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THE STUDY OF WIRELESS TRANSMISSION QUALITY IN A DS–CDMA SYSTEM

BY

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Abstract. The results of a study concerning the quality of transmission of mobile communication systems using DS – CDMA (Direct Sequence – Code Division Multiple Access) technology are presented. The aim of this study is to follow the evolution of bit error rate (BER) in a Gaussian noise (AWGN) environment, and in a fading (Rayleigh) environment, based on the number of users in the system. For this study we have used three types of code sequences: 1° *M* sequence, 2° Gold sequence and 3° Orthogonal Gold sequence. For each type of code sequence we have performed simulations with 4, 10 and 30 users. In order to simulate the transmission, we have used the QPSK modulation. The simulations have been performed using a Matlab-based program, called *algorithm CDMA*.

Key words: *M* sequence; Gold sequence; Orthogonal Gold sequence; bit error; bit energy/noise (Eb/NO) ratio.

1. Introduction

The development of communication and information processing technologies has created new opportunities for the mobile communication services. In the case of mobile communication systems, it is necessary that a

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large number of users to can send and receive in the same time signals from one or more base stations. For more users, to can use in the same time the resources of communications, it is necessary to establish a mode in which these resources be allocated to each user. The technique which assigns a common communication channel to multiple users is known as ***multiple access***. Fig. 1 illustrates a multiple access system.

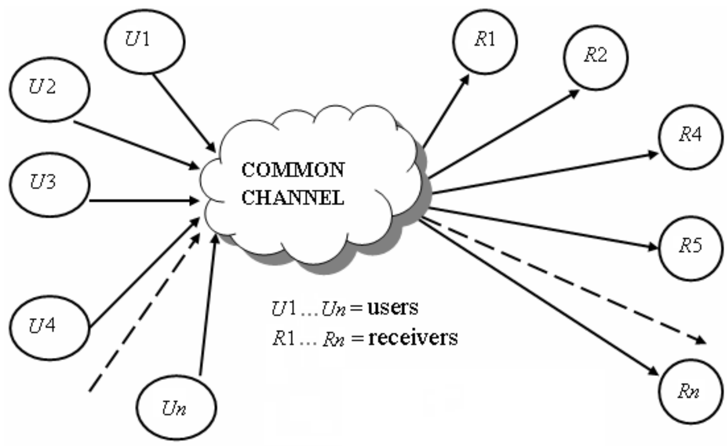

Fig. 1– Multiple access system.

According to Fig. 1, a number of users share a common communication channel to send information to a receiver.

2. Code Division Multiple Access

The CDMA (Code Division Multiple Access) technology is a multiple access communication technology in which the multiple access capacity is obtained through coding. In CDMA, to each user is assigned a unique code sequence which he uses to code the signal. The receiver recipient knows the code sequences used (Viterbi, 1995; Bogdan, 2008) by the sender and is able to decode the received signal and retrieve the original data (Ipatov, 2001). There are several techniques used to encode the useful signal, but the most widely used one is DS–CDMA (Direct Sequence – Code Division Multiple Access). The direct sequence is the best spread-spectrum technique known so far. The information signal (data signal) in DS–CDMA protocols is directly modulated with a ***pseudorandom noise*** digital code signal (a sequence of “chips”) having a very high rate (Shannon, 1949; Benedettos & Biglieri, 2008). The data signal can be analogous or digital. In most cases it is digital. In case of the digital signal, the data signal is directly multiplied by the spread sequence (code sequence), and the resulting signal modulates a wideband carrier. The name of the DS–CDMA protocol itself comes from this direct multiplication (Viterbi, 1995).

3. Configuration of a DS–CDMA System

Fig. 2 illustrates the configuration of a DS–CDMA system.

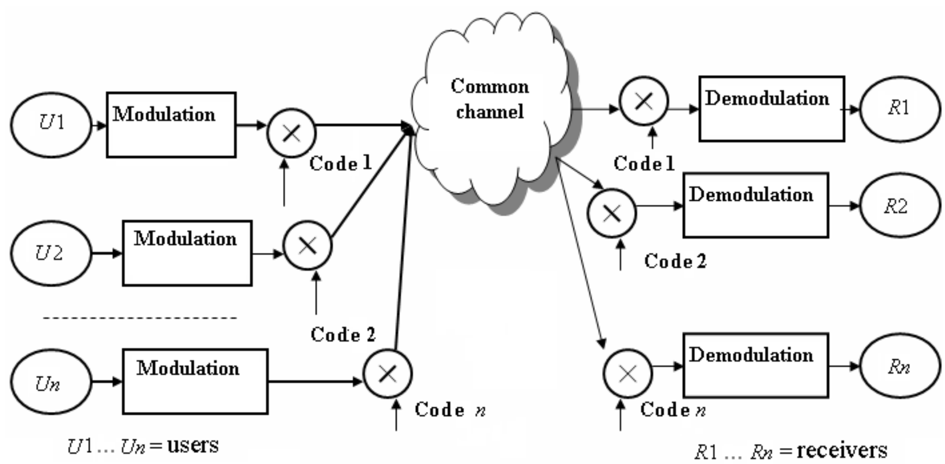

Fig. 2 – A synchronous DS–CDMA system.

In a DS-CDMA system, the users use their own code sequences to spread the data. The user data are modulated with the QPSK (Quadrature Phase Shift Keying) or BPSK (Binary Phase Shift Keying) modulation (Ipatov, 2001). After modulation, the first bits of the modulated data are spread using a code sequence: *M* sequences, Gold sequences and Orthogonal Gold sequences. The spread data of all users are simultaneously sent to the base station using the same communication channel. The base station detects each user's information-carrying data by correlating the received signal with a code sequence assigned to each user.

4. Assessing Bit Error Rates in an AWGN Environment

We have assessed the bit error rate in an AWGN environment using three types of code sequences: 1° *M* sequence, 2° Gold sequence and 3° Orthogonal Gold sequence. For each type of code sequence we have performed simulations with 4, 10 and 30 users. For all the simulations, we have taken into account an Eb/NO signal/noise ratio variation of 0…10 dB. In order to simulate the transmission, we have used the QPSK modulation. The simulations have been performed using a Matlab-based program, called *CDMA algorithm*. Figs. 3,…,5 illustrate the results of the simulations.

Fig. 3 illustrates the evolution of bit error rate (BER) for *M* sequence in an AWGN environment. The data yielded by the simulations, which the graphs are based on, are as follows: for 4 users, BER varies between 7.897500e-002 and 0.000000e+000, for 10 users, BER varies between 7.966500e-002 and

1.500000e-005, and for 30 users, BER varies between 8.426333e-002 and 2.100000e-004. The results show an ascending trend of the BER when the number of users in the system increases. This increase is determined by the fact that the autocorrelation of *M* sequences in the synchronization point is different from zero, and this different-from-zero value becomes a disturbing signal for the other users in the system. The more users there are, the stronger the disturbance is.

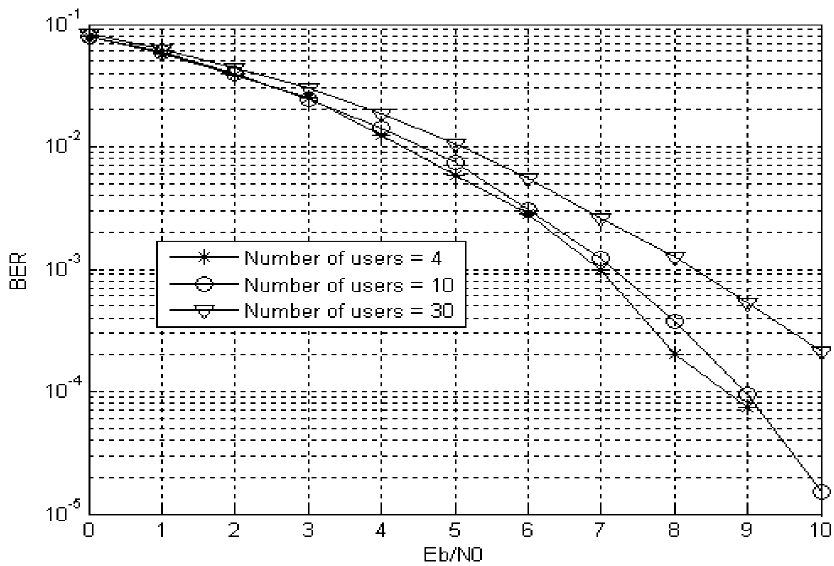

Fig. 3 – BER for M sequence in an AWGN environment, with 4, 10 and 30 users.

Fig. 4 illustrates the evolution of bit error rate (BER) of Gold sequence in an AWGN environment. The simulations have yielded the following data: for 4 users, BER varies between 7.873750e-002 and 1.250000e-005, for 10 users, BER varies between 7.932500e-002 and 3.000000e-005, and for 30 users, BER varies between 8.441500e-002 and 2.083333e-004. The results show an ascending trend of the BER when the number of users in the system increases. This evolution resembles to that of *M* sequences. This can be explained by the fact that both for *M* sequences simulation, and for the generation of Gold sequences, we have used preferred pair *M* sequences. The small differences are due to the *random function* in Matlab (Ghinea, 1997), which helps to generate the Gaussian noise.

Fig. 5 illustrates the evolution of bit error rate for the Orthogonal Gold sequence in an AWGN environment. The data yielded by the simulations, which the graphs are based on are as follows: for 4 users, BER varies between 7.783500e-002 and 5.000000e-006, for 10 users, BER varies between 7.866700e-002 and 3.000000e-006, and for 30 users, BER varies between 7.874833e-002 and 3.000000e-006. The results show that the bit error rate (BER) remains constant when the number of users in the system increases.

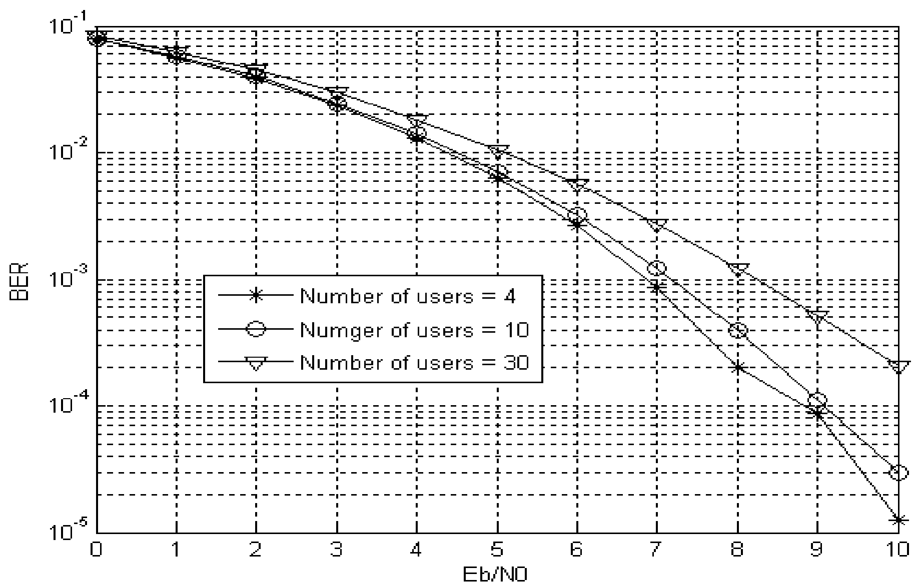

Fig. 4 – BER for Gold sequence in an AWGN environment, with 4, 10 and 30 users.

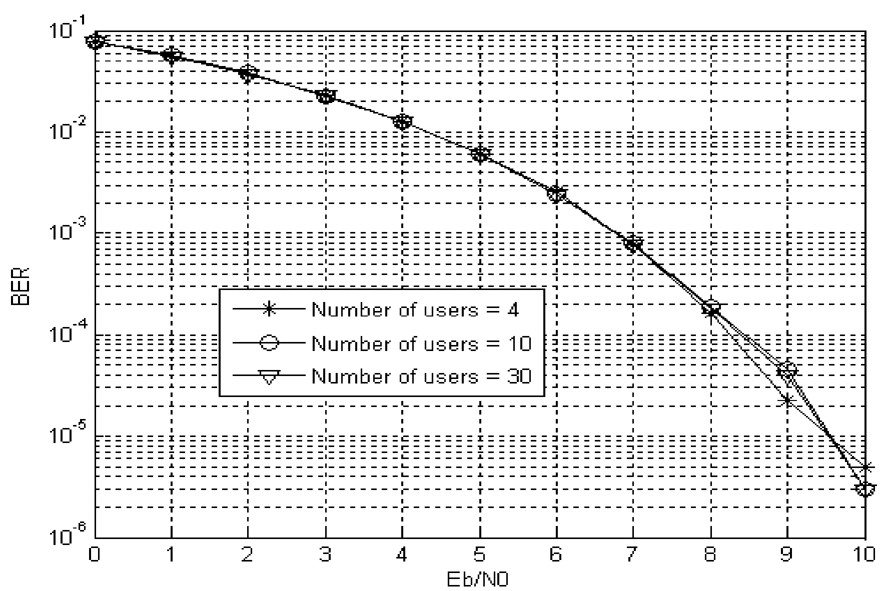

Fig. 5 – BER for Orthogonal Gold sequence in an AWGN environment, with 4, 10 and 30 users.

5. Assessing the Bit Error Rate in a Rayleigh Environment

The study takes into account three types of code sequences: 1° *M* sequence, 2° Gold sequence and 3° Orthogonal Gold sequence. For each type of code sequence we have performed simulations with 4, 10 and 30 users. For all the simulations we have taken into account an Eb/NO signal/noise ratio variation of 0…20 dB. In order to simulate the transmission, we have used the QPSK modulation. The simulations have been performed using a Matlab-based program, called *CDMA algorithm*.

The results of the simulations are shown in Figs. 6,…,9.

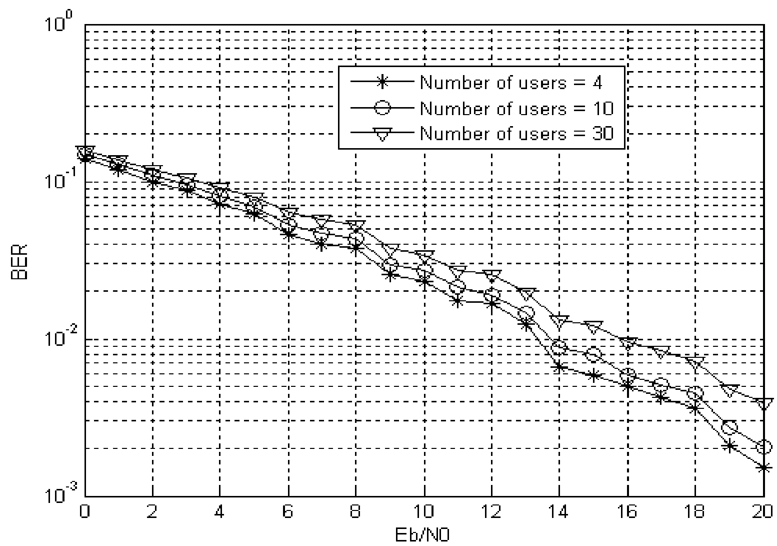

Fig. 6 – BER for *M* sequence in a Rayleigh environment, with 4, 10 and 30 users.

Fig. 6 illustrates the evolution of BER for the *M* sequences in a Rayleigh environment. The data yielded by the simulations, which the graphs are based on, are as follows: for 4 users, BER varies between 1.396400e-001 and 1.510000e-003, for 10 users, BER varies between 1.485250e-001 and 2.042500e-003, and for 30 users, BER varies between 1.576129e-001 and 3.930000e-003. The results indicate an ascending trend for an increase of the number of users in the system. This increase is determined by the fact that the autocorrelation of *M* sequences in the synchronization point is different from zero, and this different-from-zero value becomes a disturbing signal for the other users in the system. At the same time we have noticed that the BER in a Rayleigh environment is bigger than the BER in an AWGN environment. This difference is the result of the fading phenomenon which occurs in a Rayleigh environment. In order to minimize this phenomenon, the correlation of sequences has to have least value possible. The value of correlation in the case of *M* sequences has several maximums over one period. The least value of correlation occurs in the case of preferred pair *M* sequences.

Fig. 7 illustrates the evolution of BER for a non-preferred pair *M* sequences. The data yielded by the simulations, which the graphs are based on, are as follows: for 4 users, BER varies between 1.396400e-001 and 1.510000e-003, for 10 users, BER varies between 1.485250e-001 and 2.042500e-003, and for 30 users, BER varies between 3.585100e-001 and 3.437500e-001. The results show an accelerating increase of BER when the number of users increases. Thus, when we have 30 users in the system, the BER remains 10^{-1} and thus the data cannot be retrieved. This result shows that the non-preferred pair *M* sequences in a Rayleigh environment are not suitable for spreading the signal.

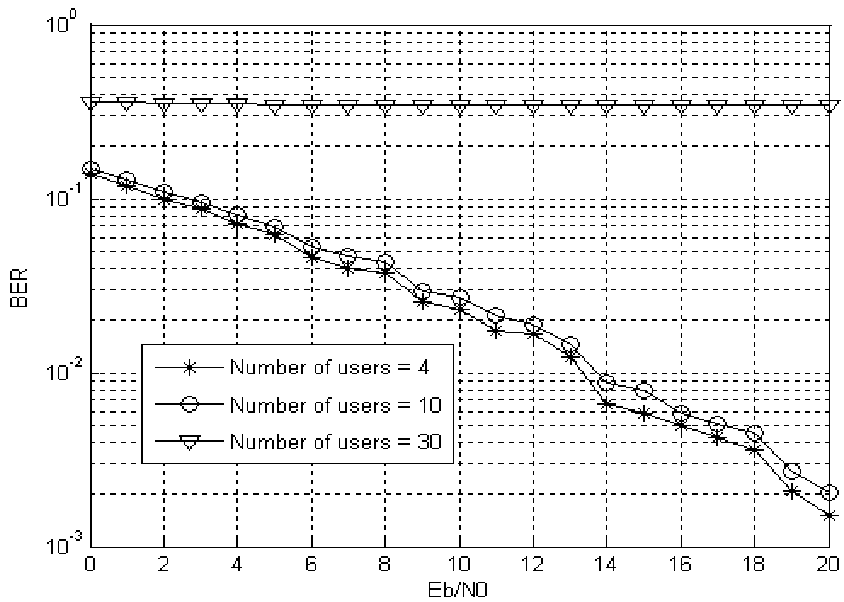

Fig. 7 – BER for a non-preferred pair *M* sequences, with 4, 10 and 30 users.

Fig. 8 illustrates the evolution of BER for the Gold sequence in a Rayleigh environment. The data yielded by the simulations, which the graphs are based on, are as follows: for 4 users, BER varies between 1.386300e-001 and 1.660000e-003, for 10 users, BER varies between 1.488675e-001 and 2.077500e-003, and for 30 users, BER varies between 1.572671e-001 and 3.834286e-003. The obtained results show an increase of the BER once the number of users in the system increases. This evolution resembles to that of the non-preferred pair *M* sequences.

Fig. 9 illustrates the evolution of BER for the Orthogonal Gold sequence in a Rayleigh environment. The simulations have yielded the following results: for 4, 10 and 30 users, BER varies between 1.392100e-001 and 1.660000e-003. This shows that BER remains constant as we increase the number of users in the system.

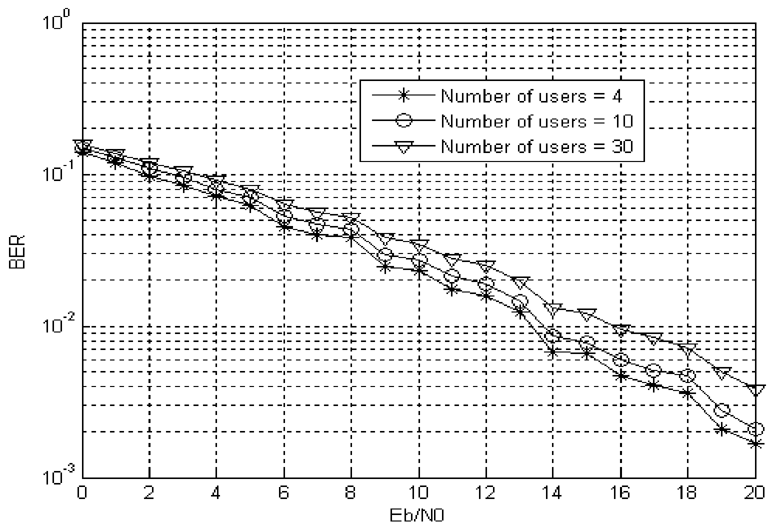

Fig. 8 – BER for Gold sequence in a Rayleigh environment, with 4, 10 and 30 users.

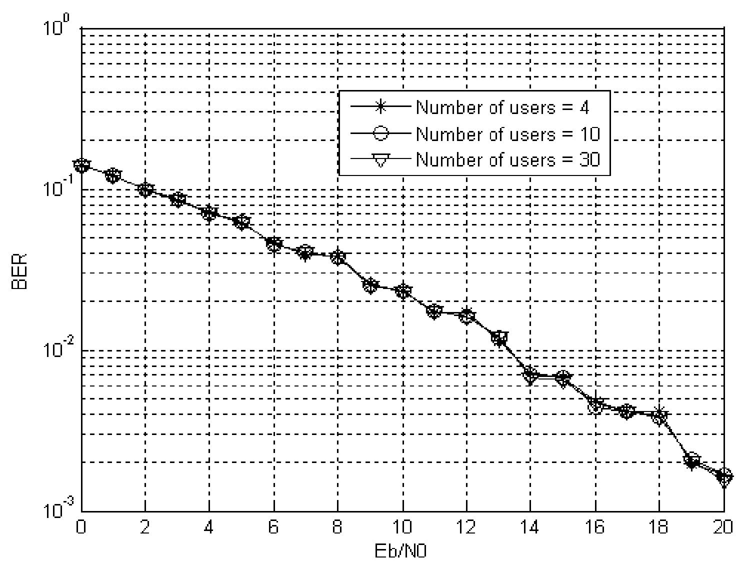

Fig. 9 – BER for Orthogonal Gold sequence in a Rayleigh environment, with 4, 10 and 30 users.

6. Conclusions

Based on the analysis of the simulation results and of the graphs above, we can draw the following conclusions:

1° When using *M* sequences to spread the signals both in an AWGN, and in a Rayleigh environment, the bit error rate (BER) increases once the number of users in the system increases as well. The bit error rate depends very much on the type of *M* sequences being used. If we use preferred pair *M* sequences, the BER is less compared to the case when we use ordinary *M* sequences. This difference is noticeable only in the Rayleigh environment. The behaviour of the *M* sequence in AWGN and Rayleigh environments can be explained as follows:

a) When increasing the number of users, the bit error rate has an ascending trend because the autocorrelation of *M* sequences is different from zero in the synchronization point, and this different-from-zero value becomes a disturbing signal for the other users in the system. This phenomenon influences BER both in an AWGN and in a Rayleigh environment.

b) The dependence of BER on the type of *M* sequences used to spread the signal in a Rayleigh environment could be explained through the fact the preferred pair sequences have a better correlation than the ordinary *M* sequences. In order to minimize the fading effect in a Rayleigh environment, the correlation of sequences has to have least value possible. From this point of view, the preferred pair *M* sequences are the most suitable.

2° In the case of Gold sequences, the bit error rate (BER) is similar to the one of *M* sequences. This can be explained by the fact that both for *M* sequences simulation, and for the generation of Gold sequences, we have used preferred pair *M* sequences.

3° When using Orthogonal Gold sequences to spread the signal, the bit error rate (BER) remains constant when we increase the number of users. This can be explained by the fact that the autocorrelation of Orthogonal Gold sequences is zero in the synchronization point. Thus, the data can be retrieved with a very small error even when the system has many users. At the same time, we notice that the BER is bigger in a Rayleigh environment than in an AWGN one. This can be explained by the fact that, even the correlation of the Orthogonal Gold sequence is zero during the period of a code sequence, it is different from zero on certain areas, and this different-from-zero value produces big errors when retrieving the data.

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STUDIUL CALITĂȚII TRANSMISIEI WIRELESS ÎNTR-UN SISTEM CU ACCES MULTIPLU DS–CDMA

(Rezumat)

S-a efectuat un studiu al calității transmisiei pentru un sistem de comunicație mobilă care utilizează tehnologia *Acces Multiplu cu Divizare in cod cu Secvență Direct*ă (DS – CDMA Direct Sequence – Code Division Multiple Access). Scopul acestui studiu este de a urmări evoluția erorii de bit (BER) în mediu cu zgomot Gaussian (AWGN) şi în mediu cu fading (Rayleigh) în funcție de numărul de utilizatori din sistem. Studiul s-a realizat pentru trei tipuri de secvențe de cod: 1° secvență *M*, 2° secvență Gold şi 3° secvență Gold ortogonal, iar pentru fiecare tip de secvență de cod s-au realizat simulări cu 4, 10 şi 30 utilizatori. Pentru toate simulările s-a considerat o variație a raportului semnal zgomot, Eb/NO, cuprins între 0...20 dB. Tipul de modulație folosit pentru simularea transmisiei este QPSK. Simulările s-au realizat cu ajutorul programului realizat în Matlab, numit *algoritm CDMA*.