

**PERFORMANCE ANALYSIS OF A MULTI-USER
MULTIPLE INPUT MULTIPLE OUTPUT (MIMO) WIRELESS
LINK OVER A RAYLEIGH AND Rician FADING
ENVIRONMENT.**

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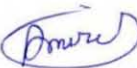
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DECLARATION

We hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.


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Supervisor

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ABSTRACT

The performances of a MIMO wireless link are analyzed considering Rayleigh and Rician fading. Maximal ratio combining technique has been considered in the receiver. The expressions for signal to noise ratio and bit error rate (BER) are derived for multiple Transmitter and Receiver antenna configurations. Performance result are evaluated by Matlab to find the improvement in system performance over SISO environment it is found that if we increase number of transmitting antenna ,we are able to get better performance over high variance for MIMO (multiple input multiple output) systems.

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CHAPTER: 01

INTRODUCTION

1.1 PROJECT OVERVIEW

MIMO (multiple input multiple output) is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver). The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO systems are theoretically able to provide increased throughput, and better error performance than traditional systems. In conventional wireless communications, a single antenna is used at the source, and another single antenna is used at the destination. This effect occurs when the radio signals sent from the transmitter bounce off intermediate objects such as hills, canyons, buildings, and utility wires before reaching the receiver. Some of these reflected signals may travel along entirely separate paths, and even reach the receiver at different times. The late arrival of scattered portions of the signal causes problems such as fading, cut-out and intermittent reception. In digital communications systems such as wireless Internet, it can cause a reduction in data speed and an increase in the number of errors. The use of two or more antennas, along with the transmission of multiple signals (one for each antenna) at the source and the destination, eliminates the trouble caused by multi path wave propagation, and can even take advantage of this effect. Modern wireless communication systems are typically used in urban settings, where the radio transmission environment is usually characterized by multi-path propagation. In the urban setting there may be many large buildings and structures between the transmitter and receiver. These are the obstacles that cause multi-path propagation. A simplified diagram of this multi-path propagation can be seen below.

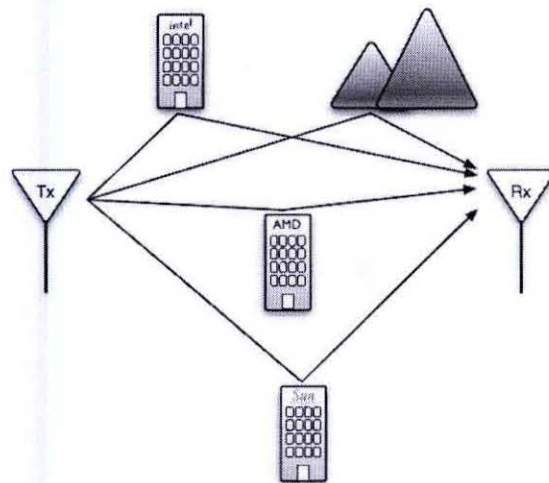


Figure 1: simplified diagram of the idea about multi path propagation

Generally MIMO systems are designed to exploit the multi-path propagation to obtain a performance improvement. MIMO systems aim to use the multiple communications channels that potentially exist between the multiple transmitter and receiver antennas, as demonstrated in the diagram below. ²

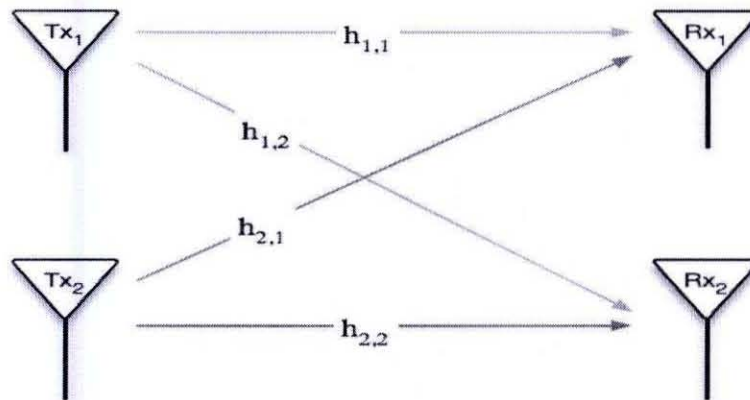


Figure 2: Multiple communications channels between the multiple transmitter and receiver antennas

From the diagram we can see that the signal received by a particular antenna at the receiver is actually a "mixture" of the signals transmitted from both the transmit antennas. The actual proportion of each transmitted signal that is received depends on the transmission channel in between the particular transmitter and receiver antennas. A simplified equation for the signal received at the top receive antenna is:

$$Rx_1 = (h_{1,1} \times Tx_1) + (h_{2,1} \times Tx_2)$$

Multi-user MIMO (MU-MIMO) is a set of advanced MIMO, multiple-input and multiple-output, technologies that exploit the availability of multiple independent radio terminals in order to enhance the communication capabilities of each individual terminal. To contrast, single-user MIMO only considers access to the multiple antennas that are physically connected to each individual terminal.

Multi-user MIMO can leverage multiple users as spatially distributed transmission resources, at the cost of somewhat more expensive signal processing. In

comparison, conventional, or single-user MIMO considers only local device multiple antenna dimensions. Multi-user MIMO algorithms are developed to enhance MIMO systems when the number of users, or connections, numbers greater than one.

1.2 Multi-user MIMO can be generalized into two categories

- MIMO Broadcast Channels (MIMO BC)
 - MIMO Multiple Access Channels (MIMO MAC)
- For downlink and uplink situations, respectively.

*Advantages:*¹

- Enhance the communication.
- Increased throughput
- Better error performance
- The costs and hassles of running cables through the home have been removed.
- Consumers have an easy, reliable and convenient way to connect and get reliable coverage.
- With MIMO performance wireless digital home can become reality.

*Disadvantage:*¹

- Somewhat expensive signal processing system.
- Transmitter dynamic range: For transmitter, under certain level of fading it must increase its power by that same level. In most cases which is not possible.
- Transmitter does not have any knowledge of the channel experienced by the receiver except in system where the uplink and downlink transmissions are carried over the same frequency.

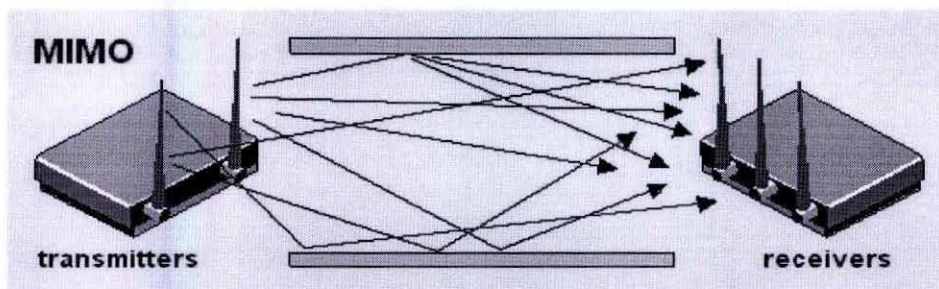


Figure 3: A general idea about multi path propagation

Challenges and Solutions

We faced several challenges throughout our thesis work that we had to overcome for implementation and success of the overall project. The significant problems and solutions that we have faced while doing our thesis work are discussed below.

1.3 Understanding SISO environment ¹¹

SISO is an acronym for single-input and single-output system. In control engineering usually refers to a simple control system with one input and one output. In radio it is the use of only one antenna both in the transmitter and receiver. SISO systems are typically less complex than Multiple-Input Multiple-Output (MIMO) systems.

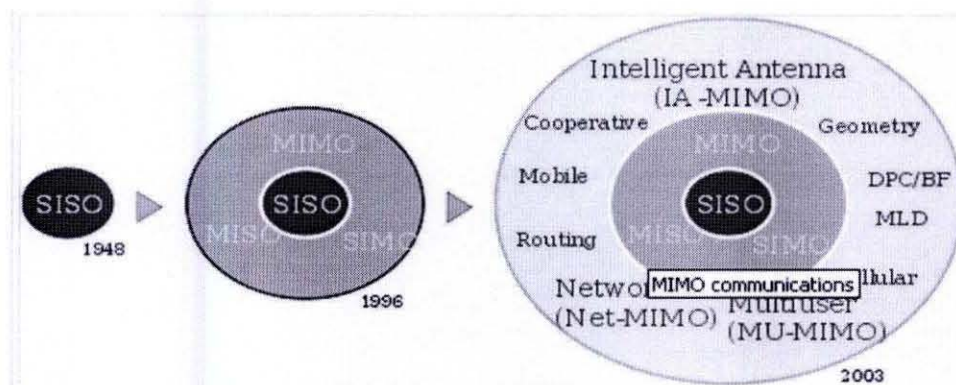


Figure 4: MIMO Revolution

1.4 Understanding Fading

In wireless communications, fading is deviation of the attenuation that a carrier-modulated telecommunication signal experiences over certain propagation media. The fading may vary with time, geographical position and/or radio frequency, and is often modeled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. The presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each signal copy will experience differences in attenuation, delay and

phase shift while traveling from the source to the receiver. This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. Strong destructive interference is frequently referred to as a deep fade and may result in temporary failure of communication due to a severe drop in the channel signal-to-noise ratio.

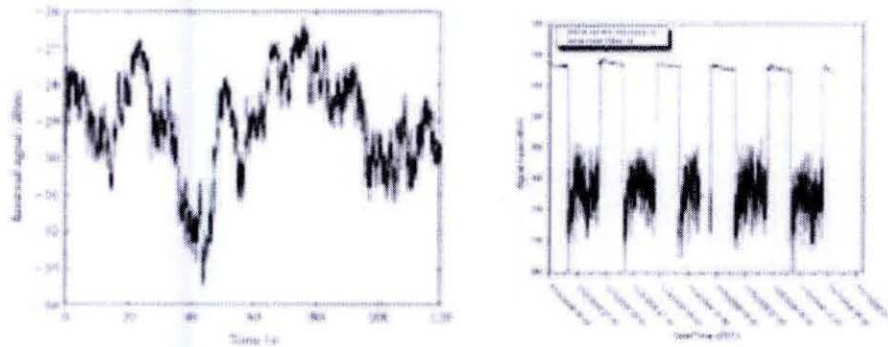


Figure 5: Basic idea about fading

1.5 The Concept of Diversity^{7,8}

In telecommunications, a diversity scheme refers to a method for improving the reliability of a message signal by utilizing two or more communication channels with different characteristics. Diversity plays an important role in combating fading and co-channel interference and avoiding error bursts. It is based on the fact that individual channels experience different levels of fading and interference. Multiple versions of the same signal may be transmitted and/or received and combined in the receiver. Alternatively, a redundant forward error correction code may be added and different parts of the message transmitted over different channels. Diversity techniques may exploit the multipath propagation, resulting in a diversity gain, often measured in decibels.

■ Diversity are of six types:

- ☐ Time diversity
- ☐ Frequency diversity
- ☐ Polarization diversity
- ☐ Space diversity
- ☐ Angle diversity
- ☐ Path diversity

The following classes of diversity schemes can be identified:

Time diversity: Multiple versions of the same signal are transmitted at different time instants. Alternatively, a redundant forward error correction code is added and the message is spread in time by means of bit-interleaving before it is transmitted. If the identical signals are transmitted in different time slots, the received signals will be uncorrelated, provided the time difference between time slot and channel coherence. This system will occur in the environment where fading occurs independent movement of receiver. The mobile unit may stand still at any location that has a weak local mean or is caught in fade. Although fading still occurs even when mobile is still, the time delayed signals are correlated and time diversity will not reduce the fade. In practice, time diversity is more frequently through bit interleaving, forward error correction, automatic retransmission request (ARQ).

- Frequency diversity: The signal is transferred using several frequency channels or spread over a wide spectrum that is affected by frequency-selective fading. Middle-late 20th century microwave radio relay lines often used several regular wideband radio channels, and one protection channel for automatic use by any faded channel. Later examples include:
 - OFDM modulation in combination with sub-carrier interleaving and forward error correction
 - Spread spectrum, for example frequency hopping or DS-SS.
- Polarization diversity: The horizontal and vertical polarization components transmitted two polarized antennas at the base stations and received by two polarized antennas at the mobile stations can provide two uncorrelated fading signals. Multiple versions of a signal are transmitted and received via antennas with different polarization. A diversity combining technique is applied on the receiver side.
- Space diversity: The signal is transferred over several different propagation paths. In the case of wired transmission, this can be achieved by transmitting

via multiple wires. In the case of wireless transmission, it can be achieved by antenna diversity using multiple transmitter antennas (transmit diversity) and/or multiple receiving antennas (reception diversity). In the latter case, a diversity combining technique is applied before further signal processing takes place. If the antennas are far apart, for example at different cellular base station sites or WLAN access points, this is called macro diversity. If the antennas are at a distance in the order of one wavelength, this is called micro diversity. A special case is phased antenna arrays, which also can be used for beamforming, MIMO channels and Space-time coding (STC).

- Angle diversity: When the operating frequency is $>10\text{GHz}$, the scattering of signals from transmitter to receiver generates received signal from different direction that are uncorrelated with each other, Thus two or more directional antennas can be pointed in different direction at the receiving site and provide signal to the combiner. The scheme is more effective in mobile station than at the base station since the scattering is from local buildings and vegetation and is more pronounced at street level than at the height of the base station antennas. Angle diversity can be viewed as a special case of space diversity since it also requires multiple antennas.
- Path diversity: In code division multiple access (CDMA) systems, the use of direct sequence spread spectrum modulation allows the desired signal to be transmitted over a frequency bandwidth much larger than the channel coherence bandwidth. the spread spectrum signal can be resolved in multipath signal component provided path delays are separated by at least one chip period. A Rake receiver can separate the received signal components from different propagation paths by using code correlation and can then combine them constructively. In CDMA exploiting the path diversity reduces the transmitted power needed and increases the system capacity by reducing interference.

1.6Phase-shift keying (PSK)

PSK is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite

number of phases, each assigned a unique pattern of binary bits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal — such a system is termed coherent (and referred to as CPSK).

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \quad \text{or} \quad P_b = \frac{1}{2} \operatorname{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Where Q is the Marcum function,

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-t^2/2} dt = \frac{1}{2} \operatorname{erfc}\left(\frac{x}{\sqrt{2}}\right), \quad x \geq 0. \quad 9$$

Where,

- E_b = Energy-per-bit
- E_s = Energy-per-symbol = kE_b with k bits per symbol
- T_b = Bit duration
- T_s = Symbol duration
- $N_0 / 2$ = Noise power spectral density (W/Hz)
- P_b = Probability of bit-error
- P_s = Probability of symbol-error⁹

1.7 Bit Error Rate (BER)

Standard transmission-error rate of a media such as copper wire, coaxial cable, or fiber-optic cable. Used as a measure of transmission quality, it is the ratio of error-bits received to the total bits sent. BER is expressed usually as a negative power of ten:

In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent.

1.8 Signal to Noise Ratio (SNR)

SNR is short for signal-to-noise ratio, the ratio of the amplitude of a desired analog or digital data signal to the amplitude of noise in a transmission channel at a specific point in time. SNR is typically expressed in logarithmic decibel (db).

SNR measures the quality of a transmission channel or an audio signal over a network channel. A SNR of zero indicates that the desired signal is virtually indistinguishable from the unwanted noise.

The ratio of the power or volume (amplitude) of a signal to the amount of disturbance (the noise) mixed in with it. Measured in decibels, signal-to-noise ratio (SNR or S/N) measures the clarity of the signal in a circuit or a wired or wireless transmission channel. The greater the ratio, evidenced by a larger number, the less noise and the more easily it can be filtered out. The lowest number is an SNR of 0, which means that noise and signal levels are the same. Although signals contain non-random intelligence and can be isolated and separated, with a 0 SNR, it would be extremely difficult to isolate the signal in real time. It would be more easily accomplished offline. The quantity that measures the relationship between the strength of an information-carrying signal in an electrical communications system and the random fluctuations in amplitude, phase, and frequency superimposed on that signal and collectively referred to as noise. For analog signals, the ratio, denoted S/N, is usually stated in terms of the relative amounts of electrical power contained in the signal and noise. For digital signals the ratio is defined as the amount of energy in the signal per bit of information carried by the signal, relative to the amount of noise power per hertz of signal bandwidth (the noise power spectral density), and is denoted E_b/N_0 . Since both signal and noise fluctuate randomly with time, S/N and E_b/N_0 are specified in terms of statistical or time averages of these quantities. The magnitude of the signal-to-noise

ratio in a communications systems is an important factor in how well a receiver can recover the information-carrying signal from its corrupted version and hence how reliably information can be communicated. Generally speaking, for a given value of S/N the performance depends on how the information quantities are encoded into the signal parameters and on the method of recovering them from the received signal. The more complex encoding methods such as phase-shift keying or quadrature amplitude-shift keying usually result in better performance than simpler schemes such as amplitude- or frequency-shift keying.

1.9 Considering Rayleigh and Rician fading⁴

Rayleigh fading is a statistical⁵ model Mathematical mode for the effect of a propagation. Wave environment on a radio signal, such as that used by wireless. Wireless devices Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium will vary randomly, or fade.

Rayleigh fading is viewed as a reasonable model for tropospheric scatter and ionospheric reflection. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable.

Rician fading is a stochastic⁶ model for radio propagation anomaly caused by partial cancellation of a radio signal by itself — the signal arrives at the receiver by two different paths, and at least one of the path is changing (lengthening or shortening). Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others.⁴

CHAPTER: 02

ANALYSIS

2.1 Rayleigh Distribution

In probability theory and statistics, the Rayleigh Distribution is a continuous probability distribution. It usually arises when a two –dimensional vector has its two orthogonal components normally and independently distributed the absolute value will then have a Rayleigh Distribution. The Rayleigh Distribution also may arise in the case of random complex numbers whose real and imaginary components are normally and independently distributed. The absolute value of these numbers will then be Rayleigh Distributed.

The probability function is:

$$f(x; \sigma) = \frac{x}{\sigma^2} \exp\left(\frac{-x^2}{2\sigma^2}\right)$$

Understanding the method of using MATLAB

Using MATLAB for simulation and analyzing was one of the hardest tasks that we had to overcome during our thesis work. As for the completion of thesis work demanded a huge amount of work to be done using MATLAB. We have encountered few new formulas and equations as our thesis work progressed.

2.2 Using Maximal ratio combining technique ^{8,10}

It is a method for implementing diversity reception to counteract effects of channel fading on a transmitted information signal. In diversity receive paths, estimates of complex channel gain are computed based upon pilot symbols inserted from time to time in the transmitted information symbol stream. Phase corrected and weighted samples from the diversity paths are summed prior to the decision process. The squared magnitudes of the diversity path channel gains are summed to provide the proper threshold adjustment.

In maximal ratio combining M signals are weighted proportionally to their signal to noise ratios and then summed,

$$r_M = \sum a_i r_i(t)$$

Where, a_i = weight of i_{th} branch

M = number of branches

Since noise in branch is weighted according to noise

$$\text{power } \overline{n_i^2(t)} = \sum_{j=1}^M \sum_{i=1}^M a_i a_j \overline{n_i(t) n_j(t)}$$

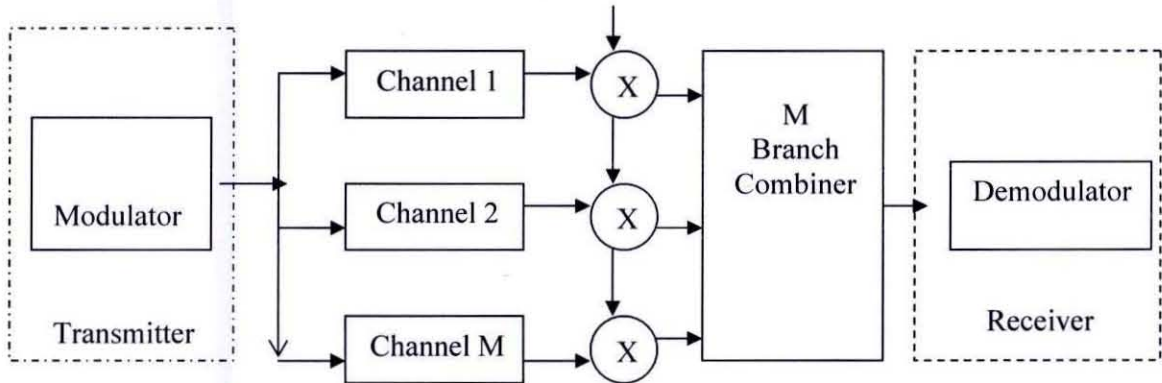


Figure 6: Block diagram of Maximal ratio Combiner

$$N_T = \sum_{i=1}^M a_i^2 \overline{n_i^2(t)} = \sum_{i=1}^M |a_i|^2 N_i$$

Where, N_T = average Noise power

$$\overline{n_i^2(t)} = 2N_i$$

The SNR at the output is given as:

$$\xi_M = \frac{1}{2} \frac{\left| \sum_{i=1}^M a_i r_i(t) \right|^2}{\sum_{i=1}^M |a_i|^2 N_i}$$

we want to maximize ξ_M . This can be done using the Schwartz inequality.

$$\sum_{i=1}^M a_i r_i^2 \leq \left[\sum_{i=1}^M |r_i|^2 \right] \left[\sum_{i=1}^M a_i^2 \right]$$

If $a_i = r_i(\sqrt{N_i})$, then using eqn5 to define Equation 6, we get,

$$E_{m_{\max}} = 1/2 \sum_{i=1}^M \frac{r_i^2}{N_i} = \sum_{i=1}^M E_i$$

Thus, the SNR at the combiner output equals the sum of the SNR of the branches.

$$\Xi_M = 1/2 \sum_{i=1}^M E_i = M \xi_0$$

Finding improvement in system performance of MIMO over SISO environment

This is one of the most difficult challenges. In our case, we had to analyze and find the expressions for signal to noise ratio (SNR) and bit error rate (BER) for multiple transmitter and receiver antenna configurations. And also we had to evaluate the performance of MIMO over SISO.

Analyzing the performance of a MIMO wireless link

To compare between:

- ☐ Selection combining technique
- ☐ Maximal ratio technique
- ☐ Analyze the performance using MATLAB.

CHAPTER: 03

RESULTS AND FINDINGS

3.1 The performance analysis of Bit Error Rate (BER) using MATLAB

The performance of SNR (signal to noise ratio) and BER (Bit error rate) for MIMO (multiple input multiple output) has been evaluated using MATLAB. The performance has been analyzed without considering diversity. We have used the following equation for BER

$$\text{BER} = Q \sqrt{\frac{n_t * 2 * \alpha^2 (E_b / N_0)}{n_t + (E_b / N_0) \sigma_1^2}}$$

σ_1^2 = Per unit variance for MAI

n_t = Number of transmitting Antennas

α = Attenuation factor

E_b/N_0 = CNR

3.2 With variable number of transmitting antennas

For $n_t=1$,

The Figure shows the plot of BER versus (E_b/N_0) . Here the number of transmitter antenna is considered to be 1 ($n_t=1$). Different values of variance σ^2 have been taken. We see that for different values the curve shows different characteristics. As the value of the variance is increased the bit error rate also increases respectively. The values of variance (σ^2) that are considered here are 0.01, 0.05, 0.07, 0.1, 0.12, 0.15, 0.2, 0.3, 0.4 and 0.5.

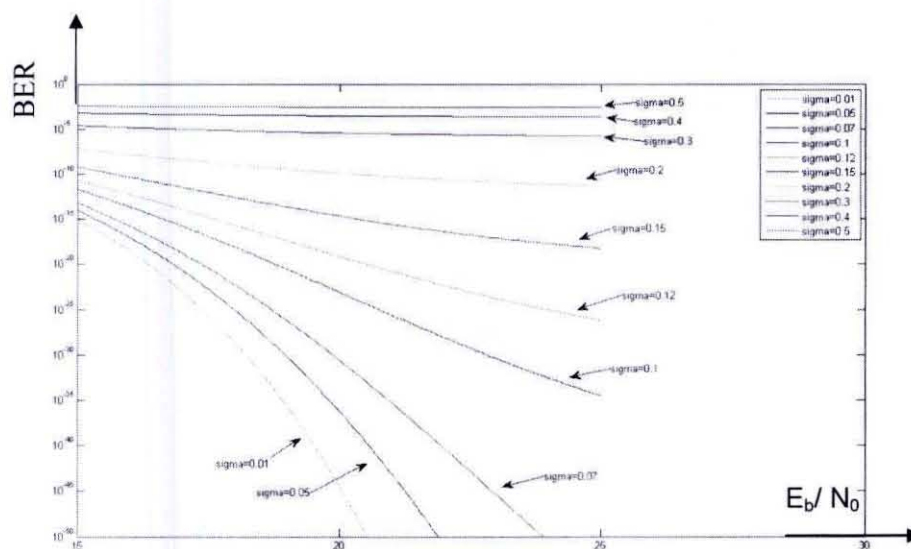


Figure7: BER over E_b/N_0 for $n_t=1$

For $n_t=2$,

The Figure is drawn considering the number of transmitter antennas to be 2 ($n_t=2$). Different values of variance have been taken. As the value of the variance is increased the bit error rate also increases respectively. It also shows that with compared to the graph for $n_t=1$, the curves are less steeper. The ability to capture variance (σ^2) is higher than $n_t=4$. The values of variance (σ^2) that are considered here are 0.01, 0.05, 0.07, 0.1, 0.12, 0.15, 0.2, 0.3, 0.4 and 0.5.

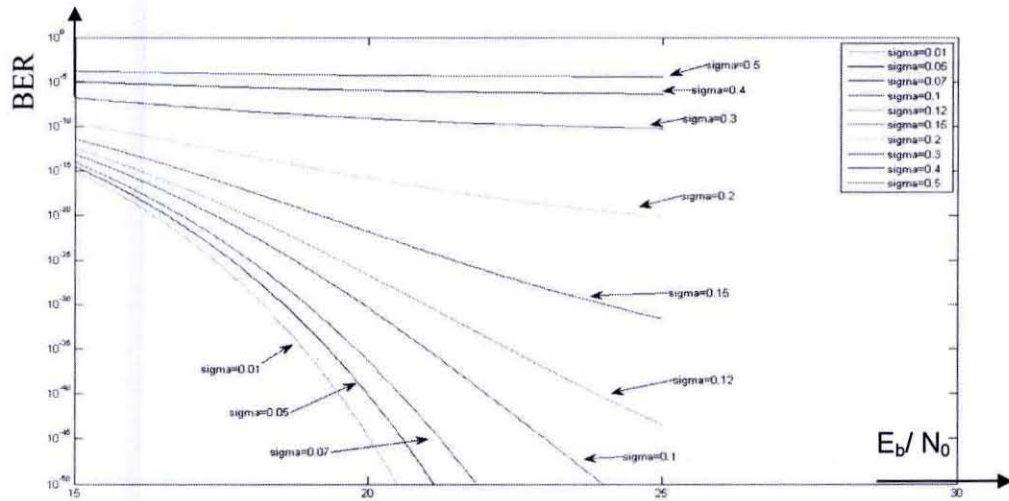
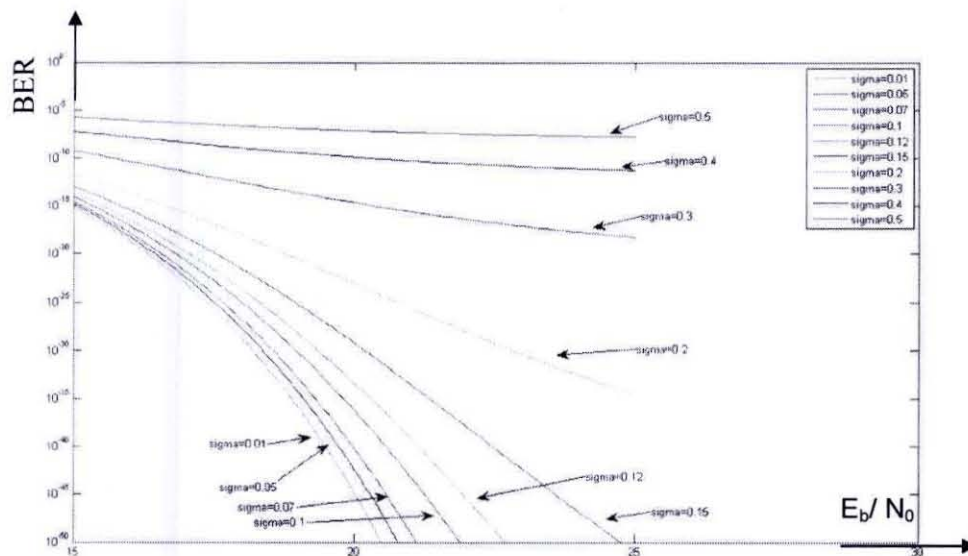


Figure 8: BER over E_b/N_0 for $n_t=2$

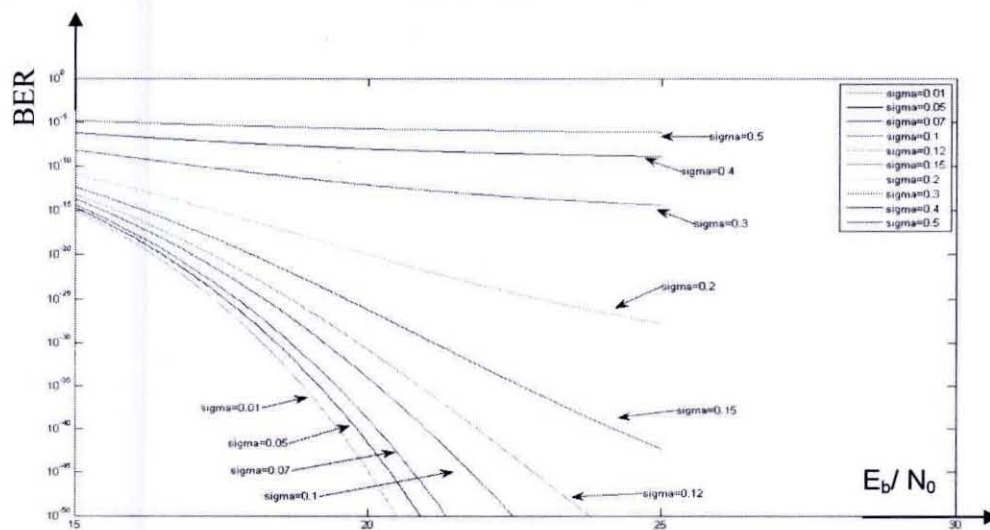
For $n_t=3$,

The Figure is drawn considering the number of transmitter antennas to be 3 ($n_t=3$). Different values of variance have been taken. As the value of the variance is increased the bit error rate also increases respectively. It also shows that with compared to the graph for $n_t=2$, the curves are less steeper. The ability to capture variance (σ^2) is higher than $n_t=4$. The values of variance (σ^2) that are considered here are 0.01, 0.05, 0.07, 0.1, 0.12, 0.15, 0.2, 0.3, 0.4 and 0.5.

Figure 9: BER over E_b/N_0 for $n_t=3$

For $n_t=4$,

The Figure shows the plot of BER versus (E_b/N_0) , here the number of transmitter antenna is considered to be 4 ($n_t=4$). Different values of variance have been taken. We see that for different values the curve shows different characteristics. As the value of the variance is increased the bit error rate also increases and with compared to the graph for $n_t=3$, the curves are less steeper. The ability to capture variance (σ^2) is higher than $n_t=3$. The values of variance (σ^2) are kept same here.

Figure 10: BER over E_b/N_0 for $n_t=4$

For $n_t=5$,

The Figure shows the plot of BER versus (E_b/N_0), here the number of transmitter antenna is considered to be 5 ($n_t=5$). Different values of variance have been taken. We see that for different values the curve shows different characteristics. As the value of the variance is increased the bit error rate also increases and with compared to the graph for $n_t=4$ the curves are less steeper. The ability to capture variance (σ^2) is higher than $n_t=4$. The values of variance (σ^2) are kept same here.

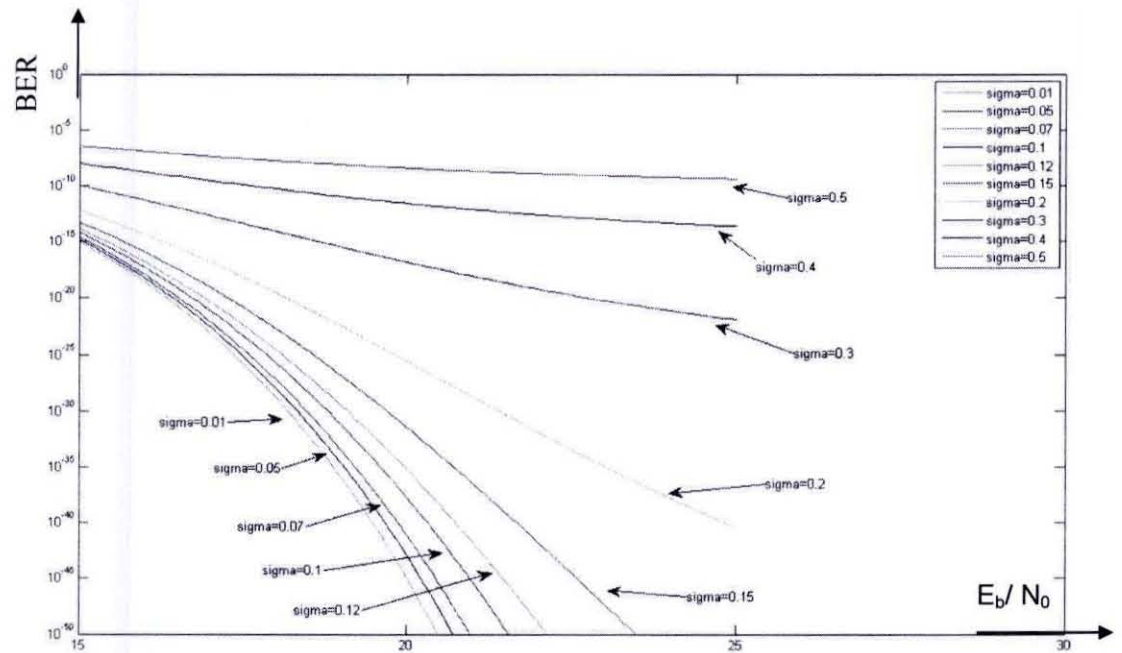


Figure 11: BER over E_b/N_0 for $n_t=5$

3.3 With different values of variance

The following Figures show the plots of BER Vs E_b/N_0 . In these graphs we have considered different values of variance and tried to show the difference shown by the curves in their characteristics. For different value of transmitting antennas (n_t) we get different characteristics for the curves. From the curve we can see that when we consider higher number of antennas we get better gain, eventually resulting in better performance in BER (bit error rate). The values of variance that we have considered here are 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45 and 0.5.

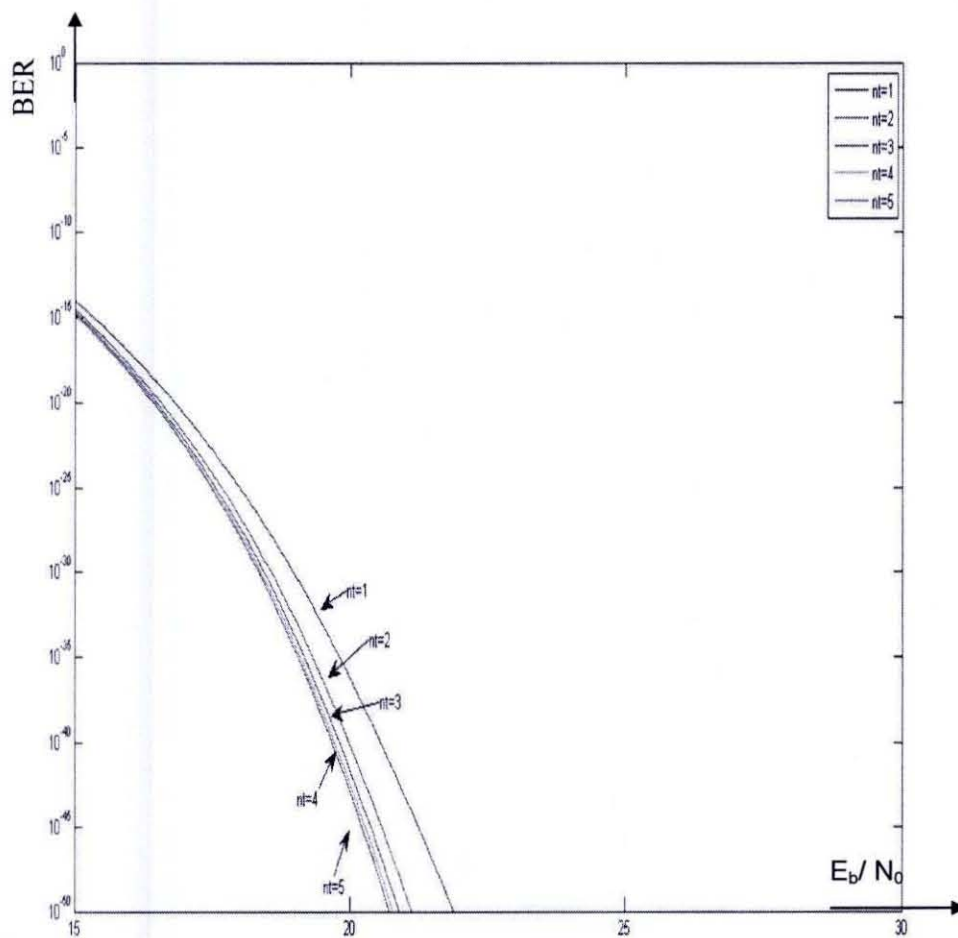


Figure 12: BER over E_b/N_0 for variance $(\sigma^2) = 0.05$

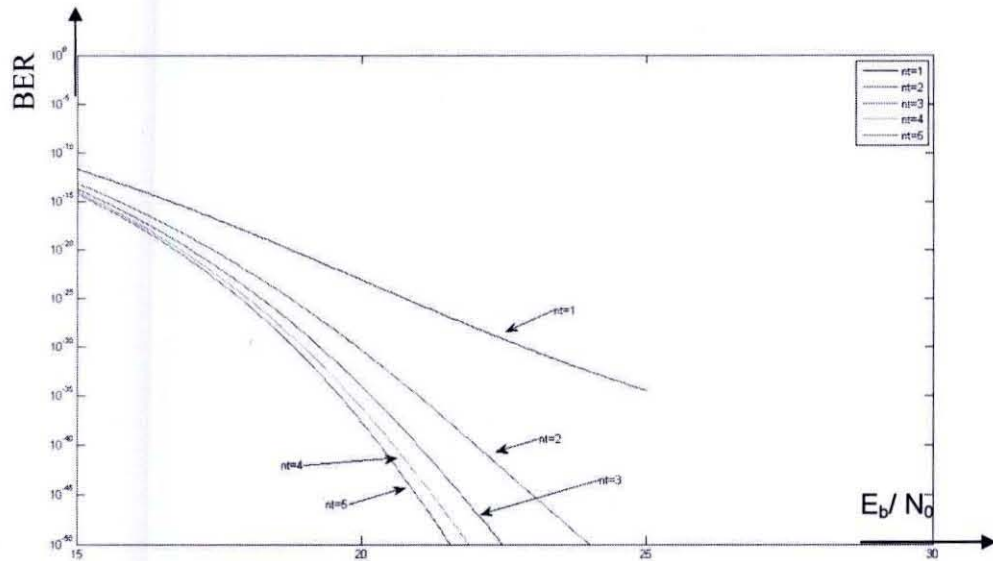


Figure 13: BER over E_b/N_0 for variance $(\sigma^2) = 0.1$

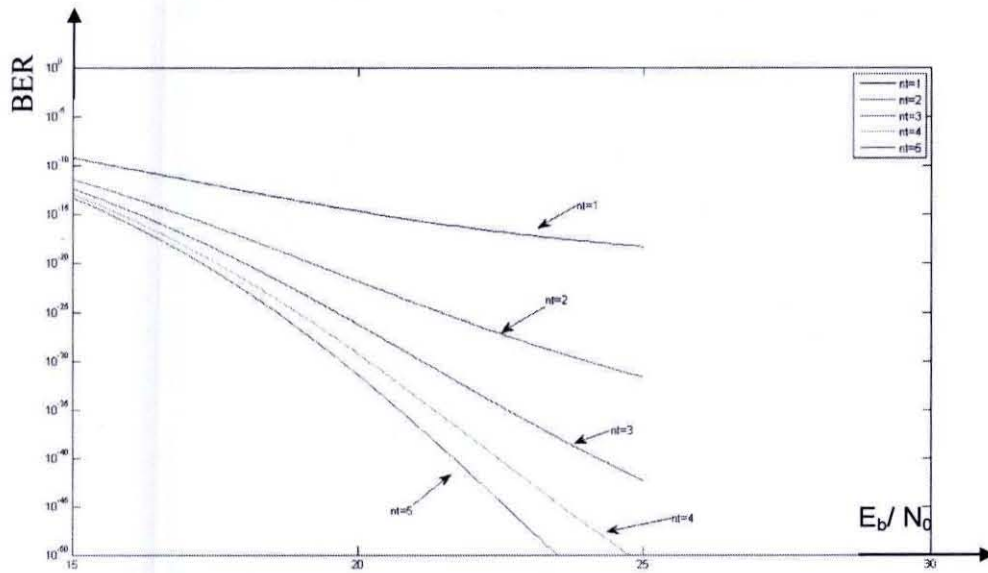


Figure 14: BER over E_b/N_0 for variance $(\sigma^2) = 0.15$

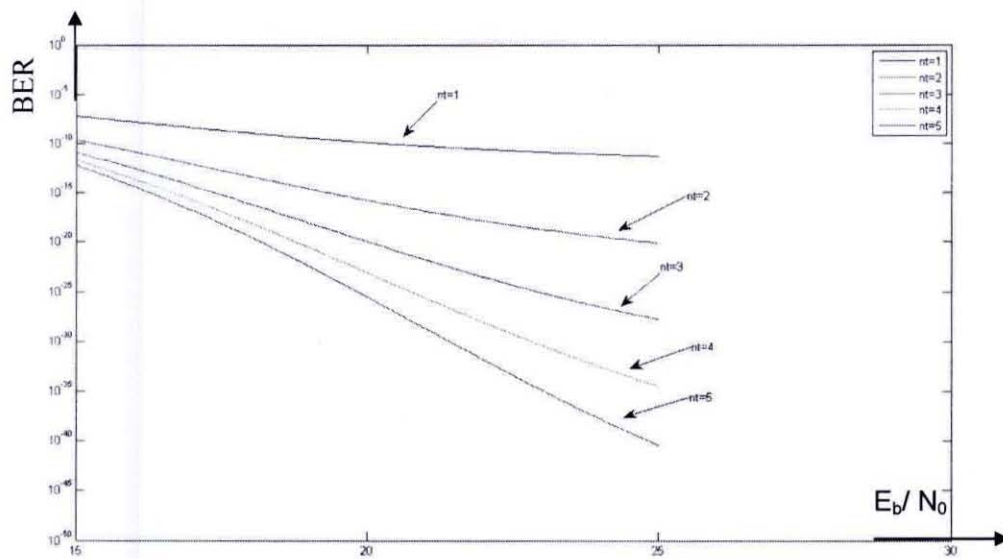


Figure 15: BER over E_b/N_0 for variance (σ^2) = 0.2

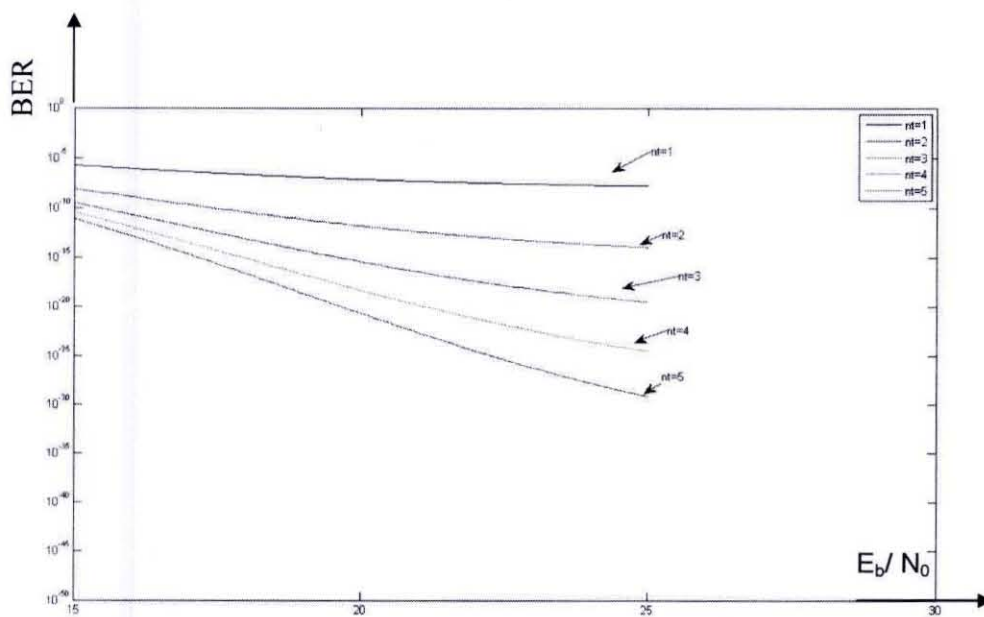


Figure 16: BER over E_b/N_0 for variance(σ^2)=0.25

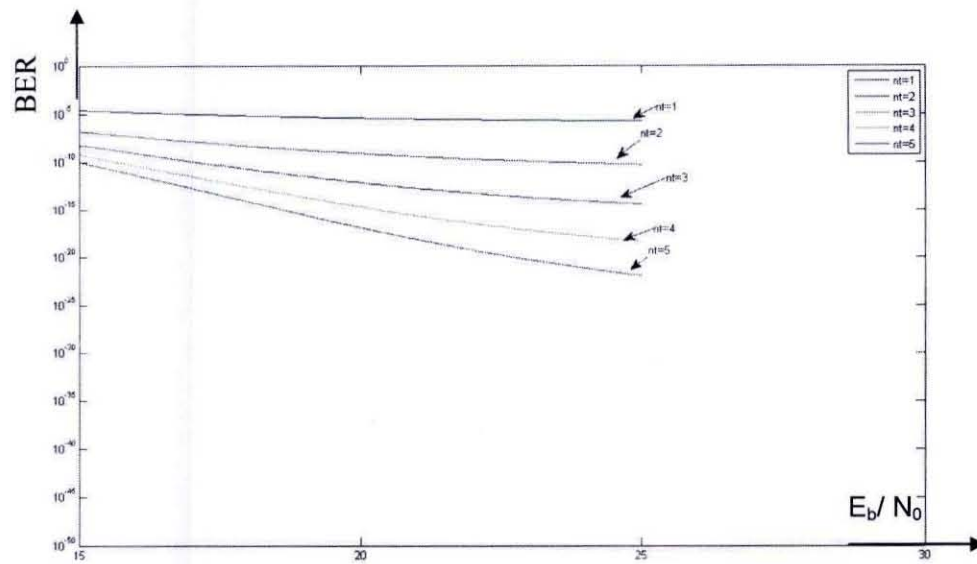


Figure 17: BER over E_b/N_0 for variance $(\sigma^2)=0.3$

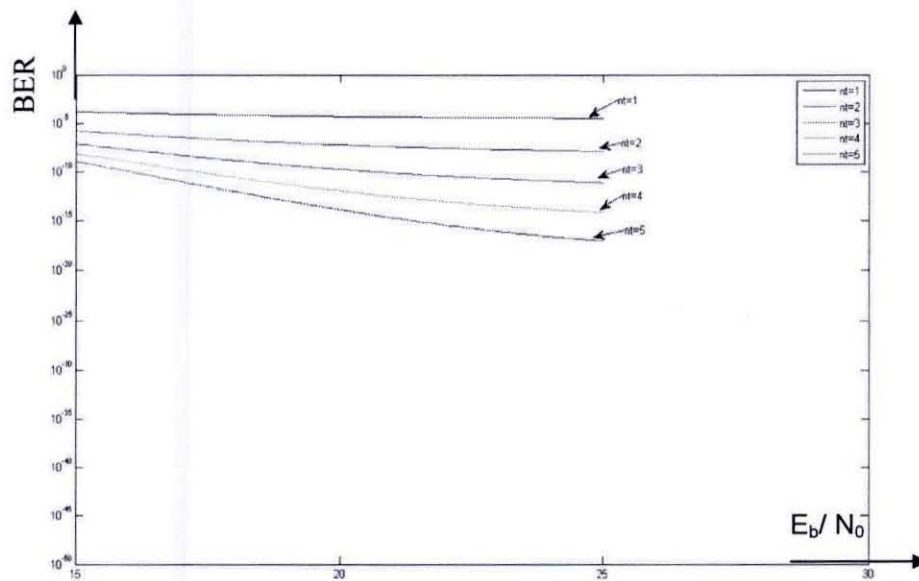


Figure 18: BER over E_b/N_0 for variance $(\sigma^2)=0.35$

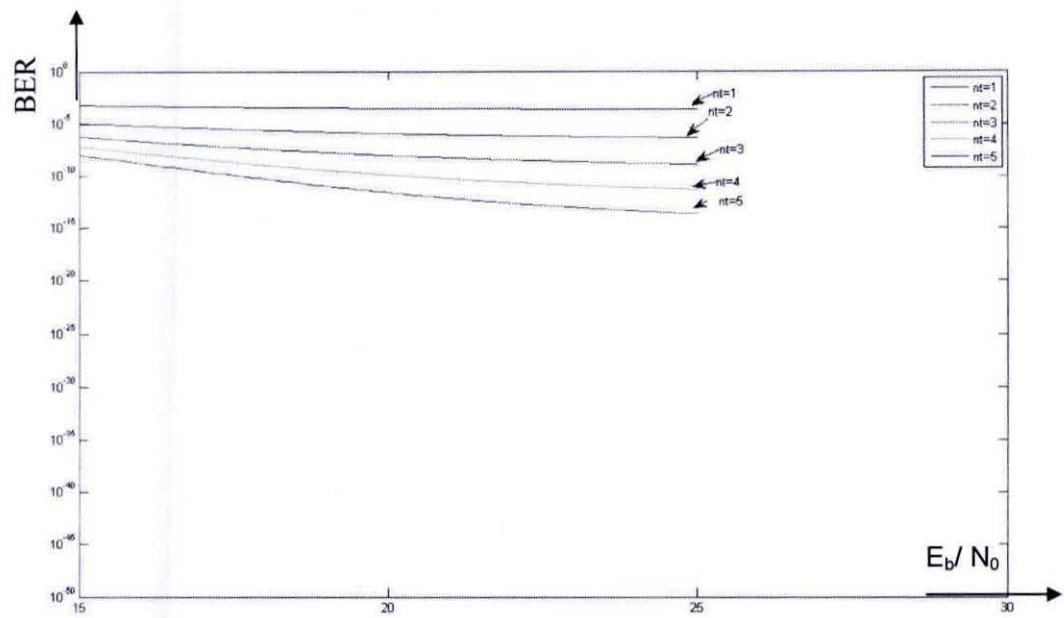


Figure 19: BER over E_b/N_0 for variance (σ^2)= 0.4

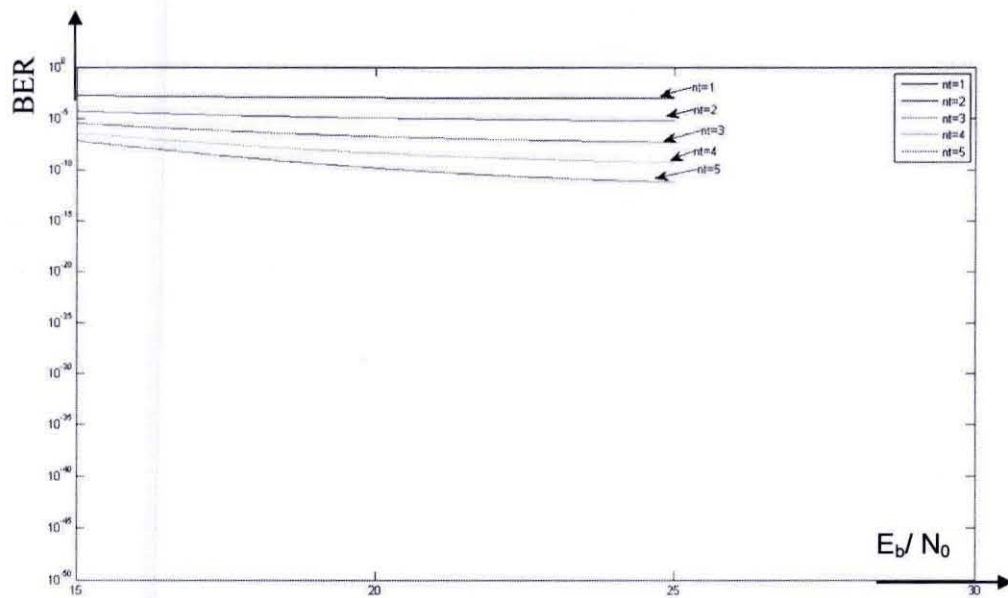


Figure 20: BER over E_b/N_0 for variance (σ^2)= 0.45

Figure 20: BER over E_b/N_0 for variance $(\sigma^2)=0.45$

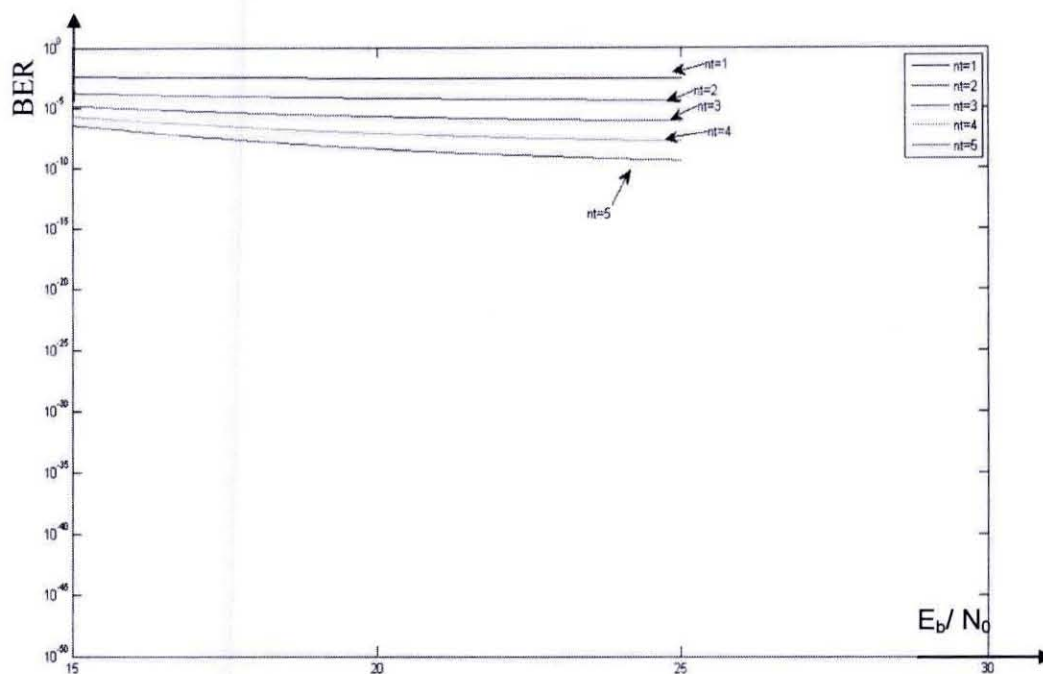


Figure 21: BER over E_b/N_0 for variance $(\sigma^2)=0.5$

3.4 Finding Power Penalty with variable variance(σ^2)

In the following Figure value of variance that are considered are 0.01, 0.05, 0.07, 0.1, 0.12, 0.15, 0.2, 0.3, 0.4 and 0.5 and thus the graph is plotted for PP (power penalty) versus variance. The curves vary according to the different values of number of transmitting antennas (n_t). The different values that have been taken here for transmitting antennas are 1, 2, 3, 4 and 5. The curves show that for $n_t = 1$, as the variance gets higher the curve gets steeper. For $n_t = 2$, it gets less steeper. Following the trend for higher values of n_t the curves get less and less steeper. From here we can deduce that as we are considering higher number of transmitting antennas, the ability of the system increases to absorb more noise. Therefore the power penalty is less for higher amount of antennas.

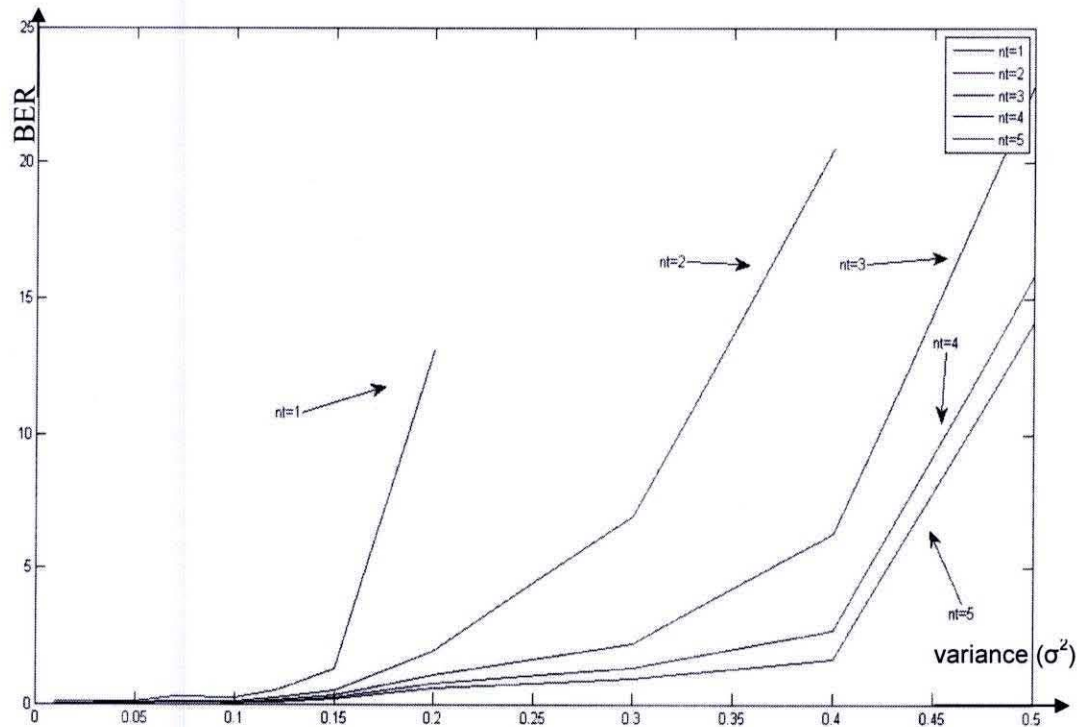


Figure 22: power penalty (ppdb) over variance (σ^2)

CHAPTER: 04

CONCLUSION

4 Conclusion

Following the analysis in chapter 2, where we have evaluated the performance of bit error rate (BER) without considering fading, When we were working with fixed variance σ^2 (sigma) and number of transmitting antenna $n_t = 1, 2, 3, 4, 5$, it was found that as we were raising variance for number of antennas, keeping the number of transmitter's value (n_t) =1, the output SNR (E_b/n_0) was low and which is not satisfactory. As we know, higher SNR is always desirable and means better performance as a whole.

After that it was found that with increasing number of antennas, we got better performance. The numbers of antenna were varied and the value of the variance was also varied. It was found that when we used lower number of Antennas, for higher value of variance, we got high BER (bit error rate) value. This is really undesirable because higher BER means less efficiency for the system. But it was seen that increasing the number of transmitting antennas were able to solve this problem. The power penalty was calculated for different value of variance and from the calculation it was found that when number of transmitting antenna has a negative relationship with BER (bit error rate) .It means the more the number of antenna can be increased the value of BER will be lesser. Even considering higher value of variance, better results were achievable.

Finally, with our thesis work and analyzing simulation graph we can deduce that, if we increase number of antenna and we are able to get better performance over high variance for MIMO (multiple input multiple output)

We finished working on MIMO wireless link considering Rayleigh fading. We started working on MIMO considering Rayleigh distribution but due to time constraint and other unavoidable circumstances, we were unable to finish the work in the given span. However, it must be noted that given more time and resources the project can see completion.

LIST OF REFERENCES

- | | |
|---|----|
| http://www.etopiamedia.net/mimow/pdfs/drc1.pdf | 1 |
| http://videos.dac.com/42nd/papers/26_2.pdf | 2 |
| Leandro Juan-Llacer, <i>Senior Member, IEEE</i> | 3 |
| http://en.wikipedia.org/wiki/Rayleigh_fading | 4 |
| http://www.absoluteastronomy.com/topics/Statistics | 5 |
| http://en.wikipedia.org/wiki/Stochastic | 6 |
| http://en.wikipedia.org/wiki/Diversity_sch | 7 |
| Wireless Communications by Vijay k. Garg | 8 |
| http://en.wikipedia.org/wiki/Phase-shift_keying | 9 |
| http://www.freepatentsonline.com/5140615.html | 10 |
| http://en.wikipedia.org/wiki/Siso | 11 |
| T. Haustein, E. Jorswieck, V. Jungnickel, U. Krueger, V. Pohl, C. von Helmolt
Heinrich-Hertz-Institut fur Nachrichtentechnik Berlin GmbH
10587 Berlin, Einsteinufer 37, GERMANY | 12 |
-
- MIMO Channel Sounder Based on Two Network Analyzers
- Jose-Maria Molina-Garcia-Pardo, *Member, IEEE*, José-Víctor Rodríguez, and
- <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=00957091>
- <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=730453> A Simple Transmit
- Diversity Technique for Wireless Communications
- http://en.wikipedia.org/wiki/File:MIMO_communications.svg
- <http://www.wiziq.com/tutorial/13013-MIMO>
- <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=00957091>
- <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=00957091>