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Performance Analysis of Multi User Detectors for Synchronous Ds-Cdma Systems

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ABSTRACT: A Direct sequence code division multiple access (DS-CDMA) is a popular wireless technology. This system suffers from Multiple Access Interference (MAI) caused by Direct Sequence users and near –far effect. Multi-User Detection schemes are used to detect the users' data in presence of MAI and near- far problem. In this dissertation, we present comparative study between linear multiuser detectors and conventional single user matched filter in DS-CDMA system. Analysis and simulations are conducted in synchronous AWGN channel, and Gold sequence and Kasami sequence are used as the spreading codes. Simulation results depict the performance of three detectors, conventional detector, Decorrelating detector and MMSE (Minimum Mean Square Error) detector. It shows that the performance of these detectors depends on the length of PN code used and Number of users. Linear multiuser detectors perform better than the conventional matched filter in terms of BER performance.

KEYWORDS: AWGN CHANNEL, BER, MAI, MMSE.

I. INTRODUCTION

The communication system has challenge of accommodating many users in a small area. The wireless domain is the current area of interest. The conventional systems used either frequency spectrum sharing or timesharing and hence there was the limitation on the capacity. With the advent of spread spectrum and hence CDMA, fixed bandwidth was used to accommodate many users by making use of certain coding properties over the bandwidth. But this system suffers from MAI (Multiple Access Interference) caused by direct sequence users. Multiuser Detection Technique is going to be the key to this problem. These detection schemes were introduced to detect the users' data in the presence of Multiple Access Interference (MAI), Inter Symbol Interference and noise. Spread spectrum CDMA systems (DS/CDMA) are becoming widely accepted and promise to play a key role in the future of wireless communications applications because of their efficient use of the channel and there allowness for nonscheduled user transmissions. Hence recent interests are in techniques, which can improve the capacity of CDMA systems. The focus of most current research is on Wideband CDMA (W-CDMA) or NG (next generation) CDMA. In W-CDMA, the multimedia wireless network will become feasible. Not only voice, but also images, video and data can be transmitted by mobile phones or other portable devices. Achieving a higher data rate and higher capacity are two major goals for W-CDMA, which makes the multiuser interference problem more and more crucial. As Mobile communication systems based on CDMA are inherently subject to Multiple-Access Interference (MAI), since it is impossible to maintain orthogonal spreading codes in mobile environments. MAI (Multiple-Access Interference) limits the capacity of Conventional detectors and brings on strict power control requirements to alleviate the Near-Far problem.

II. DS-CDMA MODEL

The rapid worldwide growth in cellular telephone subscribers over the past decade has evidently showed that the wireless communication is an effective means for transferring information in today's society. Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) are two approaches that have contributed to this advancement in the telecommunications industry.However, the widespread success of these communications systems has led to the development for newer and higher technology techniques and standards in order to facilitate high-speed communication for multimedia, data and video in addition to voice transmission. Code Division Multiple Access (CDMA) is today's dominant technology for the evolution of third generation (3G) mobile communications systemswith the development of two major schemes: Wideband CDMA (W-CDMA) and CDMA2000.

A. Synchronous DS-CDMA system transmitter model:

Consider a DS-CDMA communication system with K users. Assuming Binary Phase Shift Keying (BPSK) signaling, at the transmitter, the signal for the kth user can be written as

$$r_k(t) = A_k b_k s_k(t - iT_b) iT_b \le t < (i+1)T_b$$

$$s_k(t) = 1/\sqrt{N}\sum_{n=1}^{N} s_{kn}\,\mathrm{rect}(t-(n-1)Tc)$$

rect (t) =u (t)-u (t-Tc) (1)

u(t) is the unit step function, and b_k (i) 2 $\{-1, +1\}$. Tb is the bit duration, Tc is the chip duration and N = Tb/Tc is the spreading gain. s_k (N × 1) vector is the chip spreading sequence for the kth user.

Define the time-correlation between the signature waveforms of users i and j as

$$R_{ij} = \int_0^{T_b} s_i(t)s_j(t)dt \quad (2)$$

Since more than one user can transmit at the same time, we assume all K users to be simultaneously active. Assuming a synchronous AWGN channel (i.e. the data from all users arrives at the receiver at the same instant of time), we can write the received signal at the receiver as follows.

$$r(t) = \textstyle\sum_{i=1}^{K} r_k(t) + n(t) \quad (3)$$

$$r(t) = \sum_{i=1}^{K} A_k b_k s_k(t - iT_b) + n(t)$$

$$i\,T_b \le t < (i+1)T_b$$

Where,A_k is gain of the channel and n(t) is the AWGN noise process with zero mean and variance σ^2. Assuming that the receiver is interested in the data of all users (e.g. in the case of uplink communication, this receiver can be the base station), the objective of the receiver is to estimate the vector $b(i) = [b_1(i) \ldots \ldots \ldots \ldots b_k(i)]$ of

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transmitted symbols for all time intervals i.

B. Synchronous DS-CDMA system Receiver model:

To simplify the discussion, we make assumptions that all carrier phases are equal to zero. This enables us to use baseband notation while working only with real signals. We also assume that each transmitted signal arrives at the receiver over a single path

$$r(t) = \sum_{i=1}^{K} A_k b_k s_k(t - iT_b) + n(t)$$

$$iT_b \le t < (i+1)T_b \qquad (4)$$

The bank of matched filters consists of K filters matched to the individual spreading codes.

This detector is a matched filter to the desired signal. Other users' signals are treated as noise (self noise). These self-noise limit the system's capacity and can jam out all communications in the presence of a strong nearby signal (Near-Far Problem).

The output of the kth user matched filter is

$$y_j = \int_0^{T_b} r(t)s_j(t)dt$$

$$=A_j b_j + \sum_{\substack{k=1 \\ k\neq j}}^{K} A_k b_k(i) R_{kj} + n_j \qquad (5)$$

The first term is desired information. The second term is interference from other users

C. Spreading Codes:

The PN sequence is produced by the pseudo-random noise generator that is simply a binary linear feedback shift register, consisting of XOR gates and a shift register. This PN generator has the ability to generate an identical sequence for both the transmitter and the receiver, and yet retaining the desirable properties of a noise-like randomness bit sequence. A PN sequence has many characteristics such as having a nearly equal number of zeros and ones, very low correlation between shifted versionsof the sequence and very low cross correlation with any other signals such as interference and noise. However, it is able to correlate very well with itself and its inverse. Another important aspect is the autocorrelation of the sequence as it decides the ability to synchronize and lock the spreading code to the received signal. This effectively combats the effects of multipath interference and improves the SNR. M-sequences, Gold codes and Kasami sequences are examples of this class of sequences.

III. MULTI USER DETECTION

The DS/CDMA receivers are divided into Single-User and Multi-User detectors. A single user receiver detects the data of one user at a time whereas a multi-user receiver jointly detects several users' information. Single user and multi user receivers are also sometimes called as decentralized and centralized receivers respectively.

Conventional Matched Filter Detector:

This is the simplest way to demodulate the received signal: a bank of matched filters, one matched to each user's spreading waveform, is applied to the received signal.Thus, it demodulates all users independent of each other.

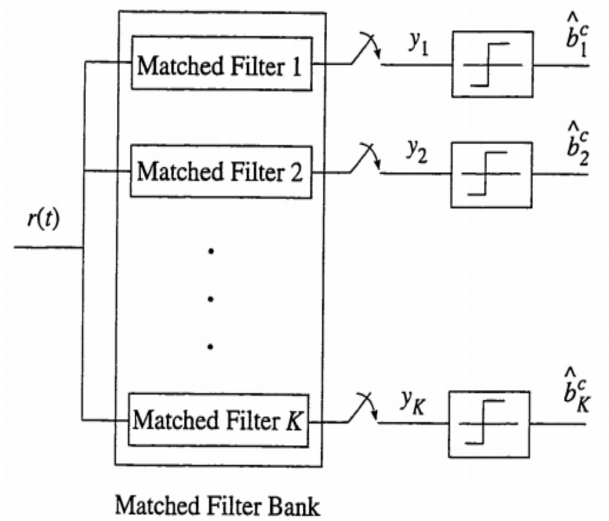

Fig1 Conventional Matched Filter Detector

The out of matched filter bank is

$$y_j = \int_0^{T_b} r(t)s_j(t)dt$$

$$=A_j b_j + \sum_{\substack{k=1 \\ k\neq j}}^{K} A_k b_k(i) R_{kj} + n_j \ (6)$$

Hence

$$\hat{b} = \text{sign}(y_j)$$

The first term is desired information .The second term is interference from other users. The interference from other user is called multiple access interference (MAI).This method ignores MAI and tread as noise (self noise). These self-noise limit the system's capacity and can jam out all communications in the presence of a strong nearby signal (Near-Far Problem).

IV. LINEAR MULTIUSER DETECTORS

These class of algorithms involve applying a linear transformation to the matched filter (single user detector) outputs. The output of the matched filter can be written in matrix form as

$$y_{MF}\text{=RAb+n}$$

A. De-correlating Detector

The Decorrelating receiver applies the inverse of the correlation matrix to the output of the matched filter in order to decouple the data.

In the synchronous channel

Consider the output of the bank of K matched filters

y = RAb+n;

Where n is a Gaussian random vector with zero mean and covariance matrix σ^2R. If we process the output vector as

$$R^{-1}y = Ab + R^{-1}n$$

Clearly the kth component of vector $R^{-1}y$ is free from interference caused by any other users for any k (since A is diagonal). Note that the cross correlation matrix R is invertible if signature sequences are linear independent. If the background noise is vanishing, that is, σ= 0, then

$\widehat{b_k}$= Sgn($R^{-1}y$ $)_k$=Sgn($(Ab)_k$

Hence, in absence of background noise, we get error free performance. In the presence of the background noise, decision is affected only by the background noise, that is

$\widehat{b_k}$= Sgn($R^{-1}y$ $)_k$=Sgn($(Ab + R^{-1}n)_k$) (7)

This is why the detector is called the decorrelating detector

B. Minimum Mean-Squared Error (MMSE) Detector:

The MMSE detector implements a linear mapping L which minimizes the mean squared error $E[|(b_k - Ly)|]^2$

The detection scheme can be written as

$\tilde{b}$= sign(Ly)

The approach here is to turn linear multi-user detection problem into a linear estimation problem.

Idea: Require MSE between the kth user bit b_k and the output of the linear transformation $m_k^T yk$ to be minimized.

V. SIMULATION RESULTS

Detectors that are simulated include conventional single user matched filter (MF), Decorrelating and Minimum mean-squared error (MMSE). First of all, the BER performance comparison between the conventional detector and two suboptimal linear multiuser detectors is conducted. The performance evaluation with increasing number of active users is carried out. These simulations are done with the assumption that all active users have equal power.

BER PERFORMANCE OF THREE DETECTORS USING GOLD SEQUENCE

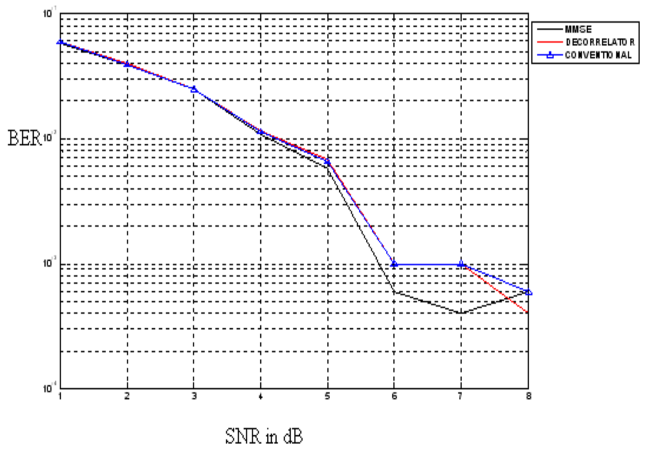

Fig 2.Gold Sequence Of Length 31 And 2 Users

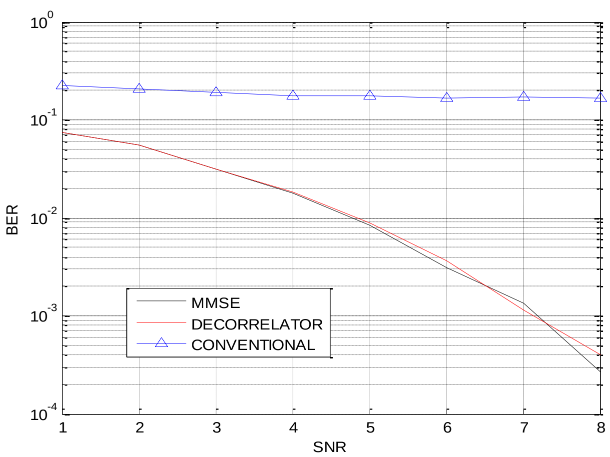

Fig 3. Gold Sequence Of Length 31 And 4 Users

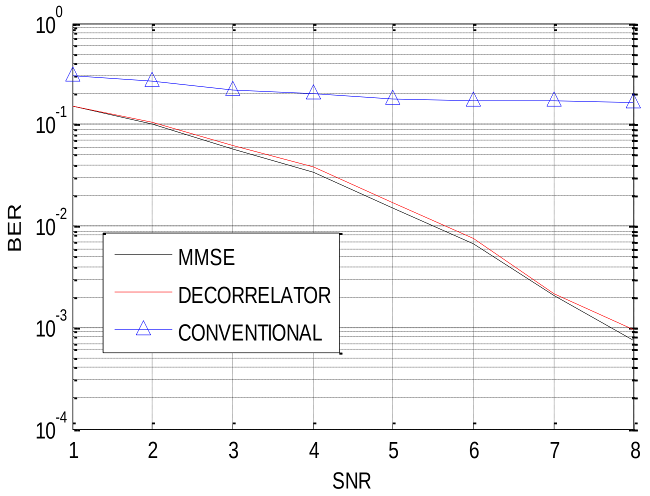

Fig 4. Gold sequence of length 31 and 8 users

Ber performance for three detectors for kasami code

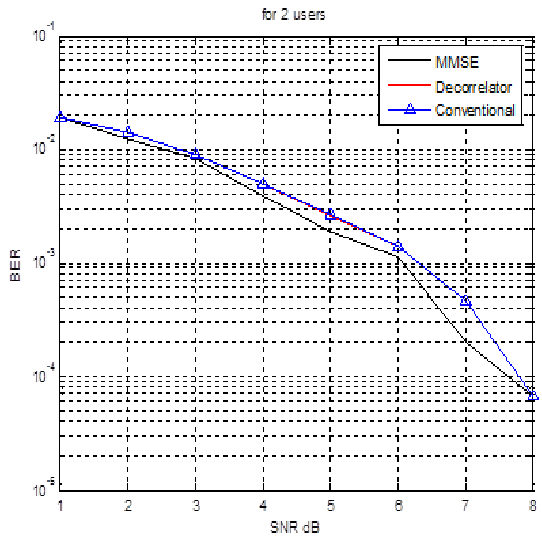

Fig 5.Kasami Length 63 And 2 Users

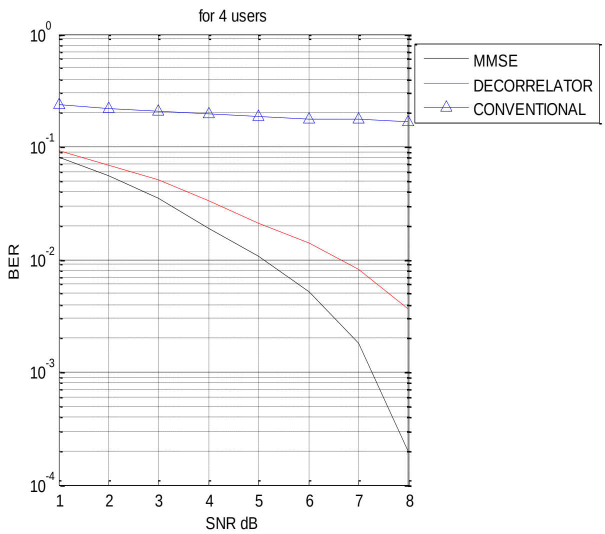

Fig 6. Kasami Length 63 And 4 Users

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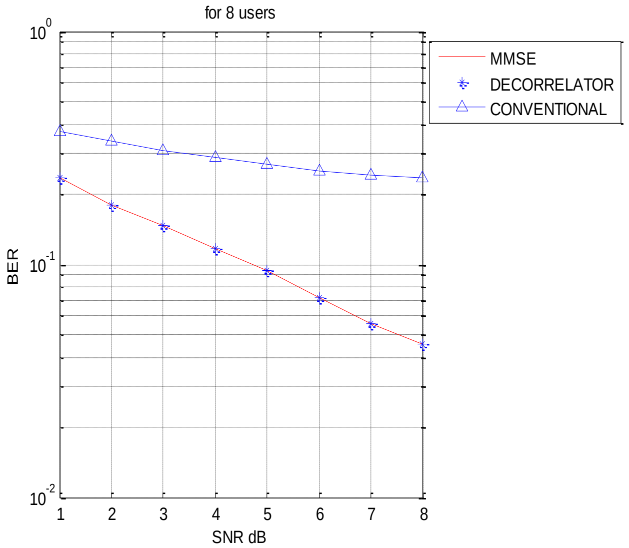

Fig 7. Kasami Length 63 And 8 Users

VI. CONCLUSION

The optimal multiuser detector performs better than the conventional matched filter and the linear multiuser detectors. However, this detector is too complex for practical DS-CDMA system. MMSE detector generally performs better than the Decorrelating detector because it takes the background noise into account. With increasing in the number of users, the performance of all detectors will degrade as well. This is because as the number of interfering users increases, the amount of MAI becomes greater as well. Thus there is a trade of between the performance measure and the practicality measure (complexity and detection delay). Depending on the situations, a suboptimum receiver satisfying the implementation constrains can be chosen.

Multiuser detection holds promise for improving DS-CDMA performance and capacity. Although multiuser detection is currently in the research stage, efforts to commercialize multiuser detectors are expected in the coming years as DS-CDMA systems are more widely deployed. The success of these efforts will depend on the outcome of careful performance and cost analysis for the realistic environment.

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