Performance Analysis of Parallel Interference Cancellation (PIC) Over Rayleigh Channel In DS- CDMA Systems

Sanmati Jain, Sandeep Agrawal, Asif Iqbal

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.

Index Terms— MRC; Multi-path interference Parallel interference cancellation; Rayleigh fading; Serial interference cancellation (SIC);

I. 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.

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Sanmati Jain, M.E Scholar, Electronics & Communication Engineering Depatrtment, R.G.P.V Bhopal./Mahakal Institute of Technology/Ujjain,India.

Prof. Sandeep Agrawal Associate Professor, Electronics & Communication Engineering Depatrtment, R.G.P.V Bhopal. /Mahakal InstituteofTechnology/Ujjain, India.

Asif Iqbal, M.E Scholar, Electronics & Communication Engineering Depatrtment, R.G.P.V Bhopal. /Mahakal Institute of Technology/Ujjain, India.

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.

II. 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.

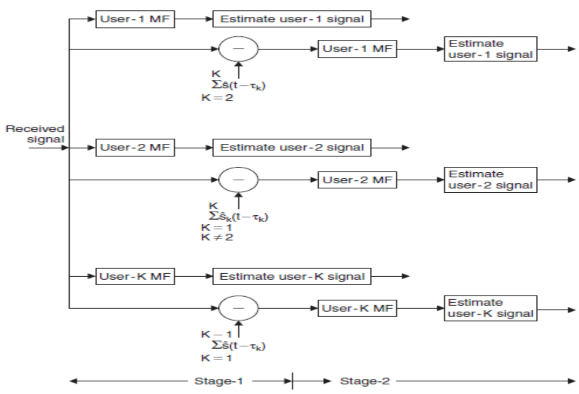

Fig no.1 Schematic of 2-Stage PIC

III. MULTIUSER DETECTOR (MUD'S)

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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.

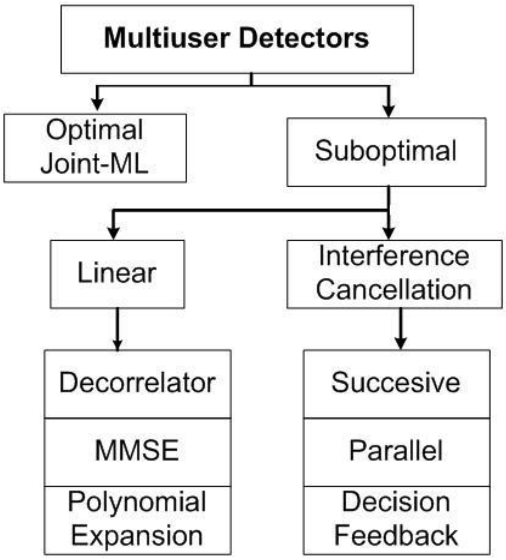

Fig no.2 Types of MUD 's

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.

A) SUCCESSIVE INTERFERENCE CANCELLATION

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:

E1 > E2 > E3, ... >EK (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:

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

where C1(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:

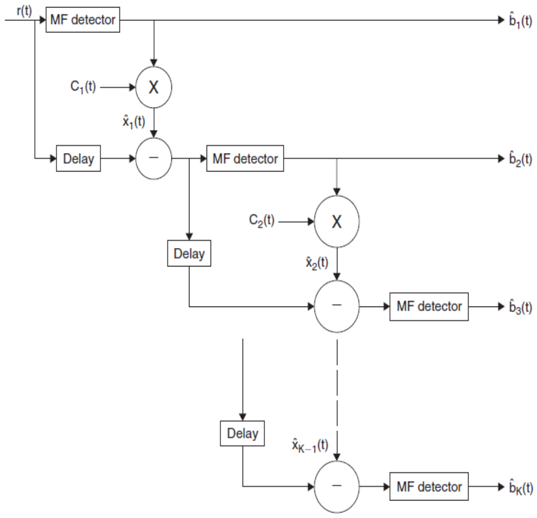

Fig (3) Successive Interference Cancellation

$$r(t) - \hat{x}_1(t) \quad \ldots\ldots\ldots \quad (3)$$

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).

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B) PARALLEL INTERFERENCE CANCELLATION

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.

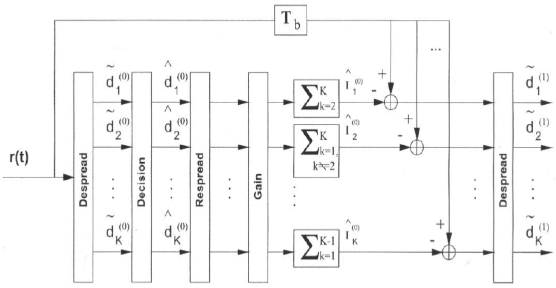

Fig.no.5 Parallel Interference Cancellation (PIC)

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.

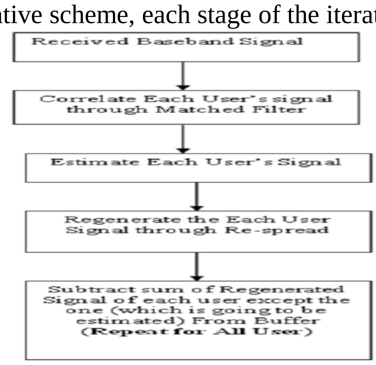

Fig no.4 Algorithm of PIC

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

IV. PROPOSED TRANSMITTER MODEL

In this section proposed transmitter model for DS-CDMA is described .This model consist 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 consist 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.

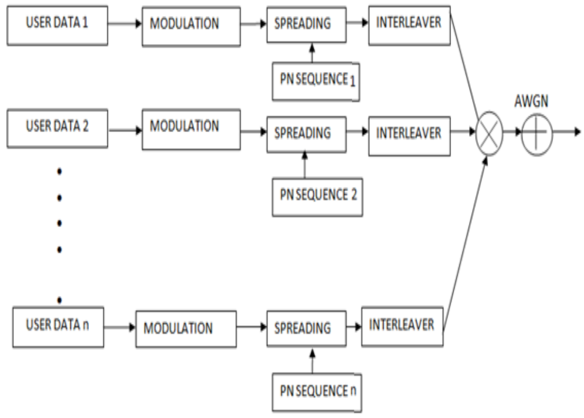

Fig no.6. Proposed Transmitter Model

V. CHANNEL

A wireless channel is nothing, it is a radio frequency over which signal is made to transfer from one node to otherAdditive 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 consider. 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 if flat for all frequencies.

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

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

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

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VI. RAYLEIGH FADING MODEL

The phase of each path can change by 2π radian when the delay $\tau_n(t)$ changes by $1/f_c$. If f_c is large, relative small motions in the medium can cause change of 2π 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 2π 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 σ^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 numberofreflectors.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**.**

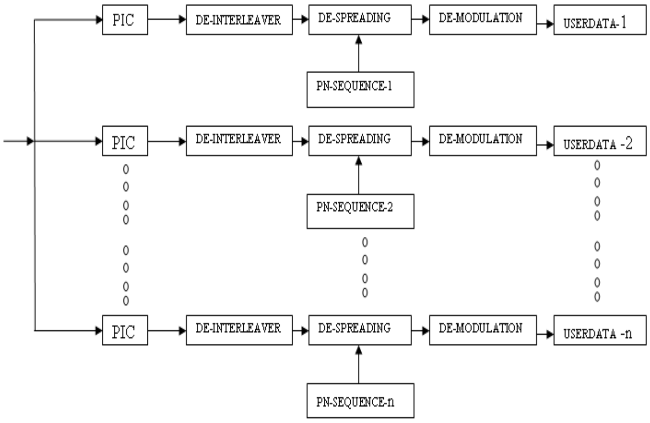

Fig.no.8 Proposed Receiver Model of PIC

VII. 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 transmmision of 7 user data. As the data is transmitted simultaneously so interference is from each other is also noticed. Next reult is comparitive simulation of 30 user, 15 user and 10 user which is shown in figure. All this result are taken without PIC.

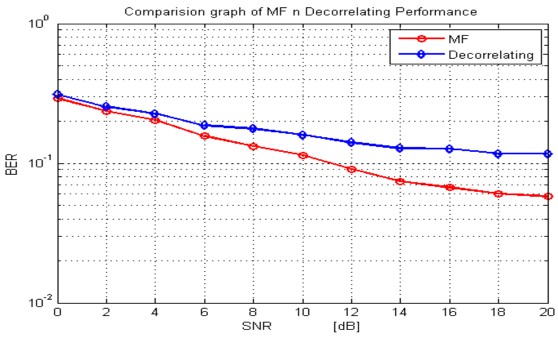

Fig.9.1 performance analysis of matched filter and decorelator

Tableno1 BER Performance of MF

NR	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

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Table no2 BER Performance of DC

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

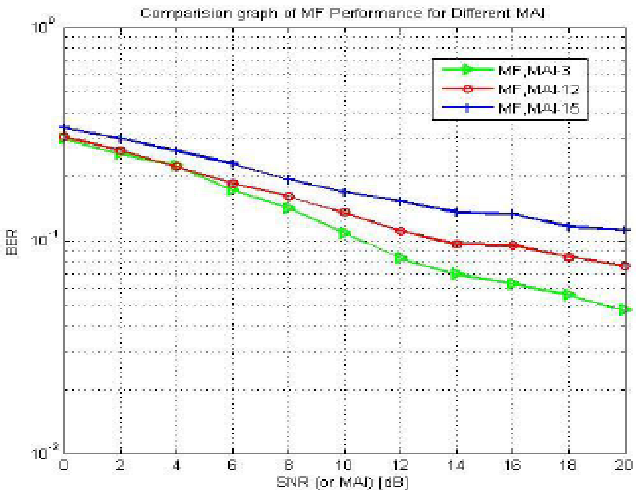

Fig 9.2 Performance analysis of MF on different MAI

Table no.3 BER Performance of MF on different MAI

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

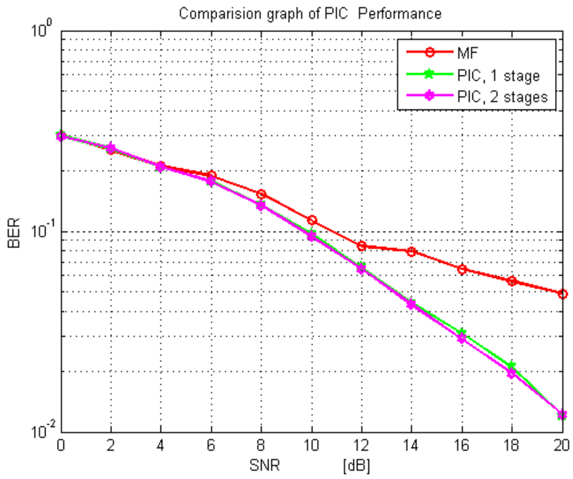

Figure 9.3 Performance analysis of MF and PIC stages

VIII. ACKNOWLEDGMENT

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