# Chapter-1

## Introduction :

### 1.1 introduction to wireless communication:

Wireless communication is the transfer of information over a distance without the use of electrical conductors or "wires”. The distances involved may be short (a few meters as in television remote control) or long (thousands or millions of kilometers for radio communications). When the context is clear, the term is often shortened to "wireless". It encompasses various types of fixed, mobile, and portable two-way radios, cellular telephones, personal digital assistants (PDAs), and wireless networking. Other examples of wireless technology include GPS units, garage door openers and or garage doors, wireless computer mice, keyboards and headsets, satellite television and cordless telephones.

The following situations justify the use of wireless technology:

To span a distance beyond the capabilities of typical cabling,

To provide a backup communications link in case of normal network failure,

To link portable or temporary workstations,

To overcome situations where normal cabling is difficult or financially impractical, or

To remotely connect mobile users or networks.

## 1.2 history:

The early wireless systems consisted of a base station with a high-power transmitter and served a large geographic area. Each base station could serve only a small number of users and was costly as well. The systems were isolated from each other and only a few of them communicated with the public switched telephone networks. Today, the cellular systems consist of a cluster of base stations with low-power radio transmitters. Each base station serves a small cell within a large geographic area. The total number of users served is increased because of channel reuse and also larger frequency bandwidth. The cellular systems connect with each other via mobile switching and directly access the public switched telephone networks. The most advertised advantage of wireless communication systems is that a mobile user can make a phone call anywhere and anytime. Products for enhanced communication services, such as data, electronic mail, high resolution digital video or even full multimedia communication entered the market. Services such as the GSM Short Message Service greatly extent the capabilities of pagers. I-mode is a successful text and multimedia service in Japan, and Europe is bettering on WAP: The Wireless Application Protocol. The projected growth of the number of Internet users to 500 Million worldwide indicates potential when wireless and computing technologies are merged. The revolutionary development of such systems appeared is focused towards larger capacity, better quality, more bandwidth, wider coverage, lower power consumption and more services. This development remains a technical challenge, with many issues still to be resolved.

The last two decades have seen an explosion in the growth of radio systems. Wireless communication systems migrated from the first-generation (1G) narrowband
analog systems in the 1980s, to the second-generation (2G) narrowband

digital systems in the 1990s, to the current third-generation (3G) wideband multimedia
systems that are being deployed. Meanwhile, research and development in the 4th generation wideband multimedia radio systems is actively being pursued worldwide. In 2002, mobile phones worldwide began to outnumber fixed-line phones. By November 2007, the total number of worldwide mobile phone subscriptions had reached 3.3 billion, and by 2007 over 798 million people around the world accessed the Internet or equivalent mobile Internet services at least occasionally using a mobile phone 1. This also makes the mobile phone the most common electronic device in the world. In addition to its multimedia services such as speech, audio, video, and data, the pervasive use of wireless communications has also entered many aspect of our life, including health care, home automation, etc.

## 1.3 wireless communication link :

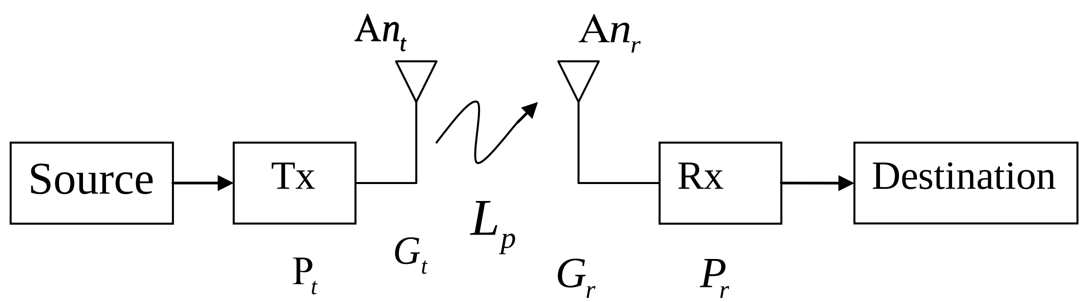



**Fig.1 Generic Block diagram**

- Source – source of information to be transmitted
- Destination- destination of transmitted information
- Tx and Rx – transmitter and receiver
- $An_t$ & $An_r$ – Tx and Rx antennas
- PC- propagation channel
- Tx includes coding/modulation circuitry (or DSP), power amplifiers, frequency synthesizers etc.
- Rx includes LNA, down conversion, demodulation, decoding etc.
- Examples: cellular phones, radio and TV broadcasting, GPS, cordless phones, radar, etc.
- Main advantages: flexible (service almost everywhere), low deployment cost(compare with cable system).
- Main disadvantages: PC is very bad, limits performance significantly, almost all development in wireless communication during last 50 years were directed to combat PC.

## 1.4 Limitations of Wireless Communication:

Signal propagation through a guided wire (e.g. coaxial cable or an optical fiber) is relatively free of interference. With a wireless channel, the impairments are much more severe. A signal propagating through the wireless channel will be subject to additive background noise, and will experience signal fading, time dispersion or delay spread, co-channel interference, adjacent channel interference, Doppler shift etc. These problems are needed to be tackled in this research work.

### Fading:

When the delay differences among various distinct propagation paths are very small compared with the symbol interval in digital transmission, the multipath components are almost indistinguishable at the receiver. Those multipath components can add constructively or destructively, depending on the carrier frequency and delay differences. As the mobile station moves, the position of each scattered with respect to the transmitter and receiver may change. The overall effect is that the received signal level fluctuates with time, a phenomenon called fading.

### Small scale multiple fading:

Here the multipath channel is characterized by N distinct scatters in which the nth scatter is associated with a gain $\alpha_n(t)$ and a delay $\tau_n(t)$, where n = 1,2,….N. Considering digital transmission over the channel at the carrier frequency $f_c$ with a symbol interval much larger than the channel multipath delay spread. The received signal at base band, in the absence of background noise, is:

$$r(t) = \sum_{n=1}^{N} \alpha_n(t) \exp^{-j2\pi f c \tau_n(t)} x(t - \tau_n(t))$$

$$\approx \left[ \sum_{n=1}^{N} \alpha_n(t) \exp^{-j2\pi f c \tau_n(t)} \right] x(t - \bar{\tau})$$

Here the approximation is reasonable as long as the delay spread is much smaller than the symbol interval.

## Shadowing:

When mobile moves in uneven terrain, it often travels into a propagation shadow behind a building or a hill or other obstacle much larger than the wavelength of the transmitted signal, and the associated received signal level is attenuated significantly. This phenomenon is called shadowing.

As a mobile user moves away from its base station, the received signal becomes weaker because of the growing propagation attenuation with the distance. Let $\bar{L}_p(d)$ denote the long distance path loss, which is a function of the distance d separating the transmitter and the receiver. We can write the equation below:

$$\overline{L}_p(d) = \overline{L}_p(d_0) + 10_k \log_{10}\left(\frac{d}{d_0}\right) db, d \geq d0$$

Long term fading is a combination of long-distance path loss and long normal shadowing. A long normal distribution is a popular model for characterizing the shadowing process.

Let, $\varepsilon(db)$ be a zero-mean Gaussian distributed random variable (in dB) with standard deviation $\sigma_\varepsilon(db)$ (in dB) with standard deviation .

Let $L_p(d)$ denote the overall path loss with shadowing (long-term fading) in dB. Then,

$$L_p(d) = \overline{L}_p(d) + \varepsilon(db)$$
$$= \overline{L}_p(d_0) + 10_k \log_{10}\left(\frac{d}{d_0}\right) db + \varepsilon(db)(dB), d \geq d0$$

## Rician Fading: (LOS Propagation)

Rician fading is a 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 paths 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. In Rician fading, the amplitude gain is characterized by a Rician distribution.

If there exists an LOS path, the channel gain can be represented by,

$$Z(t) = Z_c(t) - j Z_s(t) + \Gamma(t)$$

$\Gamma(t) = \alpha_0(t)\exp^{-j\theta(t)}$ is the deterministic LOS component

And $Z_c(t) - j Z_s(t)$ represents all NLOS components

The Rician fading has a very important parameter called the K factor.

$K \triangleq$ power of the LOS component / total power of all other scattered components

$$= \frac{\alpha_0^2}{2\sigma_z^2}$$

As K approaches to zero (0), the Rician distribution approaches to Rayleigh distribution. i.e. LOS → NLOS (fading)

## **Rayleigh Fading: (NLOS Propagation)**

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver.
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. It is the specialized model for fading when there is no line of sight signal, and is sometimes considered as a special case of the more generalized concept of Rician fading. In probability theory and statistics, the Raleigh 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.

In this case,

$$E[Z_c(t)] = E[Z_s(t)] = 0$$

Assume, at any time t, for n=1,2,….,n

the values of $\theta_n(t)$ are statistically independent, each being uniformly distributed over [0,2π] the values of $\alpha_n(t)$ are identically distributed random variables , independent of each other and of the $\theta_n(t)$'s.

As K approaches to infinity (∞), the Rayleigh distribution approaches to Rician distribution. i.e. NLOS → LOS (no fading)

As a result, wireless channel approaches an AWGN (Additive White Gaussian Noise) channel.φ

## Delay spread:

Multipath delays occur as a transmitted signal is reflected by objects in the environment between a transmitter and a receiver. These objects can be buildings, tree, hills, or even trucks and cars. The reflected signals arrive at the receiver with a random phase offset, since each reflected signal generally follows a different path to reach the user's receiver, resulting in a random signal that fades as the reflections destructively or constructively superimpose on one another. This effectively cancels or adds part of signal energy for brief periods of time. The degree of fading will depend on the delay spread of the reflected signals as embodied by their relative phases, and their relative power.

Time dispersion occurs when the channel is band-limited or when the coherence bandwidth of the channel is smaller than the modulation bandwidth. The time dispersion leads to inter-symbol, thereby increasing the bit-error rate (BER).

In many instances, the fading due to multipath delay will be frequency selective, randomly affecting only a portion of the overall channel bandwidth at a given time. In the case of frequency selective fading, the delay spread exceeds the symbol duration. On the other hand, when there is no dispersion and delay spread is less than the symbol duration, the fading will be flat, thereby affecting all frequencies in the signal equally. Flat fading can lead to deep fades of more than 30 to 40 dB.

## Doppler shift:

Doppler shift is the random changes in a channel introduced as a result of a mobile user’s mobility. Doppler spread has the effect of shifting or spreading the frequency components of a signal. This is described in terms of frequency dispersion. Like the coherence bandwidth, coherence time is defined as the time over which the channel can be assumed to be constant. The coherence time of the channel is the inverse of the Doppler spread.

## 1.5 Multiple Access Techniques:

## FDMA (Frequency-division multiple access):

**Frequency Division Multiple Access** or **FDMA** is a channel access method used in multiple-access protocols as a channelization protocol. FDMA gives users an individual allocation of one or several frequency bands, or channels. Multiple Access systems coordinate access between multiple users. Each user transmits and receives at different frequencies as each user gets a unique frequency slot.

It is important to distinguish between FDMA and frequency-division duplexing (FDD). While FDMA allows multiple users simultaneous access to a certain system, FDD refers to how the radio channel is shared between the uplink and downlink (for instance, the traffic going back and forth between a mobile-phone and a base-station). Furthermore, frequency-division multiplexing (FDM) should not be confused with FDMA. The former is a physical layer technique that combines and transmits low-bandwidth channels through a high-bandwidth channel. FDMA, on the other hand, is an access method in the data link layer.

FDMA also supports demand assignment in addition to fixed assignment. Demand Assignment allows all users apparently continuous access of the radio spectrum by assigning carrier frequencies on a temporary basis using a statistical assignment process.

This requires expensive and bulky duplex filters to avoid strong transmit signals leaking into the receiver. An example of FDMA is AM or FM radio broadcasting, where each station has its own channel.

## TDMA(Time division multiple access):

TDMAis a channel access method for shared medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using his own time slot. This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only a part of its channel capacity. TDMA is used in the digital 2G cellular systems such as Global System for Mobile Communications (GSM), IS-136, Personal Digital Cellular (PDC) ,and in the Digital Enhanced Cordless Telecommunications (DECT) standard for portable phones. It is also used extensively in satellite systems, and combat-net radio systems. TDMA is a type of Time-division multiplexing, with the special point that instead of having one transmitter connected to one receiver, there are multiple transmitters. In the case of the *uplink* from a mobile phone to a base station this becomes particularly difficult because the mobile phone can move around and vary the *timing advance* required to make its transmission match the gap in transmission from its peers.

## CDMA(Code division multiple access):

**Code division multiple access** (**CDMA**) is a channel access method utilized by various radio communication technologies. It should not be confused with the mobile phone standards called cdmaOne and CDMA2000 (which are often referred to as simply "CDMA"), which use CDMA as an underlying channel access method.

One of the basic concepts in data communication is the idea of allowing several transmitters to send information simultaneously over a single communication channel. This allows several users to share a bandwidth of different frequencies. This concept is called multiplexing. CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow multiple users to be multiplexed over the same physical channel. By contrast, time division multiple access (**TDMA**) divides access by time, while frequency-division multiple access (**FDMA**) divides it by frequency. CDMA is a form of "spread-spectrum" signaling, since the modulated coded signal has a much higher data bandwidth than the data being communicated. The CDMA channel is nominally 1.23 MHz wide. CDMA networks use a scheme called soft handoff, which minimizes signal breakup as a handset passes from one cell to another. The combination of digital and spread-spectrum modes supports several times as many signals per unit bandwidth as analog modes. CDMA is compatible with other cellular technologies; this allows for nationwide roaming. One of the early applications for code division multiplexing is in GPS. This predates and is distinct from cdmaOne.

## 1.6 Multiplexing techniques:

Multiplexing is the process where multiple channels are combined for transmission over a common transmission path.

There are two predominant ways to multiplex:

i) Frequency Division Multiplexing
ii) Time Division Multiplexing

## Frequency Division Multiplexing (FDM):

In FDM, multiple channels are combined onto a single aggregate signal for transmission. The channels are separated in the aggregate by their frequency. FDM means that the total bandwidth available to the system is divided into a series of nonoverlapping frequency sub-bands that are then assigned to each communicating source and user pair. Figures a and b show how this division is accomplished for a case of three sources at one end of a system that are communicating with three separate users at the other end. Note that each transmitter modulates its source's information into a signal that lies in a different frequency sub-band (Transmitter 1 generates a signal in the frequency sub-band between 92.0 MHz and 92.2 MHz, Transmitter 2 generates a signal in the sub-band between 92.2 MHz and 92.4 MHz, and Transmitter 3 generates a signal in the sub-band between 92.4 MHz and 92.6 MHz). The signals are then transmitted across a common channel.

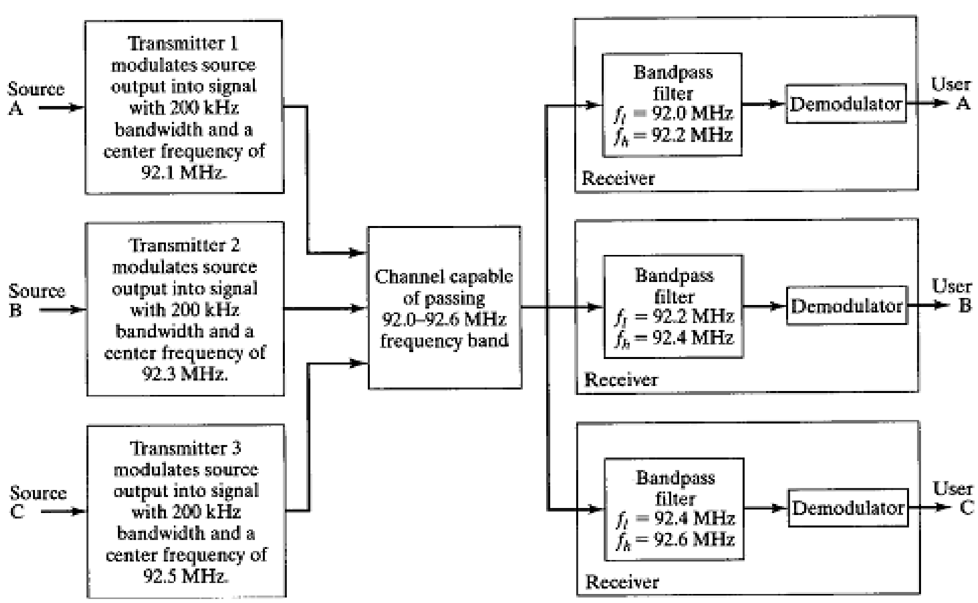
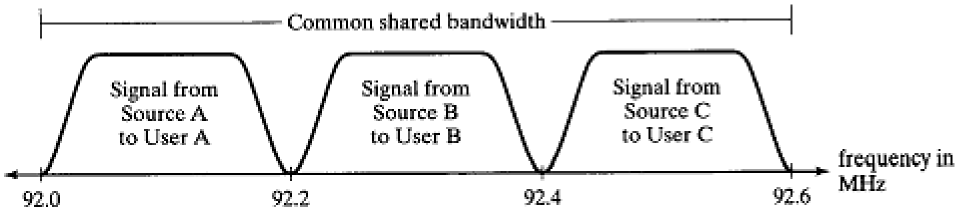



**Figure 2**—A system using frequency division multiplexing.




Figure

**Figure 3**—Spectral occupancy of signals in an FDM system.

At the receiving end of the system, bandpass filters are used to pass the desired signal (the signal lying in the appropriate frequency sub-band) to the appropriate user and to block all the unwanted signals. To ensure that the transmitted signals do not stray outside their assigned sub-bands, it is also common to place appropriate passband filters at the output stage of each transmitter. It is also appropriate to design an FDM system so that the bandwidth allocated to each sub-band is slightly larger than the bandwidth needed by each source. This extra bandwidth, called a  guardband allows systems to use less expensive filters (i.e., filters with fewer poles and therefore less steep rolloffs).

## Time Division Multiplexing (TDM):

It's often practical to combine a set of low-bit-rate streams, each with a fixed and pre-defined bit rate, into a single high-speed bit stream that can be transmitted over a single channel. This technique is called time division multiplexing (TDM) and has many applications, including wireline telephone systems and some cellular telephone systems. The main reason to use TDM is to take advantage of existing transmission lines. It would be very expensive if each low-bit-rate stream were assigned a costly physical channel that extended over a long distance.

Consider, for instance, a channel capable of transmitting 192 kbit/sec from Chicago to New York. Suppose that three sources, all located in Chicago, each have 64 kbit/sec of data that they want to transmit to individual users in New York. As shown in Figure c, the high-bit-rate channel can be divided into a series of time slots, and the time slots can be alternately used by the three sources. The three sources are thus capable of transmitting all of their data across the single, shared channel. Clearly, at the other end of the channel (in this case, in New York), the process must be reversed (i.e., the system must divide the 192 kbit/sec multiplexed data stream back into the original three 64 kbit/sec data streams, which are then provided to three different users). This reverse process is called demultiplexing.

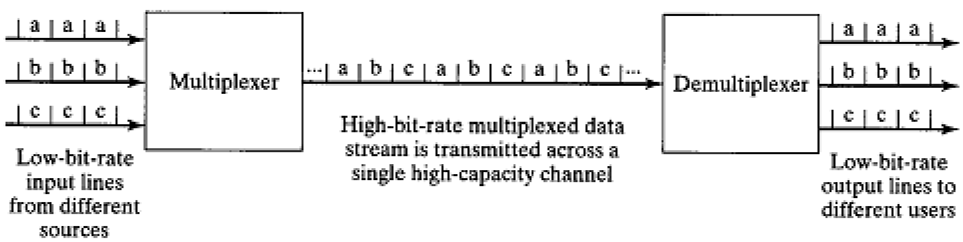



**Figure 4**—Time division multiplexing.

Choosing the proper size for the time slots involves a trade-off between efficiency and delay. If the time slots are too small (say, one bit long) then the multiplexer must be fast enough and powerful enough to be constantly switching between sources (and the demultiplexer must be fast enough and powerful enough to be constantly switching between users). If the time slots are larger than one bit, data from each source must be stored (buffered) while other sources are using the channel. This storage will produce delay. If the time slots are too large, then a significant delay will be introduced between each source and its user. Some applications, such as teleconferencing and videoconferencing, cannot tolerate long delays.

## Demultiplexing:

Separating two or more signals that have been combined into one signal. Demultiplexing is the extraction of the original channels on the receiver side. A device that performs the demultiplexing process is called a demultiplexer (DEMUX). The demultiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals. The individual signals are then passed to a demodulator that separates them from their carriers and passes them to the output lines.

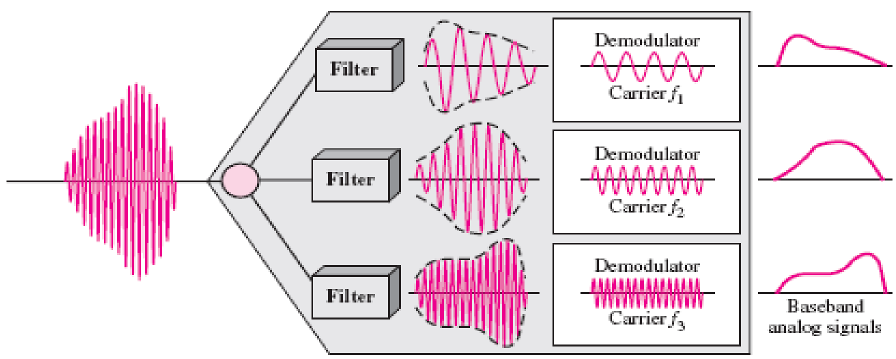



**Figure-5**

## 1.7 Diversity in Wireless Communication:

To combat multipath fading diversity is an efficient way.

## Why  Diversity ?

Diversity improves transmission performance by making use of more than one independently faded version of the transmitted signal. If several replicas of the signal, carrying the same information, are received over multiple channels the chances that all the independently faded signal components experience deep fading simultaneously are greatly reduced. That will significantly improve transmission accuracy as transmission errors are most likely to happen when SNR (signal to noise ratio) is low during deep fading period.  So diversity is a common used technique in wireless system to combat channel fading.

## Types of Diversity:

The following sections describe the various ways of obtaining independently faded signals:

## Frequency Diversity:

The desired message is transmitted simultaneously over several frequency slots. The separation between adjacent frequency slots should be larger than the channel coherence bandwidth such that channel fading over each slot is independent of that in any other slot. By using redundant signal transmission, this diversity improves link transmission quality at the cost of extra frequency bandwidth.

## Time Diversity:

The desired message is transmitted repeatedly over several time periods. The time separation between adjacent transmissions should be larger than the channel coherence time such that the channel fading experienced by each transmission is independent of the channel fading experienced by all of the other transmission. In addition to extra system capacity (in terms of transmission time) due to the redundant transmission, this diversity introduces a significant signal processing delay, especially when the channel coherence time is large. In practice, time diversity is more frequently exploited through interleaving, forward-error correction, and automatic retransmission request (ARQ).

## Space diversity:

The desired message is transmitted by using multiple transmitting antennas and/or receiving antennas. The space separation between adjacent antennas should be large enough to ensure that the signals from different antennas are independently faded. In a Rayleigh fading environment, it can be shown that, if two antennas are separated by half of the carrier wavelength, the corresponding two signals experience independent fading. Taking into account the shadowing effect, usually a separation of at least 10 carrier wavelengths is required between two adjacent antennas. This diversity does not require extra system capacity; however, the cost is the extra antennas needed.

## Angle Diversity:

The desired message is received simultaneously bt several directive antennas pointing in widely different directions. The received signals consists of waves coming from all directions. It has been observed that the scattered signals associated with the different (non overlapping) directions are uncorrelated. Angle diversity can be viewed as a special case of space diversity since it also requires multiple antennas.

## **Path Diversity:**

In CDMA cellular networks, the use of direct sequence spread spectrum modulation techniques permits the desired signal to be transmitted over a frequency bandwidth much larger than the channel coherence bandwidth. The spread spectrum signal can resolve multipath signal components as long as the path delays are separated by at least one cheap period. A rake receiver can separate the received signal components from different propagation paths by using code correlation and can then combine the signal components constructively. In CDMA, exploiting the path diversity reduces the transmitted power needed and increases the system capacity.

## **Polarization Diversity:**

The horizontal and vertical polarization components transmitted by two polarized antennas at the base station and received by two polarized antennas at the mobile station can provide two uncorrelated fading signals. Polarization diversity results in 3dB power reduction at the transmitting site since the power must be split into two different polarized antennas.

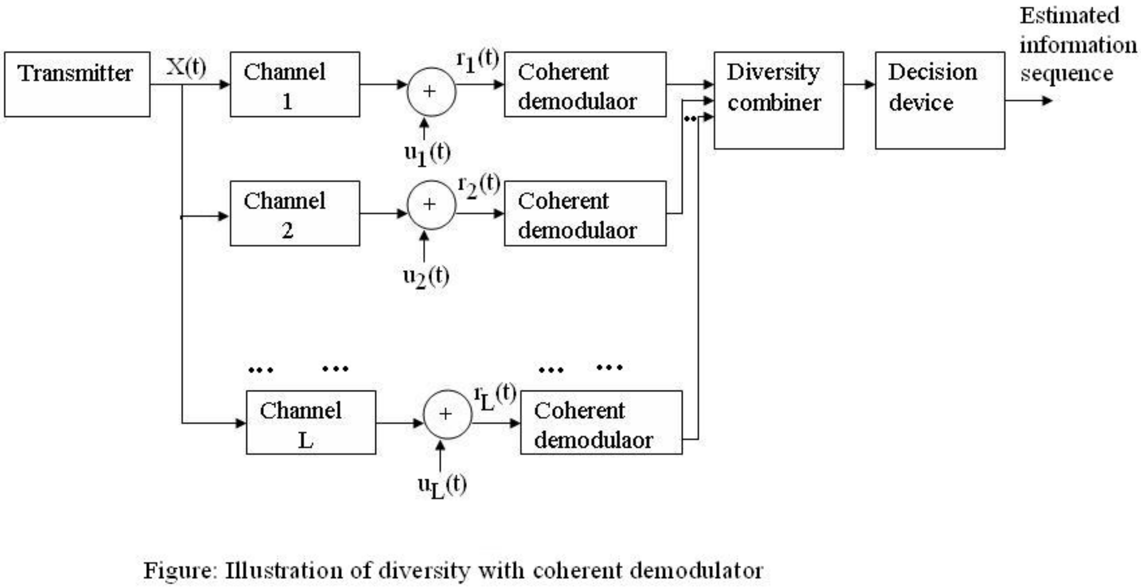



**Fig 6: diversity with coherent demodulator**

## 1.8 Combining techniques:

## Linear Combining:

After obtaining independently faded signal components at the output of the demodulators ,the next step is to combine these signal components for transmitted symbol detection. Various methods have been proposed for combining independently faded signal components , and the tradeoff among these methods is receiver complexity versus transmission performance improvement .Linear combining techniques include those discussed in the following sections.

## Different types of Linear Combining :

## Maximal ratio Combining:

In this combining technique the receiver is able to accurately estimate the amplitude fading and carrier phase distortion for each diversity channel .with the complex channel gains ,the receiver coherently demodulates the received signal from each branch .The phase distortion is removed from the L-th branch by multiplying the signal component with complex term. The coherently detected signal is then weighted by the corresponding amplitude gain .The weighted received signals from all the L branches are then summed together and applied to the decision device .Maximal ratio combining achieves the best performance.

## Equal-Gain Combining:

The maximal ratio combining approach an accurate estimate of the channel amplitude gain .Which increases the receiver complexity .An alternative approach is to weight all the signals equally after coherent detection ,which removes the phase distortion .the coherently detected signals from all the L branches are simply added and applied to the decision device .As the receiver does not need to estimate the amplitude fading ,its complexity is reduced as compared with that of maximal ratio combining.

## Selective Combining:

In this scheme ,the receiver monitors the SNR value of each diversity channel and chooses the one with the maximum SNR value for signal detection .Compared with the preceding two schemes ,selective diversity is much easier to implement without much performance degradation ,especially located in different base stations ,which would make it difficult to use maximal ratio combining or equal gain combining.

## Why we used Maximal Ratio Combining?

Among the three combining schemes, selective combining is  easier to implement without much performance degradation. But Maximal Ratio Combining achieves the best performance.

## 1.9 Digital Modulation:

There are different types of digital modulations- MPSK (M-ary phase shift keying), QPSK ( Quadrature phase shift keying), DQPSK (differential quadrature phase shift keying), MSK (minimum shift keying), BPSK (binary phase shift keying), FSK (frequency shift keying)  etc. Throughout our work we have considered a coherent PSK reception over an AWGN channel.

## 1.10 Phase-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.

## 1. 11 Objective of the Thesis Work:

Performance analysis is carried out for an wireless communication system incorporating multiple transmitting antenna and multiple receiving antenna with space time block coding (STBC). The analysis includes the effect of channel impairments like fading, delay spread. The results are evaluated numerically to evaluate the effect of channel impairments on the system performance and to find the improvement in performance due to multiple transmitting and receiving antenna configuration. The Maximal Ratio Combining technique is used to find the performance results.

## 1.12 Project Overview:

### 1.12.1 STBC coded MIMO System:

The application of multiple- input multiple- output (MIMO) technologies will be a key ingredient for future wireless systems with high data rate, particularly WLAN and 4G cellular systems. All proposals for the new WLAN standard IEEE 802.11n include MIMO modes.

MIMO is one of several forms of smart antenna technology .The motivation for using multiple antennas at transmitter and receiver (MIMO) comes from information theory. Huge capacity gains are promised in rich scattering fading environments. Link range without additional bandwidth or transmit power, and link reliability or diversity (reduced fading) are also reasons that the system has attracted attention in wireless communications. More specific, it is shown that the capacity can be increased linearly with the number of transmit antennas as long as at least as many receive antennas as transmit antennas are used.

A large number of proposals for transmission schemes which try to exploit those capacities has been published during the last years. Virtually all of them can be viewed as hybrid forms of two fundamental approaches: Spatial Multiplexing and Transmit Diversity.

In spatial multiplexing, independent data is transmitted simultaneously from different antennas. Another strategy is to transmit same data via different transmit antennas in order to obtain transmit diversity. This is the goal of space-time-codes. Space time block coding (STBC) is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. The fact that the transmitted signal must traverse a potentially difficult environment with scattering, reflection, refraction and so on and may then be further corrupted by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This redundancy results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal. In fact, space–time coding combines *all* the copies of the received signal in an optimal way to extract as much information from each of them as possible. STBC provides maximum possible level of spatial diversity. Simply put, spatial multiplexing provides “more bits” whereas transmit diversity provides “better bits”.

### 1.12.2 Why MIMO ? - Antenna diversity

• Antenna diversity techniques are commonly utilized at the base stations due to less constraints on both antenna space and power. In addition, it is more economical to add more complex equipment to the base stations rather than at the remote units.

• To increase the quality of the transmission and reduce multipath fading at the remote unit, it would be beneficial if space diversity also could be utilized at the remote units.

• In 1998, S. M. Alamouti published a paper entitled ”A simple transmit diversity technique for wireless communications". This paper showed that it was possible to generate the same diversity order traditionally obtained with SIMO system with a Multiple-Input Single-Output (MISO) system.

• The generalized transmission scheme introduced by Alamouti has later been known as Space-Time Block Codes (STBC).

### 1.12.3 <u>Why STBC ? – Capacity perspective</u>

• STBC are useful since they are able to provide full diversity over the coherent, flat-fading channel.

• In addition, they require simple encoding and decoding.

• Although STBC provide full diversity at a low computational cost, it can be shown that they incur a loss in capacity because they convert the matrix channel into a scalar AWGN channel whose capacity is smaller than the true channel capacity.

(S. Sandu, A. Paulraj,"Space-time block codes: A capacity perspective," IEEE Communications)

• The capacity difference is a function of the channel singular values. This can used to determine under which conditions STBC is optimal in terms of capacity.

• When the channel matrix is a rank one matrix, there is only a single non-zero singular value, i.e., a space-time block code is optimal (with respect to capacity) when it is rate one ($K = T$) **and** it is used over a channel of rank one [Sandhu,2000].

• For the i.i.d. Rayleigh channel with $n_R > 1$, the rank of the channel matrix is greater than one, thus a space- time block code of any rate

used over the i.i.d. Rayleigh channel with multiple receive antennas
always incurs a loss in capacity.

• A full rate space-time block code used over any channel with one
receive antenna is always optimal with respect to capacity.

• Essentially, STBC trades off capacity benefits for low complexity encoding
and decoding.

### 1.12.4 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.

### 1.12.5 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.

# Chapter-2

## Theoretical Analysis of Wireless Link with fading

### 2.1 Diversity and Combining Techniques of System:

A system is characterized by how it responds to input signals. In general, a system has one or more input signals and one or more output signals. Therefore, one natural characterization of systems is by how many inputs and outputs they have:

- SISO (Single Input, Single Output)
- SIMO (Single Input, Multiple Outputs)
- MISO (Multiple Inputs, Single Output)
- MIMO (Multiple Inputs, Multiple Outputs)

It is often useful (or necessary) to break up a system into smaller pieces for analysis. Therefore, we can regard a SIMO system as multiple SISO systems (one for each output), and similarly for a MIMO system. By far, the greatest amount of work in system analysis has been with SISO systems, although many parts inside SISO systems have multiple inputs (such as adders).

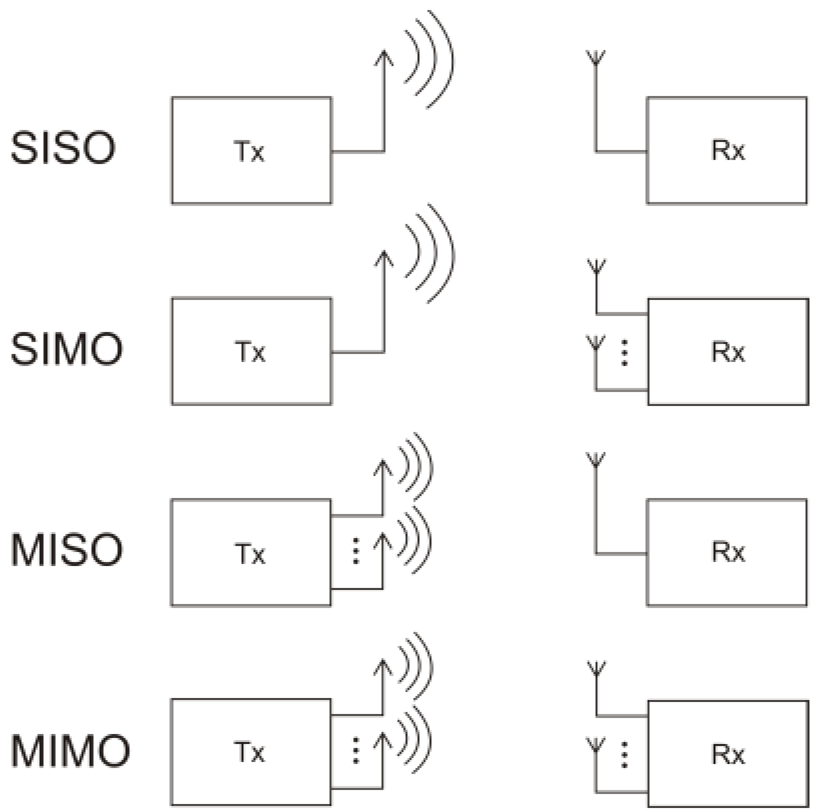



**Figure7- Diversity and Combining Techniques of System**

## SISO (Single Input, Single Output) :

**SISO** is an acronym for single-input and single-output system. Single Input Single Output is a form of antenna technology for wireless communications in which a single antenna at both the transmitter and at the destination (receiver) are used.

## SIMO: Single Input Multiple Output

Single Input Multiple Output (SIMO) is a form of smart antenna technology for wireless communications in which a single antenna at the transmitter and multiple antennas are used at the destination (receiver). An early form of SIMO, known as diversity reception, has been used by military, commercial, amateur, and shortwave radio operators at frequencies below 30 MHz since the First World War.

## MISO: Multiple Input, Single Output

Multiple Input Single Output (MISO) is a smart antenna technology that uses multiple transmitters and a single receiver on a wireless device to improve the transmission distance. MISO technology can be applied in areas such as Digital TeleVision (DTV), Wireless Local Area Networks (WLANs), Metropolitan Area Networks (MANs), and mobile communications. The implementation of MISO would include multiple antennas at the source, or transmitter, and the destination, or receiver, has only one antenna -- the antennas are combined to minimize errors and optimize data speed

## .MIMO (multiple-input and multiple-output):

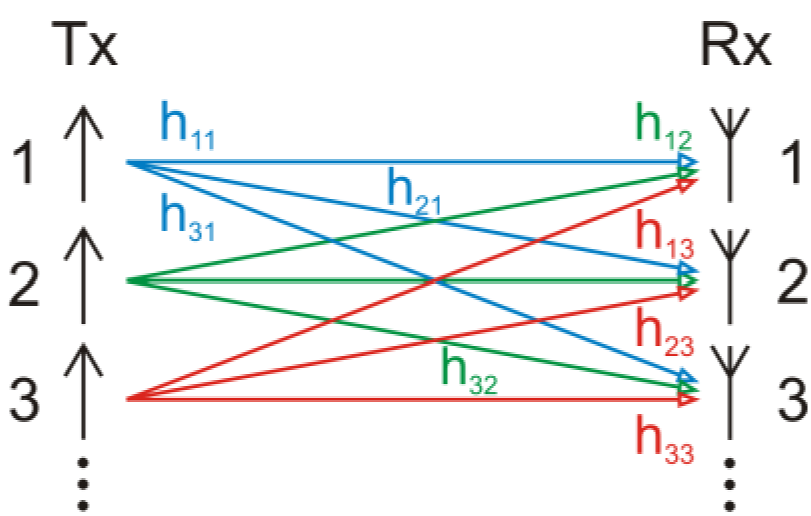



**Fig 8: MIMO**

A technique for increasing wireless bandwidth by spatial antenna diversity, MIMO is incorporated into IEEE 802.11n specifications for wireless LAN (WLAN) and 802.16 specifications for broadband wireless access (BWA), more commonly known as WiMAX. As radio signals travel from transmitter to receiver in an enclosed space, they propagate along multiple paths. The signal elements traveling a direct path along a line of sight (LOS) arrive first and strongest. Those that travel the least direct paths, having reflected off walls, floors, ceiling, potted plants, people, and other obstructions, not only arrive last, but also suffer the greatest attenuation due to absorption, diffusion, and other contributing factors. MIMO technology employs multiple spatially diverse transmit antennas to actually encourage the signals to traverse multiple paths and multiple receive antennas to extract additional information from the signals that do so. MIMO algorithms in the receive device correlate and recombine the signals, realizing diversity gain, i.e., an increase in signal strength, in the process. MIMO technology doubles the spectral efficiency. The 802.11n MIMO technology, for example, is expected to yield a theoretical maximum signaling rate of 108 Mbps, compared to the 54 Mbps yielded by the earlier 802.11g technology. See also 802.11g, 802.11n, 802.16, absorption, attenuation, bandwidth, BWA, diffusion, gain, IEEE, LOS, spatial diversity, spectral efficiency, WiMAX, and WLAN.

From the fig. MIMO we can see that, In MIMO systems, a transmitter sends multiple streams by multiple transmit antennas. The transmit streams go through a matrix channel which consists of multiple paths between multiple transmit antennas at the transmitter and multiple receive antennas at the receiver. Then, the receiver gets the received signal vectors by the multiple receive antennas and decodes the received signal vectors into the original information.

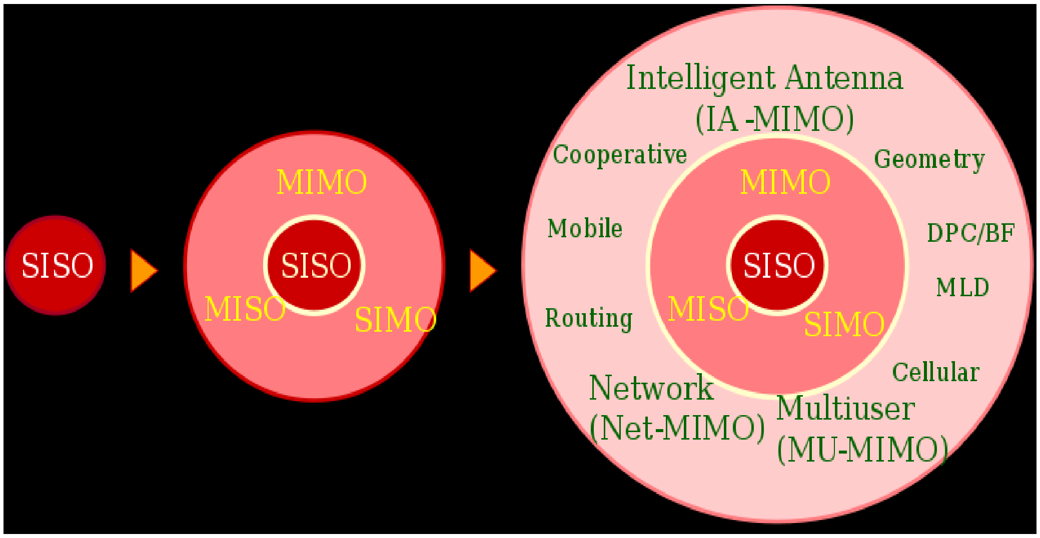



**Fig 9: from SISO to advanced MIMO system**

## 2.2 System Model

In this paper we propose a distributed system for facilitating MIMO transmissions in networks without multiple antenna devices. MIMO diversity is achieved by employing multiple antenna in the source and destination to help with the transmission. Space-time block codes (STBC) and code combining are used to utilize spatial diversity. The BER of the proposed system is shown and discussed on the result part.

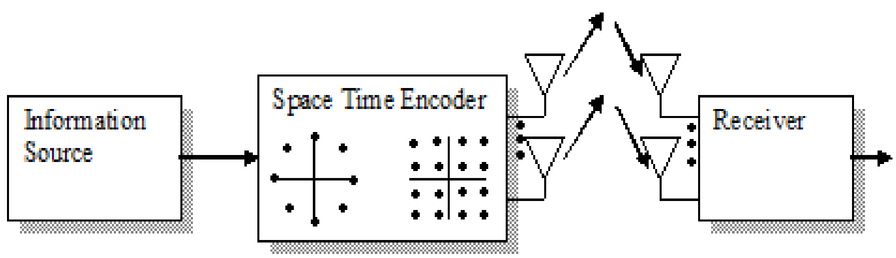



Figure: Space Block Diagram

**Fig-10 space block diagram**

## 2.2.1 Alamouti STBC codes with 2 transmitting and 2 receiving antennas:

For the discussion, we will assume that the channel is a flat fading Rayleigh multipath channel and the modulation is BPSK. The principle of space time block coding with 2 transmit antenna and one receive antenna is explained in the post on Alamouti STBC. With two receive antenna’s the system can be modeled as shown in the figure below.

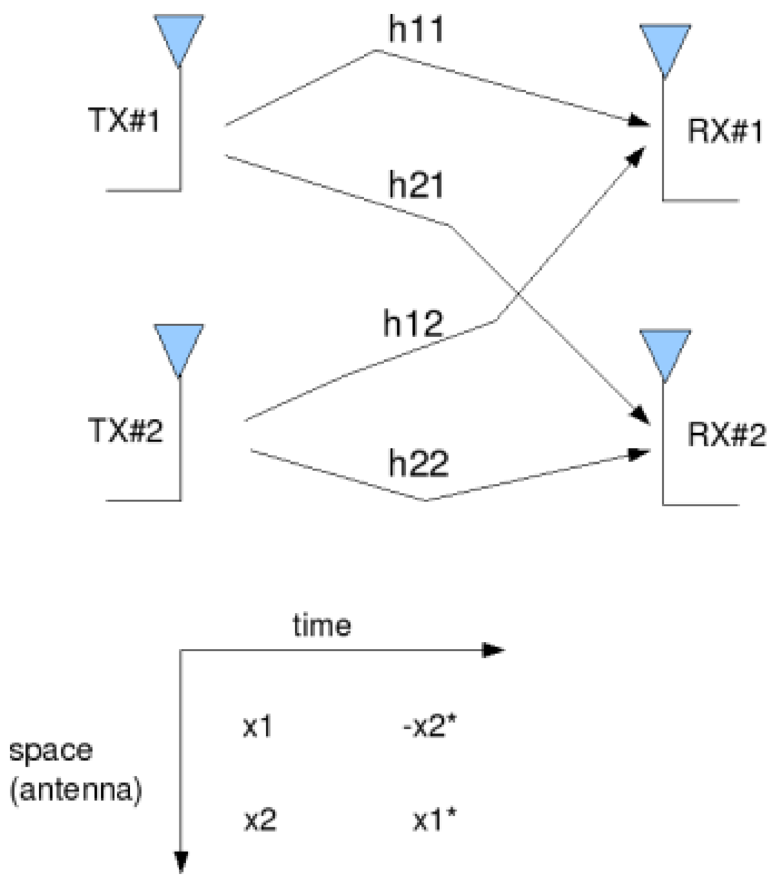



**Figure 11- 2 Transmit 2 Receive Alamouti STBC**

The received signal in the first time slot is,

$$\begin{bmatrix} y_1^1 \\ y_2^1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_2^1 \end{bmatrix}$$

Assuming that the channel remains constant for the second time slot, the received signal is in the second time slot is,

$$\begin{bmatrix} y_1^2 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} -x_2^* \\ x_1^* \end{bmatrix} + \begin{bmatrix} n_1^2 \\ n_2^2 \end{bmatrix}$$

Where $\begin{bmatrix} y_1^1 \\ y_2^1 \end{bmatrix}$ are the received information at time slot 1 on receive antenna 1, 2

respectively,

$\begin{bmatrix} y_1^2 \\ y_2^2 \end{bmatrix}$ are the received information at time slot 2 on receive antenna 1, 2

respectively,

$h_{ij}$ is the channel from $i^{th}$receive antenna to $j^{th}$transmit antenna,

$x_1$, $x_2$are the transmitted symbols,

$\begin{bmatrix} n_1^1 \\ n_2^1 \end{bmatrix}$ are the noise at time slot 1 on receive antenna 1, 2 respectively and

$$\begin{bmatrix} n_1^2 \\ n_2^2 \end{bmatrix}$$ are the noise at time slot 2 on receive antenna 1, 2 respectively.

Combining the equations at time slot 1 and 2,

$$\begin{bmatrix} y_1^1 \\ y_2^1 \\ y_y^{2^*} \\ y_2^{2^*} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_2^1 \\ n_y^{2^*} \\ n_2^{2^*} \end{bmatrix}$$

## 2.2.2 STBC-MIMO transmission:

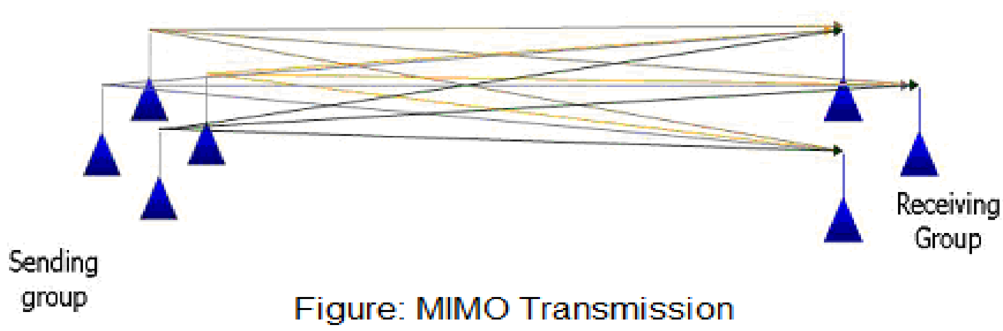



**Fig-12 MIMO Transmission**

Once the encoded signal is received at the transmitter, the transmitting antenna sources encodes the information bits of the data packet using error correction codes.

The source antenna also specifies which row in the STBC matrix it is supposed to use. The distance between the transmitting antennas is quite short. Although the configuration of STBC is smart enough to detect the appropriate signals for each antenna.

## Data collection and combining :

After receiving the data from the transmitting antennas, each antenna in the receiving
side uses the channel state information and estimated carrier frequency offsets
to decode

the space-time block coded data. After decoding for STBC, each antenna in the receiving group matches the space-time block coded data. If the original data is decoded correctly, the signal is transmitted properly. Otherwise retransmission is required.

## 2.2.3 Analysis of BER without fading : SISO

Without any fading, over a coherent AWGN (Additive White Gaussian Noise) channel the probability of symbol error or bit error rate (BER) of an antenna is,

$$P_b = Q\sqrt{\frac{2E_b}{N_0}}$$

Here, Q is the Marcum's Q function

Eb/N0 is the signal to noise ratio, SNR

## 2.3 Analysis of BER ( Bit Error Rate) with fading:

### 2.3.1 Analysis of BER ( Bit Error Rate) with fading for SISO:

Now we consider a stationary flat and slow fading channel where (a) the delay spread antroduced by the multipath propagation environment is negligible compared with the symbol interval

(b) channel fading status does not change much over a number of symbol intervals.

The transmitted signal is considered to have a constant bit energy $E_b$ and the received signal has instantaneous bit energy equal to $\alpha^2 E_b$ , where $\alpha$ is the amplitude fading in the symbol interval. Based on the transmission performance analysis for an AWGN channel, for given modulation scheme, its probability of bit error can be represented as a function, $P_b$ , of the received bit energy to the one-sided noise power spectral density $E_b / N_0$ (or SNR/bit) , denoted by $\gamma_b$ . In the following , we will extend the analysis to a fading channel in two steps (a) to find the conditional probability of bit error ,given the amplitude fading, $\alpha$ ; and

(b) to average the conditional probability with respect to the pdf of $\alpha$ at $\alpha = x$ , in order to take into account the effect of all possible amplitude fading values on the transmission performance. Therefore,

$$P_b(\bar{\gamma}_b) = \int_{-\infty}^{\infty} P_{b/\alpha}(\gamma_{b/x}) f_\alpha(x) \mathrm{dx}$$

where $\bar{\gamma}_b$ is the average received SNR/bit with respect to $\alpha^2$ ,

$$\bar{\gamma}_b = \int_{-\infty}^{\infty} x^2 \gamma_b f_\alpha(x) \mathrm{dx}$$

$$= \gamma_b E(\alpha^2)$$

and $E(\alpha^2) = 2\sigma_\alpha^2$ .In this case we have, $\bar{\gamma}_b = 2\sigma_\alpha^2 \gamma_b$ . For coherent BPSK, probability of average received SNR/bit is

$$P_b(\bar{\gamma}_b) = 0.5\left[1 - \sqrt{\frac{\bar{\gamma}_b}{1+\bar{\gamma}_b}}\right]$$

## 2.3.2 Analysis of BER ( Bit Error Rate) with fading for SIMO:

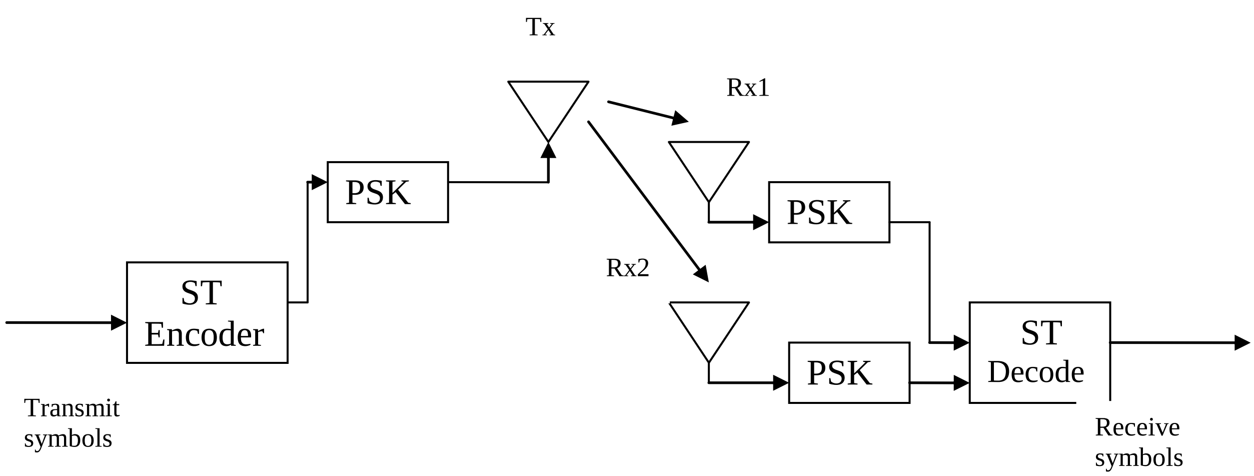



**Fig 13: Block diagram of an Alamouti coded PSK system incorporating one transmitting antenna and two receiving antenna (SIMO system)**

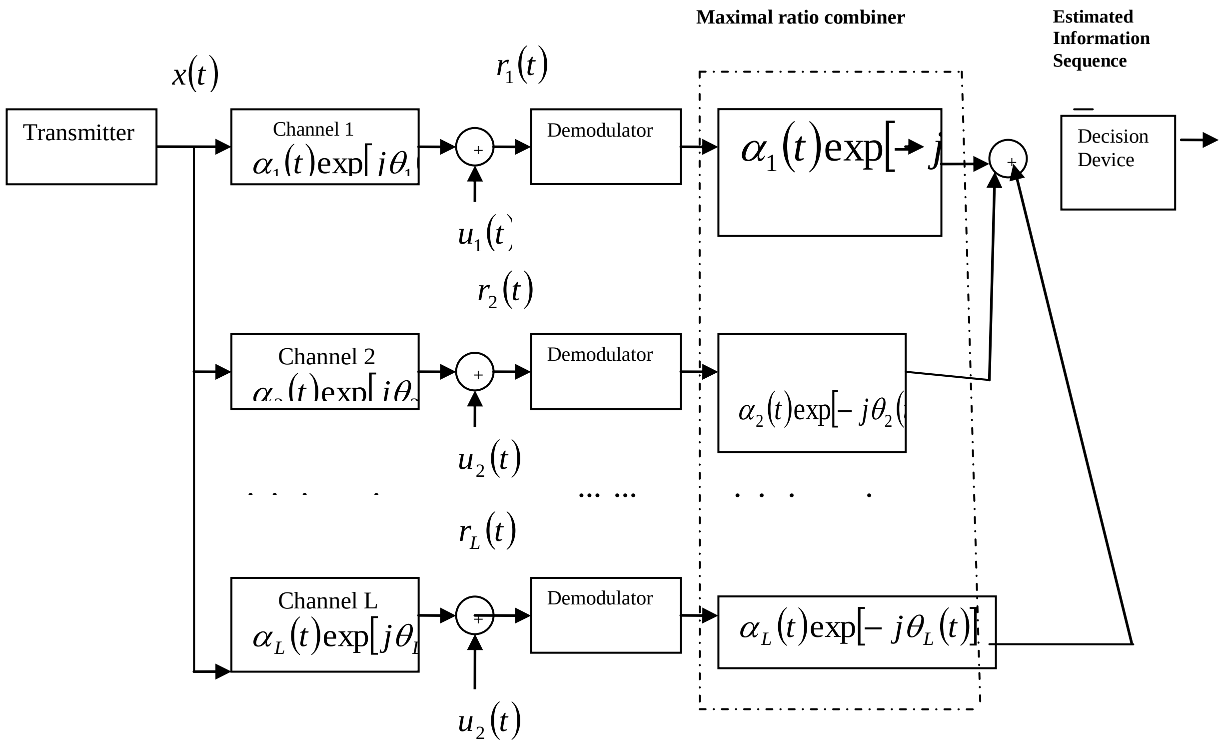



**Fig 14 : Diversity reception with Maximal Ratio Combining**

Consider transmission of a digital modulated signal x(t) over flat slow Rayleigh fading channels using coherent demodulation with Lth order diversity.

It is assumed that (a) the channel fading processes are mutually statistically independent

(b) the additive white Gaussian noise processes are mutually statistically independent, and (c) the channel fading processes and additive noise processes are independent of each other. For a slow fading channel, the complex channel gain cab be assumed to be a complex constant over each symbol interval. The demodulator in each channel is optimum for an AWGN channel.

Therefore, the output of the demodulator of the lth branch at the end of the kth symbol interval is the complex channel gain of the lth channel over the kth symbol interval. Considering maximal ratio combining

l=1,2……….L

$\Gamma_c = 2\sigma^2 E_b / N_0$ is average SNR per bit in each diversity channel.

The mean SNR per bit after the combining is

$$\Gamma_b = L\Gamma_c$$

which increases linearly with L.

Maximal ratio combining indeed gives better performance as the chances for a small instantaneous SNR are further reduced from those with selective diversity, especially with a large L. This is because maximal ratio combining makes use of the signal components in all the diversity channels and the mean SNR per bit increases linearly with L. The analysis of the probability of the bit error over a Rayleigh fading channel can be extended to the case with diversity, so that

$$\mathrm{P}_b = [0.5(1-\mu)]^L \sum_{l=0}^{L-1} \binom{L-1+l}{l} [0.5(1+\mu)]^l$$

$$\mu = \sqrt{\frac{\Gamma_c}{1+\Gamma_c}}$$

for $\Gamma_c$ >>1, the probability of error can be approximated by

$$\mathrm{P}_b \approx \left(\frac{1}{4\Gamma_c}\right)^L \binom{2L-1}{L}$$

## 2.3.3 Analysis of BER ( Bit Error Rate) with fading for MIMO:

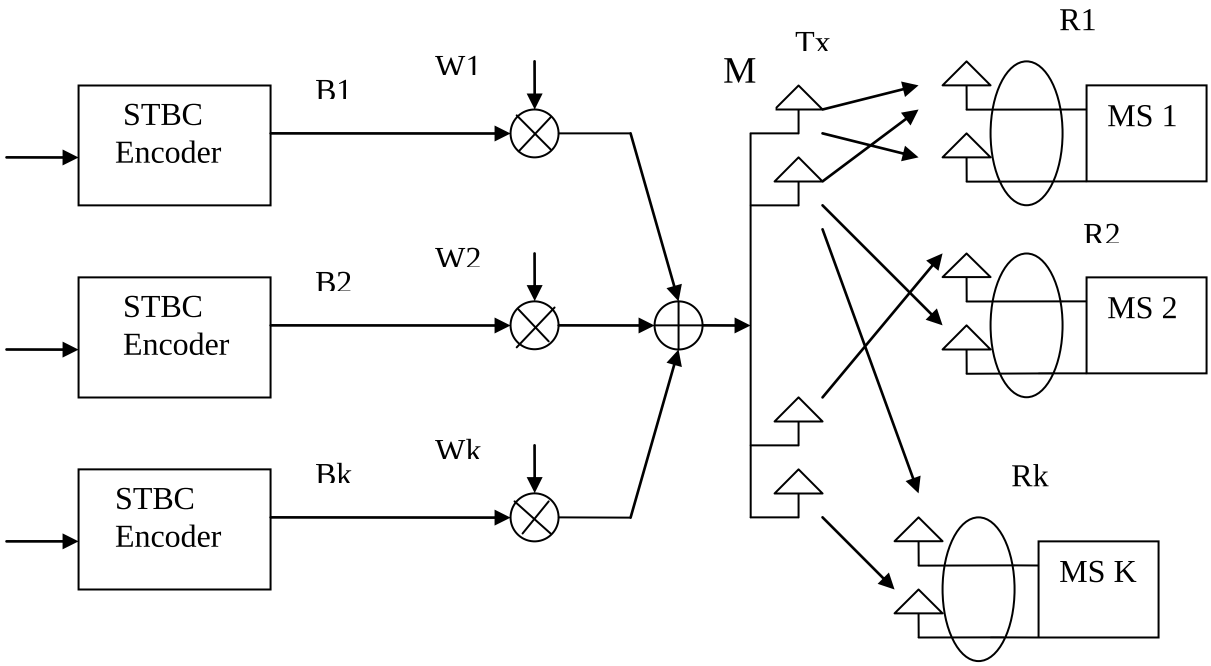



**Fig-15 Block diagram of BER ( Bit Error Rate) with fading for MIMO**

Maximal ratio combining method rises on the complex channel gains, so the weights are chosen as $w_n = h_n$.

The probability of conditional BER can be expressed as:

$$BER(u) = \frac{(1-\rho)\dfrac{(CNIR * u)}{2} + 1}{2\left\{\dfrac{(CNIR * u)}{2} + 1\right\}} \exp\left\{\frac{k\dfrac{(CNIR * u)}{2}}{\dfrac{(CNIR * u)}{2} + 1}\right\}$$

Where,

$u = |h|^2$

$h = [h_1, h_2, .....h_{n_r}]$

$\rho = J(2\pi f_D T_s)$ is the time correlation function.

When the different channels are i.i.d Rayleigh distributed, the pdf of u can be expressed as:

$$P_u(u) = \frac{1}{(n_r - 1)!} u^{n_r - 1} e^{-u}$$

Where,

$n_r = 1,2,3,......$ = no. of receiving antenna.

The expression for the Probability of BER of a MIMO System over fading channel can be expressed as:

$$P_{mimo} = \int_0^{\infty} BER(u) \cdot P(u) du$$

# Chapter-3

## Results and Discussions

### Figure-16

### SNR Improvement by Selective Diversity Over Rayleigh Fading for SIMO:

Here we have considered a coherent BPSK reception over an AWGN channel, considering the detection of a symbol transmitted over time interval [0, $T_b$]. The transmitted signal is

$$x(t) = \begin{cases} \sqrt{E_{b\varphi_{1(t)}}} & \text{, for symbol "1"} \\ -\sqrt{E_{b\varphi_{1(t)}}} & \text{, for symbol "0"} \end{cases}$$

The probability of symbol error or bit error rate (BER) is,

$$P_b = Q\sqrt{\frac{2E_b}{N_0}}$$

Here Q is a function, $E_b$= signal energy of bit, $N_0$= noise

Now we consider Lth-order diversity with selective combining in a Rayleigh fading propagation environment .each diversity channel exhibits independent and identically distributes fading.

We have the cdf (cumulative distribution function),that is

$$F_\gamma(x) = \left[1 - \exp\left(\frac{-x}{\Gamma_c}\right)\right]^L$$

Let x is the SNR; then pdf of x is given by,

$$f_\gamma(x) = \frac{dF_\gamma(x)}{dx} = \frac{L}{\Gamma_c}\exp\left(\frac{-x}{\Gamma_c}\right)\left[1-\exp\left(\frac{-x}{\Gamma_c}\right)\right]^{L-1}, x \geq 0$$

Now we plotted the pdf equation in Matlab; to see the SNR improvement.

Here we have taken value,

Antenna diversity L= 1,2,4,8

Mean SNR per bit, $\Gamma_c$ =1

Received SNR, x=0 : 6

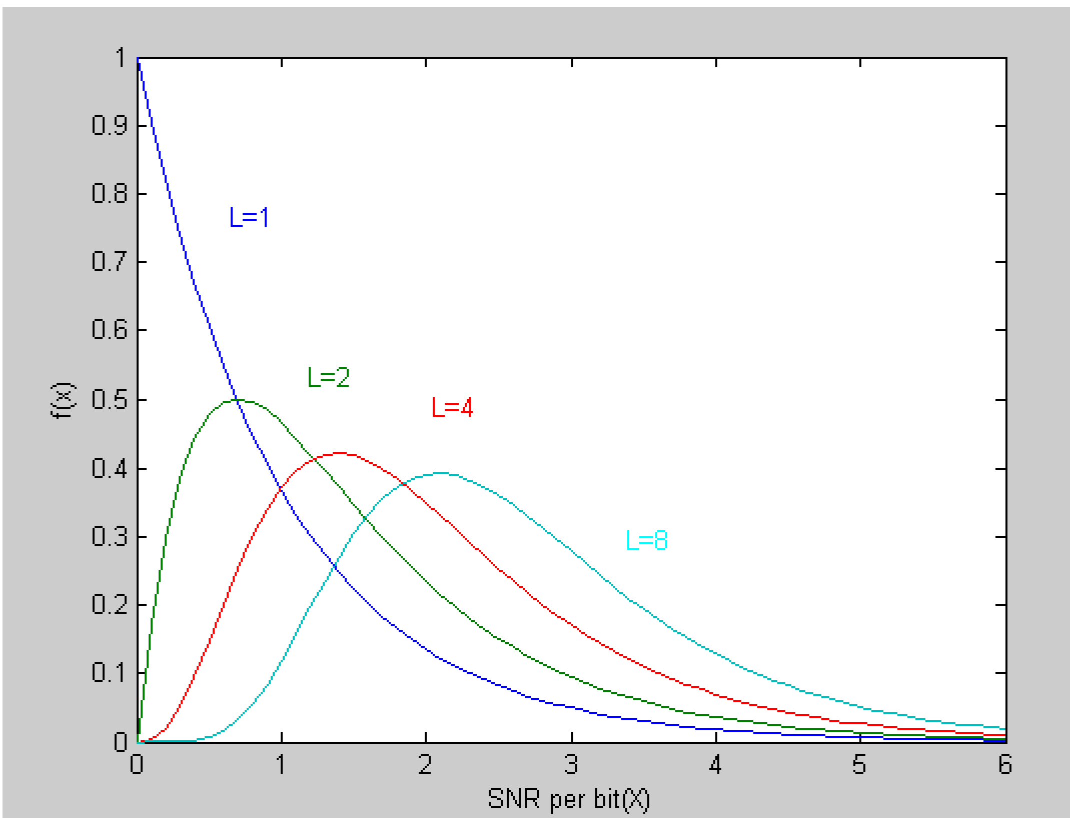



**Fig 16: probability density function (pdf) of the received SNR per bit with Selective Diversity for SIMO system**

From the figure we see that, as L increases from 1 to 8, the Pdf curve shifts from left to right explaining that SNR increases which results in better transmission performance.

**Figure-17**

## SISO - Without fading

Without fading, the probability of symbol error or bit error rate (BER) of an antenna is,

$$P_b = Q\sqrt{\frac{2E_b}{N_0}}$$

Here, Q is the Marcum's Q function

$E_b / N_0$ is the signal to noise ratio, SNR

Here we have taken values, $E_b / N_0$ =0 : 0.1 :6

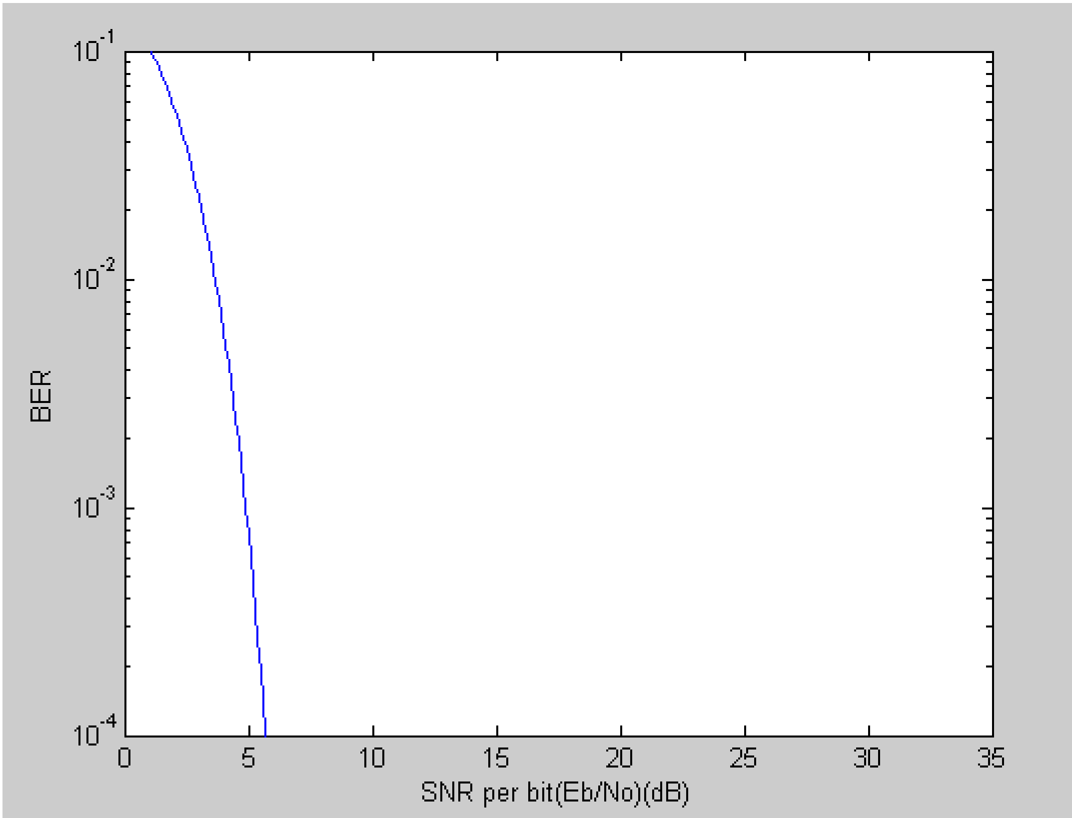



**Fig.17- SISO - Without fading**

from the figure we see that, without any fading for a transmitter antenna and a receiver antenna in an AWGN channel , as the BER decrease the SNR increases. At lowest bit error rate 10^-4 signal to noise ratio is 5.5. The graph is plotted for ideal case, that is for no fading , and no combining. This is for only an antenna. So it is for no diversity also. So the system is SISO.

## Figure-18

## SISO - With fading

In a coherent flat slow Rayleigh Fading channel ,for coherent BPSK, probability of average received SNR/bit is

$$P_b(\bar{\gamma}_b) = 0.5\left[1 - \sqrt{\frac{\bar{\gamma}_b}{1+\bar{\gamma}_b}}\right]$$

$$\bar{\gamma}_b = \gamma_b E(\alpha^2)$$

$$E(\alpha^2) = 2\sigma_\alpha^2$$

where $\bar{\gamma}_b$ is the average received SNR/bit with respect to $\alpha^2$ .In this program, we have taken values,

Received SNR/bit, $\gamma$ = 2 :0.1 :25

$\sigma$ =0.2

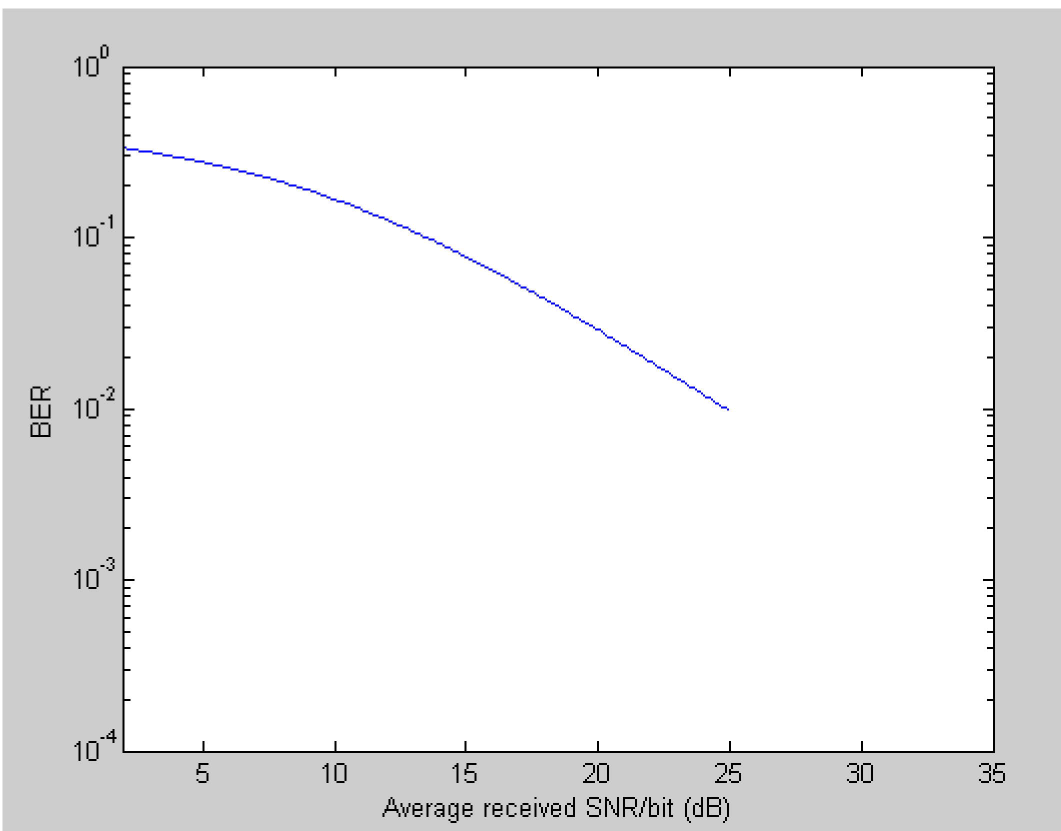



**Fig.18- SISO - With fading**

This figure shows the BER transmission performance of coherent BPSK, QPSK and MSK in a Rayleigh fading channel and an AWGN channel, respectively. It is observed that the amplitude fading severely degrades the transmission performance. In an AWGN channel, for a large value of $\gamma_b$ , the probability of error decreases linearly with respect to $\gamma_b^2$ . However, in a Rayleigh fading channel, the probability of error decreases linearly wit respect to $\bar{\gamma}_b$ for $\bar{\gamma}_b$ >> 1. The smaller the value required, the worse the performance degradation. This is because, in the fading environment the received signal amplitude changes with time. When the signal is in deep fading (i.e., $\alpha(t)$ << 1), the instantaneous SNR/bit drops significantly, resulting in a very high chance of transmission error, even though most of the time the instantaneous $\gamma_b$ value of the received signal is larger than the corresponding one in AWGN channel.

## Figure-19

## SIMO - With fading

Over a flat slow Rayleigh fading for single input multiple output antenna system

$\Gamma_c = 2\sigma^2 E_b / N_0$ is average SNR per bit in each diversity channel.

The mean SNR per bit after the combining is

$$\Gamma_b = L\Gamma_c$$

for maximal ratio combining,

l=1,2……….L

Probability of bit error is

$$\mathrm{P}_b = [0.5(1-\mu)]^L \sum_{l=0}^{L-1} \binom{L-1+l}{l} [0.5(1+\mu)]^l$$

where $\mu = \sqrt{\dfrac{\Gamma_c}{1+\Gamma_c}}$

for $\Gamma_c$>>1, the probability of error can be approximated by

$$\mathrm{P}_b \approx \left(\frac{1}{4\Gamma_c}\right)^L \binom{2L-1}{L}$$

Here we have taken values

Antenna diversity, L= 1,2,4,8

$\sigma^2 = 1.0$

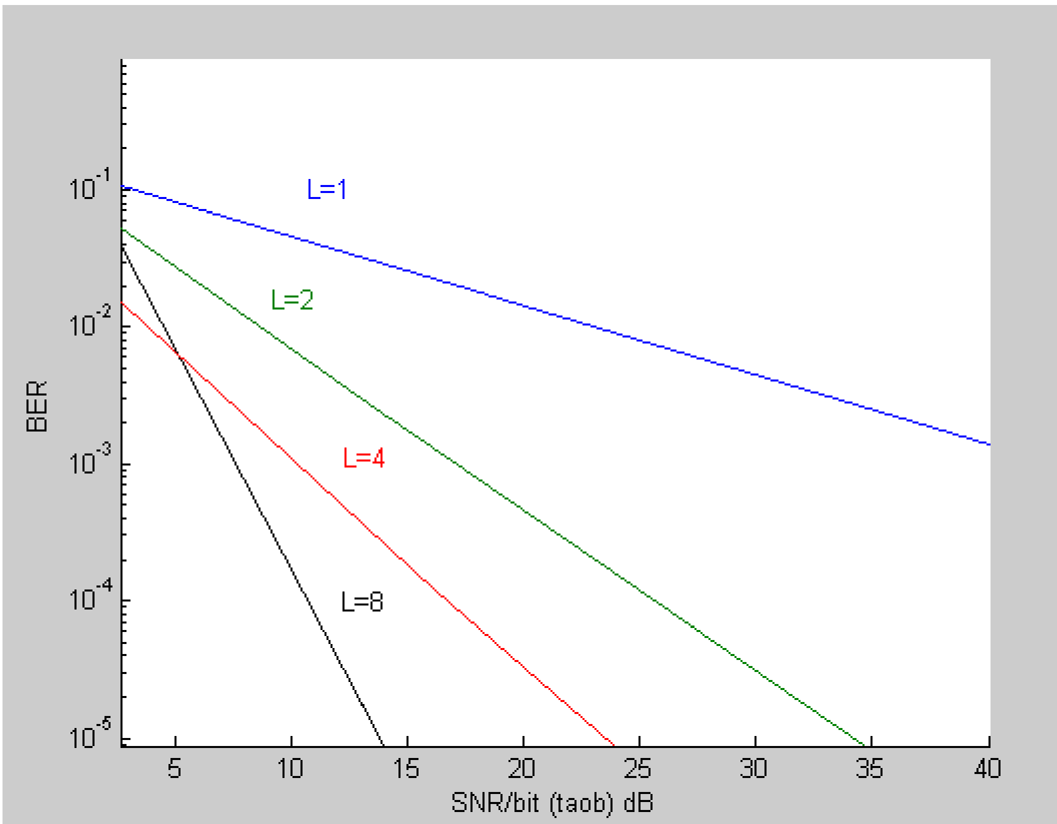



**Fig:19- SIMO - With fading**

This graph is obtained by increasing antenna at the receiver side. The system is SIMO.

From the graph we see that, with the increase of diversity from L=1 to 8 SNR (dB) reducing , but BER is also reducing. This happened since we have used maximal ratio combining, it proposes better performance, where selective diversity proposed better SNR. The figure shows the BER transmission performance improvement achieved by diversity with maximal ratio combining for coherent BPSK over Rayleigh fading channels. The following observations can be made:

a) Diversity can dramatically improve the transmission performance

b) The improvement is most significant when L increases from 1 to 2.

As L increases, the BER curve moves towards that for an AWGN channel. In fact, it can be proved that when L approaches infinity, the BER curve with diversity will converge to the AWGN curve.

c) At a low $\Gamma_b$ value, diversity with L=8 may perform worse than diversity with L=4. This is because, for the same value, for L=8 is 3dB less than for L=4. With a low $\Gamma_b$ , the effect of the much larger channel noise in the case of L=8 on BER is stronger than the effect of diversity gain achieved by increasing L from 4 to 8.

## Figure-20

$\sigma^2 = 0.8$

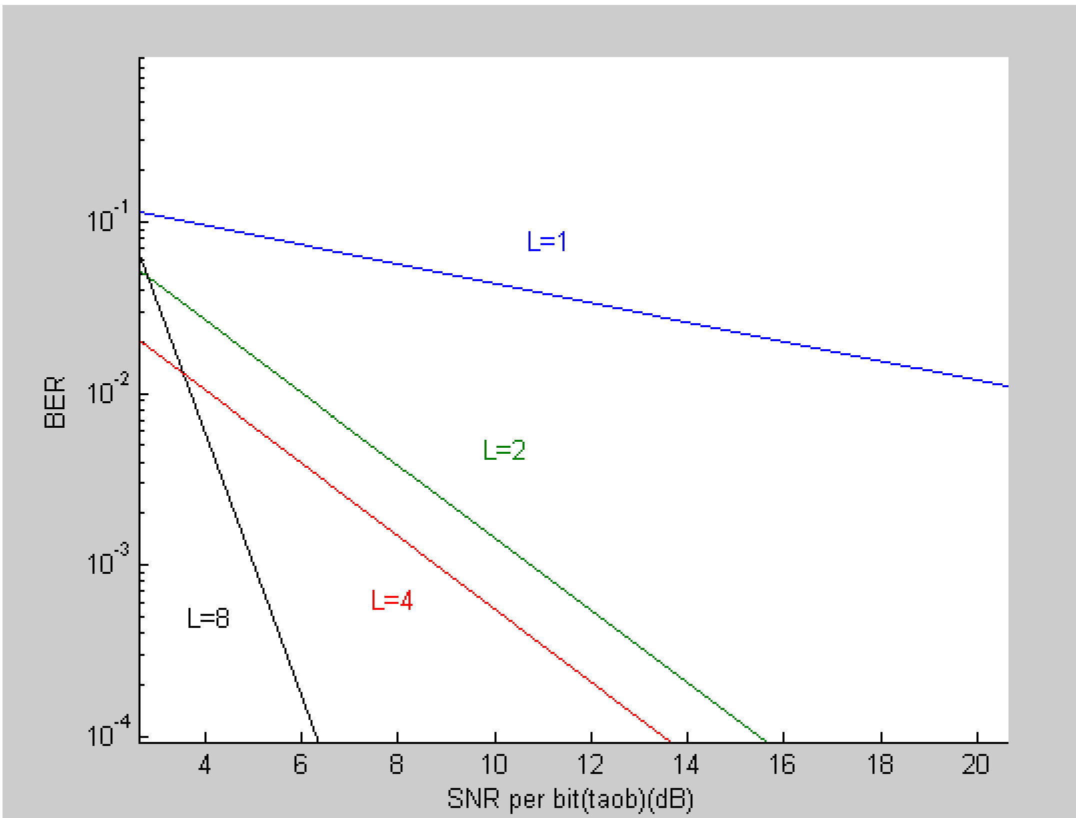



**Fig:20- SIMO - With fading**

**Figure-21**

$\sigma^2 = 0.5$

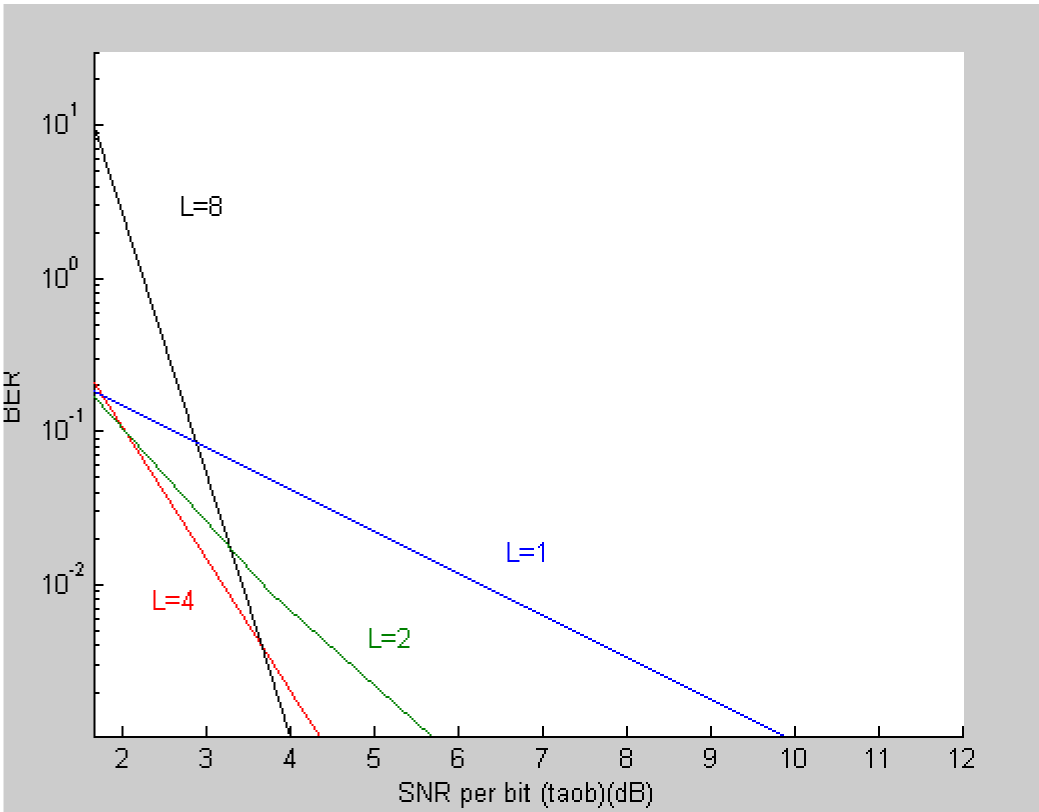



**Fig 21: SIMO - With fading**

## Figure-22

$\sigma^2 = 0.05$

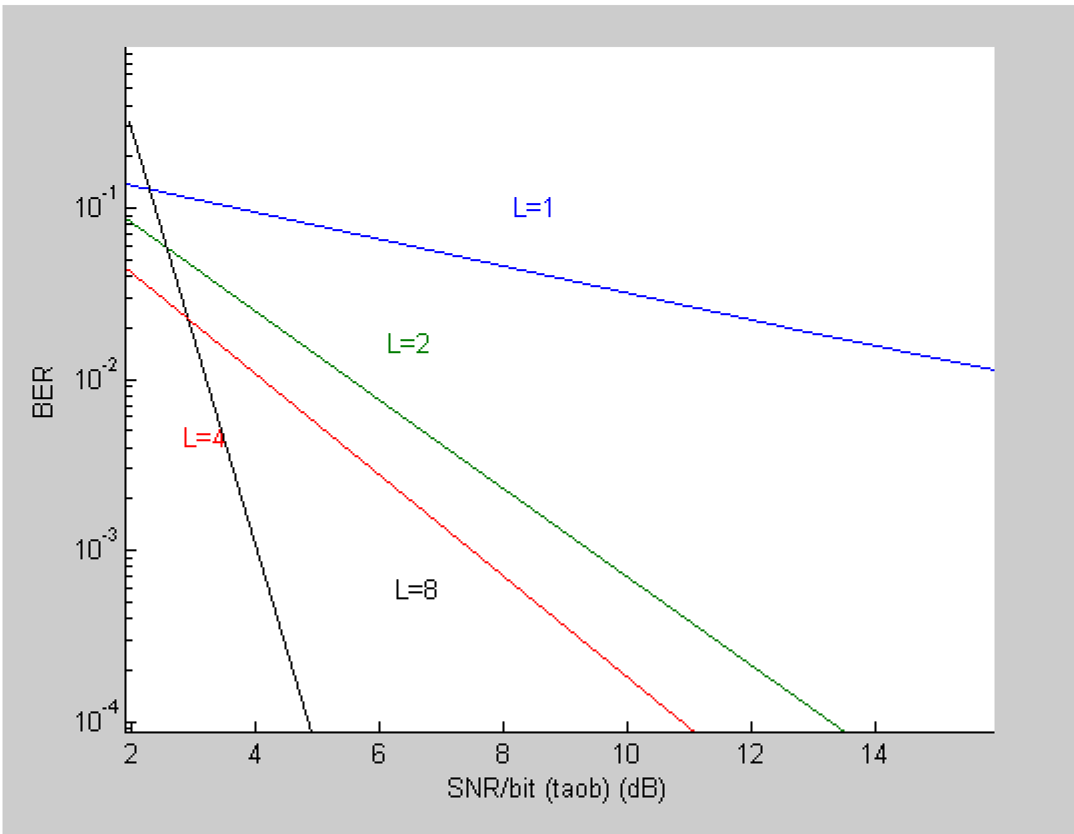



**Fig: 22- SIMO - With fading**

## Figure-23

$\sigma^2 = 1.0$

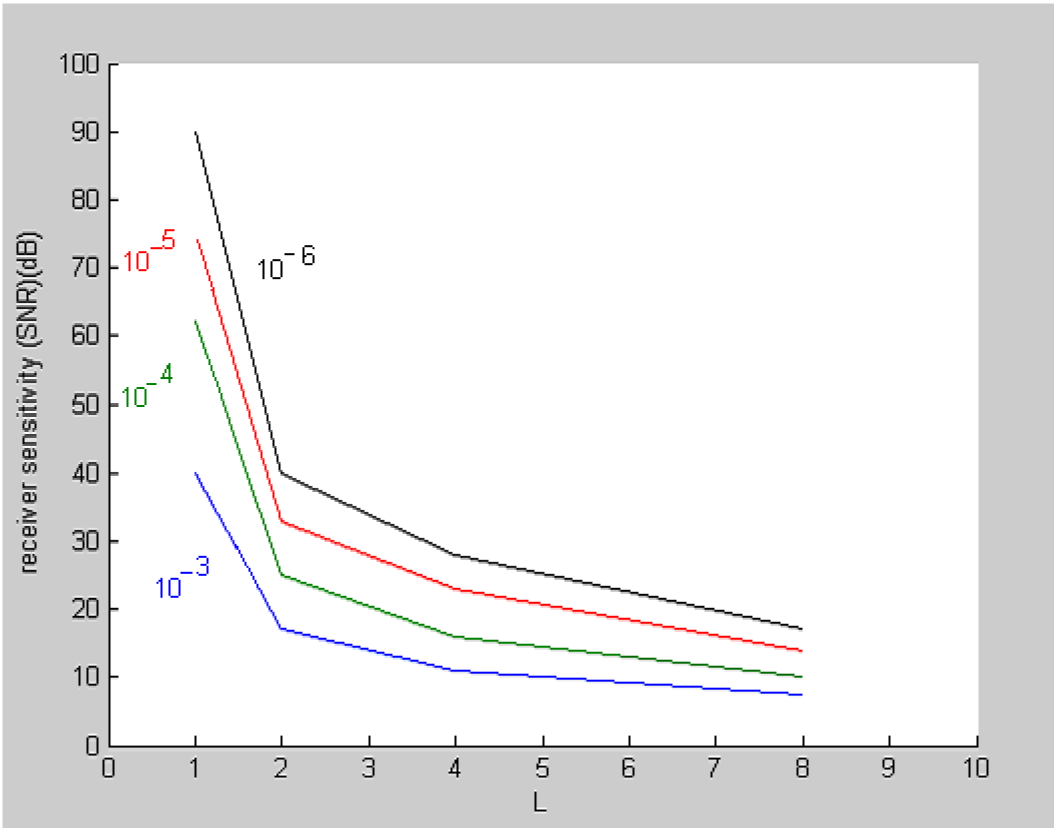



**Fig:23- SIMO - With fading**

## Figure-24

$\sigma^2 = 0.8$

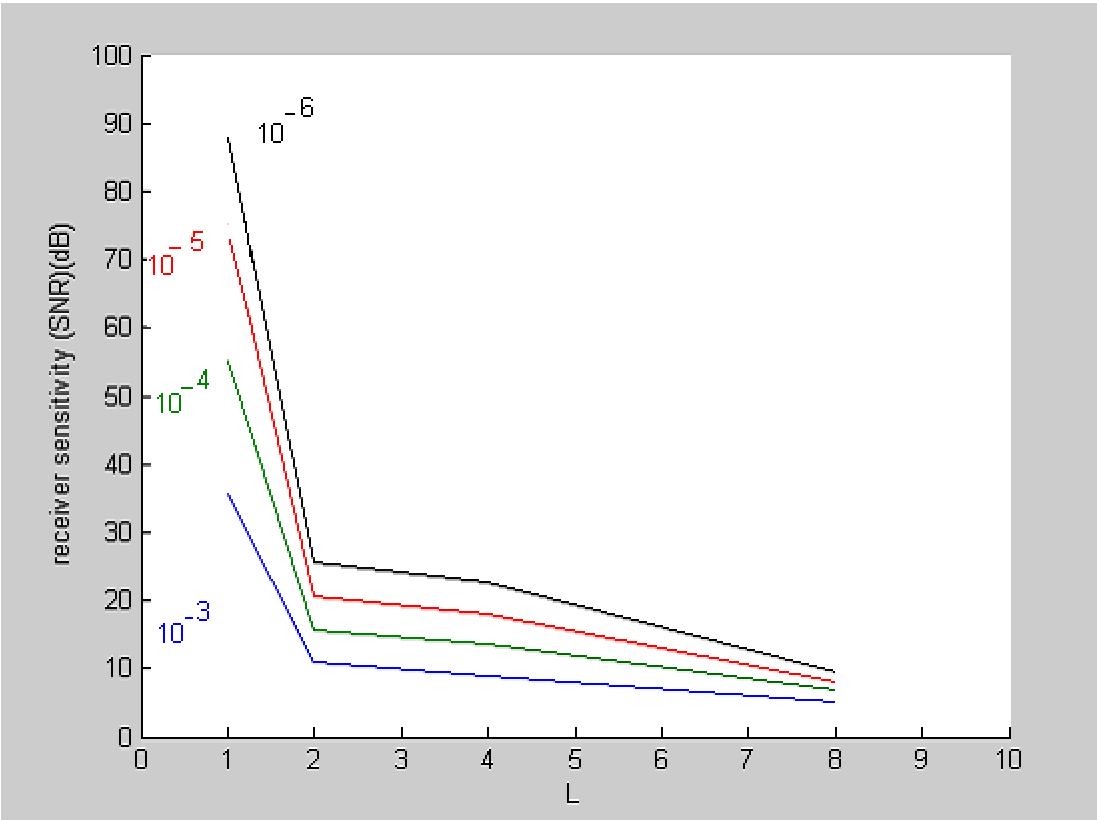



**Fig:24- SIMO - With fading**

**Figure-25**

$\sigma^2 = 0.5$

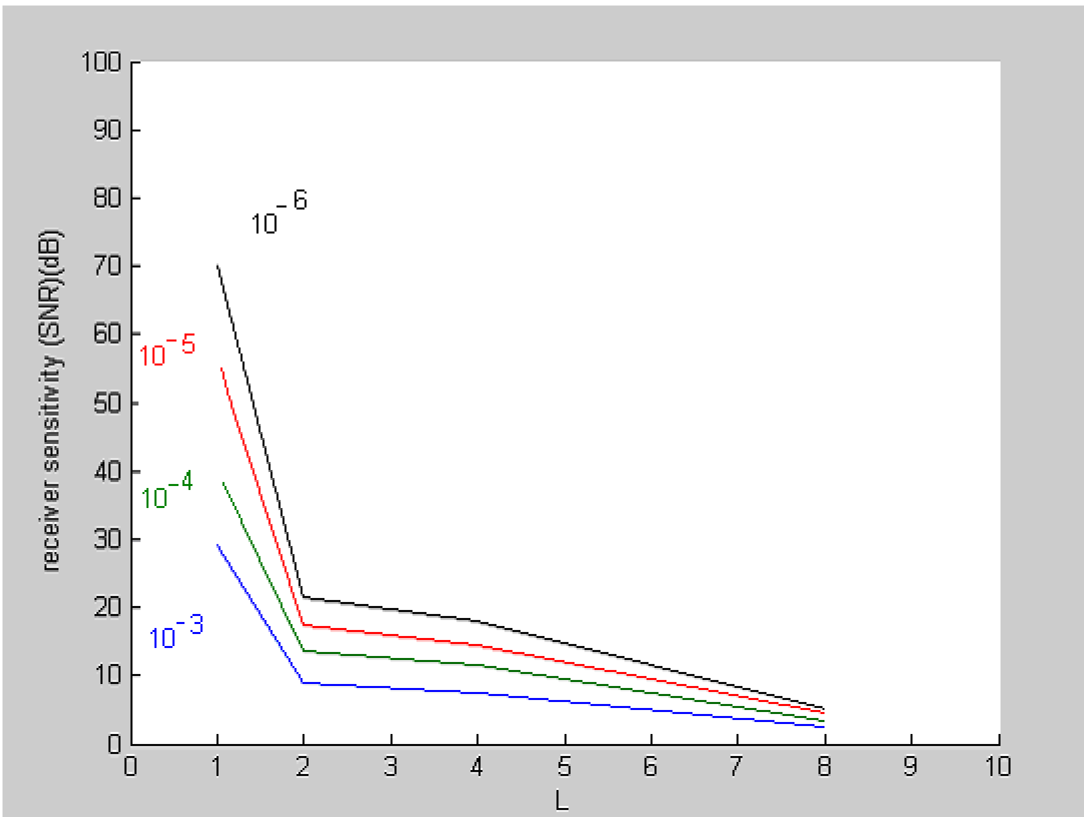



**Fig: 25-SIMO - With fading**

## Figure-26

$\sigma^2 = 0.05$

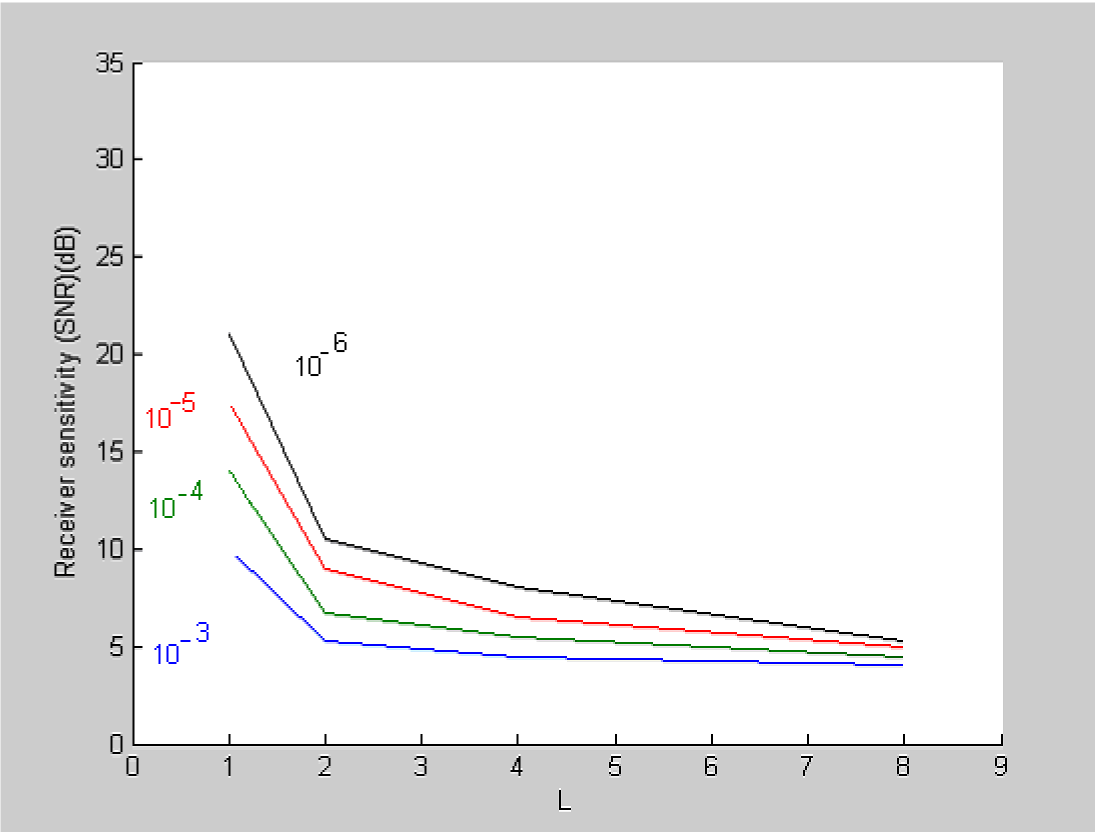



**Fig: 26- SIMO - With fading**

From these figures 7,8,9,10 with different variance value we see that,

as variance $\sigma^2$ decreases from 1 to 0.05 , from lower to higher diversity antenna SNR (dB) value decreases, but BER (dB) performance improves.

For example, for $\sigma^2$ =1,

At highest BER 10^-3, for L=1, SNR is 40 db, where for L=1 SNR is 7.5 db

at lowest BER 10^-6 , for L=1 SNR is 90 db, whereas for L=8 SNR is 17.

So at lower BER, more antenna have lower SNR.

Thus , the more variance value reduces, highest diversity antenna have more lower SNR value.

**Figure-27**

**MIMO-with fading**

The probability of conditional BER can be expressed as:

$$BER(u)=\frac{(1-\rho)\quad\frac{(CNIR*u)}{2}\quad+1}{2\left\{\frac{(CNIR*u)}{2}\quad+1\right\}}\exp\left\{\frac{k\frac{(CNIR*u)}{2}}{\frac{(CNIR*u)}{2}\quad+1}\right\}$$

$\rho=J(2\pi f_D T_s)$ is the time correlation function.

Pdf of u will be

$$\mathrm{P}_u(u)=\frac{1}{(n_r-1)!}u^{n_r-1}e^{-u}$$

$n_r=1,2,3,......$ =no. of receiving antenna.

The expression for the Probability of BER of a MIMO System over fading channel can be expressed as:

$$P_{mimo}=\int_0^{\infty}BER(u)\cdot P(u)du$$

here we have taken values

u= 1: 10

$n_r$ = receiving antenna= 1:4

CNIR= carrier to noise and interference ratio= 1 :60

K=Rayleigh factor

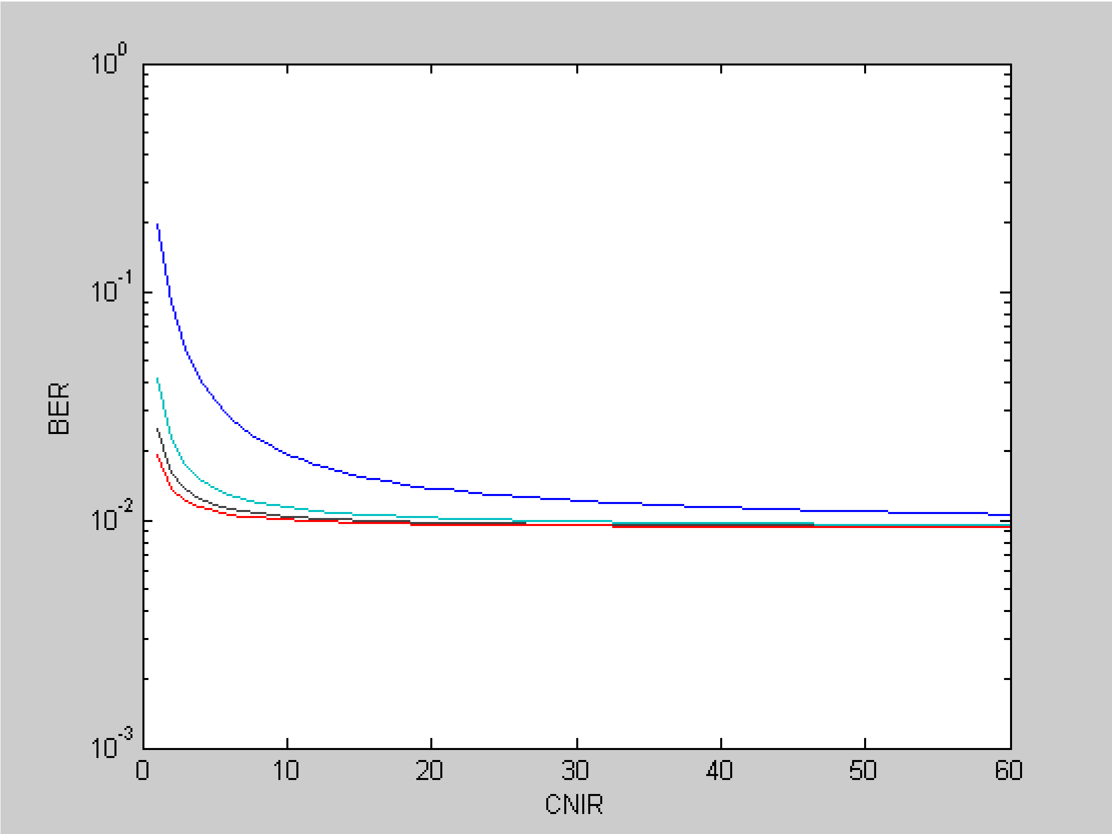



**Fig. 27- BER vs. CNIR**

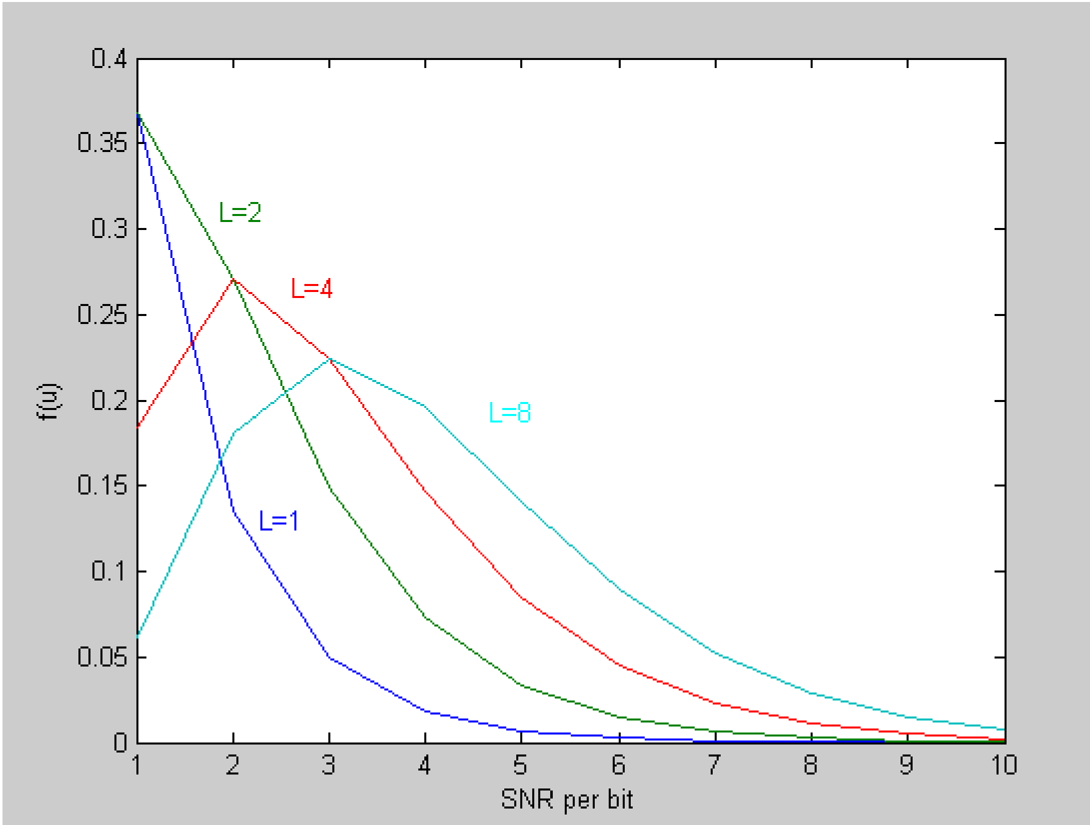



**Fig. 28- Pdf vs. SNR**

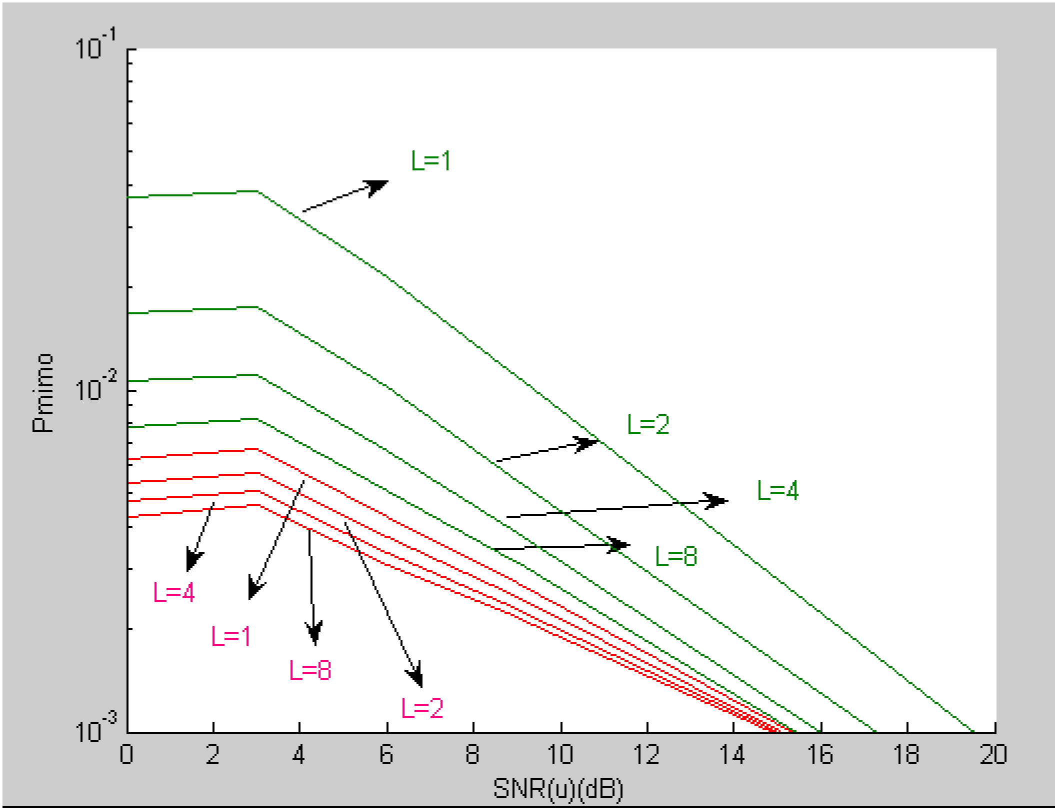



**Fig 29- BER vs. SNR**

From the graph we see that, for 4 transmitting and 4 receiving antenna we get better performance in BER as in BER decreases, SNR (dB) decreases, thus noise increases . at receiver antenna, for L=1, SNR (db) is 15.5,

for L=8 SNR is 14.8

so for more antennar SNR (db) is decreasing.

# Chapter-4

## Conclusion and Future Work:

We have worked extensively on our thesis and verified our work theoretically. We have used all established equations, without changing any form of them. We have carried out the performance analysis for a STBC coded MIMO system. We started working with fading for SISO. Then analysis extended to MIMO (Multiple input multiple output). Result is carried out for increased number of transmitter and receiver. Performance is obtained high in this case.

Following the analysis in chapter 2, where we have evaluated the performance of bit error rate (BER) with fading, When we were working with fixed variance $\boldsymbol{\sigma^2}$ (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. It was found that 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, and SNR ($E_b / N_0$). 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  we are able to get better performance for MIMO (multiple input multiple output).

Hence we conclude saying that the bit error rate (BER) should be kept lower due to decrease in signal to noise ratio (SNR) as in increase in noise. For further work , some coding technology can be used to reduce the effect of fading. Error correction can be modified. 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 reach completion.

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