ANALYSIS OF DATA TRANSMISSION TECHNIQUES IN RAYLEIGH, RICIAN AND NAKAGAMI FADING MODEL UNDER VARIOUS MODULATION SCHEMES

A Thesis submitted in partial fulfillment of the
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CERTIFICATE

I, Yogender Singh Gill hereby certify that the work which is being presented in this thesis entitled **"Analysis of data transmission techniques in Rayleigh, Rician and Nakagami fading model under various Modulation schemes "** by me in partial fulfillment of the requirements for the award of degree of Masters of Engineering in Electronics and Communication Engineering from Thapar University, Patiala is an authentic record of my own work carried under the supervision of Dr. Rajesh Khanna and referred other researcher's work which are duly listed in the reference section.

The matter presented in this report has not been submitted in any University/Institute for the award of Masters of Engineering.

Yogender Singh Gill

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This is certified that the above statement made by the candidate is correct to best of my knowledge.

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Abstract

The requisite for wireless communication and its abstruse nature is upsurging from the past few decades. In future it is believed to be more challenging and complicated with the evolution of different types of fading model. There are different types of fading models striving in urban and rural areas. Rayleigh fading model is considered to be most common fading model, found in urban environment. In Rayleigh fading model there is no line of sight communication, where the signal is received after several reflections and scattering .Rician fading consists of line of sight communication and found to be more applicable for satellite communication. Nakagami fading model is mostly suited for urban multipath propagation and it is sought to be most practical model,specially used in mobile communication. The signal ought to be send in most productive way so that the signal received at receiver must be accurate and precise to transmit the information reliably. So,the most expeditious and high-octane method is block coding which is used to impart the information carrying signal veraciously at the receiver. Modulation scheme also plays a vital role in improving performance of signal when it travels through a channel. In order to achieve error free signal at the receiver the choice of modulation scheme should be done wisely. The combination of best efficient modulation scheme along with the block coding helps in getting the signal error free at the receiver. The condition of signal is decided by SNR v/s BER (bit error rate) simulation. Our main objective is to get error free result at the receiver ,so for this different data transmission techniques are used to transmit the data from transmitter to receiver in various fading channels under different modulation schemes. Effect of shape factor on Nakagami fading is also covered in this thesis to get efficient results. Alamouti's space time coding is used to further lower the bit error rate (BER). Later on it is found that Nakagami fading channel is the best channel for wireless communication system. Modulation schemes also plays an important role in achieving the signal error free at the receiver. So, BPSK modulation comes out to be best and efficient modulation schemes to get error free signal at the receiver.

ACKNOWLEDGEMENT

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List of Abbreviations

LAN	Local Area Network
Mbps	Mega bit per second
Gbps	Giga bit per second
WiMax	World Wide Interoperability For Microwave Access
LTE	Long Term Evaluation
WLAN	Wireless Local Area Network
BPSK	Binary Phase Shift Keying
QPSK	Quadrature Phase Shift Keying
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
PRK	Phase Reversal Keying
PSK	Phase Shift Keying
CDMA	Code Division Multiple Access
DVB-S	Digital Video Broadcasting-Satellite
Db	Decibels
MIMO	Multiple Input Multiple Output
SISO	Single Input Single Output
MISO	Multiple Input Single Output
SIMO	Single Input Multiple Output
i.i.d	identically independent distributed
AWGN	Additive White Gaussian Noise
SNR	Signal Noise Ratio
MRC	Maximum Ratio Combining
LOS	Line Of Sight
BER	Bit Error Rate
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
Pdf	Probability Density Function
AM	Amplitude Modulation
FM	Frequency Modulation

Chapter 1: INTRODUCTION

1.1 History of wireless communication[1]

- The first wireless network were developed in pre industrial age, where smoke signals, flashing mirrors, signal flares were used to transmit information over line of sight distances.
- In 1838, Samuel Morse invented telegraph network which replaced the early communication network. Later on in 1895, telephone was invented.
- Radio communication was born when Marconi demonstrated the first radio transmission from Isle of Wight to a tugboat 18 miles away. Earlier radio signals were analog in nature , but now a days radio system transmit signal digitally.
- The introduction of wired Ethernet technology in 1970s steered many commercial companies away from radio based networking. The data rate of Ethernet is far better than the radio communication, so the companies did not mind running cables to take advantage of these high data rates.
- In 1985 the concept of wireless LAN came. Initially the wireless LANs had very poor performance in terms of data rates and coverage. But now a days wireless LANs comes under the family of IEEE 802.11 standards. Although the data rates are still low(around tens of Mbps) and coverage area is still small(around 100 metres) as compared to Ethernet range (1 Gbps). Despite their low data rates ,wireless LANs are becoming popular in many homes , offices, campus environment due to convenience and freedom from wires.
- WiMax and LTE also provide higher data rates than WLAN.

1.2 Wireless communication system-

There are three basic elements of communication system namely, transmitter, channel and receiver.

Figure 1.1: block diagram of wireless communication

Transmitter-The main function of transmitter is to produce a signal which is suitable for transmission to receiver over the specific channel.

Channel- channel is a medium which is used to transmit the information from transmitter to receiver. During transmission noise is usually added to the transmitting signal which degrade the information of transmitting signal. In wireless communication fading is another degradation which adds during transmission.

Receiver – The main function of receiver is to reproduce the original signal from the received signal because the received signal is usually degraded by noise.

1.3 Factor that limit the performance of wireless communication

As wireless channel are extremely random in nature , so it is difficult to analyse because signal transmitted from a fixed source will encounter multiple objects in environment that produce reflected, diffracted or scattered copies of the transmitted signal. These additional copies of transmitted signal is known as multipath components. The multipath and transmitted signal are summed together at the receiver, which often produce distortion in the received signal relative to the transmitted signal[3].

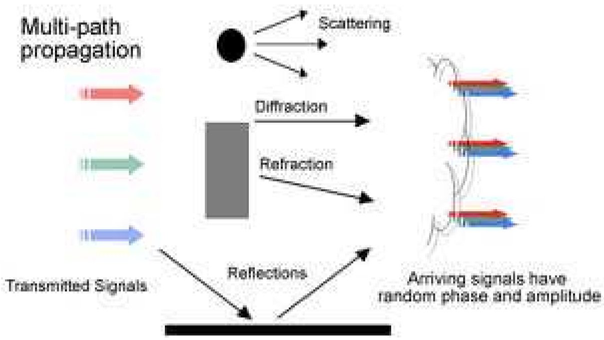

Figure 1.2: Diagram of multipath[2]

1.3.1 Reflection
Reflection occurs when electromagnetic waves bounce off objects whose dimensions are large compared with the wavelength of the propagating wave. They usually occur from the surface of the earth and off buildings and walls[4].

1.3.2 Diffraction
Diffraction occurs when the transmitted signal "bends around" an object in its path to the receiver. Diffraction results from many phenomena, including the curved surface of the earth, hilly or irregular terrain, building edges, or obstructions blocking the LOS path between the transmitter and receiver[3].

1.3.3 Scattering-
Scattered waves are produced when the radio signals is obstructed by the objects which have dimensions small as compared to wavelength. . Scattered waves are produced by rough surfaces, small objects, or by other irregularities in the channel[4]

1.4 Fading
Due to the multiple paths, the receiver of the signal will observe variations of amplitude, phase and angle of arrival of the transmitted signal. These variations originate the phenomenon referred as multipath fading.

1.4.1 According to Mutipath

Large Scale Effect- large-scale fading, refers to path loss caused by the effects of the signal traveling over large areas. Large-scale fading characterizes the losses due to considerably big physical objects in the signal's path like hills or forests.

Small Scale Effect -small-scale fading characterizes the effects of small changes in the separation between a transmitter and a receiver. These changes can be caused by mobility of the transmitter, receiver or the intermediate objects in the path of the signal. Small scale changes result in considerable variations of signal amplitude and phase.

1.4.2 According to Delay Spread[3]
There are two types of fading according to the effect of Delay Spread. These are Flat Fading and Frequency Selective Fading.

Frequency selective fading- From the time domain point of view, frequency selective fading occurs when the maximum spread in time of a symbol is greater than the duration of the symbol. From the frequency domain point of view, frequency selective fading occurs when the spectral components of a signal are affected in different ways by the channel In particular, frequency selective fading occurs when
the channel's coherence bandwidth (the channel's bandwidth in which all components experience approximately the same fading characteristics) is smaller than the signal's bandwidth.

Flat fading-When the conditions described above, for frequency selective fading are not met, the degradation is referred as flat fading. In this case the channel characteristics are approximately flat for all frequencies.

1.5 Wireless channel

The channel is a communication medium through which the transmitted data propagates. Wireless channel is random in nature, so the signal are received from transmitter by multipath i.e reflection, diffraction and scattering in addition to direct line of sight path. So there are three types of channel model considered-

1. Rayleigh fading channel
2. Rician fading channel
3. Nakagami fading channel

1.5.1 Rayleigh Fading Channel

Rayleigh fading is considered as the most effective model for tropospheric and ionospheric signal propagation, as well as the effect of heavily built up urban environment on radio signals. Rayleigh fading is considered when there is no line of sight communication between the transmitter and receiver. Experimental work in Manhattan has found Rayleigh fading there[8]. If there is much scatter in the environment that scatter the radio signals before it arrives at the receiver, then in this case central limit theorm holds. Such process will have zero mean and phase evenly distributed between 0 and 2Π radians. The envelope of channel response will be Rayleigh distributed[3]

$$P_z(z) = \frac{2z}{P_r}\exp\left[\frac{-z^2}{P_r}\right], x \geq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.1$$

Where P_r is the average received power of the signal. For any two Gaussian random variables X and Y, both with mean zero and equal variance σ^2, it can be shown that

$Z = \sqrt{X^2 + Y^2}$,is Rayleigh distributed as given in equation 1.1 and Z is exponentially distributed[3].

1.5.2 Rician fading channel

Rician fading model is applicable most when in addition to scattering there is a strongly dominated signal is seen at the receiver, usually caused by line of sight. During such random process, mean will no longer be zero. In this case mean will vary around the power level of the dominant path. The envelope of channel response will be rician distributed.

$$p_z(z) = \frac{z}{\sigma^2} \exp\left[\frac{-(z^2 + s^2)}{2\sigma^2}\right] I_0\left(\frac{zs}{\sigma^2}\right), z \geq 0 \ldots\ldots\ldots\ldots 1.2$$

Where $2\sigma^2$ is the average power in the non-LOS multipath components and s^2 is the power in the LOS component. I_0 is the modified Bessel function of the 0th order[3].

1.5.3 Nakagami fading

The Nakagami-k fading channel model has been widely used to model the fading distribution in various wireless channels. While the Rayleigh and Rice distributions can indeed be used to model the envelope of fading channels in many cases of interest, it has been found experimentally that the Nakagami distribution offers a better fit for a wider range of fading conditions in wireless communications. Since the value of k is an indicator of the severity of the fading channel conditions and influences the BER, the knowledge of its values range can be used in the evaluation and design of different wireless communications techniques[27] .The Nakagami fading distribution, is given by[3].

$$P_z(z) = \frac{2k^k z^{2k-1}}{\Gamma(k) P_r^k} \exp\left[\frac{-kz^2}{P_r}\right], k \geq .5 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.3$$

Thus, k is the ratio of the power in the LOS component to the power in the other (non-LOS) multipath components. The fading parameter k is therefore a measure of the severity of the fading: a small k implies severe fading, a large k implies more mild fading.

P_r is the average received power and $\Gamma(.)$ is the gamma function. The Nakagami distribution is parameterized by P_r and the fading parameter k.

1.6 Diversity techniques

To combat the impact of fading on the error rate, diversity techniques are usually employed. The principle of diversity is to provide the receiver with multiple versions of the same transmitted signal. Each of these versions is defined as a diversity branch. If these versions are affected by independent fading conditions, the probability that all branches are in a fade at the same time reduces dramatically. Hence, diversity helps stabilize the link through channel hardening which leads to improved performance in terms of error rate. Because fading may take place in time, frequency and space, diversity techniques may similarly be exploited in each of these domains[10].

1.6.1 Time diversity

Time diversity means replicas of the transmitted signal are provided across time by a combination of channel coding and time interleaving strategies. In this case for diversity to be effective is that the channel must provide sufficient variations in time.

1.6.2 Frequency diversity

Frequency diversity means providing replica of transmitted signal in frequency domain. It is found in cases where the coherence bandwidth is small when compared with the bandwidth of the signal.

1.6.3 Spatial diversity

Spatial diversity means providing replica of original transmitted signal across different antennas of receiver. For independent fades antenna spacing should be larger than the coherent distance.

Spatial diversity can be further categorized in to two-

1. Receive diversity
2. Transmit diversity

Receive diversity

Receive diversity uses maximum ratio combining technique to improve the quality of the signal. It is expensive to use maximum ratio combining technique in mobile phones. This reason makes transmit diversity popular because it is easier to implement at base station.

Transmit diversity

Transmit diversity is popular diversity because of its easier implementation at the base station. However this scheme requires complete channel knowledge at the transmitter, but with the rise of Alamouti's space time code, transmit diversity is implemented without the knowledge of channel.

Maximum ratio combining

Maximum ratio combining is a technique which is used at the receiver side to receive the signal coming through different paths and perform combining to improve the signal quality. In this signals from all the paths are weighted according to their SNR and then summed.

Assumptions-

- $\mathbf{s}_1$ is the original signal transmitted from antenna 1.
- $\mathbf{h}_1$ is the channel coefficient between transmit antenna and receive antenna 1.
- $\mathbf{h}_2$ is the channel coefficient between transmit antenna and receive antenna 2.
- $\mathbf{n}_1$ is the Gaussian noise added to receiver1.
- $\mathbf{n}_2$ is the Gaussian noise added to receiver 2.

After adding noise , the received signal at both the receiver will be:

$$\mathbf{r}_1 = \mathbf{h}_1\mathbf{s}_1 + \mathbf{n}_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.5$$

$$\mathbf{r}_2 = \mathbf{h}_2\mathbf{s}_1 + \mathbf{n}_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots 1.6$$

Where $\mathbf{r}_1$ and $\mathbf{r}_2$ is the received signal at receiver 1 and receiver 2 respectively.

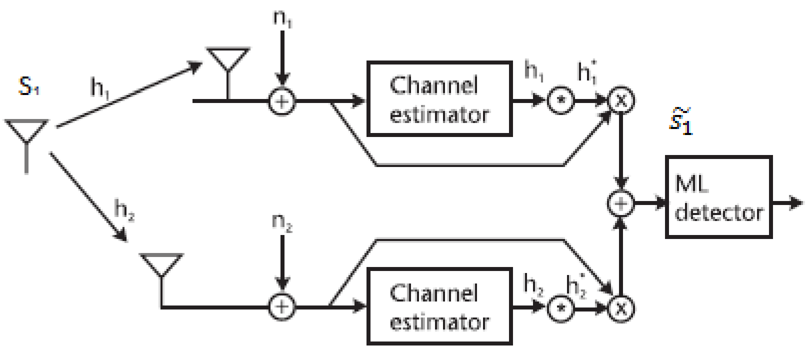

Figure 1.3: Diagram of 1 transmitter and 2 receiver[4]

Then the MRC receiver will combine the received signal. We get:

$$\tilde{\mathbf{s}}_1 = \mathbf{h}_1^*\mathbf{r}_1 + \mathbf{h}_2^*\mathbf{r}_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.7$$

Put the equation 1.5 and equation 1.6 in equation 1.7,then we get

$$\tilde{\mathbf{s}}_1 = \mathbf{h}_1^*(\mathbf{h}_1\mathbf{s}_1 + \mathbf{n}_1) + \mathbf{h}_2^*(\mathbf{h}_2\mathbf{s}_1 + \mathbf{n}_2) \ldots\ldots\ldots\ldots 1.8$$

$$\tilde{\mathbf{s}}_1 = (\boldsymbol{\beta}_1^2 + \boldsymbol{\beta}_2^2)\mathbf{s}_1 + \mathbf{h}_1^*\mathbf{n}_1 + \mathbf{h}_2^*\mathbf{n}_2 \ldots\ldots\ldots\ldots\ldots 1.9$$

Where $\boldsymbol{\beta}_1^{\ 2} = \mathbf{h}_1\mathbf{h}_1^{\ *}, \boldsymbol{\beta}_2^{\ 2} = \mathbf{h}_2\mathbf{h}_2^{\ *}$

$\tilde{\mathbf{s}}_1$ is maximum likelihood estimate of original transmitted signal $\mathbf{s}_1$ and $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ are the constants. After that maximum likelihood decision rule is used to choose which signal was actually transmitted.

Alamouti's scheme

Alamouti's scheme is a simple transmit diversity scheme which have two transmit antennas. In this first of all signals are modulated using M-PSK modulated scheme. Then these modulated scheme are given to transmit antenna according to the code matrix[4].

$$\mathbf{S} = \begin{bmatrix} \mathbf{s}_1 & -\mathbf{s}_2^{\ *} \\ \mathbf{s}_2 & \mathbf{s}_1^{\ *} \end{bmatrix} \text{..................}1.10$$

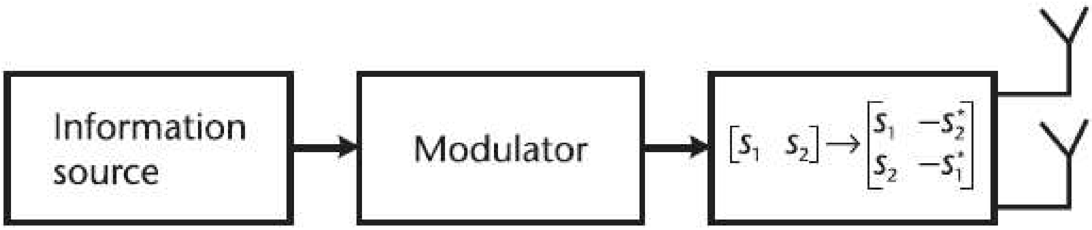

Figure 1.4: Block diagram of alamouti space time encoder[4]

Assumptions-

- $\mathbf{s}_1$ is the symbol transmitted from antenna 1 to receiver 1.
- $\mathbf{s}_2$ is the symbol transmitted from antenna 2 to receiver 1.
- During the first symbol period, the first antenna transmits $\mathbf{s}_1$ and second antenna transmits $\mathbf{s}_2$.
- During the second symbol period, the first antenna transmits $-\mathbf{s}_2^{\ *}$ and second antenna transmits $\mathbf{s}_1^{\ *}$.
- $\mathbf{h}_1(\mathbf{t})$ is the fading coefficients from transmit antenna 1 to receiver antenna 1 at time t.
- $\mathbf{h}_2(\mathbf{t})$ is the fading coefficients from transmit antenna 2 to receive antenna 1 at time t.
- $\mathbf{n}_1$ and $\mathbf{n}_2$ are Gaussian noise at time t and $t+T$ respectively.

By assuming these fading coefficients constant across two consecutive symbols:

$$\mathbf{h_1(t) = h_1(t+T) = h_1 = \beta_1 e^{j\alpha_1}} \text{ ....1.11}$$

$$\mathbf{h_2(t) = h_2(t+t) = h_2 = \beta_2 e^{j\alpha_2}} \text{ ....1.12}$$

Where $\mathbf{h_1}$ and $\mathbf{h_2}$ are the amplitude gain from transmit antenna 1 and transmit antenna 2 respectively. While $\boldsymbol{\alpha_1}$ and $\boldsymbol{\alpha_2}$ are the phase shifts for the path from transmit antenna 1 to receive antenna1 and from transmit antenna 2 to receive antenna 1 respectively and $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_2}$ are the constants.

Now, the received signal after passing through receiver will be

$$\mathbf{r_1 = h_1 s_1 + h_2 s_2 + n_1} \text{ ....1.13}$$

$$\mathbf{r_2 = -h_1 s_2^* + h_2 s_1^* + n_2} \text{ ....1.14}$$

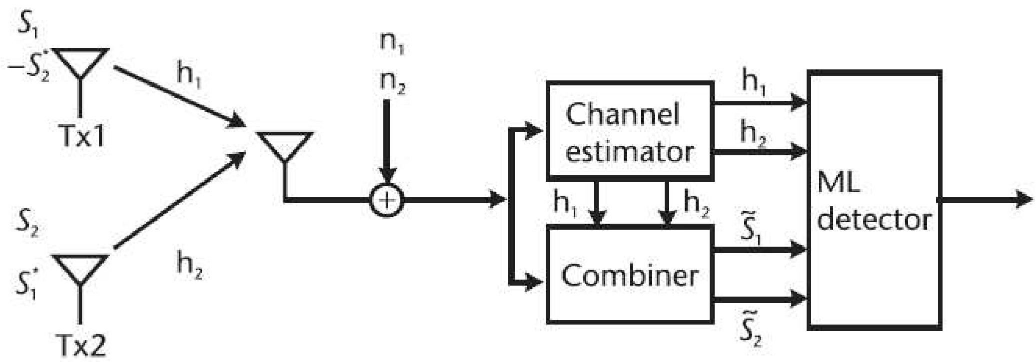

Figure 1.5: Alamouti's two-antenna transmit diversity scheme[4].

Now the combiner combines the received signal as:

$$\mathbf{\tilde{s}_1 = h_1^* r_1 + h_2 r_2^* = (\beta_1^2 + \beta_2^2) s_1 + h_1^* n_1 + h_2 n_2^*} \text{ ....1.15}$$

$$\mathbf{\tilde{s}_2 = h_2^* r_1 - h_1 r_2^* = (\beta_1^2 + \beta_2^2) s_2 - h_1 n_2^* + h_2^* n_1} \text{ ....1.16}$$

Then these signals are send to maximum likelihood detector which choose which symbol was actually transmitted for each of signal $\mathbf{s_1}$ and $\mathbf{s_2}$.

1.7 Digital modulation schemes

The choice of digital modulation scheme will significantly affect the characteristics, performance and resulting physical realisation of a communication system. There is no universal 'best' choice of scheme, but depending on the physical characteristics of the channel, required levels of performance and target hardware trade-offs, some will prove a better fit than others. Consideration must be given to the required data rate, acceptable level of latency, available bandwidth, anticipated link budget and target hardware cost, size and current consumption. The goal of a modulation technique is not only to transport a message signal through a radio channel, but to achieve this with the best quality, power efficiency, and the least amount of bandwidth possible. In order to study the techniques for occupying less bandwidth and reducing power consumption per channel, a closer study of transmission techniques are explored in order to determine a favourable modulation technique for a particular wireless application[5].

1.7.1 Transition of modulation schemes

Over the past few years a major transition has occurred from simple analog Amplitude Modulation (AM) and Frequency/Phase Modulation (FM/PM) to new digital modulation techniques[4]. Examples of digital modulation include-

BPSK(binary phase shift keying)

QPSK(quadrature phase shift keying)

QAM(quadrature amplitude modulation)

1.7.2 Bit rate and symbol rate

To understand and compare different modulation format efficiencies, it is important to first understand the difference between bit rate and symbol rate as shown in figure 1.6. The signal bandwidth for the communications channel needed depends on the symbol rate, not on the bit rate.

Symbol rate= bit rate/the number of bits transmitted with each symbol.

Bit rate is the frequency of a system bit stream. Take, for example, a radio with an 8 bit sampler, sampling at 10 kHz for voice. The bit rate, the basic bit stream rate in the radio, would be eight bits multiplied by 10K samples per second, or 80 Kbits per second. The symbol rate is the bit rate divided by the number of bits that can be transmitted with each symbol. If one bit is transmitted per symbol, as with BPSK, then the symbol rate would be the same as the bit rate of 80 Kbits per second. If two bits are transmitted per symbol, as in QPSK, then the symbol rate would be half of the bit rate or 40 Kbits per second. Symbol rate is sometimes called baud rate. Note that baud rate is not the same as bit rate. These terms are often confused. If more bits can be sent with each symbol, then the same amount of data can be sent in a narrower spectrum. This is why modulation formats that are more complex and use a higher number of states can send the same information over a narrower piece of the RF spectrum[6].

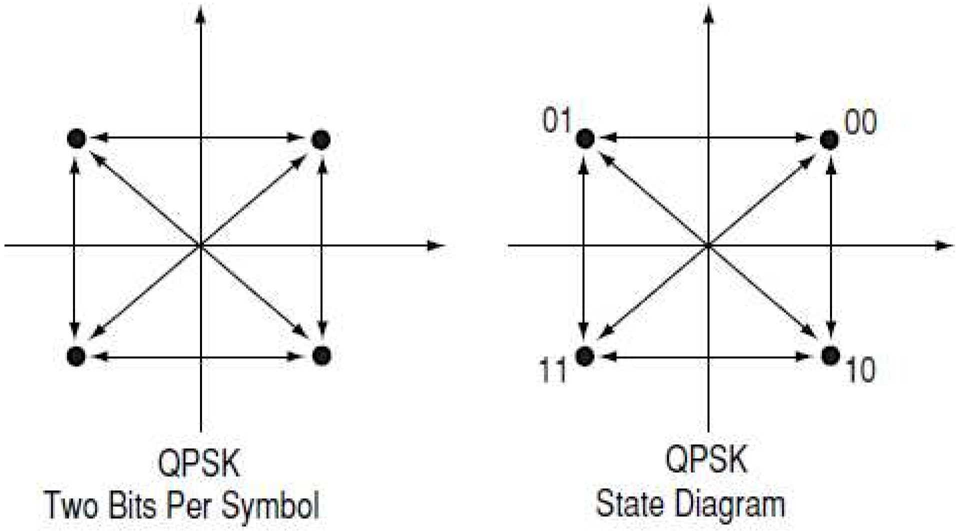

Figure 1.6: Bit Rate and Symbol Rate[6]

1.7.3 BPSK(Binary phase shift keying)[10][11][12]

BPSK (also sometimes called PRK, Phase Reversal Keying, or 2PSK) is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, at 0° and 180°. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate applications when bandwidth is limited[10][11][[12].

In the presence of an arbitrary phase-shift introduced by the communications channel, the demodulator is unable to tell which constellation point is which. As a result, the data is often differentially encoded prior to modulation.

Implementation

The general form for BPSK follows the equation[10][11][12]:

$$s_b(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\Pi f_c t + \Pi(1-n)), n = 0,1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.17$$

This yields two phases 0 and Π .In the specific form, binary data is often conveyed with the following signals:

$$s_0(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\Pi f_c t + \Pi) = -\sqrt{\frac{2E_b}{T_b}} \cos(2\Pi f_c t) \text{ for binary 0. } \ldots\ldots 1.18$$

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\Pi f_c t) \text{ for binary 1. } \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.19$$

Where f_c is frequency of carrier wave.

Hence the signal space can be represented by the single basis function.

$$\Phi(t) = \sqrt{\frac{2}{T_b}} \cos(2\Pi f_c t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.20$$

Where 1 is represented by $\sqrt{E_b}\Phi(t)$ and 0 is represented by $-\sqrt{E_b}\Phi(t)$

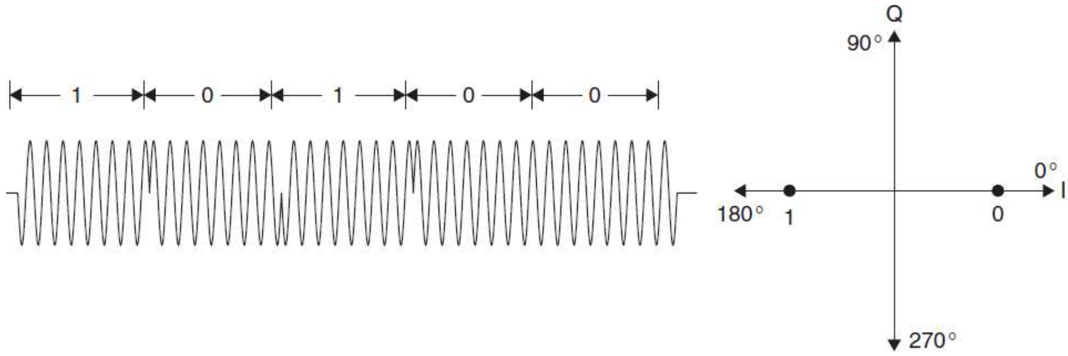

Figure 1.7: Multiamplitude and multiphase keying of BPSK[7]

1.7.4 QPSK(Quadrature phase shift keying)[6]

Quadrature means that the signal shifts between phase states which are separated by 90 degrees. The signal shifts in increments of 90 degrees from 45 to 135, –45, or –135 degrees. It is used extensively in applications including CDMA (Code Division Multiple Access) cellular service, wireless local loop, Iridium (a voice/data satellite system) and DVB-S (Digital Video Broadcasting — Satellite)[6].

Implementation[10][11][12]

The general form for QPSK follows the equation:

$$s_n(t) = \sqrt{\frac{2E_s}{T}} \cos(2\Pi f_c t + (2n-1)\frac{\Pi}{4}), n = 1,2,3,4. \ldots\ldots\ldots 1.21$$

This yields the four phases $\frac{\Pi}{4}, \frac{3\Pi}{4}, \frac{5\Pi}{4}, \frac{7\Pi}{4}$ as needed.

This results in a two dimensional function signal space with unit basis functions

$$\Phi_1(t) = \sqrt{\frac{2}{T_s}} \cos(2\Pi f_c t) \ldots\ldots\ldots\ldots\ldots 1.22$$

$$\Phi_2(t) = \sqrt{\frac{2}{T_s}} \sin(2\Pi f_c t) \ldots\ldots\ldots\ldots\ldots 1.23$$

The first basis function is used as the in-phase component of the signal and the second as the quadrature component of the signal. Hence, the signal constellation consists of the signal-space 4 points.

$$(\pm\sqrt{\frac{E_s}{2}}, \pm\sqrt{\frac{E_s}{2}})$$

The factors of 1/2 indicate that the total power is split equally between the two carriers. Comparing these basis functions with that for BPSK shows clearly how QPSK can be viewed as two independent BPSK signals. Note that the signal-space points for BPSK do not need to split the symbol (bit) energy over the two carriers in the scheme shown in the BPSK constellation diagram.

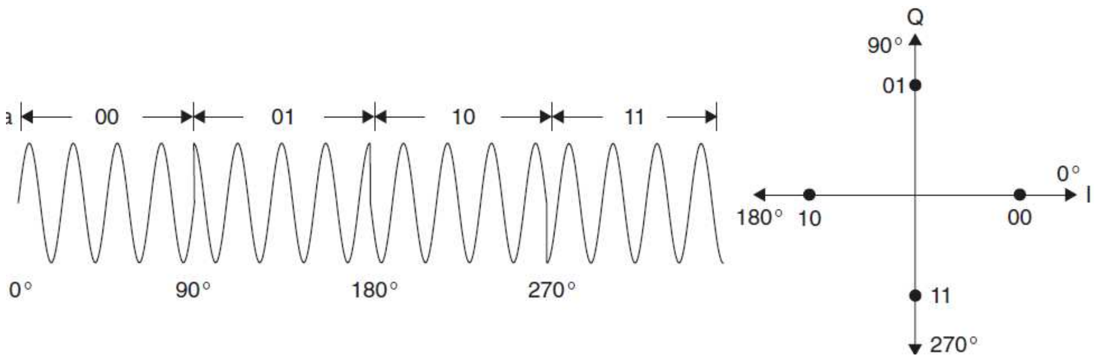

Figure 1.8: Multiamplitude and multiphase keying of QPSK[7]

1.7.5 QAM(Quadrature amplitude modulation)[10][13][14]

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation(AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90 ° and are thus called quadrature carriers or quadrature components — hence the name of the scheme. The modulated waves are summed, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK), or (in the analog case) of phase modulation (PM) and amplitude modulation. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. PSK modulators are often designed using the QAM principle, but are not considered as QAM since the amplitude of the modulated carrier signal is constant. QAM is used extensively as a modulation scheme for digital telecommunication systems[10][13][14].

Implementation

Digital QAM

Like all modulation schemes, QAM conveys data by changing some aspect of a carrier signal, or the carrier wave, (usually a sinusoid) in response to a data signal. In the case of QAM, the amplitude of two waves, 90 degrees out-of-phase with each other (in quadrature) are change to represent the data signal. Amplitude modulating two carriers in quadrature can be equivalently viewed as both amplitude modulating and phase modulating a single carrier[10][13][14].

Analog QAM

When transmitting two signals by modulating them with QAM, the transmitted signal will be of the form[10][13][14]:

$$s(t) = I(t)\cos(2\Pi f_0 t) + Q(t)\sin(2\Pi f_0 t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.24$$

Where $I(t)$ and $Q(t)$ are two modulating signals and f_0 is the carrier frequency.

At the receiver, these two modulating signals can be demodulated using a coherent demodulator. Such a receiver multiplies the received signal separately with both a cosine and sine signal to produce the received estimates of I(t) and Q(t) respectively. Because of the orthogonality property of the carrier signals, it is possible to detect the modulating signals independently. In the ideal case $I(t)$ is demodulated by multiplying the transmitted signal with a cosine signal[10][13][14]:

$$r_i(t) = s(t)\cos(2\Pi f_0 t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.25$$

Putting the equation 1.24 in to equation 1.25 we get,

$$= I(t)\cos(2\Pi f_0 t)\cos(2\Pi f_0 t) + Q(t)\sin(2\Pi f_0 t)\cos(2\Pi f_0 t) \ldots\ldots 1.26$$

Using standard trigonometric identities we get,

$$r_i(t) = \frac{1}{2}I(t)[1+\cos(4\Pi f_0 t)] + \frac{1}{2}Q(t)\sin(4\Pi f_0 t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.27$$

$$r_i(t) = \frac{1}{2}I(t) + \frac{1}{2}[I(t)\cos(4\Pi f_0 t) + Q(t)\sin(4\Pi f_0 t)] \ldots\ldots\ldots\ldots\ldots\ldots 1.28$$

Low-pass filtering $r_i(t)$ removes the high frequency terms (containing $4\pi f_0 t$), leaving only the $I(t)$ term. This filtered signal is unaffected by $Q(t)$, showing that the in-phase component can be received independently of the quadrature component. Similarly, we may multiply $s(t)$ by a sine wave and then low-pass filter to extract $Q(t)$ [10][13][14].

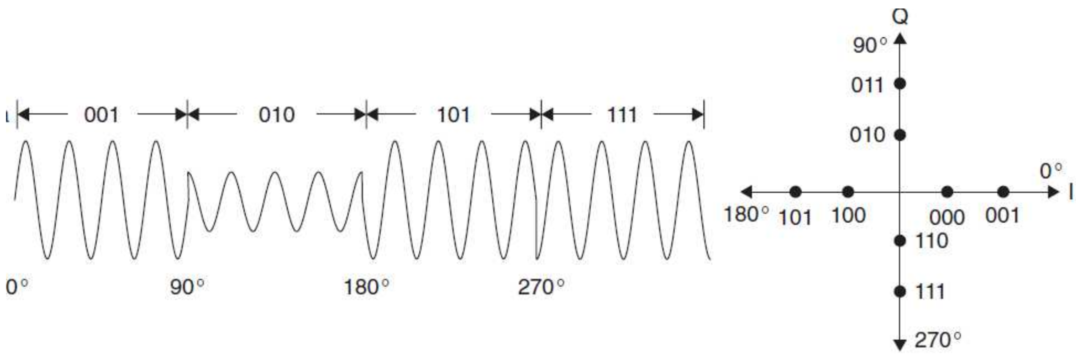

Figure 1.9: Multiamplitude and multiphase keying of QAM[7]

1.8 Data transmission techniques

The combination of best efficient modulation scheme along with the best data transmission techniques helps in getting the signal error free at the receiver.

1.8.1 Application of data transmission techniques

Single bit data transmission technique-

Single bit data transmission may be preferred when channel is stationary for the complete data transmission time. It is possible when the users are communicating within sight of each other. It can be adopted for indoor environment.

Block bit data transmission technique-

Wireless channel is well suited for long distance communication where the probability of channel remain stationary for complete data transmission is less. So in that case block bit data transmission technique is used. It is mainly applicable for mobile and satellite communication.

1.9 Objective of thesis

The main objective of thesis is

- To analyse different data transmission techniques i.e single bit data transmission technique and block bit data transmission technique in various fading channel by different modulation techniques, so that error free data is achieved at receiver.
- To study the effect of shape factor in Nakagami fading.
- To study the alamouti space time coding in various fading channels under different modulation schemes.
- To study the capacity of various antenna configuration in different fading channel.

1.10 Organisation of thesis

This thesis is organised in five chapters

Chapter 1 provides brief idea about the introduction of wireless communication, history of wireless communication, performance limiting factor of wireless communication, wireless channels, diversity techniques, digital modulation schemes and different data transmission techniques.

Chapter 2 presents the overview about the literature survey which proves beneficial in carrying out this work.

Chapter 3 gives the brief introduction about the MIMO system and capacity of the MIMO system.

Chapter 4 is the core chapter of this thesis which gives the Simulation Results carried out by Matlab tool.

Chapter 5 is dedicated to conclusion of thesis and future work.

Chapter 2

Literature review

T. Rappaport[1] presented that small-scale fading characterizes the effects of small changes in the separation between a transmitter and a receiver. These changes can be caused by mobility of the transmitter, receiver or the intermediate objects in the path of the signal. Small scale changes result in considerable variations of signal amplitude and phase. Small-scale fading is also known as Rayleigh fading since the fluctuation of the signal envelope is Rayleigh distributed when there is no predominant line of sight between the transmitter and receiver. When there is a predominant line of sight between the transmitter and receiver the fluctuations are statistically described by a Rician probability distribution function.

B. Sklar[15] presented that large-scale fading, refers to path loss caused by the effects of the signal traveling over large areas. Large-scale fading characterizes the losses due to considerably big physical objects in the signal's path like hills or forests. The path loss is characterized by a mean loss (due to the distance between the transmitter and the receiver and the propagation environment characteristics) and a variation around the mean loss.

Jack h. winters[16] proposed the concept of MIMO in1987 for two basic communication system.

1) First is communication between multiple remotes and a base station with multiple antennas, and

2)Second is communication between two users, each with multiple antennas. For these systems, we determine the information-theoretic capacity and the efficiency index (maximum data rate for a given error rate) in bits/cycle (bits/s/Hz) for different processing techniques. Note that since the multipath changes with position, the capacity (and efficiency index) is a random variable. Therefore, we study the distribution of the capacity and present results for given outage probability.

Morever, optimum combining is only the best Linear processing technique for the receiver, and other techniques can be used to further improve performance. In addition, coding can further improve performance. Finally, performance can also be improved by cooperation between transmit antennas, i.e., appropriate combining of the signals prior to transmission (with multiple transmit antennas at the remotes).

G.J. FOSCHINI and M.J. GANS[17] proposed that MIMO aims to separate data streams occupying the same bandwidth relying on the decorrelation of the multiple received signals in the presence of multipath .Therefore ,the fundamental analysis of MIMO system is based on the assumption of independent flat rayleigh fading and constrained total power. Morever analyzing the narrowband case where the bandwidth is taken to be narrow enough that the channel can be treated as flat over frequency. So they expressed capacity in units of bps/Hz, or, equivalently, bits/cycle. For illustrative purposes, they concentrate on the case of an equal number of transmit and receive antennas but our numerical results will also include comparisons with more standard diversity methods like when there is only one transmitting antenna but many receiving antennas and viceversa .They often assume an environment of a large number of scatterers so that the Rayleigh fading model is appropriate. The assumption of independent Rayleigh paths that we will also often make, is to be thought of as an idealized version of the result that for antenna elements placed on a rectangular lattice with half wavelength spacing, the path losses tend to roughly decorrelate.

Babak Hassibi and Bertrand M. Hochwald[18] proposed that the data are transmitted in bursts,such that the channel can be assumed quasi stationary and that the channel is known at the receiver through the transmission of training sequence but not necessarily at the transmitter. The training sequence enables the receiver to acquire adequate knowledge of the channel coefficients to extract the multiple data streams . The required training interval grows approximately linearly with the number of transmit antennas. To maximise the overall transmission rate ,the number of transmit antennas is chosen such that half of the interval is used for training and half the interval for data transmission .Channel knowledge at the transmitter is generally considered to be beneficiary in the sense that the transmitter can optimise its transmission on the good channels adaptively. However this approach is not necessarily practical since it requires the channel coefficients to be fed back to the transmitter at the rate at which the channel is changing.

Sergey Loyka and Ammar Kouki[19] derived a universal upper bound on the mean (ergodic) MIMO channel capacity, which is independent of the scenario considered and accounts for both the Tx and Rx end correlations, using Jensen's inequality and concavity of logdet function. No assumption of the channel correlation matrix factorization is made. The bound is expressed in terms of the Tx and Rx correlation matrices in such a way that the comparison of the Tx and Rx end contributions to the capacity reduction can be made in a general case. The well-known correlation matrix models developed for the diversity combining systems can also be applied to the MIMO system. The capacity is given by

$$\mathbf{C} = \log_2 \det[\mathbf{I_m} + \frac{\rho}{n}\mathbf{R}] b/s/Hz$$

Where $\mathbf{R}$ is the normalised channel correlation matrix whose components are given by $\mathbf{r_{ij}} = \sum_{\mathbf{k}} \mathbf{h_{ik}} \mathbf{h_{jk}}^*$ where the index i is for receive antenna and j is for transmit antenna and takes in to account the effect of correlation at both the transmit and receive end.

Dimitry Chizhik, Farrokh Rashid-Farrokhi, Jonathan Ling, and Angel Lozano[20] proposed that these high spectral efficiencies are enabled by the fact that a scattering environment makes the signal from every individual transmitter appear highly uncorrelated at each of the receive antennas. As a result, the signal corresponding to every transmitter has a distinct spatial signature at the receiver. These different spatial signatures allow the receiver to effectively separate, with adequate signal processing, the data streams radiated—simultaneously and on the same frequency— by the different transmit antennas. In a sense, the scattering environment acts like a very large aperture that makes it possible for the receiver to resolve the individual transmitters and decode their data. The high spectral efficiency is reduced if the signals arriving at the receivers are correlated. To take the correlation effects in to account , it is proposed to express the channel matrix as ideal iid matrix which is modified by the correlation coefficients at the transmitter and at the receiver. This results in the equation:

$$\mathbf{C} = \log_2\left(\det\left(\mathbf{I} + \frac{\rho}{n}\mathbf{\Phi_R H \Phi_T H^{tc}}\right)\right) b/s/Hz$$

Where $\mathbf{\Phi_T}$ and $\mathbf{\Phi_R}$ are the covariance matrices of transmit and receive arrays respectively.

Da-shan Shiu, Gerard J. Foschinit, Michael J. Gamt, and Joseph M. Kahn[21] proposed that capacity is the sum of the capacities of several subchannels. The fading correlation modifies the distributions of the gains of these subchannels. As fading correlation becomes higher, more and more subchannels have gains that are too small to convey information at any significant rate. The fading correlation can be determined from the geometrical parameters of the model, e.g. antenna spacing and angle of arrival. To quantify the effect of fading correlation, we will focus on the information theoretic channel capacity. These subchannels can be considered as a number of parallel SISO pipes with gain equal to respective eigen values. In this case capacity can be expressed as:

$$\mathbf{C} = \sum_{i=1}^{k} \log_2 \left[1 + \frac{\rho}{n} \lambda_i \right] \mathbf{b/s/Hz}$$

Where k is the rank of matrix which is ideally equal to $\min(n, m)$ and λ_i is the eigen values.

Burr[22] proposed the factors which limit the MIMO channel capacity are the number of scatters i.e the number of multipath components where it has been shown that the number of independent channels is determined by the smaller number of transmit or receive antennas or the number of scatters.

Alamouti's contribution [23]

Alamouti presented a new diversity scheme (Alamouti's scheme). They assume independent and identically distributed (i.i.d.) fading at different antenna elements, and assume that the transmitter does not know the channel while the receiver is able to track the channel perfectly. The important results obtained were as follows-

Using two transmit antenna and one receive antenna, the new scheme provides the same order of diversity as the maximal-ratio receive combining (MRRC) with one transmit antenna and two receive antenna.

The scheme can be easily generalized to two transmit antennas and R receive antennas to provide a diversity of 2R.

When compared with MRRC, if the total radiated power is to remains the same, the transmit diversity scheme has a 3-dB disadvantage because of the simultaneous transmission of two distinct symbols from two antennas.

Teletar's contribution[24]

First they assumed that the channel state information is available only at the receiver and showed that for i.i.d slowly Rayleigh fading channels with T transmit and R receive antennas,

Capacity C grows linearly with min(T, R) for a given fixed transmitter power and bandwidth.

For T = 1, Capacity increases logarithmically with the increase in the number of Receive antennas R.

For R = 1, Capacity does not increase at all with the increase in the number of transmit antenna T.

However, they also showed that when the channel parameters are known at the transmitter, i.e., if the channel state information (CSI) is available at the transmitter, the capacity can be increased by assigning the transmitted power to various antennas according to the “water-filling” algorithm.

Ji-hua Lu and Yu Han[25] concluded that an increase on the k parameter reduces the severity of fading. Since the value of k is an indicator of the severity of the fading channel conditions and influences the BER, the knowledge of its values range can be used in the evaluation and design of different wireless communications techniques.

$$P_z(z) = \frac{2k^k z^{2k-1}}{\Gamma(k) P_r^k} \exp\left[\frac{-kz^2}{P_r}\right], k \geq .5$$

Thus K is the ratio of the power in the LOS component to the power in the other (non-LOS) multipath components. The fading parameter K is therefore a measure of the severity of the fading: a small K implies severe fading, a large K implies more mild fading. P_r is the average received power and $\Gamma(.)$ is the gamma function. The Nakagami distribution is parameterized by P_r and the fading parameter k.

Lorenzo Rubio, Juan Reig, and Narcís[27] Cardona presents a range of possible values of the m parameter based on the analysis of a measurement campaign carried out in an urban environment. A measurement campaign at 900 MHz band was performed in the urban area of Valencia (Spain) in order to estimate the values range of the m parameter. The envelope of the received signal was measured on several paths with a total length of 5 km. The measurement equipment was basically a narrowband power meter connected to a vertically polarised antenna mounted on a van and synchronised with a navigation system. The transmitting antenna was placed in an operative base station (BS) of mobile communications, property of Telefonica Moviles (spanish operator of mobile communications). The height of the transmitting antenna was 35 m from the ground. The measurements were carried out at nights to facilitate a constant speed of the van of about 20 km/h. With this speed, the spatial resolution of the measurement was about $\frac{\lambda}{4}$ (distance between two samples).

The estimation of the k parameter, $\hat{k}$, from the measured envelope (empirical data) was made using an estimation based on the moments method of the Nakagami distribution given by:

$$\hat{\mathbf{k}} = \frac{\mathbf{4.4}}{\sqrt{\mathbf{u_2}}} + \frac{\mathbf{17.4}}{\mathbf{1.92u_2}}$$

Where $\mathbf{u_2} = \frac{\mathbf{1}}{\mathbf{N}\sum_{\mathbf{i=1}}^{\mathbf{N}}(\mathbf{u_i} - \mathbf{u_1})^2}, \mathbf{u_1} = \frac{\mathbf{1}}{\mathbf{N}\sum_{\mathbf{i=1}}^{\mathbf{N}}\mathbf{u_i}}$

$$\mathbf{u_i} = \mathbf{log r_i}$$

r_i is *ith* measured envelope sample and N is the total number of envelope samples considered in the estimation of k. The estimation of m requires a set of N received envelope samples over a short displacement of the receiving antenna. This short displacement guarantees the presence of short-term fading conditions, equivalent to filter the long-term fading . The total paths were divided into sub-paths, called optimum windows, using the standard deviation method proposed by Rathgeber . A total of 1500 sub-paths were analysed, with optimum windows length from 45λ to 60λ, equivalent to 180 and 240 measured envelope samples, respectively. The k parameter in the urban area under study is between 0.5 and 3.5. A parameter below 1 corresponds to severe fading worse than the Rayleigh fading (m=1). In our analysis, this last case appears in the 3.3% of all situations. An increase on the k parameter reduces the severity of fading. The average estimated value of k is 1.56, with a standard deviation of 0.34. Since the most likely value of k oscillates between 1 and 2, it is necessary to consider non-integer values for the fading parameter in analytical studies related to Nakagami fading in urban environments.

Chapter 3

3.1 MIMO(Multiple input Multiple output) overview

MIMO stands for Multiple Input Multiple Output. It is a system which have multiple antennas at the transmitter side and multiple antennas at the receiver side. Due to upsurging nature of wireless communication and invention of new devices like laptops, mobiles, palm-top there is a constant demand of bandwidth and frequency spectrums which is an uphill task to meet. Morever the exigency of high coverage and high capacity is challenge for subscriber and there is a need of high speed and high quality for consumer.

MIMO technology comes after smart antennas ,which is used for improving wireless communication in presence of multi path propagation and fading. Smart antennas improves the wireless communication by encoding independent streams of data onto different paths or linear combinations of paths, thereby increasing the data rate, or they can encode data redundantly onto paths that fade independently to protect the receiver from catastrophic signal fades, thereby providing diversity gain. But after the smart antennas ,MIMO technology came which transmit separate encoded data signal independently from each of the transmit antenna and then at the receiving side receiver antennas received the superposition of all the transmitted signals, thus improving the capacity and efficiency.

Before going to MIMO system it is important to take a look of Single input single output, Single input multiple output, Multiple input single output, Multiple input multiple output system.

SISO(Single Input Single Output)

SISO system is a system where the transmitter and receiver both has single antenna. The performance of SISO system largely depends on the behaviour of the channel when signal is transmitted from transmitter to receiver.

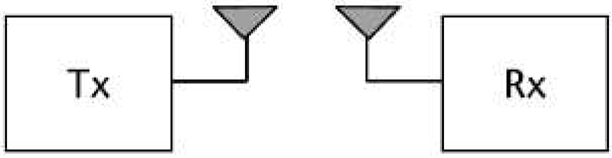

Figure 3.1: diagram of SISO system[4].

SIMO(Single Input Multiple Output)

SIMO system is a system which have a single antenna at the transmitter side and multiple antennas at the receiver side. SIMO system makes use of various combining techniques to recover the transmitted signal.

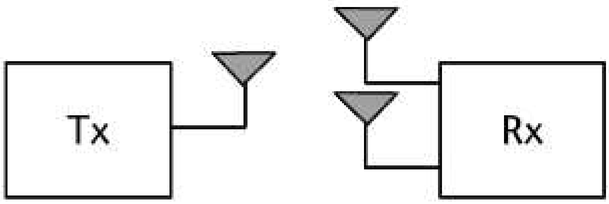

Figure 3.2: Diagram of SIMO system[4].

MISO(Multiple Input and Single Output)

MISO system is a system which have multiple antennas at the transmitter side and single antenna at the receiver side. It make use of transmitter diversity to transmit the signal from transmit antennas.

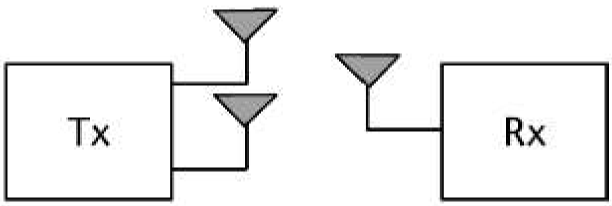

Figure 3.3 Diagram of MISO system[4]

MIMO(Multiple Input and Multiple Output)-

MIMO system is a system which have multiple antennas at the transmitter side and multiple antennas at the receiver side. MIMO architectures can be used for combined transmit and receive diversity, as well as parallel transmission of data or spatial multiplexing. When used for spatial multiplexing MIMO technology promises high bit rates in a narrow bandwidth and as such it is of high significance to spectrum users[3] .

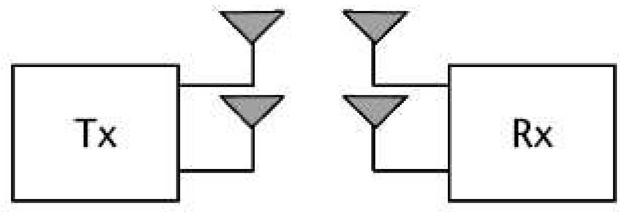

Figure 3.4: Diagram of MIMO system[4]

3.2 Reason for MIMO system

The most important reason for advancement of MIMO system is shanon capacity. A measure of how much information that can be transmitted and received with a negligible probability of error is called the channel capacity[3].

3.2.1 Capacity of SISO system

Assumptions-

1. The channel is assumed to be stationary.
2. The channel is corrupted by additive white Gaussian noise(AWGN).

Then capacity can be expressed as:

$$C = \log_2(1+\rho) b/s/Hz \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where ρ is SNR(signal noise ratio).

3.2.2 Capacity of SIMO system

SIMO stands for single input multiple output. In SIMO system there is single transmit antenna and there are M_R receive antennas.

Assumptions-

1.The channel is assumed to be time varying and random fading.

2.The channel is assumed to be unknown at the transmitter.

The capacity can be expressed as:

$$C = \log_2 \det(1 + M_R \rho) b/s/Hz \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where ρ is SNR(signal noise ratio).

The addition of receive antennas yields a logarithmic increase in capacity in SIMO channels. In this knowledge of the channel at the transmitter will provides no additional benefit.

3.2.3 Capacity of MISO system

MISO stands for multiple input single output. In MISO system there are M_T transmit antennas and single receive antenna.

Assumptions-

1. The channel is assumed to be time varying and random fading.
2. The channel is assumed to be unknown at the transmitter.

The capacity can be expressed as:

$$C = \log_2(1+\rho) b/s/Hz \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

Where ρ is SNR(signal noise ratio).

The capacity obtained in equation is same as of SISO system because the transmitter has no knowledge of channel so there is no array gain at the transmitter.

Now when the transmitter has the knowledge of channel, then the capacity is expressed as:

$$C = \log_2 \det(1+M_T \rho) b/s/Hz \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

Where ρ is SNR(signal noise ratio).

3.2.4 Capacity of MIMO systems

MIMO stands for multiple input and multiple output. In MIMO system there are m transmit antenna and n receive antennas.

Assumptions-

1. channel is assumed to be narrowband rayleigh faded.
2. channel is corrupted by additive white Gaussian noise.
3. channel is known at receiver.
4. total transmitted power remains same irrespective of the number of transmit antennas.
5. channel matrix is normalised such that $\sum_{\mathbf{i,j=1}}^{\mathbf{n}} \left|\mathbf{h_{ij}}\right|^{\mathbf{2}} = \mathbf{n}$.
6. All the received powers are equal so $\sum_{\mathbf{j=1}}^{\mathbf{n}} \left|\mathbf{h_{ij}}\right|^{\mathbf{2}} = \mathbf{1}$.

Then Capacity can be expressed as[4].

$$\mathbf{C} = \log_2 \det\left[\mathbf{I_M} + \left(\frac{\rho}{n}\right)\mathbf{HH^{tc}}\right] b/s/Hz \text{ ....3.5}$$

$$\mathbf{C} = \log_2 \det[\mathbf{I_m} + \frac{\rho}{n}\mathbf{R}] b/s/Hz \text{ ....3.6}$$

Where tc is the complex response, ρ is average signal to noise ratio and $\mathbf{R}$ is normalised channel correlation matrix.

Correlation of the received signal also plays an important role in capacity of MIMO system. So to take correlation effect in to consideration channel matrix should be iid. Then the equation 3.6 becomes:

$$\mathbf{C} = \log_2\left(\det\left(\mathbf{I} + \frac{\rho}{n}\mathbf{\Phi_R H \Phi_T H^{tc}}\right)\right) b/s/Hz \text{ ....3.7}$$

Where $\mathbf{\Phi_T}$ and $\mathbf{\Phi_R}$ are the covariance matrix of the transmit and receive array respectively.

Equation 3.5 can be expressed by singular values of H .Then the capacity equation comes out to be expressed as:

$$\mathbf{C} = \sum_{\mathbf{i=1}}^{\mathbf{k}} \mathbf{\log_2}\left[\mathbf{1} + \frac{\boldsymbol{\rho}}{\mathbf{n}}\boldsymbol{\lambda}_\mathbf{i}\right] \mathbf{b/s/Hz} \text{ ....3.8}$$

Where k is the rank of matrix and $\boldsymbol{\lambda}_\mathbf{i}$ is the eigen mode of $\mathbf{HH^{tc}}$.

When above equation is expressed in terms of eigen values,we get

$$\mathbf{C} = \left\{\sum_{\mathbf{i=1}}^{\mathbf{k}} \mathbf{\log_2}\left(\mathbf{1} + \frac{\boldsymbol{\rho}}{\mathbf{n}}\boldsymbol{\sigma}^\mathbf{2}{}_\mathbf{i}\right)\right\} \mathbf{b/s/Hz} \text{ ....3.9}$$

If the channel is known at the transmitter then capacity can be increased by giving more power to the good channels. This results in capacity expression

$$\mathbf{C} = \sum_{\mathbf{i=1}}^{\mathbf{k}} \mathbf{\log_2}\left[\mathbf{1} + \frac{\mathbf{p_i}}{\boldsymbol{\sigma}^\mathbf{2}}\boldsymbol{\lambda}_\mathbf{i}\right] \mathbf{b/s/Hz} \text{ ....3.10}$$

Where p_i is power in the ith channel.

Since we know that channel varies randomly ,then channel capacity is determined by ergodic capacity. Then the capacity expression given in equation3.5 becomes

$$\mathbf{C} = \mathbf{E}\left\{\mathbf{\log_2}\left[\mathbf{det}\left(\mathbf{I_n} + \frac{\boldsymbol{\rho}}{\mathbf{n}}\mathbf{HH^{tc}}\right)\right]\right\} \mathbf{b/s/Hz} \text{ ....3.11}$$

where ρ is the average SNR.

When n is very large then in this case product of channel matrix and its transpose conjugate is equal to identity matrix. Then the capacity is

$$\mathbf{C = E\{n.log_2(1+\rho)\} b/s/Hz} \text{ ....3.12}$$

Which shows that capacity increases linearly with n.

Chapter 4- Simulation Results

Data can either transmitted in single or blocks using multiple antennas to increase data rate and use the spectrum effectively.

Single bit data transmission technique(one bit at a time)-In single bit data transmission technique each bit is sent one by one from each transmit antenna to each receive antenna. Single bit data transmission may be preferred when channel is stationary for the complete data transmission time.

Block bit data transmission technique(a block of few bits at a time)- The probability of channel remain stationary for complete data transmission is less. Hence, data is divided into blocks of certain length and a block is sent for the time in which channel is considered to be stationary. Thus, in this way every block undergoes an independent fading and only a part of transmitted data is corrupted even if the channel is in a deep fade.

The system with Mt transmit antennas and Mr receive antennas and assuming slow fading over the bandwidth of interest, the output at a given time instant may be represented as the output,

$$\mathbf{y} = \mathbf{Hx} + \mathbf{N} \quad \text{...4.1}$$

where,

$$\mathbf{H} = \begin{bmatrix} \mathbf{H}_{1,1} & \mathbf{H}_{1,2} & . & . & \mathbf{H}_{1,M_T} \\ \mathbf{H}_{2,1} & \mathbf{H}_{2,2} & . & . & \mathbf{H}_{2,M_T} \\ . & . & & & . \\ . & & . & & . \\ \mathbf{H}_{M_R,1} & \mathbf{H}_{M_R,2} & . & . & \mathbf{H}_{M_R,M_T} \end{bmatrix}$$

$\mathbf{x}$ is the input vector and $\mathbf{N}$ is the AWGN noise in the channel. The channel is assumed to be independent identically distributed (i.i.d) with Rayleigh, Rician and Nakagami faded. A maximal ratio combining of the received signals is done at the receiver side in order to maximize the output SNR.

Firstly, single bit data transmission was achieved assuming the channel to be Rayleigh faded with zero mean and variance 1. However, crucial data may be lost if there is a deep fade in the channel, hence the received signal is error prone. Secondly, these bits were retransmitted using blocks of certain length, over which the channel is assumed to be stationary and undergoes a slow fading, and the performance was found to be better than the earlier case. The performance of the system gets further enhanced if we use diversity techniques at the transmitter and receiver side. The procedure was repeated for the Rician and Nakagami fading channel which contains atleast one line of sight (LOS) path which have non zero mean.

4.1 Comparison of different fading channel using single bit simulation technique for different modulation techniques.

Assumptions-

1. The channel is assumed to be Rayleigh,Rician and Nakagami faded.
2. The modulation technique used is BPSK.
3. Single bit data transmission technique is used.

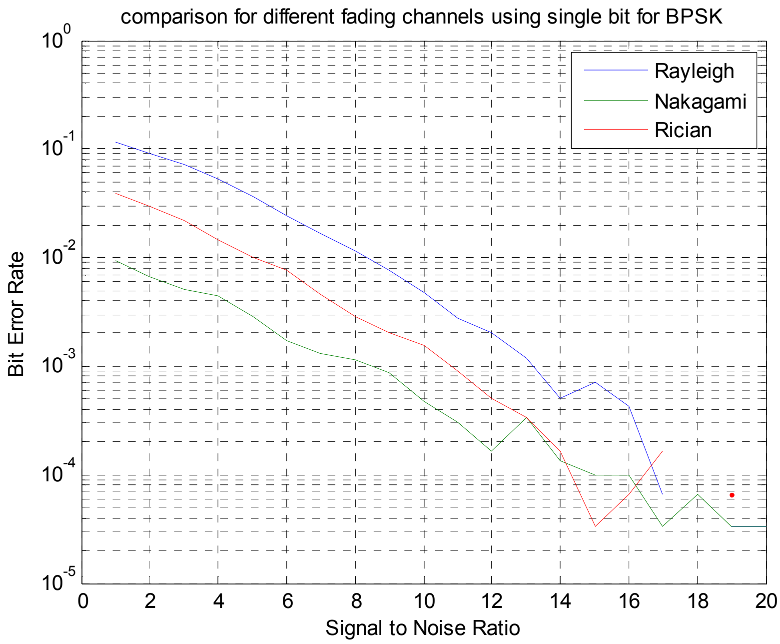

Figure 4.1: Comparison for different fading channels using single bit for BPSK.

The simulated results in figure 4.1 shows that when data is send from transmitter to receiver by single bit simulation technique using BPSK modulation in Rayleigh, Rician and Nakagami fading channel, then data experience less BER in Nakagami fading channel.

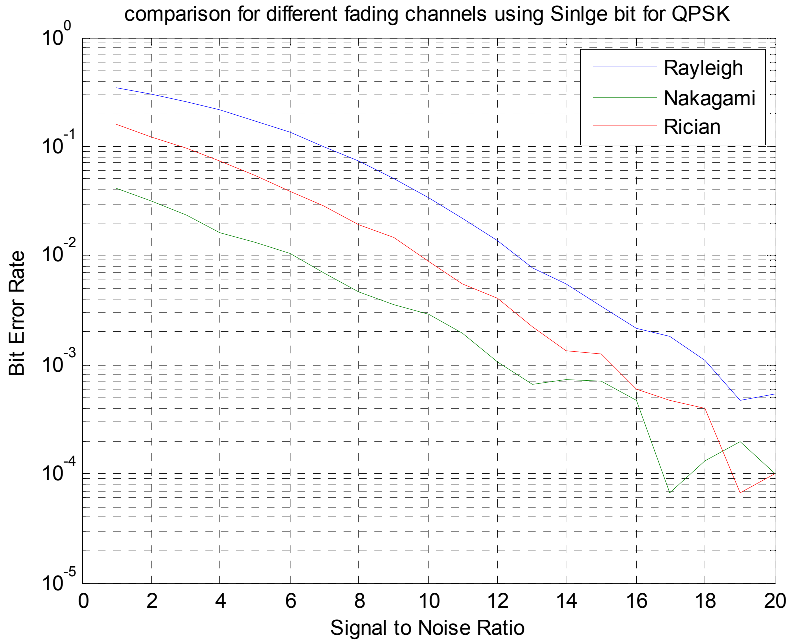

Figure 4.2: Comparison for different fading channel using single bit for QPSK.

The simulated results in figure 4.2 shows that when data is send from transmitter to receiver by single bit simulation technique using QPSK modulation in Rayleigh, Rician and Nakagami fading channel, then data experience less BER in Nakagami fading channel.

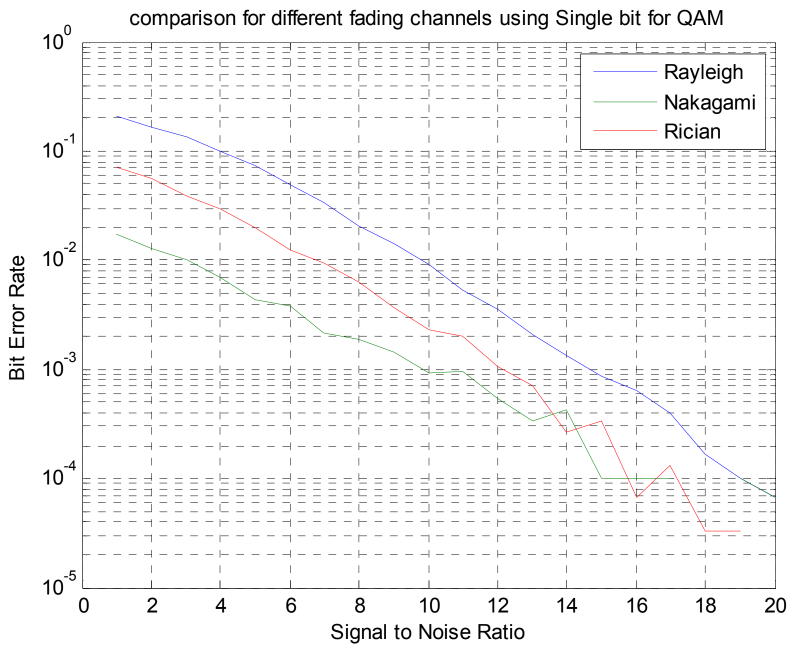

Figure 4.3: Comparison for different fading channel using single bit for QAM.

The simulated results in figure 4.3 shows that when data is send from transmitter to receiver by single bit simulation technique using QAM modulation in Rayleigh, Rician and Nakagami fading channel, then data experience less BER in Nakagami fading channel.

Analysis-

Depending upon the simulated results of figure 4.1, figure 4.2 and figure 4.3, the analysis has been done in the form of Table 1.

Table 1

Comparison of different fading channel using single bit simulation for different modulation schemes at 8 dB SNR.

	Rayleigh channel	Rician channel	Nakagami channel
BPSK	0.01133	0.0029	0.001133
QPSK	0.0742	0.01897	0.0047
QAM	0.0204	0.0063	0.001867

Hence it can be inferred from table 1 that Nakagami channel gives the less BER for a given SNR using single bit simulation technique.

4.2 Comparison of different fading channel using block bit simulation technique for different modulation techniques

Assumptions-

1. The channel is assumed to be Rayleigh,Rician and Nakagami faded.
2. The modulation technique used is BPSK.
3. Block bit data transmission technique is used.

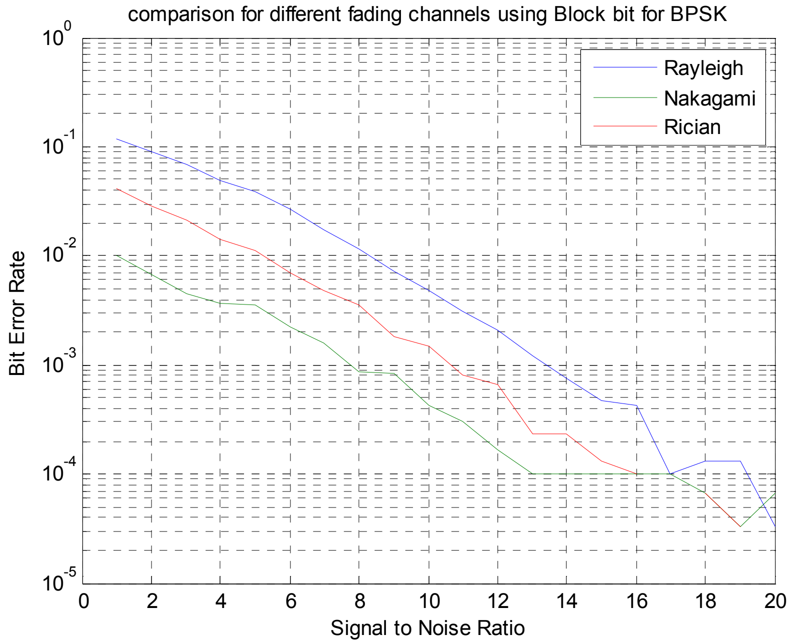

Figure 4.4: Comparison for different fading channel using block bit for BPSK

The simulated results in figure 4.4 shows that when data is send from transmitter to receiver by block bit simulation technique using BPSK modulation in Rayleigh, Rician and Nakagami fading channel, then data experience less BER in Nakagami fading channel.

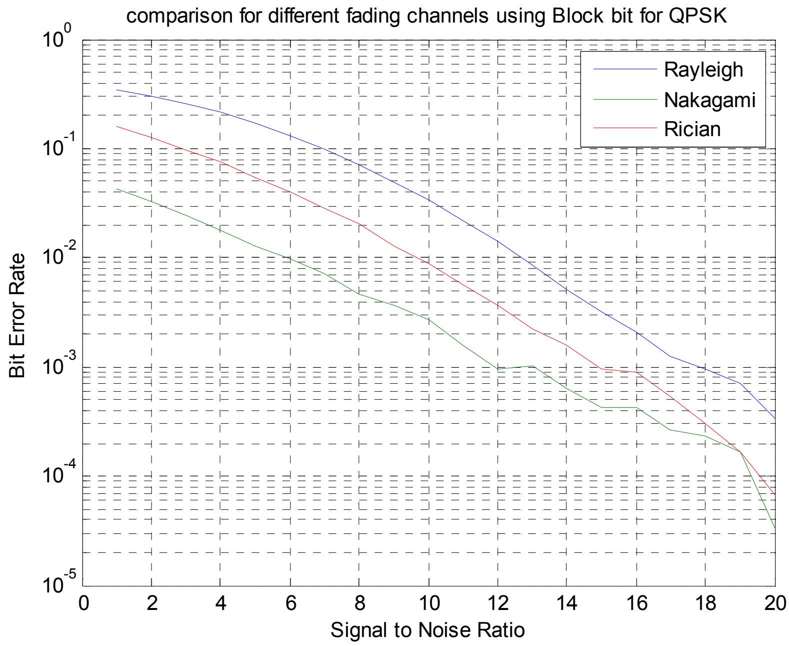

Figure 4.5: Comparison for different fading channel using block bit for QPSK.

The simulated results in figure 4.5 shows that when data is send from transmitter to receiver by block bit simulation technique using QPSK modulation in Rayleigh, Rician and Nakagami fading channel, then data experience less BER in Nakagami fading channel.

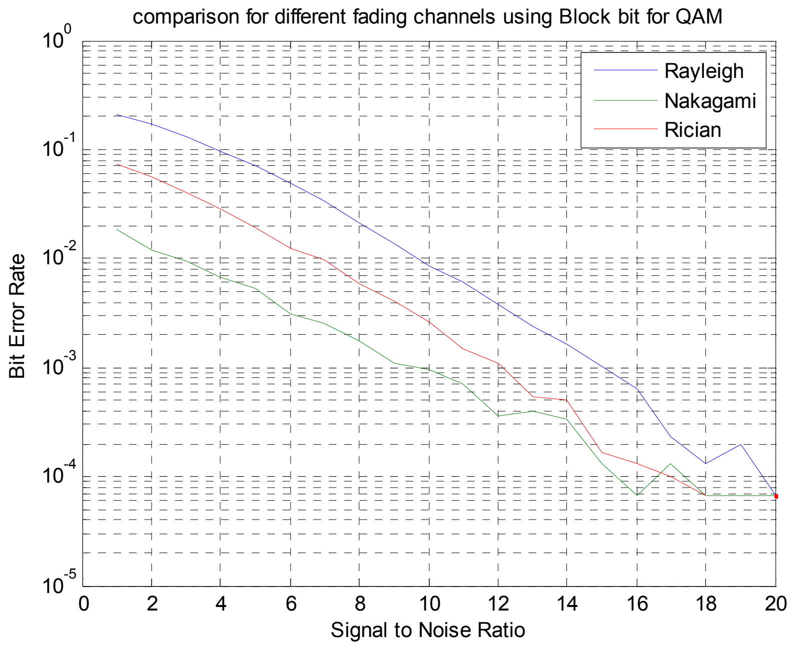

Figure 4.6: Comparison for different fading channel using block bit for QAM.

The simulated results in figure 4.6 shows that when data is send from transmitter to receiver by block bit simulation technique using QAM modulation in Rayleigh, Rician and Nakagami fading channel, then data experience less BER in Nakagami fading channel.

Analysis-

Depending upon the simulated results of figure 4.4, figure 4.5 and figure 4.6, the analysis has been done in the form of Table 2.

Table 2

Comparison of different fading channel using block bit simulation for different modulation schemes at 8 dB SNR.

	Rayleigh channel	Rician channel	Nakagami channel
BPSK	0.01163	0.0036	0.0008667
QPSK	0.07017	0.02047	0.0047
QAM	0.0215	0.0059	0.001767

It can be inferred from table 2 that Nakagami channel gives the less BER for a given SNR using block bit simulation technique. So, Nakagami channel is the best channel for wireless communication.

4.3 Comparison of different modulation techniques using single bit simulation techniques in Rayleigh channel by varying the number of transmitters.

Assumptions-

1. The channel is assumed to be Rayleigh faded.
2. The modulation technique used is BPSK,QPSK and QAM.
3. Number of transmitters taken as 1,2,3 and 4.
4. Single bit simulation is carried out.

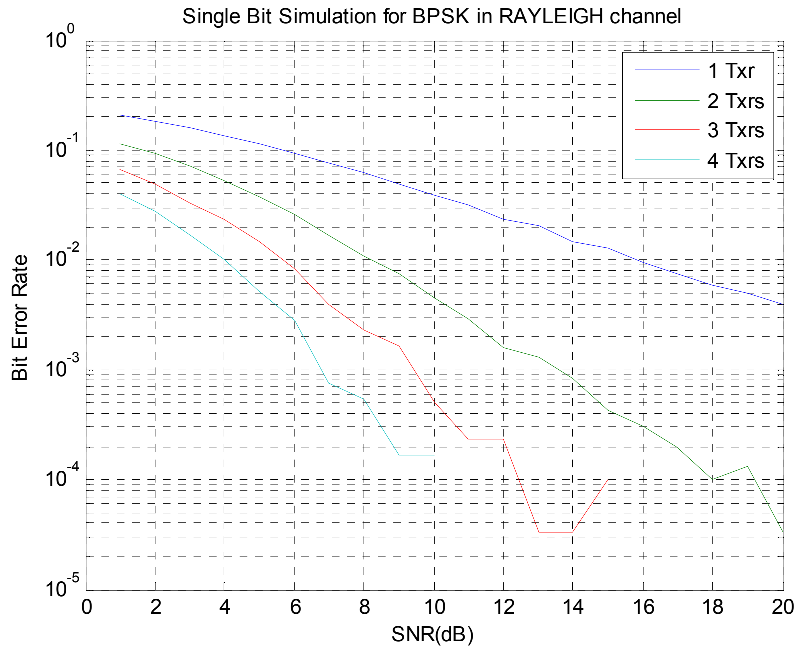

Figure 4.7: Comparison of SNR V/S BER using single bit simulation for BPSK in Rayleigh channel.

The simulated results in figure 4.7 shows that when data is send from transmitter to receiver by single bit simulation technique using BPSK modulation and transmit diversity in Rayleigh, fading channel, then data experience less BER as the number of transmitter increases.

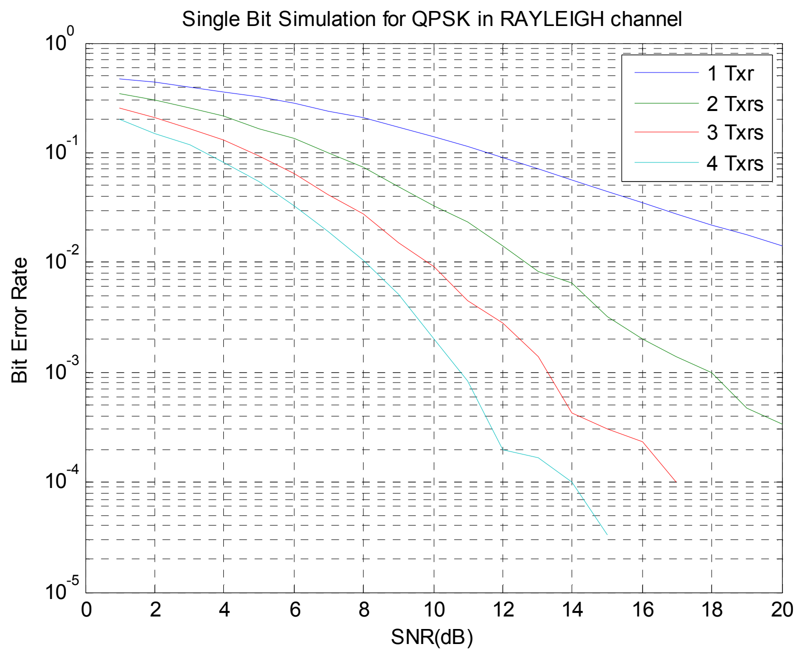

Figure 4.8: Comparison of SNR V/S BER using single bit simulation for QPSK in Rayleigh channel

The simulated results in figure 4.8 shows that when data is send from transmitter to receiver by single bit simulation technique using QPSK modulation and transmit diversity in Rayleigh, fading channel, then data experience less BER as the number of transmitter increases.

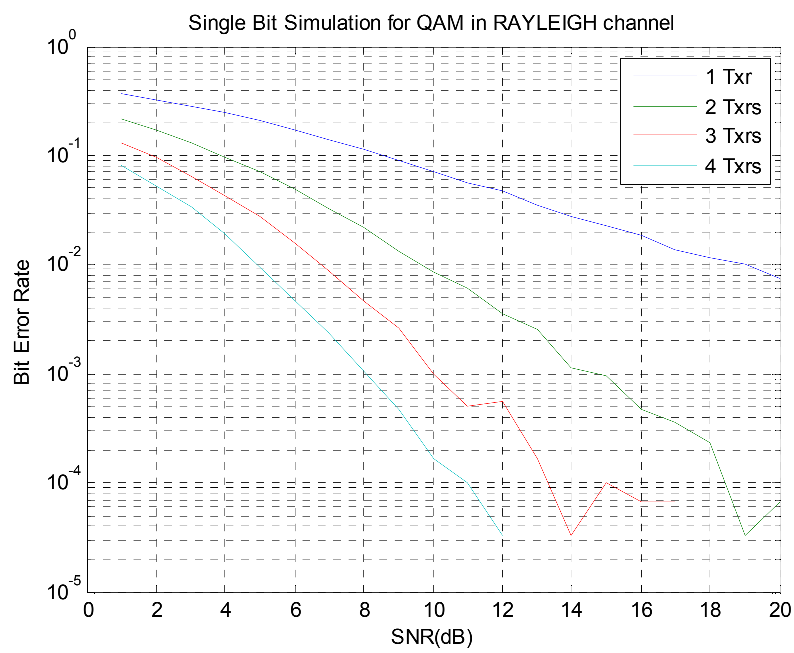

Figure 4.9: Comparison of SNR V/S BER using single bit simulation for QAM in Rayleigh channel.

The simulated results in figure 4.9 shows that when data is send from transmitter to receiver by single bit simulation technique using QAM modulation and transmit diversity in Rayleigh, fading channel, then data experience less BER as the number of transmitter increases.

Analysis-

Depending upon the simulated results of figure 4.7, figure 4.8 and figure 4.9, the analysis has been done in the form of Table 3.

Table 3
Comparison of different modulation schemes in Rayleigh channel using single bit simulation by varying the number of transmitters.

Number of transmitters	BPSK	QPSK	QAM
1	0.06147	0.2081	0.1151
2	0.01087	0.0738	0.02173
3	0.002267	0.0276	0.004633
4	0.0005333	0.01037	0.001067

The simulated results of figure 4.7, figure 4.8 and figure 4.9 were illustrated in table 3. It can be inferred from table 3 that BPSK modulation gives less BER in comparison to QPSK and QAM using single bit simulation technique in Rayleigh channel. So BPSK modulation is best fit modulation technique.

4.4 Comparison of different modulation techniques using single bit simulation techniques in Rician channel by varying the number of transmitters.

Assumptions-

1. The channel is assumed to be Rician faded.
2. The modulation technique used is BPSK,QPSK and QAM.
3. Number of transmitters taken as 1,2 3and 4.
4. Single bit simulation is carried out.

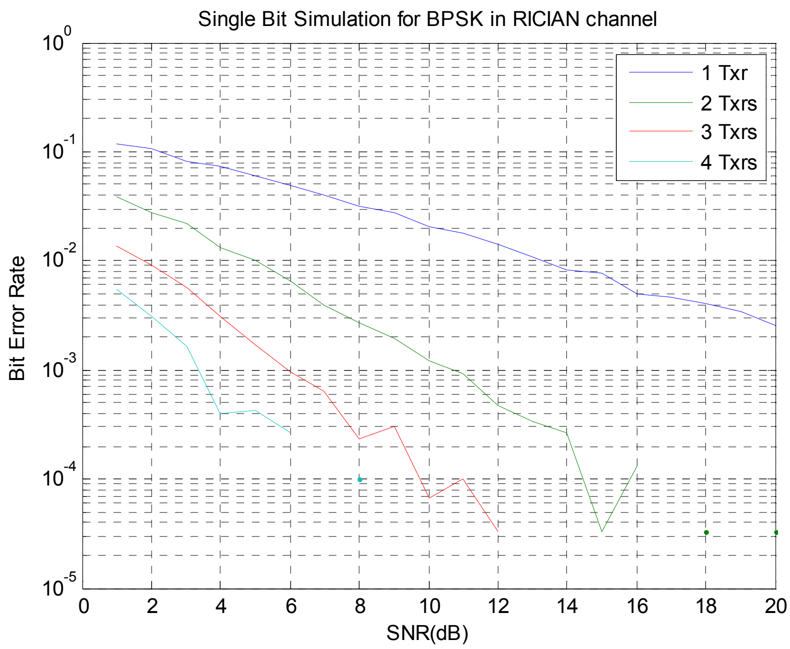

Figure 4.10: Comparison of SNR V/S BER using single bit simulation for BPSK in Rician channel

The simulated results in figure 4.10 shows that when data is send from transmitter to receiver by single bit simulation technique using BPSK modulation and transmit diversity in Rician, fading channel, then data experience less BER as the number of transmitter increases.

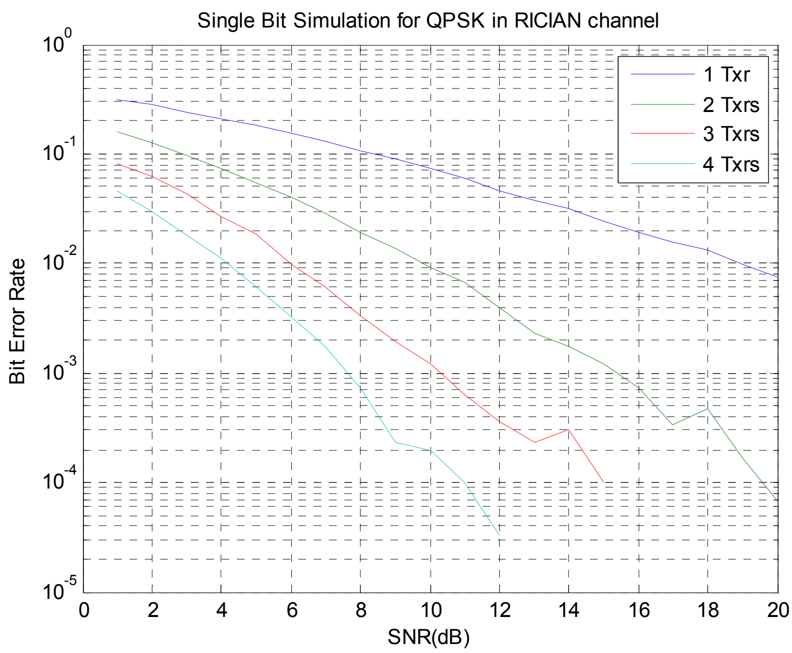

Figure 4.11 : Comparison of SNR V/S BER using single bit simulation for QPSK in Rician channel

The simulated results in figure 4.11 shows that when data is send from transmitter to receiver by single bit simulation technique using QPSK modulation and transmit diversity in Rician, fading channel, then data experience less BER as the number of transmitter increases.

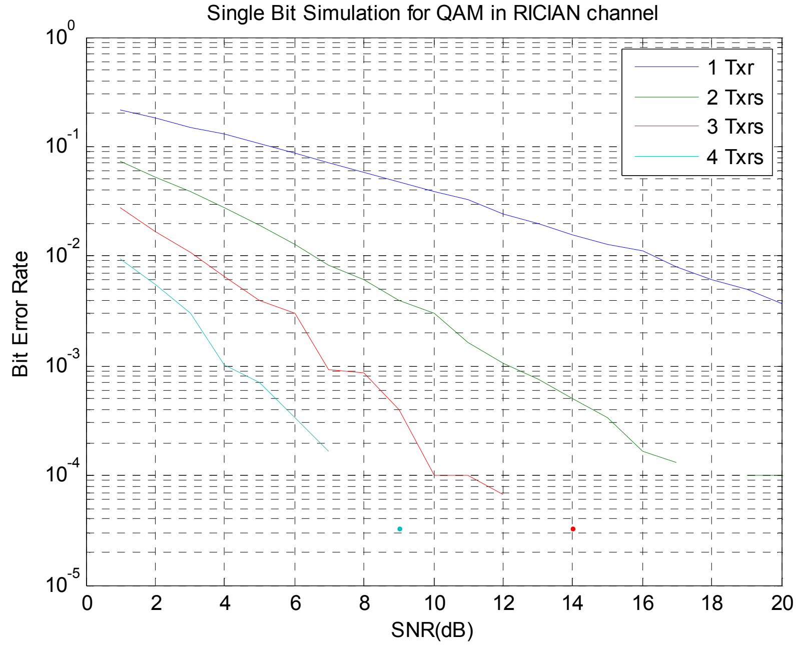

Figure 4.12: Comparison of SNR V/S BER using single bit simulation for QAM in Rician channel

The simulated results in figure 4.12 shows that when data is send from transmitter to receiver by single bit simulation technique using QAM modulation and transmit diversity in Rician, fading channel, then data experience less BER as the number of transmitter increases.

Analysis-
Depending upon the simulated results of figure 4.10, figure 4.11 and figure 4.12, the analysis has been done in the form of Table 4.

Table 4

Comparison of different modulation schemes in Rician channel using single bit simulation by varying the number of transmitters

Number of transmitters	BPSK	QPSK	QAM
1	0.03207	0.1075	0.05793
2	0.0027	0.01933	0.006133
3	0.0002333	0.0033	0.0008667
4	0	0.0007333	0

The simulated results of figure 4.10, figure 4.11 and figure 4.12 were illustrated in table 4. It can be inferred from table 4 that BPSK modulation gives less BER in comparison to QPSK and QAM using single bit simulation technique in Rician channel. So BPSK modulation is best fit modulation technique.

4.5 Comparison of different modulation techniques using single bit simulation techniques in Nakagami channel by varying the number of transmitters.

Assumptions-

1. The channel is assumed to be Nakagami faded.
2. The modulation technique used is BPSK,QPSK and QAM.
3. Number of transmitters taken as 1,2,3 and 4.
4. Single bit simulation is carried out

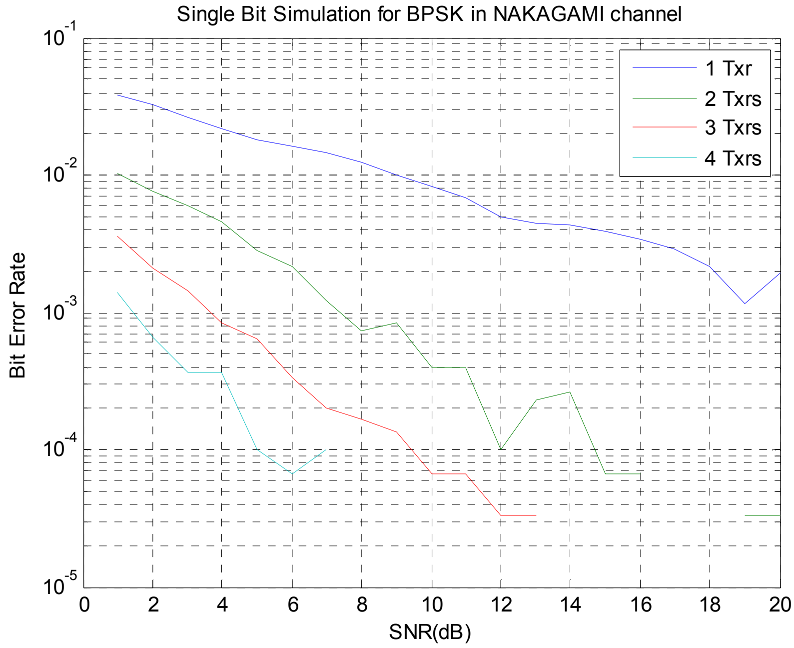

Figure 4.13 : Comparison of SNR V/S BER using single bit simulation for BPSK in Nakagami channel

The simulated results in figure 4.13 shows that when data is send from transmitter to receiver by single bit simulation technique using BPSK modulation and transmit diversity in Nakagami fading channel, then data experience less BER as the number of transmitter increases.

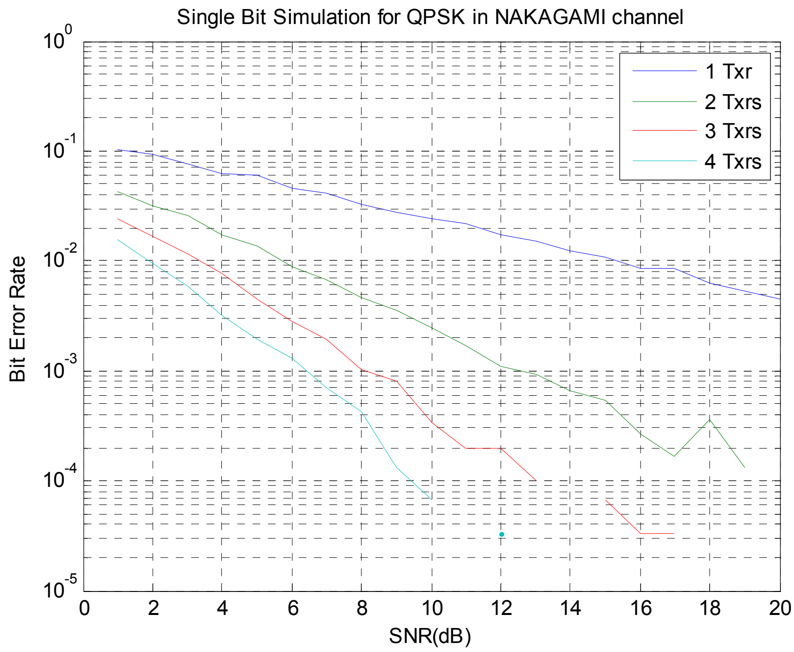

Figure 4.14: Comparison of SNR V/S BER using single bit simulation for QPSK in Nakagami channel

The simulated results in figure 4.14 shows that when data is send from transmitter to receiver by single bit simulation technique using QAM modulation and transmit diversity in Nakagami fading channel, then data experience less BER as the number of transmitter increases.

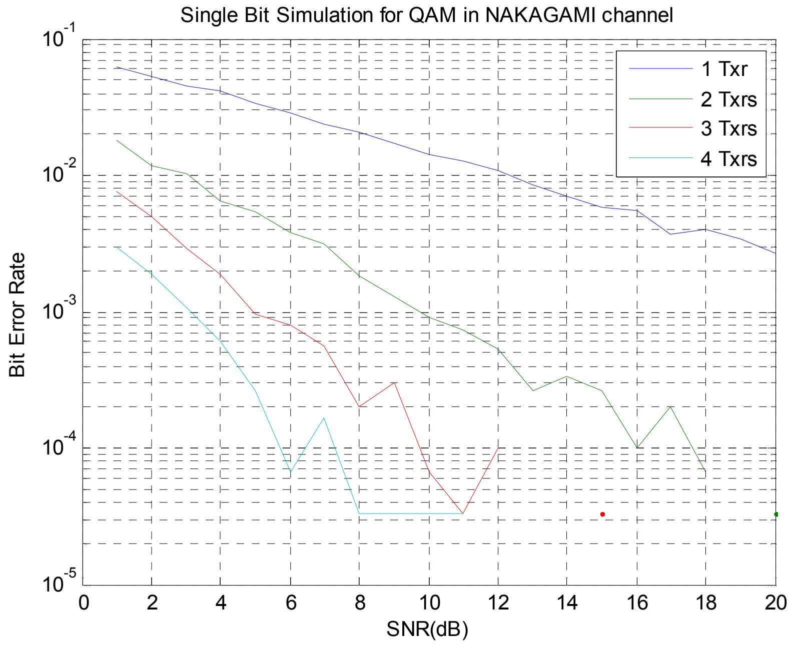

Figure 4.15: Comparison of SNR V/S BER using single bit simulation for QAM in Nakagami channel.

The simulated results in figure 4.15 shows that when data is send from transmitter to receiver by single bit simulation technique using QAM modulation and transmit diversity in Nakagami fading channel, then data experience less BER as the number of transmitter increases.

Analysis-

Table 5

Comparison of different modulation schemes in Nakagami channel using single bit simulation by varying the number of transmitters

Number of transmitters	BPSK	QPSK	QAM
1	0.01253	0.0331	0.0207
2	0.0007333	0.0047	0.0013
3	0.00016667	0.001033	0.0002
4	0	0.0004333	$3.333e-005$

The simulated results of figure 5.13, figure 5.14 and figure 5.15 were illustrated in table 5. It can be inferred from table 5 that BPSK modulation gives less BER in comparison to QPSK and QAM using single bit simulation technique in different fading channel. So BPSK modulation is best fit modulation technique.

When table 5 is compared with table 4 and table 3, it is found that when data is transmitted from transmit antenna to receive antenna using BPSK modulation in Nakagami channel ,data is less errorenous.

4.6 Comparison of different modulation techniques using block bit simulation techniques in Rayleigh channel by varying the number of transmitters.

Assumptions-

1. The channel is assumed to be Rayleigh faded.
2. The modulation technique used is BPSK,QPSK and QAM.
3. Number of transmitters taken as 1,2,3 and 4.
4. block bit simulation is carried out

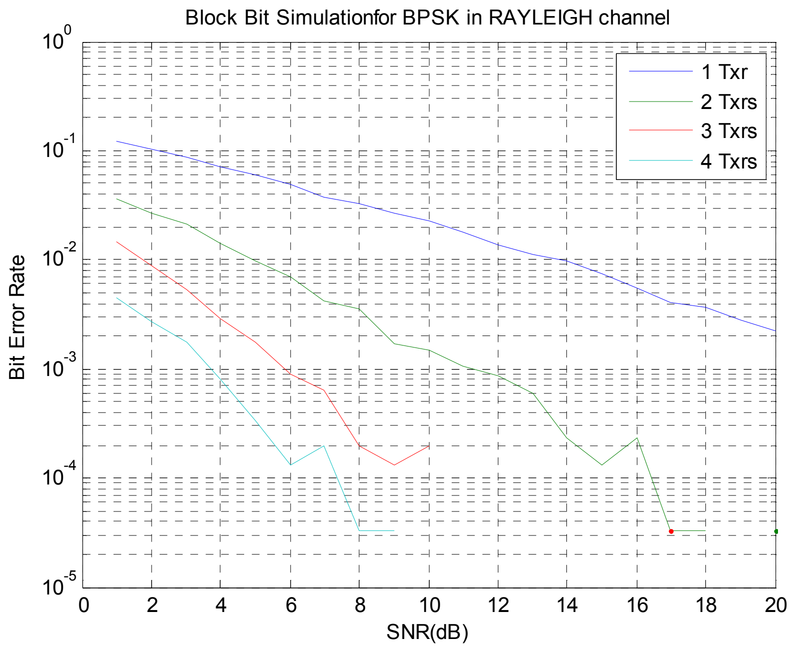

Figure 4.16: Comparison of SNR V/S BER using block bit simulation for BPSK in Rayleigh channel

The simulated results in figure 4.16 shows that when data is send from transmitter to receiver by block bit simulation technique using BPSK modulation and transmit diversity in Rayleigh fading channel, then data experience less BER as the number of transmitter increases.

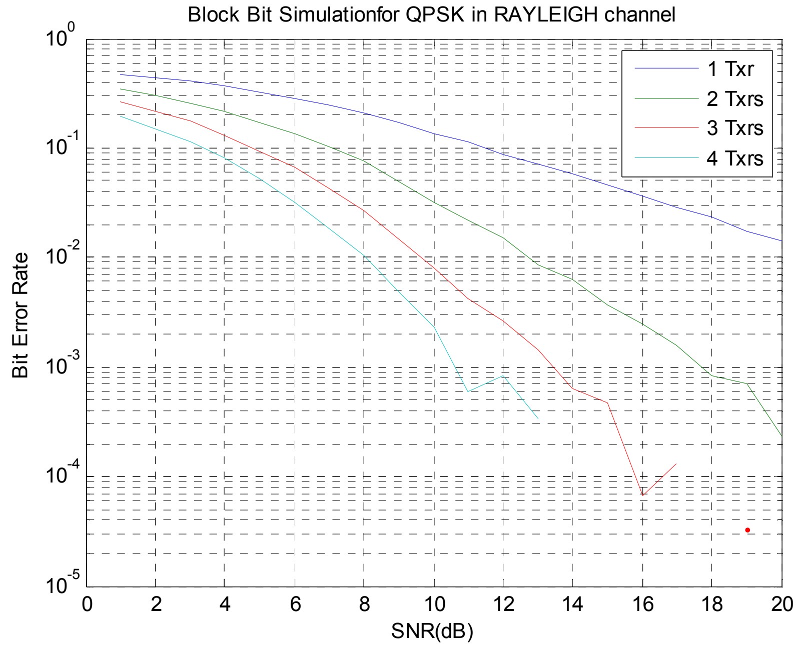

Figure 4.17: Comparison of SNR V/S BER using block bit simulation for QPSK in Rayleigh channel

The simulated results in figure 4.17 shows that when data is send from transmitter to receiver by block bit simulation technique using QPSK modulation and transmit diversity in Rayleigh fading channel, then data experience less BER as the number of transmitter increases.

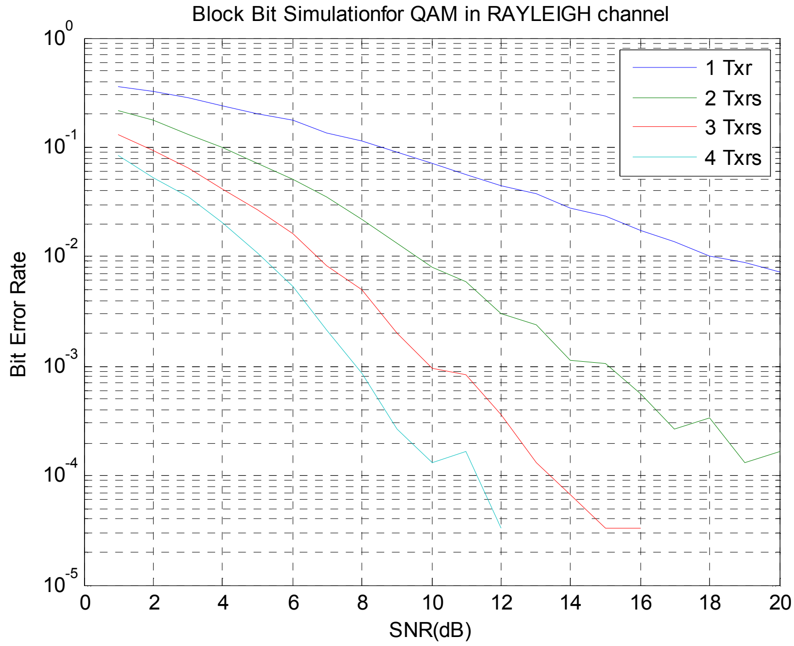

Figure 4.18: Comparison of SNR V/S BER using block bit simulation for QAM in Rayleigh channel.

The simulated results in figure 4.18 shows that when data is send from transmitter to receiver by block bit simulation technique using QAM modulation and transmit diversity in Rayleigh fading channel, then data experience less BER as the number of transmitter increases.

Analysis-

Table 6

Comparison of different modulation schemes in Rayleigh channel using block bit simulation by varying the number of transmitters

Number of transmitters	BPSK	QPSK	QAM
1	0.03293	0.2064	0.1129
2	0.003567	0.0753	0.0217
3	0.0002	0.02697	0.004967
4	$3.333e-005$	0.0104	0.0008667

The simulated results of figure 4.16 figure 4.17 and figure 4.18 were illustrated in table 6. It can be inferred from table 6 that BPSK modulation gives less BER in comparison to QPSK and QAM using block bit simulation technique in Rayleigh channel. So BPSK modulation is best fit modulation technique.

4.7 Comparison of different modulation techniques using block bit simulation techniques in Rician channel by varying the number of transmitters.

Assumptions-

1. The channel is assumed to be Rician faded.
2. The modulation technique used is BPSK,QPSK and QAM.
3. Number of transmitters taken as 1,2,3 and 4.
4. block bit simulation is carried out

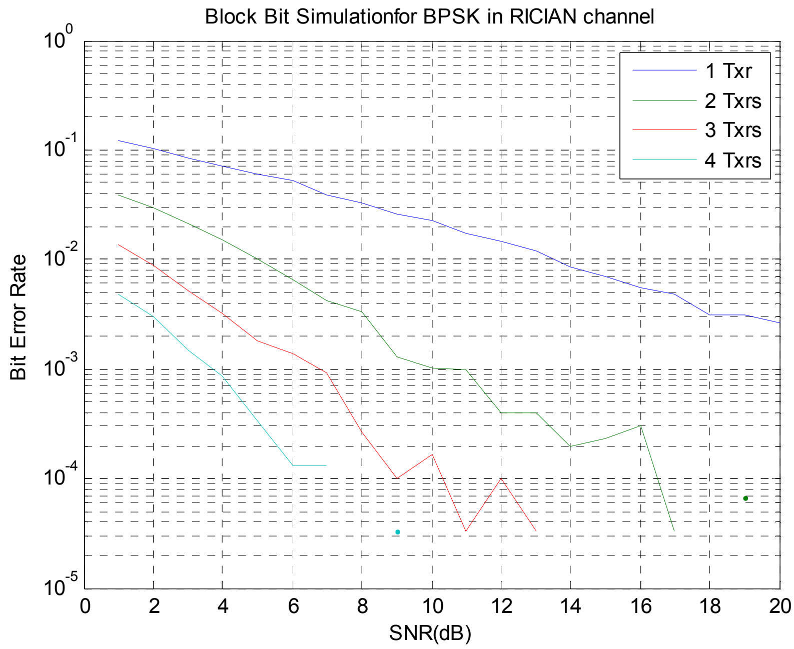

Figure 4.19: Comparison of SNR V/S BER using block bit simulation for BPSK in Rician channel.

The simulated results in figure 4.19 shows that when data is send from transmitter to receiver by block bit simulation technique using BPSK modulation and transmit diversity in Rician fading channel, then data experience less BER as the number of transmitter increases.

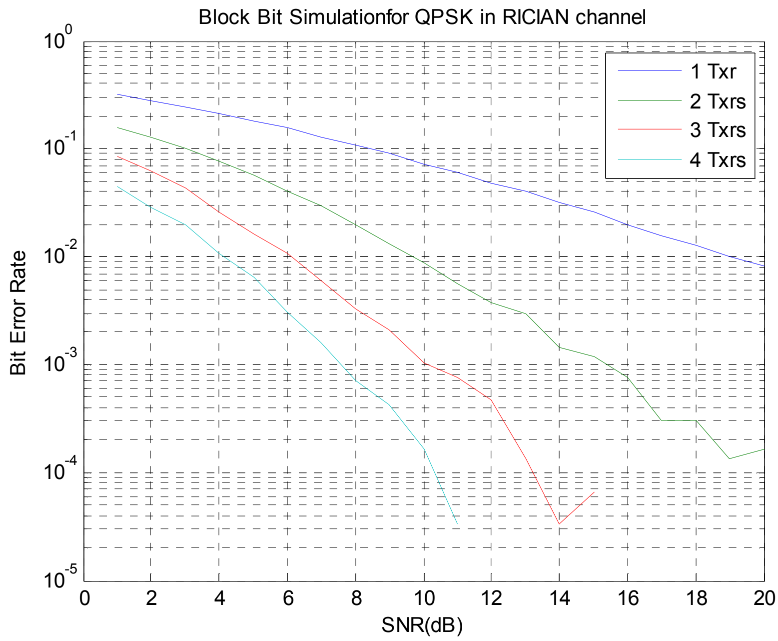

Figure 4.20: Comparison of SNR V/S BER using block bit simulation for QPSK in Rician channel

The simulated results in figure 4.20 shows that when data is send from transmitter to receiver by block bit simulation technique using QPSK modulation and transmit diversity in Rician fading channel, then data experience less BER as the number of transmitter increases.

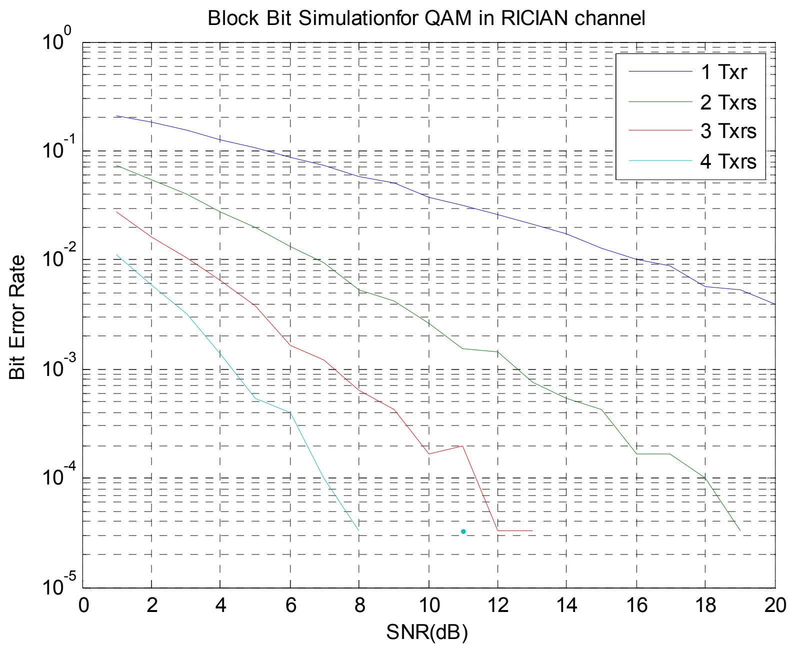

Figure 4.21: Comparison of SNR V/S BER using block bit simulation for QAM in Rician channel

The simulated results in figure 4.21 shows that when data is send from transmitter to receiver by block bit simulation technique using QAM modulation and transmit diversity in Rician fading channel, then data experience less BER as the number of transmitter increases.

Analysis-

Table 7

Comparison of different modulation schemes in Rician channel using block bit simulation by varying the number of transmitters

Number of transmitters	BPSK	QPSK	QAM
1	0.03283	0.1095	0.05887
2	0.0033	0.01953	0.0053
3	0.0002667	0.0033	0.0006333
4	0	0.0007	$3.333e-005$

The simulated results of figure 4.19 ,figure 4.20 and figure 4.21 were illustrated in table 7. It can be inferred from table 7 that BPSK modulation gives less BER in comparison to QPSK and QAM using block bit simulation technique in Rician channel. So BPSK modulation is best fit modulation technique.

4.8 Comparison of different modulation techniques using block bit simulation techniques in Nakagami channel by varying the number of transmitters.

Assumptions-

1. The channel is assumed to be Nakagami faded.
2. The modulation technique used is BPSK,QPSK and QAM.
3. Number of transmitters taken as 1,2,3 and 4.
4. block bit simulation is carried out.

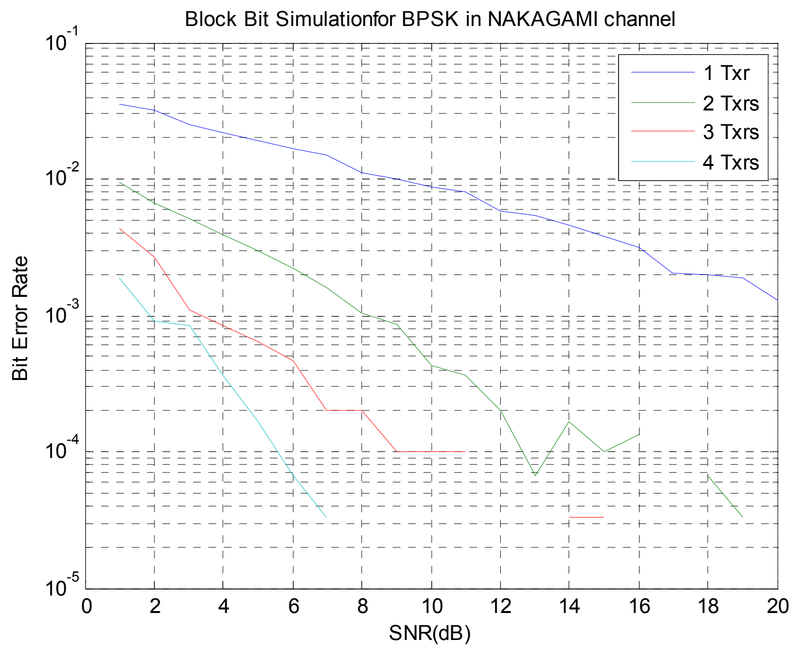

Figure 4.22: Comparison of SNR V/S BER using block bit simulation for BPSK in Nakagami channel

The simulated results in figure 4.22 shows that when data is send from transmitter to receiver by block bit simulation technique using BPSK modulation and transmit diversity in Nakagami fading channel, then data experience less BER as the number of transmitter increases.

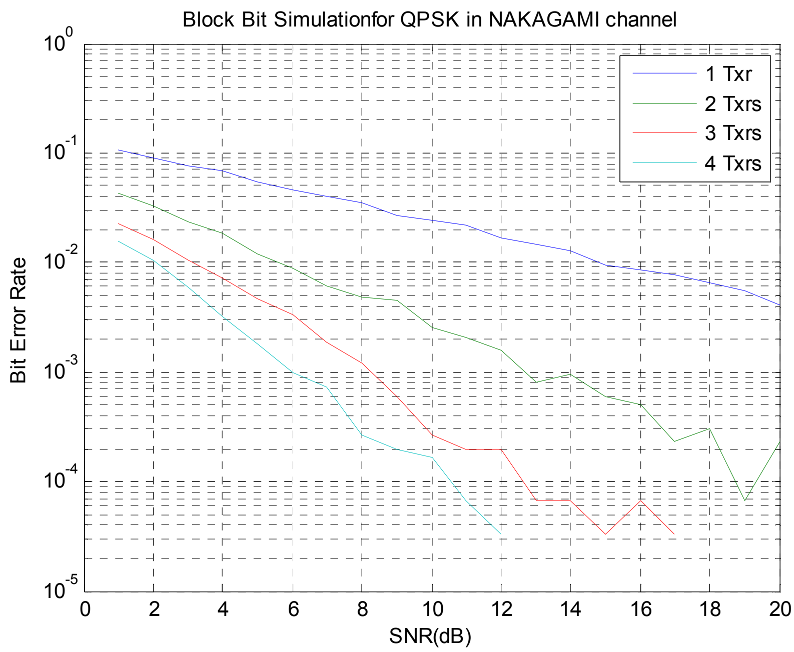

Figure 4.23: Comparison of SNR V/S BER using block bit simulation for QPSK in Nakagami channel

The simulated results in figure 4.23 shows that when data is send from transmitter to receiver by block bit simulation technique using QPSK modulation and transmit diversity in Nakagami fading channel, then data experience less BER as the number of transmitter increases.

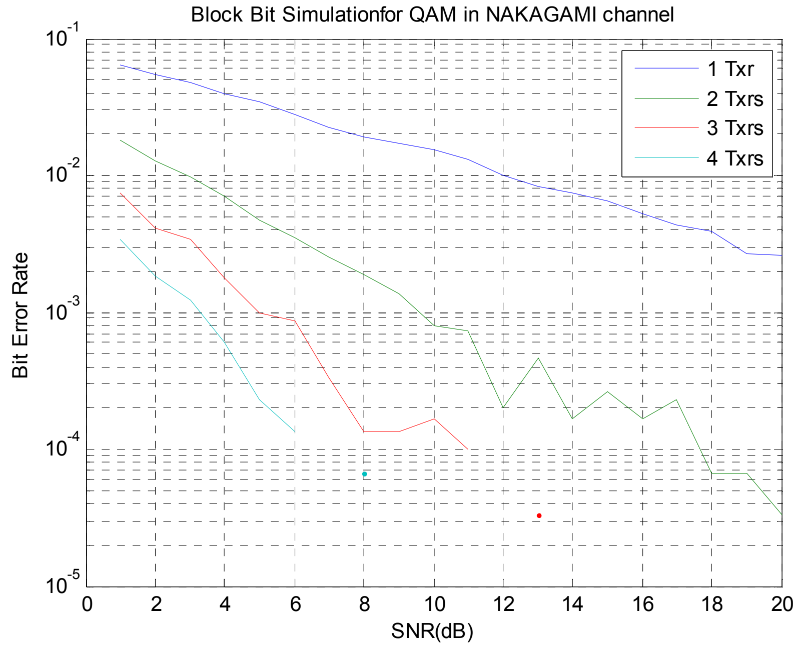

Figure 4.24: Comparison of SNR V/S BER using block bit simulation for QAM in Nakagami channel.

The simulated results in figure 4.24 shows that when data is send from transmitter to receiver by block bit simulation technique using QAM modulation and transmit diversity in Nakagami fading channel, then data experience less BER as the number of transmitter increases.

Analysis-

Table 8

Comparison of different modulation schemes in Nakagami channel using block bit simulation by varying the number of transmitters

Number of transmitters	BPSK	QPSK	QAM
1	0.01117	0.03477	0.0193
2	0.0012	0.004833	0.001867
3	0.0002	0.0012	0.0001333
4	0	0.0002667	0

The simulated results of figure 4.22, figure 4.23 and figure 4.24 were illustrated in table 8. It can be inferred from table 8 that BPSK modulation gives less BER in comparison to QPSK and QAM using block bit simulation technique in Nakagami channel. So BPSK modulation is best fit modulation technique.

When table 8 is compared with table 7 and table 6, it is found that when data is transmitted from transmit antenna to receive antenna using BPSK modulation in Nakagami channel , data is less errorenous.

4.9 Comparison of different data transmission techniques for BPSK in different fading channels.

Assumptions

1. The channel is assumed to be Rayleigh,Rician and Nakagami faded.
2. The modulation technique used is BPSK.
3. Single bit and Block bit data transmission technique is used.

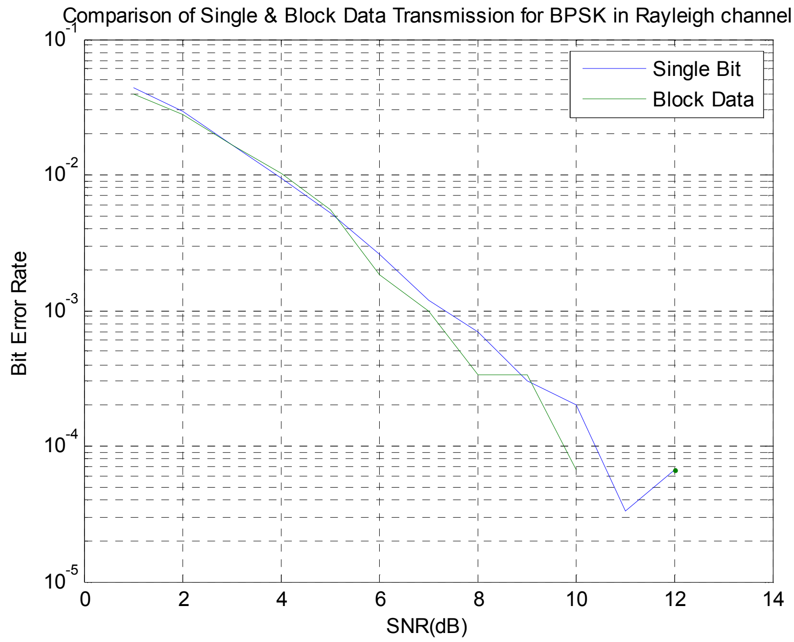

Figure 4.25: Comparison of Single & Block Data Transmission for BPSK in Rayleigh Channel

The simulated results in figure 4.25 shows that block bit transmission technique is the best technique to send the data in Rayleigh channel using BPSK modulation.

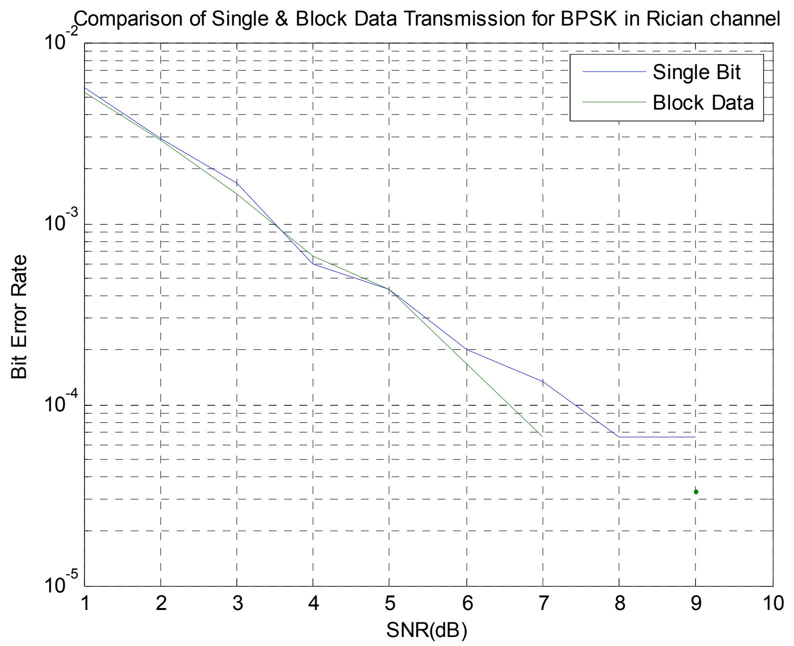

Figure 4.26: Comparison of Single & Block Data Transmission for BPSK in Rician Channel

The simulated results in figure 4.26 shows that block bit transmission technique is the best technique to send the data in Rician channel using BPSK modulation.

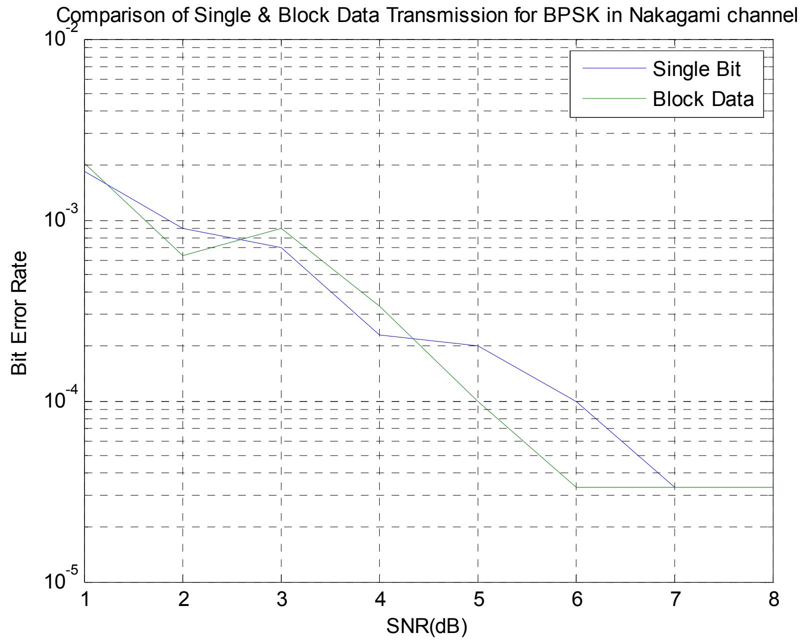

Figure 4.27: Comparison of Single & Block Data Transmission for BPSK in Nakagami Channel

The simulated results in figure 4.27 shows that block bit transmission technique is the best technique to send the data in Nakagami channel using BPSK modulation.

4.10 Comparison of different data transmission techniques for QPSK in different fading channels.

Assumptions

1. The channel is assumed to be Rayleigh,Rician and Nakagami faded.
2. The modulation technique used is QPSK.
3. Single bit and Block bit data transmission technique is used.

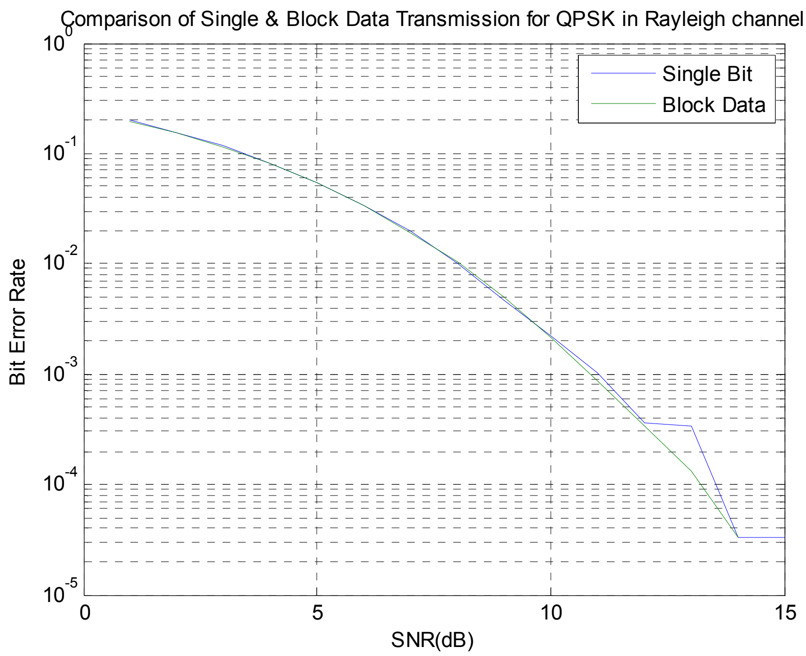

Figure 4.28:Comparison of Single & Block Data Transmission for QPSK in Rayleigh Channel

The simulated results in figure 4.28 shows that block bit transmission technique is the best technique to send the data in Rayleigh channel using QPSK modulation.

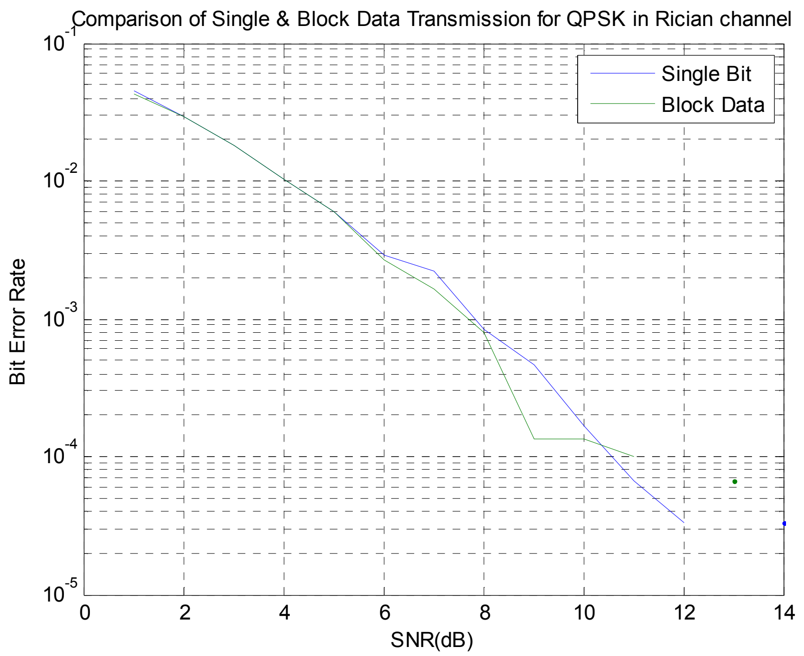

Figure 4.29: Comparison of Single & Block Data Transmission for QPSK in Rician Channel

The simulated results in figure 4.29 shows that block bit transmission technique is the best technique to send the data in Rician channel using QPSK modulation.

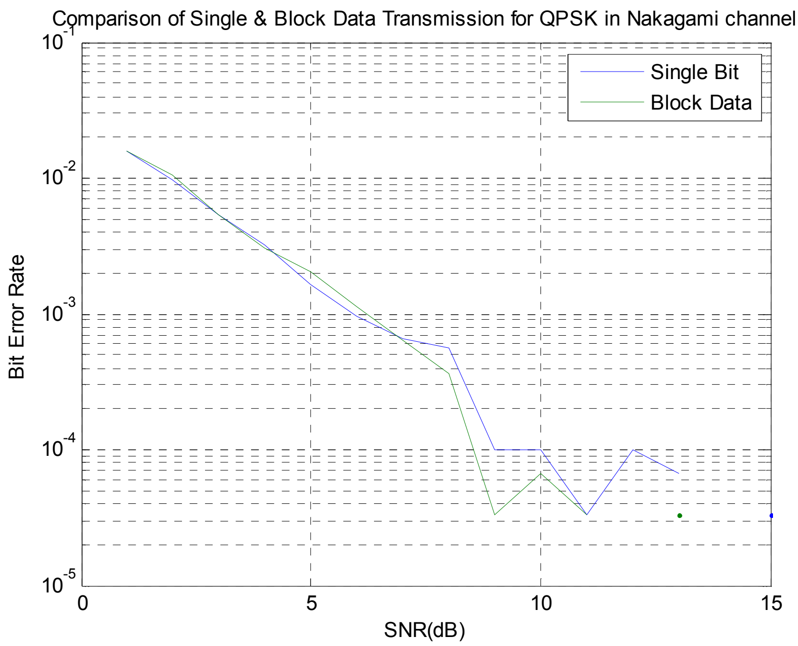

Figure 4.30: Comparison of Single & Block Data Transmission for QPSK in Nakagami Channel

The simulated results in figure 4.30 shows that block bit transmission technique is the best technique to send the data in Nakagami channel using QPSK modulation.

4.11 Comparison of different data transmission techniques for QAM in different fading channels.

Assumptions

1. The channel is assumed to be Rayleigh,Rician and Nakagami faded.
2. The modulation technique used is QAM.
3. Single bit and Block bit data transmission technique is used.

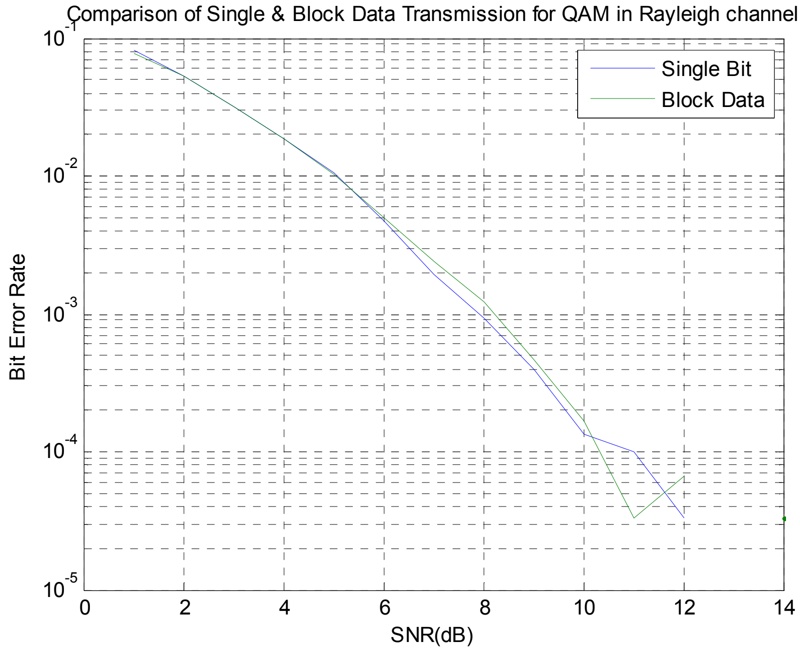

Figure 4.31: Comparison of Single & Block Data Transmission for QAM in Rayleigh Channel.

The simulated results in figure 4.31 shows that block bit transmission technique is the best technique to send the data in Rayleigh channel using QAM modulation.

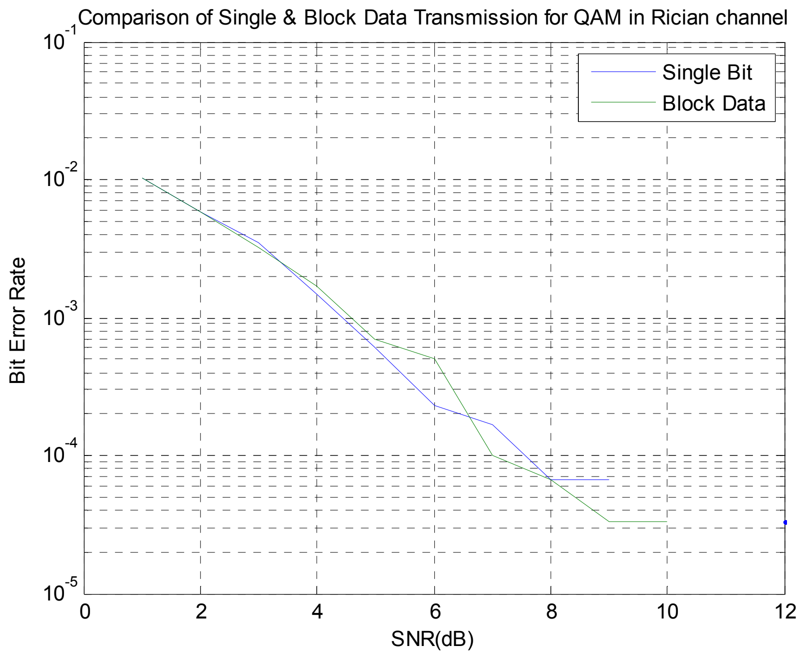

Figure 4.32: Comparison of Single & Block Data Transmission for QAM in Rician Channel

The simulated results in figure 4.32 shows that block bit transmission technique is the best technique to send the data in Rician channel using QAM modulation.

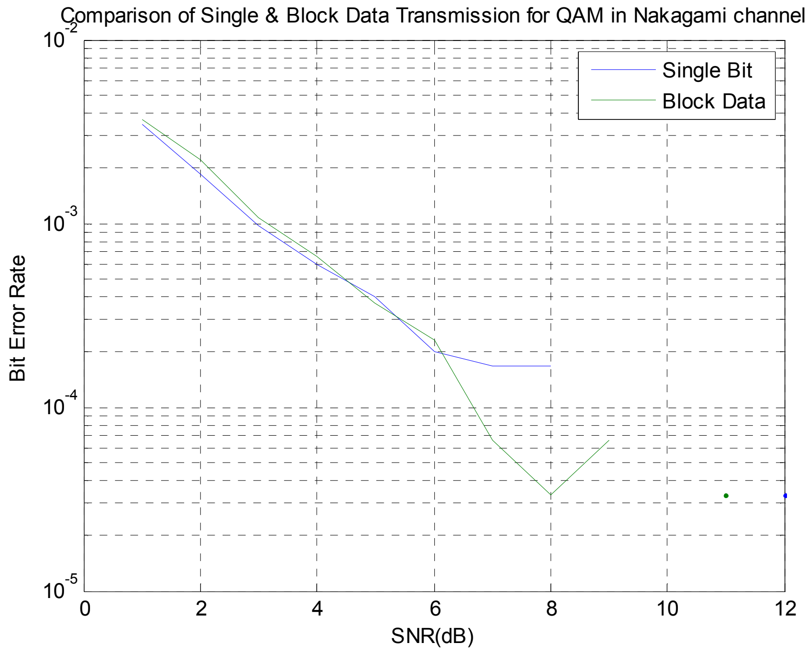

Figure 4.33: Comparison of Single & Block Data Transmission for QAM in Nakagami Channel.

The simulated results in figure shows that block bit transmission technique is the best technique to send the data in Nakagami channel using QAM modulation.

4.12 Effect of shape factor in nakagami fading for different value of scale factor.

Assumptions-

1. The channel is assumed to be Nakagami faded.
2. The value of shape factor ranges from 0.5 to 3.
3. The value of scale factor ranges from 1 to 3.

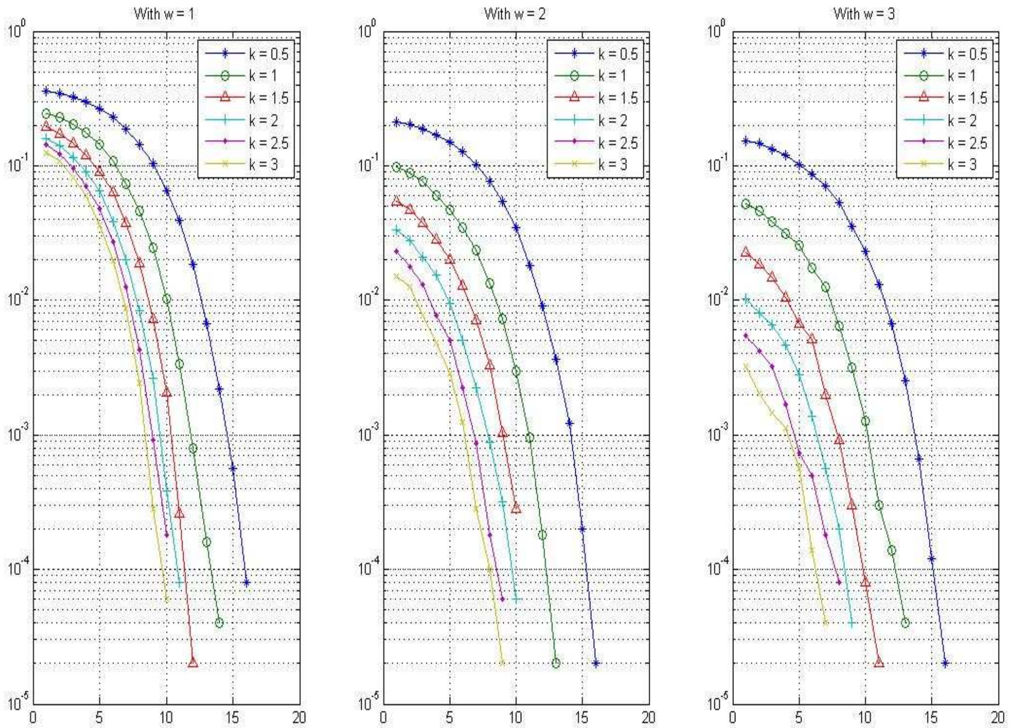

Figure 4.34: Comparison of SNR V/S BER for different shape factor in nakagami fading.

The simulated results in figure 4.34 shows that when data is send from transmitter to receiver in Nakagami fading channel , then data experience less BER as the value of k and w i.e shape factor and scale factor respectively increases.

Analysis-

Table 9

Comparison of SNR V/S BER for different values of shape factor and scale factor at a fixed SNR of 8dB.

K / W		SHAPE FACTOR					
		K=0.5	K=1	K=1.5	K=2	K=2.5	K=3
SCALE FACTOR	W=1	0.143	0.0476	0.0193	0.0089	0.0045	0.0026
	W=2	0.0767	0.0144	0.0035	0.0084	0.0026	0.0008
	W=3	0.0515	0.0067	0.0011	0.0002	0.00002	0.00002

From the table 9 it can be inferred that at a fixed SNR of 8db as k increase BER decreases. It is also noticed from table 9 that at a fixed SNR of 8 db as scale factor w increases BER decreases.

4.13 Comparison of no space time code and alamouti's code for different modulation techniques in Rayleigh channel.

Assumptions-

1. The channel is assumed to be Rayleigh faded.
2. The modulation taken is BPSK,QPSK and QAM.

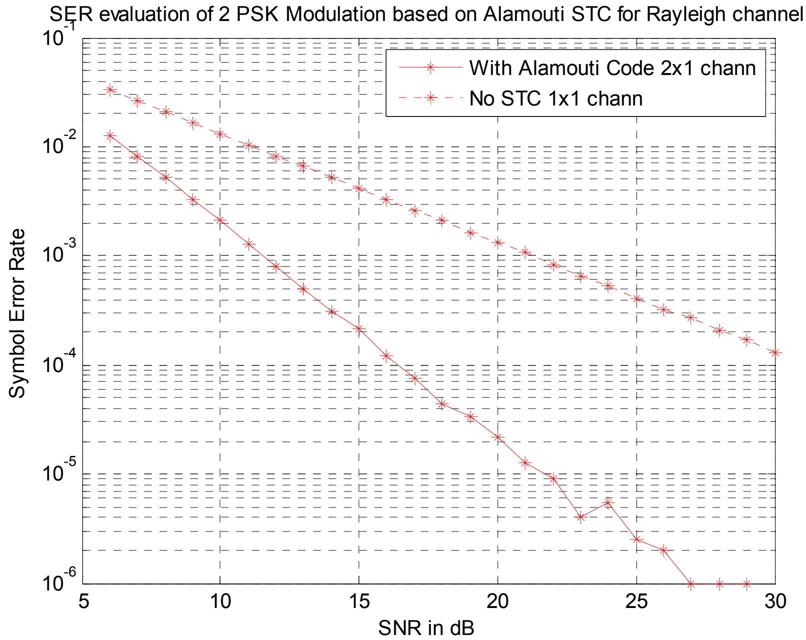

Figure 4.35:Comparison of SNR V/S BER for BPSK modulation based on alamouti STC for Rayleigh channel.

The simulated results in figure 4.35 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Rayleigh fading channel using BPSK modulation when data is transmitted from transmitter to receiver.

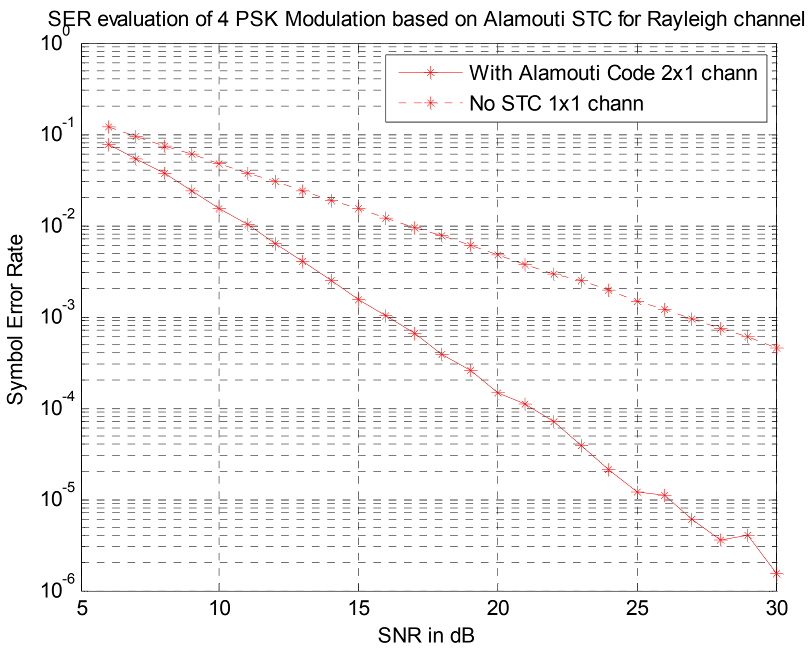

Figure 4.36:Comparison of SNR V/S BER for QPSK modulation based on alamouti STC for Rayleigh channel.

The simulated results in figure 4.36 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Rayleigh fading channel using QPSK modulation when data is transmitted from transmitter to receiver.

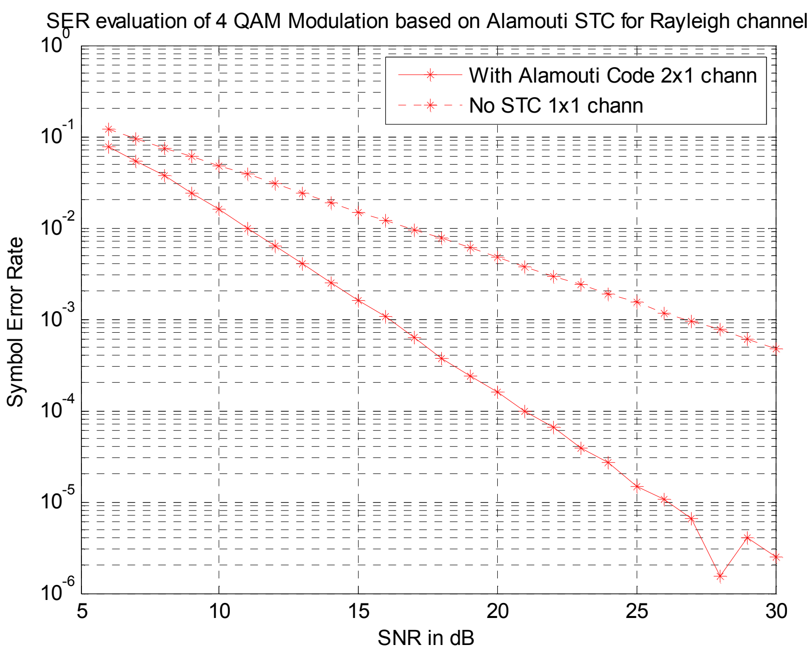

Figure 4.37:Comparison of SNR V/S BER for QAM modulation based on alamouti STC for Rayleigh channel.

The simulated results in figure 4.37 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Rayleigh fading channel using QAM modulation when data is transmitted from transmitter to receiver.

Analysis-

Table 10

Comparison of no space time coding and alamouti's code in Rayleigh channel using different modulation schemes at 15dB SNR.

Modulation types	No.space time coding	Alamouti's code
BPSK	0.004112	0.000216
QPSK	0.01512	0.001559
QAM	0.01491	0.001566

The simulated results of figure 4.35, figure 4.36 and figure 4.37 were illustrated in table 10. It can be inferred from table 10 when data is transmitted from transmit antenna using alamouti's space time coding in Rayleigh channel the data received at receive antenna is most error free.

4.14 Comparison of no space time code and alamouti's code for different modulation techniques in Rician channel.

Assumptions-

1. The channel is assumed to be Rician faded.
2. The modulation taken is BPSK,QPSK and QAM.

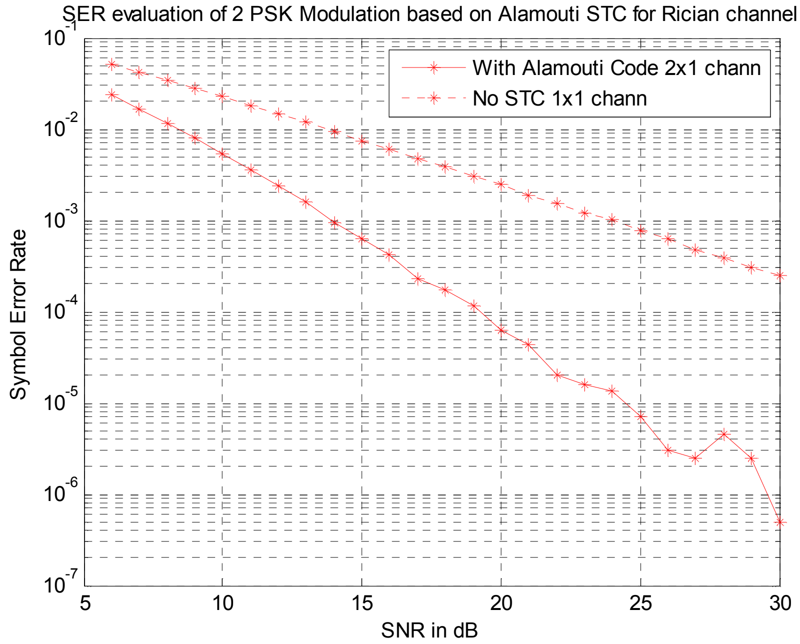

Figure 4.38: Comparison of SNR V/S BER for BPSK modulation based on alamouti STC for Rician channel

The simulated results in figure 4.38 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Rician fading channel using BPSK modulation when data is transmitted from transmitter to receiver.

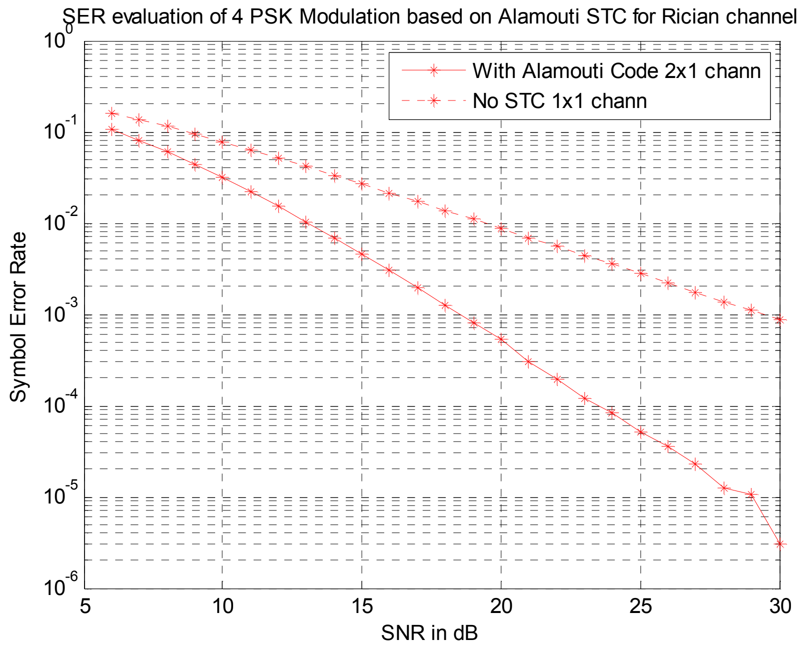

Figure 4.39: Comparison of SNR V/S BER for QPSK modulation based on alamouti STC for Rician channel

The simulated results in figure 4.39 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Rician fading channel using QPSK modulation when data is transmitted from transmitter to receiver.

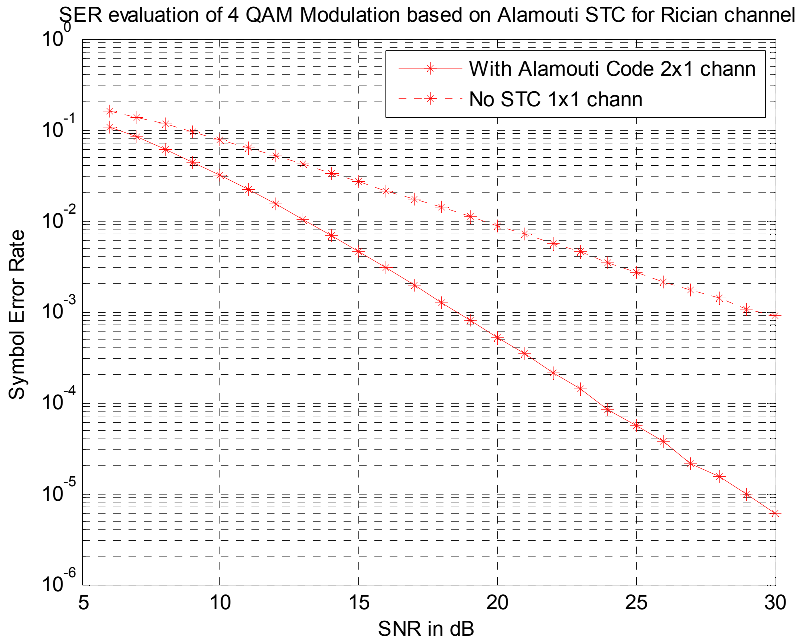

Figure 4.40: Comparison of SNR V/S BER for QAM modulation based on alamouti STC for Rician channel.

The simulated results in figure 4.40 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Rician fading channel using QAM modulation when data is transmitted from transmitter to receiver.

Analysis-

Table 11

Comparison of no space time coding and alamouti's code in Rician channel using different modulation schemes at 15dB SNR

Modulation types	No space time coding	Alamouti's coding
BPSK	0.007514	0.0006325
QPSK	0.02685	0.004583
QAM	0.02659	0.00448

The simulated results of figure 4.38, figure 4.39 and figure 4.40 were illustrated in table 11. It can be inferred from table 11 alamouti's space time coding gives the data error free at receiver.

4.15 Comparison of no space time code and alamouti's code for different modulation techniques in Nakagami channel.

Assumptions-

1. The channel is assumed to be Nakagami faded.
2. The modulation taken is BPSK,QPSK and QAM.

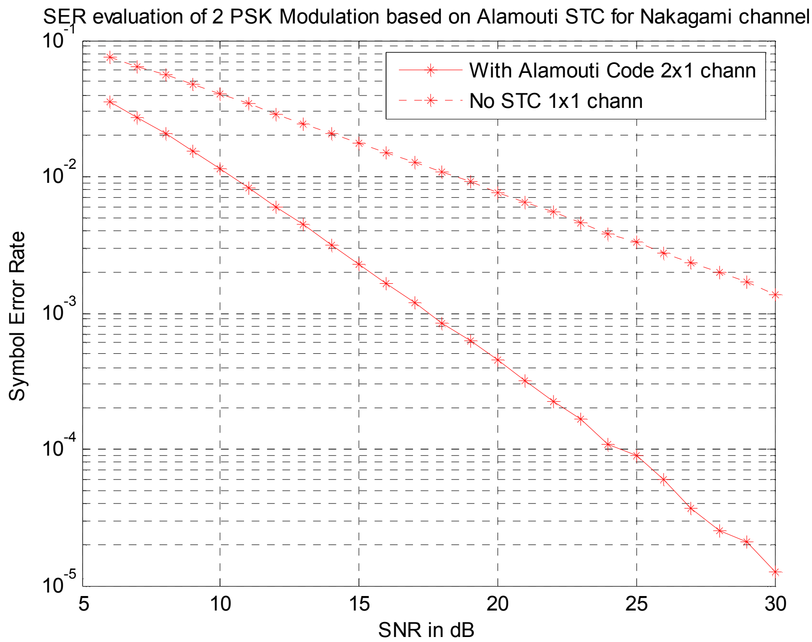

Figure 4.40: Comparison of SNR V/S BER for BPSK modulation based on alamouti STC for Nakagami channel.

The simulated results in figure 4.40 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Nakagami fading channel using BPSK modulation when data is transmitted from transmitter to receiver.

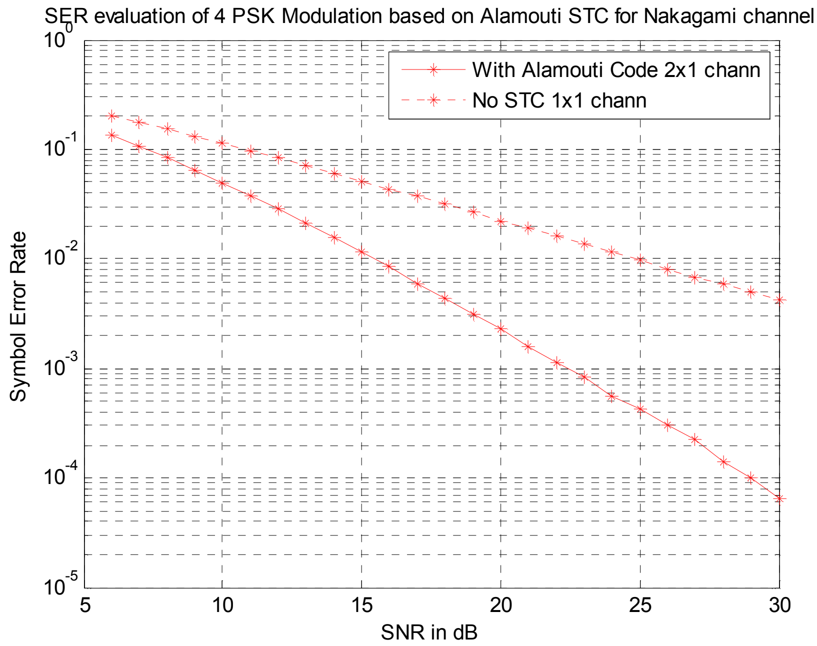

Figure 4.41: Comparison of SNR V/S BER for QPSK modulation based on alamouti STC for Nakagami channel.

The simulated results in figure 4.41 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Nakagami fading channel using QPSK modulation when data is transmitted from transmitter to receiver.

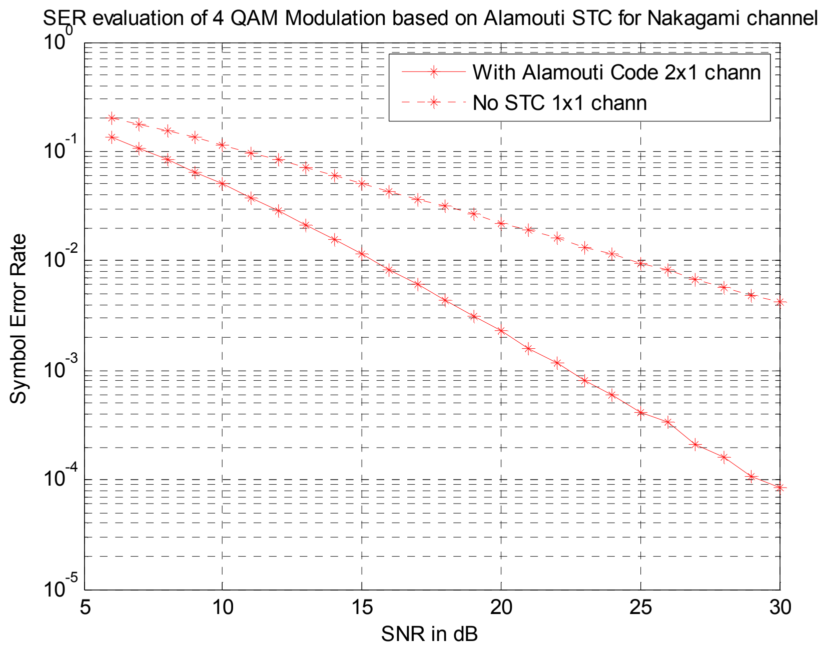

Figure 4.42: Comparison of SNR V/S BER for QAM modulation based on alamouti STC for Nakagami channel.

The simulated results in figure 4.42 shows that alamouti's space time coding gives less BER in comparison to no space time coding in Nakagami fading channel using QAM modulation when data is transmitted from transmitter to receiver.

Analysis-

Table 12

Comparison of no space time coding and alamouti's code in Nakagami channel using different modulation schemes at 15dB SNR

Modulation types	No space time coding	Alamouti's coding
BPSK	0.01764	0.002295
QPSK	0.05163	0.01142
QAM	0.0515	0.01137

The simulated results of figure 4.40, figure 4.41 and figure 4.42 were illustrated in table 12. It can be inferred from table 12 alamouti's space time coding in Nakagami provides error free data.

4.16 Comparison of MIMO capacity for different fading channel for different antenna configurations.

Assumptions-

The channel assumed is Rayleigh, Rician and Nakagami faded.

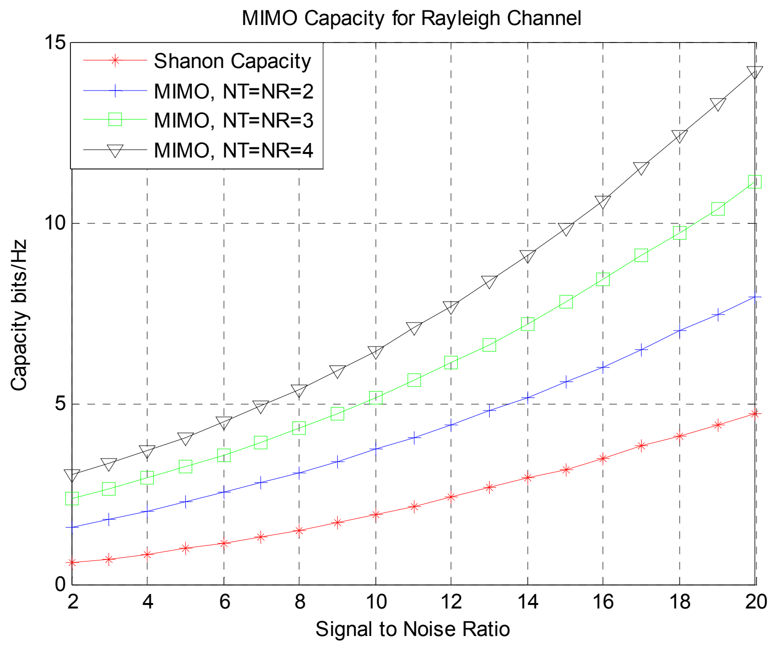

Figure 4.43: Comparison of SNR V/S CAPACITY for MIMO capacity in Rayleigh channel.

The simulated results in figure 4.43 shows that as the number of tranmit and receive antenna increases, MIMO capacity increases in Rayleigh channel.

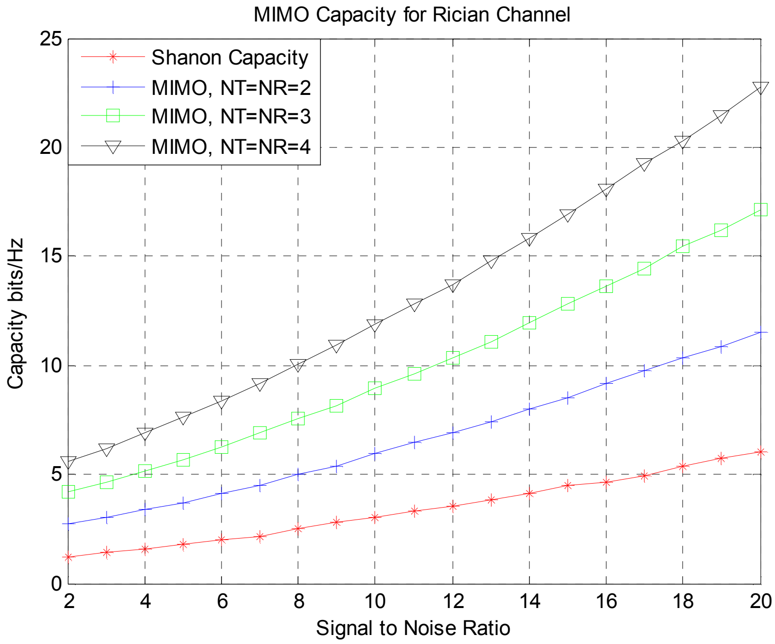

Figure 4.44: Comparison of SNR V/S CAPACITY for MIMO capacity in Rician channel

The simulated results in figure 4.44 shows that as the number of tranmit and receive antenna increases, MIMO capacity increases in Rician channel.

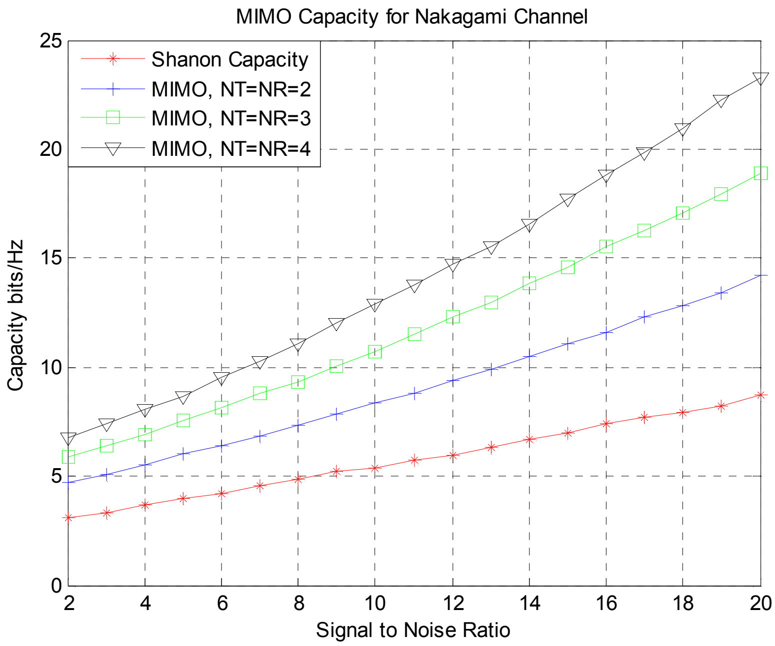

Figure 4.45: Comparison of SNR V/S CAPACITY for MIMO capacity in Nakagami channel

The simulated results in figure 4.45 shows that as the number of tranmit and receive antenna increases, MIMO capacity increases in Nakagami channel.

Analysis-

Table 13

Comparison of MIMO capacity for different types of channel at 12dB SNR.

Different antenna configurations	Rayleigh channel	Rician channel	Nakagami channel
Shannon capacity	4.075	3.523	5.964
Nt=Nr=2	6.689	6.912	9.388
Nt=Nr=3	10.11	10.36	12.33
Nt=Nr=4	13.44	13.74	14.74

The simulated results of figure 4.43, figure 4.44 and figure 4.45 were illustrated in table 13. It can be inferred from table 13:

1. As the number of transmitter and receiver antenna increases, capacity increases.
2. Nakagami channel is the best fit model as it gives maximum capacity for a given SNR.

Chapter 5- conclusion and future work

The conclusion of simulated results is that -

- When data is transmitted from transmit antenna to receive antenna through different channels i.e Rayleigh, Rician and Nakagami fading channels using different data transmission techniques, we find that Nakagami channel is the best fit model.
- BPSK modulation gives less BER in comparison to QPSK and QAM using different data transmission technique in different fading channel i.e Rayleigh,Rician and Nakagami fading channel. So BPSK modulation is best fit modulation technique.
- When data is send from transmitter to receiver in Nakagami fading channel , then data experience less BER as the value of k and w i.e shape factor and scale factor respectively increases.
- Alamouti's space time coding gives less BER in comparison to no space time coding in different fading channel using different modulation techniques when data is transmitted from transmitter to receiver.
- Capacity of a MIMO system increases with the increase in the number of transmit and receive antennas. Capacity of a MIMO system increases when data is transmitted from transmitter to receiver through Nakagami fading channel.

Future work-

This thesis is limited to reducing BER for different fading channel using different data transmission techniques. However ,further works could be done in other fields such as increasing data rate , spectral efficiency etc. Morever channel modelling is also the area which needs to be explored.

Need to have high data rate:

As the world is heading towards 3G wireless communication or may be 4G , so there is urgent demand of increasing the data rate. Data rate can be increased by spatial multiplexing. So spatial multiplexing needs to be looked.

Channel modelling:

To increase the data rate and capacity of wireless communication channel modelling is the area which needs to be researched because:

- To understand the characterstics and variation of channel.
- To determine the impact of these variations on the data rate.

List of paper published

Yogender singh gill,Dr Rajesh Khanna"Comparitive study of data transmission techniques over rayleigh and rician fading channels in a multi antenna system",International conference on advances in electrical and electronics engineering,held at MIT Moradabad,pp-17,25-26 february 2011.

Yogender singh gill, Dr Rajesh Khanna"Effect of shape factor in nakagami fading"14th punjab science congress,held at SLIET Longawal,pp-176-177,7-9 february 2011.

Yogender singh gill, Dr Rajesh Khanna"Performance analysis for single bit transmission in transmit diversity under various fading channels,spin 2011,held at amity university noida,pp-179-181,24-25 february 2011.

Yogender singh gill, Dr Rajesh Khanna"Analysis of data transmission techniques in rayleigh,rician and nakagami fading model under various modulation schemes",International journal of VLSI and Signal processing applications,vol 1,issue 2, 20 may2011.

References

[1]Rappaport, T. S., Wireless Communications: Principles and Practice, Upper Saddle River, NJ: Prentice Hall, 1996.

[2]http://www.google.co.in/imgres?imgurl=http://www.airstream.org.au/files/propagation.png.

[3] Andrea goldsmith "wireless communications".

[4] *M.Jankiraman* Space-Time Codes and MIMO Systems. 2004 ARTECH HOUSE.

[5] Geoff Smithson "Introduction to digital modulation schemes",Plextek Ltd, London Road, Great Chesterford, Essex.

[6] Agilent technologies "agilent digital modulation in communication systems-An introduction. Application note 1298.

[7] digital communications "electronic and electrical servicing" pp 215-229.

[8] Dmitry Chizhik, Jonathan Ling, Peter Wolniansky, Reinaldo Valenzuela "Multiple Input Multiple Output Measurements and Modeling in Manhattan" Wireless Research Laboratory Lucent Technologies" 0-7803-7467-3/02/$17.00 ©2002 IEEE.

[9] MIMO_ Space-Time Code Design by *claude Oestgesand Bruno Clerckx*.

[10]Proakis, John G. (1995). Digital Communications. Singapore: McGraw Hill. ISBN 0-07-113814-5.

[11]Couch, Leon W. II (1997). Digital and Analog Communications. Upper Saddle River, NJ: Prentice-Hall. ISBN 0-13-081223-4.

[12]Haykin, Simon (1988). Digital Communications. Toronto, Canada: John Wiley & Sons. ISBN 0-471-62947-2.

[13] http://www.barnardmicrosystems.com/L4E_comms_2.htm.

[14] Howard Friedenberg and Sunil Naik. "Hitless Space Diversity STL Enables IP+Audio in Narrow STL Bands". 2005 National Association of Broadcasters Annual Convention. Retrieved April 17, 2005.

[15] Sklar, B "Rayleigh fading channels in mobile digital communication systems. I. Characterization" Sep 1997 Volume: 35 Issue: 9,PP: 136 – 146 Communication magazine IEEE.

[16] Jack H. Winters "on the capacity of radio communication systems with diversity in a Rayleigh Fading Environment" AT&T Bell Laboratories, Holmdel, 0733-8716/87/0600-0871$01.00 0 1987 IEEE.

[17] G.J. Foschini, M.J. Gans, “On limits of wireless communication in a fading environment when using multiple antennas,” *Wireless Personal Communications*,vol. 6, no. 3, pp. 311-335, Mar. 1998.
[18] Babak Hassibi and Bertrand M. Hochwald “How Much Training is Needed in Multiple-Antenna Wireless Links?, Bell Laboratories, Lucent Technologies, 0018-9448/03$17.00 © 2003 IEEE.
[19] Sergey Loyka, Ammar Kouki “New Compound Upper Bound on MIMO Channel Capacity” School of Information Technology and Engineering (SITE), University of Ottawa, Ottawa, 1089-7798/02$17.00 © 2002 IEEE.
[20] Sergey Loyka, Ammar Kouki “ On MIMO Channel Capacity, Correlations, and Keyholes: Analysis of Degenerate Channels” School of Information Technology and Engineering (SITE), University of Ottawa, 0090-6778/02$17.00 © 2002 IEEE.
[21] Dimitry Chizhik, Farrokh Rashid-Farrokhi, Jonathan Ling, and Angel Lozano, “Effect of Antenna Separation on the Capacity of BLAST in Correlated Channels” 1089–7798/00$10.00 © 2000 IEEE.
[22] Da-shan Shiu, Gerard J. Foschinit, Michael J. Gamt, and Joseph M. Kahn, “Fading Correlation and Its Effect on the Capacity of Multi-Element Antenna Systems” 211-138 Cory Hall, University of California Berkeley, CA 94720, 0-7803-5106 1/98/$10.00 0 1998 IEEE.
[23] Burr, “channel capacity evaluation of multi-element antenna system using spatial channel model” AP2000 Davos,paper 231.
[24]S.M. Alamouti, “A simple transmit diversity technique for wireless communication IEEE J. Select. Areas Commun., vol. 16, no. 8, pp. 1451–1458, Oct. 1998.
[25]I.E.Telatar, "Capacity of multi-antenna gaussian channels," Europea Transactions on Telecommunications, vol. 10, no. 6, pp. 585-595, 1999. D. G. Brennan, “Linear diversity combining techniques”, Proceedings of the IEEE vol. 91, no. 2, pp. 331-356, Feb. 2003.
[26] Ji-hua Lu, Yu Han “Application of Multipath Shape Factors in Nakagami-m fading channel” School of Information and ElectronicsBeijing Institute of Technology Beijing, China, 978-1-4244-5668-0/09/$25.00 © 2009 IEEE.
[27] Lorenzo Rubio, Juan Reig, Narcís Cardona, “Evaluation of Nakagami fading behaviour based on measurements in urban scenarios” Communications Department, Technical University of Valencia, Int. J. Electron. Commun. (AEÜ) 61 (2007) 135 – 138.

[28] *Xiwu Lv, Kaihua Liu, Yongtao Ma*, 'some results on the capacity of rayleigh fading channel', School of Electronic and Information Engineering, Tianjin University, Tianjin, China, 978-1-4244-3709-2/10/ ©2010 IEEE.

[39] S. Salous " Multiple input Multiple output systems: capacity and channel measurements", Department of electrical engineering and electronics UMIST.

[30] Bengt Holter "On the capacity of MIMO channel-A Tutorial Introduction" Norwegian University of Science and Technology Department of Telecommunications.