



## BER performance analysis of Subtractive interference cancellation (SIC) Using Rayleigh channel in DS-CDMA Receiver system

Mr. Wasim khan

Lecturer, Girl's Polytechnic college, Indore, INDIA.

Mrs Nilofar Khan

Assistant Professor, CDSE Indore, INDIA.

nilofarwkhan@gmail.com

Mr. Sanmati Jain

Assistant Professor, MIT Indore, INDIA.

sanmati2984@gmail.com

### 1. Abstract

In this paper, we present and analyze the performance of a parallel interference cancellation (PIC) scheme for multicarrier (MC) direct-sequence code-division multiple-access (DS-CDMA) systems. In order to mitigate the multi-path interference (MPI) in the DS CDMA system. At each cancellation stage in the proposed PIC scheme, on each subcarrier, a weighted sum of the soft outputs of the other users in the current stage is cancelled from the soft output of the desired user to form the input to the next stage. At the last stage, the interference cancelled outputs from all the subcarriers are maximal ratio combined (MRC) to form the decision statistic. Parallel interference elimination is first proposed in this paper the multi-path interference are evaluated by tentative decision and known user information. Then the performance over Rayleigh fading channel are analyzed and compared to Matched filter, Decorelator, successive interference cancellation (SIC) and conventional parallel interference cancellation (PIC). It is shown that PIC performance can be improved greatly by using this method with simple structure and easy implementation.

### Key words:

Parallel interference cancellation; Serial interference cancellation (SIC) ; Multi-path interference; Rayleigh fading; MRC.

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## 2. Introduction

Code division Multiple Access (CDMA) has emerged as the technology of choice for the wireless industry because it provides a number of attractive features over the other multiple access schemes – Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) – to meet the high capacity and other performance requirements for the emerging personal communication services (PCS). Some of these features are spectrum sharing, rejection of multipath signal components or utilizing them for recombining, and having a frequency reuse factor of one, in the cellular case. However, the capacity of CDMA systems employing the conventional matched filter detector at the receiver end is often limited by interference due to other users in the system, known as multiple-access interference (MAI). MAI is introduced in CDMA systems due to the inability to maintain complete orthogonality of users' signature sequences over the hostile wireless communication channels. Multiple Access Interference (MAI) is a factor, which limits the capacity and performance of CDMA system. The conventional detector does not take into account the existence of MAI. Hence, a Multi-User Detection strategies used for mitigating the effects of MAI. Novel receiver structures that take advantage of knowledge of MAI signal parameters are termed as Multi-user receivers and are more complex than conventional ones. This is because of their capability of using MAI signal information to help recover the desired user. Interference cancellation receivers have received a great deal of attention due to its advantages when compared with the other multi-user detectors. The interference cancellation techniques can be broadly broken into successive and parallel schemes for cancelling multiple access interference. Problem Domain In general, a major problem with multi-user detectors and interference cancellers is the maintenance of simplicity. Even the suboptimal linear detectors have considerably complex processing, especially in the asynchronous channel. Certain schemes where the users' signals are detected collectively turn out to have a complex parallel structure. An alternative to parallel cancellation is to perform successive cancellation. The successive cancellation not only requires less hardware but is also more robust in doing cancellations. Our approach successively cancels strongest users but assumes no knowledge of the users' powers. The analysis of successive interference is difficult because the statistics of the users differ from each other. To limit the computational complexity for implementation aspects the power profile is optimized under the constraint of maximum number of iterations.

## 3. System description along with PIC

A simple two stage Parallel interference cancellation (PIC) model is shown in figure Since Parallel interference cancellation (PIC) cancelled interference simultaneous from the entire user. Hence it takes delay of few bits duration, So it is the trade of between complexity and speed.

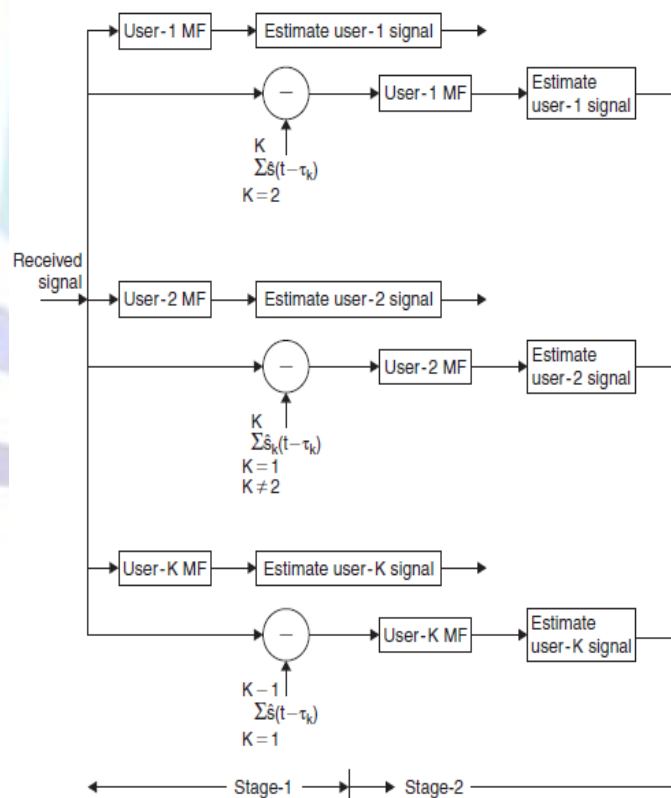


Fig no.1 Schematic of 2-Stage PIC

### 4. Multiuser Detector (MUD's)

Multiuser Detector (MUD's) are many types, they are mainly divided into two type optimal and suboptimal detectors. Suboptimal detectors further divided into Linear and interference cancellation.

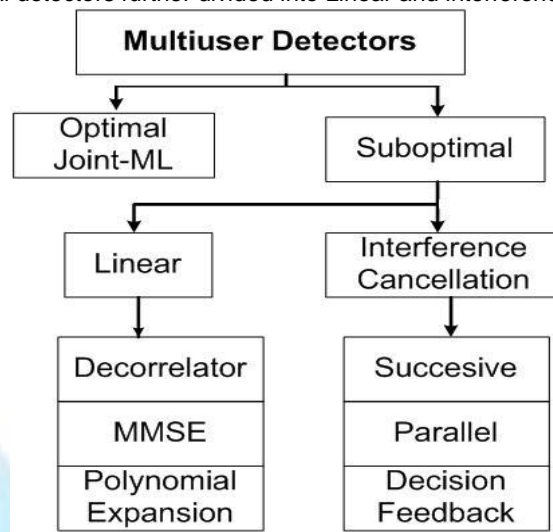


Fig no.2 Types of MUD 's

Simultaneously using the channel then spreading chips information bit. Since it is impossible to derive the interference to zero in that situation. Interference Cancellation MUD attempts to remove Multi Access Interference (MAI) after decoding. It also relaxes a number of requirements of the filtering approaches to MUD, such as accurate priori channel estimates, and is typically much closer in design to existing and proves CDMA receivers.

#### 4.1 Successive Interference cancellation MUD:

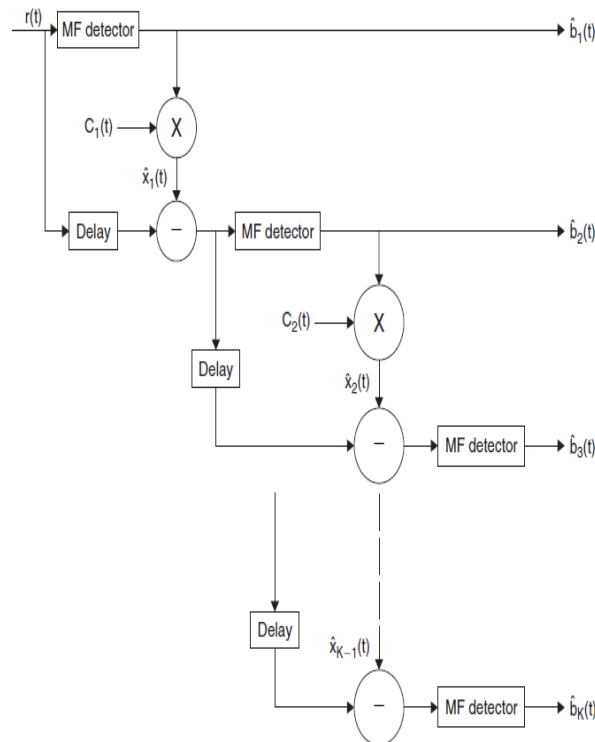
The successive IC scheme is simpler to implement in hardware than the parallel IC scheme, but more robust in cancelling the interference since it successively subtracts the interference from the received signal. The strongest interferer can be detected in the presence of the weaker interferer, and its removal from the received signal enhances the detection of the weaker signals, so we start with detecting the strongest interferer. This implicitly implies that we first have to rank the received signals according to their strength such that:

$$E_1 > E_2 > E_3, \dots \dots \dots > E_K \tag{1}$$

Where  $E_k$  is the energy of the  $k^{th}$  user. For simplicity and without loss of generality, we assume that the signal from user-1 is the largest followed by signal from the user-2 signal, and so on. The implication is that the signal from the  $k^{th}$  user is the weakest. Once the ranking of the received signals is achieved, the detection of the user-1 signal using the conventional Matched Filter (MF) receiver can be accomplished. Let user-1 detected symbol be  $\hat{b}_1(t)$  which will be used to regenerate user-1 signal  $\hat{x}_1(t)$  as:

$$\hat{x}_1(t) = \sqrt{E_1} \hat{b}_1(t) C_1(t) \tag{2}$$

where  $C_1(t)$  is signature waveform for user-1. Subtracting (7) from the received signal  $r(t)$  we get the input to the next stage of the IC as:



**Fig (3) Successive Interference Cancellation**

$$r(t) - \hat{x}_1(t)$$

(3) Repeating the above procedure on the next strongest user signal (user-2) enables the detection of  $\hat{b}_2(t)$  and the generation of the feedback signal  $\hat{x}_2(t)$ . The input to the next stage IC is:

$$r(t) - \hat{x}_1(t) - \hat{x}_2(t) \quad (4)$$

The procedure can be repeated until the user with the weakest signal (kth user) is detected  $\hat{b}_K(t)$  and the input to the final stage is:

$$r(t) - \sum_{i=1}^{K-1} \hat{x}_i(t) \quad (5)$$

The computation complexity of the successive IC algorithm is linear in the number of users. This scheme, though simple, has a number of disadvantages, the most prominent of which is that, since the IC proceeds serially; a delay of the order of K computation stages is required to complete the multi-user detection. Furthermore, an erroneous detection at any stage will be fed back to cause error propagation in the following stages which increases, rather than decreases, the interference level. Another disadvantage is that the first user to be processed sees the interference from K-1 users whereas each user downstream sees less and less interference so that the service quality of the system is not the same. It is easy to implement. But it Suffers from the drawback of error propagation and Requires channel estimates to be available at the receiver. Algorithm of SIC is as follows:

- I. Recognize the strongest signal (one with maximum correlation value).
- II Decode the strongest user.
- III. Estimate the amplitude of the decoded user from the output of the correlator.
- IV. Regenerate the strongest users' signal using its chip sequence and the estimate of its amplitude.
- V. Cancel the strongest user.
- VI. Repeat (until all users are decoded or a permissible number of cancellations are achieved).

## 4.2 Parallel Interference Cancellations MUD:

Optimum ML detector computes the likelihood function for estimation of the signal and hence complexity grows exponentially with number of users. It is impractical even for moderate number of users. Whereas Suboptimal MUD's has Better near-far resistance than matched filter Detector and Lesser complexity (linear complexity) than Optimum Detector. Linear suboptimal MUD is going complex structure as the number of user increases. Therefore Interference cancellation scheme in suboptimal detector proves to be less complex algorithm/structure. The Interference Cancellation techniques are based on the principle that it is possible to remove the multiple access interference from each user's received signal before making data decisions. The IC techniques can be grouped into two categories: *successive IC* where the interference is cancelled serially and in stages starting with the strongest interferer. The *parallel IC* which is achieved by cancelling the interference from all users simultaneously and could be carried out in multi-stages as well. Parallel interference cancellation (PIC) takes less delay in cancellation the interference as it does the work parallel to each user . Both IC schemes use the conventional matched filter as a first stage detector. It must be emphasized that IC techniques deal effectively with intra cell interference and have no control over the interference coming from other cells (inter cell interference) since these interferers cannot be controlled by the serving base station and consequently cannot be cancelled. Since the IC is performed in parallel, the delay required for interference removal is, at most, of a few bits duration. In order to cancel the interference, an estimate of the interference is required.

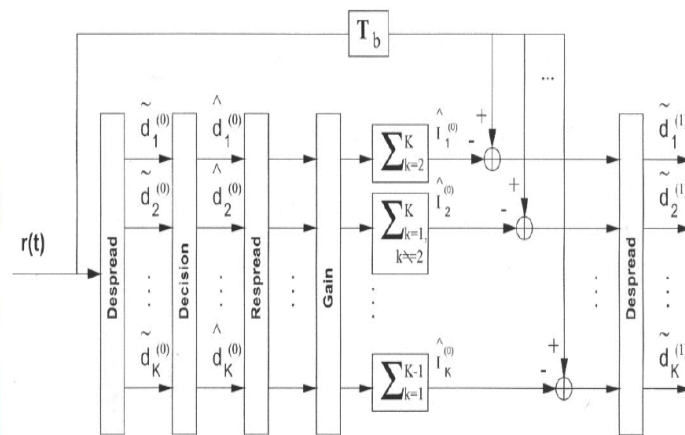


Fig.no.4 Parallel Interference Cancellation (PIC)

However, such estimate is poor in the early stages of multistage PIC process. Therefore, it is preferable to use 'partial IC' and to increase the portion of the IC as the interference estimation improves in the later stages. In the parallel iterative scheme, each stage of the iteration.

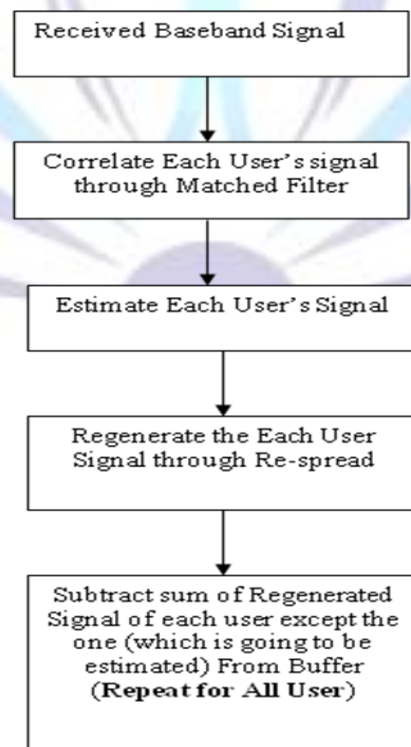


Fig no.5 Algorithm of PIC

Produces a new and better estimate of user bits based upon those obtained in the previous stage which improves the interference estimates.

### 5. Proposed Transmitter Model

In this section proposed transmitter model for DS-SS is described. This model consists of a modulation unit in which BPSK/QPSK modulation is used, a spread spectrum unit in which PN sequence is used for spread. Besides these units, it also consists of Inter-leaver which protects the data from burst error. Simulation has been done on variable no. of user. These data are further made to pass through AWGN channel as; this channel model shows the practical real life channel.

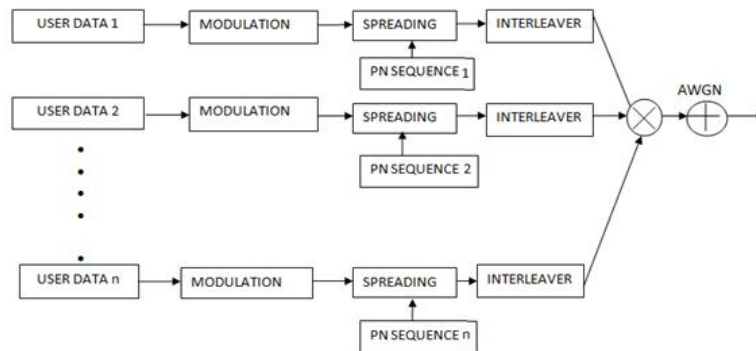


Fig no.6. Proposed Transmitter Model

### 6. Channel

A wireless channel is nothing, it is a radio frequency over which signal is made to transfer from one node to other. Additive white Gaussian noise (AWGN) and Rayleigh channel are the practical channels, which is used in this project. Additive white Gaussian noise (AWGN) is a channel in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. Where Rayleigh fading is a reasonable channel model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. In this simulation both type of channel is considered. The transmitted waveform gets corrupted by noise  $n$ , typically referred to as Additive White Gaussian Noise (AWGN).

**Additive:** As the noise gets 'added' (and not multiplied) to the received signal

**White:** The spectrum of the noise is flat for all frequencies.

**Gaussian:** The values of the noise  $n$  follows the Gaussian probability distribution function,

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

$$\mu = 0 \text{ and } \sigma^2 = \frac{N_0}{2}$$

### 7. Rayleigh fading model

The phase of each path can change by  $2\pi$  radian when the delay  $\tau_n(t)$  changes by  $\frac{1}{f_c}$ . If  $f_c$  is large, relative small motions in the medium can cause change of  $2\pi$  radians. Since the distance between the devices are much larger than the wavelength of the carrier frequency, it is reasonable to assume that the phase is uniformly distributed between 0 and  $2\pi$  radians and the phases of each path are independent. When there are large number of paths, applying Central Limit Theorem, each path can be modeled as circularly symmetric complex Gaussian random variable with time as the variable. This model is called Rayleigh fading channel model. A circularly symmetric complex Gaussian random variable is of the form,

$$Z = X + jY,$$

where real and imaginary parts are zero mean independent and identically distributed Gaussian random variables. For a circularly symmetric complex random variable  $Z$ ,

$$E[Z] = E[e^{j\theta} Z] = e^{j\theta} E[Z].$$



The statistics of a circularly symmetric complex Gaussian random variable is completely specified by the variance,

$$\sigma^2 = E[Z^2]$$

The magnitude mode  $|Z|$  which has a probability density,

$$p(z) = \frac{z}{\sigma^2} e^{-\frac{z^2}{2\sigma^2}}, \quad z \geq 0$$

is called a Rayleigh random variable.

This model, called Rayleigh fading channel model, is reasonable for an environment where there is large number of reflectors.

Gaussian random variable is of the form,

$$h = h_{re} + jh_{im},$$

where real and imaginary parts are zero mean independent and identically distributed Gaussian random variables with mean 0 and variance  $\sigma^2$ .

The magnitude  $|h|$  which has a probability density,

$$p(h) = \frac{h}{\sigma^2} e^{-\frac{h^2}{2\sigma^2}}, \quad z \geq 0$$

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

## 8. Proposed receiver model

In this section proposed receiver model for DS-CDMA with PIC is described and shown in fig. This model consist a match filter in its early stage, basically match filter is part of PIC. PIC detect the data with reduced interference, by applying the given above algorithm Fig in the report. These data is then passed through De-Inter-leaver and then demodulate with the help of a De-modulation unit in which BPSK/QPSK is used. Finally user data of individual user is recovered.

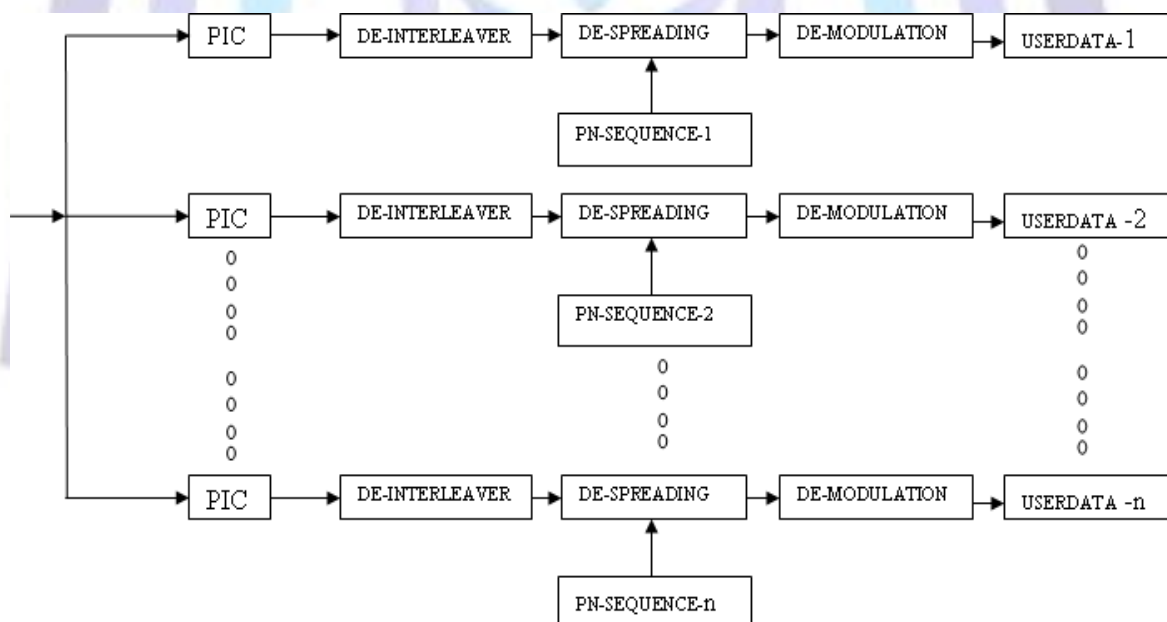


Fig.7 Proposed Receiver Model of PIC



## 9. Simulation and Results

We have chosen communication toolbox of MATLAB, to do the project simulation. Simulation has been done on MATLAB 7.9.0, some result has been obtain in order to show the performance of Matched filter, De-correlator and Parallel interference cancellation receiver. Figure shows that how BER decreases with increase in SNR (Signal to Noise ratio), this simulation is done by assuming AWGN channel for simultaneous transmission of 7 user data. As the data is transmitted simultaneously so interference is from each other is also noticed. Next result is comparative simulation of 30 user, 15 user and 10 user which is shown in figure. All this result are taken without PIC.

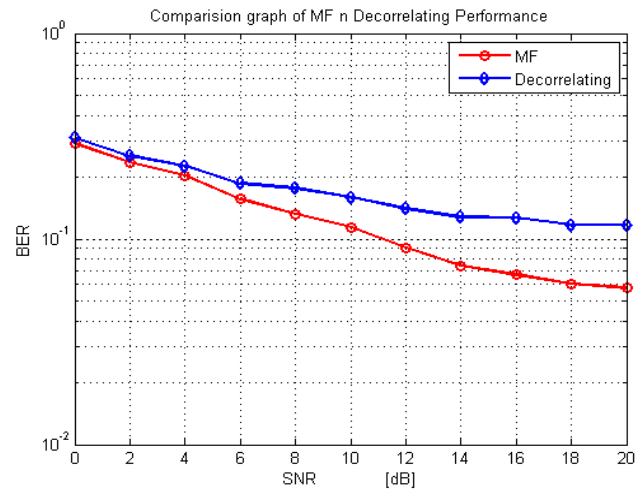


Fig.9.1 performance analysis of matched filter and decorrelator

SNR	BER
0	0.2968
2	0.2682
4	0.2318
6	0.1876
8	0.159
10	0.1292
12	0.1144
14	0.0978
16	0.0886
18	0.0814
20	0.0766

Table No. 9.1 Matched filter





SNR	BER
0	0.3066
2	0.2832
4	0.2574
6	0.215
8	0.1968
10	0.1726
12	0.168
14	0.1522
16	0.1402
18	0.1388
20	0.1318

**Table No.9.2 decorelator**

MF MAI 3		MF MAI 12		MF MAI 15	
SNR	BER	SNR	BER	SNR	BER
0	0.3078	0	0.3078	0	0.3378
2	0.2554	2	0.02654	2	0.3018
4	0.2226	4	0.2226	4	0.2644
6	0.173	6	0.1864	6	0.2293
8	0.1422	8	0.1614	8	0.1938
10	0.1088	10	0.1358	10	0.169
12	0.0828	12	0.1112	12	0.1531
14	0.0694	14	0.096	14	0.1357
16	0.0628	16	0.095	16	0.1337
18	0.0554	18	0.084	18	0.1167
20	0.0472	20	0.0762	20	0.1121

**Table 9.3 Performance of MF for different MAI**

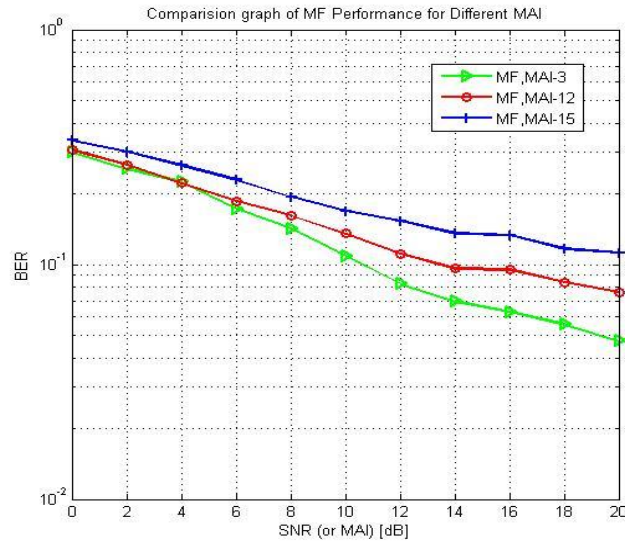


Figure 9.2 Performance of MF for different MAI

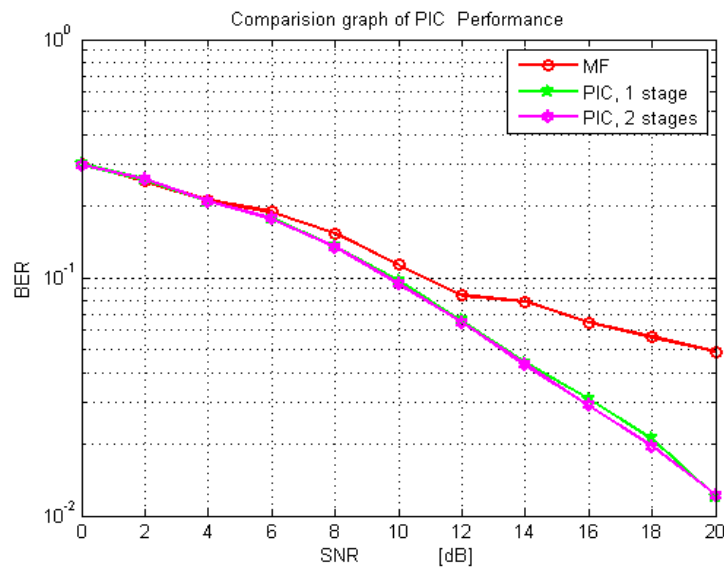
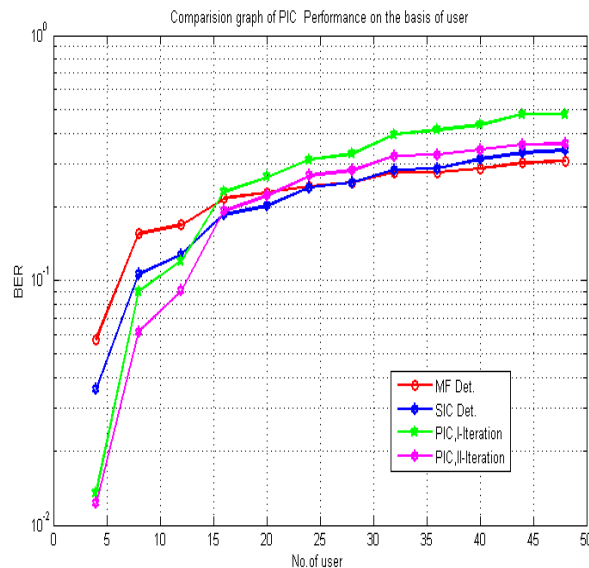


Figure 9.3 Performance analysis of PIC



**Figure 9.4 Performance analysis of PIC on the basis of user**

## 10. Conclusion

The aim of the work presented here was to improve the downlink capacity of DS-CDMA systems by implementing MUD techniques at the mobile receiver. This thesis focuses primarily on new multiuser receiver design using the PIC multiuser detection principle.

Parallel interference cancellation (PIC) in a CDMA receiver shows significant improvement in the performance relative to that of conventional CDMA receiver where no interference cancellation is attempted. In code-division multiple-access (CDMA) systems transmitting over time-varying multipath channels, both inter-symbol interference (ISI) and multiple-access interference (MAI) arises. From the comparison results, it is clear that parallel interference cancellation schemes have better performance than the conventional detector, and at the same time, is simpler and less complex than the optimum detector, where complexity is increases rapidly as the number of user increase, which made it impractical to implement. PIC superior over SIC in time delay, Since SIC cancel the interference serially, so the time required is very large as the user increases. PIC is also better than Matched filter, Decorrelator and also with SIC in well-power controlled environment.

## 11. References

- [1] Analysis of Successive Interference Cancellation in CDMA systems 2012 Second International Conference on Advanced Computing & Communication Technologies
- [2] J.Arun and J.Muralidharan "Highly Efficient BER Performance analysis for interference cancellation in on linear DS CDMA detectors using Dripple algorithm" 2010 IEEE International Conference on Computational Intelligence and Computing Research.
- [3] A New Parallel Interference Cancellation Algorithm for RAKE systems 2009 Third International Conference on Genetic and Evolutionary Computing.
- [2] Guoxiong Xu and Liangcai Gan. "New Parallel Interference Cancellation for DS/CDMA Systems over Rayleigh Fading Channel". 1-4244-1312-5/07 2007 IEEE International Conference.
- [4] Mohamad Dosararian Moghadam<sup>1</sup>, Hamidreza Bakhshi<sup>2</sup>, and Gholamreza Dadashzadeh "DS-CDMA Cellular Systems Performance with Base Station Assignment, Power Control Error, and Beamforming over Multipath Fading" International Journal of Computer Networks & Communications (IJCNC) Vol.3, No.1, January 2011.
- [5] J. M. Holtzman, "Successive interference cancellation for direct sequence code division multiple access", Military Communications Conference, vol. 3, pp. 997- 1001, 2-5 Oct. 1994.
- [6] Peng Hui Tan, and Lars K. Rasmussen "Multiuser Detection in CDMA—A Comparison of Relaxations, Exact, and Heuristic Search Methods". IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 3, NO. 5, SEPTEMBER 2004.
- [7] D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*. Cambridge Univ. Press, 2005..
- [8] S. Verdú, *Multiuser Detection*. Cambridge Univ. Press, 1998.
- [9] Syed S. Rizvi and Khaled M. Elleithy "A Closed-Form Expression for BER to Quantify MAI for Synchronous DS CDMA Multi-user Detector" February 24, 2010.



- [10] J. Kazemitabar and H. Jafarkhani, "Performance analysis of multiple antenna multi-user detection," in *Information Theory and Applications Workshop*, 2009.
- [11] Alexandra Duel-Hallen, Jack Holtzman and Zoran Zvonar "Multiuser Detection for CDMA Systems" IEEE Personal Communications (1995-04). Tan F. Wong: Spread Spectrum & CDMA," Multi-User Detection.
- [12] Mark C. Reed, Paul D. Alexander," Iterative Multi-User Detection for CDMA with FEC: Near-Single-User Performance", IEEE transactions on communications, vol. 46, no. 12, December 1998
- [13] Nevio Benvenuto, Giambattista Carnevale and Stefano Tomasin," Energy Optimization of CDMA Transceivers using Successive Interference Cancellation"
- [14] Peng Hui Tan†, Lars K. Rasmussen† and Teng Joon Lim," Iterative Interference Cancellation as Maximum-Likelihood Detection in CDMA", Centre for Wireless Communications, National University of Singapore.
- [15] R. Michael Buehrer, Neiyer S. Correal-Mendoza, and Brian D.Woerner," A Simulation Comparison of Multiuser Receivers for Cellular CDMA", IEEE transactions on vehicular technology, vol. 49, no. 4, July 2000.
- [16] Lars.K.Rasmussen, Teng.J.Lim, Ann-Louise Johansson," A Matrix Approach to Successive Interference Cancellation in CDMA", submitted to IEEE.

