PERFORMANCE ANALYSIS OF NEW BINARY ORTHOGONAL CODES FOR DS-CDMA COMMUNICATION OVER AWGN CHANNEL

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ABSTRACT

Direct Sequence - Code Division Multiple Access (DS-CDMA) is a communication system in which a particular random signal is multiplied with message signal to produce noise-like spectrum. These random signals are called user codes. There are two types of user codes, orthogonal and non-orthogonal codes. Orthogonal codes are very important in direct sequence CDMA communication, since they ensure minimum correlation error. There are many types of user codes available with different advantages. In this paper we have put immense efforts to highlight their performance in comparison with new orthogonal codes. MATLAB simulation software is used in order to find autocorrelation and cross-correlation properties of each user code. Bit Error Rate (BER) is also considered as a very important parameter for comparing the performance of all user codes. We have limited our studies to single and two users over AWGN channel in order to work with all popular codes such as Gold, Kasami, Hadamard–Walsh and new orthogonal sequence with an intention of highlighting adaptive nature and increased capacity of new orthogonal sequence for DS-CDMA.

Keywords: AWGN channel, Binary orthogonal codes, DS CDMA.

1. INTRODUCTION

In the communication sector, spectral resources are often very limited. So it becomes very crucial to make sure that they are used to maximum productivity. In order to use the spectrum efficiently, multiple access techniques are used. Basically there are three major multiple access techniques. They are Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). CDMA has upper hand over FDMA and TDMA since it can accommodate infinite number of users (theoretically). Eventually performance
decreases as number of users increase. In order to ensure good performance user codes are supposed to have good cross correlation property in order to avoid cross-correlation error.

In CDMA, it is a well known fact that users are distinguished by their codes. CDMA system performs correlation operation between message and user code to introduce encryption in transmitter and again correlation is done between received signal and synchronizing code. To obtain perfect recovery cross-correlation error is supposed to be zero. So each code should be orthogonal with all other user codes. For specific number of bits, there is limited number of codes with perfect orthogonal property. In order to increase the capacity, we have an algorithm that produces maximum possible number of orthogonal codes.

Some of the popular user codes are Gold codes, Hadamard Walsh code and Kasami codes. Gold codes are generated by modulo addition of two preferred polynomials of maximal length sequences. Gold sequences are nearly orthogonal with non-linear phase. As they are not perfectly orthogonal, cross-correlation error is not zero. Since limited number of preferred polynomials is available, only limited number of user codes can be obtained and so the capacity is limited. Hadamard Walsh codes are generated in powers of 2 by using Hadamard matrices recursively. Walsh codes are perfectly orthogonal, linear phase codes with unique number of zero crossings within the set and are a subset of orthogonal codes present in n-length sequence. Length of Walsh sequence is always even. Use of Walsh is limited to synchronous communication only. Kasami code is binary sequence which has good cross-correlation. Kasami sequence is obtained by decimation of two sequences. There are two types of Kasami sequences, small set and large set. Small Kasami sets are used for reverse channels in IS 95 mobile communication standard. Cross-correlation of Kasami approaches nearly the Welch lower bound. Hardware implementation of Kasami sequence is very complex and requires very high frequency of clock.

<table>
<thead>
<tr>
<th>7-length Gold Code set</th>
<th>8-length Walsh code set</th>
<th>7-length Kasami Code set</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1 -1 -1 1 1 -1 -1 1 1</td>
<td>-1 -1 1 1 1 -1 -1 1 1</td>
<td>-1 -1 -1 1 1 1 -1 -1</td>
</tr>
<tr>
<td>1 -1 1 -1 1 1 1 1 1</td>
<td>1 1 -1 1 1 1 -1 -1 1</td>
<td>1 1 -1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>-1 1 1 1 -1 -1 1 1 1</td>
<td>1 1 1 1 -1 -1 1 1 1</td>
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<tr>
<td>1 1 1 1 -1 -1 1 1 1</td>
<td>1 1 1 1 -1 -1 1 1 1</td>
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<td>1 1 1 1 -1 -1 1 1 1</td>
<td>1 1 1 1 -1 -1 1 1 1</td>
</tr>
</tbody>
</table>

New orthogonal codes are flexibly available for both even and odd symmetry. This flexibility has expanded the search area for orthogonal code in binary sample space. Due to availability of good computational resources, we have adopted a complex algorithm to explore new orthogonal codes in the given sample space. Proposed code has good cross-correlation and BER performance which is explained in the later part of this paper.
Rest of the paper is organized as follows: Section-2 describes the procedure to generate binary orthogonal codes. In Section-3, time, frequency, auto-correlation and cross-correlation properties of all user codes are discussed. Section-4 presents the BER performance comparison of the proposed codes with the existing popular spreading codes. The paper is concluded finally with the applications and merits of the proposed code in Section-5.

2. DESIGN METHODOLOGY FOR BINARY ORTHOGONAL CODES

The design methodology discussed here is similar to the construction technique discussed in [1]. This design methodology can be applied to construct orthogonal code set of any length. In this paper, we are restricting ourselves to fixed power orthogonal codes of length 8 bits. Though for 8 bits a total of 256 combinations are possible, only the first half of the numbers excluding the DC component are considered as the second half set of binary numbers are complement to the first half. Thus orthogonal search is performed in the region 1 to 127.

Step-1: Initially all the numbers from 1 to 127 are represented in radix-2 format or binary format.

Step-2: As the binary spreading codes have two chip levels \([1, -1]\), all the binary representations are converted to Bipolar Non Return to Zero (NRZ) form (i.e. 0 as -1 and 1 as 1) and are stored in two matrices of size 127X8 each.

Step-3: For generation of the desired mutually orthogonal set, an exhaustive computer search is performed. For a code length of 8, 8 mutually orthogonal codes are obtained.

Step-4: Orthogonal code sets with good correlation properties are limited for 8 bit code words because of the small sample space.

Step-5: Taking into consideration zero mean and linear phase conditions, a total of 22 codes are available in the entire sample space for a code length of 8.

One such orthogonal code set is displayed in Table 2. Orthogonal code set of any length can be constructed using this technique.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Decimal Equivalent</th>
<th>NRZ Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>7</td>
<td>-1 -1 -1 -1 1 1 1</td>
</tr>
<tr>
<td>3.</td>
<td>49</td>
<td>-1 -1 1 1 -1 -1 -1</td>
</tr>
<tr>
<td>4.</td>
<td>62</td>
<td>-1 -1 1 1 1 1 -1</td>
</tr>
<tr>
<td>5.</td>
<td>82</td>
<td>-1 1 -1 1 -1 1 -1</td>
</tr>
<tr>
<td>6.</td>
<td>93</td>
<td>-1 1 -1 1 1 -1 1</td>
</tr>
<tr>
<td>7.</td>
<td>100</td>
<td>-1 1 1 -1 1 -1 -1</td>
</tr>
<tr>
<td>8.</td>
<td>107</td>
<td>-1 1 1 -1 1 -1 1</td>
</tr>
</tbody>
</table>

3. TIME, FREQUENCY, AUTO AND CROSS-CORRELATION PROPERTIES

This paper discusses the performance of the new set of proposed codes in comparison with Walsh (8 bit length), Gold and Kasami (7 bit length) codes by using the parameters like auto correlation, cross correlation, magnitude and phase plot. Fig.1 displays the time domain representations of typical code words of all spreading codes. Fig.2 and Fig.3 represent magnitude and phase functions of codes respectively. The proposed orthogonal codes are more evenly spread when compared to other user codes like Gold and Kasami codes whereas phase is non-linear for both proposed orthogonal codes and Gold codes.
Fig.1  Time domain representation of typical 7-length Gold code, 8-length Walsh code, 7-length Kasami code and 8-length proposed orthogonal code

Fig.2 Magnitude plot of Walsh, Gold, Kasami and proposed orthogonal codes

Fig.3 Phase plot of Walsh, Gold, Kasami and proposed orthogonal codes
The ability of a DS-CDMA receiver to detect the desired signal relies to a great extent on the auto-correlation properties of the spreading codes and on the other hand multi-user interference rejection depends on cross correlation properties of the spreading sequences. In synchronous DS-CDMA system, the code sequence in the receiver is exactly same as that in the transmitter. Orthogonal codes are most suitable for synchronous communication. Two sequences are said to be orthogonal when the cross-correlation (inter-code correlation) between them is zero. Codes with high auto-correlation and low cross-correlation are preferred in synchronous communication. Auto-correlation sequence for all user codes is shown in Fig.4.

![Auto-Correlation sequences of Walsh, Gold, Kasami and proposed codes](image1)

**Fig.4** Auto-Correlation sequences of Walsh, Gold, Kasami and proposed codes

Fig.5 displays the cross-correlation property of all user codes. It can be inferred from the figure that auto-correlation and cross-correlation sequences of Gold and proposed code are almost similar. Deviation value of Gold code is comparable to proposed code.

![Cross-correlation sequences of Walsh, Gold, Kasami and proposed codes](image2)

**Fig.5** Cross-correlation sequences of Walsh, Gold, Kasami and proposed codes
4. BER PERFORMANCE OVER AWGN CHANNEL

Bit Error Rate (BER) specifies the ratio of the number of bits which are received with error to the number of bits transmitted. Very low value of BER is desired for good performance of the system. In this paper, the code with decimal equivalent 49 and 107 are used for BER performance for two users over AWGN channel. Fig.6 and Fig.7 show the BER performance of all user codes with single and two users in the system respectively. BER curve of Walsh and proposed codes is very closely spaced.

![BER performance of Walsh, Gold, Kasami and proposed codes for synchronous DS CDMA communication over AWGN channel in a single user scenario](image)

**Fig.6** BER performance of Walsh, Gold, Kasami and proposed codes for synchronous DS CDMA communication over AWGN channel in a single user scenario

![BER performance of Walsh, Gold, Kasami and proposed codes for synchronous DS CDMA communication over AWGN channel in a two users scenario](image)

**Fig.7** BER performance of Walsh, Gold, Kasami and proposed codes for synchronous DS CDMA communication over AWGN channel in a two users scenario
5. CONCLUSION

Flexible size orthogonal codes can be used in emerging applications of multiple carrier CDMA communication system. The proposed orthogonal codes have better performance in comparison to other user codes. It is clear that the capability of synchronous CDMA system can be improved by employing the proposed orthogonal user codes. The extension of the proposed orthogonal codes to channels with multiple users is to be investigated.

REFERENCES


