BER ANALYSIS AND COMPARISON OF SPREADING CODES IN LINEAR MULTI-USER DETECTORS OF DS-CDMA SYSTEM FOR UPLINK DESIGN

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Abstract

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

1. INTRODUCTION

The DS/CDMA receivers are divided into Single-user and Multi-user detectors. A single user receiver detects the data of one user at a time where as a multi-user receiver jointly detects several users' information. Multi-user detector (MUD) techniques exploit the character of the MAI by removal of the multi-user interference from each users received signal before making data decision [1].

2. SINGLE USER DETECTOR

2.1 Conventional Matched Filter Detector

Conventional detectors detect each user separately, and do not take MAI into consideration. The conventional CDMA is an interference limited system when MAI is increasing with the number of active users, and when signals are received with different power levels due to near/far problem.

Conventional single user detection, when optimized for additive white Gaussian noise (AWGN), orthogonal codes and synchronous symbols, depends on power control, which is susceptible to degradation when the channel condition changes [2]. This is the simplest way to demodulate the received signal: a bank of matched filters, one matched to each users spreading waveform, is applied to the received signal. Thus, it demodulates all users independent of each other [3].

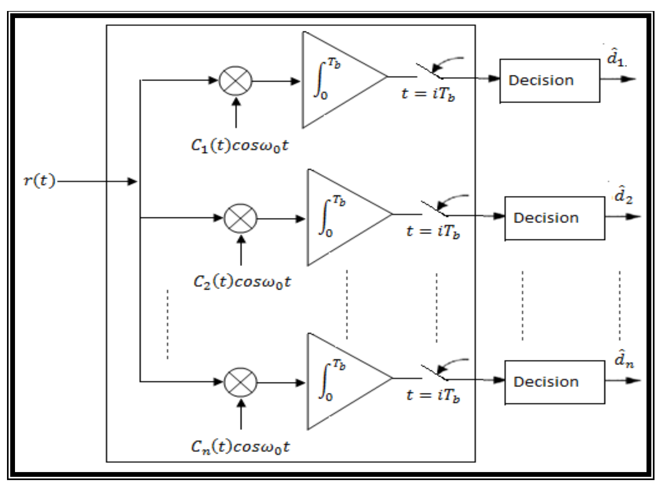

Fig-1: The conventional DS-CDMA detector

The baseband received signal is given by:

$$r(t) = \sum_{k=1}^{K} A_k(t)\, S_k(t)\, b_k(t) + n(t) \qquad (1)$$

where $A_k(t)$, $S_k(t)$ and $b_k(t)$ are the amplitude, signature code waveform and modulated data of the k^{th} user respectively and n(t) is additive white Gaussian noise (AWGN), with a two sided power spectral density of $N_O/2$ W/Hz [4].

The output of matched filter bank is given by:

$$y_j = \int_0^{T_b} r(t)S_j(t)\,dt \tag{2}$$

$$y_j = A_j b_j + \sum_{\substack{k=1 \\ k\neq 0}}^{K} A_k b_k R_{kj} + n_j \tag{3}$$

Hence,
b= sign(y_j) (4)

The first term is desired information. The second term is interference from others users. The interference from other user is called multiple access interference (MAI). This method ignores MAI and treats as noise (self space noise). These self noise limits the system capacity and can jam out all communications in the presence of a strong nearby signal (near-far problem) [3].The performance of the conventional receiver deteriorates rapidly as the number of users increases [5].

Multiple access interference (MAI) is a factor which limits the capacity and performance of DS-CDMA systems. MAI refers to the interference between direct-sequence users. 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 [6].

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 [7].

3. 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 are also called as user codes [8]. 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.

3.1 Gold code

Gold codes are product codes achieved by the exclusive or-ing (modulo-2 adding) of two maximum-length 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(Fig-2).

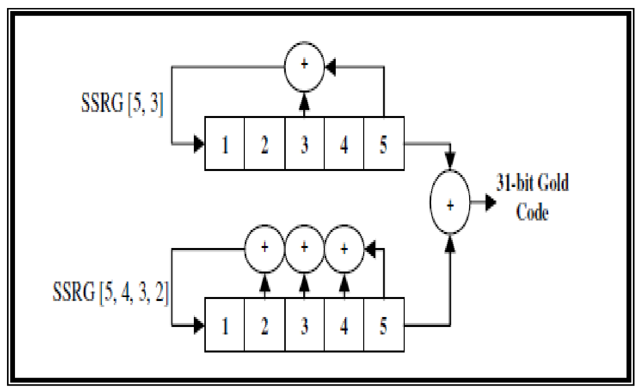

Fig-2: 31-bit Gold Code Generator

Consider an m-sequence represented by a binary vector a of length N, and a second sequence a' obtained by sampling every q^{th} symbol of a. The second sequence is said to be a decimation of the first, and the notation a'= a[q] is used to indicate that a' is obtained by sampling every q^{th} symbol of a. a'= a[q] has period N if and only if gcd (N,q) = 1 where gcd denotes the greatest common divisor. Any pair of m-sequences having the same period N can be related by a' = [q] for some q [9].

Two m-sequences a and a' are called the preferred pair if :

- $n \neq 0$ (mod 4); that is, n odd or n = 2 (mod 4) (5)
- a' = a[q], where q is odd and either $q = 2^k + 1$ or $q = 2^{2k} - 2^k + 1$ (6)
- gcd(n,k) =1 for n odd

$$2 \text{ for } n=2 \pmod 4 \qquad (7)$$

The cross-correlation spectrum between a preferred pair is three-valued, where those three values are {–t(n),-1,t(n)-2}

where

$$t(n) = \begin{cases} 1 + 2^{(n+1)/2} & \text{for n odd} \\ 1 + 2^{(n+2)/2} & \text{for n even} \end{cases} \qquad (8)$$

The autocorrelation functions are not two-valued, and it takes the same three values as cross correlation [9].

Gold sequences are defined for lengths of $2n$-1, where n is not a multiple of 4. That means, Gold sequences are not defined for lengths of 15,255, etc. These codes are simple to generate, but sizes of the available codes are limited for multi user communications.

The benefit of Gold codes is that a large number of these codes are available for a given length *N* while having controlled cross-correlation properties. However, the downside is that the autocorrelation properties of Gold codes are inferior to those of *m*-sequences [9].

3.2 Walsh code

Walsh codes are perfectly orthogonal codes and are used in synchronous communication from base station to the mobile hand-held user . They perform poorly in asynchronous conditions due to poor cross correlation between the codes. Walsh codes are perfectly orthogonal codes and are ideal for synchronous CDMA communication [8]. Hadamard form of Walsh transform so called Walsh-Hadamard transform (WHT) is iteratively generated from the Kernels. Higher length Walsh code sets are iteratively generated from the lower length Walsh code sets using Kronecker product.

The Hadamard-Walsh codes are constructed for block length N= 2^n. These matrices contain one row of all zeros, and the remaining row each have equal numbers of ones and zeros [9].

$$H_N = \begin{matrix} H_{N/2} & H_{N/2} \\ H_{N/2} & -H_{N/2} \end{matrix} \qquad (9)$$

with $H_0 = [1]_{1X1}$.

Availability of these code sets is limited and these sequences are not useful for asynchronous communication with random delays [8].

4. SIMULATION RESULTS

The multi-user CDMA analysis using Gold and Walsh code has been carried out. The performance is analyzed for K=2 number of users.

The simulation results are shown in Fig 3 and Fig 4 respectively.

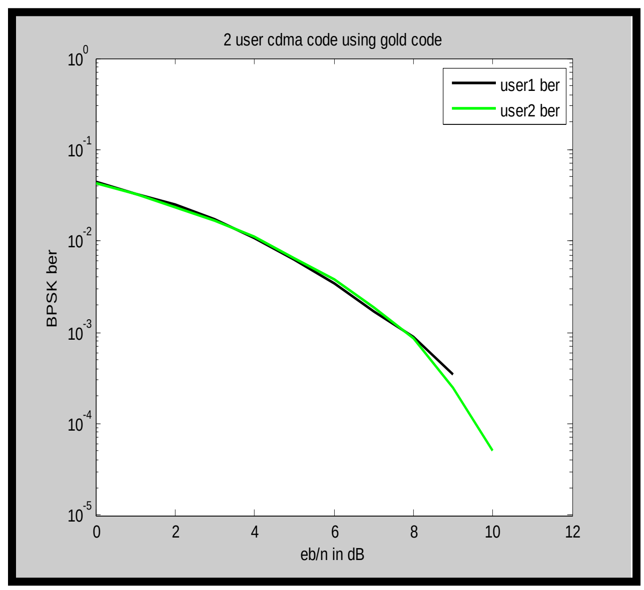

Fig-3: Two user BER using Gold code

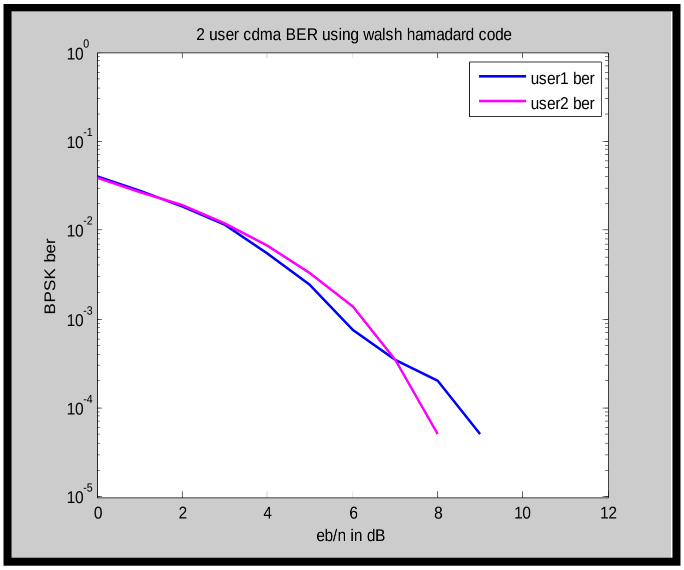

Fig-4: Two user BER using Walsh code

The performance comparison between the two users is carried out. The obtained simulation results are in Fig-5.

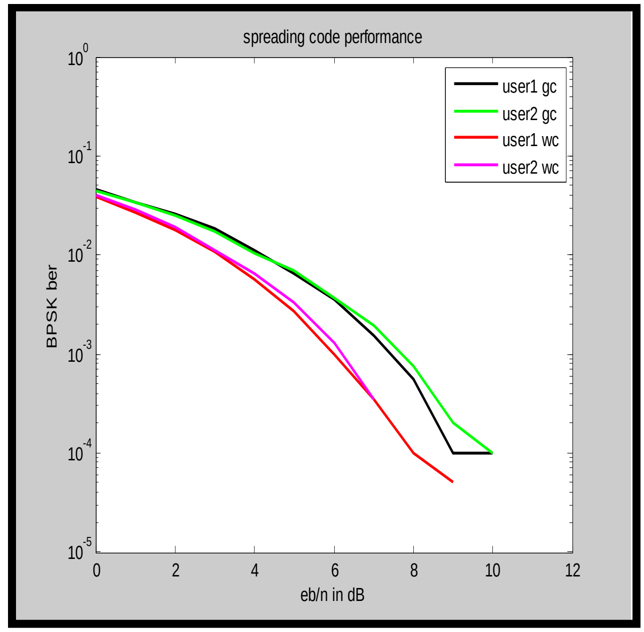

Fig-5: Comparison between spreading codes.

The performance evaluation with increasing number of active users is carried out i.e. K=4, K=8. The simulation results thus obtained are shown in Fig 6 and Fig 7 respectively.

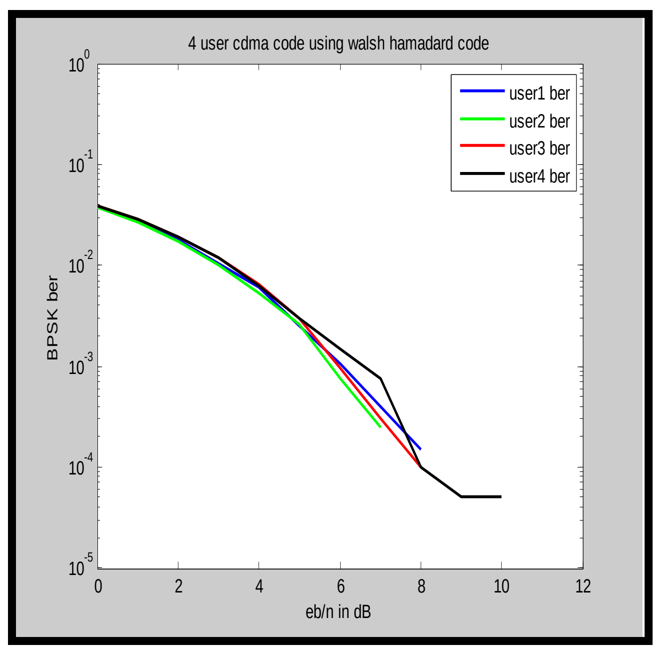

Fig-6: Four user BER using Walsh code

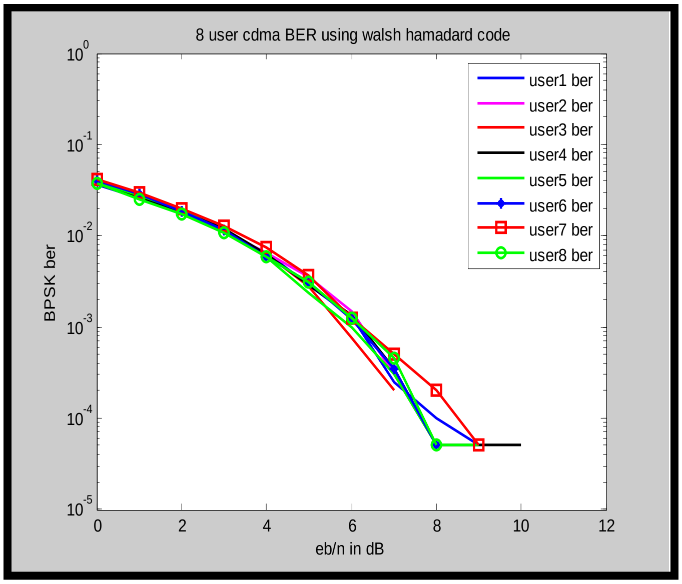

Fig-7: Eight user BER using Walsh code

5. CONCLUSION

The simulation results show that Walsh code provides better performance than gold code for conventional matched filter.

Further, we applied Walsh code for increasing number of active users with the assumption that all users have equal power.

With increase in the number of users, the performance of the detector degrades.

The Walsh code may further be utilized for the analysis of linear detectors.

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