# POLARIZED MODULATION (PMOD) IN MIMO SATELLITE COMMUNICATION

**A PROJECT REPORT**

**PHASE-II**

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**VANATHI G**

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**(An Autonomous Institution Affiliated to Anna University,Chennai)**

**COIMBATORE-641 049.**

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# BONAFIDE CERTIFICATE

Certified that this project report titled **"POLARIZED MODULATION (PMOD) IN MIMO SATELLITE COMMUNICATION"** is the bonafide work of **VANATHI G** **[Reg. No. 15MCO012]** 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. K. RAMPRAKASH**
**HEAD OF PG PROGRAMME**
Department of ECE
Kumaraguru College of Technology
Coimbatore-641 049

The Candidate with **Register No. 15MCO012** was examined by us in the project viva –voce examination held on...........................

**INTERNAL EXAMINER** **EXTERNAL EXAMINER**

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# ABSTRACT

The development of Satellite communication systems for high bit rate data transmission and high-quality information exchange between terminals is becoming one of the new challenging targets in communications research. Achieving an increase in the spectral efficiency (SE) has always been a major driver in the design of satellite systems. So, in order to improve the efficiency in satellite communication the concept of POLARIZED modulation is employed. POLARIZED Modulation (PMod) the Combination of Dual polarized antenna and spatial modulation achieves an improvement in throughput efficiency.

The Multiple-Input Multiple-Output (MIMO) systems have been emerged as a technical breakthrough for high-data-rate in wireless transmission. Thus, the use of MIMO techniques in mobile communications has achieved significant benefits in improving the system throughput. The basic underlying concept of MIMO is to exploit the signal and channel characteristics to eliminate interference between multiple transmissions. Multiple-input multiple-output (MIMO) are used in wireless communications to achieve high data rates within the limited frequency spectrum. Multiple-input multiple-output (MIMO) technology has recently emerged as one of the most significant technical breakthroughs in modern digital communications due to its promise of very high data rates at no cost of extra spectrum and transmits power. In order to have an improvement in the efficiency the idea of MIMO technique is being used in along with the POLARIZED Modulation and it is seen that by using the MIMO technique there is an enhancement in the performance.

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| | |
|---|---|
| MIMO | Multiple Input Multiple Output |
| SNR | Signal to Noise Ratio |
| SISO | Single Input Single Output |
| SM | Spatial Multiplexing |
| DC | Diversity Coding |
| SDMA | Space Divison Multiple Accessing |
| OFDM | Orthogonal Frequency Division Multiplexing |
| SE | Spectral Efficiency |
| CSIT | Channel State Information at Transmitter |
| NOD | Near Optimal Detector |
| MLD | Maximum Likelihood Detection |
| QOS | Quality Of Service |
| BER | Bit Error Rate |
| AWGN | Additive White Gaussian Noise |
| BPSK | Binary Phase Shift Keying |
| MAP | Maximum A Posteriori |
| AP | A Posteriori |
| BLAST | Bell Laboratories Layered Space Time |
| CINR | Carrier to Information Noise Ratio |
| CQI | Channel Quality Indicator |
| LTE | Long Term Evolution |
| CN | Condition Number |

| | |
|---|---|
| UE | User Equipment |
| RF | Radio Frequency |
| RI | Radio Indicator |
| RS | Reference Signal |
| ZF | Zero Forcing |
| SIC | Successive Interference Cancellation |
| PIC | Parallel Interference Cancellation |
| VBLAST | Vertical Bell Laboratories Layered Space Time |
| OSTBC | Orthogonal Space  Time Block Coding |

# CHAPTER 1

# INTRODUCTION

## 1.1Overview of Wireless Communication:

Reliable and high speed wireless communication systems have ubiquitous demand. One of the breakthroughs in the area of wireless communications is the development of Multiple Input Multiple Output (MIMO) systems that multiple antennas at transmitter and receiver. Many techniques have been developed to upgrade the performance of MIMO systems in variety of applications.

Satellite Communication offers an interesting application for MIMO systems. Such systems are also often associated with challenging conditions such as low bandwidth and Signal to Noise Ratio (SNR) and throughput efficiency. In this case a Single Input Single Output (SISO) system, that is a communication system with one transmitter and one receiver antenna, may suffer a severe degradation of performance because of a large fraction of the transmit power directed away from the receiver. MIMO systems can effectively address these issues by reducing the probability of loss of link, improve the error rate, and generally increase performance.

## 1.2 SATELLITE COMMUNICATION:

A Satellite is a solid object which revolves around some heavenly body due to the effect of gravitational forces which are mutual in nature. We can categorize satellites in two types, namely Passive Satellites and Active satellites. Passive satellites are not like active satellites. Even a moon can be a passive satellite. Thus passive satellites are relay stations in space. A passive satellite can be further subdivided into two types, namely Natural satellites and artificial satellites. A moon is a natural satellite of earth. But spherical balloon with metal coated plastic serve as artificial satellites.

Active satellites are complicated structures having a processing equipment called Transponder which is very vital for functioning of the satellite. These transponders serve dual purpose i.e. provides amplification of the incoming signal and performs the frequency translation of the incoming signal to avoid interference between the two signals.

The term Satellite communication is the communication of the satellite in space with large number of earth stations on the ground. Users are the ones who generate baseband signals, which is processed at the earth station and then transmitted to the satellite through dish antennas. Now the user is connected to the earth station via some telephone switch or some dedicated link.

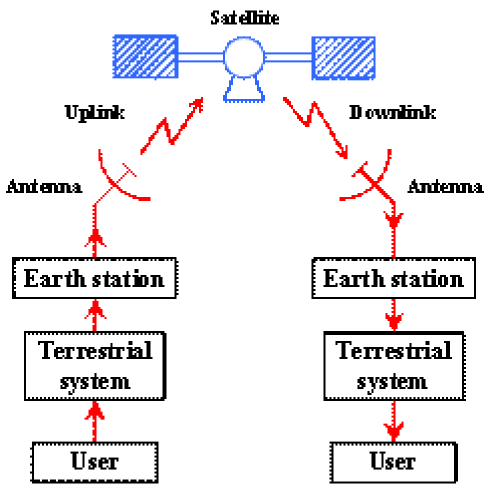



**Figure.1.1 Communication via uplink and downlink in satellite**

. The satellite receives the uplink frequency and the transponder present inside the satellite does the processing function and frequency down conversion in order to transmit the downlink signal at different frequency. The earth station then receives the signal from the satellite through parabolic dish antenna and processes it to get back the baseband signal. This baseband signal is then transmitted to the respective user via dedicated link or other terrestrial system. Previously satellite communication system used large sized parabolic antennas with diameters around 30 meters because of the very faint and weak signals received. But nowadays satellites have become much stronger, bigger and powerful due to which antennas used have become automatically smaller in size. Thus the earth station antennas are now not large in size as the antennas used in olden days. A satellite communication system operates and works in the millimeter and microwave wave frequency bands from 1 GHZ to 50 GHZ. There are various frequency bands utilized by satellites but the most recognized of them is the uplink frequency of 6 GHZ and the downlink frequency of 4 GHZ. Actually the uplink frequency band is 5.725 to 7.075 GHZ and the actual downlink frequency band is from 3.4 to 4.8 GHZ.

The major components of a Satellite Communication system is spacecraft and one or more earth earths.

## 1.3 CHARACTERISTICS:

Satellite communications links need to be designed to enable the inherent link characteristics to be accommodated:

- ***Propagation delay - latency:*** In view of the altitude of many satellites - those in geostationary orbit - there are significant propagation delays. This can affect signalling and extended timeout windows may be required to accommodate the latency of the system.
- ***Limited bandwidth:*** Bandwidth is an issue for all users of the radio spectrum. Some satellites are affected more than others. Accordingly many systems will require to use the available bandwidth very effectively. Data compression schemes are normally used.
- ***Noise:*** The path length and the fact that power levels are limited, especially on the satellite means that signals do not operate with a large margins. To overcome this, directive antennas are normally employed. However in addition to this robust error correction techniques are normally required for data transmission.

### 1.4 SATELLITE COMMUNICATION FLAWS:

The area of improvement in satcom are

- Demand for throughput
- Capacity degradation
- Bandwidth efficiency and spectral efficiency is upto the requirements
- Interference mitigation
- Transmission delay
- Fading with respect to high frequency range
- Independent fading profile over space segment

- Huge free space loss along the earth space link
- Communication problem in space due to polarization
- Power budget is restricted

## 1.5 MULTIPLE INPUT MULTIPE OUTPUT (MIMO):

### 1.5.1 INTRODUCTION:

Multiple-Input Multiple-Output (MIMO) technology is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. MIMO technology takes advantage of a radio-wave phenomenon called multipath where transmitted information bounces off walls, ceilings, and other objects, reaching the receiving antenna multiple times via different angles and at slightly different times.


**Figure.1.2 MIMO technology to transfer multiple data at same time**

MIMO technology leverages multipath behavior by using multiple, “smart” transmitters and receivers with an added “spatial” dimension to dramatically increase performance and range. MIMO allows multiple antennas to send and receive multiple spatial streams at the same time. MIMO makes antennas work smarter by enabling them to combine data streams arriving from different paths and at different times to effectively increase receiver signal-capturing power. Smart antennas use spatial diversity technology, which puts surplus antennas to good use. If there are more antennas than spatial streams, the additional antennas can add receiver diversity and increase range.

## 1.5.2 MIMO BASICS:

As a result of the use of multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel. By increasing the number of receive and transmit antennas it is possible to linearly increase the throughput of the channel with every pair of antennas added to the system. This makes MIMO wireless technology one of the most important wireless techniques to be 3 employed in recent years. As spectral bandwidth is becoming an ever more valuable commodity for radio communications systems, techniques are needed to use the available bandwidth more effectively. MIMO wireless technology is one of these techniques.

## MIMO

MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used.

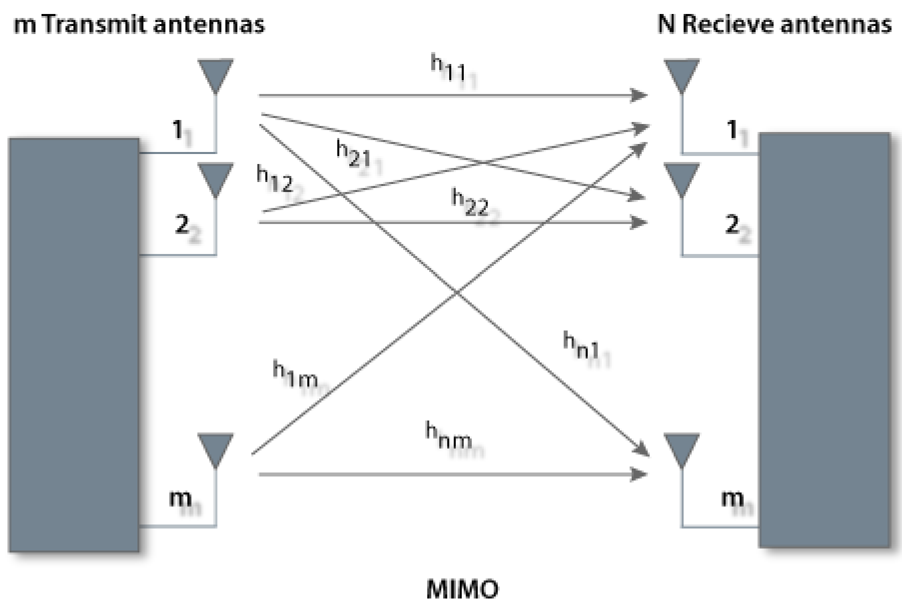



**Figure.1.3 Multi-Input Multi Output (MIMO)**

One of the core ideas behind MIMO wireless systems space-time signal processing in which time is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas, i.e. the use of multiple antennas located at different points. Accordingly MIMO wireless systems can be viewed as a logical extension to the smart antennas that have been used for many years to improve wireless.It is found between a transmitter and a receiver, the signal can take many paths. Additionally by moving the antennas even a small distance the paths used will change. The variety of paths available occurs as a result of the number of objects that appear to the side or even in the direct path between the transmitter and receiver. Previously these multiple paths only served to introduce interference. By using MIMO, these additional paths can be used to advantage. They can be used to provide additional robustness to the radio link by improving the signal to noise ratio, or by increasing the link data capacity.

MIMO can be categorized into three:

1. Preceding
2. Spatial Multiplexing
3. Diversity Coding

**Precoding:**

Precoding is a multi-stream beam forming – the narrowest form of a definition. In general, it is can be termed as the spatial processing that happens at the transmitter. In beam forming, the emitted signals from the transmitting antennas with an appropriate phase and gain weighting such that the signal power gets maximized at the receiver input. The assistance of this beam forming is to increase the gain of received signals, by making the emitted signals from different antennas to add up positively, and to decrease the multipath fading effect. When the receiver has multiple antennas, the transmitted beam forming cannot maximize the signal level of the receiver antennas simultaneously, and the precoded multiple streams are used.

**Spatial Multiplexing:**

Spatial multiplexing needs MIMO antenna configuration. In spatial multiplexing, a signal placed at high rate splits into lower rate streams in multiples and each stream is transferred from different transmitting antennas in a similar frequency channel. If this transmitted signal reaches the receiver antenna array with different spatial signatures, the receiver can discrete these streams parallel into channels. Spatial multiplexing is a very influential method used for increasing channel capacity at higher signal-to-noise ratios

(SNR). The maximum number of spatial streams is limited by the lesser number of antennas placed at both the transmitter and receiver ends. This multiplexing technique can be used with or without any transmitting knowledge of the channel. Spatial multiplexing can also be used for transmission of data to multiple receivers simultaneously; this method is also known as Space Division Multiple Accessing.

**Diversity Coding:**

Diversity coding technique is used to increase the link reliability in the occurrence of fading conditions. With this technique, same data can be encoded in multiple versions and that encoded data can be transmitted over multiple antennas. The encoding adds sometimes diversity level. The multiple signals that are propagated by using different paths are affected differently with fading process. The receiver then improves the original stream either by selecting the received signal or by merging all the information received.

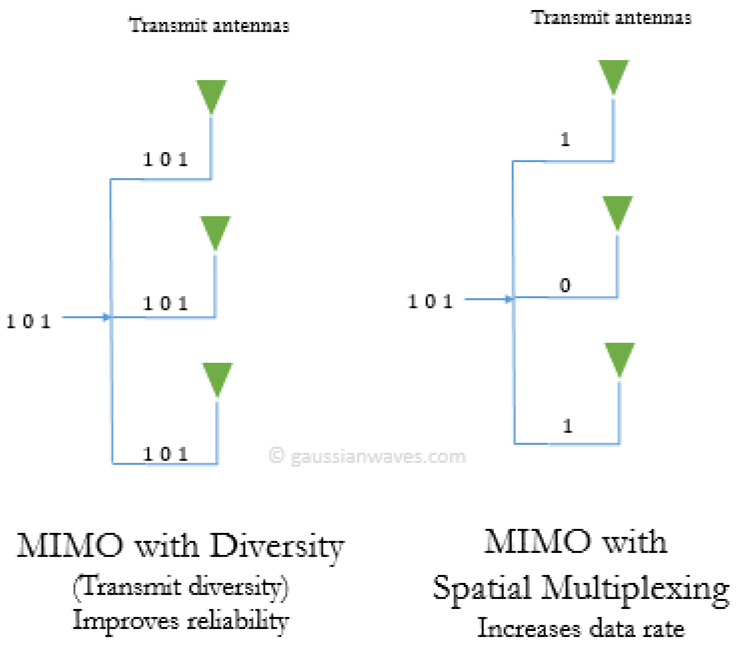



**Figure.1.4 MIMO with Diversity and Spatial Multiplexing.**

## 1.5.3 BENEFITS OF MIMO:

(1) Multiple antenna configurations can be used to overcome the detrimental effects of multi-path and fading when trying to achieve high data throughput in limited-bandwidth

channels. Multiple-input, multiple-output (MIMO) antenna systems are used in modern wireless standards, including in IEEE 802.11n, 3GPP LTE, and mobile WiMAX systems. The technique supports enhanced data throughput even under conditions of interference, multi-path and fading. The demand for higher data rates over longer distances has been one of the primary motivations behind the development of MIMO orthogonal- frequency-division-multiplexing (OFDM) communications systems.

(2) Superior Data Rates, Range and Reliability Systems with multiple antennas at the transmitter and receiver – also referred to as Multiple Input Multiple Output (MIMO) systems – offer superior data rates, range and reliability without requiring additional bandwidth or transmit power. By using several antennas at both the transmitter and receiver, MIMO systems create multiple independent channels for sending multiple data streams.

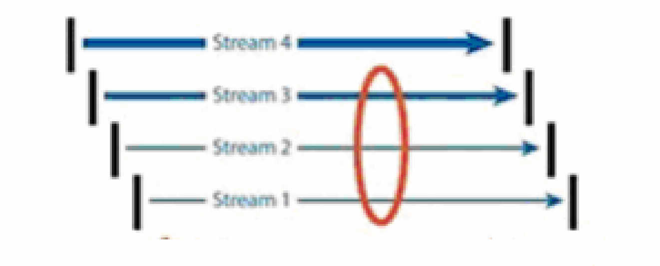



**Figure.1.5 Stream combining for enhanced reliability**

A 4x4 MIMO system supports up to four independent data streams. These streams can be combined through dynamic digital beam forming and MIMO receiver processing (in the red oval) to increase reliability and range. The number of independent channels and associated data streams that can be supported over a MIMO channel is equivalent to the minimum number of antennas at the transmitter or receiver. Thus, a 2x2 system can support at most two streams, a 3x3 system can support three streams and a 4x4 system can support four streams. Some of the independent streams can be combined through dynamic digital beam forming and MIMO receiver processing, as shown in the red oval, which results in increased reliability and range.

# CHAPTER 2

# LITERATURE SURVEY

## 2.1 Dual Polarized Hybrid Mobile Satellite System Using MIMO:

Space frequency coding techniques are commonly used in wireless broadband system as they provide full rate full diversity to the user. However the use of space frequency codes exploit the transmission delay and also to provide the better quality of service to the user. We propose a dual polarized hybrid mobile satellite system with space frequency codes that can be used to avoid fast time variations and also frequency selective problem. We also propose a multiple input multiple output- orthogonal frequency division multiplexing technique to improve the performance and to provide the high data rate to the hybrid mobile satellite system. In this paper the performance of turbo codes and the silver codes are considered. The proposed code performances are analyzed and showing a significant improvement through various parameters like diversity, coding gain, bit error rate. Finally we hope that the proposed code will improve the performance of hybrid mobile system and provide the higher capacity to the MIMO system. In hybrid mobile system dual polarized antennas are used at both links to transmit and receive the data. For these systems space frequency codes are considered to reduce the transmission delay and hence to improve the bit error rate.

## RESULT:

The space frequency coding method improve the system performance. The performance comparison of turbo and silver code shows the elimination of error and provide spectral efficiency to the system. The capacity of MIMO was improved into certain level. The scattering problem was also eliminated.

## 2.2 Dual Polarized Modulation and Receivers for Mobile Communications in Urban Areas:

Achieving an increase in the spectral efficiency (SE) has always been a major driver in the design of communication systems. The use of MIMO techniques in mobile communications has achieved significant benefits in improving the system throughput. The basic underlying concept of MIMO is to exploit the signal and channel characteristics to eliminate interference between multiple transmissions.. The goal is to increase the SE without an increment of radiated energy without any Channel State Information at Transmitter (CSIT) and feedback at the transmitter and maintaining a very low computational complexity at the receiver. Although a priori additional power is required to increase the SE, we demonstrate that the proposed Polarized Modulation (PMod) scheme exploits the polarization diversity reducing the required EbN0 and adding an extra bit. We also introduce two receivers to demodulate this scheme of different computational complexities. We describe a Near Optimal Detector (NOD) which achieves almost the same performance as the optimal detector based on the Maximum Likelihood Detection (MLD), but with lower computational complexity. Finally, the results demonstrate that the PMod requires less EbN0 compared with the single polarization case, guarantees the robustness in the presence of the cross-polarization and validates that PMod can multiplex two streams of different Quality of Service (QoS).

## RESULT:

The work describes that the spectral efficiency increases by a factor of 1 + b−1 in the absence of CSIT. The results demonstrated that the PMod consumes less energy to increase the SE and improves the robustness in the presence of cross-polarization when compared with single polarization scenarios.

## 2.3 Capacity and Error Rate Analysis of MIMO Satellite Communication Systems in Fading Scenarios:

In this paper, we investigated the capacity and bit error rate (BER) performance of Multiple Input Multiple Output (MIMO) satellite systems with single and multiple dual polarized satellites in geostationary orbit and a mobile ground receiving station with multiple antennas. We evaluated the effects of both system parameters such as number of satellites, number of receive antennas, and SNR and environmental factors including atmospheric signal attenuations and signal phase disturbances on the overall system performance using both analytical and spatial models for MIMO satellite systems. We consider three different models for our evaluations in this paper. The models are the cluster based spatial satellite MIMO model Loo distribution based analytical model and the physical - statistical land mobile satellite mode.

## RESULT:

We analyzed the capacity and BER of different multiple satellite scenarios using different models. Simulation results showed that increasing the number of satellite and/or ground receive station antennas can significantly increase the capacity and decrease the bit error rate.

## 2.4 Capacity Improvement for a Land Mobile Single Satellite MIMO System:

This paper investigates a land mobile single satellite multiple-input–multiple-output (MIMO) system, polarization-time coded for capacity gain and provides complementary cumulative distribution function capacity predictions using experimental data. Capacity results obtained for a single satellite, single antenna terminal [single-input–single-output (SISO)], and a dual polarized single satellite, dual polarized antenna terminal (2x2 MIMO) system are compared, showing the benefit of satellite-MIMO. It demonstrates the above concept through measurements, and compares the available capacity in a single polarization single-input–single-output (SISO) system, with a single satellite dual polarized 2x2 MIMO system, under low elevation conditions, representative of many geostationary satellite systems. Comparison is made through the complementary cumulative distribution function capacity curves obtained in a main road (typical major road in the U.K. but narrower than a motorway/highway), in a suburban and an urban environment.

## RESULT:

It has shown the benefit of utilizing a dual polarization scheme in a land mobile single satellite MIMO scenario. Potential capacity gain has been shown to be significantly improved over a SISO system. Future land mobile satellite systems can take advantage of MIMO technology to boost data-rates in resource limited allocated spectrum. The potential gains have been shown by way of experiment. Although the LMS channel at low elevations is harsh, a significant increase in capacity can be achieved using polarization-time coding from a single satellite MIMO system.

# CHAPTER 3

# PROPOSED METHODOLOGY

In the proposed methodology the system model is being performed in order to increase the bit error rate and the throughput.

## 3.1 SYSTEM MODEL

Let us consider a MIMO system where transmitter and receiver are equipped with a single antenna with dual polarization, and a Rician frequency flat channel. Each symbol contains b + 1 bits of information, where b bits are modulated within the constellation S and the remaining bit is used for polarization selection. This remaining bit is denoted as c and the modulated bits as s∈C. We would like to remark that the information is conveyed through the symbols as well as bit c. The channels across the polarizations 1 and 2 are denoted$h_{11}$∈C and$h_{22}$∈C respectively and their respective cross-channels as $h_{21}$∈C and$h_{12}$∈C. All channel coefficients $h_{ij}$ follow a Rice statistical distribution with (K, $\sigma_h$) parameters with a pair-wise correlation $\rho_{ij}$ = [0, 1]. The receive signals for polarizations 1 and2 are denoted as$y_1$∈C and$y_2$∈C, respectively, and $\omega_i$∈C follows Additive White Gaussian Noise (AWGN), $\omega \sim CN(0,N_0I_2)$

Depending on the value of c ∈ {0,1}, the s symbols are conveyed using one polarization or the other. Hence, we can formulate the system model as

$$\begin{bmatrix} y1 \\ y2 \end{bmatrix} = \begin{bmatrix} h11 & h12 \\ h21 & h22 \end{bmatrix} \begin{bmatrix} 1-c \\ c \end{bmatrix} s + \begin{bmatrix} w1 \\ w2 \end{bmatrix} \quad (3.1)$$

Or in a more compact way as:

$$y = [h_1\ h_2]cs+w$$

$$y= Hcs+w \quad (3.2)$$

Where,

$h_i$ is the channel corresponding to $i^{th}$ polarization

c-polarization bits

s- signal

w-noise

y- modulated output

The above system is modelled using the matrix equation as shown in the figure:

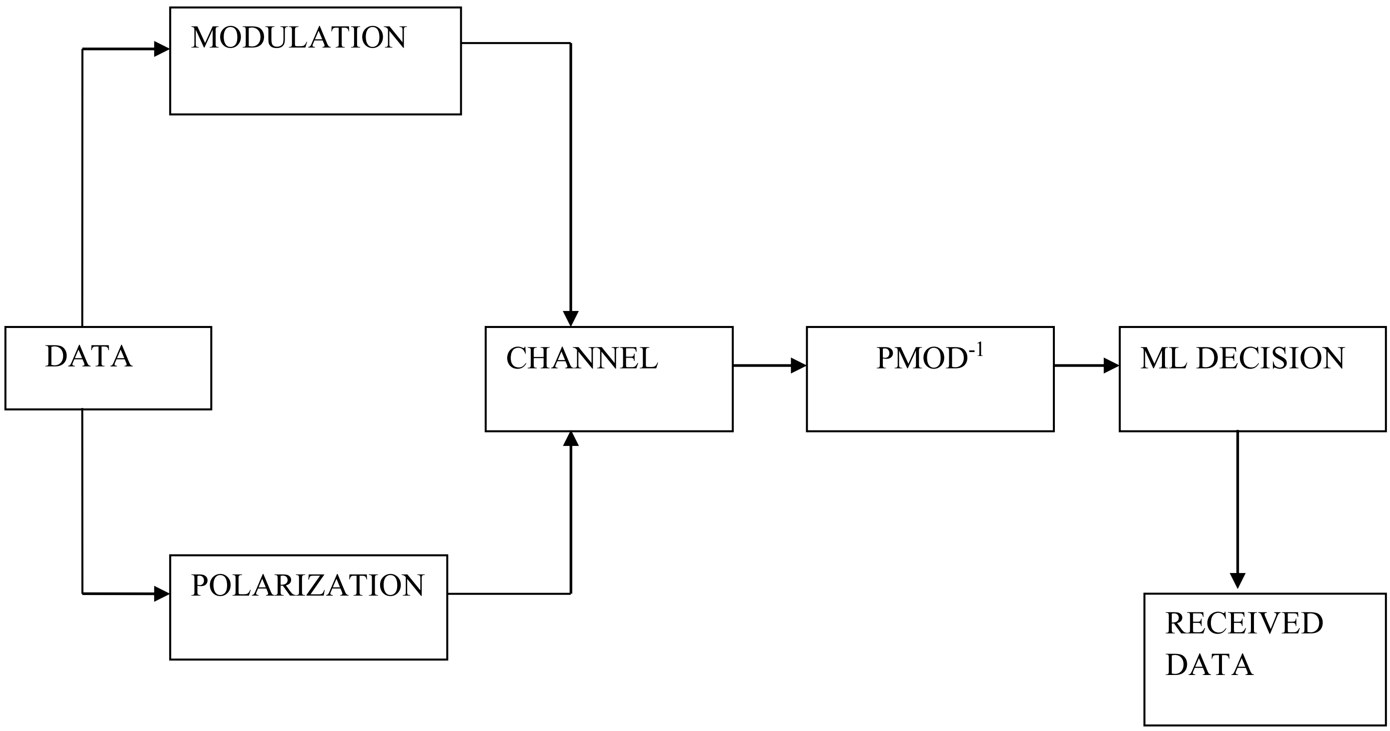



**Figure.3.1 System Model**

## 3.2 DATA:

The uniform pseudorandom binary data source generates equal likely bits [0,1].

## 3.3 MODULATION:

In BPSK modulation, the carrier wave is modulated by changing the phase by π and 0 for the input binary bit '0' and '1', respectively, for each bit interval Tb. To simulate the phase change of π radians for 0 and 1, the binary data 0 and 1 are mapped to -1 and+1, respectively, according to the relation n = 2*m – 1, where m = [0,1].

BPSK is a common digital modulation technique that maps binary data, 0 and 1 to$\sqrt{Eb}$ or -$\sqrt{Eb}$, respectively, where Eb is the average energy per bit. The input binary sequence is modeled as an independent and identically distributed random variable that is probability of 0 and 1 is equal to 50%. The baseband modulation can be perceived as asummation of shifted pulse waveforms.

$$p(t) = \begin{cases} 1, & 0 \leq t \leq Tb \\ 0, & \text{otherwise} \end{cases}$$

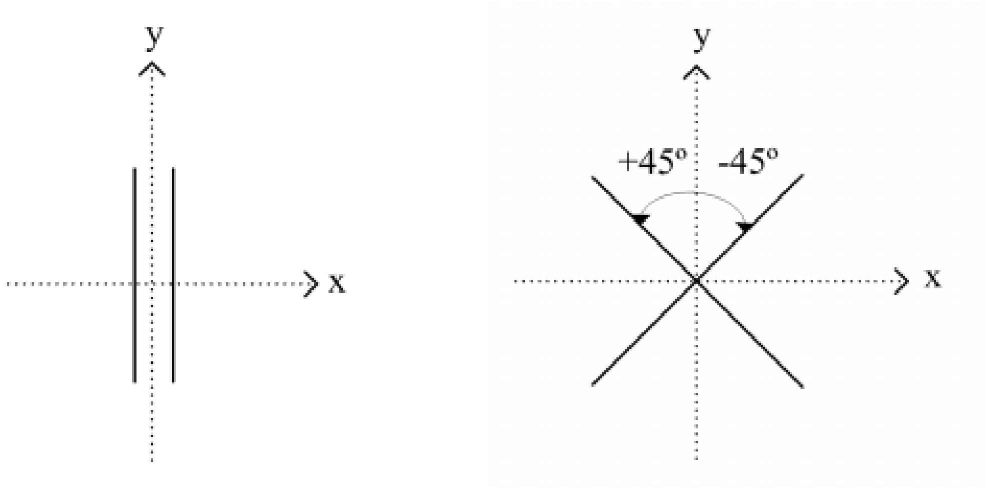
Here Tb refers to a bit interval.

## 3.4 POLARIZATION:

A single polarized antenna is one that responds only to one orientation of polarization – either horizontal or vertical. Thus radio waves that are received or transmitted by a single polarized antenna will be either horizontal or vertical polarized.

A dual polarized antenna**,** however, can respond to both horizontally and vertically polarized radio waves simultaneously. The use of both polarizations in this way increases the traffic handling capacity of the system. For example, one transmitter/receiver combination can be set on vertical polarization, while a second independent transmitter/receiver combination can be set on horizontal polarization.

With our single polarized antennas there will be a single waveguide connection point, or port, at the customer interface. The polarization (vertical or horizontal) is sometimes denoted by an arrow placed adjacent to the port. The orientation of the waveguide cable will determine the polarization; if the broad wall of the guide is in the horizontal plane, the antenna is vertically polarized, and if the broad wall is in the vertical plane, the antenna is horizontally polarized.The option to orientate the polarization in the desired direction is often facilitated by rotation either of the complete waveguide system or by a component of the waveguide system.




(a) single polarization (b) dual polarization

**Figure.3.2 Polarization Technique**

## 3.5 DEMODULATION SCHEME:

The implementation of the receiver derives into several approaches depending on the scenario constraints. Since PMod transmits a single stream, we aim to extract this stream to be processed into a SISO decoder. This scheme offers two main advantages:

• Reduces the complexity drastically since the signal processing is one dimensional.

• Can be combined with existing SISO decoders, maintaining the compatibility with the current standard

With this scheme, PMod1 implements one of the four demodulation schemes that are introduced in this section, estimates the bit c and manipulates the received signal y to produce the signal r, which is capable to be used by a SISO decoder.The optimal demodulation scheme is based on the Maxi-mum a Posteriori (MAP) criteria, which is equivalent to the Maximum-Likelihood (ML) criteria for the case where the transmitted symbols are equiprobable. Thus, the optimal receiver can be derived from the expression

$$\hat{x} = \arg\max p(y|x, H) \quad (3.3)$$

Based on the expression proposed in four different de-modulators are proposed:

• First approach: zero forcer.

Second approach: per-symbol detection.

• Third approach: per-hard-bit detection.

• Fourth approach: per-soft-bit detection.

### 3.5.1 FIRST APPROACH-ZERO FORCER:

In this approach a zero forcing pre-filter is applied before detecting the information in x. We note that the zero forcer is the solution of $df/dx^H = 0$, where $f(x) = ||y - Hx|^2$ This is equivalent to apply the filter

$$W = (H^H H)^{-1} HH \tag{3.4}$$

Therefore we obtain the signal after the processing as follows:

$$z = W_y = cs + (H^H H)^{-1} H^H \omega \tag{3.5}$$

In the case where the signal is being transmitted through polarization 1, i.e, c= 0, z1 contains the signal plus noise and $z_2$ only receives the noise; and the reciprocal case for c= 1,$z_1$ contains only the noise and $z_2$ conveys the signal plus the noise. Therefore, to decide on c we propose a power detector. It is denoted as

$$\hat{c} = \arg\max (|zi|)^2 \tag{3.6}$$

Once the receiver knows the used polarization path, it is able to decode the symbol s based on the signal $r = z_{\hat{c}+1}$.This solution presents a simple implementation but it is not a sufficient statistic to decode the whole problem (symbol s and bit c). Since it computes the envelope of the vector, the information conveyed through the phases is lost and therefore it is not sufficient.

### 3.5.1.a DRAWBACK:

Nevertheless, this solution presents a major disadvantage.$H^H H$ could be badly conditioned and thus it may produce an excessive noise enhancement, doing impossible the demodulation.

### 3.5.2 SECOND APPROACH: PER-SYMBOL DETECTION:

As we stated in the previous section, applying the W filter may introduce important distortions. Since the solution has to lie in the subset M, the solution of the first approach may not be the optimal. Thus, the optimal approach to solve (3.6) is performing an exhaustive search over the subset M.

In the particular case of PMod, the transmitted vector x can be restricted to the subset x∈M, where the first vector $\begin{bmatrix} S \\ 0 \end{bmatrix}$ of the set defines the transmission using the first polarization and the second vector $\begin{bmatrix} 0 \\ S \end{bmatrix}$ of the set, using the second polarization.Hence, the decision rule for demodulating the bit c is based on c^= 0 if x^= $\begin{bmatrix} S \\ 0 \end{bmatrix}$ and c^= 1 if x^= $\begin{bmatrix} S \\ 0 \end{bmatrix}$.In the same way, the signal r can be written as $r=x_{c\hat{}+1}$

This scheme, however, presents a notable increase of computational complexity. The exhaustive search requires to find the solution among several possibilities. The complexity of the initial search $O(2^{b2})$ but due to the restriction of the set aforementioned, the complexity is reduced to $O(2^{b+1})$, which is equivalent to the complexity of the SISO case where b+1 bits are conveyed.Furthermore, the previous demodulation schemes introduce hard decisions that induce non-linearities, such as sign() or abs() functions. In the presence of coded information, as it can be seen in, soft decoding outperforms the previous ML implementation. In the following sections we describe schemes that introduce soft information.

### 3.5.2.a DRAWBACK:

1. Increase in complexity

2. Produce Non-linearity in the demodulation due to hard decision of c bits.

### 3.5.3 THIRD APPROACH: PER-HARD-BIT DETECTION:

Usually to deal with channel impairments,the transmitted bits are coded.The channel decoder computes the metrics based on likelihood of the received signal and it is able to estimate the uncoded bits.The third approach is based on philosophy and c is based on likelihood ratio. The likelihood ratio is defined as

$$\wedge(y)=\frac{P2}{P1}=\frac{P(C=\frac{1}{Y})}{P(C=\frac{0}{Y})} \qquad (3.7)$$

The decision rule for estimating c depends only on the sign of log(^(y)).In the case the likelihood ratio is greater than 1 it means that it is more probable c=1 and vice-versa. Assuming that only b bits are coded, an estimator for uncoded c can be stated as,

$$c\hat{}=\frac{1+sign(\log(^{\log(y)}))}{2} \tag{3.8}$$

Once the receiver obtains the estimation of c,it knows which polarization is used thus it can recover the symbol s,using the signal $r=y_{c\hat{}+1}$.Although this scheme uses soft information in the decoding of symbols, the decision of bit c is still hard. Thus, if this bit is also coded, the result is suboptimal. In the next section we describe how to obtain a soft version of bit c.

**3.5.3a DRAWBACK:**

1. The decision of c bit is hard

2. The result obtained is sub optimal.

## 3.5.4 FOURTH APPROACH: PER-SOFT-BIT-DETECTION:

The three approaches described above perform hard decision for the estimation of bit c. However, they can introduce errors the system conveys coded information as it was mentioned. The soft version of bit c corresponds to the log-likelihood, exactly as the bits b. That is

$$c\hat{}= \log((y)). \tag{3.9}$$

After that, the bit c is soft and can be passed to the soft decoder. However, there is the problem of which polarization to choose for decoding. In the previous schemes, since the bit c is hard, it is possible to process the received signal on the polarization indicated by c. In the present scheme it is not possible to decide which polarization conveys information.

To solve this issue we compute the average received signal:

$$r = P_1 y_1 + P_2 y_2 \tag{3.10}$$

Using the likelihood ratio (y) computed as in (3.5), and using

$$P_2=P(c=1|y) =1-P(c=0|y) =1-P_1 \tag{3.11}$$

We can rewrite

$$P2=P(c=1|y)=\frac{\hat{}(Y)}{1+\hat{}(Y)} \quad (3.12)$$

Therefore, the receiver can recover the signal by weighting the received signals from both polarizations by $P_1=1-P_2$ and $P_2$, respectively. If we assume that the bit c is transmitted with equal probability, the averaged received signal takes the following form:

$$r = (1 - P_2)y_1+P_2y_2=\frac{1}{1+\hat{}(Y)}(y_1+y_2\hat{}(y)) \quad (3.13)$$

Finally, the combined signal r is passed to the decoder in order to obtain the b bits.

### 3.5.4.a DRAWBACK:

1. The decision of c bits can be done for both hard and soft can be done for both polarization, but they cannot be done simultaneously.

## 3.6 MAXIMUM LIKELIHOOD (ML) RECEIVER:

ML receivers are based on optimal vector decoding and they minimize error probability. ML equalization involves calculation of the Euclidian distance between the estimate $\hat{x}$ and all possible transmitted signals (x) and detection of transmitted signal vector that corresponds to the minimum distance. The complexity of this receiver increases for higher order of modulation schemes.

The design criterion of ML receiver is presented below. The objective of the ML receiver is to minimize the probability of error in decoding the transmitted message that is to minimize

$Pe = p(\hat{x} \neq x_i|y(t))$ or to maximize $p(\hat{x} = xi|y(t))$. Signal constellation points have a one-to-one relation with a transmitted message an equivalent condition is to maximize p(si sent |y(t)). Correspondingly, the decision regions (Z1,...,ZN) are seen to be the sub-sets of the signal space.

$$Zi = (y: p(si\ sent|y) > p(sj\ sent|y)\ \forall j \neq i) \quad (3.14)$$

## 3.7 RECIEVED DATA:

The received data is the output which is obtained after performing the system which is being modelled followed by demodulation scheme and the ML decision processed and the throughput efficiency is calculated using the received data and the graph is plotted and the result is being analyzed. It is seen that the soft demodulation produce enhanced throughput efficiency when compared with other demodulation technique employed.

# CHAPTER 4

# MULTIPLE INPUT MULTIPLE OUTPUT

## 4.1 INTRODUCTION:

MIMO is an acronym for Multiple Input, Multiple Output and is a significant departure in the architecture and technology from the current SISO (Single Input, Single Output) WLAN products. This is accomplished through the implementation of multiple transmitters and receivers in a single WLAN station, AP or client.

A principle problem in wireless systems is multipath interference. This is commonly referred to as reflections, refractions, echoes, coverage holes or "dead spots". In the cellular world this can best be expressed by having a perfect 5-bar signal and a clear call, then taking a few steps and hearing static. This problem is particularly the case in existing WLANs where systems are characterized, in part, by their tolerance to inter symbol interference, or delay spread. Delay spread is the difference, in time, between arriving copies of the same signal caused by multipath and is due to path length differences.

Existing WLAN technologies attempt to compensate for multipath by implementing a rake receiver to allow for specific amounts of delay spread. As delay spread increases, the multipath situation worsens and the arriving symbols begin to interfere with each other beyond the capability of the receiver to recover. This results in common complaints to the help desk with the generic "wireless doesn't work" intermittent reports which cannot be reliably recreated. Further, the throughput capability of the WLAN with MIMO is extended to be more comparable with wired LANs. The current IEEE 802.11n draft includes link rates up to 600 Mbps. The commonly used value for link overhead in WLAN systems is 40% giving a throughput potential of about 360 Mbps in a single cell. This is an idealized value and is highly dependent on the operating environment and the composition of clients associated with a particular AP.A basis for MIMO was created at Bell Labs in the 1997 to 2002 period called BLAST for Bell Labs Layered Space-Time. Using MIMO-like techniques, multiple transmitters and receivers, BLAST exploits multipath to gain very high spectral efficiencies (10s of bits/sec/Hz were measured).

The spectral efficiency of a wireless system can be increased significantly through these technologies. However, in a Wireless LAN, the space available for the additional antennas is limited and consequently, three sets has been the chosen number based on the inter-antenna spacing required to reduce co-site interference. With applications including social media, high definition video streaming, mobile banking, and full-featured web browsing, broadband cellular applications provide exciting opportunities for consumers and network operators alike. However, these data-intensive applications also create new bandwidth delivery challenges for mobile operators. In order to expand available wireless network capacity to meet the demands of data-intensive applications, operators have invested heavily in acquiring radio frequency bandwidth. Even so, RF spectrum remains a finite resource, with the industry as a whole facing a spectrum crunch, as acknowledged the United States' Federal Communications Commission chairman, Julius Genachowski.1 Therefore, network operators must look to new technologies such as LTE to generate more throughput from existing bandwidth. While LTE can provide increased capacity using standard antenna techniques, widespread deployment and optimization of MIMO (Multiple-Input Multiple-Output) antenna techniques can have a multiplicative effect on LTE's data throughput. MIMO techniques, in turn, present their own unique challenges, requiring a new approach to network measurement and optimization The degree to which transmissions on the same channel appear to the Rx to be the same. Low channel correlation indicates the transmissions can be distinguished, allowing multi-layer transmission. CINR Carrier to Interference plus Noise Ratio Closed Loop Transmissions are configured with detailed feedback from the UE CN Condition Number – a measure of channel correlation CQI Channel Quality Indicator – overall measurement of channel conditions under a particular transmission mode eNodeB LTE's equivalent for a base station Layer Data stream to be transmitted over particular time frequency resources. Transmissions with multiple layers transmit more than one data stream over the same time frequency resources. LTE Long Term Evolution, 3GPP's next-generation wireless protocol. LTEAdvanced 3GPP Release 10 standard for ITU-Advanced-compliant 4G wireless protocol MIMO Multiple-Input Multiple-Output MISO Multiple-Input Single-Output MU-MIMO Multi-User MIMO Open Loop Transmissions are configured with minimal feedback from the UE Rank Equal to the number of layers in an LTE spatial multiplexing transmission RF Radio Frequency RI Rank Indicator – indication of the number of layers that can be supported on a given channel RS Reference Signal Rx Receive antenna SIMO Single-Input Multiple-Output SISO Single-Input Single-Output SM Spatial Multiplexing – transmission scheme in which different spatial paths carry different data streams, enabling multi-layer transmissions SNR Signal-to-Noise Ratio SU-MIMO Single-User MIMO Tx Transmit antenna UE User Equipment.

MIMO systems use more than one transmit antenna (Tx) to send a signal on the same frequency to more than one receive antenna (Rx). Although MIMO has been deployed for years in WLAN networks,2 it is a relatively new feature in commercial wireless networks. MIMO technology is a standard feature of next-generation LTE networks, and it is a major piece of LTE's promise to significantly boost data rates and overall system capacity. However, MIMO also represents a new challenge for network operators.

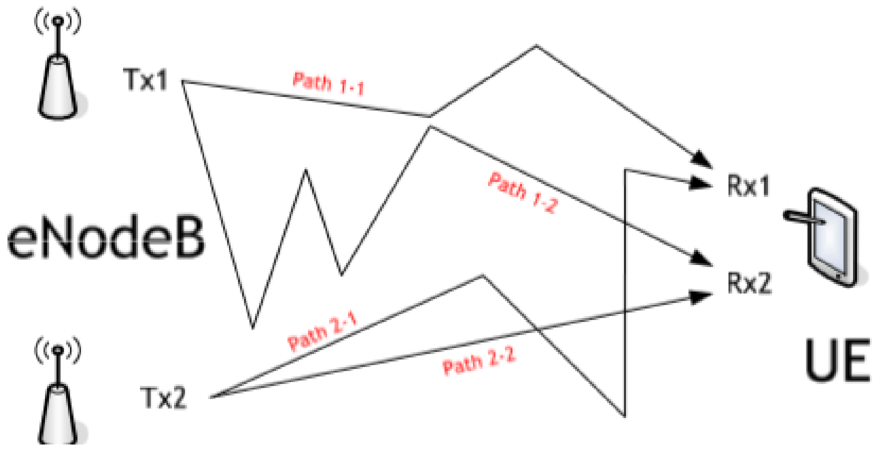



**Figure.4.1 MIMO Data transfer**

Traditionally, cellular networks generally provide the best service under line-of-sight conditions. MIMO thrives under rich scattering conditions, where signals bounce around the environment. Under rich scattering conditions, signals from different Tx take multiple paths to reach the user equipment (UE) at different times, as shown in Figure 1. In order to achieve promised throughputs in LTE systems, operators must optimize their networks' multipath conditions for MIMO, targeting both rich scattering conditions and high SNR for each multipath signal. This optimization process requires accurate measurement of these multipath conditions in order to achieve the best performance for a given environment while avoiding the time and expense of guesswork. With strong measurements, however, an optimized MIMO system can result in massive throughput gains without the expenses associated with adding spectrum or eNodeBs.

## 4.2 MIMO SATELLITE COMMUNICATION:

MIMO technology has its roots in more widely deployed antenna techniques. MIMO builds on Single-Input Multiple-Output (SIMO), also called receive diversity, as well as Multiple-Input Single-Output (MISO), also called transmit diversity. SIMO techniques have been around for decades, while MISO is used in most advanced cellular networks today. Both of these techniques seek to boost signal-to-noise ratio (SNR) in order to compensate for signal degradation. As a radio frequency (RF) signal passes from Tx to Rx, it gradually weakens, while interference from other RF signals also reduces SNR. In addition, in crowded environments, the RF signal frequently encounters objects which will alter its path or degrade the signal. Multiple-antenna systems can compensate for some of the loss of SNR due to multipath conditions by combining signals that have different fading characteristics, since the path from each antenna will be slightly different. SIMO and MISO systems achieve SNR gain by combining signals that take multiple paths to the Tx and Rx in a constructive manner, taking the best piece of each signal.3 Because different antennas receive or transmit the same signal, these systems can achieve SNR gains even in line of sight situations. The boost in SNR can then be used to increase the range of the connection or boost data rates by using a modulation scheme such as 16QAM or 64QAM rather than QPSK. MIMO can work as a combination of SIMO and MISO techniques, resulting in even greater SNR gains, further boosting coverage and data rates. However, when SNR is high, additional throughput gains are minimal, and there is little benefit from further boosting SNR. To achieve throughput gains where SNR is already very high, LTE uses a MIMO technique called spatial multiplexing. In spatial multiplexing, each Tx sends a different data stream to multiple Rx. These data streams are then reconstructed separately by the UE. It may seem counterintuitive that two signals sent at the same time and frequency within the same sector can result in increased throughput rather than interference. However, spatial multiplexing can be compared to conventional spectrum re-use, where signals are transmitted in the same frequency in different cells. For spectrum re-use, the cells must be far enough apart—that is, they must occupy different space—in order to avoid interference. With spatial multiplexing, the signals, instead of occupying a completely different cell, occupy different space-time in the same cell. Good multipath conditions create the signal orthogonality that effectively turns a single cell into multiple cells with respect to the amount of data that can be sent on a particular frequency band. In addition to good multipath conditions, spatial multiplexing depends on high SNR to produce large throughput gains. In spatial multiplexing, even though multiple data streams are transmitted, the total power of the transmission remains the same. Essentially, spatial multiplexing distributes the total SNR between these multiple data streams, each of which has a lower power level. The result is that each data stream contains a lower SNR than would be possible with a single data stream. However, because there are diminishing returns for additional SNR when SNR is already high each of the multiple data streams may be capable of transmitting nearly as much data as a single stream. The increased data capacity that results from sharing SNR between multiple data streams means that, while spatial multiplexing may be used to encode the same data differently and boost SNR of the recombined data streams, it can also be used to send completely different data through each Tx. In LTE, each set of data sent through the antennas in a spatial multiplexing operation is called a layer. Under ideal conditions, each layer of a spatial multiplexing transmission will contain as much data as a single-Tx LTE transmission. The result is that spatial multiplexing can theoretically multiply throughput by the transmission rank. This multiplicative effect on throughput means that MIMO technology is essential for achieving the full benefits of LTE. With the 2x2 (2 TX and 2 Rx) antenna configuration expected to be deployed initially, effective use of MIMO could nearly double throughput both for individual users and for each cell as a whole. However, these throughput gains depend on three factors: maximizing rich scattering conditions within a cell, configuring the eNodeB to properly match MIMO settings to real-world conditions, and ensuring that UEs can take full advantage of the multipath conditions that are present. Scanning receivers that can provide accurate real-world measurements of multipath conditions and potential throughput are essential tools for evaluating the performance of all three of these factors. With these measurements, mobile operators can maximize the data rates and reliability of LTE networks, resulting in a premium return on their LTE equipment investments while improving customer satisfaction.

MIMO systems demonstrate greater overall throughput using two separate methods. First, the ability to provide a higher data-rate vs. range means improved throughput over a much larger coverage range than traditional SISO antennas. Second, additional throughput can be gained by operating the MIMO AP with 40 MHz channels to increase the available bandwidth for the signal and increase the channel bit rate. While the first technique is applicable to any client device, the second requires a MIMO based client to utilize the additional channels.

However, MIMO is not without its drawbacks, although there are relatively few when balanced against the gains. These are largely due to the increased component costs within an

Access Point required for the MIMO implementation. Multiple antennas, and the use of higher performing CPU and DSP chips mean that, initially, manufacturer's costs of goods per AP may rise, however, as these components become mass produced it is likely that their prices will quickly fall. Additionally, the operation of multiple radio chains requires more power than the SISO (legacy) systems, both in transmit and receive operations. Clients that use standby mode to preserve battery life may have shorter cycle times, but work is already underway by client manufacturers to operate in single chain mode until a "wake-up" signal is detected.

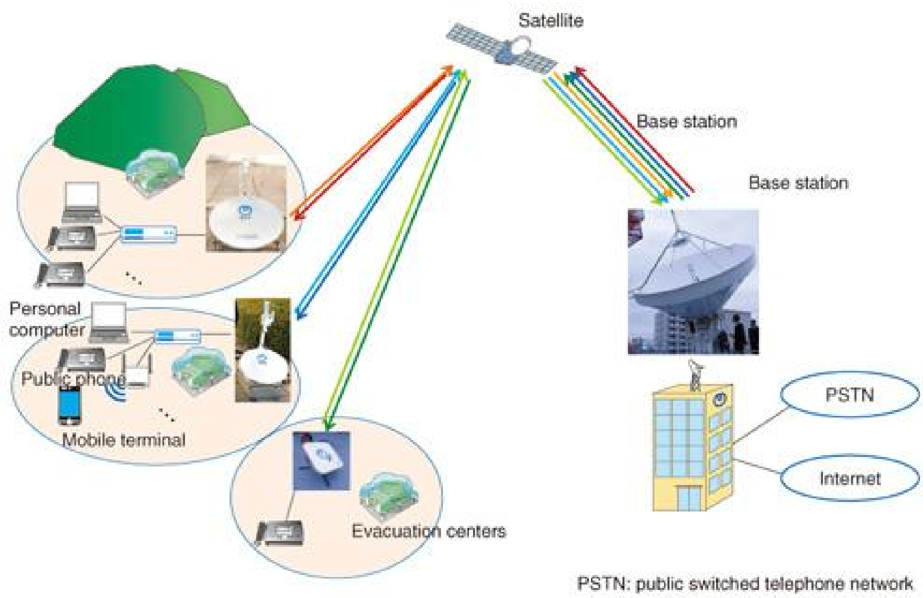



**Figure.4.2 Data transfer from satellite using MIMO**

## 4.3 MIMO OPTIMIZING TO IMPROVE THROUGHPUT:

The goal of optimizing a MIMO system is to achieve the highest throughput and connectivity possible in a given environment by leveraging the multipath potential of the environment. Optimization is necessary for successful rollout of MIMO systems, while continued optimization of active networks helps maintain return on investment as multipath environments change and UEs evolve. The first part of MIMO optimization is configuration of antennas at the eNodeB to create the best multipath conditions possible. This may involve altering the placement, tilt, or selection of antenna equipment. Second, MIMO optimization includes evaluating UEs to ensure that they have the processing power and antenna configurations necessary to take advantage of multipath conditions created by the interaction between the environment and antenna configuration. Finally, LTE MIMO systems must optimize the algorithms the eNodeB uses to select the best MIMO mode given UE capabilities and multipath conditions.All three elements of MIMO optimization require accurate, UE-agnostic measurements of real-world multipath conditions. Without these measurements, operators have no way of knowing whether antenna configurations have produced the expected multipath conditions throughout the sector. Furthermore, only real-world, UE-agnostic measurements allow operators to determine whether MIMO mode selection and UE capabilities are successfully meeting the throughput potential of existing multipath conditions.

Real-world MIMO measurements should include power and quality measurements of each multipath signal, as well as indications of signal orthogonality and the overall throughput potential of the multipath environment. Together, these measurements allow operators to evaluate each multipath signal as they would a single transmitted signal, and also evaluate how well the multiple transmitted signals are working together to create multipath conditions. Test mobiles provide real-world data, but can only estimate achievable throughput for that particular UE. Mobiles also lack the scan speeds or dynamic range necessary to achieve an accurate picture of the variations in multipath conditions throughout a given sector. Data collected by the eNodeB is similarly limited by the capabilities of the UEs active within the sector. Furthermore, eNodeB data may be unavailable or inadequate when no or few MIMO-capable UEs are in use, or when UEs operate in open loop mode. Only high-powered scanning receivers with the capability to simultaneously receive and analyze multiple signals using optimally placed multiple antennas can provide the complete and accurate multipath data necessary for full MIMO optimization.

## 4.4 MIMO DETECTION:

A MIMO detector which is used for detecting receive symbols, corresponds to symbols transmitted through transmit antennas from receive signals, when the transmit data transmitted by the terminal group are received through receive antennas. In MIMO detection the detector calculates an estimate of the transmitted signal as an output of the detector based on the received signal and the estimated channel matrix. After estimating and calculating the channel matrix, the LTE-A system recovers the transmitted signal from the received signal as an output of the detector. Modern silicon technology allows detectors to take full advantage of constrained maximum likelihood (ML) search techniques, and can calculate a posteriori probability (APP) soft information based on the received symbols. ML search is the optimum detection method and minimizes the bit error rate (BER). In general, the detection algorithm can be classified into three types:

 Linear equalization algorithms

 Non linear equalization algorithms

 Optimal detection algorithms

Linear equalization algorithms include zero forcing (ZF) and MMSE algorithms. Of these, ZF is the simplest detection algorithm with the lowest computational complexity. MMSE is a high complexity algorithm, but offers high performance. Optimal detection algorithms include maximum likelihood (ML) and sphere decoding. These have preferable performance, but have the highest complexity. Non linear equalization algorithms include Successive interference cancellation (SIC), Parallel interference cancellation (PIC),Vertical Bell labs layered space time (V-BLAST) and QR decomposition algorithms. They have lower complexity and better performance than the optimum detection algorithms. The ZF receiver completely nulls out the influence of the interference signals coming from other transmit antennas and detects every data stream separately. The disadvantage of this receiver is that due to cancelling the influence of the signals from other transmit antennas, the additive noise may be strongly increased and thus the performance may degrade heavily.

As mentioned earlier, MIMO methods are used to enhance mobile communications by two ways. The two ways are: the increasing of overall data rates and, the increase in dependability in communication links. The algorithms in MIMO used in LTE are categorized broadly into four areas namely receive diversity; transmit diversity, beam forming and spatial multiplexing. In the case of transmit diversity the redundant information is transmitted on different antennas. Transmitting in different antennas will not contribute to enhancements in the data-rates that are intended to be achieved rather the communication link becomes more robust. In the case of spatial multiplexing, the LTE system transmits independent or non-redundant information using multiple antennas. In this MIMO scheme data rate is significantly boosted for any link given. The improvement in data rates is linearly proportional to transmit antenna numbers used in transmission. The LTE standard accommodates up to four transmit antennas to accommodate this data rate in downlink specification.In the case of LTE advanced, the down-link transmission uses up to eight transmit antennas.

### 4.4.1 Receive and Transmit Diversity in MIMO:

In LTE systems, the technique for multiple antenna transmission depends on the use of more than single antenna at both ends, via the receiver and transmitter. This is carried out using methods in advanced signal processing. However multiple antenna techniques add to computing complexities in the implementation. In spite of the complexities multiple antennas are used to provide enhancements in system performance and this also includes the capacity of the system. By utilizing multiple antennas, many different aims can be fulfilled at both the receiver and sender locations.

## 4.5 MIMO SYSTEM MODEL:

In order to increase the throughput efficiency for data transfer in satellite communication, the mimo technique is being employed in the demodulation side and the flow diagram for the model is illustrated as shown below in the figure,

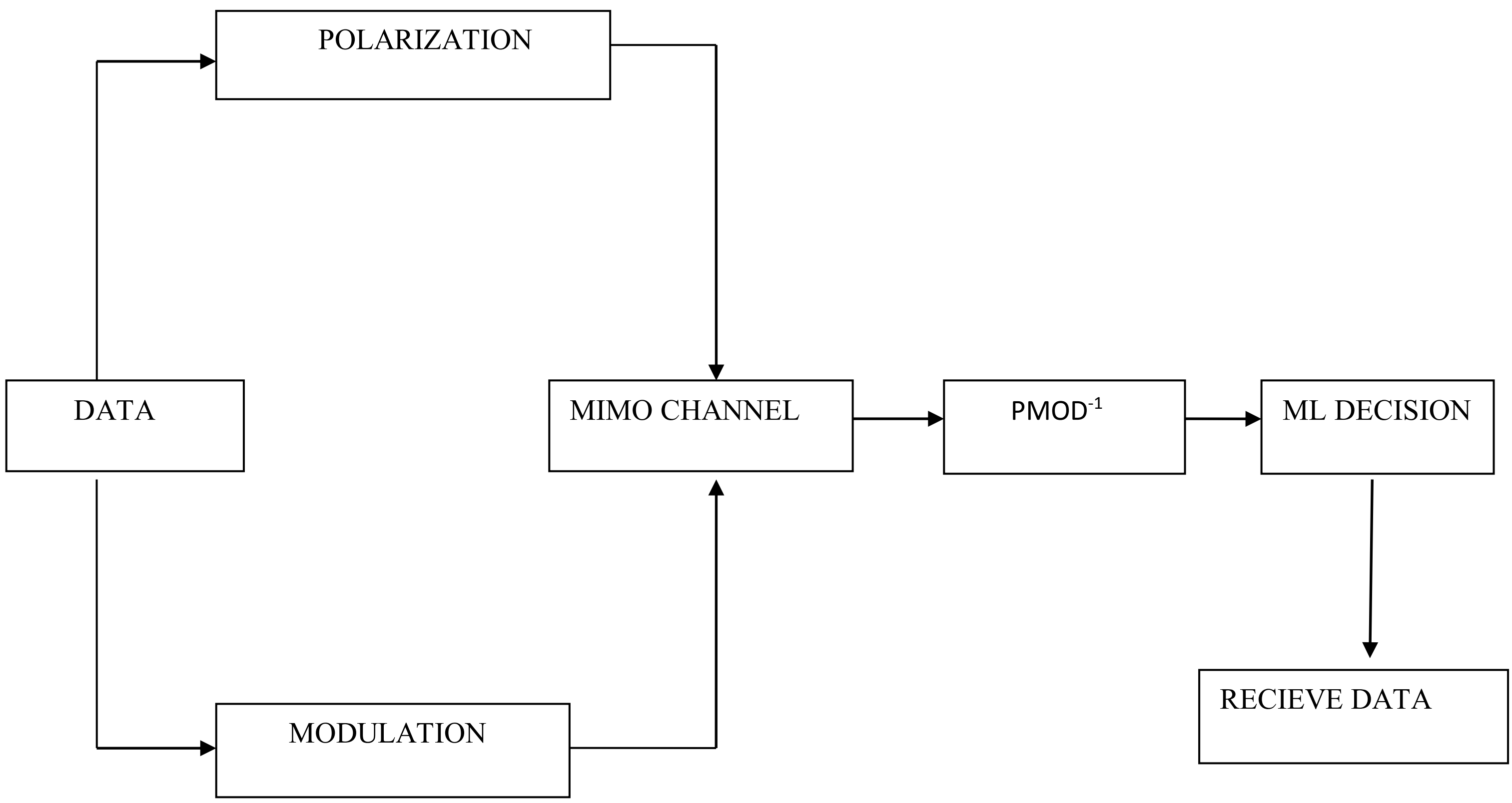



**Figure.4.3 MIMO System Model**

In this system model first the data is being spilt for polarization and the modulation, the polarization is either chosen as (say c=0,c=1) and the BPSK modulation is carried out after that the MIMO channel is being applied to the separated data by using the matrix equation,

Depending on the value of c ∈ {0, 1}, the s symbols are conveyed using one polarization or the other. Hence, we can formulate the system model as

$$\begin{bmatrix} y1 \\ y2 \end{bmatrix} = \begin{bmatrix} h11 & h12 \\ h21 & h22 \end{bmatrix} \begin{bmatrix} 1-c \\ c \end{bmatrix} s + \begin{bmatrix} w1 \\ w2 \end{bmatrix} \tag{4.1}$$

or in a more compact way as:

$$y=[h_1\ h_2]cs+w \tag{4.2}$$

Using mimo technique,

$$y1=h1cs1+w1 \tag{4.3}$$

$$y2=h2cs2+w2 \tag{4.4}$$

Where,

$h_i$ is the channel corresponding to ith polarization

csi-polarization bits corresponding to number of antenna

wi-noise added to corresponding antenna

yi-modulated output for the antenna

After the modulated output is being obtained the system model output is being demodulated using the four modulation and the MIMO technique is being applied to each demodulation scheme and the ouput is obtained i n oreder to increase the throughput effiency,the process for the demodulation is carried out as shown below in the flowchart.

**FLOWCHART:**

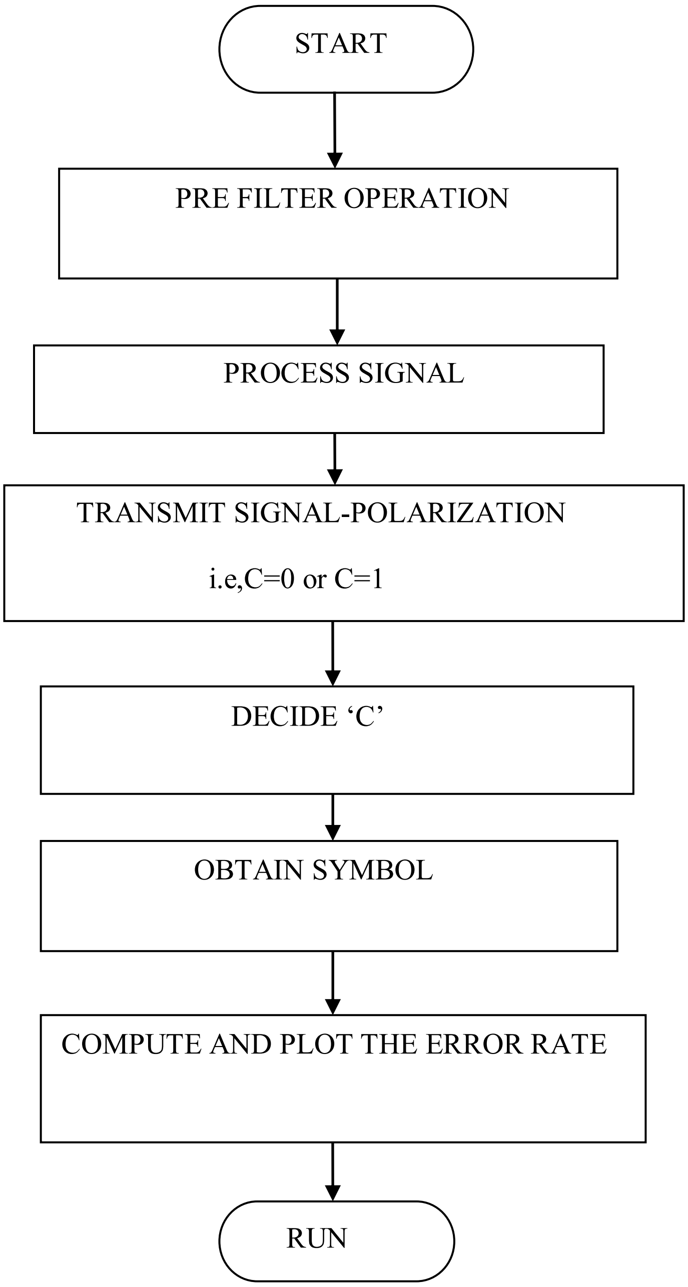



**Figure.4.4 Flow Diagram for Demodulation**

Thus the process involves the pre-filter operation to set the desired frequency and the signal is being processed followed by the polarization,where the polarization is decided and selected, according to the polarization bit ‘c’ is selected the symbol is being produced and the error rate is obtained and the graph is plotted.

# CHAPTER 5

# SIMULATION RESULTS AND FUTURE WORK

The system model result by using the matrix equation for the given randomly generated channel input is taken and the corresponding channel output is obtained.

The input is taken as the random bits and it is being spilted for polarization and modulation and the system is being modelled using the matrix equation and then the demodulation process is carried out by four approaches and then ML Decision is performed and then the bits are received and the graph is being plotted. In the next case, the MIMO technique is used to model the system and the graph is being plotted for the received bits.

## 5.1 CHANNEL INPUT:

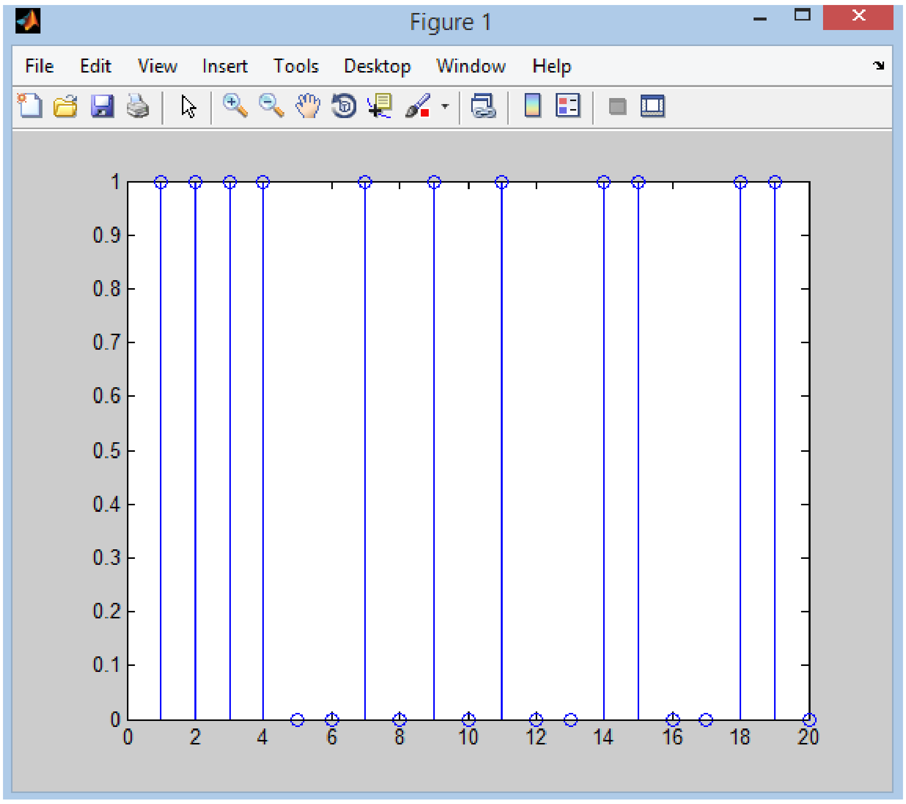



**Figure.5.1 Channel Input**

### 5.1.2 CHANNEL OUTPUT:

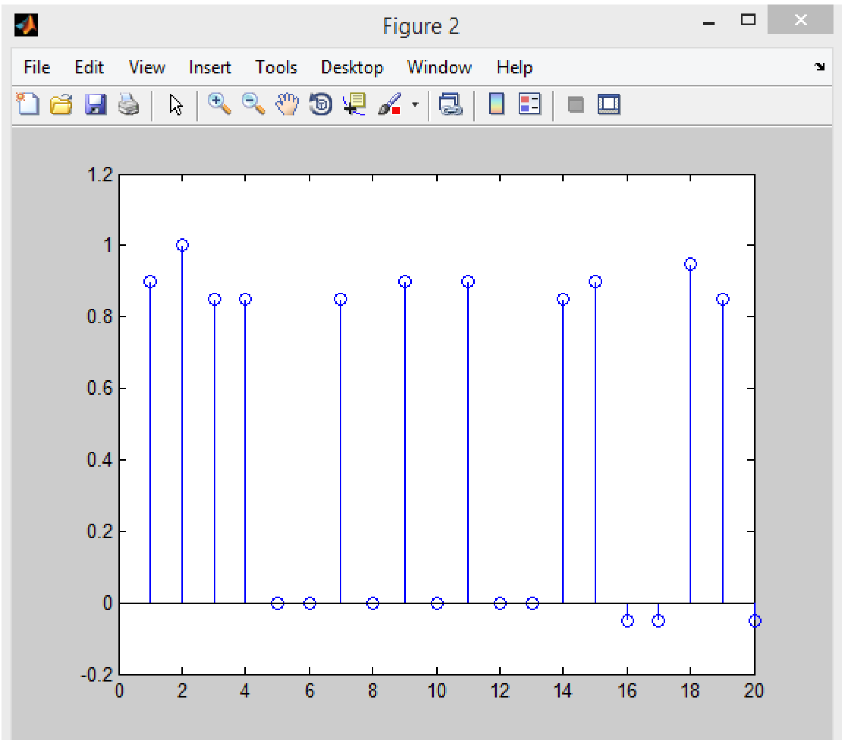



**Figure.5.2 Channel Output**

### 5.1.3 MIMO CHANNEL INPUT:

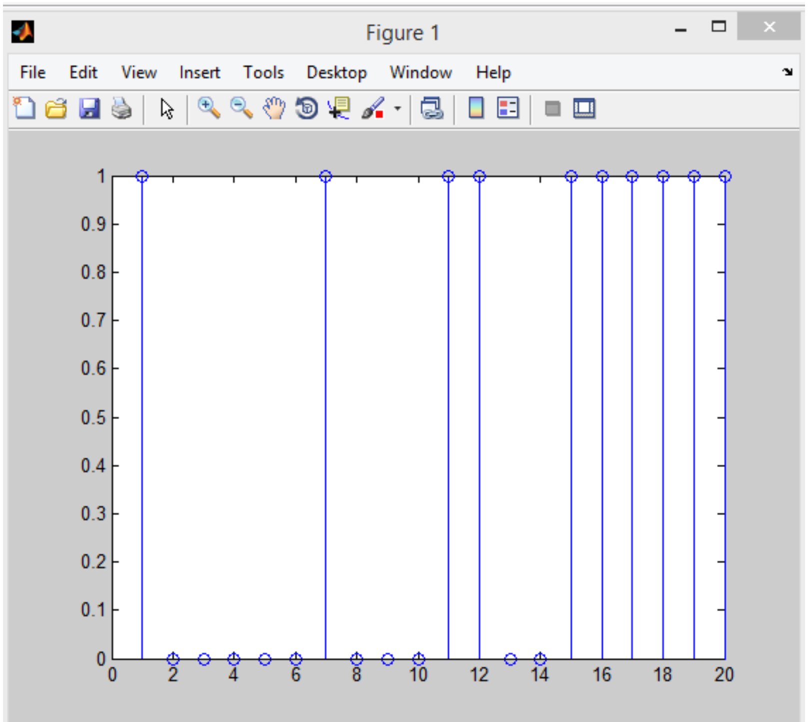



**Figure.5.3 MIMO Channel Input**

## 5.1.4 MIMO CHANNEL OUTPUT:

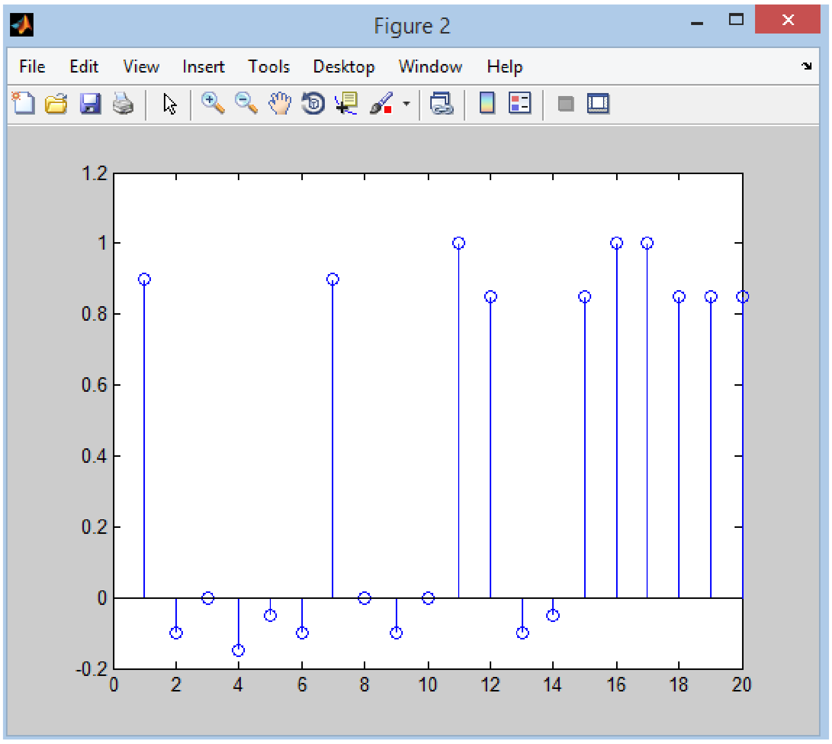



**Figure.5.4 MIMO CHANNEL OUTPUT**

## 5.1.5 INFERENCE:

The input binary data is being separated for the modulation and polarization,the BPSK modulation is used to spilt the data and the polarization 'c' bits is either chosen as 0 or 1 and it is multiplied with the signal and the noise is being added and the channel output y is obtained.

## 5.2 DEMODULATION SCHEME:

The demodulation scheme using the inverse Polarization modulation ($PMOD^{-1}$) based on the four approaches based on the matrix equation and the MIMO technique is compared and the result is obtained.

### 5.2.1 FIRST APPROACH-ZERO FORCER:

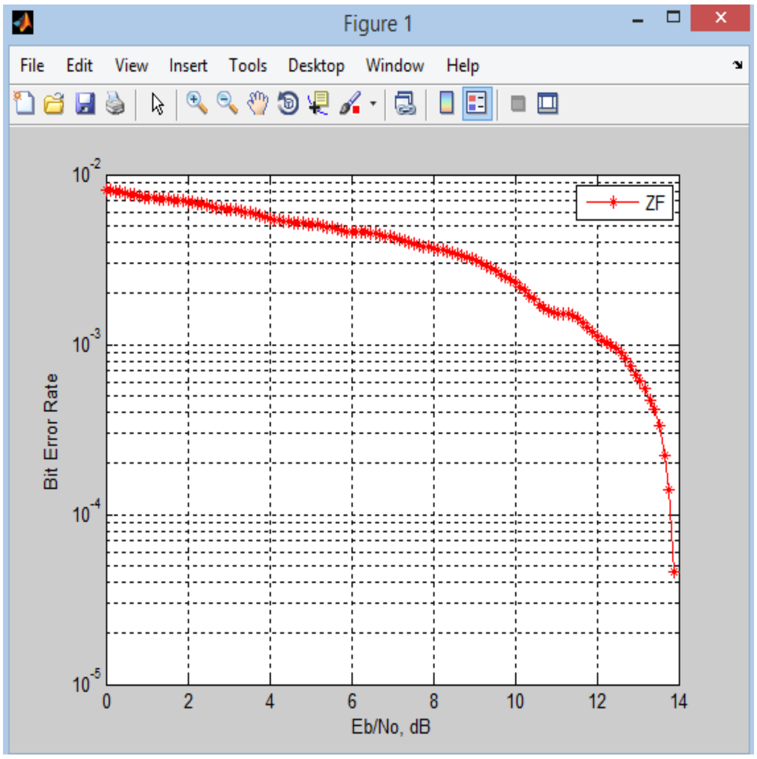



**Figure.5.5 Zero Forcer**

### 5.2.2 MIMO ZERO FORCER:

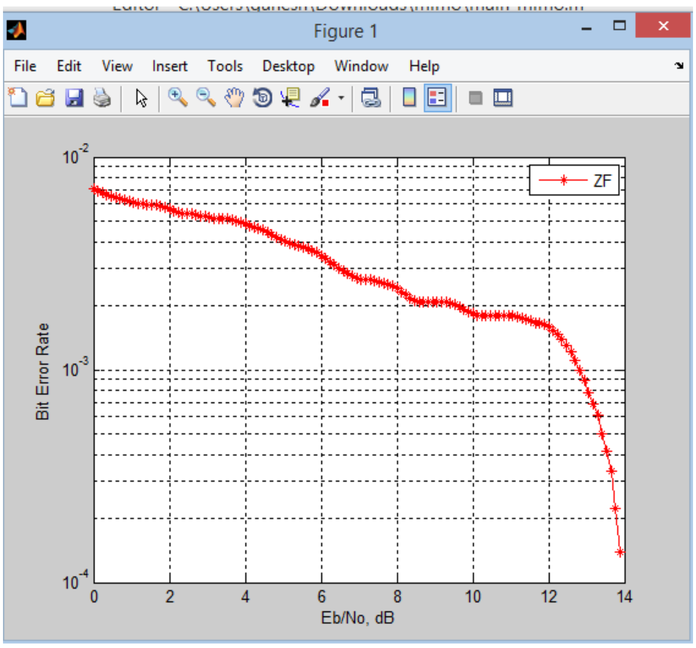



**Figure.5.5 MIMO Zero Forcer**

## 5.2.4 SECOND APPROACH-PER SYMBOL DETECTION

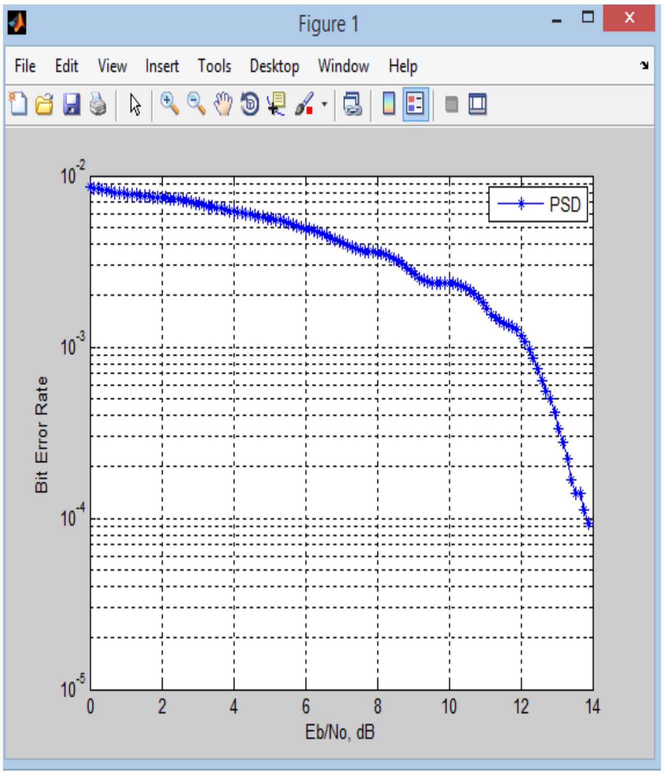



**Figure.5.7 Per Symbol Detection**

## 5.2.5 MIMO PER SYMBOL DETECTION:

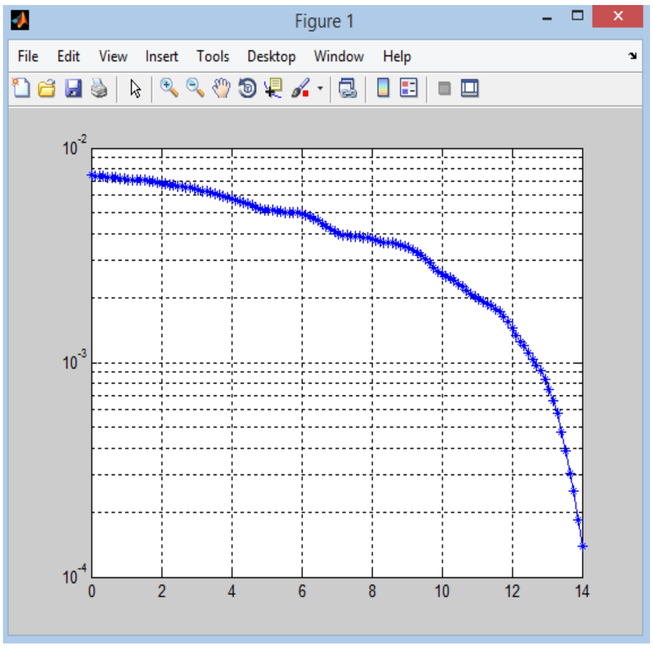



**Figure.5.8 MIMO Per Symbol Detection**

## 5.2.6 THIRD APPROACH- PER-HARD-BIT DETECTION

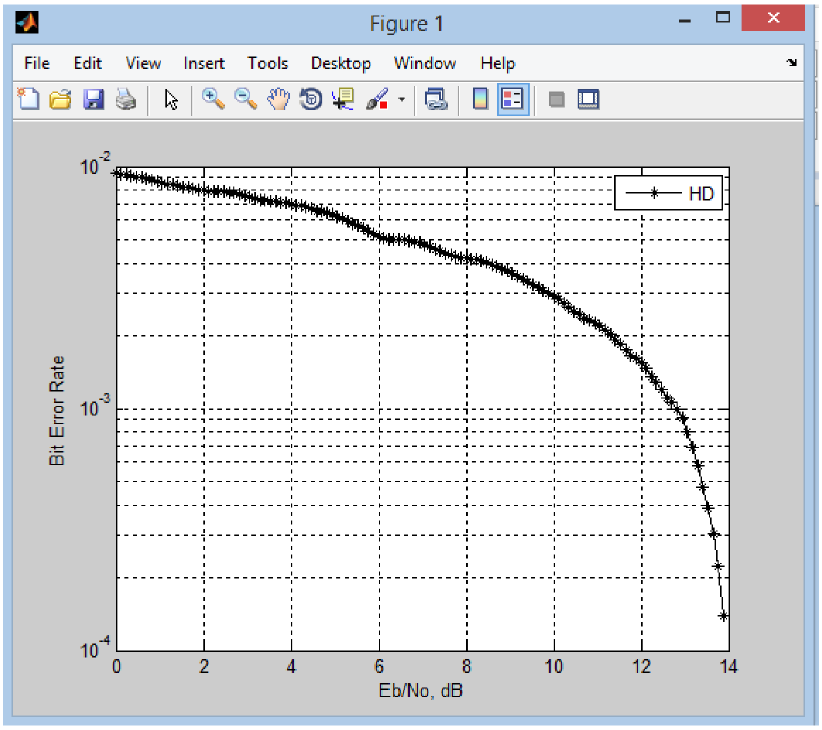



**Figure.5.9 Per-Hard-Bit Detection**

## 5.2.7 MIMO PER-HARD-BIT DETECTION

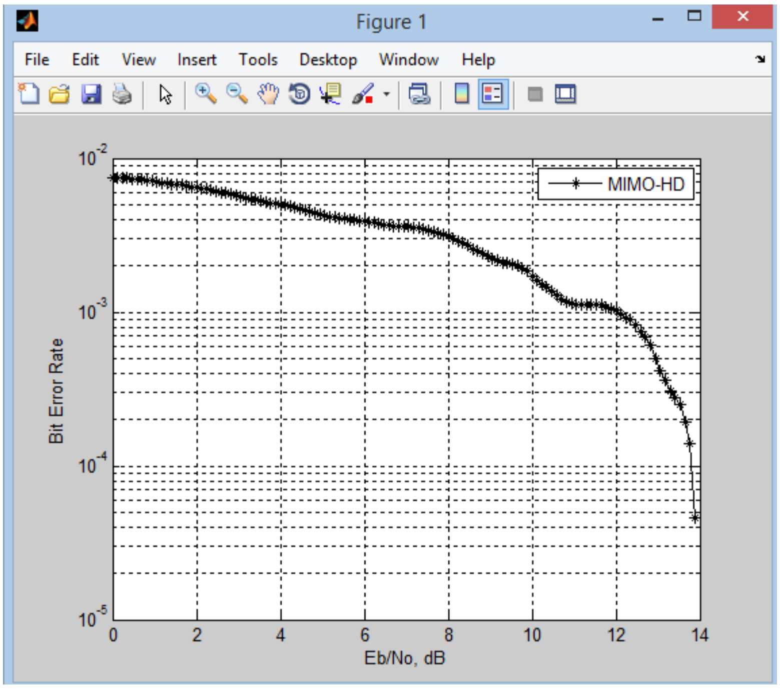



**Figure.5.10 MIMO Per-Hard-Bit Detection**

### 5.2.8 FOURTH APPROACH- PER-SOFT-BIT DETECTION

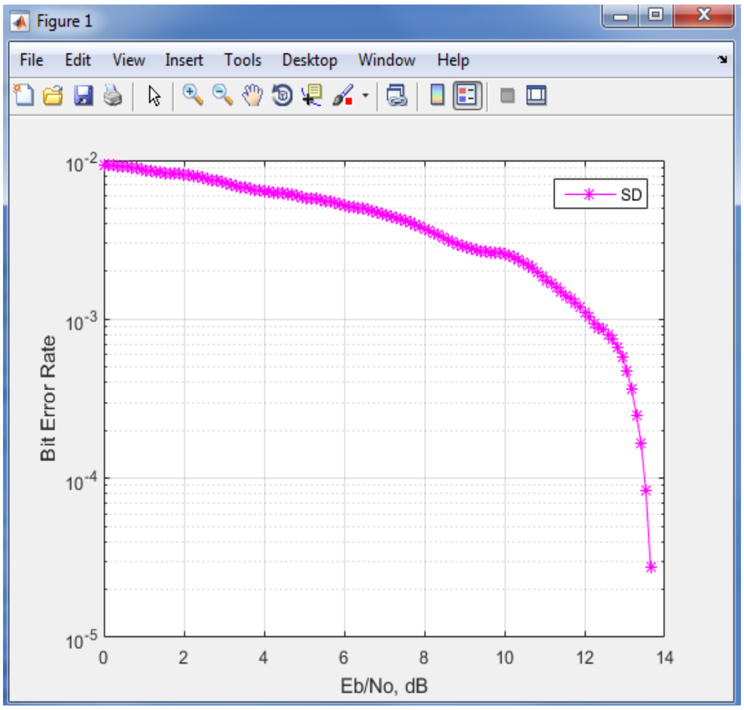



**Figure.5.11 Per- Soft-Bit Detection**

### 5.2.9 MIMO PER-SOFT-BIT DETECTION

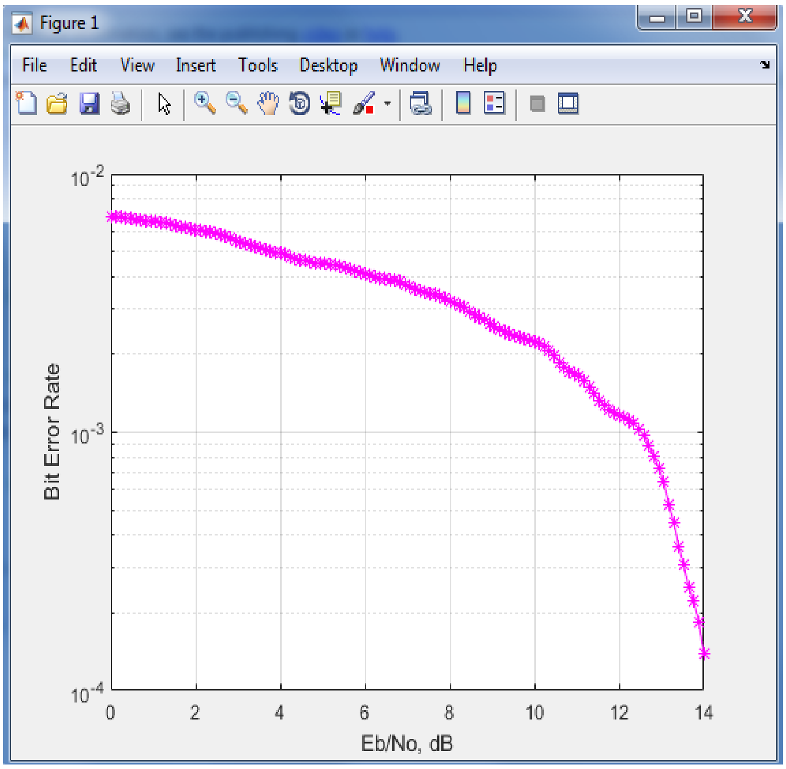



**Figure.5.12 MIMO Per-Soft-Bit Detection**

## 5.3 COMBINED OUTPUT-SYSTEM MODEL:

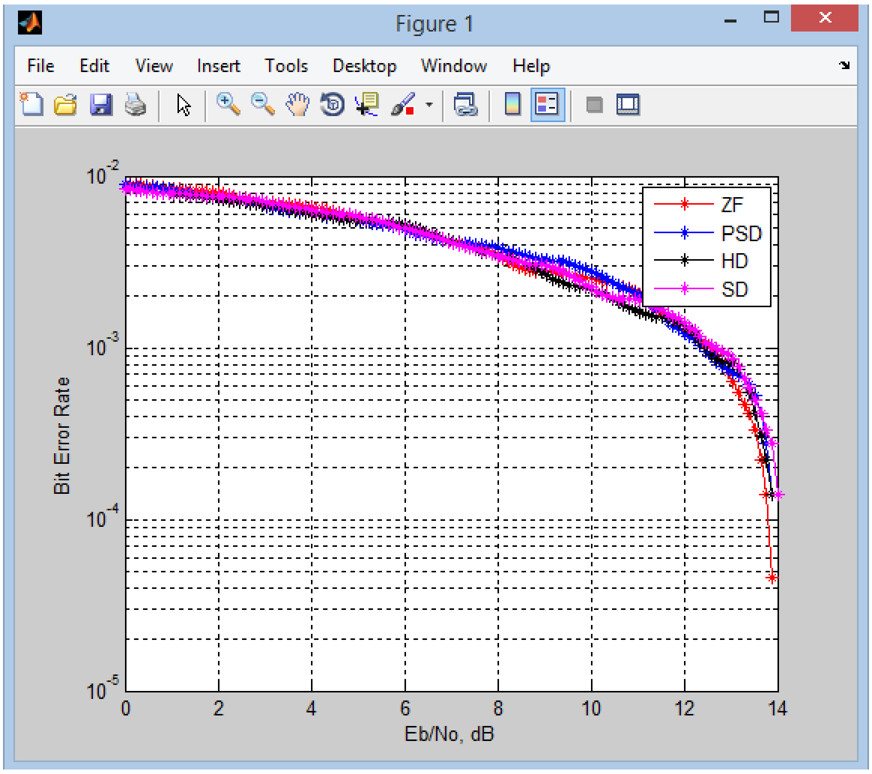



**Figure.5.13 Combined Output**

## 5.3.1 USING MIMO TECHNIQUE

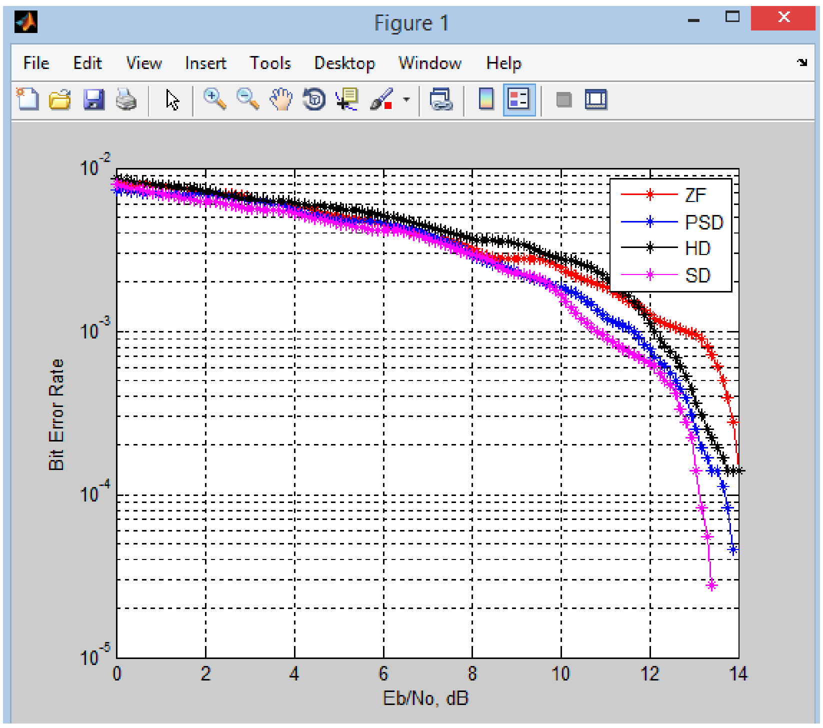



**Figure. 5.14 Combined Output using MIMO Technique**

**5.4 RESULT ANALYSIS:** Throughput efficiency calculation:

| DEMODULATION | 1ST DATA | 2ND DATA | 3RD DATA | 4TH DATA | 5TH DATA |
|---|---|---|---|---|---|
| ZERO FORCER | 0.85 | 0.66 | 0.45 | 1.2 | 1.3 |
| PERSYMBOL DETECTION | 0.99 | 0.63 | 0.5 | 1.1 | 1.25 |
| PER HARD BIT DETECTION | 0.83 | 0.56 | 0.35 | 1.02 | 1.32 |
| PER SOFT BIT DETECTION | 0.65 | 0.55 | 0.43 | 1.03 | 1.1 |

**Table.5.1 Data evaluation for system model**

## 5.4.1.USING MIMO TECHNIQUE:

| DEMODULATION | 1ST DATA | 2ND DATA | 3RD DATA | 4TH DATA | 5TH DATA |
|---|---|---|---|---|---|
| ZERO FORCER | 0.678 | 0.45 | 0.41 | 0.99 | 1.25 |
| PERSYMBOL DETECTION | 0.78 | 0.56 | 0.53 | 1.22 | 1.34 |
| PER HARD BIT DETECTION | 0.89 | 0.67 | 0.59 | 1.34 | 1.32 |
| PER SOFT BIT DETECTION | 0.54 | 0.45 | 0.34 | 0.88 | 1.22 |

**Table.5.2 Data evaluation for system model using MIMO technique.**

### 5.4.2 INFERENCE:

The four curves are labelled in the same order that they have been introduced (from the first to the fourth approach).As we stated the ML solution provides the lowest error rate, immediately followed by the fourth solution. As expected, in the absence of channel coding, the ML receiver becomes the optimal solution. Although we remark that ML uses a reduced search space of order $O(2^{b+1})$, the computational complexity is sensibly higher with respect to the other solutions. Next to the curve of ML is the pure soft scheme (the fourth).If we examine the magnified area, we observe the gap between the ML solution with the pure soft is tight. Hence, we conclude that the fourth demodulation scheme stays very close to the optimal solution. Finally, the third approach, which does not use the conditional mean of the signal, performs close to PMod SD, whereas the first approach PMod ZF obtains the highest BER.Hereinafter, we choose the fourth approach, PMod SD, to compare it with other schemes different to PMod.

# CHAPTER 6

# CONCLUSION AND FUTURE WORK

## 6.1 CONCLUSION:

This paper introduces a novel application to mobile communications of the entitled Polarized Modulation. The work describes that the spectral efficiency increases by a factor of 1 + b−1 in the absence of CSIT. The results demonstrated that the PMod consumes less energy to increase the SE and improves the efficiency. Two techniques are proposed depending on the computational complexity. The first one is being PMod technique modelled using matrix equation and in order to increase the throughput efficiency and the other is the MIMO technique is employed to improve efficiency. The Multiple-Input Multiple-Output (MIMO) systems have been emerged as a technical breakthrough for high-data-rate in wireless transmission. Thus, the use of MIMO techniques in mobile communications has achieved significant benefits in improving the system throughput. Thus in proposed system the system is being modelled and the demodulation is performed based on the four demodulation scheme using matrix equation and it is inferred that the soft demodulation produces the better result of throughput efficiency, in order to enhance the throughput efficiency furthermore, the system model is being extended with MIMO and it is seen that the soft detection produces the lower bit error rate and has increased throughput efficiency and it is best suited for dual polarization antenna.

## 6.2 FUTURE WORK

The four demodulation schemes are being employed and it is seen that soft decision is better when compared with other schemes, the future work can be carried out with the soft decision with the VBLAST and OSTBC technique to enhance the throughput efficiency and the result can be compared.

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