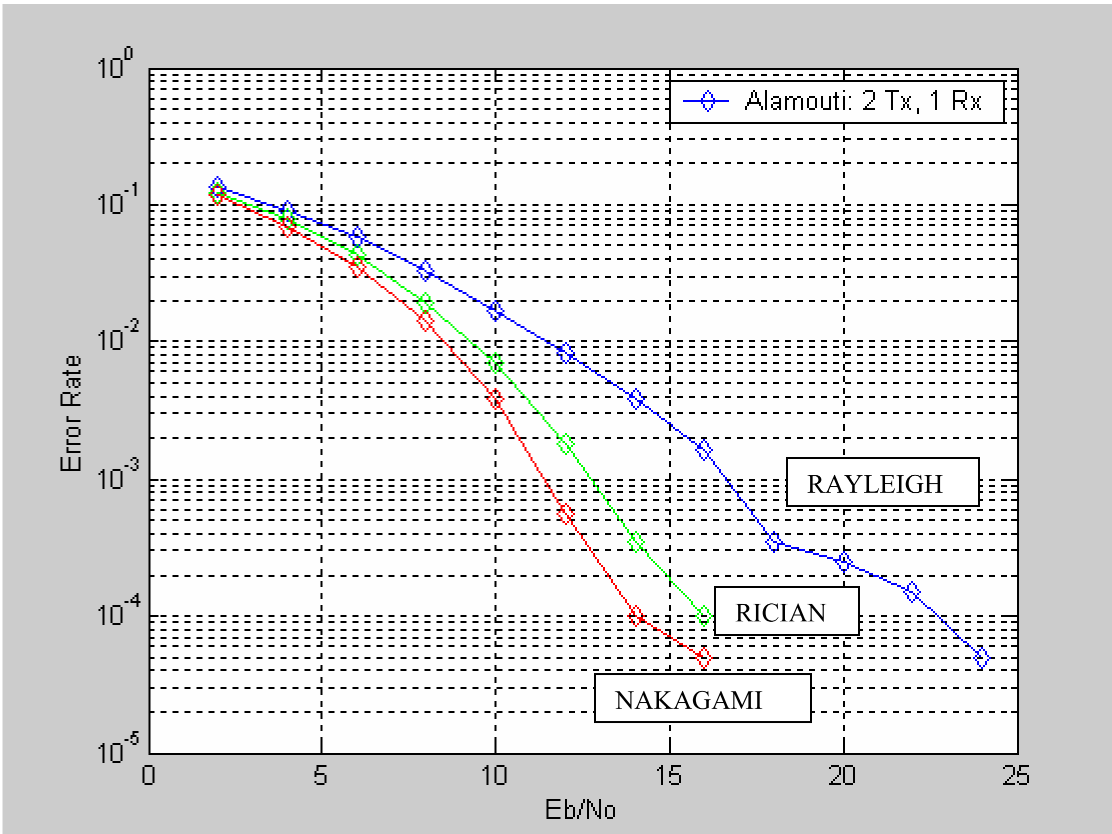

Figure-6.4: BER performance of 8-QAM under different modulation techniques

The figure-6.4 shows that in case of 8-QAM modulation scheme, NAKAGAMI fading requires approximately 3db less power as compared to RAYLEIGH fading at an error rate of 10^{-2}. For the same error rate RICIAN fading requires approximately 2db less power as compared to RAYLEIGH fading. So, the performance of RICIAN fading lies in between NAKAGAMI and RAYLEIGH fading. Hence the performance of the system is better in case of NAKAGAMI fading environment.

The scheme does not require any feedback from the receiver to the transmitter and its computational complexity is low. As the scheme transmits two symbols in 2 time intervals so its rate is 1.

FUTURE SCOPE OF WORK

This thesis examined the performance of a 2:1 MISO SYSTEM for various modulation techniques. The opportunity exists to improve upon the system. Some of the possible areas for future scope of work are:

- In this system co-channel interference and inter-symbol interference (ISI) are not considered and so it is called as an open loop system. The effect of these two parameters can be considered for future scope of work.
- This thesis is based on rate 1 scheme and this criterion can be taken forward for future work. Different rates such as rate<1 and rate>1 can be taken to analyze the performance of the systems.
- Different modulation techniques other than BPSK, QPSK, 8PSK, QAM can be considered.
- Fading other than RAYLEIGH, RICIAN, and NAKAGAMI can also be employed to analyze the performance of the channel and the system.
- Practical implementation of the 2:1 MISO model can be taken up as further study to verify the results obtained theoretically.

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LIST OF PUBLICATIONS

- Presented a paper on **"SMART ANTENNAS"** in conference on **INFORMATION & COMMUNICATION TECHNOLOGY** at JMIT, RADAUR in February 2006.

- Submitted a paper on "**PERFORMANCE OF 2:1 MISO SYSTEM IN WIRELESS COMMUNICATIONS"** in conference on **NATIONAL CONFERENCE ON WIRELESS NETWORKS AND EMBEDDED SYSTEMS AT** CHITKARA INSTITUTE OF ENGG & TECH, CHANDIGARH in June 2006.

- Presented a paper on **"WAP TECHNOLOGY AND ITS APPLICATIONS"** in conference on **ELECTRONIC CIRCUITS AND COMMUNICATION SYSTEMS** at THAPAR INSTITUTE OF ENGG. & TECH., PATIALA in February 2006.

- Presented a paper on **"SOFTSWITCH"** in conference on **BIOINFORMATICS** at THAPAR INSTITUTE OF ENGG. & TECH., PATIALA in February 2005.