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Estimation and analysis of PIC on DSCDMA

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Abstract- This paper deals with the design of sub-optimal detectors in an interference channel with fading and with Additive White Gaussian Noise (AWGN). Parallel interference detector (PIC) is one of the Multiuser Detection (MUD) techniques, where it employs canceling or suppressing interfering users from the desired signals. The conventional detectors typically either ignore the interference or treat other user interference (Multiple Access Interference) as merely noise. But Multiple Access Interference (MAI) has a structure which can be exploited in the detection process. This paper quantifies the significant performance gain if the detector exploits the MAI structure through Multiuser detection technique, which not only improves the capacity of the channel but also reduce requirement for power control. The simulation result shows the better performance of PIC detector over conventional detector.

Index Terms - **Interference Channel, SNR, Multi user detector, Parallel interference cancellation, Crosstalk**.

I. INTRODUCTION

Wireless communication is one of the epoch making technologies that has revolutionized our lives completely. Due to the exponential growth of wireless technology, the mobile telecom industry is worth quite a few trillion US$ in annual revenues for services and equipment, which is even more than the GDP of some of the world's richest countries. Current research and development efforts in future wireless systems have focused on achievable peak bit rates of up to 1 Gbit/s. These rates will be facilitated by the deployment of such systems where antennas acting as simple transmit/receive terminals and are placed densely inside the coverage areas, and their signals are conveyed to central units with high-bandwidth links such as fiber, where they are processed jointly[2]. For such a High bit rates system full frequency reuse is desirable. For this reason, the designs of wireless transceivers that have the ability to communicate reliably in the presence of interferers are of crucial importance in future wireless systems. In conventional wireless transceiver design, interference is commonly viewed as an error at high signal-to-noise ratios (SNRs) [2]. However, this is true only if the received power of each signal is equal and the detectors that are employed do not take into account the structure of the interference properly. In fact, in practical systems, interference may often be less harmful than noise of equal power, because contrary to Gaussian noise, the signals emitted by the interferers belong to discrete constellations. This paper shows that in many cases, the performance of the system is fundamentally limited by the noise rather than the interference. In other word SIR (Signal to Interference ratio) is less harmful than SNR (Signal to Noise ratio). Thus, conventional detectors are typically interference limited rather than noise-limited. The main objective of this paper is to show that we can utilize the interference structure using multiuser detection technique.

With the emergence of multiple access techniques, there has been an increase in the interest in performing simultaneous estimation and detection over all users [5]. MAI can be prevented by selecting mutually orthogonal signature waveforms for all the active users [6, 3]. However, it is not possible to ensure perfect orthogonality among received signature waveforms in a mobile environment, and thus MAI arises. In order to mitigate the problem of MAI, Verdu [7] proposed and analyzed the optimum multiuser detector for asynchronous Gaussian multiple access channels.

Mathematical function to represent MAI [12]

$$\mathrm{R}_k = s_k \left\lfloor (SNR)\, Q\left[\frac{\sqrt{10SNR}}{\sqrt{1+10\sigma^2 SNR}}\right]\right\rfloor + \sum_{k=2}^{K} A_k U_k + \eta_K \qquad (1)$$

The first two terms of (1) can be used to approximate the error rate and the MAI for a user *k*. It should be noted that the second term gives an average variance of the MAI over all possible operating conditions that can be used to compute the required SNR for a desirable BER performance. We use (1) in conducting the simulation result and performing the experimental verification by giving the non folded amplitude of the *k* signal and computing the corresponding MAI as a Gaussian random variable with zero mean. Similarly, the first terms of (1) can be used to approximate the suppression of MAI for a desirable BER performance. Since there is no closed-form mathematical relationship exists between the first two terms of (1), we believe this is the optimal approximation of the MAI.

II. MULTIUSER DETECTION SYSTEM

The superposition of the signals transmitted by the users in a multiple access spread spectrum, also known as Code Division Multiple Access (CDMA), system cause considerable interference to the desired signal if the users' signature waveforms are not orthogonal to each other all the time, a situation which is unlikely to occur in mobile-originated calls [13]. A lot of research has focused on reducing or cancelling the multiple access interference in order to improve the CDMA receivers' performance [1]. The initial approach was to design an improved single-user detector operating efficiently in multi-user channel by applying advanced adaptive signal processing algorithms. It is worth noting that these detectors are preferred by individual mobile users because knowledge of the parameters (signature waveforms, timing, amplitude and phase) of the interfering users is not desired. The second approach considers the detection of signals associated with a group of users where spreading codes, timing information and possibly signals amplitude and phase are known and used jointly to better detect each user [1]. These devices are called multi-user detectors.

Conventional CDMA [1] systems independently detect each user in parallel using a matched filter which consists of the unique spreading code used by that user. These spreading codes are designed such that different ones are highly uncorrelated in order to suppress other users' signals and treat it as simple additive white noise. This approach proves to be very suboptimal since these interfering signals need not be treated as random noise. Instead, the information in these interfering signals can be used to enhance the desired user's signal-to-noise ratio (SNR), thereby raising the capacity of the system. Multiuser detectors attempt to do exactly that, i.e. detect interfering signals and cancel them out from the desired user's signal.

III. TYPES OF MULTIUSER DETECTOR'S

There are many types of MUD's; basically they are divided into two types Optimal and Suboptimal detectors [5].

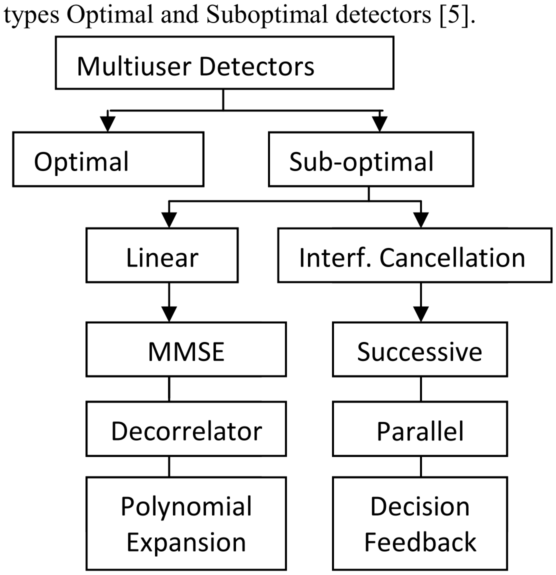

Fig.1

The matched filter detector was believed to be the optimum detector until proved by Verdu [7] in the early 80's.
Optimum ML detector is one of the MUD's which computes the likelihood function

$$\Lambda(\underline{b}) = \int_0^T \left[r(t) - \sum_{k=1}^{K} \sqrt{E_k} b_k c_k(t) \right]^2 dt \quad (2)$$

and selects the sequence $\{b_k, 1 \le k \le K\}$

that minimizes $\Lambda(\underline{b})$

A. *Optimal Multiuser Detector*

Optimum receivers for multiple access CDMA systems are designed according to two different strategies: the individually optimum strategy used to minimize the probability of error for each individual user in the group; that is, for the i^{th} user, select the estimated data b_e that minimizes P [b_e =bi]. The other strategy, called the jointly optimum detection, maximizes the a posteriori probability P [b_i|{y (t)}] for i=1, 2, K where K is the number of active users sharing the CDMA channel [8]. In the latter scheme we maximize the likelihood decisions for the group of users. However, this strategy may not achieve minimum probability of error for each individual user in the group. Optimum Multiuser Detector is highly complex and the complexity grows exponentially with number of users. This complexity is impractical even for moderate number of users. Although, the optimum detector has been shown to dramatically increase the capacity of the system, its complexity deems it infeasible to implement in the real world. The work done by Verdu [7] gave hope that the capacity can ultimately increase using sub-optimal multiuser detectors that balance between the two extreme cases of using the optimal detector or the matched filter detector. In order to reduce complexity in the system, suboptimal technique is being used.

Sub-optimum Multiuser Detectors have better near-far resistance than Matched Filter Detector and have lesser complexity (linear complexity) than Optimum Detector (exponential complexity). Sub-optimal detectors can be classified into two categories: linear
detectors and interference cancellation detectors. The linear detectors employ linear mapping (transformation) at the output of the conventional detector to reduce the access interference and provide better performance.

B. *Sub-optimum Multiuser Detectors*

(i)Linear Detectors
(a)MMSE
(b)Decorrelator
(ii)Nonlinear Detectors
(a)Interference cancellation detectors
(Successive IC, Parallel IC)
(b)Decision Feedback Detectors

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The simplest technique in linear detector is Mean Minimum Square Error (MMSE) technique [10], in which we choose the linear transformation that minimizes the mean square error between the Matched Filter (MF) outputs and the transmitted data vector. MMSE detector tries to minimize the square of the residual noise plus interference. Several adaptation algorithms has been used to employ this techniques i.e. LMS, RLS etc. other technique which is also used to employ MMSE is Blind techniques [10]. MMSE requires accurate channel and user information, along with this it requires a KxK matrix inversion which becomes extremely complex to evaluate as K increases.

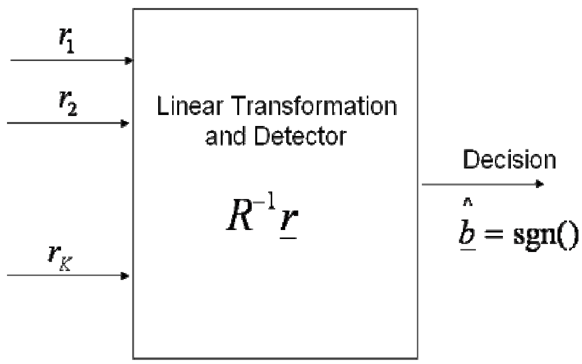

Fig2 . Sub-optimal Linear detector

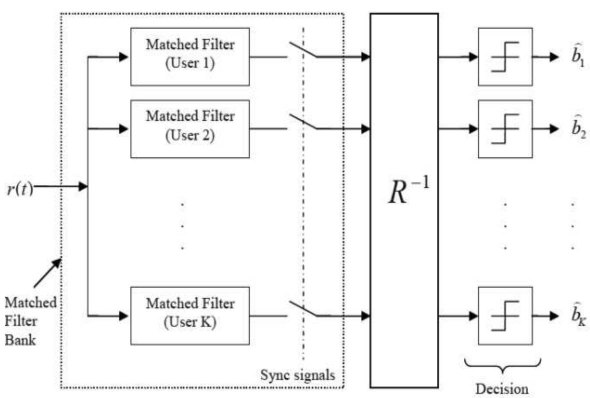

Fig3. Decorellator detector

Other Sub-optimal Linear detection technique is Decorrelator technique, in which we correlate the received signal with the modified signature waveforms, in this way the MAI is tuned out i.e. decorrelated. And hence its name is Decorrelator. The Decorrelating detector attempts to completely eliminate all MAI. Decorrelating detector is a special case of the MMSE detector, where the noise is zero. The decorrelating detector has the same noise enhancement problem as zero-forcing equalizer. It is also undefined when there are more users simultaneously using the channel than spreading chip per information bit, since it is impossible to drive the interference noise to zero in this situation.

Linear sub-optimal detectors has limited by no. of user, as the no. of user is increased the complexity is also increases linearly. On the other hand Non linear sub-optimal detectors have the advantage that complexity of designing the detector is less than Linear detectors. Non-Linear sub-optimal detectors can be divided into two types: Interference cancellation detectors (SIC, PIC) and Decision Feedback Detectors [14]. They have common that feedback is used to reduce MAI for future attempts at detection.

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. The main stages involved in the IC schemes are the estimation of the received signal amplitudes (energies) of the active users, the regeneration of the appropriate interfering signals and the subtraction of the interfering signal from the received signal. Both IC schemes use the conventional matched filter as a first stage detector. In the first IC stage of the MAI is first estimated and then subtracted from the received composite signal Interference Cancellation approaches can be Serial (or successive) Interference Canceller (SIC) sequentially recovers users (recover one user per stage) data estimate in each stage is used to regenerate the interfering signal which is then subtracted from the original received signal.

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The parallel IC scheme accomplishes parallel processing of the access interference, and removes the interference from all users simultaneously. 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. 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 produces a new and better estimate of user bits based upon those obtained in the previous stage which improves the interference estimates.

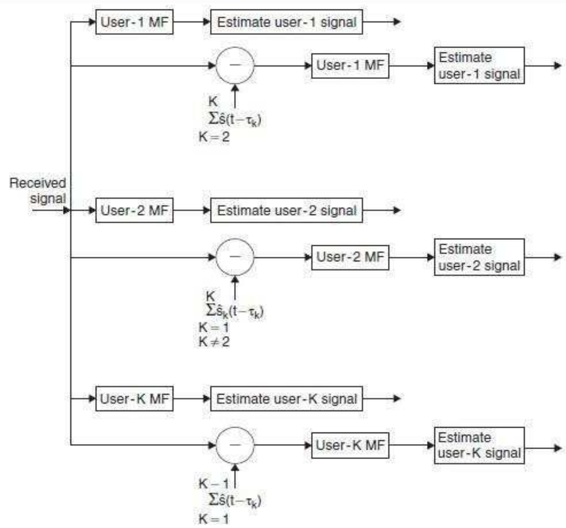

Figure 4 . Stage of PIC.

IV. SIMULATION RESULT

In this section, we present the results obtained by simulations. The number of users is taken to be 15 in all simulations. We adopt short spreading codes with spreading factor N=31 which are randomly generated for each user. The frame size of the information bits for each user is 128. We assume all the users transmit their signals with equal power, i.e., $P1= P2=\ldots PK$. Simulation have been done in MATLAB-version 7.9.0. First we have calculated BER performance of conventional detector among the different modulation scheme, in that we have shown comparison between BPSK(1/2 rate), QPSK(1/2 rate), QPSK(3/4 rate), 16QAM(1/2 rate) and 16QAM(3/4 rate). Performance of BPSK is better any other modulation scheme for various SNR.

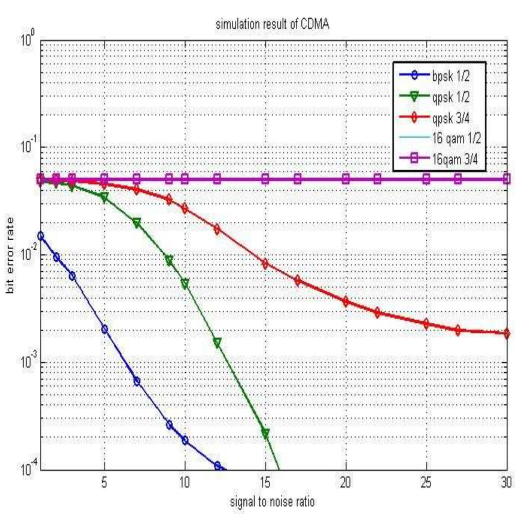

Fig.5 Performance of various modulation scheme

Simulation result shows that bit errror performance between without PIC and with PIC in BPSK modulation in Rayleigh channel is shown in figure 6. It has been easly seen that the performance of PIC is better than simple reciever. Same simulation has been also done using QPSK channel shown in figure7.

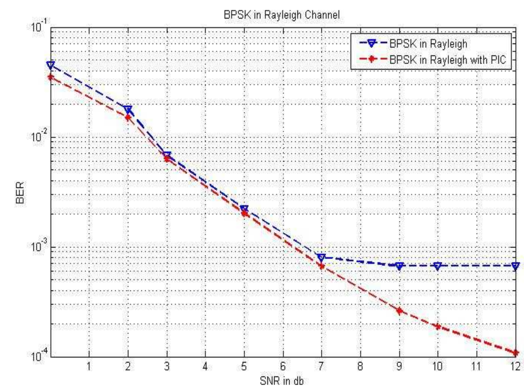

Fig.6 Performance comparison of PIC in QPSK.

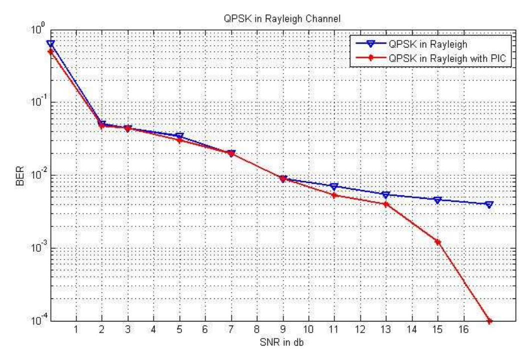

Fig.7 Performance comparison of PIC in QPSK.

V. CONCLUSION

First, this paper analyzed the performance of the various modulation schemes in the basic model of CDMA on AWGN channel. Simulation result shows the comparison of BPSK, QPSK and QAM with different rates. BPSK is come out with a better modulation, but require more bandwidth .so there is always trade of between bandwidth and BER. Secondly, this paper also focuses on the joint MUD's for the Gaussian Interference Cancellation [11]. Unlike the interference-ignorant detector, these joint detectors exploit knowledge of the distribution of the interference rather than treating the interference as Gaussian noise [11]. Furthermore the SNR performance of these detectors was compared analytically. Comparison of different PSK technique has been shown by simulation in MATLAB for interference mitigation through PIC in CDMA system. This paper shows that joint detection turns an interference limited channel into a noise-limited channel

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