THE STUDY OF BIT ERROR RATE EVOLUTION IN A MOBILE COMMUNICATIONS SYSTEM USING DS – CDMA TECHNOLOGY

POPA ION*

Technical University "Gheorghe Asachi" Bd. Dimitrie Mangeron, nr 67, 700050 Iasi
Departament: Faculty of Electronics, Telecommunications and Information Technology

Abstract: This paper follows the study of bit error rate evolution in a mobile communications system using DS – CDMA (Direct Sequence – Code Division Multiple Access) technology. We have assessed the bit error rate (BER) based on the signal/noise ratio, Eb/N0, and the number of users in the system. For this purpose, we have used M sequence and Orthogonal Gold sequence and the AWGN (Additive white Gaussian noise) transmission medium**.**

Keywords: M sequence, orthogonal Gold sequence, bit error, cross-correlation

1. INTRODUCTION

The development of communication and information processing technologies created new opportunities for the new wireless communication services. In case of the wireless mobile communication systems, there is the need of an increasing number of users to send and receive signals simultaneously from one or more base stations. In order to manage this problem in a correct manner, one must find ways and techniques to distribute the resources as efficiently as possible, so that all users could gain access to enough resources which would facilitate an optimum transmission quality. The technique which assigns a common communication channel to multiple users is known as ***"multiple access".***

The CDMA (*Code Division Multiple Access*) technology is a multiple access communication technology in which the multiple access capacity is attained by means of encoding. In CDMA (*Code Division Multiple Access*), each user is assigned a unique code sequence which he uses to code the signal. The recipient knows the code sequences used by the sender and is able to decode the received signal and retrieve the original data. 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 [1]. 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. 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 [1]. Figure 1 shows the basic principle of a digital communication system based on direct-sequence spread spectrum (SS-DS).

*Corresponding author, email: ioanpopa57@yahoo.com

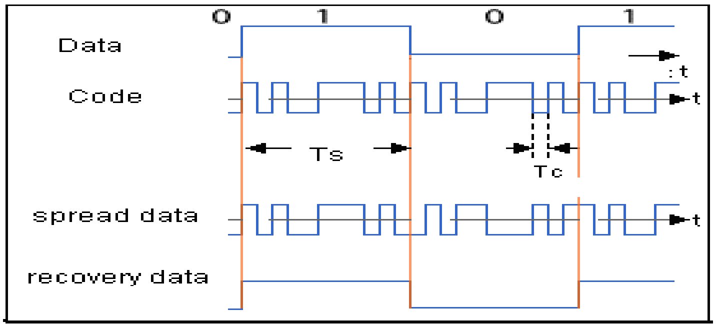

Fig. 1. Direct-sequence spread spectrum.

The symbol rate is $R_s = 1/T_s$ and the chip rate is $R_c = 1/T_c$. Each time symbol T_s in time multiple chips $T_c << Ts$. $N = T_s/T_c$ ratio represents the bandwidth extension rate (spread factor or processing gain). This coding spreads the original power of the signal over a much larger bandwidth, which entails a much smaller power density. The ratio between the transmission band and the information signal band is called "the processing gain", G_p, of the spread spectrum system:

$$G_p = \frac{B_t}{B_i} \tag{1}$$

were B_i represents the information band and B_t is the transmission band. The spread data of all the users are simultaneously sent to the base station. The base station detects each user's data and correlates the received signal with a code sequence which is synchronously generated with the code sequence assigned to each user. The useful signal (the data signal sent by the user) is obtained through the process of correlating the received signal

2. THE PROPERTIES OF SPREAD SPECTRUM

Due to the coding and larger bandwidth, certain properties of the spread spectrum signals differ from those of the narrowband. We shall review the most interesting properties from the point of view of communication systems. We shall briefly explain each property.

2.1. Multiple-access capability

If several users transmit a spread spectrum signal simultaneously, the receiver will be able to differentiate between the users if each one of these has a unique code which presents a small enough correlation with other codes. The correlation of the received signal with the code sequence of a certain user will result in the signal re-compression of that user, while the rest of the signals will remain with spread spectrum. Thus, within the band width of the information signal, the power of the wanted user will be much stronger than the interference power, provided there isn't much interference, and so the signal can be extracted. Figure 2 shows the multiple access capacity.

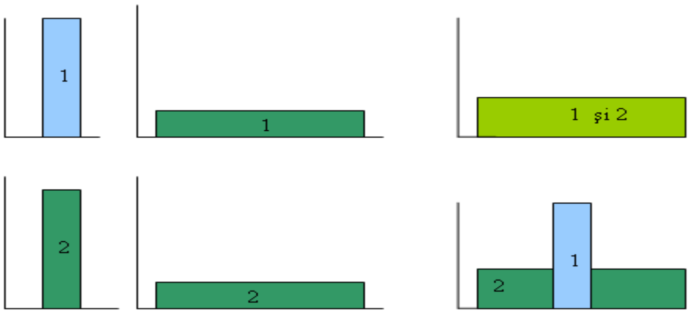

Fig. 2. Principles of SS multiple access:
a) spread; b) "un-spread".

Figure 2(a) shows the situation of two users who generate a spread spectrum signal from the narrowband data signals. In Figure 2(b), both users transmit the spread spectrum signals simultaneously. While being received, only the signal coming from user 1 is "un-spread" and the date can be retrieved.

2.2. Privacy
The code for a certain group of users is sent only to the authorized users. Thus the communication is protected against eavesdropping, because the transmission cannot be decoded by the unauthorized users, who do not know the code [2].

2.3. Interference rejection
The cross-correlation of the code signal and narrowband signal will spread the power of the band signal, thus reducing the power of interference in the band of the information signal. Figure 3 illustrates the above mentioned case. The spread spectrum signals receive narrowband interference. While being received, the spread spectrum signal is "un-spread", while the interference signal is spread, which makes it look like background noise compared to the "un-spread" signal [3].

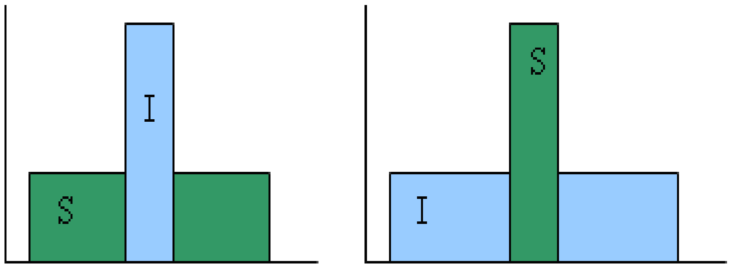

Fig. 3. Interference rejection.

2.4. Antijamming capability especially narrowband jamming
The jamming source cannot use observations on the signal to increase its performances and must use jamming techniques which are independent from the signal to be jammed. Due to the fact the narrowband data signal is spread over a wide domain, the jamming source, which has a fixed total power (in order to completely disrupt communication) has two choices: either to spread this power over the entire domain, thus reducing its interference power over each portion, or to use its entire power to jam a small portion of the band, while the rest of the domain remains clear of jamming.

***2*.5. Low probability of interception or cover operation**
Due to its low density, the spread spectrum signal is hard to detect t.

2.6. Protection against multipath interference
A radio channel contains several paths between the emitter and the receiver. Due to the reflection and refraction processes, the useful signal can reach the receiver on several paths. The signals arriving on different paths are duplicates of the transmitted signal, with different amplitudes and phases. For certain frequencies, adding these signals to the original, transmitted signal can have a positive impact, while for others it can have a negative impact. If the added signals are in sync, the amplitude of the resulting signal will increase. If the signals are out of sync, the amplitude will decrease. This phenomenon is known as fading. The spread spectrum modulation can counteract these interferences, but this depends very much on the type of modulation being used. In case of a FDMA (*Frequency-division multiple access*) set-up, the user being assigned a certain portion of the spectrum will experience a serious communication disturbance as long as there is fading. In case of a TH-TDMA set-up, communication will be affected as long as the user "hops" into a portion of spectrum which is affected by fading. In case of CDMA, the fading will affect the communication of all users as long as it is active [3].

3. AWGN CHANNEL

The quality of the received signal depends very much on the communication channel being used. In the case of wireless communication, the transmission channel is the environment itself, whose properties could affect the quality of a transmission. In case of a wireless transmission, the degree of disturbance depends on the configuration of the environment. If the transmission between the user and the base station is achieved solely by means of a direct wave (no obstacles between the user and the base station), and the transmitted signal reaches the user through a single path, the quality of the received signal will be affected solely by the Gaussian noise specific to the environment, herein known as **AWGN**.

If the transmission between the user and the base station takes place in cities or in an environment with large obstacles, such as hills and mountains, where the transmission does not reply solely on the direct wave, and the transmitted signal reaches its destination over several paths, due to the reflections against the relief, the quality of received signal is very much affected by the presence of reflected and diffracted, which reach the receiver at the same time as the direct wave. In this case, the transmission is affected by fading, and the medium it takes place is known as **Rayleigh fading environment**.

In order to study the performance of a AWGN noise channel, first we have to build the mathematical model of that channel. The mathematical model of a transmission channel with AWGN noise is based on the idea that this channel adds the Gaussian white noise to the useful signal, as illustrated in Figure 4 [4].

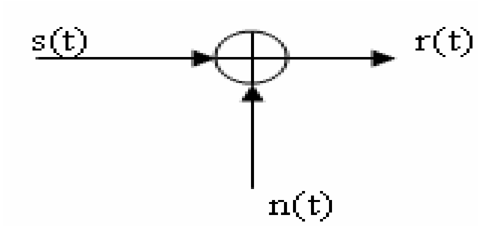

Fig. 4. Additive white Gaussian noise.

In this case, the received signal is calculated using the formula below (2),

$$r(t) = s(t) + n(t) \quad (2)$$

where r(t) is the received signal, s(t) is the transmitted signal, and n(t) is the Gaussian white noise. In order to generate such a signal, we can use *"randn" function* in Matlab software. If we mark the input signal of the communication channel as *indata(t)*, the output signal of the communication channel, being affected by the Gaussian white noise, marked with *iout* is given by (3) [4]:

$$iout(t) = indata(t) + randn(t) \quad (3)$$

Taking into account that we calculate BER performance o by varying the power of the noise signal, which is marked as *npow*, and also that the input signal is a voltage, we must define a variable which changes the notation of *npow* from power into voltage. This variable will be known as *attn* and is given by (4):

$$attn = \frac{1}{2}\sqrt{npow} \quad (4)$$

Under these circumstances, the output signal of the communication channel, being affected by the voltage Gaussian noise, *npow*, is given by (5):

$$iout(t) = indata(t) + attn \times randn(t) \quad (5)$$

Using this data, we are able to conceive a program which would help us simulate the addition of AWGN signal to any useful signal transmitted through the communication channel.

We have used the QPSK modulation for the performance study of a DS-CDMA system [5].

4. RESULTS OF THE ASSESSMENT

Figure 5 illustrates the BER assessment of a DS-CDMA system in an AWGN environment. In case of M sequence, the value of cross-correlation is not 0 at the point of synchronization. Thus, this different from zero correlation becomes interference for other users. As a consequence, as the number of users increases, BER increases. On the other hand, in case of an Orthogonal Gold sequence, the value of cross-correlation between users is 0 at the point of synchronization. This means that, as the number of users increases, the value of BER reaches the theoretical value. The BER assessment for an Orthogonal Gold sequence is illustrated in Figures 6, 7 8 and 9.

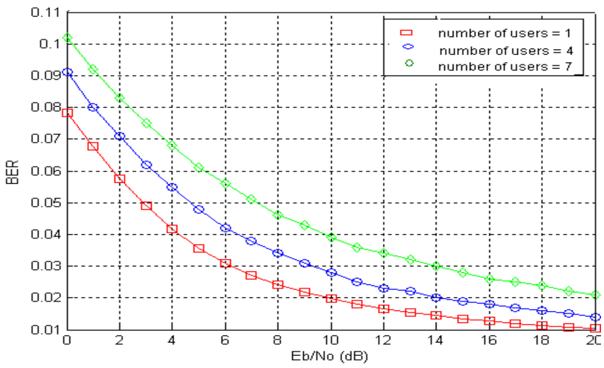

Fig. 5. BER assessment in a AWGN environment, using the M sequence for one, four and seven users.

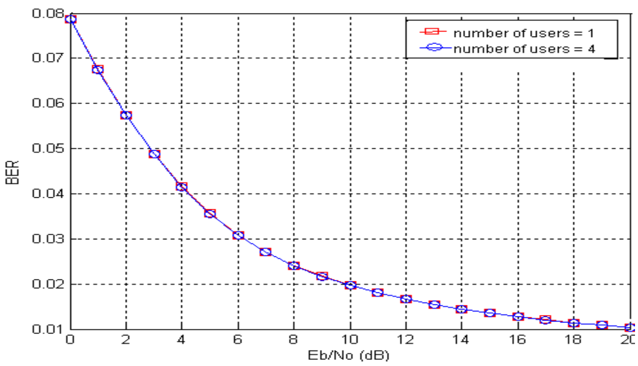

Fig. 6. BER assessment in a AWGN environment, using the Orthogonal Gold sequence for one and four users.

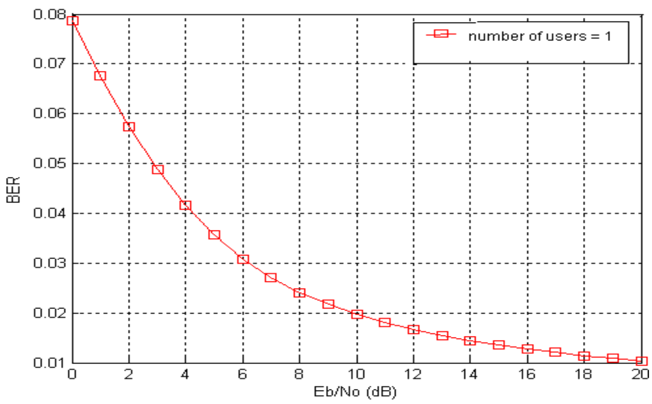

Fig. 7. BER assessment in a AWGN environment, using the Orthogonal Gold sequence for one user.

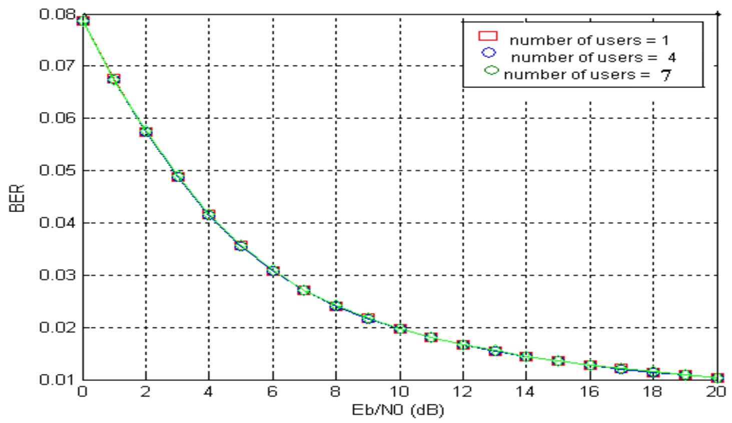

Fig. 8. BER assessment in a AWGN environment, using the Orthogonal Gold sequence for one, four and seven users.

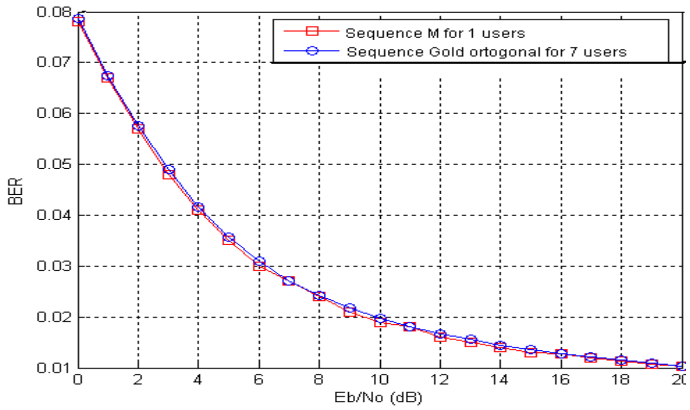

Fig. 9. BER assessment in AWGN environment using the M sequence with one user and orthogonal Gold sequence with seven users.

5. CONCLUSIONS

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

1) When using M sequences for spreading the signals in an AWGN environment, as the number of users increases, the bit error rate (BER) increases, too. See Figure 5. This phenomenon can be explained by the fact that the self-correlation of M sequences is not zero at the point of synchronization, and this different from zero value becomes interference for the other users in the system.

2) When using Orthogonal Gold sequences for spreading the signals, the value of bit error rate (BER) is closer to the theoretical value and it remains unchanged as the number the users increases (see Figures 6, 7 and 8). This phenomenon can be explained by the fact that the self-correlation of Orthogonal Gold sequences is zero at the point of synchronization.

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