Performance improvement in DS-CDMA system with Blind detector

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Abstract - Direct Sequence Code Division Multiple Access (DS-CDMA) system is well known wireless technology. Multiple Access Interference (MAI) is a major problem in DS-CDMA system caused by its users. When the number of users increases the MAI is also increases, hence the system performance gradually decreases. In this paper, we proposed blind multiuser detector for improvement of performance in DS-CDMA system and also examines the performance of proposed detector with existing multi-user detectors (Decorrelating and MMSE) in DS-CDMA system. Simulation results shows that the proposed blind detector performed well compared to existing detectors.

Keywords: Matched filter, Decorrelator, Minimum Mean square error, Blind detector.

I. INTRODUCTION

In wireless communication systems, Direct Sequence Code Division Multiple Access (DS-CDMA) system performance is limited by its users. A promising techniques such as power control, antenna beam foaming and Multiuser Detection techniques are used to reduce the interference. Multiuser detection technique is crucial one to improve the system performance of DS-CDMA system.

In Direct Sequence Code Division Multiple Access communication system, user signals are multiplied with different sequences than by using frequency slots or time slots respectively. A matched filter detector is a single user detection technique in which every user signal is like a filter just treats the Multiple Access Interference as Additive White Gaussian Noise (AWGN). However, Additive White Gaussian Noise, Multiple Access Interference has a good correlative structure that means both are treated separately as a signal, while the remaining user signals are measured as interference.

Multiuser Detection (MUD) technique is one of the interference reduction techniques in wireless system. Transmitted bits are detected by MUD in the presence of Multiple Access Interference. Multiple Access Interference occurs in multiple access wireless communication systems like Code Division Multiple Access, Time Division Multiple Access and Frequency Division Multiple Access where simultaneously going on digital stream of information obstruct with one another. Single user Conventional and multiuser detectors depends on the matching of cross-correlation matrix of the spreading sequences. Hence, multiuser detectors considered for better performance compared with matched filter detectors[1]-[8],[13].

II. SYSTEM MODEL

Multi-user Detection technique is essentially for the design of signal processing algorithms. The basic diagram of MUD as shown in Figure 1. These algorithms are considered for the correlative structure of the Multiple Access Interference. The basic Code Division Multiple Access system model has been used for the development of this system.

The signal is received at the receiver is

$$y(t)=\sum_{k=1}^{K}A_kB_kS_k(t)+n(t)--(1)$$

Where

S_k - k^{th} user of the signature sequence

A_k - k^{th} user of the amplitude

B_k - k^{th} user of the input bit

$n(t)$ - is additive white Gaussian noise with with PSD.

The cross-correlation of the spreading signature sequences are defined as

$$\rho_{ij}=\langle S_iS_j\rangle=\sum_{k=1}^{N}S_i(k)S_j(k)---(2)$$

Where N is the length of the signature sequence

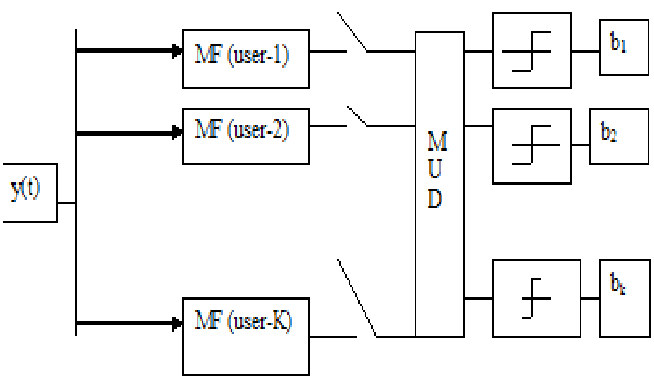

Figure 1: A typical multi-user detector

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i) CONVENTIONAL DETECTOR

In Digital / wireless communication systems, the matched filter is used to generate sufficient information for signal detection. But in multi user detection system, the detector consists of matched filters. Conventional MF detector diagram as shown in Figure 2. It is significance mentioning that we need exact knowledge of the users spreading sequences and the signal timing is in order to implement this detector [9].

The output of the Kth matched filter is given by

$$y_k = \int_0^T y(t) s_k(t) dt --- (3)$$

Expanding this equation

$$y_k = \int_0^T \left\{ \sum_{j=1}^{K} A_j B_j S_j(t) + n(t) \right\} S_k(t) dt -- (4)$$

Therefore

$$y = RAb + n -- (5)$$

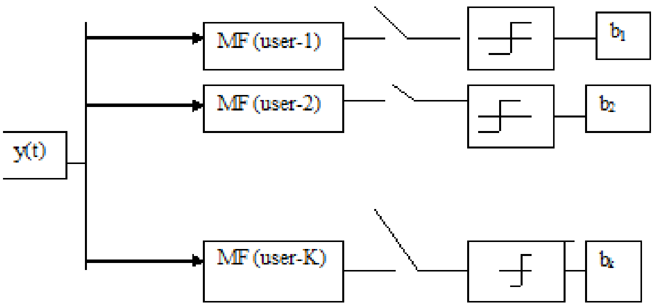

Figure 2: A matched filter bank

ii). DECORRELATING DETECTOR

The decorrelating detector improve the performance of the system than matched filter detector. The decorrelating detector structure as shown in Figure 3, the decorrelator operates by processing the output of the matched filter bank with the $\mathbf{R}^{-1}$ operator where $\mathbf{R}$ is the cross-correlation matrix.

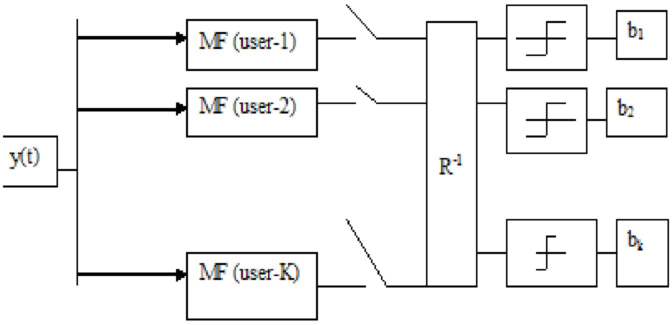

Figure 3. Decorrelating Detector

$$\hat{b} = sgn(R^{-1}(RAb + n)) -- (6)$$

$$\hat{b} = \mathrm{sgn}(Ab + R^{-1}n) -- (7)$$

So, here we observe that in the absence of background noise in the decorrelator achieves perfect demodulation unlike the matched filter [9].

iii) MMSE LINEAR DETECTOR

The Minimum Mean Square Error detector is also one of the important multiuser detector in linear multi user detectors. The account of The Minimum Mean Square Error detector can be graphically represented as shown in Figure 4. The Minimum Mean Square Error detector implements the linear mapping that means reduces the mean-squared error at the output of the conventional detector. The MMSE detector output from the linear detector

$$\hat{b} = \left(R + N_0 A^{-2}\right)^{-1} -- (8)$$

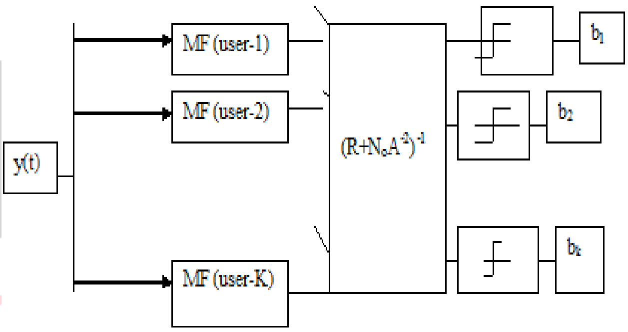

Figure 4 MMSE Detector

III. BLIND MULTI USER DETECTOR

The Blind detection is very attractive because of its ease of implementation. This detection method doesn't require any calculation of impulse response, knowledge of cross-correlations. In general, this technique requires transmission of spreading sequences, a string of data known to the receiver, prior to the transmission of actual data. For its convenience assumed that the desired user is represented by user 1, similarly the same reasoning can of course be applied to all users in the system [10].

The blind detector is also called as a multiuser detector. So the spreading sequence s is replaced by a new spreading sequence *m*. A multiuser detector for user 1 can be considered by the new sequence m_1, which is the sum of two orthogonal components. One component is the spreading sequence of user 1 is s_1. The other component is $x1$, so

$$m_1 = s_1 + x_1$$

with $m_1, s_1, x_1 \in \mathrm{R}^N$,

Where N is the number of bits per symbol and

$$\langle s_1, x_1 \rangle = 0$$

Since x_1 is orthogonal to s_1, any x_1 can be preferred to reduce the correlation between the MAI and new sequence m_1, while the correlation with user 1 remains constant. The Blind detector makes its decision only for user 1 based on the sign of the output of the MF with new sequence for user 1, so

$$\hat{b}_1 = \text{sgn}(\langle y, m_1 \rangle).$$

The output of the MF with new sequence for user 1 is equal to

$$Z_1 = \langle y, m_1 \rangle$$

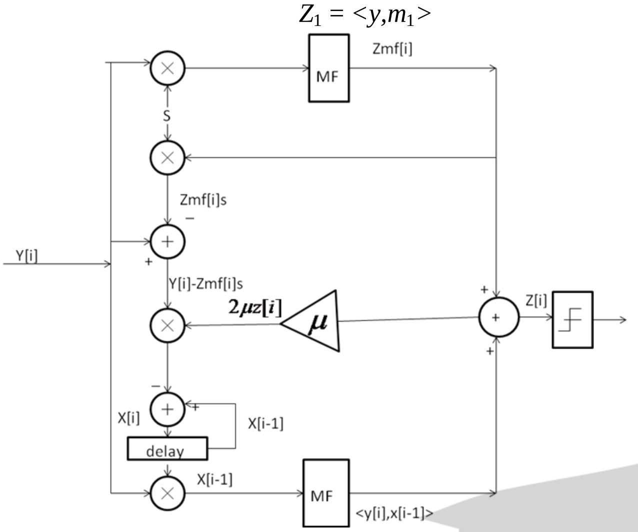

Figure 5: Blind adaptive multiuser detection.

a) Minimizing Mean Output Energy

The blind detector is used to reduce the Mean Output Energy (MOE) and the Mean Square Error (MSE) [11-12]. The Mean Output Energy of a blind detector of user 1 is defined as

$$\text{MOE} \triangleq E[(\langle y, m_1 \rangle)^2]$$

The Mean Output Energy (MOE) and the Mean Square Error (MSE) of the user 1 as

$$\text{MOE}(x_1) = E[(\langle y, s_1 + x_1 \rangle)^2]$$

and

$$\text{MSE}(x_1) = E[(A_1 b_1 - \langle y, s_1 + x_1 \rangle)^2]$$

b) Adaptive Implementation

The gradient decent method can be used to find the x sequence x_{opt} that minimizes the Mean Output Energy. To minimize the Mean Output Energy the x sequence is adapted each bit period using the gradient descent algorithm. So the gradient descent algorithm for adaptation of the x sequence can be written as

$$x_1[i] = x_1[i-1] - \mu \nabla(\langle y[i], s_1 + x_1[i-1] \rangle)^2$$

Here y[i] represents the received signal for the bit period of the i^{th} bit in the bit stream. x[i−1] is the value of the x sequence obtained from the previous received signal y[i−1] during the previous iteration of the algorithm. The output of the MF for user 1 for the i^{th} bit period is written as:

$$Zmf_1[i] = \langle y[i], s_1 \rangle.$$

Similarly, the output of the adaptive filter for user 1 for the i^{th} bit period is written as:

$$Z_1[i] = \langle y[i], s_1 + x_1[i-1] \rangle =$$
$$Z_{mf}[i] + \langle y[i], x_1[i-1] \rangle.$$

The output of the adaptive filter $Z_1[i]$ is used as the decision statistic of the blind detector for user 1:

$$\hat{b}_1[i] = \text{sgn}(Z_1[i]) = \text{sgn}(Z_{mf}[i] + \langle y[i], x_1[i-1] \rangle).$$

IV. SIMULATION RESULTS

Multiuser detectors like MF detector, decorrelator and MMSE detectors are investigated. From Figure 6 to 9 shows that the BER performance of the MF, Decorralator, MMSE and blind detectors. In each case the number of users increases the multiple access interference also increases, so the system performance becomes degraded. From figure 10 to 12 shows that the system performance comparison between MF, DEC, MMSE and Blind detectors for 2, 5, and 10-users. Here the blind detector is well performed compared to the MF, DEC and MMSE detectors in all cases.

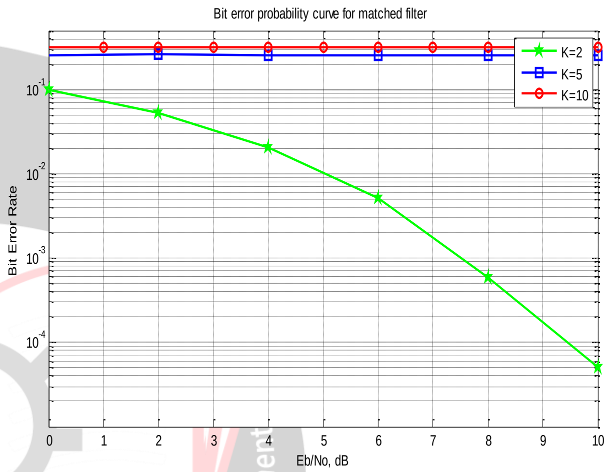

Figure-6: performance of Matched filter

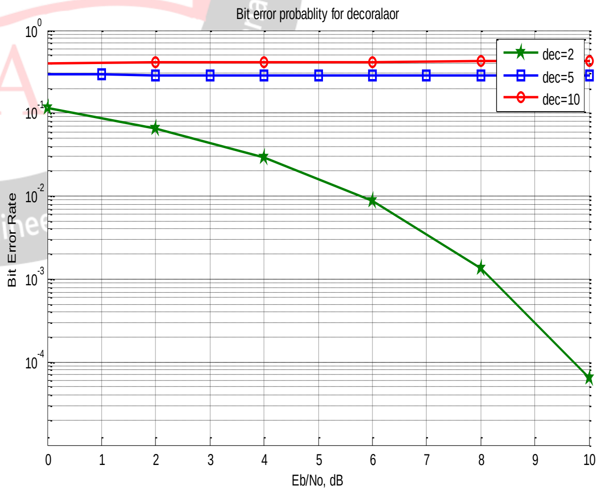

Figure-7: performance of Decoralator

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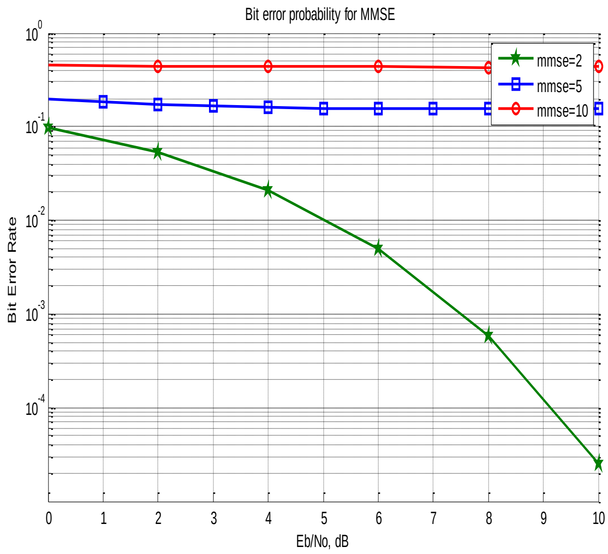

Figure-8: performance of MMSE

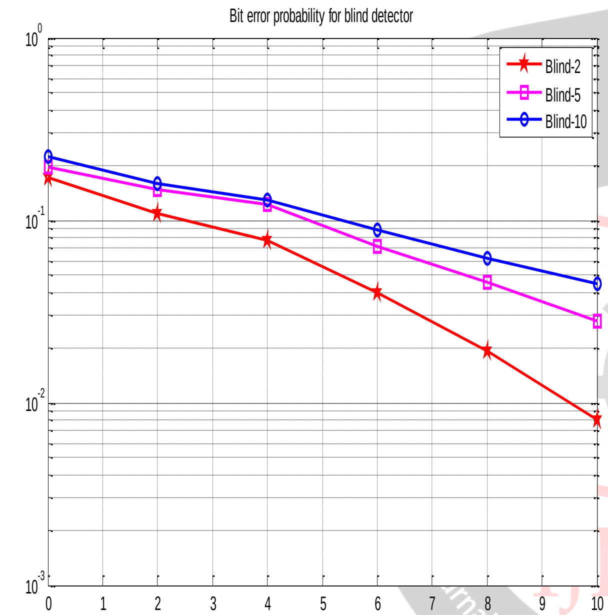

Figure-9: performance of Blind detector

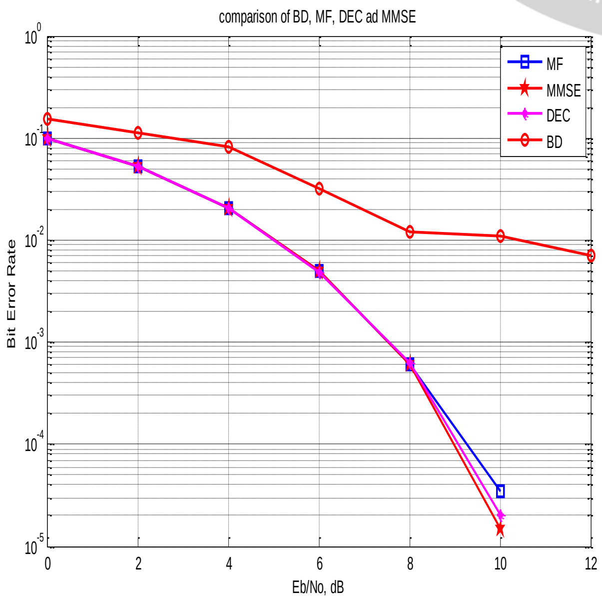

Figure-10: Comparison of Detectors for 2 -user

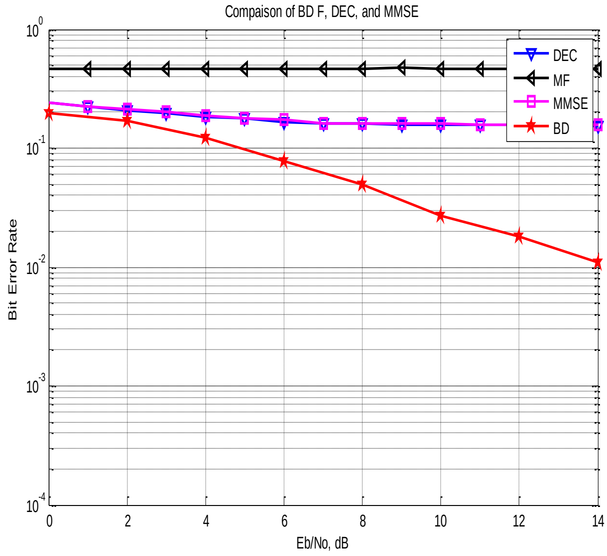

Figure-11: Comparison of Detectors for 5 –user

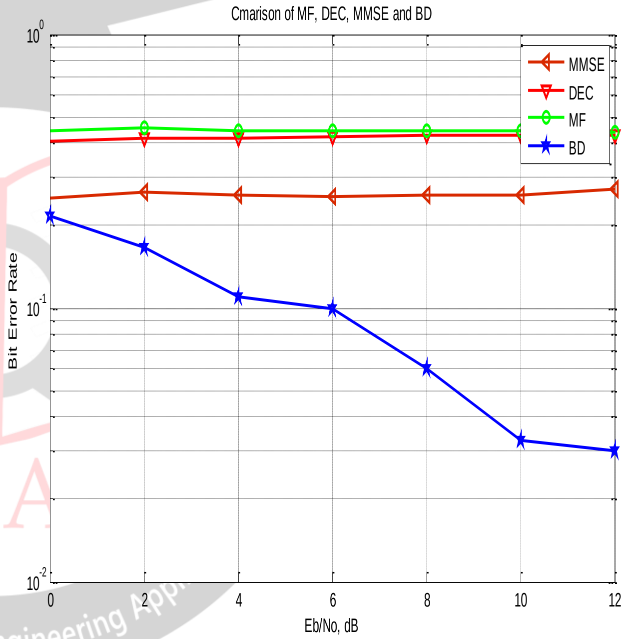

Figure-12: Comparison of Detectors for10 –user

V. CONCLUSIONS

This Paper is a collection of various linear multi-user detection methods. The MMSE linear detector was performed better than decorrelating detector and conventional MF detector at high SNRs. Finally the Blind detector is well performed compared MF, Decorrelator and MMSE in all cases.

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