ANALYSIS OF MIMO SYSTEM FOR IMAGE TRANSMISSION

DISSERTATION-II

Submitted in partial fulfillment of the
Requirement for the award of the
Degree of

MASTER OF TECHNOLOGY

In

Electronics and Communication Engineering

By

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Under the Guidance of

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LOVELY PROFESSIONAL UNIVERSITY

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SCHOOL OF ELECTRONICS AND ELECTRICAL ENGINEERING,

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Phagwara-144002, Punjab (India)

May-2017

TOPIC APPROVAL PERFORMA

School of Electronics and Electrical Engineering

Program : P175::M.Tech. (Electronics and Communication Engineering) [Full Time]

COURSE CODE : ECE521 **REGULAR/BACKLOG :** Regular **GROUP NUMBER :** EEERGD0003

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Qualification : ________________________ **Research Experience :** ________________________

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PROPOSED TOPIC : Compressive Sensing Detection for Spatial Modulation in Large-Scale Multiple Access Channels

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	7.50
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.50
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5	Social Applicability: Project work intends to solve a practical problem.	7.50
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	7.50

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Final Topic Approved by PAC: **Analysis of MIMO system for image transmission.**

Overall Remarks: Approved (with minor changes)

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CERTIFICATE

This is to certify that the Dissertation-II entitled **''Analysis of MIMO system for Image Transmission''** which is being submitted by ***Manpreet Kaur,*** is in partial fulfillment of the requirements for the award of degree Master's of Technology in Electronics and Communication Engineering to Lovely Professional University, Jalandhar, Punjab is a record of the candidates own work carried out by her under my supervision. The matter embodied in this report is original and has not been submitted for the award of any other degree.

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ACKNOWLEDGEMENT

Foremost, I wish to express my sincere thanks to **Mr. Lavish Kansal**, Assistant professor, in the School of Electronics and Electrical Engineering. I am extremely grateful and indebted to him for sharing his expertise and sincere and valuable guidance and encouragement extended to me.

I am thankful to management of Lovely Professional University for giving me an opportunity to carry out studies at the university and providing the proper infrastructure like internet facility which is pool of vast knowledge to work in.

I owe my heartiest thanks to my parents & all those guidepost who really acted as lightening pillars to enlighten my way throughout this project that has led to successful and satisfactory completion of my Dissertation-II.

At last but not the least I am thankful to all my friends, , who have been instrumental in creating proper, healthy and conductive environment and including new and fresh innovative ideas for me during the last date of submission of project. Without them, it would have been extremely difficult for me to prepare the project report in a time bound framework.

I would like to thank God for the strength that keeps me standing and for the hope that keeps me believing that this report would be possible.

.

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DECLARATION

I, Manpreet Kaur, student of M. Tech under Department of School of Electronics and Electrical Engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation-II report is based on my own intensive research and is genuine.

This Dissertation-II does not, to the best of my knowledge, contain part of my wok which has been submitted for the award of my degree either of this university or any other university without proper citation.

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ABSTRACT

This work includes the communication of an image over a wireless channel in order to recover it clearly at the receiving side. Generally, in such framework, fewer signals to noise ratio (SNR) value or an identical antenna at the receiver side limits the multiple-input multiple-output (MIMO) System. Here, performance of image transmission by making use of MIMO system based on diversity technique is estimated. This estimation is done using Space-time block codes over Rayleigh channel with Phase shift keying modulation technique, and the detection is done using the Zero-forcing equalizer. The space-time block codes used are Alamouti space-time block code, Orthogonal space-time block code and Quasi-orthogonal space-time block code.

Here, the BER analysis for image sent by making use of MPSK modulation scheme is attained. 0dB to 40dB are the values of SNR taken with the difference of 10dB, i.e. (0dB, 10dB, 20dB, 30dB, and 40dB). 8PSK, 16PSK, 32PSK and 64PSK are M values taken for the purpose of modulation using MPSK scheme. The simulation of the results of image communication is done using the MATLAB. By spatial diversity, the reconstruction of transferred image is done, and its BER performance is examined. The varying qualities of an image with respect to varying number of receiver antennas and varying SNR values are shown in the results. It is also revealed in the results that the lower level modulation results in the better image quality whereas the higher level modulations worst the image quality. It is determined that the reconstructed image will be clearer with the increment in the value of SNR, but it becomes unclear with the increment in the M value of modulation scheme. The performance analyzed is best for the higher number of antennas and high SNR values.

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LIST OF ABBREVIATIONS

AAS	Adaptive Array System
BER	Bit Error Rate
BLAST	Bell Laboratories Layered Space-Time
CSI	Channel State Information
IEEE	Institute of Electrical and Electronics Engineers
ISI	Inter Symbol Interference
LSTC	Layered Space-Time Code
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
MISO	Multiple Input Single Output
ML	Maximum Likelihood
MMSE	Minimum Mean Square Error
MRC	Maximum Ratio Combining
OSTBC	Orthogonal Space-Time Block Coding
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QOSTBC	Quasi-orthogonal Space-Time Block Coding
QPSK	Quadrature Phase Shift Keying
SDMA	Spatial Division Multiple Access
SIMO	Single Input Multiple Output
SISO	Single Input Single Output
SM	Spatial Multiplexing
SNR	Signal to Noise Ratio
STBC	Space-Time Block Code
STTC	Space-Time Trellis Code
TX-AA	Transmitter Adaptive Antenna
UE	User Equipment
Wi-MAX	Worldwide Interoperability for Microwave Access
ZF	Zero Forcing

CHAPTER 1 INTRODUCTION

As the demand of high performance communications using wireless media is increasing day by day, therefore, various technologies have been developed. One of these technologies is Multiple-Input-Multiple-Output (MIMO) systems. MIMO system defines the utilization of huge numbers of transmitting and receiving antennas just to deliver parallel data stream. Its advantage is that more data can be delivered within the less time. Since the different paths are followed to transmit the information, hence, a MIMO system provides high data rates and spectral efficiency. It also increases the reliability of the system and all it is done through both spatial diversity and spatial multiplexing schemes [1]. Unlike Single-Input-Single-Output (SISO) systems, MIMO is advantageous. Its two most important advantages are:

(1) A valuable increase in the reliability of system, capacity of system and spectral efficiency: The spatial diversity used in the MIMO system increases the reliability of system and the spatial multiplexing used in the same increases the system capacity and the spectral efficiency with the use of less frequency resources and total transmission power. Also, lesser the amount of transmitter/ receiver antennas more will be the capacity of the system.

(2) Reduced fading effects because of the increased diversity: The increase in the diversity reduces the effects of fading occurred because of multipath propagation. This is advantageous when the different channels fade independently [2].

1.1 MIMO

Multiple-input-multiple-output comprises of huge amount of transmitter/receiver antennas at both the transmission and receiving side just to bring down the fading effects and to upgrade the execution of communication system. It comes under the form of smart antenna technology. MIMO technology has attracted much attention over the last decade in almost all areas of wireless communication since it allows for increased capacity and reliability without additional power or bandwidth. So many advantages are provided by MIMO system over the SISO system. Hence, it is more beneficial. It enhances the system capacity through spatial multiplexing without additional requirement of power or bandwidth [3]. Fading effects provided because of multipath propagation can be decreased with the help of spatial diversity. The capacity is linearly proportional to the minimum amount of antennas used at the transmitter or the receiver. With the use of the spatial diversity among the antennas, the average capacity can be increased and the outage probability can be reduced in a fading channel. Higher the number of antenna elements, higher will be the channel capacity. Unlike the SISO and MISO systems, having logarithmic-increase of capacity of channel, there is direct increase in the channel capacity with the antenna elements in MIMO system.

The spatial multiplexing (SM) concept using MIMO was given in 1993. It emphasized on "wireless broadcast communications" applications. The space-division multiple accesses' (SDMA) multi-user MIMO concept was given by Richard Roy. They give draw attention to "receiving antennas' arrays at the base station" and "plurality of remote users". Bell Labs determine the laboratory prototype of a special technology in 1998 to improve the MIMO communication systems' performance, which is named as spatial multiplexing.

On the basis of different amount of antennas allocated on transmission and receiving side, the categories of multi-antenna types are:

(1) Single-Input/Single-Output (SISO)

(2) Single-Input/Multiple-Output (SIMO)

(3) Multiple-Input/Single-Output (MISO)

(4) Multiple Input/Multiple Output (MIMO)

1.1.1 Single Input Single Output (SISO):

Single-input/single-output is simplest type of radio link having single transmitter and receiver antenna. Because of simple architecture, no additional diversity processing is required in it. But its performance is not best due to interference and fading effects as no diversity is used here. Also, efficiency of the system relies upon the bandwidth of channel and SNR. Suppose that for a provided channel having bandwidth as B and transmitting power as P, the received signal has an average signal-to-noise ratio.

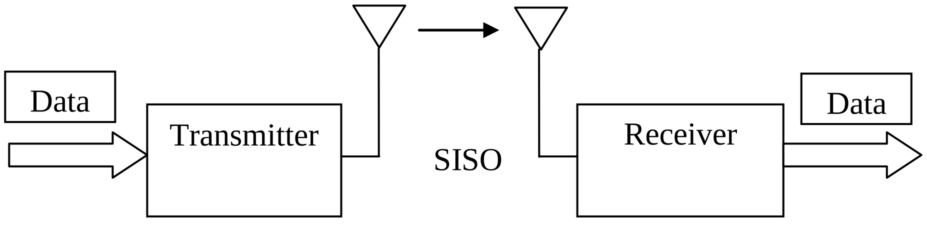


Fig. 1.1: Single Input Single Output

Its capacity of channel is given by:

$$C = B * log_2(1 + SNR) \quad (1.1)$$

1.1.2 Single Input Multiple Output (SIMO):

Single-input/multiple-output consists of large amount of antennas at the receiving side with an identical antenna at the transmission side. It is also known as Receiver Diversity. Its implementation is very simple and easy. It overcomes the effect of ionospheric fading and interference. Because of receiver diversity, it requires some additional processing on the receiver side and the size, cost and battery drain may limit this processing level. Its channel capacity is as follows:

$$C = N_R * B * log_2(1 + SNR) \quad (1.2)$$

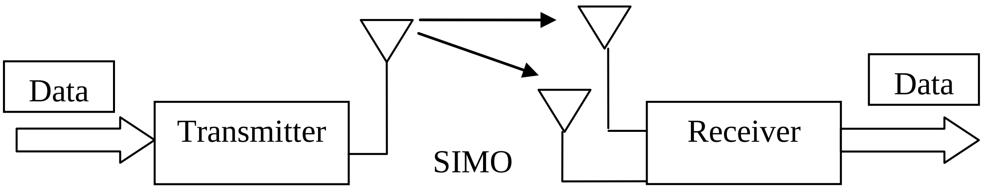


Fig. 1.2: Single Input Multiple Output

1.1.3 Multiple Input Single Output (MISO):

Multiple-input/single-output is also known as Transmit Diversity, in which transmitter side consists of various antennas and receiving side containing single antenna only. In this system, multiple copies of the similar data are transmitted from various transmitter antennas and the receiver receives the optimum to extract the original data. Its battery consumption is less as compared to Single-input-multiple-output (SIMO) as the lower level of processing is required at the side of transmission. The Channel capacity is approximately given by:

$$C = N_T * B * log_2(1 + SNR) \quad (1.3)$$

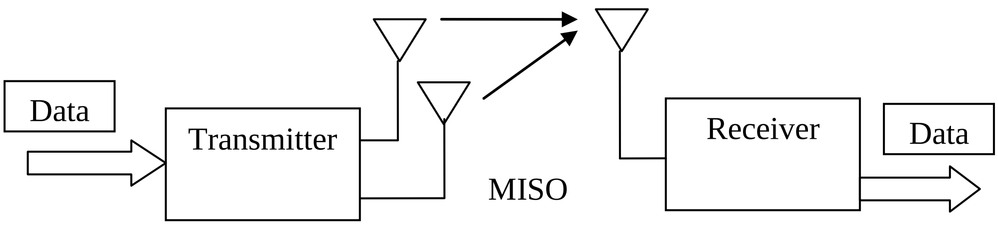


Fig. 1.3: Multiple Input Single Output

1.1.4 Multiple Input Multiple Output (MIMO):

Multiple-input/multiple-output is the system having various numbers of antennas at both the transmission and reception side which enables signal to follow multiple paths to carry data. Its capacity is given by:

$$C = min\,(N_T, N_R) * B * log_2(1 + SNR) \qquad (1.4)$$

Thus, as we can say that the there is direct increment in capacity with the amount of transmitter antennas (N_T). Hence, it is advantageous to use various antennas for the transmission purpose rather than using one antenna.

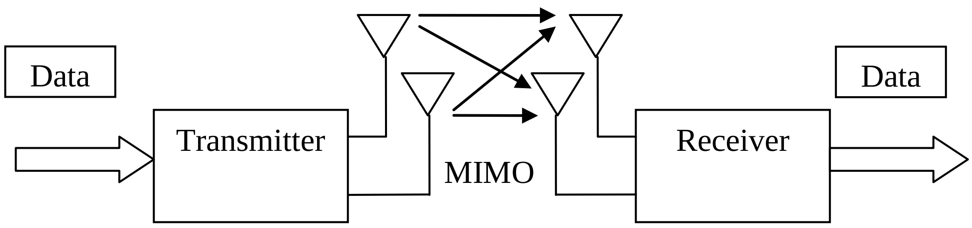


Fig. 1.4: Multiple Input Multiple Output

1.2 MIMO System Block Diagram

MIMO innovation constitutes a leap forward in wireless communication system design. So many benefits are offered by the technology that overcomes the drawbacks and challenges occurred by the impairments in the wireless medium and resource constraints. Unlike traditional single-antenna (single-input/single-output) wireless systems, the realization of MIMO is done by taking advantage of the spatial dimension given by the various antennas at the transmission side and the receiving side. The basic elements of MIMO system are presented in Fig. 1.5. The transmitted data bits are encrypted using convolutional encoder and then they are interleaved. The mapping of interleaved dataword to symbols like quadrature amplitude modulation (QAM) is done via symbol mapper and is given to a space-time encoder as an input which in results gives multiple spatial data streams as an output. Their mapping is done to the sender antennas by using space time precoding. These mapped signals are transmitted through the channel and are retrieved at the receiving end. Now at the receiver end, each operation of the transmitter is reversed to decode the data in which space-time processing is done followed by space-time decoding. After this, de-mapping, de-interleaving and decoding of the symbol are done.

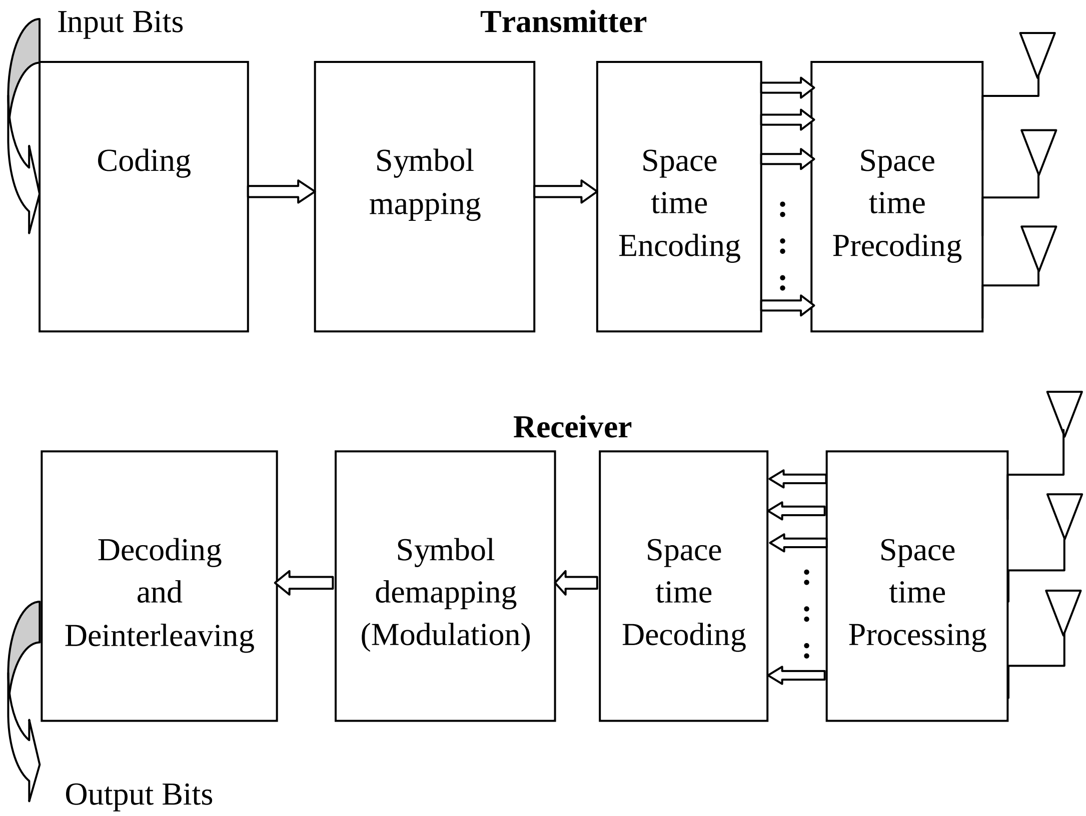


Fig. 1.5: Basic Block Diagram of MIMO Communication System

1.3 Types of MIMO System

Two forms of MIMO are:

(1) Single User vs. Multi User

(2) Open loop vs. Close loop

1.3.1 Single user vs. Multi user

a) Single user:

It is a system in which for a single UE (User Equipment), the data rate is increased.

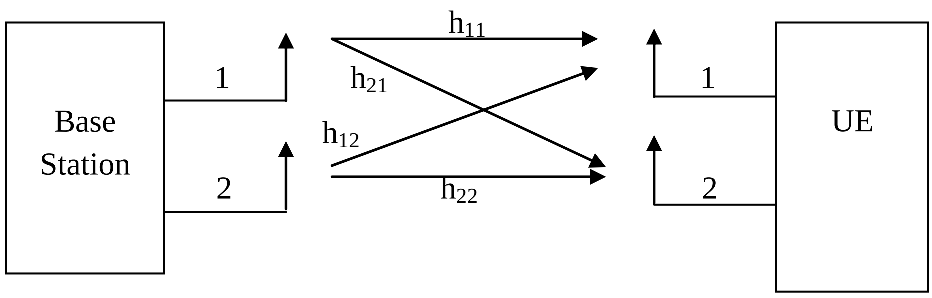


Fig. 1.6: Single User MIMO (SU-MIMO)

b) Multiple user:

Multi user MIMO (MU-MIMO) is system in which various users are assigned with the individual streams. As the utilization of identical antenna at the transmission side reduces the complexity on the UE side, therefore, it is particularly useful in the uplink and is known as “collaborative MIMO”.

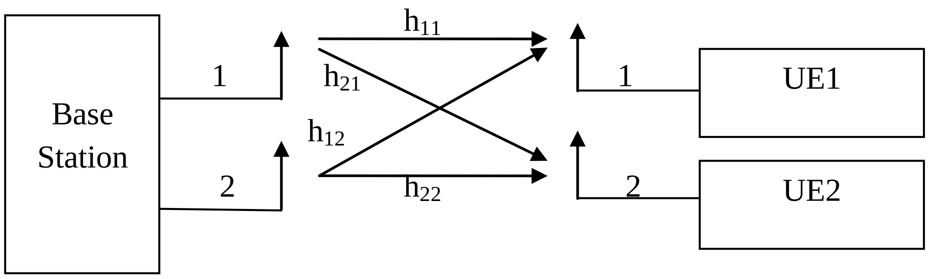


Fig. 1.7: Multi User MIMO (MU-MIMO)

1.3.2 Open loop MIMO vs. Close loop MIMO

In applications, Open Loop MIMO techniques are most commonly used MIMO terminology. Closed Loop MIMO techniques are said to be Transmitter Adaptive Antenna (TX-AA) methods and are considered as "beamforming" [4].

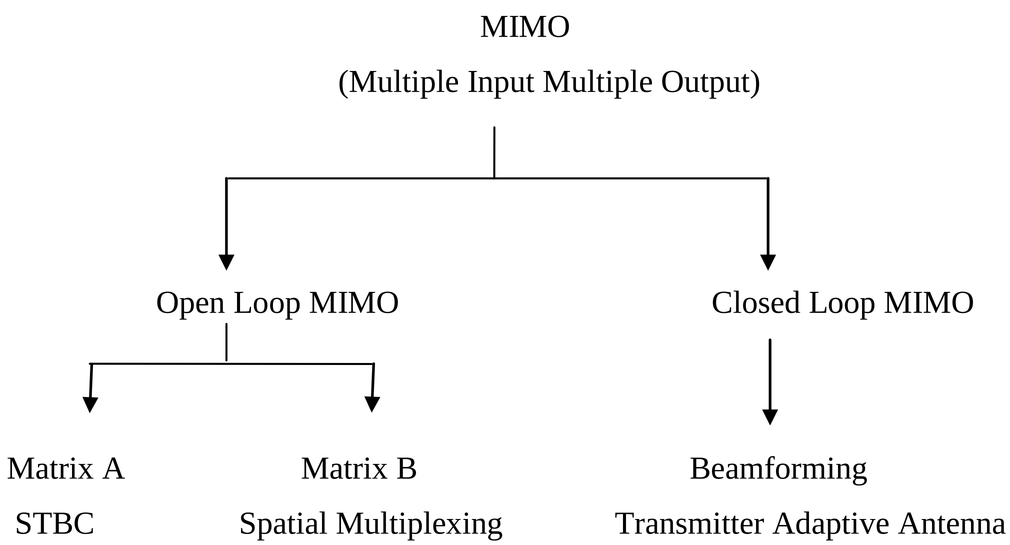


Fig. 1.8: MIMO Classification

a) Open loop MIMO:

The MIMO system, in which no any information regarding propagation channel of the communications channel is used i.e. no any information regarding channel is needed to be known at the transmission side which is known as Open Loop MIMO. The feedback is not required from the user equipment (UE) to do the adjustment of coding and to better the system performance. Some of the Open Loop MIMO techniques are:

(1) Spatial Diversity
(2) Spatial Multiplexing (SM)
(3) Collaborative Uplink MIMO

- **Spatial Diversity**

Spatial diversity is the basic form of the MIMO system having large number of multiple antennas. In this diversity system, multiple xerox of same information is transmitted through different transmitter antennas and the desired signals are received at the receiving side which varies in terms of SNR. The main aim of this technique is to reduce errors and make the performance better with the help of a diversity gain and a coding gain [5]. Thus a full diversity order may be attained by exploitation of MIMO channels via space-time coding techniques, like STBCs and STTCs. Spatial diversity is used in two ways like receiver diversity and transmitter diversity. The receiver diversity consists of single input antenna at transmitter with multiple numbers of antennas at receiver whereas the transmit diversity consists of single output antenna at receiver with multiple numbers of transmitter antennas. As the huge numbers of antennas used at the receiver in receive diversity helps to extract the desired signal output, therefore, it is very helpful in the reduction of harmful fading effects occurred because of multipath propagation. Maximum ratio combining (MRC) is an optimal scheme used by one of the types of fading known as frequency-flat fading to increase the SNR at the receiving side.

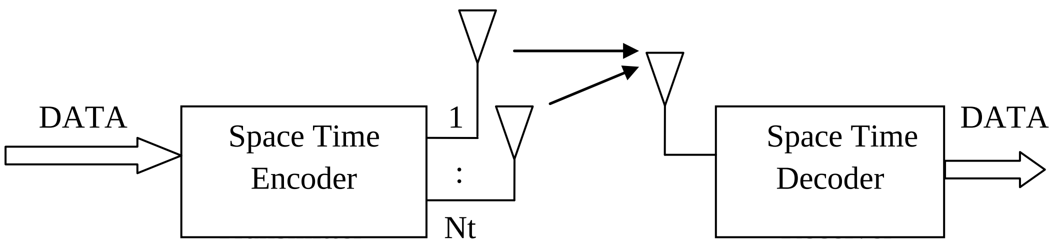


Fig. 1.9: Principle of Spatial Diversity

The complete information regarding the channel must be known at the side of receiver in this technique. Transmit diversity having huge antennas at the transmission side and distinct antenna at the reception side, helps in the reduction of processing complexity at the side of receiver. Space-Time Trellis Codes (STTCs) are the trellis structure based power efficient method of communication system introduced with more data rate and bandwidth [6]. The decoding of these trellis codes at the receiver can be done using soft-decision viterbi decoding techniques. These two methods increase the SNR value and also make the system more reliable better analogous to the various types of fading.

- **Spatial Multiplexing**

Spatial multiplexing is a multiplexing method in MIMO in which multiple data signals are transmitted using multiple transmitter antennas. These independent data signals transmitted are known as 'streams'. In SM, the division of a signal with high rate data is done into various streams with lower data rates. The splitted lower rate data streams are sent via different transmit antenna over the same frequency channel. A superposition of all the transmitted signals is received at the receiving antenna array. At the receiver, the detection of the transmitted symbols is done by de-multiplexing the spatial channels. Linear receivers like zero-forcing or minimum-mean-square-error algorithm are utilized to reduce the system complexity. Unlike single-input/single-output (SISO) systems, without any extra requirement of bandwidth or extra transmission power, MIMO capacity raises linearly with min(N_T,N_R), i.e. minimum amount of transmitter and receiver antenna respectively. It is more powerful technique as it increases capacity of channel at large SNR values.

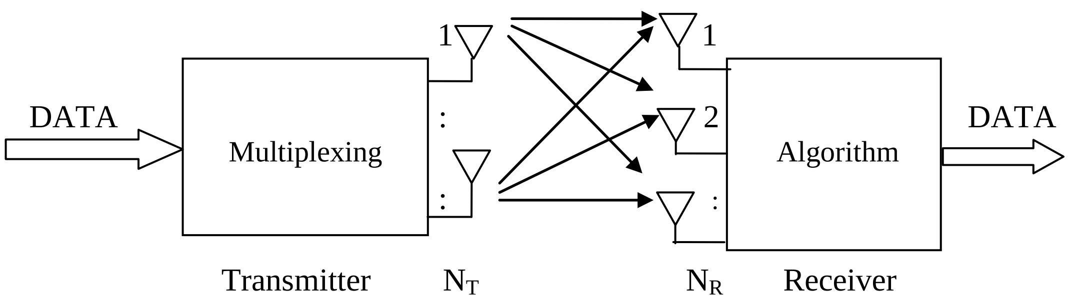


Fig. 1.10: Spatial Multiplexing

- **Collaborative Uplink MIMO**

Two main applications of MIMO which makes use of huge number of transmitter and receiver antennas with an objective of transmitting distinct informative streams over the similar frequency channel via different directions are Wi-MAX and LTE. But the main disadvantage of MIMO system is that they might not be compatible with small handheld devices, i.e. it might be impossible to use several antennas with these small devices due to their small size or the additional cost incurred. Hence, they cannot make use of MIMO. Therefore, it reduces the overall speed of the network which degrades the system performance. The remedy to this problem is the "uplink collaborative MIMO" or multi user MIMO (MU-MIMO). In this system, two mobiles transmit simultaneously via different-different MIMO paths over the same frequency channel.

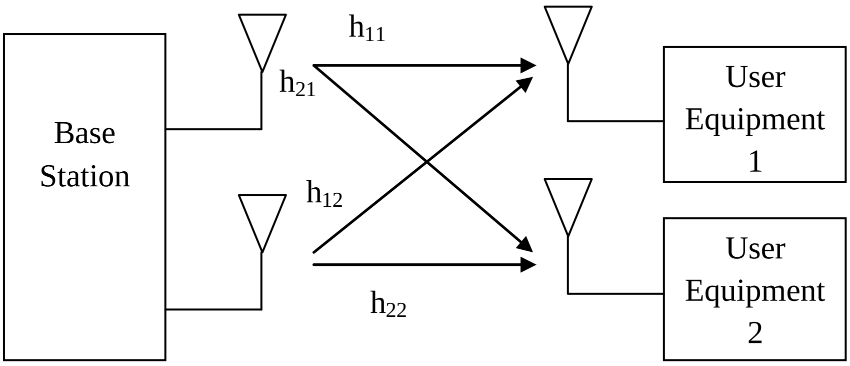


Fig. 1.11: Collaborative Uplink MIMO

MIMO capable base station will selects the signals independently from each other if the main energy of each signal arrives from a different direction. This system improves the sector efficiency without any requirement of multiple transmitter antennas at the mobile station. The main comparison between Collaborative Spatial Multiplexing and general spatial multiplexing is that various information streams are sent from various antennas on the similar device, i.e. requires multiple antennas in regular spatial multiplexing whereas there is no any requirement of multiple transmitter antennas in the collaborative spatial multiplexing.

b) Closed Loop MIMO

The MIMO system, in which some information regarding propagation channel of the communications channel is used i.e. which requires some information regarding the channel at the side of transmitter are known as Closed Loop MIMO. There is the feedback provided from the user equipment (UE), i.e. from the receiving end to the transmitting end to do the adjustment of coding and to make the system performance better. Hence, some closed loop operations are performed to execute dynamic adjustment dependent on the UE feedback. It utilizes Channel State Information (CSI) at the transmitting side [7]. This information might be incomplete or complete channel state information dependent of feedback provided. The presence of partial information of channel at the sender is because of the drawback of the feedback channel. Normally we use smart antennas which have antenna directive pattern and can be self-restrained to provide the wanted performance. Smart antennas can be categorized into two parts:

1) Phased array systems
2) Adaptive array systems

- **Phased array systems**

Phased array systems are shifted array systems having number of already defined designs in which the suitable antenna array is switched in accordance to the required direction. The DoA is calculated by the switched beamformers shift to the fixed beam. The best signal strength is attained along the beam centre.

- **Adaptive array systems (AAS)**

There are an unlimited number of designs in adaptive beamformer and it handles the trouble and make changes in the beam in real time to the mobile UE. The beam is directed in the required direction. This system has high complexity and cost as comparative to the phased array system.

1.4 Functions of MIMO

MIMO can be classified into three parts:
(1) Precoding
(2) Spatial Multiplexing (SM)
(3) Diversity Coding

1.4.1 Precoding

Precoding is characterized as various stream beamforming which is regarded as spatial processing happening on the side of transmission. Conventionally, the single-stream beamforming transmits similar information from each transmitter antennas with proper phase and gain with the maximum signal power at the receiver input. It is a technique in which transmit diversity is exploited by transmitting the coded information to the recipient keeping in mind to have the information of the channel. There is necessity of knowledge of information about channel on the transmitting side and receiving side in precoding. Two types of precoding are there-

a) Precoding for Point-to-Point MIMO Systems

b) Precoding for Multi-user MIMO Systems

a) Precoding for Point-to-Point (Single-user) MIMO Systems

Point-to-point MIMO system includes a sender having huge number of antennas to exchange information with a receiver having huge number of antennas [8]. The narrowband, slow fading is assumed in most elegant precoding, i.e. the channel response remains same for a particular period of time. Practically, achievement of these channels can be via OFDM. The increase in channel capacity depends on the information regarding channel and it is classified as-

(1) Statistical channel state information

(2) Full channel state information

- **Statistical channel state information**

If the channel matrix is present at the receiver and the incomplete information is present at the transmitter, then the system capacity is achieved by Eigen beamforming. Here, multiple streams are emitted by the transmitter in Eigen directions of the channel covariance matrix.

- **Full channel state information**

If the knowledge regarding the channel matrix is fully notable, then the precoding used to gain the channel capacity of MIMO is the Singular Value Decomposition (SVD). Here diagonalization of the channel matrix is done by taking a SVD and with the pre-multiplication at the transmitting side and post-multiplication at the receiving side, two unitary matrices are removed. Then, the transmission of single data stream per singular value can be done without any interference.

b) Precoding for Multi-user MIMO Systems

In multi-user MIMO, simultaneous communication is done between a multi-antenna transmitter and multiple receivers and it is referred as Space-division multiple accesses (SDMA). On the basis of implementation, precoding algorithms is further distinguished into linear precoding and nonlinear precoding. The nonlinear precoding approaches achieve high capacity whereas the reasonable performance is gained by the linear precoding approach at reduced complexity. The examples of linear precoding approaches are Maximum ratio transmission (MRT), Zero-Forcing (ZF) precoding, and Transmit Wiener precoding. Random beamforming is the precoding strategy customized for feedback of information about at low-rate. The designing of non-linear precoding is done dependent on the dirty paper coding (DPC) concept. Because of maximizing performance in point-to-point MIMO, simultaneous maximization of performance for all users cannot be done by multi-user system. The main motive is to maximize the capacity of one of the users. Its remedy is the selection of a system utility function.

1.4.2 Spatial Multiplexing

Configuration of MIMO antenna is required in Spatial Multiplexing. In it, multiple streams are transmitted via different multiple antennas after the conversion of a single signal with high rate into various streams with lower-rate. Its transmission is done over the same frequency channel. Then these streams are separated into parallel channels at the side of receiver. The capacity of the channel is increased at higher SNR in spatial multiplexing. We can use spatial multiplexing when no CSI is present at the side of transmitter, but if CSI is present then we can use its combination with precoding [9]. We can also use spatial multiplexing to transmit streams to various receivers, at one time. This is also termed as Space-division multiple access. The information regarding channel is needed at the side of transmitter.

1.4.3 Diversity Coding

Diversity Coding is the techniques, used without channel state information at the side of transmission. Unlike various streams in spatial multiplexing, a distinct stream is sent in diversity scheme. The coding of this stream is done by space-time coding. The transmission of the signal is done via full or near orthogonal coding. Diversity coding takes advantage of the multipath propagation to strengthen the signal diversity. As no any state information regarding channel is used at the transmitter, therefore, no array gain is achieved from diversity coding. If any information regarding channel is present at the transmission side, then combination of diversity coding and spatial multiplexing is used.

1.5 Modulation Techniques

Modulation is the process defined with the variation of characteristics of a continuous waveform called the carrier signal with a modulating signal that commonly includes data to be transmitted. The main motive behind the analog modulation is the transmission of an analog signal over an analog bandpass channel. This transmission is done at the different frequency, for e.g. a cable TV network channel. For M-ary PSK, M symbols are arranged on a circle with radius $\sqrt{E_S/T_S}$ resulting in fixed symbol energy [10].

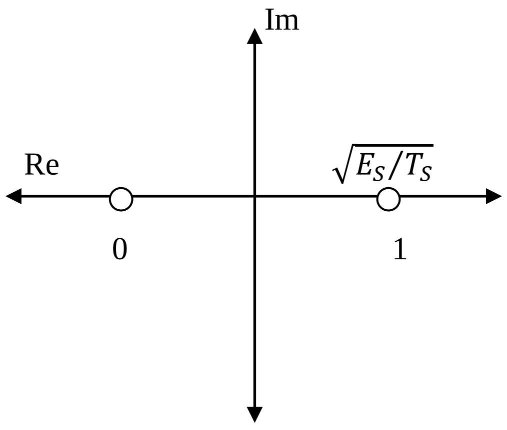


Fig. 1.12: Constellation Diagram for BPSK

On the other hand, a balanced of π/M can be decided for Quaternary Phase Shift Keying (QPSK) and 8-PSK. Binary Phase Shift Keying (BPSK) for M=2 and QPSK for M=4 presents the unique cases, since they can be allocated to the class of amplitude modulation methods, as well (2-ASK and 4-QAM, respectively). For M>4, real and imaginary parts are dependent of each other and must be distinguished at same time. For anti-clockwise numbered symbols, Euclidean distance between two symbols X_μ and X_v is given by:

$$\Delta^2_{\mu,v} = \frac{|X_\mu - X_v|^2}{E_S/T_S} = 4Sin^2\left(\frac{(\mu - v)\pi}{M}\right) \tag{1.5}$$

BPSK is the simpler version of PSK, also referred as Phase Reversal Keying (PRK) or 2-PSK. The separation of two phases is done by 180°.

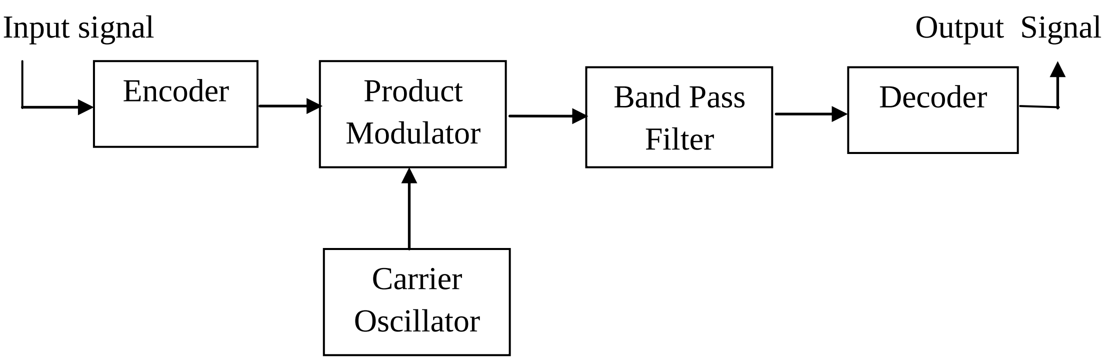


Fig. 1.13: BPSK Block Diagram

Therefore, it is called as 2-PSK. The exact position of constellation points doesn't matter particularly and here, they are shown on the real axis, at 0° and 180°. Among all the PSKs, it is best one because noise or distortion is taken by it to have an incorrect decision by the demodulator. But it modulates only at 1 bit/symbol; hence it is not suitable for the applications with high data-rates. Practically, BPSK is similar to 2-QAM modulation. BPSK has a bandwidth which is lower than BFSK signal. It has best performance of all the systems in presence of noise. It gives the minimum possibility of error. It has very good noise immunity. It is used for high bit rates even higher than 1800 bits/sec. The probability of error is given as:

$$p_S^{BPSK} = \frac{1}{2} \cdot erfc \left\langle \sqrt{\frac{E_S}{N_o}} \right\rangle \tag{1.6}$$

Two parallel BPSK schemes can be treated as QPSK with similar E_b/N_0. Hence, the bit error probabilities are similar.

$$p_S^{QPSK} = \frac{1}{2} \cdot erfc \left\langle \sqrt{\frac{E_b}{N_o}} \right\rangle = \frac{1}{2} \cdot erfc \left\langle \sqrt{\frac{E_S}{2N_o}} \right\rangle \tag{1.7}$$

Four points are used by QPSK, on the constellation diagram, which are spaced equally around a circle. It is also defined as quaternary PSK, 4-PSK, or 4-QAM. With 4 phases, two bits per symbol can be encoded by QPSK using gray coding that reduces BER -sometimes perceived incorrectly as double the BPSK's BER. Mathematically, it can be seen from the points that as compared to BPSK, the utilization of QPSK can be done to make twice the information, keeping the signal bandwidth constant, to balance the BPSK data rate by making bandwidth half. After this, for the second point, the QPSK's BER is similar to the BPSK's BER.

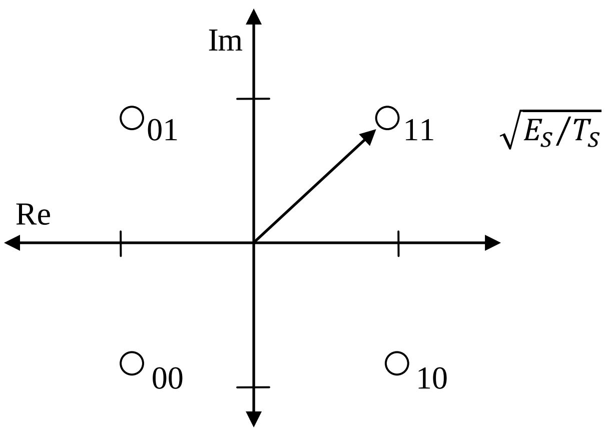


Fig. 1.14: Constellation Diagram for QPSK

The agencies like Federal Communication Commission allocates the radio communication channels with the appointed (maximum) bandwidth, QPSK's advantage over BPSK becomes noticeable: as compared to data rate of BPSK, the transmission rate of QPSK is twice in a provided bandwidth at the similar BER. But the complexity of senders and receivers of QPSK is more complex than that of BPSK's. As there are some ambiguity problems in phase with the BPSK, at the receiver end. Therefore, often, QPSK is used practically. Sine and cosine waves form of symbols in constellation diagram, used to transmit are:

$$s_n(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right) \tag{1.8}$$

This returns the 4 phases (π/4, 3π/4, 5π/4 and 7π/4) as required:

$$\varphi_1(t) = \sqrt{\frac{2}{T_s}} \cos\,(2\pi f_c t) \tag{1.9}$$

$$\varphi_2(t) = \sqrt{\frac{2}{T_s}} \sin\,(2\pi f_c t) \tag{1.10}$$

The signal-space 4 points are included in the signal constellation, and they are:

$$\pm\sqrt{\frac{E_s}{2}}, \pm\sqrt{\frac{E_s}{2}} \tag{1.11}$$

Here, the division of total power is done equally between 2 carriers and is indicated by the factor of 1/2. The representation of QPSK is simple as two different modulated quadrature carriers. With this representation, in-phase component of the carrier are modulated using the even (or odd) bits, while the quadrature-phase component of the carrier are modulated using odd (or even). To demodulate individually, the utilization of BPSK is done on both carriers. Hence, the probability of bit-error is same for both QPSK and BPSK:

$$P_b = Q\left(\sqrt{\frac{E_b}{N_0}}\right) \tag{1.12}$$

Because of simultaneous transmission of two bits, twice the power is used by QPSK, to attain the bit-error probability similar to BPSK. The expression of symbol error rate is done as:

$$P_s = 1 - (1 - P_b)^2 \tag{1.13}$$

$$P_s \approx 2Q\sqrt{\frac{E_b}{N_0}} \tag{1.14}$$

In quadrature amplitude modulation (QAM), real and imaginary parts of a symbol are individually selected from each other. Consequently, as per real-valued $M`$-ASK with $M` = 2m`$, the mapping of $m' = m/2$ bits is done onto both real and imaginary symbol parts. Due to $M = M`^2$, the parameter e for M-QAM can be calculated to:

$$e = \sqrt{\frac{3}{2(M-1)} \cdot \frac{E_S}{T_S}} \tag{1.15}$$

and the minimum squared Euclidean distance is:

$$\Delta_0^2 = \frac{(2e)^2}{E_S/T_S} = \frac{6}{M-1} \tag{1.16}$$

1.6 Channels

The transmission with wireless medium utilizes air to transfer data. The radio spread is rough unlike transmission with wired medium because arrived signal is coming specifically from the sender, as well as mix of reflected, diffracted, and scattered duplicates of sent signal. The striking of a signal on the surface where fractional vitality is reflected and the rest is sent into the surface causes Reflection. Reflection coefficient is utilized for determining the proportion of reflection and transmission relies on the characteristics of objects. Diffraction happens if a signal is deterred by an abrupt obstacle which infers optional waves. The causes of Scattering are if a signal encroaches on harsh surfaces, or little objects. Arrived signal is some of time more grounded as compared to the reflected and diffracted signal because it scatters the vitality every which way and subsequently gives extra vitality for the receiving side which can get more than one duplicates of the signal in numerous ways with various stages and powers.

Communication channels might be named as fast fading channels and slow fading channels. The rough changes in the impulse at the symbol rate are termed as fast fading channel. The slow fading channel remains unaltered for a few symbols. The formula of Shannon's capacity is estimated hypothetically the most extreme attainable transmission rate for a provided channel having bandwidth B with power P and one side noise spectrum relying on the supposition of white channel.

$$C = B \ \log_2 \left(1 + \frac{P}{N_0 B}\right) \tag{1.17}$$

1.6.1 AWGN Channel

Additive White Gaussian Noise is a general form of channel. It is used for examining modulation techniques. It adds the White Gaussian noise to the signal, i.e. the amplitude frequency response of the channel is flat and phase frequency response of the channel is straight in order to send the modulated signals having no any decease in amplitude and deformation in phase of frequency parts [11]. The only distortion added is by the AWGN with no any fading existence. The input-output relationship is:

$$y = \sqrt{\rho x + n} \tag{1.18}$$

where x is input of channel, y is output of channel, and n denotes the AWGN. The introduced noise is the complex Gaussian random variable. Its mean is zero and variance is 1/2 dimensionally. It is assumed that at various applications of the channel, the noise terms are not dependent. Also it is assumed that the channel input satisfies the power constraint $E[|x|^2] \leq 1$, ρ is a constant that denotes the SNR at the receiving side. It is proved that the input organization which increases the mutual information is zero mean complex Gaussian with variance 1/2 dimensionally and the resultant capacity of channel is expressed as:

$$C = log\ (1 + \rho) \tag{1.19}$$

1.6.2 Rayleigh Channel

Rayleigh Channel is a creative and damaging quality of different paths segments in flat fading channels which is estimated by Rayleigh distribution having none observable pathway which implies if none immediate way is there amongst sender and receiver [12]. The simplification of arrived signal can be:

$$r(t) = s(t) * h(t) + n(t) \tag{1.20}$$

where h(t) represents the channel matrix and n(t) denotes the AWGN. The Rayleigh distribution is defined as the magnitude of the summation of 2 equivalent unique orthogonal Gaussian random variables. The pdf of this distribution is expressed as:

$$\frac{p}{r} = \frac{r}{\sigma^2} e^{\frac{-r^2}{2\sigma^2}} \qquad 0 \leq r \leq \infty \tag{1.21}$$

where σ^2 represents the time-average power of the arrived signal. The phase and the gain components of a channel's deformation are symbolized as a complex number often. Here, it is assumed for the exhibition of Rayleigh fading that the modeling of response's real and imaginary parts is done by individual allocated zero-mean Gaussian processes.

1.6.3 Rician Channel

Rician distribution is defined as a distribution with the presence of a line of sight between transmitting side and receiving side, i.e. direct path between transmission and reception end which goes into more fade as contrasted with the multipath parts. In Rician fading, the characterization of gain of amplitude is done by a Rician distribution. Its pdf is given by:

$$\frac{p}{r} = \frac{r}{\sigma^2} I_o [\frac{A_r}{\sigma^2}]\, e^{\frac{-(r^2+A^2)}{2\sigma^2}} \qquad r \geq 0 \tag{1.22}$$

Where, I_o is modified zero-order Bessel function and A is the peak amplitude of dominant signal.

1.7 Signal Detection of MIMO System

An issue experienced in the plan of receivers for exchanging information digitally is the recognition of information from estimations with noise of the sent data. For a practical solution, the receiver is because of the disturbance bound making incidental mistakes or errors. Accordingly, planning a receiver with the characteristics of likelihood of blunder is insignificant is engaging, practically and a hypothetically. Lamentably, such outlines tend to bring out computationally complex receivers and hence they are frequently surrendered for computationally less complex yet problematic recipients. It is outstanding that for some situation, the gap in execution amongst problematic and the ideal receivers is considerable. This by itself makes the ideal recipients fascinating. Furthermore, the diminishing expense of calculation will bring about computationally attainable ideal outlines.

1.7.1 Zero-Forcing Equalizer

Zero-Forcing Equalizer is a linear detection strategy that is utilized in the transmission systems for detection purpose and was introduced by Robert Lucky. In this algorithm, the frequency response of channel is reversed. The signal received at the receiving side is multiplied by the inverse of the channel which in results removes the intersymbol interference (ISI). It is ideal for a channel without having any noise whereas for a channel with noise, the noise also gets amplified greatly at frequency f where the little magnitude is there in channel response $H(j2\pi f)$ in the attempt to reduce the channel completely. At the side of transmission, if the channel state information (CSI) is known perfectly, then the system capacity can be achieved for huge number of users by ZF-precoding. For the incomplete channel state information available at the transmitter (CSI_T), the performance of ZF-precoding decreases depending on the accuracy of CSI_T. To attain the complete multiplexing gain, ZF precoding requires the essential feedback overhead. Due to multiuser hindrances, incomplete CSI_T lowers the throughput. The nullification of these hindrances is done with beams made by incomplete CSI_T. On multiplying the input signal with the reverse of channel response, effects of channel are removed from the received signal, i.e. intersymbol interference (ISI). For the extraction of 2 symbols, interfering with each other, in the first time slot, the received signal on the first receive antenna is:

$$Y_1 = h_{1,1} x_1 + h_{1,2} x_2 + n_1 = (h_{1,1} \;\; h_{1,2}) \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + n_1 \tag{1.23}$$

The output on the 2nd receiver antenna is:

$$Y_2 = h_{2,1} x_1 + h_{2,2} x_2 + n_2 = (h_{2,1} \;\; h_{2,2}) \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + n_1 \tag{1.24}$$

whereY_1, Y_2 are the received symbol on the first and second antenna respectively,

$h_{1,1}$ represents the channel from 1st sender to 1st receiver.
$h_{1,2}$ represents the channel from 2nd sender to 1st receiver.
$h_{2,1}$ represents the channel from 1st sender to 2nd receiver.
$h_{2,2}$ represents the channel from 2nd sender to 2nd receiver.

In the form of matrix, equation is given by:

$$Y = Hx + n \tag{1.25}$$

To calculate the value of x, it is required to find a matrix W which fulfills WH=1. To fulfill this constraint, the Zero Forcing (ZF) linear detector is given by:

$$W = (H^H H)^{-1} H^H \tag{1.26}$$

It is otherwise called the pseudo reverse for a common m x n matrix. Keeping notice to off askew terms in the matrix $H^H H$ are non-zero. Due to non-zero off diagonal terms, the zero forcing equalizer tries to invalid out the interfering terms when executing the equalization, i.e. when explaining for x_1 interference from x_2 is attempted to be zero and vice versa [13]. At same time, amplification of noise may be there. Hence Zero Forcing equalizer is not the best one. However, it is non-complex and implementation is very easy.

1.7.2 Maximum Likelihood (ML) Algorithm

Maximum likelihood is a perfect detection technique in terms of less error and it fully uses the available diversity. ML receiver attains the most effective execution, i.e. highest diversity and smallest BER is achieved, only at the cost of complex detection method. The ML receiver figures all conceivable arrived signals without noise by changing all conceivable sent signals by the acknowledged MIMO channel transfer matrix. At that point, it looks for that signal ascertained ahead of time, which limits the Euclidean distance to the really arrived signal. The non-disturbed sent signal that prompts this smallest distance is taken to be no doubt sent signal. Take note that depicted detection method is ideal in sense of BER for white Gaussian noise. $\hat{x}$ is discovered by the ML receiver which limits,

$$J = |y - H\hat{x}|^2 = \left|\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} - \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix}\begin{pmatrix} \hat{x}_1 \\ \hat{x}_2 \end{pmatrix}\right|^2 \tag{1.27}$$

Because of BPSK modulation, the defined values of both x_1 and x_2 are +1 or -1. In order to calculate the ML solution, it's compulsory to calculate smallest value among 4 combinations of x_1 and x_2. On the basis of smallest value, the evaluation of the sent symbol is chosen, i.e if the smallest value is, $J_{+1,+1} \Rightarrow [11]$, if the smallest value is $J_{+1,-1} \Rightarrow [10]$, if smallest value is $J_{-1,+1} \Rightarrow [01]$ and if smallest value is $J_{-1,-1} \Rightarrow [00]$. The requirement is the detection of the smallest value among the 4 possible sent data combinations, dependent on the smallest value chose the evaluation of the sent symbol and repetition for various values of E_b/N_0.

1.7.3 Minimum Mean Square Error (MMSE) Algorithm

There is a compromise between the enhancement of noise and interference in signal in MMSE receiver. The mean square error present between the transferred data and the detected data is minimized. Hence, its results are the combination of sent pulses and some residual interference and noise [14]. After equalization process done by MMSE, detection of all information pulses is done separately. Practically, to attain the precise values of noise parameter can be complex that is essential for optimal detection of signal and only a little enhancement as comparative to the ZF receiver can be attained. Hence, it is unused practically. A coefficient named W is calculated by using MMSE scheme which limits the criterion:

$$E[W_{y-x}][W_{y-x}]^2 \tag{1.28}$$

To calculate x, it's required to calculate matrix W that satisfies WH=I. To fulfill this constraint, the MMSE detector is given by:

$$W = [H^H H + N_0 I]^{-1} H^H \quad (1.29)$$

Where W denotes the Equalization Matrix and H denotes the Channel Matrix, also known as the pseudo reverse for a common m x n matrix [15].

$$H^H H = \begin{pmatrix} h_{1,1}^* & h_{2,1}^* \\ h_{1,2}^* & h_{2,2}^* \end{pmatrix} \begin{pmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{pmatrix} = \begin{pmatrix} |h_{1,1}|^2 + |h_{2,1}|^2 & h_{1,1}^* h_{1,2} + h_{2,1}^* h_{2,2} \\ h_{1,2}^* h_{1,1} + h_{2,2}^* h_{2,1} & |h_{1,2}|^2 + |h_{2,2}|^2 \end{pmatrix} \quad (1.30)$$

The MMSE equalizer becomes Zero-Forcing equalizer, when the noise term tends to zero.

1.8 Image Transmission

The communication of an image from transmitter end to receiver end, over any propagation medium is known as image transmission. Generating an efficient communication of an image instead of voice signal over a medium is the requirement for a mobile radio link. There is a requirement of the compatibility of an image with the characteristics of a channel like bandwidth for this transmission purpose [16]. Large bandwidth is needed for the image communication. Large information is required for the representation of an image which leads data at high rates, and hence, results in distorted image. To recover the distortionless image at the receiving side, the transmission can be done using various techniques. Some of the techniques used for this transmission are Alamouti space time block codes, orthogonal space time block codes and Quasi-orthogonal space time block codes etc.

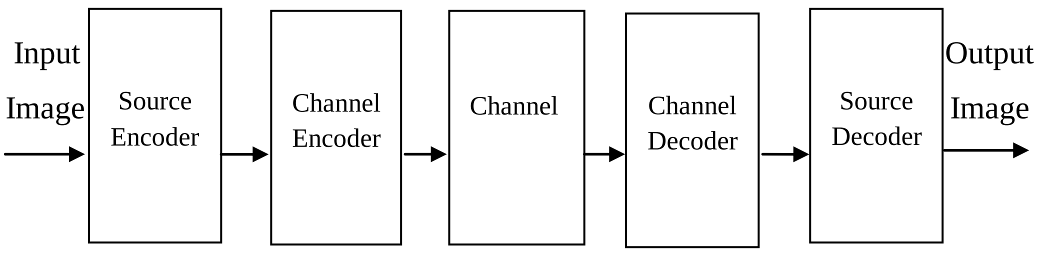


Fig. 1.15: Basic Block diagram of Image Transmission System

The basic transmission of an image from one end to another end involves some blocks like image as an input, source encoding, channel encoding, propagation channel, channel decoder, source decoder and output as shown in Fig. 1.15. Firstly, the image used as an input is converted into its binary equivalent form and then the encoder used, encodes the converted data and propagates it over the communication channel. At the receiving side, the data is decoded using the detector and the image is reconstructed back as an output.

1.9 Objective of Thesis

The main objective of this research is to combine MIMO along with Space time block codes over the Rayleigh channel and to investigate the results with their improved behavior and also study its performance. Specific objectives of the research are:

- **Performance enhancement: -** To study the performance of MIMO-STBC for various scenarios of SNR values taken over Rayleigh channel and considered the various characteristic elements of MIMO. Performance enhancement has been done by combining MIMO along with STBC.

- **Diversity Gain:** - Main objective of spatial diversity is to provide diversity gain i.e. less bit error rate and having M input antennas at transmitting side and N output antennas at receiving side i.e. M*N. Diversity gain helps to achieve better transmission and reception through diversity order which is taken into consideration.

- **Efficient Image Reception:** - To analyze and perform image transmission in MIMO-STBC for better and efficient image reception using various M-PSK techniques with less count of antennas.

1.10 Organization of Work

This thesis includes total five chapters which are organized as below:

Chapter 1: Introduction, it is consisting of an overview, the rationale of study, scopes and objectives of the study, introduction to MIMO system, then a brief introduction about the nonlinear channels, modulation techniques and image communication. The various detection algorithms for signal detection in MIMO system are also discussed

Chapter 2: Literature Review, the study of work done in the field of MIMO systems for image transmission and effects of fading on the system is discussed; research papers of related field in sequence are also discussed.

Chapter 3: Space time block encoding, in this chapter, the MIMO system with Space time block encoding techniques such as Alamouti space time block code, Orthogonal space time block code and Quasi-orthogonal space time block code have been discussed in detail.

Chapter 4: Research Methodology, it includes the procedure of image transmission using space-time block encoding techniques like Alamouti space time block code, Orthogonal space time block code and Quasi-orthogonal space time block.

Chapter 5: Results and Discussion, in this chapter the expected outcome of the study is discussed. All the results simulated in MATLAB-2013a have been discussed over the Rayleigh channel for M-PSK modulation technique and different antenna configurations. A complete analysis of BER is presented for the various fading channels.

Chapter 6: Conclusion, in this chapter the whole work has been concluded and future scope has been discussed.

The use of coding techniques in multiple-input-multiple-output (MIMO) systems is an effective means to gain higher data rate over wireless channels. But the increase in the complexity in the implementation of these systems is of main concern. The main applications of MIMO systems are current standards with wireless medium, including in IEEE 802.11n, 3GPP LTE and mobile WiMAX systems. Even under the circumstances of interferences because of multipath propagation, the scheme holds improved data throughput. The main motive behind the evolution of MIMO systems is the increasing requirement for the large data rates over the large distances and the utilization of MIMO system for the image transmission is to improve the system efficiency, i.e. to transmit and receive the image over the propagation channel efficiently.

2.1 MIMO System

Multiple-Input, Multiple-Output (MIMO) is a technique included in the wireless systems which enhances the spectral efficiency with the utilization of spatial multiplexing and increases reliability via spatial diversity. The effects of the selection of an antenna on the MIMO system's performance over nonlinear communication channels were discussed by **V. S. Hendre** [17]. The PWEP performance of space-time trellis codes was evaluated with the derivation of analytical expressions over nonlinear MIMO channel, case of Rayleigh fading, when the employment of choosing antenna is done at the receiving side. With the less number of receiver antennas selected at the receiving side, degradation in the system performance get reduced because of nonlinearity in the channel.

An approach to take the advantage of the MIMO system capacity was explained by **K. Tan** [18]. It was spatial multiplexing where transmission of distinct data streams is done from the antennas with their separation at the receiving side by using some of the detection techniques like ML which attains ideal efficiency or linear receivers like ZF which give sub-optimal efficiency. The computational complexity also gets reduced with the utilization of this Zero-forcing detector, with the bearable performance degradation.

X. Wang et al. [19] compares the typical Single-Input Single-Output (SISO) system with the MIMO system. The link throughput is also enhanced along with the improvement in the spectral efficiency by the MIMO system. Over continuous flat fading channels, the BER analysis of MPSK for MIMO using ZF receiver was presented by the authors. It was concluded from the results that the BER performance depends on Doppler spread along with the channel estimation error and the variations between amount of transmitter and receiver antennas. Better BER performance depends upon the larger difference between theses antennas.

S. Alamouti [20] allows the transmission of two signals at a time by utilizing two transmit antennas. The diversity is optional at the receiver side. The utilization of one transmitting antenna with two receiving antennas provides the diversity order similar to the diversity order of MRRC. The diversity order of 2N can be attained by utilizing two antennas at the transmitter end and N antennas at the receiver end. No any extra bandwidth and feedback from receiver to transmitter is required in this scheme. The computational complexity provided in this scheme is equivalent to that of MRRC.

R. Tanbourgi et al. [21] proposed a low-rate feedback channel method which was used in multimode antenna selection just to enhance the multiplexing system's error rate execution with the linear receivers. On the basis of limited feedback from the receiving side, dynamic adjustment of mapping of sub-streams to the antennas is done for a defined complete data rate. The diversity gain is attained by using the dual-mode selection, where selection of spatial multiplexing or selection diversity is done. Dynamic selection of any amount of sub-streams enhances the additional array gain and this process is known as multimode selection. The different ways for the selection of amount of sub-streams and for mapping the sub-streams to transmit antennas was derived by the authors. Between the selection process and the Eigen modes of the channel, the relationship is created. A probabilistic evaluation of the selection process is offered for Rayleigh fading channels.

2.2 MIMO System with Space Time Block Coding

By designing the channel codes, the performance of data rates and the reliability of the communication is enhanced over the Rayleigh channel with the utilization of multiple antennas at the transmitter side, by **V. Tarokh et al.** [22]. Encoding of the data is done using a channel code and is divided into various streams for the simultaneous transmission using various transmitter antennas. On the receiving side, the reached signal is a linear superposition of the various sent signals distorted by noise. The performance criterion was derived by the authors for making such codes under the supposition of slow and frequency non-selective fading. The observation of performance is done by the matrices generated from pairs of individual code orders. Among these matrices, the diversity gain is quantified by the minimum rank whereas the coding gain is quantified by the minimum determinant. Then, the results were advanced to the fast fading channels. To acquire the MIMO system capacity, the useful way is the utilization of space-time (ST) coding, which is made with the use of various transmitter antennas. The signals are sent via various antennas at the different time periods and they are correlated by performing the coding in both spatial and temporal domains. The exploitation of MIMO channel fading and the minimization of the transmission errors at the receiving side are done by this spatial-temporal correlation. Transmit diversity and power gain can be attained by using space-time coding over spatially encoded systems without extra requirement of bandwidth.

Some of the methods of coding, named as STTC, STBC and LST codes were described by H. **Wang et al.** [23]. STTC stands for space time trellis codes, STBC stands for space-time block codes, and LST stands for layered space-time codes. Here, the main work is to take the advantage of effects of multipath propagation, to attain higher spectral efficiencies and performance gains. The applications of Space-time coding are the cellular communications and wireless LAN. Some of the works on space-time coding is to improve the performance of the probability of wrongly recovered data packets by using additional sender antennas. Generally, the space-time code's implementation is done to find a matrices constellation satisfying the optimality criteria. Particularly, there is a trade-off among the system complexity, the error performance and the information rate with designing of space-time coding schemes. Initially, the research of STC concentrated on narrowband flat-fading channels only. For multi-user wideband frequency-selective channels, there is requirement for developing some novel and high-performance signal processing algorithms for the purpose of channel estimation, joint equalization and decoding, and suppression of interference.

The tradeoff among data rate, advantage of diversity, and complexity of trellis is provided by these designed codes. For wideband wireless communications, an effective space-time coding was implemented. Using trellis codes and fading, the enhanced performance and diversity gains of a space time (ST) coding system was introduced by **O. Bayer et al.** [24]. The designed simulator's versatility for guessing the ST coding system's performance was presented by the results under various coding and channel conditions. The multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) scheme was implemented over frequency selective fading channels, in order to attain spectrally efficient transmissions which in results enhance the capacity or throughput of the system for distinct users. OFDM is used in this proposed scheme to convert the frequency selective fading into flat fading. A single frequency selective fading channel is converted into various flat fading sub-channels, on which space-time block coding is employed.

The performance analysis of a wireless communication system using multi-carrier OFDM with MIMO system along with Space-Time Block Coding (STBC) was evaluated by **M. M. Kamruzamman et al.** [25]. The Bit Error Rate (BER) was evaluated for the PSK modulation. The results presents that power penalty is there because of fading which can be decreased by incrementing the amount of receiving antennas. It is observed that, QPSK provides the best system performance among all the different modulation schemes. The receiver's SNR of STBC (space-time block codes) over Rayleigh fading channels was elaborated, on which basis; the closed impression of BER (bit error rate) of STBC is inferred with M-PSK modulation. It was concluded that the efficiency of system in environment of multipath propagation is enhanced with the addition of STBC to MIMO-OFDM system. In order to lowers the decoding complexity as much possible; simplified decoding is used at the receiver end.

The comparison between the quasi-orthogonal space-time block coding (QOSTBC) and orthogonal space-time block coding (OSTBC) such as Alamouti code was done by **H. Jafarkhani** [26]. To improve the diversity gain of a system, an algorithm for the code selection between QOSTBCs was introduced by authors on the basis of QOSTBC having 4 antennas at the transmitting side. As compared to general closed-loop algorithm dependent on QOSTBC, the diversity gain and the system efficiency is enhanced by this algorithm, without a rate loss. As the computational complexity of maximum likelihood receiver is very high, hence, only simple linear receivers, such as the zero-forcing receiver and minimum mean square error receiver can use this algorithm. The probability density function (PDF) of two signal-to-interference and noise ratios (SINRs) is derived and by using the derived PDF, an approximated bit error rate (BER) performance of the proposed system is also derived.

W. Su et al. [27], analyzed that the execution of quasi-orthogonal space-time codes can be enhanced by phase-shifting the constellations of the symbols constituting the code. The ideal turn of the symbols builds the minimum distance of the comparing space time code words, prompting significantly enhanced execution. A few new examples to enhance the group of quasi-orthogonal STBC dependent upon the investigation of existing transmission matrices of quasi-orthogonal space-time block codes were also derived. It is desired to have the quasi-orthogonal STBCs with complete diversity to guarantee good performance at high SNR. Specifically, it was proposed that half of the symbols in a quasi-orthogonal design are chosen from a signal constellation set (A) and the other half of them is chosen from a rotated constellation (ejυ A). The resulting STBCs can guarantee both full diversity and fast ML decoding. Moreover, the optimum selections of the rotation angles υ for some commonly used signal constellations are achieved. The proposed codes outperform the codes from orthogonal designs at both low and high SNRs.

A. Lotfi-Rezaabad et al. [28], analyzed the efficiency of a quasi-orthogonal space-time block code with antenna choice. The antenna selection at transmitter and receiver is discussed. The authors proposed a new selection rule that minimizes the normal BER and accomplishes complete diversity regardless of the possibility that a simple zero-forcing receiver is utilized. QOSTBC accomplish complete code rate at the cost of loss in diversity gain.

Two feedback methods were proposed for QO-STBCs to achieve full diversity and full code rate by **D. Mishra** [29]. In the first method, signals radiated from various antennas are rotated by phasors according to feedback from the receiver, whereas the second method is based upon antenna weighting/selection. The performance improvement is also investigated for these closed-loop methods when the transmitted signal is error control coded.

Analyzing the various structure and character of several issues of the quasi-orthogonal space-time block code (QOSTBC), **J. Hu et al.** [30], proposed two novel quasi-orthogonal space-time block codes for four antennas. The novel codes are enriched in the family of QOSTBC. Experiment results indicate that these two codes have good performance as Jafarkhani schemes, while the decoding complexity is the same as other quasi-orthogonal codes. By using zero-forcing decoding algorithm for novel codes, simulation results show that zero-forcing algorithm has better bit error rate performance as compared to the existing typical codes and can reduce the computation complexity at receiver.

Z. Li et al. [31], proposed new decoding schemes for reducing complexity at the decoder. By using Quasi-ZF based on the traditional Zero Forcing technique and Quasi-MMSE based on the traditional minimum mean squared error (MMSE) technique, we can have channel interference parameter be zero. As a result, only diagonal components remain. Eventually, we can detect the transmitted symbols easily with single ML detector. The proposed scheme can be used in case that all channel interference parameters are pure imaginary values in QOSTBC. Quasi-orthogonal space-time block code (QOSTBC) accomplishes complete code rate however at the cost of loss in diversity gain. With a specific end goal to increase complete diversity and code rate, two feedback strategies are utilized for QOSTBC. In the primary technique, signals sent from different antennas are pivoted by phasors as per input from the recipient, though the second strategy depends on antenna weighting/determination. The execution enhancement is additionally examined for these closed-loop strategies when the sent signal is error control coded.

2.3 Beamformimg MIMO System

Beamforming is a transmission plan that takes the advantage of the spatial measurements in MIMO channels. In a noise constraint MIMO channel, MRC solution is the optimal beamforming that delivers the maximum output signal-to-noise ratio. MIMO wireless systems can acquire meaningful diversity and array gains by using single-stream transmits beamforming and receive combining. The performance of MIMO beamforming systems with quantized feedback for uncorrelated Rayleigh fading channels was analyzed. The loss of receive SNR and outage probability are characterized by lower bounds for M_t X 1 and 2 X M_r systems and approximations for arbitrary M_t X M_r systems. The analysis of beamforming scheme along with quasi-orthogonal space-time block codes (QOSTBC) was discussed M. Norouzi et al. [32]. In quasi-orthogonal space-time block coding, signals are transmitted via four different transmit beams at the transmitting side. On the side of receiver, a pair wise decoding algorithm is used. The simulation is done over a flat Rayleigh fading channel model demonstrate keeping in mind of the end goal to look at the execution of introduced method with the conventional quasi-orthogonal space-time block codes (QOSTBC) scheme where four non-dependent transmit antennas are utilized.

2.4 Signal Detection in MIMO System

The examination of the cheap and powerful transmission technique was done that utilizes the basic spatial multiplexing at the transmitting side and zero-forcing at the receiving in multiuser MIMO planning frameworks. By consolidating the mathematical tool of request insights, the PDFs of successful sub-channel output SNR for an assortment of planning algorithms were derived by **M. Gao et al.** [33]. The execution was broke down for three sorts of equalizer for MIMO wireless receivers. The settled antenna MIMO antenna specifications was examined and contrasted the execution with all the three sorts of equalizer based receiver in particular ZF, ML, and MMSE. The Zero Forcing Equalizer expels all ISI and is perfect just when the channel is noiseless. At that point when the channel is noisy, the Zero Forcing Equalizer tends to will amplify the noise and suits the static channels with large SNR. ML is low computational multifaceted nature and it limits the likelihood of grouping mistakes and is favored for portable communication link. In view of scientific demonstrating and the simulation results, it is proved that the best one equalizer is the ML equalizer.

2.5 Image Communication

For transmission of an image over a wireless medium, different features like decreased propagation time, less consumption of power and large bit rate with an efficient bandwidth were discussed by **N. R. Deepak et al.** [34]. There is need to lowers the data size of transmitted image, because of restriction of bandwidth of wireless channel. The process of reducing the data size of an image is defined as image compression, hence, image to be represented in compact format. The implementations of Pre-processing methods are done to enhance image quality before compress the data effectively. The Pre-processing methods are such as image enhancement, segmentation and representation.

The work was done in the field of medical image compression by **M. Bearceanu et al.** [35]. For transmitting a medical image over a wireless medium requires its compression for preserving the information needed for medical diagnosis. Region of interest (ROI) is selected from the image which is important in view of medical diagnosis and remaining part of image set as background. ROI based compression is used to improve compression ratio. Important features of a medical image are extracted and represented as the region of interest, which ultimately reduce the size image which is required to transmit at destination for the medical benefit. Compressed image is transformed in spatial domain coefficient. The ROI compression uses Discrete Cosine Transform (DCT) and wavelet coding used as in JPEG2000, Embedded Block Coding with Optimal Truncation (EdBCOT), Max-shift and in general scaling. In image transmission ROI to be transmit with higher priority in comparison to background. Max-shift is used in scaling of ROI which scales the coefficient associated with higher bit plane.

The execution of K-RLE compression method for a textual data was analyzed by **P. S. Kumar** and **P. Swapna** [36]. The categorization of image compression method is done as lossy and lossless. The lossless compression technique includes Run length Encoding (RLE) whereas the lossy compression technique includes Run Length Encoding with K-Precision (K-RLE).

In order to evaluate the image transmission performance over an orthogonal frequency division multiplexing (OFDM) telecommunication system by employing multi carrier code division multiple access (MC-CDMA), the Binary Phase Shift Keying (BPSK) modulation technique was used by **S. Jindal** and **D. Agarwal** [37]. Chaotic and helical interleaving techniques were used in system. The requirement of interleaving techniques is to combat the effect of bursty errors occurred because of fading, interference and multipath propagation in wireless communication. By using Linear Minimum Mean Square Error (LMMSE) equalization at receiver they analyzed the system by using helical and chaotic interleaving. On the basis of observations of peak signal to noise ratio (PSNR) and root mean square error (RMSE) for both interleaving techniques concluded that chaotic interleaving performs better than helical interleaving. 16-Quadrature Amplitude Modulation (16-QAM) and orthogonal frequency division multiplexing (OFDM) system were used to evaluate transmission of three gray scale images in presence of generalized K-fading channel. In QAM, amplitude and phase get varied, resulting higher transmission rate of data. On the basis of observed bit error rate (BER) with respect to channel noise with maximum fading and shadowing parameters, concluded that at higher order of QAM higher amount of information is transmitted.

M. A. Kader [38] used 16-HQAM (hierarchical quadrature amplitude modulation) for picture transmission which has enhanced bandwidth efficiency with non-presence of dc-component from sent signal and Median Filter to decrease noises at noisy AWGN channel. HQAM is the extended form of QAM at similar data transmission rate with enhanced protection of the particular area in an image from the added noise in channel. The region of interest (ROI) is mapped at most significant bit and background mapped to slightest significant bit positions, which enhanced picture quality even at lower SNR. They utilized MATLAB-7.8 (R2009a) for simulating transmission and reception of gray scale picture via erroneous channel with wireless medium. Depending on the measurements of peak signal to noise ratio (PSNR) and modulation parameter (a) where a is equivalent to the proportion of distance amongst quadrants and distance between points in a quadrant, the PSNR increases with increase value of a. The higher need information is more secured higher estimations. High need bits in a quadrant are kept fixed while low priority bits get altered according to the position change in constellation diagram.

The robust joint source-channel coding for image transmission over noisy channel which is the extension of optimal joint source channel coding (OJSCC) with addition of filters was discussed by **K. Tahiro et al.** [39]. A fixed length robust joint source channel coding (RJSCC) technique is used to transmit an image over wireless channel. They derived a rate-distortion (R-D) function for image in binary symmetric channel, additive white Gaussian channel and Gilbert-Elliott Channel. In fact, noises are undesired signal in digital images. The artifacts, unrealistic edges, unseen lines, corners, blurred objects and disturb background scenes are produce undesirable effects produced by noises. Noises get introduced during image acquisition, coding and transmission. To reduce these undesirable effects caused by noises a prior learning of noise models is essential for further processing. The utilization of nonlinear filter is done to remove non-Gaussian noise present in transmitted data. Median filters perform better on long-tail type noises, while alpha trimmed median is the tradeoff between median and running average filters. A problem to select best value of trimming coefficient a, this problem can be sorted out by using adaptive filter where a-value change according to local statistics of image. It was concluded that Taguchi filter is preferred when variance of noise is known and Jaeckel filter is preferred when short-tailed high impulse noise is present. The wavelet transform and hybrid filter for image de-noising were used when the image is corrupted by AWGN. The combination of 4^{th} order partial differential and bi-variate shrinkage function non-linear filters is the hybrid filter. However high peak signal to noise ratio and low mean square error are important parameter to measure but don't imply the good image quality therefore a feature similarity index for image quality assessment is used. On the basis of comparison between observations taken of fruits, houses, and Lena concluded that the hybrid filter is most effective when noise variance is high.

CHAPTER 3 SPACE-TIME BLOCK ENCODING

Depending on requests for limit in wireless communications, driven by cellular mobile, internet and multimedia services have been quickly expanding around the world. On the other hand, the accessible radio range is restricted and the correspondence limit needs can't be met without a noteworthy increment in correspondence spectral efficiency. Advances in spectral efficiency are accessible via incrementing the amount of antennas at both the transmitting and the receiving side, which is referred as multiple-input multiple-output (MIMO) channels. The capacity limits highlight the potential spectral efficiency of MIMO channels, which develops approximately in linear fashion with the amount of antennas, supposing perfect propagation. The limit is communicated by the most extreme achievable information rate for an arbitrarily low probability of error, providing that the signal may be encoded by an arbitrarily long space-time code. It has been shown that the Bell Laboratories Layered Space Time (BLAST) coding strategy can accomplish the spectral efficiencies up to 42 bits/sec/Hz. On contrary to present attainable spectral efficiency (2-3 bits/sec/Hz) in mobile and WLAN systems, it presents a spectacular enhancement. In the communication having wireless medium, the attention has been attracted by MIMO technology has attracted attention, as significant enhancement in data throughput and link range is offered by it, without any demand of extra bandwidth or transmit power. This goal is attained by scattering the equal total transmit power over the antennas in order to attain an array gain which enhances the spectral efficiency or to obtain a diversity gain that enhances the link reliability, i.e. decreased fading effects. Due to these features, MIMO is an necessary unit of current communication standards having wireless medium like IEEE 802.11n, 4G, 3GPP LTE, Wi-MAX etc.

Space Time Block Codes are the easiest forms of spatial temporal codes that take advantage of the diversity provided in networks with fewer transmitting antennas. In 1998, a simple technique for diversity transmission was designed by **S. Alamouti** [39]. It consists of a system with 2 transmitting antennas. Complete diversity order was provided by this technique and non-complex operations are needed at both transmitting and receiving side. The encoding/decoding methods are done with blocks of transmission symbols. Theoretically, fewer forms can be taken by STBC but practically, linear STBCs are by far the most widely used. The main motive behind STBC is to scatter data symbols spatially in time to enhance either the diversity gain, or the spatial multiplexing rate, or both the diversity gain and the spatial multiplexing rate.

3.1 Space-Time Coding Techniques

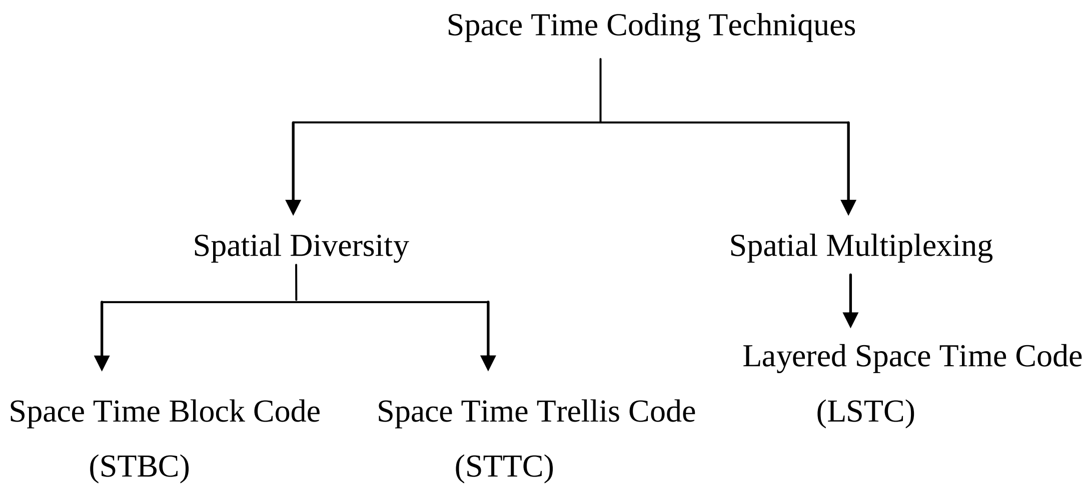


Fig. 3.1: Space-Time Coding Techniques

Space time coding techniques are categorized accordingly two functions namely spatial diversity and spatial multiplexing. Dependent on these functions, they are classified as:

3.1.1 Spatial Diversity

a) Space Time Block Code (STBC)

Space time block coding is a least complex and useful way of acquiring transmits diversity. The generalization of these codes can be done easily to the instance of various receiving antennas, hence, providing receive diversity in addition to transmit diversity. Also, the decoding can be done efficiently at the receiver by applying linear processing on received signals at distinct receiver antennas. It provides diversity gain however no coding gain [40].

b) Space Time Trellis Code (STTC)

Space time trellis coding is an alternate coding method for MIMO systems. Its concept is equivalent to the concept of convolutional coding having a basic trellis structure that distinguishes the (coded) symbols to be transmitted via different antenna. Its main advantage is its “coding advantage” provided over the technique of STBC, only at the cost of large decoding complexity. It provides both diversity gain and coding gain.

3.1.2 Spatial Multiplexing

a) Layered Space Time Code (LSTC)

Based on the code structure, layered space time code provides bandwidth efficiency, transmission rate and diversity gain.

3.2 MIMO with Space Time Block Coding

Space time block codes have impressively developed throughout the years. While they initially pilled in much consideration because of their low decoding complexity, they have been the object of a renewed interest at the light of the diversity-multiplexing trade-off. Space Time Block Codes are the easiest sorts of spatial temporal codes that endeavour the diversity offered in systems with few transmit antennas. It may be viewed as a mapping of Q symbols (complex or real) onto a codeword C of size $n_t \times T$. Those codewords are uncoded as in no error amending code is contained in the STBC. Theoretically, STBCs may take a few structures, however for all intents and purposes; linear STBCs are by long shot the most generally utilized. The thought behind linear STBCs is to scatter information symbols in space and time with a specific end goal to enhance either the diversity gain, or the spatial multiplexing rate, or both the diversity gain and the spatial multiplexing rate [40], [41].

3.2.1 Alamouti Space-Time Coding

One of the 1st space time codes is because of Alamouti, who described the instance of two transmitting antennas (n_t= 2). In transmit diversity scheme [42], [43] consider we have sequence [x_1, x_2, x_3, ……..x_n].

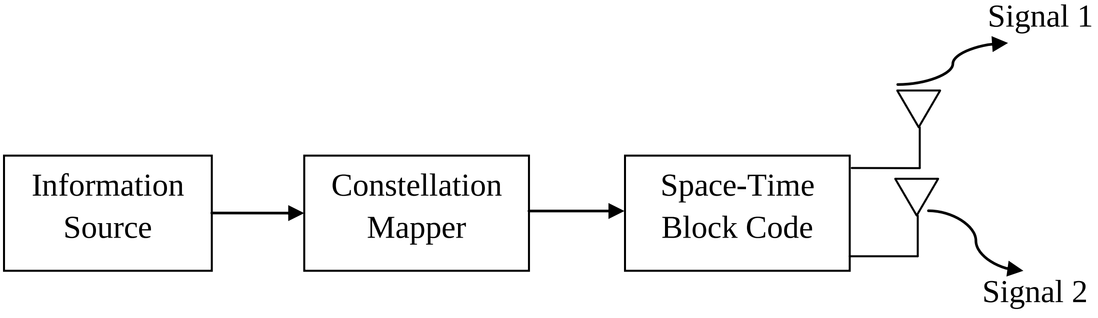


Fig. 3.2: Spatial transmit diversity with Alamouti's space–time block code

Normally, we will transmit x_1 in 1^{st} time slot and x_2 in 2^{nd} time slot and so on. Alamouti suggested grouping the symbols into groups of two and simultaneously transmitting $n_x = 2$ complex symbols x_1 and x_2 during N = 2 time intervals by transmitting the following matrix:

$$X = \begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix} \tag{3.1}$$

In 1^{st} time slot, S_1 and S_2 will be transmitted from antenna T_1 and T_2 and in 2^{nd} time slot, $-S_2^*$ and S_1^* will be transmitted from antenna T_1 and T_2. Though the two symbols are grouped, still two time slots are required to transmit 2 symbols, i.e. no change in data rate. Now, in receive diversity scheme, in 1^{st} time slot, the received signal will be:

$$Y_1 = h_1 x_1 + h_2 x_2 + n = (h_1 \quad h_2) \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + n_1 \tag{3.2}$$

And in 2^{nd} time slot, the received signal will be

$$Y_2 = -h_1 x_2^* + h_2 x_1^* + n_2 = (h_1 \quad h_2) \begin{pmatrix} -x_2^* \\ x_1^* \end{pmatrix} + n_2 \tag{3.3}$$

Where Y_1 and Y_2 are the arrived symbols on 1^{st} and 2^{nd} slot, h_1 and h_2 are the channels from 1^{st} and 2^{nd} transmitter to receiver antennas respectively. x_1 and x_2 are symbols to be sent and n_1 and n_2 are noise on the 1^{st} and 2^{nd} time slot respectively.

$$E = \begin{pmatrix} n_1 \\ n_2^* \end{pmatrix} (n_1^* \;\; n_2) = \begin{pmatrix} |n_1|^2 & 0 \\ 0 & |n_2|^2 \end{pmatrix} \tag{3.4}$$

It is observed that BER is similar to that of Maximal Ratio Combining (MRC). With transmitting from two antennas, total transmitter power will be twice with that used in MRC i.e. BER performance of 2 transmitters, 1 receiver case is 3dB poorer than 1 transmitter, 2 receivers MRC case [44].

3.2.2 Orthogonal Space Time Block Code

S. Alamouti designed the transmit diversity method having two transmit antennas only. This method belongs to a common category of codes namely STBC or OSTBCs, since they are dependent on the theory of orthogonal designs. The uncommon sub-class of linear STBC is orthogonal space time block codes (OSTBC) [45]. They have surprising features which make them to a great degree simple to decode, while as yet accomplishing a full-diversity of n_t n_r. To be sure, OSTBCs are with the end goal that the MIMO ML decoding decouples into few SIMO

ML decoding. Each sent symbol is in this manner decoded autonomously of the other sent symbols within the similar block. However, OSTBCs have a substantially smaller spatial multiplexing rate than Spatial Multiplexing methods [46]. OSTBCs are linear STBCs described by the two following properties:

(1) The basis matrices are wide unitary.

(2) The basis matrices are pair wise skew-hermitian.

The attribution of 1st discussed OSTBC for 2 transmit antennas is given to Alamouti [Ala98]. The advancement in the construction is done to higher amount of antennas in [TJC99]. The development of codes is dependent on the theory of amicable orthogonal designs. The orthogonal codes are classified into two classes, namely real symbol constellations (real OSTBC) or complex symbol constellations (complex OSTBC). The designing of real OSTBCs with spatial multiplexing rate $r_s = 1$ can be done for any amount of transmit antennas. The main motive of STBCs development is dependent on distinguishing coding matrices X that can fulfill the following condition:

$$X.X^{H} \;=\; p.\sum_{i=1}^{n} |x_i|^2.\, I_{M_T} \tag{3.5}$$

In this equation, X^H denotes the Hermitian of X, I_{M_T} denotes the identity matrix of order $M_T \times M_T$, where M_T is the amount of transmit antennas, and n is the total transmitted symbols (x_i) per transmission block in X. By the orthgonality property of STBC, it is meant that orthgonality lies among all rows of matrix X, i.e. the series sent from 2 distinct antenna elements are orthogonal to each other for each transmission block. It is possible for a real signal to achieve full rate. But for complex signals, it is not possible. The encoding/decoding with the pattern mentioned in Alamouti's scheme [47]. For complex signals, the coding matrices can be generated by using theory of orthogonal designs which achieve a transmission rate of 1/2 for the cases of 3 and 4 transmission antennas:

$$X_{1/2} = \begin{bmatrix} x_1 & -x_2 & -x_3 & -x_4 & x_1^* & -x_2^* & -x_3^* & -x_4^* \\ x_2 & x_1 & x_4 & -x_3 & x_2^* & x_1^* & x_4^* & -x_3^* \\ x_3 & -x_4 & x_1 & x_2 & x_3^* & -x_4^* & x_1^* & x_2^* \end{bmatrix} \tag{3.6}$$

To generate STBCs, the theory of orthogonal design is not necessarily the optimal approach. For 3 or 4 amount of transmit antennas, some sporadic provides the transmission rate of 3/4.

$$X_{3/4} = \begin{bmatrix} x_1 & -x_2^* & x_3^* & 0 \\ x_2 & x_1^* & 0 & -x_3^* \\ x_3 & 0 & -x_1^* & x_2^* \end{bmatrix} \quad (3.7)$$

$$X_{3/4} = \begin{bmatrix} x_1 & 0 & x_2 & -x_3 \\ 0 & x_1 & x_3^* & x_2^* \\ -x_2^* & -x_3 & x_1^* & 0 \\ x_3^* & -x_2 & 0 & x_1^* \end{bmatrix} \quad (3.8)$$

During the transmission of a block of symbols X, it must be noticed that the coefficients of channel must be fixed. The deduction of STBC's decoding from the encoding matrix is easy. Suppose that to evaluate symbols x_j and described by r_j^k the signal reached from antenna j at time instance k. At the combiner, the values to be added are:

+ $(h_{j,i})^*.r_j^k$ if x_p at column k and line (transmit antenna) i of X
- $(h_{j,i})^*.r_j^k$ if $-x_p$ at column k and line (transmit antenna) i of X
+ $(h_{j,i}).(r_j^k)^*$ if $(x_p)^*$ at column k and line (transmit antenna) i of X
- $(h_{j,i}).(r_j^k)^*$ if $(-x_p)^*$ at column k and line (transmit antenna) i of X

The linear combiner sum is realized for all receive antennas j.

3.2.3 Quasi Orthogonal Space-Time Coding

It is well recognized that when channel information is accessible at the transmitting side, transmit beamforming plan can be utilized to upgrade the execution of a various antenna system. Y. Lee discussed about an execution criterion in view of incomplete channel side information at the transmitting side. With this criterion, an optimal beamforming matrix was developed for the orthogonal space-time block codes. In any case, the similar technique has not been connected to the recently proposed quasi-orthogonal space-time block codes (QSTBCs) due to the non-orthogonal nature of the quasi-orthogonal designs.

The issue of consolidating of beamforming with QSTBCs was addressed by H. Jafarkhani [26]. In view of his asymptotic examination; the beamforming method was advanced by him and the beamforming matrices were built for the quasi-orthogonal designs. Full transmission rate and full-order spatial diversity was accomplished with this beamforming method. The presentation of a new QSTBC beamformer is done by a novel four-directional or eight-directional eigen-beamformer that works for systems with four or more transmit antennas [48]. Let suppose for four number of transmitter antennas, Alamouti code be X_{12} and X_{34} in which 12 and 34 used as subscript indicates indeterminate x_1, x_2, x_3, x_4 in the matrix [49], [50].

$$X_{12} = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \text{ and } X_{34} = \begin{bmatrix} x_3 & x_4 \\ -x_4^* & x_3^* \end{bmatrix} \tag{3.9}$$

Now, the space time block code for 4X4 matrix having number of transmitter antennas (N_t) equals to number of receiver antennas (N_r) = 4 is described as follows-

$$Z = \begin{bmatrix} X_{12} & X_{34} \\ -X_{34}^* & X_{12}^* \end{bmatrix} = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & -x_4^* & x_1^* & x_2^* \\ x_4 & -x_3 & -x_2 & x_1 \end{bmatrix} \tag{3.10}$$

is the 4X4 matrix channel. Hence, the MIMO system corresponding to QOSTBC with four transmitter and receiver antennas is achieved.

The research methodology includes the transmission of an image using the MIMO-STBC channel over the Rayleigh fading channel. The space time block codes used for the transmission are Alamouti space time block code, Orthogonal space time block code and Quasi-orthogonal space time block code. In orthogonal space-time block codes, the OSTBC3 and OSTBC4 are used, i.e. orthogonal space time block codes with amount of antennas equivalent to 3 and 4 are used. The zero-forcing equalizer is employed for the purpose of equalization. The transmitted image is modulated using M-PSK modulation technique, and its reconstructed version is plotted as an output function. The image transferred is shown in Fig. 4.1. 2X2 Alamouti STBC encoder is used for the transmission. Modulation performed is M-PSK technique done before encoding. The system performance is examined with the plot of SNR and BER values achieved.

Fig. 4.1: Original Image.

4.1 Image Transmission using Alamouti Space Time Block Code

Here, the transmission of an image is done using the Alamouti space time block code, in which transmission is done using two transmitter antennas. The following flowchart represents the workflow that has been carried out.

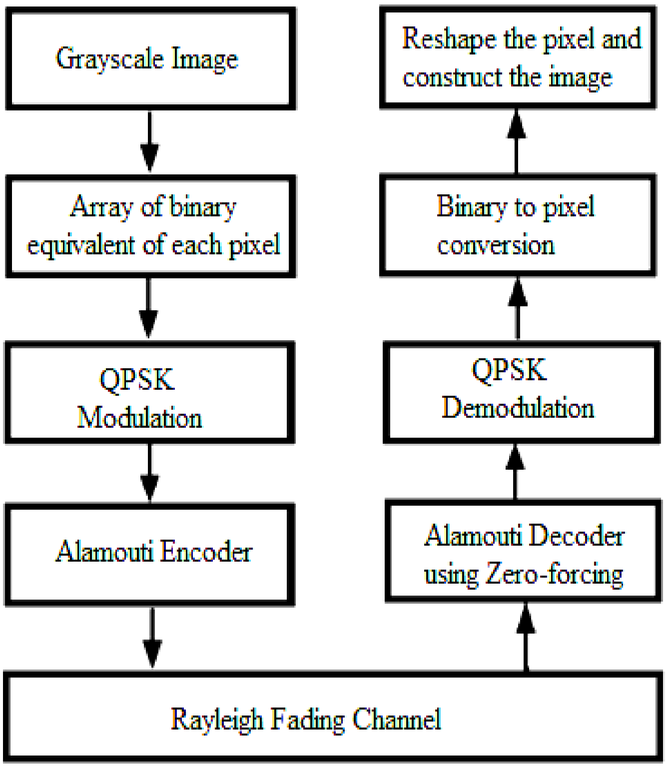


Fig. 4.2: Flowchart of Image Transmission using MIMO-Alamouti coding.

Here, the whole procedure of transmission of an image is discussed. The image transmitted is retrieved at the receiver end after passing through modulation and encoding process. Fig. 4.2 presents the sequence by sequence procedure followed for the transmission of an image. An image to be sent is converted into its binary equivalent matrix form, followed by M-PSK modulation. The image is modulated using 8PSK, 16PSK, 32PSK and 64PSK. After modulation, encoding is performed by employing Alamouti encoding scheme followed by the transmission of the image after multiplication with channel equation over Rayleigh fading channel, which doesn't follow the direct path, i.e. no any line of sight. Now at the receiving side, Zero-forcing equalizer is employed to detect the sent image followed by the demodulation using M-PSK demodulator. Now, the demodulated matrix form of data is converted back into its pixel form. The pixel values are rearranged to retrieve the image. In this way, the transmission and reception of image is done, and BER analysis is done for different values of M.

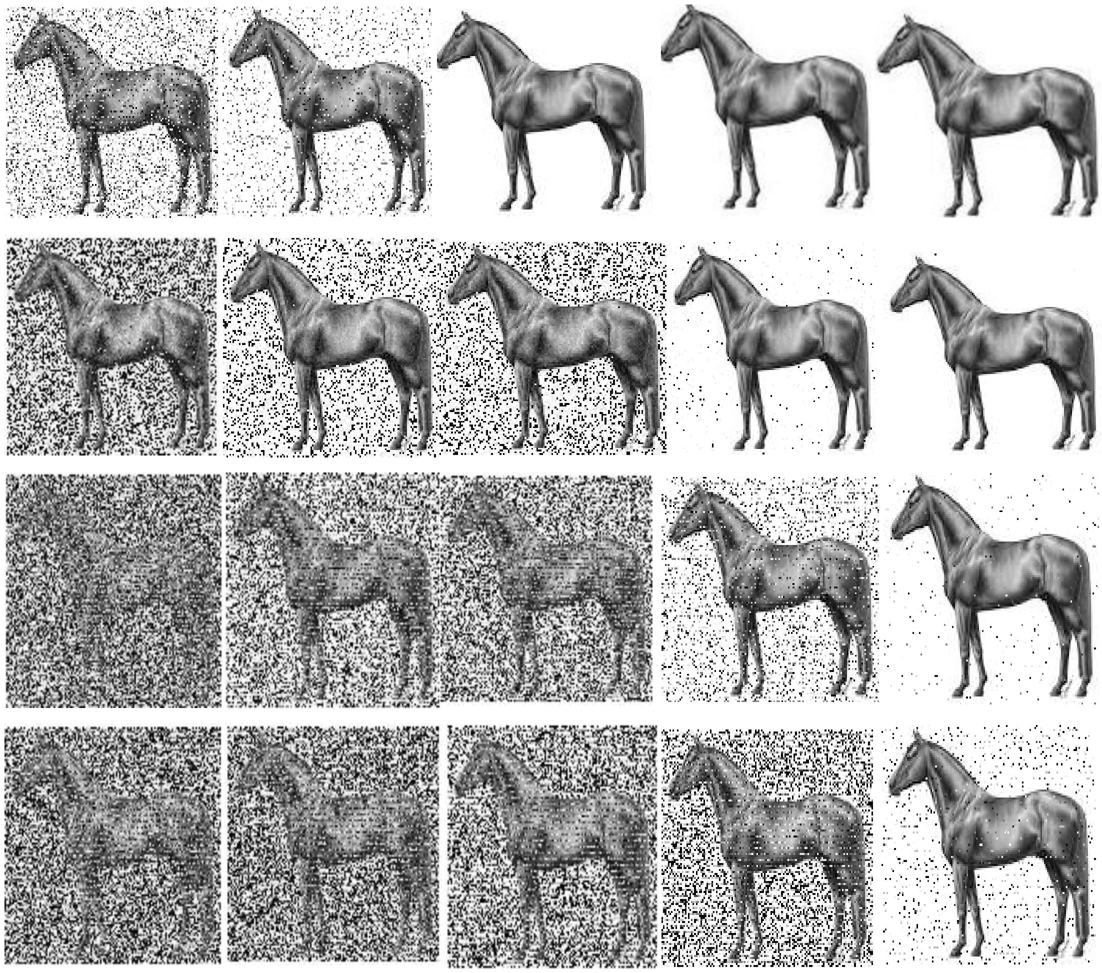


Fig. 4.3: Image received for M-PSK using Alamouti Space-Time Coding with 1 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK).

The reconstructed images at the receiver side using Alamouti Space-time block code with receiver 1 for MPSK modulation is presented in Fig. 4.3. The images are received considering 0dB, 10dB, 20dB, 30dB and 40 dB as SNR values for the 8PSK, 16PSK, 32PSK and 64PSK modulation levels. The SNR values are taken in the columns, and the values of modulation levels are taken in the rows. It is depicted from the figure that for 8-PSK modulation level, the BER for image retrieved at 0dB is more than the BER at 10dB, 20 dB, 30dB and 40db, i.e. BER decreases with the increase in SNR value and image becomes more clear but as we go from 8-PSK to 64-PSK, i.e. with the increase in the M value, the BER increases.

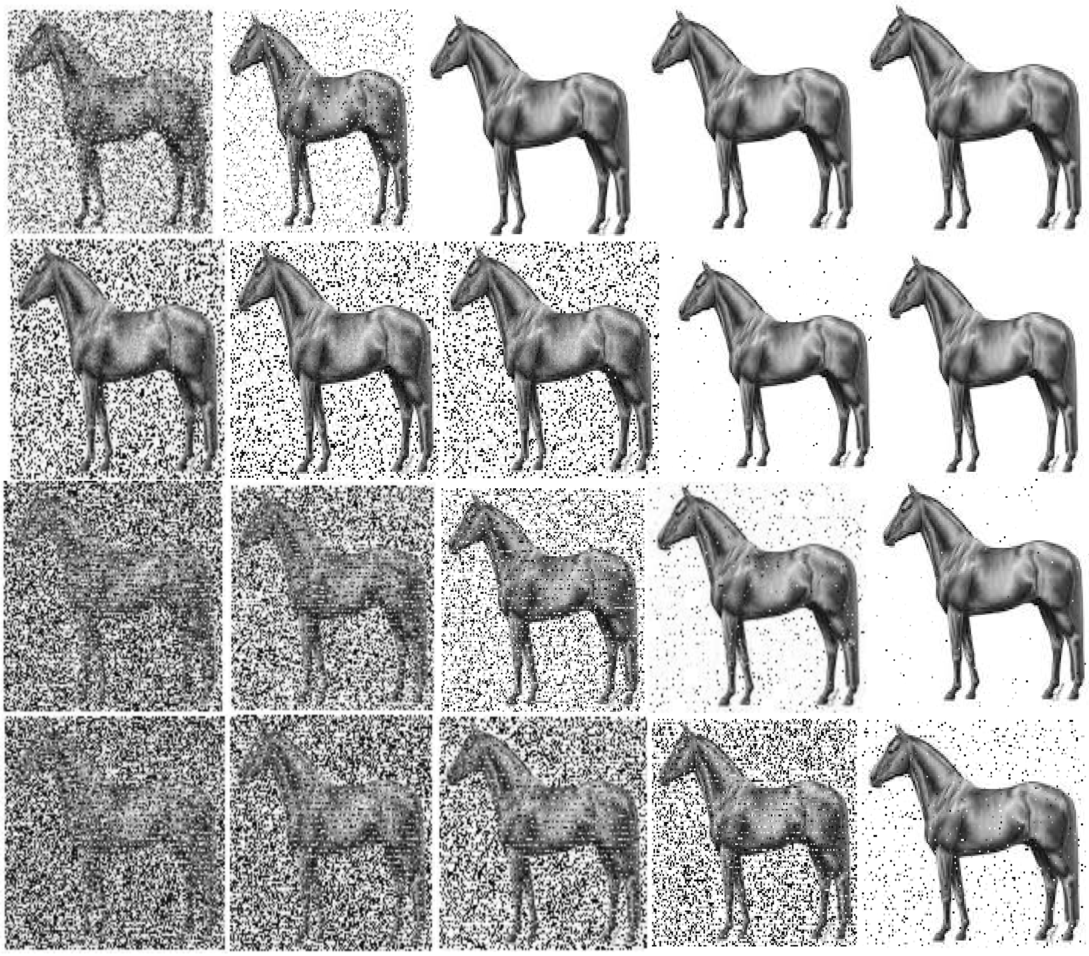


Fig. 4.4: Image received for M-PSK using Alamouti Space-Time Coding with 2 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK).

The reconstructed images at the receiver side using Alamouti Space-time block code with receiver 2 for MPSK modulation is presented in Fig. 4.4. The images are received by taking 0dB, 10dB, 20dB, 30dB and 40 dB as SNR values for the 8PSK, 16PSK, 32PSK and 64PSK modulation levels. The SNR values are taken in the columns, and the values of modulation levels are taken in the rows. It is depicted from the figure that for 8-PSK modulation level, the BER for image retrieved at 0dB is more than the BER at 10dB, 20 dB, 30dB and 40db, i.e. BER decreases with the increase in SNR value and image becomes more clear but as we go from 8-PSK to 64-PSK, i.e. with the increase in the M value, the BER increases. On comparing Fig. 4.4 with Fig. 4.3, it is also analyzed that, with the increment in the amount of antennas, the BER also decreases and the image retrieved using 2 receiver antennas are clearer than the image retrieved using 1 receiver antenna.

4.2 Image Transmission using Orthogonal Space-Time Block Code with 3 antennas (OSTBC3)

Here, the transmission of an image is done using the Orthogonal space-time block code with 3 antennas, in which transmission is done using three transmitter antennas and the reception is done by varying antennas at the receiving side.

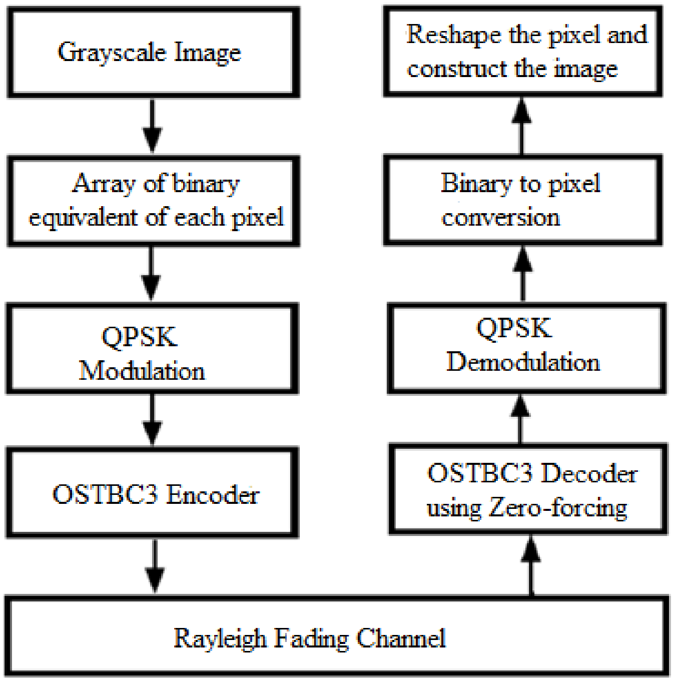


Fig. 4.5: Flowchart of image transmission using OSTBC3 and MIMO

Here, the process of an image transmission is described. The image to be sent is reconstructed at the receiver end by going through the process of modulation and encoding. The sequential procedure of image transmission is presented in Fig. 4.5. The binary equivalent matrix form of an image to be sent is made by conversion, followed by the modulation process. 8PSK, 16PSK, 32PSK and 64PSK are modulation levels used to modulate the binary form of the image. Now, by utilizing Alamouti space time block code, the encoding is done, followed by the transmission after multiplication with channel equation over Rayleigh fading channel. For the detection purpose, the equalizer named Zero-forcing equalizer is used to detect the image sent, which is followed by the demodulation process. Now, the pixel form of the image is made by converting the demodulated data back into its matrix form. Rearranging the pixel values will help to retrieve the image back. In this way, the image is received, and the BER performance analysis is done for different modulation levels.

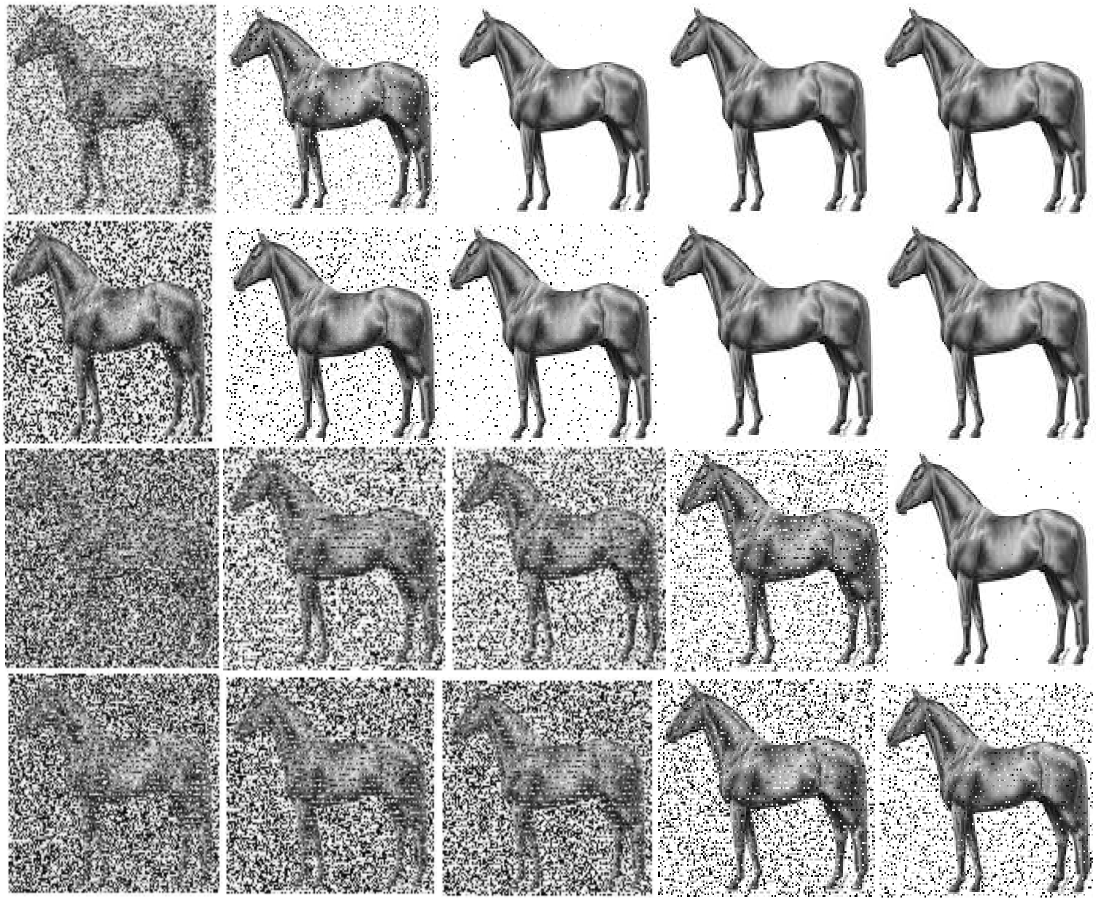


Fig. 4.6: Image received for OSTBC3 Space-Time Coding with 1 receiving antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK)

The images received at the receiver end using OSTBC3 with receiver 1 for MPSK are shown in Fig. 4.6. 0dB, 10dB, 20dB, 30dB and 40 dB are the SNR values, using which the images are received for the 8PSK, 16PSK, 32PSK and 64PSK modulation levels. In columns, SNR values are taken, and in rows, the modulation levels are taken. Figure depicts that the BER of image received at 0dB for 8-PSK modulation level is more than the BER of images received at 10dB, 20 dB, 30dB and 40db for the same M value, i.e. with the increase in SNR value, the BER value decreases and distortions in the image get reduced but with the increase in the modulation level, i.e. the BER value increases because of increasing constellation points.

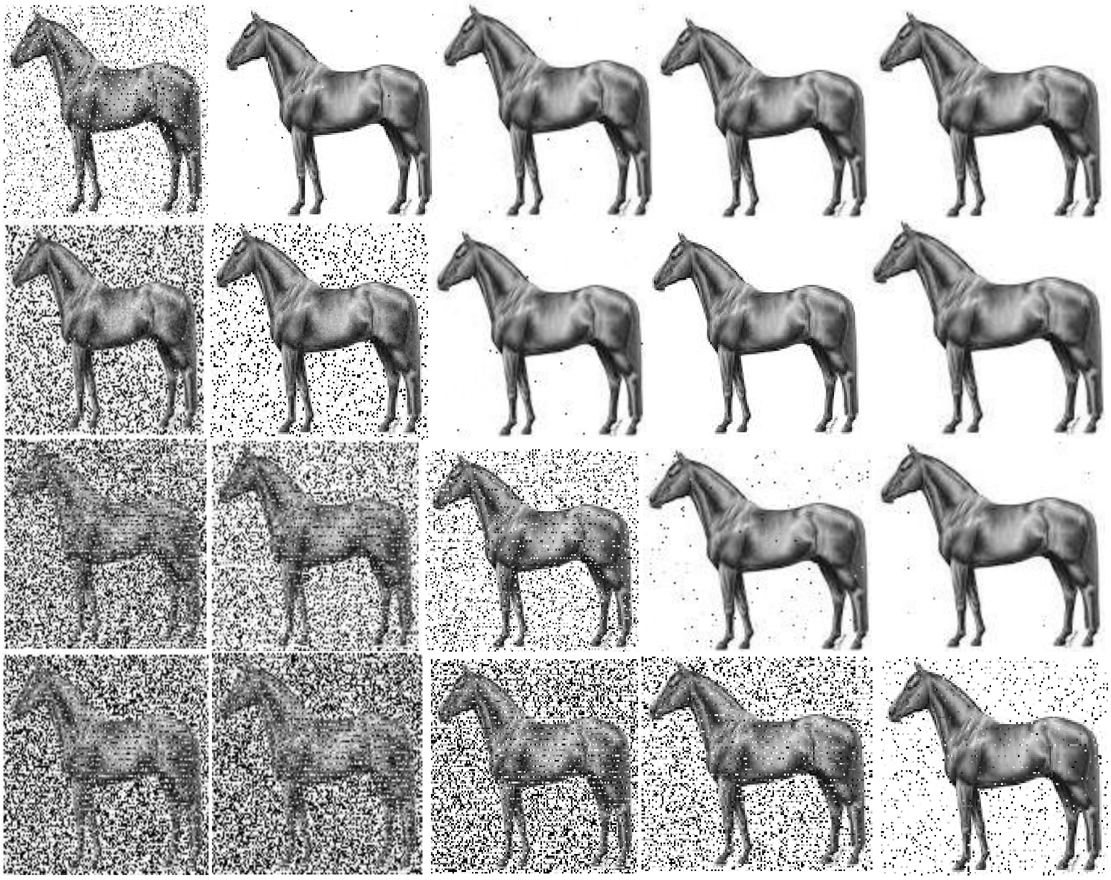


Fig. 4.7: Image received for MPSK using OSTBC3 Space-Time Coding with 2 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK)

The images received at the receiver end using OSTBC3 with receiver 2 for MPSK are shown in Fig. 4.7. 0dB, 10dB, 20dB, 30dB and 40 dB are the SNR values, using which the images are received for the 8PSK, 16PSK, 32PSK and 64PSK modulation levels. In columns, SNR values are taken, and in rows, the modulation levels are taken. Figure depicts that the BER of image received at 0dB for 8-PSK modulation level is more than the BER of images received at 10dB, 20 dB, 30dB and 40db for the same M value, i.e. with the increase in SNR value, the BER value decreases and distortions in the image get reduced but with the increase in the modulation level, i.e. the BER value increases because of increasing constellation points. On comparing Fig. 4.7 with Fig. 4.6, it is examined that, increase in the amount of receiver antennas from 1 to 2 results in the decrease in BER and the image retrieved using 2 receiver antennas are clearer than the image retrieved using 1 receiver antenna.

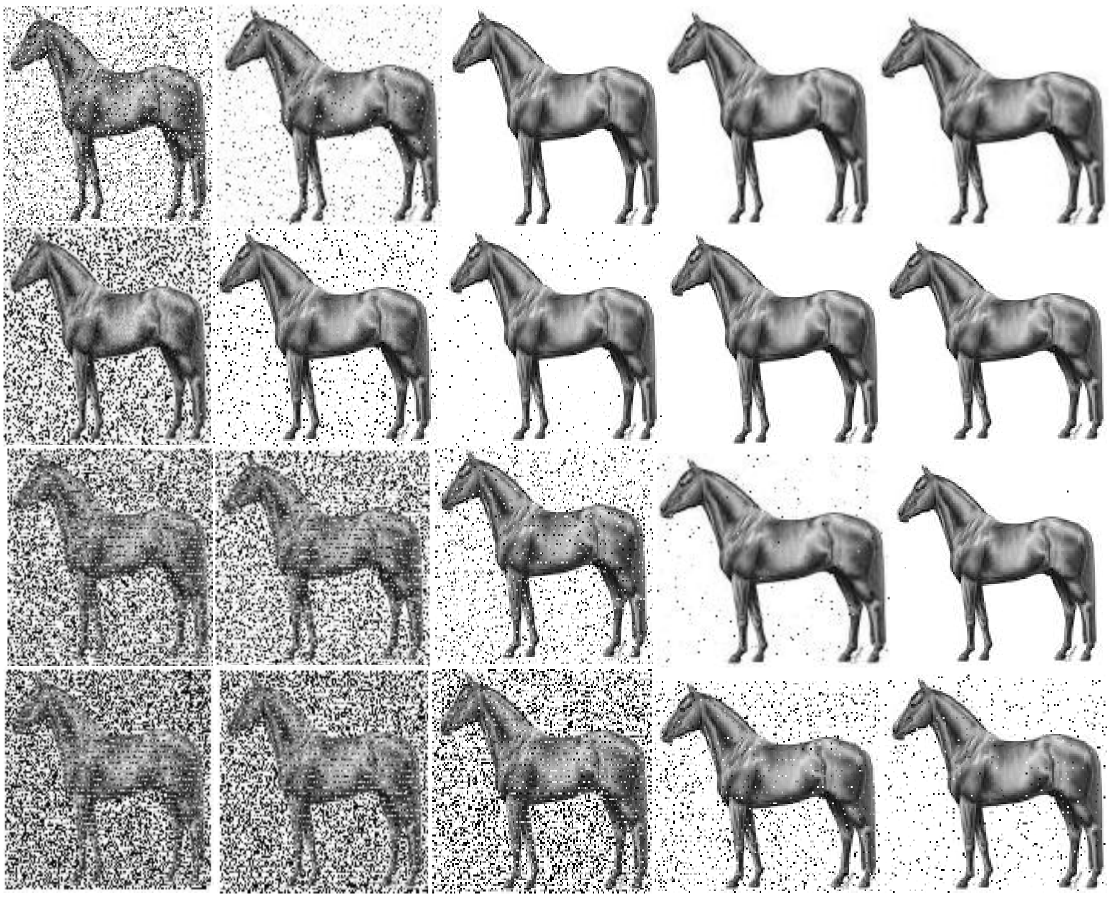


Fig. 4.8: Image received for MPSK using OSTBC3 Space-Time Coding with 3 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK)

The images received at the receiver end using OSTBC3 with receiver 3 for MPSK are shown in Fig. 4.8. 0dB, 10dB, 20dB, 30dB and 40 dB are the SNR values, using which the images are received for the 8PSK, 16PSK, 32PSK and 64PSK modulation levels. In columns, SNR values are taken, and in rows, the modulation levels are taken. Figure depicts that the BER of image received at 0dB for 8-PSK modulation level is more than the BER of images received at 10dB, 20 dB, 30dB and 40db for the same M value, i.e. with the increase in SNR value, the BER value decreases and distortions in the image get reduced but with the increase in the modulation level, i.e. the BER value increases because of increasing constellation points. On comparing Fig. 4.8 with Fig. 4.7 and Fig. 4.6, it is examined that, increase in the amount of receiver antennas from 1 to 3 results in the decrease in BER and the image retrieved with the use of 3 receiver antennas are more clearer than the image retrieved with the use 1or 2 receiver antenna. Hence, an increment in the amount of receiver antennas leads to the best results.

4.3 Image Transmission using Orthogonal Space Time Block Code with 4 antennas (OSTBC4)

An approach to transmitting an image is presented step by step in Fig. 4.9. Firstly, the grayscale image is represented in the binary equivalent matrix form. Then the MPSK modulation is done using 8PSK, 16PSK, 32PSK and 64PSK modulation levels. After modulation, encoding is done using OSTBC4 encoding scheme, and then the transmission is done over the Rayleigh fading channel. After this transmission, the reception of image is done using the reverse process of transmission. The Zero-forcing equalizer is used to detect the transmitted sent, following the demodulation process. Now, the conversion of matrix form is done into its pixel values, and the image will be retrieved by rearranging the pixel. Hence, the image transmission supported diversity is done.

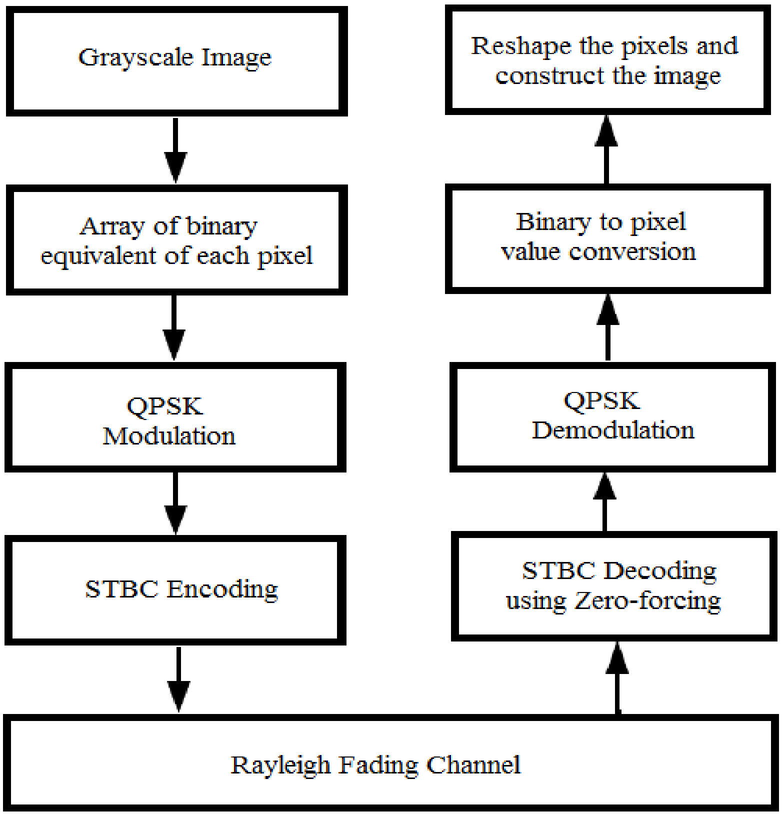


Fig. 4.9: Flowchart of Image Transmission using OSTBC4 and MIMO

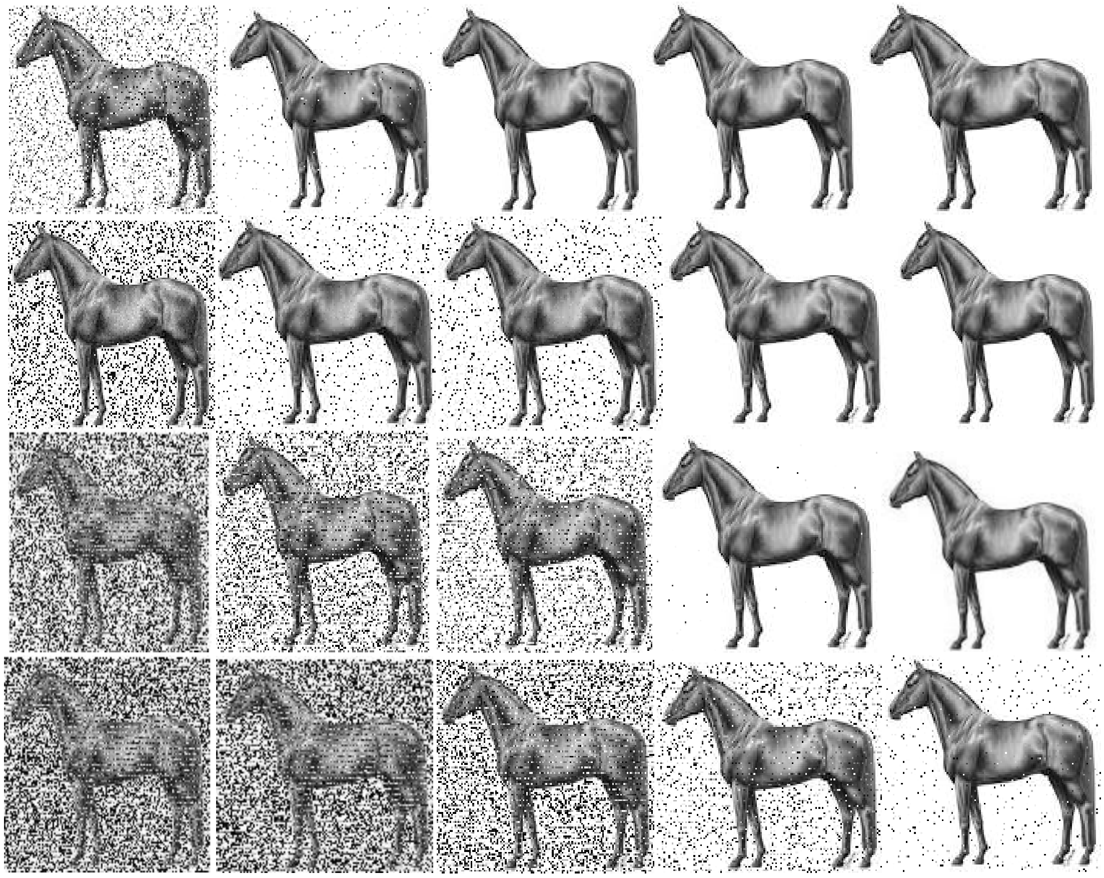


Fig. 4.10: Image received for MPSK using OSTBC4 Space-Time Coding with 1 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK)

The improvement in the performance of the images received with varied SNR values for 1 receiver antenna is shown in the Fig. 4.10, where the performance is evaluated using OSTBC4 architecture for MPSK. The range of SNR considered is 0-40dB taken in the columns 1 to 5 using 8PSK-64PSK modulation levels taken in the rows 1 to 5. The Figure depicts the fact that the BER value is inversely proportional to the SNR value and this relation provides us the best results. The image received at low SNR value for lower level modulation is having more BER as compared to the images received at increased SNR value for the similar modulation level, i.e. on increasing the SNR values, BER value decreases and this proves the fact and distortions in the image get reduced but with the increase in the modulation level, i.e. an increase in constellation points results in increasing BER.

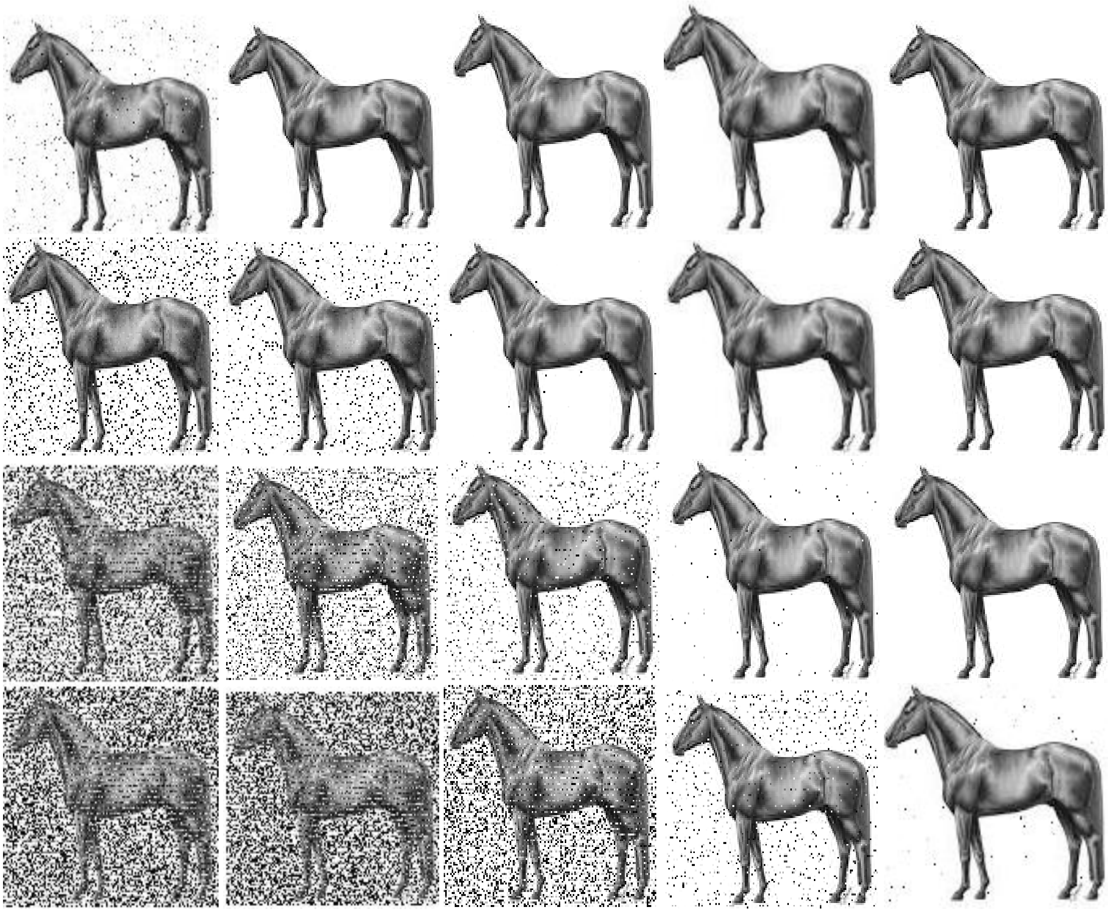


Fig. 4.11: Image received for MPSK using OSTBC4 Space-Time Coding with 2 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK)

The increase in the quality of the images received with the two receiver antennas is shown in the Fig. 4.11, where the performance is evaluated using OSTBC4 architecture for MPSK. The range of SNR considered is 0-40dB taken in the columns 1 to 5 using 8PSK-64PSK modulation levels taken in the rows 1 to 5. The Figure depicts the fact that the BER value is inversely proportional to the SNR value and this relation provides us the best results. The image received at low SNR value for lower level modulation is having more BER as compared to the images received at increased SNR value for the similar modulation level, i.e. on increasing the SNR values, BER value decreases and this proves the fact and distortions in the image get reduced but with the increase in the modulation level, i.e. an increase in constellation points results in increasing BER. After comparing Fig. 4.11 with Fig. 4.10, it is examined that, variations in the range of receiver antennas from 1 to 2 results in the low BER and the quality of image retrieved using 2 receiver antennas are clearer than the image quality retrieved using 1 receiver antenna.

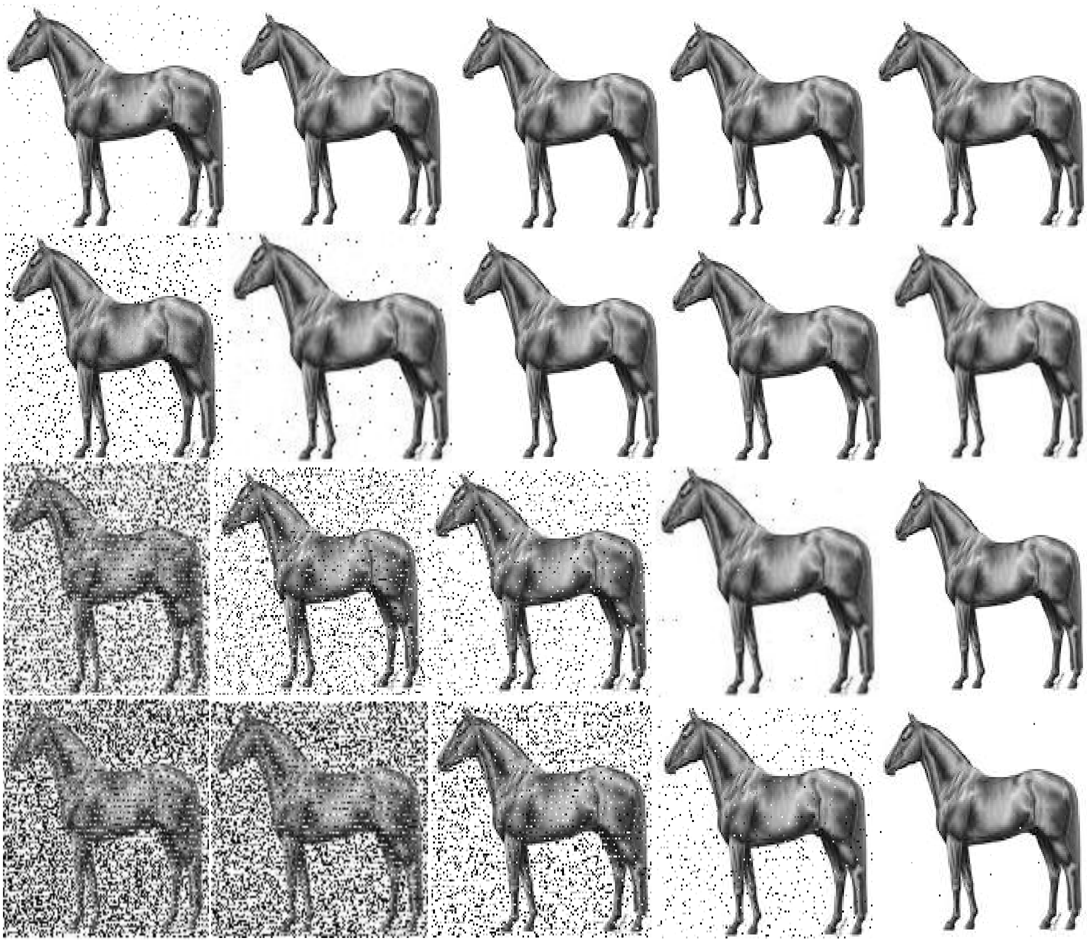


Fig. 4.12: Image received for MPSK using OSTBC4 Space-Time Coding with 3 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK)

The improvement in the performance of the images received with varied SNR values for 3 receiver antennas is shown in the Fig. 4.12, where the performance is evaluated using OSTBC4 architecture for MPSK. The range of SNR considered is 0-40dB taken in the columns 1 to 5 using 8PSK-64PSK modulation levels taken in the rows 1 to 5. The Figure depicts the fact that the BER value is inversely proportional to the SNR value and this relation provides us the best results, i.e. an increment to SNR lowers the BER value and distortions in the image get reduced but with the increase in the modulation level, i.e. an increase in constellation points results in increasing BER. On comparing Fig. 4.12 with Fig. 4.11 and 4.10, it is examined that, variations in the range of receiver antennas from 1 to 3 results in the low BER and the images retrieved with the use of 3 receiver antennas are more superior to the images retrieved with the use 1or 2 receiver antenna. Hence, an increment in the amount of receiver antennas leads to the best results.

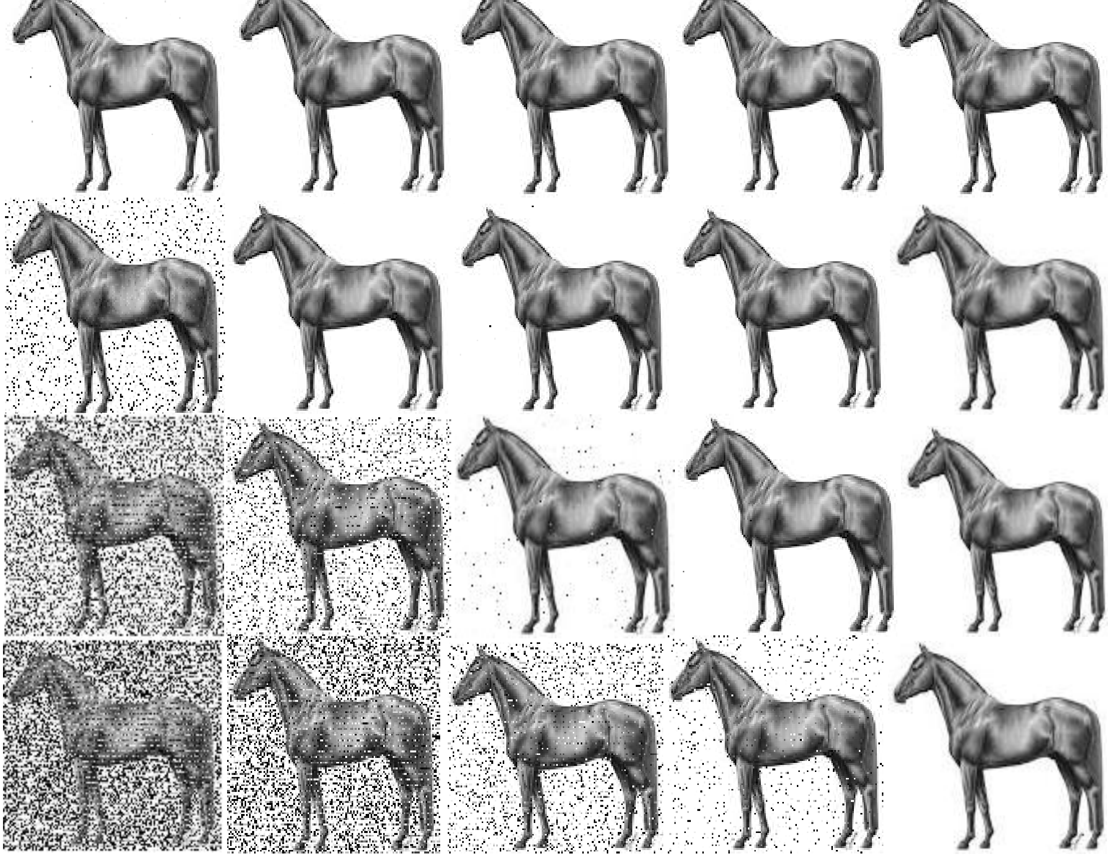


Fig. 4.13: Image received for MPSK using OSTBC4 Space-Time Coding with 4 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK)

The improvement in the performance of the images received with varied SNR values for 4 receiver antennas is shown in the Fig. 4.13, where the performance is evaluated using OSTBC4 architecture for MPSK. The range of SNR considered is 0-40dB taken in the columns 1 to 5 using 8PSK-64PSK modulation levels taken in the rows 1 to 5. The Figure depicts the fact that the BER value is inversely proportional to the SNR value and this relation provides us the best results, i.e. an increment to SNR lowers the BER value and distortions in the image get reduced but with the increase in the modulation level, i.e. an increase in constellation points results in increasing BER. On comparing Fig. 4.13 with Figure 4.12 ,4.11 and 4.10, it is examined that, alterations in the range of receiver antennas from 1 to 4 makes the BER low and the quality of images retrieved with the use of 4 receiver antennas is better than the quality of images retrieved with the use 1 or 2 or 3 receiver antennas. Hence, the best results are gained with the increased number of receiver antennas.

4.4 Image Transmission using Quasi-orthogonal Space-Time Block Code with 4 antennas (QOSTBC4)

Here, the transmission of an image is done using the Quasi-orthogonal space time block code with 4 antennas, in which transmission is done using four transmitter antennas and the reception is done by varying antennas at the receiving side. The process followed for the transmission of an image is explained in a flowchart manner as shown in Fig. 4.14.

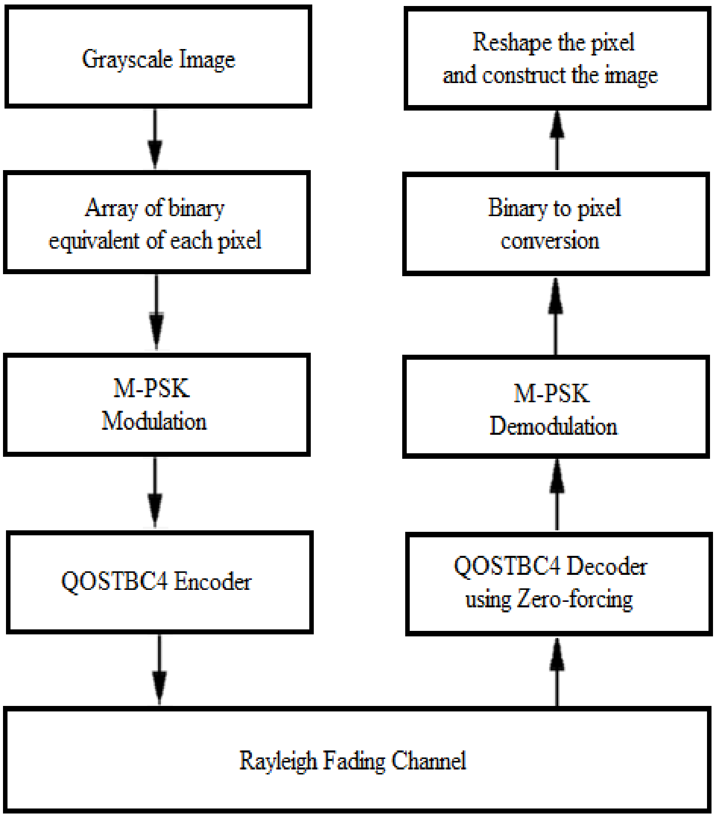


Fig. 4.14: Flowchart of Image Transmission using MIMO-QOSTBC4.

The procedure utilized for the image transmission includes the grayscale image (which is used as an input/ to be sent), array conversion (in which each pixel value of a gray scale image is converted into its binary form), modulator (in which the binary equivalent form is modulated using the M-Phase shift keying modulation scheme), QOSTBC4 encoder (in which the encoding of the modulated data is done using the 4 transmitter antennas) and Rayleigh fading channel (over which the encoded data is transmitted to the receiver end). At the reception medium, same process is followed in the reverse order in which decoding is done using zero-forcing decoder, followed by the demodulation and pixel conversion and then the image is reconstructed back. The performance of image quality is evaluated for the different modulation levels.

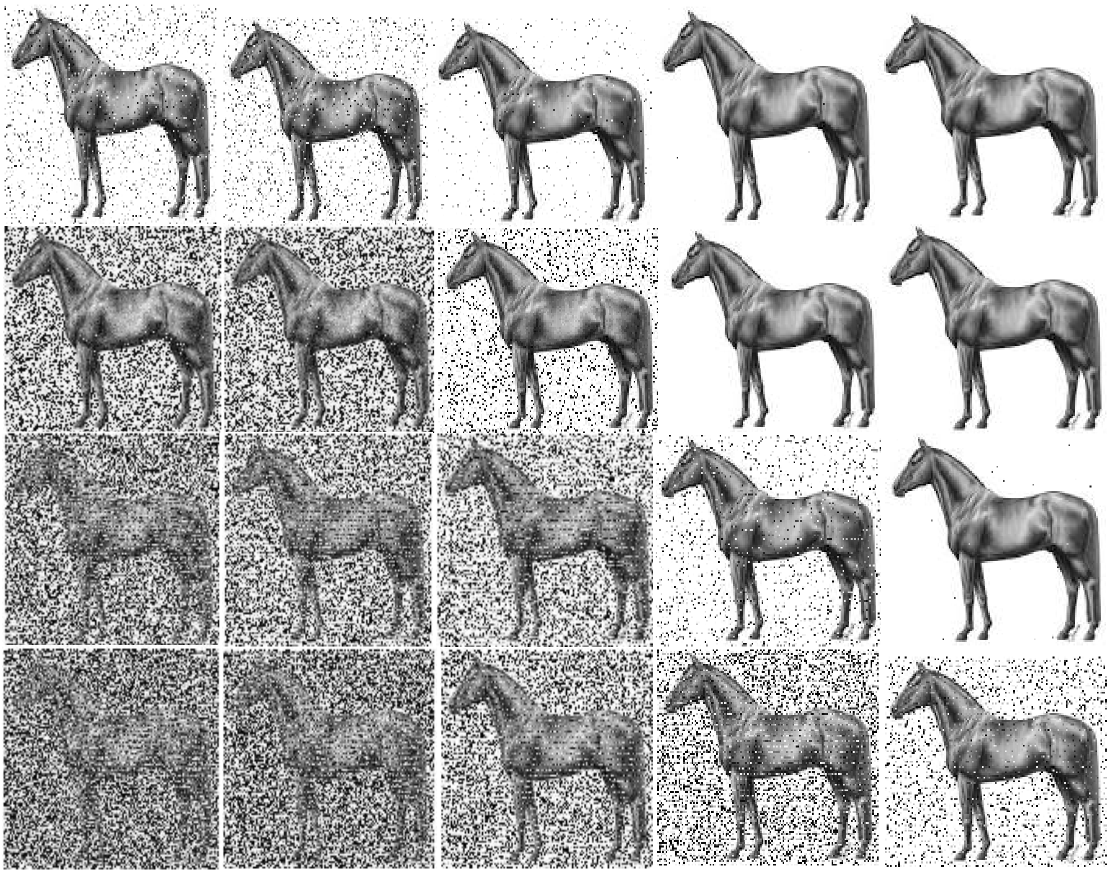


Fig. 4.15: Image recovered for M-PSK using Quasi-Orthogonal Space-Time Coding with 1 receiver antenna at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK).

It is evaluated from the above Fig. 4.15, that the quality of an image recovered using the higher SNR values is best than that of image recovered using higher level of modulation. Large symbols of constellations increase the interference which in results decreases the quality of an image and hence degrades the system performance. Here, the images are recovered using the one receiver antenna by taking different SNR values for different modulation levels. The columns indicate the SNR values ranging from 0dB to 40dB with the difference of 10dB each and the rows indicate the modulation levels ranging from 8-PSK to 64-PSK. The results provide the inverse relationship between the BER and the SNR values.

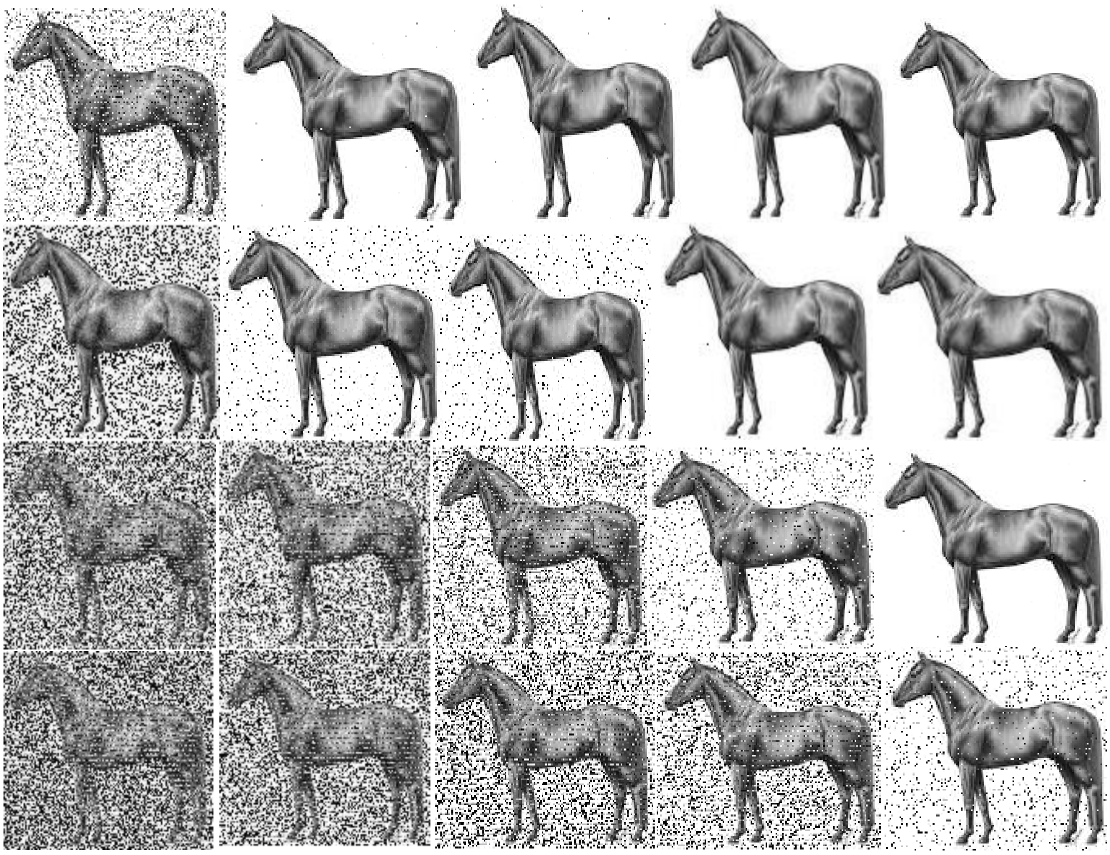


Fig. 4.16: Image recovered for M-PSK using Quasi-Orthogonal Space-Time Coding with 2 receiver antennas at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK).

The representation of the images received using 2 receiver antennas is done in Fig. 4.16, which evaluates that the image recovered using the higher SNR values is best in quality than that of image recovered using higher level of modulation. Increased symbols of constellations result in the interference which decreases the quality of an image and hence degrades the system performance. Here, the recovery of image is done using the two receiver antennas by taking different SNR values for different modulation levels. The columns indicate the SNR values ranging from 0dB to 40dB with the difference of 10dB each and the rows indicate the modulation levels ranging from 8-PSK to 64-PSK. The results evaluate that there is an inverse relationship between the BER and the SNR values and direct link between the number of receiver antennas and the quality of received image.

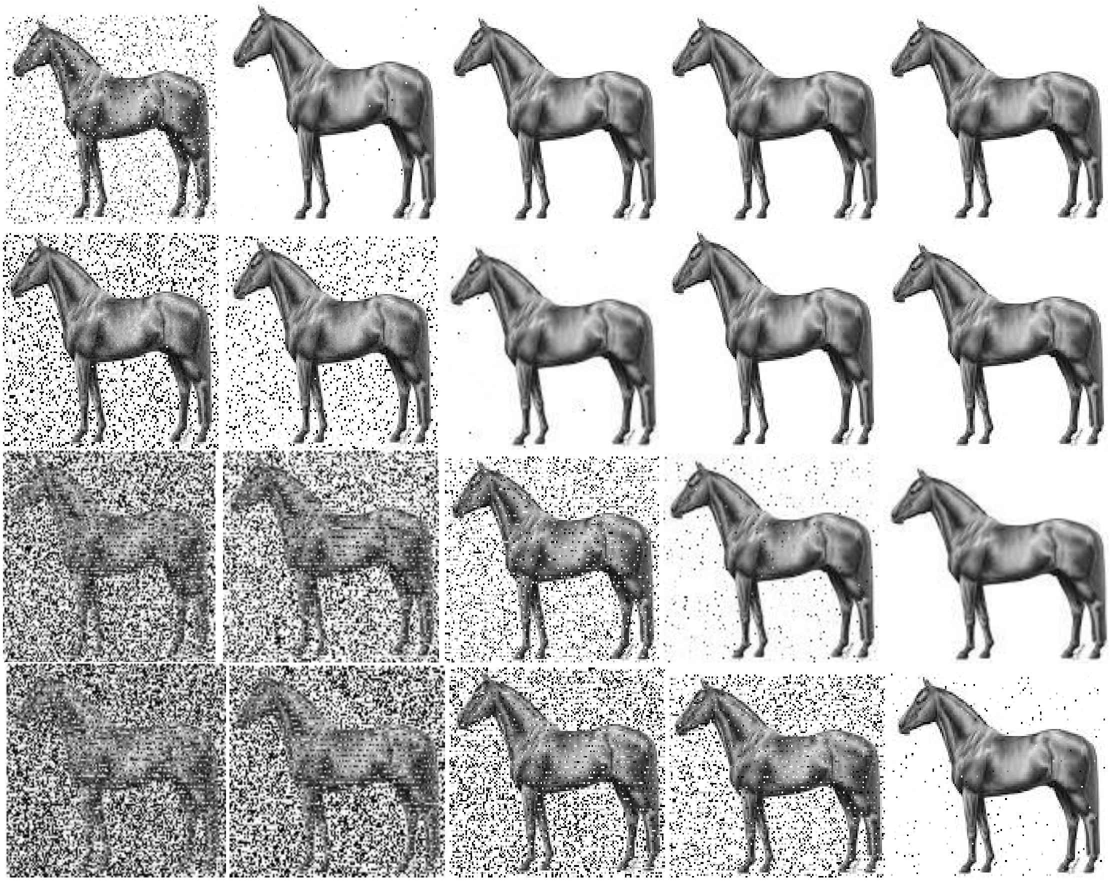


Fig. 4.17: Image recovered for M-PSK using Quasi-Orthogonal Space-Time Coding with 3 receiver antennas at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK).

The reconstructed images using 3 receiver antennas are presented in Fig. 4.17, which analyze that using the higher SNR values provide the best image quality than that of higher level of modulation. An increment to the symbols of constellations results in the interference which makes the image noisy and hence degrades the system performance. Here, the reconstruction of image is done using the three receiver antennas by taking different SNR values for different modulation levels. The columns indicate the SNR values ranging from 0dB to 40dB with the difference of 10dB each and the rows indicate the modulation levels ranging from 8-PSK to 64-PSK. The results evaluate that there is an inverse relationship between the BER and the SNR values and direct link between the amount of receiver antennas and the quality of received image.

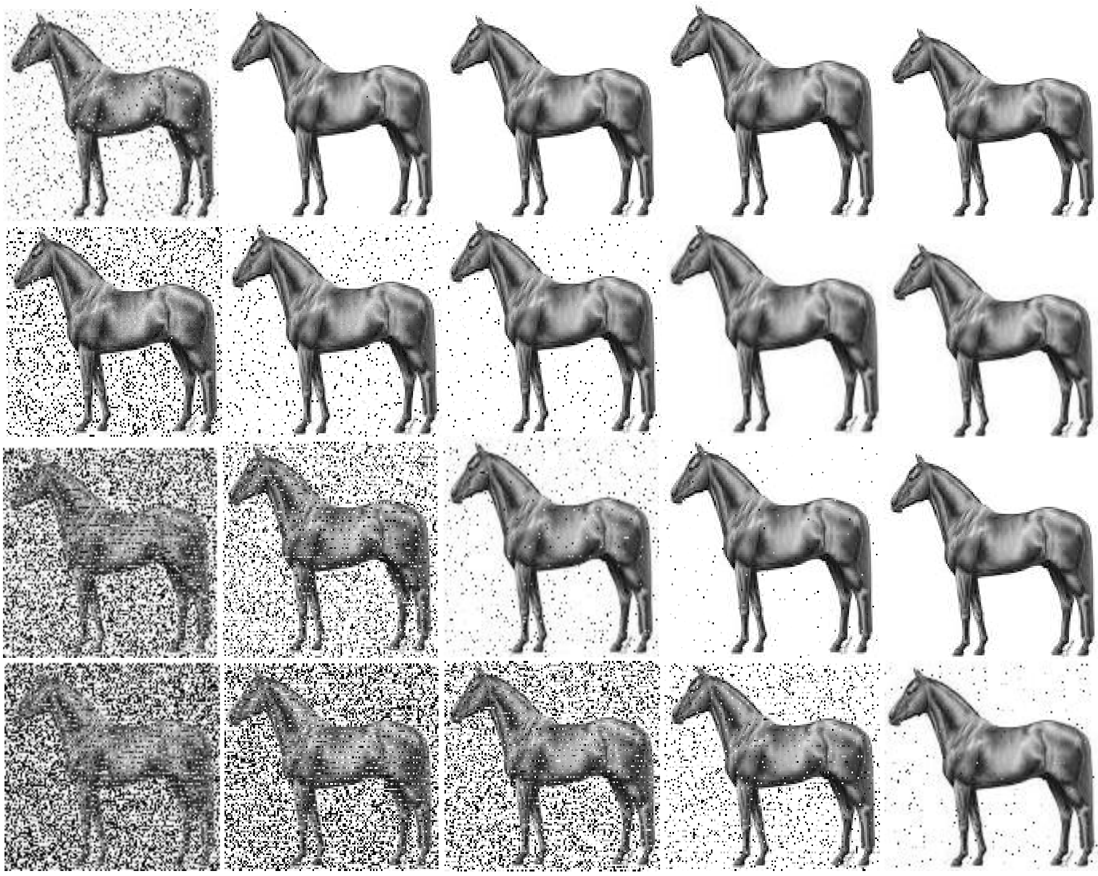


Fig. 4.18: Image recovered for M-PSK using Quasi-Orthogonal Space-Time Coding with 4 receiver antennas at different SNR values (Column-wise: 0dB, 10dB, 20dB, 30dB and 40dB) for diverse modulation levels (Row-wise: 8PSK, 16PSK, 32PSK and 64PSK).

The reconstructed images using 4 receiver antennas are presented in Fig. 4.18, which analyze that using the higher SNR values provide the best image quality than that of higher level of modulation. An increment to the symbols of constellations results in the interference which makes the image noisy and hence degrades the system performance. Here, the reconstruction of image is done using the three receiver antennas by taking different SNR values for different modulation levels. The columns indicate the SNR values ranging from 0dB to 40dB with the 10dB as a difference value and the rows indicate the modulation levels ranging from 8-PSK to 64-PSK. The results evaluate that there is an inverse relationship between the BER and the SNR values and direct link between the amount of receiver antennas and the quality of received image.

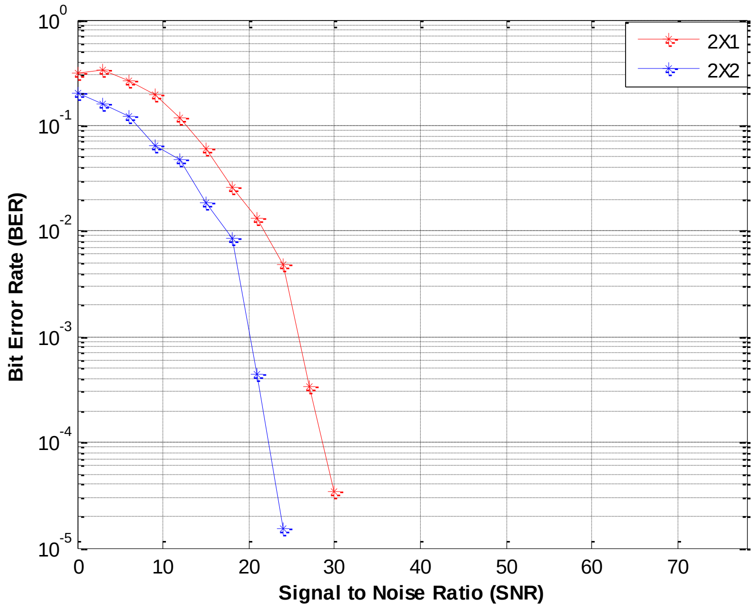
Here, the transmission of an image is done by taking the Bit Error Rate, in order to measure the MIMO system's performance analysis. The performance is measured over the Rayleigh channel using M-PSK modulation technique. The image is transmitted using space-time block codes such as Alamouti space time block code, Orthogonal space time block code and Quasi-orthogonal space time block code. The reconstruction of an image is done by using zero-forcing decoder at the receiving side. The amount of antennas is varied at the receiving end and the performance analysis is done between the BER and the SNR values, which indicates that an increase in amount of antennas results in the better BER performance, i.e. with the increment in amount of antennas at the transmitting and receiving side, the Bit Error Rate decreases.

5.1 Simulation Results

The performance analysis of BER in case of MIMO system will be done using STBC codes (Alamouti, OSTBC3, OSTBC4 and QOSTBC4) with different number of receiver antennas. BER is analyzed for the M-ary modulation techniques (M-PSK) over the Rayleigh channel. The value of M for the modulation techniques will be 8, 16, 32 and 64. Firstly, the BER is analyzed for Alamouti code using different values of M (M-PSK) over Rayleigh channel and then same is done for the OSTBC3, OSTBC4 and QOSTBC4 over Rayleigh channel.

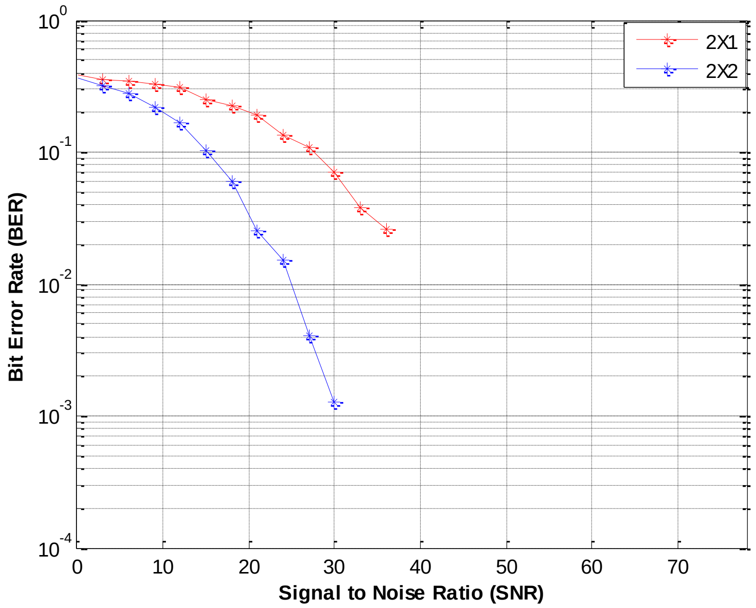
5.2 BER Analysis of Image transmission using MIMO System with Alamouti space-time block coding

Here, BER performance for M-PSK using Alamouti MIMO channel model with diverse antenna configurations over Rayleigh channel is evaluated. The employment of Zero-forcing equalizer is done for the detection and in M-PSK modulation, the M value is altered like 8, 16, 32, and 64 for all antenna architectures. The antennas at the receiver side are taken as 1 and 2 respectively for analysis purpose.



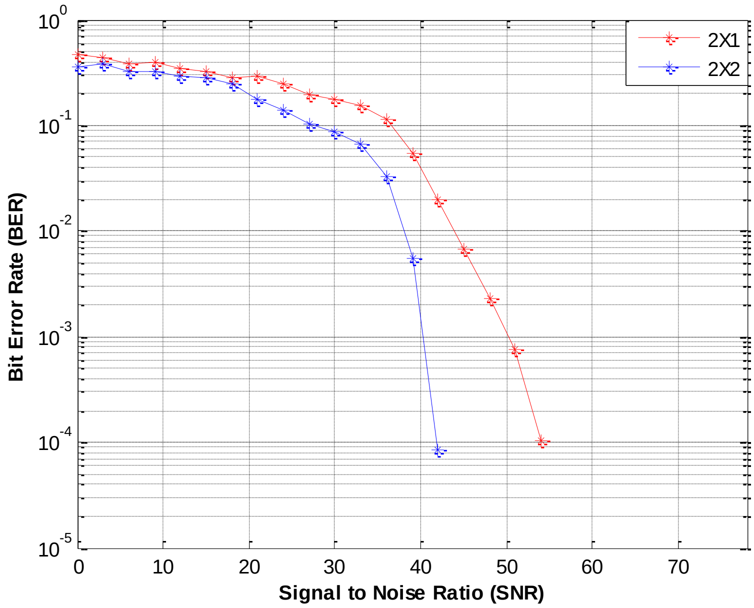
2X1
2X2
Bit Error Rate (BER)
Signal to Noise Ratio (SNR)

(a)

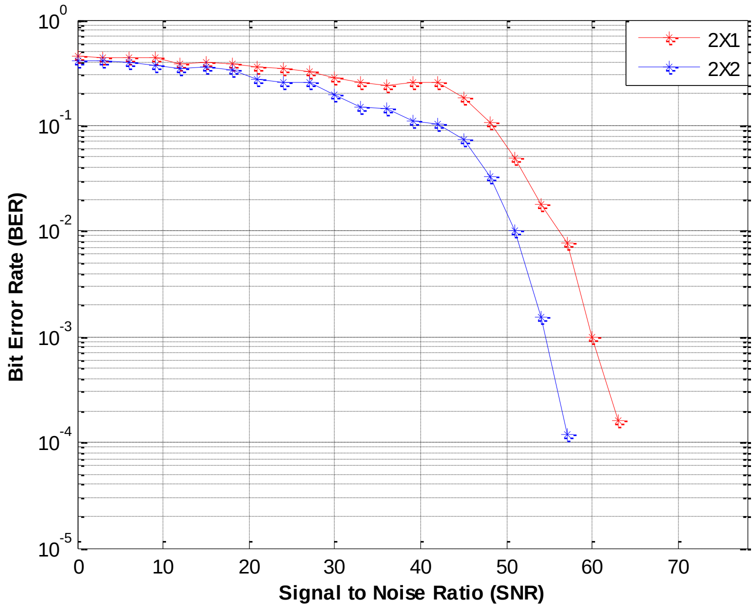


2X1
2X2
Bit Error Rate (BER)
Signal to Noise Ratio (SNR)

(b)



(c)



(d)

Fig. 5.1: SNR vs. BER plots for M-PSK using Alamouti MIMO channel model with diverse antenna configurations over Rayleigh channel a) 8PSK b) 16PSK c) 32PSK d) 64PSK

The representation of SNR vs. BER plot of MIMO system for image transmission with M-PSK modulation over Rayleigh channel for all antenna architectures using Alamouti MIMO channel model with zero forcing detectors is given in Fig. 5.1. The analysis done from the graph is that

BER decreases with the increment in the number of receiver antennas and it happens because of space diversity. Also, it is analyzed that higher value of SNR results in the improved system efficiency.

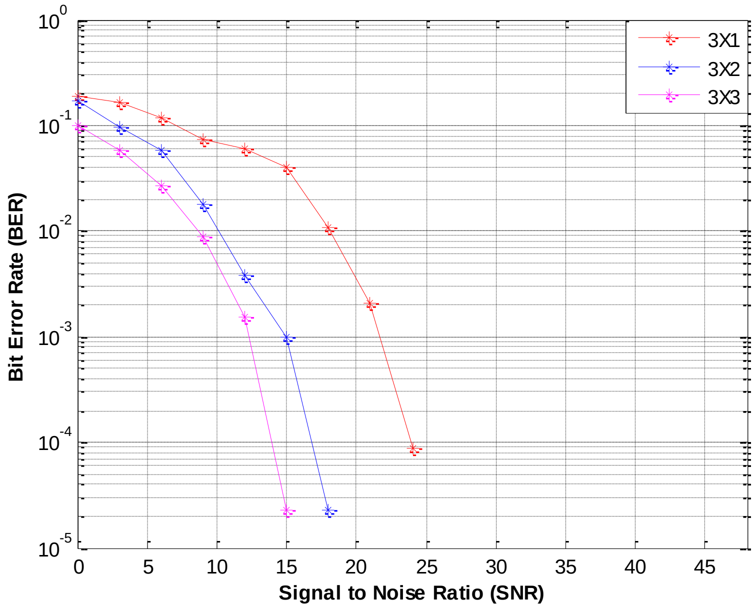
Table 5.1: SNR values for various M values using Alamouti space-time coding over Rayleigh fading channel

Number of Receiver Antennas	SNR values for various values of M in M-PSK (in dB)			
	8PSK	**16PSK**	**32PSK**	**64PSK**
1	28	36	54	64
2	23	30	42	57

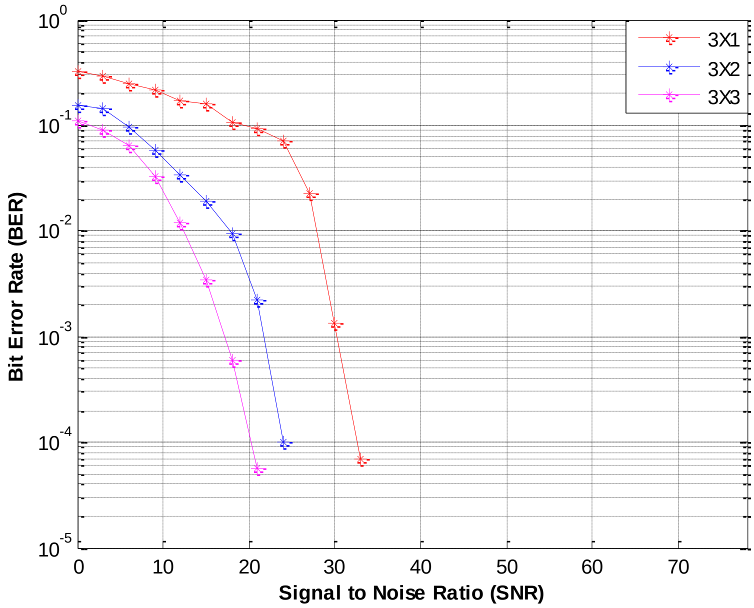
For different values of M such as 8PSK, 16PSK, 32PSK and 64PSK, the different SNR values using Alamouti MIMO channel model with diverse antenna configurations are represented in Table 5.1. It is depicted that for 8-PSK, the values of SNR for 1 and 2 receiver antennas are 28dB and 23dB respectively having a difference of 5dB. Similarly, for 16-PSK, the values of SNR for 1 and 2 receiver antennas are 36dB and 30dB having difference of 6dB, for 32-PSK, the values of SNR for 1 and 2 receiver antennas are 54dB and 42dB having difference of 12dB and for 64-PSK, the values of SNR for 1 and 2 receiver antennas are 64dB and 57dB having difference of 7dB. Therefore, it is analyzed that with the increment in the amount of antennas at the receiving side from 1 to 2, the SNR improvement in the range of 5dB to 12dB is there for the same value of BER.

5.3 BER Analysis of Image transmission using MIMO System with Orthogonal space-time block coding having 3 antennas

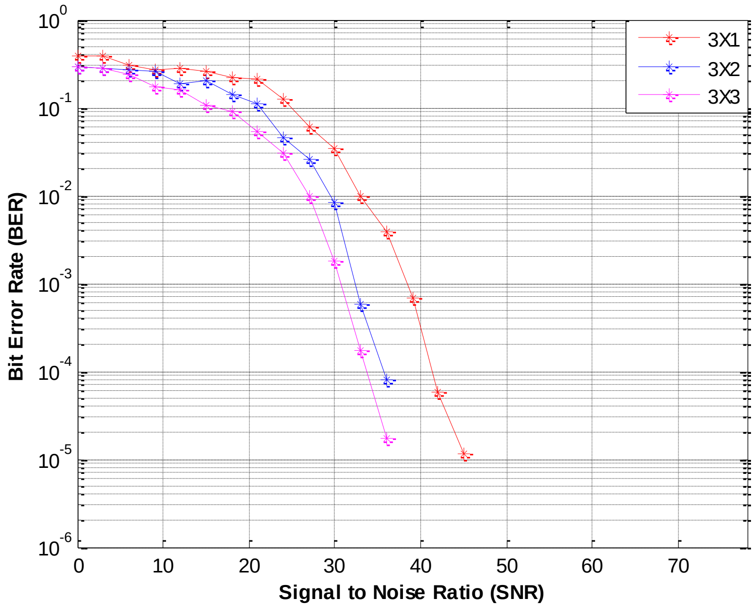
Here, the evaluation of BER of OSTBC3-MIMO channel over Rayleigh channel is done by making use of OSTBC3 coding method. The Zero-forcing equalizer is used for detection purpose for MPSK Modulation. The altered M values are 8, 16, 32, and 64 for various antenna specifications and the altered values of receiver antennas are 1 to 3.


Bit Error Rate (BER)
Signal to Noise Ratio (SNR)
3X1
3X2
3X3

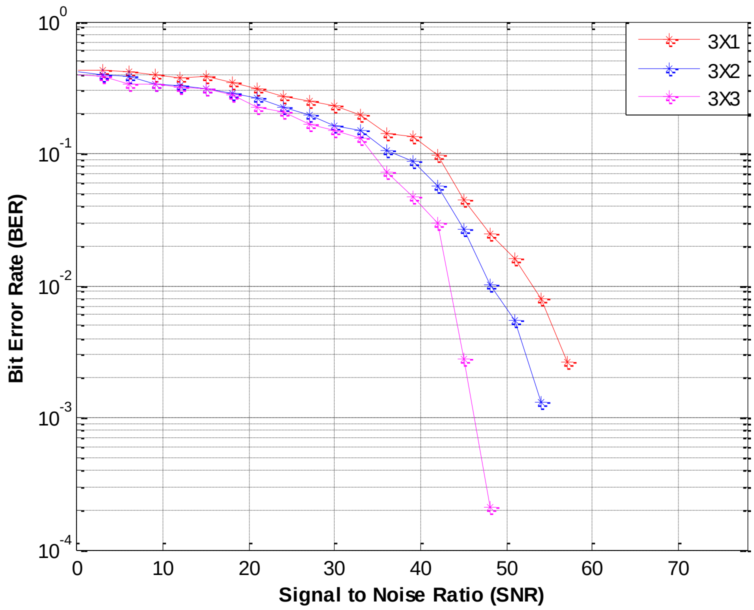
(a)


Bit Error Rate (BER)
Signal to Noise Ratio (SNR)
3X1
3X2
3X3

(b)



(c)



(d)

Fig. 5.2: SNR vs. BER plots for MPSK using OSTBC3 MIMO channel model with diverse antenna specifications over Rayleigh channel a) 8PSK b) 16PSK c) 32PSK d) 64PSK

The BER plot of OSTBC3 MIMO system with respect to SNR values over Rayleigh channel for MPSK with various antenna specifications by utilizing zero forcing detectors is shown in Fig. 5.2. It is examined from the plot that increment in amount of receiver antennas will decrease the BER because of space diversity. Hence, BER performance acquired is better than other antenna architectures.

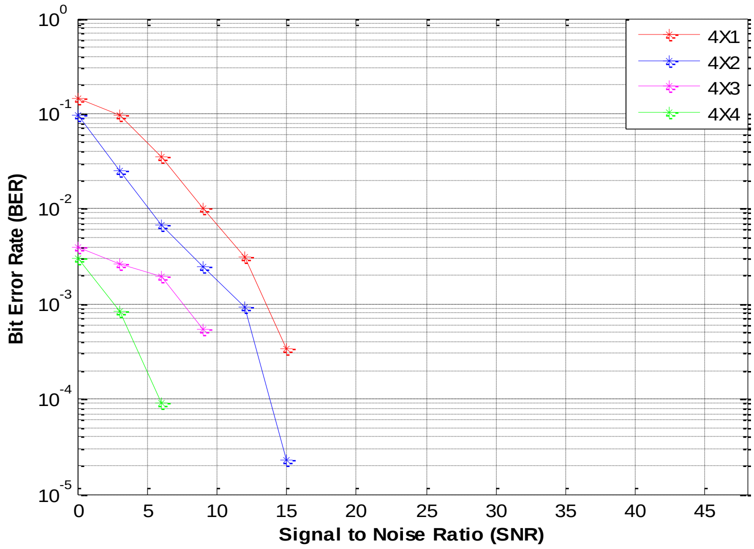
Table 5.2: SNR values for various M values using OSTBC3 space-time coding over Rayleigh Channel

Number of Receiver Antennas	SNR values for various values of M in M-PSK (in dB)			
	8PSK	**16PSK**	**32PSK**	**64PSK**
1	24	32	41.5	58
2	17	24	36	54
3	14	20	34.5	45

The different SNR values for different modulation levels such as 8PSK, 16PSK, 32PSK and 64PSK, using OSTBC3 MIMO channel model with diverse antenna configurations are represented in Table 5.2. It is depicted from the table that for 8-PSK, the values of SNR for 1, 2 and 3 receiver antennas are 24 dB, 17dB and 14dB respectively having the difference of 9dB. Similarly, for 16-PSK, the values of SNR for 1, 2 and 3 receiver antennas are 32dB, 24dB and 20dB having difference of 12dB, for 32-PSK, the values of SNR for 1, 2 and 3 receiver antennas are 41.5dB, 36dB and 34.5dB having difference of 9dB and for 64-PSK, the values of SNR for 1, 2 and 3 receiver antennas are 58dB, 54dB and 45dB having difference of 13dB. Therefore, it is examined by increasing the receiver antennas from 1 to 3, the SNR values changes from 9 dB to 13 dB and BER value decreases.

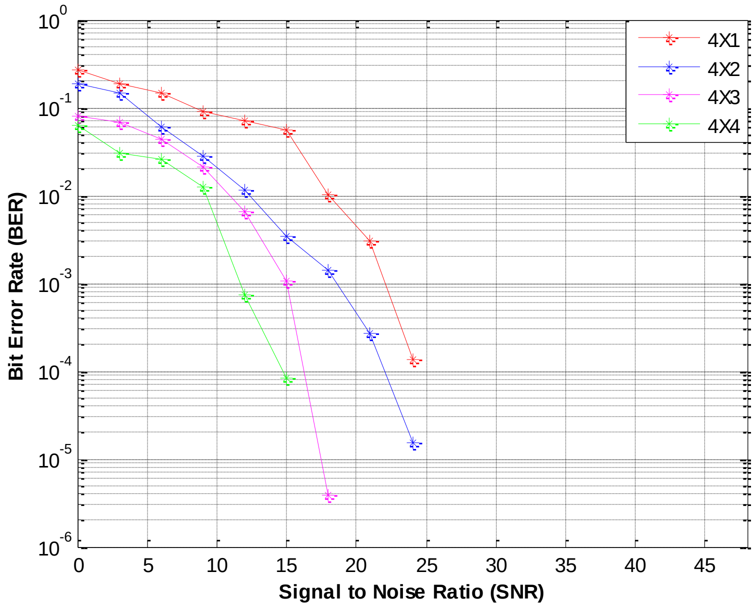
5.4 BER Analysis of Image transmission using MIMO System with Orthogonal space-time block coding having 4 antennas

Here, the evaluation of BER for OSTBC4-MIMO channel is over Rayleigh channel. The detection is done using the Zero-forcing equalizer for MPSK modulation. The M value is varied such as 8, 16, 32, and 64 for various antenna architectures. The receiver antennas are varied from 1 to 4.



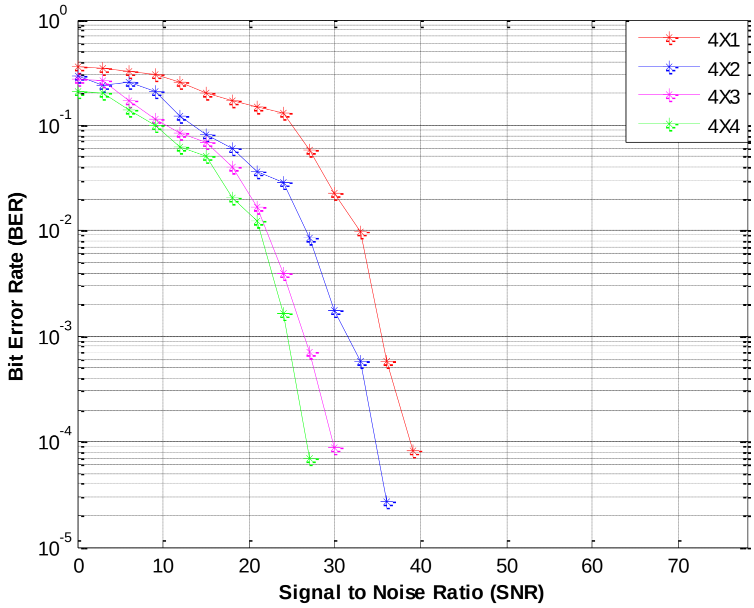
Bit Error Rate (BER)
Signal to Noise Ratio (SNR)
4X1
4X2
4X3
4X4

(a)

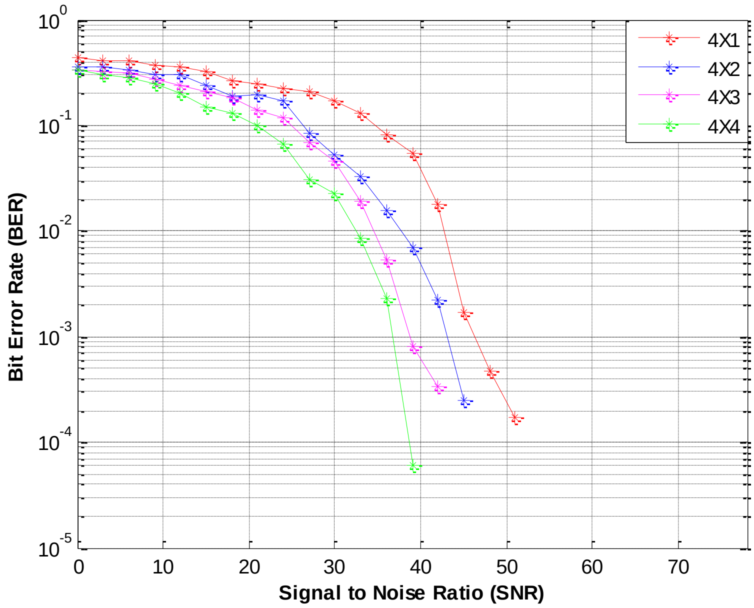


Bit Error Rate (BER)
Signal to Noise Ratio (SNR)
4X1
4X2
4X3
4X4

(b)



(c)



(d)

Fig. 5.3: SNR vs. BER plots for MPSK using OSTBC4 MIMO channel model with diverse antenna configurations over Rayleigh channel a) 8PSK b) 16PSK c) 32PSK d) 64PSK

The BER plot corresponding to SNR values for OSTBC4 MIMO channel with various antenna specifications by utilizing MPSK modulation over Rayleigh channel with zero forcing detectors is displayed in Fig. 5.3. It is analyzed from the graph that, higher the number of receiver antennas, lesser will be the BER because of space diversity. However, on comparing with other antenna architectures, enhanced BER realization is acquired.

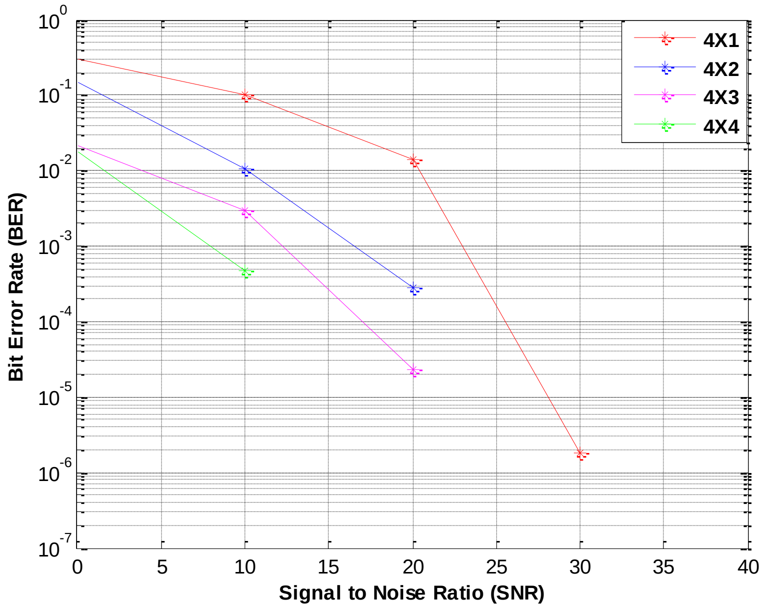
Table 5.3: SNR values for various M values using OSTBC4 space-time coding over Rayleigh channel

Number of Receiver Antennas	SNR values for various values of M in M-PSK (in dB)			
	8PSK	**16PSK**	**32PSK**	**64PSK**
1	17	24.5	39	51
2	14	22	35	45
3	11	16.5	30	42
4	6	14.5	27	39

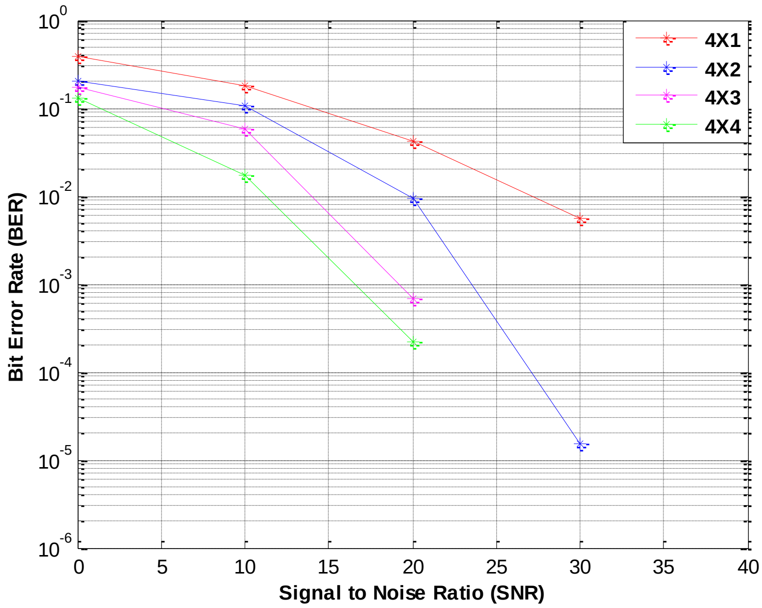
The variations among the BER values corresponding to the various antennas are shown in the above Table 5.3, from where it can be seen that for different antenna values, we obtained corresponding different SNR values using various modulation techniques by using OSTBC4 MIMO channel model. Analysis can be explained in the way that for 8-PSK, taking 1 to 4 receiver antennas for which we are getting 10dB difference by having 17dB, 14dB, 11dB and 6dB SNR values. Similarly, for 16-PSK, for same receiver antenna architectures, we are getting 10dB difference by having 24.5 dB, 22dB, 16.5dB and 14.5dB SNR values, for 32-PSK, there is 12dB difference using 39dB, 35dB, 30dB and 27dB SNR values and for 64-PSK, the SNR values for 1 to 4 receiver antennas respectively, 51dB, 45dB, 42dB and 39dB having difference of 12dB. Therefore, it can be concluded from the above table and calculations shows that the difference lays between 10dB to 12dB by incrementing the receiver antennas from 1 to 4 or more which decreases the BER values.

5.5 BER Analysis of Image transmission using MIMO System with Quasi-orthogonal space time block coding having 4 antennas

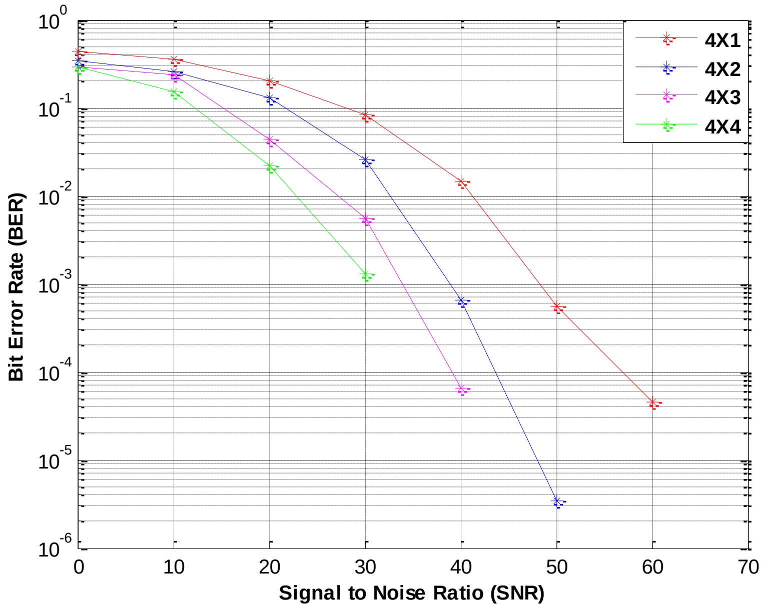
The performance of the image communication over the 4X1, 4X2, 4X3 and 4X4 antenna configurations using lower level modulation techniques is discussed. The transmission is done over the Rayleigh channel and is decoded using the zero-forcing decoder. The diversity is performed by varying the antennas from one to four at the receiving side.


Bit Error Rate (BER)
Signal to Noise Ratio (SNR)
4X1
4X2
4X3
4X4
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0 5 10 15 20 25 30 35 40

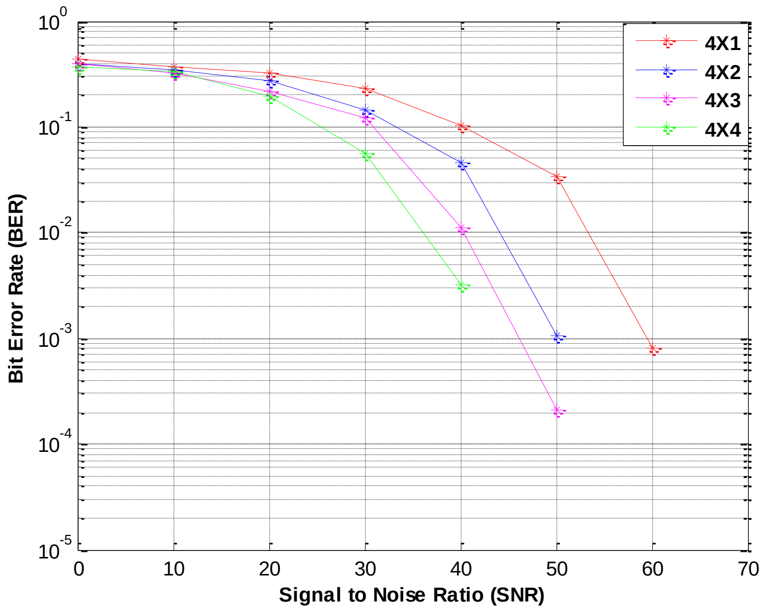
(a)


Bit Error Rate (BER)
Signal to Noise Ratio (SNR)
4X1
4X2
4X3
4X4
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0 5 10 15 20 25 30 35 40

(b)



(c)



(d)

Fig. 5.4: SNR vs. BER plots for M-PSK using QOSTBC4-MIMO channel model with diverse antenna configurations over Rayleigh channel a) 8PSK b) 16PSK c) 32PSK d) 64PSK.

To identify the quality of the image received at the receiver side by propagating through the Rayleigh channel using the QOSTBC4-MIMO scheme with the zero-forcing detector, the evaluation is done by plotting between BER and SNR values and is presented in Fig. 5.4. The graphs are plotted by varying the number of receiver antennas from one to four and by increasing the modulation level from 8-PSK to 64-PSK, which provides the variations in the quality of an image received depending upon the increased modulation level and the varied receiver antennas.

Table 5.4: SNR values for various M values using QOSTBC4 Space-time coding over Rayleigh Channel.

Number of Receiver Antennas	**SNR values for various values of M in M-PSK (in dB)**			
	8PSK	**16PSK**	**32PSK**	**64PSK**
1	23	35	48	69
2	16.5	23.5	38.5	50
3	12	19.5	34	46
4	7.5	16	31.5	43.5

By utilizing the quasi-orthogonal space time block coding along with MIMO channel for the diverse antenna configurations like 4X1, 4X2, 4X3 and 4X4, the various SNR values achieved for different modulation levels are shown in Table 5.4. For 8-PSK modulation, the SNR values 1 receiver antenna to 4 receiver antennas are 23dB, 16.5dB, 12dB and 7.5dB respectively, whereas for 16-PSK modulation level, the values are 35dB, 23.5dB, 19.5dB and 16dB respectively. Similarly, for 32-PSK modulation level, the SNR values from 1 receiver antenna to 4 receiver antennas are 48dB, 38.5dB, 34dB and 31.5dB respectively, whereas 64-PSK modulation, the values are 69dB, 50dB, 46dB and 43.5dB respectively, which indicates that with an increase in amount of antennas at the receiving side, the SNR values decrease which enhances the BER performance, i.e. the system efficiency is improved with the high amount of receiver antennas whereas it is reduced with higher level of modulation.

CHAPTER 6 CONCLUSION AND FUTURE SCOPE

In this work, the performance of image transmission using MIMO-STBC configuration over Rayleigh channel using M-phase shift keying modulation schemes with Zero Forcing detector is presented. This implementation is done using M-PSK modulation technique in which the values of M (8, 16, 32 and 64) are varied in order to increase the rates of transmission of data and to decrease the BER. The space time block codes used for the transmission are Alamouti space time block code, Orthogonal space time block code and Quasi-orthogonal space time block code. The binary form of an image is encoded using Space time block code encoder and is decoded using the zero-forcing detector. It is shown in the results that the quality of an image recovered with the 8-PSK and 16-PSK modulation level is better than the quality of an image received with the 32-PSK and 64-PSK modulation level, i.e. an increase in the modulation level degrades the system performance. For Alamouti Space-time block code, with the increase in amount of antennas from 1 to 2 using diverse modulation techniques, the SNR requirement varies from 5dB to 12dB. For OSTBC3, with the increase in amount of antennas from 1 to 3 using diverse modulation techniques, the SNR requirement varies from 7dB to 12dB. Similarly, for OSTBC4, with the increase in amount of antennas from 1 to 4 using diverse modulation techniques, the SNR requirement varies from 10dB to 12dB For QOSTBC4, with the increase in amount of antennas from 1 to 4 using diverse modulation techniques, the SNR requirement varies from 15.5dB to 25.5dB. It is evaluated from the results that increase in the amount of antennas results in the better BER performance. Also, it is analyzed that the quality of an image recovered with the higher SNR values is better than the image recovered with lower SNR values, i.e. high SNR values makes the images more clearer. Also, it is analyzed that quality of image recovered using four number of receiver antennas is best than that of using lower number of receiver antennas, i.e. increase in the amount of receiver antennas enhances the image quality. Therefore, the overall result discussed in this thesis is that there is an inverse relationship between the BER and the SNR values and direct relationship between the amount of receiver antennas and the quality of received image along with direct relationship between the SNR values and the image quality.

In future, this work can be extended to analyze the performance of image transmission using MIMO system along with the other space-time block codes. Also, we can increase the performance of MIMO-STBC channel using different modulation techniques with different receiver architectures over different fading channels. Further, the work can be extended to increase the reconstruction performance of the image using different detectors. Also, the performance can be enhanced by using spatial multiplexing. We can also implement the MIMIO-STBC channel by increasing the amount of antennas at both the transmitting and receiving side, in order to improve the system performance. Some algorithms can also be utilized for the reconstruction of the images.

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