# Performance of the Microstatistic Multi-User Receiver in the Base-Band DS-CDMA Transmission System

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***Abstract* - In this paper, the microstatistic multi-user detection receiver (MSF-MUD) will be described. MSF-MUD belongs to the non–linear single–stage multi-user receivers' (NSS–MUD) family. The output of the MSF-MUD is taken as the sign of the multi-channel nonlinear transformation of the output of a bank of the matched filters (BMF). This nonlinear transformation is done by multi-channel conventional microstatistic filter (MSF). The performance of the MSF-MUD receiver is near the optimum receiver and his computational complexity is relatively high [2], [3], [4].**

***Index terms* – MSF, MSF–MUD, NSS-MUD, BMF, GA**

## I. INTRODUCTION

The theoretical analysis of a decision boundary in the direct sequence spread spectrum code division multiple access (DS-CDMA) receivers has been shown that the optimum decision boundary is nonlinear [1]. The optimum receiver approximates this non–linear boundary perfectly, but this can be achieved at the expense of the computational complexity. The NSS–MUD receiver can approximate this non–linear boundary well and outperform the linear receiver structures [2].

MSF-MUD receiver is a member of the NSS-MUD receivers' family. The output of the MSF–MUD receiver is taken as the sign of the non–linear transformation of the BMF output (Fig. 1). The non–linear transformation is produced by the MSF.

In order to work MSF-MUD in an optimum way, the estimation of the optimum threshold decomposer values is very important. For the estimation, it can be used e.g. the method of the minimization of the BER by scanning whole of possible values (obtained from the histogram of the output of the BMF) or by using the genetic algorithm (GA) [3].

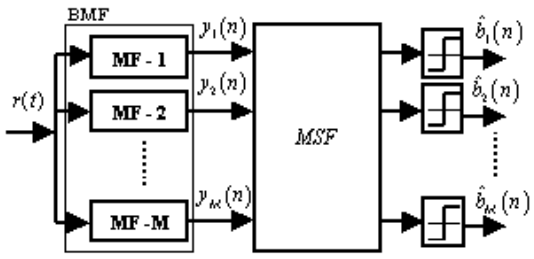


**Fig. 1:** MSF-MUD receiver

In this paper, MSF-MUD will be briefly described. In the next section, the estimation of the threshold values of the decomposer will be described. In the Section 3, the simulations results are presented, to compare performance of the MSF–MUD, the conventional BMF MUD receiver, the decorrelating MUD receiver (D-MUD), the minimum mean-square error MUD receiver (MMSE-MUD) and the optimum MUD receiver with Viterbi algorithm.

## II. MICROSTATISTIC FILTER (MSF)

The MSF consists of *M* threshold decomposers (TD) and multi–channel Wiener filters (M-WF). The performance of the *i*-th TD can be described as the decomposition operation of the signal $y^{(i)}(n)$ (Fig. 1) into a set of the $O=2L$ signals $y^{(i,j)}(n)$ as [4]

$$y^{(i,j)}(n)=\begin{cases}0 & for \quad y^{(i)}(n)<l_{j-1}^{(i)}\\ y^{(i)}(n)-l_{j-1}^{(i)} & for \quad l_{j-1}^{(i)}<y^{(i)}(n)<l_{j}^{(i)}\\ l_{j}^{(i)}<l_{j-1}^{(i)} & for \quad l_{j}^{(i)}<y^{(i)}(n)\end{cases}, \qquad (1)$$

for $y^{(i,j)}(n)\geq 0, l_{L}^{(i)}=\infty, i\in\{1,2,\ldots,M\}, j\in\{1,2,\ldots,L\}$ and

$$y^{(i,j)}(n)=\begin{cases}0 & for \quad y^{(i)}(n)<l_{j-1}^{(i)}\\ y^{(i)}(n)-l_{-j+1}^{(i)} & for \quad l_{-j+1}^{(i)}>y^{(i)}(n)\geq l_{-j}^{(i)}\\ l_{-j}^{(i)}<l_{-j+1}^{(i)} & for \quad l_{-j}^{(i)}>y^{(i)}(n)\end{cases}, \qquad (2)$$

for $y^{(i,j)}(n)<0, l_{-L}^{(i)}=-\infty, i\in\{1,2,\ldots,M\}, j\in\{1,2,\ldots,L\}$. The parameters $l_{j}^{(i)}$ and $l_{-j}^{(i)}$ are referred as the threshold values of the $TD_i$ are confined as $-\infty=l_{-L}^{(i)}<\ldots<l_{1}^{(i)}<l_{L}^{(i)}=\infty$.

The details of the design and mathematical description of the MSF-MUD can be found in [2] and [4].

In order to find the optimum coefficients of the MSF, we minimize the mean–square error of the difference between desired signals $b_k(n)$ and the estimated $\hat{b}_k(n)$ signals. Than, for the optimum coefficients of the MSF can be written

$$\mathbf{H}_{k}^{opt}(n)=\mathbf{R}^{-1}(n)\mathbf{P}_{k}(n) \qquad (3)$$

where $\mathbf{P}_k(n)$ is the cross–correlation vector of the desired signals and the signals at the output of the $TD_i$ and $\mathbf{R}(n)$ is the cross–correlation function of the signals at the output of the $TD_i$ [2].

In order to reach the optimum performance of the MSF–MUD, we need to determine the optimum number and values $l_i$ of the threshold decomposers. The optimum values can be determined from the histogram of the signal at the output of the BMF by scanning the whole interval of the possible values or by the GA [3]. It can be shown, that the MSF-MUD design with GA is about 3 times faster as the MSF-MUD by the scanning method.

## III. SIMULATIONS AND RESULTS

In our simulations we used the DS–CDMA base-band transmission system with AWGN channel. Each of the users

send a stream of 10000 information bits. In our simulation the Gold codes with period 31 as spreading codes, was applied. In the MSF–MUD, 4 decomposer threshold values was used, where $l_1 = -l_{-1}$ and $l_2 = -l_{-2}, l_{-2} = -\infty$ .

As the index performance, the curves of BER vs. Eb/No for 1, 2, 5, 7, 10, 20 and 30 users was used. The results are given in the Fig. 2. In the Fig. 3 – Fig.5, the near-far resistances of different MUD including MSF-MUD are illustrated. There $A_i$ represents the amplitude of signal due to $i$-th user at the input of the receiver.

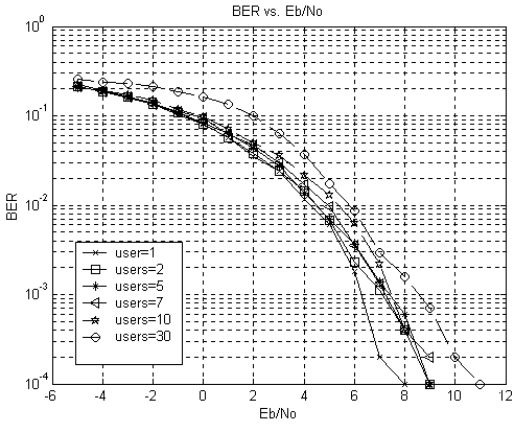


**Fig. 2:** BER vs. Eb/No for the different number of users.

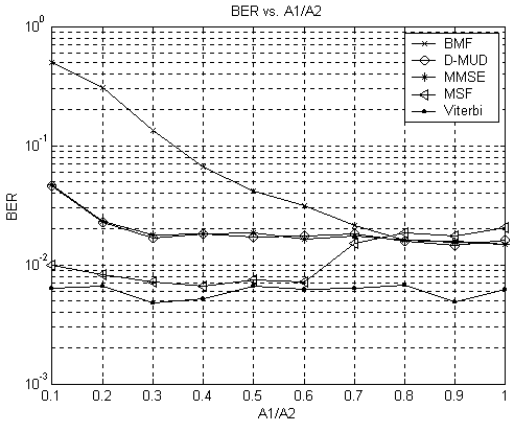


**Fig. 3:** BER vs. A1/A2 for 1-st user, number of users=2.

## IV. CONCLUSIONS

In this paper, we compared the MSF-MUD receiver to the BMF-MUD, D-MUD, MMSE-MUD and optimum MUD based on Viterbi algorithm. As we can see from the simulation results, the MSF-MUD receiver is relatively near-far resistant and its dependence on the MAI is relatively low.

The next research of ours will be intent on finding the optimum number of decomposer threshold values, finding the optimum configuration of the GA for MSF–MUD receiver design and to examine the performance of the MSF-MUD in asynchronous CDMA transmission system.

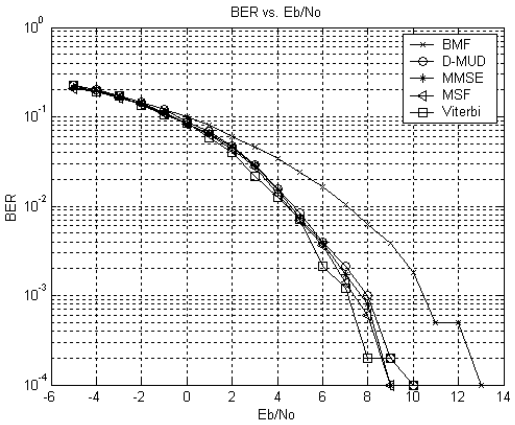


**Fig. 4:** BER vs. Eb/No for the 1-st user, number of users=5, A1/A2=1.

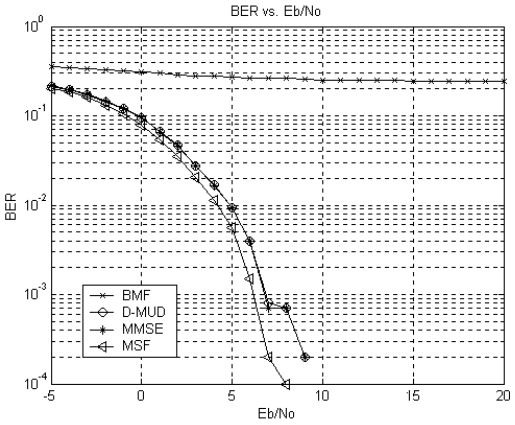


**Fig. 5:** BER vs. Eb/No for 1-st user, number of users=5, A1/A2=0.1.

## REFERENCES


[1] Verdu, S: Multi–user Detection. Cambridge University Press, UK 1998.

[2] Kocur, D.–Čížová, J.–Marchevský, S.: Adaptive Multi–Channel Microstatistic Filters. *48. Internationales Wissenschaftliches Kolloquium, Ilmenau,* Germany, 22.-25.09.2003, pp.91-92.

[3] Čížová, J.: Microstatistic Multi-User Receiver with determining the Decomposer Threshold Values by Genetic Algorithm. *Proceedings of IV. PhD. conference FEI TU Košice*, May 2004. Accepted for publication.

[4] Kocur, D.–Čížová, J.–Marchevský, S.: Microstatistic Multi-User Detection Receiver. *Proceedings of IEEE International Conference on Computational Cybernetics*, ICCC 2003, Siofok Hungary, 29.-31. August 2003, pp. 363-366.