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Multiuser Systems Implementations in Fading Environments

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1. Introduction

The theory of multiuser detection technique has been developed during the 90s [Verdu, 1998], but its application gained a high potential especially for large mobile networks when the base station has to demodulate the signals coming from all mobile users [Verdu, 1998; Sakrison, 1966].

The performances of multiuser detection systems are affected mostly by the multiple access interference, but also by the type of channel involved and the impairments it might introduce. Therefore, important roles for improving the detection processes are played by the type of noise and interferences affecting the signals transmitted by different users. Selection of spreading codes to differentiate the users plays an important role in the system performances and in the capacity of the system [Halunga & Vizireanu, 2009]. There are important conclusions when the signals of the users are not perfectly orthogonal and/or when they have unequal amplitude [Kadous& Sayeed, 2002], [Halunga & Vizireanu, 2010].

In a wireless mobile communication system, the transmitted signal is affected by multipath phenomenon, which causes fluctuations in the received signal's amplitude, phase and angle of arrival, giving rise to the multipath fading. Small-scale fading is called Rayleigh fading if there are multiple reflective paths that are large in number and there is no line-of-sight component. The small-scale fading envelope is described by a Rician probability density function [Verdu, 1998], [Marcu, 2007].

Recent research [Halunga & Vizireanu, 2010] led us to several conclusions related to the performances of multiuser detectors in different conditions. These conditions include variation of amplitudes, selective choice of (non) orthogonal spreading sequences and analysis of coding/decoding techniques used for recovering the original signals the users transmit. It is very important to mention that the noise on the channel has been considered in all previous simulations as AWGN (Additive White Gaussian Noise).

This chapter implies analysis of multiuser detection systems in the presence of Rayleigh and Rician fading with Doppler shift superimposed over the AWGN noise. The goal of our research is to illustrate the performances of different multiuser detectors such as conventional detector and MMSE (Minimum Mean-Square Error) synchronous linear detectors in the presence of selective fading. The evaluation criterion for multiuser systems performances is BER (Bit Error Rate) depending on SNR (Signal to Noise Ratio). Several conclusions will be withdrawn based on multiple simulations.

2. Multiuser detection systems

Multiuser detection systems implement different algorithms to demodulate one or more digital signals in the presence of multiuser interference. The need for such techniques arises notably in wireless communication channels, in which either intentional non-orthogonal signaling (e.g., CDMA – Code Division Multiple Access) or non-ideal channel effects (e.g., multipath) lead to received signals from multiple users that are not orthogonal to one another [MTU EE5560].

The influence of multiple access interference (MAI) is critical at the receiver end, whether this is the mobile or base station. In CDMA system a tight power control system prevents more powerful users to affect the performances of less powerful ones. In order to reduce the negative effects of near-far problem or any kind of impairments [Halunga S., 2009] several error-correcting codes can be used. Usually the mathematical formulas for defining multiple-access noise are complicated and can be implemented in a very complex structure, and certainly much less randomness than white Gaussian background noise. By exploiting that structure, multi-user detection can increase spectral efficiency, receiver sensitivity, and the number of users the system can sustain [Verdu, 2000].

Several types of multiuser detectors will be analyzed in different transmission/reception environment and they include conventional detector and MMSE multiuser detector.

2.1 Conventional multiuser detector

The conventional matched-filter detector, the optimal structure for single user scenario [Verdu, 1998], is the simplest linear multiuser detector. By correlating with a signal that takes into account the structure of the multiple access interference, it is possible to obtain a rather dramatic improvement of the bit-error rate of the conventional detector [Poor, 1997], but the complexity of the receiver increases significantly.

The detector consists of a bank of matched filters and the decision at the receiver end is undertaken, based on the sign of the signal from the output of filters.

The block diagram of the conventional detector is shown in fig. 1. [Verdu, 1998], [Halunga, 2010]
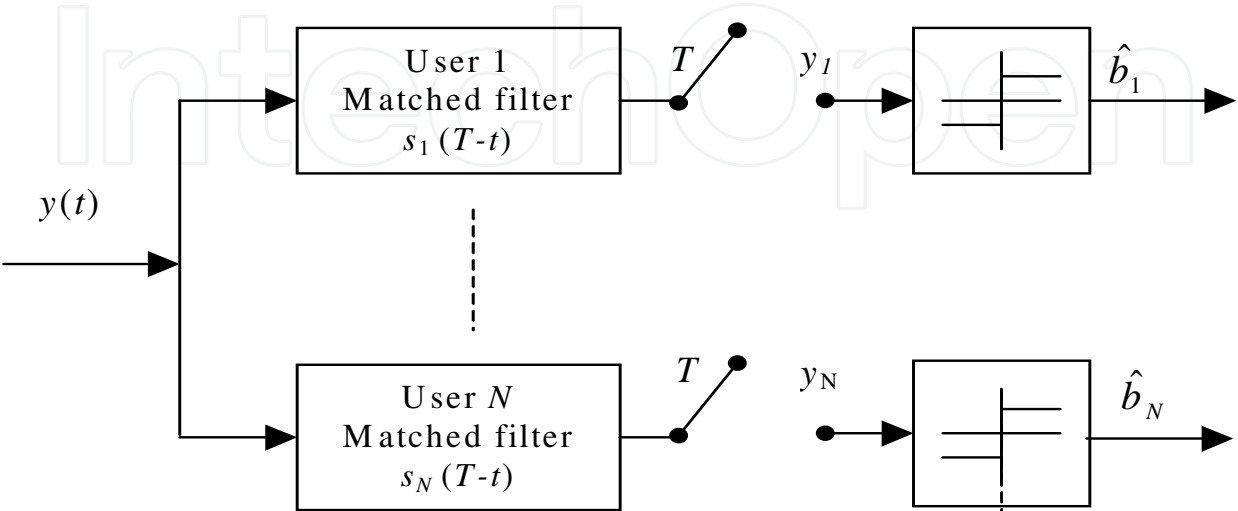

Fig. 1. General architecture of conventional multiuser detector

The outputs of matched filters can be written in matrix representation as

$$Y = RAb + N \tag{1}$$

- $\mathbf{Y} = [y_1, y_2, \dots y_N]^T$: column vector with the outputs of the matched filters;
- R : cross-correlation matrix containing correlation coefficients (ex.: ρ_{kj} represent the correlation coefficient between signal of the user k and signal of the user j);
- $\mathbf{A} = diag\{A_1, A_2, \dots A_N\}$: diagonal matrix of the amplitudes of the received bits;
- $\mathbf{b} = [b_1, b_2, \dots b_N]^T$: column vector with bits received from all users;
- $\mathbf{N} = [n_1, n_2, \dots n_N]^T$: sampled noise vector.

The estimated bit, after the threshold comparison, is

$$\hat{b}_k = \mathrm{sgn}(y_k) = \mathrm{sgn}\left(A_k b_k + \sum_{j \neq k} A_j b_j \rho_{kj} + n_k \right) \tag{2}$$

The random error is thus influenced by the noise samples n_k, correlated with the spreading codes, and by the interference from the other users [Halunga, 2009].

2.2 MMSE multiuser detector

It is shown that MMSE detector, when compared with other detection schemes has the advantage that an explicit knowledge of interference parameters is not required, since filter parameters can be adapted to achieve the MMSE solution. [Khairnar, 2005]

In MMSE detection schemes, the filter represents a trade-off between noise amplification and interference suppression. [Bohnke, 2003]
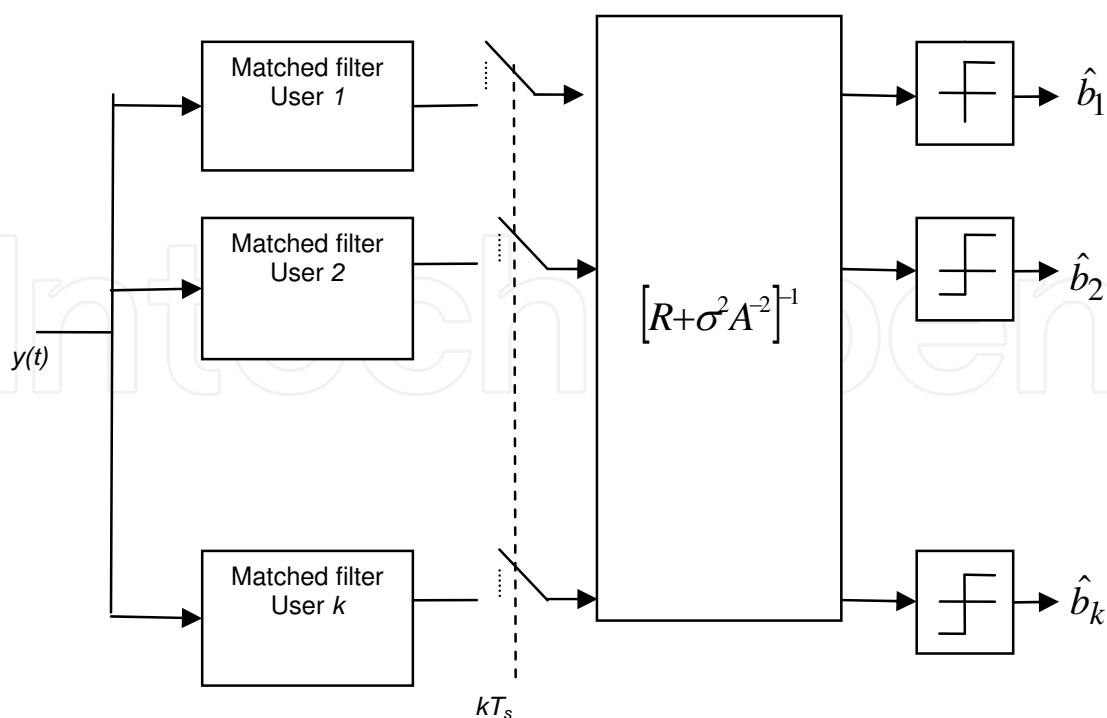

Fig. 2. MMSE multiuser detector

The principle of MMSE detector consists of minimization between bits corresponding to every user and the output of matched filters. The solution is represented by a linear mathematical transformation that depends on the correlation degree between users' signals, amplitude of the signals and on the noise on the channel. In addition to the conventional multiuser scheme, the blocks containing this transformation is placed after the matched filter output and before the sign block [Verdu, 1998], [Halunga, 2010].

This linear transformation can be expressed as:

$$\left[R + \sigma^2 A^{-2} \right]^{-1} \tag{3}$$

After finding this value, one can estimate for every k user the transmitted data by extracting the correponding column for each of them. This way the decision on the transmitted bit from every k user is: [Verdu, 1998]

$$\hat{b}_k = \text{sgn}\left(\frac{1}{A_k} \left(\left[R + \sigma^2 A^{-2} \right]^{-1} y \right)_k \right) = \text{sgn}\left(\left(\left[R + \sigma^2 A^{-2} \right] y \right)_k \right) \tag{4}$$

where every parameter is detailed in Eq. (1) and σ^2 is the variance of the noise.

3. Fading concepts

In mobile communication systems, the channel is distorted by fading and multipath propagation and the BER is affected in the same manner. Based on the distance over which a mobile moves, there are two different types of fading effects: large-scale fading and small-scale fading [Sklar, 1997]. It has been taken in consideration the small-scale fading which refers to the dramatic changes in signal amplitude and phase as a result of a spatial positioning between a receiver and a transmitter.

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used in wireless devices. [Li, 2009] The probability density function (pdf) is:

$$p(w_0) = \begin{cases} \dfrac{w_0}{\sigma^2} \exp\left[-\dfrac{w_0^2}{2\sigma^2} \right] & for \ w_0 \geq 0 \\ 0 & elsewhere \end{cases} \tag{5}$$

where w_0 is the envelope amplitude of the received signal and σ^2 is the pre-detection mean power of the multipath signal.

The Rayleigh faded component is sometimes called the random or scatter or diffuse component. The Rayleigh pdf results from having no mirrored component of the signal; thus, for a single link it represents the pdf associated with the worst case of fading per mean received signal power. [Rahnema, 2008].

When a dominant non-fading signal component is present, the small-scale fading envelope is described by a Rician fading. As the amplitude of the specular component approaches zero, the Rician pdf approaches a Rayleigh pdf, expressed as:

$$p(w_0) = \begin{cases} \dfrac{w_0}{\sigma^2} \exp\left[-\dfrac{\left(w_0^2 + A^2\right)}{2\sigma^2} \right] I_0\left(\dfrac{w_0 A}{\sigma^2} \right) & for \ w_0 \geq 0, A \geq 0 \\ 0 & elsewhere \end{cases} \tag{6}$$

where σ^2 is the average power of the multipath signal and A is the amplitude of the specular component.

The Rician distribution is often described in terms of a parameter K defined as the ratio of the power in the non-fading signal component to the power in multipath signal. Also the Rician probability density function approaches Rayleigh pdf as K tends to zero. [Goldsmith, 2005]

$$K = \frac{A^2}{2\sigma^2} \tag{7}$$

4. Simulation results

All simulations were performed in Matlab environment. Our analysis started from the results obtained with multiuser detectors in synchronous CDMA system. In addition we introduced a small-scale fading on the communication channel. This fading component was added to the already existing AWGN and we observed its influence on the overall performances of multiple access system.

The communication channel is used by two users transmitting signals simultaneously.

For both conventional and MMSE detectors the received signals that will be processed by the matched filters are:

$$y\_rec = A_k b_k + \sum_{j \neq k} A_j b_j \rho_{kj} + n_k + Mat\_fading \tag{8}$$

where b_j are the transmitted bits; ρ_{kj} represents the correlation coefficient between user's j signal and user's k signal; n_k is the AWGN and *Mat_fading* represents the matrix containing values of Rayleigh/Rician fading superimposed on AWGN.

Fading parameters have been created in Matlab environment and for both Rayleigh and for Rician fading there were defined: the sample time of the input signal and the maximum Doppler shift.

Simulations include analysis of equal/non-equal amplitudes for signals and the vectors for amplitudes are:

$$A = [3 \ 3] \ (V) \tag{9}$$

$$A = [1.5 \ 4] \ (V) \tag{10}$$

Since correlation between users' signals lead to multiple access interference, we studied the influence of this parameter in presence of AWGN and fading. In order to create the CDMA system we have used orthogonal/non-orthogonal spreading sequences. We have combined their effect with the effects of imperfect balance of the users' signals powers.

The normalized orthogonal/non-orthogonal spreading sequences are given in Eq. (11), (12):

$$S_1 = [1 \ 1 \ 1 \ \text{-}1 \ 1 \ 1 \ 1 \ \text{-}1] / \sqrt{8}$$
$$S_2 = [1 \ 1 \ 1 \ \text{-}1 \ \text{-}1 \ \text{-}1 \ \text{-}1 \ 1] / \sqrt{8} \tag{11}$$

$$S_1 = [1 \ \text{-}1 \ \text{-}1 \ 1 \ 1 \ \text{-}1 \ 1 \ \text{-}1] / \sqrt{8}$$
$$S_2 = [1 \ \text{-}1 \ 1 \ \text{-}1 \ \text{-}1 \ 1 \ \text{-}1 \ 1] / \sqrt{8} \tag{12}$$

The significances of the symbols on figures in this chapter are:

M1 – multiuser detector for user 1

M2 – multiuser detector for user 2

M1 Rayleigh/Rician – multiuser detector for user 1 in presence of Rayleigh/Rician fading phenomenon

M2 Rayleigh/Rician – multiuser detector for user 2 in presence of Rayleigh/Rician fading phenomenon

All figures presented in this chapter include analysis of equal/unequal amplitudes of the signals, different correlation degrees between users' signals and the influence of fading over the global performances of the CDMA system.

4.1 Conventional multiuser detector

4.1.1 Signals with equal powers; Correlation coefficient=0

This simulation includes usage of amplitudes in Eq. (9) and orthogonal spreading sequences in (11). The results are illustrated in Fig.3.
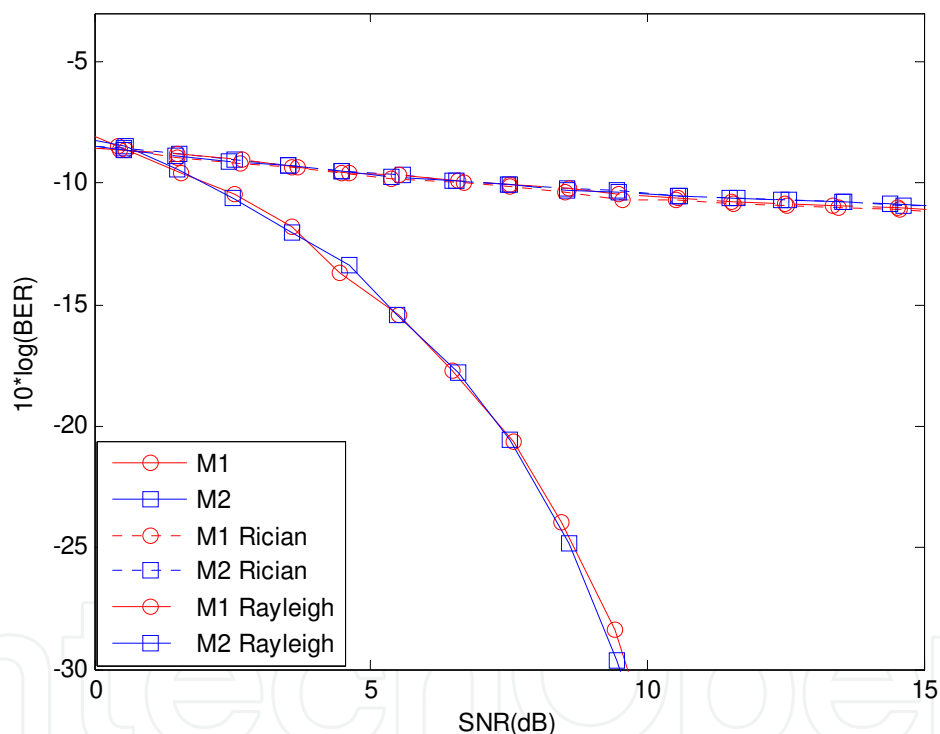

Fig. 3. Performances of conventional detector using signals with equal amplitudes, orthogonal spreading sequences, in the presence of Rayleigh/Rician fading

From Fig. 3 several observations can be made:

- Conventional multiuser detector leads to good performances when the noise on the joint channel is AWGN. The curve for BER values decreases faster reaching -32,4 dB for SNR=10 dB. When signal's level is the same as the AWGN level, the performance is still acceptable since BER is approx. -8,5 dB and it is important to mention that AWGN does not influence the performances for both users.
- If Rayleigh/Rician fading is added over the already existing AWGN, the performances are very poor and the values for BER stay almost constant at -8dB for small SNR values

and decrease slow reaching -11 dB for large SNR values. This way it can be said that the performances of this communication system are significantly influenced by fading presence superimposed on the AWGN.

- The importance of dominant component existing in Rician fading is not relevant in this case because the differences in BER values for both type of fading are very small.
- From BER values point of view it is obvious that the presence of fading is critically affecting the performances, but when fading is not added on AWGN, BER decreases with almost 38 dB as SNR varies from 0 to 15 dB.

In order to support the conclusions presented above, Table 1 illustrates the performances of the system in all three cases.

SNR (dB)	Multiuser Rayleigh BER (dB)	Multiuser Rician BER (dB)	Multiuser Detector BER (dB)
0	-8,65	-8,65	-8,49
5	-9,64	-9,64	-13,88
10	-10,42	-10,42	-32,4
15	-11	-11	-46

Table 1. BER values for equal/orthogonal case for conventional detector

4.1.2 Signals with equal powers; Correlation coefficient=0.5

This simulation includes usage of amplitudes in Eq. (9) and non-orthogonal spreading sequences in (12). Results are illustrated in Fig.4.
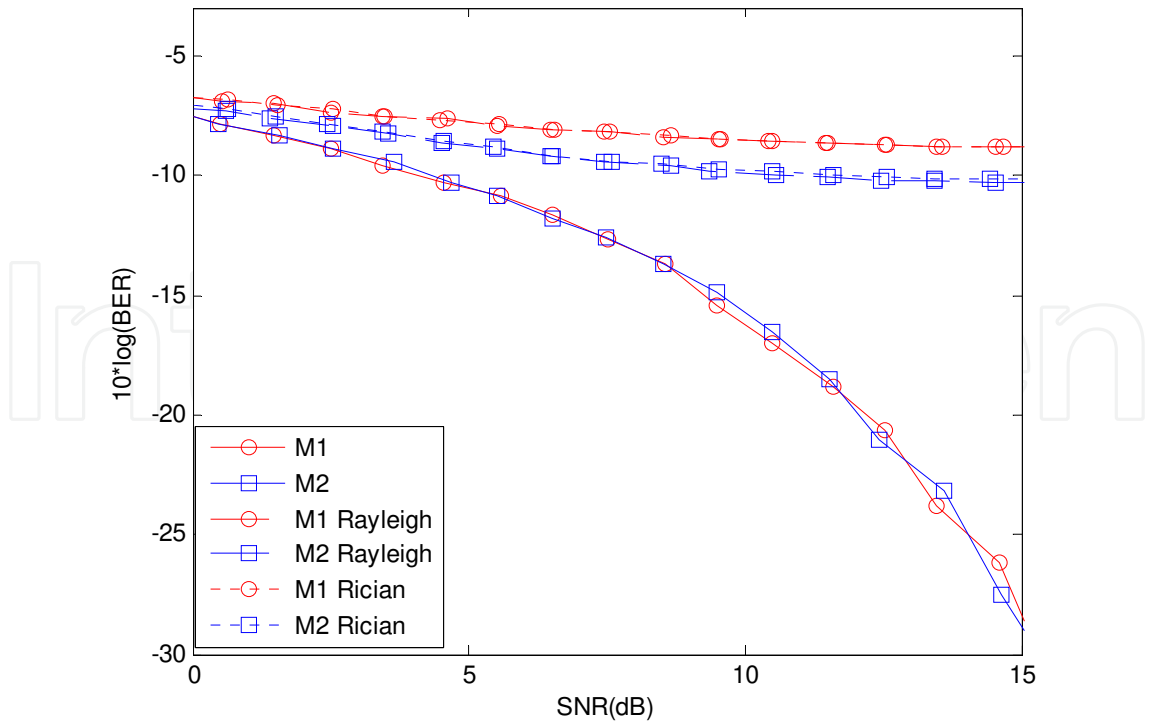

Fig. 4. Performances of conventional detector using signals with equal amplitudes, non-orthogonal spreading sequences, in the presence of Rayleigh/Rician fading

- From Fig.4 we can see that if the signals are correlated, the performances are deteriorated significantly; still the effect is not obvious in the case in which the channel is affected by AWGN only;
- Addition of Rayleigh or Rice fading decrease the BER results even more than in the previous case;
- With respect to the case studied in 4.1.1., the decrease **induced** by the fading in the correlated-users case is not very large (less than 2 dB on average);
- It appears also a small difference between the two users (around 1,5 dB).
- Yet BER values are not decreasing as much as in the previous case, and this can be interpreted as the influence of cross-correlation. For SNR=0 dB in presence of fading BER≈ -8dB represents a satisfactory performance.

A more conclusive analysis is given in Table 2.

SNR (dB)	Multiuser Rayleigh BER (dB)		Multiuser Rician BER (dB)		Multiuser Detector BER (dB)
	User1	User2	User1	User2	
0	-7,25	-7,3	-7,25	-7,3	-7,82
5	-7,8	-8,82	-7,8	-8,82	-10,53
10	-8,53	-9,83	-8,53	-9,83	-16,55
15	-8,8	-10,28	-8,8	-10,28	-28

Table 2. BER values for equal/non-orthogonal case for conventional detector

4.1.3 Signals with non-equal powers; Correlation coefficient=0

This simulation includes usage of amplitudes values from Eq. (10) and non-orthogonal spreading sequences in (11). The results are illustrated in Fig.5.
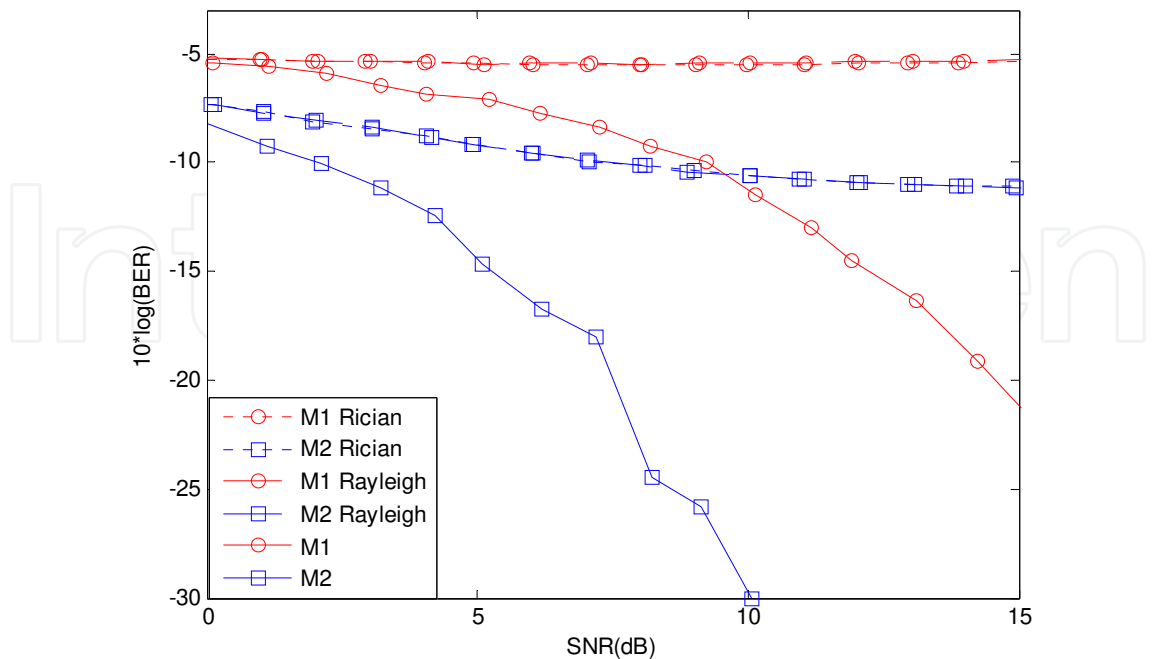

Fig. 5. Performances of conventional detector using signals with unequal amplitudes, orthogonal spreading sequences, in the presence of Rayleigh/Rician fading

Analysis of Fig. 5 provides the following conclusions:

- Regardless the communication conditions, the performances of conventional detector are notable just in the case of AWGN and only for the user with the highest power of the signal. All performances are influenced by the imperfect balance of the signals' powers and by the presence of Rayleigh/Rician fading.
- An important difference between the performances obtained for the two users can be seen only for simple conventional detector in the case of AWGN channel. This way for lower SNRs there is a difference in BER value of 8-11 dB between the performances of both users and it increases up to almost 28 dB for SNR=15dB.
- The second user, with the smallest amplitude of signal, has very poor performances: it barely achieves -6dB and decreases very slowly, for the simple conventional detector, up to -21dB for SNR=15dB which, at this point, represents a good performance.
- When Rayleigh / Rice fading is added over the AWGN, the performances of both users deteriorates dramatically, due to the inter-correlation induced by the fading and Doppler shift. The BER performances stay almost constant with SNR.
- When the signal power increase, when fading is present, the performances are not significantly improved with respect to the low power signal. The gain is about 6dB for both Rayleigh and Rician fading for large SNRs values.

From these results it is obvious that performances of simple conventional detector can be improved only with use of more powerful averaging, interpolation or equalization algorithms in order to decrease the BER as SNR increase.

SNR (dB)	Multiuser Rayleigh BER (dB)		Multiuser Rician BER (dB)		Multiuser Detector BER (dB)	
	User1	User2	User1	User2	User1	User2
0	-5,11	-7,34	-5,11	-7,34	-5,43	-8,38
5	-5,42	-9,32	-5,42	-9,32	-6,94	-14,69
10	-5,43	-10,59	-5,43	-10,59	-11,32	-30
15	-5,25	-11,15	-5,25	-11,15	-21	-48,12

Table 3. BER values for non-equal/orthogonal case for conventional detector

4.2 MMSE multiuser detector
4.2.1 Signals with equal powers; Correlation coefficient=0

Fig. 6 illustrates the results as BER vs. SNR in the case of MMSE multiuser detector when the users' signals have the same power given in Eq. (9) and the spreading sequences used are orthogonal (11).

Observing Fig. 6 several conclusion can be highlighted:

- The presence of Rayleigh/Rician fading channel affects significantly the performances of MMSE multiuser detector. Even when the communication is achieved in an ideal environment (equal powers of signals and orthogonal spreading codes), this type of detector does not manage to reduce the effect of fading and therefore BER values are poor, regardless the SNR values.
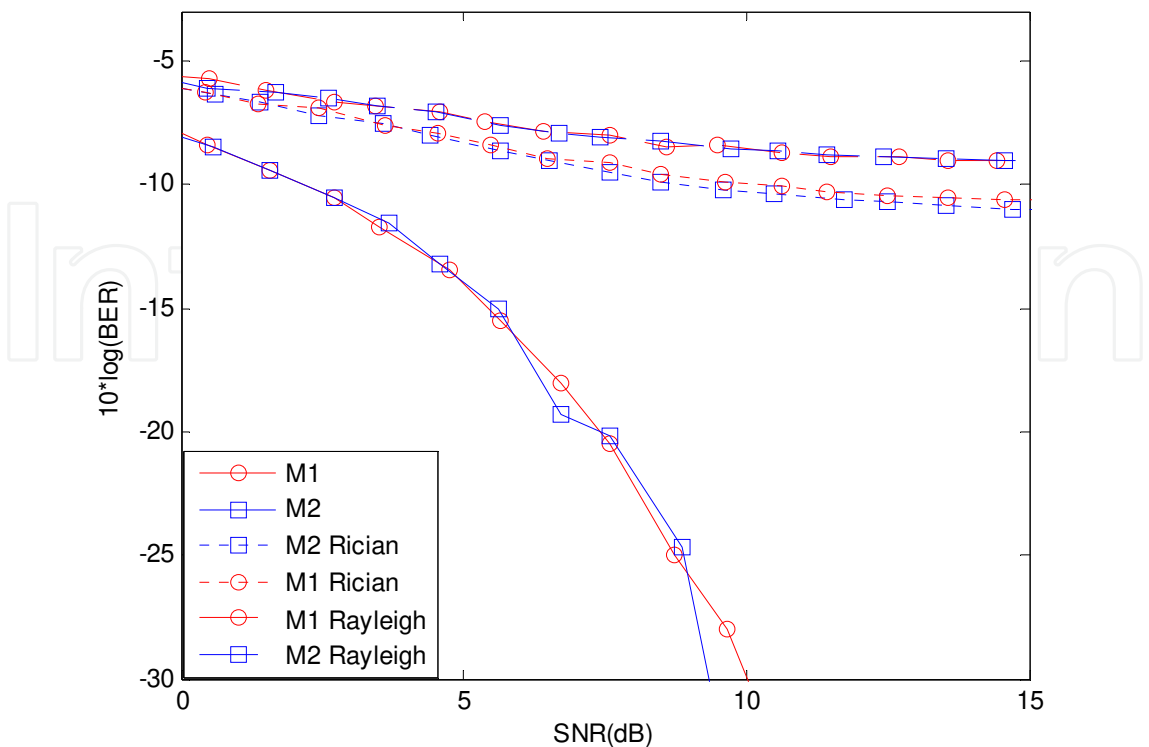
Fig. 6. Performances of MMSE detector using signals with equal amplitudes, orthogonal spreading sequences, in the presence of Rayleigh/Rician fading

- A gain of 5,6 dB can be observed for SNR between (0-15) dB in the case of Rician fading, but for Rayleigh fading the increase is 1,5 dB less than in the Rician case. For a better supervision of fading effects under these conditions one solution might be the significant increase of SNR values.
- Simple MMSE detector leads to BER=-8dB for SNR=0dB which represents a good performance of the system. The performance of simple conventional detector illustrated a BER equals also -8dB when the transmission/reception of signals was achieved in identical conditions. This is the result of MMSE detector taking into account the multiple access interference which obviously affects the performances of the system.
- In general, the results obtained with the MMSE detector are closed to the performances achieved with the conventional detector when fading is not superimposed over the AWGN channel.

Table 5 summarizes several BER values gathered from Fig.6.

SNR (dB)	Multiuser Rayleigh BER (dB)	Multiuser Rician BER (dB)	Multiuser Detector BER (dB)
0	-5	-5	-8
5	-7,37	-8,2	-13,89
10	-8,65	-10,14	-28,12
15	-9,05	-10,6	-45

Table 5. BER values for non-equal/orthogonal case for MMSE detector

4.2.2 Signals with equal powers; Correlation coefficient=0.5

The simulation conditions are: same power for signals in Eq. (9) and non-orthogonal spreading sequences in (12). Fig. 7 illustrates the behaviour of simple MMSE detector in presence of AWGN channel and in presence of Rayleigh/Rician fading channel.
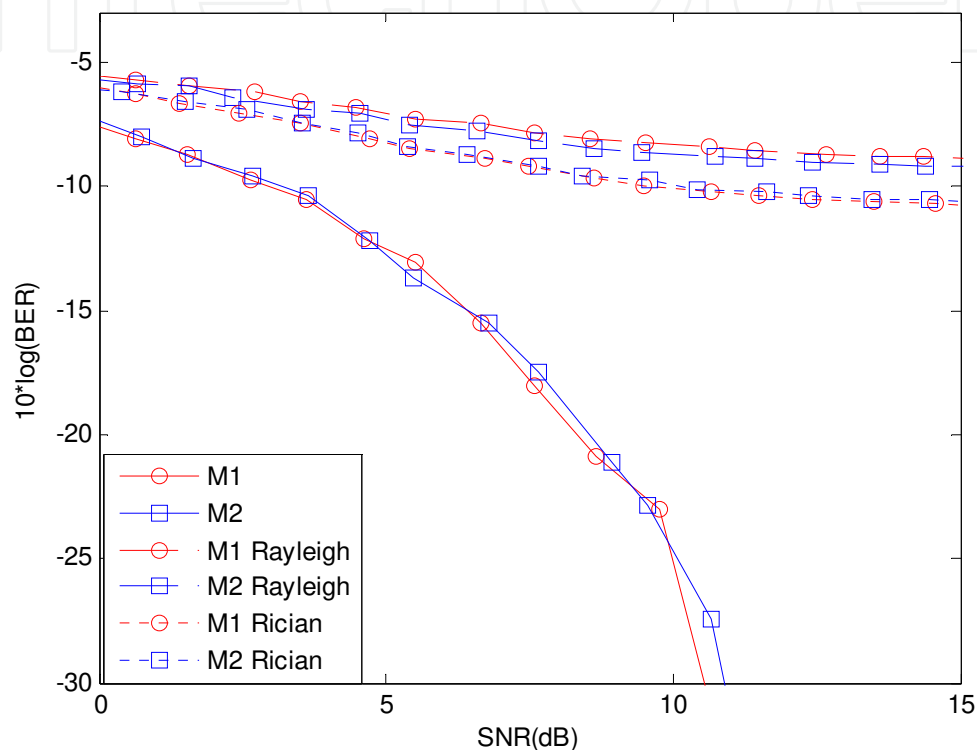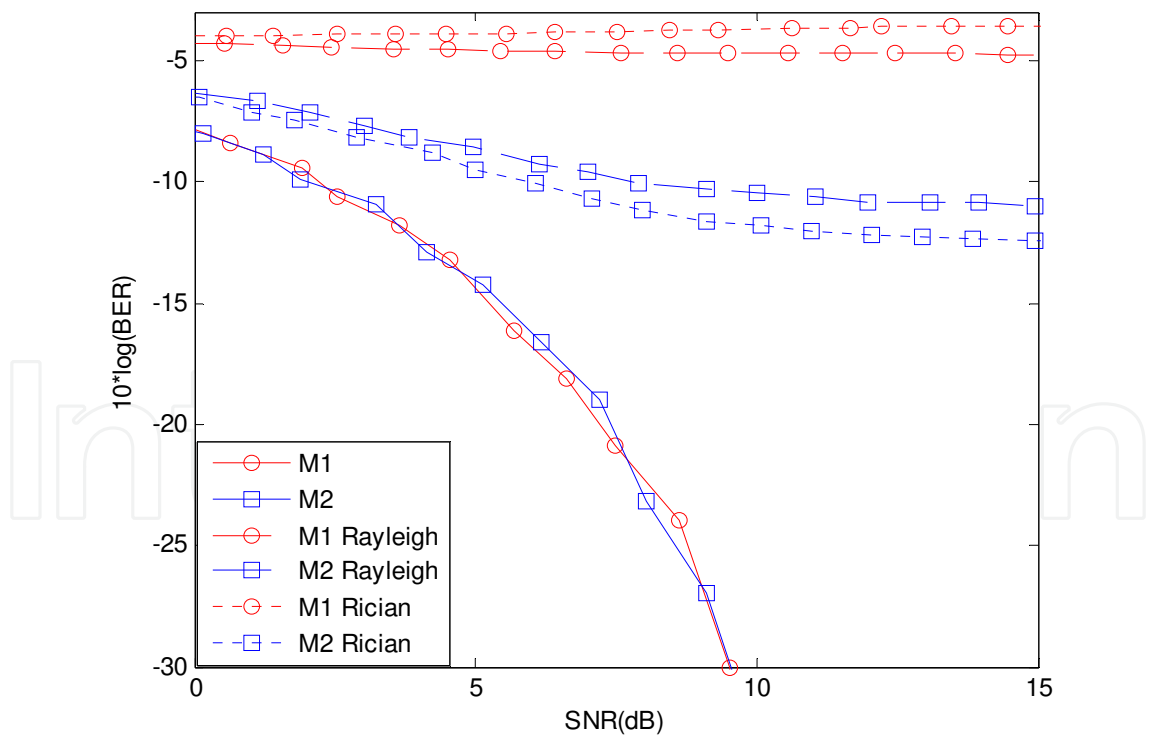

Fig. 7. Performances of MMSE detector using signals with equal amplitudes, non-orthogonal spreading sequences, in the presence of Rayleigh/Rician fading

Based on Fig.7 it can be stated:

- The influence of correlation coefficient does not affect the performances of simple MMSE detector as much as the performances of the conventional one, since both users lead to similar performances. BER values are similar to the ones obtained in the ideal case with a difference of 1dB for SNR=15dB.
- By comparison, if Rayleigh/Rician fading occurs, the performances are improved in the case of Rician fading. As SNR values increase, BER values for Rayleigh fading tend to remain constant and distant from the values achieved with Rician fading.
- In the case of Rayleigh fading the performances are degrading and, in effect, the influence of correlation between users' signals and fading superimposed on AWGN represent critical parameters for this CDMA communication system when MMSE multiuser detectors are involved.

- Under conditions of non-orthogonality between signals and Rician fading, the system can lead to acceptable BER values but only for large SNR values.

Table 6 comes as support for the conclusions extracted from Fig. 7.

SNR (dB)	Multiuser Rayleigh BER (dB)	Multiuser Rician BER (dB)	Multiuser Detector BER (dB)
0	-6,11	-6,11	-7,64
5	-6,81	-7,83	-12,83
10	-8,21	-9,76	-23,01
15	-9,2	-10,73	-50

Table 6. BER values for equal/non-orthogonal case for MMSE detector

4.2.3 Signals with non-equal powers; Correlation coefficient=0

Simulation assumed that users have signal with different powers (determined by the amplitudes in Eq (9)) and signals are not correlated (spreading sequences given in Eq. (10)).

Fig. 8. Performances of MMSE detector using signals with unequal amplitudes, orthogonal spreading sequences, in the presence of Rayleigh/Rician fading

Discussion on Fig. 8 leads to the following conclusions:

- The performances of the simple MMSE multiuser detector are improved in this case, being comparable to performances obtained in the ideal case. For SNR=5dB, it can be achieved a BER approx. -14 dB. This proves that MMSE detector, in an AWGN channel, can overcome the deficiency of imperfect ballast signals.
- For the low-power user, the performances degrade as SNR increase when fading is added over the AWGN. It appears that BER remains constant at about -4,5 dB for larger SNRs.
- Acceptable values for BER can be obtained in the case of Rician fading for the high-power user. It can be seen that BER values decrease constantly for all SNR interval studied. For SNR=15 dB, BER equals -12,41 dB but still far from the performance achieved with simple MMSE detector (BER≈-44dB for the same SNR value).
- In the presence of fading added over the AWGN, MMSE detector cannot reduce the effect of non-equal powers of signals and, in conclusion, the behaviour of the system, for each user, is completely different. Good performances are achieved for the user with the highest power of the signal.
- As an advantage, if the channel is described only by AWGN, MMSE detector can reduce/almost eliminate the theoretical disadvantage introduces by imperfect balanced amplitudes of signals. Both users illustrate the same behaviour for all SNR values.

Table 7 consists of values of BER for every user in all studied cases presented in Fig.8.

SNR (dB)	Multiuser Rayleigh BER (dB)		Multiuser Rician BER (dB)		Multiuser Detector BER (dB)
	User1	User2	User1	User2	User1-2
0	-4,3	-6,55	-4	-6,55	-8
5	-4,58	-8,55	-3,93	-9,48	-14,23
10	-4,73	-10,47	-3,73	-11,76	-33,98
15	-4,76	-10,99	-3,6	-12,41	-43,64

Table 7. BER values for non-equal/orthogonal case for MMSE detector

The final section "Conclusion" summarizes the conclusions deduced from all simulation results and enumerated in Chapter 4.

5. Conclusion

The analysis of multiuser detection technique is still under research because of the changes appearing in the communication environment. Phenomenon such as fading may occur due to propagation of the signals on multiple paths between transmitter and receiver or may appear when the signals are shadowing from obstacles from the propagation paths

(affecting the wave propagation). Both conventional and MMSE multiuser detector's performances are significantly affected by the fading phenomenon.

- In the case of conventional detector, the best BER values are achieved in the case of perfect orthogonality of signals and when all users have the same amplitude of the signal. This way BER can reach -14 dB for SNR=5dB and the curve of BER values decreases very fast as SNR increases.

- When fading is added to the AWGN on the channel, conventional detector cannot eliminate this disadvantage and therefore BER values tends to remain constant. The performances are very poor whether we analyse Rayleigh or Rician fading and BER goes around -8dB for all SNR values.

- In the case of conventional multiuser detector, the effect of imperfect balanced signals is important and it represents a critical parameter that affects the performances of the system. This way the user with low-power signal may not achieve its communication due to the fact that he cannot cross a BER value equal to -8dB and can reach -11 dB for large SNR values. Instead, the user with high-power signal achieves rapidly very good values of BER. For SNR=15dB it achieves BER approx. -13 dB.

- By comparison with performances of conventional detector, the MMSE multiuser detector is not capable to compensate almost any disadvantage and its performances are poor. Though it is obvious from Fig. 7 and Fig. 8 that MMSE detector manages to illustrate the same behaviour for both user regardless the conditions, the values for BER are still small.

- In the case of MMSE detector the worst performances are achieved when Rayleigh/Rician fading occurs. This observation is available in the case of imperfect ballast powers of the signal. Evidently, this type of detector cannot be used in presence of fading when the powers of the signals are small. Even for the user with high power signal the values for BER are not very good but the decrease of its values is constant and therefore this detector might be applied for systems in which the powers of the signals are increased.

- MMSE detector behaves well in the case of correlation between users' signals and the values of BER start from -8dB for SNR=0 dB and reach -50dB for SNR=15dB.

- In conclusion, regardless the type of studied multiuser detector the global performances are affected when fading is superimposed over the AWGN. In addition to this critical component is the effect of imperfect ballast powers of the signals. Conventional detector succeeds in compensating in a certain measure this disadvantage but for MMSE detector the performances are seriously affected. This detector might be used only in systems with high-power users. This way the best performances are achieved with conventional detector.

- The overall analysis led to the conclusion that the best performances can be achieved in presence of AWGN. If fading phenomenon occurs, better performances of the systems have been obtained in the presence of Rician fading instead of Rayleigh fading especially when high-power user is involved.

- Our future work will include integration of Rayleigh/Rician fading in optimal detector and, for all three types of detectors, a coding/decoding technique such as convolutional or turbo will be applied in order to increase the performances of these systems.

6. Acknowledgment

7. References

Verdu S. (1998). *Multiser Detection*, 1st ed. Cambridge University Press, 1998

Sakrison D. J. (1966). *Stochastic approximation: A recursive method for solving regression problems*, Advances in Communication Systems, no. 2, pp. 51-106, 1966

Halunga S., Vizireanu D.N. (2009). "Performance evaluation for conventional and MMSE multiuser detection algorithms in imperfect reception conditions", Digital Signal Processing, Elsevier, ISSN: 1051-2004, p 166-168, 2009

Sayeed A.M., Kadous T.A. (2002). *Equivalence of Linear MMSE Detection in DS-CDMA and MC-CDMA Systems over Time and Frequency Selective Channels*, EURASIP Journal on Advances in Signal Processing, Vol. 2002,Issue: 12 Pages, record No.: 1335-1354

Halunga S., Vizireanu D.N, Fratu O. (2010)„Imperfect cross-correlation and amplitude balance effects on conventional multiuser decoder with turbo encoding", Digital Signal Processing, 2010, Elsevier, ISSN: 1051-2004, p. 191-200 (ISI Web of Knowledge) (2010)

Marcu I., Halunga S., Fratu O., Constantin I. (2007)., *Turbocoding Performances with and without Fading*, ECAI 2007 - International Conference – Second Edition, Electronics, Computers and Artificial Intelligence, 29th – 30th June, 2007, Piteşti MTU EE5560: *Multiuser Detection*, CRN #13888; Section: 0A, Spring 2005

Halunga S., Marcu I., Fratu O., Marghescu I. (2009). *Orthogonality, amplitude and number of users efects on conventional multiuser detection using turbo decoding*, EUROCON 2009, 18-23 May 2009, Sankt Petersburg, Rusia, pp. 2000-2004

Verdú S (2000). *Wireless Bandwidth in the Making*, IEEE Communications Magazine, pp.53-58, ISBN 0163-6804, July 2000

Poor V (1997). *Probability of Error in MMSE Multiuser Detection*, IEEE Transactions On Information Theory, vol. 43, no. 3, pp.858-871, May 1997

Khairnar K., Nema S. (2005). *Comparison of Multi-User Detectors of DS-CDMA System*, World Academy of Science, Engineering and Technology 10, pp. 193-195

Bohnke R., Wubben D., Kuhn V., Kammeyer K-D. (2003). *Reduced complexity MMSE detection for BLAST architectures*, IEEE Global Telecommunications Conference, 2003. GLOBECOM '03, vol.4, pp. 2258 – 2262, ISBN: 0-7803-7974-8, 1-5 Dec. 2003

Sklar B. (1997). *Rayleigh Fading Channels in Mobile Digital Communication Systems*, Part I: Characterization," IEEE Commun. Mag., vol. 35, no. 9, Sept. 1997, pp. 136–46

Li, G., Fan, P., Letaief, K.B. (2009). *Rayleigh fading networks: a cross-layer way*, IEEE Transactions on Communications, vol. 57, pp. 520 – 529, ISSN: 0090-6778, 2009

Rahnema M. (2008). *UMTS Network Planning, Optimization, and Inter-Operation with GSM*, Wiley Publishing House, N-13: 978-0470823019, 320 pp, 2007

Goldsmith A.(2005). *Wireless Communications*, Cambridge University Press, ISBN 978-0-521-83716-3, 672 pp., 2005

The book consists of 24 chapters illustrating a wide range of areas where MATLAB tools are applied. These areas include mathematics, physics, chemistry and chemical engineering, mechanical engineering, biological (molecular biology) and medical sciences, communication and control systems, digital signal, image and video processing, system modeling and simulation. Many interesting problems have been included throughout the book, and its contents will be beneficial for students and professionals in wide areas of interest.

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