COMPARATIVE PERFORMANCE ANALYSIS OF CHANNEL CODES

DISSERTATION II

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

MASTER OF TECHNOLOGY
IN
Wireless Communication

By

Jasvir kaur (11507996)

Under the Guidance of

MR. SHAKTI RAJ CHOPRA

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA (DISTT. KAPURTHALA), PUNJAB

School Of Electrical and Electronics Engineering
Lovely Professional University
Punjab

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Supervisor Name : Shakti Raj Chopra **UID :** 11636 **Designation :** Assistant Professor

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SR.NO.	NAME OF STUDENT	REGISTRATION NO	BATCH	SECTION	CONTACT NUMBER
1	Jasvir Kaur	11507996	2015	E1514	9465980137

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CERTIFICATE

This is to certify that the Dissertation-II titled "**Comparative Performance Analysis of channel codes**" that is being submitted by "**Jasvir kaur**" is in partial fulfillment of the requirements for the award of MASTER OF TECHNOLOGY DEGREE, is a record of bonafide work done under my /our guidance. The contents of this Dissertation-II, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Mr. Shakti Raj Chopra
Assistant Professor
School of Electronics Engineering
Lovely Professional University
Phagwara, Punjab.

Date :

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JASVIR KAUR
Reg. No. 11507996

DECLARATION

I, **JASVIR KAUR,** student of **MASTER OF TECHNOLOGY (WIRELESS COMMUNICATION)** under Department of ELECTRONICS AND COMMUNICATION 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, to the best of my knowledge, does not contain any part of my work which has been submitted for the award of my degree without proper citation.

Date: **JASVIR KAUR**

Reg. No. 11507996

ABSTRACT

Wireless systems are rapidly developing to provide high speed voice, text and multimedia messaging services which were traditionally offered by wire line networks. To support these services, channels with large capacities are required and also channel coding techniques are used for combating the effect of noise which cause distortion of original data. Information theoretic investigations have shown that Multiple Input Multiple Output (MIMO) channels can achieve very high capacities. Space-Time Coding (STBC) is potential scheme which utilize the diversity offered by MIMO channels to provide reliable high date rate wireless communication.

With an increasing demand for high data rate, there has been a lot of research in the field of wireless communication. This report deals with the fundamentals of space-time coding for wireless communication systems. A well-known technique known as Space-Time Coding has been adopted in the systems using multiple antennas for high speed and reliable communication. The basic idea of space-time coding deals with the designing of two-dimensional signal matrix that is to be transmitted over an interval of time from a number of transmitting antennas. High data rate and improved bit error performance can be achieved by exploiting diversity in the spatial dimensions by designing appropriate signal structure. Space-Time Block Coding is a MIMO transmit strategy which exploits transmit diversity and high reliability.

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LIST OF ABBREVATIONS

ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise
BER	Bit-Error Rate
BPSK	Binary Phase Shift Keying
CDM	Code multiple access
CRC	Cyclic Redundancy Check
FDM	Frequency Division Multiplexing
LOS	Line-Of-Sight
OSTBC	Orthogonal Space Time Block Coding
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RS	Reed Solomon
SNR	Signal-to-Noise Ratio
STC	Space Time Coding
MIMO	Multiple-Input Multiple-Output
SECDED	Single Error Check Double Error Detection
SISO	Single-Input Single-Output
STBC	Space Time Block Code
STTC	Space Time Trellis Code
TCM	Trellis Coded Modulation
TDM	Time Division Multiplexing
Wifi	Wireless Fidelity
4G	Fourth Generation

CHAPTER 1 INTRODUCTION

1.1 Overview

Wireless communication systems have integral contribution in our daily day to day life and wireless area is evolving continuously as the services offered by them are widely accepted and their demand is increasing rapidly. In wireless communication, data is sent over the wireless channel instead of wired channel which gives rise to major issue of noise addition in the information sent over the wieless channel where noise gets added to data and causes distortion of information. There comes the main motive of error detection and correcting codes. These codes are used for efficient transnsmission of data from transmitter side and are used to efficiently decode the transmitted data at receiver side and thus causing significant reduction in BER. At the receiver side these codes provides efficient decoding by detecting the errors if any occurred while transmission through channel and after detection of error, these codes provides removal/correction of that error. This error detection and correction of errors occurred in original data is referred to as channel coding.

Another main challenge in wireless communication field is to achieve reliable communication with flexible data rate providing services to large capacity under the restraint of limited power and limited available spectrum bandwidth and power [1]. Due to this constraint MIMO communication comes into picture. Multiple input multiple output communications offers high data throughput and link range. MIMO systems are implemented using space-time codes (STC). In MIMO technique, the objectives of maximum coding gain, maximum diversity i.e multiple transmit and receive antenna and maximum possible throughput can be fullfilled by using space time codes. MIMO exploits the diversity capability to achieve its goal by combining the output from multiple de-correlated antenna elements at receiver side which causes a significant improvement in SNR value and decrease in BER value even after the random fading is caused by multipath propagation in space [2]. STBC technique can be basically considered as modulation technique where full diversity is achieved due to application of multiple transmit and receive antenna but no coding gain is provided. Space time trellis coding is also a STC code which provides both coding gain and diversity gain and has better bit error rate performance. Further multiple antennas can be used to enhance the capacity of wireless links.

Multiple antenna technique can be called as the major technology which helps in achieving the necessary data rate for the next generation technologies of wireless interface like WiMAX , 3GPP-LTE and Wifi because of the spatial dimension complementing in time (TDM), frequency (FDM), and code (CDM) multiple access technologies. Some of the practical applications of MIMO are

- Wireless Local area network – Wifi 802.11n
- Mesh Networks
- Wireless Metropolitan area network – WiMAX 802.16e
- Fourth Generation Mobile communication
- Radio Frequency Identification.
- Digital Home

In Wifi 802.11n, high throughput is accompolished by using the space diversity(MIMO) which increases the data rate to 600 Mbps with the application of signal processing techniques and multiple antennas. Typical examples of this application include High resolution streams, backup of large files, home entertainment etc. MIMO in Ad-Hoc Network is a combination of multiple wireless mobile nodes which made network by configuring themselves and communication between any two nodes can be performed with high capacity links and are scalable due to mobilit and offers many multimedia applications. Here nodes configures itself and are mobile, so there is no requirement of fixed infrastructure. Any node can join network by authenticating itself within the prescribed range and can leave the network. Mobile-WiMAX 802.16e provides up to 4-6 mbps per user for a few km by using multiple antenna systems exploiting the spatial diversity, spatial multiplexing capability MIMO. MIMO is also used in RFID for increasing read reliability using diversity in space and increasing read range and read throughput.

CHAPTER 2 TERMINOLOGY

- **AWGN:** Additive white Gaussian noise is the idle channel where noise gets linearly added to the propagating data signal.
- **BER:** It is ratio of number of bit errors to the total number of bits transferred called as bit error rate.
- **Beamforming:** It is a technique where transmission and reception of signal is performed at particular angles.
- **Channel:** It is a medium for transmission of data from transmitter to receiver.
- **Coding:** It is encoding technique employed at transmitter side by adding redundant bits in some pattern to the original message.
- **Decoding:** It is decoding technique employed for error detection and correction at receiver side.
- **Diversity:** It is wireless technique where multiple copies of same data are transmitted over the multiple independent fading channels.
- **Graph:** Graph is a method to represent the calculated results in 2-D (x and y axis) graphical forms.
- **Modulation:** It is defined as a technique where characteristics such as amplitude, frequency and phase of the carrier are changed with respect to modulating signal.
- **Multipath:** Transmission of data from the free space channel where it undergoes scattering, diffraction, reflection, refraction etc causing multiple data signals to be reached at receiver from different paths.
- **MIMO:** It is the wireless communication technique where data is transmitted and received over multiple transmit and receive antennas.
- **Packet:** The transmission of data in the form of synchronization pattern and accepted by the receiver
- **Rayleigh**: It is fading channel where received signal is impaired by multipath fading as well as AWGN.
- **Simulation:** It is model to explain the building block of system and it is used to evaluate

the performance of system.

- **SNR:** It is defined as ratio of signal power to the noise power called as signal to noise ratio.
- **Sequence:** Representation of data in serial or logical order.
- **Technique:** It is the way of express the system employing the particular mechanism.
- **Wireless communication system:** It is a system via which sender communicates with the receiver by transmitting data through the wireless channel.

CHAPTER 3 REVIEW OF LITERATURE

3.1 [3] S.M. Alamouti has described the diversity and orthogonal code:

In October, 1998 Alamouti presented a paper, which utilizes the transmit diversity scheme and allows low effective bit error rate (BER). It is extremely difficult to reduce the effect of the multipath fading channel. In AWGN channel, it requires 1 or 2 dB change in Signal to noise ratio(SNR) so as to reduce the bit error rate from 10^{-2} to 10^{-3}. However, it may require about 10 dB improvements in SNR in multipath fading. The improvement in value of SNR cannot be achieved by increasing the power of transmission or increasing bandwidth, because it is contrary to the next generation requirements. The paper shows that this reduction in bit error rate can be achieved using diversity. This is one of the popular and simple techniques for MIMO technology. The encoding technique of symbols has the orthogonality property to a low complexity maximum likelihood decoding of the transmitted signals. This transmission scheme was presented for 2 transmit antenna and 1 receive antenna, which achieves full rate and full diversity of 2 over complex constellation symbols. It is also shown that it has dual diversity property i.e. it can achieve same full diversity of 2 with one transmit antenna and 2 receive antenna using maximal-ratio receiver combining (MRRC). This transmission technique can be extended for 2 transmit antenna and *M* receive antennas which again provides a full diversity of order of 2M. So by this scheme, neither feedback from receiver to the transmitter is required nor expansion in bandwidth is needed. This is the only scheme which achieves the full rate over complex constellation symbols.

3.2 [4] V. Tarokh et. al. has described design criteria for space time codes:

The paper has unveiled the new codes popularly called as space time block code (STBC). In this paper, new channel codes were developed for reliable transmission over multiple fading channels using multiple antennas and high data rate. The channel codes are used to encode the data. These encoded data are splited into ‘m’ streams and ‘m’ transmit antennas are used for transmitting them. A design criterion has been derived for designing the channel codes. The design criterions are derived for a channel which is slow fading and frequency non-selective. The design criterion quantifies the diversity gain by the minimum rank of the difference matrix and coding gain by the determinant of the difference matrix. The encoding and decoding complexity of the code is comparable with trellis codes. The received signals are the linear combinations of the *'m'* transmitted signals at each receiver antenna. The results are simulated for 2 and 3 bit/symbols over fast fading channels. The paper gave an insight to the operating bandwidth efficiencies and the decoding complexity of the codes is almost equivalent to the codes used in practical on gaussian channels.

3.3 [5] V. Tarokh et. al. has described the new family of space time block codes and its limitations:

This paper was an extension of [4], which has shown some constraint on the number of transmit antenna. The paper gave a name to the codes developed in [4] as Space Time Block Code (STBC). The codes must be orthogonal to each other for simple and linear decoding of the transmitted signals at the receiver end. The paper applies the theory of orthogonal designs to construct the space time block codes which is analogues to Alamouti's scheme. This paper generalizes the space time block code for more than two transmit antenna over real and complex constellation both. The paper studied the property of the complex orthogonal designs and proved for complex constellation, it is not possible to apply orthogonality over more than two antennas. Therefore it states the scheme proposed by Alamouti [3] as a special case. The paper also developed the theory of complex generalized orthogonal designs. These designs have a linear and simple maximum likelihood decoding for arbitrary number of antenna. The designs provide half of the maximum possible rate and full diversity over complex constellation. There are several other codes were developed as a special case for 2, 3 and 4 transmit antenna which provide the ¾ of possible maximum rate.

3.4 [6] Shikha Gupta et. al. has described the performance analysis of Alamouti and OSTBC in MIMO System in Rayleigh channel:

Here this paper provides the performance analysis of BER for the STBC codes using generalized orthogonality principles with the QAM modulation technique. In this performance analysis, change in bit error rate Correspondance to change in value of SNR is evaluated by changing the different parameters as the variations in channel and configuration of transmit and receive antennas employed. They have analyzed the performance of Alamouti Space time block code and

OSTBC code with half code rate in rayleigh fading channel with different configuration of antenna at transmtter and receiver side and compared them for better BER performance. It is observed that intersymbol interference(ISI) in frequency selective fading channel is removed by using space time block codes of MIMO technology and they perform better in mitigating the effect of intersymbol interference if orthogonality property is applied. The most prominent OSTBC code is Alamouti code. In OSTBC, simple algorithms for detection of symbols employed at receiver side can separately recover transmit symbols thus providing full diversity. Full diversity is possible but full transmission rate cannot be acheived for complex constellation OSTBC when greater than two antennas are considered at transmitter side. It results that acheivement of full data rate and diversity with 2 transmitting antennas is only possible with Alamouti OSTBC . It has been concluded that the BER performance of OSTBC with half code rate for maximum likelihood decoding performs better.

3.5 [7] C. Arunachalaperumal et. al. has described performance evolution of Trellis coding in MIMO Communication Systems:

This paper discusses the evolutional variants of Space Time Trellis Code developed over a decade. With use of trellis coded modulation along with space time trellis codes (STTC), coding gain can be achieved with efficient bandwidth utilization. These new trellis codes perform better as compared to previously existing codes within the range of low to medium value of signal to noise ratio. Here performance evaluation of STTCs with 4-PSK modulation technique with 3 and 4 transmitting antennas in quasi static flat fading channel is analyzed and compared with codes with 2 transmit antennas. It is observed that BER performance of STTCs with more than 2 transmitting antennas in fading channel is better as compared to codes with 2 transmit antennas. The objective of space–frequency trellis codes is to design the STTCs both in fast and slow fading channels jointly. It is also found that the design developed is robust against the time delay of multipath. The communication performance of the new space-time bit trellis coding (STbitTC) is comparable to state of the art systems for lower data rates and outstanding for very high data rates.

3.6 [8] Munia Patwary et. Al. has described Study of STC Schemes for choosing antennas at transmitter:

There has been described that effect of multipath fading and intersymbol interference has been mitigated and improvement in BER performance or data rate can be achieved by employing signal processing and diversity techniques at both the sender and recipient side. It is also observed that capacity of system varies linearly with the count of antennas employed at both the sides and thus increase the reliability of wireless communication. It reviews results on familiar antenna selection diversity, followed by a discussion of performance of different space time coding gains and error probability at the transmit side. In this paper, it is deduced that for higher value of SNR, coding gain of the STTC is higher than that of space time block code (STBC) as the error probability of STTC is lower than STBC, the same diversity being achieved by both the codes. By increasing the amount of transmit and receive antenna, diversity can be increased and vice-versa. The same phenomena are applicable for more count of antennas at sender and receiver. The error probability for 4 transmit and 4 receive antennas is improved in comparison to 3 transmit and 3 receive antennas, and the error probability for 5 transmit and 5 receive antennas is further improved in comparison to 4 transmit and 4 receive antennas.

3.7 [9] Siavash M. Alamouti et. Al. has described Trellis Coded Modulation (TCM) and Transmit Diversity design criteria and performance evaluation:

Here in this paper, design procedure for choosing trellis codes with simple transmit diversity scheme is described. Using this method both diversity and coding gain can be achieved using 2 transmitting and one receiving antenna. For designing this method, firstly they derived the arrangements for soft decision viterbi decoding which are optimum and then using these optimum metrics, asymptotic coding gains are calculated. It has been shown that optimal trellis codes designed for additive white Gaussian channel are also desirable for using either scheme of transmit diversity in slow rayleigh fading and coding gain achieved by using both the channels is equivalent to each other.

3.8 [10] Nazia Parveen et. Al. has implemented Space Time Block code(STBC) using 2 transmit and 2 receive antennas:

In this paper, a basic overview of multiple input multiple output system is provided by introducing Alamouti's scheme of Space time coding technique. They have used the binary phase shift keying(BPSK) modulation technique and BER performance for constant 13 dB value of SNR is calculated. They have implemented the space time coding technique using Alamouti code and estimated the symbols at receiver side using the two transmit and two receive antennas. A comparison of Alamouti scheme with MRC scheme has been performed and concluded that

Alamouti scheme performs better than MRC scheme for constant value of 13 dB of SNR. In the end, there is further recommended that this work can be extended over other modulation schemes and more number of transmit and receiving antennas.

3.9 [11] Khushbu Sethi et. Al. has evolved the Performance of Different STBC codes with Linear Receiver:

This paper documented the performance of STBC over the multipath propagation i.e. Rayleigh fading channel using different configuration of transmit antenna and one receive antenna. It is also analysed that full diversity and transmission rate cannot be achieved using orthogonal criteria for space time block codes over the complex constellation for more than 2 antennas. Here performance evaluation for STBC and OSTBC with different configuration of 4 transmit and 1 receive antenna with the condition that transmitter has no knowledge of channel. After this performance evaluation, a new scheme for space time blovl code has been proposed and its comparison with other schemes is made.

3.10 [12] Zahoor Ahmed Baloch et. Al. has provided criteria for improving efficiency of Space Time Block Codes:

This paper proposed an approach for improving the spectral efficiency of space time code while retaning the full rate and diversity gain and it is flexible so as to be applicable to any configuration of transmit antennas. In their research, they have taken 4 transmit antenna in general and it is further concluded that this scheme can be employed to any number of transmitting antennas. They have designed a scheme where it is possible to send more information symbols in transmission block as compared to its counter part and it retained improve in efficiency of code with simple decoding.

3.11 [13] Umakanta Parida et. Al. has Analyzed Channel Coding in Fading Channels for MIMO Systems:

Here in this paper, a scheme of concatenation of OSTBC with TCM using different number of transmit and receive antennas has been proposed using the quasi static rayleigh fading channel with addition of AWGN noise. This model offers the combined advantage of orthogonality and trellis coded modulation as OSTBC provides the spatial diversity gain while coding gain is achieved by trellis coded modulation. This provided an improvement in performance as full diversity is achieved along with more than 2 dB coding gain without the requirement of interleavers/deinterleavers. The trellis structure of 8 states with 8 PSK modulation scheme is used Here the main disadvantage is for than 2 transmit antennas full transmission rate is not possible with OSTBC codes over complex constellation. Future work for design of new OSTBC scheme for full transmission rate over more than two transmit antennas and high state trellis has been recommended.

3.12 [14] P. Srinivasa Rao et. Al. has done performance evaluation of multiple input multiple output Systems using TCM and comprised with OSTBC:

This paper presents performance evaluation of different stbc schemes. They have evaluated the performance of high coding rate stbc and orthogonal stbc coded for antenna configuration of 3×4. they have also implemented the concatenated the OSTBC codes with trellis coded modulation to achieve full diversity and coding gain using QPSK scheme. Generalized pair-wise error probability (PEP) for the STBC was presented. Lastly it is concluded that concatenation of OSTBC with TCM provides significant improvement in performance and data rate can be increased using high code rate in STBC.

3.13 [15] Yi Gong et. Al. has done analysis of Concatenated STBC with TCM in Fading Channels:

In this paper, a new design criterion for construction of concatenated STC with trellis coded modulation(TCM) over the slow flat fading channels is presented. It presented an equation of error event probability for concatenated scheme which showed dominant factors degrading the performance of system over slow fading channels even in presence of perfect interleavers. Through simulation results it is shown that concatenating of interleaved streamed of these codes with space time block codes gives better error performance as compared to traditional existing codes over fading channels. These new designed codes are also evaluated over quasi static fading channel. Lastly it is concluded that system performance is better for concatenation of space time block coded with TCM as compared to concatenation of space time trellis codes with TCM under same considerations.

3.14 [16] Ramandeep Singh et. Al. has provided review of Space Time Trellis Codes with ideal beamforming for quasi-static Rayleigh fading channel:

This paper has compared the performance of STTCs with the use of beamforming and without the use of beamforming employed at transmitter side. They have called the space time trellis codes with beamforming at transmitter as Weighted Space Time Trellis Codes (WSTTC). It is deduced that more reliable wireless communication can be achieved with weighted pace time trellis codes as compared to traditional STTC without beamforming. Also it is concluded that FER performance of WSTTC is better than STTC.

3.15 [17] Santumon.S.D et. Al. has provided techniques for Space Time Block Coding (STBC) for Wireless Networks:

In this paper a basic overview of MIMO technology has been presented by employing Alamouti code over the Rayleigh fading channel. This Alamouti scheme is implemented using different modulation schemes i.e. BPSK, QPSK, 16-QAM and 64-QAM and is compared over these modulation schemes in Rayleigh fading channel. After that orthogonal STBCs for different modulation schemes and different code rates using 4 antennas at transmitting side and 1 receive antenna is implemented and compared and concluded that different application requires different modulation scheme. It is concluded that better performance is achieved with more count of transmit and receive antenna.

3.16 [18] Peh Keong TEH et. Al. has provided comparison of Beam Pattern Scanning (BPS) versus Space Time Block Codes (STBC) and Space Time Trellis Codes (STTC):

Here in this paper, a comparison of space time codes with beam pattern scanning scheme is performed. STCs include both the STBCs and STTCs and both are compared with this new scheme. The comparison is based on parameters like capacity of network, spectrum efficiency, error performance and in terms of complexity. It is shown that with BPS scheme, antennas elements over the base station are having time controlled varying weight vectors which provided the facility to antennas arrays to rotate in direction of required user and the receiver is having simple combining technique which helps in achieving time diversity of fast fading channel. It is concluded that BPS scheme performs better with smaller dimension of antenna, high capacity, and low complexity but with slight decrease in spectrum efficiency.

3.17 [19] Won Mee JANG et. Al. has provided Performance of STBCs in Wireless Channel Dynamics:

In this paper, it is observed the performance of STBCs with changing parameters of channel. The design and construction of block codes is simple in slow fading channel but is complex in quasi static fading channel. It is shown in results that with serial transmission in some channel features, convolutional coding outperforms the STBCs. This result also shows the requirement of robust STBCs in dynamically changing fading channel in wireless environment. It is expected that better performance in dynamically changing wireless channels ca n be achieved when space time block codes are employed with self encoded spread spectrum.

3.18 [20] Naintara Ghorela et. Al. has provided Weighted Space Time Bit Trellis Coded Modulation for Quasi-Static Rayleigh Fading Channel:

Herein this paper, three presented the new concept where ideal beamforming is combined with space time bit trellis codes. And this combined effect produced a new code termed as weighted space time bit trellis code. Here the results are evaluated for weighted space time bit trellis codes over slow fading cannel using 4-QAM modulation scheme with data rate of 2 bits per channel with antenna configuration of 4x4 at transit an receive side and it is concluded that this schemes performs better than traditional STTCs. Further it is shown that better performance can be achieved with weighted space time trellis coding with channel state information(CSI) is available at transmitter side.

3.19 [21] Dharmvir Jain et. Al. has provided adaptively Grouped Multilevel Space Time Trellis Codes(AGMLSTTCs):

This paper presented a new code termed as adaptively grouped MLSTTCs. This code is designed for better performance than conventional space time trellis coding as it combines the simultaneous benefits of multilevel coding (MLC), Space Time Trellis coding (STTC), antenna grouping and CSI at transmitter. Due to the combined effects of all the schemes concatenated in single scheme, there occurs an improvement in coding gain, diversity gain, and spectral efficiency is also increased. Further improvement in performable is achieved when transmitter is known to channel state information which is used for grouping of antennas adaptively at transmit side. The grouped multilevel space time trellis codes (GMLSTTCs) also combine the benefits of multilevel coding (MLC), space time trellis coding (STTC) and antenna grouping. The performance of GMLSTTCs can be limited by antenna grouping predefinement. Lastly simulation results have shown that AGMLSTTCs enable to transmit more than one data symbol per time slot with improved error performance over GMLSTTCs with predefined transmit antenna grouping.

CHAPTER 4 RATIONALE AND SCOPE OF THE STUDY

4.1 Overview

In this thesis, our motive is to portray an analysis that is general and comprehensive. We extend existing results as well as present new ones. We present the analysis of channel codes, convolution codes, STBC code, STTC code and adaptively grouped multilevel code.

In particular,

- We give general analysis with respect to different modulation techniques.
- We derive the error probability for the AWGN channel and Rayleigh channel.
- We give general analysis with number of transmit and receive antennas.

Here first we have implemented and compared the linear block codes in AWGN channel using BPSK modulation technique. Then comparison between linear block codes and convolution code as channel coding technique in AWGN using 16-QAM modulation technique is performed which concludes that convolution code as channel coding technique provides us better performance. As AWGN channel is the idle channel but in real environment, transmission of data suffers from multipath propagation and fading, so performance of convolution code is evaluated over Rayleigh fading channel. The performance of convolution code in Rayleigh fading channel is compared using different modulation techniques. We have also implemented the MIMO system where STBC code is implemented using different antenna configuration. After that performance of STTC code using multiple antenna configuration is compared with regard to different modulation techniques and QAM modulation technique gives us better performance. Then STTC code is evaluated using the concept of with beamforming and without beamforming. In the end, implementation of multilevel code using different antenna configuration in AWGN and Rayleigh channel is performed and compared.

The thesis is divided into sections.

Chapter 1, "Introduction" presents the basic introduction to thesis topic and brief review to its challenges and solutions.

Chapter 2, “Terminology” gives the insight of frequently used terms in the thesis.

Chapter 3, “Review of Literature” presents the previous work done by researchers and their discussions on the resultant outputs.

Chapter 4, “Rationale and scope of the study” tells about the scope of work done in thesis and outline of the thesis.

Chapter 5, “Objectives of the study” introduces the main objectives implemented in this research work.

Chapter 6, “Material and Research Methodology” describes the simulator, techniques used and steps included in implementing the work.

Chapter 7, “Channel Encoding” presents us with concepts, practical applications and advantages of channel coding. Furthermore, it also deals with two major channel coding techniques namely convolution codes and linear block codes.

Chapter 8, “Multiple antennas wireless communication system” introduces the concepts related to MIMO wireless communication and discusses the modeling of the system. It also gives insights into STCs i.e. STBC and STTC.

Chapter 9, “Results and Discussion” presents the simulation results, which include the SNR vs BER performance of the coding techniques and space time codes.

Chapter 10, “Conclusions and future work” summarizes the analyzed results explained in the previous chapter and discusses about future work for this thesis.

CHAPTER 5 OBJECTIVES OF THE STUDY

5.1 Overview

MIMO communication system are of great practical importance for two main reasons: First, a transmitter with multiple antennas can communicate at a higher data rate and more reliably than a transmitter with a single antenna. Second, power and size constraints prevent many devices, especially in mobile applications, from having more than 2 antennas. Several STBCs have been proposed specically for this practically important configuration.

Space time trellis codes (STTC) are one of STCs designed for multiple input multiple output (MIMO) enviroment where multiple antenna configuration is employed at sender and receiver side. This multiple antenna configuration is used to transmit multiple copies of data over the channel and these multiple copies are received by multiple antennas at receiver side and is recovered actual transmitted data using Viterbi decoder. STTC are better than STBC codes because both the diversity gain as well as coding gain can be achieved by STTC. But they are more complex to construct as compared to STBC codes and are decoded using Viterbi decoding while STBC only requires simple decoding.

For instance, main objective is to :

- Implementation and comparison of channel coding techniques in linear block codes using BPSK(Binary phase shift keying) in AWGN channel.
- Implementation and comparison of channel coding techniques i.e linear block codes and convolution code using QAM(Quadrature Amplitude Modulation) in AWGN channel.
- Implementation and comparison of convolution code using different modulation techniques in Rayleigh channel.
- Implementation and comparison of Space time trellis code using different modulation techniques in Rayleigh channel.
- Implementation of grouped multilevel space time code.

CHAPTER 6 MATERIAL & RESEARCH METHODOLOGY

6.1 Overview

MATLAB TM is a software package which provides simulation results in technical computing, integrating programming, visualization, mapping, graphical representaion, mathematical modelling and computation in a flexible and compatible environment. It has best advantage of extensibility with its own upgraded versions. Common uses of MATLAB TM involve :

- Mathematics (Arrays and matrices, linear algebra, etc.)
- Programming development (Function, data structures, etc.)
- Modeling and simulation (Signal Processing etc.)
- Data analysis (statistics etc.)
- Visualization (graphics, animation etc.)
- Algorithm development
- Application development, including Graphical user interface building

All the simulations were performed by automation programs(.m files) which were created by me.

6.2 Methodology

The proposed steps for the research carried out in this thesis is as follows:

- Generation of random bits on the transmitter side.
- Encoding of the randomly generated bits as per the requirement of the coding technique used.
- Modulation of the encoded data using modulation techniques.
- Passing the modulated data from the transmitter antenna over the channel.
- Addition of the noise to the transmitted data over the channel.
- Equalisation of the received data on the receiver side to compensate the effect of channel.
- Demodulation of the received data using corresponding technique used on the transmitter side.
- Decoding of the demodulated data using the same technique which is used on transmitter side.

- Calculation of the bit error rate by comparing original transmitted data by decoded data.
- Plotting of the BER over the different multiple SNR values.

Here for the modulation of the encoded data, we have used PSK and QAM modulation techniques. The channels used are AWGN channel and Rayleigh channel. Implementation of linear block codes and convolution code are carried in SISO channel while STBC, STTC and Multilevel codes are implemented in MIMO channel with different antenna configurations. In STTC and Multilevel codes, 128 state trellis structure is used. The performance of these techniques is evaluated by plotting BER over SNR range in between (0-30)db.

CHAPTER 7 CHANNEL ENCODING

7.1 Introduction

Channel coding or error control coding is one of the main pillar of modern communication system. In the today's age, information has become the key to success and this information is exchanged in form of 0's and 1's i.e. binary data. Since this data is going to be travel through channel and prior transmission of this digital data, it is required to modulate it by analog carrier signal. While transmission through channel, there is very high probability of the data being corrupted and there comes the role of error control coding/channel coding. Specifically, reduction in error rate can be made to communication system for enhancing its reliability by employing particular coding scheme [22].

7.1.1 Noise

A simple and good model to understand the net effect of noise on the transmitted signal is additive white Gaussian noise. In this model, noise is

1. Additive: consider y(k) sample is received at k^{th} time and it is interpreted as combination of two components: one is noise free component $y_o(k)$ and another is noise component w(k) which is presumed to be not dependent on input waveform.

$$y(k) = y_o(k) + w(k)$$

2. White: It refers to the equal distribution of power at all the frequency components of noise signal.

3. Gaussian: The random noise component w(k) quantity is taken from Gaussian probability distribution with zero mean(μ) and some value of variance(σ^2) independent of input waveform. If the Gaussian noise variable is independent from one sample from another, then the above process can be called to as additive white Gaussian noise.

Probability density function (PDF) for Gaussian distribution is written as:

$$fW(w) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(\omega-\mu)^2/2\sigma^2}$$

Value of μ is taken as zero for zero mean noise i.e. $\mu = 0$.

Assuming that PDF given as fW(w) is governing all the values given by noise distribution of noise samples w[k] then fW(w) determines the probability that W or w[k] occupies values in vicinity of w. Specifically,

$$P(w \leq w[k] \leq w + dw) \approx fW(w)\, dw\ .$$

In particular, the probability that value of w[k] lies between two values w1 and w2 is presented by:

$$P(w_1 \leq w[k] \leq w_2) = \int_{w1}^{w2} fW(w)d(w)$$

Also the capacity (*C)* of AWGN channel is given by

$$C = B \log2\ (1 + \text{SNR})\ \text{bits/sec},$$

Where, *B* is called as channel bandwidth and SNR is referred as signal to noise ratio [23].

7.1.2 Bit Errors

Bit errors are generated by noise when received voltage samples affected by noise are incorrectly interpreted by receiver, thus decreasing the quality of communication between transmitter and receiver user. When we calculate the fraction of erroneous received bits after transmitting the large amount of known bits then we incur a measure which asymptotically approaches the BER, which gives the probability of occurrence of bit error referred to as P(error) which causes the receiver to identify “1” as “0” and “0” as “1” due to disruption of noise.

There are two mutually exclusive possibilities when bits are incorrectly interpreted at receiver:

1. The transmitter transmits d = 0 at voltage $V1= - \sqrt{Es}$ and the value received is greater than zero;
2. The transmitter transmits d = 1 at voltage $V2= + \sqrt{Es}$ and the value received is less than zero.

The probability when values are taken larger than $\sqrt{Es}$ by zero-mean Gaussian noise variable W is referred to as BER given as:

$$\text{BER} = \text{P(error)} = \frac{1}{\sqrt{2\pi\sigma^2}} \int_{\sqrt{Es}}^{\infty} e^{-w^2/2\sigma^2} dw$$

We will denote $2\sigma^2$ by N_0 also called as the noise power and σ^2 is a measure of the probable power in the underlying AWGN process. By performing some operations, equation reduces to

$$\text{BER=P(error)} = \frac{1}{\sqrt{\pi}} \int_{\sqrt{Es/N_0}}^{\infty} e^{-v^2} dv$$

This equation defines probability distribution of Gaussian function and can be represented using two important functions called the error function, erf(z) and the complementary error function, erfc(z)=1− erf(z)

$$\text{erf(z)} = \frac{2}{\sqrt{\pi}} \int_0^z e^{-v^2} dv \quad \text{and}$$

$$\text{erf(z)} = 1\text{- erf(z)} = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-v^2} dv$$

After simplification, BER equation for AWGN channel for binary signaling scheme can be written as:

$$\text{BER} = \text{P(error)} = \frac{1}{2}\,\text{erfc}\sqrt{\frac{E_S}{N_o}}$$

Thus BER for our bipolar keying scheme can be determined by ratio of power required to send a bit or energy referred to as E_s of the voltage sample chosen from equivalent time slot at receiver with assumption of no noise to the noise power (N_o) came across during reception of signal by using specific decision rule at the receiver . This ratio is called as the SNR(signal to noise ratio) of the communication scheme.

7.2. Channel Coding

As the data is transmitted through channel and we are familiar of the fact that all real life channels are affected by noise which gives rise to errors or discrepancies in the actual data. If we consider the case of a typical noisy channel then chances of occurrence of error or probability of bit error can be as large as 10^{-2} which means on mean one bit is corrupted or flipped out of every hundred bits transmission of data through channel.

The main aim of forward error control coding/channel coding is to provide resistance to the digital communication system over the noise in the channel for reliable communication [24]. This motive of protecting the data from the noise is achieved by adding the redundant bits in the original transmitted data in a restrained manner. The addition of redundant bits in transmitted data sequence is done by channel encoder and after encoding of data, it is sent on noisy channel. At the receiver side, the received data is decoded/reconstructed back into its original form by decoder. So, the channel coding is providing reliability at the cost of reduction in data rate as redundancy is added. The achievement of proper and efficient transmission of data depends on the environment and type of the channel and the parameters of code used for channel coding [25].

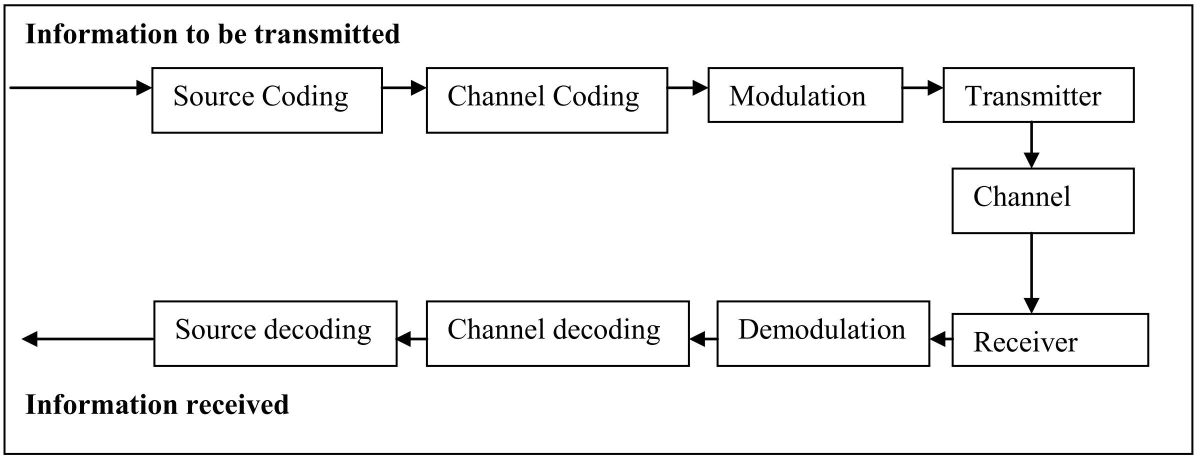

Figure 7.1 Channel coding in communication system.

7.2.1 Classification of Channel Codes

Channel coding uses two types of codes, namely

1. Block code
2. Convolutional code.

Block codes are usually referred to as (n,k) codes used for detection or correction of error. They consists of set of fixed codewords called as block length denoted by ‘n’ where (n-k) redundant bits are added to original ‘k’ bit message giving rise to final codeword of length ‘n’. These (n-k) redundant bits are checking bits used at receiver side for approval of occurrence of error and correction of error.

Another channel coding method is known as a convolutional code and is frequently used code in real life applications. There is very much difference in these duo codes. Linear code operations are usually algebraic and are memory less means decoding decisions relies on current codeword. While convolution codes can be represented by polynomials and requires memory because decoding decisions relies not only on current codeword but also on past codeword. Viterbi algorithm is one of most commonly used decoding strategy in convolution coding.

In many cases, convolutional codes are used in combination with block codes known as concatenated error correction codes.

7.3 Linear Block Codes

Linear block codes are (n,k) code where incoming data stream is first divided into block of ‘k’ information symbols and then these ‘k’ length information blocks are encoded into ‘n’ length codeword by adding redundancy of (n-k) bits. After addition of error correcting bits, these codewords are sent over channel. However, very large codewords has a disadvantage that unless the whole codeword is received at receiver side, we cannot start the decoding process which results in decay causing degradation in performance of communication system.

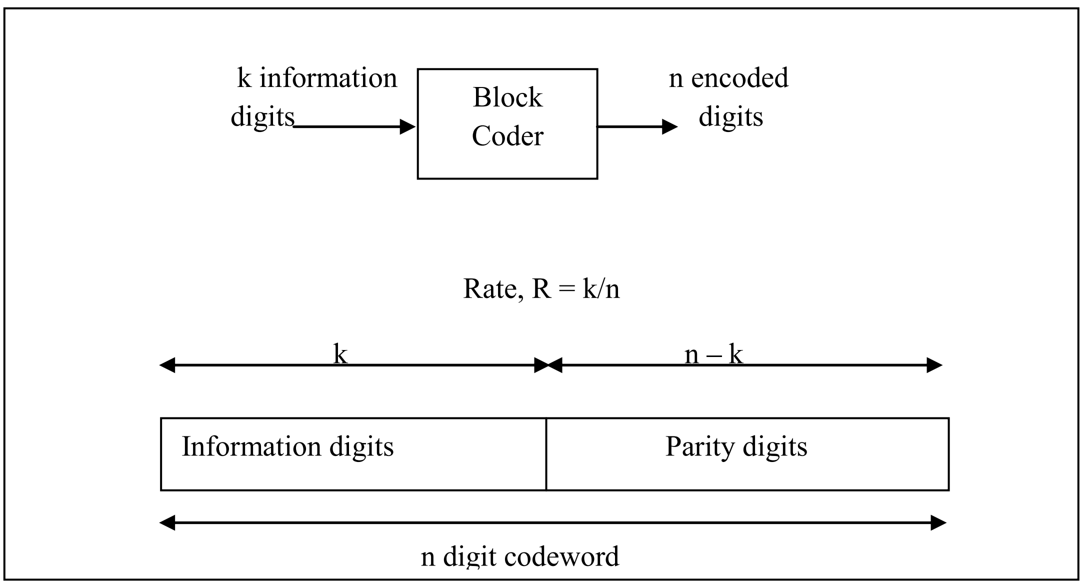

Figure 7.2 Structural Representation of linear block code.

Consider a block encoder which takes data blocks i.e. datawords, $d=(d_0,d_1,....d_{k-1})$ containing ‘k’ number of bits and is creating other blocks called as codeword $c=(c_0,c_1,....c_{k-1})$ containing ‘n’ number of bits where encoded bits are greater than information digits. This is called as (n, k) block code with a code rate of k/n. The ratio of k/n is called as code rate(R). The value of code rate for any code is usually less than unity(1). If the value of code rate is small then this implies that more number of redundant bits is added per message block. This may reduce the effect of noise on data but will increase the coding overhead as more number of redundant bits is transmitted instead of information bits.

This (n,k) code is considered to be systematic when the dataword ‘d’(d = n-k) is subset of codeword ‘c’ i.e. c = (b,d) where d consists of redundantly added bits called as parity bits.

Another important characteristic of linear block code are hamming distance and weight. The hamming distance among 2 given codewords gives the count of difference bits between codewords while weight w(c) of codeword c tells about the count of 1’s in that codeword. There is an another parameter called as minimum distance(d_{min}) between codewords used to characterize the code and using this, ‘t’ errors can be discovered by LBC if and only if

$$d_{min} \geq t+1$$

and recovers up to ‘t’ errors if and only if

$$d_{min} \geq 2t+1$$

if there is equality’=’ in both the above written mathematical statement for d_{min} then code is considered to be perfect code.

The process of coding the data is accomplished by

$$c=dG$$

Where d = dataword,

G = Generator matrix containing matrix P defining computation of parity bits and identity matrix I_k of (k × k) matrix.

$$G = [P,I_k]$$

The parity check matrix H helps to detect and correct the error at receiver end.

$$H = [I_{n-k},P^t]$$

At the receiver end, decoding is done by syndrome matrix S.

$$S = [\hat{c},H^t]$$

Where ĉ (received codeword) = c ⊕ e , e = error.

7.3.1 Hamming Code

In 1950, Hamming codes were invented by Richard Hamming and they are part of family of linear block codes. They are 1st class of linear codes devised for error correction [26]. Hamming codes are able to achieve minimum distance of three and the highest possible rate for codes with their block length, thus also called as ‘perfect codes’. A property *p*-error correcting code has the feature that there is exact distance of ‘p’ between every codeword lying in Hamming space [26].

Hamming code can detect error of 2 bits but only 1 bit error can be corrected using the property of largest value of minimum hamming distance (d_{min}) [27]. Thus they are also called as SEDDED which means single error detection double error detection. They are widely used for correction of errors in data storage systems.

For any integer(positive) say $a \geq 3$ exists a Hamming code having the following parameters:

parameters	**Values**
Length of the codeword, n	$2^a -1$
Length of the message symbols, k	$2^a -1-a$
Length of the control/parity symbols, a	n-k
Error-correction symbols, t	$(d_{min}-1)/2$, i.e. t=1(d_{min}=3).

Table No. 7.1 Parameters of Hamming code

The disadvantage of hamming codes is that as the number of bits increases, they become increasingly inaccurate.

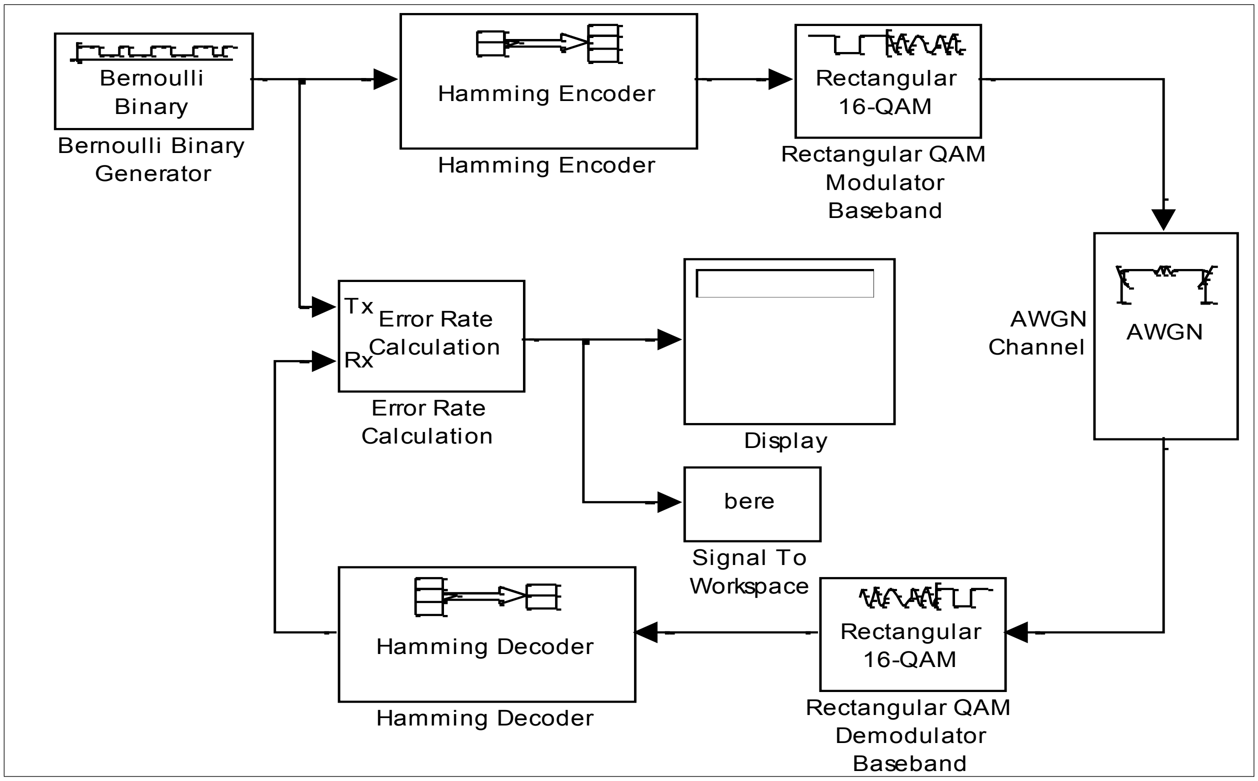

Figure 7.3 Simulink model for hamming code

7.3.2 Reed Solomon code

Reed-Solomon codes are important subset of BCH codes(Bose,Chaudhuri and Hocquenghem code) and they form one class of linear block codes that are non binary as well as cyclic code in nature [28]. Reed-Solomon codes were discovered in 1960 by Larry S. Reed and Gustave Solomon, who wrote "Polynomial Codes over Certain Finite Fields" [29]. They are widely used in many application areas like in digital communication, satellite communication, mobile communication and modems(ADSL) etc.

In (n,k) RS code, t symbols causing error in codeword can be corrected by RS decoder where 2t = n-k. It is possible to attain the minimum distance of the linear code to be largest via the use of same input to encoder and output block length in case of Reed Solomon code [30].
RS codes are good at dealing with bursts of errors. In CD technology, current implementation of RS code can cope up with burst error of 4000 consecutive bits.

RS (n, k) exists for $0 < k < n < 2m + 2$. The parameters of Reed-Solomon codes are:

parameters	values
Length of the codeword, n	$2^m - 1$
Length of the message symbols, k	2^m-1-2t
Length of the control or parity symbols, 2t	n-k
Minimum distance of codeword, d_{min}	n-k+1
Error correction capability, t	(n-k)/2

Table No. 7.2 Parameters of RS code

The structural representation of Reed-Solomon Code is shown in Fig. 7.4. Here length of codeword is 'n' symbols consisting of 'k' message symbols and '2t' parity symbols.

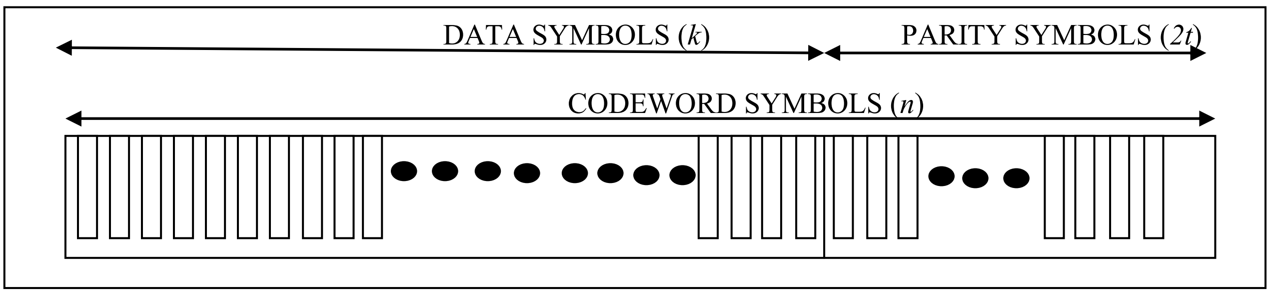

Figure 7.4 Structural Representation of Reed Solomon code.

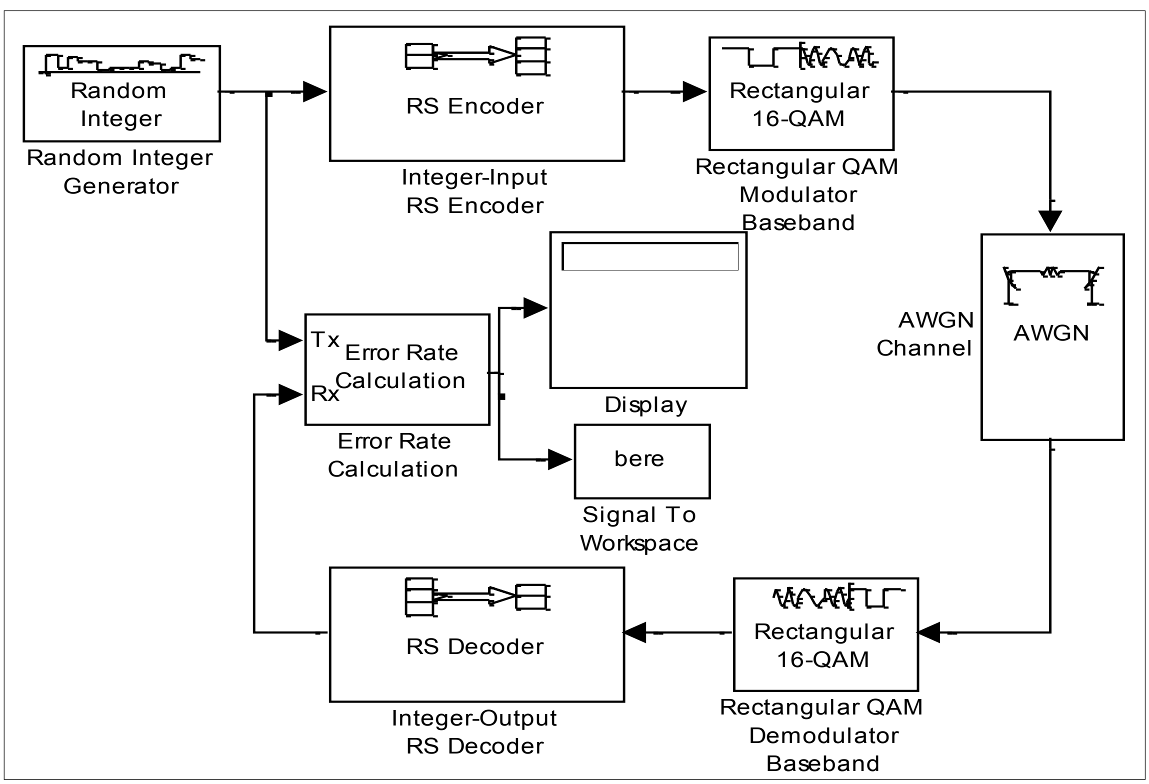

Figure 7.5 Simulink model for Reed Solomon code.

7.3.3 Cyclic Redundancy Check Coding

Cyclic codes were first studied by Prange [31]. Cyclic redundancy check coding is a cyclic error-control coding technique where cyclic constraint implies that cyclic shift of codeword results in another codeword which is implemented using shift registers. CRC codes are also called as polynomial codes. Unlike block codes, CRC codes are only able to detection of errors but not able to correct it. So, after the error is detected at the receiver side, a request is sent to the transmitter side to retransmit the data. CRC codes are able to detect burst errors.

In CRC coding technique, a specific rule or pattern is followed to create checking bits called as checksum or syndrome and this checksum is the appended to the message word. At the receiver side, same pattern or rule is followed to recover the original data. In case if data is corrupted by noise, then we don't get non zero value of the resulting checksum and receiver will request the sender to retransmit the data. If the value of checksum is zero then it means no error has occurred.

The CRC library contains blocks that implement the CRC algorithm:

- CRC-N Generator
- CRC-N Syndrome Detector

The CRC-N Generator block calculates the checksum of 'N' bits for each input frame and these checksum bits are added to the message word to generate the final codeword which is sent over the channel. The CRC-N Syndrome Detector block is at the receiver side which computes the checksum from received codeword. It has two outputs: - message word without checksum and a binary error flag which is zero if checksum calculated from received codeword is 0 and 1, otherwise.

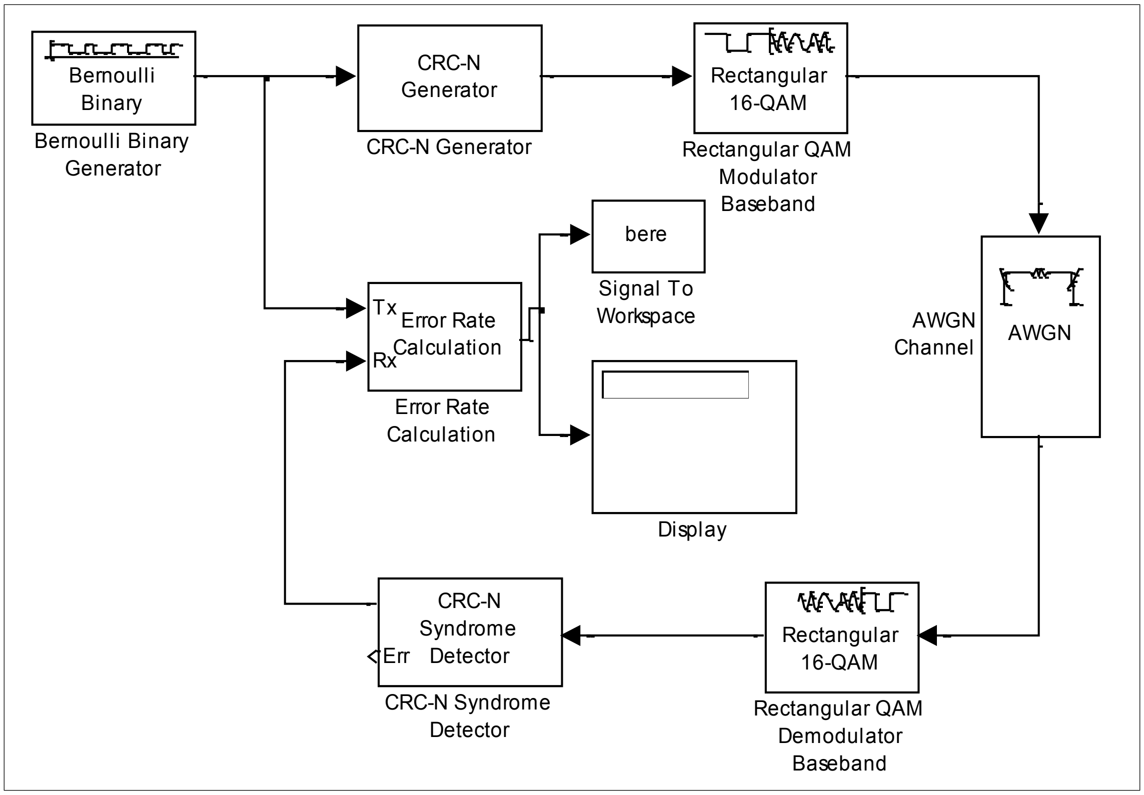

Figure 7.6. Simulink model for CRC code.

As cyclic codes can be represented by polynomials. So, codeword 'y' is written as:

$$y(\chi) = y_o x^o + y_1 x^1 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + y_{n-1} x^{n-1}$$

With modulo-2-arithmetic, polynomial division is performed to divide $f(\chi)$ and $h(\chi)$ such that

$$f(\chi) = q(\chi) \, . \, h(\chi) + r(\chi)$$

Where $q(\chi)$ defines the quotient and $r(\chi)$ is the remainder defined as:

$$r(\chi) = f(\chi) \mod h(\chi)$$

An (n,k) cyclic code can be specified by a polynomial of degree (n-k) called as generator polynomial $g(\chi)$ which is also a factor of $(1 + x^n)$. Generator matrix of (n,k) cyclic code is expanded as:

$$g(\chi) = 1 + \sum_{i=1}^{n-k-1} gi \, x^i + x^{n-k}$$

where gi is a coefficient equal to 0 or 1.

Now each codeword is written as:

$$y(\chi) = a(\chi).g(\chi)$$

where a(χ) is a polynomial of degree k-1. It is also to be considered that concluding code is not systematic. The (n,k) cyclic code can also be specified by an another polynomial of degree 'k' called as parity check polynomial h(χ) which is also a factor of $(1 + x^n)$ which is related to generator polynomial as:

$$g(\chi) . h(\chi) = 0 \bmod (1 + x^n) \quad \text{or}$$

$$g(\chi) . h(\chi) = (1 + x^n)$$

In modulo-2- arithmetic, $(1+x^n)$ has same values as $(1-x^n)$. For simplicity, we considered systematic code c = (b,d) and encoding is carried out by following equations:

$$y(\chi) = b(x) + x^{n-k}d(x) = (x^{n-k}d(x) \bmod g(\chi)) + x^{n-k}d(x)$$

with $$b(x) = x^{n-k}d(x)$$

This encoded codeword y(χ) is transmitted over channel and received codeword is expressed as:

$$\hat{y}(x) = y(x) \oplus e(\chi)$$

Where e(χ) is certain error pattern. The syndrome polynomial is defined as $s(\chi) = \hat{y}(\chi) \bmod g(\chi)$. It is derived as $s(\chi) = e(\chi) \bmod g(\chi)$ which means syndrome polynomial also depends upon error polynomial e(χ) . If the error pattern weight is found to be less than $(d_{min}/2)$, then syndrome of e(χ) is unique giving us decoding criteria where we need to find error pattern with less weight and syndrome polynomial s(χ) .

7.3.4 BCH Code

In coding theory BCH codes are linear cyclic errors correcting code which were invented independently by French mathematician Alexis Hocquenghem in 1959 and Raj Bose and D.K. Ray Chaudhuri in 1960.

BCH codes are known for their multiple errors correction ability and ease of their simple encoding and decoding via an algebraic method known as syndrome decoding. This simplifies the design of the decoder for these codes, using small low-power electronic hardware.

For any integer $m \geq 3$ and $t < 2^{m-1}$ there exists a primitive BCH code with the following parameters:

parameters	values
Length of the codeword, n	$2^m - 1$
Length of the message symbols, k	2^m-1-mt
Length of the control or parity symbols, mt>=	n-k
Minimum distance of codeword, $d_{min>=}$	2t+1
Error correction capability, t	(n-k)/m

Table No. 7.3 Parameters of BCH code

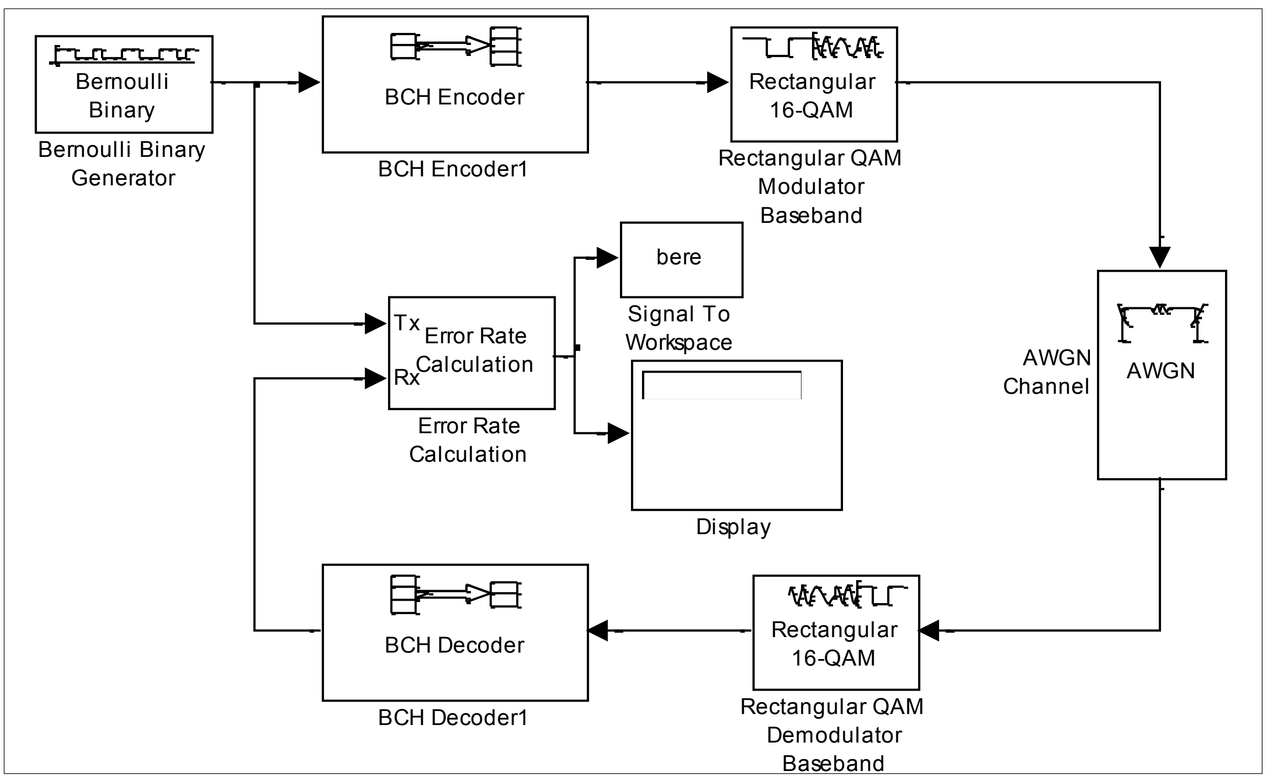

Figure 7.7 Simulink model for BCH code.

7.4 Convolutional Code

Convolution codes are one of the most practically used codes for channel coding in communication systems. In convolution coding decoding decisions are based on present codeword as well as past codeword. Here firstly incoming stream of data is broken into segments called as information frame and these information frames are then encoded by encoder. The encoder consists of two main parts: - memory (usually a shift register) to store previous codeword and a logic circuit. The constraint length of encoder gives the number of the bits that can be stored in its memory. They do not have a predefined code length as block code [32]. Each time a new frame arrives at the encoder, it computes the codeword frame using the current frame and previously stored frame. The computation of this new codeword is accomplished by logic circuit. Then shifting of new codeword frame along with discardation previously stored frame is made. It should also be noted that same information frame may not generate the same codeword because the generated codeword also relies on previous stored frame along with current frame.

Two types of decoding criteria of convolution codes are there: - soft decision decoding and Viterbi decoding. Viterbi decoding is developed by Andrew J. Viterbi 1967 [33]. Viterbi decoding is mostly used decoding algorithm for convolutional coding with advantage of high speed, easy implementation, high satisfactory bit error performance and low cost.
The ratio of codeword symbols i.e. ‘n’ to the message/data symbols i.e. ‘k’ is referred to as base code rate.

The Viterbi algorithm finds the maximum likelihood estimate of the transmitted sequence over the channel. Consider an information sequence $v = (v_o,......,v_{M-1})$ of length kM is encoded into codeword $y = (y_o,.....,y_{M+m-1})$ of length $N = n(M+m)$ and Q-ary sequence $r = (r_o,.....,r_{M+m+1})$ is received over a binary input, Q-ary output discrete memory less channel(DMC). Now maximum likelihood decoder for DMC will choose estimate $\hat{y}$ of codeword y which maximises the value of log-likelihood function log P(r|y)

$$P(r|y) = \prod_{i=0}^{M+m-1} P(r_i \mid y_i) = \prod_{i=0}^{N-1} P(r_i \mid y_i)$$

It follows that

$$\log P(r|y) = \sum_{i=0}^{M+m-1} \log P(r_i \mid y_i) = \sum_{i=0}^{N-1} \log P(r_i \mid y_i)$$

Where $P(r_i \mid y_i)$ is the channel transition probabality and there is minimum error probabality decoding rule when all codewords are equally likely.

The log likelihood function log P(r|y) is a term associated with path v and is denoted S(r|y) and the terms in summation of $P(r_i \mid y_i)$ are called branch metrics denoted as $S(r_i|y_i)$.

$$S(r|y) = \sum_{i=0}^{M+m-1} S(r_i \mid y_i) = \sum_{i=0}^{N-1} S(r_i \mid y_i)$$

A partial path term for the first j branches of a path can be represented as:

$$S([r|y]_j) = \sum_{i=0}^{j-1} S(r_i \mid y_i)$$

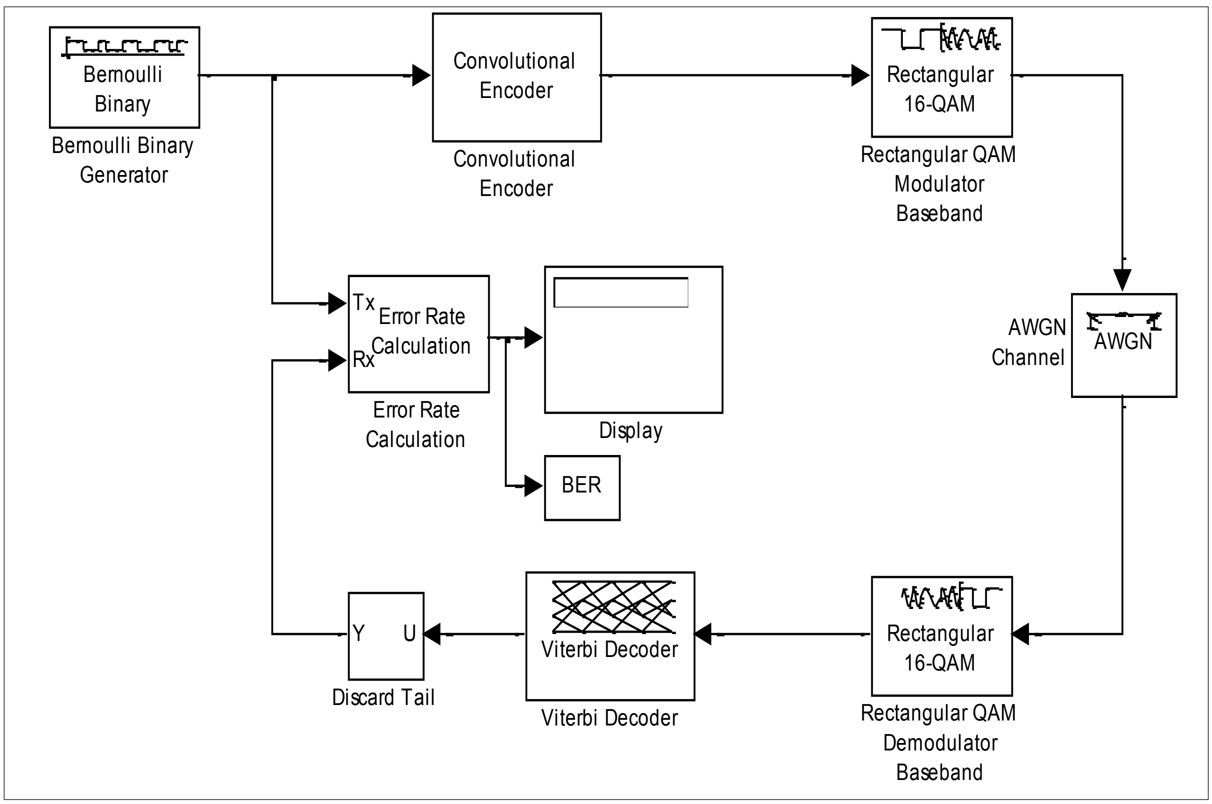

Figure 7.8. Simulink model for Convolution code.

The log likelihood function log P(r|y) is a term associated with path v and is denoted S(r|y) and the terms in summation of $P(r_i \mid y_i)$ are called branch metrics denoted as $S(r_i|y_i)$.

$$S(r|y) = \sum_{i=0}^{M+m-1} S(r_i \mid y_i) = \sum_{i=0}^{N-1} S(r_i \mid y_i)$$

A partial path term for the first j branches of a path can be represented as:

$$S([r|y]_j) = \sum_{i=0}^{j-1} S(r_i \mid y_i)$$

This algorithm is applied to receiver sequence r from a DMC to find the path through the trellis with largest term i.e. maximum likelihood path. The algorithm processes r in a repetitive manner. At each step, it compares the terms of all paths entering each state, and stores the path with largest term, called survivor, together with its term. This final survivor is the maximum likelihood path i.e.

$$S([r|\hat{y}]) \geq S(r|y) ; \qquad \text{all } y \neq \hat{y}.$$

CHAPTER 8 MULTIPLE ANTENNA WIRELESS COMMUNICATION SYSTEM

8.1 Channel Model

In the wireless communication technology, data is propagated in the form of em radiation from the sender to the receiver over the wireless channel where it suffers from multipath propagation, interference, scattering, reflection, refraction, diffraction due to presence of buildings, environment, mountains and other objects. Transmitted waves are received at receiver through many different paths. These separate versions of signal experiences different path loss, phases and reach at the receiver at the different times [34]. It is often complex to obtain an absolute model of deterministic channel due to difficult calculation of electromagnetic wave equation taking into consideration of all the obstruction caused by ground, buildings, and vehicles. Thus we resort to the statistical models to characterize the signal propagation [35].

In general there are two channel models commonly used, one is AWGN and another is Rayleigh channel.

8.1.1 AWGN Channel Model

A simple and good model to understand the net effect of noise on the transmitted signal is additive white Gaussian noise. In this model, noise is

1. Additive: consider y(k) sample is received at k^{th} time and it is interpreted as combination of two components: one is noise free component $y_o(k)$ and another is noise component w(k) which is presumed to be not dependent on input waveform [36].

$$y(k) = y_o(k) + w(k)$$

2. White: It refers to the equal distribution of power at all the frequency components of noise signal.

3. Gaussian: The random noise component w(k) quantity is taken from Gaussian probability distribution with zero mean(μ) and some value of variance(σ^2) independent of input waveform. If

the Gaussian noise variable is independent from one sample from another, then the above process can be called to as additive white Gaussian noise.

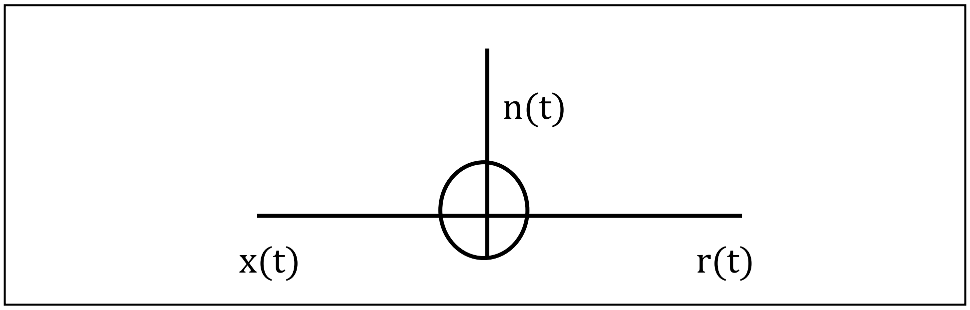

Figure 8.1 AWGN Channel Model

8.1.2 Rayleigh Fading Channel Model

In Rayleigh fading channel, the received signal is impaired by multipath fading as well as AWGN. Based on bandwidth(BW) of channel and signal, it can be divided into two models.

Narrowband systems or flat frequency: In this type of systems, coherance BW of channel is more than the transmitted signal BW; this type is also referred to as frequency non-selective due to equal fading of all the frequency components of signal.

$$\text{BW(channel)} > \text{BW(signal)}$$

Wideband systems: In this type of systems, coherance BW of channel is less than the transmitted signal BW; this type is also referred to as frequency selective due to independent fading of the frequency components of signal [37].

$$\text{BW(channel)} < \text{BW(signal)}$$

In the presence of wideband or narrow band system, the received signal is represented as:

$$\gamma(t) = h(t)\chi(t) + \eta(t)$$

Where χ(t) is the transmitted signal , γ(t) is the received signal, $\eta(t)$ is the noise signal and *h(t)* is the channel state information (CSI). *h(t)* causes the transmitted signal a random phase rotation and random amplitude fluctuation.

8.2 Diversity

The fading of channel results in inefficient and unreliable transmission of data. Fading causes gradual decrease in the power of transmitted signal due to which effective value of SNR drops dramatically on the receiver side. So the diversity techniques are extensively used in wireless system to remove the effect of fading in the channel. In diversity techniques, multiple copies of same data are transmitted over the multiple independent fading channel with probability that all signals will encounter the same effect of fading will be minimized [38].

At the receiver side, decoding can be performed by selecting maximum SNR signal or by assembling the multiple received signals. This is most important technique of wireless communication to mitigate the effect of fading. Several techniques of achieving diversity are available [39]. Some of them are discussed below:

8.2.1 Time Diversity

In this scheme, different time slots are used for transmitting the copies of information signal. To achieve time diversity, adjacent time slots must be separated by more than channel coherance interval so that the replicas of the signal experience independent fades. In this manner, we get multiple uncorrelated repetitions of the signal at the receiver.

Time diversity provides multiple replica of signal without increase in power of transmitted signal, but this scheme is not bandwidth efficient due to redundancy as the same data is transmitted in different slots of time [40].

8.2.2 Frequency Diversity

In this scheme, different carrier frequencies are used for transmitting the copies of information signal. To achieve frequency diversity, carrier frequencies must be separated by more than channel coherance bandwidth so that the copies of the signal experience independent fades.

It suffers from bandwidth deficiency and extra power is required to transmit signal over different carrier frequencies. For every carrier frequency, the receiver has to be tuned.

8.2.3 Spatial Diversity

Multiple transmitting and/or receiving antenna are used in spatial or antenna diversity. These are also called an antenna array and each element in the array is separated in distance [40]. The minimum distance between two adjacent antennas must be at least ½ of the signal wavelength to achieve diversity. In this manner, signal corresponding to different antenna fade independently. Spatial diversity does not suffer from bandwidth deficiency as is the case in temporal and frequency diversity [41]. But the use of multiple antennas has an area constraint in small handheld devices, due to the fact that a minimum physical separation is needed between antennas to achieve diversity.

Two types of space diversity:

- **Receive Diversity**

In receive diversity, multiple antennas are used on the receiver side assuming that fading will occur independently and these multiple received signals are combined at receiver causing significant reduction in fading effect. Receive diversity is equal to number of receive antennas used.

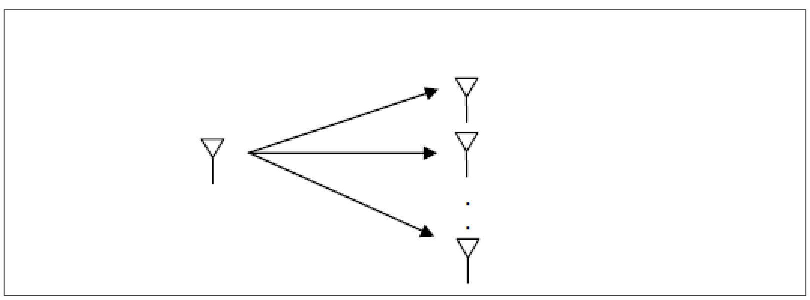

Figure 8.2 Receive Diversity

- **Transmit Diversity**

In transmit diversity, multiple antennas are used on the transmitter side assuming that fading will occur independently and transmit diversity is equal to number of transmit antennas used [42].

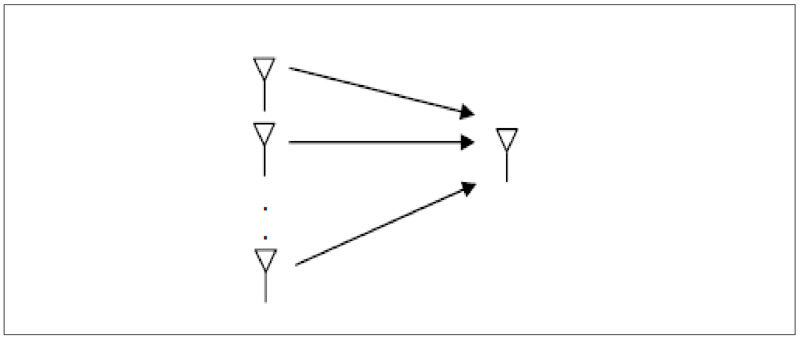

Figure 8.3 Transmit Diversity

8.2.4 Angular Diversity

In angular diversity, directional antennas are used. The beamwidth of receive antenna is restricted to a certain angle by the use directional antenna at the receiver and these different angles are used to receive different copies of transmitted signal.. Hence the received signal via multiple paths appears to be uncorrelated.

Angular diversity is good for small devices due to the fact that it does not need to separate physical locations of antennas like spatial diversity. However, requires a sufficient number of directional antennas to span all possible directions of arrival.

8.2.5 Polarization Diversity

In polarization diversity, signals are polarized horizontally and vertically to achieve diversity. Unlike spatial diversity, polarization diversity does not require separate physical locations for the antennas. However, polarization diversity can only provide a diversity order of two and not more.

8.3 Beamforming

It is MIMO technique where same data is transferred over multiple antennas with different angles pointing towards the receiver. Here power of the signal is concentrated towards the direction of the receiver. All the data signals received from the multiple antennas are combined coherently for the best optimal signal. This concept of beamforming leads to transmit and receive diversity scheme where SNR value is improved and it requires large value of SNR as compared to separate distinct channel configuration.

Thus, there is a design tradeoff in MIMO systems between capacity and diversity.

8.4 The MIMO System

MIMO technology is mostly used technology in wireless communication where multiple antennas are employed at transmitted and receiver end. In real life scenario, transmission suffers from fading and multiple scatteres and MIMO take advantage of this [43][44]. This technology improves the throughput, range, quality of service(QoS) and data rate. Many space time codes are implemented using the MIMO system where antenna arrays are used to provide diversity. Antenna arrays are used to transmit and receive data and data on receiver side is combined to get the resultant output thus by reducing the effect of fading.

The source data stream is fed to the transmitter block, after a series of data processing including data compression and channel coding, the data stream is encoded and divided into different stream of symbols, which can be independent, partially redundant or fully redundant. Each symbol stream is then sent to one of the transmit antennas and transmitted over the wireless channel after frequency up conversion and amplification.

At the receiver, the signal received by each receive antenna is a linear combination of the signals transmitted from all TN transmit antennas plus noise. After amplification and frequency down conversion, the decoder combines the received signals from all R N receive antennas into one data stream and detects the transmitted data streams.

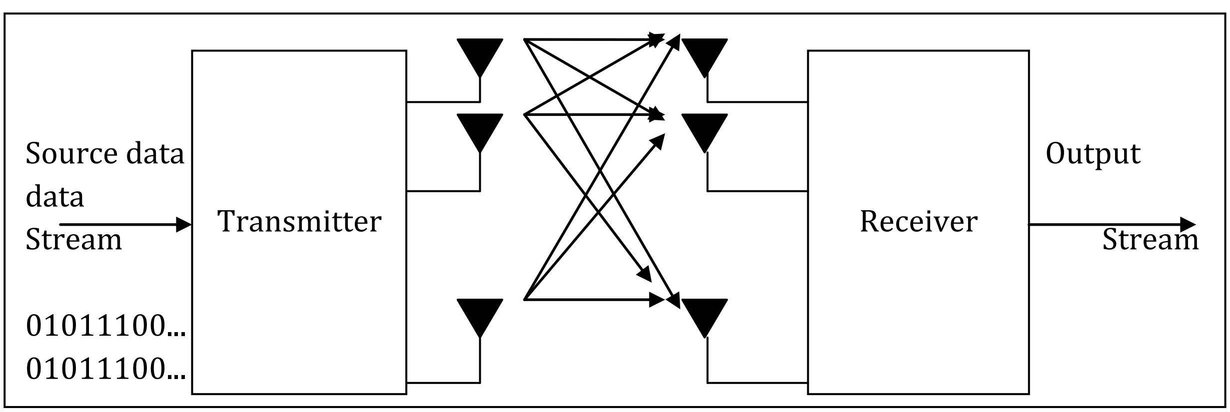

Figure 8.4 Block Diagram of MIMO System

8.5 Space-Time Coding

Space time coding is technique employed in wireless communication system where multiple copies of data is transmitted to the receiver using antenna arrays [45][46][47] assuming that at least one copy of the transmitted data will be received properly in good condition so as to be decoded reliably [48].

Space time codes could be divided into two types.

First, space–time trellis codes (STTCs) distribute a Trellis code over multiple antennas and multiple time-slots [45]. And it provides both the coding gain as well as diversity gain. However, the scheme requires a good trade-off between constellation size, data rate, diversity advantage, and Trellis complexity. The second type of STCs is space–time block codes [46] [47]. They act on a block of data and it ahs disadvantage that it only provides diversity gain, not the coding gain [49].

A generalized system block diagram implementing space time coding is shown below:

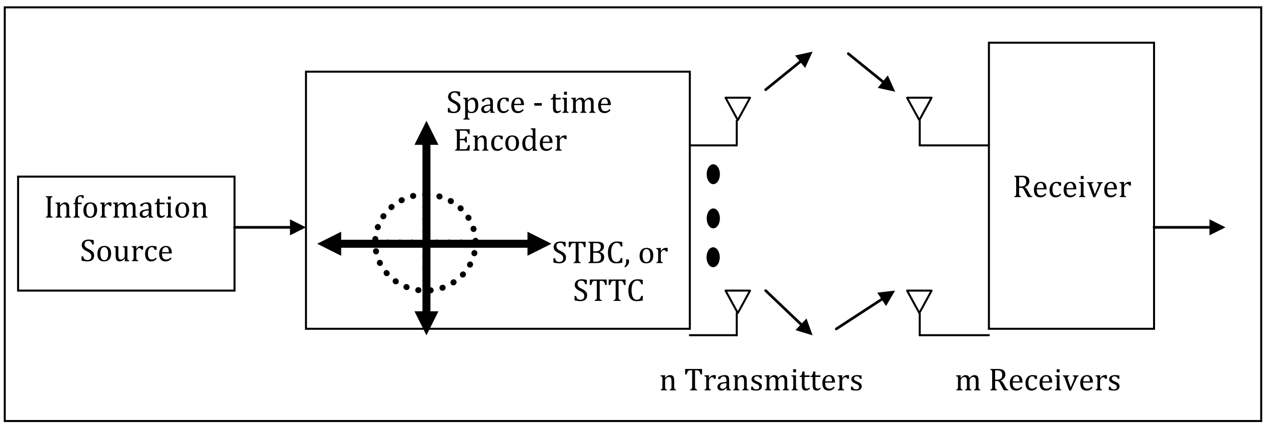

Figure 8.5 System block diagram

8.5.1 Space-Time Trellis Codes

STTC was first presented by Tarokh et al. in 1998 [4]. Transmitting a trellis codes over multiple transmit antennas and time slots, this scheme provides high transmit diversity and coding gain at the price of higher decoding complexity.

An example of a four state STTC trellis is described here. In this example, there are two transmit antennas and number of receive antennas should be one or grater than one. The initial state is represented as S0 and next state is determined by next information symbol. Then two transmit antennas simultaneously transmit these two adjacent encoded symbols. Table 8.1 shows an example of this transmission sequence.

The information sequence after 4-PSK modulation is 1,3,1,2,0,1,0,0,3,…. then after the initial state, the second state is S1 because the first symbol is 1. In the first time slot, two symbols 0 and

1 will be transmitted by antenna 0 and 1, respectively. The encoding process keeps on going like this until all of the information symbols are encoded. The bandwidth efficiency of this scheme is 2 bits/sec/Hz.

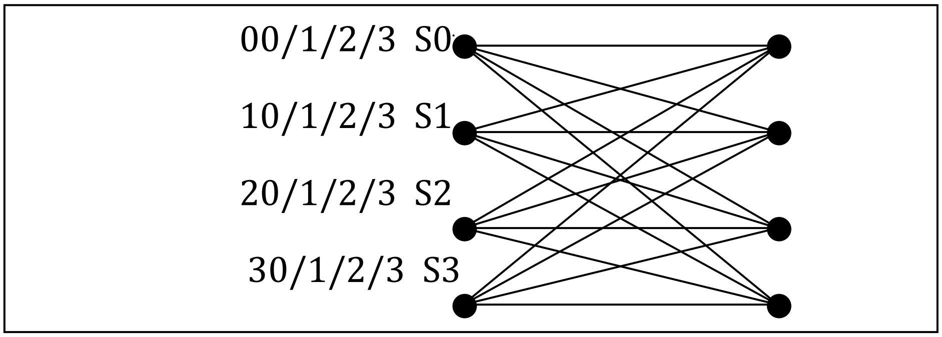

Figure 8.6 Four-State Space-Time Trellis Diagram.

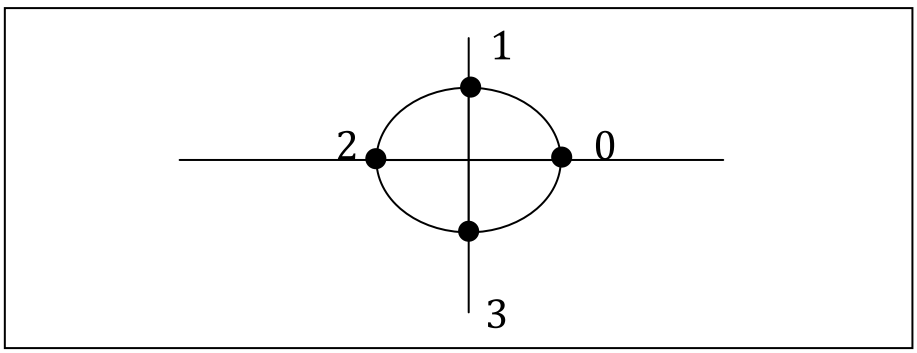

Figure 8.7 4-PSK Modulation Constellation.

Information symbol sequence: 1, 3, 1, 2, 0, 1, 0, 0, 3 …						
Transmit antenna	Time slot 1	Time slot 2	Time slot 3	Time slot 4	Time slot 5	Time slot 6
0	0	1	3	1	2	0
1	1	3	1	2	0	1

Table 8.1 Transmission Sequence of Four-State STTC.

The main problem in implementation of STTC code is that there is exponential increase in decoding complexity with increase in number of antennas and transmission rate [50]. In this scenario, space-time block coding is more appropriate to use due to its low decoding complexity.

The STTC codes are further extended called as multilevel code where data to be sent is divided into blocks and then coded and modulated and using this technique, it provides bandwidth efficiency, improved diversity and coding gain.

8.5.2 Space-Time Block Codes

Space time block codes are extensively used in wireless MIMO systems where multiple copies stream of data symbols are encoded prior to transmission and are transmitted and received over multiple antennas across time in order to improve the reliability. In this way, STBC codes uses both the time and space diversity and provide significant gains, At the receiver side, multiple copies of transmitted data are received and combined in optimal way to get the best of received data and compensating the effect of fading and noise.

A matrix is used to present the STBC code where time slots are represented by rows and each column represents one antenna's transmissions over time. If the modulated symbol is transmitted in i^{th} time slot over the j^{th} antenna, them it is represented as Sij.

$$\begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{m1} & \cdots & S_{mn} \end{bmatrix}$$

8.5.2.1 MIMO Alamouti coding

The MIMO Alamouti scheme is transmit diversity scheme for two transmit antennas that does not require transmit channel knowledge. The MIMO Alamouti code is a simple space time block code that he developed in 1998.The scheme is as follows:

1. Consider a sequence of data to be transmitted, for example {x1, x2, x3,…., xn} .

2. In normal transmission, x1 is transmitted in the first time slot, x2 in the second time slot, x3 and so on.

3. But in Alamouti scheme, symbols are groped in two groups. Two symbols x1 and x2 are sent from the first and second antenna respectively in the first time slot, $-x2^*$ and $x1^*$ from the first and second antenna in second time slot, x3 and x4 from the first and second antenna in third time slot, $-x4^*$ and $x3^*$ from the first and second antenna in four time slot and so on.

4. Here data rate will not be changed because we are transmitting two symbols in two time slots as we have groped two symbols.

In Alamouti STBC, mechanism for transmission of data is shown .

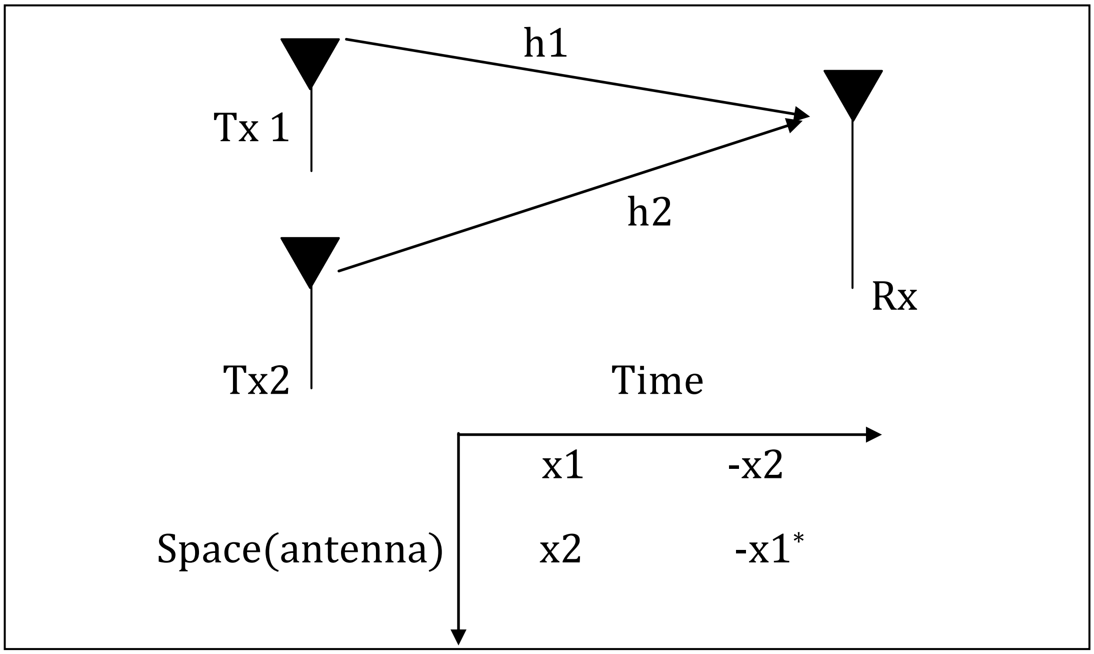

Figure 8.8 Two transmit and one receive antenna Alamouti STBC

Other Assumptions

1. The channel is frequency non selective fading.
2. The effect of channel on data transmitted by each transmit antenna will be different and independent from the channel effect on other transmit antennas.
3. For the i^{th} transmit antenna, each transmitted symbol gets multiplied by a randomly varying channel coefficient h_i. As the channel under consideration is a Rayleigh channel, the real and imaginary parts of h_i are Gaussian distributed having mean $\mu_{hi} = 0$ and variance $\sigma_{hi}^2 = 1/2$.
4. The data transmitted between each transmitting to receiving antenna will suffer different channel which is changing in time. However constant behaviour of channel will be experienced by 2 slots of time.
5. At the receiving antenna, the noise n has the Gaussian pdf(probability density function) with

$$p(n) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(n-\mu)^2}{2\sigma^2}} \text{ with } \mu = 0 \text{ and } \sigma^2 = \frac{N_0}{2}.$$

7. The channel coefficients h_i are known to the receiver end.

Receiver with Alamouti STBC

In the first time slot, the received signal is,

$$y_1 = h_1 x_1 + h_2 x_2 + n_1 = [\, h_1 \;\; h_2] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1$$

In the second time slot, the received signal is,

$$y_2 = -h_1 x_2^* + h_2 x_1^* + n_2 = [\, h_1 \;\; h_2] \begin{bmatrix} -x_2^* \\ x_1^* \end{bmatrix} + n_2.$$

Where

y_1 , y_2 is the symbol received on the 1st and 2nd time slot

h_1 is the channel from 1st transmitting end to receive end,

h_2 is the channel from 2nd transmitting end to receiving end,

x_1 , x_2 are the transmitted symbols and

n_1 , n_2 is the noise on 1st , 2nd time slots.

Since the two noise terms are independent and identically distributed,

$$E\left\{ \begin{bmatrix} n^1 \\ n_2^* \end{bmatrix} [n_1^* \; n_2] \right\} = \begin{bmatrix} |n_1|^2 & 0 \\ 0 & |n_2|^2 \end{bmatrix}$$

For simplicity, the above equation can be written in matrix notation as follows:

$$\begin{bmatrix} y_1 \\ y_2^* \end{bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n^1 \\ n_2^* \end{bmatrix}$$

Let us define $H = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}$. To solve for $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$, we know that we need to find the inverse of *H.*

We know, for a general m x n matrix, the pseudo inverse is defined as,

$$H^+ = (H^H H)^{-1} H^H$$

Since this is a diagonal matrix, the inverse is just the inverse of the diagonal elements, i.e.

$$(H^H H)^{-1} = \begin{bmatrix} \frac{1}{|h_1|^2 + |h_2|^2} & 0 \\ 0 & \frac{1}{|h_1|^2 + |h_2|^2} \end{bmatrix}$$

The estimate of the transmitted symbol is,

$$\widehat{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}} = (H^H H)^{-1} H^H \begin{bmatrix} y_1 \\ y_2^* \end{bmatrix}$$

$$= (H^H H)^{-1} H^H \left(H \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix}\right)$$

$$= \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + (H^H H)^{-1} H^H \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix}$$

CHAPTER 9 RESULTS AND DISCUSSION

The main motivation of using Channel coding is efficient transmission and reception of data through channel such that as to reduce the ber(bit error rate). This error detection and correction codes reduces the errors caused in the data due to the noise while transmitting through communication channel. Two important types of channel coding are there:- Block coding and convolutional coding. Here we have compared the performance of Block codes and convolution code by using bit error rate(ber) V/s Eb/No performance using BPSK and 16-QAM(Quadrature amplitude modulation). After that implementation of Alamouti STBC has been done with different number of transmitter and receiver antennas with BPSK and QAM modulation. Then OSTBC is combined with TCM for sending the information over MIMO channel with two sending antennas and one receiving antenna. As AWGN channel is the idle channel but in real environment, transmission of data suffers from multipath propagation and fading, so performance of convolution code is evaluated over Rayleigh channel. The performance of convolution code in Rayleigh channel is compared using different modulation techniques. After that performance of STTC code using multiple antenna configuration is compared with regard to different modulation techniques and QAM modulation technique gives us better performance. Then STTC code is evaluated using the concept of with beamforming and without beamforming. In the end, implementation of multilevel code using different antenna configuration in AWGN and Rayleigh channel is performed and compared using 128 trellis states.

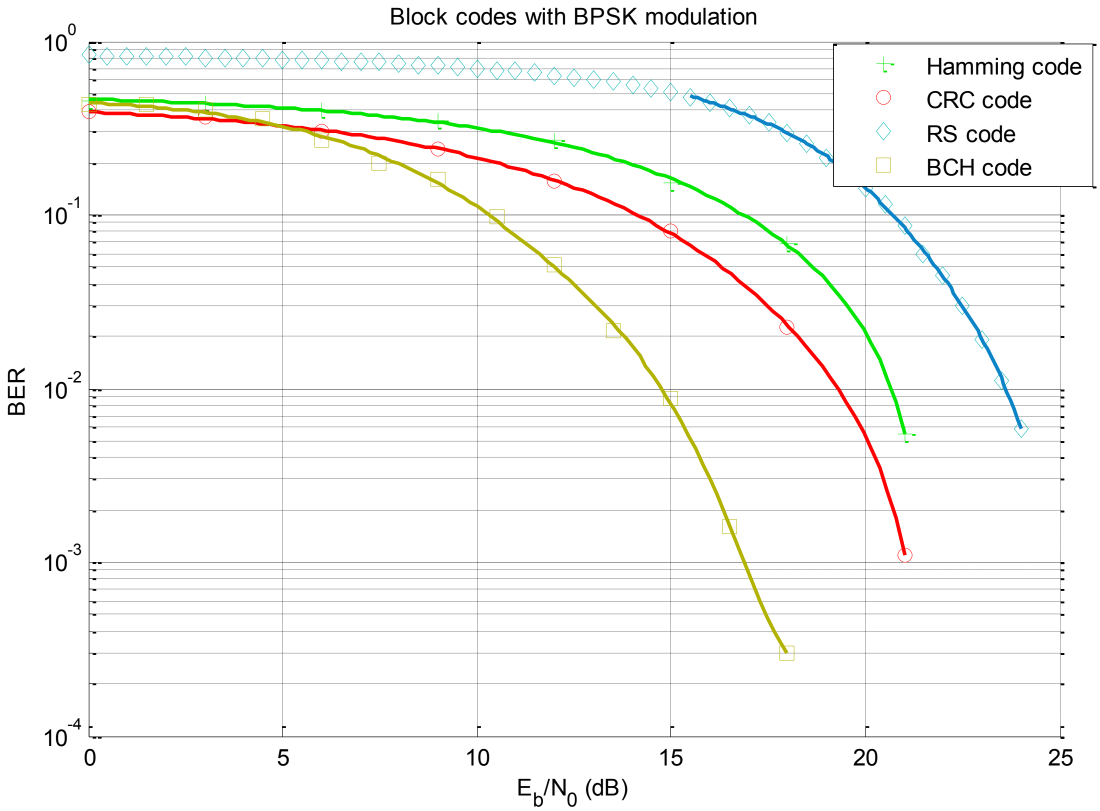

Figure 9.1 Block codes with BPSK modulation

In figure 9.1, we analyzed the performance of block codes i.e. hamming code, reed Solomon code ,CRC code and BCH code by taking binary phase shift keying(BPSK) as the modulation technique and transmitting through them AWGN channel. Out of these block codes, BCH has better BER performance and RS code has worst BER performance among them.

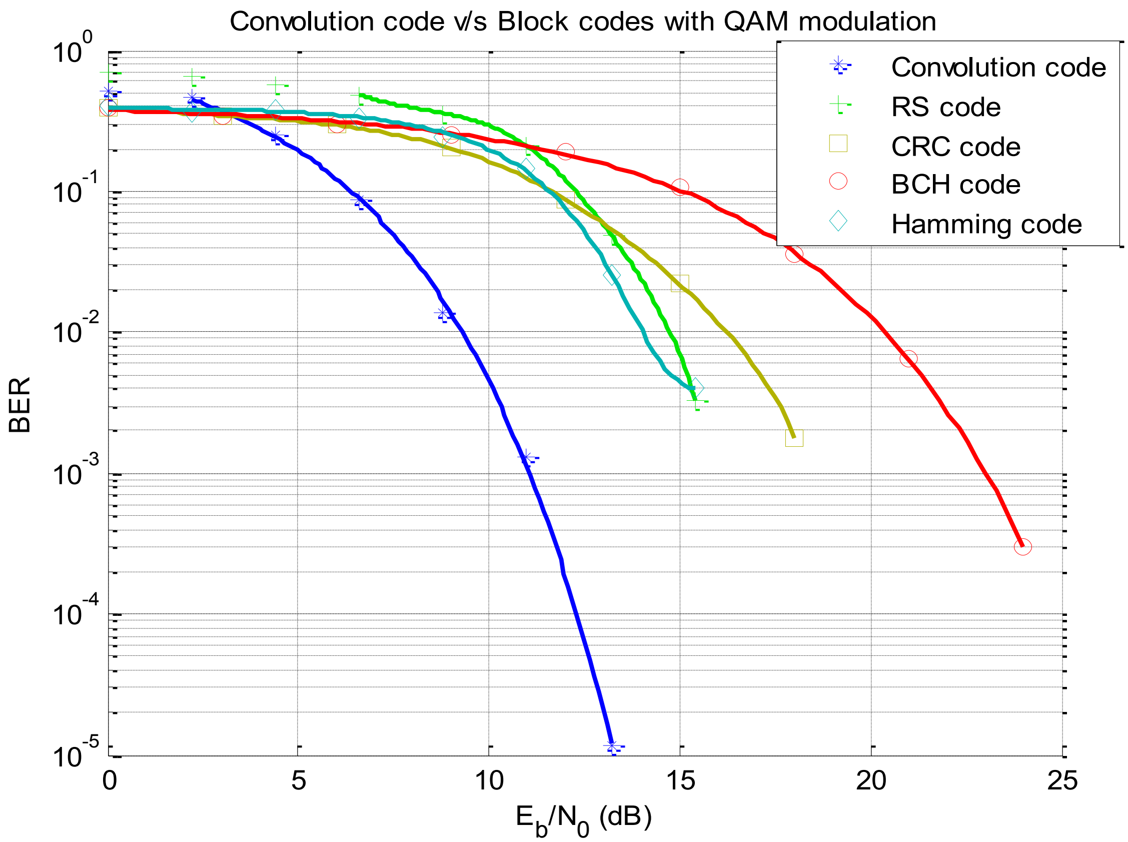

Figure 9.2 Convolution code v/s Block codes with QAM modulation

In figure 9.2, performance of block codes and convolution code by taking binary QAM as the modulation technique has been analyzed and it shows that the convolution code has better error controlling and correction capabilities in comparison to block code and the hamming code has better error controlling and correction capabilities in comparison to other block codes and BCH has least error controlling and correction capability among them.

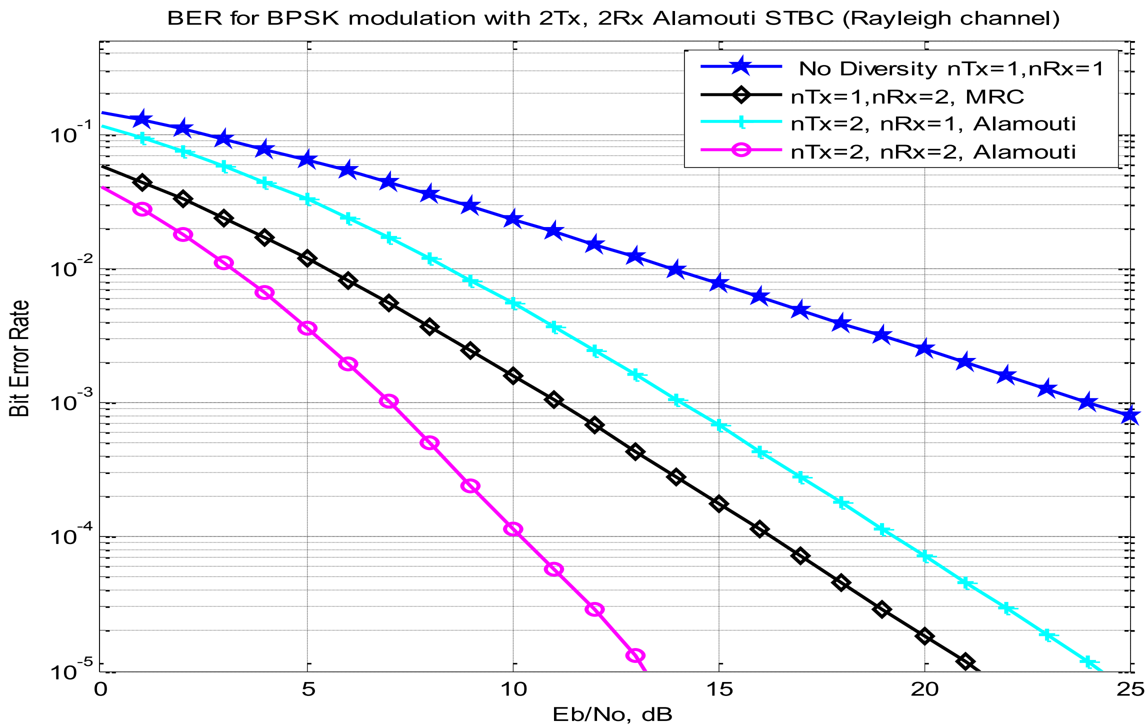

Figure 9.3 Alamouti STB code with BPSK modulation

In figure 9.3, we have compared the diversity of 2 in two cases wherein first case takes 2 transmitting antenna and one receive antenna and second case involves two receiving antennas and one transmitting antenna with BPSK modulation scheme over the Rayleigh channel. The resulting simulation proves that both the cases provide the same diversity and also transmit diversity has a 3 dB disadvantage when compared to MRC receive diversity. Further as the diversity order is increased i.e. two transmit antenna and two receive antenna (2×2), Performance of system is improved.

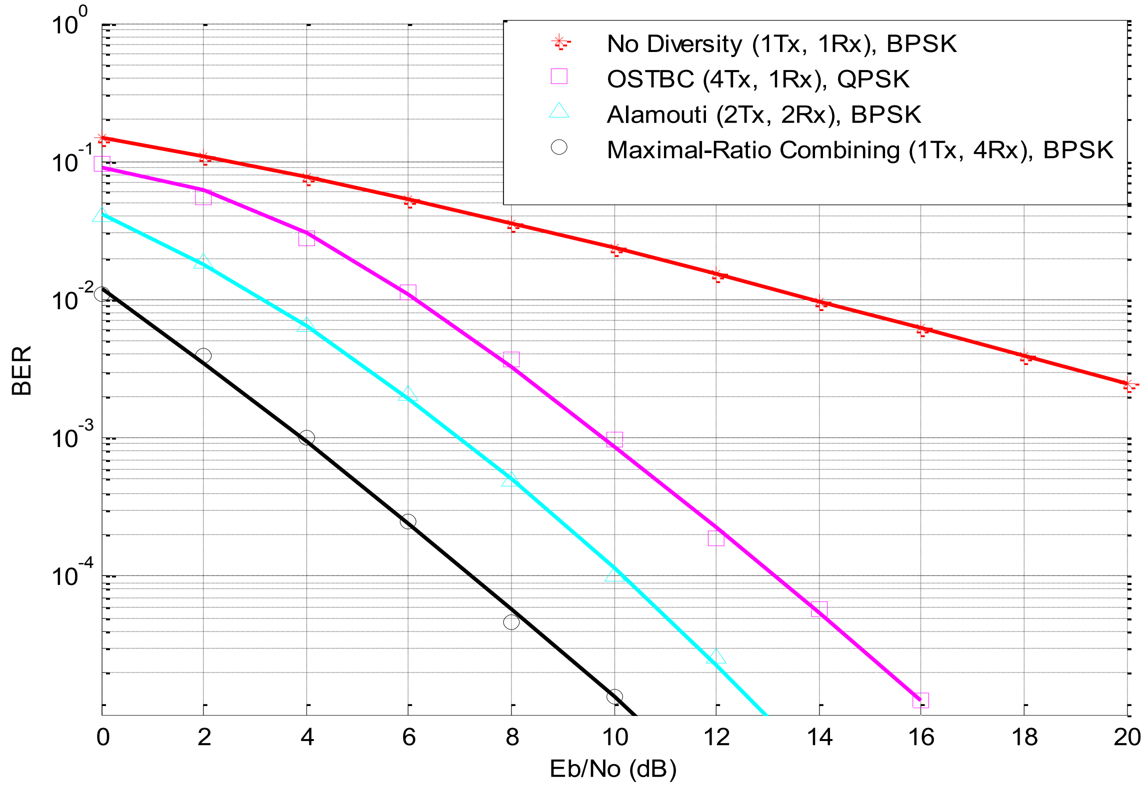

Figure 9.4 Alamouti STB code and OSTBC

In figure 9.4, we have implemented STBCs code with different configuation of antenna to achieve diversity of 4. Comparison between antenna configuration of (nTx=1, nRx=4), (nTx=2, nRx=2) with BPSK modulation scheme and (nTx=4, nRx=1) with QPSK modulation scheme is performed. The same pattern of BER curve for all the configuration (nTx=1, nRx=4), (nTx=2, nRx=2) and (nTx=4, nRx=1) indicates same order of diversity and 3 dB penalty for the 4x1 system that can be attributed to the same total transmitted power assumption made for each of the three systems.

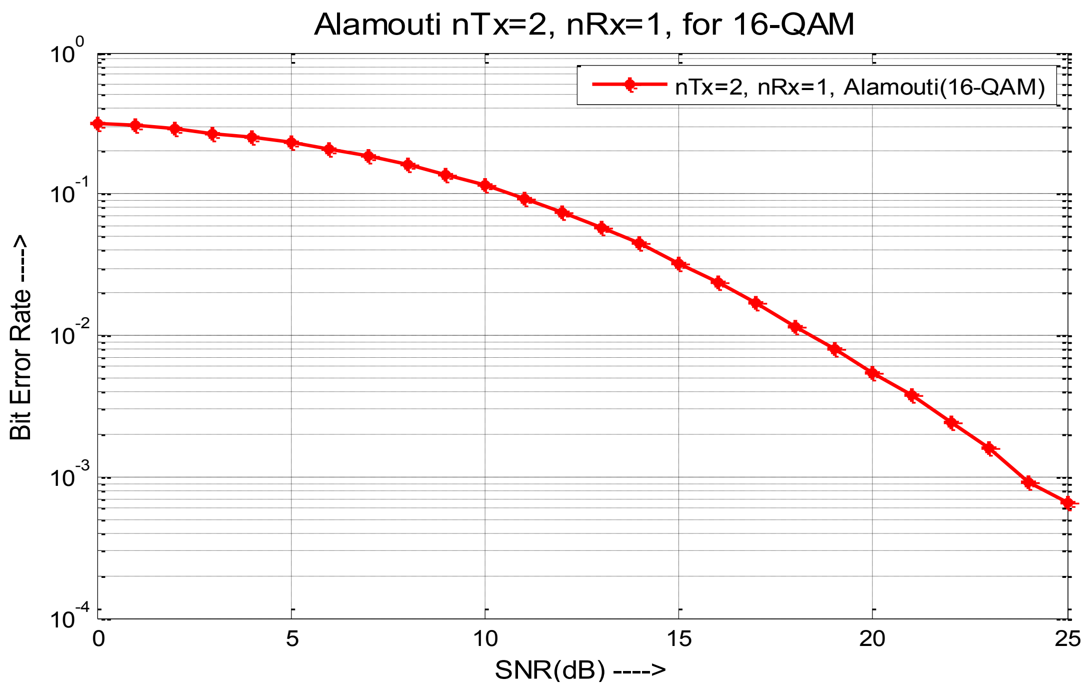

Figure 9.5 Alamouti STB code(nTx=2,nTx=1) with QAM modulation

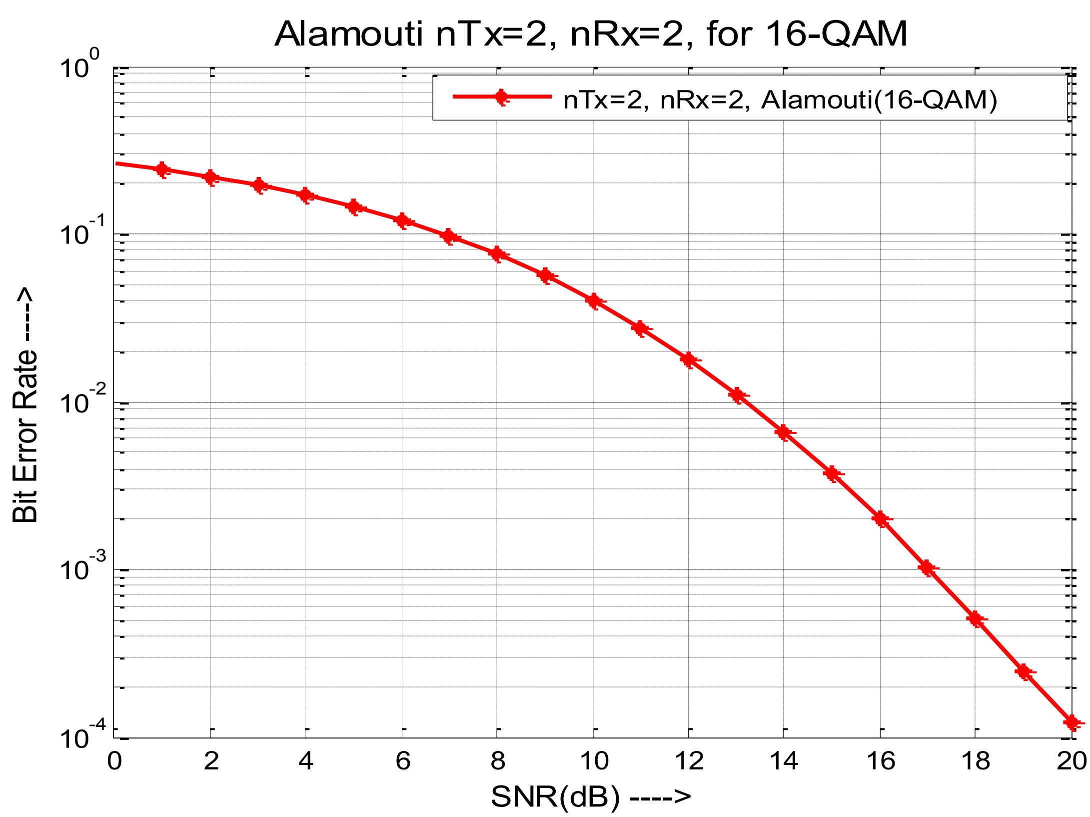

Figure 9.6 Alamouti STB code(nTx=2,nTx=2) with QAM modulation

In figure 9.5 and 9.6, Alamouti STBC code for system to offer diversity order of 2 and 4 are implemented with 16-QAM modulation. For diversity order of two, we employed 2 transmit antenna and 1 receive antenna(2×1) and for diversity order of four, we employed 2 transmit antenna and 2 receive antenna(2×2). The performance of system is improved as the diversity order is increased,

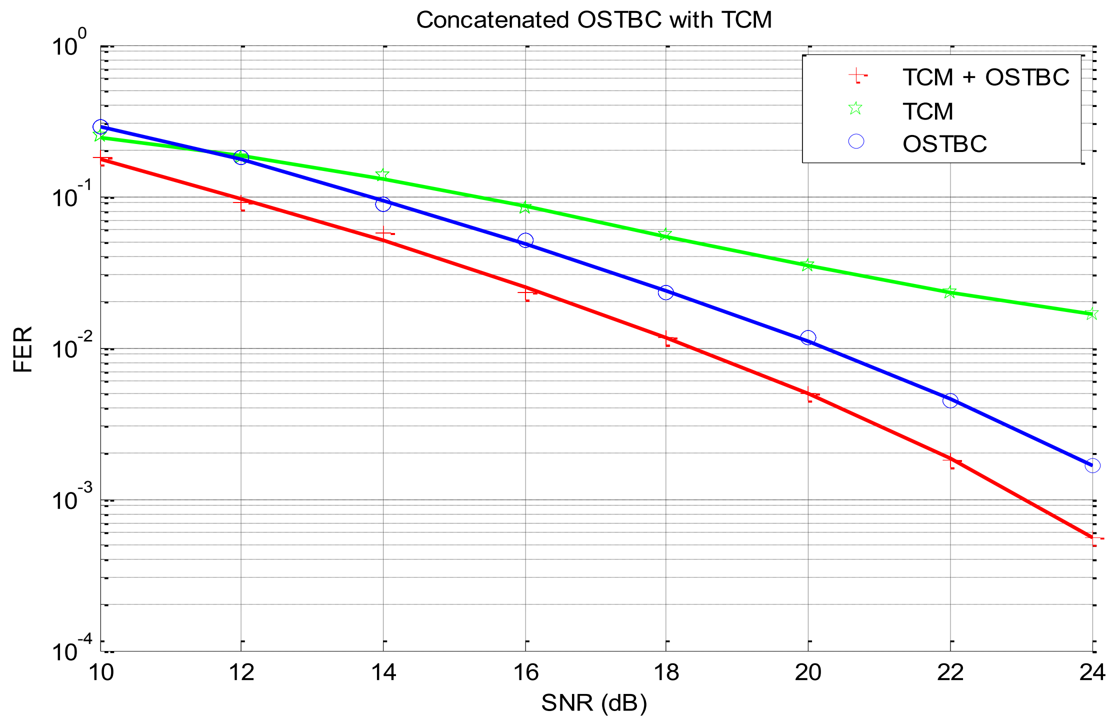

Figure 9.7 Concatenation of OSTBC with TCM

In figure 9.7, we have implemented OSTBC in combination of TCM which sends the data over the MIMO channel with diversity order of 2 (nTx=2, nRx=1). This scheme provides the advantages of OSTBC code with TCM as diversity gain is provided by OSTBC while coding gain of 2 db is provided by TCM technique.

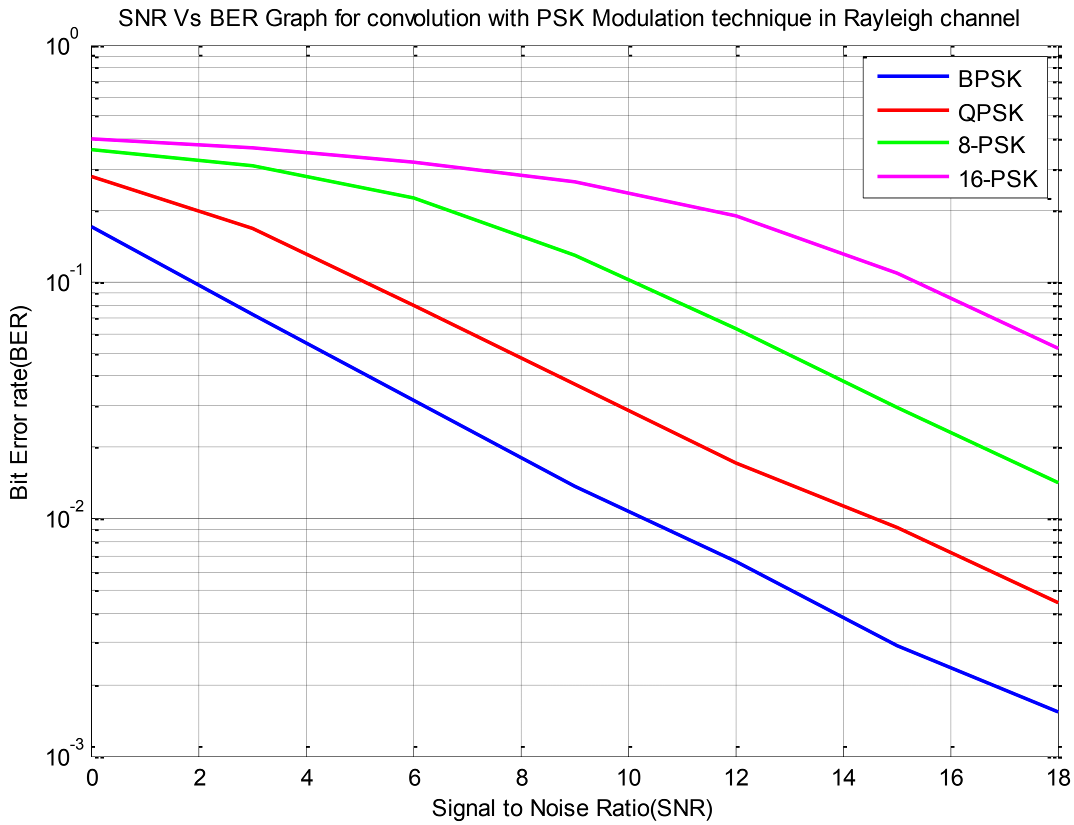

Figure 9.8 Convolution code with PSK modulation in Rayleigh channel

In figure 9.8, performance of convolution code by taking PSK as the modulation technique has been analyzed over the Rayleigh channel and it shows that the convolution code has better error controlling and correction capabilities in BPSK technique as compared to other PSK techniques.

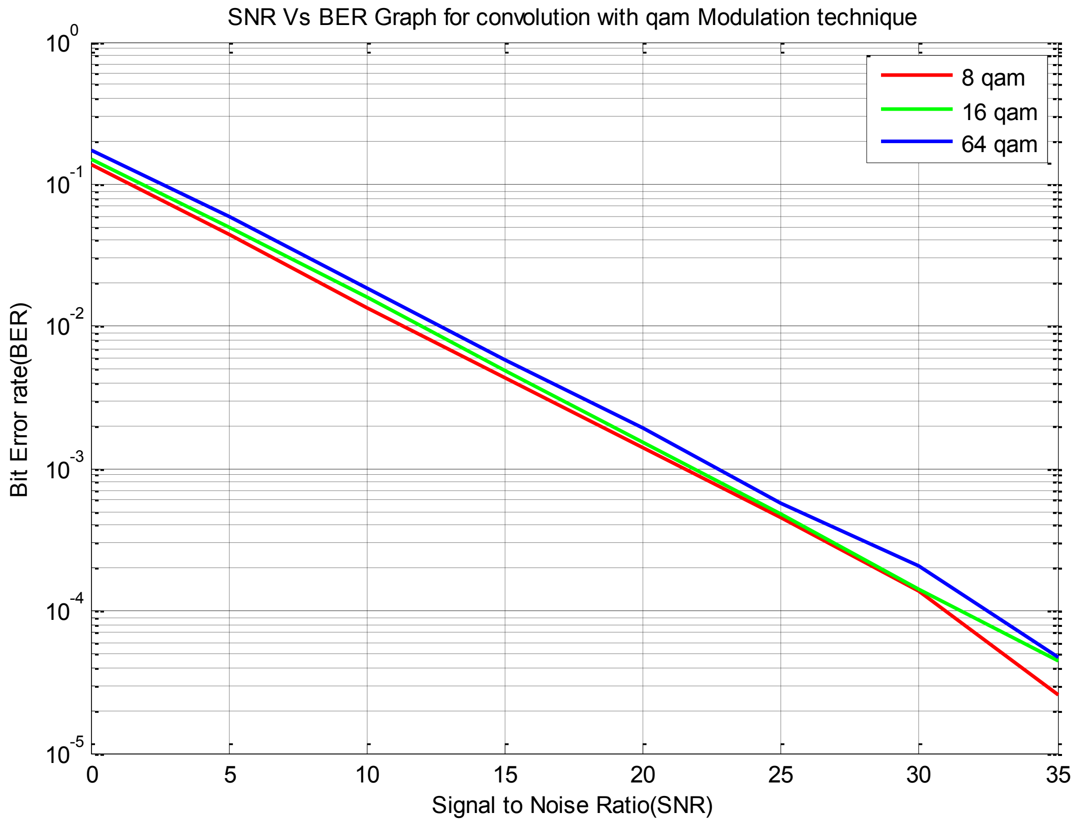

Figure 9.9 Convolution code with QAM modulation in Rayleigh channel

In figure 9.9, implementation of convolution code by taking QAM as the modulation technique over the Rayleigh channel has been evaluated and it shows that the convolution code has better error controlling and correction capabilities in 8-QAM technique as compared to other QAM techniques.

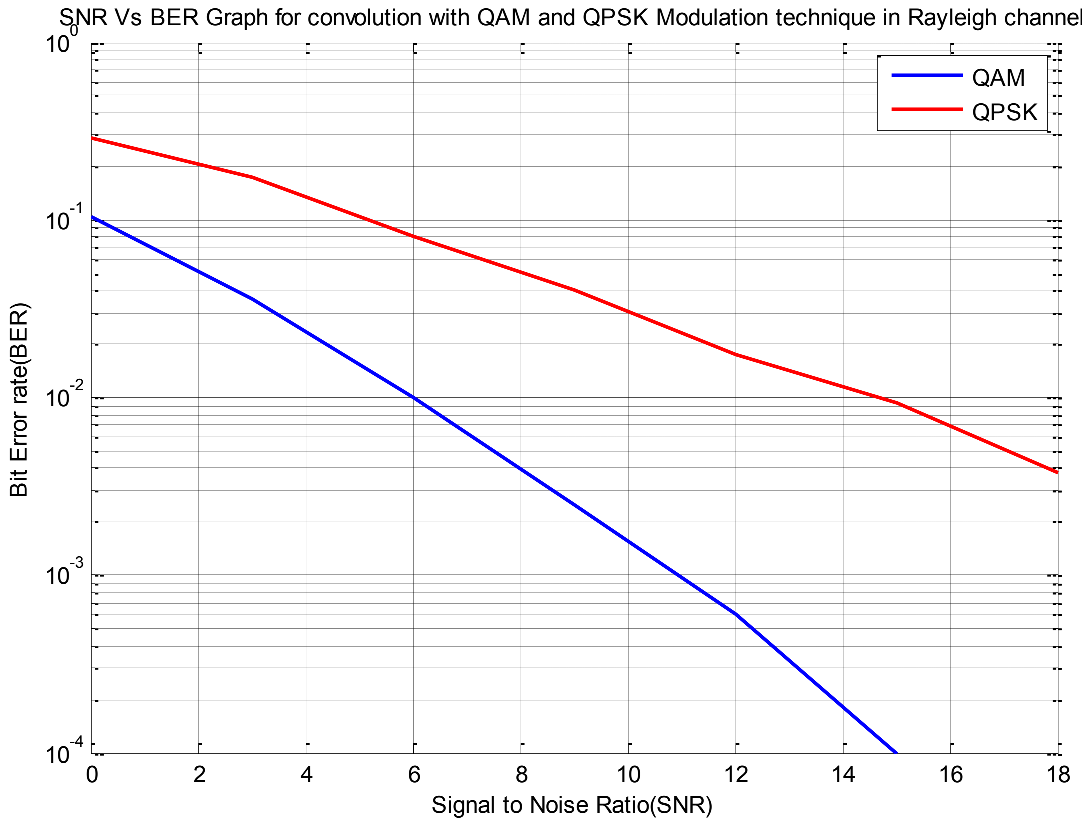

Figure 9.10 Convolution code with QAM and QPSK modulation in Rayleigh channel

In figure 9.10, performance of convolution code by taking QPSK and 4-QAM as the modulation technique has been analyzed over Rayleigh channel and it shows that the convolution code has better error controlling and correction capabilities in 4-QAM technique as compared to QPSK technique because more constellation points are used in QAM technique.

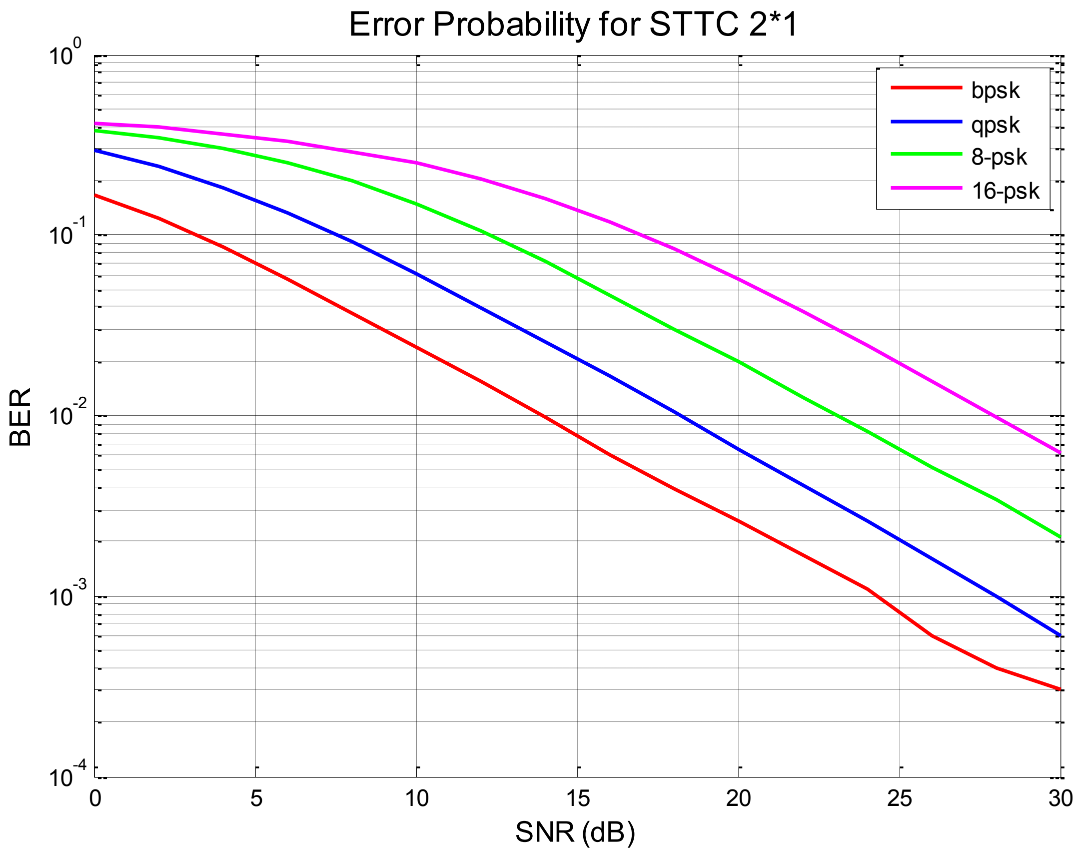

Figure 9.11 STTC code(nTx=2,nRx=1)with PSK modulation in Rayleigh channel

In figure 9.11, we have implemented the STTC code using transmit diversity where 2 transmitting antennas and 1 receive antenna is used. Comparison of STTC code over different types of PSK modulation techniques is performed and it results that STTC performs better over BPSK technique and performance of code degrades as number of bits in modulation technique increases which also results in increase in complexity.

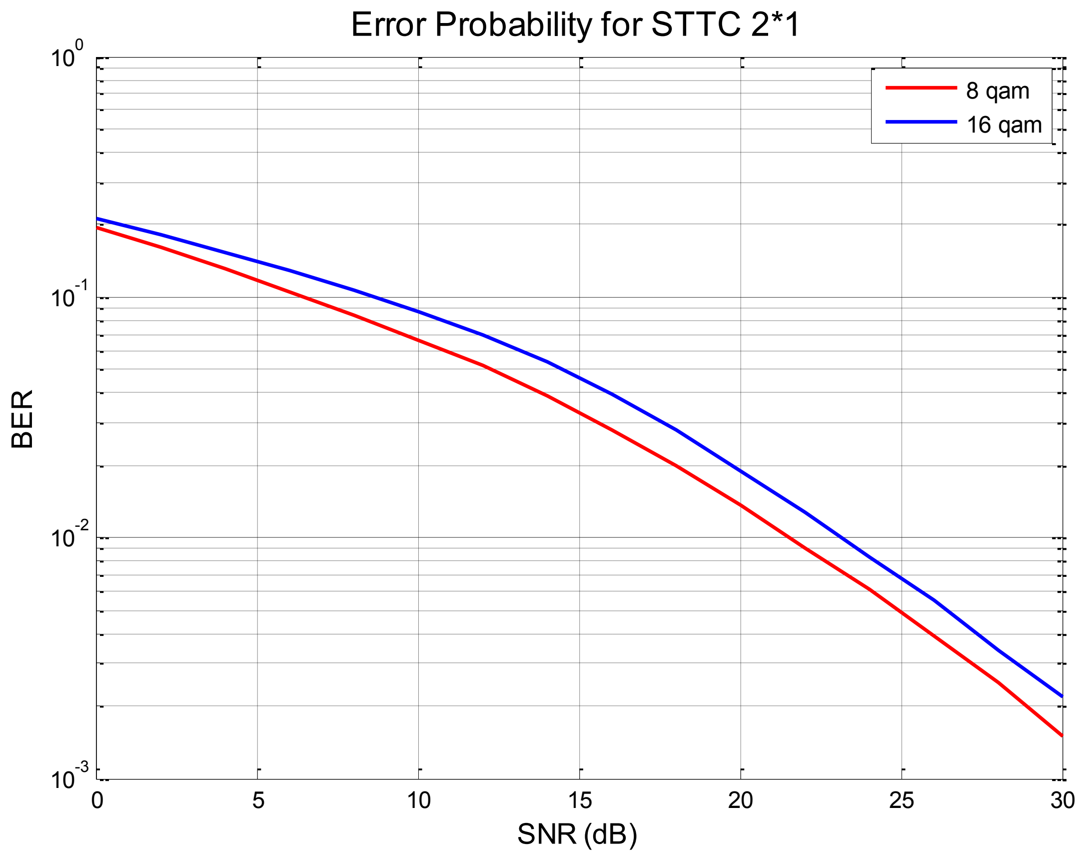

Figure 9.12 STTC code (nTx=2,nRx=1) with QAM modulation in Rayleigh channel

In figure 9.12, we have implemented the STTC code using transmit diversity where 2 transmitting antennas and 1 receive antenna is used. Comparison of STTC code over different types of QAM modulation techniques is performed and it results that STTC performs better over 8-QAM technique and performance of code degrades as number of bits in modulation technique increases which also results in increase in complexity.

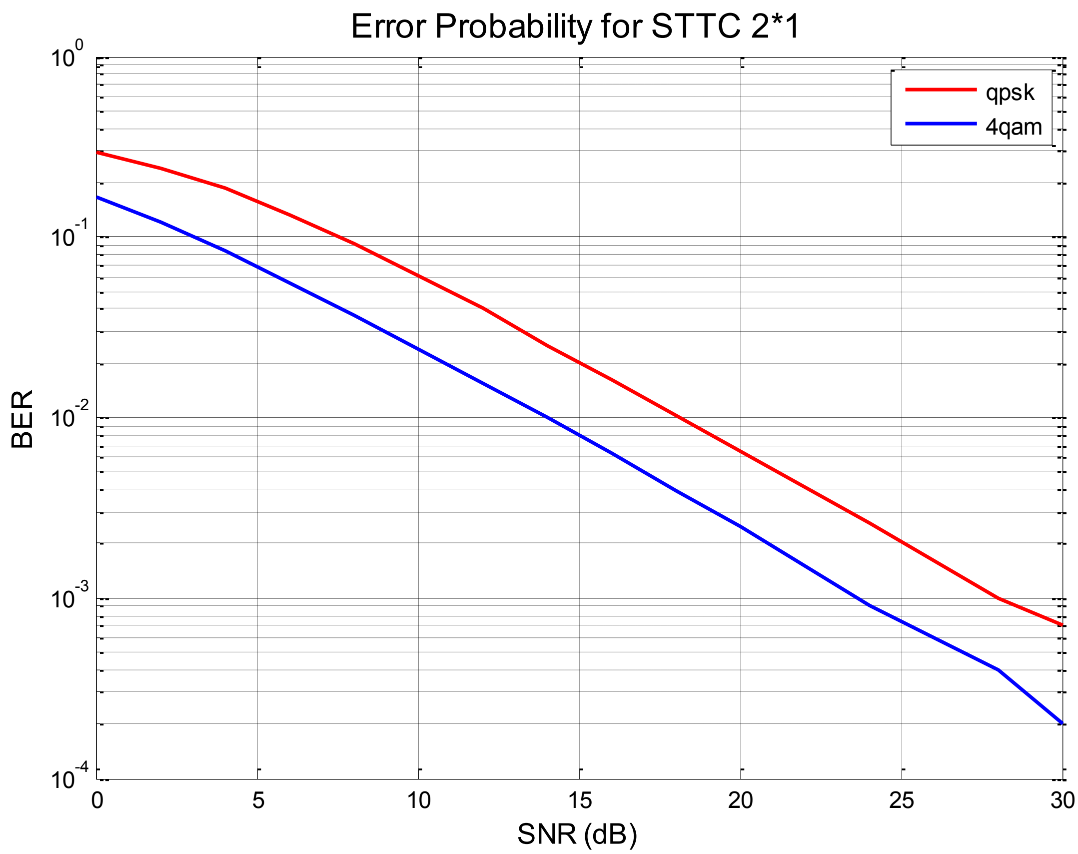

Figure 9.13 STTC code (nTx=2,nRx=1) with QAM and QPSK modulation in Rayleigh channel

In figure 9.13, performance of STTC code using transmit diversity i.e.two transmitting antennas and 1 receive antenna is evaluated over QPSK and 4 QAM. It results that STTC performs better over 4-QAM technique because more constellation points are used in QAM technique.

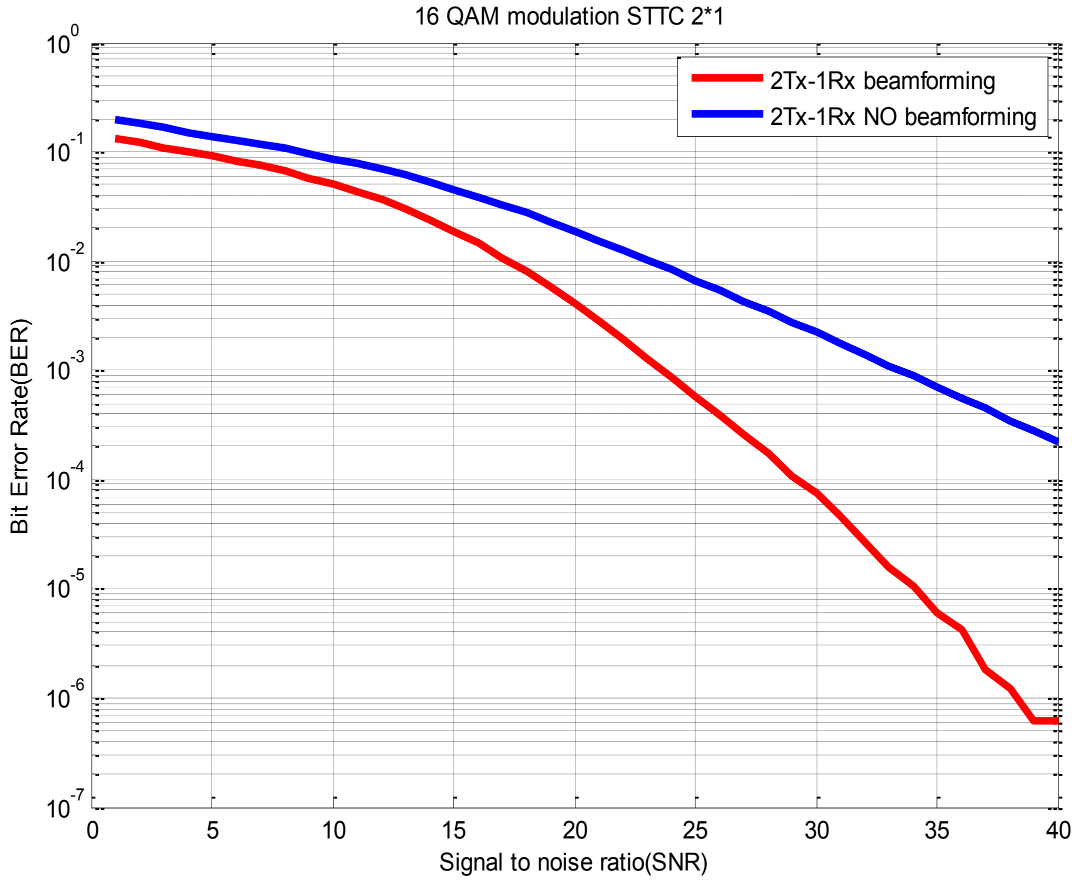

Figure 9.14 STTC code (nTx=2,nRx=1) with 16-QAM modulation (with and without beamforming) in Rayleigh channel

In figure 9.14, performance of STTC code using transmit diversity i.e. two transmitting antennas and 1 receiving antenna is evaluated using 16-QAM as modulation technique. Comparison between STTC code with beamforming and STTC code without beamforming is analyzed. It results that STTC performs better when beamforming is applied as it transmits the data to the particular angle where receiver is located.

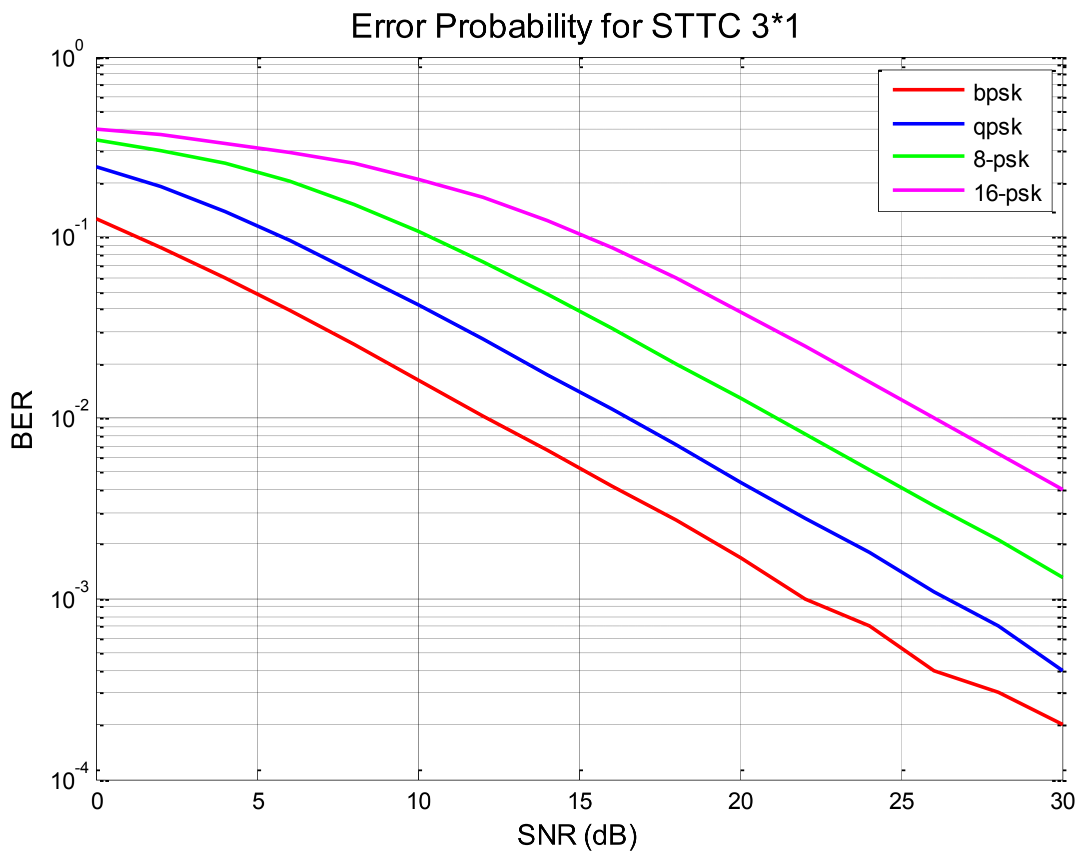

Figure 9.15 STTC code (nTx=3,nRx=1) with PSK modulation in Rayleigh channel

In figure 9.15, we have implemented the STTC code using transmit diversity where three transmitting antennas and 1 receiving antenna is used. Comparison of STTC code over different types of PSK modulation techniques is performed and it results that STTC performs better over BPSK technique and performance of code degrades as number of bits in modulation technique increases which also results in increase in complexity.

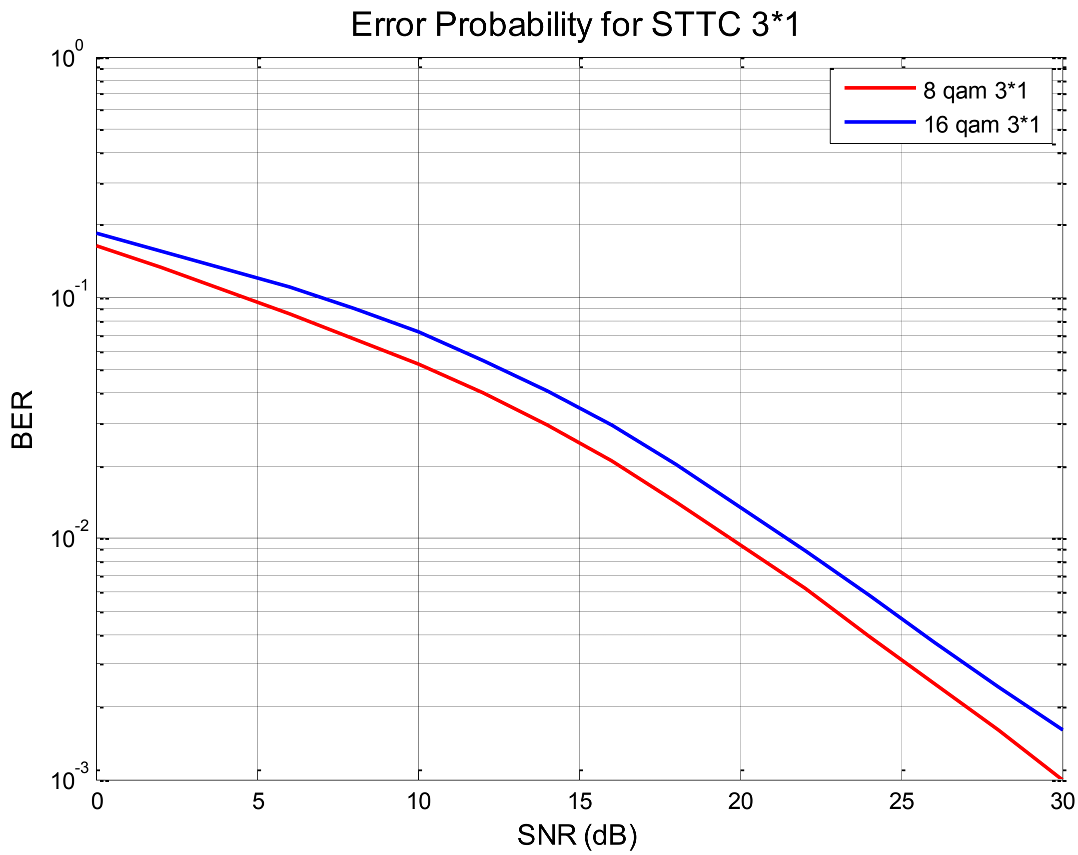

Figure 9.16 STTC code (nTx=3,nRx=1) with QAM modulation in Rayleigh channel

In figure 9.16, we have implemented the STTC code using transmit diversity where three transmitting antennas and 1 receiving antenna is used. Comparison of STTCs over different types of QAM modulation techniques is performed and it results that STTC performs better over 8-QAM technique and performance of code degrades as number of bits in modulation technique increases which also results in increase in complexity.

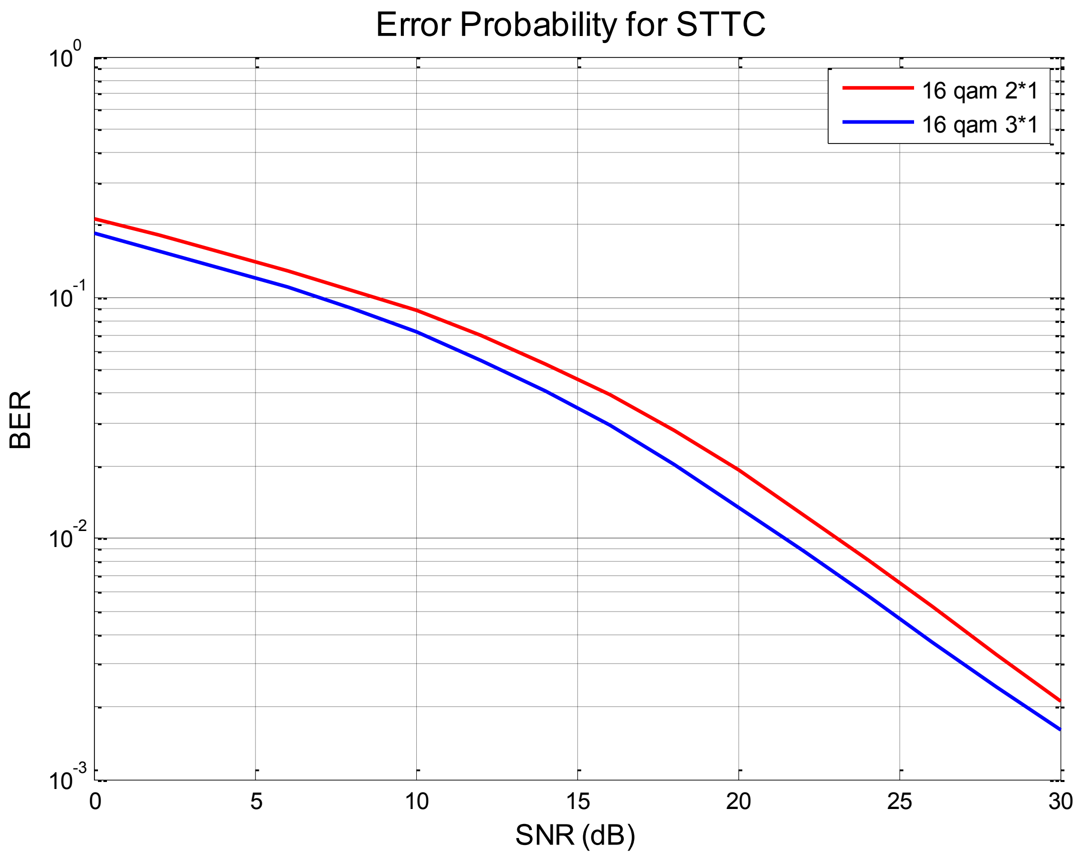

Figure 9.17 STTC code (nTx=2,3 and nRx=1) with 16-QAM modulation in Rayleigh channel

In figure 9.17, performance of STTC code using transmit diversity (nTx=2, nRx=1) and transmit diversity (nTx=3, nRx=1) using 16-QAM as modulation technique is evaluated and compared. It results that STTC performs better in transmit diversity of 3 as more number of transmit antennas are employed here.

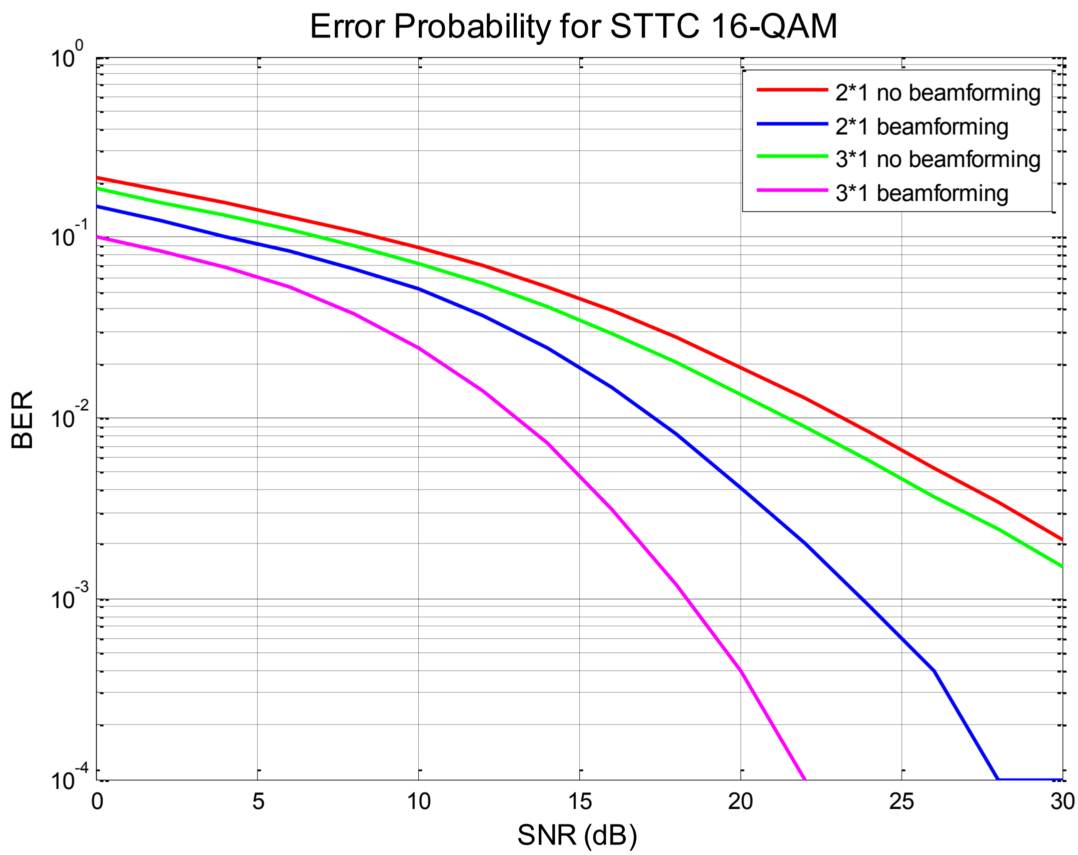

Figure 9.18 STTC code (nTx=2,3 and nRx=1) with 16-QAM modulation (with and without beamforming) in Rayleigh channel

In figure 9.18, performance of STTC code using transmit diversity (nTx=2, nRx=1) and transmit diversity (nTx=3, nRx=1) using 16-QAM as modulation technique is evaluated by taking STTC code with beamforming and STTC code without beamforming into consideration. It results that STTC performs better when beamforming is applied in transmit diversity of 3 as it transmits the data to the particular angle where receiver is located and performance degrades in case of transmit diversity of 2 when no beamforming is applied.

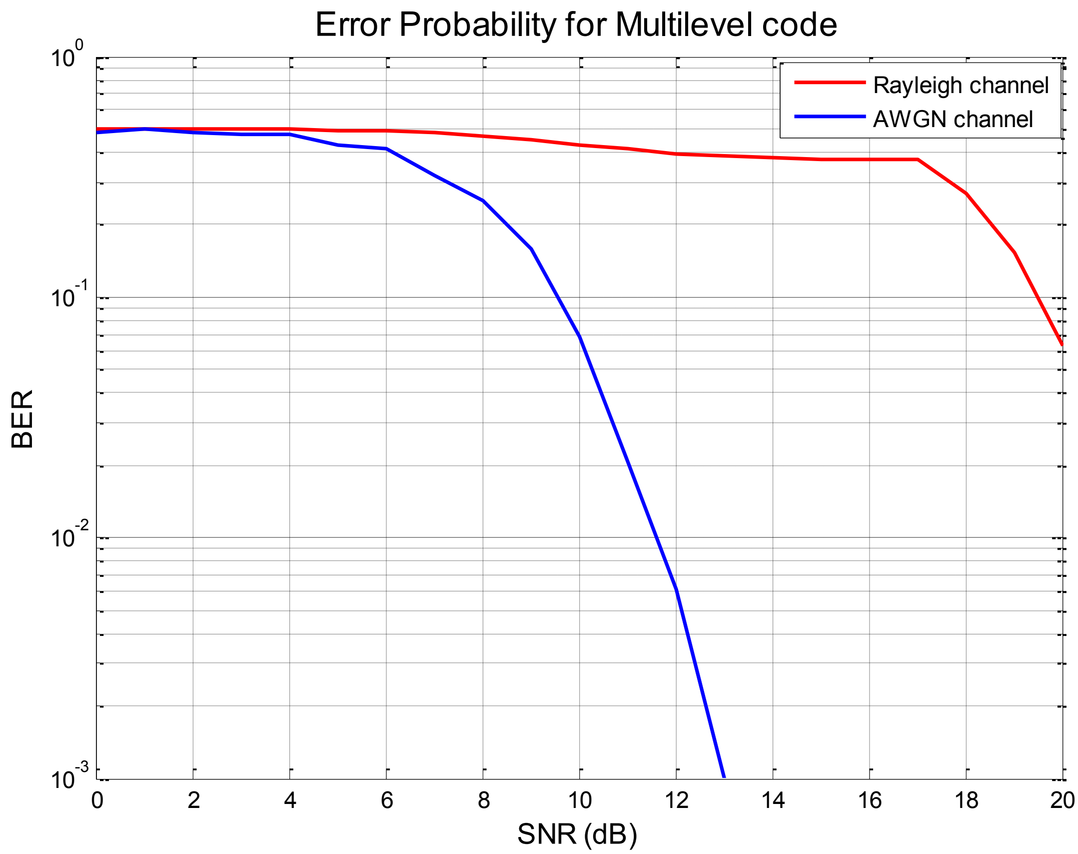

Figure 9.19 Multilevel code with 16-QAM modulation in AWGN and Rayleigh channel

In figure 9.19, performance of multilevel code using 16-QAM as modulation technique is evaluated and compared using AWGN and Rayleigh channel. It results that multilevel code performs better in non fading AWGN channel whereas transmitted signal suffers from fading in Rayleigh channel.

CHAPTER 10 CONCLUSION AND FUTURE SCOPE

We explored channel encoding techniques and Space Time Codes are explored using different order of diversity i.e changing the configuration of transmitting and receiving antenna in wireless Rayleigh channel. Performance of these codes is evaluated and comparison among them is made for better results.

We have implemented channel coding techniques i.e. linear block code and convolution code with BPSK and QAM technique in AWGN channel and comparison between them is made. After that implementation of STBC Alamouti code with different diversity is made with BPSK and QAM in Rayleigh channel is done. Then OSTBC code is implemented and combined with TCM and their comparison is made. The performance of convolution code in Rayleigh fading channel is compared using different modulation techniques. After that performance of STTC code using multiple antenna configuration is compared with regard to different modulation techniques and QAM modulation technique gives us better performance. Then STTC code is evaluated using the concept of with beamforming and without beamforming. In the end, implementation of multilevel code using different antenna configuration in AWGN and Rayleigh channel is performed and compared using different trellis states. The performance of multilevel code is also implemented using the beamforming concept called as adaptively grouped multilevel space time code.

Here for the modulation of the encoded data, we have used PSK and QAM modulation techniques. The channels used are AWGN channel and Rayleigh channel. Implementation of linear block codes and convolution code are carried in SISO channel while STBC, STTC and Multilevel codes are implemented in MIMO channel with different antenna configurations. In STTC and Multilevel codes, 128 states trellis structure is used. The performance of these techniques is evaluated by plotting bit error rate over SNR range in between (0-30) db.

In future this research can be extended over higher levels of modulation techniques. The performance of space time codes can be evaluated using rician and nakagami channel and is compared for better results. We can also implement the same space time codes using receive diversity and transmit diversity order can be increased further. The number of trellis states used is

4 and 128 and space time codes can be implemented using more number of sates for improved results.

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