Performance of Quasioptimal Algorithm for Multiuser Detection and M-QAM Modulations

Ilia Georgiev Iliev[1] and Boyan Ruzhkov Kehayov[2]

Abstract – **The paper presents a research on previously developed quasioptimal algorithm for MUD [1]. There have been many experiments and analysis (with different modulation rates, number of surrounding vectors and number of iterations) to compute the final decision on our MUD algorithm. Program models are realized in MATLAB, in order to research the algorithm performance. Graphic presentations from the measurements are given to prove the exactness of the analytical formulas.**

Keywords* – *MUD, CDMA, M-QAM, BER performance.

I. Introduction

CDMA is an efficient method for sharing a mobile radio channel. The noise resistance of the system decreases due to internal system interference – MUI (multi user interference). The correlation receiver is optimal when no MUI exists. The multi user detection (MUD) is used to minimize the influence of the MUI [2].

The MUD receiver, based on the maximum likelihood criteria (ML) [2], gives an optimal solution and checks all possible combinations of transmitted symbols. The number of the calculations grows exponentially with the number of the active users, which is a disadvantage of ML MUD. There are many suggested methods and algorithms for suboptimal receiving, decreasing the needed number of detection calculations. They are compromise between calculation complexity and quality parameters of the receiver. [6,7].

The research is focused on the parameters and performance of the quasioptimal algorithm of MUD, developed in [1]. The algorithm uses discrete consecutive search. The fast-response of the algorithm is due to strong criteria of search discontinuation and selection of start point of the optimization after the single correlation receiving.

A block diagram of Fig. 2 is used for programming of the algorithm. The result of the analysis is the error probability of the algorithm, the dependency of its accuracy from the number of iterations, users and modulation type.

II. Block Diagram of Quasioptimal Algorithm for MUD

The block schematic of the studied system is shown on Fig.1. The processing is in baseband and consists of K number of receivers. It is supposed that the signals from different transmitters are statistically independent. K users transmit synchronously signals with direct spread spectrum (DSS) and M-QAM modulation.

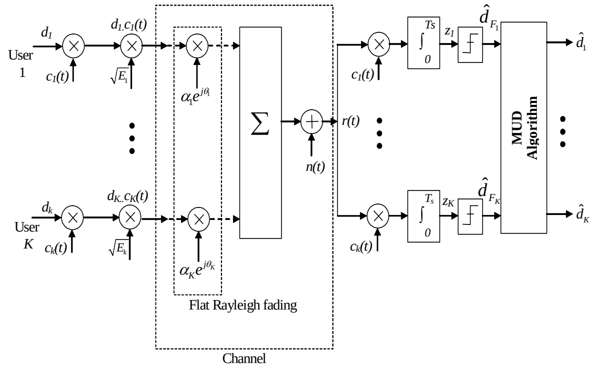

Fig.1

Every branch is a correlation receiver with output the received vector $\boldsymbol{z}$, $\boldsymbol{d}=[d_1,d_2,...,d_K]^T$ is a vector column that consists the value of the modulated symbol with duration T_s coming from the k user. $n(t)$ is the realization of complex additive white Gaussian noise (AWGN) in the input of the receiver with independent real and imaginary component and each of them has $\sigma^2=No/2$ [W/Hz]. $\boldsymbol{H}=diag[\alpha_1e^{j\theta_1},\alpha_2e^{j\theta_2},....,\alpha_Ke^{j\theta_K}]$ is a diagonal matrix and the elements in the main diagonal are the complex transmission coefficients of the channel for each user in k-th channel. The channel is supposed to be with slow flat Raleigh fading. The amplitudes have Raleigh distribution; the phase difference distribution in the channel is uniform in the interval [0,2π]. It is assumed that the channels for each user are statistically independent. $\boldsymbol{E}=diag\left[\sqrt{E_1},\sqrt{E_2},....,\sqrt{E_K}\right]$ is a diagonal matrix. $\sqrt{E_k}$ is the symbol energy for the k-th user, $\boldsymbol{c}$ – is a matrix with rows the spreading sequence for each user and $c_k^{(n)}\in\{-1,+1\}$. The length of the sequences is equal to N - $N=T_S/T_c$, T_c is the element duration.

A block diagram of the algorithm is shown on figure 2. The two base parameters are number of iterations and number of vectors that are independent points on the diagram of states.

The objective function of likelihood for the algorithm is expressed in matrix form as:

$$\Omega(\boldsymbol{d})=\left|(r-H^*.d)\right|^2. \tag{1}$$

The decision for the transmitted symbols is made by:

[1] Ilia Iliev is with the Faculty of Telecommunications, TU-Sofia, Kliment Ohridski 8, Sofia 1000, Bulgaria, E-mail: igiliev@tu-sofia.bg

[2] Boyan Kehayov is with the Faculty of Telecommunications, TU-Sofia, Kliment Ohridski 8, Sofia 1000, Bulgaria, E-mail: bkehayov@tu-sofia.bg

$$\hat{\boldsymbol{d}} = \arg\left\{\min_{\boldsymbol{d}}\left[\Omega(\boldsymbol{d})\right]\right\}. \quad (2)$$

The work of algorithm is described with following five steps:

1. d_{MF} is hard decision vector from demodulator.
2. Generation of K+1 vectors *d*. They have vector space with Hamming distance H_d=1 with consecutive changes of each element of the vector. d_{K+1} vector is d_{MF} vector. If modulation rate is higher, Hamming distance can be set to 2 or 3. Then the number of vector K will be higher, as is shown on figure 3.
3. Calculate Ω function for every K+1 vectors and find minimum value of Ω and number of corresponding vector in *d*.

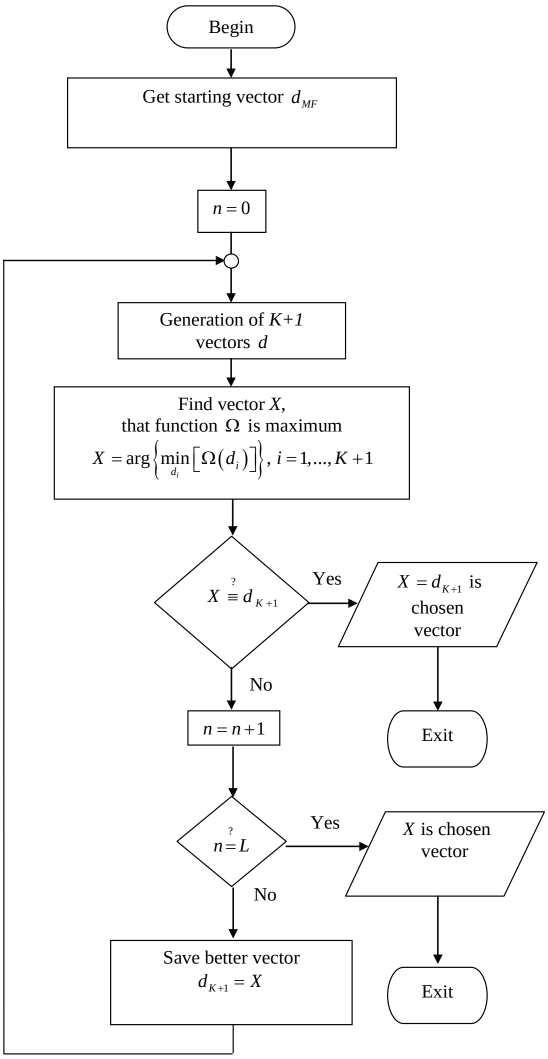

Fig. 2. Block diagram

4. If X is equal to d_{K+1} vector, the initial state d_{MF} is optimum and exit is reached.
5. If $\boldsymbol{X}$ is not equal with d_{K+1} vector, new best vector is estimated and d_{K+1} vector became $\boldsymbol{X}$ vector. This process stop after *L* iterations.

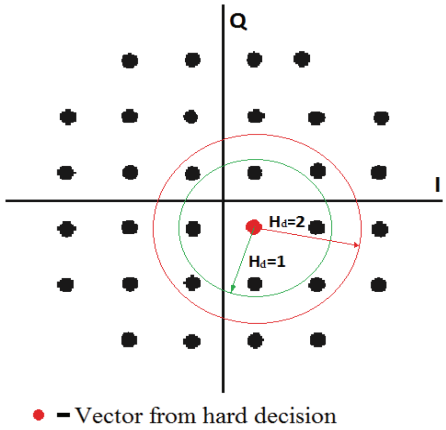

Fig. 3. 32 QAM vector diagram and number of vectors when H_d = 1, 2

With this block diagram different values of Hamming distance can be evaluated. Also different values of number of cycles can be investigated.

III. Results of Simulations

For the purposes of the research a model program in MATLAB, which finds bit error probability (BER) in different cases, is created.

Studies have been made in base band under the following conditions. The CDMA processing gain of the spreading sequences is *N* = 31, and the sequences are randomly generated. Perfect power control and synchronisation is assumed. The channel is modelled as AWGN with slow Raleigh fading, and channels transmission coefficients are known. Hamming distance for all simulations is H_d=1.

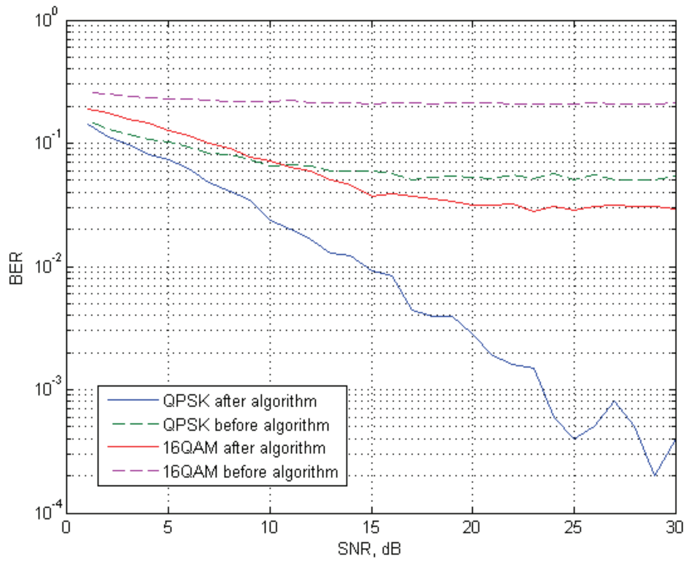

Fig. 4. BER depending on *SNR* and K=5

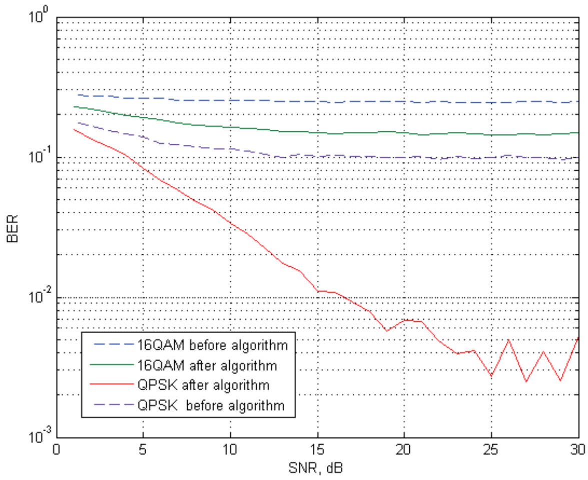

Fig. 5. BER depending on *SNR* and K=10

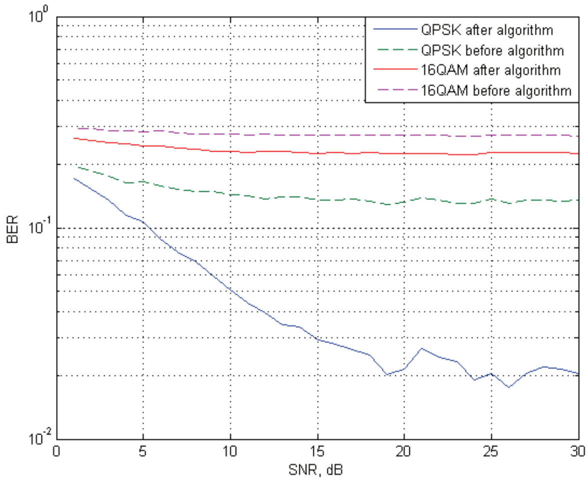

Fig. 6. BER depending on *SNR* and K=15

The results of figures were obtained in five iterations of the algorithm, *L*=5. As described above, experiments were done for 5, 10 and 15 users of the system in two types of modulation QPSK and 16QAM.

On figure 4, 5 and 6 is shown BER depending on SNR and modulation type for five, ten and fifteen active users respectively. Curves from hard decision ML receiver are marked as "before algorithm" and curves after MUD algorithm are marked as "after algorithm". It is seen from figure 4,5 and 6 that the algorithm for MUD reduces error probability in contrast of hard decision ML receiver.

When increasing the modulation rate *M*, values of BER increases and the algorithm needs more iterations to reach the same levels of bit error probability as at lower modulation rate.

Changing the number of iterations of the algorithm has great influence on BER. The results are shown in the next figures – fig.7, fig.8.

Experiments were made with 1, 3 and 5 iterations of the algorithm, two types of modulation QPSK and 16QAM and ten users of the system.

It is important to note that each next algorithm's iteration reduces the BER. This continues until a certain optimum value for the number of cycles *L*. After reaching this value BER decrease stops and increase of *L* becomes meaningless.

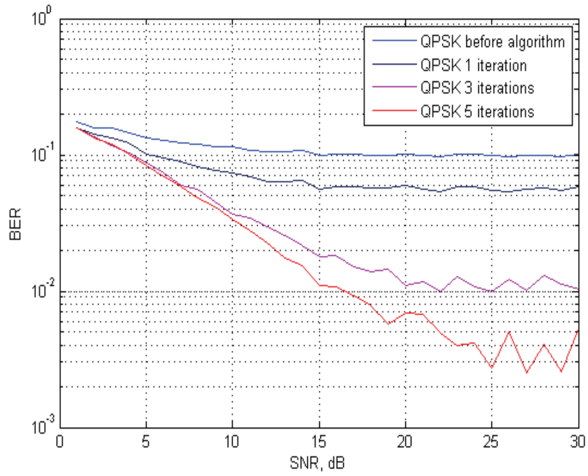

Fig. 7. BER depending on *SNR* and number of iterations *L* for QPSK modulation K=10

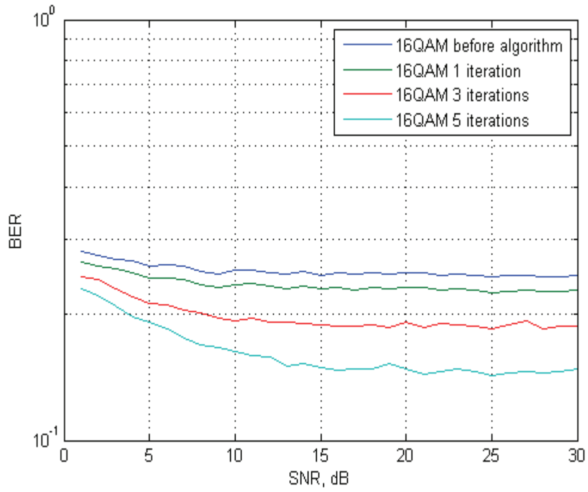

Fig. 8. BER depending on *SNR* and number of iterations *L* for 16QAM modulation K=10

Figure 9 presents BER depending of number of users *K* for hard decision (before algorithm) and after proposed quasioptimal algorithm for MUD. Curves present values for QPSK and 16QAM modulations by SNR=20dB.

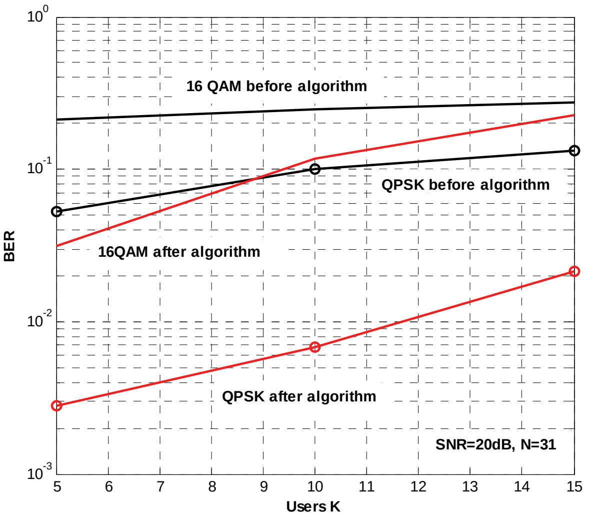

Fig. 9. BER depending on *K* for QPSK and 16QAM

IV. Conclusion

The paper presents a development of quasioptimal algorithm for multiuser detection. Through it identifies: performance of the algorithm - respectively the lower limit of the bit error probability in a channel with Rayleigh flat fading and dependency on modulation rate and number of iterations. Program model of system is realized in MATLAB, in order to research the algorithm performance and their parameters. Graphic presentations from the measurements are given to prove the exactness of the analytical formulas.

The results show that the algorithm for MUD reduces error probability in contrast of hard decision ML receiver. By increasing the modulation rate *M*, values of BER increases and the algorithm needs more iterations to reach the same levels of bit error probability as at lower modulation rate.

Smaller values of BER after algorithm are expected outcome of the experiments and can be recorded from charts. In the model have not been used any time and phase distortion or synchronization methods. This would lead to lower values of BER under the same parameters. These are plans for future research.

References

[1] Iliev I. G., Nedelchev M. V., Kehayov B. K., Theoretical model of the MUD algorithm based on the diagram of states and Markov's chains, ICEST 2010, Ohrih, Proceedings of Papers, pp.169,172.

[2] S. Verdú, Multiuser Detection. New York: Cambridge Univ. Press,1998.

[3] Z. Xie, R. Short, and C. Rushforth, A family of suboptimum detectors for coherent multiuser communications, IEEE Journal on Selected Areas in Communications, vol. 8, pp. 683-690, May 1990

[4] C. Ergun and K. Hacioglu, Multiuser detection using a genetic algorithm in CDMA communications systems, IEEE Trans. Commun., vol. 48, pp. 1374–1383, Aug. 2000.

[5] Peng Hui Tan, Lars K. Rasmussen, Multiuser Detection in CDMA—A Comparison of Relaxations, Exact, and Heuristic Search Methods, IEEE TR. WIRELESS COMM., VOL. 3, N 5, SEPT. 2004

[6] Iliev I. G., Nedelchev M. V., Performance Analysis of a suboptimal multiuser detection algorithm, ICEST 2007, Macedonia, pp.531 - 534

[7] Iliev I. G., Nedelchev M. V., Antenna Diversity Multhi User Detection Algotithm for Synchronous CDMA System, ICEST 2009, V. Tarnovo, Proceedings of Papers, pp.67-71