A

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on

"Performance Analysis of Cooperative Communication using Amplify and Forward Protocol"

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MASTER OF ENGINEERING

IN

WIRELESS COMMUNICATION

Submitted By

Vikas Anand

(Roll No—801263029)

Under the guidance of

Dr. Surbhi Sharma

Assistant Professor, ECED

Thapar University, Patiala

ELECTRONICS & COMMUNICATION ENGINEERING DEPARTMENT

THAPAR UNIVERSITY

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DECLARATION

I hereby declare that the work, which is being presented in the report, entitled "**Performance Analysis of Cooperative Communication using Amplify and Forward Protocol**" in partial fulfilment of the requirements for the award of Master of Engineering in Wireless Communication at Electronics and Communication Engineering Department of Thapar University, Patiala which is an authentic record of my own work carried out under the guidance of **Dr. Surbhi Sharma** Assistant Professor, Electronics and Communication Department during the fourth semester, June-2014.

The matter presented in this thesis has not been submitted in any other University/Institute for the award of Master of Engineering.

Date: 26/6/2014

Vikas Anand

Vikas Anand

Roll no: 801263029

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

Date:- 27/6/14

27/6/14

Dr. Surbhi Sharma

Assistant Professor, ECED

Thapar University, Patiala

Dr. Sanjay Sharma

Professor and Head, ECED

Thapar University, Patiala

Dr. S.K. Mohapatra

Dean of Academic Affairs

Thapar University, Patiala

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ABSTRACT

With the rapid development of applications of wireless technology, future generation demands higher data rates and a more reliable transmission link while maintaining quality of service. In order to achieve these requirements, multiple-input multiple-output (MIMO) systems have been considered as an effective technique to meet these requirements by offering significant multiplexing and diversity gains over single antenna systems without increasing various parameters of wireless environment like bandwidth and power. Although MIMO systems results in very large benefits in cellular base stations, they may face problems when it comes to their implementation in mobile handsets. In particular, the typically compact-size of handheld devices makes it impractical to implement multiple antennas. To overcome this drawback, the concept of Cooperative Communications has recently been addressed and gained large interest in the research community.

The main concept behind Cooperative Communication is to form a virtual MIMO antenna array by using a third terminal, a so-called relay node, which assists the direct communication. After receiving the source's message, the relay processes and forwards it to the destination. With this approach, the benefits of MIMO systems can be attained in a distributed fashion. Furthermore, cooperative communications can efficiently combat the severity of fading and shadowing effects through the assistance of relay terminals. It has been shown that using the relay can extend the coverage of wireless networks. Different combining schemes and diversity protocols has been studied. In this thesis, the main focus is to evaluate the performance of Cooperative Communication systems using Amplify and Forward protocol. By using this approach second order diversity has achieved. A new transmission scheme is proposed in Cooperative Communication using Amplify and Forward protocol which results in high diversity gain that can overcome the drawback of noise amplification in Classical Cooperative Communication System using Amplify and Forward protocol.

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LIST OF ABBREVIATIONS

Abbreviation	Description
AAF	Amplify and Forward Protocol
AWGN	Additive White Gaussian Noise
BPSK	Binary Phase Shift Keying
CDF	Cumulative Distribution Function
C-STC	Cooperative Space Time Coding
DAF	Decode and Forward Protocol
EGC	Equal Gain Combining
FDM	Frequency Division Multiplexing
MGF	Moment Generating Function
MISO	Multiple Input Single Output
MRC	Maximal Ratio Combining
PDF	Probability Density Function
QPSK	Quadrature Phase Shift Keying
RS	Relay Selection
SEP	Symbol Error Probability
SER	Symbol Error Rate
SISO	Single Input Single Output
SNR	Signal to Noise Ratio
ST-AF	Space Time Amplify and Forward

CHAPTER-1

INTRODUCTION

Wireless Communications has made tremendous growth over the last few decades and it is anticipated to move forward in future. The applications based on wireless network have been increasing according to the demands of user [1]. Services such as mobile multimedia, live video streaming, on-demand service requires high data rate, speed and reliability. On the other hand, transmission of signal from source to destination in wireless environment suffers from fading of signal due to multipath propagation which results in variation in amplitude, phase and delay of the received signal. The deterioration caused to the signal can be overcome by different techniques such as: increasing transmitter or receiver power, bandwidth or use of error control coding. However by increasing power and bandwidth results in increase in expenditure of the system and error control coding results in reducing transmission rate.

In order to achieve high data rate without compromising reliability and with less added cost are the major challenges in wireless environment. To reduce effects of fading, the concept of diversity technique come into picture. Diversity also enhances the reliability of signal transmitted [2]. It provides more than one copies of signal at destination in such a fashion that signals are not correlated [3]. It provides better signal quality at very low cost [5]. Diversity can be classified into different categories: temporal, frequency and spatial diversity [4]. In several conditions, however the wireless environment is time-invariant and flat faded. This drive the possibility of positioning more than one antenna at both the source and destination end in order to gain spatial diversity [6]. Multi-Input Multi-Output (MIMO) technology has appealed great attention for wireless environment which fruitfully yields in high data rate, low power consumption and network reliability. Due to size of mobile devices, cost and hardware implementation makes it hard for MIMO technology to be applied in small handheld devices. In order to compensate this restriction the concept of cooperative diversity has been introduced where mobile users share their antennas with others users in order to have space diversity gain at destination by making a virtual group of antenna [7]. In cooperative environment several copies of the source information signals results in improvement of system performance and robustness [8]. In cooperative communication, diversity is realized by using a third station as a relay. The channels containing thermal noise, Rayleigh fading and path loss are modeled. Cooperative communication approach results in various advantages: increases spectral and power efficiency improve network coverage and reduce outage probability [9]. Different cooperative diversity protocols have been studied [10]. Cooperative communication uses two major protocols: Amplify and Forward (AAF) and Decode and Forward (DAF) [11]. In AAF protocol, relay receive the noisy version of signal and amplify it and forward to the destination. AAF has less design complexity and achieves space diversity which results in increasing network reliability. In DAF protocol, relay decode the signal transmitted by source and forward it to the destination.

In this thesis, the main focus is to study performance of classical cooperative communication system and modified cooperative communication system using AAF protocol. In modified cooperative communication system, the concept of spatial as well as temporal diversity is utilized in order to obtain high diversity gain as compare to classical cooperative communication without increasing the complexity of the system and number of antennas at source or destination node. The basic system model of the both the systems are same but the difference lies in the transmission scheme of modified system. Modified cooperative system overcome the main drawback of classical cooperative system using amplify and forward protocol that is noise amplification by improving its diversity gain.

1.1 Historic Prospective of Cooperative Communication

The main thought behind cooperative environment can be describe by the study done by Cover and El Gamal on information theoretic attributes of the relay station [12]. The study analyzed the capacity of the source, relay and destination. In Cooperative communication, information is transmitted to relay and destination station from the source station and after processing the information at relay station, it is transmitted to the destination [12]. In several situations it is assumed that cooperative environment is dissimilar from relay channel. Cover and El Gamal analyzed the capacity in additive white gaussian noise (AWGN) channel. In relay channel, relay’s main function is to help main channel, on the other hand in cooperation, users act as both information source and relay.

1.2 Objectives of the Thesis

The objectives of the thesis are:

- Performance analysis of cooperative system vs non cooperative system with and without combining techniques.
- To evaluate the probability of symbol error rate for cooperative system using different combining techniques.
- To analyze the effect of uneven power distribution between source and relay station.
- To analyze the impact on the performance of serial and parallel relay topologies on cooperative communication system.
- Performance analysis of modified cooperative system and classical cooperative system using amplify and forward protocol.

1.3 Outline of the Thesis

Thesis is organized in the following chapters:

Chapter 2 includes the Literature survey.

Chapter 3 explains effects and types of Fading in wireless environment and also discusses Diversity techniques to overcome fading effect.

Chapter 4 explains Direct transmission link model using different modulations schemes. This chapter also explains Cooperative transmission technique using relay station, various Cooperative protocol and Combining methods.

Chapter 5 presents the concept of Modified cooperative communication using Amplify and Forward Protocol and compare the result with Classical cooperative communication.

Chapter 6 contains Conclusion and possible suggestion for future work.

CHAPTER-2

LITERATURE REVIEW

Sendonaris I et al.[7] proposes a new space diversity scheme in which diversity gain is achieved with the help of mobile users. Paper is sectioned into two parts. Part I describes the user cooperation strategy while Part II focuses on implementation issues and performance analysis. Result highlights that even though the channel between users is noisy, cooperation leads in increase in capacity and more robust system.

Sendonaris II et al.[8] has studied the cooperation scheme and also practical issues associated to its implementation. Author also considers high rate code division multiplexing access implementation and cooperation strategy with assumption that channel state information is relaxed. In all the cases, cooperation scheme is far better which increases the system throughput and cell coverage as well as decreasing sensitivity to channel variation.

Weifeng Su et al.[9] has studied symbol error rate (SER) performance analysis and optimum power allocation for uncoded cooperative communications in wireless networks with either decode and forward (DAF) or amplify and forward (AAF) cooperation protocol, in which source and relay send information to destination through orthogonal channels. In both the DAF and AAF cooperation systems, it turns out that an equal power strategy is good, but in general not optimum in cooperative communications. The optimum power allocation depends on the channel link quality. An interesting result is that the optimum power allocation does not depend on the direct link between source and destination, it depends only on the channel links related to the relay.

J. Nicholas Laneman et al.[10] develop and analyze low-complexity cooperative diversity protocols that combat fading induced by multipath propagation in wireless networks. Paper outline several strategies employed by the cooperating radios, including fixed relaying schemes such as amplify-and-forward and decode-and-forward, selection relaying schemes that adapt based upon channel measurements between the cooperating terminals and incremental relaying schemes that adapt based upon limited feedback from the destination terminal. The result shows that except for fixed decode-and-forward, all other cooperative diversity protocols are efficient in the sense that they achieve full diversity (second order diversity in the case of two terminals).

Pravin W.Raut et al.[13] explain diversity technique which is helpful in reducing fading problem in wireless environment. In diversity technique, destination receives multiple copies of transmitting signals which passed over different fading channels. There is very less probability that all the copies of signals will fade at the same time. The uncorrelated faded signals are combined in-order to improve the performance of system. Different types of diversity techniques are studied and they are combined to get best result to mitigate fading problems.

Aria Nosratinia et al.[15] introduced the concept of cooperative communication. As transmit diversity demands multiple antennas at transmitter. However, many wireless devices have small size or complex hardware structure. In a multi-user environment, cooperative communication enables single mobile antenna to share their antennas and generate a virtual multiple antenna transmitter that allows them to achieve transmit diversity.

Andreas Meier et al.[16] analyzes an adhoc network with a base station, a mobile and a third station acting as relay. The channels are modeled using path loss, Rayleigh fading and thermal noise. Different combining methods and diversity protocols are compared. In the simulation amplify and forward protocol shows better performance than decode and forward protocol. Whatever combination of diversity protocol and combining method is used, second level diversity is observed. The relative distance between the relay and the stations has a large effect on the performance.

Lin Fei et al.[17] analyzes the symbol error rate (SER) performance for a two-user amplify and forward cooperative system. The closed-form SER formulation and corresponding upper bound are derived by using M-PSK modulation. According to the SER performance analysis, if the power allocation to the source and relay is equal, an interesting conclusion has been drawn that the SER performance for such topology shows a symmetry property and the optimum relay location is just in the middle with respect to the source and destination.

M.Abrar et al.[19] provides performance analysis of cooperative communication using AAF and DAF protocol and error rate performance comparison of cooperative system with non-cooperative SISO and MISO systems under the same power constraints. Cooperative communication has found its applications in almost every wireless network from cellular to adhoc and sensor networks. The basic idea of cooperative communication is to use the concept of virtual antenna array to mimic a multi antenna system and hence get improved performance.

Rui Cao et al.[20] investigates the relative effects of error rate versus outage probability, modulation type and cooperative communication relaying protocols on the system. Cooperative networks provide enhanced system performance by exploiting spatial diversity in a distributed manner. Optimum resource allocation improves the performance of cooperative networks and increases the efficiency of resource usage. A resource optimization technique that minimizes the total transmit energy is formulated. The analysis and simulations suggest that the error rate and outage probability metrics yield similar optimization results for AAF relaying cooperative system, relaying protocol determines the optimization results while the modulation type has no effect and the difference between various relaying protocols diminishes when the number of relays increases.

P.Mangayarkarasi et al.[21] has studied relay selection (RS) strategy for amplify and forward protocol. The performance of the cooperative network is enhanced by RS. The spectral efficiency of RS acts better when compared to energy efficiency. Moreover, when the number of hops between the source and the destination is less RS will perform better. There are many methods used at the receiver end such as Maximal Ratio Combining (MRC), selection combining etc. In this paper, selection combining is employed at the receiver. After performing relay selection, those users having SNR larger than the threshold value are selected.

Zhenzhou Tang [22] explains energy efficient optimal power allocation scheme and relay selection strategy using AAF protocol. According to the relay selection criteria distance between source and relay such that less transmission power of source, relay or total can be obtained. Low complexity and easily applicable algorithm is presented. Result shows that relay location according to the proposed strategy, system is highly energy efficient.

Xiangdong jia et al. [23] investigates Nth best relaying schemes with AAF protocol over independent and non-identically distributed Nakagami fading channels and Rayleigh channel. For such schemes closed form expression to the PDF and CDF of the instantaneous end to end SNR is found. Then from the obtained CDF and PDF, three main parameters are discussed: outage probability, average symbol error ratio and ergodic capacity. Result shows that increase in the number of relay N causes severe loss in performance. This loss in performance can be reduced greatly when Nth relay system have larger fading severity parameters like Nakagami-m-fading channel rather than Rayleigh channel.

Haci Ilhan [24] presents a design of two-way communication system with relay selection in two-way cooperative communication system across cascaded Nakagami-m fading channels. In this scheme all the terminals are in motion. Two users first send their information to relays. Relay which adopt min-max criterion that is minimize the maximum SER of two sources will be selected. Outage probability and SER expression are analyzed by cumulative distribution function and moment generating function of end to end signal to noise ratio.

Nuri Kapucu et al.[25] analyzed the performance of AAF cooperative diversity over asymmetric fading channels. Source-relay and relay-destination links suffer from Rayleigh fading and source-destination link suffers from generalized gamma fading. PDF and MGF of source-relay-destination are derived and for source-destination path, moment generating function is derived. Moreover SER performance of N-relay AAF protocol is studied for M-ary phase shift keying and M-ary quadrature amplitude modulation.

Anas M. Salhab et al.[26] investigates the performance of a two hop fixed gain AAF relay system in presence of co-channel interference at destination. Different fading environment are assumed in the study Rician/Nakagami-m, Rician/Rician and Nakagami-m/Rician. Outage probability and symbol error probability (SEP) of above environments are derived. For the Rician/Nakagami-m environment, Interferes channel is independent, non-identically distributed and for rest of the cases independent identically distributed case is assumed.

Result shows that different fading models of interferer channels have the same diversity order and interference degrades the system performance by reducing coding gain.

Desheng Wang et al.[27] has studied the performance of cooperative relay communication. Cooperative communication is very powerful tool inorder to combat fading problem in wireless environment at low power. In this paper cluster relay model is considered for cooperative communication to analyze SER, outage probability and outage capacity. Closed form expression for average SER in Rayleigh fading channel is derived by using MGF.

Doudou Samb et al.[28] has investigated the cooperative communication system using AAF protocol for wireless environment which results in high network reliability and less error rate. Optimal power allocation scheme is used for power constraint system. In the cooperative communication system source sends symbols to destination with the help of relay using AAF protocol. Symbol error rate is calculated by MGF using M-ary phase shift keying modulation. Cooperation scheme is studied which chooses the best relay that maximizes SNR and further improve the performance of the system.

Chengliang Huang et al.[29] has studied cooperative relay networks which possesses virtual MIMO environment to ameliorate the wireless communication system performance. In this paper, outage probability of cooperative relay networks with different numbers of antennas used at transmitter and relay has studied and it is compared to outage probability of MISO system. Result shows that cooperative communication with multiple relays performs better as compare to those with multiple antennas and performance of system is significantly affected by location of relays.

Kai Yan Zhu et al.[30] proposed ST-AAF cooperative system that consists of two antenna source, single antenna relay and destination. Alamouti space-time coding is used at source to transmit symbol which adopt AAF protocol. Symbol error rate approximation of ST-AAF and C-STC is compared. Analysis shows that ST-AAF obtains more diversity gain and higher diversity order than C-STC. Optimum power allocation scheme is used for ST-AAF cooperative system and result shows that this scheme depends on channel link related to the relay not on the direct link between source and destination.

Jung-Woo Han et al.[31] exercises the application of cooperative communication in underwater wireless system. In this paper Amplify and Forward protocol is used in cooperative diversity for underwater wireless communication. In this model each relay amplifies the received signal from source and further transmits to the destination. Result shows that cooperative communication system using Amplify and Forward protocol in underwater wireless communication system shows better performance than direct transmission.

CHAPTER-3

FADING AND DIVERSITY TECHNIQUES

3.1 Fading

Transmission of radio wave signal in wireless environment is a perplexed process distinguished by different factors like multipath and shadowing. For controlled communication systems analyses particular mathematical details of this process is either not known or too difficult. However, various efforts have been dedicated to the statistical modeling and characterization of these different effects. As a result, number of quite simple and precise statistical models for fading channels which rely on the exact propagation environment and underlying communication scenario has been discussed. The statistical models are dependent on evaluation made for communication system or bandwidth allocation. An important advantage of the wireless channel models is the flexibility which means by varying the statistical parameters, the similar model can be utilized to evaluate the channel under variety of conditions. Propagation models have mainly discussed on predicting the average received signal strength at a defined distance from transmitter, as well as the variability of signal strength in close spatial proximity to a desired location. Large scale propagation models determine the mean signal strength for any source-destination separation, thereby estimating the radio coverage of source. On the other hand propagation model that determines speedy variations of received signal strength over small travel distance (a few wavelengths) or small time interval (on the order of seconds) is called as small scale fading model.

3.1.1 Small scale fading

Small scale fading defines as the fast variations of the amplitude, phases or multipath delays of radio signal over small time interval or distance travelled, so that large scale path loss effects may be ignored. Fading is due to intermingling of two or more varieties of transmitted signals which come at destination at very small time difference. These waves are called as multipath waves which combine at the destination antenna to get an output signal whose amplitude and phase largely changes, depending on the distribution of intensity and relative travelling time of the waves and spectral width of transmitted signal. In small scale fading, power of the signal received at destination may differ by as much as three or four order of magnitude (30 or 40 dB) when destination is moved by small distance.

In the metropolitan cities where the height of building surrounding the mobile antenna is quite high, so there is not even one LOS to the base station. Even if the LOS occurs, multipath takes place due to the reflections from the ground and near-by buildings. The signal which reaches the destination at anywhere in the space may comprise of huge amount of plane waves which are randomly distributed with respect to amplitudes, phases and angle of arrival. At destination antenna these randomly distributed signals aggregate vectorially and results in fading. Unlike destination antenna is not moving, the signal received at destination may fade or distort because of the displacement of nearby objects in radio environment. If the mobile station is moving, with surrounding objects to be stationary then the fading is only a spatial process. The spatial fluctuations of the resulting signal are assumed as time fluctuations by the receiver as it displaces through the multipath environment. Due to constructive and destructive effects of multipath wave aggregating at different location in the space, a destination antenna moving at fast speed can pass through various fades in very less duration of time. In a more drastic situation, a receiver is static at a particular situation at which signal received is in deep fade. For this case sustaining effective communication is not so easy task, although nearby objects like automobiles or people moving nearby the destination antenna may affect the field pattern which result in received signal goes into deep fade for a long duration of time. In order to prevent received signal from deep fade, concept of Antenna space diversity come into picture. Antennas are adjusted in such a manner that if signal received from antenna one is in deep fade or null, then antenna second is adjusted in such a manner that at the same location we get maxima of second antenna, therefore diminishing the effects of deep fade.

Another bad effect of mobile channel is Doppler shift which is due to relative motion between mobile station and source. Doppler shift describe the apparent frequency shift that each multipath feels due to relative motion between mobile station and source. If moving object is travelling in the direction of arrival of wave then Doppler shift is positive that is apparent received frequency is increased and if moving object is travelling away from the direction of arrival of wave, then Doppler shift is negative. Multipath, Inter symbol interference and Doppler shift all are associated to variability that is because of motion of user and different varieties of environments that signal travels through. Altogether effects of these process results in decrease in signal strength at receiver, inadequate mobile receiver performance and hence not satisfactory quality of service of wireless system.

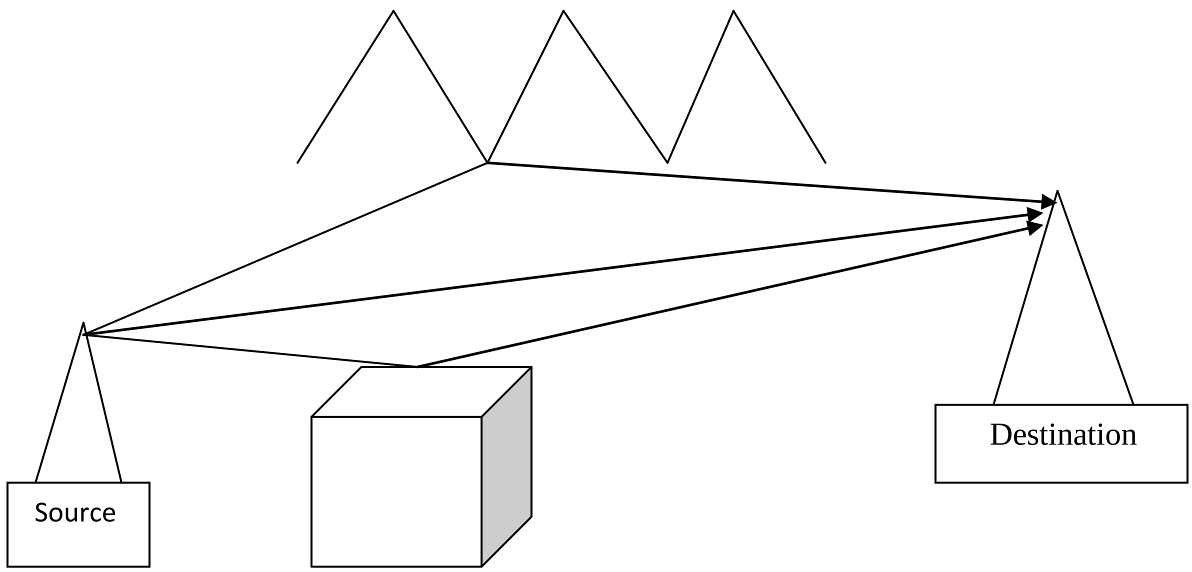

Figure 3.1: Multipath Propagation of the Signal

3.2 Types of small scale fading

When the waves of multipath signal are not in phase with each other, that result in fading. The type of fading occurred by the signal travelling through wireless environment depends on the nature of transmitted signal with respect to the parameters of the channel. Depending on the relation between the signal parameters such as bandwidth, symbol period etc and channel parameters such as root mean square delay spread and Doppler spread, various transmitted signals will undergo different types of fading. The received signal strength will vary downward, resulting a momentary but periodic decrease in quality. The small scale signal fading is because of time dispersion and frequency dispersion mechanism in mobile channel could be sorted out into four major categories which depends on nature of the transmitted signal, channel and mobile velocity.

3.2.1 Fast Fading

Fast fading effects arises due to Doppler spread. Depending on how fast the transmitted signal varies as compared to the rate of variation of the channel, a channel may be categorize into different types- Fast fading channel or Slow fading channel. In fast fading channel, the impulse response of channel vary quickly within the symbol period that is symbol period of the transmitted signal is greater than the coherence time of the channel where coherence time is defined as time interval at which the channel impulse response is invariant. This results in frequency dispersion due to Doppler spread which causes distortion of signal.

In frequency domain, distortion of signal is because of fast fading increases with increasing Doppler spread as compare to transmitted signal bandwidth.

$$T_S > T_C$$

And $$B_S < B_D$$

where T_S is the symbol period, T_C is the coherence time, B_S is the bandwidth of symbol and B_D is the Doppler spread. Fast fading channel only deals with rate of change of channel due to motion.

3.2.2 Slow Fading

In slow fading channel impulse response vary at slow rate than the transmitted baseband signal. The channel is considered as stationary over one or various reciprocal bandwidth intervals. In the frequency domain, bandwidth of signal is much higher than the Doppler spread of the channel. Therefore slow fading occurs if

$$T_S \ll T_C$$

and $$B_S \gg B_D$$

where T_S is the symbol period, T_C is the coherence time, B_S is the bandwidth of symbol and B_D is the Doppler spread.

3.2.3 Frequency Selective Fading

The channel creates frequency selective fading on the received signal, if the channel has a fixed gain and linear phase response over the bandwidth which is smaller than bandwidth of transmitted signal.

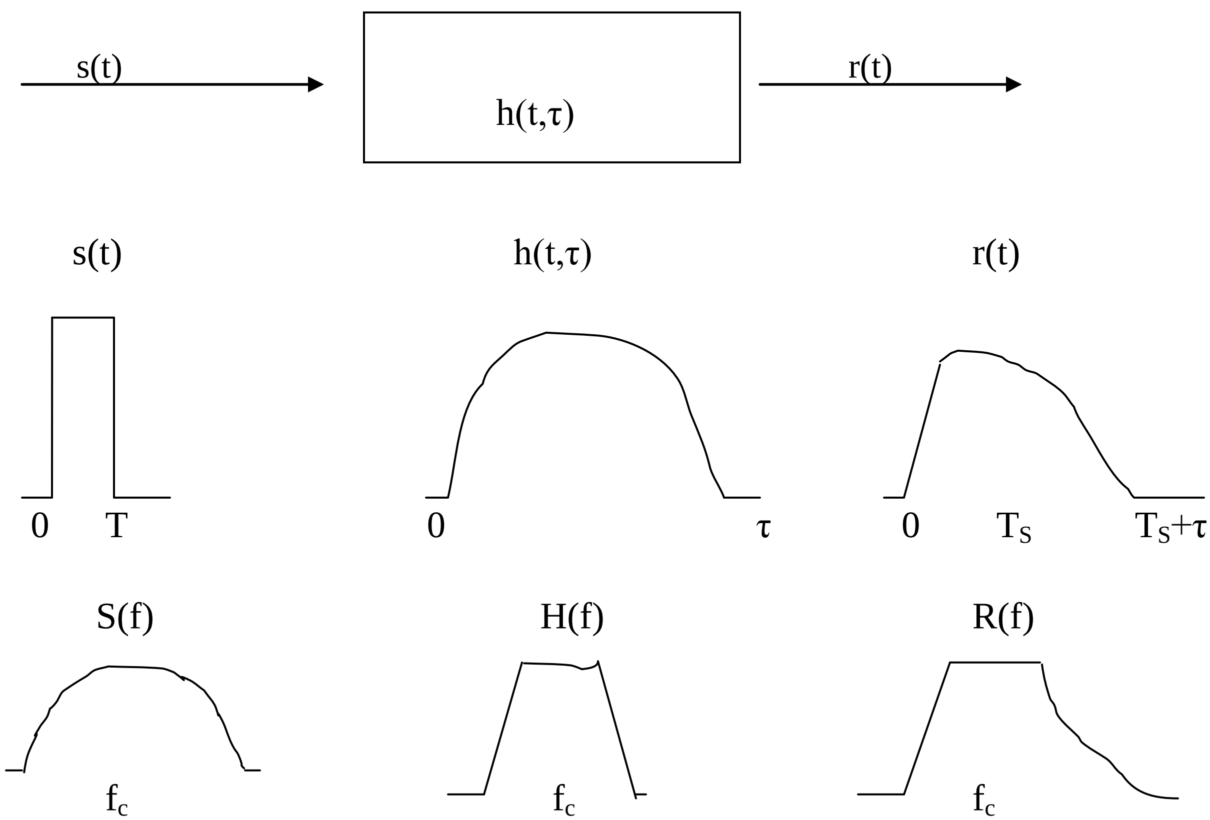

Fig 3.2: Frequency Selective Fading Channel Characteristics

Under these situations, impulse response of channel has multipath delay spread which is greater than symbol period of transmitted signal. This take place, when received signal has more than one form of transmitted waveform which are faded and delayed in time and hence received signal is distorted. Within the channel, frequency selective fading takes place because of time dispersion of symbols transmitted and inter symbol interference. From the frequency domain point of view, some frequency components in the received signal spectrum have larger gains than other. As compare to flat fading channels, frequency selective fading channels are quite hard because each multipath signal has to be modeled and channel must be assumed to be linear filter. In frequency selective fading, the bandwidth of signal transmitted should be larger than coherence bandwidth B_C of the channel.

Frequency selective fading channels are also called as wideband channels as bandwidth of signal is wider than bandwidth of channel impulse response.

$$B_S > B_C$$

And

$$T_S < \sigma_\tau$$

where B_S is bandwidth of transmitted signal, B_C is coherence bandwidth of channel, T_S is symbol period and σ_τ is root mean square delay spread.

3.2.4 Flat Fading

Received signal will suffer from flat fading, if the mobile radio channel whose gain is fixed and phase has linear response over a bandwidth which is larger than bandwidth of the transmitted signal. Due to variation of gain of channel caused by multipath the strength of received signal vary with time. If channel gain varies with respect to time, variation of amplitude occurs in the received signal.

In flat fading, symbol time is much larger than multipath time delay spread of channel. Flat fading channel are also called as narrowband channel.

$$B_S \ll B_C$$

And

$$T_S \gg \sigma_\tau$$

where B_S is bandwidth of transmitted signal, B_C is coherence bandwidth of channel, T_S is symbol period and σ_τ is root mean square delay spread.

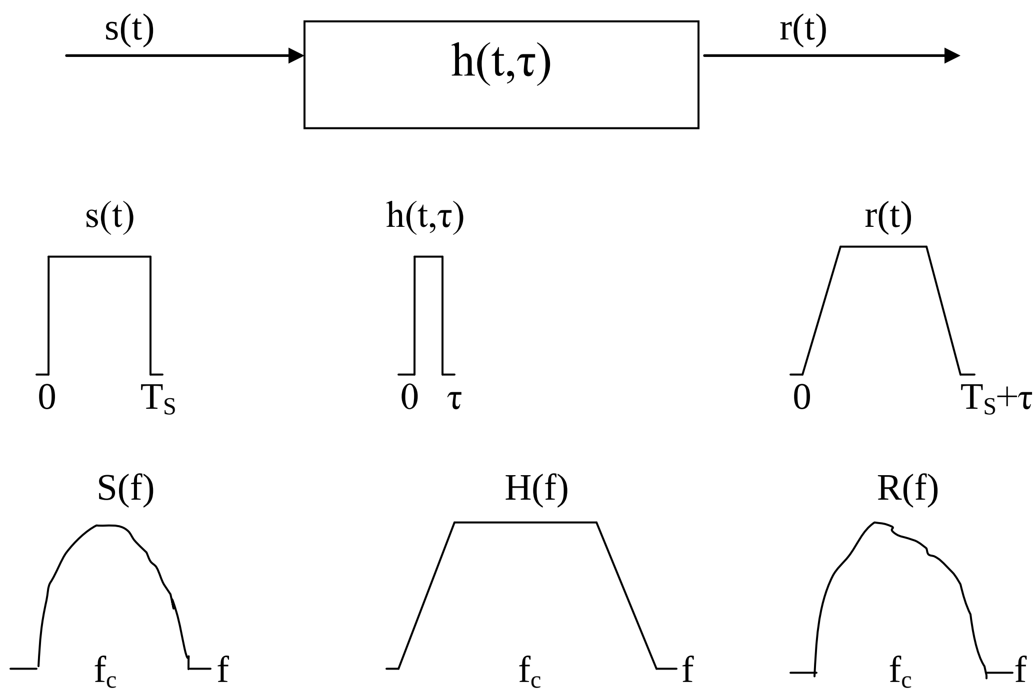

Fig 3.3: Flat Fading Channel Characteristics

3.3 Diversity

Diversity is the tool to overcome the effects of fading in wireless environment. In Next generation wireless link, Diversity plays very important part in endorsing such speedy connections over wireless environment by reducing the consequences of interference and fading. It decreases the effect of channel fading and enhances the reliability of transmitted signal. Diversity provides more than one input at the destination in such a manner that fading process among these inputs are not correlated. If one radio path undergoes deep fade at particular instant of time another uncorrelated path may have strong signal at that time. Let the total number of channels are M and probability of deep fade of one channel is p, then probability for M channel in deep fade is p^M. It can be explained with the help of example that if there are five signals receiving at receiver, there is very less probability that all the signals get faded. There is at-least one signal which is received properly. The main objective of Diversity is to combine the multiple signals in such a manner that effect of fading is reduced. In frequency selective fading environment Diversity technique is used to scale down the effect and interval of the fading at receiver.

3.3.1 Advantages of Diversity Technique

- Unlike Equalization, no training overheads are required in case of diversity.
- It provides significant link improvement with less added cost.
- It exploits random nature of wave propagation by exploits uncorrelated signal paths for communication.

3.3.2 Types of Diversity

In this section, the type of diversity technique used in wireless environment is studied. Usually diversity systems are employed at receiver instead of transmitter since no more transmitted power is required to employ the receiver diversity. Broadly Diversity can be classified into two types: Macroscopic Diversity and Microscopic Diversity.

Macroscopic Diversity

Macroscopic diversity scheme is utilized for combining several numbers of long-term lognormal signals, which are obtained through independently faded paths received from different multiple antennas at base stations. Due to the different geographical conditions between the mobile transmitter and the base station receiver, the local mean strength changes. Single antenna used at the mobile station may not be able to transmit signal to the base station receiver due to the terrain conditions like mountains between them. Therefore two antennas separated by certain distance can be used to receive signals and combine them to reduce long term fading. Selection combining technique is used in macroscopic diversity.

Microscopic Diversity

Microscopic diversity scheme is utilized for combining several numbers of short-term Rayleigh signals which are obtained through independent fading paths received from different antennas but only at one receiving co-site. Microscopic diversity prevents small scale fading which is caused due to multiple reflections from the surroundings. Small scale fading is characterized by deep and rapid variations which take place as the mobile antenna displace over distance of a few wavelengths. This fading can be overcome by selecting an antenna which gives a strong signal. In order to nullify the effects of fading, diversity technique come into picture. Diversity is the process of obtaining multiple versions of transmitted signal via several dimensions like time, frequency, space and polarization.

(a) Time Diversity

Time diversity technique is applicable for transmission of digital data over fading channel. In time diversity, same data is transmitted over channel at different time intervals. Separation between multiple copies of the transmitted signal should be greater than coherence time. Coherence time (Δt) is defined as time interval over which the channel impulse response is fixed. There is no need to increase the numbers of antenna. Figure shows the time diversity scheme where multiple copies of signal s(t) is transmitted at different time intervals.

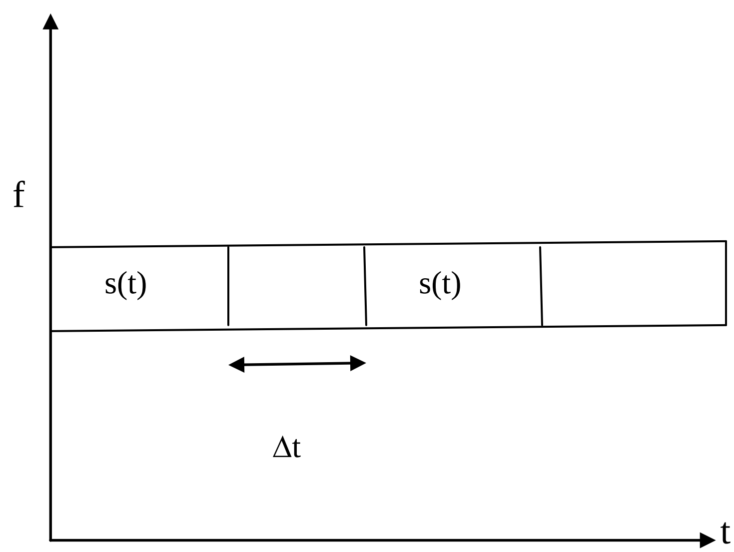

Fig 3.4: Time Diversity

(b) Frequency Diversity

In frequency diversity scheme transmission of same signal at different frequency slots and the frequency separation between them should be at least coherence bandwidth (Δf). Coherence bandwidth is defined as range of frequencies over which channel can be considered to be flat. In frequency diversity different copies of signal undergoes independent fading. There is no need for increasing numbers of antenna. Total transmitted power is divided among the different carriers. But the major drawback of this scheme is increase in bandwidth consumption. So that's why it is less preferred in case of bandwidth limited application. It is often used in microwave line of sight links which carries several channels in frequency division multiplex mode (FDM).

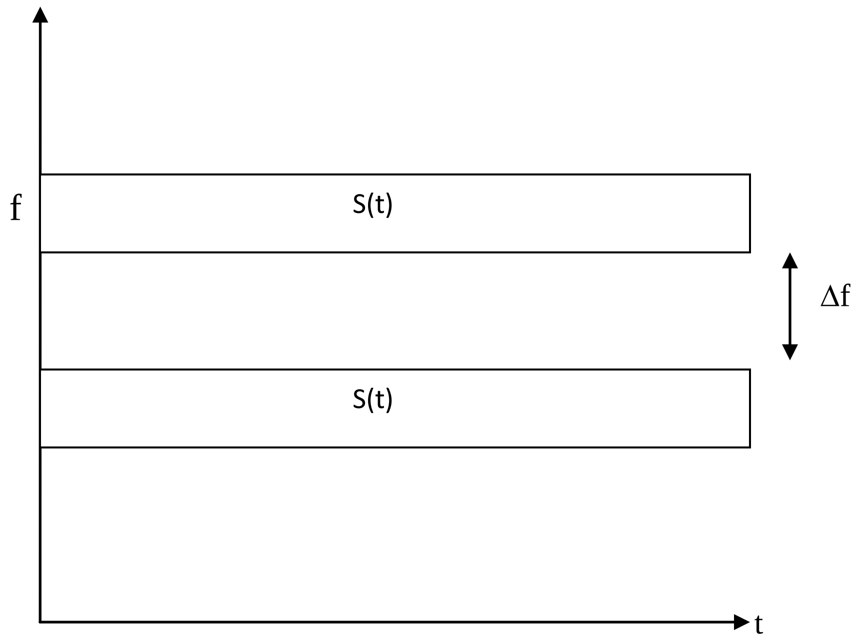

Fig 3.5: Frequency diversity

(c) Polarization diversity

Transmitted signals may be in horizontal or vertical electric fields which are not correlated at the transmitting end and receiving end. The horizontal and vertical polarization components E_x and E_y transmitted by two polarized antennas at the transmitting end and received by two polarization antennas at receiving end which provides two uncorrelated fading signals. Polarization diversity results in 3db power loss at transmitting site since power is divided into different polarized antennas.

(d) Spatial diversity

In spatial diversity, multiple antennas are placed at different spatial locations which are separated by small distance (few wavelengths) and they will not experience fading of signal altogether at the same time instant. If one antenna experiences signal null, other might experience signal peak and destination will select the antenna with best signal at that time. In spatial diversity multiple antennas can be used at transmitter site or receiver site depending on the situation. There are several configurations of spatial diversity like: Transmitter Space diversity, Receiver Space diversity and Transmitter-Receiver Space. M different antennas used at transmitter or receiver site will experience independent fading of signal.

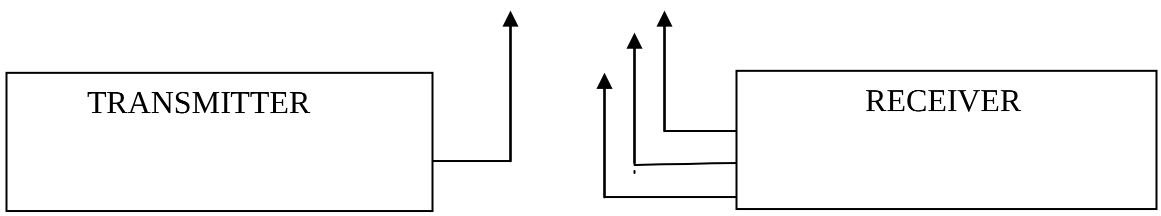

Fig 3.6: Receiver Space Diversity

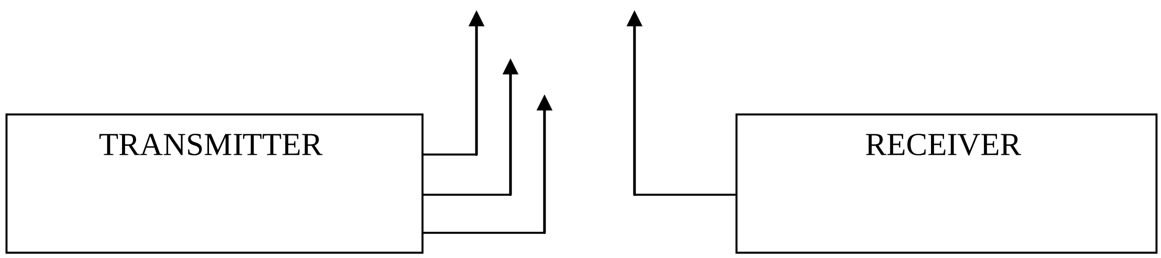

Fig 3.7: Transmit Space Diversity

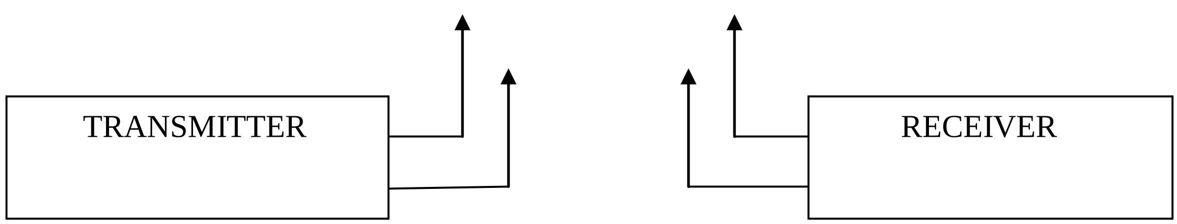

Fig 3.8: Transmit-Receiver Space Diversity

Transmit-Receiver Space Diversity has various advantages like increase in capacity, no extra bandwidth requirement, high reliability and throughput. But the main drawbacks are that it is not suitable for handheld device, implementation cost is very high. In-order to enjoy same benefits without increasing cost and complexity factor, a new class of cooperative communication come into picture. In this source antenna share antenna with other user in order to achieve diversity so that fading effects in wireless environment can be overcome.

CHAPTER-4

COOPERATIVE COMMUNICATION

4.1 Modulation Techniques

The information which is to be transmitted is in the form of 1 or 0 bit sequence modulated by either BPSK or QPSK. QPSK basically comprises of two orthogonal BPSK systems and has twice bandwidth as compared to BPSK.

4.1.1 BPSK Mathematical Equation

BPSK signal can be represented as

$$S_n(t) = \sqrt{\frac{2E_b}{T_b}} Cos(2\pi f_c t + \pi(1-n)), n = 0,1 \quad (4.1)$$

Where E_b = Energy per bit, n = bits per symbol, T_b = Bit duration, f_c is the carrier frequency.

This results in two phases 0 and π which can be represented as:

$$S_0(t) = \sqrt{\frac{2E_b}{T_b}} Cos(2\pi f_c t + \pi) \text{, for binary 0} \quad (4.2)$$

$$S_1(t) = \sqrt{\frac{2E_b}{T_b}} Cos(2\pi f_c t) \text{ , for binary 1} \quad (4.3)$$

The signal space of BPSK can be written by basis function:

$$\varnothing(t) = \sqrt{\frac{2}{T_s}} Sin(2\pi f_c t) \quad (4.4)$$

Where 1 is represented by " $\sqrt{E_b}\varnothing(t)$ " and 0 is represented by " $-\sqrt{E_b}\varnothing(t)$ "

Bit error rate

The bit error rate of BPSK in AWGN can be written as:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \tag{4.5}$$

Where $\frac{N_0}{2}$ = Noise power spectral density (W/Hz)

4.1.2 QPSK Mathematical Equation

QPSK signal can be represented:

$$S_n(t) = \sqrt{\frac{2E_s}{T_s}} Cos(2\pi f_c t + (2n-1)\frac{\pi}{4}), n = 1, 2, 3, 4 \tag{4.6}$$

Where E_s = Energy per symbol = nE_b, T_s = Symbol duration, f_c is carrier frequency, n =bits per symbol. QPSK has four phases $\frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}$ and $\frac{7\pi}{4}$

This results in two dimensional signal space with unit basis functions

$$\varnothing_1(t) = \sqrt{\frac{2}{T_s}} Cos(2\pi f_c t) \tag{4.7}$$

$$\varnothing_2(t) = \sqrt{\frac{2}{T_s}} Sin(2\pi f_c t) \tag{4.8}$$

$\varnothing_1(t)$ is used as the in phase component and $\varnothing_2(t)$ is used as the quadrature component of signal.

Bit Error Rate

The probability of bit-error for QPSK is same as for BPSK:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_o}}\right) \tag{4.9}$$

where P_b = Probability of bit-error. The symbol error rate is given by:

$$P_S = 1-(1-P_b)^2 \qquad (4.10)$$

where P_S = Probability of Symbol-error

4.2 Channel Model for Direct Link Transmission

In a wireless environment, the data which is transmitted from a source to a destination has to travel via air. During propagation several phenomena will distort the signal. In this model, thermal noise, path loss and Rayleigh fading are considered, as illustrated in Fig 4.3. Path loss and fading are multiplicative, noise is additive.

$$y_{s,d} = h_{s,d}\,.x_S + \mathrm{n}_{s,d} = d_{s,d}.a_{s,d}.x_S + \mathrm{n}_{s,d} \qquad (4.11)$$

x_S x_S x_S

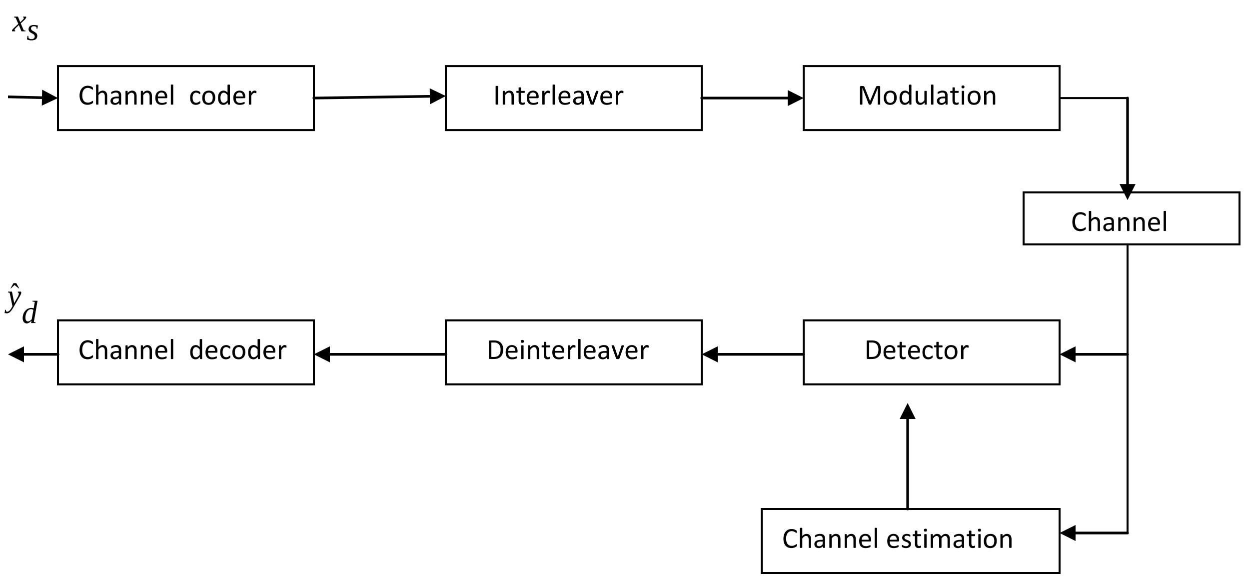

Fig 4.1: Basic Transmission block diagram

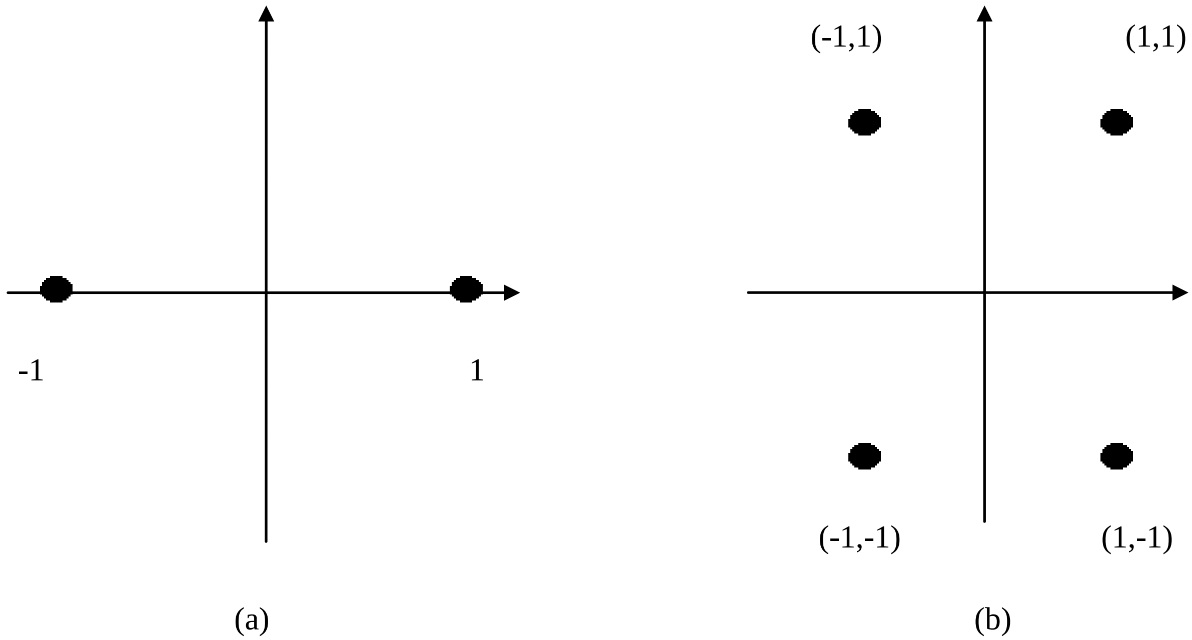

Fig 4.2: a) BPSK, b) QPSK.

where s, d denote source to destination, x_s is the transmitted symbol and $y_{s,d}$ the received symbol at the destination from source.

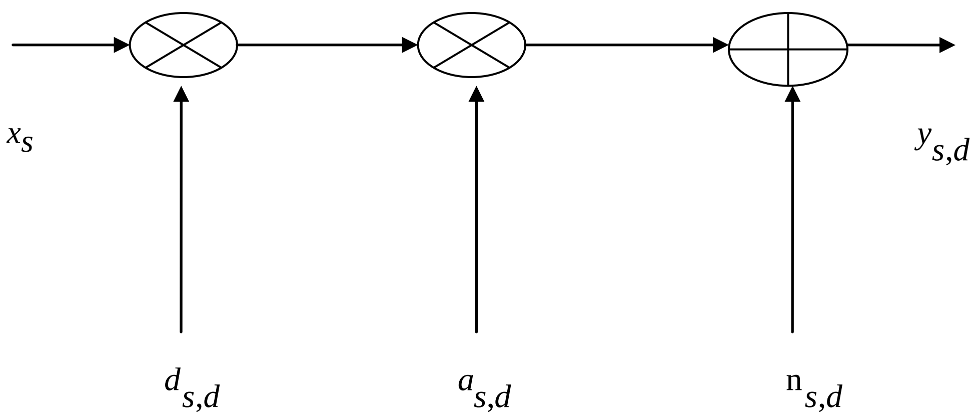

Fig 4.3: Channel model: path loss $d_{s,d}$, fading $a_{s,d}$ and noise $n_{s,d}$.

4.2.1 Noise

The main sources of noise in a wireless environment are interference and electronic components like amplifiers. If the latter dominates, thermal noise can be assumed, which can be characterized as additive complex gaussian noise. It is due to random motion of free electrons and vibrating ions in the conductor. Scalar $n_{s,d}$ noise component can be modeled as the sum of a real and imaginary noise vector, both gaussian distributed, mutually independent (orthogonal) and zero mean with variance σ^2. The total noise power will be $N_o = 2\sigma^2$

4.2.2 Signal to Noise Ratio

The signal to noise ratio (SNR) is a parameter which is used to suggest the signal quality at the destination. If its value is high that indicates the reliability of the signal received at the destination.

$$SNR = \left(\frac{S}{N_o} \right) = \frac{\left| h_{s,d} \right|^2 E\left[\left| x_s \right|^2 \right]}{N_o} \tag{4.12}$$

Where $E\left[\left| x_s \right|^2 \right]$ denotes the energy of transmitted signals and N_o the total power of the noise.

4.2.3 Path Loss and Fading

The signal is weakened mainly due to the effects of free space path loss and fading, both included in $h_{s,d} = d_{s,d} . a_{s,d}$. The path loss $d_{s,d}$ (assuming a plane-earth model) is inversely proportional to R^2. As long as the distance between the sender and receiver does not change too much, it can be assumed to be constant for the whole transmission. The power of the received signal is attenuated by inversely proportional R^4.

In a wireless environment, many times non line of sight condition occurred. Rather than direct transmission, the signal will travel to the destination in several ways. This occurs mostly in metro cities, where buildings acts as obstacle in the line of sight link but enables different non line of sight paths for indirect connection by reflecting the propagating signal. This effect is known as multi-path propagation.

Only slight variations in the whole system might change the characteristic of the channel and therefore the signal quality considerably. This effect, known as fading, will alter the signal by weakening it and adding a phase shift to it. The fading coefficient $a_{s,d}$ is prototyped as a zero mean, complex Gaussian random variable with variance $\sigma^2_{s,d}$. This means that the angle of fading coefficient $a_{s,d}$ is uniformly distributed on [0, 2π) and the magnitude of fading coefficient $a_{s,d}$ is Rayleigh distributed. This Rayleigh distributed magnitude has worst effect on the quality of signal at the destination. Even a system having high SNR might suffer from significant errors due to fading

Block Fading

In a fast fading channel, the channel features vary within one burst of data. The block fading channel model pays attention to this effect. The burst is divided into smaller pieces, blocks, which can then be presumed to have a fixed channel features. In order to estimate the channel features perfectly, the block length should be large enough. The magnitude and the angle of the fading coefficient $a_{s,d}$ of the block is acknowledge to the destination. In a block fading channel, there is a prominent chances that burst errors occur, i.e. that there are a large number of errors within one block. Such bursts of errors are very hard to correct with an error correcting code. To prevent them occurring, the signal can be interleaved to get the errors distributed uniformly over the whole signal.

4.3 Destination Model

The destination detects the received signal symbol by symbol. In the case of a BPSK modulated signal the symbol/bit is detected as

$$\hat{y}_d = +1(\mathrm{Re}\{y_d\}) \geq 0$$

$$\hat{y}_d = -1(\mathrm{Re}\{y_d\}) < 0$$

For a QPSK modulated signal there are two bits transferred per symbol, which are detected as

$$\hat{y}_d = [+1,+1] \quad (0^o \leq \angle y_d < 90^o)$$

$$[-1,+1] \quad (90^o \leq \angle y_d < 180^o)$$

$$[+1,-1] \quad (-90^o \leq \angle y_d < 0^o)$$

$$[-1,-1] \quad (-180^o \leq \angle y_d < -90^o)$$

The channel consists of path loss and Rayleigh fading which are multiplicative components and thermal noise which is additive. Further this simple single link model is extended to a diversity technique using one direct link and one multi-hop link to destination via relay.

4.4 Cooperative Communication

There are several techniques to deploy diversity in a wireless environment. Multiple antennas can be used to achieve space diversity. But in some applications implementation of multiple antennas are not always feasible or the destination is very far away to get good signal quality. In order to enjoy the benefits of diversity, an ad-hoc network is build up with the help of relay station. The model of such a system is described in Fig. 4.4. The source S, sends the data to the destination D, as well as the relay station R in first level of the transmission and in second level relay process the data and transmit to the destination, where the two received signals are combined at destination. In Cooperative Communication different users enhances the quality of service by sharing of information in the wireless environment. Orthogonal channels are used for the two transmissions. Time division multiplexing is used in order to transmit signal to destination.

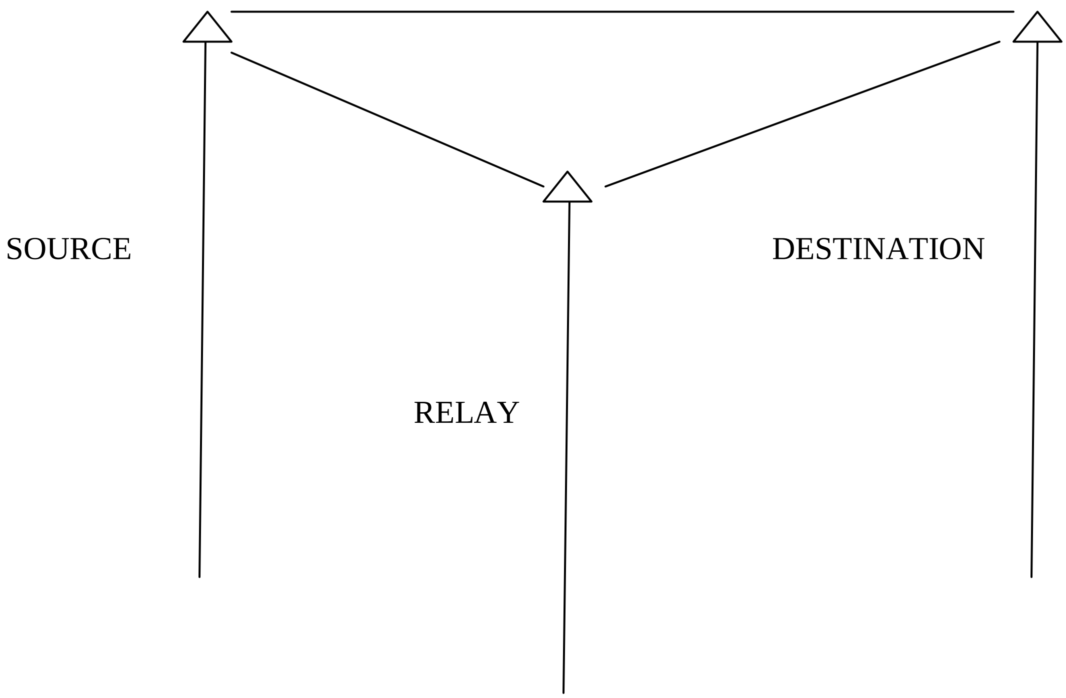

Fig 4.4: System Model of Cooperative Communication.

4.5 Cooperative Transmission Protocols

Depending upon the protocol used at relay station, cooperative communication process can be broadly classified into two major categories: Amplify and Forward (AAF) or Decode and Forward (DAF). These protocols depict the behavior of relay station and tell what actions are performed at relay station before the transmission of information to the destination.

4.5.1 Amplify and Forward

Amplify and Forward protocol is used when the relay has restricted period of time and power or in-order to avoid delay occurred at relay station while using decode and forward protocol.

Basic approach behind this protocol is quite simple. As the signal received at the relay station was weakened and it is required to be amplified before it is transmitted to the destination. While doing so the noise present in the signal is also get amplified, that is the main limitation of this protocol.

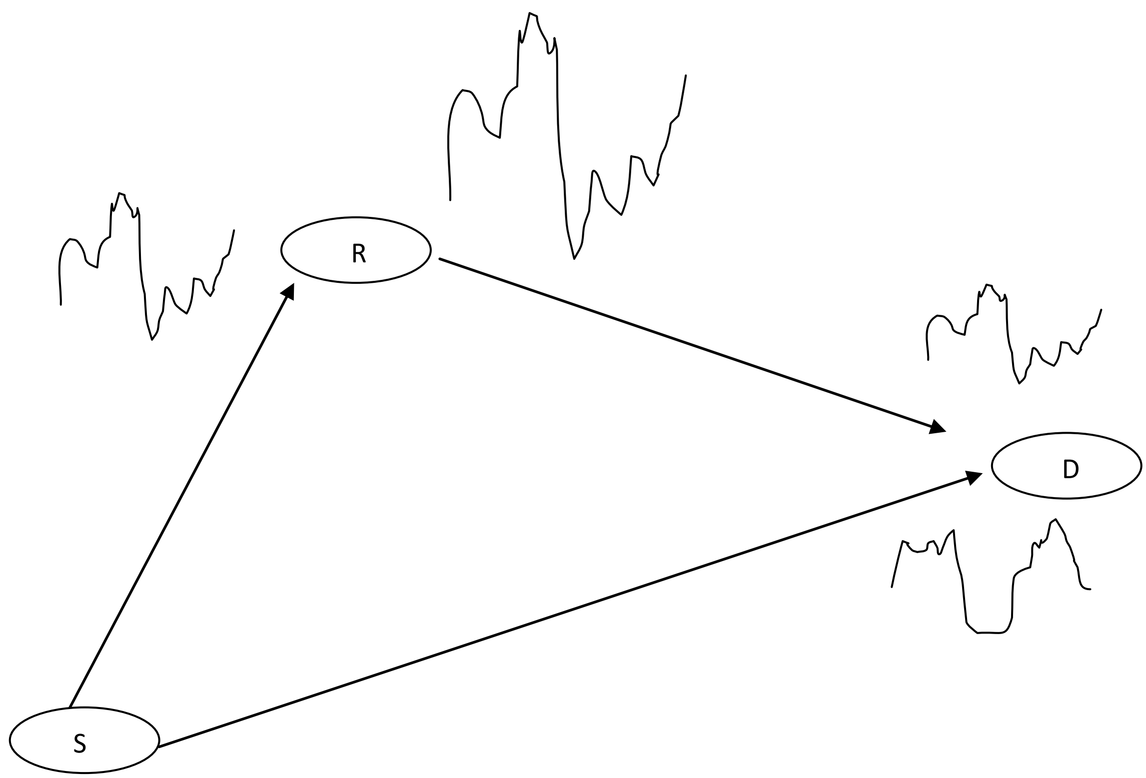

Fig 4.5: Amplify and Forward Protocol

Cooperative communication process using Amplify and Forward protocol can be divided into two phases. In the first phase, information is transmitted to the relay station and destination. In the second phase, relay received the noisy version of transmitted signal from the source and further transmits it to the destination after amplification. The incoming signal is amplified block wise.

In the first phase, source broadcast its signal to both destination and relay. $y_{s,d}$ and $y_{s,r}$ received signal from source to destination and source to relay respectively.

$$y_{s,d} = \sqrt{P_1} h_{s,d} . x + n_{s,d} \tag{4.13}$$

$$y_{s,r} = \sqrt{P_1} h_{s,r} . x + n_{s,r} \tag{4.14}$$

where P_1 is the transmitted power of the source, x is transmitted information symbol. $h_{s,d}$ and $h_{s,r}$ are channel gain from source to destination and source to relay respectively. Noise terms $n_{s,d}, n_{s,r}$ and $n_{r,d}$ are prototyped as zero mean complex gaussian random variable and are assumed to be equal to n.

In the second phase, relay amplify noisy version of the signal received from the first phase and forward it to the destination with power P_2. $y_{r,d}$ is the received signal from relay to destination. $h_{r,d}$ is the channel gain from relay to destination.

$$y_{r,d} = \beta h_{r,d} . y_{s,r} + n_{r,d} \tag{4.15}$$

where $$\beta = \sqrt{\frac{P_2}{P_1 \left|h_{s,r}\right|^2 + N_o}} \tag{4.16}$$

and N_o is noise variance and it is related to source to relay path.

$$y_{r,d} = \sqrt{\frac{P_1 P_2}{P_1 \left|h_{s,r}\right|^2 + N_0}} h_{r,d} h_{s,r} x + n_{r,d} \tag{4.18}$$

Advantages of Amplify and Forward Protocol

- Base station receives two independently faded versions of the signal and can make better decisions on the detection of information.
- For the two-user case, this method achieves diversity order of two, which is the best possible outcome at high SNR

- It is very simple to implement and cost effective.
- No delay occurs in this case.
- Required less computing power.

Disadvantage of Amplify and Forward Protocol

- Major drawback of this protocol is Noise amplification occurs at relay. At relay along with signal, noise also get amplified which is not desirable.

4.5.2 Decode and Forward

Basic system model and transmission strategy is same as in the case of Amplify and Forward protocol. The only difference lies in the working of relay station. Relay station, simply decode the received signal and then re-encode the information which is sent to the destination. This protocol is preferred when relay has large computing time and power. Error correcting techniques are used in order to achieve correct information at the destination. If the received information is not correct then it is discarded at relay station. Without using error correcting techniques the performance of Decode and Forward protocol is worst as compare to the Amplify and Forward protocol. Error correcting techniques increases the complexity at the relay station, as relay has to decode the whole signal which is transmitted by the source and send the encoded version of signal to the destination. But there is no problem of noise amplification as in the case of Amplify and Forward protocol. In this thesis, the main focus is to study the performance of cooperative communication using amplify and forward protocol. Figure 4.6 shows decode and forward relaying protocol used in cooperative communication system.

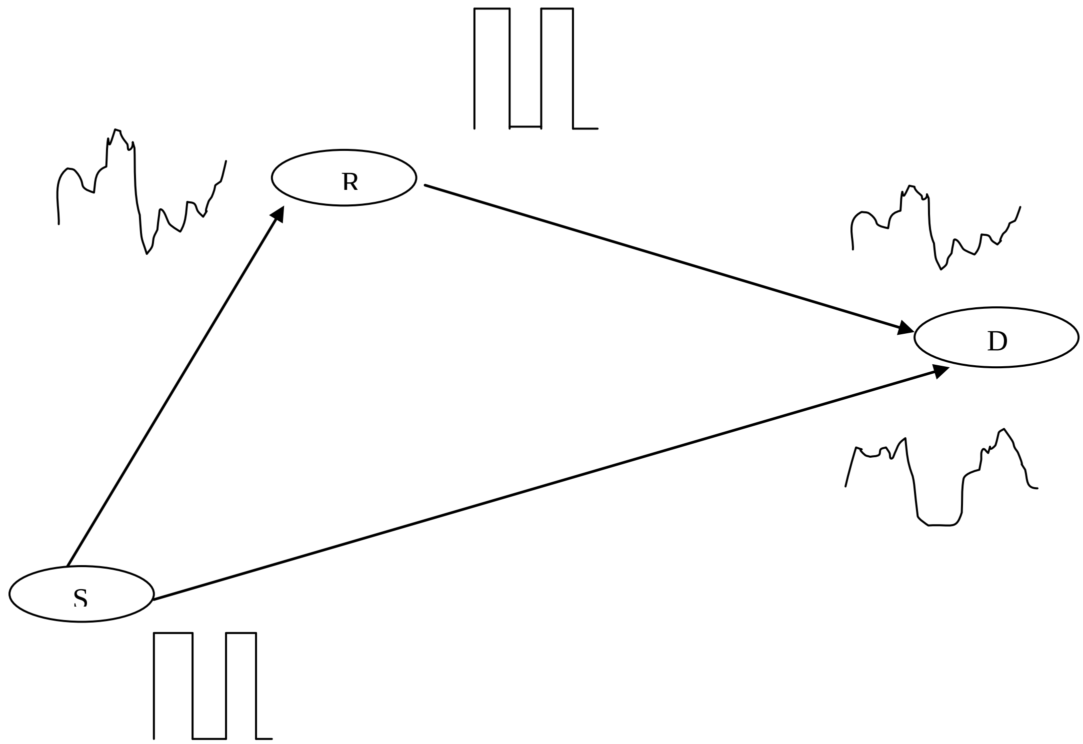

Fig 4.6: Decode and Forward Protocol

Advantages of Decode and forward Protocol

- There is no problem of noise amplification as this occurs in amplify and forward protocol.
- Correct signal is received at receiver as channel coding is used in order to detect errors.

Disadvantages of Decode and forward Protocol

- Complexity of the system increases in this case.
- Problem of delay occurs.
- If the source to relay link is poor then there is possibility of not getting the signal at the receiver.

4.6 Combining Type

Combining of independently faded signal branches can be merged in a different ways in order to increase the received signal to noise ratio at destination. By employing combining schemes both the instantaneous and average signal to noise ratio at receiver can be improved. The improvement in average and instantaneous signal to noise ratio depends upon type of combining approach used. Since there are very less chances that all the uncorrelated branches have deep fade at any particular instant of time. Combining them altogether can reduce the effect of fading. Three major combining schemes used are: Selection Combining, Equal Gain Combining and Maximal Ratio Combining.

4.6.1 Selection Combining

Selection diversity combining technique is simplest of all other combining schemes. It is based on probability that received signal is greater than threshold. Signal with highest signal to noise ratio of all the branches is selected by the ideal selection combiner, so that output SNR is highest of incoming signal and make it available to receiver at any time. Several branches will improve the probability of having highest SNR at receiver.

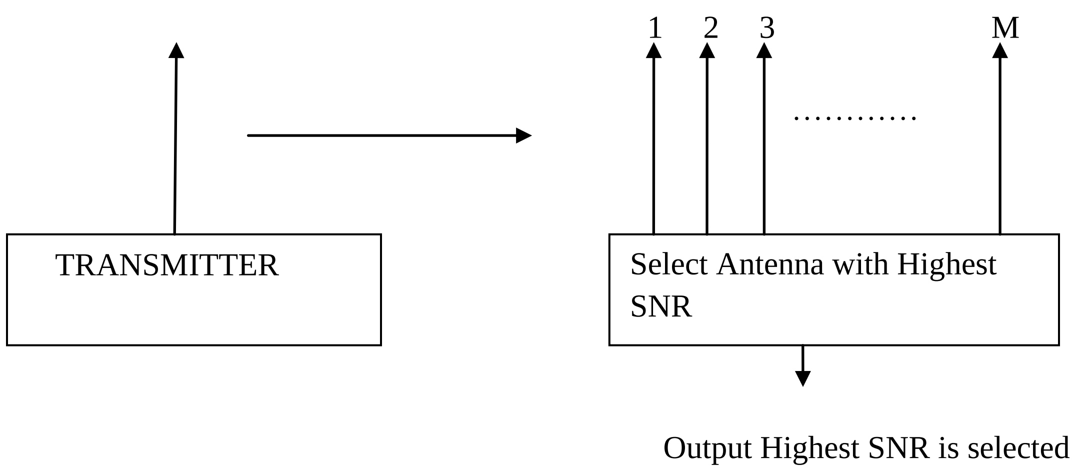

Fig 4.7: Selection Combining

4.6.2 Maximum Ratio Combining (MRC)

In MRC, all the uncorrelated branches of signal are co-phased and weights are selected according to their respective SNR and then add it. MRC is the most complex combining scheme which yields in highest SNR. MRC achieves the best possible performance by multiplying each input signal with its corresponding conjugated channel gain. It presents that receiver SNR is direct sum of all the individual SNR in the branches. The channel's phase shift and attenuation is perfectly known by the receiver.

$$y_d = \sum_{i=1}^{k} h_{i,d}^{*} \cdot y_{i,d} \qquad \text{or}$$

$$y_d = h_{s,d}^{*} y_{s,d} + h_{r,d}^{*} y_{r,d} \tag{4.19}$$

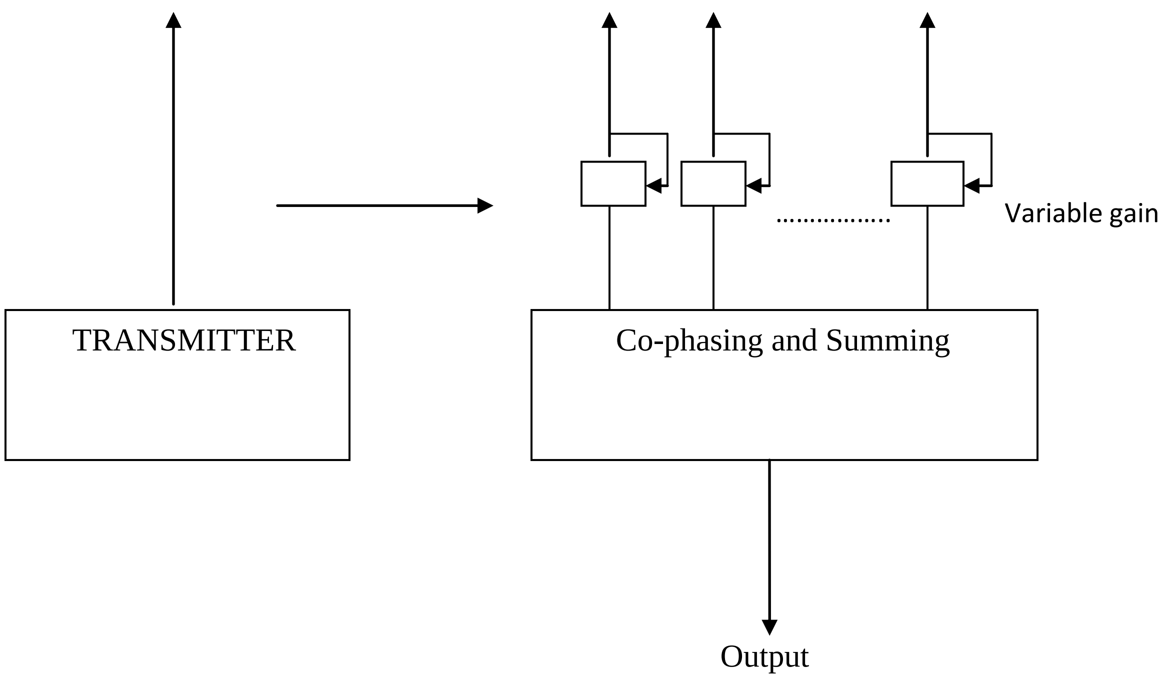

Fig 4.8: Maximal Ratio Combining

4.6.3 Equal Gain Combining (EGC)

Equal gain combining diversity receiver is of practical interest because of reduced complexity as compare to maximal ratio combining. If computing time is a crucial point or the channel quality could not be estimated, all the received signals can just be added up in order to increase signal to noise ratio at the receiver. This is the easiest way to combine the signals, but the performance will not be that good in return. EGC is similar to MRC, but the difference lies in weight selection as in order to simplify a_i=1, thus output signal of EGC is given by

$$y_d = \sum_{i=1}^{k} y_{i,d}$$

Here in this case one relay station is used, so the equation simplifies to

$$y_d = y_{s,d} + y_{r,d} \tag{4.20}$$

where $y_{s,d}$ denotes the received signal from the sender to destination and $y_{r,d}$ is the received signal from relay to destination. $h^*_{s,d}$ is the conjugate of channel gain from source to destination and $h^*_{r,d}$ is the conjugate of channel gain from relay to destination.

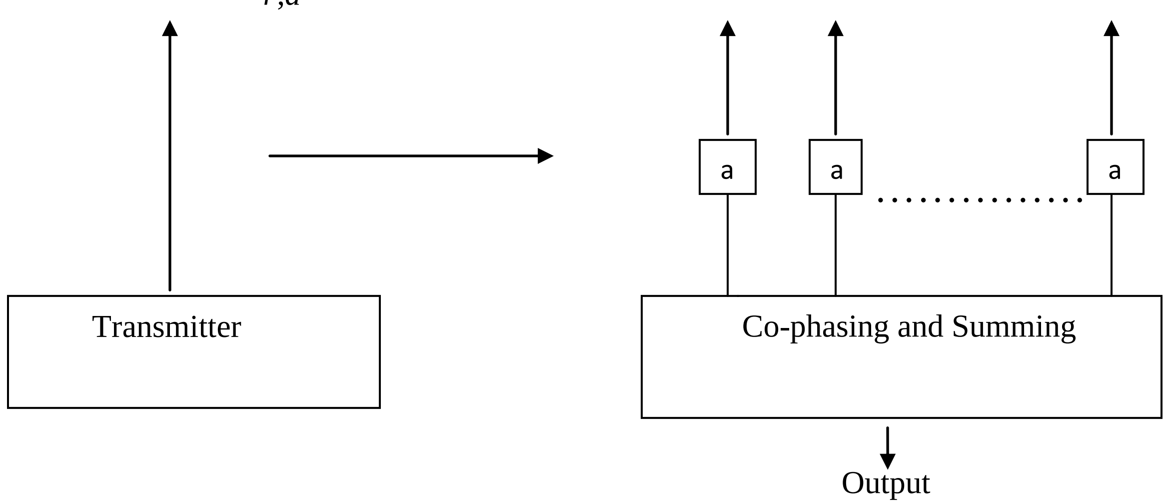

Fig 4.9: Equal Gain Combining

4.7 Uneven Power Distributions and Different Relay Arrangement

4.7.1 Uneven Power Distribution

Effect of uneven power distribution between relay and source station has been studied. Different cases have been analyzed in-order to study the performance of the system. In first case source power is made higher than relay power and in second case relay power is made higher than source power. Both the cases are simulated and compared with equal power distribution between source and relay.

4.7.2 Different Relay Arrangement

Multiple relays are used and they are arranged in cascaded and parallel topology. The performance of Cascaded relay transmission is compared with Parallel relay transmission topology.

(a) Cascaded relay transmission

Cascaded relay transmission is employed where the distance between source and destination is very large. In this arrangement, information travels from one relay to another and reaches the destination. Orthogonality between neighboring channels is maintained in order to nullify the effect of interference.

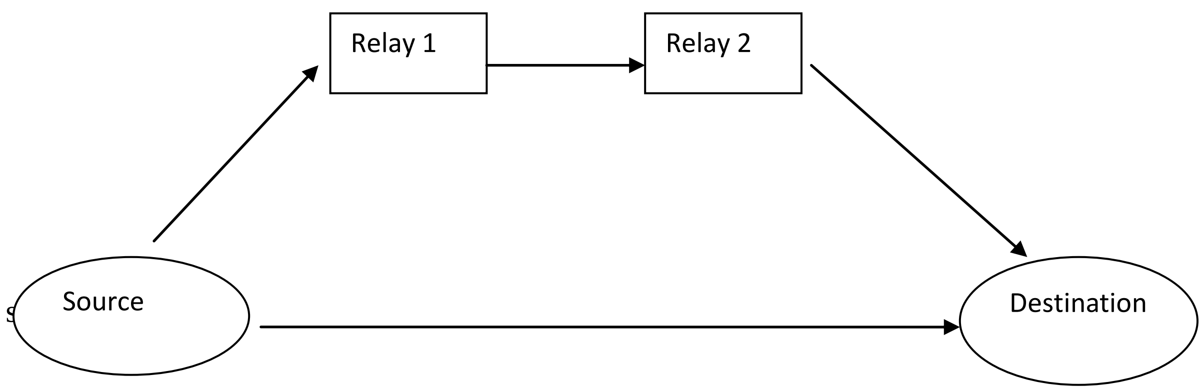

Fig 4.10: Cascaded relay transmission

(b) Parallel relay transmission

Multipath fading is the major drawback of serial relay transmission topology. Deploying multiple antennas for the non- line of sight communication is quite difficult task. Inorder to nullify the effects of multipath fading parallel relay transmission topology is used. By using relay in parallel fashion, diversity can be achieved. At the destination, different combining schemes can be used to improve the quality of the signal by increasing the instantaneous and average SNR of the received signal.

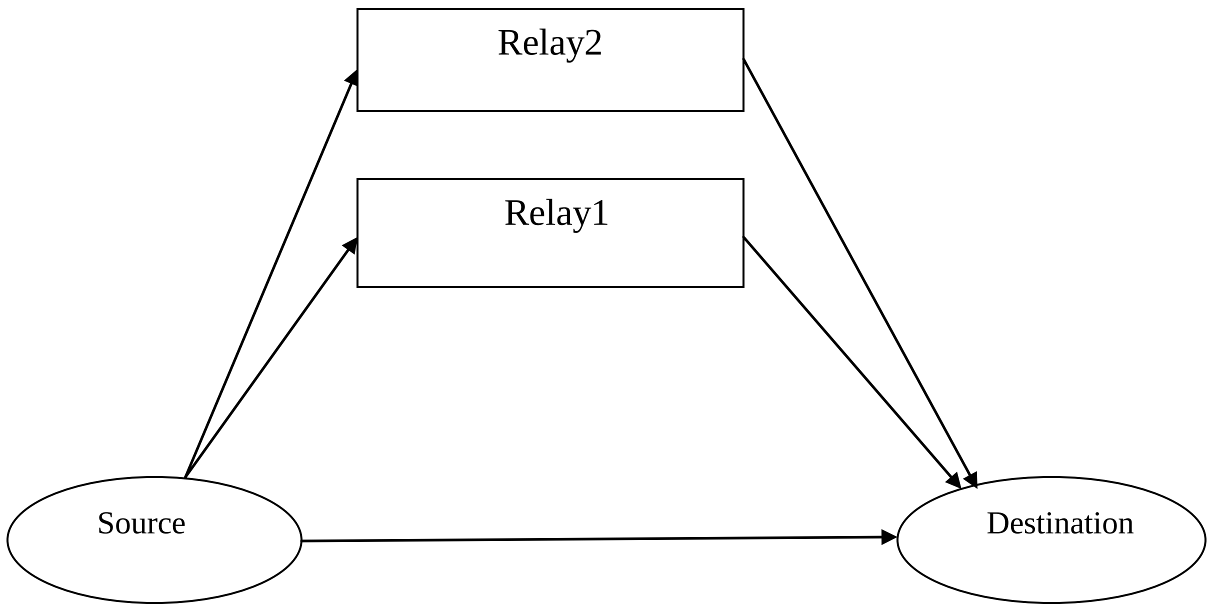

Fig 4.11: Parallel Relay Transmission

4.8 Simulation details

4.8.1 SER analysis of single link transmission using BPSK and QPSK modulation scheme.

Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = BPSK and QPSK ; Fading Type = Rayleigh

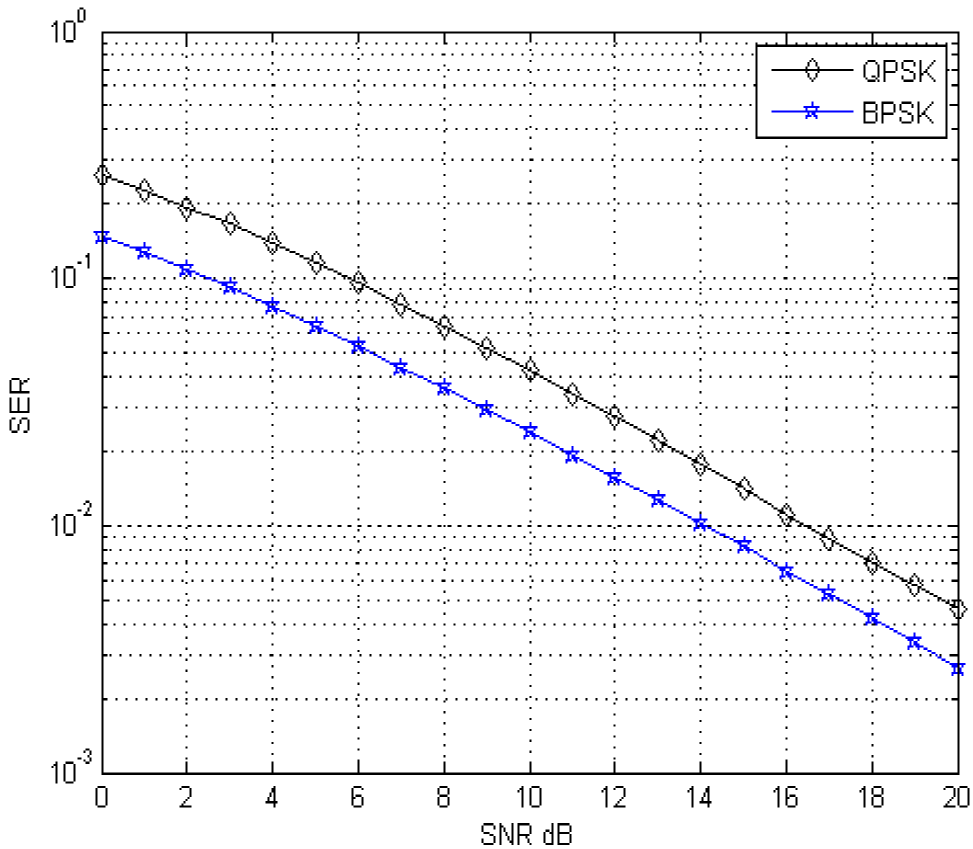

Fig 4.12: Plot of SER vs SNR of single link transmission using BPSK and QPSK modulation

From the graph between SER vs SNR for the single link transmission using two modulation schemes ie BPSK & QPSK over Rayleigh fading channel, it is observed that at 10^{-1} SER, required SNR for the BPSK modulation is 2.5 dB while for QPSK modulation is 5.78 dB. Further results are as shown in Table 4.1 for both the modulations.

SER	SNR(in dB) for	
	BPSK	QPSK
10^{-1}	2.5	5.78
10^{-2}	14	16.40

Table 4.1: SER vs SNR analysis of single link transmission using BPSK and QPSK modulation.

4.8.2 SER performance analysis of cooperative communication without combining non cooperative using QPSK modulation scheme.

Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh

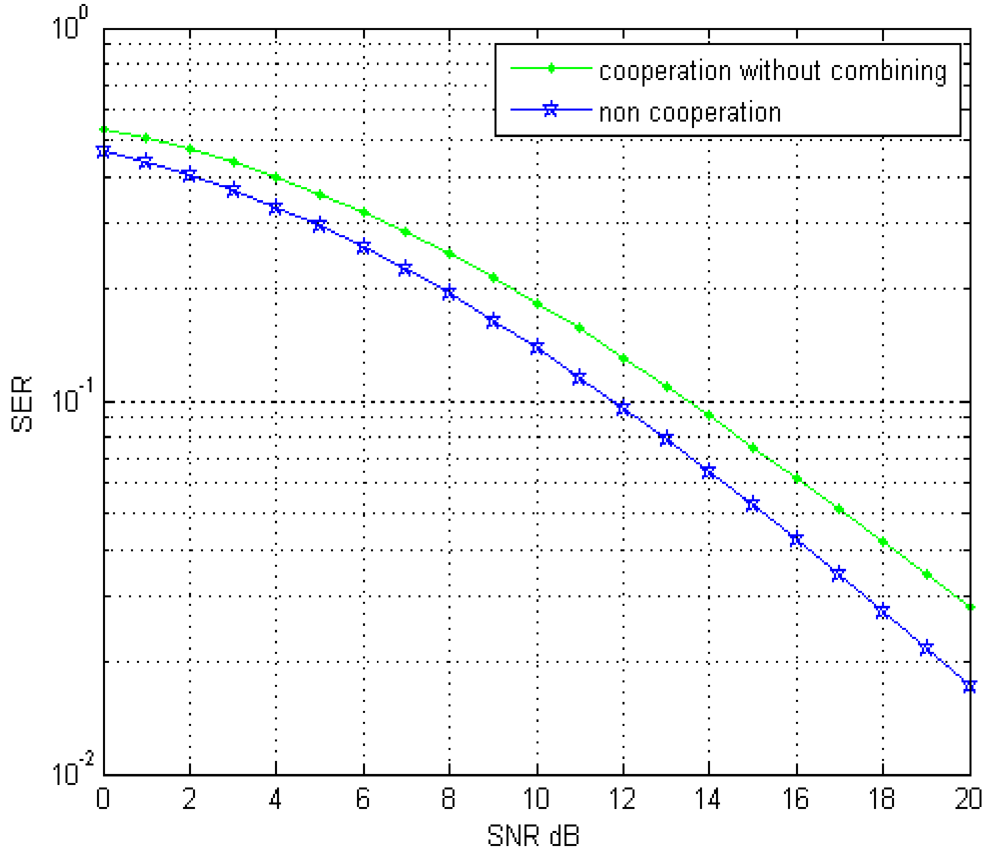

Fig 4.13: Plot of SER vs SNR of cooperative communication without combining and non-cooperative using QPSK modulation

From the graph between SER vs SNR for cooperative communication without combining and non-cooperative using QPSK modulation scheme over Rayleigh fading channel, it is observed that at 10^{-1} SER, required SNR for the Non-Cooperative system is 11.77 dB while for Cooperative without combining scheme is 13.50 dB.

4.8.3 Performance analysis of Cooperative Communication vs Non- Cooperative Communication for different Amplification factor without using Combining schemes.

(a) Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Amplification factor = 5

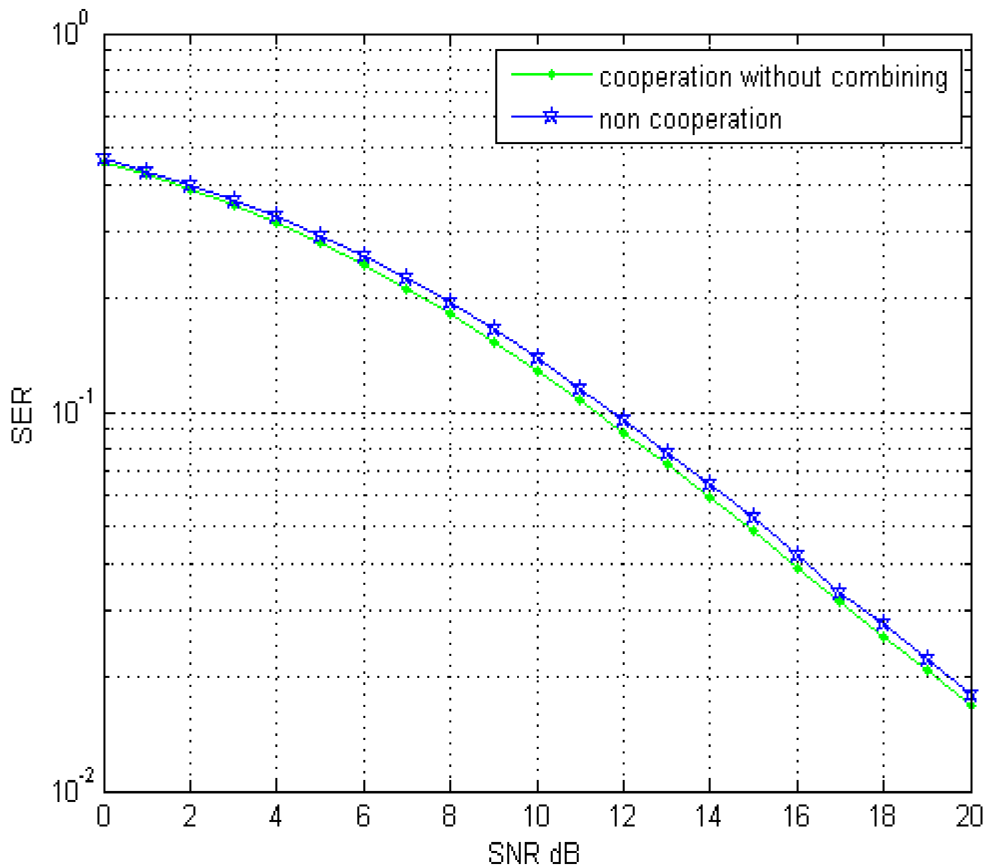

Fig 4.14(a): Plot of SER vs SNR for Cooperative Communication vs Non-Cooperative Communication for Amplification factor = 5.

At 10^{-1} SER, required SNR for the Cooperative system without combining having Amplification factor = 5 is 11.36 dB while for Non-Cooperative system is 11.74 dB.

(b) Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Amplification factor = 10

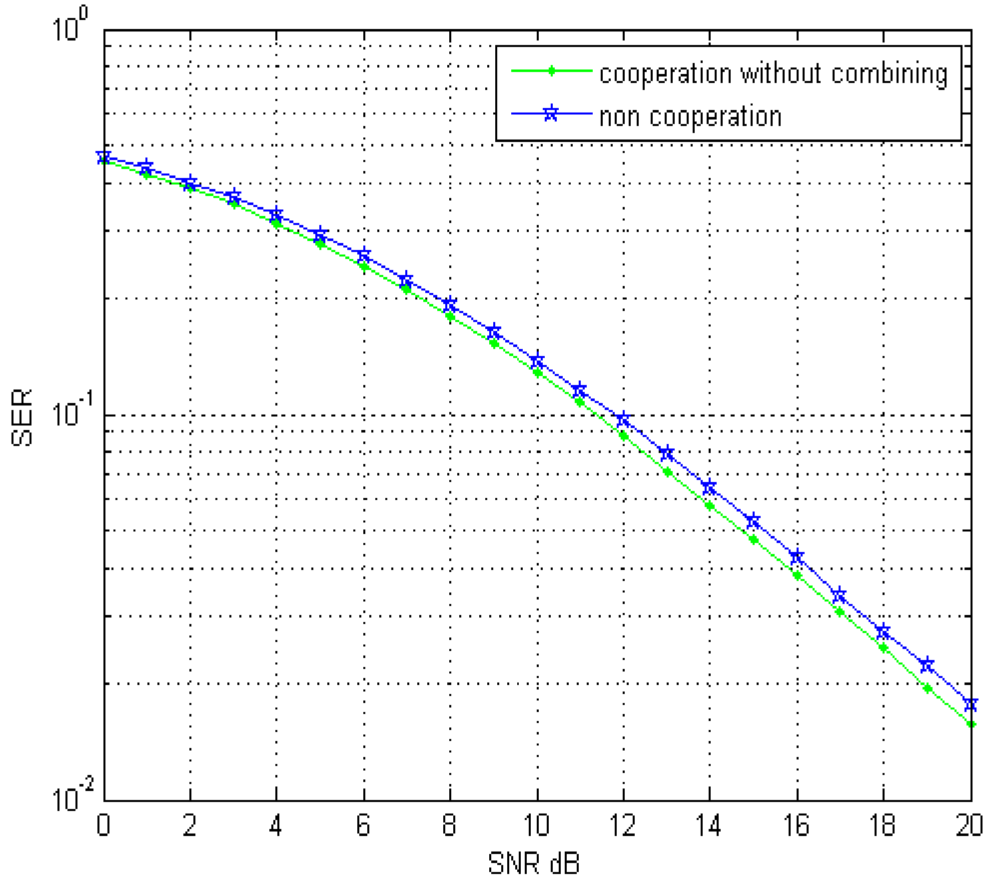

Fig 4.14(b): Plot of SER vs SNR for Cooperative Communication vs Non-Cooperative Communication for Amplification factor = 10.

At 10^{-1} SER, required SNR for the Cooperative system without combining having Amplification factor = 10 is 11.34 dB while for Non-Cooperative system is 11.80 dB.

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(c) Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Amplification factor = 15

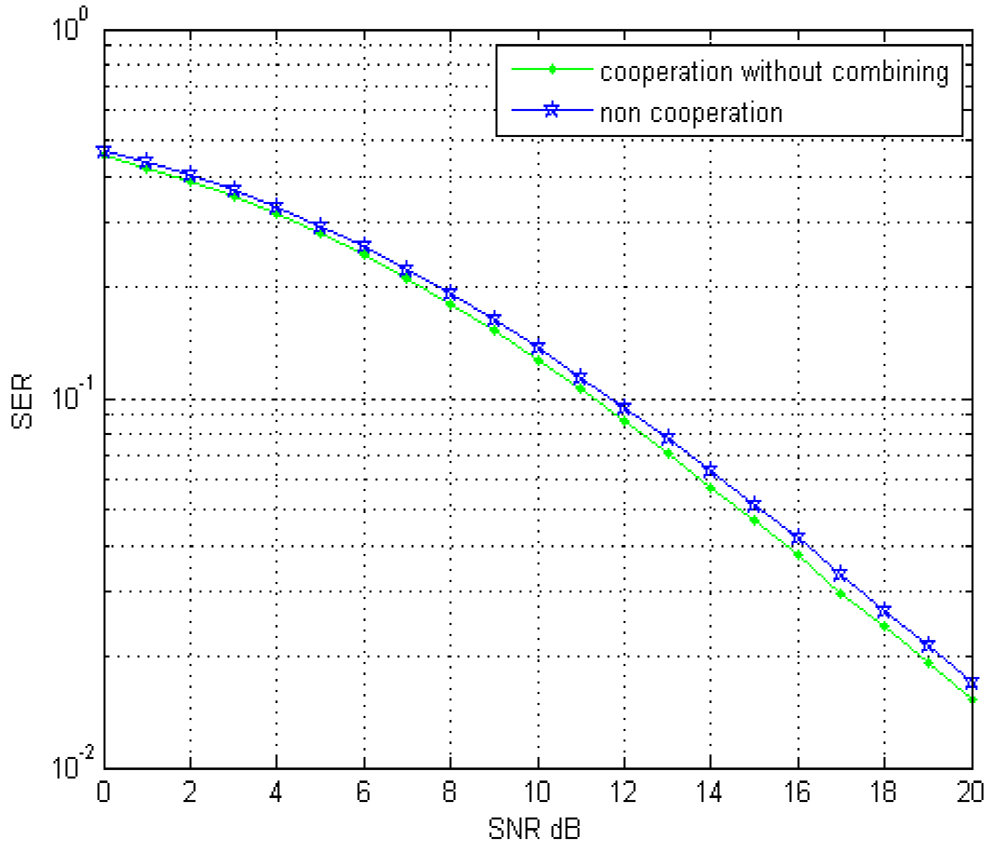

Fig 4.14(c): Plot of SER vs SNR for Cooperative Communication vs Non-Cooperative Communication for Amplification factor = 15 .

At 10^{-1} SER, required SNR for the Cooperative system without combining having Amplification factor = 15 is 11.28 dB while for Non-Cooperative system is 11.69 dB.

(d) Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Amplification factor = 20

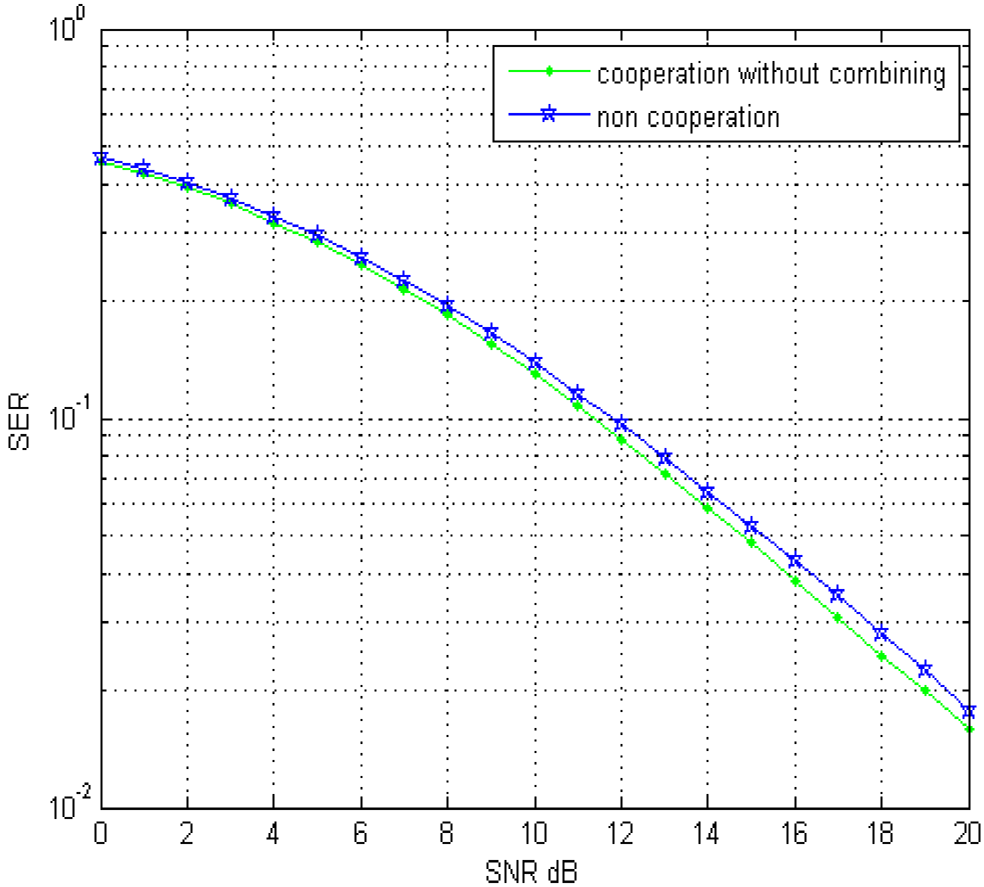

Fig 4.14(d): Plot of SER vs SNR for Cooperative Communication vs Non-Cooperative Communication for Amplification factor = 20.

At 10^{-1} SER, required SNR for the Cooperative system without combining having Amplification factor = 20 is 11.38 dB while for Non-Cooperative system is 11.78 dB. Fig 4.14(a) to 4.14(d) shows that there is minor improvement in performance of cooperative system without combining for amplification factor = 5 to 20 which is not much advantageous. This proofs that without using combining schemes very high amplification power is required which is just wastage of power resources. In order to avoid this combining schemes are used in cooperative communication systems.

4.8.4 Performance analysis of Cooperative Communication System using MRC and EGC Combining schemes.

Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Combining Schemes = MRC and EGC

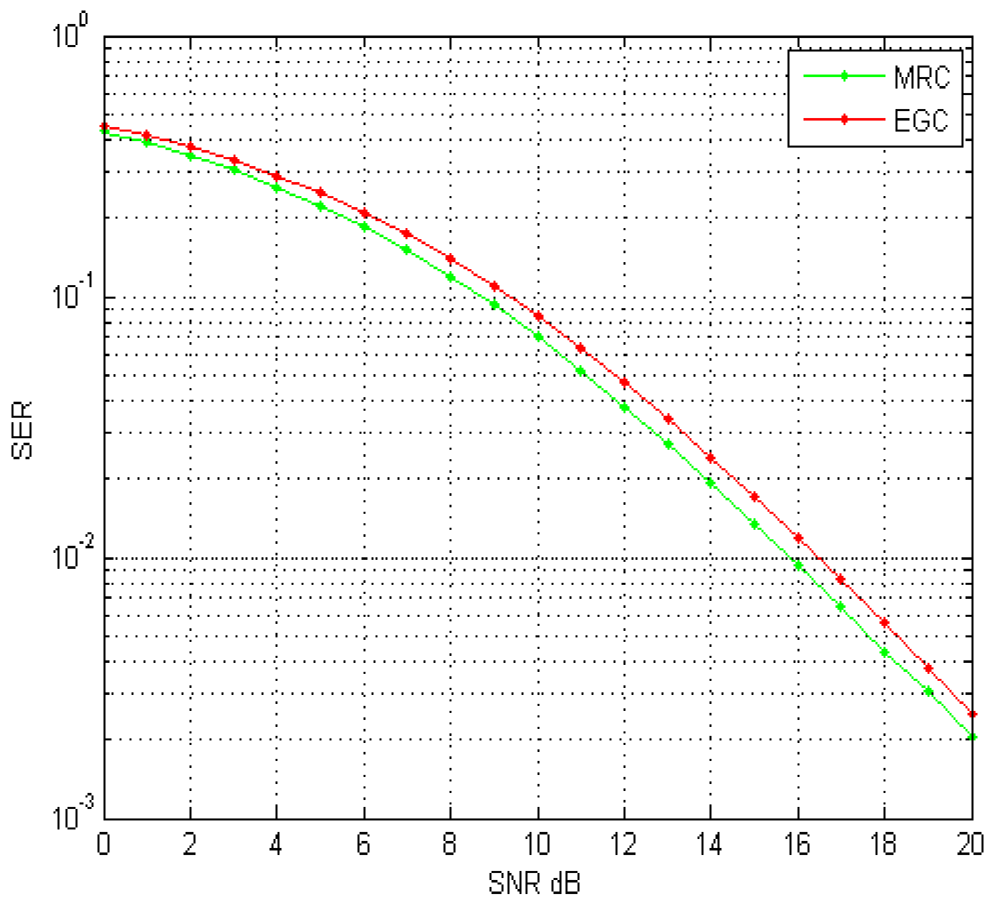

Fig 4.15: Plot of SER vs SNR for Cooperative Communication with MRC and EGC Combining Scheme

At 10^{-1} SER, required SNR for the Cooperative system using MRC Combining scheme is 8.70 dB while for the Cooperative system using EGC Combining scheme is 9.36 dB.

SER	SNR(in dB) for	
	MRC	EGC
10^{-1}	8.70	9.36
10^{-2}	15.81	16.46

Table 4.2: SER vs SNR analysis of cooperative communication system using different combining schemes.

4.8.5 Performance analysis of Cooperative Communication System using different Combining schemes, SISO System and Cooperative System without Combining Scheme

Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Combining Schemes = MRC and EGC

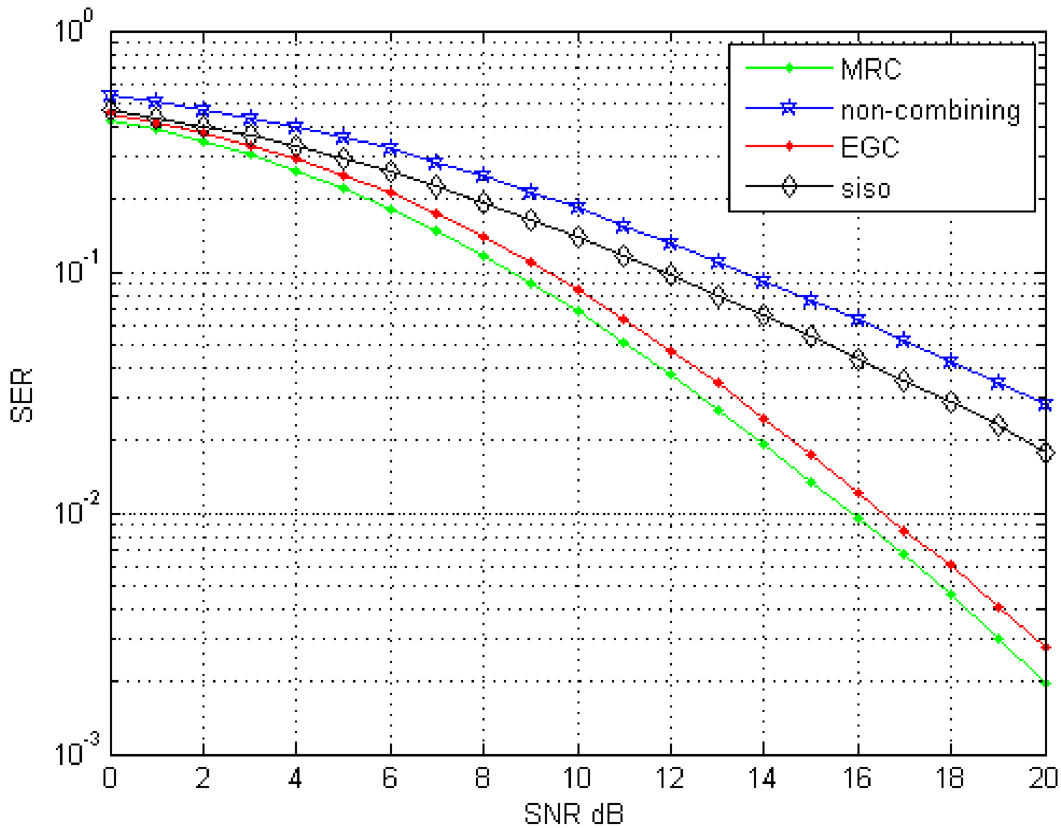

Fig 4.16: Plot of SER vs SNR for Cooperative Communication System using different Combining schemes, SISO System and Cooperative System without Combining Scheme

From the graph between SER vs SNR for Cooperative communication using different combining schemes, SISO System and Cooperative System without Combining Scheme using QPSK modulation scheme over Rayleigh fading channel, it is observed that at 10^{-1} SER, required SNR for MRC combining scheme is 8.60 dB, for EGC combining scheme is 9.34 dB, for SISO system is 11.81 dB and for cooperative system without combining scheme is 13.50 dB.

4.8.6 To analyze the effect of Uneven Power distribution between Source and Destination for the cooperative system

(a) Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Combining Schemes = MRC ; Total Power = 1 ; For uneven power distribution : Source Power Ps = 0.6 and Relay Power Pr = 0.4 and vice versa.

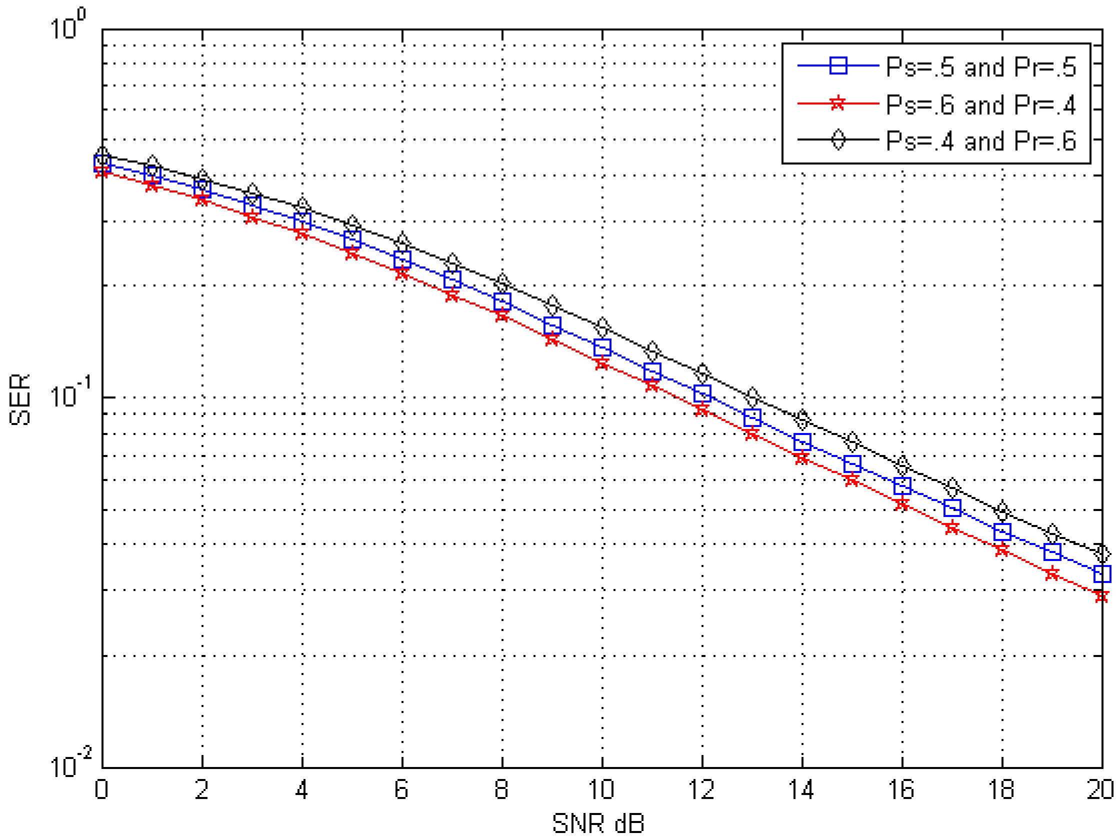

Fig 4.17(a): SER vs SNR Plot of Uneven Power distribution between Source and Destination for the cooperative system with Source Power =.6 and Relay Power =.4 and vice versa

At 10^{-1} SER, SNR for the cooperative system with Source Power = .6 and Relay Power =.4 is 11.47 dB, SNR for the cooperative system with Source Power = .5 and Relay Power =.5 is 12.14 dB and SNR for the cooperative system with Source Power = .4 and Relay Power =.6 is 13.01 dB.

(b) Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Combining Schemes = MRC ; Total Power = 1 ; For uneven power distribution : Source Power Ps = 0.7 and Relay Power Pr = 0.3 and vice versa.

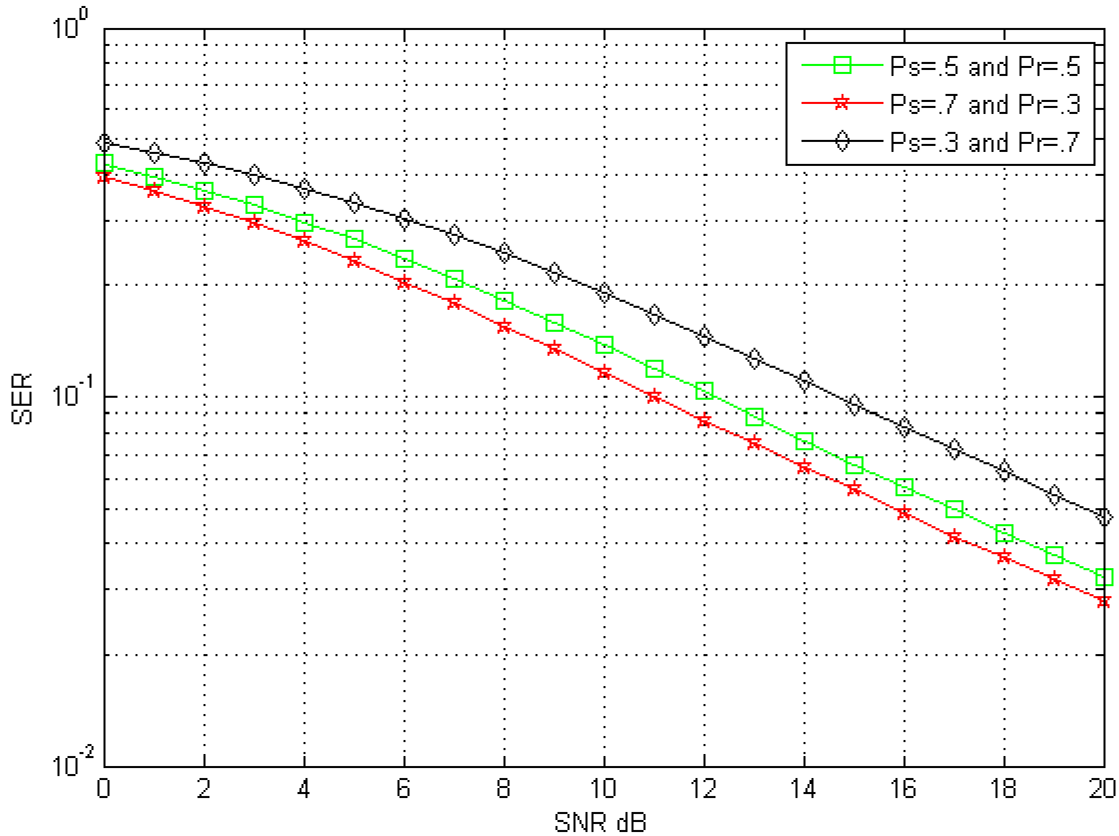

Fig 4.17(b): SER vs SNR Plot of Uneven Power distribution between Source and Destination for the cooperative system with Source Power =.7 and Relay Power =.3 and vice versa.

At 10^{-1} SER, SNR for the cooperative system with Source Power = .7 and Relay Power =.3 is 11.01 dB, SNR for the cooperative system with Source Power = .5 and Relay Power =.5 is 12.22 dB and SNR for the cooperative system with Source Power = .3 and Relay Power =.7 is 14.68 dB.

4.8.7 To analyze the effect of different relay topologies on Cooperative System.

Total number of symbols = 100000 ; SNR = [0: 20] ; Modulation = QPSK ; Fading Type = Rayleigh ; Combining Schemes = MRC ; Total Power = 1 ; Relay topology = Parallel and Cascade.

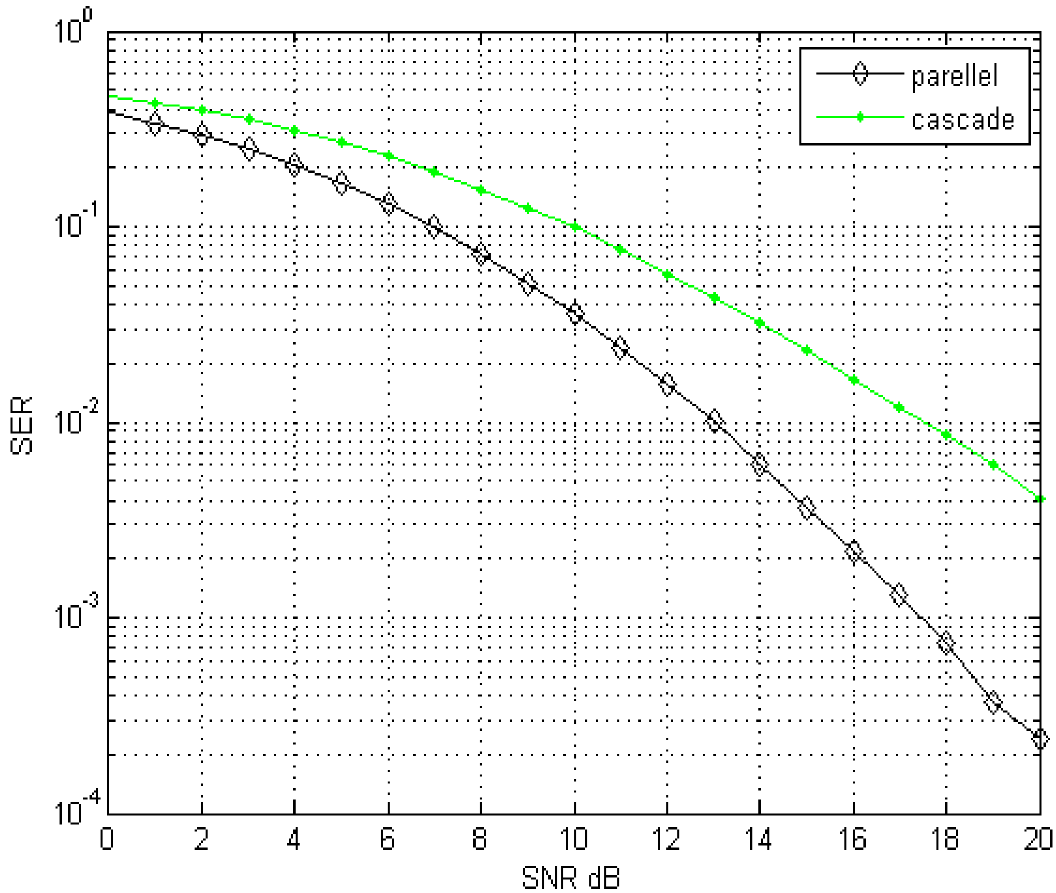

Fig 4.18: SER vs SNR plot of different relay topologies for Cooperative System

From the graph between SER vs SNR for cooperative communication using parallel and cascade relay topology over Rayleigh fading channel, it is observed that at 10^{-1} SER, required SNR for the cooperative system using parallel relay topology is 6.95 dB while for cooperative system using cascade relay topology is 9.95 dB. Further analysis of system using different topologies is as shown in Table 4.3.

SER	SNR(in dB) for	
	Parallel	Cascade
10^{-1}	6.95	9.95
10^{-2}	13.0	17.53

Table 4.3: SER vs SNR analysis of Cooperative Communication System using Cascade and Parallel relay topologies.

CHAPTER-5

PROPOSED METHOD

5.1 Modified Cooperative Communication System

Basic system model of modified cooperative communication system is same as classical cooperative communication system as shown in Figure.4.4. Difference lies only in transmission scheme of the symbols. Modified Cooperative Communication System uses the concept of spatial and temporal diversity in order to combat fading problem without increasing the cost, number of antennas and implementation complexity which are the major challenges of handheld devices.

Before discussing the transmission scheme, some assumptions are made in order to avoid system complexity:

- Channel state information is known at source and destination.
- Channel gain between source to relay and relay to destination are assume to be equal that is $h_{s,r} = h_{r,d} = h_1$ and Channel gain between source to destination $h_{s,d} = h_2$.
- Noise terms $n_{s,d}, n_{s,r}$ and $n_{r,d}$ are prototyped as zero mean complex gaussian random variable and are assumed to be equal to n.

5.1.1 Transmission Scheme

Four different time intervals t_K, t_{K+1}, t_{K+2} and t_{K+3} are used. During these time intervals channel gains are presumed to be fixed. Communication between source to destination takes place at these four time intervals.

- At t_K symbol transmitted from

Source to Relay = x_1

Source to Destination = No symbol

- At t_{K+1} symbol transmitted from

Relay to Destination = βx_o

Source to Destination = x_1

Signal obtained at destination, R_1 is the combination of time interval t_K and t_{K+1}

$$R_1 = \beta x_o h_1 + x_1 h_2 + n \tag{5.1}$$

where $x_o = x_1 h_1 + n$

- At t_{K+2} symbol transmitted from

Source to Relay = $\frac{x_1^*}{h_1}$

Source to Destination = No symbol

- At t_{K+3} symbol transmitted from

Relay to Destination = $\beta(x_1^* + n)$

Source to Destination = $-h_1^* . x_1^* = -x_o^* + n^*$

Signal obtained at destination, R_2 is the combination of time interval t_{K+2} and t_{K+3}

$$R_2 = \beta h_1 (x_1^* + n) + h_2 (\text{-x}_o^* + n^*) + n$$

$$= \beta h_1 x_1^* - h_2 x_o^* + N \tag{5.2}$$

where $N = \beta h_1 n + h_2 n^* + n$

$$R_2^* = \beta h_1^* x_1 - h_2^* x_o + N^* \tag{5.3}$$

$$\begin{bmatrix} R_1 \\ R_2^* \end{bmatrix} = \begin{bmatrix} \beta h_1 & h_2 \\ -h_2^* & \beta h_1^* \end{bmatrix} \begin{bmatrix} x_o \\ x_1 \end{bmatrix} + \begin{bmatrix} n \\ N^* \end{bmatrix} \tag{5.4}$$

which is equivalent to $R = HX + N$ (5.5)

To verify orthogonality $H^H H$ = Identity Matrix

$$\mathbf{H}^H \mathbf{H} = \begin{bmatrix} \beta^2 |h_1|^2 + |h_2|^2 & 0 \\ 0 & \beta^2 |h_1|^2 + |h_2|^2 \end{bmatrix} \tag{5.6}$$

This shows that there is a tremendous improvement in diversity gain by the factor of $\beta^2 |h_1|^2 + |h_2|^2$ and the performance of Modified Cooperative System is far better than Classical Cooperative System. This improvement in diversity gain reduces the effect of noise amplification of Classical Cooperative System using Amplify and Forward Protocol.

5.1.2 Detection Scheme

For Modified Cooperative Communication system, Zero-Forcing equalizer is used to detect transmitted symbol. Received Signal is represented as:

$$\mathbf{R} = \mathbf{HX} + \mathbf{N}$$

$$\begin{aligned} \hat{\mathbf{R}} &= \mathbf{H}^H \mathbf{R} \\ &= \mathbf{H}^H \mathbf{HX} + \mathbf{H}^H \mathbf{N} \end{aligned}$$

Therefore estimated symbols is given by

$$\begin{aligned} \hat{\mathbf{X}} &= \left(\mathbf{H}^H \mathbf{H}\right)^{\mathbf{-1}} \mathbf{H}^H \mathbf{R} \\ &= \left(\mathbf{H}^H \mathbf{H}\right)^{\mathbf{-1}} \mathbf{H}^H \mathbf{HX} + \left(\mathbf{H}^H \mathbf{H}\right)^{\mathbf{-1}} \mathbf{H}^H \mathbf{N} \end{aligned} \tag{5.7}$$

5.2 Simulation details

5.2.1 SER vs SNR analysis of Modified Cooperative Communication System and Classical Cooperative Communication System using Amplify and Forward Protocol.

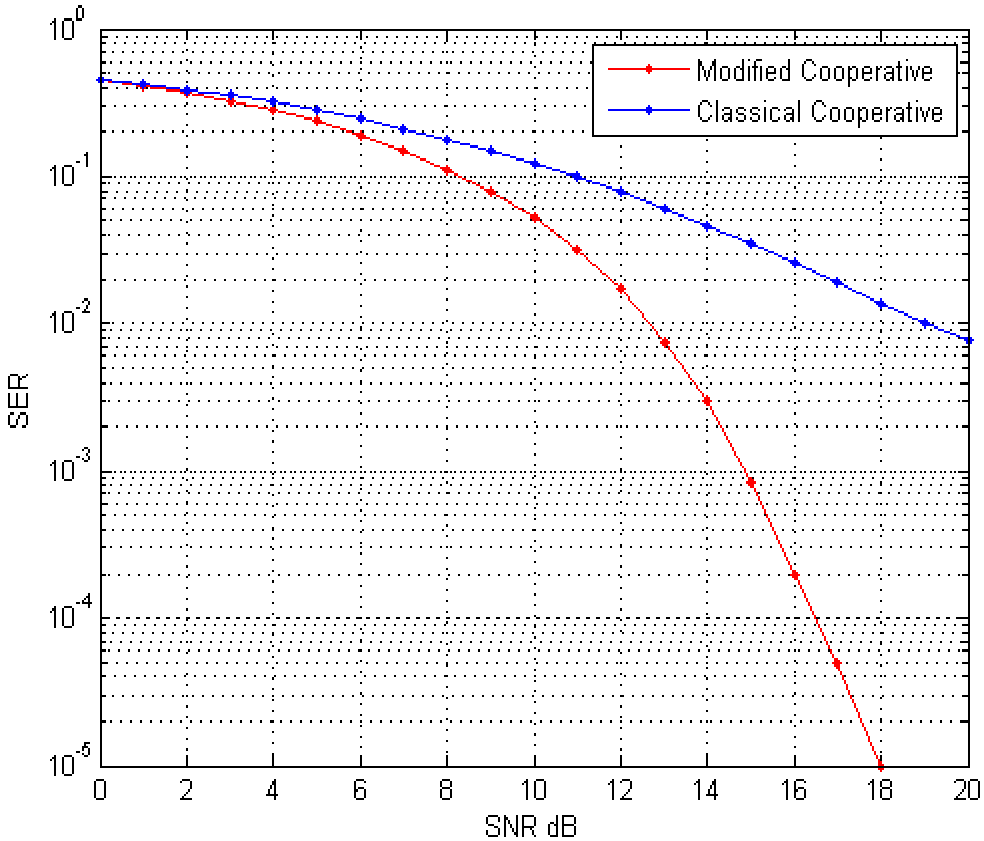

Fig 5.1: SER vs SNR Plot of Modified Cooperative System and Classical Cooperative System

From the graph between SER vs SNR for modified cooperative communication and classical cooperative communication system using QPSK modulation scheme over Rayleigh fading channel, it is observed that at 10^{-1} SER, required SNR for the modified cooperative communication system is 8.3 dB while for classical cooperative without combining scheme is 10.91 dB. Table 5.1 shows that there is a tremendous improvement in the performance of modified cooperative communication system as compare to classical cooperative communication system using amplify and forward protocol.

SER	SNR(in dB) for	
	Modified Cooperative	Classical Cooperative
10^{-1}	8.3	10.91
10^{-2}	12.65	19.08

Table 5.1: SER vs SNR analysis of Modified Cooperative Communication System and Classical Cooperative Communication System

CHAPTER-6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

In this thesis, performance of Cooperative Communication System using Amplify and Forward protocol has been analyzed under Rayleigh fading environment. First of all SER vs SNR is plotted in Simulation 4.8.1, for single link direct transmission between source to destination using QPSK and BPSK modulation technique. It is found that at particular SER value, required value of SNR for BPSK modulation is less than QPSK modulation.

In Simulation 4.8.2, performance of Cooperative Communication System without combining schemes and Non-Cooperative System using QPSK modulation has been analyzed. Result shows that Non-Cooperative System achieves better performance than Cooperative System without combining because without using combining schemes there is no improvement in average and instantaneous SNR of received signal instead of it, noise of different channels get added at the destination which further degrade the performance of system.

In Simulation 4.8.3, performance of Cooperative Communication System without combining schemes and Non Cooperative System for different Amplification factor has been analyzed. Simulation 4.8.3(a) to 4.8.3(d) show that there is minor improvement in performance of Cooperative Communication system without combining schemes as compare to Non-Cooperative using different Amplification factor. Increasing Amplification power is just wastage of power resources. So inorder to improve the system performance various combining schemes are used.

In Simulation 4.8.4 and 4.8.5, performance of Cooperative Communication System using different combining schemes are compared with SISO system and Cooperative without combining scheme. Result shows that using different combining schemes there is improvement in average and instantaneous SNR of the system. Among MRC and EGC, MRC performs better than EGC. EGC is often used in practice because of its reduced complexity as compare to MRC scheme.

Simulation 4.8.6 analyzes the effect of uneven power distribution between source and destination on Cooperative System. Total power is constant. As the source power is more than the relay power, performance of system using uneven power distribution is better than equal power distributed system and if the relay power is more than the source power, performance of system using equal power distribution is better than unequal power distribution. As relay power increases, the amplification factor also increases which further results in amplification of the noise factor and degrades the performance of system.

Simulation 4.8.7 analyzes the effect of different relay topologies on Cooperative System using Amplify and Forward protocol. Result shows that performance of parallel relay arrangement is better than cascade. As in cascade relay topology noise get amplified from one relay to another and in parallel relay topology diversity is achieved which improves the performance of system as MRC combining scheme is used at destination.

Simulation 5.2.1 analyzes the performance of Modified Cooperative System and Classical Cooperative System. Result shows that performance of Modified Cooperative System is better than the Classical Cooperative System because of high diversity gain achieved which reduces the effect of noise amplification in case of Classical Cooperative System using Amplify and Forward protocol.

6.2 Future Scope

Cooperative Communication system using Amplify and Forward protocol can be applied to more realistic frequency-selective fading channel model. Moreover work can be also extended to other combining techniques like optimal combining and adaptive combining schemes.

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