CHAPTER 3
LITERATURE SURVEY

3.1 Introduction

Mobile radio links are subject to severe multipath fading due to combination of randomly delayed, reflected, scattered and diffracted signals. Fading leads to serious degradation in Carrier-to-Noise Ratio (CNR) leading to a higher BER for a given multilevel modulation scheme. Thus fading compensation is required to improve link performance. One compensation technique requires Pilot Symbol Assisted Modulation (PSAM). This technique inserts a training sequence into the stream of data symbols to extract the channel induced attenuation and phase shift, which are then used for symbol detection. Space diversity, which combines signals received over several antenna branches, is another powerful technique to combat fading. Diversity can be combined with other fading compensation techniques to fully combat fading. Other fading compensation techniques include an increased link budget margin or interleaving with carrier coding. However these techniques are linked to worst-case channel conditions, resulting in poor utilization of channel capacity (under negligible or shallow fading conditions).

The concept of adaptive transmission was first proposed around late 1960s. It requires accurate channel estimation at the receiver and a reliable transmission path between the estimator and the receiver. Interest in these techniques was short lived, perhaps due to hardware constraints, lack of good channel estimation techniques and/or systems focusing on point-to-point radio links without transmitter feedback. The fact that issues concerning adaptive transmission are less constraining in current land mobile radio mobile systems coupled with the need for spectrally efficient communication, has revived interest in adaptive variation of the transmitted power level, symbol rate, constellation

36
size, coding rate/ scheme or any combination of these parameters. Thus, without sacrificing BER the schemes mentioned above provide a much higher average spectral efficiency by taking advantage of the time varying nature of the wireless channel.

Multi-User Detection (MUD) has the potential to reduce the Multi-Access Interference (MAI) and solve the near-far problem in the reverse link of a Code Division Multiple Access (CDMA) channel. Since the optimal multi-user detector requires much higher complexity than the conventional detector, sub optimal multi-user detection schemes with reasonable complexity are used. Among these schemes are the linear decorrelator, the multi-stage detector, the decision-feedback detector, the Successive Interference Cancellation scheme (SIC), and the Parallel Interference Cancellation scheme (PIC).

When the channel is perfectly estimated, the more complex detectors such as Two Stage (2S) detector and Decision Feedback (DF) detector can achieve the single user bound and are near-far resistant. However the simpler schemes SIC and PIC are not suitable for the high bandwidth efficient channels, and should be applied to systems with relatively low cross correlations. When the channel mismatch is present due to fast fading, the performance of the coherent multi-user detectors- the decorrelator, 2S and DF become comparable. As the Doppler frequency increases, the performance of 2S and DF over the decorrelator decreases and is limited to lower SNR region. The near far resistance is still preserved in the decorrelator, but not in the 2S and DF. For noncoherent multi-user detectors the decorrelator outperforms other systems, and retains the near far resistance property. These results indicate that the decorrelator is the most robust multi-user detector for the realistic fading channels.

The development of Spread Spectrum Multiple Access (SSMA) systems for personal mobile systems requires inherent trade off between coding and spreading. Personal communications is very popular in the area of radio communication systems. Integrating different radio networks has led to supplementing traditional cellular systems with indoor systems. One of the most promising modulation and multiple access technique is Code Division Multiple Access (CDMA). Certain characteristics make CDMA suited to a number of different application areas, starting from traditional mobile systems to broadcasting audio systems.

37
A Direct Sequence Spread Spectrum Multiple Access (DS/CDMA) demodulator correlates the received signal with a specific user signature, followed by a hard decision on the correlator output. This kind of receiver is optimized for an Additive White Gaussian Noise (AWGN) channel without MAI coming from other users sharing the same bandwidth. The amount of MAI immunity depends on selection of signature sequences.

The CDMA near far problem can be envisaged differently by multi-user detection[38]. Instead of overlooking other users in the system, here, the information about the interfering users is made to reject the interference and thus make better decisions about the data symbols. This approach solves the near far problem [39]. The demand on the cross-correlation properties of the user signature sequence can hence be greatly relaxed. But it results in increased complexity of the receiver.

3.2 CDMA RECEPTION

There are two different methods by which Multi-User Detection (MUD) can be implemented. By means of parallel detection, all user streams are estimated at the same time. If it is detected serially, the receiver deals with the outputs of matched filter bank iteratively and information bits are estimated one at a time. The optimum AWGN MUD is based on a Viterbi algorithm. Several sub-optimum MUD structures are in use, which utilize another device than Viterbi decoder.

A linear MUD structure performs a linear transformation on the matched filter outputs before hard decisions are made [40]. Another family of MUD structure performs linear transformation and is a type of non-adaptive decision-feedback equalizer. Another alternative is based on an artificial neural network trained for an initial transmission of known data [41], [42]. In a serial MUD, the user with the maximum output is responsible for the decision of the transmitted bit. The effect of the strongest user is cancelled out by subtracting the signal re-spread with the proper signature sequence from the received CDMA signal. Another serial MUD structure is based on implementation orientation [43].

The parallel MUD structures for AWGN channels do not perform optimally in the presence of multipath propagation. They are not fading resistant. If optimum MUD is modified properly, it becomes fading resistant. Considerable improvements of serial
MUD schemes on a fading channel exist [44]. The wideband signal waveforms that are transmitted through the multipath channels resolve the multipath components with a time resolution of 1/W, where W is the signal bandwidth. Generally, such wideband signals are generated as direct sequence spread spectrum signals, in which the PN (Pseudo Noise) spreading sequences are the outputs of linear feedback shift registers. Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Differential Phase Shift Keying (DPSK) are the modulation techniques used with them [45].

The performance of several multi-user detectors under the assumption of ideal channel estimation conditions has been studied [46]. The more complex detectors (2S (Two Stage Detector) and DF (Decision Feedback Detector)) can effectively eliminate MAI and perform as good as single user system. The simpler schemes (SIC (Serial Interference Cancellation) and PIC (Parallel Interference Cancellation)) do not give that good performance especially in high bandwidth efficient channels. In the presence of channel mismatch, the performance of coherent multi-user detectors is comparable. The performance degradation of the 2S and DF is due to channel estimation errors of all users, whereas the decorrelator is only affected by the desired user. The decorrelator outperforms the 2S and DF in high SNR region and preserves the near-far resistance. For noncoherent multi-user detectors the decorrelator has a large performance gain over the SIC and the PIC [47]. It implies that the decorrelator is the most robust multi-user detector for the realistic fading channels.

The multi-user detection theory has demonstrated that Multiple-Access Interference (MAI) induced by a number of users simultaneously accessing a code division multiple access (CDMA) network is not a real limitation, as far as the processing gain is large enough [48], [49]. As a consequence, Wideband Code Division Multiple Access (WCDMA) systems are emerging as strong competitors to other multiple access techniques to obtain large processing gains without compromising on bit rate. To increase it further, signal length may be increased beyond bit signaling interval, hence resulting in Inter-Symbol Interference (ISI), whose effect may be disregarded [50]. There is scarcity of radio frequency bandwidth. So the CDMA networks and external narrowband systems share some frequency sub band in the form of overlay architecture [51]. The external system is little affected by the CDMA system as it accepts very little of the power spread.
over large bandwidth, whereas Narrowband interference (NBI) causes a lot of disturbance because its average power is contained in the bandwidth of CDMA systems [52].

The ideal situation for nonlinear estimator-subtractor methods of NBI suppression is as shown in Fig. 3.1. In this ideal case, it is assumed that the Spread Spectrum (SS) signal is always accurately estimated by the nonlinear filter and subtracted from observations. Therefore, the NBI signal is estimated only in the presence of Gaussian noise, and the estimation by the linear predictor or linear interpolator is optimal. These methods form a replica of the NBI, which can be subtracted from the received signal to enhance the wide-band components. The linear estimator-subtractor methods involve the use of linear transversal prediction or interpolation filters to create the NBI replica. This estimate is subtracted from the appropriately timed received signal to obtain the error signal to be used as input to the SS user signature sequence correlator. In Fig. 3.1 shows the block diagram of illustration of nonlinear NBI suppression, where $A$, $b$, $s(k)$ are the received amplitude, transmitted symbol and normalized signature waveform of the kth user. Also, $i(k)$ and $n(k)$ denote the narrowband interference signal and ambient noise introduced in the received signal of the kth user. $\hat{i}(k)$ is the prediction of the received signal.

![FIG. 3.1 Block Diagram showing illustration of Nonlinear NBI Suppression.](image)

The receiver has to face multiple access interference (MAI) as well. The Multiple Access Interference (MAI) arises from the data frames sent by the transmitter for the other users in the system. Each user has its own code that provides orthogonality among the various users. The frames are time aligned with each other and with that of the desired user. So, additional interfering data frames are generated along with the frame for
the desired user. They are summed up with the frame of the desired user, passed through the pulse shaping filter and subsequently received at the receiver after passing through the time varying channel. The frames are assumed to be of equal power [53].

As discussed by Tulino [54], Maximum Likelihood Sequence Detection for the user bits is required. Both linear one shot detection and block-detection show that the presence of an external narrow band interferer results in the need for time-varying processing. Linear one shot receivers are amenable to a blind implementation. Implementation of periodically time-varying minimum mean square error receiver using Recursive Least Squares (RLS) algorithm shows that periodically time variation of the receiver structure induced by the presence of a data like narrow band interferer can be tracked [55]. The problem of interference suppression is tackled by a unified approach to the design of linear receivers. It shows that the presence of a narrow band interferer requires time-varying processing. The family of linear time-varying block detectors shows that decoding a set of bits at a time may be a viable means of reducing the need for signal-space over sampling and observation window enlargement and sometimes saving in terms of required memory storage capability.

Narrowband signal powers on the adjacent channel increase the detected interference levels in the mobile because of nonideal receive filtering. The difference between wideband and narrowband carriers decides the adjacent channel interference. The effect of filtering can be defined by adjacent channel protection, which gives the attenuation of narrow-band interferer in the receive chain as a function of carrier separation. Wide-band noise refers to interference components from the narrowband base station transmitter, the effect of phase noise of the local oscillator, modulation products and spurious emissions [56]. The constant upper limit obtained from the system parameters of the narrow band system decides the wide band noise. The intermodulation products are introduced at the output of the components due to their nonlinearities. In CDMA, the mobile transmission and reception takes place simultaneously and the transmission can leak to the receiver due to nonlinearities in the duplex filtering. So the single tone from the interfering site and transmission leakage can lead to intermodulation components. Cross modulation is caused by modulation between a transmitted, amplitude modulated signal and an external narrow-band interference.
The problem of blind detection has been approached by an adaptive blind RLS procedure, which outperforms the conventional procedures. The effect of fading is further considered. It is realized that the zero forcing techniques may experience noise-enhancement due to multipath. So, MMSE is the solution as an extension of the RLS strategy to suppress both MAI and NBI over fading. Prediction based methods take advantage of the difference in bandwidths of the spread-spectrum signal and the NBI without making use of any knowledge of the specific structure of the spread-spectrum data signal as illustrated in Fig. 3.2. The discrepancy in predictability of narrowband signals form an accurate replica of the NBI that can be subtracted from the received signal to suppress the NBI. The received signal $r(t)$ consists of wideband components $\{S(t)+N(t)\}$, where $S(t)$ is useful data signal, NBI is wideband ambient noise and the narrowband interference component $I(t)$. If a linear prediction of $\{r(t)\}$ is generated, the values predicted will consist of a prediction of $\{I(t)\}$. Such a prediction forms a replica of NBI, which can then be suppressed from the received signal. A residual signal $r(t) - \hat{r}(t)$ is formed, where $\hat{r}(t)$ is a prediction of $r(t)$ from past observations. The effect of subtraction is to significantly reduce the narrowband component of $\{r(t)\}$. The prediction residual is then passed on for despreading and demodulation.

![FIG. 3.2 Predictive method of NBI suppression](image)

The evolution of mobile networks from second to third generation requires flexible utilization of available frequency bands. It results in decreased tolerance to interference from systems operating at adjacent frequency bands. The interference from the WCDMA base station to the narrow band system increases the base station powers of the narrowband system because of its quality based power control. It results in increased interference to the WCDMA system [57-58].
In DS/CDMA systems, performances are limited by Multiple Access Interference (MAI) and Intersymbol Interference (ISI). To mitigate these interferences and increase the capacity and increase data rates, multi-user detection techniques are used. The detectors used are decorrelator and Minimum Mean Square Error (MMSE) receivers. They can be used in both linear and nonlinear fashion [59]. But implementing such a structure in commercial device results in loss of parallelism. The linear decorrelator receiver uses the inverse of the cross correlation matrix to improve the performance of conventional receivers. The cross correlation matrix helps to decrease MAI but is inefficient. The linear MMSE receiver becomes an extension of the decorrelator detector when an addition in the form of Wiener estimator is done. Taking account of noise variance, performance degradation is reduced and thereby output signal to noise ratio is maximized. But complexity of such receivers is a negative point. Alternatively, adaptive linear receivers are used. The drawback of such receivers is the huge size of the filters in order to reach a suitable error floor [60]. Also, it performs poorly in the fast fading channels. The solution lies in using a pre-combining adaptive receiver prior to RAKE receiver [61]. Alternatively, decision directed algorithm can be used. Another adaptive MUD technique is Cascade Filter MUD. It removes residual multiple access interference and intersymbol interference. It minimizes the dimensions of the filters used to process the different users.

The proposed optimal and suboptimal detection approaches have the drawback of being complex in implementation. A simple receiver allows users to overcome the near-far effect [62]. The proposed receiver in its first stage of two-stage parallel structure has an individual Rake receiver, which processes every received signal. The decision variable at each receiver output is compared with a suitable threshold value. If the decision variable overcomes the threshold, the received signal is considered reliable, otherwise it is assumed to be unreliable. In the second stage of the receiver, MAI of reliable signals on the other signals are cancelled.

The BER performance of downlink DS/CDMA in a frequency selective fading channel by using Frequency Domain Equalization (FDE) is based on minimum mean square error criterion [63]. But the presence of residual Interchip Interference (ICI) after FDE produces the orthogonality distortion among the spreading codes and the BER
performance degrades as the number of multiplex order increases. ICI can be cancelled to improve the BER performance. The residual ICI replica in the frequency domain is generated and subtracted from each frequency component of the received signal. The processing gain schemes used with DS/CDMA systems are more complex. So, a sub-optimal detector, the group wise successive interference cancellation receiver was considered for DS/CDMA system. User signals are divided into groups according to data rates and interference from each group is estimated and subtracted successively from the received signal in order of decreasing data rate. To extend it, an extra stage is added which takes interference from lower rate users to higher rate users. Initial bit estimates are obtained, which cancel MAI between groups. The performance may be improved by advanced initial bit detection scheme. As advancement, adaptive MMSE detection is introduced and parallel interference cancellation is applied to mitigate effect of MAI between users in the same group. The effect of MAI between intra group users is mitigated by PIC. Then interference from group one users is regenerated. Initial estimates for the group two users are obtained from the received signal with MAI from group one users being cancelled. Updated bit estimates for the group one users are obtained using adaptive MMSE detector. The adaptive MMSE detection is implemented by LMS (Least Mean Squares) algorithm. It achieves significant performance improvement over the conventional receivers.

A certain type of coding called space-time coding combat fading and achieves antenna diversity and coding gain [64], whereas the use of multiple antennas at the transmitter results in Inter Symbol Interference (ISI) and Multiple Access Interference (MAI). So an enhanced multi-user detector is required to tackle this high interference scenario. As discussed by Tjhung [65], conventional multi-user detector has been used for a CDMA system. This architecture is further enhanced by accounting in the cancellation process also the interference from the other sources and by considering asynchronous reception of the signal transmitted by different antennas. Also the iterative multi-user MMSE detector is derived by equalizing directly the received signal at the chip level. The turbo principle applied to MMSE equalization is shown to be able to be cope with the interference from the other users by a process of regeneration and cancellation.
The capacity of a DS/CDMA system is primarily limited by Multiple Access Interference (MAI) and multipath fading. An important property of wideband DS/CDMA signals is the mitigating of Rayleigh fading when operating in multipath channels. Various multi-user receivers for DS/CDMA systems have been under research over the past few years [66]. The performance of a convolutionally coded CDMA system with a MMSE receiver for interference suppression has been analyzed. The trade-off between the time-diversity, achieved by convolutional coding and interleaving, and the interference suppression, achieved by the adaptive MMSE receiver shows that unlike a CDMA system with a conventional matched filter receiver, lower rate convolutional codes are a sub-optimum choice on Rayleigh fading channels [67].

The performance of turbo-coded DS/CDMA system with the MMSE receiver is studied by Divalsar [68]. The trade-off between the bandwidth allocation and spreading is also investigated. The performance of the turbo coded system is compared to a convolutionally coded system. The combination of a MMSE receiver and turbo coding can provide improvement compared to matched filter receiver system in a multipath fading environment. The MMSE receiver increases the capacity of the system. For a small block size turbo codes do not bring much improvement unless a low BER is targeted. The system capacity is reduced to a large extent by finite interleaving. If looser delay constraints allow the use of turbo codes with larger block size, further improvement can result.

In a convolutionally coded code-division multiple-access, which employs a linear Minimum Mean Square Error (MMSE) receiver for interference suppression for a flat Rayleigh fading channel, convolutional coding and interleaving are employed to combat the effects of fading [69]. The MMSE receiver with coding can provide a substantial gain over the matched-filter receiver in a rapidly varying Rayleigh fading channel.

The performance of a turbo-coded code division multi-access system with a MMSE receiver for interference suppression is analyzed in [70]. Two improvements are proposed on the conventional union bounds: the information of the minimum distance of a particular turbo interleaver is used to modify the average weight spectra, and the tangential bound is extended to the Rayleigh fading channel. It is seen that in majority of the scenarios MMSE receiver with a rate ½ turbo-codes will outperform a rate ¼ turbo
code. Also for low bit error rates, the capacity of the system is increased by using turbo codes over convolutional codes even with small block size.

### 3.3 DIVERSITY RECEPTION

Channel-time variation, intersymbol interference and co-channel interference constitute the major sources of impairment in wireless channels. These pose several challenges. There has been extensive work on the problem of detection in the presence of Intersymbol Interference (ISI) and channel time-variation over the past two decades. In the presence of additive white Gaussian noise and perfect channel information, the optimal minimum sequence error probability receiver is the Maximum Likelihood Sequence Estimation (MLSE) receiver using the Viterbi algorithm. When the channel is time varying, adaptive equalization techniques have been proposed to track channel variations. For better performance, an adaptive MLSE receiver has also been proposed for slow time-varying frequency-selective channels. But it may not perform well in fast time-varying channels because data are only detected after some decoding delay inherent in the Viterbi algorithm and hence estimated channel using these data can be very different from the current channel.

Co-Channel Interference (CCI) presents a different problem for the mobile receiver. Interference rejection techniques have been used by the military to suppress hostile jammers. With the possible exception of spread spectrum systems, most of these techniques rely on the use of a spatially distributed array of antenna elements at the receiver for the unwanted interference to be rejected. These work on the underlying principle of the desired user signature being different from that of the intentional jammers. An antenna array at the receiver can mitigate CCI here. Spatial processing along with temporal processing is used. Another approach, which is based on decision directed scheme (suitable for time-invariant channels), is a linear equalizer.

Multipath induced selective fading has a high impact on medium and high capacity digital radio links. There are two main ways of counteracting the effects of dispersive fading: equalization and diversity [71].

Broadband digital multimedia communication is a fast growing segment of the total traffic that will be carried by third generation cellular and other wireless
communications systems. Rapid growth and increasing demands for bandwidth and wide coverage, combined with the performance usually associated with wired or fibered systems pose difficult challenges for wireless system designers. Each broadband data signal will occupy a relatively large portion of the overall allocated system bandwidth, thus necessitating efficient frequency reuse among different users in the same small area. The use of smart antennas can meet many of these design challenges [72]. Adaptive antenna arrays at both the ends can reduce or eliminate the effects of fading and multipath delay spread [73]. Antenna gain can be increased by increasing the effective antenna aperture. With large separation among elements, they can counteract the effects of large-scale signal variations [74]. Through their interference and fading mitigation properties, adaptive arrays can also provide a useful complement to equalization and coding techniques. A receiving antenna array comprises a set of individual antenna elements arranged in a 2- or 3-dimensional pattern, whose outputs are combined.

Diversity protection against fading can be provided by selection, equal gain or maximal ratio combining. Spatial processing can also reduce interference from signals of other users of the same cellular communication system [75], [76]. Since the capacity of cellular systems is mainly determined by their ability to withstand co-channel and adjacent channel interference, smart antenna arrays can have a direct and positive impact on system capacity. Spatial processing can also be combined with temporal processing. Space division multiple access is also possible, where different users’ signals in the same vicinity, and using the same frequency band, can coexist without excessive interference [77]. Spatial processing can shape an antenna pattern so as to emphasize desired signals and null out undesired signals [78]. Spatial processing is complementary to temporal processing, which can eliminate or minimize intersymbol and co-channel interference from sampled channel responses [79].

Adaptive spatial and temporal linear combining both have the ability to minimize intersymbol interference from multipath, and co-adjacent-channel interference in multi-user wireless digital communications. They can be used singly or together, to allow a number of users to share the same time, bandwidth and space [80]. The number of interfering signals which can be separated at a receiver is proportional to the number of antenna elements and also to the received signals’ excess bandwidth. Smart antennas
have a capacity-multiplying effect in cellular systems that employ them [81]. Smart antennas have been proposed for capacity and reliability enhancement in Third Generation wireless systems. Indoor and outdoor broadband cellular systems will also benefit from the use of smart antennas, starting first with directive, switched-beam systems and eventually incorporating full array adaptation and temporal processing for interference and multipath mitigation.

A very efficient numerical expression has been described for MRC (Maximal Ratio Combining) diversity performance in a Nakagami fading channel with arbitrary parameters including all possible conditions of received signal strength and arbitrary fading figures by authors in [82].

In [83] bit error rate is analyzed theoretically for diversity reception in Nakagami fading environment using an M-branch Maximal Ratio Combiner (MRC). Coherent and incoherent reception of Frequency Shift Keying (FSK) is considered, using the multiple branch diversity system for both identical and different branch fading parameters. The results are extended to include Coherent Phase Shift Keying (CPSK) and Differential Phase Shift Keying (DPSK).

In [84] an exact expression derived for the performance of maximal ratio combiner diversity with L correlated branches in Nakagami fading. Bit error rate is also evaluated for both coherent and non-coherent binary phase shift keying. Evaluation of performance of MRC slow and nonselective fading is considered so that the amplitude of the received signal can be done within the bit time interval.

In [85], several methods of diversity combining for a Rayleigh fading channel are evaluated and compared. The methods considered are for coherent reception, Maximal Ratio Combining (MRC), Selection Combining (SC) and a generalization of SC, whereby the two signals with the two largest amplitudes are coherently combined. Similar techniques are also studied for non-coherent reception with Equal Gain Combining (EGC) replacing MRC and non-coherent versions. The bit-error rate performance relative to that achievable with SC and under certain conditions approaches the performance achieved by MRC or EGC. The performance enhancement of SC2 (Second Order Selection Combining i.e. when the two branch signals which have the two largest amplitudes are combined) and SC3 (Third Order Selection Combining) is especially
noticeable for non-coherent reception, where EGC provides the best performance only for low Bit Error Rate (BER) values. So, combining two or three largest signals offer significant improvement over the performance of just selecting the largest signal.

A polarization diversity system for mobile radio is proposed by Lee [86]. This is a two branch receiver diversity system with the advantage that the base station antennas can be spaced as closely desired.

In [87], the author has given the brief idea of polarization diversity in mobile communication. Signal in the vertical and horizontal polarizations at the base station have been measured by transmitting from a principally vertically polarized mobile. The condition for this is that there is no direct line of sight path between the mobile and the base. General expressions and their graphical interpretation for a rotatable polarization diversity antenna at the base station have been given.

The error rate performance of M-ary DPSK signals received over slow Nakagami fading channels for integer fading index has been analyzed in [88]. A relatively simple expression for computation of the error rate is presented. This expression has been extended to obtain the error rates of DPSK signals for MRC diversity reception in Nakagami fading.

In [89], the Signal to Noise Ratio (SNR) of a generalized selection combining scheme is derived in which the m diversity branches with the largest instantaneous SNR are selected and coherently combined. A Rayleigh fading channel is assumed and a simple closed expression for the SNR is found which is upper bounded by the average SNR of maximal ratio combining and lower bounded by average SNR of conventional selection combining.

In [90], the error performance of post detection combiners for noncoherent detection of DPSK and FSK signals over Nakagami channels with an arbitrary covariance matrix has been studied. The error probability from the characteristic function of decision of variables, resulting in closed form solutions involving matrix differentiation has been directly determined. The performance calculation is further simplified by developing a recursive technique. The theory is illustrated by analyzing two feasible antenna arrays used in base stations for diversity reception, ending up with some findings of interest to system design.
An efficient technique to simplify the error performance calculation is that if channel gain remains unchanged over two successive symbol intervals, the error probability of DPSK has the same expression as Noncoherent Frequency Shift Keying (NFSK) except that the matrix used for NFSK is replaced by for DPSK. Without this condition, the error probability of DPSK would take a different form.

In [91], average bit error probability expressions for non-coherent post-detection combining of BPSK and BFSK signals in Nakagami fading channels have been derived. The distinction between predetection and post detection combining has been dealt with for the average probability of bit-error analysis. Particular cases of interest for independent and correlated channels have been explicitly given.

An analytical expression for the probability density function of the Signal to Noise Ratio (SNR) at the output of a two branch maximal ratio and selection diversity system is given by the authors in [92]. The two branches are assumed to be Rayleigh fading, correlated, as well as of unequal SNRs. Measurements of the Cumulative Distribution Function (CDF) after selection and Maximal Ratio Combining (MRC) are made in Rayleigh fading channel and compared with analytical results.

In [93], author has defined the unified approach to evaluate the error rate performance of digital communication system operating over a generalized fading channel. The recognition of the desirable form for alternate representation of the Gaussian and Marcum Q-Functions that are characteristic of error probability expression for coherent differentially coherent and noncoherent forms of detection enables the unification. By employing alternate form of the Gaussian and Marcum Q-Functions, it is possible to unify the error probability performance of coherent, differentially coherent and non-coherent communication in the presence of generalized fading conditions under a single common framework where the results are with little exception expressible in a form that lends itself to simple evaluation and furthermore provides additional insight into the dependence of this performance on the system parameters.

The performance of L-branch Equal Gain Combining (EGC) and Maximal Ratio Combining (MRC) over Weibull fading channels has been studied in [94]. Closed form expressions have been derived for the moments of the Signal to Noise Ratio (SNR) at the output of the combiner and significant performance criteria, for both independent and
correlative fading, such as average output SNR. Amount of fading and spectral efficiency at the low power regime are studied. It has been observed that although an increase of correlation between the diversity branches leads to an increase of normalized average output SNR, the outage probability deteriorates.

In [95], author has analyzed the cutoff rate performance for space diversity in Rayleigh fading channels without Channel State Information (CSI). All combining techniques have been used for space diversity such as Selection Combining (SC), Maximal Ratio Combining (MRC) and Equal Gain Combining (EGC). It is finally shown that Maximal Ratio Combining (MRC) is most effective to achieve a given cutoff while Selection Combining (SC) is least effective.

In [96], the authors have studied the performance of optimum combining Maximal Ratio Combining schemes in an interference limited Rice fading channel.

Thus in this chapter, literature survey has been carried out. The limitations of the previous approaches have been discussed. The path leading to the selection of the present topic of the thesis has been presented.