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Ethiopian Institute of Technology-Mekelle

School of Electrical and Computer Enginnering

Semester Project title on:

Performance analysis of wireless channel over different fading effects

A Project Submitted to School of Electrical and Computer Engineering, stream of Electronics and Communication Engineering

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Abstract

With any communication system the received signal varies from the transmitted signal because of several transmission impairments. Fading is a major impairment when transmitting a signal in wireless communication channel. It is caused by multipath propagation. That is signals from different paths can constructively or destructively interfere with each other. Thus, it becomes very necessary to reduce this effect, to transmit the signal effectively to the receiver. Various channel models are available to transmit data from one place to another. Rayleigh, rician and additive white Gaussian noise) fading channels are commonly used models of real world phenomena in wireless communication. The received signal follows a Rayleigh distribution when there is no line of site between the transmitter and the receiver and it follows a rician distribution if one such path is present. The performance of these channels is measured by calculating the bit error rate versus signal to noise ratio.

This paper deals on analyzing the performance of those channels concluded from bit error rate versus signal to noise ratio plot using a modulation technique which is a binary phase shift keying. The performances were analyzed and compared using matrix laboratory (MATLAB) Software. This paper examines fading and it various types. Different techniques being employed to reduce the effect of fading using Diversity specifically on the maximal combining ratio.

This paper concludes that nakagami fading channel has a better performance. Because nakagami fading channel uses maximal combining ratio to reduce the bit error rate under the binary phase shift keying modulation technique

Acknowledgment

First and foremost, we would like to sincerely thank our remarkable and startling advisor, instructor Ephrem. And also we would like to say thank you for his effort in guidance and motivation to do this project. We also thanks to Mekelle University for its excellent resources and working environment like digital library and wireless communication or Wi-Fi.

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List of abbreviations

AWGN .... aditive white gaussian noise
BER..Bit error rate
BPSK...binary phase shift keying
BW .... band width
CLT ....central limit
dB ....decible
Eb ....energy of bit
EM...electro magnetic
erfc .... error function
FEC ....forward error correction
Hz .... hertz
ICI ....inter channel interference
ISI.. inter symbol interference
LOS .... line of sight
MATLAB.. matrix labratory
Mhz ....mega hertz
MIMO .... multiple input multiple out put
MPSK... M- array phase shift keying
MRC... Maximal ratio combining
No..energy of noise
OFDM ....See orthogonal frequency division multiplexing
pdf ....probability of density function
QPSK ....quadrature phase shift keying, quadrature phase shift keying
rms...root mean square
SNR...signal to noise ratio

Chapter One: Introduction

1.1 back ground information

Communicating data from one location to another requires some form of path way or, medium. These pathways are called communication channels. Use two types of media. These are Cable (twisted pair wire, cable, and fiber optic cable) and broadcast (microwave, satellite, radio and infrared). Cable or wire line media uses physical wires of cables to transmit data and information. Twisted pair wire and coaxial cables are made of copper, and fiber optic cable is made of goals [1].

A communication channel is a type of media that is used to transfer a message from one point to another. A channel is used to convey an information signal. For example a digital bit stream, from one or several senders or transmitters to one or several receivers. A channel has certain capacity for transmitting information, often measured by its bandwidth in hearth (Hz) or its data rate in bits per second.

Fading is the time variation of received signal power due to changes in transmission medium or paths. Fading depends on various factors. In fixed scenario fading depends fading depends on atmospheric conditions such as rainfall; lightening etc. in mobile scenario, fading depends on obstacles over the path which are varying with respect to time. These obstacles create complex transmission effects to the transmission signal.

Modeling the terrestrial wireless propagation is of importance for the design and performance analysis of wireless communication systems. unlike wired propagation scenarios which are stationary and predictable [2], in a typical mobile radio propagation scenario the received signal presents both small scale power fluctuation also known as multi path fading and large scale power fluctuation also known as shadowing. In the former the transmitted signal experiences reflection, diffraction, scattering and delays , where by the multipath phenomena is caused by a relatively fast constructive and destructive random combinations of the received signal copies. Large scale signal power fluctuations, on the other hand, are caused by the presence of large obstacles between the transmitter and receiver. The small scale fading results in very rapid fluctuations around the main signal level, while large-scale gives rise to relatively slow variations of the mean signal level[3].

1.2 Literature Review

Different studies has been done on performance of different fading channel models such as **Theodore S. Rapparot** [1];deals with over all the wireless communication operations and fading channel models .this focuses more on mitigation techniques to reduce the effect of fading effects using diversity, equalization and channel coding.

Juan M. Romero-Jerez et al [2]; studies on analyzing the performance of a wireless link under Hoyt (Nakagami) fading in a very simple way and introduced the Hoyt transform approach as a way to obtain easy-to-compute finite range integral expressions of different performance metrics in Hoyt fading channels, as well as simple upper and Lower bounds which become asymptotically tight as $q \rightarrow 1$, by simply leveraging existing results for Rayleigh fading channels. As a direct application, have derived new expressions for several scenarios of interest in information and communication theory: (a) capacity analysis of adaptive transmission policies in Hoyt fading (nakagami) channels, (b) wireless information-theoretic security in Hoyt fading, and (c) outage probability analysis of Hoyt fading channels with arbitrarily distributed interference and background noise.

Elizzna Pajala.et,al [3], Studies on a simple simulation model for Nakagami-*m* fading channels. First show, via measurement data, that the Nakagami-*m* distribution provides the best fit for the fading amplitudes of the satellite-to-indoor and satellite-to outdoor channels.

Sanjiv Kumar.et,al [4], deals with the effect of additive white Gaussian noise and fading models specially on racian and Rayleigh. Compares the effect of additive white Gaussian noise with racian and Rayleigh channel using mat lab simulation.

1.3 Problem Statement and Justification

When transmitting signal in wireless channel the signal may not receive effectively to the destination due to the fading effect which is caused by multipath propagation. That is signals from different paths can constructively or destructively interfere with each other. Thus, it must be reduced this effect to transmit the signal effectively to the receiver. To minimize the effect of fading, using diversity technique is possible solution.

1.4 Motivation

In recent years, radio-engineering requirements have become more stringent and necessitate not Only more detailed information on signal level, but also much more exact knowledge on fading Statistics in both ionospheres and tropospheric modes of propagation. statistics in both ionosphere Such circumstances demanded a large number of experiments and number of theoretical investigations to be performed. Field tests in a mobile environment are considerably more expensive and may require Permission of regulatory authorities. It is difficult to generate repeatable field test results due to Random, uncontrollable nature of the mobile communication path. Atmospheric conditions and Cost also plays a key role in field test measurements. These limitations can be overcome by means of simulation.

Modeling the wireless channel has historically been one of the most difficult parts of the Communication system design and is typically done in a statistical manner, based on Measurements made specifically for a designated communication system or spectrum allocation.

Generally, the fading, which is caused due to multi-path propagation and moving terminal In a communication channel, challenges the wireless communication engineer who tries to establish a reliable communication path between transmitter and receiver.

Indeed, a first step Towards reducing the challenges is to understand the nature and characteristics of these effects Through producing models of and simulating this phenomenon So the motivation behind this work is to model the wireless channel when the mobile terminal is Moving in a time varying speed and simulating the parameters (BER, fading rate, fading duration And the fading probability) of the channel so that the performance at the receiver is easily Determined and reduce the challenges. Sum of sinusoid model and the impulse response model are simple models based on the constant speed of the mobile terminal. But real world Communication terminals may be either at rest, moving in a constant speed, moving in a time varying speed both in magnitude as well as direction, i.e in accelerating motion. This work primarily seeks to model and simulate the wireless channel considering the parameters like: Motion information of the transmitter and receiver (magnitude of the speed as well as Direction and channel fluctuation) Type of scenario (communication environment type indoor, suburban and urban) Signal and channel parameters (channel bandwidth, bit rate and rms delay spread).

1.5 Objectives

1.5.1General Objective

- The main objective is to analysis performance of wireless channel under different fading effect.

1.5.2 Specific Objectives

The specific objectives considered to address the main objective of the work include:

- To compare different digital modulation techniques such as PSK, DPSK and FSK.
- To evaluate the performance characteristics of wireless channel over fading effects such as Rayleigh, racian, weibul, and nakagami. .
- To mitigate the effect of fading using MRC diversity technique.

1.6 Methodology

Reviewing literatures and other resources, which is the basis for this project work, is a preliminary step in order to achieve the desired objectives. Taking the ideas obtained in the literature survey, modeling a system which involves performance analysis of wireless channel under different fading effects by incorporating diversity and equalization techniques. After that it follows the analysis of the system, simulation of the overall system is performed using MATLAB software as a simulation tool. Subsequently, the performance wireless channel was analyzed, results are interpreted and conclusions are drawn based on the results.

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1.7 project organization

This project contains five chapters. Those are:

Chapter-1 deals on the introductory concepts such as communication system, literature review, objectives and the methods how to achieve the objectives.

Chapter 2: introduces basics of wireless fading channel, types of fading channels and their model, basic fading parameters and mitigation techniques in detail with MRC.

Chapter 3: the different mathematical models of the general wireless communication system, the different types of fading channels and MRC model,

Chapter 4: discusses about results and simulations. In this chapter comparison of the general Model in terms of SNR and BER simulate and the results are discussed.

Chapter 5: Presents conclusion and recommendations for future work

Chapter Two: Fading Effects and Mitigation Techniques in Wireless Channel

2.1 Introduction

Communication means to share or exchange information, views, thoughts via different medium. It is the process of sending information from source to destination. Communication system is a system that describes communication with many hardware and software tools. Typical examples of the communication system are: Radio telegraphy, Line telegraphy, Mobile communication, Radio and TV broadcasting and so on. Now a day's communication is done through website, email, and chat and so on. Every communication system exhibits the several basic elements namely:

1. **Information source:** Information source is the first step in the communication system. Any communication system serves to communicate message or information. This message originates in the information source.
2. **Transmitter:** The transmitter's function is to convert the message signal into a form which is suitable for transmission over the communication channel or medium. This technique is called modulation.
3. **Channel:** Channel implies the medium through which the message travels from the transmitter to the receiver. It can be either guided or no-guided.
4. **Receiver:** The receiver's function is to receive the signal and convert the message signal into original form. This technique is called demodulation.
5. **Destination:** Destination is the final step in the communication system. Message or information consume in the destination.

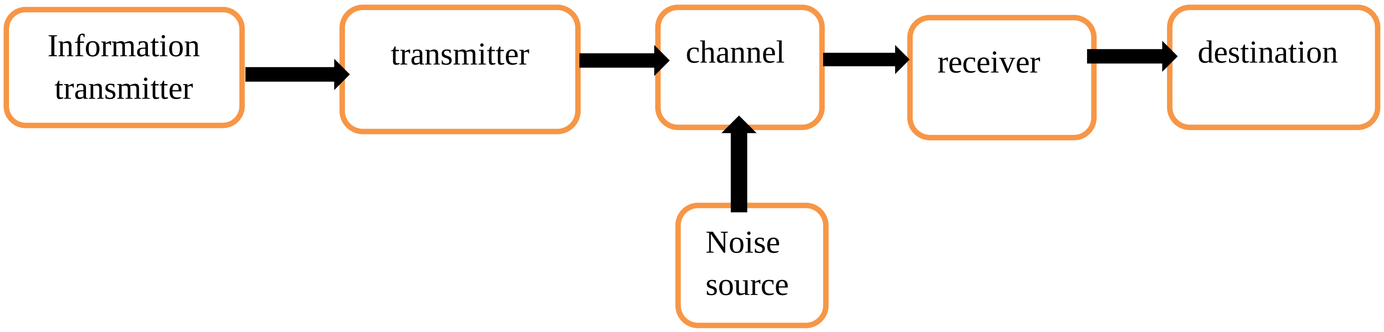


Figure2.1: Block diagram of communication system

Communication system is a system model describes a communication exchange between two stations, transmitter and receiver. Signals or information passes from source to destination through what is called channel, which represents away that signal use it to move from source to ward destination.to transmit signals in communication system, it must be first processed by several stages, beginning from signal representation, to signal shaping until encoding and modulation. After preparing the transmitted signal, it passed to the transmission line of channel and due to signal crossing this media it faces many impairments such noise, attenuation and distortion. Based on the medium they used communication system broadly classified in to two. These are wired communication system and wireless communication system.

Wireless communication is one of the most active areas of technological development. This development is being driven primarily by the transformation of what been a medium for supporting voice telephony into a medium for supporting other services such as transmission of video, images, text, and data e.t. c. basically communication system deals witch information or data transmission from one point to another.

Wired communication is referring to transmission of data over a wire based Examples include telephone networks, cable television or internet access, and fiber-optic communication. Also waveguide (electromagnetism), used for high-power applications, is considered as wired line. Local telephone networks often form the basis for wired communications that are used by both residential and business customers in the area. Most of the networks today rely on the use of fiber-optic communication technology as a means of providing clear signaling for both inbound and outbound transmissions.

A communication channel or simply channel refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel in telecommunications and computer networking. A channel is used to convey an information signal, for example a digital bit stream, from one or several senders or transmitters to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second.

Communicating data from one location to another requires some form of pathway or medium. These pathways, called communication channels, use two types of media: cable (twisted-pair wire, cable, and fiber-optic cable) and broadcast (microwave, satellite, radio, and infrared). Cable or wire line media use physical wires of cables to transmit data and information. Twisted-pair wire and coaxial cables are made of copper, and fiber-optic cable is made of glass.

A wireless network enables people to communicate and access applications and information without wires. This provides freedom of movement and the ability to extend applications to different parts of a building, city, or nearly anywhere in the world. Wireless networks allow people to interact with e-mail or browse the Internet from a location that they prefer.

2.2 Fading effects

In wireless communications, fading is variation of the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency. Fading 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, weather (particularly rain), or 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. Fading may be large scale fading or small scale fading. Based on multipath time delay spread small scale fading is classified as flat fading and frequency selective fading. If bandwidth of the signal is smaller than bandwidth of the channel and delay spread is smaller than relative symbol period then flat fading occurs whereas if bandwidth of the signal is greater than bandwidth of the channel and delay spread is greater than relative symbol period then frequency selective fading occurs. Based on Doppler spread small scale fading may be fast fading or slow fading. Slow fading occurs when the coherence time of the channel is larger relative to the delay constraint of the channel. The amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. Slow fading can be caused by events such as shadowing, where a large Obstruction such as a hill or large building comes in the main signal path between the transmitter and the receiver. Fast fading occurs when the coherence time of the channel is small relative to the delay constraint of the channel. The amplitude and phase change imposed by the channel varies considerably over the period of use. In a fast-fading channel, the transmitter may take advantage of the variations in the channel conditions using time diversity to help increase robustness of the communication.

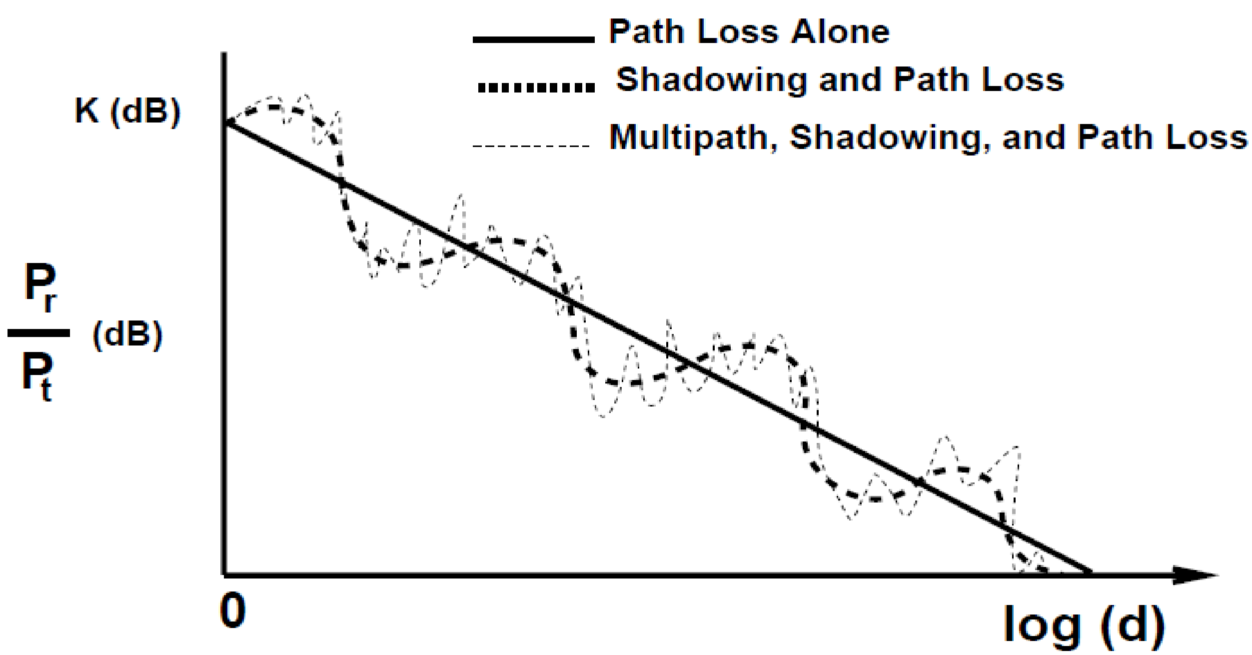


Figure 2.2: Fading effects comparison

2.3.1 Fading types:

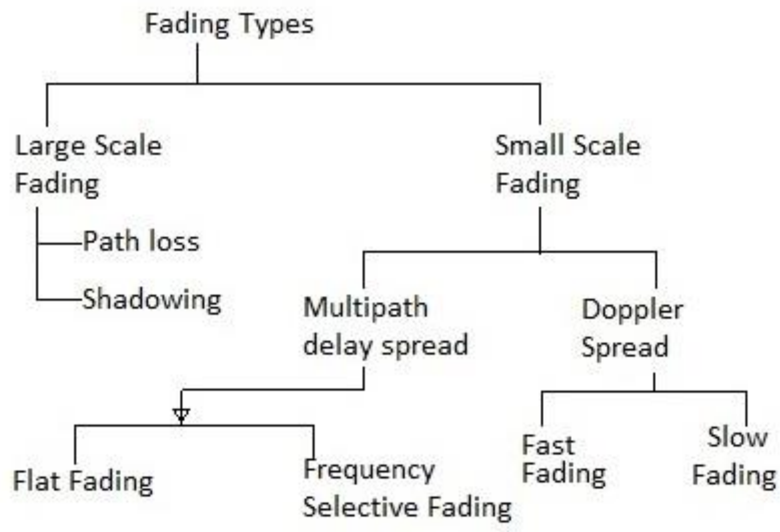


Figure2.3: Classifications of fading effect

2.2.1.1 Large scale fading

Large scale fading occurs when an obstacle comes in between transmitter and receiver. This interference type causes significant amount of signal strength reduction this is because EM wave is shadowed or blocked by the obstacle. It is related to large fluctuation of the signal over distance. Large scale fading cause by:

A. Path loss is the phenomenon which occurs when the received signal becomes weaker and weaker due to increasing distance between mobile and base station.

The free space path loss can be expressed as follows.

$$p_t/p_r=\{(4*\pi*d)^2/\lambda^2\}=(4*\pi*d*f)^2/c^2 \qquad (2.\ 1)$$

Where p_t= transmit power

p_r=receive power

d = distance between transmitting and receiving antenna

c = speed of light

From this equation it implies that transmitted signal attenuates over distance as the signal is being spread over larger and larger area from transmit end to wards receive end

B. Shadowing effect: it is observed in wireless communication. Shadowing is deviation of received power of electromagnetic signal from average value. It is the result of obstacles over the path between transmitters and receivers. It depends on graphical position as well as radio frequency of EM waves.

2.2.1.2 Small scale fading

This is concerned with rapid fluctuations of received signal strength over very short distance and short time period. Based on multipath delay spread there are two types of small scale fading. Those are flat fading and frequency selective fading. These multipath fading types depend on propagation environment. Due to this effect the transmitted data may not be received exactly.

A. flat fading: the wireless channel is said to be flat fading if it has constant gain and a linear phase response over bandwidth which is greater than the bandwidth of the transmitted signal. In this type of fading all the frequency components of the received signal fluctuate in same proportions simultaneously. It is known as non-selective fading.

Signal BW<< channel BW

Symbol period>>delay spread

The effect of flat fading is seen as decrease in SNR. These flat fading channels are known as amplitude varying channels or narrow band channels.

B. Frequency selective fading: it affects different spectral components of a radio signal with different amplitudes. Hence the name selective fades.

Signal BW> channel BW

Symbol period<delay spread

Based on Doppler speed there are two types of fading. Those are fast fading and slow fading. These Doppler spread fading types depend on mobile speed. i.e. speed of receiver with respect to transmitter.

C. **Fast fading:** the phenomena of fast fading are represented by rapid fluctuations of signal over small areas (BW). When the signals arrive from all the directions in the plane, fast fading will be observed for all directions of motion. Fast fading occurs when channel impulse response changes very rapidly within the symbol duration.

- High Doppler spread
- Symbol period>coherence time
- Signal variation<channel variation

These parameters result in to frequency dispersion or time selective fading due to Doppler spread. Fast fading is result of fluctuations of local objectives and motion of objects relative to these objects. In fast fading, received signal is some of numerous signals which are reflected from various surfaces. This signal is some or difference of multiple signals which can be constructive or destructive based on relative phase shift between them. Phase relationships depend on speed of motion, frequency of transmission and relative path lengths. Fast fading distorts the shape of the baseband pulse. This distortion is linear and creates ISI.

D. **Slow fading:** is result of shadowing by buildings, hills, mountains and other objects over the path.

- Low Doppler spread
- Symbol period<<coherence time
- Signal variation>>channel variation

Slow fading results in loss of SNR.

2.3 Fading models

There are different types of fading models in wireless communication channel. from those some of them will be discussed on this paper.

2.3.1 Nakagami fading model

Considers the instance for multipath scattering with relatively large delay-time spreads, with different clusters of reflected waves with in any one cluster, the phases of individual reflected waves are random, but the delay times are approximately equal for all waves. As a result the envelope of each cumulated cluster signal is Rayleigh distributed. The average time delay is assumed to differ significantly between clusters. If the delay times also significantly exceed the bit time of a digital link, the different clusters produce serious inter symbol interference, so the multipath self-interference then approximates the case of co channel interference by multiple incoherent Rayleigh-fading signals. The NL fading model is a mixture of Nakagami-*m* distribution and Log normal distribution obtained by averaging the instantaneous Nakagami-*m* fading average power over the pdf of the Lognormal shadowing as follows

$$\boldsymbol{f_{\alpha}(\alpha)\int_{0}^{\infty} f_{\alpha}(\alpha/\sigma)f_{\sigma}(\sigma)d_{\sigma}} \tag{2. 2}$$

Where $f_{\sigma}(\alpha/\sigma)$is the nakagami-m distribution given

$$\boldsymbol{f_{\alpha}(\alpha/\sigma)\frac{2m^{m}}{\sigma^{m}\Gamma(m)}\alpha^{2m-1}e^{-m\frac{\alpha^{2}}{\sigma}}} \tag{2. 3}$$

The distribution of the amplitude and signal power can be used to find probabilities on signal outages if the envelope is nakagami distributed, the corresponding instantaneous power is gamma distributed ,the parameter m is called the 'shape factor' of the nakagami or the gamma distribution.

2.3.2 Rayleigh fading model

Rayleigh fading is the name given to the form of fading that is often experienced in an environment where there are a large number of reflections present. The Rayleigh fading model uses a mathematical approach to analyze the propagation, and can be used in a number of environments.

The Rayleigh fading model is also appropriate for tropospheric radio propagation because, again there are many reflection points and the signal may follow a variety of different paths.

Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution. the radial component of the sum of two uncorrelated Gaussian random variables.

The Rayleigh fading model is particularly useful in scenarios where the signal may be considered to be scattered between the transmitter and receiver. In this form of scenario there is no single signal path that dominates and a statistical approach is required to the analysis of the overall nature of the radio communications channel.

Rayleigh fading is a model that can be used to describe the form of fading that occurs when multipath propagation exists. In any terrestrial environment a radio signal will travel via a number of different paths from the transmitter to the receiver. The most obvious path is the direct, or line of sight path.

However there will be very many objects around the direct path. These objects may serve to reflect, refract, etc. the signal. As a result of this, there are many other paths by which the signal may reach the receiver.

When the signals reach the receiver, the overall signal is a combination of all the signals that have reached the receiver via the multitude of different paths that are available. These signals will all sum together, the phase of the signal being important. Dependent upon the way in which these signals sum together, the signal will vary in strength. If they were all in phase with each other they would all add together. However, this is not normally the case, as some will be in phase and others out of phase, depending upon the various path lengths, and therefore some will tend to add to the overall signal, whereas others will subtract.

As there is often movement of the transmitter or the receiver this can cause the path lengths to change and accordingly the signal level will vary. Additionally, if any of the objects being used for reflection or refraction of any part of the signal moves, then this too will cause variation. This occurs because some of the path lengths will change and in turn this will mean their relative phases will change, giving rise to a change in the summation of all the received signals.

The Rayleigh fading model can be used to analyses radio signal propagation on a mathematical basis. It operates best under conditions when there is no dominant signal (e.g. direct line of sight signal), and in many instances cellular telephones being used in a dense urban environment fall into this category. Other examples where no dominant path generally exists are for ionosphere propagation where the signal reaches the receiver via a huge number of individual paths. Propagation using tropospheric ducting also exhibits the same patterns. Accordingly, all these examples are ideal for the use of the Rayleigh fading or propagation model. In a brief discussion on Rayleigh channel, wherein we stated that a circularly symmetric complex Gaussian random variable is of the form,

$$\boldsymbol{h} = \boldsymbol{h_{re}} + \boldsymbol{j h_{im}} \tag{2. 4}$$

Where real and imaginary parts are zero mean independent and identically distributed (iid) Gaussian random variables with mean 0 and variance σ^2. The magnitude h which has a probability density,

$$\boldsymbol{p(h)} = \frac{\boldsymbol{h}}{\boldsymbol{\sigma^2}} \boldsymbol{e}^\wedge \frac{\boldsymbol{-h^2}}{\boldsymbol{2\sigma^2}} \tag{2. 5}$$

Is called a Rayleigh random variable**.** This model, called Rayleigh fading channel model, is reasonable for an environment where there are large numbers of reflectors.

Bit Error Rate: If recall, in the post on BER computation in AWGN, the probability of error for transmission of either +1 or -1 is computed by integrating the tail of the Gaussian probability density function for a given value of bit energy to noise ratio $\frac{E_b}{N_o}$. The bit error rate is,

$$P_b = \frac{\boldsymbol{erfc}(\sqrt{\frac{E_b}{N_o}})}{\boldsymbol{2}} \tag{2. 6}$$

However in the presence of channel h, the effective bit energy to noise ratio is $h^2 \ \frac{E_b}{N_o}$. So the bit error probability for a given value of h is

$$P_{b/h} = \frac{\boldsymbol{erfc}(\sqrt{\frac{h^2 E_b}{N_o}})}{\boldsymbol{2}} = \frac{\boldsymbol{erfc}(\sqrt{\gamma})}{\boldsymbol{2}} \tag{2. 7}$$

Where $\gamma = \frac{h^2 E_b}{N_o}$

To find the error probability over all random values of h^2, one must evaluate the conditional probability density function $P_{b/h}$ over the probability density function of γ.

Probability density function of γ

From our discussion on chi-square random variable, we know that if $|h|$ is a Rayleigh distributed random variable, and then h^2 is chi-square distributed with two degrees of freedom. Since h^2, is chi square distributed, γ is also chi square distributed. The probability density function of γ is,

$$.P(\gamma) = \frac{1}{(E_{b/N_0})} e^{\wedge \frac{-\gamma}{(E_{b/N_0})}} \quad \boldsymbol{,\gamma \geq 0} \tag{2. 8}$$

Error probability

So the error probability is,

$$P_{b=\int_0^\infty \frac{1}{2}} erfc(\gamma) P(\gamma) d\gamma. \tag{2. 9}$$

Somehow, this equation reduces to

$$P_b = \frac{1}{2}(1 - \sqrt{\frac{(E_b/N_{0)}}{(E_{b/N_0})+1}}). \tag{2. 10}$$

2.3.3 Racian fading model

Considers that the dominant wave can be a phaser sum of two or more dominant signals, e.g. the line-of-sight, plus a ground reflection, this combined signal is then mostly treated as a deterministic (fully predictable) process, and that the dominant wave can also be subject to shadow attenuation. This is a popular assumption in the modeling of satellite channels. Besides the dominant component, the mobile antenna receives a large number of reflected and scattered waves.

Rician Fading model is used to simulate environments that produce multipath components and also a dominant Line Of Sight (LOS) component. The LOS component is called “specular” component and the multipath component is called “random or scatter” component. The amplitude distribution of the specular component will have non-zero mean, whereas, the random component will have zero-mean.

2.3.3.1Rican Distribution

Consider two Gaussian random variables X and Y. Here X models the specular component (LOS) and Y models the random/scatter component. By definition, X has non-zero mean (m), Y has zero mean and both have equal variance σ2σ2. Then the transformation $\sqrt{Z} = X_2 + Y_2$ is Rician Distributed. The ratio of power of specular component to the power of random component is called Rician κ factor and it defined a

$$k = m^2 2\sigma^2 2k \tag{2. 11}$$

It can be immediately ascertained that Rayleigh Fading is related to central Chi Square distribution (due to zero mean) and the Rician Fading is related to non-central Chi Square distribution (due to non-zero mean).

$$\boldsymbol{Z = X_2 + Y_2} \tag{2. 12}$$

2.3.4 Weibull Fading Model

The Weibull distribution is useful for modeling multipath fading signal amplitude. Recall that the Rayleigh distribution is commonly used to model the multipath fading in an urban environment where there are a large number of received radio wave paths. Hence, the Rayleigh model is derived theoretically by using a central limit theorem (CLT) argument. However, when the number of incoming radio paths is limited, the Rayleigh distribution may not be an appropriate fading model since the conditions for validity of the CLT may not hold. Some evidence indicates that the signal amplitude can be well described by a Weibull distribution in this situation. Experimental data supporting the appropriateness of the Weibull model was reported in and Hashemi considered its use as a model for indoor fading channels in. Recent measurements by Babich and Lombardi have revealed that the Weibull distribution gives the best fit to a path-loss model of a narrow-band digital enhanced cordless telecommunications (DECT) system at reference frequency 1.89 GHz. Based on fading channel data obtained from a recent measurement program at 900 MHz, Tzeremes and Christodoulou also reported that the Weibull distribution can be used to model.

2.3.4.1 The Weibull Distribution

The Weibull distribution provides an excellent fit for indoor and outdoor environments. For instance, it is was shown adequate in characterizing a multipath environment Associated with mobile radio systems operating in the 800/900 MHz , and it is expressed as

$$\mathrm{f}_{\alpha(\alpha)} = \mathrm{m}\frac{[1+\frac{2}{\mathrm{m}}]}{\Omega}\alpha^{\mathrm{m}-1}\mathrm{e}^{[\frac{-\alpha^2}{\Omega}\Gamma\left(1+\frac{2}{\mathrm{m}}\right)]} \tag{2. 13}$$

The corresponding instantaneous SNR distribution is

$$f_{\gamma}(\gamma) = \frac{m}{2}\left(\frac{\left(\Gamma(1+2/m)\right)^{\frac{\beta}{2}}}{\gamma_{\circ}}\gamma^{\frac{m}{2}-1}e^{-\left[\frac{\gamma}{\gamma_{\circ}}\right]\Gamma\left(1+\frac{2}{m}\right)}\right)^{m/2} \quad \textbf{(2. 14)}$$

2.4 Mitigation techniques

Fundamentally, fading causes poor performance in traditional communication systems because the quality of the communications link depends on a single path or channel and due to fading there is a significant probability that the channel will experience a deep fade. The probability of experiencing a fade (and associated bit errors as the signal-to-noise ratio drops) on the channel becomes the limiting factor in the link's performance. The effects of fading can be combated by using diversity to transmit the signal over multiple channels that experience independent fading and coherently combining them at the receiver.

Equalization: Equalization is a technique used for compensating Inter Symbol Interference. An Equalizer within a receiver compensates for the average range of expected channel amplitude and delay characteristics. Equalizers must be adaptive as the channel is generally unknown and time varying. ISI has been recognized as the major obstacle to high speed data transmission over mobile radio channels.

Channel coding: It is the technique which improves mobile communication link performance by adding redundant data bits in the transmitted message. In this technique, to the baseband portion of the transmitter, a channel coder maps a digital message sequence into another specific containing greater number of bits than originally contained in the message. The coded message is then modulated for transmission in the wireless channel.

Channel Coding is used by the receiver to detect or correct some or all of the errors introduced by the channel in a particular sequence of message bits.

The added coding bits increases the raw data used in the link, and, hence, it increases the bandwidth requirement for a fixed source data rate. This reduces BW efficiency of the link in high SNR conditions, but provides excellent BER performance at low SNR. There are three basic types of codes: Block codes, Convolutional codes, Turbo codes.

Channel codes are designed as Error detection codes and detect the presence of an error. Error correction codes, or forward correction codes (FEC) Designed to detect and correct errors without retransmission and it is widely used in wireless networks

In Error Detection Process at a transmitter side for a given frame, an error-detecting code (check bits) is calculated from data bits and Check bits are appended to data bits.

At the Receiver side there are steps to detect errors as follow

Step 1 separates incoming frame into data bits and check bits

Step 2 Calculates check bits from received data bits

Step 3 Compares calculated check bits against received check bits

Step 4 Detected error occurs if mismatch

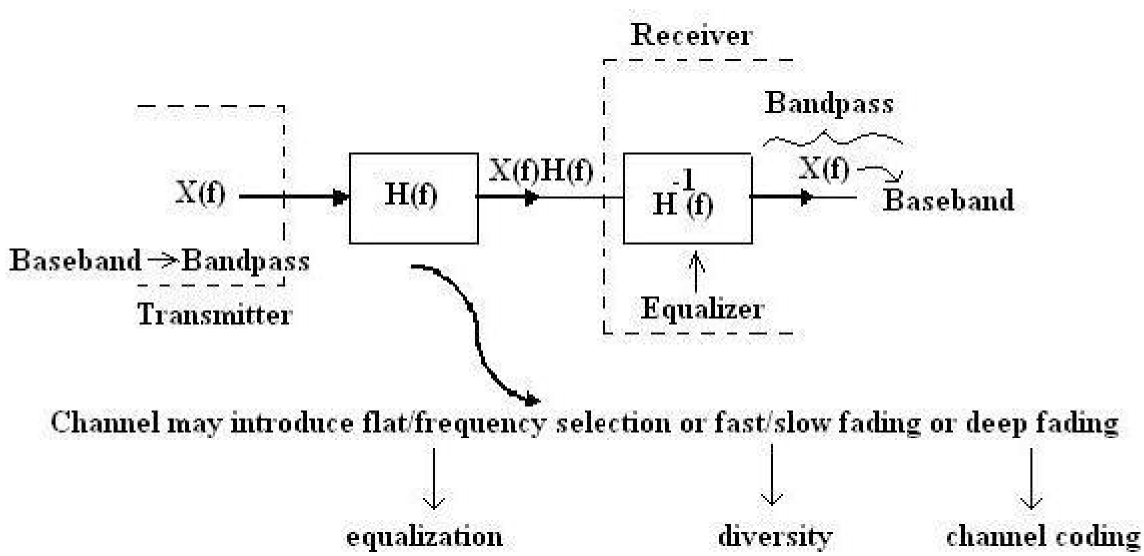


Figure2.4: types of mitigation technique

The probability of experiencing a fade in this composite channel is then proportional to the probability that all the component channels simultaneously experience a fade, a much more unlikely event. Diversity can be achieved in time, frequency, or space. Common techniques used to overcome signal fading include: · Diversity reception and transmission · OFDM · Rake receivers · Space–time codes · MIMO. The fallowing sections describe methods that can help reduce the problem of fading in wireless communication channels; they are Diversity for fast and slow fading , Equalization for flat and frequency selection fading , Rake receiver for multipath fading and Channel Coding for deep fading.

2.5.1 Diversity

A diversity scheme is a method that is used to develop information from several signals transmitted over independent fading paths. It is a very simple concept where in one path undergoes a deep fade and another independent path may have a strong signal. As there is more than one path to select from, both the instantaneous and average SNRs at the receiver may be improved, often as much as 20-30 dB.

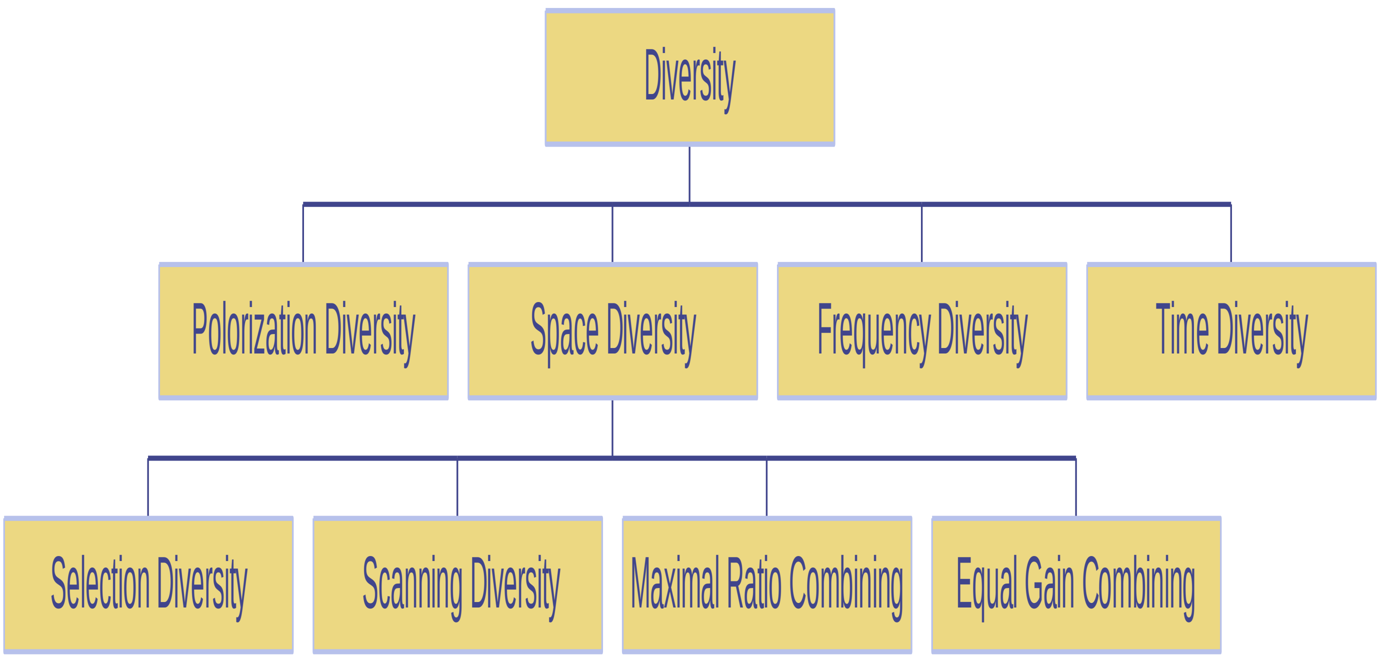


Figure2.5: Classification of diversity technique

2.5.1.1 Space diversity

A method of transmission or reception, or both, in which the effects of fading are minimized by the simultaneous use of two or more physically separated antennas, ideally separated by one half or more wavelengths.

In this technique multiple antennas are strategically spaced and connected to common receiving system. While one antenna sees a signal null, one of the other antennas may see a signal peak, and the receiver is able to select the antenna with the best signal at any time.

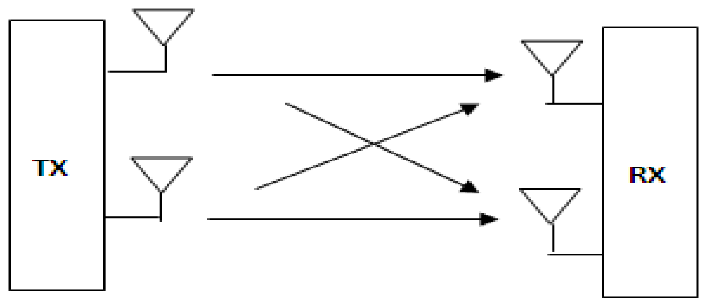


Figure2.6: space diversity

Maximal combining ratio (MRC)

In telecommunications, maximum-ratio combining (MRC) is a method of diversity combining in which: the signals from each channel are added together, The gain of each channel is made proportional to the rms signal level and inversely proportional to the mean square noise level in that channel. In, MRC different proportionality constants are used for each channel.

It is also known as ratio-squared combining and pre detection combining. Maximum-ratio combining is the optimum combiner for independent additive white Gaussian noise channels.

MRC can restore a signal to its original shape. The technique was invented by American engineer Leonard R. Kahn in 1954. MRC has also been found in the field of neuroscience, where it has been shown that neurons in the retina scale their dependence on two sources of input in proportion to the signal-to-noise ratio of the inputs.

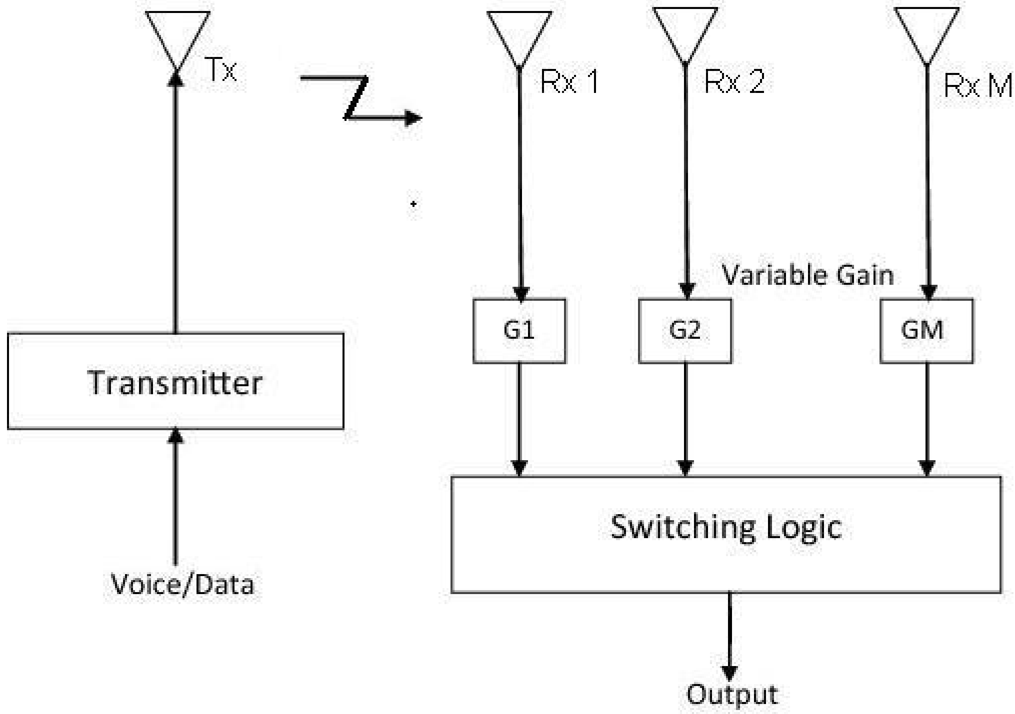


Figure2.7: maximal combining ratio

This figure implies that the data can be transmitted and received through different antennas to reduce the effect of fading's in wireless channels

Chapter Three: System Model and Analysis of Wireless Channel under Different Fading Effects

3.1 System model for wireless communication system

In this paper, focuses on the link spectral efficiency, defined as the average transmitted data rate per unit bandwidth for a specified average transmit power and bit error rate (BER). Over the last three decades, researchers have looked at various ways to improve the link spectral efficiency of wireless systems. In what follows, first briefly summarize the major steps and progress achieved in that arena.

Multilevel modulation schemes, such as BPSK, increase link spectral efficiency by sending multiple bits per symbol. Unfortunately, mobile radio links are subject to severe multipath fading due to the combination of randomly delayed reflected, scattered, and diffracted signal components. Fading leads to serious degradation in the link signal -to-noise ratio (SNR), resulting in either a higher BER or a higher required transmit power for a given multilevel modulation technique. Thus, fading compensation is typically required to improve link performance. Diversity can often be combined with other fading compensation methods to mitigate most of the fading degradation. For example, use of maximal ratio combining (MRC) antenna Diversity was proposed in [7], and field trials with this technique demonstrated considerable performance improvement Over BPSK without compensation [8], [9]. Other fading compensation techniques include an increased link budget margin or interleaving with channel coding [11]. However, these techniques are designed relative to the worst case channel conditions, resulting in poor utilization of the full channel capacity a good percentage of the time. Adapting certain parameters of the transmitted signal to the channel fading leads to better utilization of the channel capacity.

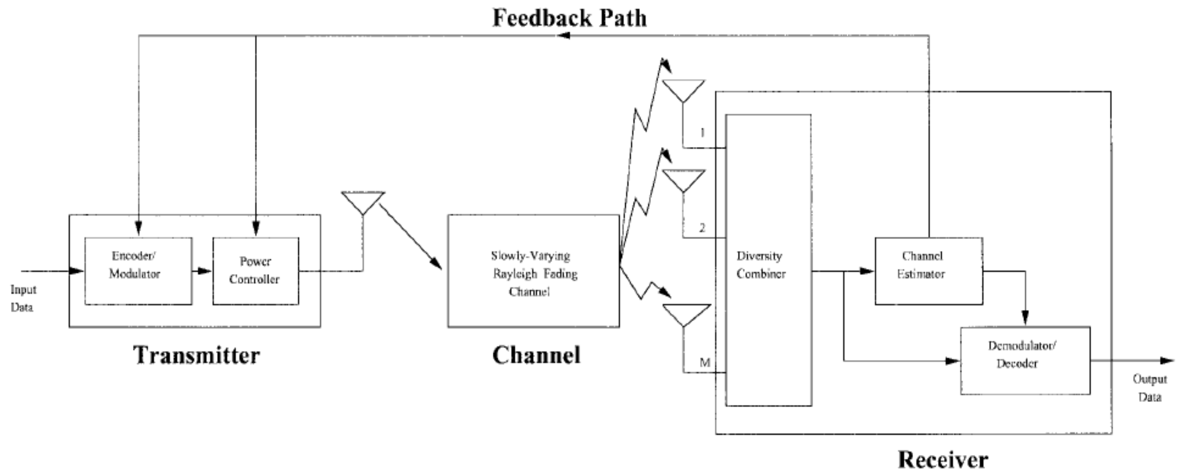


Figure3.1: block diagram for transmission system

In this section, we describe the channel and communication system model. A block diagram of the transmission system is shown in Fig. 1. We assume that the channel changes at a rate much slower than the data rate, so the channel remains constant over hundreds of symbols. We call this a slowly varying channel. We assume a Rayleigh fading channel so that the probability distribution function (PDF) of SNR (γ) is given by an exponential distribution

$$P_{\gamma}(\gamma) = \frac{e^{\frac{-\gamma}{\gamma}}}{\gamma}, \qquad \boldsymbol{\gamma \geq 0} \tag{3. 1}$$

Where γ is the average received SNR.

We consider both MRC and SC diversity combining of the received signal. MRC diversity combining requires that the individual signals from each branch be weighted by their signal voltage to noise power ratios then summed coherently .In our MRC analyses, we assume perfect knowledge of the branch amplitudes and phases, which we call perfect combining. MRC with perfect combining is the optimal diversity scheme [4], and therefore provides the maximum capacity improvement relative to all combining techniques. The disadvantage of MRC is that it requires knowledge of the branch parameters and independent processing of each branch. Let γ_k denote the average SNR on the k^{th} branch. For independent branch signals and equal average branch SNR

$$\gamma_k = \gamma \text{ , for all } k\epsilon\{1,2,3, \dots M\} \tag{3. 2}$$

For all the PDF of the received SNR at the output of a perfect M branch MRC combiner is a chi-square distribution with $2M$ degrees of freedom given by

$$p_{\gamma}^{mrc}(\gamma) = \frac{\gamma^{M-1} e^{\frac{-\gamma}{y}}}{(M-1)!y^{-M}}, \quad (3.\ 3)$$

SC diversity only processes one of the diversity branches. Specifically, the combiner chooses the branch with the highest SNR. Thus, this diversity-combining technique is simpler than MRC, but also yields suboptimal performance. Since the output of the SC combiner is equal to the signal On one of the branches, the coherent sum of the individual branch signals is not required. Assuming independent branch signals and equal average branch SNR, the PDF of the received SNR at the output of an M branch SC combiner is given by

$$p_{\gamma}^{sc}(\gamma) = \frac{M}{\gamma}(1 - e^{\frac{-\gamma}{y}})^{M-1} e^{\frac{-\gamma}{y}}, \quad \gamma \geq 0 \quad (3.\ 4)$$

Note that using the binomial expansion, we can rewrite as

$$p_{\gamma}^{sc}(\gamma) = \frac{M}{\gamma} \sum_{k=0}^{M-1} -1^k \binom{M-1}{k} e^{\frac{(-1+k)\gamma}{y}} \quad (3.\ 5)$$

Where $\binom{M-1}{k}$ denotes the binomial coefficient given by

$$\binom{M-1}{k} = \frac{(M-1)!}{(M-k-1)!k!} \quad (3.\ 6)$$

We assume throughout our analyses that the variation in the combined output SNR is tracked perfectly by the receiver. We also assume that the variation in γ is sent back to the transmitter via an error-free feedback path. The time delay in this feedback path is assumed to be negligible compared to the rate of the channel variation. All these assumptions, which are reasonable for high-speed data transmission over a slowly fading channel, allow the transmitter to adapt its power and/or rate relative to the actual channel state.

3.2 Types of Fading Channel Models

3.2.1Rayleigh system Model

The received signal in Rayleigh fading channel is of the form, $y = hx + n$, y is the received symbol, h is complex scaling factor corresponding to Rayleigh multipath channel, x is the transmitted symbol (taking valuaes+1's and -1's) and n is AWGN.

Assumptions

1. The channel is flat fading – In simple terms, it means that the multipath channel has only one tap. So, the convolution operation reduces to a simple multiplication.

2. The channel is randomly varying in time – meaning each transmitted symbol gets multiplied by a randomly varying complex number h . Since h is modeling a Rayleigh channel, the real and imaginary parts are Gaussian distributed having mean 0 and variance 1/2**.**

3. The noise n has the Gaussian probability density function with.

$$\mathrm{p(n)} = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\wedge\frac{-(n-\mu)^2}{2\sigma^2}} \text{ With } \boldsymbol{\mu}=0 \text{ and } \boldsymbol{\sigma^2} = \frac{\boldsymbol{N_o}}{\boldsymbol{2}} \qquad \textbf{(3. 7)}$$

4. The channel h is known at the receiver. Equalization is performed at the receiver by dividing the received symbol y by the priory known h i.e.

$$\gamma = \frac{y}{h}=\frac{hx+n}{h}=x + \frac{n}{h} \qquad \textbf{(3. 8)}$$

Where

$\frac{n}{h}$is the additive noise scaled by the channel coefficient.

Simulation model Rayleigh fading

It will be useful to provide a simple Matlab/Octave example simulating a BPSK transmission and reception in Rayleigh channel. The script performs the following

(a) Generate random binary sequence of +1′s and -1′s.

(b) Multiply the symbols with the channel and then add white Gaussian noise.

(c) At the receiver, equalize (divide) the received symbols with the known channel

(d) Perform hard decision decoding and count the bit errors

(e) Repeat for multiple values of $\frac{E_b}{N_O}$and plot the simulation and theoretical results.

3.2.2 System Model of Rician fading channel

When there is line-of-sight, direct path is normally the strongest component goes into deeper fade compared to the multipath components. This kind of signal is approximated by Rican distribution. As the dominating component run into more fade the signal characteristic goes from Rican to Rayleigh distribution. The derivation of the probability density function of the amplitude is more involved than for Rayleigh fading, and a Bessel function occurs in the mathematical expression. In the presence of such a path, the transmitted signal can be written as:

$$s(t)=\sum_{i=1}^{N-1} a_i \cos(\omega_c t+\omega_{di} t + \varphi_i) + k_d \cos(\omega_c t+\omega_{dt}) \quad \textbf{(3. 9)}$$

Where the constant $k_d$is the strength of the direct component, w_d is the Doppler shift along the line-of-sight path, and ω_{di} is are the Doppler shifts along the indirect paths. The envelope in this case has a Rican density function given by:

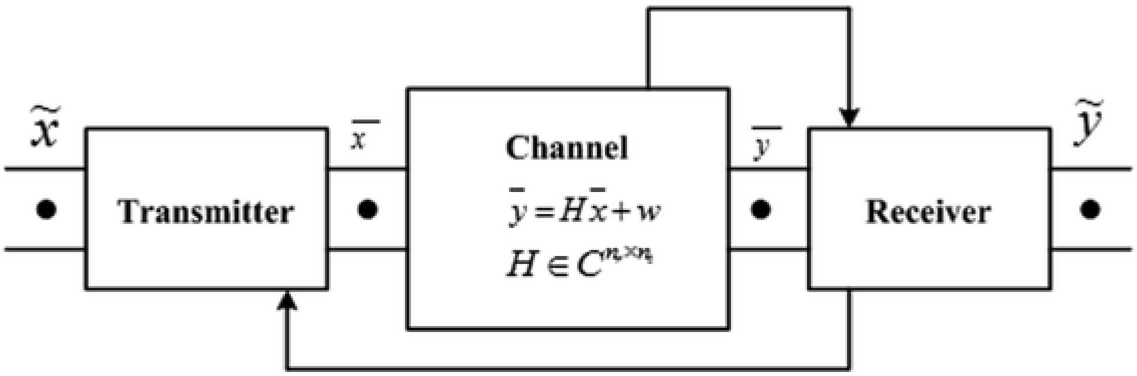
$$f(r)=\frac{r}{\sigma^2} e^{\wedge -\{\frac{r^2+kd^2}{2\sigma^2}\}} I_o\{\frac{rk_d}{\sigma^2}\} \quad \textbf{(3. 10)}$$

where$I_o(0)$ the 0 order is modified Bessel function of the first kind.

System model of nakagami channel model

$$p_{\alpha(\alpha)} = \frac{2m^m \alpha^{2m-1}}{\Omega^m \Gamma(m)} e^{\left(\frac{m\alpha^2}{\Omega}\right)}$$

Where, m is the Nakagami-m fading parameter which ranges from 12 to ∞. The below figure shows the Nakagami m PDF for Ω = 1 and various values of the m parameter.



[1] System model

It is often used to model propagation paths consisting of one strong direct LOS component and many random weaker components. Here the channel fading amplitude follows the distribution

Where, n is the Nakagami-n fading parameter which ranges from 0 to 1 and which is related to the Rician K factor by $K = n2$. The Rice factor K is the relation between the power of the LOS component and the power of the Rayleigh component. When K = 0, no LOS component and Rayleigh PDF is equal to the Ricean .

System model of weibull model

consider signal transmission over slow, frequency on selective Weibull fading channels. The received signal

$$s_o = \sum_i^L w_{i[s_i + n_i]}$$

where *si* is the signal component and it is assumed to have unity power, i.e., $E[s2i\ ] = 1$. In this paper, two diversity combining methods are considered. When selection combining (SC) is employed, the weighting factors become $wj = 1$, $wi = 0$, $\forall i$ _= j, $i, j = 1, \ldots, L$ where max{$X2$

$I \} = X2\ j$, and when maximal ratio combining (MRC) is employed, the weighting factors become $wi = Xie{-}j\alpha i,\ i = 1, \ldots, L$ where Xi is the ith branch fading amplitude and αi is the ith branch fading phase, and they are both assumed to be perfectly estimated. We further assume that the background noise has unity power, i.e., $E[n2i\ ] = 1$. Under these assumptions, the SNR per symbol on the ith diversity branch becomes ${x^2}_i$

3.3 System model for MRC

1. We have N receive antennas and one transmit antenna.

2. The channel is flat fading – In simple terms, it means that the multipath channel has only one tap. So, the convolution operation reduces to a simple multiplication.

3. The channel experienced by each receive antenna is randomly varying in time. For the i^{th} receive antenna, each transmitted symbol gets multiplied by a randomly varying complex number h_i. As the channel under consideration is a Rayleigh channel, the real and imaginary parts of h_i are Gaussian distributed having mean $\mu_{hi=0}$ and variance $\delta_{hi}^2 = \frac{1}{2}$

4. The channel experience by each receive antenna is independent from the channel experienced by other receive antennas.

5. On each receive antenna, the noise n has the Gaussian probability density function with

$$\mathrm{p(n)} = \frac{1}{\sqrt{2\pi\delta^2}}\, \mathrm{e}\wedge \frac{-(\mathrm{n}-\mu)^2}{2\delta^2}\ \text{With}\ \mu = 0\ \text{and} \delta^2 = \frac{N_0}{2}. \tag{3. 11}$$

The noise on each receive antenna is independent from the noise on the other receive antennas.

6. At each receive antenna, the channel h_i is known at the receiver.

7. In the presence of channel h_i, the instantaneous bit energy to noise ratio at i^{th} receive antenna is. $\frac{|h_i|^2 E_b}{N_0}$ For notational convenience, let us define,

$$.\gamma_i = \frac{|h_i|^2 E_b}{N_0} \quad \textbf{(3. 12)}$$

In Maximal Ratio Combining (MRC) on the i^{th} receive antenna, the received signal is,

$y_i = h_i x + n_i$Where

y_i Is the received symbol on the i^{th}receive antenna,

h_i is the channel on the i^{th}receive antenna,

x is the transmitted symbol and

n_i is the noise on i^{th}receive antenna.

Expressing it in matrix form, the received signal is,

$$y = hx + n \text{ Where}$$

$y = [y_1 y_2 \ldots y_N]$Is the received symbol from all the receive antenna

$h = [h_1 h_2 \ldots h_N]^T$ Is the channel on all the receive antenna

$[n_1 n_2 \ldots n_N]^T$ Is the noise on all the receive antenna. The equalized symbol is,

$$x = \frac{h^H y}{h^H h} = \frac{h^H h_x}{h^H h} + \frac{h^H n}{h^H h} = x + \frac{h^H y}{h^H h} \quad \textbf{(3. 13)}$$

It is intuitive to note that the term,

$$h^H{}_h = \sum_{i=1}^{N} h_i{}^2 \quad \textbf{(3. 14)}$$

i.e. sum of the channel powers across all the receive antennas.

Note: The equations in the post refer the note on Receive diversity by Prof. RaviRaj Adve.

Effective E_b/N_o with Maximal Ratio Combining (MRC) earlier, we noted that in the presence of channel h_i, the instantaneous bit energy to noise ratio at i^{th}receive antenna is

$$\gamma_i = \frac{|h_i|^2 E_b}{N_0} \quad \textbf{(3. 15)}$$

Given that we are equalizing the channel withh^H, with the $\boldsymbol{N}$ receive antenna case, the effective bit energy to noise ratio is,

$$\gamma = \sum_{i=1}^{N} \frac{|h_i|^2 E_b}{N_0} \qquad \textbf{(3. 16)}$$

Effective bit energy to noise ratio in a N receive antenna case is N times the bit energy to noise ratio for single antenna case**.** Recall, this gain is same as the improvement which we got in Receive diversity for AWGN case.

Chapter Four: Simulation Results and Discussions

4.1 simulation parameters

As it is presented in the previous chapters different fading reduction techniques has been chosen in order to improve the wireless communication system performance.in this chapter different simulation results are presented using appropriate parameters with brief discussions on the output results. The simulation results are plotted in terms of bit error rate (BER) and signal to noise ratio (SNR). BPSK modulation is considered for the performance comparison. This is because BPSK is relatively less affected by carrier frequency off set as compared to higher order modulation techniques.

Number	Parameters	Values
1	Fading effects	Rayleigh, racian, nakagami and weibul
2	Modulation technique	BPSK
3	Mitigation technique	MRC
4	Number of antennas	2,4,8
5	Performance measurements	BER and SNR
6	System model	Mathematical modeling

Table 4.1 Simulation parameters

4.1 Simulation result for Rayleigh fading channel in BPSK modulation technique

The simulation result for the Rayleigh fading channel can be seen as the random fluctuations of received signal at different random samples as illustrated in figure 4.1.

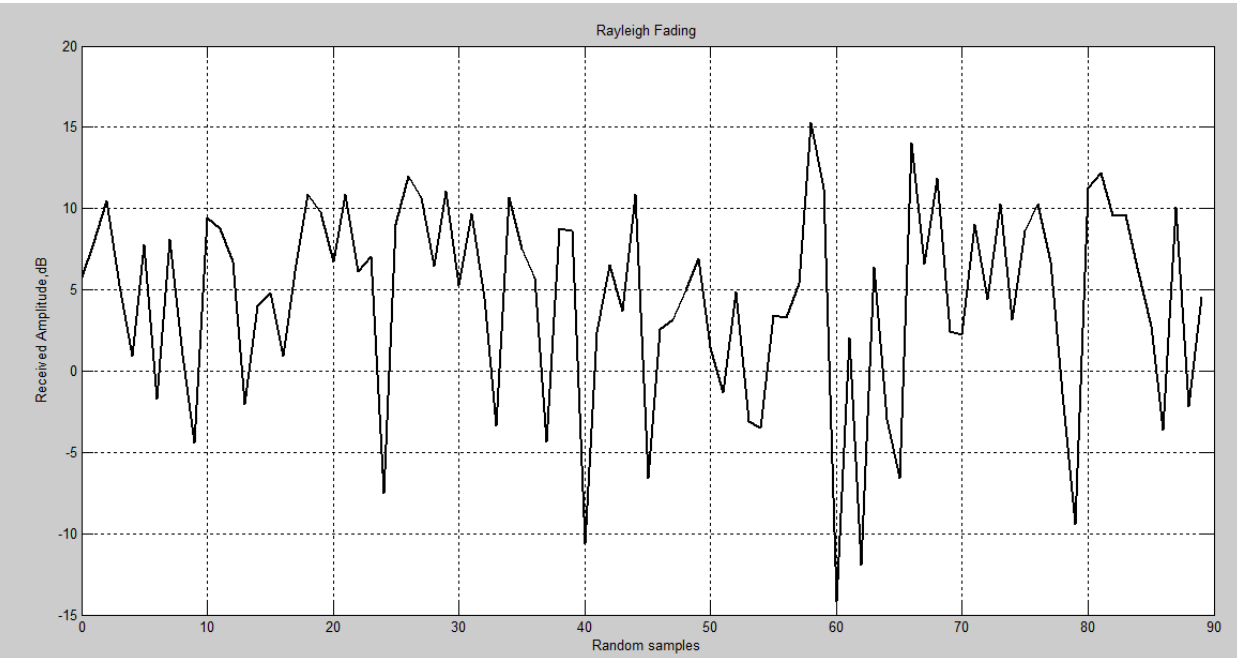


figure 4. 1simulation result of Rayleigh fading channel

From figure 4.1 it observed that the signal or the received amplitude is fluctuated or varying at different samples of time when it is transmitted through the rayleigh fading channel. Here we can compare the performance of the channel by increasing or decreasing the number of samples. If the number of samples increases we observe rapid fluctuation of received signal as shown in figure 4.2.

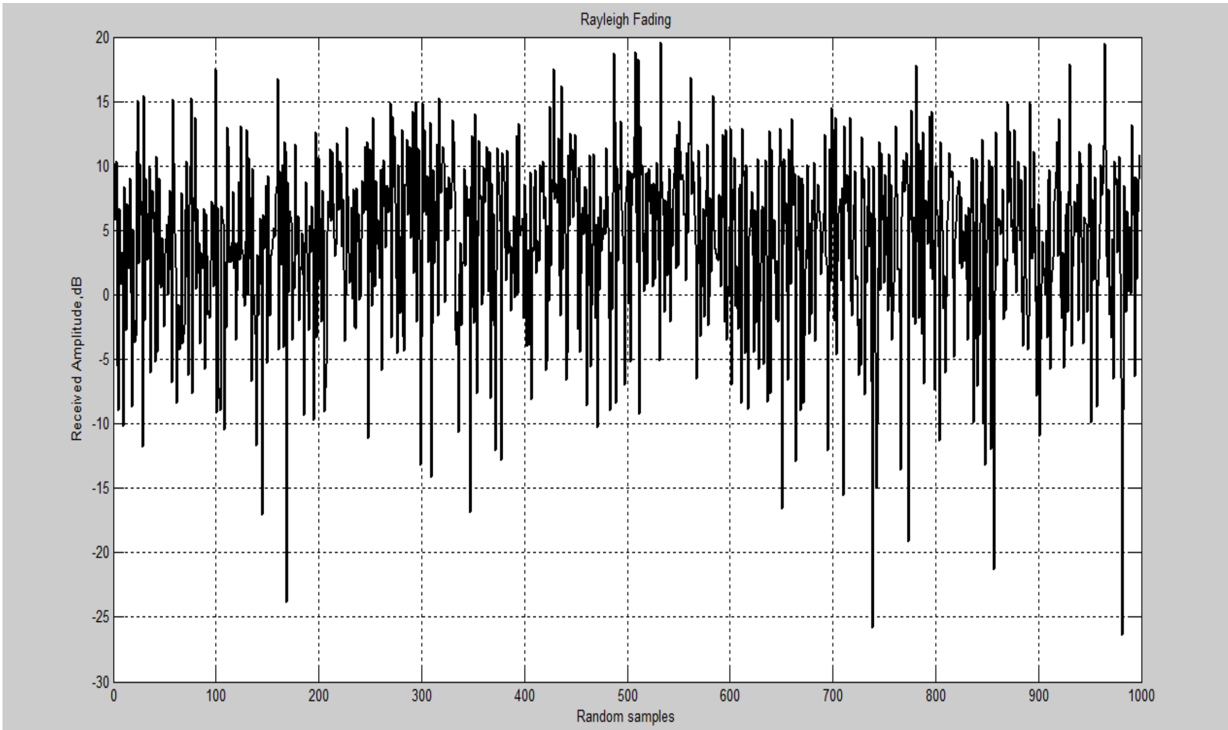


Figure4.2graph for very faded Rayleigh channel

From figure 4.2 The system performance degrades as the average number of multi-path components N increase. One should note here that; no equalization is used. This is due to the fact that as N decreases the signal level concentrates to the symbol of the first signal,

4.2 BER for Rayleigh fading channel in BPSK

This simulation result analyzed the performance of Rayleigh fading channel on the basis of BER. Rayleigh fading channel results in high bit error as illustrated in figure 4.3.

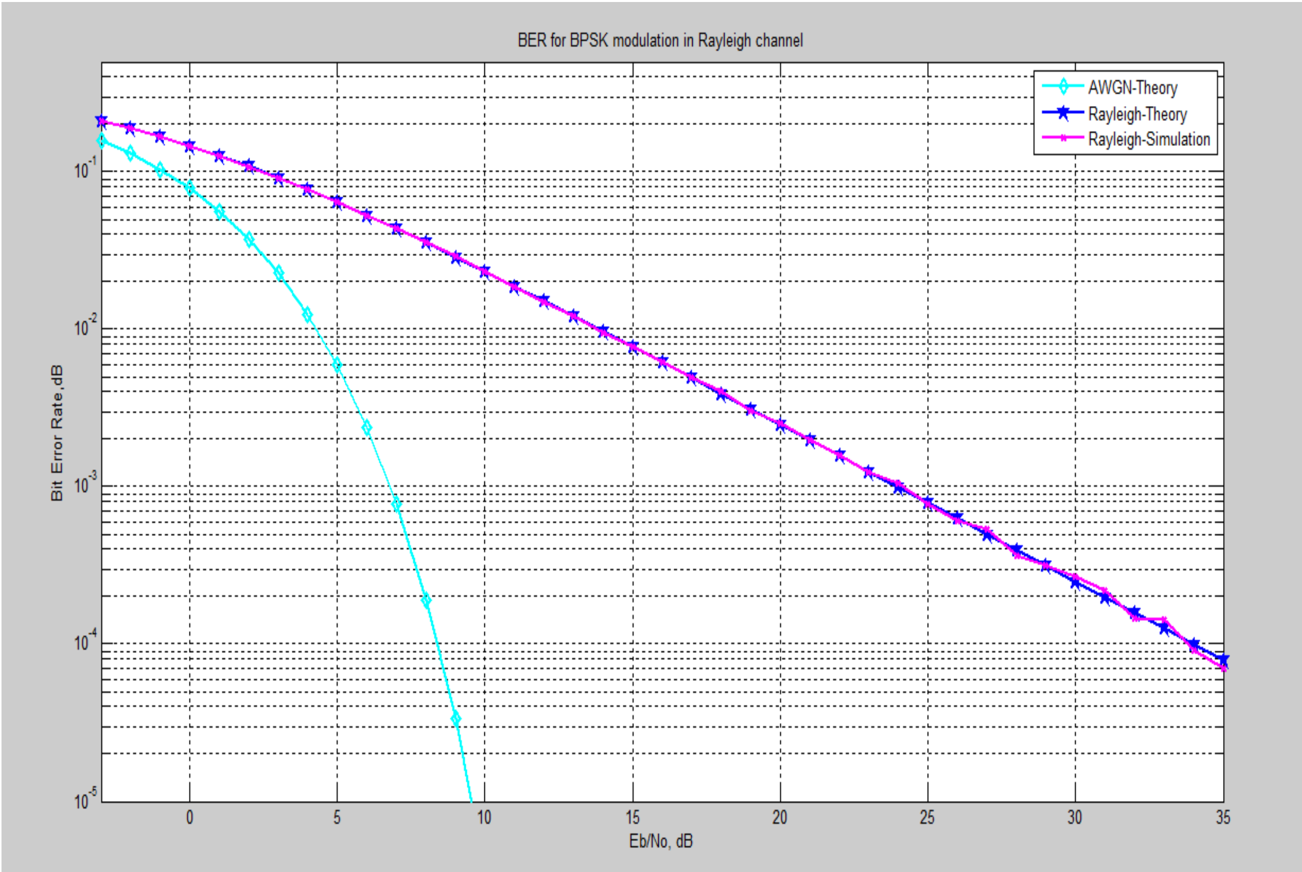


Figure4.3:BER curve for BPSK with Rayleigh channel

In figure 4.3 the performance of BPSK with AWGN and Rayleigh fading distribution was evaluated. Graphical results show the improvement in BPSK with Rayleigh fading channel compared to its performance in AWGN channel. The graphical results prove that simulated BER of BPSK is the same as that of theoretical BER of BPSK. The reported BER can be further reduced by using suitable diversity scheme.

4.3 simulation results for racian fading

This simulation result shows racian fading channel for different signal amplitudes. It observed that different received amplitude for different random variables.

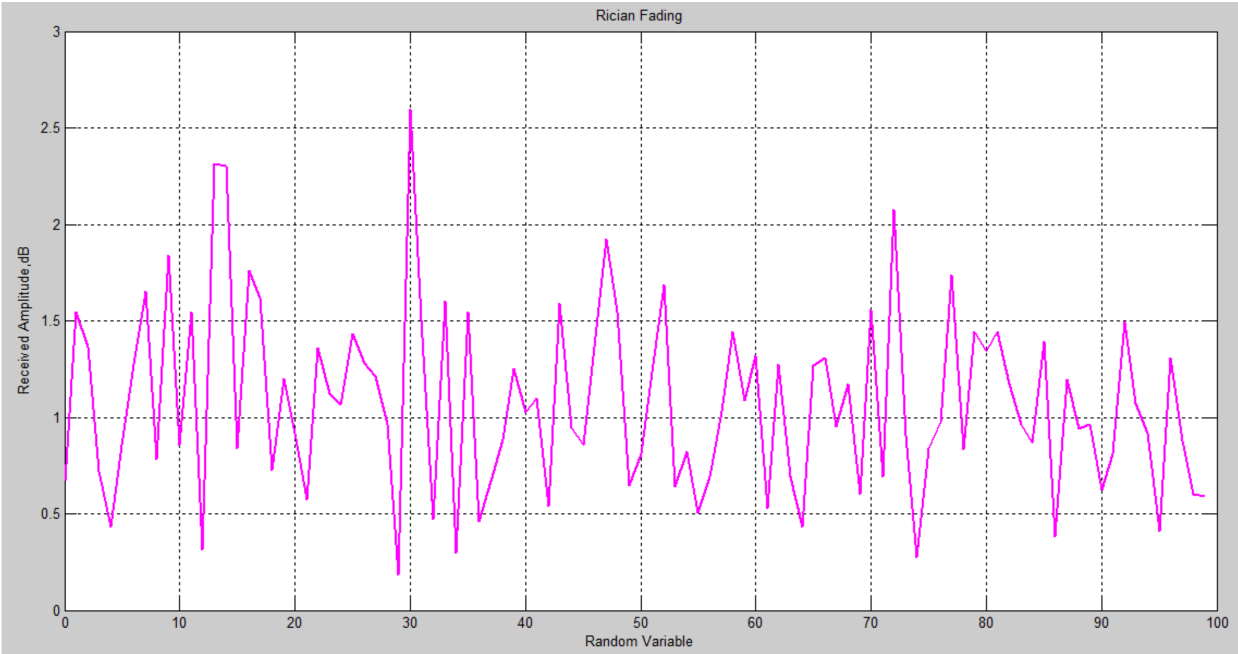


Figure4.4simulation results for racian fading channel

4.3.1 BER for racian fading channel

Racian fading channel results minimum error rate as compared to the Rayleigh fading channel shown in figure 4.3

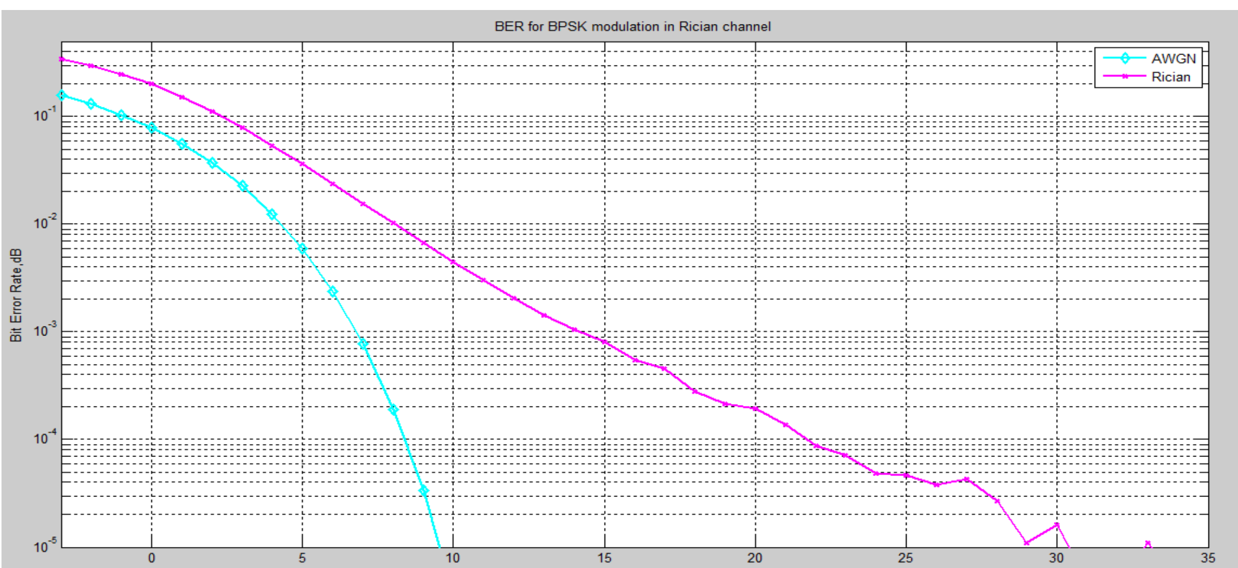


figure 4.5BER result for racian fading channel

In figure 4.5 the performance of BPSK with AWGN and Racian fading distribution was evaluated. The Graphical results show the improvement in BPSK with Racian fading channel compared to its performance in AWGN channel. The graphical results prove that simulated BER of BPSK is reduced as SNR increase. Racian results are related to some extent of AWGN based on their BER or performance. From figure 4.3 and figure 4.5 graphical results we can observed that racian fading channel has a minimum bit error rate.

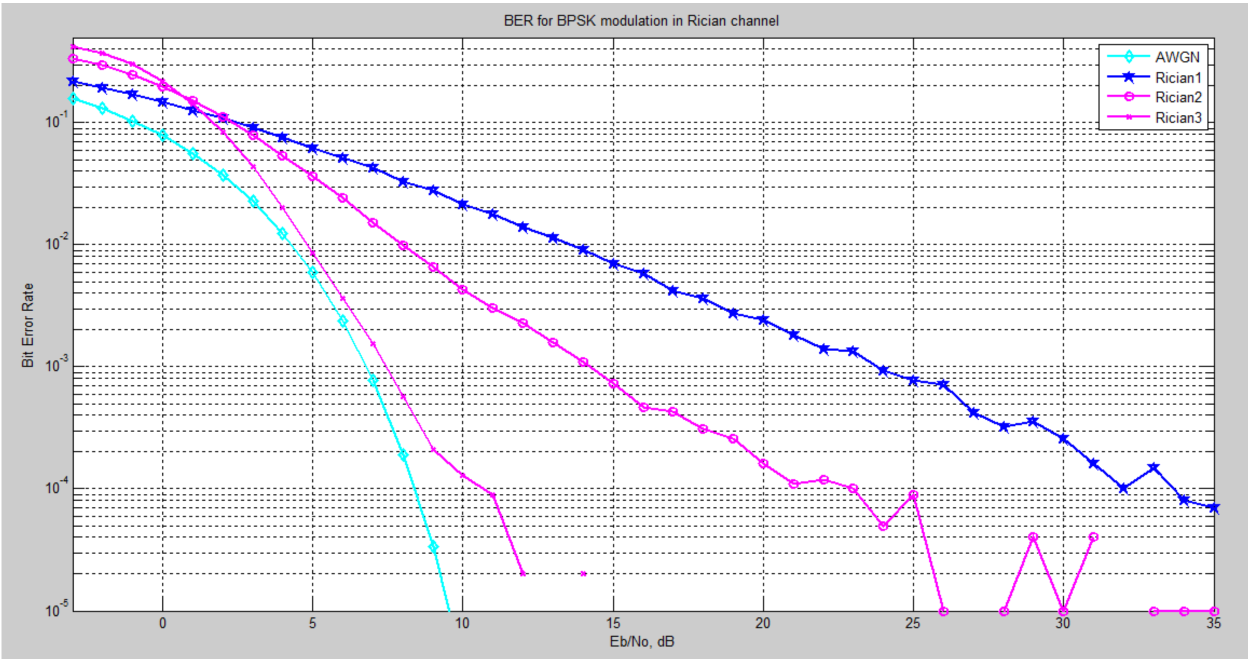


Figure 4.6 BER for different racian fadings

From this result we observed that as the signal to noise ratio increase the BER decreases under BPSK modulation techniques.

4.4 simulation result for Weibull fading channel

This graph results for BER of Weibull fading channel under BPSK modulation techniques.

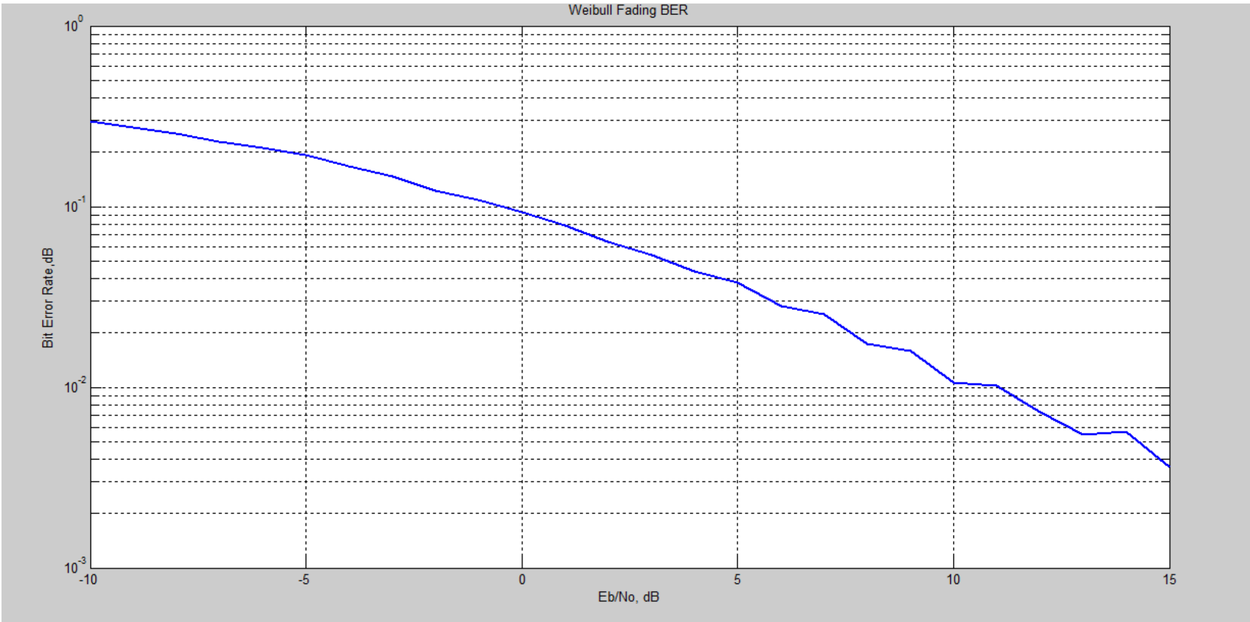


Figure 4.7 simulation result of weibull fading channel

From this figure we observe that the decrement of The BER as the SNR increases. It has a better performance next to the nakagami and AWGN .

4.5 simulation result for nakagami fading channel

This graph results in nakagami fading channel. the result of nakagami fading channel is expected to be efficient.

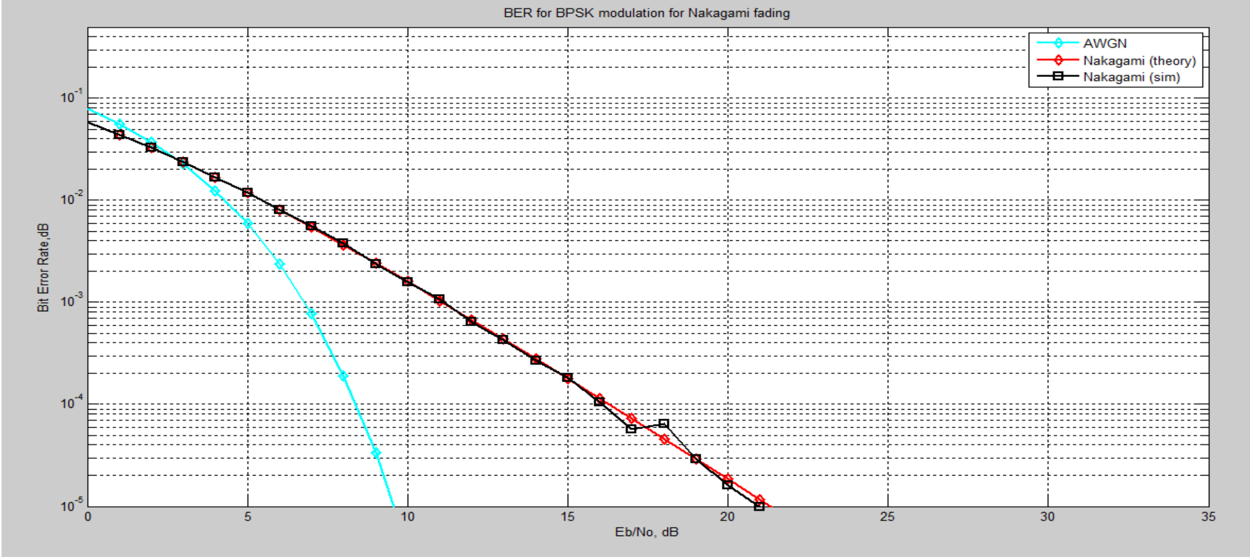


Figure 4.8 graph of nakagami fading channel

From this figure we can observe that the BER is decays fastly as compared to the other type of fading channels.

4.6 performance comparison of different fading

This simulation result compares the performance of the four fading channel models Those are Rayleigh, racian, nakagami and weibul fading channels in a combined form.

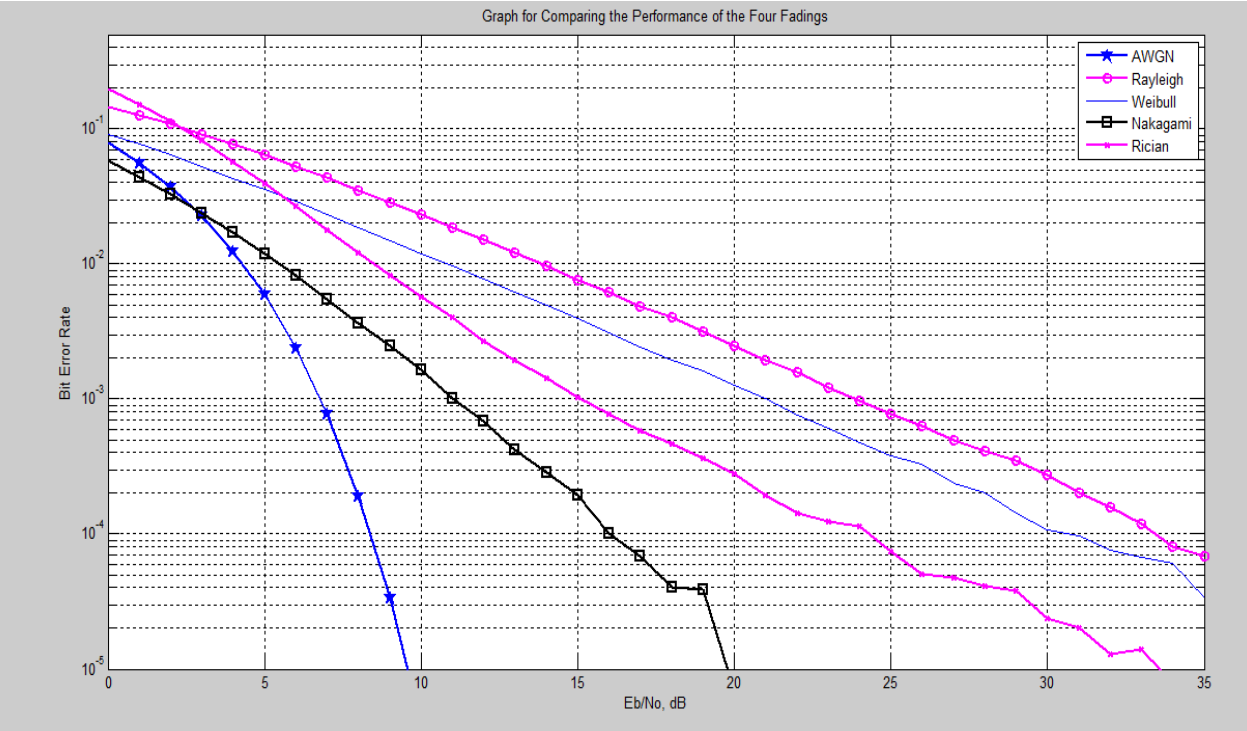


Figure 4.9: graph of BER for combined channels

This figure shows the general performance comparison of the fading channels over a BPSK modulation technique. from those fading channels Rayleigh channel have the worst BER i.e. low performance and racian have again have a worst BER as compared to the nakagami and weibul fading but better than Rayleigh fading channel. Over all conclusion of this graph is nakagami fading channel is the better in performance next to the AWGN.

4.7 Comparisons of different modulation orders

There are different digital modulation techniques. Some of them are BPSK, QPSK, and MPSK. When we compare their immunity to error BPSK is more efficient than the other, As the order of the modulation increase the amount of error occurrence also increase the modulation increase the

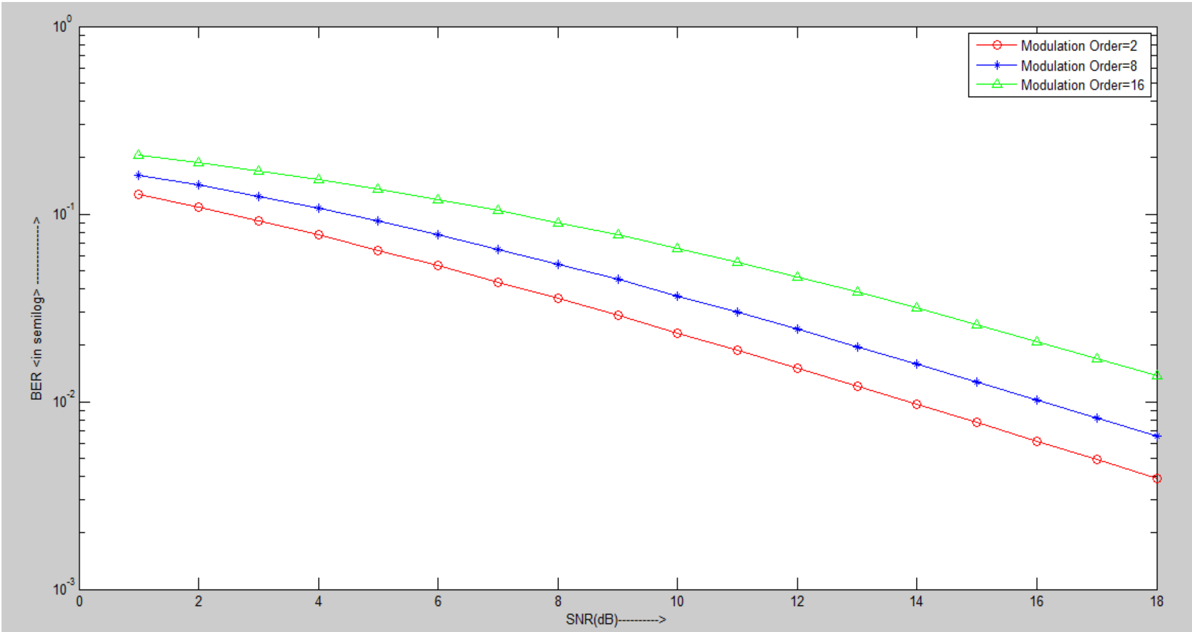


Figure 4.10 performance comparision of different modulation ordersof psk

From this figure it can be cinclude that a mudulation technique with lowest order is well performed than the other modualtion orders interms of BER.

4.9 performance comparision of modulation type

This graph shows or compares the different modulation type techniques as shown bellow.

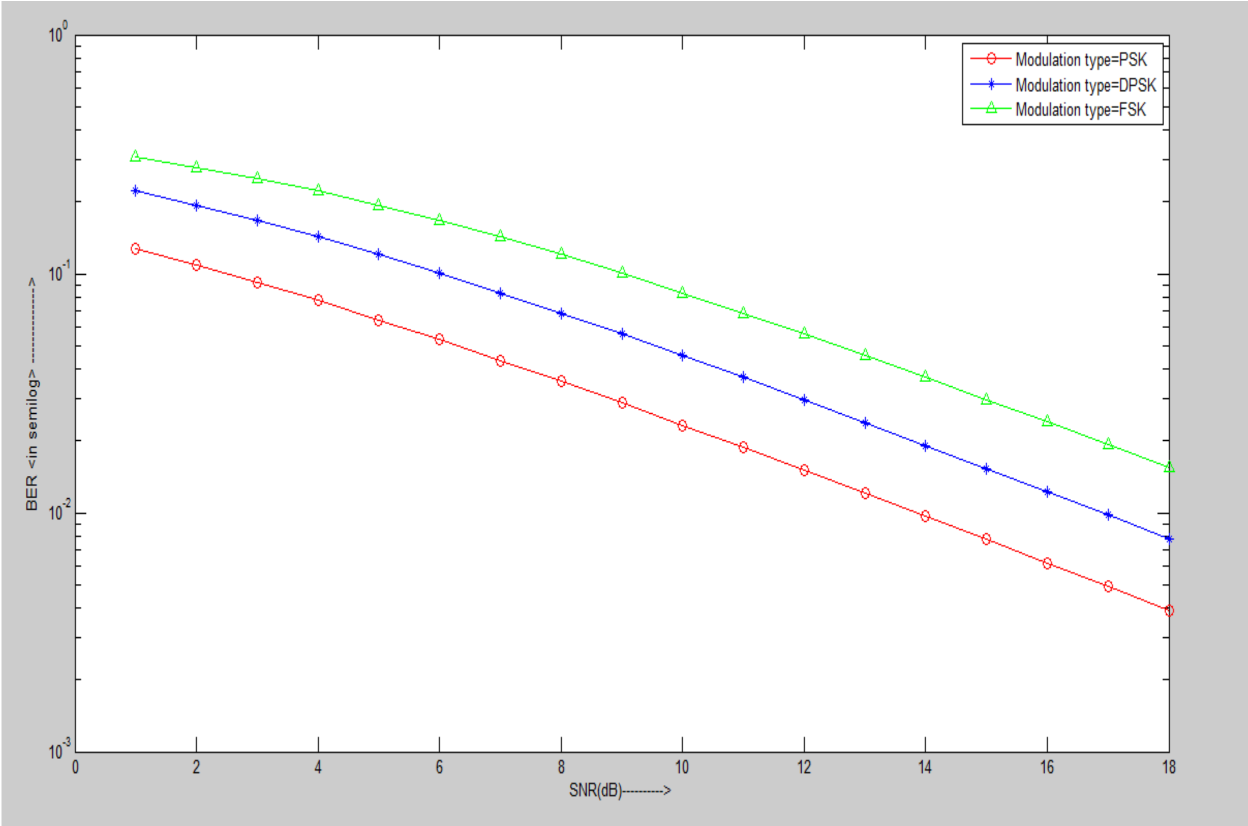


Figure 4.11 performance comparison for modulation types

From this figure it can be conclude that the binary phase shift keying have the lowest BER as compared to the modulation techniques.

4.10 performance comparison different number of antennas

This compares the performance of wireless fading channel under different number of antennas.

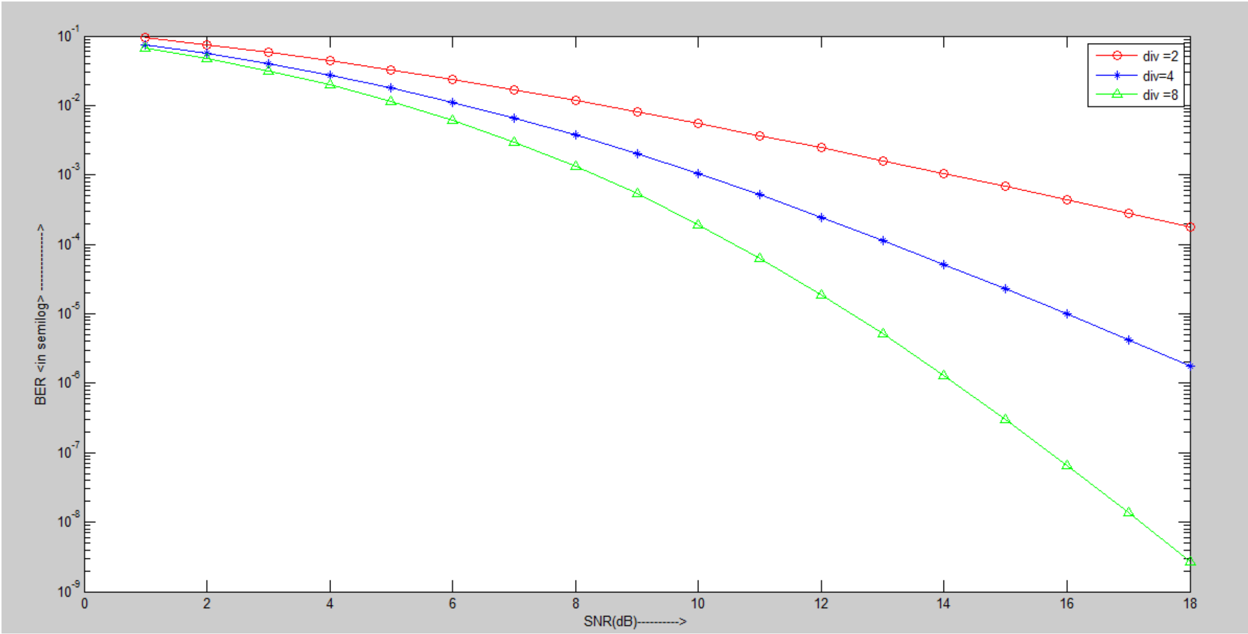


Figure 4.11 performance comparison of different number of antennas

From this figure it can be conclude that a diversity technique with large number of antenna is well performed than using small number of antennas in terms of BER. But it may be disadvantage in terms of cost and power requirement.

Chapter Five: Conclusion and Recommendation

5.1 Conclusion

The current work uses AWGN, Rayleigh fading channel, racian fading channel, nakagami and Weibull fading channels, to simulate a wireless channel. from the simulation results, The Bit Error Rate of a digital communication system is an important figure of merit used to quantify the integrity of data transmitted through the system by implementing the different modulation techniques, the criterion is comparison of the variation of BER for different SNR. this paper also works on the improvement of the performance of the wireless channel using maximal combining ratio technique.

The experimental results show that AWGN has less bit error rate as compared to the other fading channels and the Rayleigh fading channel has the highest bit error rate. It is observed that the BER is always present in all types of fading channels. the nakagami fading channel gives very small amount of BER as compared to the other types of fading channels.

It can be concluding that using nakagami fading channel is better to use out of the other fading techniques for transmitting and receiving data. because nakagami fading channel uses MRC fading mitigation technique.

5.2 Recommendation for future work

Though all the impairments of wireless channel have been analyzed in this project, only mitigation of diversity is implemented. Hence, other techniques such as pulse shaping, extended Kalman filter, and/or implementation of better equalization and channel coding techniques can be applied for ICI reduction and to provide further improvement in performance.

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