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Performance Analysis of CDMA System using Direct Sequence Spread Spectrum and Frequency Hopping Spread Spectrum Techniques

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Keywords : AWGN, CDMA, DS-CDMA, BER, ISI, FFT, OFDM, SNR.

GJCST-E Classification : C.2.3

PERFORMANCE ANALYSIS OF CDMA SYSTEM USING DIRECT SEQUENCE SPREAD SPECTRUM AND FREQUENCY HOPPING SPREAD SPECTRUM TECHNIQUES

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I. Introduction

CODE-DIVISION multiple-access communication (CDMA) is an important emerging technology for underwater acoustic networks for both civilian and military purposes. CDMA permits random, overlapping access to a shared communication channel as required in an autonomous ocean-sampling network (AOSN) scenario. In combination with code-division multiple-access (CDMA) techniques, multicarrier modulation has attracted a lot of attention in the past decade for the future-generation wireless communications on account of countering channel frequency selectivity and removing inter-symbol interference (ISI) while supporting high-rate applications, providing frequency diversity, collecting the entire energy spread in the frequency domain, and simple implementation through Fast-Fourier-Transformation (FFT) techniques [1].

On the one hand, different configurations of multicarrier CDMA (MC-CDMA) schemes as combinations of direct-sequence CDMA (DS-CDMA) and orthogonal frequency-division multiplexing (OFDM) were developed after 1993 [1][2]. The performance and design of such systems have been investigated extensively in different non-fading and fading channels since then [2-8].

On the other hand, frequency-hopping spread-spectrum (FH-SS) techniques in combination with OFDM or MC-CDMA received considerable attention recently, and as a result, various multicarrier frequency-hopping (MC-FH) systems were proposed [9-11][13]. MC-FH schemes, on account of fewer subcarriers transmitted in each symbol interval, have smaller peak-to-average-power ratio (PAPR) than MC-CDMA systems, making the implementation of MC-FH systems less complex than MC-CDMA schemes especially in the uplink, where linear amplification with a large dynamic range at the transmitter side is not viable. The MC-FH system studied in this paper is the one described in [13][14], wherein the frequency spacing between diversity hopping sub-carriers in distinct frequency sub-bands is implemented in a way to diminish the correlation of fading gains on different sub-carriers, while keeping the region of hopping for a single sub-carrier so small that phase-shift keying (PSK) modulation and coherent detection are practically feasible [13]. This scheme was developed from a frequency-diversity spread-spectrum system, called FD-SS [12], for countering band-limited jamming interference [13]. It has been examined in a single-user fading channel [14], as well as in multi-user non-fading and fading channels with and without coding [15].

The purpose of this paper is to simulate and analysis the performance of CDMA system for that we will present: Signal to noise ratio on the BER performance using QPSK modulation techniques, Effect of number of multi-user on the BER performance and bit error performance(BER) for various estimation rates with a maximum Spread Spectrum.

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a) Introduction Code Division Multiple Access (CDMA)

The third multiple access technology which was designed to increase both the system capacity and the service quality is called CDMA. CDMA is a form of spread spectrum technology a family of digital communication techniques that have been used in military applications for many tears. It spreads the information contained in a particular signal of interest over a much greater bandwidth than the original signal at the same data rate, the capabilities of the spread spectrum technique for both anti-jam and low probability of undesired interception; make this technology suitable for multi-user applications. Fig.1 shows a general scheme of a CDMA system.

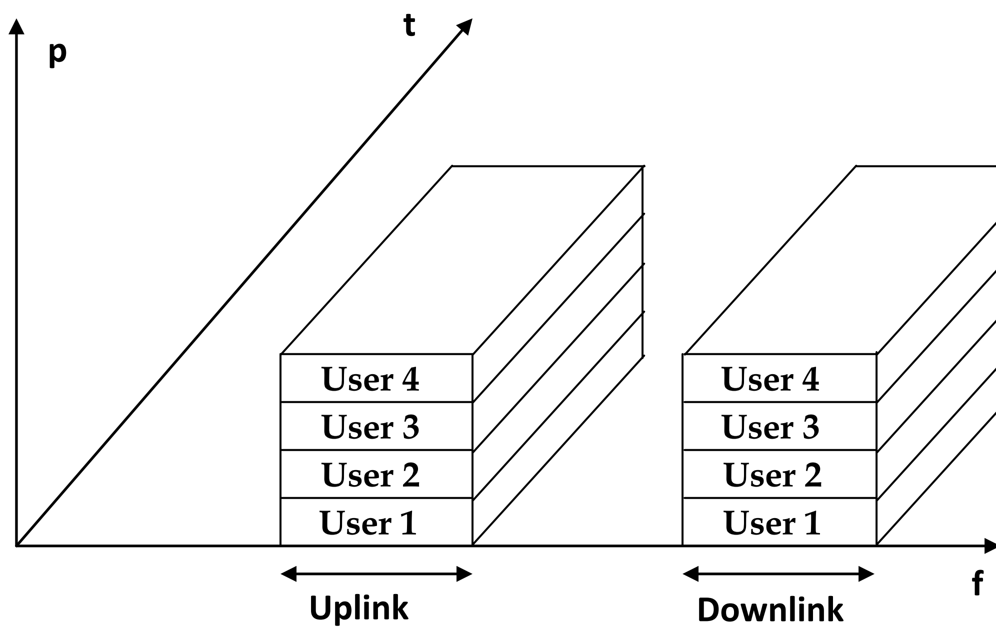

Figure 1 : General Scheme of a CDMA system

When CDMA is implemented in cellular systems, all users share a common channel in time and frequency. The separation is done using a code. Each user transmits with unique code, the spreading sequence, and since the receiver knows the user's code it can demodulate and extract the information. Usually, within a network there are two channels, one for the uplink (mobile to base station) and one for the downlink (base station to mobile). All users share both channels at the same time. The number of users which can communicate simultaneously is dependent, among other factors, such as, the length of the spreading sequence (code, a series of binary data), channel quality, receiver type, etc.

b) Spread Spectrum Concept

DS-CDMA systems are based on spread spectrum communications principles that provide a flexible and efficient framework for coverage and capacity sharing. The spread spectrum schemes are increase the radio links robustness against fading and interference.

1. Direct Sequence Spread Spectrum (DSSS) and
2. Frequency Hopping Spread Spectrum.

c) Direct Sequence Spread Spectrum (DSSS)

A pseudo-noise sequence pnt generated at the modulator, is used in conjunction with an M-ary PSK modulation to shift the phase of the PSK signal pseudo randomly, at the chipping rate Rc (=1/Tc) a rate that is an integer multiple of the symbol rate Rs (=1/Ts).The transmitted bandwidth is determined by the chip rate and by the base band filtering. The implementation limits the maximum chip rate Rc (clock rate) and thus the maximum spreading. The PSK modulation scheme requires a coherent demodulation.

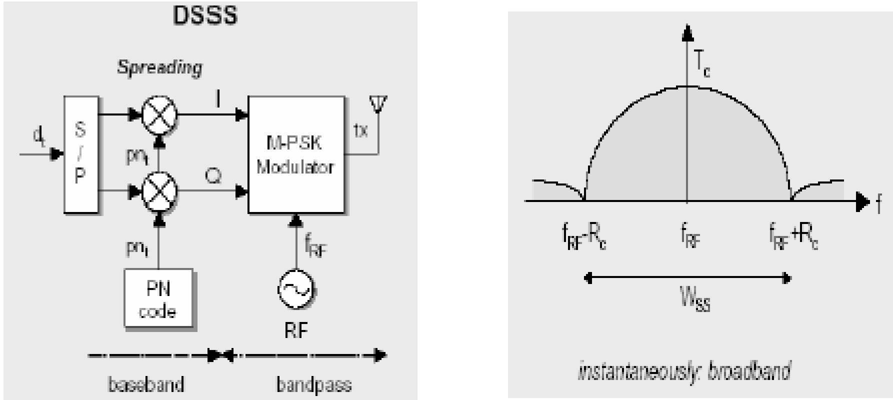

Figure 2 : Direct Sequence Spread Spectrum

A short-code system uses a PN code length equal a data symbol. A long-code system uses a PN code length that is much longer than a data symbol, so that a different chip pattern is associated with each symbol.

d) Frequency Hopping Spread Spectrum

A pseudo-noise sequence pni generated at the modulator is used in conjunction with all M-ary FSK modulation to shift the carrier frequency of the FSK signal pseudo randomly, at the hopping rate Rh .The transmitted signal occupies a number of frequencies in time, each for a period of time Th (=1/Rh), referred to as dwell time . FHSS divides the available bandwidth into N channels and hops between these channels according to the PN sequence. The PN generator feeds the frequency synthesizer a frequency word FW (a sequence of n chips) which dictates one of 2n frequency positions fhi transmitter and receiver follow the same frequency hop pattern.

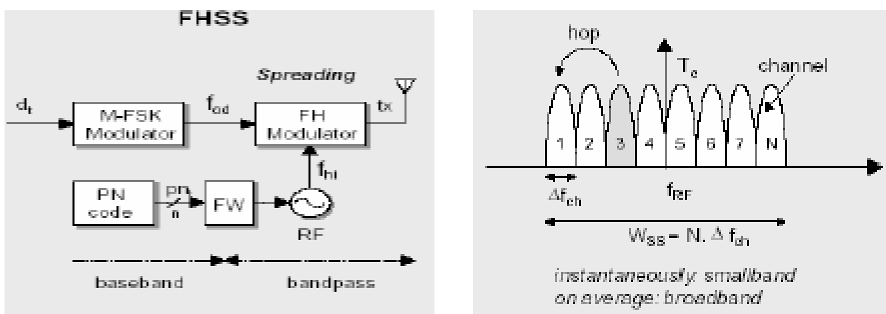

Figure 3 : Frequency Hopping Spread Spectrum

The transmitted bandwidth is determined by the lowest and highest hop positions and by the bandwidth per hop position (fch). For a given hop, the instantaneous occupied bandwidth is identical to bandwidth of the conventional M-FSK, which is typically much smaller than Wss. So the FSSS signal is a narrowband signal, all transmission power is concentrated on one channel. In the transmitter, the binary data dt is 'directly' multiplied with the PN sequence.

e) Pseudo Random (PN)

The pseudo random (PN) sequence is a bit stream of '1's and '0's occurring randomly, or almost randomly, with some unique properties. The pseudo random (PN) is widely used in direct sequence spread spectrum wireless communication systems, for example, synchronous CDMA or asynchronous CDMA. Due to the periodic nature of the PN sequence the frequency spectrum has spectral lines which become closer to each other with increasing sequence length Nc. Each line is further smeared by data scrambling, which spreads each spectral line and further fills in between the lines to make the spectrum more nearly continuous. The DC component is determined by the zero-one balance of the PN sequence.3.5 Spreading and Scrambling in the Uplink of DS-CDMA.

The most common PN code families are Walsh-Hadamard codes, m-sequences, Gold codes and Kasami codes. Walsh-Hadamard codes are orthogonal on zero code delay whereas the m-sequence, Gold codes and Kasami codes are nonorthogonal with varying cross-correlation properties. Walsh-Hadamard codes and Gold codes are used in uplink communication of WCDMA. In this section, we will emphasize Walsh-Hadamard codes and Gold-codes.

f) Hadamard Hadamard-Walsh Codes

The Hadamard-Walsh codes are generated in a set of N=2n. The generating algorithm is simple:

$$H_N=\begin{bmatrix} H_{N/2} & H_{N/2} \\ H_{N/2} & -H_{N/2} \end{bmatrix} \quad \text{with } H_0=[1]$$

The rows (or columns) of the matrix HN are the Hadamard-Walsh codes. In each case the first row (row 0) of the matrix consists entirely of 1s and each of the other rows contains N/2 0s and N/2 1s. Row N/2 starts with N/2 1s and ends with N/2 0s.

$$H_2=\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad H_4=\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \quad H_8=\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$$

The distance (number of different elements) between any pairs of rows is exactly N/2

Figure 4 : PN Sequence generator

g) DS-CDMA Simulation Model

There are many features of an DS-CDMA system that are more easily manipulated in a software situation. A very powerful and useful engineering software package is Matlab by MathWorks. It has many useful digital signal processing functions and features, which will prove to be useful in DS-CDMA simulation. A DS-CDMA system was modeled using Matlab to allow various parameters of the system to be varied and tested. The model is shown in Figure 5.6.

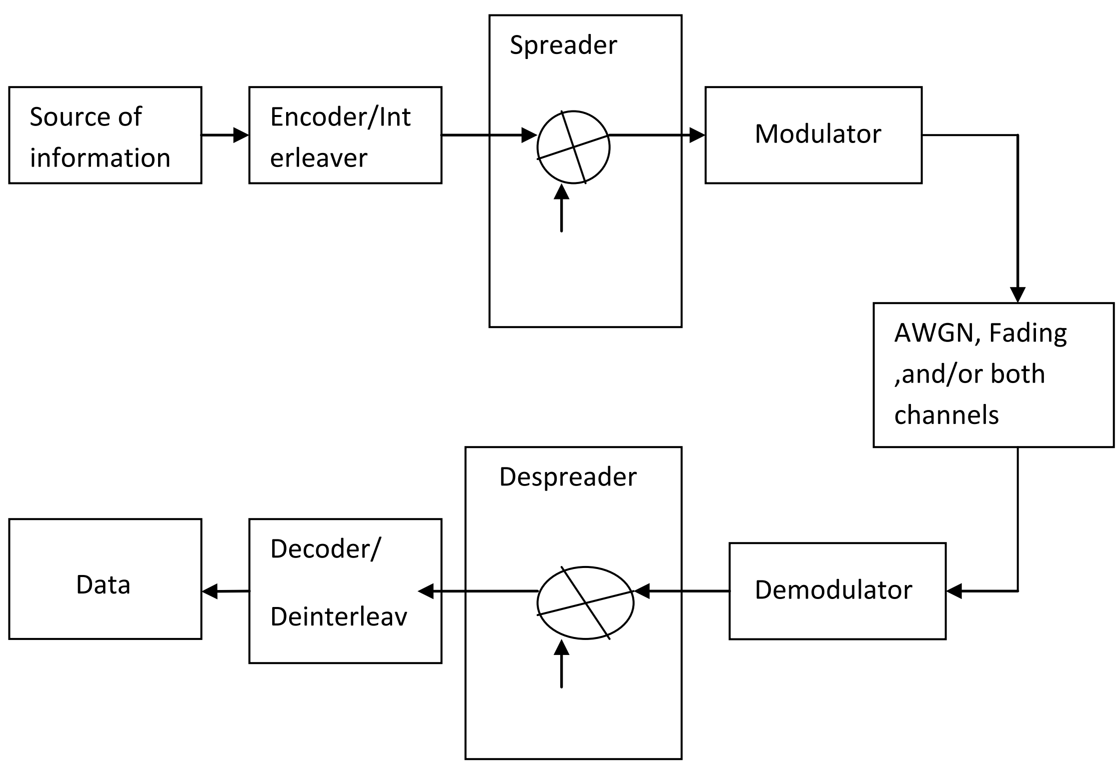

Figure 5 : Block diagram of the baseband model of DS-CDMA

The aim of doing these simulations was to measure the performance of DS-CDMA under different channel conditions, and to allow for different DS-CDMA configurations to be tested. Using Matlab7 the DS-CDMA Transmitter and Receiver was modeled and simulated. The Simulation includes all the stages for Transmitter and Receiver, according to the figure. A brief description of the model is presented below.

h) Simulation of BER Performance vs. SNR using AWGN channel

The signal is modulated using QPSK modulation technique. The signal is passed away through AWGN channel. Here, the number of user=12, the desired user=12, the chips length=7, using coding technique with and without Hamming code.

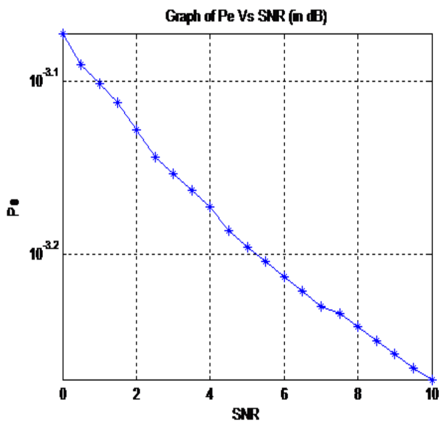

Figure 6(a) : Hadamard – Walsh

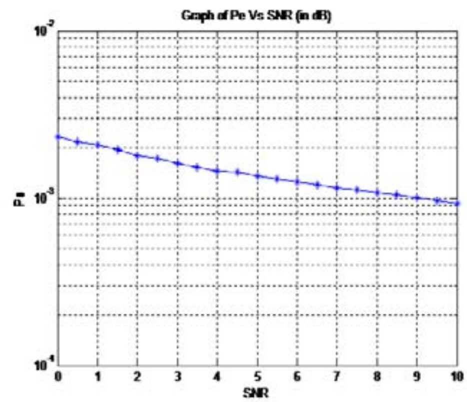

Figure 6(b) : PN Sequence

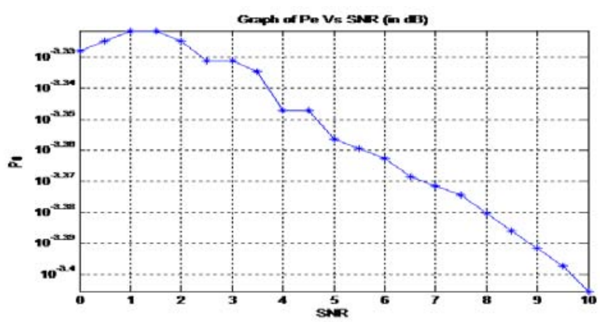

Figure 6(c) : Gold Code

Figure 6 : The signal passed away through the AWGN channel without coding

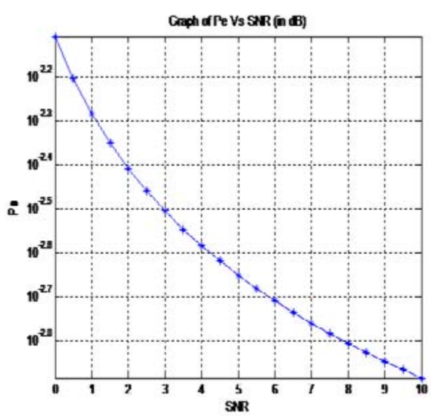

Figure 7(a) : Hadamard – Walsh

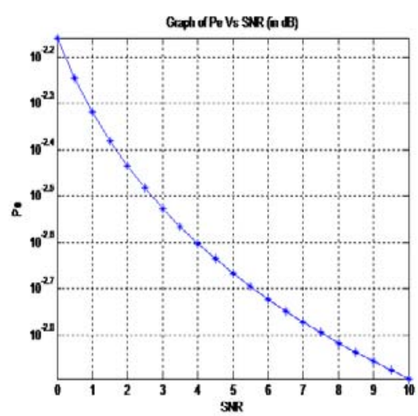

Figure 7(b) : PN Sequence

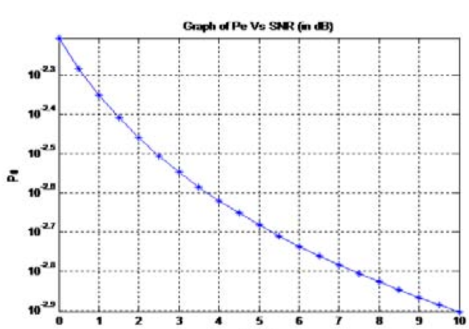

Figure 7(c) : Gold Code

Figure 7 : The signal passed away through the AWGN channel with Hamming coding

II. Conclusion

CDMA, which has been very attractive for future high rate wireless communication is providing high transmission data rate with high spectral efficiency. One drawback of WCDMA is its multipath fading and AWGN noise. This noise destroys the original signal, leading to the significant performance degradation. The transmitted signal is corrupted by multipath and multiple access interference. The signal is further corrupted by AWGN at the front end of the receiver. Several simulations were carried out for estimation of the performance of CDMA with spreading and scrambling, error correct and detection coding technique. The error detects and correct coding technique leads to significant increase performance of CDMA. In this paper, the Additive White Gaussian Noise (AWGN) corrupted the transmitted signal and this resulted in a different received constellation than the original constellation. For small SNR values the calculated error rate was quite large and Multipath fading was produce due the relative high power of noise. As SNR was increased the error rate was decreasing, as expected. In fact, for SNR value greater than 10 dB for QPSK, the error was zero. From Fig-6 show that the signal-noise ratio (SNR) increase then BER non-linearly decrease. From fig-7 show that the signal-noise ratio (SNR) increase then BER linearly decrease. AWGN channel with Hamming coding is better than AWGN channel without Hamming coding

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