Performance Analysis of Blind Adaptive Multi-user Detection in DS-CDMA

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ABSTRACT

This paper examines the performance analysis 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, Blind . Gold sequence.

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].

II. SYSTEM MODEL

MUD is basically the design of signal processing algorithms that run in the black box shown in figure1. 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

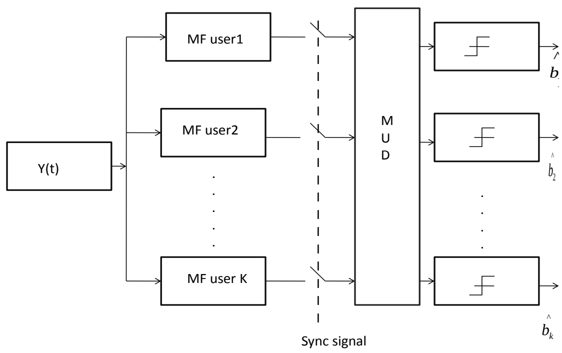

Figure.1 A typical multi-user detector

The signal at the receiver is given by

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

Where Sk is the signature waveform of the kth user (Sk is normalized to have unit energy) i.e.,

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

Where

. Ak is the received amplitude of the kth user

•Bk is the input bit of the kth user, bk ∈ {-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

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

Where N is the length of the signature sequence
The cross-correlation matrix is then defined as

$$R = \{\rho_{ij}\}$$

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).

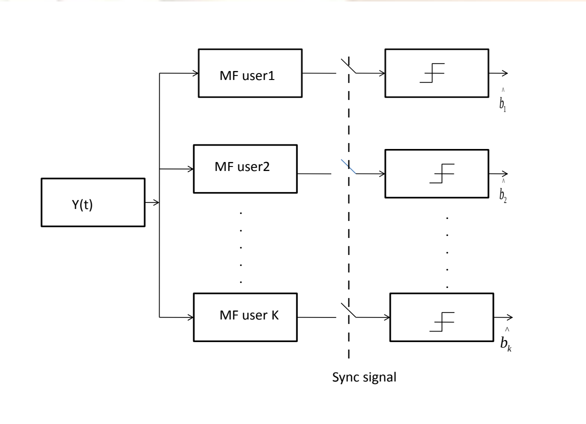

Figure 2 A matched filter bank

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 user's signature sequences and the signal timing in order to implement this detector [8].

The decision statistic the output of the Kth matched filter is given by

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

Expanding this equation

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

Therefore

$$y = RAb + n \qquad (5)$$

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 **R**-1 operator where **R** is the cross-correlation matrix.

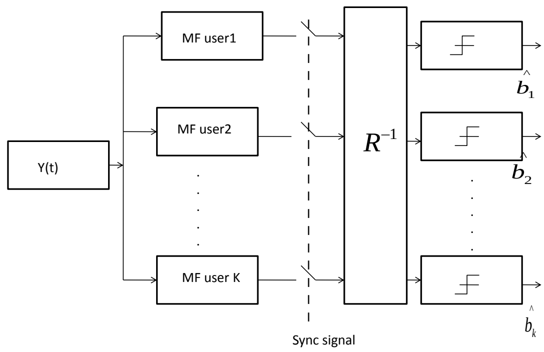

Figure 3. Decorrelating Detector

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

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

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 kth 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

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

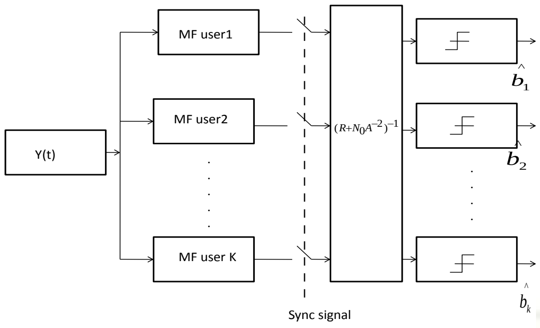

Figure 4 MMSE linear detector

VI. ADAPTIVE BLIND MULTI USER DETECTOR

The adaptive MMSE linear multi-user detection scheme is attractive mainly because of its ease of implementation. This adaptive MMSE detection method does not require on-line computation of impulse response, knowledge of cross correlations, and in general, the signature waveforms of interfering users. The adaptive implementation of MMSE can learn the desired filter impulse response from the received waveform, provided that the data of the desired user is known to the receiver. In practice, this scheme requires transmission of a training sequence, a string of data known to the receiver, prior to the transmission of actual data. The receiver uses an adaptive law to adjust its linear transformation while the training sequence is in transmission. If correlations and amplitudes vary over time, training sequences can be sent periodically to readjust the receiver. It is also common to perform fine adjustment of the linear transformation (once the adaptive algorithm has converged and the transmission of training sequence is completed) by letting the adaptive algorithm run with decisions made by the detector instead of the true transmission data. For convenience it will be assumed that the desired user is user 1, but the same reasoning can of course be applied to all users in the system[9].

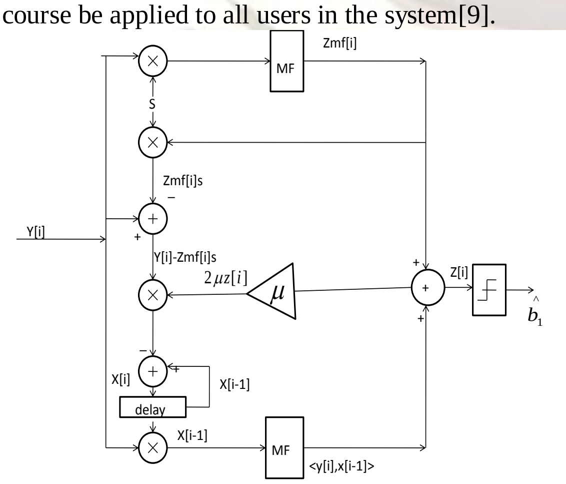

Figure 5: Blind adaptive multiuser detection.

The blind adaptive MMSE detector is an example of a linear multiuser detector. Linear multiuser detectors apply a linear transformation to the outputs of the matched filter bank to produce a new set of outputs, which hopefully provide better performance when used for estimation. Since matched filtering is also a linear operation, the matched filter bank followed by a linear transformation used in linear multiuser detection can be seen as a matched filter bank with modified sequences. So the signature sequence *s* is replaced by a modified signature sequence *m*. A linear multiuser detector for user 1 can be characterized by the modified sequence *m*1, which is the sum of two orthogonal components. One of these components is the signature sequence of user 1, s_1. The other component is denoted as *x*1 and will be referred to as the *x* sequence, so

$$m_1 = s_1 + x_1 \text{ -------(9)}$$

with $m_1, s_1, x_1 \in R^N$, where *N* is the number of bits per symbol and

$$<s_1, x_1> = 0$$

Since x_1 is orthogonal to s_1, any x_1 can be chosen to minimize the correlation between the multiple access interference and m_1, while the correlation with user 1 remains constant. Thus The linear detector makes its decision for user 1 based on the sign of the output of the matched filter with modified sequence for user 1, so

$$\hat{b}_1 = \text{sgn}(<y,m_1>)\text{.-------(10)}$$

Every linear multiuser detector can be written in this form, so it is a canonical representation for linear multiuser detectors [9]. The output of the matched filter with modified sequence for user 1 is equal to

$$Z1 = <y,m_1> \text{ --------(11)}$$

Minimizing Mean Output Energy

The blind adaptive MMSE detector in fact minimizes the Mean Output Energy (MOE), in contrary to what its name implies. In this section it will be shown that by minimizing the Mean Output Energy, the Mean Square Error (MSE) is also minimized [10-12]. The Mean Output Energy of a linear multiuser detector for user 1 is defined as MOE The Mean Output Energy and the Mean Square Error of the linear detector for user 1 can be written as, respectively,

$$MOE(x_1) = E[(<y,s_1 + x_1>)^2]$$

and

$$MSE(x_1) = E[(A_1 b_1 - <y, s_1 + x1>)^2]$$

Stochastic Gradient Decent Method

The stochastic gradient descent method is based on the *gradient decent* method. The gradient descent method is used to find the parameter θ*min* that minimizes the following θ function

$$\omega(\theta) = E[g(X, \theta)].$$

Where X is a random variable and $g(\cdot)$ is a function. If the function φ is convex, then for any initial condition θ_0, the gradient descent algorithm converges to the minimum of φ. The algorithm follows the direction of steepest descent (i.e., the direction opposite to the gradient∇ φ):

$$\theta_i = \theta_{i-1} - \mu\nabla \varphi(\theta_{i-1}),$$

Adaptive Implementation

The stochastic gradient decent method can be used to find the x sequence $xopt$ that minimizes the Mean Output Energy. The MOE function, given as

$$MOE(x1) = E[(<y, s1 + x1>)2]$$

is than the equivalent of the φ(θ) function, the x sequence is the equivalent of θ and the received signal y is the equivalent of X. To minimize the Mean Output Energy the x sequence is adapted each bit period using the stochastic gradient descent algorithm This means that one iteration of the stochastic gradient descent algorithm is performed for each bit period. Since subscripts are already used to indicate users, the iteration number is indicated with an index [i]. So the stochastic gradient descent algorithm for adaptation of the x sequence can be written as

$$x_1[i]=x1[i-1]-\mu\nabla (<y[i],s_1+x_1[i-1]>)^2$$

Here $y[i]$ indicates the received signal for the bit period of the ith bit in the bit stream.1 $x[i-1]$ is the value of the x sequence obtained from the previous received signal $y[i-1]$ during the previous iteration of the algorithm. Note that $s1$ has to remain the same for all bit periods, which implies the use of a short code CDMA system. The output of the matched filter for user 1 for the ith bit period is written as:

$$Zmf_1[i] = <y[i], s_1>.$$

Analogously, the output of the adaptive filter for user 1 for the ith bit period is written as:

$$Z_1[i] = <y[i], s_1 + x_1[i-1]>$$
$$= Zmf[i] + <y[i], x_1[i-1]>.$$

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

$$\hat{b}[i]=sgn(Z1[i])=sgn(Zmf[i]+<y[i],x1[i-1]>).$$

Regarding the implementation of this adaptive algorithm, we make the following observations

1. Implementation with finite-dimensional vectors rather than continuous-time signals. For the Sake of reducing computational complexity and improved speed of convergence, it is desirable to use vector space with lowest dimension that contains the desired and interfering signals.
2. Improved convergence with more complex recursions.
3. Implementation in asynchronous channels.

VII. SIMULATION RESULTS

Linear detectors are investigated like matched filter,

decorrelator and MMSE detectors. Here AWGN channel is used. gold sequence is used for spreading sequence is 31 length. From Figure 5 to Figure 8 shows the Bit error rate performance of the matched filter. Decorralator , MMSE and adaptive blind detectors. The simulation scenario is observed that as the MAI increases (the number of users increases) the

performance becomes degraded. But the decorralator is better performanced than MF. Similarly the MMSE is better performed than decorralator and matched filter. Similarly like this the Blind detector is also well performed compared to MF, DEC and MMSE detectors.

Figure 9 shows the performance of MF, DEC, MMSE and Blind detectors for 2-users. Here the MMSE detector is better performed compared to the MF, DEC and Blind. But the number of users increases the performance is degraded, figure 10 shows the performance of the MF, DEC, MMSE and Blind detectors for 5-users. Here the number of users increases the performance is degraded. The blind detector is better performed compared to the MF, DEC and MMSE. Similarly figure 11 shows the performance of same detectors above said here also the blind detector is well performed compared to the other detectors for 10-users.

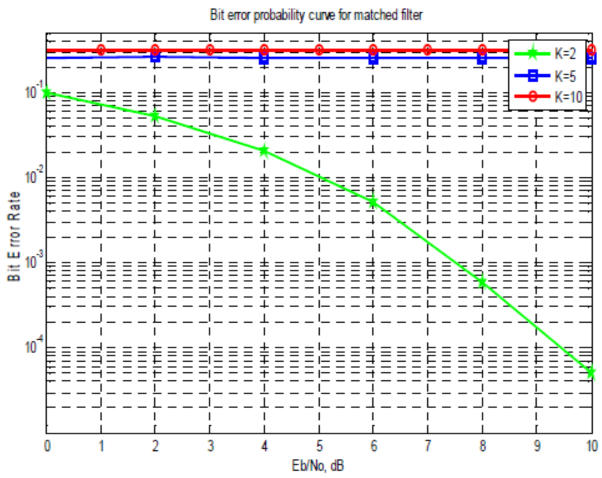

Figure-5: performance of Matched filter

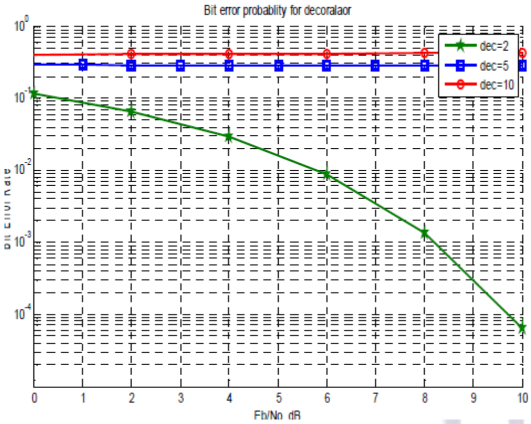

Figure-5: performance of decorrelator

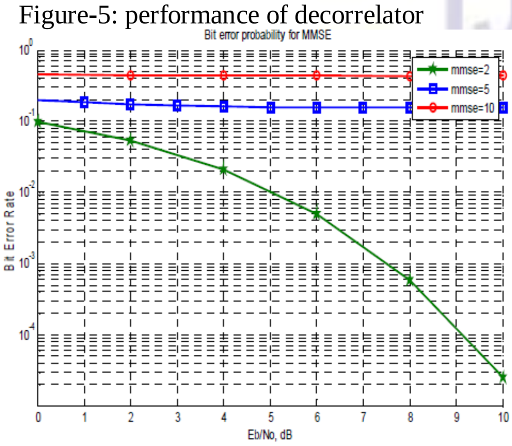

Figure-5: performance of MMSE

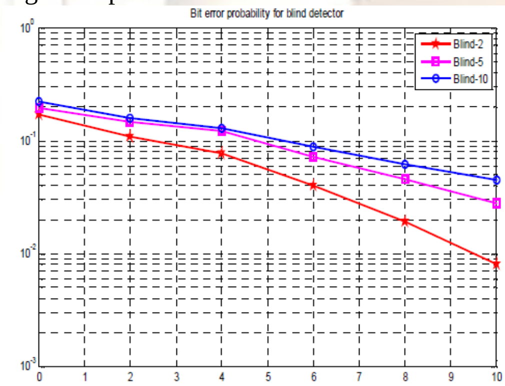

Figure-8: performance of Blind detector

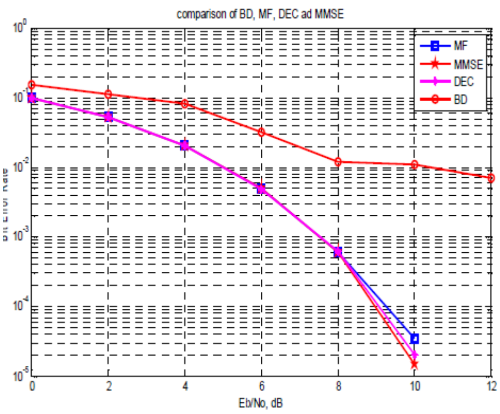

Figure-9: Comparison of Detectors for 2 -user

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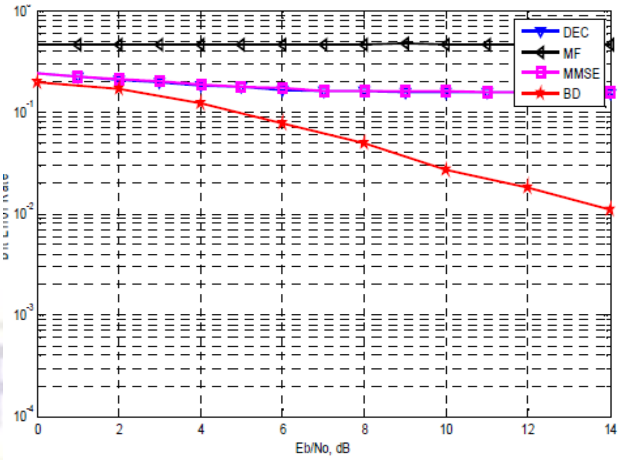

Figure-10: Comparison of Detectors for 5-user

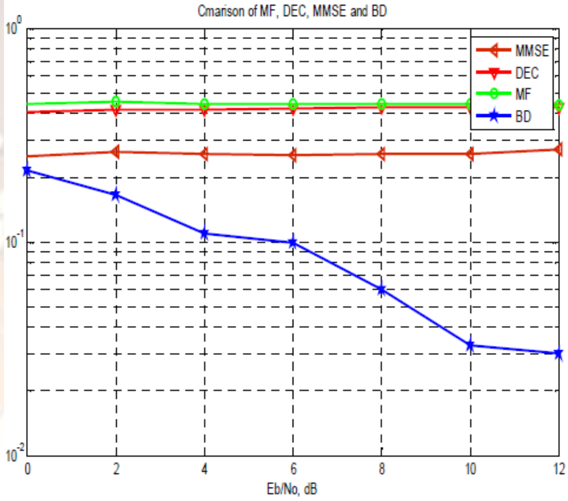

Figure-11: Comparison of Detectors for 10 –user

VIII. CONCLUSIONS

This Paper is a compilation of different approaches to linear multiuser 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 noiseis totally absent (infinite SNR). Finally the Blind 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.

References

[1] A J. Viterbi (1994), "*The Orthogonal-RandomWaveform Dichotomy for Digital Mobile Personal Communications, IEEE Pers. Commun, 1st qtr., pp. 18-24".*

[2] C. Kchao and G. Stuber (1993), *"Performance Analysis of a Single Cell Direct Sequence Mobile Radio System, IEEE Trans. on Commun., vol . COM-41, no 10, pp. 1507-1516".*

[3] Clark, George C., Jr., and J. Bibb Cain (1981), "*Error-Correction Coding for Digital Communications, New York: Plenum Press".*

[4] D. V. Sarwate and M. B. Pursley (1980), "*Cross correlation Properties of Pseudorandom and Related Sequences, Proc. IEEE, vol. 68, no. 5, pp. 593-619*".

[5] J. C. Liberti (1996), "*Spatial Processing for HigherWireless Systems, Bellcore Pub. IM-558".*

[6] J.G. Proakis (1995), "*Digital Communications,3rd Edition, New York: McGraw-Hill".*

[7] Jochen Schiller (2003)," *Mobile Communications,2nd Edition, Addison-Wesley*".

[8] S. Verdu, "*Multiuser Detection Cambridge University Press, 1998*".

[9] Duel-Hallen, J. Holtzman, and Z. Zvonar, "*Multi-user detection for CDMA systems,"*. IEEE Personal Communications Magazine, April 1995.

[10] M. Honig, U. Madhow, and S. Verd´u. "Blind Adaptive Multiuser Detection. *IEEE Transactions on Information Theory",* 41(4):944–960, July 1995.

[11] J. Potman. "*Development of a Multiuser Detection Testbed.*" Master's thesis, University of Twente, May 2002.

[12] David Gesbert, Joakim Sorelius, Petre Stoica, and A. Paulraj, "*Blind Multiuser MMSE Detector for CDMA Signals in ISI Channels*," IEEE Communications Letters, Vol. 3, No.8, August 1999.

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