BIT ERROR RATE PERFORMANCE OF ORTHOGONAL CODES FOR DS-CDMA MULTIUSER SYSTEM IN AWGN CHANNEL

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Abstract- Direct sequence code division multiple access (DS-CDMA) is a popular wireless technology. This system suffers from Multiple Access Interference (MAI) caused by direct sequence users. This paper presents comparative study of BER performance of conventional matched filter using Gold, Hadamard and Walsh code as the spreading sequence. The simulations are conducted in AWGN channel.

Keywords- Awgn, Ber, Gold Code, Walsh Code, Hadamard Code.

I.INTRODUCTION

In DS-CDMA [1] system, all of the users signals overlap in time and frequency cause mutual interference. The general structure of these detectors [3] consists of a bank of matched filters. The detection is done on the basis of a filter matched to the pseudo-random sequence of the user. This detector is known as the conventional matched filter detector. Since the conventional matched filter was designed for orthogonal signature waveforms, it suffers from many drawbacks due to the MAI term. Orthogonal codes are integral part of DS-CDMA based communication system. Walsh Hadamard orthogonal are extensively employed in present day CDMA systems. In this paper, the different orthogonal codes namely Gold, Walsh and Hadamard codes are compared in terms of average BER performance. The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted. BER= (Bits in Error) / (Total bits received). In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. [7] BER measurement is the number of bit error or destroys within a second during transmitting from source to destination.

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. It is an important parameter of the physical layer of Local Area Wireless Network (LAWN) [4]. Noise strength, in general, can include the noise in the environment and other unwanted signals (interference).

\( E_b/N_0 \) is an important parameter in digital communication or data transmission. It is a normalized signal to-noise ratio (SNR) measure, also known as the "SNR per bit". It is especially useful when comparing the bit error rate (BER) performance of different digital modulation schemes without taking bandwidth into account.

\( E_b/N_0 \) is equal to the SNR divided by the "gross" link spectral efficiency in (bit/s)/Hz, where the bits in this context are transmitted data bits, inclusive of error correction information and other protocol overhead [8]. When forward error correction (FEC), \( E_b/N_0 \) is routinely used to refer to the energy per information bit (i.e. the energy per bit net of FEC overhead bits); in this context, \( E_b/N_0 \) is generally used to relate actual transmitted power to noise.

Additive-White Gaussian Noise (AWGN) environment is preferred in a wireless communication system or proximity detector or a local positioning system based on Time-of-flight. Additive white Gaussian noise (AWGN) is used to transmit signal while signals simulate background noise of channel on propagation

\[ y(t) = s(t) + n(t) \] (1)

that passed through the AWGN channel where \( s(t) \) is transmitted signal and \( n(t) \) is background noise.

II.SYSTEM DESCRIPTION

There are three primarily different types of CDMA technologies: Direct Sequence (DS) CDMA, Frequency Hopping (FH) CDMA and Time Hopping (TH) CDMA. This paper deals only with DS-CDMA system, which is the simplest and the most popular CDMA scheme. Fig.1 shows the block diagram of the DS-CDMA system.

A. Transmitter: At the transmitter \( k \) number of orthogonal codes are generated, uniquely spread and added up. Then it is transmitted through a AWGN channel where the noise gets added up with the signal.

B. Receiver: At the receiver end the transmitted signal is despread using the corresponding codes used at the transmitted end and the BER is calculated and is plotted against various values of \( E_b/N_0 \) in dB.

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receiver deteriorates rapidly as the number of users increases. MAI is a factor which limits the capacity and performance of DS-CDMA systems. The conventional detector does not take into account the existence of MAI. It follows a single-user detection strategy in which each user is detected separately without regard for other users. Conventional CDMA systems independently detect each user in parallel using a matched filter which consists of the unique spreading code used by that user. These spreading codes are designed such that different ones are highly uncorrelated in order to suppress other users’ signals and treat it as simple additive white noise. Multiuser detectors attempt to do exactly that, i.e. detect interfering signals and cancel them out from the desired users’ signal. The conventional CDMA approach proves to be sub-optimal since the interfering signals need not be treated as random noise. Instead, the information in these interfering signals can be used to enhance the desired users signal-to-noise ratio (SNR), thereby raising the capacity of the system.

IV. SPREADING CODES

Spreading codes are used to distinguish users and spread the signal to occupy much wider bandwidth than the minimum required bandwidth. Spreading codes [5-6] are also called as user codes. The PN sequence is produced by the pseudo random noise generator that is simply a binary linear feedback shift register, consisting of XOR gates and a shift register. This PN generator has the ability to generate an identical sequence for both the transmitter and the receiver, and yet retaining the desirable properties of a noise-like randomness bit sequence.

A. Gold code: Gold codes are product codes achieved by the exclusive or-ing (modulo-2 adding) of two PN sequences with the same length. The code sequences are added chip by chip by synchronous clocking. Every change in phase position between the two generated m-sequences causes a new sequence to be generated. When specially selected m-sequences, also called preferred m-sequences are used, the generated code is called the Gold code. The benefit of Gold codes is that a large number of these codes are available for a given length N while having better cross-correlation properties.

B. Walsh Codes: Walsh code generates orthogonal spreading codes for multicarrier CDMA system. Orthogonal codes avoid Multiple Access Interference under perfect synchronization. These functions are generated by mapping code word rows of a special square matrix called Hadamard matrix. So N length Walsh code can offer N number of codes which can assist maximum N number of CDMA users, and that can be generated by a standard repetitive procedure:
\[ W_i = [0], \quad W_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}, \quad W_3 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix} \]

\[ W_{n+1} = \begin{bmatrix} W_n & W_n \\ W_n & -W_n \end{bmatrix} \]

Here Walsh matrix contain first row of all zeros and the next rows have equal number of ones and zeros. N is a power of 2 and over score implies the binary complement of corresponding bits in the matrix. Each row of the matrix represents a Walsh code by mapping 0 to 1 and 1 to -1. So these generated codes are orthogonal and between any pair cross-correlation value is zero.

**C. Hadamard Codes:** A Hadamard matrix H of order n is an \( n \times n \) matrix of 1s and -1s in which \( HH^T = nI_n \). (In is the \( n \times n \) identity matrix.) Equivalently, Hadamard matrix is an \( n \times n \) matrix of 1s and -1s in which any two distinct rows agree in exactly \( n/2 \) positions (and thus disagree in exactly \( n/2 \) positions).

**V. SIMULATION RESULTS**

The bit error rate performance of gold, Walsh and Hadamard codes for DS-CDMA multiuser system in AWGN channel has been carried out. The performance is analyzed for \( K = 5, 10, 15, 20 \) and 25 number of users. The simulation results thus obtained are shown in the following figures:

![Fig.2 E_b/N_0 Vs BER Performance For 5 Users](image)

The figure 2 shows the BER performance for 5 users. It is observed from the simulation result that for a BER of \( 10^{-3} \) hadamard code gives an improvement of 2.45 dB over Gold code and Walsh gives an improvement of 1 dB and 3.45 dB over Hadamard and Gold respectively.

![Fig.3 E_b/N_0 Vs BER Performance For 10 Users](image)

The figure 3 shows the BER performance for 10 users. It is observed from the simulation result that for a BER of \( 10^{-3} \) the performance of Hadamard code and Walsh code are approximately similar. Hadamard and Walsh code gives an improvement of 0.55 dB over Gold code.

![Fig.4 E_b/N_0 Vs BER Performance For 15 Users](image)

The figure 4 shows the BER performance for 15 users. It is observed from the simulation result that for a BER of \( 10^{-3} \) Walsh code gives an improvement of 1.65 dB over Gold code and Hadamard gives an improvement of 1 dB and 2.65 dB over Walsh and Gold respectively.

![Fig.5 E_b/N_0 Vs BER Performance For 20 Users](image)
The figure 5 shows the BER performance for 20 users. It is observed from the simulation result that for a BER of $10^{-3}$ Walsh code gives an improvement of 1.4 dB over Gold code and Hadamard gives an improvement of 0.4 dB and 2.4 dB over Walsh and Gold respectively. However when the number of active users are increased by 25 BER performance of Hadamard and Walsh is same and both are better than Gold code giving an improvement of 2 dB at a BER of $10^{-3}$.

**REFERENCES**


