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Analysis of Interleaving Schemes in CDMA System Using Simulink

Nayeem Qammar[1], Maninder Singh[2]

M. Tech., Student, ECE Department, Haryana Engineering College, Jagadhri, Haryana, India[1]

Assistant Professor, ECE Department, Haryana Engineering College, Jagadhri, Haryana, India[2]

Abstract: CDMA (Code Division Multiple Access) is one of the most developing technology in modern mobile communication. It has gained widespread international acceptance by cellular radio system operators as an upgrade that will dramatically increase both their system capacity and the service quality. The core principle of spread spectrum is the use of noise-like carrier waves, and, as the name implies, bandwidths much wider than that required for simple point-to-point communication at the same data rate. Most third-generation mobile communication systems are using CDMA as their modulation technique. In CDMA interleaving is used for multiplexing of several input data over shared media. In CDMA system different type of interleaving schemes are used. In this paper we analyze the performance of these interleaving schemes in multipath fading and Additive White Gaussian Noise (AWGN) channels. We conclude that different interleaving schemes has different data rates and bit error rate.

Keyword: CDMA, System Model of CDMA, Interleaving, BER

I. INTRODUCTION OF CDMA

The use of CDMA in wireless and cellular mobile communication has received considerable attention. In this paper, we consider the problem of computing the bit error rate of CDMA over multipath fading and additive white Gaussian noise channels which occur in various transmission mediums such as the indoor wireless and the cellular mobile communication environments.

The principle of CDMA is to spread a data symbol with a spreading sequence $c^{(k)}(t)$ of length L,

$$c^{(k)}(t) = \sum_{t=0}^{L-1} c_l^{(k)} P_{T_c}(t - lT_c) \qquad (1)$$

assigned to user k, k = 0, . . . , K − 1, where K is the total number of active users. The rectangular pulse $P_{Tc}(t)$ is equal to 1 for $0 \le t < T_c$ and zero otherwise. T_c is the chip duration and $c_l^{(k)}$ are the chips of the user specific spreading sequence $c^{(k)}(t)$. After spreading, the signal $x^{(k)}(t)$ of user k is given by

$$x^{(k)}(t) = d^{(k)} \sum_{l=0}^{L-1} c_l^{(k)} P_{T_c}(t - lT_c), \qquad 0 \le t < T_d \qquad (2)$$

for one data symbol duration $T_d = LT_c$, where $d^{(k)}$ is the transmitted data symbol of user k. The multiplication of the information sequence with the spreading sequence is done bit-synchronously and the overall transmitted signal $x(t)$ of all K synchronous users results in

$$x(t) = \sum_{k=0}^{K-1} x^{(k)}(t) \qquad (3)$$

The received signal y(t) obtained at the output of the radio channel with impulse response h(t) can be expressed as

$$y(t) = x(t) \otimes h(t) + n(t) = r(t) + n(t)$$

$$= \sum_{k=0}^{K-1} r^{(k)}(t) + n(t) \qquad (4)$$

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where $r^{(k)}(t) = x^{(k)}(t) \otimes h(t)$ is the noise-free received signal of user k, n(t) is the additive white Gaussian noise (AWGN), and $\otimes$ denotes the convolution operation. The impulse response of the matched filter (MF) $h_{MF}^{(k)}(t)$ in the receiver of user k is adapted to both the transmitted waveform including the spreading sequence $c^{(k)}(t)$ and to the channel impulse response h(t),

$$h_{MF}^{(k)}(t) = c^{(k)*}(-t) \otimes h^{*}(-t) \qquad (5)$$

The notation x^{*} denotes the conjugate of the complex value x. Finally, a threshold detection is performed to obtain the estimated information symbol.
Ideally, the matched filter receiver resolves all multipath propagation in the channel [1]. In practice a good approximation of a matched filter receiver is a rake receiver. A rake receiver has D arms to resolve D echoes where D might be limited by the implementation complexity. In each arm d, d = 0, . . . ,D − 1, the received signal y(t) is delayed and despread with the code $c^{(k)}(t)$ assigned to user k and weighted with the conjugate instantaneous value h_d^{*}, d = 0, . . . ,D − 1, of the time-varying complex channel attenuation of the assigned echo. Finally, the rake receiver combines the results obtained from each arm and makes a final decision.

II. SYSTEM MODEL OF CDMA

A CDMA system has the three main parts: transmitter, channel and receiver. The basic block diagram of a CDMA system is shown in the Figure 1. The source information has to be coded into a digital form in order for it to be further processed by the digital communication system. It is a raw data which is subjected to be processed. It is called primary data. After the source information is coded into a digital form, redundancy needs to be added to this digital baseband signal [7]. This is done to improve performance of the communication system by enabling the signal to better withstand the effects of channel impairments, such as noise and fading. Then interleaving techniques are used for randomizing the bits in a message stream so that burst errors introduced by the channel can be converted into random errors. Different types of interleavers are used in CDMA namely Convolutional, Matrix, Helical, Random etc [5].
This interleaved data is spreaded either by Direct Sequence Spread Spectrum or by Frequency Hopping. In a CDMA system, all the users are transmitted in the same RF band. In order to avoid mutual interference on the forward link, Walsh codes are used to separate individual users while they simultaneously occupy the same RF band. Filtering is used to confine the transmitting signal to the available channel bandwidth. Usually filtering using interpolation method is used. Then this filtered data is passed to channel for ideal communication [7].

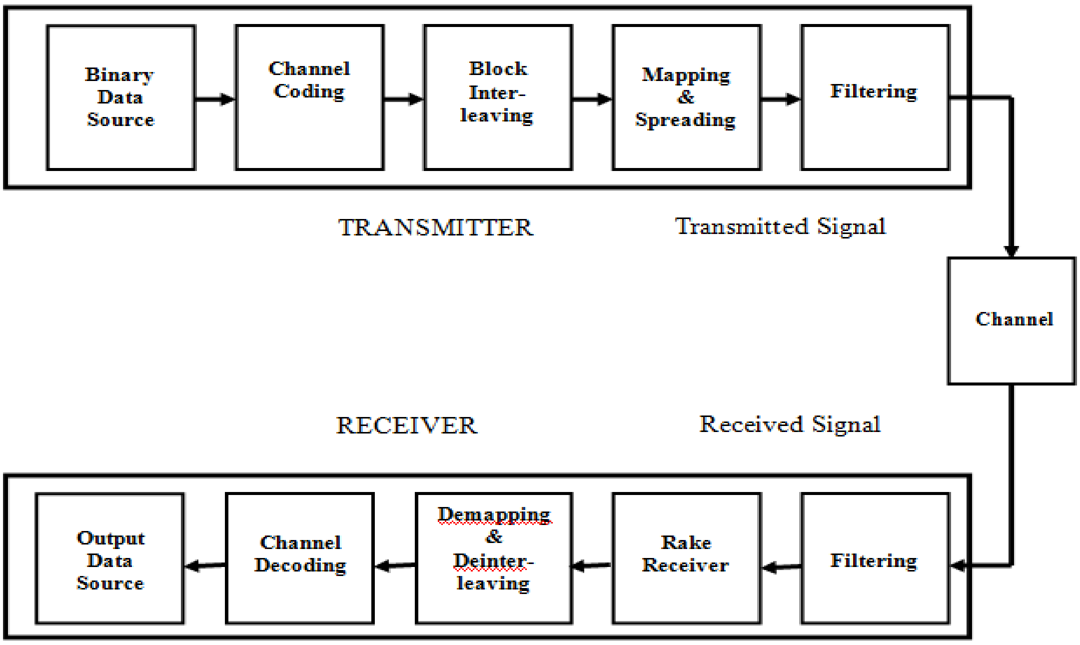

Figure 1. Block Diagram of CDMA

The channel is anticipated by additive white Gaussian noise where it is free from intersymbol interference. The primary source of performance degradation is thermal noise generated in the receiver. AWGN is the effect of thermal noise

generated by thermal motion of electron in all dissipative electrical i.e. resistors, wires and so on [9]. In a wireless mobile communication system, a signal can travel from transmitter to receiver over multiple reflective paths, this phenomenon is referred to as multipath propagation. The effect can cause fluctuations in the received signal's amplitude, phase and angle of arrival, is called multipath fading. The multipath channel affects the signal in many ways. It can attenuate the signal amplitude and cause a time delay in the arriving signal, which results in a phase shift. Also, the Doppler shift is possible if the user is moving at certain speed, but it is not major issue for some application. The problem with multipath channels is that the received signals may combine destructively or constructively. And this problem could be significant if delay spread is smaller than the chip width, which causes interchip interference. In such cases, Rake receiver must be used to improve the system performance [9].
At receiver end the data is received but with some error due to the transmission channel. Because in a transmission channel there is some Multipath Fading and Additive White Gaussian Noise which is added in transmitted signal during transmission process, which results in errors.

III. CDMA INTERLEAVING SCHEMES

Interleaving is a way to arrange data in a non-contiguous way to increase performance. It is typically used in error-correction coding, particularly within data transmission, for multiplexing of several input data over shared media. In telecommunication, it is implemented through dynamic bandwidth allocation mechanisms, where it may particularly be used to resolve quality of service and latency issues. In streaming media applications, it enables quasi-simultaneous reception of input streams, such as video and audio. In CDMA different type of interleaving schemes can be used such as:
Block Interleaver: The Block Interleaver rearranges the elements of its input without repeating or omitting any elements. The input can be real or complex. If the input contains N elements, then the Elements parameter is a vector of length N that indicates the indices, in order, of the input elements that form the length-N output vector. For example, if Elements is [4,1,3,2] and the input is [40;32;59;1], then the output vector is [1;40;59;32].
Convolutional Interleaver: A convolutional interleaver consists of a set of shift registers, each with a fixed delay. In a typical convolutional interleaver, the delays are nonnegative integer multiples of a fixed integer[5]. Each new symbol from an input vector feeds into the next shift register and the oldest symbol in that register becomes part of the output vector. A convolutional interleaver has memory; that is, its operation depends not only on current symbols but also on previous symbols[6].
Matrix Interleaver: The Matrix Interleaver block performs block interleaving by filling a matrix with the input symbols row by row and then sending the matrix contents to the output port column by column. The Number of rows and Number of columns parameters are the dimensions of the matrix that the block uses internally for its computations. For example, if the Number of rows and Number of columns parameters are 2 and 3, respectively, then the interleaver uses a 2-by-3 matrix for its internal computations. Given an input signal of [1; 2; 3; 4; 5;6], the block produces an output of [1; 4; 2; 5; 3;6].
Helical Interleaver: The Helical Interleaver block permutes the symbols in the input signal by placing them in an array in a helical fashion and then sending rows of the array to the output port. The block uses the array internally for its computations[7]. If C is the Number of columns in helical array parameter, and N is the Group size parameter, then the block accepts an input of length C*N at each time step. For example, Suppose that C = 3, N = 2. After receiving inputs of [1:6]', [7:12]', and [13:18]', the block's internal array looks like the schematic below. The coloring of the inputs and the array indicate how the input symbols are placed within the array. The outputs at the first three time steps are [1; -1; -1; 2; 3; -1], [7; 4; 5; 8; 9; 6], and [13; 10; 11; 14; 15; 12].
Random Interleaver: The Random Interleaver block rearranges the elements of its input vector using a random permutation. The Number of elements parameter indicates how many numbers are in the input vector. If the input is frame-based, then it must be a column vector [8].

IV. PERFORMANCE ANALYSIS OF INTERLEAVING SCHEMES

CDMA performance analysis presented in this section is based on computer simulations. The basic scenario of our simulation is represented by the CDMA transmission system performing through multipath fading and AWGN transmission channel, at sample time (20e-3*1)/172 and 172 samples per frame. As the spreading sequences, Walsh codes with period of 64 chips is used. The simulation results of CDMA system is shown below:

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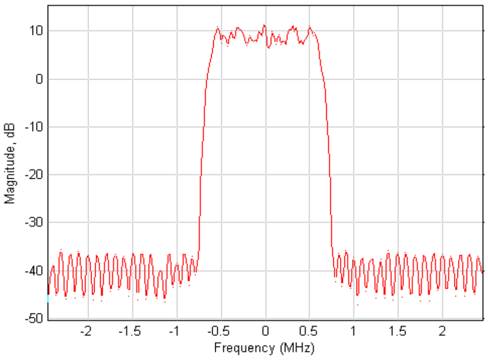

Figure 2. CDMA Transmitted Signal

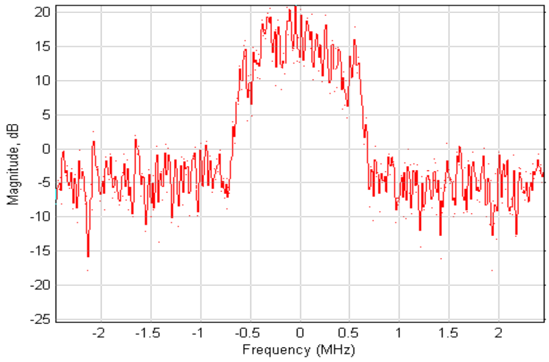

Figure 3. CDMA Received Signal

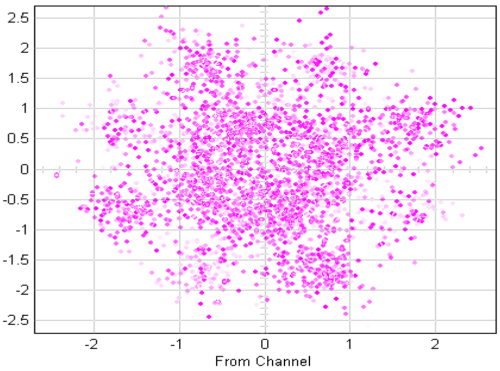

Figure 4. Scatter Plot of CDMA Transmitted Signal

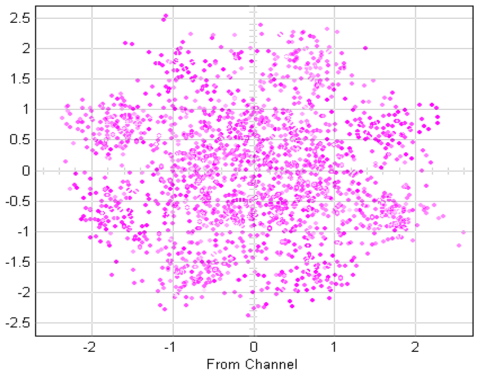

Figure 5. Scatter Plot of CDMA Received Signal

Figure 2 shows the CDMA transmitted signal to the channel. This signal is passed through the multipath fading and additive white Gaussian noise channel. After passing this signal from channel we get the CDMA received signal as shown in Figure 5 which is full of distortions. Figure 4 shows the scatter plot of transmitted signal of CDMA system. The scatter plot is used to reveal the modulation characteristics, such as pulse shaping or channel distortions of the signal. Similarly Figure 5 shows the scatter plot of CDMA received signal. The scatter plot illustrates the effect of fading on the signal constellation.
For all the interleaving schemes the transmitted and received signal has same bandwidth but these schemes effect the transmission rate and bit error rate of CDMA system. These effect of interleaving schemes is shown in tabular form in Table 1.

Table 1

Interleaver	Total Bits Transmitted	Bit Loss	Bit Error Rate (BER)
Block Interleaver	84280	4200	0.04983
Convolutional Interleaver	84280	3472	0.04119
Matrix Interleaver	84280	4216	0.05002
Helical Interleaver	84280	4169	0.04947
Random Interleaver	84280	4305	0.05108

On comparing these interleaving schemes we get that the transmission rate of all the interleaving schemes used in CDMA system is same but the bit error rate if different. From all these interleaving schemes convolutional interleaving scheme is best suitable for CDMA system because it has very low bit error rate as compare to other schemes.

V. CONCLUSION

In CDMA interleaving is used for multiplexing of several input data over shared media. In CDMA system different type of interleaving schemes are used. The transmission bandwidth of the CDMA system with all these interleaving schemes is same. But in a transmission system main concern is on efficient transmission i.e. number of error or distortion is less. So CDMA system with convolutional interleaving is more efficient because it has less BER as compared to other interleaving schemes. So, we conclude that between all these interleaving schemes CDMA system achieves better BER results with convolutional interleaving scheme for the same bandwidth efficiency.

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