BER Performance of Linear Multi-user Detectors in DS-CDMA

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Abstract: - This paper examines the Bit Error Rate (BER) performance of Linear Multi-user Detectors in Direct Sequence Code Division Multiple Access (DS-CDMA) system. Multiple access interference (MAI) limits the capacity of Direct Sequence Code Division Multiple Access (DS-CDMA) systems. In CDMA systems MAI is considered as additive noise and a matched filter bank is employed. Multi-user detectors are classified as optimal and suboptimal. The main drawback of the optimal multi-user detection is complexity so that suboptimal approaches are being sought. Much of the present research is aimed at finding an appropriate tradeoff between complexity and performance. These suboptimal techniques have linear and non-linear algorithms. In this paper, introduce linear Multi-user Detectors in Direct Sequence Code Division Multiple Access (DS-CDMA) system. Analysis is to be carried out and simulations to be done.

Keywords**:** DS-CDMA, MF, Decorrelator, MMSE, ZF .MAI, Gold sequence.

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I. INTRODUCTION

The Capacity of Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA) or hybrids, common in the 2nd generation, is well defined when RF channels or time slots are no longer available no more customers can be accommodated. It is possible to include more users, although at the price of a slightly worse signal-to-interference ratio for everyone.

In DS-CDMA communication system, users are multiplexed by distinct codes rather than by orthogonal frequency bands or by orthogonal time slots. A conventional DS-CDMA detector follows a single user detection strategy in which each user is filter just treat the MAI as additive white Gaussian noise (AWGN). However, unlike AWGN, MAI has a nice correlative structure that is quantified treated separately as a signal, while the other users are considered as either interference or noise. Multi-user detection is a technology that spawned in the early 80's. It has now developed into an important, full-fledged field in multi-access communications. Multi-user Detection (MUD) is the intelligent estimation / demodulation of transmitted bits in the presence of Multiple Access Interference (MAI). MAI occurs in multi-access communication systems (CDMA/ TDMA/FDMA) where simultaneously occurring digital streams of information interfere with each other. Conventional detectors based on the matched by the cross-correlation matrix of the signature sequences. Hence, detectors that take into account this correlation would perform better than the conventional matched filter-bank [1-7].

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II. SYSTEM MODEL

MUD is basically the design of signal processing algorithms that run in the black box shown in figure 1. These algorithms take into account the correlative structure of the MAI. The K-user discrete time basic synchronous CDMA model has been used throughout the development of this paper. The case of antipodally modulated user information (BPSK modulation) spread using BPSK

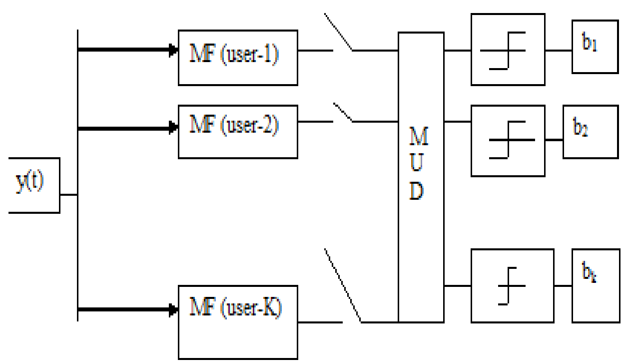

Figure.1 A typical multi-user detector

The signal at the receiver is given by

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

Where

S_k is the signature waveform of the k[th] user (S_k is ormalized to have unit energy) i.e.,

$$<S_{K,}S_K>=1$$

Where

. A_k is the received amplitude of the kth user

• B_k is the input bit of the k^{th} user, $bk \in \{-1,1\}$.

• n(t) is additive white Gaussian noise with PSD No .

Since synchronous CDMA is considered, it is assumed that the receiver has some means of achieving perfect chip synchronization.

The cross-correlation of the signature sequences are defined as

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

Where N is the length of the signature sequence

The cross-correlation matrix is then defined as

$$R = \rho_{ij}$$

R is a symmetric, non-negative definite, toeplitz matrix

III. MATCHED –FILTER

Introduces and analyses the matched filter bank detector which was the conventional and simplest way of demodulating CDMA signals (or any other set of mutually interfering digital streams). The matched filter also forms the front-end in most MUDs and hence understanding the operation is crucial in appreciating the evolution of MUD Technology. In conventional single-user digital communication systems, the matched filter is used to generate sufficient statistics for signal detection. In the case of a multi-user system, the detector consists of a bank of matched filters (Each matched to the signature waveforms of different users in the case of CDMA). This is shown in figure 2. This type of detector is referred to as the conventional detector in MUD literature. It is worth mentioning that we need exact knowledge of the users signature sequences and the signal timing in order to implement this detector [8].

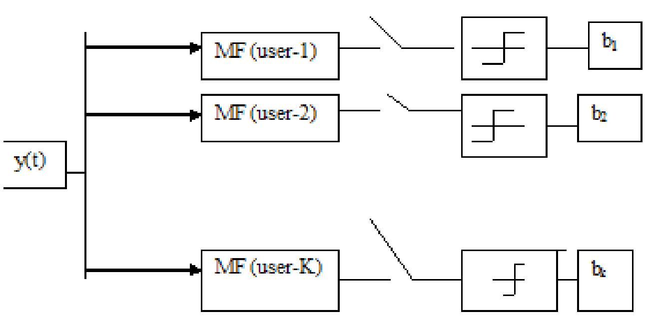

Figure 2 A matched filter bank

The decision statistic the output of the K^{th} 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

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

IV. DECORRELATING DETECTOR

An optimal receiver must be capable of decoding the bits error-free when the noise power is zero. The decorrelating detector is investigated. This detector makes use of the structure of MAI to improve the performance of the matched filter bank. The decorrelating detector falls into the category of linear multi-user detectors. As shown in figure 3, the decorrelating detector operates by processing the output of the matched filter bank with the $\mathbf{R}^{-1}$ operator where **R** is the cross-correlation matrix.

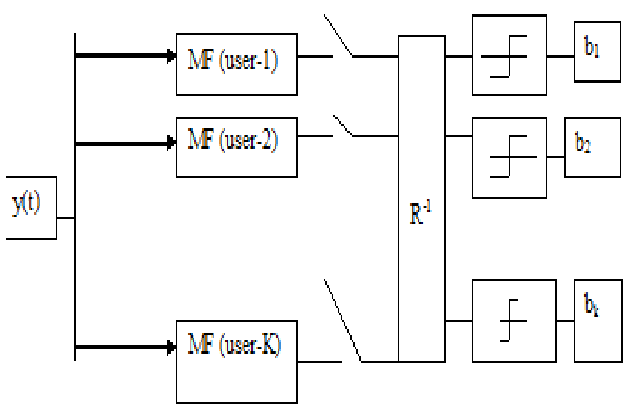

Figure 3. Decorrelating Detector

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

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

Hence, we observe that in the absence of background noise the decorrelating detector achieves perfect demodulation unlike the matched filter bank. One advantage of the decorrelating detector is that it does not require knowledge of the received signal amplitudes. The decorrelating receiver performs only linear operations on the received statistic and hence it is indeed a linear detector. The decorrelating detector is proved to be optimal under 3 different criteria: least squares, near-far resistance and maximum-likelihood [8].

V MMSE LINEAR DETECTOR

The MMSE receiver is another kind of linear multi-user receivers. The description of MMSE detector can be graphically represented in Figure 4. The MMSE implements the linear mapping which minimizes the mean-squared error between the actual data and the soft output of the conventional detector, so the decision for the k^{th} user is made based on in this approach where the mean squared error between the output and data is minimized. The detector resulting from the MMSE (minimum mean square error) criterion is a linear detector.

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

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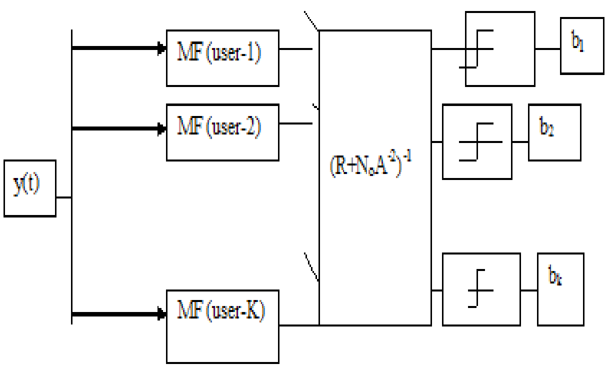

Figure 4 MMSE linear detector

VI. ZERO-FORCING DETECTOR

The zero-forcing receiver is a natural progression of the decorrelating detector. Now that we have removed the MAI, we want to eliminate the ISI as well. This can be done by taking into consideration each users channel impulse response. The zero forcing equalizer is successful at eliminating MAI and ISI, but has some tradeoffs. Also, the zero-forcing equalizer suffers the noise enhancement problems as does the decorrelating detector. But In order to improved performance in the zero forcing detector in presence of noise[9].

VII. SIMULATION RESULTS

Figure A, B, C and D show the error rate performance of the bank of matched filter. Decorralator , MMSE and ZF. The simulation scenario is observed that as the MAI increases (the number of users increases) the performance becomes poor. But the decorralator is better performanced than MF. Similarly the MMSE is better performed than decorralator and matched filter. Similarly like this the zero forcing detector is also well performed compared to other detectors.

Figure E, F, and G shows the comparison of error performance of different detectors. The zero forcing detector is well performed compared to the other detector in all cases like 2-user, 5-user and also 10-user case .

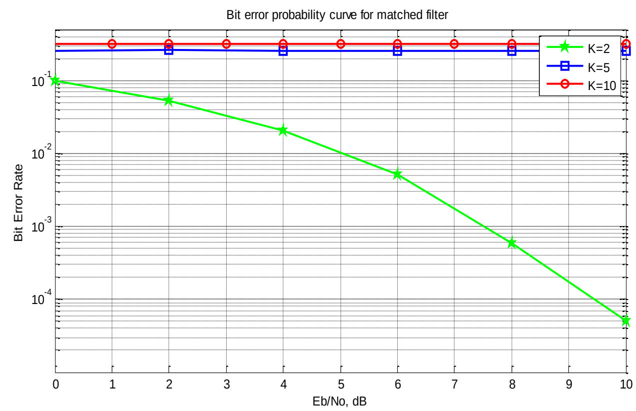

Figure-A: performance of Matched filter

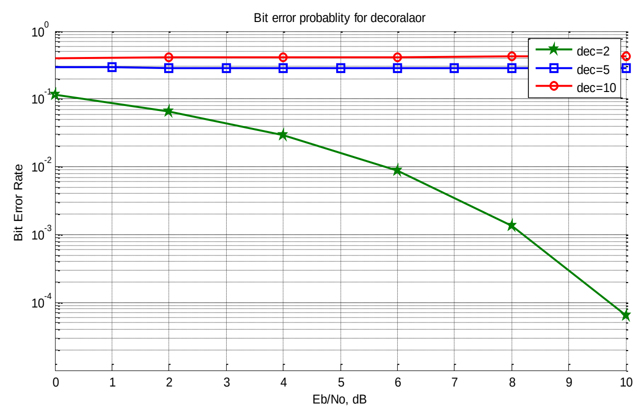

Figure-B: performance of Decoralator

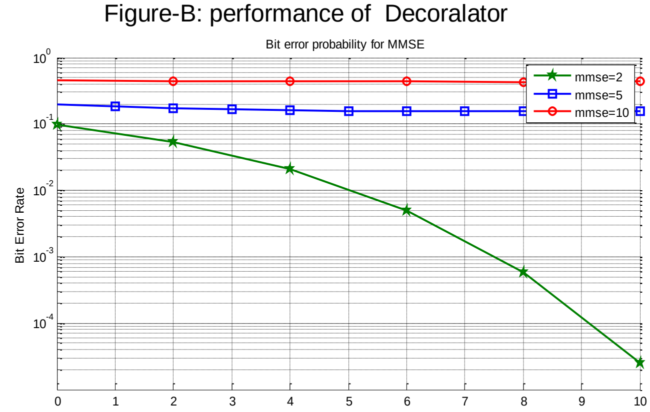

Figure-C: performance of MMSE

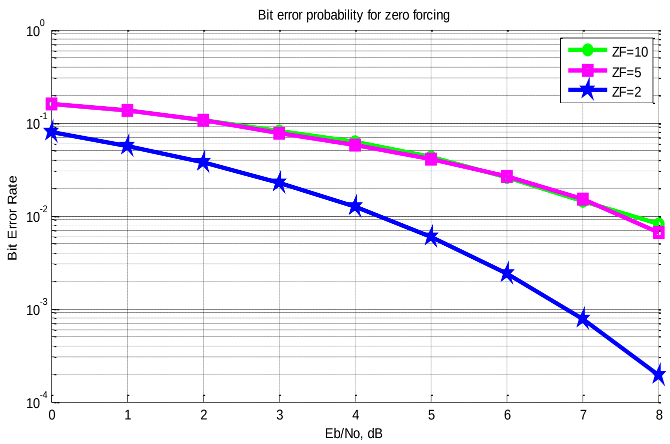

Figure-D: performance of ZF

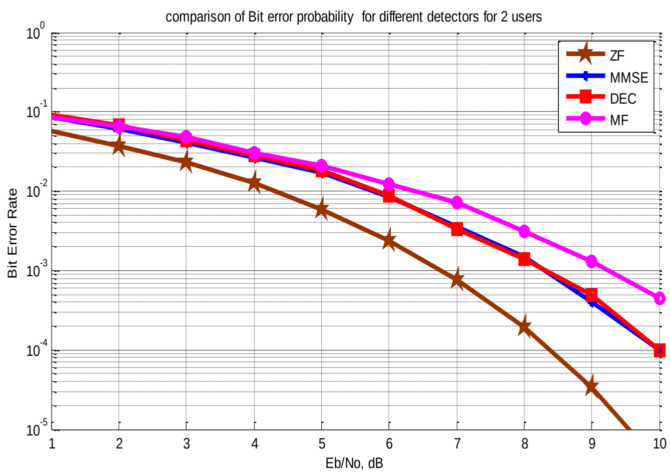

Figure-E: Comparison of Detectors for 2 -user

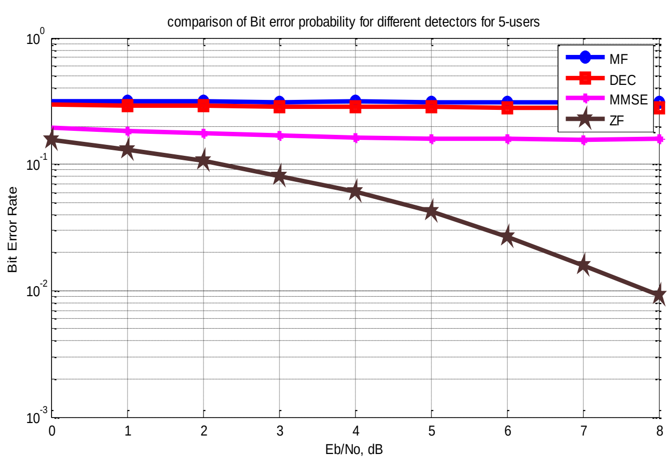

Figure-F: Comparison of Detectors for 5 -user

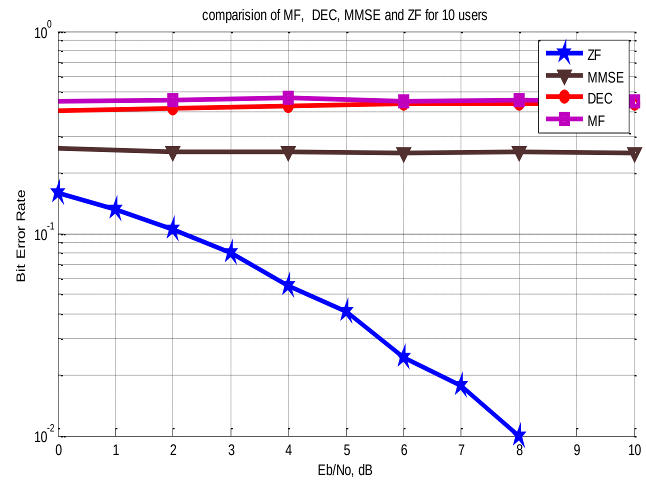

Figure-G: Comparison of Detectors for10 -user

VIII. CONCLUSIONS

This Paper is a compilation of different approaches to linear multi-user detection. The requirement of this technology was motivated by studying the conventional detector. The matched filter bank just ignores the correlative structure of the MAI present in CDMA systems. Further, it was also shown that in the absence of noise, the conventional detector is a totally unreliable detector. This called for the need for better detectors. The decorrelating detector was then introduced which takes the conventional detector one step further by incorporating the correlative structure of the MAI in the detection. This implied that the decorrelating detector could be improved upon. The MMSE linear detector was then shown to take the decorrelating detector one step further by incorporating some SNR information along with the correlative structure of MAI. Thus, the performance was better than the decorrelating detector at high SNRs. It must also be noted that when the background noise is totally absent (infinite SNR). Finally the zero forcing detector is well performed. The choice of the MUD algorithm depends on a lot of factors like the application, channel information available, availability of training sequences, complexity cost and overhead involved.

IX. References

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