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Evaluation of Error Rate Performance of Code Spread CDMA System using Simulations

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Abstract: - This paper discusses the low rate channel coding technique. Its BER performance is compared to that of direct sequence spreading. Also the CS – CDMA (Code – spread system) and DS – CDMA (traditional CDMA) systems are studied for different channels and modulation schemes. Results are evaluated in terms of BER versus the signal – to – noise ratio. The CS – CDMA system gives a better performance than the traditional CDMA systems. It is observed that the choice of the modulation scheme depends on the channel and has a profound effect on the BER.

Key-Words: - CDMA, Low error rate, Optimum distance spectrum code, Rayleigh Channel, AWGN Channel, Interleaver.

1 Introduction

CDMA systems [1][2] are currently a subject of great interest in wireless communication because of their inherent robustness in multi-path fading channels [2] and as a multiple access technique [3]. Traditional CDMA [4] can be described as a low rate repetition coding followed by scrambling. Repetition codes have a minimum distance which is far from the best for the given rate. Moreover, in most applications the information bits are channel coded [5] before being applied to the CDMA modulator. An alternative [6][7] is to do the coding and spreading using one single low rate channel code. Such a system is called as code – spread system [8]. In [9] it is proposed to use orthogonal convolutional codes for spreading. A comparison between orthogonal and bi-orthogonal codes is given in [10]. By modifying the orthogonal codes, one can obtain an improved class of low rate codes called super orthogonal convolutional codes [11]. In [8] a detailed comparison between all these codes is presented. In this paper an attempt is made to show that the code spread system based on ODS codes [12] performs better than the conventional systems in different transmission scenarios. In this context, simulation results are presented using different modulation schemes, interleaver sizes and channels.

2 Problem Formulation

2.1 System Description

2.1.1 Code-Spread System

The code – spread CDMA system investigated in this paper is schematically shown in Fig. 1

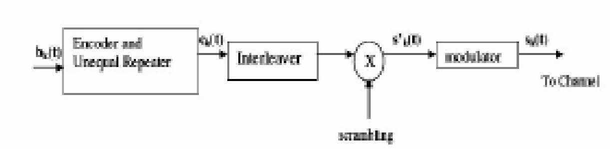

Fig. 1 Code – Spread System

The bandwidth expansion is achieved by a low rate (R=1/n) convolutional code, producing n coded symbols per information bit. The convolutional code is an ODS code. The symbols are then interleaved by a block interleaver. The interleaved sequence is randomized by a scrambler and finally modulated by the modulator. The signal from the kth user sk(t) is transmitted over the mobile radio channel. Similar signals from other users add to it resulting in the received signal.

2.1.2 Conventionally coded and spread CDMA system

In conventional systems, most of the bandwidth expansion is due to direct sequence spreading. The conventional system considered for simulations is shown in Fig. 2. The channel interleaving is performed before spreading. In literature such systems are called as symbol interleaved systems.

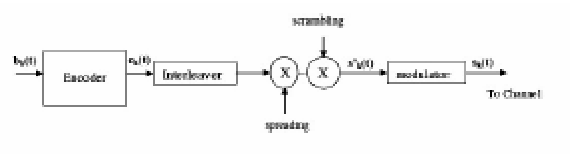

Fig.2. Conventional coding and spreading

2.1.3 Performance Evaluation

The bit error performance of convolutional codes can be approximated by applying a union bound [13][14] on the bit error probability given by

$$P_b < \sum_{d=d_f}^{\infty} c_d P_d \qquad (1)$$

where c_d is the sum of bit errors of distance d and d_f is the free distance code. Furthermore P_d is the probability that an error path of distance d is chosen instead of the all zero path. This pairwise error probability P_d depends on the channel. For coherent BPSK or an AWGN channel.

$$P_d = Q\left(\sqrt{(2dE_b)/(N_0)}\right) \qquad (2)$$

where E_b represents the received energy per information bit, $N_0/2$ is the double – sided power spectrum density of the noise process and $Q(x) = (\sqrt{2\pi})^{-1}\int_x^{\infty} e^{-z^2/2}dz$. For BPSK modulation on an uncorrelated Rayleigh – fading channel with perfect channel estimates and soft – decision decoding P_d is given by [13].

$$P_d = q^d \sum_{l=0}^{d-l} \binom{d-1+l}{l} (1-q)^l \qquad (3)$$

with $q = \frac{1}{2}(1-\sqrt{\bar{\gamma}_b/(1+\bar{\gamma}_b)})$ where $\bar{\gamma}_b$ is the effective signal to noise ratio. An expression for $\bar{\gamma}_b$ is obtained using the Gaussian approximation [14] and is given by

$$\bar{\gamma}_b = \left(\gamma_b^{-1} + \frac{2(kL-1)}{3\beta}\right)^{-1} \qquad (4)$$

where k is the no. of users

L is the no. taps in the channel.

$\beta = N_{spread}$ (spreading factor)

and $\gamma_b = RE_b / LN_0$

In this when only coding is used for bandwidth expansion N_{spread} is taken to be unity.

Similar analysis [13] can be done for BPSK and DFSK using

$$q = \begin{cases} \frac{1}{2}\left(1-\sqrt{\frac{\bar{\gamma}_b}{2+\bar{\gamma}_b}}\right) & \text{for binary coherent FSK} \\ \frac{1}{2(1+\bar{\gamma}_b)} & \text{for binary coherent DPSK} \end{cases}$$

(5)

3 Problem Solution

Two different coding configurations are considered for simulation e.g.

a) Conventional system using rate 1/2 encoder with spreading factor of 8.

b) Code – spread system using rate 1/16 encoder with unity spreading factor. Fig. 3 shows the results obtained for the Code – spread system with (k=) 2, 4, 8, 16 and 32 users with a 64 x 64 block interleaver.

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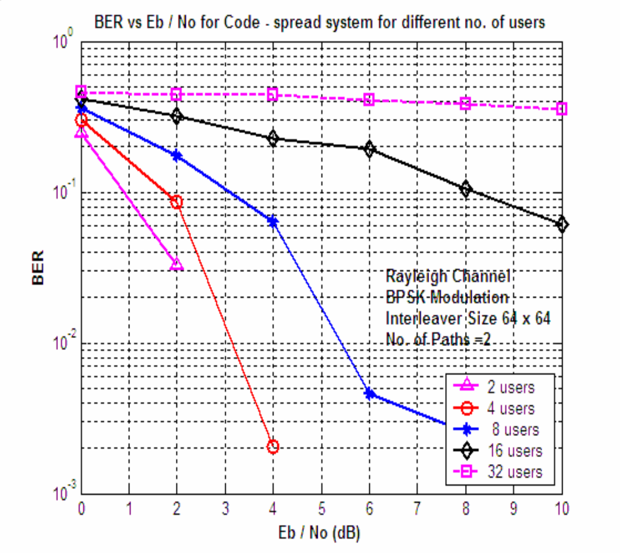

Fig. 3 BER as a function of Eb / No for the Code – spread system, n=16,Nspread=1,K=8 and k = 2,4,8, 16,32 users for interleaver size of 64 x 64 and Rayleigh Channel.

It is assumed that the channel is Rayleigh fading and the modulation is BPSK. It can be seen that the BER for the Code – spread system increases as the number of interfering users increase. Similar graphs are shown in fig. 4 for interleaver size 32 x 32.

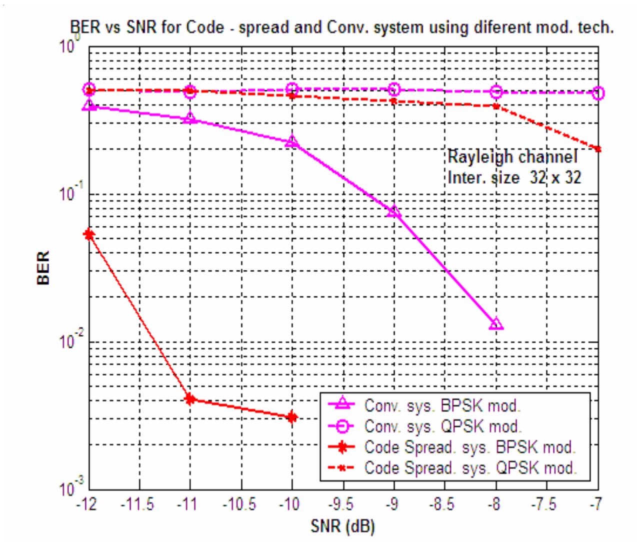

Fig. 4. BER as a function of SNR for (i) Code – spread system, n=16, Nspread 1 (ii) Conventional system, n=2, Nspread =8 with K = 8 for interleaver size of 32 x 32. Results are shown using BPSK and QPSK modulation techniques for Rayleigh Channel.

From both the plots it can be observed that the performance improves as the interleaver size is increased. For large interleaver sizes, the BER decreases rapidly to zero as E_b/N_0 is increased. This is because of the combating of the burst errors due to interleaving. However, the decrease in BER is not significant for very large interleaver size.Also from the simulation results presented in figure 4,it can be noted that Code – spread system performs better than the conventional system.

We now extend our analysis to different 2–ary modulation schemes to validate the results given by (1). Fig. 5 presents the comparison of the Code–spread system for three binary modulation schemes BPSK, BFSK and BASK. Relative comparisons with the DPSK based system is also presented. The system performs its best when BPSK modulation is used. The performance is somewhat similar for the system employing BASK technique. The system performs poorly when BFSK and DPSK techniques are used. This is quite justified in case of DPSK because of its inherent error propagation problem.

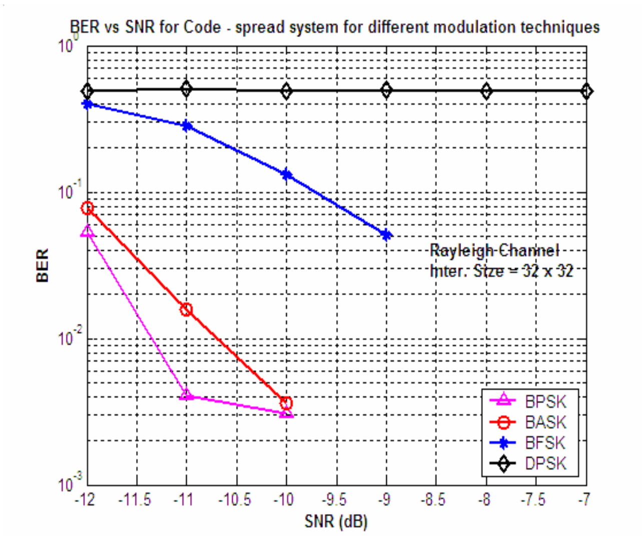

Fig. 5. BER as a function of SNR with constraint length K=8 for Code – spread system, N=16, N spread = 1 for interleaver size of 32 x 32. Results are shown for BPSK, BASK and DPSK modulation techniques for Rayleigh Channel.

While we have focused on Rayleigh channel for the simulation, similar results can be obtained using AWGN channel as well. Fig. 6 illustrates the effect of increasing the modulation order on the system. As in Rayleigh channel the system performs the best when BPSK modulation is used. Also the Code – spread system outperforms the conventional system in AWGN channel for the same modulation scheme.

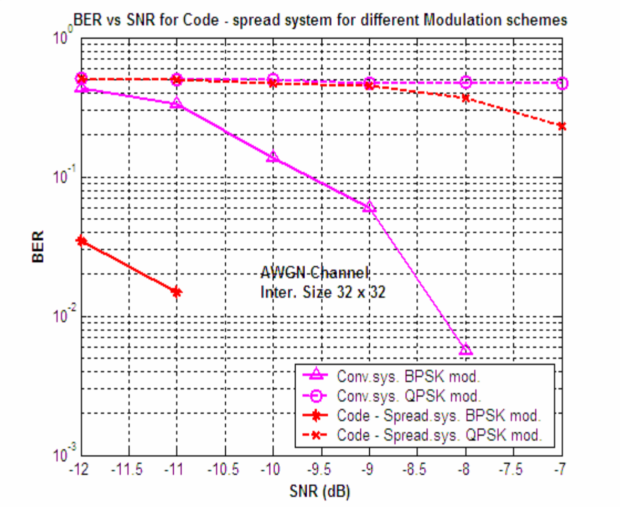

Fig. 6. BER as a function of SNR for (i) Code – spread system, n=16, Nspread = 1 (ii) Conventional system, n=2, Nspread =8 with = 8 for interleaver size of 32 x 32 . Results are shown using BPSK and QPSK modulation techniques for AWGN Channel.

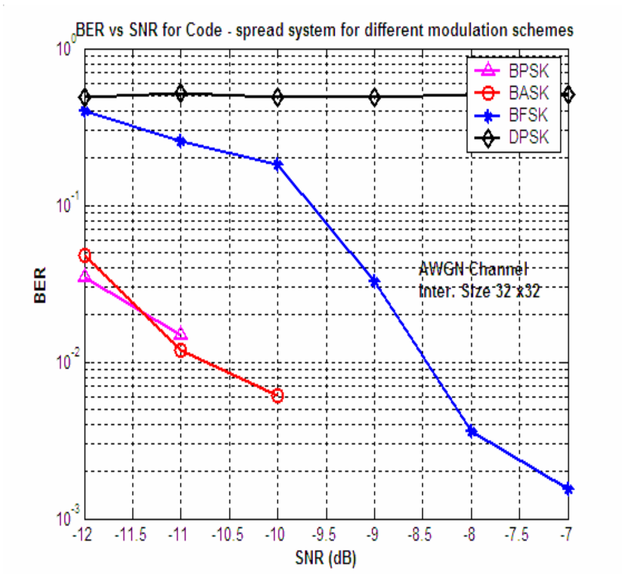

Fig. 7. BER as a function of SNR with constraint length K=8 for Code – spread system, N=16, Nspread = 1 for interleaver size of 32 x 32. Results are shown for BPSK, BASK and DPSK modulation techniques for AWGN Channel.

For systems using 2 – ary modulation scheme (Fig. 7) it can be observed that BPSK is a better option than DPSK and BFSK. This conclusion very well matches the system analysis done in [14]. In conclusion, Code – spread system may outperform the conventional system interms of error rate performance.

4 Conclusion

The interleaving and modulation schemes have been studied in detail using simulations for Code – spread systems. From these studies it is observed that the interleaver size influences the performance of the system. It is expected that these results may serve as a baseline for designing more efficient and less complex systems. Conventional system BPSK modulation used in both code spread system and conventional system give better performance on an AWGN channel.

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