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Performance Enhancement of Downlink Multiuser DS-CDMA Detectors in Multipath Channels over AWGN Channels

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Abstract: In this paper, we have introduced the diversity scheme maximum ratio combining (MRC) as preprocessor to the adaptive multiuser-detector (MUD) in direct-sequence code-division multiple-access (DS-CDMA) downlink systems to enhance its performance in multipath channels over AWGN channels. The performance of DS-CDMA is limited by multiple-access interference (MAI). To reduce the effects of MAI, MUDs are used at the receiver side. MUDs work by taking into account the information like spreading codes of the users and system parameters, but these values are not constant and also not known beforehand. Thus MUDs were advanced to adaptive MUDs which take into account the changing parameters by employing adaptive technique for e.g. LMS or RLS algorithms. These adaptive MUDs require each transmitter to send a training sequence at startup which the receiver uses for initial adaptation. However, if there is any drastic change in interference environment, decision directed adaptation becomes unreliable, and data transmission must be temporarily suspended and yield to a fresh training sequence. Therefore MRC as preprocessor to the adaptive MUD of DS-CDMA system is used. As shown by simulation results, the BER performance achieved by the proposed detector outperforms the conventional MF detector with a good margin and is promising.

Keywords: Multiuser detection (MUD); Direct Sequence-Code Division Multiple Access (DS-CDMA); Additive White Gaussian Noise (AWGN) channel; Multipath channel.

I. Introduction

Direct-sequence code-division multiple access (DS-CDMA), a specific form of spread-spectrum transmission, has been adopted as the multi-access technology for non-orthogonal transmission in the third-generation (3G) mobile cellular systems [15]. DS-CDMA techniques does not requires time or frequency coordination among the mobile stations, rather a unique spreading code [18] is assigned to each user to identify the user to the system, which is used to modulate and demodulate the user's data.. However the performance of DS-CDMA system is limited by multiple-access interference (MAI) and multipath channel distortion. The conventional matched filter detector fails to combat these problems and optimal receivers [20] are far too complex for practical implementations and hence several suboptimal receivers [l-3] for multiuser communications have been proposed.
Suboptimal detectors can be classified in two categories namely linear and non-linear multiuser detectors. In linear multiuser detector, a linear transformation is applied to the soft outputs of the conventional detectors in order to produce new sets of decision variables with multiple access interference greatly decoupled. The two most cited multiuser detectors are the decorrelating detector, and the Minimum Mean Square Error (MMSE) detector [1]. The decorrelating detector offers many desirable features, e.g. it yields optimal value for near far performance metric, and does not need to estimate the received amplitudes, the computational complexity is lower than that of the maximum likelihood sequence detection, etc. MMSE detection takes into account the background noise and utilizes the knowledge of the received signal powers. As it takes into noise hence it gives better performance than that of the decorrelating detector. As the noise is reduced to zero the MMSE detector reduces to decorrelating detector. In the nonlinear multiuser detection which is also called the subtractive detection, the interference estimates are generated and then removed from the received signal before detection. Multistage interference cancellation (IC) is one of the most interesting in the nonlinear detector category. In multistage IC the cancellation can be either

successively or may be in parallel. Subtractive interference cancellation is much simpler that that of the linear multiuser detector but have inferior performance. Another disadvantage of successive interference cancellation scheme is that they usually need to estimate the amplitude and carrier of the active users. One of the approaches to reduce the MAI is adaptive multiuser detection [4] which employs adaptive technique called least mean square (LMS) and recursive least square (RLS) algorithms [5]. The typical operation of those adaptive multiuser detectors requires each transmitter to send a training sequence at startup which the receiver uses for initial adaptation. After the training phase ends, adaptation during actual data transmission occurs in decision-directed mode. However, any drastic change in the interference environment, a fresh training sequence is required. Therefore the diversity scheme called maximum ratio combining (MRC) [6], [17] as preprocessor to the adaptive MMSE detector of DS-CDMA system is proposed which eliminates the use of training sequences. MRC is optimum way (in the sense of the least Bit error Rate (BER)) to use information from different paths to achieve decoding in multipath channel [16]. It corrects the phase rotation caused by a multipath channel and then combines the received signals of different paths proportionally to the strength of each path. Since each path undergoes different attenuations, combining them with different weights yield an optimum solution under multipath channel [6].

Recently, adaptive implementations of the MMSE receivers have received. The focus of this paper is on enhancing the performance of adaptive MMSE receivers by introducing MRC as a preprocessor in multipath channels. The proposed Adaptive MMSE-MRC algorithm is applied to the downlink (base station to mobile) of DS-CDMA system. Fortunately and as expected, we have come up with satisfying and promising results over BER performance enhancement using the proposed multiuser detector.

We organized this paper in following: in section II, we consider model of DS-CDMA system briefly. In Section III, we investigate linear multi-user detectors and adaptive MMSE detector for DS-CDMA and weak/strong points of such systems. A Maximal-ratio combining (MRC) scheme is studied in section IV and proposed adaptive MMSE-MRC detector is investigated in section V. Eventually, we compare simulation results in section VI and main conclusions are summarized in Section VII.

II. DS-CDMA CHANNEL MODEL

In general, Multiuser downlink DS-CDMA system has been showed in fig. 1 [10]&[14].

The transmitted signal model for every user is

$$b_k^{(n)} A_k s_k^{(n)}(t-\tau_k) \tag{1}$$

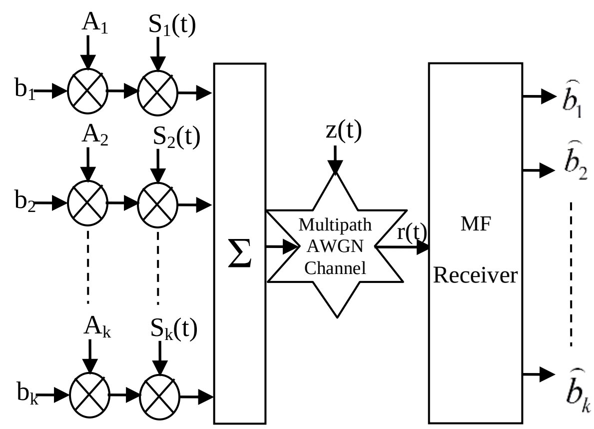

Fig. 1. Multiuser downlink DS-CDMA system

Where $b_k^{(n)}$ is n[th] bit in user k, A_k is complex transmitted signal amplitude which can write as $A_k = \sqrt{E_k / T}$, E_k is the energy per symbol. $s_k^{(n)}(t-\tau_k)$ denotes user k spreading code during to sending of symbol n where s_i and s_j for i≠j are orthogonal and

$$\int_0^T \left| s_k^{(n)}(t) \right|^2 dt = 1 \tag{2}$$

Where, τ_k is received signal delay due to different distances from Base Station (BS). In general, we can represent $s_k^{(n)}$ as follow:

$$s_k^{(n)}(t) = \sum_{m=0}^{N_c-1} s_{k,m}^{(n)} \psi(t - mT_c) \tag{3}$$

Where $s_{k,m}^{(n)}$ shows m*th* chip for user k during a period of time of symbol n, $N_c(t) = T/T_c$ denotes processing gain and $\psi(t)$ determines chip shape as Gaussian or rectangular.

Here we assume $s_{k,m}^{(n)} \in \{-1,1\}$ and choose BPSK for modulation. Also, signal transmissions are done synchronously.

That means, $\tau_1 = \tau_2 = \ldots = \tau_k = 0$. Channel is modeled as a linear filter with impulse response and given to $c_k^{(n)}(t)$.

If frequency selective channel is consist of discrete multipath components then, it writes as

$$c_k^{(n)}(t) = \sum_{l=1}^{L} c_{k,l}^{(n)} \delta(t - \tau_{k,l}^{(n)}) \tag{4}$$

Where, L is number of multipath components and $c_{k,l}^{(n)}$ is complex gain for *lth* multipath component of user k, and

$\tau_{k.l}^{(n)} \in (0, T_m)$ shows delay of lth multipath component of user k in time period of symbol n. T_m is spread channel delay (under assumption of T_m <T) and $\delta(t)$ is Dirac function. Received CDMA signal in each user, is result of convolution of transmitted signal (1) with channel impulse response in addition to channel additive Gaussian noise and is given by:

$$\sum_{n=0}^{N_b-1}\sum_{k=1}^{K} b_k^{(n)} A_k s_k^{(n)}(t-nT-\tau_k) * c_k^{(n)}(t) + z(t) = \sum_{n=0}^{N_b-1}\sum_{k=1}^{K} b_k^{(n)} A_k \sum_{l=1}^{L} c_{k,l}^{(n)} s_k^{(n)}(t-nT-\tau_k-\tau_{k,l}) + z(t) \quad (5)$$

Where N_b is number of transmitted data packet, sign of $*$ denotes convolution operator and z(t) is additive white noise with zero mean and power spectrum density of σ^2.

It has been showed that match filter outputs are sampled for data detection in every symbol period [7],[8]. Match filter sample for *l*th path and *k*th user is

$$y_{k,l}^{(n)} = \int_{nT+\tau_k+\tau_{k,l}}^{(n+1)T+\tau_k+\tau_{k,l}} r(t) s_k^{(n)}\left(t-nT-\tau_k+\tau_{k,l}\right) dt \quad (6)$$

We define output samples of MF as a vector is given by

$$y_k^{(n)} = \left(y_{k,1}^{(n)}, y_{k,2}^{(n)}, \dots, y_{k,L}^{(n)}\right)^T \in €^{\mathrm{L}} \quad (7)$$

And rewrite it as a matrix for all of user in form of

$$y^n = \left(y_1^{T(n)}, y_2^{T(n)}, \dots, y_k^{T(n)}\right)^T \in €^{\mathrm{KL}} \quad (8)$$

Also we can concatenate them in a total data packet for K users and define as

$$\left(y^{T(1)}, y^{T(2)}, \dots, y^{T(N_b)}\right)^T \in €^{N_b KL} \quad (9)$$

Since the real channel is non-ideal, thus chip codes are not orthogonal to each other and so, in receiver side we will have correlation matrix as $R^{(n)}(i) \in (-1,1)^{KL\times KL}$

Matrix form of received signal in Mobile Station (MS) is modeled as, r = $SHAb + w$ (10)

The channel considered is synchronous. S is matrix of pseudo noise chip codes of all users and H denotes channel matrix. Also A and b represent amplitude of transmitted symbols and BPSK symbol vector, respectively. *w* is additive noise vector in entrance of receivers. If channel is frequency selective, we can rewrite this model as r = $RCAb + w$ [13]. r is a matrix which represents all possible received signals. These signals are then fed to the preprocessor, which is a bank of matched filters. Based on this compact model in equation (10), the conventional Matched Filter (MF) detection scheme is summarized next.

The standard matched filter (MF) is a single user detection process which utilizes the user's own signature sequence only. At the receiver end, the received signal is passed through a group of correlators in order to recover the information stream transmitted by each user. Hence the output of the k^{th} correlator under synchronous condition would be,

$$\hat{b}_{k(MF)} = sign\left(S_k^H r\right) \quad (11)$$

Where $S_k^H = [0....s_k....0]$, s_k being the k^{th} user's signature code. Equation (12) may be given as,

$$\hat{b}_{k(MF)} = sign\left(b_{MF}\right) \quad (12)$$

Where, $b_{MF} = RHAB + w$ (13)

In equation (13), R is the normalized cross-correlation matrix of the spreading sequences and w is noise component of MF output. If there was no multipath and mutually orthogonal spreading sequences were chosen, the conventional (MF) detector would result in optimal demodulation. However multipath destroys any orthogonality present in the spreading sequences and the demodulated results are unacceptably erroneous. Hence this b_{MF} is then used as an input to multi-user detectors to improve the bit-error performance [2], [5] and [8].

III. DS-CDMA LINEAR AND ADAPTIVE MUDS

There has been great interest in improving DS-CDMA detection through the use of multi-user detectors. In multi-user detection, code and timing (and possibly amplitude and phase) information of multiple users are jointly used to better detect each individual user. The important assumption is that the codes of multiple users are known to the receiver a priori [2].

An important group of multi-user detectors are linear and adaptive linear multi-user detectors. In any detector under this group, a linear transformation is applied to the single user matched filter (SUMF) to reduce the MA1 seen by each user [2]. In this section we briefly review the two most popular of these, the decorrelating and minimum mean-squared error linear detectors [22] and one adaptive linear detector.

A. Decorrelating Detector

It achieves perfect demodulation in the absence of noise if the spreading sequences in S are linearly independent. It is implemented by premultiplying the matched filter outputs with the inverse of the cross-correlation matrix before multiplying the sign, i.e.,

$$\hat{b}_{k(MF)} = sign\left(R^{-1} b_{MF}\right) \quad (14)$$

The Decorrelating detector is shown to have many attractive properties. Foremost among these properties are [2]:

- Provides substantial performance capacity gains over the conventional detector under most conditions.
- Does not need to estimate the received amplitudes: In contrast, detectors that require amplitude estimation are often quite sensitive to estimation error. (Note that as in the case of most multi-user detectors, the need to estimate the received phases can also be avoided through the use of non-coherent detection.
- Has computational complexity significantly lower than that of the maximum likelihood sequence detector: The per-bit complexity is linear in the number of users, excluding the costs of precomputation of the inverse mapping.

Even though the decorrelator achieves perfect demodulation in the noise-free case, it increases the effect of noise whenever noise is present. A more significant disadvantage of the decorrelating detector is that the computations needed to invert the matrix **R** are difficult to perform in real time. For synchronous systems, the problem is somewhat simplified: we can decorrelate one bit at a time. In other words, we can apply the inverse of a *K* x *K* correlation matrix. For asynchronous systems, however, **R** is of order *NK*, which is quite large for a typical message length, N.

B. Minimum Mean Square Error (MMSE) Detector

There are many ways one can view the performance of a linear detector. Perhaps the most widely used is the achieved Minimum Mean Squared Error (MMSE) [21]. A tradeoff can be made between the increase in performance due to decorrelation and the loss on performance due to increased noise level. The linear MMSE detector achieves this optimum tradeoff by making decisions as [5], [7],

$$\widehat{b}_{k(LMMSE)} = sign\left(\left[R + (No/2)A^{-2}\right]^{-1} b_{MF} \right) \tag{15}$$

The symbols for section A and B are defined as follows-

A : K x K Users’ amplitudes diagonal matrix

B : K x 1 Users’ information bits

S : 1 x K Signature waveforms vector

w : AWGN

b_{MF} : K x 1 Output of SUMF vector

R : K x K Cross-correlation matrix

N : K x 1 Noise component of SUMF outputs

An important disadvantage of this detector is that, unlike the decorrelating detector, it requires estimation of the received amplitudes. Another disadvantage is that its performance depends on the powers of the interfering users. Therefore, there is some loss of resistance to the near-far problem as compared to the decorrelating detector. Like the decorrelating detector, the MMSE detector faces the task of implementing matrix inversion. Thus, most of the suboptimal techniques for implementing the decorrelating detector are applicable to this detector as well.

C. Adaptive Linear Detector (LMS Algorithm)

Many adaptive DS-CDMA detectors are based on linear receivers, especially on MMSE receivers. In this case the goal is to minimize the MSE in the output of the linear filter. Its implementation can be done by a simple tapped delay line filter with an appropriate adaptive algorithm. Before the LMS (least mean square) algorithm is described, a brief review of the gradient descent optimization algorithm is presented [9]. The gradient descent algorithm is used for the optimization of convex penalty functions. Consider the optimization of the following convex penalty function:

$$\xi = E\left\{ g\left(X, w \right) \right\} \tag{16}$$

Where, E is the expectation operator, X is a random variable and u is the parameter to be optimized (X and w could be vectors). If ξ (is convex, then according to the gradient descent algorithm, it is possible to converge to the minimum value of ξ by starting at any point w_o and following the direction opposite to the gradient $\nabla \xi$ (steepest descent). The update rule is then given by

$$w_{j+1} = w_j - \mu \nabla \xi \left(w_j \right) \tag{17}$$

However, if the distribution of X is not known, then neither the penalty function given by (17), nor its gradient can be computed. But if a number of independent observations of X are available then it would be possible to get an estimate of the distribution of X and calculate the gradient of the penalty function and use the update rule given in (17) Therefore, at each iteration we could replace the gradient of the penalty function $\nabla \xi = E\left\{ \nabla g\left(X, w \right) \right\}$ by its approximate value $\nabla g\left(X_{j+1}, w \right)$. This is called the stochastic gradient descent algorithm. The update rule for the stochastic gradient is thus modified as,

$$w_{j+1} = w_j - \mu \nabla \xi \left(X_{j+1}, w \right) \tag{18}$$

If the step size is infinitesimally small, then the deviations on either side of the mean tend to cancel out and the trajectory of the stochastic descent will almost follow the steepest descent trajectory. For the special case of quadratic cost functions, the stochastic descent algorithm is also known as the least mean square (LMS) algorithm. For the case of MMSE multiuser detection in CDMA systems, the convex penalty function is given by

$$\xi = \left\{ \left\| b_1 - w^{\tau} y \right\|^2 \right\}$$

$$\nabla \xi = -\left\{ \left(b_1 - w^{\tau} y \right) y \right\}$$

Therefore the weight update is given by,

$$w_{j+1} = w_j + \mu\left(b_1(j+1) - w^{\tau}(j)\,y(j+1)\right)y(j+1) \quad (19)$$

It is seen that we need to know the data bits b1 in order to implement the LMS algorithm. This requirement is handled by sending a training sequence at the beginning of each transmission. Once the training sequence has been sent, the adaptive algorithm can be allowed to run with the decisions made by the detector instead of the true transmitted data. This mode of operation is called decision directed operation. This might fine-tune the weights if the SNR is high enough. However if the SNR is very low, the decisions of the detector are not reliable enough and may cause the weight to change drastically from the optimal value. In the simulation results presented in this report, the decision directed mode was not used. Once the training bits are sent, the weights were not changed.

The longer the training sequence, the closer are the computed weights to the optimal value. The training bits however are an overhead and the number of training bits needs to be as small as possible in order to maintain system efficiency. Hence there is a tradeoff between efficiency and error performance that needs to be considered when determining the number of training bits that needs to be used in a system.

Apart from the number of training bits another important parameter that affects the performance and convergence speed of the LMS algorithm is the step size. A large step size makes the algorithm converge faster but has a higher ripple around the optimal value. Conversely, a smaller step size takes longer to converge but has smaller residual error. Thus it would be nice to progressively decrease the step size as the LMS algorithm proceeds. A high value of step size should be used initially to cause fast convergence of the algorithm and then in later iterations a smaller step size should be used to minimize the ripple around the optimal value. One method of progressively shrinking the step size is to multiply the fixed step size by y where i is the iteration number and y is a number just less than 1. For simulation we use t =0.01 and y =0.9999.

IV. Maximum Ratio Combining Scheme

Various Multi-user detection methods have been investigated in many previous studies [2]-[5] in AWGN channel which uses a bank of MF as a preprocessor. But in a multipath fading channel, propagation delay spread merely provides multiple versions of the transmitted signal at the receiver. If these multipath components are delayed in time by more than chip duration, they appear like uncorrelated noise at a DS-CDMA receiver. Hence CDMA receiver may combine the time-shifted versions of the original signal by providing a separate correlation receiver for each of the multipath signals.

So a better technology is the Maximum Ratio Combining (MRC) which first identifies few strong multipath signals and then combines them after incorporating adjustment for delays. In this scheme, the spreading code and channel coefficients of the user of interest are only utilized for the detection process. A MF-MRC then utilizes few strongest multipath components. The outputs of each correlator are weighted to provide a better estimate of the transmitted signal than is provided by a single component. Correlator 1 is synchronized to the strongest multipath component m_1 . Second multipath component m_2 arrives τ_1 later than first component. The second correlator is synchronized to m_2 .If only a single correlator is used, once the output of this correlator is corrupted by fading, the receiver cannot correct the value. In a MF-MRC receiver, if the output from one correlator is corrupted by fading, the others may not be, and the corrupted signal may be discounted through the weighting process. The weighting coefficients α_m , are normalized to the output signal power of the correlator in such a way that the coefficients sum to unity. i.e.

$$\alpha_m = \frac{Z_m^2}{\sum_{m=1}^{M} Z_m^2} \quad (20)$$

where Z_m is the output from the m[th] correlator [11].

Mathematically the MF-MRC detector can be expressed as: $\hat{b}_{k(MF-MRC)} = S_k^H \bar{H}^H r$ (21)

Where $\bar{H}^H$ is the Hermitian of the estimated channel matrix.

In the presence of noise, the optimal LMMSE detector is considered to be the best linear detector for DS-CDMA reception [2]. The LMMSE detector for a generic single stage spreading system is given by

$$\hat{b}_{k(LMMSE-MRC)} = S_k^H \bar{H}^H \left(R + (No/2)A^{-2}\right)^{-1} \bar{r} \quad (22)$$

Where R is the auto-correlation matrix for the signal chip train received at the mobile set. No/2 is the average power of the transmitted user signals. A major drawback of LMMSE is the complexity involved in the computation of the auto-correlation matrix.

V. Adaptive MMSE-MRC Detector

From the mathematical expressions given for MF-MRC detector and LMMSE-MRC detector in the previous section one can see that except the inverse operation remaining terms are similar. Hence it is expected to achieve LMMSE performance by adding a preprocessing stage to the MF-MRC receiver. The basic principle of MF-MRC receiver is to provide link improvement through time diversity.

An adaptive least mean squares (LMS) algorithm will be developed for the proposed Adaptive MMSE-MRC detector, which iteratively produces $\left(R + (No/2)A^{-2}\right)^{-1}$. 'The modified cost function results in separate LMMSE detectors for each multipath component. Hence, the adaptive MMSE detector is actually an adaptive MRC receiver, where each receiver branch is adapted independently to suppress MAI. The outputs of adaptive receiver branches are maximal-ratio combined to reduce decision variable.

Let $r_{k,m}^{(n)}$ be the input sample vector during the n[th] symbol to the m[th] receiver branch. The received signal vectors are fed to linear filters with impulse response of $w_{k,m}^{(n)}$. The output of the m[th] receiver branch can be written as,

$$y_{k,m}^{(n)} = w_{k,m}^{(n)} r_{k,m}^{(n)} \tag{23}$$

The error functions, $e_{k,m}^{(n)}$, produced by the difference between the filter outputs and the reference signals, are used to update the filter weights.

$$e_{k,m}^{(n)} = d_{k,m}^{(n)} - y_{k,m}^{(n)} \tag{24}$$

The product of estimated channel coefficients and data symbols is the reference signal in the adaptive MMSE-MRC detector given by,

$$d_{k,m}^{(n)} = h_{k,m}^{(n)} \hat{b}_k^{(n)} \tag{25}$$

Either the data decisions or a training sequence can be used as $\hat{b}_k^{(n)}$. The data decisions produced initially by a conventional MF-MRC receiver are often reliable enough for adapting the receiver. It is also possible to use the absolute value of the estimated channel coefficients $h_{k,m}^{(n)}$.

Hence, the proposed adaptive receiver does not necessarily require separate training sequence. The optimal filter coefficients are derived using the MSE criterion, $\left(E\left[\left| e_{k,m}^{(n)} \right|^2 \right] \right)$, which leads to the optimal filter coefficients [12] $w_{k,m}$.

It is convenient to decompose the filter vector to fixed and adaptive components: $w_{k,m}^{(n)} = S_k^H + x_{k,m}^{(n)}$ (26)

Where $S_k^H = [0....s_k....0]$ is the fixed spreading sequence of the k[th] user and $x^{(n)}$ is the adaptive component. If standard LMS algorithm is used for adapting the filter, the updates for the adaptive component can be written as,

$$x_{k,m}^{(n)} = x_{k,m}^{(n-1)} + \mu_{k,m}^{(n)} e_{k,m}^{(n)} r^{*(n)}_{k,m} \tag{27}$$

Where $\mu_{k,m}^{(n)}$ is the time-variant step-size parameter, which controls the rate of convergence of the algorithm.

VI. Simulation Results

Comprehensive and extensive computer simulations have been carried out using MATLAB to demonstrate the performance of DS-CDMA detector. In this paper, we find number of error bits (BER) for Conventional Match filter, Adaptive linear and proposed receivers, for particular number of users varying Eb/No in dB and also for different number of active users.

To verify the performance of DS-CDMA system, following data/parameters have been considered.

- Data transmission is BPSK modulated.
- The spreading code/sequence used is the Walsh code of length G = 32.
- All the users have same data rate.
- The total number of bits transmitted is 100000.
- The data is corrupted by Additive White Gaussian Noise (AWGN) during the transmission.
- Varying the SNR of the noise from 0 to 14 dB.
- LMS Adaption for the proposed detector.
- Minimum-phase channel having three multipath components, $H(z) = 1 + 0.5z^{-1} + 0.25z^{-2}$

Simulation is mainly divided into two parts. The first part demonstrates the performance of the DS-CDMA system in an AWGN channel. Fig.2 shows the BER performance of conventional MF, adaptive MMSE detectors and single user bound for K=3 synchronous users with spreading code of length G = 32 in an AWGN channel. Here it is observed that as the number of users' increases (the MAI increases), the performance degrades. For the sake of comparison the BERs of these detectors have been plotted in fig.3 for different system load i.e K=1 to 7 users in an AWGN channel with signal to noise ratio Eb/No=5dB. The adaptive MMSE detector performs better than MF detector.

The second part demonstrates the performance of DS-CDMA system in multipath environment. After receiving of data vector, we combine received signals from different path with special weights. Thus, we assume that receiver know about channel coefficients. Channel components for minimum phase channel conditions have been chosen as [1 0.5 0.25] so $H(z) = 1 + 0.5z^{-1} + 0.25z^{-2}$ that means, we have three path for propagation of transmitted signal. The pole zero and bode plots of minimum-phase channel having three multipath components are shown in fig.4 and fig.5 respectively.

In order to show the performance of the adaptive method, fig.6 and fig.7 compare the BER of the adaptive MMSE detector with the conventional MF detector and single user bound (SUB) [19] for E_b/N_0 in dB and different system load (for Eb/No = 14dB and K=1 to 30 users) respectively in multipath channel considering spreading code of length 32. It is observed that the Adaptive MMSE out performs the MF detector and performing nearly as well as single user bound.

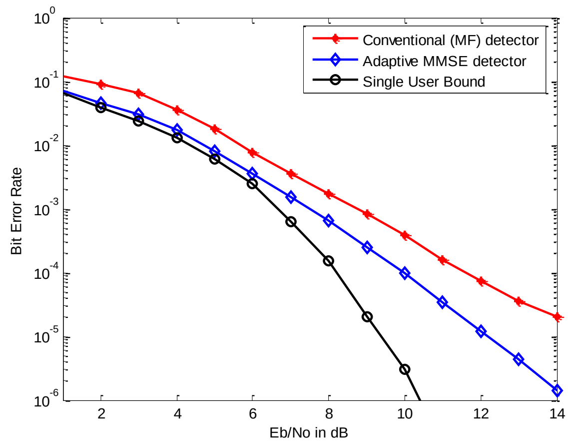

Fig. 2. A performance comparison of the adaptive MMSE with conventional and single user case in AWGN channel. G = 32, K = 3 users

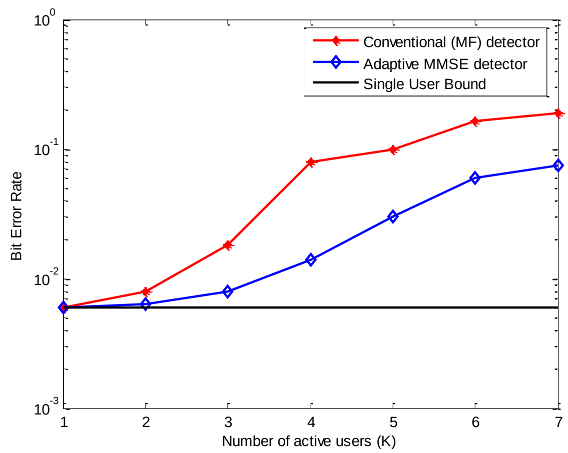

Fig. 3. A performance comparison of the adaptive MMSE detector with conventional and single user case for different system load in AWGN. G = 32, Eb/No = 5dB

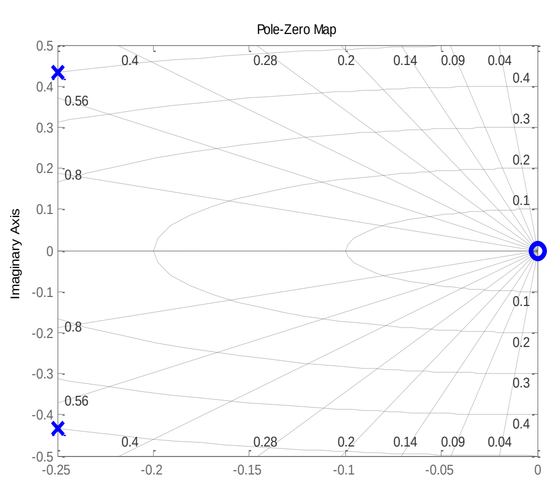

Fig. 4. Pole zero plot of minimum-phase channel having three multipath components. $H(z) = 1 + 0.5z^{-1} + 0.25z^{-2}$

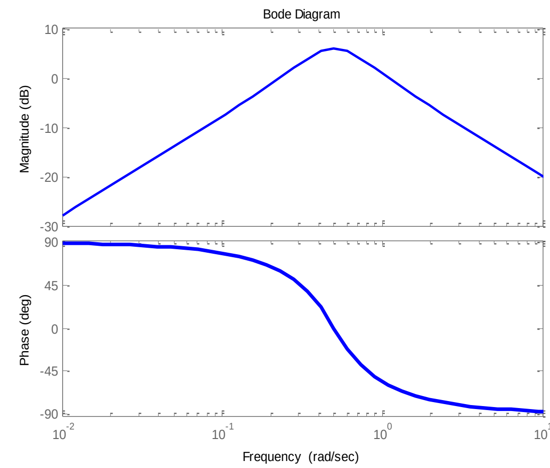

Fig. 5. Bode plot of minimum-phase channel having three multipath components. $H(z) = 1 + 0.5z^{-1} + 0.25z^{-2}$

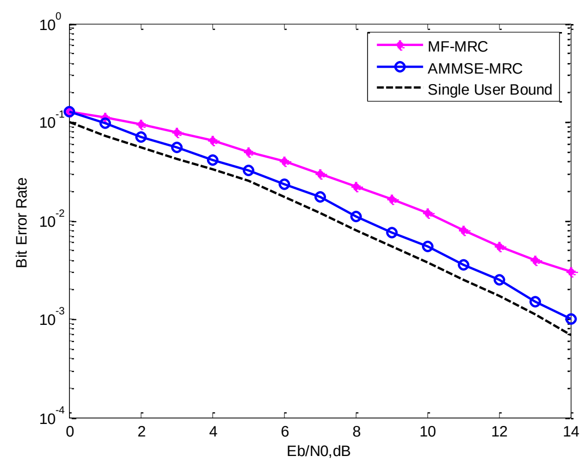

Fig. 6. BER vs SNR performance of proposed adaptive MMSE-MRC detector in multipath channel, M=3 paths, G = 32

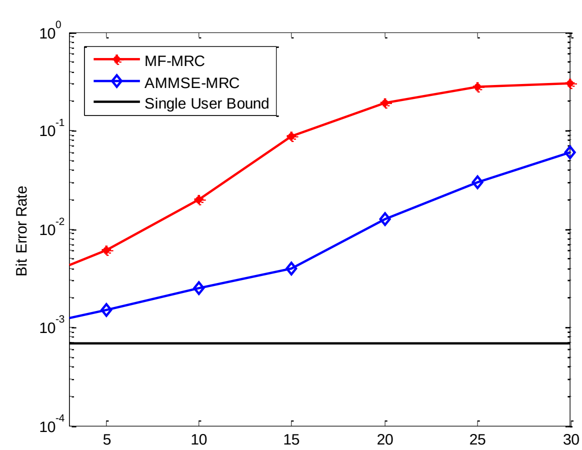

Fig. 7. Performance of the proposed adaptive MMSE-MRC detector with conventional and single user case for different system load. M = 3 paths, G = 32, E_b/N_0 = 14dB

VII. CONCLUSION

DS-CDMA is probably the most interesting multiple access method provided by spread-spectrum technology. In this paper, we have applied MRC, the diversity scheme as preprocessor to the adaptive MMSE detector for detection problem of DS-CDMA downlink signals in AWGN and multipath channels and have come up with satisfying results over BER performance enhancement. The major advantage of proposed detector is training sequences need not be required for desired signal as it is achieved by decision directed method using MRC.

The introduction of the concept has made the DS-CDMA detector even closer to the single user bound. The BER performance results achieved by the proposed detector are promising.

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