GENERALIZED SPATIAL MODULATION FOR MASSIVE MIMO WIRELESS SYSTEM

PHASE-II PROJECT REPORT

Submitted by

MEENAKSHI M

Reg. No: 15MCO006

In partial fulfillment for the requirement of award of the

degree

of

MASTER OF ENGINEERING

in

COMMUNICATION SYSTEMS

Department of Electronics and Communication Engineering

KUMARAGURU COLLEGE OF TECHNOLOGY
(An autonomous institution affiliated to Anna University, Chennai)

COIMBATORE - 641 049

ANNA UNIVERSITY: CHENNAI 600 025

APRIL-2017

BONAFIDE CERTIFICATE

Certified that this project report titled **"GENERALIZED SPATIAL MODULATION FOR MASSIVE MIMO WIRELESS SYSTEM"** is the bonafide work of **MEENAKSHI M [Reg. No. 15MCO006]** who carried out the research under my supervision. Certified further that, to the best of my knowledge the work reported herein does not form part of any other project or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

SIGNATURE

Dr.K.KAVITHA

PROJECT SUPERVISOR

Department of ECE

Kumaraguru College of Technology

Coimbatore-641 049

SIGNATURE

PROF R. RAMPRAKASH

HEAD OF PG PROGRAMME

Department of ECE

Kumaraguru College of Technology

Coimbatore-641 049

ACKNOWLEDGEMENT

First I would like to express my praise and gratitude to the Lord, who has showered his grace and blessing enabling us to complete this project in an excellent manner. He has made all things in beautiful in his time.

I express my sincere thanks to my beloved Joint Correspondent, **Shri. Shankar Vanavarayar** for his kind support and for providing necessary facilities to carry out the project work.

I would like to express my sincere thanks to our beloved Principal **Dr.R.S.Kumar M.E., Ph.D.,** who encouraged me with his valuable thoughts.

I would like to express my sincere thanks and deep sense of gratitude to my HOD, **Dr.K.Malarvizhi M.E.,Ph.D.,** and **Prof K. RamPrakash M.E.,** for their valuable suggestions and encouragement which paved way for the successful completion of the project.

I greatly privileged to express my deep sense of gratitude to the Project Coordinator and Supervisor **Dr.k.kavitha M.E., Ph.D.,** Associate Professor, for her continuous support throughout the course. In particular, I wish to thank and express my everlasting gratitude to her for the expert counselling in each and every steps of project work and I wish to convey my deep sense of gratitude to all teaching and non-teaching staff members of ECE Department for their help and cooperation.

Also I am very much thankful to the courtesy of TM Deserni, Dept. of Medical Informatics and RWTH Achen, Germany for providing their data to this research work.

Finally, I thank my parents and my family members for giving me the moral support in all of my activities and my dear friends who helped me to endure my difficult times with their unfailing support and warm wishes.

ABSTRACT

Generalized Spatial Modulation (GSM) is a relatively new modulation scheme for Multi Input Multi Output (MIMO) wireless communication. GSM inspires the proposition of an emerging wireless communications concept conceived for single Radio Frequency (RF) large-scale MIMO communications. The basic idea is to map a block of information bits to two information carrying units: A symbol that was chosen from a constellation diagram and A unique transmit antenna number that was chosen from a set of transmit antennas. The use of the transmit antenna number as an information bearing unit increases the overall spectral efficiency by the base-two logarithm of the number of transmit antennas. In MIMO technology GSM adapt for both fast fading and slow fading. GSM gives the better throughput compare to the other modulation technique. It gives the high spectral efficiency and low complexity and high data rate without increasing the required bandwidth. In fast fading GSM gives the low bit error rate and high data rate. We propose and analyze a generalized spatial modulation scheme, where depending on the bits to be spatial modulated symbols. The receiver then has to estimate the spatial modulated symbol by using the Maximum Likelihood (ML) detector for being able to reconstruct the originally transmitted bit sequence. we analyze the Bit Error Rate (BER) for generalized spatial modulation symbol.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ABBREVATION	NOMENCLATURE
ABR	Average Bit Error Rate
APM	Amplitude Phase Modulation
ASK	Amplitude Shift Keying
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
DSP	Digital Signal Processing
GSM	Generalized Spatial Modulation
IAS	Inter Antenna synchronization
LOS	Line Of Sight
MIMO	Multiple Input Multiple Output
MRC	Maximum Ratio Combining
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
SIR	Signal Interference Ratio
SISO	Single Input Single Output
SM	Spatial Modulation
SMX	Spatial Multiplexing
SNR	Signal To Noise Ratio
TA	Transmit Antenna

CHAPTER 1

INTRODUCTION

Wireless communications is a type of data communication that is performed and delivered wirelessly. This is a broad term that incorporates all procedures and forms of connecting and communicating between two or more devices using a wireless signal through wireless communication technologies and devices. Multiple-input multiple-output (MIMO) systems are being considered as one of the key enabling technologies for future wireless networks

1.1 MIMO

Multiple Input Multiple Output (MIMO) is a method for multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation. The use of multiple transmitting and receiving antennas can provide high spectral efficiency and link reliability for point-to-point communication in fading environments MIMO multiuser scenario, it is always convenient to use all transmitting antennas[2]. MIMO provides the higher bit rate and better reliability in wireless system. It was found that for some values of Signal to Noise Ratio (SNR) and Signal to Interference Ratio (SIR), allocating all power into a single transmitting antenna, rather than dividing the power equally among independent streams from the different antennas, would lead to a higher overall system mutual information.

To analyze the ergodic capacity of MIMO systems in the presence of multiple MIMO co-channel interferers and Additive White Gaussian Noise (AWGN). We consider rich scattering environments in which transmitters have no CSI, the receiver has perfect CSI, and all links undergo frequency flat Rayleigh fading. MIMO increases receiver signal-capturing power by enabling antennas to combine data streams arriving from different paths and at different times[3]. Smart antennas use spatial diversity technology, which puts surplus antennas to good use. When antennas outnumber spatial streams, the antennas can add receiver diversity and increase range.

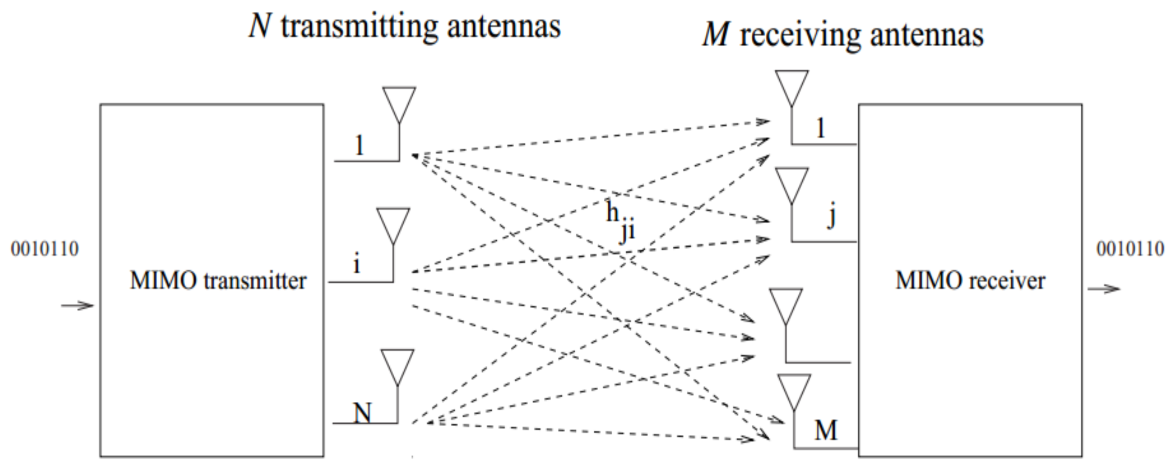

Fig 1.1 MIMO system

The key contributions are as follows,

1.Generalization of the determinant representation of hyper geometric functions with matrix arguments to the case where matrices in the arguments have eigen values with arbitrary multiplicity.

2.Derivation, using the generalized representation, of the joint probability distribution function (pdf) of the eigen values of complex Gaussian quadratic forms with arbitrary multiplicities for the eigen values of the associated covariance matrix.

3.Derivation of the ergodic capacity of single-user MIMO systems that accounts for arbitrary power levels and arbitrary correlation across the transmitting antenna elements, or arbitrary correlation at the receiver side.

4. Derivation of capacity expressions for MIMO systems in the presence of multiple MIMO interferers, valid for any number of interferers, each with arbitrary number of antennas having possibly unequal power levels.

1.2 SPATIAL MODULATION

Spatial modulation (SM) is a recently developed transmission technique that uses multiple antennas[1]. It aims to increase the data rate of a system without increasing the bandwidth requirements. The basic idea is to map a block of information bits to two information carrying units: 1) a symbol that was chosen from a constellation diagram and 2) a unique transmit antenna number that was chosen from a set of transmit antennas. The use of the transmit antenna number as an information-bearing unit increases the overall spectral efficiency by the base-two logarithm of the number of transmit antennas[7]. At the receiver, a maximum receive ratio combining algorithm is used to retrieve the transmitted block of information bits, constitutes a promising low-complexity multiple-input–multiple-output (MIMO) transmission technique

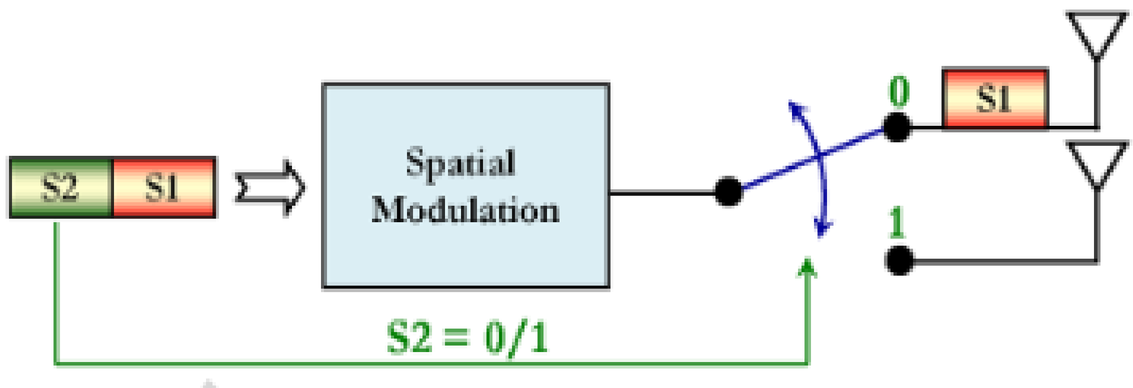

Fig: 1.2 spatial modulation

The SM-MIMO technique performed better in SNR and bit-error-rate (BER) tests over other commonly used massive-MIMO algorithms. The key is that SM-MIMO requires a lower QAM alphabet order compared to massive MIMO at the same spectral efficiency, which is a function of the increased spatial streams per user. These factors lead to higher spatial interference with traditional massive-MIMO systems[4]-[5]. The principle of wireless transmission in which the information is carried by both the index of the active antenna and the symbol transmitted through this active antenna was illustrated. In this scheme, the index of the active receiving antenna of each user in a MU-MIMO system is used to convey extra information in addition to the transmitted symbols.

1.3 SM-MIMO

SM is a recently proposed approach to multiple-input multiple-output (MIMO) systems. It aims to increase the data rate of a system without increasing the bandwidth requirements[2]. SM-MIMO scheme provided that a sufficiently large number of antenna elements is available at the transmitter and receiver[6]. SM–MIMO communications design for spectral- and energy-efficient cellular networks is centered upon two main pillars:

1) Given the performance constraints, minimize the number of active antenna elements in order to increase the EE by reducing the circuit power consumption at the transmitter (single-RF MIMO principle).

2) Given the implementation and size constraints, maximize the number of passive antenna elements in order to increase both the SE and the EE by reducing the transmit power consumption (large-scale MIMO principle). This is realized by capitalizing on the multiplexing gain introduced by mapping additional bits onto the SM constellation diagram[9].

1.4 GSM-MIMO

Generalized spatial modulation (GSM) is a relatively new modulation scheme for multiple antenna wireless communications. In MIMO technology GSM adapt for both fast fading and slow fading[16]. GSM gives the better throughput compare to the other modulation technique. It gives the high spectral efficiency and low complexity and high data rate without increasing the required bandwidth. In fast fading GSM gives the low bit error rate and high data rate.

CHAPTER 2

LITERATURE SURVEY

1) Serafimovski, Nikola, Abdelhamid Younis, Raed Mesleh, P. Chambers, Marco Di Renzo, Cheng-Xiang Wang, Peter M. Grant, Mark A. Beach, and Harald Haas. "Practical Implementation of Spatial Modulation", IEEE Transactions on Vehicular Technology, 2013.

In this paper, we seek to characterize the performance of spatial modulation (SM) and spatial multiplexing (SMX) with an experimental test bed. The digital signal processing (DSP) that formats the information data in preparation for transmission is described, along with the DSP that recovers the information data. In addition, the hardware limitations of the system are also analyzed. The average bit-error ratio (ABER) of the system is validated through both theoretical analysis and simulation results for SM and SMX under the line-of-sight (LoS) channel conditions. Activating only one antenna at a time means that only one radio-frequency (RF) chain is needed, which significantly reduces the hardware complexity of the system Moreover, the most energy-consuming parts of a base station (BS) are the power amplifiers and the RF chains that are associated with each transmitter, Where the power requirements of a BS are shown to linearly increase with the number of RF chains that are added . However, as only one RF chain is needed, SM offers a reduction in the energy consumption, which linearly scales with the number of transmit antennas.

Advantages:

i) High spectral efficiency
ii) High throughput

2) Di Renzo, Marco, Harald Haas, Ali Ghrayeb, Shinya Sugiura, and Lajos Hanzo. "Spatial Modulation for Generalized MIMO: Challenges, Opportunities, and Implementation", Proceedings of the IEEE, 2014.

This paper is intended to offer a comprehensive state-of-the-art survey on SM–MIMO research, to provide a critical appraisal of its potential advantages, and to promote the discussion of its beneficial application areas and their research challenges leading to the analysis of the technological issues associated with the implementation of SM–MIMO. The paper is concluded with the description of the world's first experimental activities in this vibrant research field. An in-depth description of the range of potential application areas for SM–MIMO communications is provided, which goes beyond the physical layer and encompasses green cellular networks, relaying and network-coded cooperative networking, as well as VLC. A critical appraisal of a range of un explored application domains and open research challenges for SM–MIMO research is offered, including its practical implementation aspects that should be addressed for industrial exploitation. Finally, experimental activities are presented, which contribute toward the implementation of SM–MIMO in a test bed platform.

Advantages:

- **i)** Energy efficient
- **ii)** High spectral efficinency

3) Jeyadeepan Jeganathan. "Spatial modulation: optimal detection and performance analysis", IEEE Communications Letters, 08/2008.

This paper provides the optimal detector for spatial modulation (SM) system. The new detector performs significantly better than the original (~4 dB gain), and we support our results by deriving a closed form expression for the average bit error probability. As well, we show that SM with the optimal detector achieves performance gains (~1.5−3 dB) over popular multiple antenna systems, making it an excellent candidate for future wireless communication standards. SM is an effective means to remove ICI and the need for precise time synchronization amongst antennas. SM is a pragmatic approach for transmitting information, where the modulator uses well known amplitude/phase modulation (APM) techniques such as phase shift keying (PSK) and quadrature amplitude modulation (QAM), but also employs the antenna index to convey information. Only one antenna remains active during transmission so that ICI is avoided, and inter-antenna synchronization (IAS) is no longer needed as in the case of V-BLAST, where all antennas transmit at the same time. We first derive the optimal detector for SM, improving over the sub-optimal detection rules suggested in [1]. Thanks to our development, SM compares favorably to other transmission schemes, such as APM with maximum ratio combining (MRC), and the well known V-BLAST. In order to support our results, we analyze the performance of the SM system, and derive a closed form expression for the bit error probability when real constellations are used.

Advantages:

i) Low complexity

ii) Optimal detection

4) Rajab M. Legnain, Roshdy H.M. Hafez1 and Abdelgader M. Legnain Improved spatial modulation for high spectral efficiency International Journal of Distributed and Parallel Systems (IJDPS) Vol.3, No.2, March 2012.

In this paper, we proposed a new MIMO transmission scheme to improve the spectral efficiency. In the scheme, we combine SM with spatial multiplexing. This new proposed SM scheme uses several antennas to transmit different symbols at the same time slot, where the active antennas are subset of a larger set of antennas. By computer simulation, BER performance for the proposed scheme was evaluated for uncorrelated Rayleigh fading channel and was compared to optimal SM and V-BLAST. To evaluate the performance of this scheme in an uncorrelated Rayleigh fading channel. Spatial Modulation (SM) is a technique that can enhance the capacity of MIMO schemes by exploiting the index of transmit antenna to convey information bits. In this paper, we describe this technique, and present a new MIMO transmission scheme that combines SM and spatial multiplexing.

Advantages:

i) Improve spectral efficiency

ii) High diversity gain

5) Marco Di Renzo, Harald Haas, and Peter M. Grant "Spatial Modulation for Multiple–Antenna Wireless Systems – A Survey", IEEE Communications Magazine (2011) pp. 182-191.

Multiple–antenna techniques constitute a key technology for modern wireless communications, which trade–off superior error performance and higher data rates for increased system complexity and cost. This paper summarize the latest research achievements and outline some relevant open research issues of this recently proposed transmission technique. Among the many transmission principles that exploit multiple–antenna at either the transmitter, the receiver, or both. Spatial Modulation (SM) is a novel and recently proposed multiple antenna transmission technique which can offer, with a very low system complexity, improved data rates compared to Single–Input–Single Output (SISO) systems, and robust error performance even in correlated channel environments. SM is an entirely new modulation concept that exploits the uniqueness and randomness properties of the wireless channel for communication. This is achieved by adopting a simple but effective coding mechanism that establishes a one–to–one mapping between blocks of information bits to be transmitted and the spatial positions of the transmit–antenna in the antenna–array.

Advantages:

i) Energy efficient

ii) Low complexity

CHAPTER 3

ANALYSIS OF SPATIAL MODULATION

The Spatial Modulation (SM) scheme aims to increase the data rate of the system without increasing the bandwidth requirements. SM increase the spectral efficiency and low complexity algorithm. In SM, in addition to the information bits conveyed through conventional modulation symbols, the index of the active transmit antenna also conveys information bits. Spatial Modulation is attractive for multi antenna wireless communications.

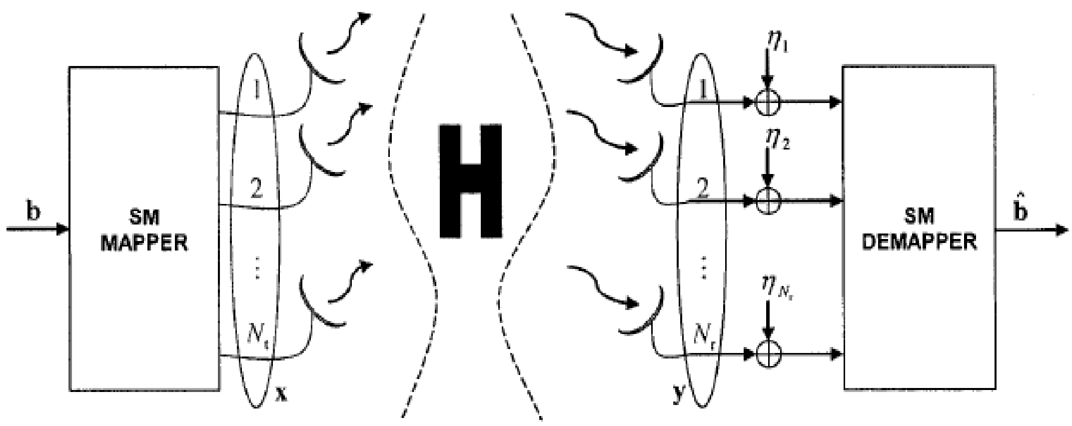

Fig 3.1.1 Spatial Modulation System model

In SM-MIMO there will be multiple transmit antennas but only one transmit RF chain, and the index of the active transmit antenna will also convey information bits in addition to information bits conveyed through modulation symbols like QAM symbols. SM-MIMO offers the advantages of reduced RF hardware complexity, size, and cost. Because of the spatial index bits, SM-MIMO can use a lower-order QAM alphabet compared to that in massive MIMO to achieve the same spectral efficiency, and for the same spectral efficiency and QAM size, massive MIMO will need more spatial streams per user which leads to increased spatial interference.

3.1 QAM Modulation

Quadrature Amplitude Modulation (QAM) is a combination of ASK and PSK so that a maximum contrast between each signal unit (bit, dibit, tribit, and so on) is achieved. The basic way in which the QAM signal can be generated is to generate to signals that are 90° out of phase with each other and then sum them. This will generate a signal that is the sum of the both waves, has a certain amplitude resulting from the sum of both signals and a phase which again is dependent upon the sum of signals.

Constellation diagrams are used to graphically represent the quality and distortion of a digital signal. In practice, there is always a combination of modulation errors that may be difficult to separate and identify, as such, it is recommended to evaluate the measured constellation diagrams using mathematical and statistically methods. In QAM, the constellation points are usually arranged in a square grid with equal vertical and horizontal spacing, although other configurations are possible.

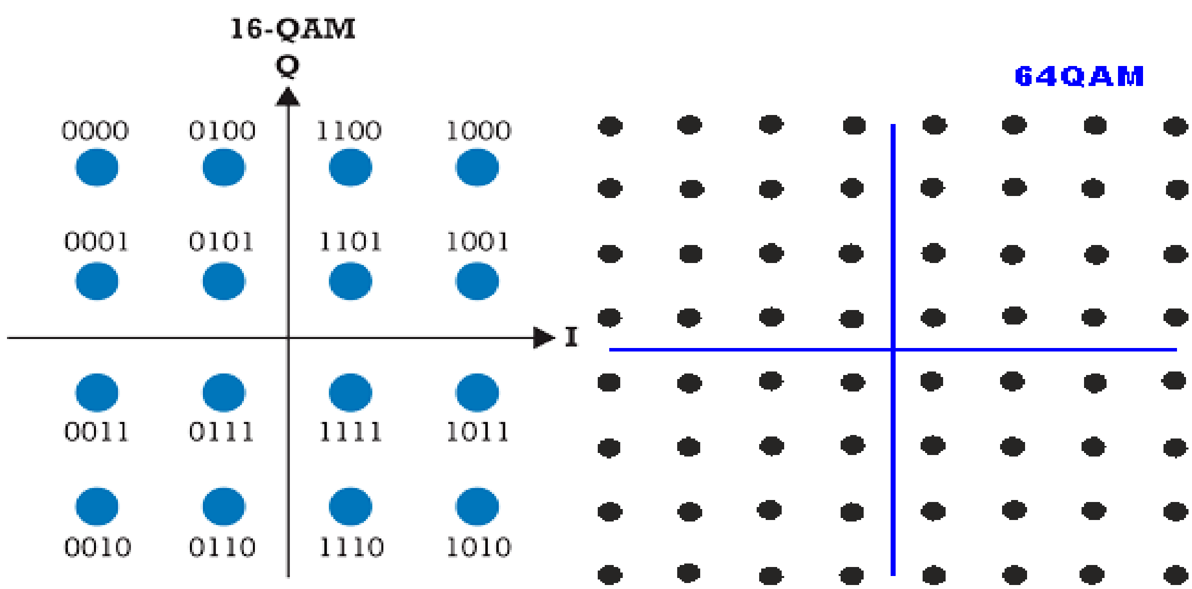

Fig 3.1.2 16-QAM and 64-QAM constellation diagram

3.2 Spatial Modulation

Spatial modulation (SM) is a recently developed transmission technique that uses multiple antennas. It aims to increase the data rate of a system without increasing the bandwidth requirements. The basic idea is to map a block of information bits to two information carrying units: A symbol that was chosen from a constellation diagram. A unique transmit antenna number that was chosen from a set of transmit antennas. The use of the transmit antenna number as an information-bearing unit increases the overall spectral efficiency by the base-two logarithm of the number of transmit antennas. At the receiver, a maximum receive ratio combining algorithm is used to retrieve the transmitted block of information bits. It's to be observed that,

i) Based on the input information bits, the TA activated may change for every channel use. Thus, switching of TA proves to be an effectual method of correlating the information bits to TA indices. This increases the rate of transmission. This has been referred to in many MIMO papers under the concept of spatial cycling using one transmitter at a time.

ii) The input information bits are mapped onto a 3-D constellation diagram, which adds a third dimension provided by the antenna indices to the known 2-D signal-constellation diagram of QAM modulation techniques. This is known as the spatial constellation diagram as shown in Fig 3.3.

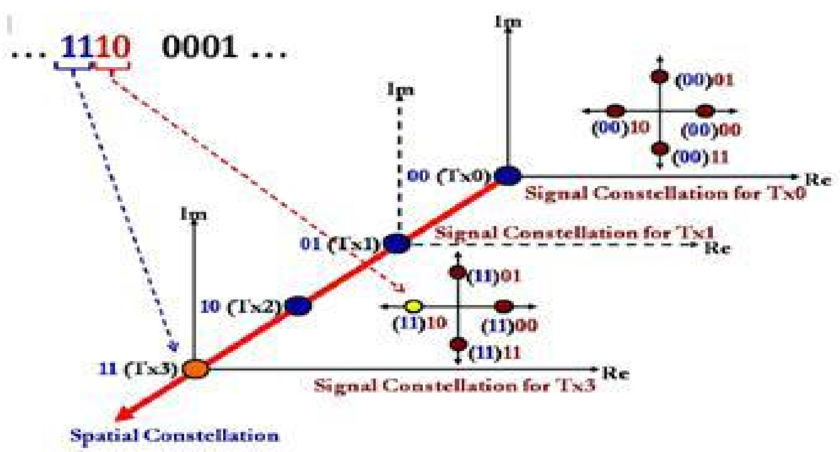

Fig 3.2 Spatial constellation diagram using 4 transmit antennas and QAM

3.3 AWGN Channel

AWGN channel is universal channel model for analyzing modulation schemes a white Gaussian noise is added to the signal passing through it. The only distortion is introduced by the AWGN Fading does not exist. AWGN channel is a theoretical channel used for analysis purpose only. At each time instant t=to, the value of n is normally distributed with zero mean and variance σ^2 at any two different time instants, the values of n are uncorrelated. The power spectral density has equal power in all frequency bands.

Mathematically, assuming a frequency-flat channel model, the SM–MIMO signal model is shown in Eq (1)

$$Y = Hx + n \qquad (1)$$

Where

y- the complex received vector

H- the complex channel matrix

n- the complex AWGN at the receiver

x- being the complex QAM modulated symbols belonging to the signal-constellation diagram in a complex modulated vector.

3.4 Operation principle of SM-MIMO

The operational principles of SM MIMO rely on transmitting part of the information bits via an implicit information-driven antenna-switching mechanism.

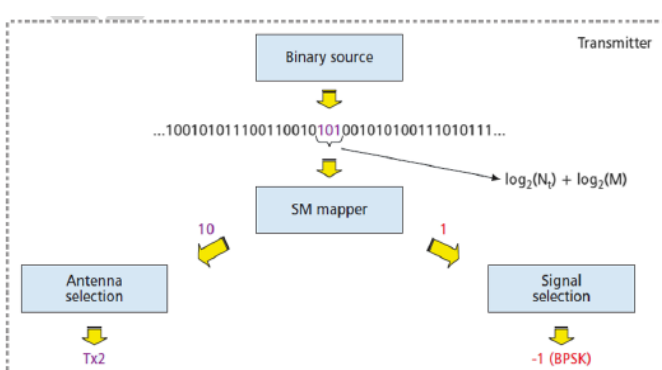

Fig 3.4.1 Bit to Symbol mapping at the transmitter

The bit-to-symbol mapping is illustrated in Fig 3.3. and the transmission process through the communication channel along with the decoding process of SM MIMO transmission is illustrated in Fig 3.4. The transmitter has two operations: Framing is defined as the input data is divided into multiple frames of 100 symbols per frame each. Modulation is defined as the framing is followed by SM modulation of each frame. The divided frames contain $log2(Nt * M)$ bits each, where M is the signal constellation size. It is mapped as follows,

i) The first part of the block, $log_2(N_t)$ bits indicate the active transmit antenna. It determines spatial-constellation point of SM. The active transmit antenna that is broadcasting is denoted by nt, where nt ∈ {1, 2, ..Nt}.

ii) The signal-constellation diagram is decided by the second part, $log2(M)$ bits. The actual complex symbol emitted by the transmit antenna.

The mapper, divides the bits into groups of $m = log2\ (M.Nt)$ bits and maps them to a constellation vector xjq. This is shown by Eq (2)

$$xjq = [0\ 0 \ldots xq\ 0 \ldots 0]T \qquad (2)$$

where

j represents the activated antenna

xq is the qth symbol from the M-ary constellation X.

B	X	Antenna j	X
[000]	1	1	$[1000]^T$
[001]	-1	1	$[-1000]^T$
[010]	1	2	$[0100]^T$
[011]	-1	2	$[0-100]^T$
[100]	1	3	$[0010]^T$
[101]	- 1	3	$[00-10]^T$
[110]	1	4	$[0001]^T$
[111]	-1	4	$[000-1]^T$

Table 3.4.1 Mapper for an SM System

Table 3.4.1 illustrates an example of the mapper for 3 bits/s/Hz transmission(N =4,M =2). Each information bit is mapped to a BPSK symbol, and transmitted on one of the four antennas. When xq is transmitted from the jth antenna, the channel output is expressed as shown in Eq (3)

$$y = \sqrt{\rho}\, hjxq + \eta \qquad (3)$$

where

hj represents the jth column of H.

In SM, only one antenna remains active during transmission and hence, only one symbol in x is nonzero (i.e., where j represents the activated antenna and xq is the q^{th} symbol from the constellation). The jth antenna remains active during transmission. Consider a generic $N_T \times N_R$ Multiple Input Single Output (MIMO) system, with Nt = 4 being the number of transmit and receive antennas, respectively. The transmitter can send digital information via BPSK signal waveforms. The basic idea of SM is to map blocks of information bits into two information carrying units [1] and [6] : A bit, which is chosen from a complex signal–constellation diagram and a unique transmit antenna index, which is chosen from the set of transmit antennas in the antenna array. The bit stream emitted by a binary source is divided into blocks at the transmitter, containing $log2\ (NT) + log2\ (M)$ bits each, with $log2\ (Nt)$ and $log2\ (M)$ being the number of bits needed to identify a transmit antenna in the antenna array and a symbol in the signal constellation diagram, respectively.

The signal can be decoded with a very low receiver complexity. Since, only one transmitting antenna is active during the transmission of a block, both energy and bandwidth are conserved. ICI can be avoided. A single RF chain at the transmitter is required due to the working mechanism All the other antennas are kept silent while a single transmit antenna is switched ON for data transmission. The multiplexing gain introduced in the spatial domain increases logarithmically with the number of transmit antenna, and is represented by the tridimensional constellation diagram in SM. A highly spectral efficient code is provided that has an equivalent code rate greater than one. The following flowchart (Fig 3.4.2) shows the steps followed for the SM system design,

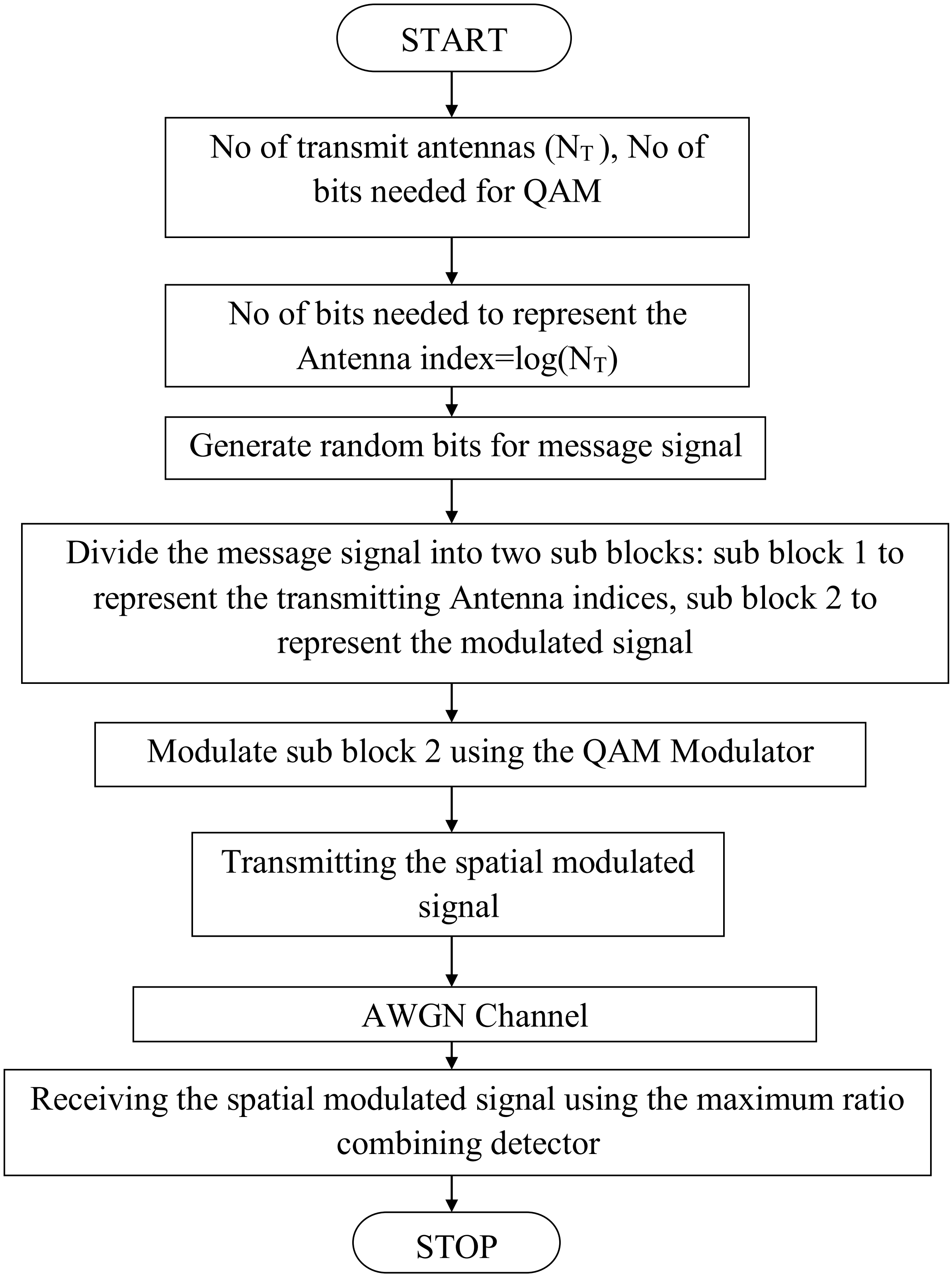

Fig 3.4.2 SM System Design

The rationale behind SM–MIMO Communications design for spectral- and energy-efficient cellular networks is centered upon two main pillars:

1) Given the performance constraints, minimize the number of active antenna elements in order to increase the EE by reducing the circuit power consumption at the transmitter (single-RF MIMO principle).

2) Given the implementation and size constraints, maximize the number of passive antenna elements in order to increase both the SE and the EE by reducing the transmit power consumption (large-scale MIMO principle). This is realized by capitalizing on the multiplexing gain introduced by mapping additional bits onto the SM constellation diagram.

CHAPTER 4
GENERALIZED SPATIAL MODULATION IN MIMO

The proposed Generalized Spatial Modulation (GSM) scheme aims to increase the reliability of the system in the fading environment. GSM is the effective transmission technique for both fast and slow fading environment. In fast fading GSM gives the high reliability and high data rate in MIMO technique without increasing the required bandwidth.

4.1 MULTIPATH PROPAGATION

In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. In digital radio communications (such as GSM) multipath can cause errors and affect the quality of communications.

4.2 FADING ENVIRONMENT

In wireless communication, fading is variation of the attenuation of a signal with various variables. These variables include time, geographical position and radio frequency. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as Multipath Fading. The presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each signal copy will experience differences in attenuation, delay and phase shift while travelling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. Strong destructive interference is frequently referred to as a deep fade and may result in temporary failure of communication due to a severe drop in the channel signal to noise ratio.

4.3 FADING EFFECT DUE TO DOPPLER SPREAD

4.3.1 SLOW FADING

In such a channel, the rate of the change of the channel impulse response is much less than the transmitted signal. We can consider a slow faded channel a channel in which channel is almost constant over at least one symbol duration.

$$BS \times BD \qquad (4)$$

Slow fading arises when the coherence time of the channel is large relative to the delay requirement of the application.

4.3.2 FAST FADING

In a fast fading channel, the channel impulse response changes rapidly within the symbol duration of the signal. Due to Doppler spreading, signal undergoes frequency dispersion leading to distortion. Therefore a signal undergoes fast fading is,

$$TS \times TC \qquad (5)$$

and

$$BS \times BD \qquad (6)$$

Where,

TC = coherence time

BD = Doppler spread

BS = signal bandwidth

TS = symbol period

Transmission involving very low data rates suffer from fast fading. Fast fading occurs when the coherence time of the channel is small relative to the delay requirement of the application. The coherence time of the channel is related to a quantity known as the Doppler spread of the channel. When a user (or reflectors in its environment) is moving, the user's velocity causes a shift in the frequency of the signal transmitted along each signal path. This phenomenon is known as Doppler Shift.

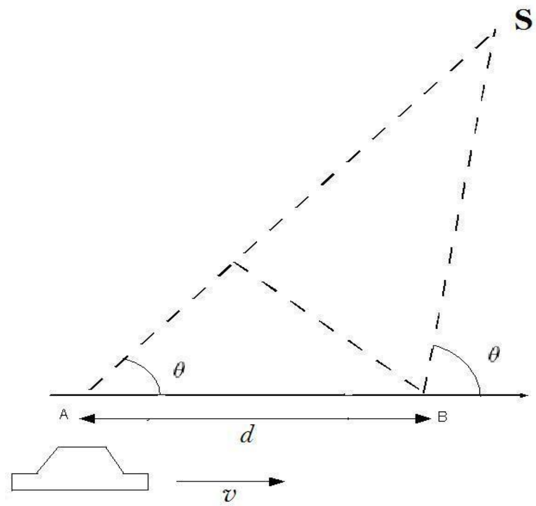

Fig 4.3.2.1 Illustration of Doppler Effect

Signals traveling along different paths can have different Doppler shifts, corresponding to different rates of change in phase. The difference in Doppler shifts between different signal components contributing to a signal fading channel tap is known as the Doppler spread. Channels with a large Doppler spread have signal components that are each changing independently in phase over time. Since fading depends on whether signal components add constructively or destructively, such channels have a very short coherence time.

In general, coherence time is inversely related to Doppler spread, typically expressed as,

$$Tc = \frac{1}{Ds} \qquad (7)$$

Where,

Tc = coherence time.

Ds = Doppler shift.

4.4 GENERALIZED SPATIAL MODULATION

Generalized Spatial Modulation (GSM) is relatively new modulation scheme for MIMO communication for high data rate without increasing the available bandwidth. GSM perfectly working in the fading environment. In fading environment GSM gives the system reliability. GSM works in both fast fading and slow fading, it gives the better throughput, high data rate. We propose and analyze a generalized spatial modulation scheme, where depending on the bits to be spatial modulated symbols. The receiver then has to estimate the spatial modulated symbol by using the Maximum Likelihood (ML) detector for being able to reconstruct the originally transmitted bit sequence. we analyze the Bit Error Rate (BER) for generalized spatial modulation symbol.

4.4.1 ML DETECTION

The object of the receiver is as previously stated to obtain an estimate of the message, s, from the given data in y and H. There are a wide variety of techniques for doing this but as stated in the introduction this work will only be concerned with the maximum likelihood (ML) detector[18]. The ML detector has the desirable property that, under the statistical assumptions, it minimizes the probability of error,

$$\boldsymbol{Pe} \triangleq \boldsymbol{P}(\boldsymbol{s} \neq \boldsymbol{s}') \qquad (8)$$

Note that minimizing the probability of error is equivalent to maximizing the probability of correctly estimating s,

$$P(s = s'|y, H) \qquad (9)$$

The Maximum Likelihood (ML) detection of s is given by,

$$S'_{ML} = \underset{s' \in s^m}{\textbf{argmax}} \|y - Hs'\|^2 \qquad (10)$$

Thus the ML detector chooses the message s' which yields the smallest distance between the received vector, y, and hypothesized message, Hs'.

In GSM to reduce the complexity of algorithm to achieve high data rate and increase throughput, high spectral efficiency. System reliability is high in fading environment by using the generalized spatial modulation in MIMO wireless communication.

.

CHAPTER 5
RESULTS AND DISCUSSION

The simulation result of bit error rate of Spatial Modulation (SM) using the Maximum Ratio Combining (MRC) detector is shown below,

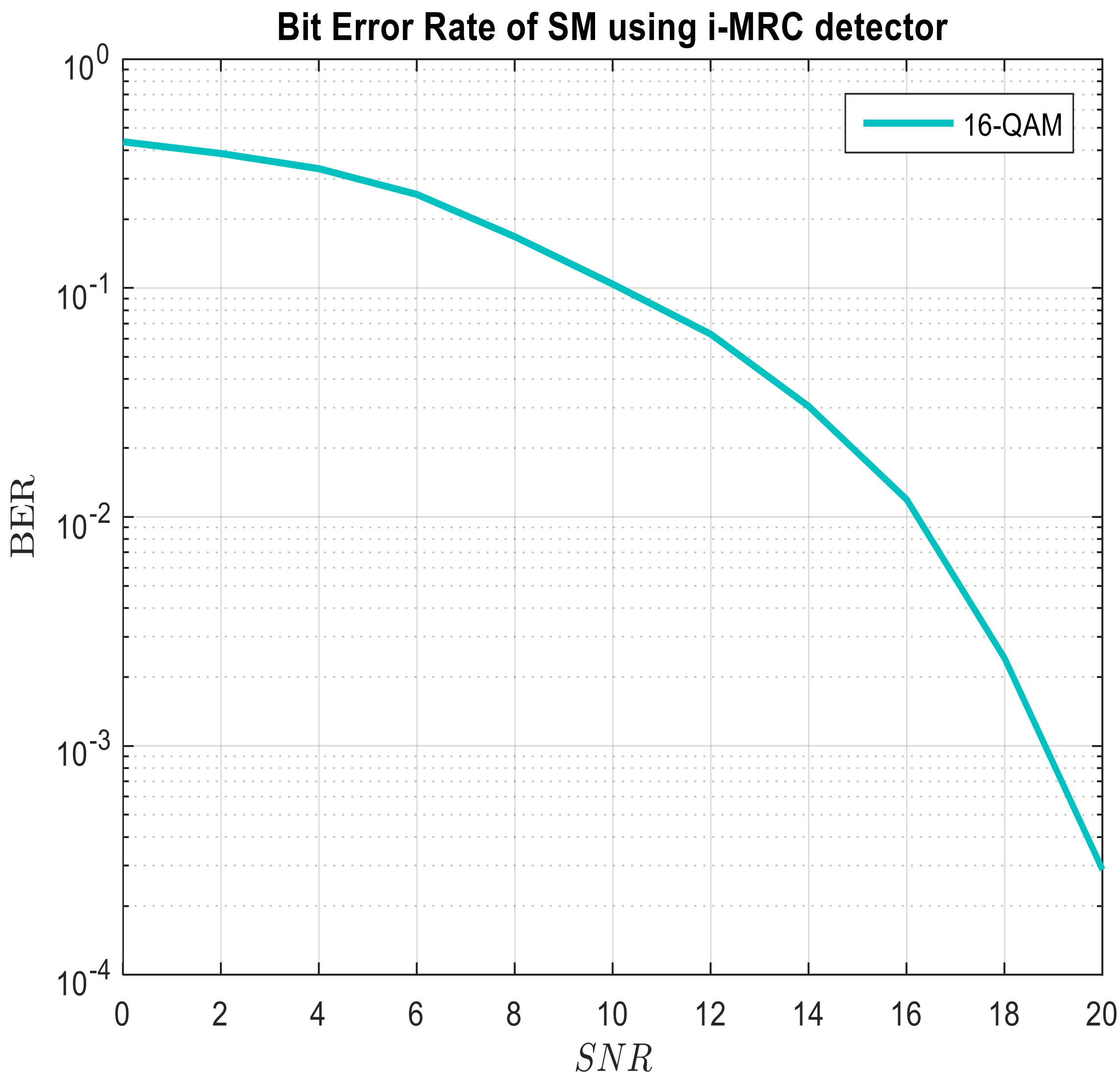

Fig 5.1 Bit Error Rate of SM using MRC Detector

The SM new modulation schemes provide the higher spectral efficiency and energy efficient. It's aims to increase the bit rate in the wireless communication system without increasing the bandwidth requirements. The bit error rate is minimum in spatial modulation compared to other modulation technique. There is no Inter Symbol Interference (ISI) in SM-MIMO.

The bit error rate comparison of different usage of detector like maximum likelihood detector and maximum ratio combining is given below,

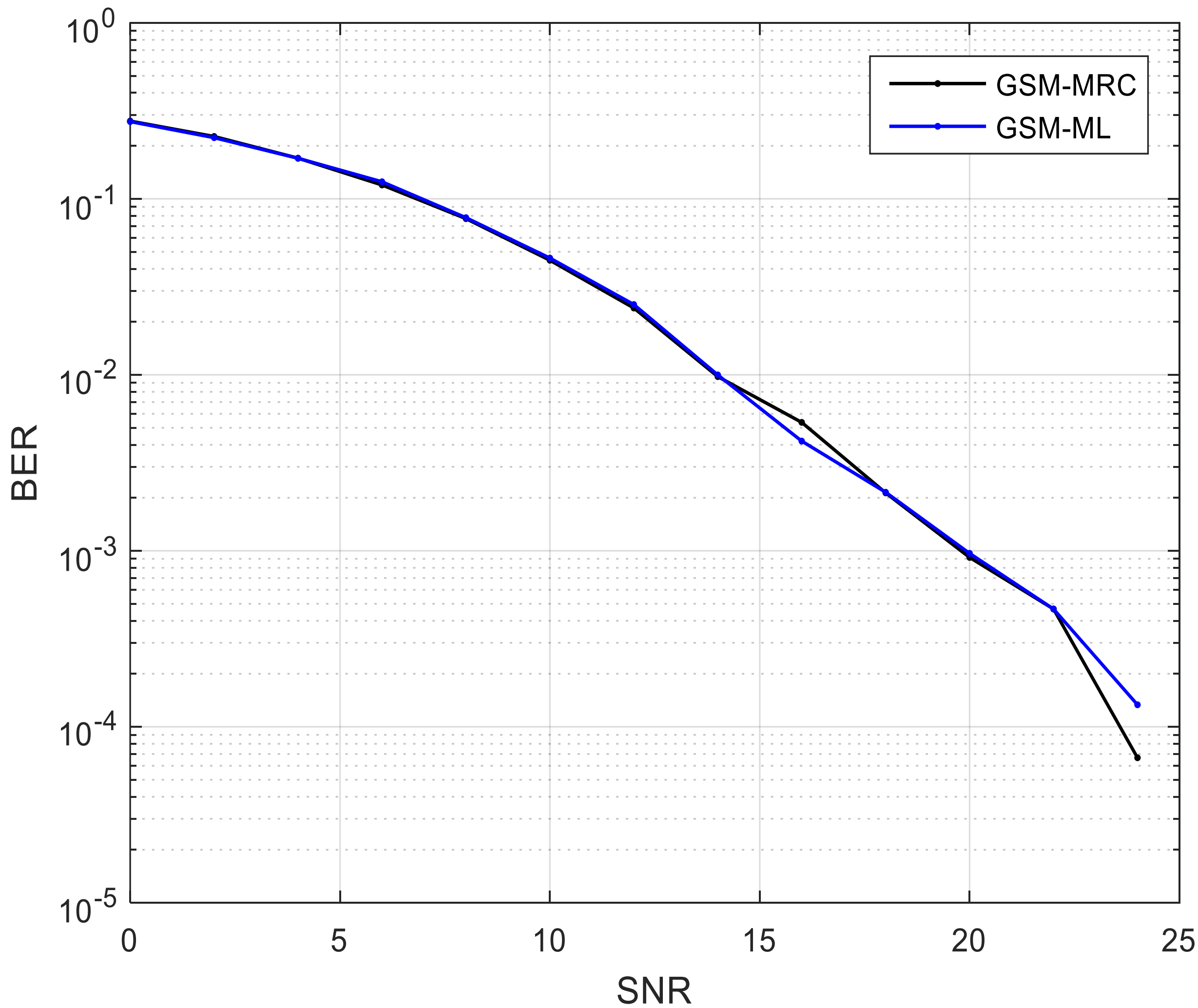

Fig 5.2 BER comparison between ML and MRC detectors

Generalized Spatial Modulation gives the low bit error rate in both Fast Fading (FF) and Slow Fading (SF) environment. The bit error rate comparison of fast fading and slow fading is given below,

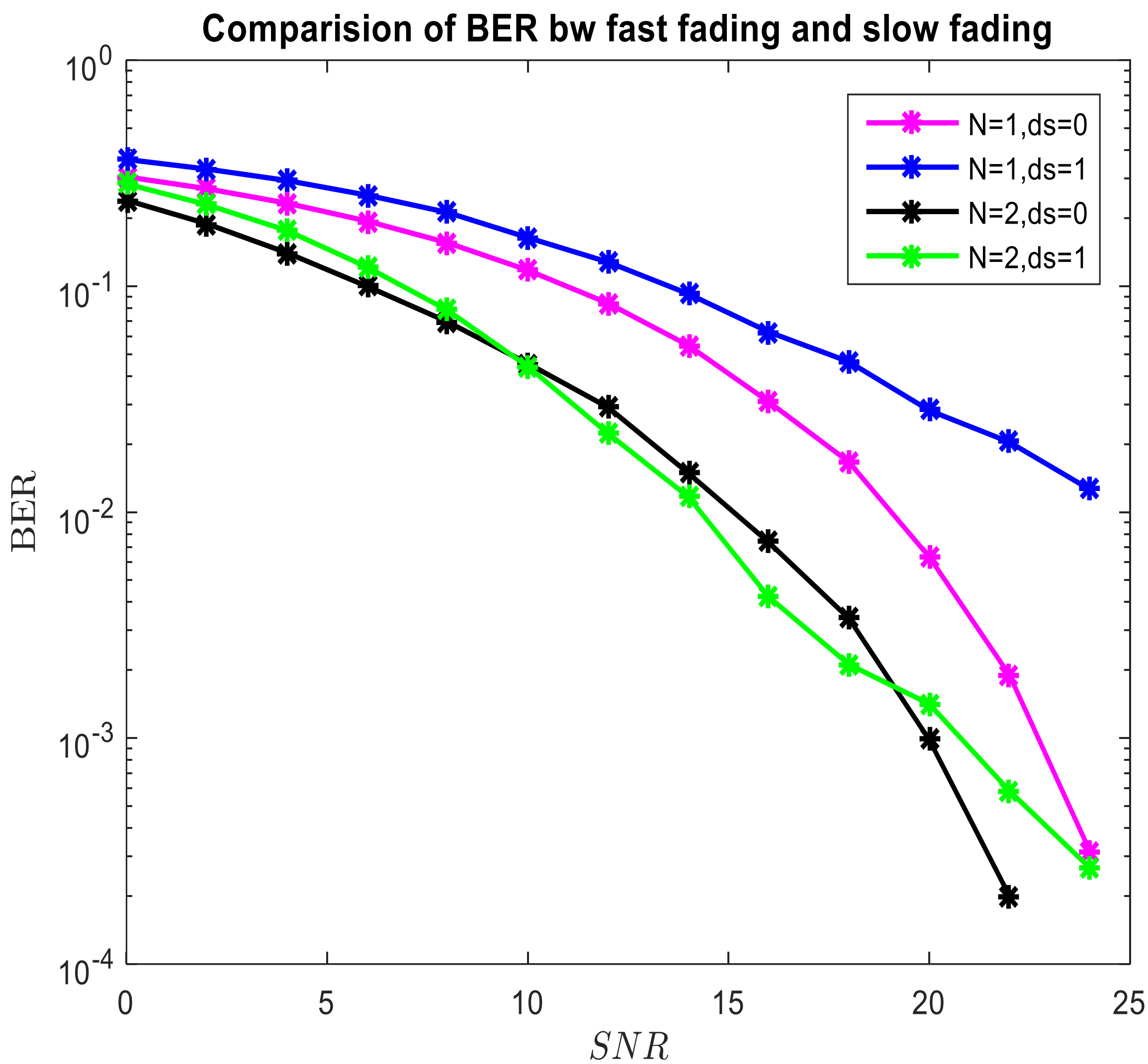

Fig 5.3 BER comparison between FF and SF

In GSM gives the low bit error rate in fast fading environment and high data rate without increasing the available bandwidth. In fast fading environment, to use other modulation scheme the signal will get destroyed so the reliability of the system is low, the efficiency of the wireless communication system is low, so to use the generalized spatial modulation scheme for both fast fading and slow fading environment.

In GSM, to use single receiver the bit error rate of the spatial modulated symbol is given below,

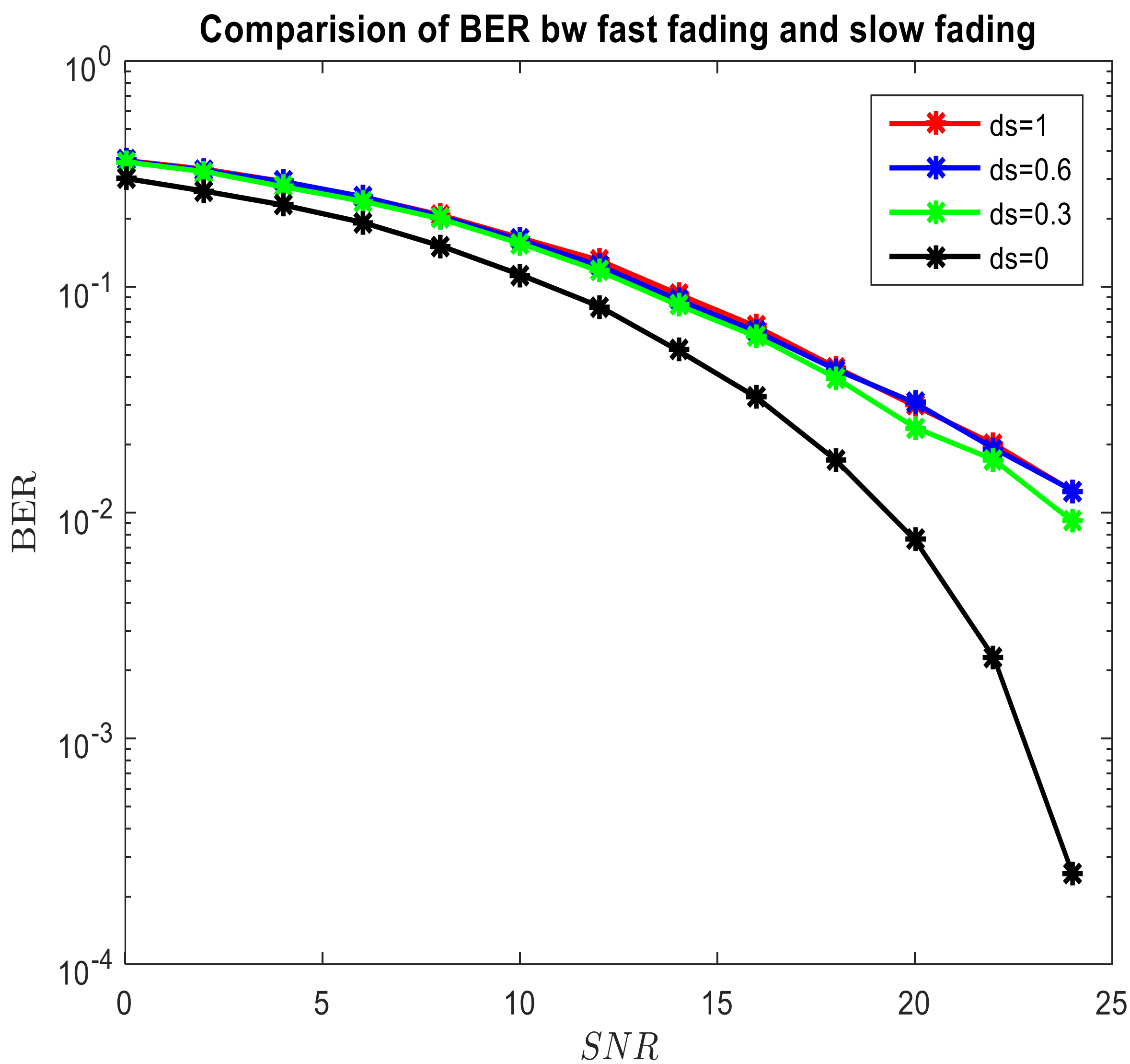

Fig 5.4 BER comparison between FF and SF with Nr=1

To use the single receive antenna the cost of the system is low and to reduce the hardware complexity, and also to achieve the high data rate with low complexity detection algorithm. The throughput of the system is high compare to the other modulation scheme.

In GSM, to increase the number of receiver antenna the bit error rate of the system is given below,

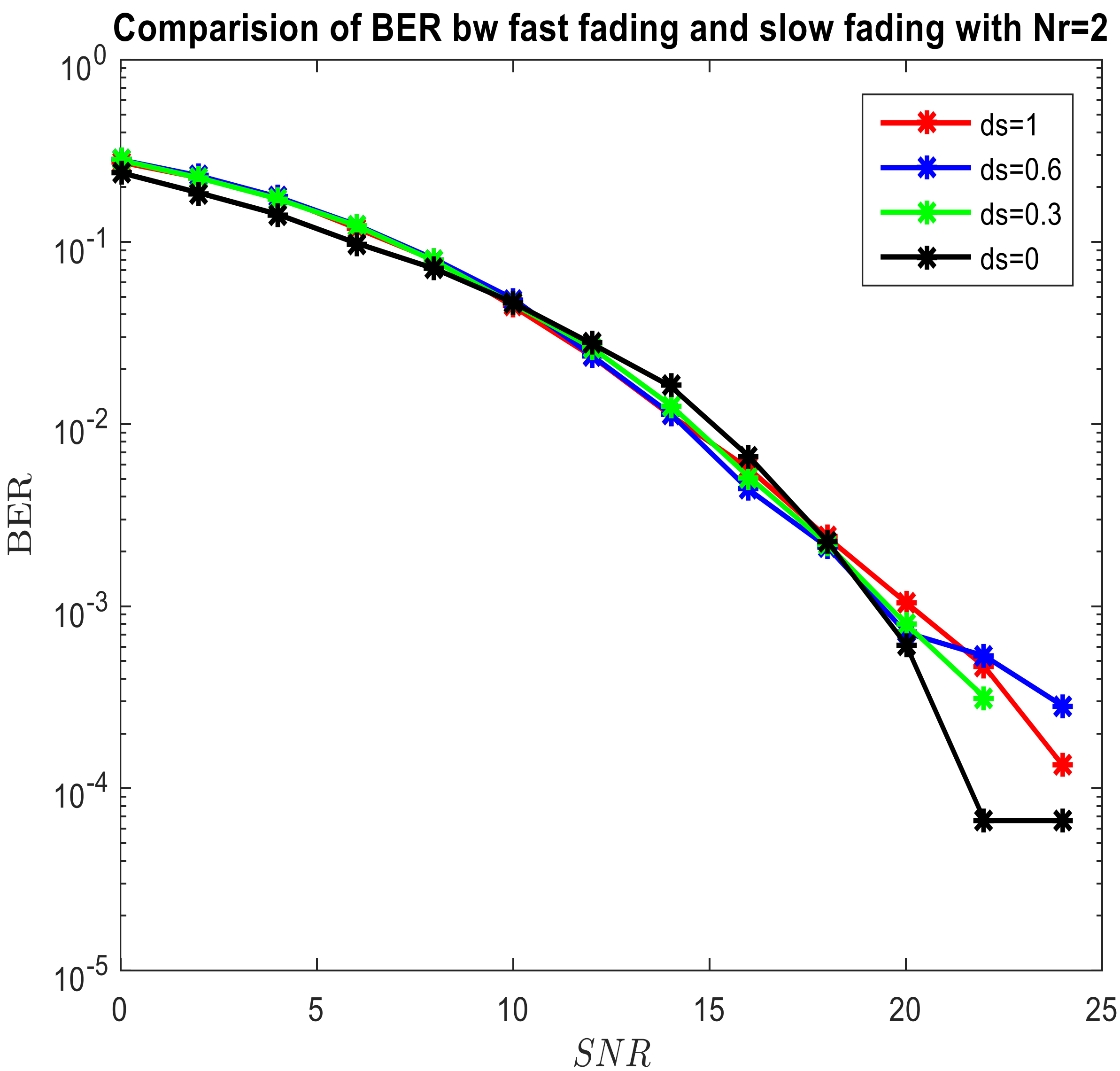

Fig 5.5 BER comparison between FF and SF with Nr=2

Fig 5.3 shows that to increase the number of receiving antenna the bit error rate of the GSM spatial modulated symbol in both fast fading and slow fading environment. GSM gives the better result in the fast fading environment compare to other modulation scheme. the reliability of the system is very high in GSM over the fast fading environment, they achieve the high data rate.

To increasing the number of receiving antennas in the MIMO system the bit error rate for fast fading environment is given below,

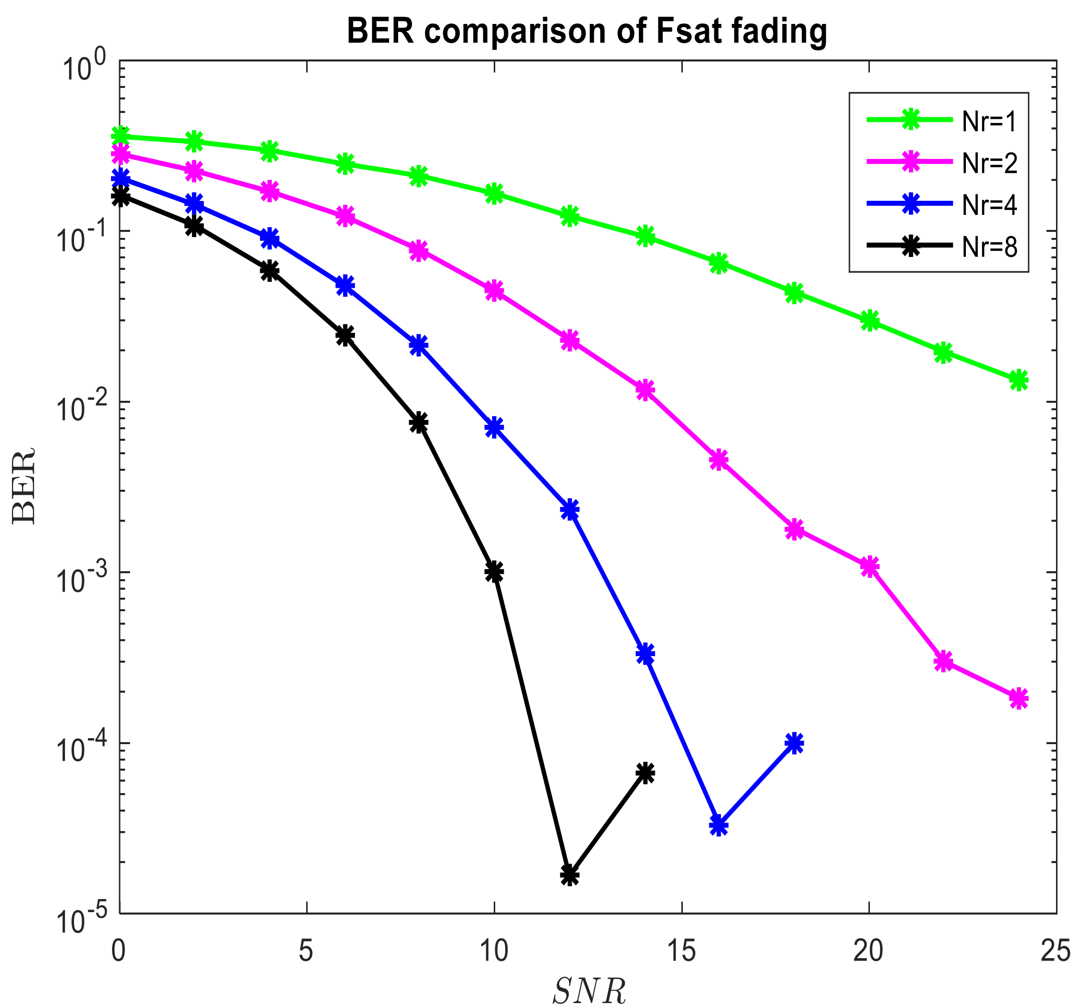

Fig 5.6 BER comparison of fast fading

In fast fading, to increase the number of receiving antennas the data rate should be very high, the system reliability is high. from the figure 5.4 we refer that, to increase the number of antenna the signal to noise ratio is reduced and the data rate of the system is decreased, the system complexity is increased. Therefore to use the one or two receiving antenna to achieve low complexity and high data rate.

To increasing the number of receiving antennas in the MIMO system the bit error rate for slow fading environment is given below,

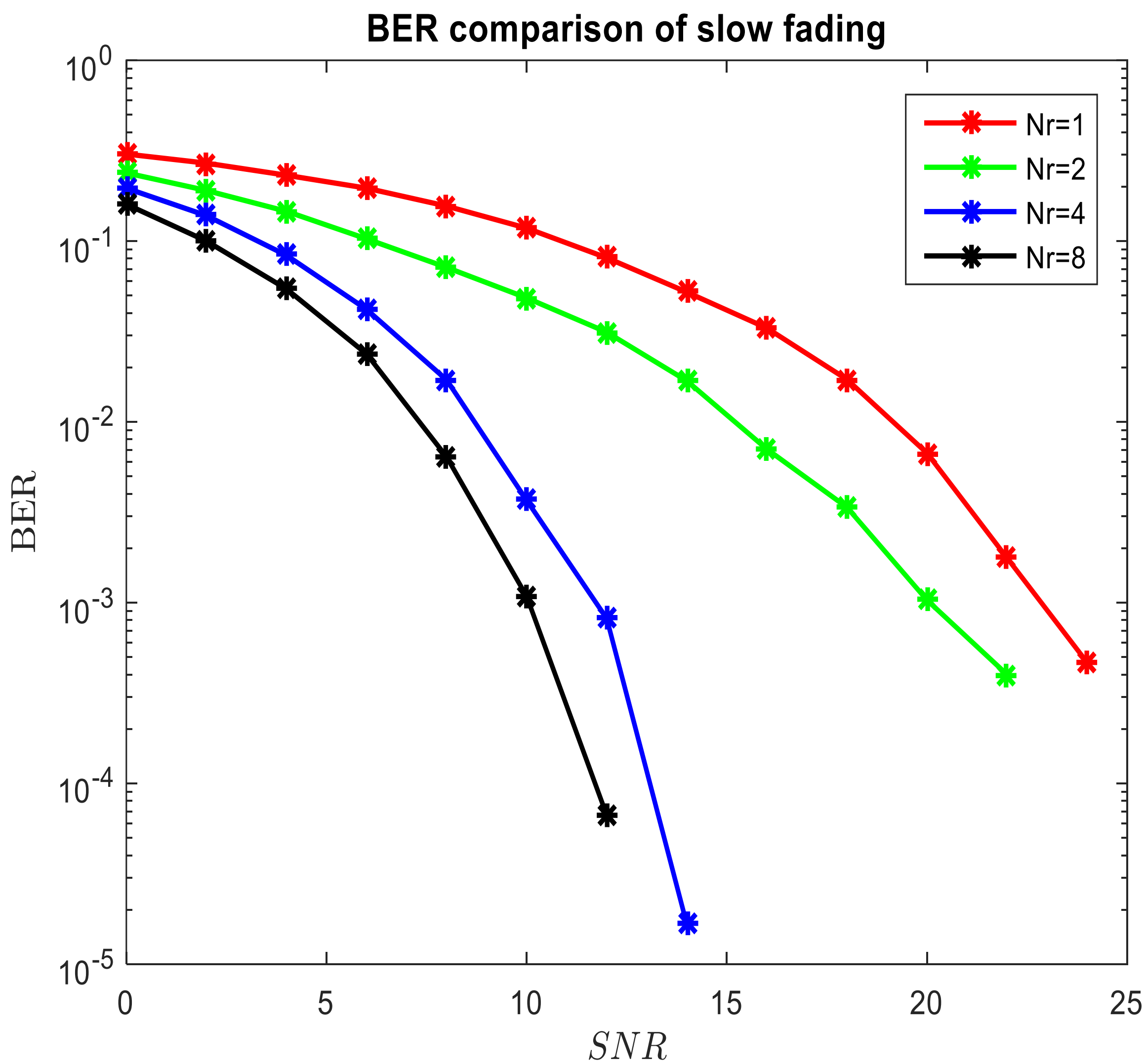

Fig 5.7 BER comparison of slow fading

In slow fading, to increase the number of receiving antennas the data rate should be very high, the system reliability is high. from the figure 5.4 we refer that, to increase the number of antenna the signal to noise ratio is reduced and the data rate of the system is decreased, the system complexity is increased. Therefore to use the one or two receiving antenna to achieve low complexity and high data rate.

CHAPTER 6
CONCLUSION

5.1 Conclusion

In Generalized Spatial Modulation (GSM) scheme is used to increase the data rate of a system without increasing the bandwidth requirements. GSM provides the higher spectral efficiency and energy efficiency. In GSM-Multi Input Multi Output (MIMO) scheme provides the low complexity. To reduce the bit error rate over the fading environment by using the generalized spatial modulation. GSM-MIMO scheme provided that a sufficiently large number of antenna elements is available at the transmitter and receiver. GSM scheme uses several antennas to transmit different symbols at the same time slot, where the active antennas are subset of a larger set of antennas. To use one or two receiving antenna in GSM, to decrease the hardware cost and system reliability and achieve the high data rate in both fast fading and slow fading.

REFERENCES

[1] Serafimovski, Nikola, Abdelhamid Younis, Raed Mesleh, P. Chambers, Marco Di Renzo, Cheng-Xiang Wang, Peter M. Grant, Mark A. Beach, and Harald Haas. "Practical Implementation of Spatial Modulation", IEEE Transactions on Vehicular Technology, 2013.

[2] Di Renzo, Marco, Harald Haas, Ali Ghrayeb, Shinya Sugiura, and Lajos Hanzo. "Spatial Modulation for Generalized MIMO: Challenges, Opportunities, and Implementation", Proceedings of the IEEE, 2014.

[3] Jeyadeepan Jeganathan. "Spatial modulation: optimal detection and performance analysis", IEEE Communications Letters, 08/2008.

[4] Rajab M. Legnain, Roshdy H.M. Hafez1 and Abdelgader M. Legnain Improved spatial modulation for high spectral efficiency International Journal of Distributed and Parallel Systems (IJDPS) Vol.3, No.2, March 2012.

[5] Marco Di Renzo, Harald Haas, and Peter M. Grant "Spatial Modulation for Multiple–Antenna Wireless Systems – A Survey", IEEE Communications Magazine (2011) pp. 182-191.

[6] J. Mietzner, R. Schober, L. Lampe, W. H. Gerstacker, and P. A. H¨oher, "Multiple–antenna techniques for wireless communications – A comprehensive literature survey", *IEEE Commun. Surveys Tuts.*, vol. 11, no. 2, pp. 87–105, 2nd quarter 2009.

[7] R. Y. Mesleh, H. Haas, S. Sinanovic, C. W. Ahn, and S. Yun, "Spatial modulation", *IEEE Trans. Veh. Technol.*, vol. 57, no. 4, pp. 2228–2241, July 2008.

[8] J. Jeganathan, A. Ghrayeb, L. Szczecinski, and A. Ceron, "Space shift keying modulation for MIMO channels", *IEEE Trans. Wireless Commun.*, vol. 8, no. 7, pp. 3692–3703, July 2009.

[9] Y. Chau and S.–H. Yu, "Space modulation on wireless fading channels", *IEEE Veh. Technol. Conf. – Fall*, vol. 3, pp. 1668–1671, Oct. 2001.

[10] H. Haas, E. Costa, and E. Schultz, “Increasing spectral efficiency by data multiplexing using antennas arrays”, *IEEE Int. Symp. Personal, Indoor, Mobile Radio Commun.*, vol. 2, pp. 610–613, Sept. 2002.

[11] S. Song, Y. Yang, Q. Xiong, K. Xie, B.–J. Jeong, and B. Jiao, “A channel hopping technique I: Theoretical studies on band efficiency and capacity”, *IEEE Int. Conf. Commun., Circuits and Systems*, vol. 1, pp. 229–233, June 2004.

[12] M. Di Renzo and H. Haas, “Improving the performance of space shift keying (SSK) modulation via opportunistic power allocation”, *IEEE Commun. Lett.*, vol. 14, no. 6, pp. 500–502, June 2010.

[13] J. Jeganathan, A. Ghrayeb, and L. Szczecinski, “Spatial modulation: Optimal detection and performance analysis”, *IEEE Commun. Lett.*, vol. 12, no. 8, pp. 545–547, Aug. 2008.

[14] Y. Yang and B. Jiao, “Information–guided channel–hopping for high data rate wireless communication”, *IEEE Commun. Lett.*, vol. 12, no. 4, pp. 225–227, Apr. 2008.

[15] R. Y. Mesleh, H. Haas, C. W. Ahn, and S. Yun, “Spatial modulation – A new low complexity spectral efficiency enhancing technique”, *IEEE Int. Conf. Commun. Networking in China*, pp. 1–5, Oct. 2006.

[16] J. Jeganathan, A. Ghrayeb, and L. Szczecinski, “Generalized space shift keying modulation for MIMO channels”,*IEEE Int. Symp. Personal, Indoor, Mobile Radio Commun.*, pp. 1–5, Sept. 2008.

[17] A. Alshamali and B. Quza, “Performance of spatial modulation in correlated and uncorrelated Nakagami fading channel”, *J. Commun.*, vol. 4, no. 3, pp. 170–174, Apr. 2009.IEEE COMMUNICATIONS MAGAZINE – OPEN CALL 16

[18] S. U. Hwang, S. Jeon, S. Lee, and J. Seo, “Soft–output ML detector for spatial modulation OFDM systems”, *IEICE Electronics Express*, vol. 6, no. 19, pp. 1426–1431, Oct. 2009.

[19] R. Y. Mesleh, M. Di Renzo, H. Haas, and P. M. Grant, “Trellis coded spatial modulation”, *IEEE Trans. Wireless Commun.*, vol. 9, no. 7, pp. 2349–2361, July 2010.