Analysis and Performance Measurement of Beamforming alongwith Equalization in MIMO-OFDM

DISSERTATION-II

Submitted in partial fulfillment of the

Requirement for the award of the

Degree of

MASTER OF TECHNOLOGY

IN

Electronic and Communication Engineering

by

Jaskirat Singh

Under the Guidance of

Mr. Shakti Raj Chopra

Assistant professor

School of Electrical and Electronics Engineering

Lovely Professional University

Phagwara,Punjab

April,2017

TOPIC APPROVAL PERFORMA

School of Electronics and Electrical Engineering

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

COURSE CODE : ECE521 **REGULAR/BACKLOG :** Regular **GROUP NUMBER :** EEERGD0267

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

Qualification : ________________________ **Research Experience :** ________________________

SR.NO.	NAME OF STUDENT	REGISTRATION NO	BATCH	SECTION	CONTACT NUMBER
1	Jaskirat Singh	11511956	2015	E1514	9530625691

SPECIALIZATION AREA : Wireless Communication **Supervisor Signature:** ___________________

PROPOSED TOPIC : Space Time Coding Techniques in MIMO

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	6.50
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.50
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.50
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	7.50
5	Social Applicability: Project work intends to solve a practical problem.	6.50
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	6.50

PAC Committee Members		
PAC Member 1 Name: Rajeev Kumar Patial	UID: 12301	Recommended (Y/N): Yes
PAC Member 2 Name: Lavish Kansal	UID: 15911	Recommended (Y/N): NO
PAC Member 3 Name: Dr. Gursharanjeet Singh	UID: 13586	Recommended (Y/N): NA
DAA Nominee Name: Amanjot Singh	UID: 15848	Recommended (Y/N): NA

Final Topic Approved by PAC: **Already a lot of work has been done on this topic. So, please change it and add some recent technologies.**

Overall Remarks: Approved (with major changes)

PAC CHAIRPERSON Name: 11106::Dr. Gaurav Sethi **Approval Date:** 05 Oct 2016

CERTIFICATE

I hereby certify that the research work which is being presented in the M.Tech. Dissertation-II entitled **"Analysis and Performance Measurement of Beamforming alongwith Equalization in MIMO-OFDM Systems",** in partial fulfillment of the requirements for the award of the **Master of Technology in Wireless Communication** and submitted to the Department of Electronics & Communication Engineering of Lovely Professional University, Phagwara(PUNJAB) is an authentic record of my own work carried out under the supervision of **Mr.Shakti Raj Chopra ,** ECE Department.

Signature of Candidate

JASKIRAT SINGH

Regd. no - 11511956

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

Signature of Supervisor(s)

Date: **MR.SHAKTI RAJ CHOPRA**

Objective of Dissertation-II is satisfied/unsatisfied

Examiner-1 Examiner-2

ACKNOWLEDGEMENT

I take this opportunity to remember and acknowledge the cooperation and support both moral and technical extended by several individuals out of which this Dissertation-II report has evolved.

I express my sincere gratitude to my Guide **Mr.Shakti Raj Chopra**,for his cooperation and guidance for preparing and presenting this report.A lot of thanks to other faculty members of the department who gave their valuable suggestions at different stages.

I am very much thankful to our parents who helped me with utmost friendliness and warmth always. I also like to thanks my classmates and friends for their support.

Jaskirat Singh

Reg. No.11511956

ABSTRACT

Multiple Antenna Communication has become one of major focuses in wireless communication research. MIMO Technology is used to enhance the system capacity. The effect of Fading and Interference can be combated to increase the capacity of a link. MIMO system uses Several Transmit and Several Receive antennas which exploit the multipath propagation in rich scattering environment.Orthogonal frequency division multiplexing (OFDM) for MIMO channels (MIMO-OFDM) is considered for transmission to mitigate inter-symbol interference and enhance system capacity. Multi-input and multi-output (MIMO) and orthogonal frequency division multiplexing (OFDM) have attracted significant attention, and become promising techniques for high data rate wireless communication systems. They have been widely studied and employed for 4G systems such as WiFi,, WiMAX and LTE.

In this paper we make use of various equalization techniques.The chief goal of equalization techniques is to rebuild real signal with help of filter or any other methods and remove the effect of ISI so that reliability of data transmission is maintained.Equalizer works by keeping the bit error rate as low as possible and SNR as high as possible.These equalization techniques proved to be very important for designing wireless system with high data rate transmission capacity. Different equalizer techniques can be used are Zero Forcing Equalizer, minimum mean square error, maximum likelihood sequence estimation.

Alongwith the Equalization techniques,the Beamforming is also done in which antennas arrays are “directed” at preferred target or origin by regulating relative phase & gain of elements of array. By adjusting phase & gain of element, antenna beam or pattern,could made to pt in any favorite route for transferring & reception of data, or to attenuate any other directions so as to lessen influence of source of interference.Beamforming could improves quality of reception & rise throughput of data in a MIMO communication system.

Index term- *Multiple Input Multiple Output (MIMO), Othogonal frequency Division Multiplexing (OFDM), Equalization schemes, Beamforming, Channel Estimation.*

DECLARATION

I, **Jaskirat Singh,** student of **"Master of Technology (Wireless Communication)"** under Department of "**Electronics and Communication Engineering"** of Lovely Professional University,Phagwara(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:

JASKIRAT SINGH

REGD NO. 11511956

CONTENTS

LIST OF FIGURES

ABBREVIATIONS

MIMO	Multiple Input Multiple Output
SISO	Single Input Single Output
SIMO	Single Input Multiple Output
MISO	Multiple Input Single Output
BER	Bit Error Rate
OFDM	Orthogonal frequency division multiplexing
ICI	Inter-carrier interference
IFFT	Inverse Fast Fourier Transform
FFT	Fast Fourier Transform
CP	Cyclic Prefix
QAM	Quadrature Amplitude Modulation
SNR	Signal to Noise Ratio
STBC	Space Time Block Coding
LS	Least Square
ZF	Zero Forcing
MSE	Mean Square Error
MMSE	Minimum Mean Square Error
MRC	Maximal Ratio Combining
MU-MIMO	Multi-user-Multiple input multiple output system

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION TO MIMO SYSTEM

In the conventional wireless communications, at the transmitter side only single antenna is used and at the receiver side another single antenna is used.Sometimes this leads to rise in the multipath effects problems.When radio signal meet with any of obstacles such as mountains, buildings then the signal get scatter, and therefore they took numerous ways to reach target.The delayed entrance of scattered signal’s portion led to many problems such as intermittent reception ,fading etc.In system of digital communications along with remote Internet, it led to loss in speed of data and rise in the errors number.The usage of 2 or extra antennas,alongwith the multiple signals transmission (1 for every one antenna) at source & target,removes trouble being caused by propagation of multipath wave,and can else take benefit of effect.MIMO technique have roused interest for the reason that of its promising uses in wireless local area network,digital television, ,metropolitan area network & mobile communicatios.MIMO is an antenna technique where data is transmitted in multiple streams on multiple transmitters in the direction of multiple receivers.MIMO increases the data rates and range both.The capacities of antenna systems obtained varies in various systems of MIMO.The expressions are estimated, but they provide perception for the derive channel capacity terms when consuming multiple antennas.

1.1.1Types of MIMO antenna technology

Several Types of MIMO are:

1.1.1.1 Technique of Single Input, Single Output(SISO)

In SISO technique only single antenna transmittin the signal towards single receiving antenna as in fig 1-1. The simplicity is the advantage of a SISO system. SISO system not want processing in terms of several types of diversity that can be used. However performance of channel of SISO is not unlimited.Assume that a given channel,with transmitter power is P ,bandwidth B, and the receiver end signal has an avg value of SNR.Then the capacity of system capacity can be given as- $C = B * \log2(1 + SNR)$

Fig 1-1: Single Input, Single Output(SISO)

1.1.1.2 Technique of Single Input, Multiple Output(SIMO)

SIMO is an antenna technique for communications in medium wireless where several antennas(NR) can be used at destination (receiver).It is primarily used to let a Rx system which accepts signal from various sources that are independent to lessen the fading effects.The capacity of channel for SIMO system is nearly equals to-

C = NR * B * log2 (1 + SNR)

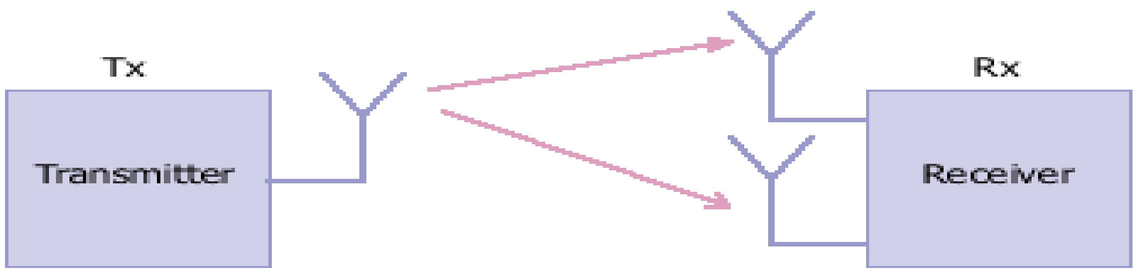


Fig1-2: Single Input, Multiple Output(SIMO)

1.1.1.3 Technique of Multiple Input, Single Output(MISO)

MISO is an antenna technique where several antennas(NT) are used at Tx. The antennas are joined for errors minimization & optimizing of data speed.The Rx side has single antenna.The entire transmitted power is divided among the branches of transmitter.If signals are coherently added at single reception antenna then we will get nearly an NT fold rise in SNR in compararison to case of SISO antenna. Thus with the total growth in value of SNR, the capacity of channel here is nearly equals to:

C = NT * B * log2 (1 +SNR)

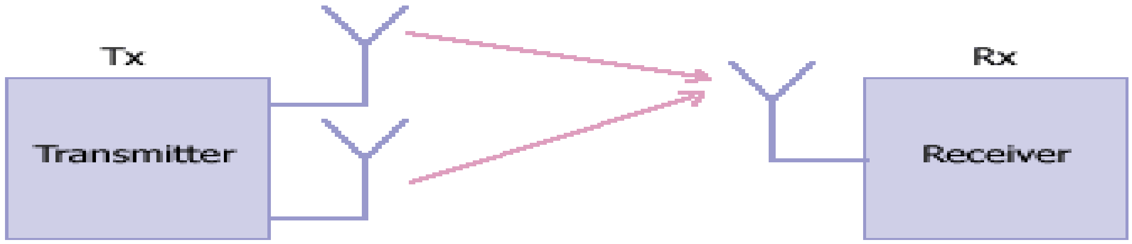


Fig1-3: Multiple Input, Single Output(MISO)

1.1.1.4 Technique of Multiple Input, Multiple Output(MIMO)

When there are several antenna at both end of link of radio,then this can be term as MIMO.It could be make in use to deliver enhancements both in channel throughput & also channel robustness.Different signals transmitted with every one antenna,with MIMO consuming similar BW & still then be capable to decode at Rx correctly. The capacity of every one of channel is equivalent to:

C = min (NT,NR) * B * log2 (1 +SNR)

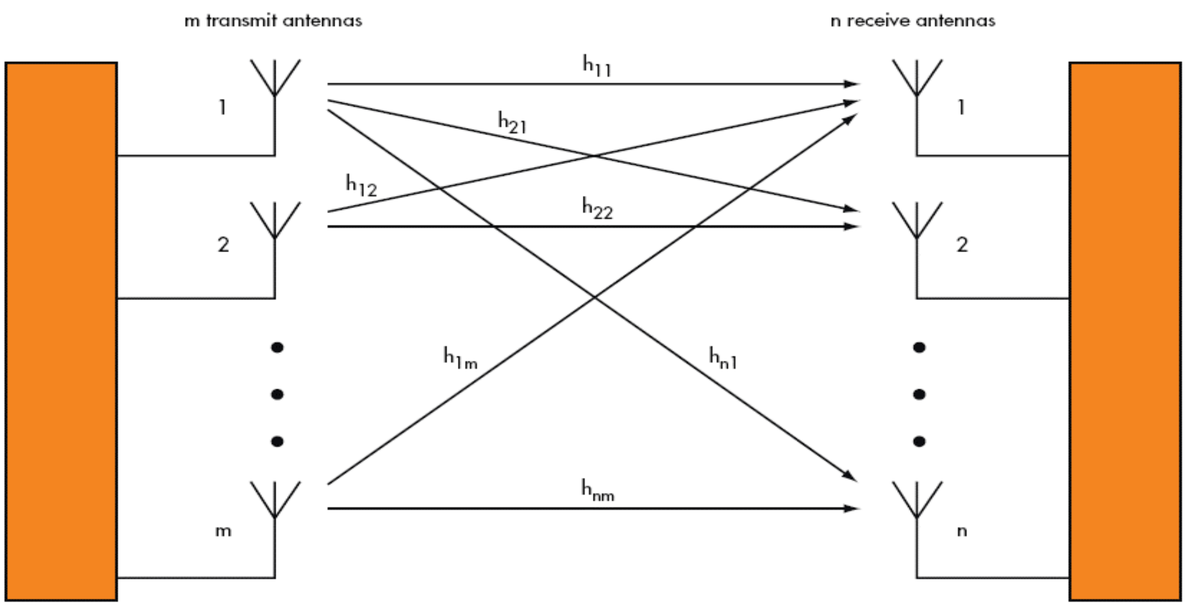


Fig1-4: Multiple Input, Multiple Output(SIMO)

1.2 Benefits of Multiple Antenna System

Array gain:Array gain is avg rise in value of SNR at Rx that rises from everal Antennas coherent joining effect.The signals incoming at the Rx side have dissimilar phases & amplitudes. The Rx can link the signals coherently to enlarge the final signal. This could improved reliability, & so system capacity.

Spatial Diversity (SD): Power of signal will vary in remote channel. When signal power falls considerably, the channel is in fade. Diversity may be used to avoid effect of fading. Spatial diversity is transfer of many, duplicates of signal at Rx.Thus, we exploited rich scattering channel nature, which suggests that probability of entire copies go through deep fading is much less. Atleast certain copies would be existed at Rx for merging. This is accomplished by use of numerous antennas at Tx known Transmit diversity & at Rx known Receive diversity.

Spatial multiplexing: It proposes linear growth in rate of transmission (in various pair of transmit-receive antenna) for similar BW without any extra expenditure of power. SM is discribe for system of 2x2. This could though be prolonged to any MIMO system. The bit streams to be transferred is demultiplexed into 2 sub-streams of half rate, transmitted & modulated cumulatively from each one transmit antenna. The spatial signatures of signal induced at Rx antenna are separated.The Rx having the information about channel, can distinguish between signals of co-channel& extracted both, afterward this demodulation provides original stream which is joined to recover back original signal.

Reduction in Interference: Interference of Co-channel is there to reuse of frequency in remote channels. When numerous antennas used,distinction between cochannel signals & spatial signatures of signal desired could be exploited to lessen the interference.

Linear Growth of Capacity: The MIMO system capacity linearly raises with amount of antennas. 2x2MIMO have capacity 2 times and 4x4MIMO have capacity multiple of 4.

Compatible with Backwards: It support FDD & TDD technique so could be used with previous version of 802.11x to rise data rate.MIMO make use many Tx and Rx antennas to permit for enlarged throughput of data over spatial multiplexing & increase range by using spatial diversity & it helps in creating products that may have Prolonged battery, Immersive entertainment and Extended wireless connectivity.

1.3 INTRODUCTION TO OFDM

OFDM is multi-carrier technique accepted by several wireless communication standards. A system of multicarrier communication with orthogonal sub-carriers is known as Orthogonal Frequency Division Multiplex (OFDM) system. The word "orthogonal" displays that there is specific mathematic relationship between the carriers frequencies of system. The OFDM basic principle is to splitting high data rate sequences into numeral of sequences with low-rate that consecutively transferred over a no. of subcarriers.As symbol interval is increased for parallel subcarriers of low rate, the comparative amount of time dispersion caused by multipath delay spread get reduced. Inter-symbol interference (ISI) is also get removed almost completely on beginning of every symbol of OFDM with guard interval.The symbol of OFDM extended cyclically in guard interval so as to exclude ICI.Thus,a selective channel of high frequency is get changed into huge set of flat fading, narrowband channels and non-frequency selective.

1.3.1 OFDM generation

To produce OFDM well the link between all carriers need to carefully controlled to keep the orthogonality of carriers.For this purpose, OFDM is created by 1st chooses the spectrum needed, based on data input, & modulation scheme used. Each carrier to created is allocated certain data to transfer. The require phase & ampl of carrier is then be calculated based on scheme of modulation. The necessary spectrum is then changed back to signal in time domain using an IFT. In maximum applications, an IFFT is used. The IFFT does the conversion efficiently, and gives easy way of confirming that carrier signal produced are orthogonal. The FFT transforms a cyclic signal of time domain into corresponding spectrum of frequency. This is done by finding of correspondent waveform, generated by amount of components that are orthogonal sinusoidal. The phase & amplitude of the sinusoidal components signify the spectrum of frequency of signal in time domain.The IFFT performs back process, converting spectrum (phase &amplitude of every component) into signal of time domain. The orthogonal carriers needed for the signal of OFDM could be simply generated by setting phase & amplitude of every data point, then carrying out IFFT.

1.3.2 Orthogonality

The spectral efficiency of a system is well-defined by the transferred bit rate in the frequency domain. In a multicarrier transmission, the gaps between two subcarriers is essential in order to have a bandwidth efficient system.If the space between the subcarriers is more, a higher bandwidth will be required to transfer a signal with same rate and hence the spectral efficiency is lower. As it can be seen in Fig1-5, avoiding subcarriers from overlapping removes the inter-channel interference at the cost of bandwidth inefficiency.

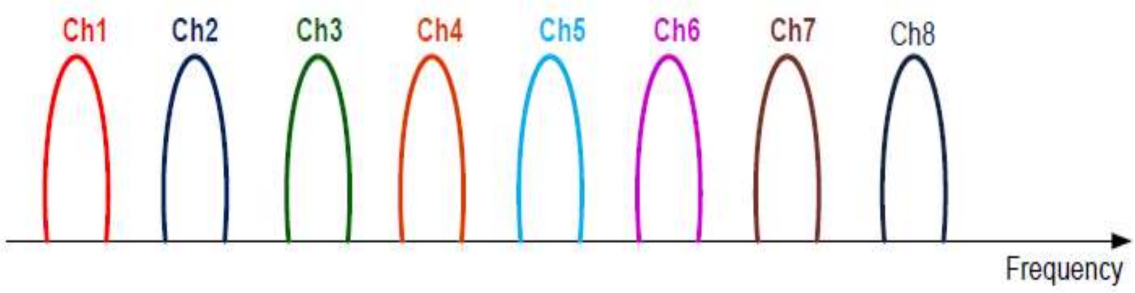


Fig1-5: Conventional Multicarrier Technique

To resolve the bandwidth inefficiency, OFDM has been presented where the center of one subcarrier is placed such that it lands into the null of the nearby subcarrier as shown in Figure 1-6, almost 50% of the bandwidth is saved by allowing the subcarriers to overlap.

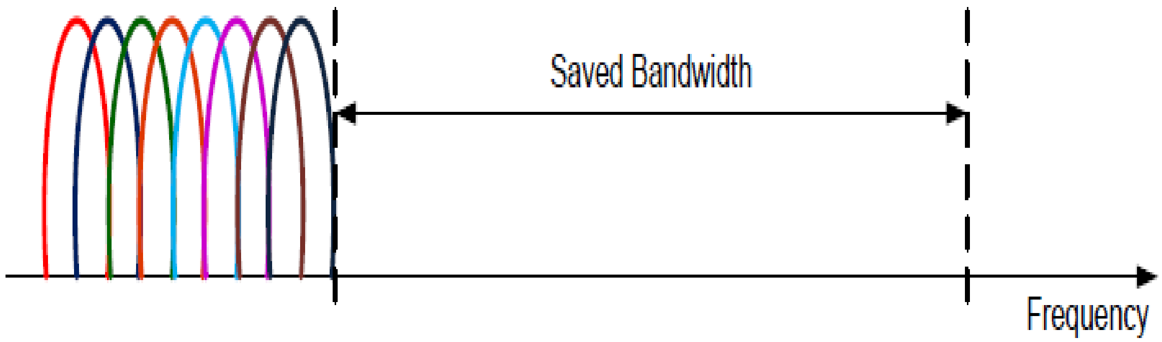


Fig1-6: Orthogonal Multicarrier Modulation Technique

1.3.3 Cyclic Prefix

The introduction of cyclic prefix (CP) between two successive OFDM symbols is used in terrestrial systems in order to minimize the effect of delay spread of multipath channels. In order to simplify the synchronization, a copy of last end of transmitted OFDM symbols is added up before the data stream, afterward the IFFT operation. The length of the CP is modifiable and must be set in order to keep a bandwidth efficient system.

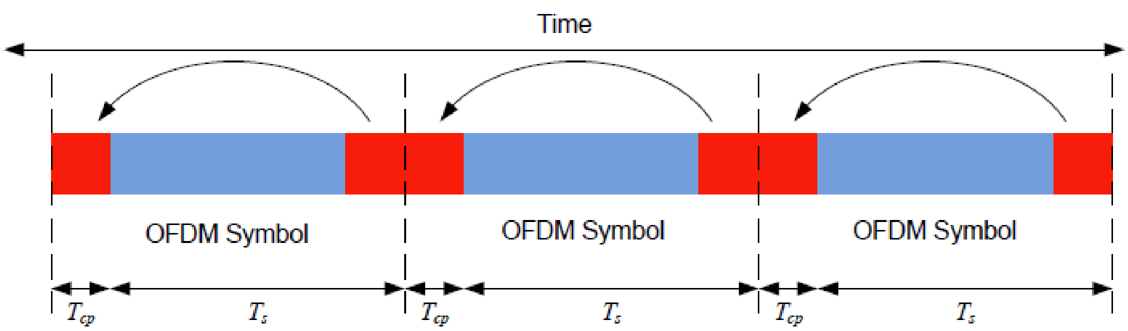


Fig 1-7: Temporal Representation of OFDM Symbols

Let *D* denote the set of symbols at last of symbol of OFDM where *Ns* is complete no. of subcarriers. The interval of the CP depends on 4 factors:

1.Channel length: In order to confirm a perfect equalization, the channel length, *L*, should be lesser than length of CP, *D*, that is $D>L$.

2. Performance of System: As the CP indicates a redundancy of the end of the OFDM symbol, the efficiency of spectrum get reduced and is given by $Ns/(Ns+D)$. In order to get a spectral efficiency close to 1, *Ns* will tends to ∞.

3. Complexity: The FFT processes are made on *Ns* blocks size, thus, in order to have a feasible system, the *Ns* value cannot be indefinitely increased. In such cases, a trade-off between complexity and spectral efficiency must be reached. Generally, the value of *Ns* is selected equals to 4D, which gives a spectral efficiency of 25%.

4. Channel type: In order to get the circularity of the convolution, the channel need to remain constant during the transmission of single OFDM symbol. In such cases, the diversity carried by the system cannot be rised even if *Ns* increase. Thus, the selection of *Ns* depends on the channel type (channel diversity, slow or fast fading).

1.3.4 Advantages of OFDM

- OFDM is also a BW efficient technique of modulation since the parallel subcarriers get overlap but are orthogonal to each other without interfering.
- Each one subcarrier could be modulated with use of different modulation techniques M-PSK or M-QAM according to the necessity of the system
- OFDM seems to be very powerful technique of modulation for systems working under frequency selective channels.
- OFDM has comparatively large PAPR which tends to lessen the efficiency of power of RF amplifier.

1.4 MIMO-OFDM MODEL

OFDM changes a channel of frequency selective into big set of individual narrowband frequency channel which is non-selective, which is appropriate for structure of MIMO which needs characteristic of non-selective frequency at each channel when rate of broadcast is higher & sufficient to make entire frequency selective channel. Hence,MIMO engaging OFDM, denotes as MIMO-OFDM, capable to attain higher spectral efficiency. However, acquisition of several elements of antenna at Tx for spatial transfer resulted in super-position of numerous transferred signals at Rx biased by there equivalent channels of multipath & made signal reception much tough. This put real test to project system practically which offers true information of spectral efficiency .If there is channel with frequency selective, then signal received are deformed by ISI, that led difficult recognition of signals transferred. OFDM had arisen as best efficient mode to eliminate ISI.

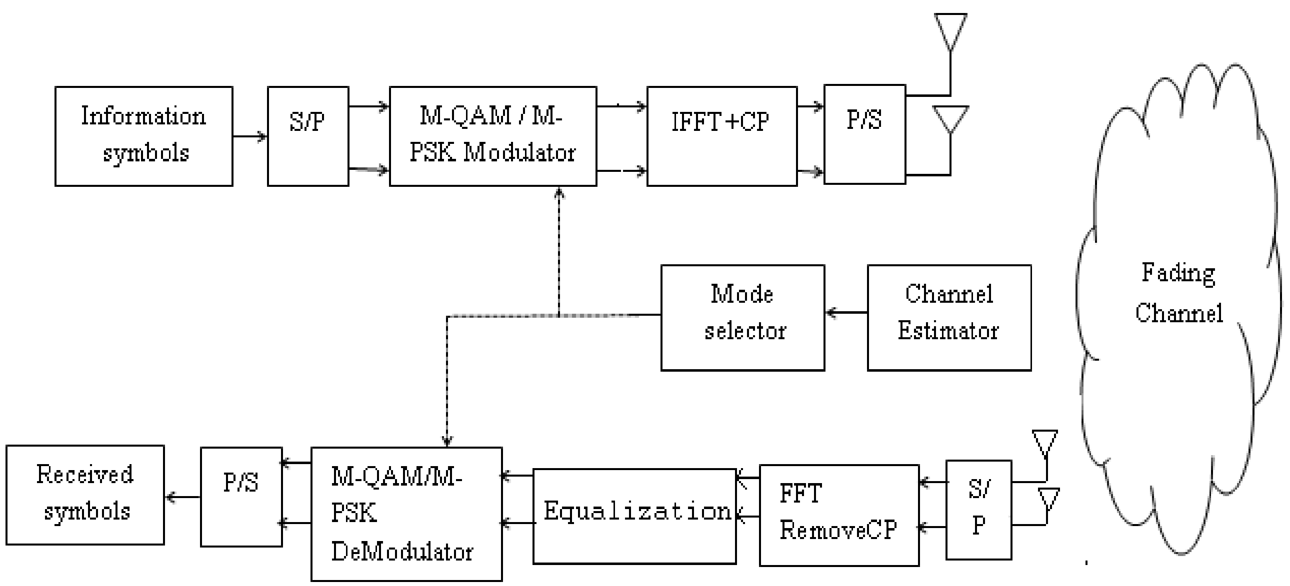


Fig 1-8:MIMO-OFDM Model

Description of model is given below:

a) Conversion from Serial to Parallel

The input stream of information in serial is organized into size of word necessary for broadcast, & moved to format of parallel.The data can then transferred parallel by allocating each one data word to single carrier in transmission.

b) Data Modulation

Data to transferred on every carrier is encoded differentially with earlier symbol, then plotted into format of PSK. As differential encoding required an inital phase reference further symbol is being added at beginning for it purpose. The data in every symbol is plotted to phase angle built on method of modulation.

c) Inverse Fourier Transform

After mandatory spectrum worked out, an IFT is used to detect corresponding waveform of time.At beginning of each symbol ,guard period is then summed up.

d) Insertion of Guard Period

The guard period has 2 sections. Partial of time of guard period is 0 amplitude transmission. The another partial of guard period is symbol’s cyclic extension to be transferred.This is to permit for timing of symbol to be simply recovered by envelope detection.However it is find that it is not require in any simulation as timing can be precisely determined samples position.

e) Mode of Channel

A channel is then employed for signal transfer. The model permits for the SNR, clipping of peak power & multipath to controlled. The S/N ratio set by addition of known quantity of white noise to transferred signal.

f) Multiple Antennas

Many Antennas (MIMO)are used on either Tx or Rx side to provide the improved efficiency with a smaller amount of interference.

g) Receiver

The Rx mainly does opposite operation to Tx.The guard period get remove. FFT of every symbol took to find original transferred spectrum. The phase angle of every transmission carrier is assessed & changed back to data word by received phase demodulation. The data words are then combining back to same size of word as data in original.

1.4.1 Advantages of MIMO-OFDM

- Lesser amount of Interference.
- Diversity in gain.
- Data Capacity rises.
- Efficiency of power
- Gain in Bandwidth

1.4.2 Limitations of MIMO-OFDM

- Antenna space should be suitable depending on the type of channel.
- Complex transmitter and receiver.

1.5 BEAMFORMING

The Beamforming concept can be describes as follow:

1.5.1 Introduction

Multipath is issue in remote systems. It led to fading as remote signal travel across various paths and interfered with one another when reaches at Rx. Preprocessing of the wireless signal at Tx using method known beamforming can mitigate the effects of multipath for improving the link robustness and throughput. IEEE 802.11n states no. of MIMO technique which use several antennas to reform performance in environment of multipath.Transmit Beamforming (TxBF) is one such technique. TxBF is elective feature in IEEE 802.11n, but there is rising industry demand for specific feature in numerous applications of wireless. The Alliance of Wi-Fi has registered beamforming as possible features in 11n program of certification. These methods greatly improve link robustness and throughput.

1.5.2 Beamforming Basics

Beamforming is wireless technique of transmission in which antennas arrays are "directed" at preferred target or origin by regulating relative phase & gain of elements of array. By adjusting phase & gain of element, antenna beam or pattern,could made to pt in any favorite route for transferring & reception of data, or to attenuate any other directions so as to lessen influence of source of interference.Beamforming could improves quality of reception & rise throughput of data in a MIMO communication system.A simple condition for transmit beamforming is usage of various elements of antenna at Tx, and usage of wireless measured channel between the Tx & Rx.

IEEE 802.11n std states various methods aimed at MIMO transmit beamforming of signal in OFDM. One method, stated to as "explicit beamforming", which requires channel of downstream might measured at Rx, & sent back to Tx.Beamformer make use of measured information of channel to derived parameters of transmited beamforming. A 2nd method defined in std is "implicit beamforming". In it implementation, beamformer measures wireless upstream channel, & this measurement derive parameters for consequent downstream beamformed broadcast.Beamforming of Implicit had benefit that beamformee doesn't require to measure & send CSI to beamformer. However 11n std. beamforming of implicit needs calibration interchange between beamformee & beamformer, which could make transceiver structure difficult.Patented design of implicit doesn't require such interchange, making it well-suited to backward with prevailing 802.11a and 802.11g items.

The fig:1-9 demonstrats process of transmit beamforming.Fig shows a traditional 1 Tx (1T) and 1-Rx (1R) which is inabsentia of beamforming. In comparison, Fig:1-10 shows a 2-Tx (2T) 1-Rx (1R) system which is using beamforming. In both cases,scheme of modulation in OFDM is used for broadcast.

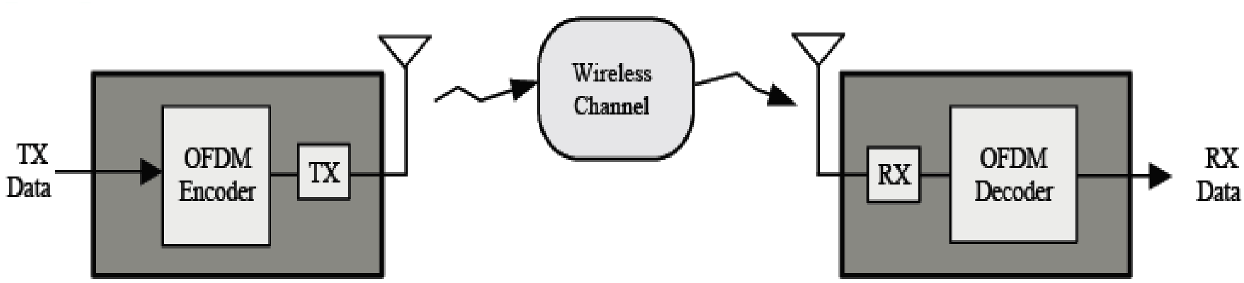


Figure 1-9: System of single antenna at transmitter and receiver.

In Fig:1-10, beamforming is employed to 1 transmit stream to create 2 streams encoded for 2 of Tx.These streams pass within multipath channel to Rx. The Rx progress joint streams for recovering original stream which is transmitted. It's supposed that coefficients of channel known at Tx, beamforming basically allows Tx to phase 2 transmissions as signal is optimally joined at input to Rx, thus avoiding cancellation of signal which can take place in random channel.

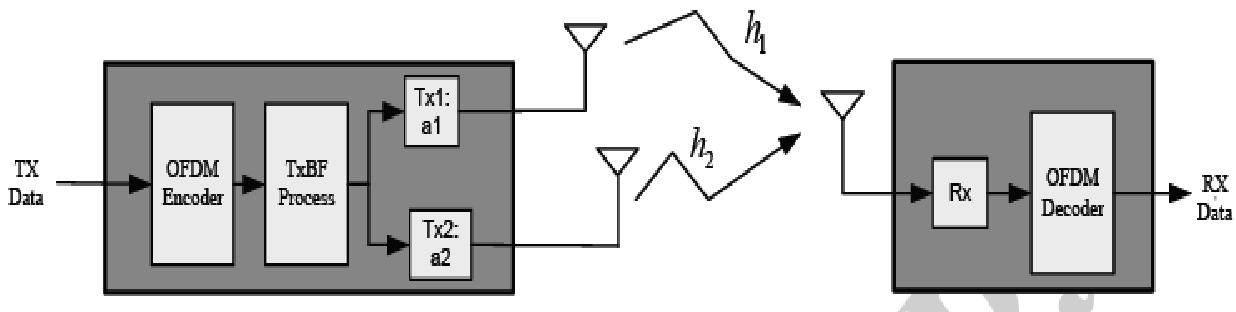


Figure 1-10: System of 2 Tx Beamformer with 1R beamformee receiver.

1.5.3 Channel Model

As basic ex.,we can take that a specific channel could demonstrated as have flat faded multipath channel of Rayleigh,& transferred modulation of signal is PSK. As shown in Fig1-10, simpler beamformiing arrangement, with 2Tx and 1Rx antennas.For flat faded model of channel mean multipath channel has 1 tap. Thus, channel process lessens to easy multiplication. For this type of simulation, channel experience in every 1Rx antenna randomly varies with time. For i^{th} Rx antenna, each transferred symbol multiplied by changing complex no. h_i . As channel in concern is channel of Rayleigh, imaginary & real parts of h_i are distributed has mean $\mu_{h_i} = 0$ & variance $\sigma_{h_i} = \frac{1}{2}$.

In addition to this, it is presumed that channel experienced by every Tx antenna to Rx antenna is free from channel experience by another Tx antenna, and lastly, on each one Rx antenna,noise has pdf of Gaussian with 0 mean, & variance of noise $\sigma_n^2 = \frac{N_0}{2}$ .As stated before, it too supposed that in each of transmitting antenna, h_i channel is being known.Note that supposition of independent of h_i , & random change over time are not probable to happen in practice, however nonetheless, such model is lot used to evaluate new technology of communication, like modulation schemes.

1.5.4 Transmit Beamforming

On Rx antenna, signal received is,

$$y = [h_1 \quad h_2]\begin{pmatrix} x \\ x \end{pmatrix} + n = (h_1 \ \ h_2)x + n$$

where *y*, is signal received, h_i are channel coefficients look from i^{th} Tx antenna, x is symbol transferred and noise n at Rx antenna. When transmit beamforming is being used, it multiply symbol by each of Tx antenna by complex no. equivalent to reverse of channel phase so to confirm that signals at Rx added up constructively. The signal received is expressed as:

$$y = [h_1 \ \ h_2] \left[\frac{e^{-j\emptyset_1}}{e^{-j\emptyset_2}}\right] x + n$$

and the channel coefficients further expressed as:

$$h_1 = e^{-j\emptyset_1}|\, h_1|$$

$$h_2 = e^{-j\emptyset_2}|\, h_2|$$

To use beamforming to such basic structure, as in Fig:1-10, set 2 parameters of beamforming $a_1 = e^{j\emptyset_1}$ & $a_2 = e^{j\emptyset_2}$ .Then signal which is beamformed incoming at Rx is:

$$y = (|h_1| + |h_2|)x + n$$

Note that effective coefficients of channel added in-phase, therefore effects of several paths can be used as benefit, ultimately improves strength of received signal.Supposing equalization of zero-forcing, we have to split *y* received symbol with newer channel i.e. effective,

$$\hat{y} = \frac{y}{(|h_1| + |h_2|)} = x + \frac{n}{(|h_1| + |h_2|)}\ .$$

1.6 CHANNEL ESTIMATION TECHNIQUES

In a link of wireless comm., information of channel state offers well-known properties of channel of link. This CSI at Rx could be estimated & generally fedback to Tx. Therefore, there can be different CSI at Tx and Rx. The CSI might be statistical or instantaneous. In CSI of Instantaneous, present conditions channel are known, which could witnessed by knowing transferred sequence impulse response.However in CSI of Statistical comprises of statistic features as channel gain ,spatial correlation,fading distribution etc. The CSI acquirement is restricted by how quickly conditions of channel are varying.

In systems of fast fading wherever conditions of channel varies quickly under broadcast of symbol information, merely CSI of statistical is reasonable. But, in slow fading scheme CSI of instantaneous could be estimate with equitable accuracy. Therefore technique of estimation of channel is presented to enhance of signal received accuracy.

In communication system the remote channel are generally multi path faded channels, which led to ISI in signal received.To eliminate signal with ISI, several algorithms for detection used at side of Rx. These algorithm must have knowledge on CIR which could provided via separate estimator of channel.

1.6.1 Classification of Channel Estimation

General clasifcation of algorithm of channel estimation is presented in fig 1-11.These are training based, semiblind chanel estimation or estimation of blind channel.The estimation of training-based of channel could be implemented by pilots of comb type or block type.In estimation of pilot block type, into whole frequency bins pilot tone are injected within intervals of blocks of OFDM. Estimation is appropriate for channels with slow fade. However in estimation of comb type , pilot injected into every symbol of OFDM with precise bins of frequency period. Such estimation of channel is more appropriate when variations even in particular block of OFDM.

The estimation of blind channel is being done by assessing statistical info of channel & particular signal properties that are transferred. This estimation of blind channel have no loss overhead & it’s only appropriate for channel i.e.slowly time-varying. However in estimation of training based of channel, pilot or training symbols which are known to Rx, are being multiplexed alongwith stream of data estimation of channel.

The estimation algorithm of Semi-blind channel is grouping of training based and estimation of blind channel which make use of pilot tone & other constraints to execute estimation of channel.

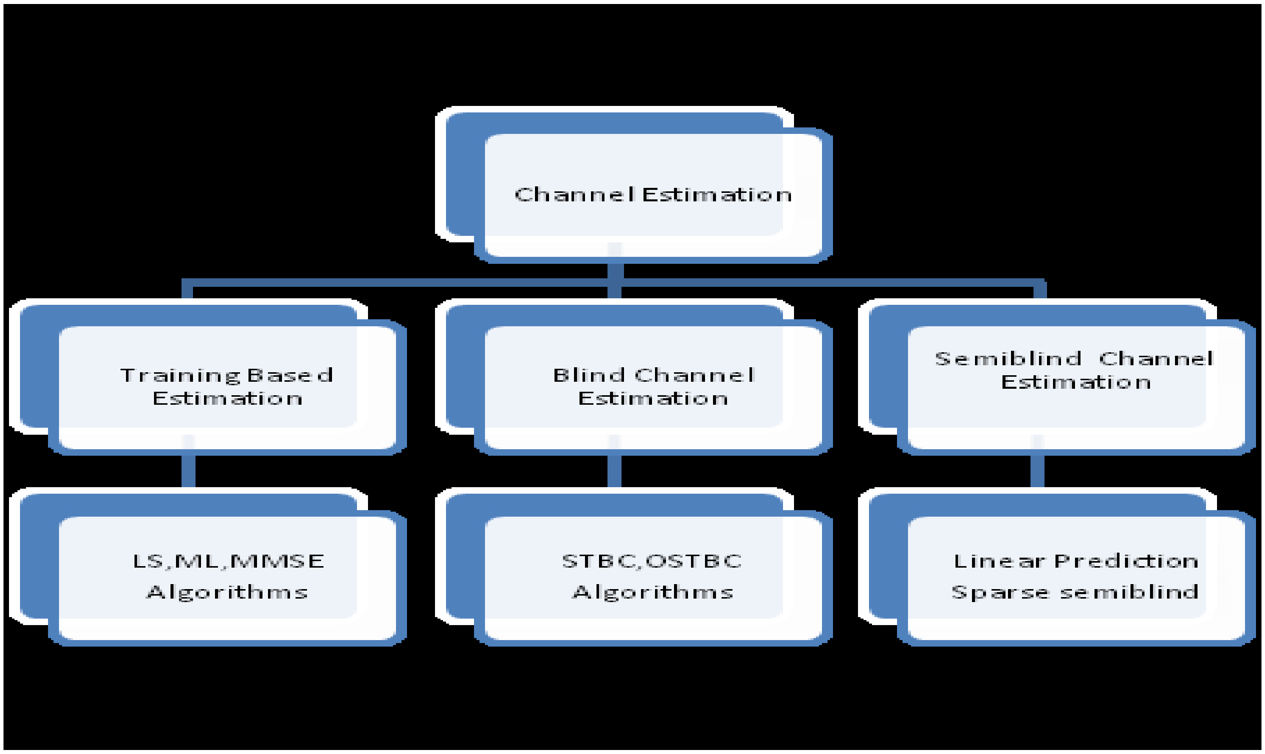


Fig. 1-11 Classification of channel estimation

1.6.2 Training Based Channel Estimation Techniques

The estimation of channel for training-based could be implemented by either one comb or block type pilots with estimation techniques of MMSE & LS.In estimation of block type, pilot are injected in each one symbol of OFDM with exact period of bins of frequency. This estimation of channel is appropriate where variations even in individual block of OFDM.

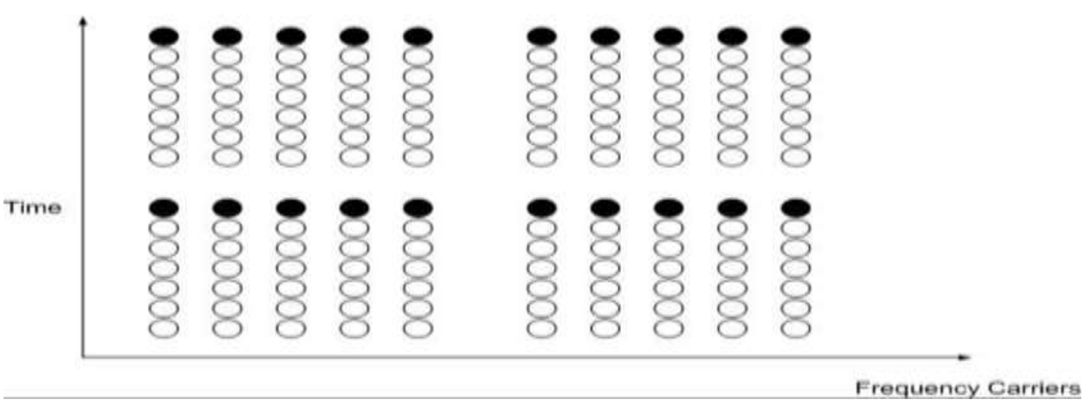


Fig:1-12 Comb type arrangement of pilots

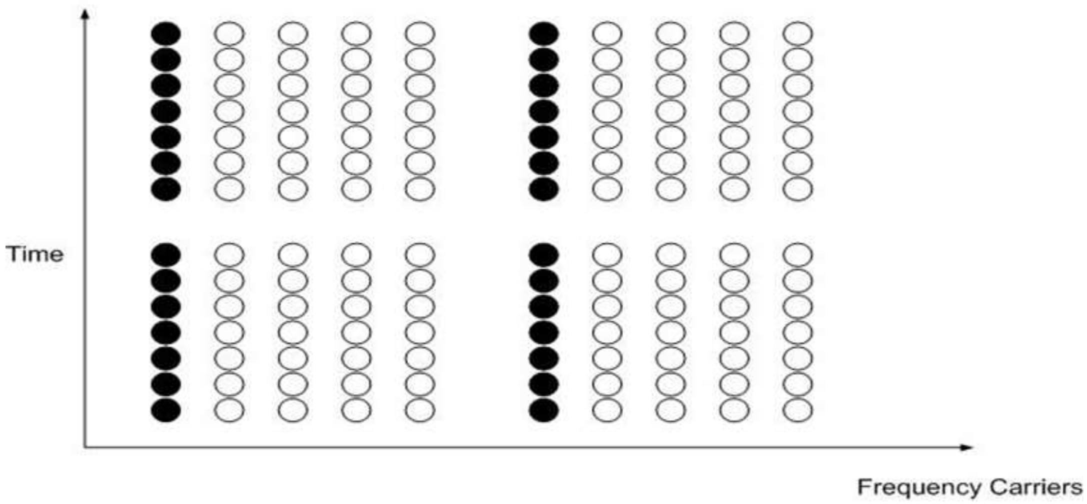


Fig. 1-13 Block type arrangement of pilot

1.7 CHANNEL EQUALIZERS

Equalization is method that use FIR filter which offers an near reverse of frequency response of channel on signal received.This method enriches performance pof comm. against ICI & ISI.Several equalizer types were used in communication such as MMSE ,zero forcing & MRC. Zero Forcing Equalizer eliminates all ISI & is perfect only where there is noiseless channel.When channel is noisy, Equalizer of Zero Forcing tends to increase noise & is more appropriate for channels of static with big value of SNR. However MMSE is equalizer i.e. balanced.It doesn’t mitigate ISI totally but instead lessens entire noise power & components of ISI at output. The equalizer of MMSE delivers least values of BER equivalent Eb /No value. Such as no. of Tx is fewer & more growing in number, & BER decrease for certain Eb/No value. BER performance of for Equalizer of MRC is better then that of equalizer of MMSE.These equalizers are described as following:-

1.7.1 ZERO FORCING EQUALIZER(ZF)

In ZF equalization scheme, component of ISI at equalizer output is forced to 0 with suitable invariant filter with linear time having appropriate transfer function.

If transferred symbol is denoted by x_1 & x_2, h_{11} signify channel from first Tx to first Rx ,h_{12} represent channel from second Tx to first Rx, h_{21} represent channel from first Tx to second Rx and h_{22} represent channel from second Tx to second Rx & n_1,n_2 denote noise on first and second Rx then symbol received on 1st Rx is given by-

$$y_1 = h_{11}x_1 + h_{12}x_2 + n_1$$

$$= [h_{11}\ \ h_{12}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1$$

And symbol received on 2nd Rx is given by

$$y_2 = h_{21}x_1 + h_{22}x_2 + n_2$$

$$= [h_{21}\ \ h_{22}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2$$

These two above equation can also be written as

$$\begin{bmatrix} \frac{y_1}{y_2} \end{bmatrix} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

It is clear from this equation that if h_{11}, h_{12}, h_{21}, h_{22} and y_1, y_2 is known & it's easier for Rx to compute x_1 & x_2. Now if we revise upper eq. then

$$y = Hx + n$$

From now it's clear, for finding x from upper equation, we must find out matrix i.e. reverse of H matrix. If W signify H inverse then it must fulfill property

$$WH=I$$

I is identity matrix here. The W matrix which satisfies above stated property is term as linear detector of zero forcing & is computed by eq:-

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

In this equation the matrix H^HH is given by

$$H^H H = \begin{bmatrix} h_{11}^* & h_{12}^* \\ h_{21}^* & h_{22}^* \end{bmatrix} \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$

From matrix it's clear that term off diagonal are non zero & hence equalizer with zero forcing cancel out signal with interference. It is duly simple to execute but its major weakness is that tends to enlarge noise & therefore give output with noise.

1.7.2 MINIMUM MEAN SQUARED ERROR

MMSE uses squared error as measurement of performance.The Rx filter is designed to accomplish criterion of minimum mean square error. Key objective of this is to lessen error between output obtained by filter & final signal. The calculation for method is as follow- If transferred symbol is denoted by x_1 & x_2, h_{11} represent channel from first Tx to first Rx,h_{12} represent channel from second Tx to first Rx, h_{21} represent c hannel from first Tx to second Rx and h_{22} represent channel from second Tx to second Rx & n_1,n_2 signify noise on 1st & 2nd receiver then symbol received on 1st Rx is as:-

$$y_1 = h_{11}\, x_1 + h_{12}\, x_2 + n_1$$

$$= [h_{11} \;\; h_{12}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1$$

And symbol received on 2nd Rx is given by

$$y_2 = h_{21}x_1 + h_{22}x_2 + n_2$$

$$= [h_{21} \;\; h_{22}] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2$$

These two above equation can also be written as

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

It is clear from this equation that if h_{11}, h_{12}, h_{21}, h_{22} and y_1, y_2 is known then it's simple for Rx to calculate x1 and x2. Now if we revised upper equation then

$$y = Hx + n$$

Now,algorithm MMSE computes the W matrix coefficient which reduce condition

$$E\left\{[w_y - x][w_y - x]^H\right\}$$

Solving above equation gives-

$$W = (H^H H + N_o I)^{-1} H^H$$

From upper eq it's clear that this eq is dissimilar from zero forcing equalizer equation by term N_oI. If N_oI is set equal to 0 in eq then equalizer MMSE turn into equalizer zero forcing.

1.7.3 EQUALIZER OF MAXIMAL RATIO COMBINING

In telecomm,MRC is scheme of diversity combining where:-

(i) Each channel signals are added up together.

(ii) Each channel gain is make proportionate to signal level of RMS & inversely proportionate to channel's mean square level of noise.

(iii) For each channel various proportionality constants used. It is also identified as pre-detection combining.MRC is optimal combiner for channels of AWGN.

[1] Najoua Achoura and Ridha Bouallegue

In this paper author describes about Transmit beamforming(TxBF) with receive combining is easy method to exploit the significant diversity provided by MIMO system, and use of OFDM permits implementation of low complexity of scheme over MIMO frequency selective channels. It discuss scheme of channel estimation for MIMO-OFDM system based on pilot carriers.Author tells that there are 2 basic estimation of channel in OFDM.The 1st one, channel estimation of block-type pilot, is established under supposition of channel of slow fading, & it done by injecting pilot tones in entire OFDM symbols subcarriers within a particular period. The 2nd one, comb-type pilot estimation of channel, is presented to fulfill necessity for equalizing whenever channel change from 1 OFDM block to forthcoming one. Thus it is performed by injecting pilots into few subcarriers in each one OFDM symbol, where projection is required to estimate data subcarriers condition.In result section author compares Estimation of LS and MMSE and also compare the estimation's result for three types of sequence: random sequences ,orthogonal phase shift sequences as defined in previous section, and sequences without interferences consisting at transmitting one symbol per carrier to avoid interferences.

[2] Kusum lata Lahre,Shikha Singh,Rashmi Kashyap

This paper reviewing of equalization techniques in MIMO system.In wireless communication ISI is major hurdle which seriously affects quality of data.The primary aim of equalization methods is to reconstruct real signal with support of filter & remove influence of ISI so as to maintained data reliability.Various kind of methods of equalization proposed has been reviewed in this paper.

[3] Yushi Shen and Ed Martinez

This paper provides overview of strategies of channel estimation used in OFDM systems.It describes protocols related to OFDM.It describe several methods of channel estimation to use in this system. The system performance of ways & complexity of implementation are compared, performance measuring in terms of SER.This paper reviewed strategies of channel estimation in

OFDM systems. It discusses channel estimators of block-type pilot-which is based on MMSE,LS using decision feedback equalizer. It also examines the channel estimators of combtype.Other estimators of channel are presented,like estimators for OFDM system alongwith several transmit antennas or estimators that are 2D arrangement pilots based.

[4] Dhruv Malik , Deepak Batra

Paper describes various detection procedures are proposed in order to lessen complexity of MIMO system, but complexity of schemes of algorithm is higher than equalizer based techniques such as Maximal Ratio Combining & Zero Forcing.Here analysis of BER is accessible using various equalizer & then method of optimal equalization is proposed .From the results,it is assumed MRC is better method of equalization in MIMO.Also,MMSE is balanced equalizer, which no removes ISI totally but otherwise lessens entire power of noise & ISI components in output.

[5] Ashish Kakadiya, M M Solanki, S K Hadia, J M Rathod

Author describes, adaptive algorithm types for estimation of channel in MIMO-OFDM. The adaptive filter can be recursive least square or kalman ,least mean square, which doesn’t required past knowledge of 2nd order statistics of noise & channel.The LMS adaptive estimation could be used for improving performance of channel.But serious estimation error & low speed of convergence led to grouping of LMS + kalman filter to more accuracy. Though, complexity of computations is improved since result is transported to kalman filter. The algorithm based on adaptive filter generally uses MMSE or LS as early estimation of channel to lessen complexity of computations.In result section, BER result of algorithm of adaptive channel estimation is compared with conventional LS estimation, also mean square error is been compared for adaptive algorithm.

[6] Raspinderjit Kaur Kahlon, Gurpreet Singh Walia, Anu Sheetal

In this paper author study several techniques & analyze them for estimation of channel in MIMO-OFDM. Different estimators such as blind channel estimator, pilot based estimator and semi-blind channel estimators are discussed and is concluded that channel estimation of pilot based is better than anothers, since semi-blind & blind channel estimator use mathematical information about transferred data & become complex. Comb type & Block type arrangement for pilot insertion are reviewed & compared. Arrangement of block type is used for channel with slow fading while arrangement of comb type is for channel with fast fading. In arrangement of block type algorithms like MMSE ,LSE. It is found that performance of MMSE is far better than LSE but computation is complex when no. of subcarrier increases in OFDM.

[7] C.Padmaja and B.L.Malleswari

This paper develops an analytical framework designed to investigate the link level performance of rate adaptation in a time-varying channel for MIMO OFDM systems. The paper addresses outdated CSI impact due to feedback delay and derived new thresholds for SNR, results are compared with simulation results. The paper checks the performances of proposed scheme which adopts the high SNR for modulation schemes of high order with high spectral efficiency and appropriate code rate can be chosen depending on the channel quality.

[8] Ramanagoud Biradar, Dr.G.Sadashivappa

In this paper,the performance of MIMO antenna (2x2)is been suggested to examine by determining transmit diversity using STBC techniques.Transmission characteristics are negotiate for QPSK & BPSK modulation. AWGN is introduced to Rayleigh flat fading channel. On Rx side, equalization techniques like Maximum Likelihood Detector & Zero Forcing are suggested for BER computing. It is understood that QPSK & BPSK modulation specialties & learned how could BER analysis made, the scheme with modulation of BPSK offers better BER result in comparison to modulation technique of QPSK.

[9] E. Ghayoula1, R. Ghayoula A. Bouallegue, and J Y.Chouinard

Here author discuss performance of capacity of several antennas for remote communication. It is assumed that channel is unknown at receiver and capacity expressions are provided for each structure. In the paper, the attempt to provide a clear image of the effect of using multiple antennas on the Capacity of wireless communication systems by using Matlab coding is shown. The results of paper shows that increasing the number of transmitting and receiving antennas for a wireless MIMO channel does improves the channel capacity that can be obtained.

[10] Davinder S. Saini and Bhasker Gupta

Author discusses that, the combination of MIMO & OFDM systems is considered for wideband transmission to lessen ISI & to enhance capacity of system. MIMO-OFDM exploit space & frequency diversity concurrently to improve performance of system.Coding is done across subcarriers of OFDM rather than symbols of OFDM.Results section shows that among numerous equalizers ML equalizers rules other mentioned equalizers. BER analysis is presented using different equalizers & then optimum method of equalization is suggested.Performance ofBER is comparatively better in bpsk rather in 16- qam.

[11] Nivedita A.Pande ,Vaishali B.Niranjane and Anjali A.Keluskar

Author describes about performance inquiry of estimation of channel over algorithms of adaptive channel estimation for estimating channel using several scheme of modulation are investigated. The channel estimation at frequencies of pilot may be based on RLS & LMS algorithm of channel estimation is considered .The estimator of RLS provide decent performance but high difficulty. The estimator of LMS has low complication but working is not good like RLS at low SNRs values. Results simulation display that for MIMO OFDM estimation delivers less BER than another system.By relating performance of LMS to RLS, it is detected that RLS is extra strong to noise in terms of estimation of channel.Author related performances of algorithm of channel estimation by computing SNR vs BER with various schemes PSK modulation.

[12] Eric Lawrey

Here Author examines the usefulness of OFDM as technique of modulation for remote applications. Essential area which has not been examined is problems that may encounter when OFDM is used in environment of multiuser. One likely difficulty which may be come across is Rx may need dynamic range large to hold huge strength of signal variation between users. Several techniques of modulation in OFDM were explored in this work including PSK, though possible system gains of performance may promising by choosing vigorously technique of modulation based on data type being transferred.

[13] P. Venkateswarlu,R.Nagendra

In this paper the wideband transceivers of Adaptive OFDM are investigated .Author validate that when targeting for greater throughput a greater proportion of OFDM subcarriers with low-quality to be used for broadcast of susceptible high-order modes of modem, transferring numerous bits for each subcarrier.They equates the different schemes of adaptive modulation.

[14] Ye (Geoffrey) Li

Here author presents 2 techniques to develop performance & lessen difficulty of parameter of channel estimation: simplified channel & optimum training-sequence design estimation. Optimal sequences of training only not simplifies initial estimation channel, but also achieve best performance of estimation.The basic estimation of channel knowingly lessens difficulty of estimation of channel at payment of minor degradation in performance.Author has presented measures for optimal design of training-sequence for OFDM with numerous transmit antennas & have also simplifies parameter of channel estimators settled previously. Using principles of design, we could build sequences of training that not optimize only, but simplifies channel estimation only during period training.

[15] Imad Barhumi, Geert Leus

This paper describes a least squares scheme of channel estimation for MIMO+OFDM centered to pilot tones.Author 1st compute the mean square error of LS estimate of channel. We then derive ideal sequences pilot & ideal assignment of pilot tones wrt to MSE. To cut overhead training, LS scheme of channel estimation over numerous symbols of OFDM is also looked. Furthermore, to enrich estimation of channel,RLS algorithm is recommended. In result simulations, it is shown that optimum sequences of pilot is derived in particular paper outclass together random & orthogonal pilot sequences. It is also presented that significant gain in SNR could obtained by using algorithm of RLS, specially in slowly varying channels of time. It also decided that growing no.of transfer antennas require additional training pilot tones & hence, drops efficiency. This effect could be lessened by approximating parameters channel over numerous symbols of OFDM.

[16] Sonali A. Bhagwatkar, B. P. Patil, Bhalchandra S. Satpute

Author presents performance of equalizer of MMSE for MIMO OFDM under fading channel of Rayleigh.Performance is examined by calculating BER for system.In simulation section it is attain that for specific BER , equalizer of MMSE displays better SNR than equalizer of ZF for similar parameters of simulation.Hence for values of BER for ZF & MMSE for MIMO OFDM of 2×2 equalizer of MMSE shows enhancement in value of SNR. Hence equalizers of MMSE demonstrats improved selection for transmission.

[17] R.S.Ganesh, Dr. J.Jaya Kumari

Author provides simple overview of MIMO-OFDM & illuminates various algorithms of channel estimation, techniques of optimization & their consumption in MIMO for 4G remote systems of communication.The various techniques of channel estimation like based on training which may performed by either comb or block type pilot, semi-blind & blind channel, channel based algorithms and their performance are discussed.Also different optimization techniques to optimize appointment & power of pilot tones of comb-type for LS estimation of channel in MIMO-OFDM system,evolutionary programming to enhance LS & MMSE algorithms for better results are reviewed to optimize LS & MMSE algorithms.

[18] Amol Kumbhare ,Smita Jolania, DR Rajesh Bodade

Here author presents comparison of performance of STBC coding with various techniques of equalizer like minimum mean square error ,Zero Forcing Equalizer & maximum likelihood sequence estimation.It describes that different equalizers might use in equalization of channel reliant on state of known channel or state of estimated channel. The grouping of maximum likely hood sequence by zero forcing or grouping of MLSE & MMSE is specified an additional benefit in equalization. The ZF equalizer reforms performance over response of channel & performance of BER is enhanced by finding MLSE.

[19] Parul Wadhwa , Gaurav Gupta

Here Author describes problem for equalization for MIMO systems is being reviewed & by using mathematical results simulate in performance of equalization methods for MIMO is being carried out & it is shown that BER decreases as no. of Rx antenna grows.

[20] Y. N. Trivedi

Here author discuss about MIMO system,make use of N Tx and 2 Rx antenna, with transmit beamforming is consider.Author select out of N only 2 antennas using CSI delayed. Then, with same CSI delayed transmit beamforming is performed. BER closed form exp is derived in basic form for modulation of BPSK. The exp is derived as correlation coefficient (ρ) function between CSI accessible at Rx & feedback delayed of it, which is used for selection of antenna.We observe that performance of BER cut down, when correlation ρ falls from 1. Author present simulation of result & compare with result analytical. For ρ low values, MIMO loose diversity gain (transmit) & its performance is corresponding to system of Rx diversity system making use of MRC equip with only 2 Rx antennas.

[21] Sinem Coleri, Mustafa Ergen, Anuj Puri, and Ahmad Bahai

Here in this particular paper the techniques of estimation of channel for OFDM based on arrangement of pilot are examined. Comb type pilot base estimation of channel is study over several algorithms for estimating of channel at frequency of pilot & channel interpolating. Channel Estimation at pilot frequency is based on LMS & LS while interpolation of channel is finished by means of linear interpolation, 2nd order of interpolation & interpolation of time domain. Author have also applied DFE for entire sub-channels tracked by pilot of block-type. Author make comparison of performances of all schemes by measuring BER with 16QAM, DQPSK, BPSK, QPSK as schemes modulation, & Rayleigh multipath fade as models of channel.

[22] Kala Praveen Bagadi, Prof. Susmita Das

This paper investigates CSI for both MIMO & SISO systems based on arrangement of pilot. Estimating channel at pilot frequencies with estimation algorithms of LS and MMSE is done with Matlab. Performance of SISO-OFDM & MIMO-OFDM are assessed on basis of level of BER. Additional improvement of performance can be attained with Maximum Likelihood Detection & maximum diversity STBC at reception & transmission end respectively. Estimation of MMSE has displayed to execute better than LS but complexity is more than LS for MIMO with pilot carriers.

[23] Anuj Kanchan, Shashank Dwivedi

Here author investigats effect of channel conditions of frequency selective, for ex fading due to multipath propagation, could be consider constant over sub channel of OFDM if sub-channel is adequately narrow banded .This leads to equalization of frequency domain possible at Rx, which is easier than equalization of time-domain use in traditional modulation of single-carrier.Equalizer has to multiply each subcarrier detected in each symbol of OFDM by complex no. in OFDM.Here Auhor has exhibited OFDM using equalizers. 2 dissimilar equalizers, namely ZF & MMSE, alongwith dissimilar tapping are being used. Multicarrier modulation is engaged, that provide benefits like reduction of ISI & high reliability. Such equalizers are accepted to remove ISI produced in data transmitted under environment of fading. Results display that, with ZFE & MMSE equalizers, performance of BER is enhanced. Further, performance of BER for MMSE is better to equalizer of ZFE.

[24] Van de Beek, Jan-Jaap; Edfors, Ove, Sandell, Magnus,Wilson, Sarah Kate, Börjesson

This paper states estimation of channel based on channel statistics in time-domain. Using common model for channel of slowly fading, author present LS & MMSE estimator & method for modification. The SER for system of QAM is displayed by means of result simulation. Depend on complexity of estimator, upto 4 dB in SNR could be gained over estimator of LS. For high value of SNR , estimator of LS is adequate & simple. However, for low value of SNR, displayed modications of estimators of LS & MMSE will allow settlement between complexity of estimator & performance.

[25] Megha Gupta, Prof. Rajesh Nema, Dr. Ravi Shankar Mishra, Dr. Puran Gour

In this paper performance of BER in OFDM - BPSK, QAM & QPSK over fading channel of Rayleigh is examined. 2 of the most algorithms of equalization are equalizer of MMSE & MLSE are used. Lastly simulations of signal of OFDM is carried with faded signals of Rayleigh to realize effect of fading channel and to attain optimum value of SNR & BER.

[26] Manish Kumar

Here Author describes that ISI always cause an issue for recovery of signal in remote communication.This could be opposed with equalizer application. Equalization compensate for

ISI created by prorogation of multipath signal within channels of time dispersive. In this paper author examine BER performance characteristics of 2 types of equalizers i.e. MMSE ,ZF, for system of BPSK. ISI multitap channel is considered. Matlab is selected as examination tool for simulation. Result Simulation display that as length of tap rises in ZF ,BER declines. It's also inferred that equalizer of MMSE out match equalizer of ZF in terms of performance characteristics of BER.

[27] N.Sathish Kumar,Dr.K.R.Shankar Kumar

This paper examines performance of equalizer of MMSE based Rx for channel of MIMO.The characteristics of BER for several antenna of transmitting & receiving is simulated in toolbox of matlab & many benefits & drawbacks of system is described. The simulation done in lab of signal processing demonstrate that equalizer of MMSE receiver is better choice for eliminating some ISI & lessens entire power of noise.The results display that BER drops as m * n configurations of antenna is increased.

[28] Cassio B. Ribeiro, Marcello L. R. de Campos and Paulo S. R. Diniz

In this article author derived condition for existence of multiuser zeroforcing detector which accomplish proper reconstruction of symbols transmitted. Compared to comparable works, conditions derived let reduction in length of filters of equalizer, while imposing no limits on order of channel and on precoder filters order. As investigation is done in time domain, filters of time-varying are too considered.

[29] Mr.Udayraj Chaudhari, Prof.K.T.Jadha

Here author describes that when data is transferred with high rate, ISI occur. To remove this effect several techniques of equalization are used. Techniques of Equalization such as MMSE ,ZFE & ML algorithms of detection could be employed. This study will examine performance of techniques of equalization by considering several transmit & receive antenna over Rayleigh flat fading channel & gives BER study of same.Transmission of MIMO by BPSK in fading channel of Rayleigh is consider. Study investigation shows that equalizer of maximum likelihood detection play crucial role to increase performance of MIMO than equalizers of MMSE & ZFE.

[30] G.J. FOSCHINI and M.J. GANS

This paper focus on techniques of Equalization, for Flat fading channel of Rayleigh. Equalization is method for combating ISI; furthermore equalization is approach of filtering which lessens error between real & desired output by continuous update of coefficients of filter. In this paper, different techniques of equalization are investigated for BER analysis in MIMO. In this article author have discussed several types of equalizer like MMSE ,ZF & Sphere decoder. using which result are decoded.The continual methods of interference beat ZF & MMSE but complexity is higher due to algorithms iterative nature. ML provides improved performance in others comparison. Sphere decoder provides finest performance .Author has observe that Sphere decoder provided high performance in comparison to other schemes

[31] Navid daryasafar, Aboozar lashkari, Babak ehyaee

The aim of this paper is to examine & suggest a method of estimation of channel for MIMO-OFDM. According to this, with inspecting method of channel estimation,one can design optimal training course for such systems & introduce associated methods based on algorithm of LMS. The efficiency of recommended algorithm of LMS could be inspected by simulation and estimation results come to comparison. LS scheme proposes precise estimation of channel.In this paper method of LS was used for initial estimation of channel.To improving accuracy of estimation of channel, algorithm of LMS is added to Rx which comprises output feedback & increases performance of BER of system . In this paper, estimation of channel is performed for MIMO-OFDM through recommended method of LMS. The LMS method is dependant extremely to parameter, μ. This method offers suitable estimation of channel through applying simple relations of recurrence.

[32] Frederick W Vook, Amitava Ghosh, Timothy A. Thomas

Here author describe architecture of MIMO where MIMO transmit processing is at baseband is implemented, RF, and combination of baseband & RF.Author focuses on performance & operation issues surrounding numerous candidate method for MU-MIMO transmission in bands of mm-wave. Authors showed several transmit MU-MIMO techniques performance for 5G & showed necessity for accurate calibration of antenna array with large scale arrays of antenna carrying out MU-MIMO.

[33] Praveen P Likhitkar and Chandrasekhar N Deshmukh

Here Author discusses that Receive Beamforming is performed with algorithm of LMS & LLMS.In this Paper, in order to implement secure broadcast of signal over wireless ,one should have used sequences of chaotic. This paper assesses Beamforming performance with & without algorithm of LMS and LLMS for MIMO-OFDM. The MATLAB is used for simulations. In this work, performance comparison of MIMO-OFDM is given with and without using adaptive beamforming. The scheme proposed has been tested in Rayleigh Fading channel ,AWGN channel & Rician Fading channel. It has been detected that system BER performance is improved by beamforming which is adaptive using modulation of BPSK compared to modulation of 16PSK ,QPSK & 256PSK.

CHAPTER 3

OBJECTIVES

3.1 Overview

In Wireless communication, multiple-input and multiple-output, or MIMO is a process for enlarging the capacity of a radio link using several transmit and receive antennas to exploit multipath propagation.In practical arrangement various schemes in MIMO system are purposed to overcome these multipath effects and offer the improved reliability and more efficiency.MIMO system employed with OFDM, denoted MIMO-OFDM, is able to accomplish high spectral efficiency.

The main objective is to:-

- Generation and reception of signal in Multiple input Multiple output(MIMO).

- Implementation of MIMO system with OFDM using M-QAM Modulation scheme in Rayleigh channel.

- Implementation of Equalization scheme alongwith Modulation schemes in MIMO-OFDM model in AWGN & Rayleigh channel.

CHAPTER 4
RESEARCH METHODOLOGY

Here we have discussed about stages sequence wise about how methods are applied to get desired output at Rx side.As displayed in flow chart the random number is generated,Modulation and IFFT is done at transmitter side and channels(AWGN) is selected and at receiver side the inverse operation is done.

Below is the Flow chart showing the steps :-

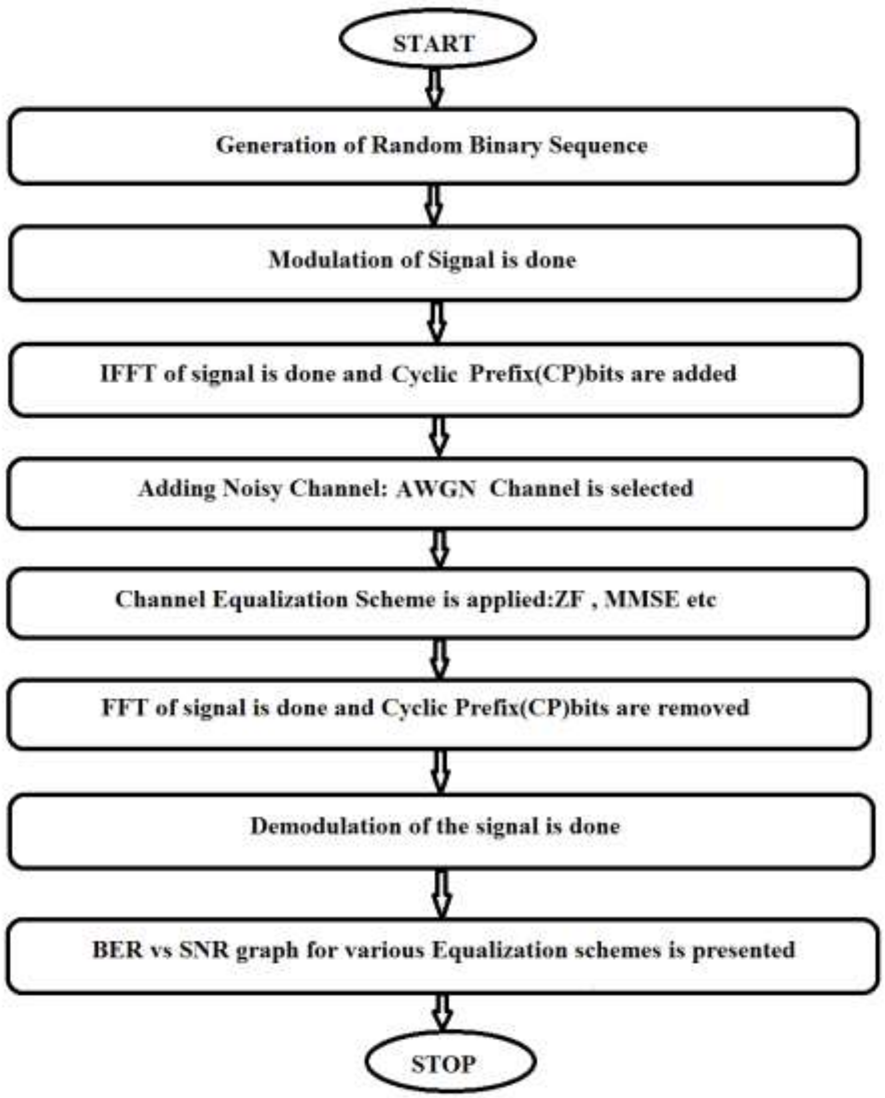


Fig4-1 : Flow chart for MIMO-OFDM system Model

CHAPTER-5

RESULTS AND DISCUSSIONS

Figure 5-1 shows simulation results that provide performance BER of modulation schemes of M-QAM is able to meet target BER.

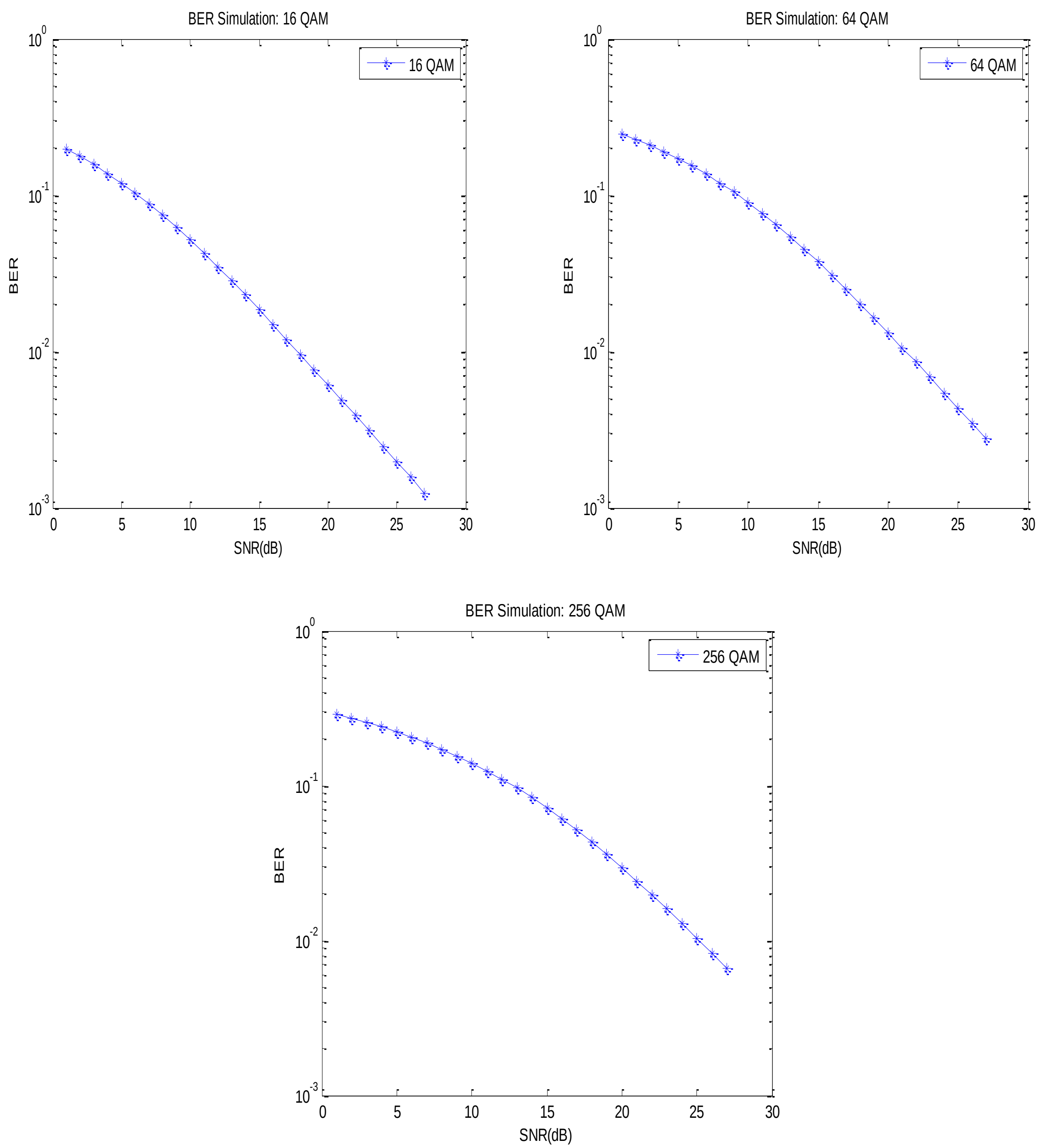
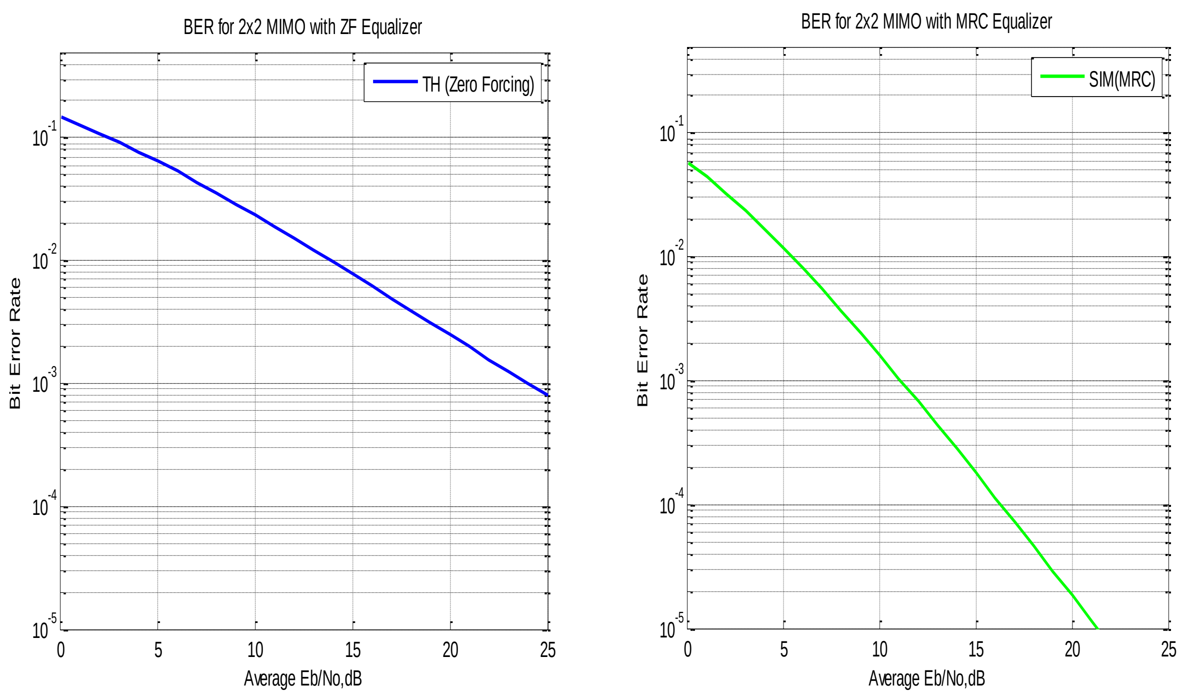


Fig 5-1: SNR vs BER graph for 16-QAM, 64-QAM and 256-QAM

At an operating BER, there is no modulation scheme that gives the desired performance at an SNR below 30 dB. And SNR higher than 30dB, 256-QAM gives best spectral efficiency while providing desired BER performance.In case of low SNR, it switched to lower-order modulation scheme, which is more robust against transmission errors but has lower spectral efficiency, if it is used.

Fig:5-2 displays simulation results which shows performance of BER for several techniques of equalization.Here shown in fig. that equalizer of MMSE delivers better results than that of equalizer of ZF.And furthermore the equalizer of MRC provide improved results than rest of equalization schemes. Furthermore the beamform concept provides better results in comparison with the conventional equalization techniques.For this the 2 transmitters antennas are used at side of source & 2 receiver antenna are used at side of destination.



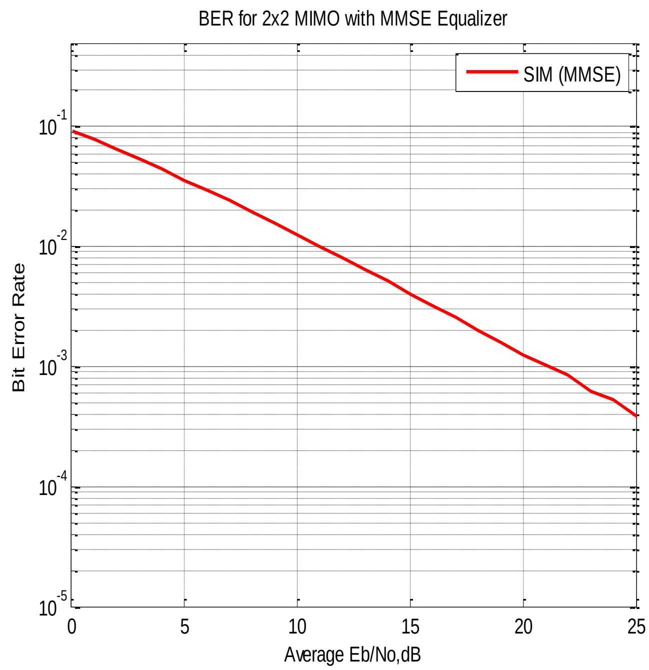


Fig 5-2: BER vs Eb/No Graph for various Equalization schemes

CHAPTER-6

CONCLUSION

At last we concluded that performances of scheme suggested provides better SNR vs BER.Different schemes of equalization have been used in technique of MIMO-OFDM.The simulation results displays that performance of an OFDM system could be significantly improved by using Maximal ratio combining,zero forcing & Min Mean square error equalizers.The comparison of performances of Signal-to-Noise Ratio(SNR) of schemes of Equalization is presented in graph. It also presented that SNR can be enhanced further if no.of receiving antennas are increased.As we look up in results that modulation schemes alongwith equalization techniques provides better results using beamforming.Wireless signal Preprocessing at Tx by usage of beamforming method can mitigate effects of multipath for improving throughput & link robustness.

Result simulation shows comparison between several schemes of equalization such as MRC,ZF & MMSE and we concluded that,MRC providing better results rather than any other technique of equalization but as simulation is done using MMSE equalizer that provide better result than ZF equalizer.Alongwith these schemes of equalization the beomforming concept is also been used which provide better results than any conventional or simple equalization technique.

REFERENCES

1. Najoua Achoura and Ridha Bouallegue,"Channel Estimation for MIMO OFDM beamforming Systems", IJCSNS 106 International Journal of Computer Science and Network Security, March 2008.
2. Kusum lata Lahre,Shikha Singh,Rashmi Kashyap," Equalization Techniques in Wireless Communication: A Review", International Journal of Trend in Research and Development, Volume 2(5), ISSN 2394-9333.
3. Yushi Shen and Ed Martinez," Channel Estimation in OFDM Systems",IEEE Transactions on Communications, March 2001.
4. Dhruv Malik,Deepak Batra ,'' Comparison of various detection algorithms in a MIMO wireless communication receiver, International Journal of Electronics and Computer Science Engineering.
5. Ashish Kakadiya, M M Solanki, S K Hadia, J M Rathod," Analysis of adaptive channel estimation techniques in MIMO-OFDMSystem", International Journal of Advancements in Research & Technology, Volume 2, Issue4, April-2013.
6. Raspinderjit Kaur Kahlon, Gurpreet Singh Walia, Anu Sheetal," Channel Estimation Techniques in MIMO-OFDM Systems – Review Article", International Journal of Advanced Research in Computer and Communication EngineeringVol. 4, Issue 5, May2015.
7. C.Padmaja and B.L.Malleswari,'' Link Level Performance Analysis of Adaptive MIMO-OFDM Systems'', IEEE WiSPNET 2016 conference.
8. Ramanagoud Biradar, Dr.G.Sadashivappa,'' Study and Analysis of 2x2 MIMO Systems for Different Modulation Techniques using MATLAB, International Journal of Advanced Research in Computer and Communication Engineering Vol. 4, Issue 7, July 2015.
9. E.Ghayoula, A.Bouallegue, R.Ghayoula, and J-Y.Chouinard,'' Capacity and Performance of MIMO systems for Wireless Communications'', Journal of Engineering Science and Technology Review, August 2014.

10. Bhasker Gupta and Davinder S. Saini,'' BER Analysis of Space-Frequency Block Coded MIMO-OFDM Systems using Different Equalizers in Quasi-Static Mobile Radio Channel'', International Conference on Communication Systems and Network Technologies,2011.
11. Vaishali B.Niranjane, Nivedita A.Pande, Anjali A.Keluskar,"Adaptive Channel Estimation Technique for MIMO-OFDM", International Journal of Emerging Technology and Advanced Engineering , January 2013.
12. Thesis of Eric Lawrey on OFDM modulation technique for wireless radio applications, submitted on October 1997.
13. P.Venkateswarlu,R.Nagendra,"Channel Estimation in MIMO-OFDM Systems", International Journal of Engineering Trends and Technology (IJETT) – Volume 15 Number 5 - Sep 2014.
14. Ye (Geoffrey) Li, Senior Member, IEEE," Simplified Channel Estimation for OFDM Systems with Multiple Transmit Antennas", IEEE Transactions on Wireless Communications, January 2002.
15. Imad Barhumi, Geert Leus, Member, IEEE, and Marc Moonen, Member, IEEE," Optimal Training Design for MIMO-OFDM System in Mobile Wireless Channels", IEEE Transactions on signal processing, June 2003.
16. Sonali A. Bhagwatkar, B. P. Patil, Bhalchandra S. Satpute," Performance of MMSE Channel Equalization for MIMO OFDM System", International Conference on Computing Communication Control and automation (ICCUBEA),2016.
17. R.S.Ganesh, Dr. J.Jaya Kumari," A Survey on Channel Estimation Techniques in MIMO-OFDM Mobile Communication Systems", International Journal of Scientific & Engineering Research, May-2013.
18. Amol Kumbhare ,Smita Jolania, DR Rajesh Bodade," BER Performance Comparison of MIMO OFDM with Channel Equalizers", International Journal of Advanced Research in Computer Science and Software Engineering, November 2013.
19. Parul Wadhwa , Gaurav Gupta."BER Analysis & Comparison of Different Equalization Techniques for MIMO-OFDM System",International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 6, June 2013.

20. Y. N. Trivedi ," Antenna Selection and Transmit Beamforming in MIMO Systems using Delayed Channel Information at the Transmitter", 2016 Intl. Conference on Advances in Computing, Communications and Informatics (ICACCI), Sept. 21-24, 2016.

21. Sinem Coleri, Mustafa Ergen, Anuj Puri, and Ahmad Bahai," Channel Estimation Techniques Based on Pilot Arrangement in OFDM Systems", IEEE TRANSACTIONS ON BROADCASTING, SEPTEMBER 2002.

22. Kala Praveen Bagadi, Prof. Susmita Das," MIMO-OFDM Channel Estimation using Pilot Carries", International Journal of Computer Applications Volume 2 – No.3, May 2010.

23. Anuj Kanchan, Shashank Dwivedi,"Comparison of BER Performance in OFDM Using Different Equalization Techniques", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-1, Issue-6, August 2012.

24. Van de Beek, Jan-Jaap; Edfors, Ove, Sandell, Magnus,Wilson, Sarah Kate, Börjesson ,"On channel estimation in OFDM systems" IEEE Vehicular Technology Conference,1995.

25. Megha Gupta, Prof. Rajesh Nema, Dr. Ravi Shankar Mishra, Dr. Puran Gour ,"Bit Error Rate Performance in OFDM System Using MMSE & MLSE Equalizer Over Rayleigh Fading Channel Through the BPSK, QPSK,4 QAM & 16 QAM Modulation Technique", International Journal of Engineering Research and Applications (IJERA).

26. Manish Kumar,"Performance analysis of BPSK system with ZF& MMSE equalization", International Journal of Latest Trends in Engineering and Technology (IJLTET).

27. N.Sathish Kumar,Dr.K.R.Shankar Kumar,"Performance Analysis of M*N Equalizer based Minimum Mean Square Error (MMSE) Receiver for MIMO Wireless Channel" International Journal of Computer Applications (0975–8887) Volume 16– No.7, February 2011.

28. C´assio B. Ribeiro, Marcello L. R. de Campos, and Paulo S. R. Diniz,"Zero-Forcing Equalization for Time-vartying systems with memory".

29. Mr.Udayraj Chaudhari, Prof.K.T.Jadha,"Study of Equalization Techniques for MIMO System,"IJEEE,2016.

30. G.J. FOSCHINI and M.J. GANS,"On Limits of Wireless Communications in a Fading Environment when Using Multiple Antennas" Wireless Personal Communications.

31. Navid daryasafar, Aboozar lashkari, Babak ehyaee,"Channel estimation in MIMO-OFDM systems based on comparative methods by LMS algorithm", IJCSI International Journal of Computer Science Issues, May 2012.

32. Frederick W Vook, Amitava Ghosh, Timothy A. Thomas,"MIMO and Beamforming Solutions for 5G Technology",Nokia Solutions and Networks.

33. Praveen P Likhitkar and Chandrasekhar N Deshmukh ,"Beamforming for MIMO-OFDM Wireless Systems", European Journal of Advances in Engineering and Technology, 2015.