Chapter Two

Literature Review

2.1 Introduction:

In the past few years, there has been a phenomenal increase in consumers' as well as manufacturers' interest in wireless communications, and the Demands for capacity in wireless communications, driven by cellular mobile, Internet and multimedia services have been rapidly increasing worldwide On the other hand, This is due to the advances of wireless communication technology providing the advantages of wide area coverage without wires, and most importantly, allowing mobility while communicating [8]. Beyond the success of the established technologies such as mobile telephony, a wide range of new wireless communications services are being developed. For example, there has been growing interest in providing broadband wireless Internet services with rich multimedia contents at near wire-line data rates. However, the wireless channel suffers from random signal attenuation and phase distortion due to the destructive superposition of multiple received signals in a multipath propagation environment, a phenomenon commonly called fading. To mitigate fading and push the capacity of wireless channel to a higher limit, the use of multiple transmitting and/or receiving antennas, or the so-called multiple-input multiple-output (MIMO) concept [9].

2.2 MIMO Channel for Wireless Communications:

Multiple - input multiple output (MIMO) systems are a natural extension of developments in antenna array communication Fading makes it extremely difficult for the receiver to recover the transmitted signal unless the receiver is provided with some form of diversity, i.e. replicas of the same transmitted signal with uncorrelated attenuation.

In fact, diversity combining technology has been one of the most important contributors to reliable wireless communications [10].

2.3 Diversity in Wireless Channels:

As we have explained, wireless fading channels present the challenge of being changing over time. In communication systems designed around a signal path between transmitter and receiver, a crippling fade on this path is a likely event that needs to be addressed with such techniques as increasing the error correcting capability of the channel coding block, reducing the transmission rate, using more elaborate detectors [11]. etc. Ways to achieve diversity include:

2.3.1 Time Diversity:

Utilizes the fact that different time intervals will suffer different amount of fading. Effect of bad channel coding can be diminished by good fading intervals. In this the copies of information signal are transmitted in time slots which are different. The time slots separation is more than the channel coherence time. But time diversity is difficult to exploit because of delay constraints [12].

2.3.2 Frequency Diversity:

Utilizes the fact that in different frequency bands, the multipath structure is different. This fact can be utilized to combat the effect of fading. In this case, in the different frequency bands the copies of information signal are transmitted [13].

The frequency separation is more than channel coherence bandwidth. But due to bandwidth limitations, the positive effects of frequency diversity are restricted. A finite source i.e. radio spectrum is used by wireless communication and by this the number of wireless users are limited and also the amount of spectrum that is provided to each user at any time is also limited.

2.3.3 Polarization diversity:

Diversity is achieved by utilizing two transmit antennas or two receive antennas with different polarization. The transmitted waves follow the same path. There are two disadvantages of polarization diversity [14]. First disadvantage is that you can have at most two diversity branches, corresponding to the two types of polarization. The second disadvantage is that polarization diversity loses effectively half the power (3 dB) because transmit or receive power is divided between the two differently polarized antennas.

2.3.4 Spatial Diversity:

Utilizes the fact that more than two antennas are either differently polarized or separated in space. Different multipath and fading characteristics a reused by different antennas and a stronger signal can be produced by this property. If the spacing of antennas is greater than half of wavelength then channels which are spatially uncorrelated are formed. Copies of information signal are transmitted over uncorrelated spatial channels and hence spatial diversity occurs. Spatial diversity does not include the problems that occur with frequency diversity and time diversity. But the one drawback of this diversity is that it includes use of multiple antennas at transmitter and receiver and thus makes it not feasible every time. Space diversity techniques employ multiple transmit and receive antennas. The antennas are separated far enough that the signals have significantly different propagation paths and hence experience independent fading. Space diversity techniques are preferred over time or frequency diversity because they do not incur extra time or bandwidth, which are valuable resources in wireless communication systems [15].

Space or antenna diversity has been popular in wireless microwave communications and can be classified into two categories: receive diversity and transmit diversity.

2.3.4.1 Receive Diversity:

It can be used in channels with multiple antennas at the receive side. The received signals are assumed to fade independently and are combined at the receiver so that the resulting signal shows significantly reduced fading. Receive diversity is characterized by the number of independent fading branches and it is at most equal to the number of receive antennas [16].

2.3.4.2 Transmit Diversity:

Transmit diversity is applicable to channels with multiple transmit antennas and it is at most equal to the number of the transmit antennas, especially if the transmit antennas are placed sufficiently apart from each other. Information is processed at the transmitter and then spread across the multiple antennas.

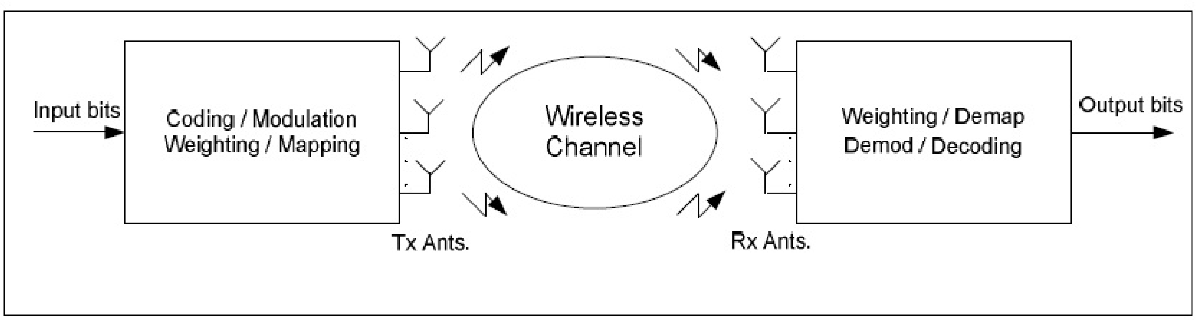

Figure (2.1): MIMO wireless communication system diagram.

Tx transmit antennas and Rx receive antennas. The MIMO transmitter potentially includes error control coding as well as a complex modulation symbol mapper.

After frequency demodulation to radio frequency (RF), filtering and amplification, the signals are transmitted through the wireless channel [17].

The signal is captured by multiple receive antennas on the receive side. The receiver performs demodulation and demapping to recover the message.

The coding method and antenna mapping algorithm may vary due to several considerations

such as channel estimation and complexity. Perfect channel state information will be assumed to be available.

For Tx transmit and Rx receive antennas, in the case of a MIMO at fading channel, the capacity of the MIMO channel is given by

$$C_{MIMO} = E_H\{log_2(det(I_{R_x} + \frac{\rho}{T_x} HH^*)) \tag{2.1}$$

EH= is the statistical expectation operator with respect to H

IRx =is the identity matrix of size Rx

p= is the SNR at any receive antenna

H =is the Tx ×Rx channel matrix, det(.) =denotes the determinant of a matrix and (.)* = denote the transpose-conjugate.

2.5 Wireless channels:

Communication through a wireless channel is a challenging task because the medium introduces much impairment to the signal. Wireless transmitted signals are affected by effects such as noise, attenuation, distortion and interference. It is then useful to briefly summarize the main impairments that affect the signals.

2.5.1 Additive white Gaussian noise (AWGN):

Some impairments are additive in nature, meaning that they affect the transmitted signal by adding noise. Additive white Gaussian noise (AWGN) and interference of different nature and origin are good examples of additive impairments. The additive white Gaussian channel is perhaps the simplest of all channels to model. The relation between the output *y(t)* and the input *x(t)* signal is given by

$$y(t) = x(t)/\sqrt{F} + n(t) \qquad (2.2)$$

where F is the loss in power of the transmitted signal *x(t)* and *n(t)* is noise. The additive noise *n(t)* is a random process with

each realization modeled as a random variable with a Gaussian distribution. This noise term is generally used to model background noise in the channel as well as noise introduced at the receiver frontend. Also, the additive Gaussian term is frequently used to model some types of inter-user interference although, in general, these processes do not strictly follow a Gaussian distribution.

2.5.2 Large-scale propagation effects:

The path *loss* is an important effect that contributes to signal impairment by reducing its power. The path loss is the attenuation suffered by a signal as it propagates from the transmitter to the receiver. The path loss is measured as the value in decibels (dB) of the ratio between the transmitted and received signal power. The value of the path losses highly dependent on many factors related to the entire transmission setup. In general, the path loss is characterized by a function of the form

$$\Gamma dB = 10v \log(d/d0) + c \qquad (2.3)$$

where Γ dB is the path loss measured in dB, *d* is the distance between transmitter and receiver, *v* is the path exponent, *c* is a constant, and *d*0 is the distance to a power.

2.5.3 Small-scale propagation effects:

From the explanation of path loss and shadow fading it should be clear that the reason why they are classified as large-scale propagation effects is because their effects are noticeable over relatively long distances. There are other effects that are noticeable at distances in the order of the signal wavelength; thus being classified as small-scale propagation effects. We now review the main concepts associated with these propagation effects.

In wireless communications, a single transmitted signal encounters random reflectors, scatterers, and attenuators during propagation, resulting in multiple copies of the signal arriving at the receiver after each has traveled through different paths.

2.6 Multiple Antenna Wireless Communication System:

Wireless communication is highly challenging due to the complex, time varying propagation medium. If we consider a wireless link with one transmitter and one receiver, the transmitted signal that is launched into wireless environment arrives at the receiver along a number of diverse paths, referred to as multipath. These paths occur from scattering and rejection of radiated energy from objects (buildings, trees ...) and each path has a different and time-varying delay, angle of arrival, and signal amplitude. As a consequence, the received signal can vary as a function of frequency, time and space. These variations are referred to as fading and cause deterioration of the system quality. Furthermore, wireless channels suffer of co-channel interference (CCI) from other cells that share the same frequency channel.

A successful method to improve reliable communication over a wireless link is to use multiple antennas. The key points that argue the above statement are:

2.6.1 Channel model:

In wireless communication system, signals arrive at a receiver via various propagation mechanisms. A highly complex transmission channel exists due to multiple scattered paths with different time-varying time delays, directions of departure and arrival, phases and attenuations. Except for the line-of-sight, all these mechanisms imply the interaction of the propagating wave with one or more arbitrary obstacles (buildings, trees, cars, human beings, etc.)

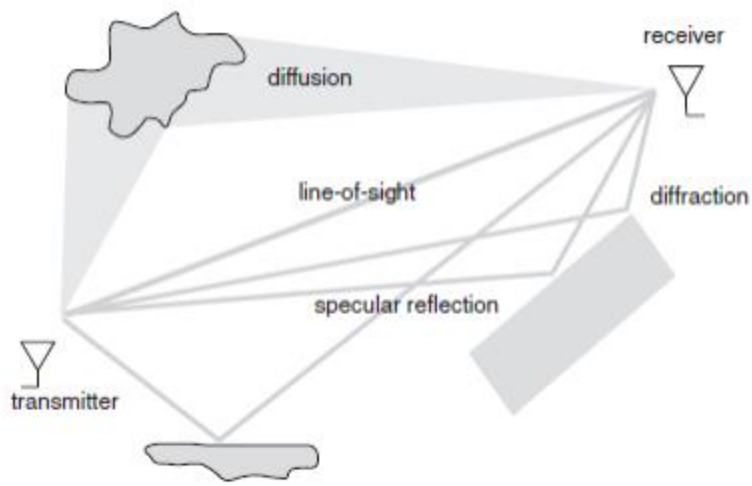

Figure (2.2): multi path scenario

Figure (2.2) illustrates this multipath propagation concept. The line-of-sight path experiences free-space loss only. Reflection occurs when a propagating wave hits against a plane surface whose dimensions are very large compared to the wavelength. Diffraction occurs when the path between the transmitter and the receiver is obstructed. Due to the obstruction there is partial absorption of energy.

2.6.2 Rayleigh fading:

The Rayleigh distribution is the most widely used distribution to describe the received envelope value. The Rayleigh flat fading channel model assumes that all the components that make up the resultant received signal are reflected or scattered and there is no direct path from the transmitter to the receiver [18]. The Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component. In the Rayleigh fading channel model, it is assumed that the channel induce amplitude which varies in time according to the Rayleigh distribution.

2.7 Receiver Decoding Techniques:

In most cases the complexity of signal processing at the transmitter side is very low and the main part of the signal processing has to be performed at the receiver. The receiver has to regain the transmitted symbols from the mixed received symbols. Several strategies can be applied at the receiver.

2.7.1 Maximum Likelihood (ML) Receiver:

ML achieves the best system performance (maximum diversity and lowest bit error ratio (BER) can be obtained), but needs the most complex detection algorithm.

The ML receiver calculates all possible noiseless receive signals by transforming all possible transmit signals by the known MIMO channel transfer matrix. Then it searches for that signal calculated in advance, which minimizes the Euclidean distance to the actually received signal. The undisturbed transmit signal that leads to this minimum distance is considered as the most likely transmit signal.

In diversity methods a single stream is transmitted but the signal is coded using techniques called Space Time Code. The signal is emitted from each of the transmit antennas using certain principles of full or near orthogonal coding. Diversity exploits the independent fading in the multiple antenna links to enhance signal diversity Space Time Code. Redundant data sent over time space domains (antennas) and the receive SNR increases for different digital modulation schemes. STBCs as originally introduced and studied are orthogonal[19]. This means that the STBC is designed such that the vectors representing any pair of columns taken sfrom the coding matrix are orthogonal. The result of this is simple, linear, optimal decoding at the receiver. Since wireless technologies become a very high demand nowadays.

2.8 Beamforming:

Beamforming or spatial filtering is a signal processing technique used in sensor arrays for directional signal transmission or reception. This is achieved by combining elements in a phased array in such a way that signals at particular angles experience constructive interference while others experience destructive interference. Beamforming can be used at both the transmitting and receiving ends in order to achieve spatial selectivity. The improvement compared with omnidirectional reception/transmission is known as the receive/transmit

Beamforming can be used for radio or sound waves. It has found numerous applications in radar, sonar, seismology, wireless communications, radio astronomy, acoustics, and biomedicine. Adaptive beamforming is used to detect and estimate the signal-of-interest at the output of a sensor array by means of optimal (e.g., least-squares) spatial filtering and interference rejection [20].

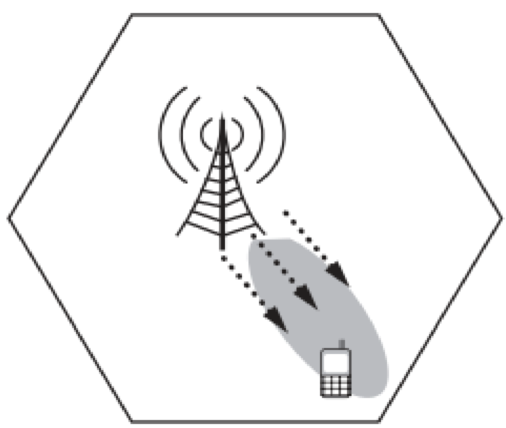

Figure (2.3): The Beamforming

2.9 Related Work:

Alamouti's scheme [21] was originally designed for flat (frequency non-selective) fading channels, but the condition for frequency selectivity is not defined exactly.

Martin Svirak, [22] presented to Simulation of Space-Time Block Coding in Broadband Indoor Fading Channel Using Matlab, presents a large effect of frequency selectivity on the space time communication system. but the main drawback of this method is that it is used inside buildings did not provide outdoor free space channels.

Another study also presented by Shreedhar A Joshi et al. [23] Where he studied Space Time Block Coding for MIMO Systems using Alamouti Method With Digital Modulation Techniques BPSK and QAM Modulation Scheme with channel state information (CSI) at the transmitter , but they used a large SNR to achieve this.

Sachin Chourasia, prabhat Pate l24] presented A Comparative analysis of orthogonal space time block code with trellis coded modulation (TCM) over Rayleigh and Rician fading channel. The BER performance of Rician channel (LOS) is better than Rayleigh channel when the line of sight (LOS) path is considered, While with no line of sight (NLOS) path is considered, this technique gives better result of about 1dB over Rayleigh fading channel as compare to the Rician fading channel. but still the problem of high SNR Exist.

Jafarkhani [25] proposed QO- STBC schemes with reducing orthogonality but increasing its complexity. In Tirkkonen, QO-STBCs were improved by using constellation rotation in order to achieve full diversity.

In Sezginer and Sari [26], a family of full-rate, full-diversity 2 × 2 space-time coding (STC), and whose detection complexity grows only quadratically with the size of the signal constellation (M) have been proposed

Kim and Cheun different approach to achieve low-complexity near-maximum likelihood (ML)

QO-STBC decoding based on iterative interference cancellation (IICIS) was proposed.

Yuen et al.[27] aiming to reduce the overall decoding complexity, minimum decoding complexity (MDC) QO-STBC structures were proposed requiring the joint detection of two-real symbols regardless of the number of transmitting antennas.