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A novel "Near orthogonal spreading codes" and its performance analysis

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ABSTRACT: Multiple access interference (MAI) and intersymbol interference (ISI) appears in wireless communication system when the communication cannel is a multipath channel and spreading codes are not orthogonal .So in order to reduce the effect of MAI and ISI many methods are used in the academic research since many years but in this paper I focus on the cross correlation and autocorrelation property of spreading codes as it is a function of MAI and ISI. This spreading code generation technology acquires a vast area in wireless communication system mainly applied in case of CDMA system. CDMA system can serve a large number of users over the same bandwidth by assigning a unique code to each of the users .For giving a support to large number of users in CDMA system we have to require a large number of distinct of spreading codes with low cross correlation values in order to reduce the effect of MAI.which increases the capacity of CDMA system. Apart from this the CDMA spreading code should maintain impulsive autocorrelation peak at zero shifts and low peak at non zero shift to reduce the chance of false synchronization. Unfortunately, the existing spreading code do not satisfy both autocorrelation and cross correlation property simultaneously hence generation of new spreading code has been emerged an important research area in the field of wireless communication. In my thesis paper I gave my best effort to generate a " Near orthogonal spreading code "to support a large number of users for CDMA system by maintaining minimum cross correlation values between them with impulsive autocorrelation peak. the proposed algorithm for generation of ' Near orthogonl spreading code '(NOSC) has been simultaneously using MATLAB7.10.It has been found that the proposed algorithm provides a large number of spreading codes by simultaneously reducing the effect of MAI and ISI in CDMA system. Here also I give an effort towards bit error rate performance of the proposed code by using AWGN channel and multi user scenario. The performance comparison between the proposed code and the existing code like Walsh code, orthogonal Gold code, PN sequences and orthogonal Kasami code. Finally the best result has been established by the proposed code over the other existing code.

KEYWORDS: MAI, ISI, CDMA, NOSC, ACF, CCF, AWGN, BER

I.INTRODUCTION

Multiple access schemes allow many users to share the radio spectrum i.e. sharing the band width efficiently among all the users. The variability of wireless channels presents both challenges and opportunities in designing multiple access communications system. Multiple access schemes are designed to maintain orthogonally and reduce interference effect. The multiple access schemes based on spread spectrum technology mainly used in CDMA system for better communication. In CDMA system the entire band width is made available to each user and it is many times larger than the band width required to transmit information and such type of system is called spread spectrum system. In spread spectrum system user specific codes are used to distinguish the users during communication is called spreading codes .Some existing spreading codes used in communication systems are Walsh code, Orthogonal Gold code, PN sequence and Kasami code. Inter symbol interference (ISI) and multiple access interference is two limiting factors in CDMA system which decreases system capacity so in order to improve system capacity improvement of MAI & ISI must takes place. As MAI & ISI is a function of cross correlation and autocorrelation property which depends on ortogonality of spreading code. Hence generation of large no of spreading code and its performance analysis is vital for this thesis.

A spread spectrum CDMA scheme is one in which the transmitted signal is spread over a wide frequency band, much wider than the minimum bandwidth required to transmit the information being sent.In [**1**] here R.C Dixon have been proposed a spread spectrum communication technique which is based on multiple access scheme used CDMA It spread the massage signal to a relatively wide bandwidth by using unique code that reduces interference, enhances system processing and differentiate users .CDMA does not require frequency and time division for multiple access , thus it improves the capacity of the communication system. In this paper he has giving a new approach towards spread spectrum modulation and CDMA concept. It presents several design considerations including the structure of the spreading signal. Then Coding is always beneficial and sometimes crucial for the suppression of interference in spread spectrum communication has been proposed in [2]. In [**3**] which presents an overview of the spreading techniques for direct sequence CDMA cellular networks. Here it has been briefly describe the theoretical background for sequences used in CDMA and wideband CDMA, and discuss the main characteristics of the Maximal length, Gold, and Kasami sequences, as well as variable- and fixed-length orthogonal codes.In [**4**] Deepak Kedia et al have been proposed Code Division Multiple Access (CDMA) is a multiple access technology and the performance of CDMA based wireless systems is based on the characteristics of user specific spreading codes. The objective of this paper is to highlight the various factors affecting the choice of these spreading codes and present a comparative evaluation of correlation properties of Orthogonal Gold codes, Orthogonal Golay complementary sequences and Walsh-Hadamard codes. In[5] Intersymbol Interference (ISI) always appears when the communication channel is a multi-path channel .Many methods are used to reduce the effect of ISI. In this paper the autocorrelation property of the spreading codes and the role it plays in minimizing the ISI effect is mainly focused, where we obtain the spreading codes with minimum autocorrelation property. The results of comparing the average autocorrelation of the obtained codes with that of the well known Hadamard codes show a great enhancement in the performance. Amayreh, A. I., & Farraj [6] proposed Multiple access interference (MAI) appears in Code Division Multiple Access (CDMA) systems when the communication channel is a multi-path channel and the spreading codes are not orthogonal. Orthogonality between spreading codes cannot be maintained at the CDMA receiver because the codes may be asynchronous due to channel delay and multi-path spread. The receiver cannot perfectly separate the different signals of the multiple access users, and the resultant MAI limits the capacity of CDMA systems. MAI is a function of the cross correlation property between used spreading codes. In this paper we focus on the cross correlation of the spreading codes, we propose a method to find spreading codes with minimum magnitude of cross correlation. Employing these codes will reduce the resultant MAI in the CDMA system; hence it will increase the system capacity. A great enhancement is shown by comparing and found minimum cross correlation spreading codes (MCCSC) with Hadamard and Gold codes. In [7], minimum correlation spreading codes are presented in order to minimize the magnitude of auto correlation and cross correlation between spreading codes other than zero-shift. The disadvantage of the work described in [5-7] is that each of them produces 'N-1' number of spreading codes for a' N' length sequence which is less than Walsh code. Inter symbol interference (ISI) and multiple access interference (MAI) appear in code division multiple access systems when the spreading codes are not orthogonal. ISI and MAI are function of the auto and cross correlation values of the spreading codes. In this paper Farraj, A. K. (2010) investigate both auto and cross correlation properties; and describe the the optimum solution for both cases i.e the solution where minimum auto and cross correlation values are attained. Minimum Correlation codes show a great enhancement in performance compared to Hadamard codes.In[**8**] Pavan M. Ingale et al have been proposed Various Correlation Properties of Orthogonal Spreading Codes for CDMA Technique **.** Spread Spectrum a means of signal modulation, in which the signal frequency is spread over a very wide bandwidth. Spread spectrum technology, which was initially used in military applications, is another approach to achieve multiple accesses. An important multiple-access technique in wireless networks and other common channel communication systems is Code-Division Multiple Access (CDMA). Each user shares the entire bandwidth with all the other users and is distinguished from the others by its signature sequence or code. The sequences which are used in CDMA should have the following properties: • There should be a balance in the number of ones and zeroes.

• The autocorrelation must be a sharp two-valued function

• The cross correlation must be as low as possible.

In this paper, the generation of the orthogonal sets of codes which are able to retain the properties of Complete Complementary (CC) codes are proposed. The proposed methods can be applied to any sequence with ideal two-level cross-correlation. The characteristics of CDMA codes for next Generation wireless CDMA systems include availability of large number of codes, impulsive auto-correlation function, zero cross-correlation value and support for variable data

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rates. The properties of Gold sequence, Kasami Sequences, Pseudo Noise Sequences and Read Muller codes have been evaluated for CDMA based wireless systems. To reduce the Multiple Access Interference (MAI) in a synchronous system like the downlink mobile radio communication channel, the spreading sequences, or codes, are chosen orthogonal. From the Spread Spectrum Characteristics of CDMA it is observe that it has low power spectral density, privacy is more, and overall good performance.
In [9] Muhammad Baqer Mollah et al have been proposed a spread spectrum modulation system all users of the channel transmit information at the same time over the whole channel. Because information transmitted this way simply resembles noise, it is hard to intercept and therefore it offers high security. This techniques have a number of advantages over other multiplexing systems includes better frequency efficiency, power utilization and noise flexibility. This paper is prepared on the basis of aims on study of correlation properties among Gold code sequence and ordinary pseudo noise codes sequence. This paper is also gives simulation of production of speared signal and re produce the original message signals. Two Gold Codes sequences and two Pseudo Noise sequences are to determine which a better means for modulating the given message is signal in terms of better noise immunity and security with the help of MATLAB. In [10] Abhisek Ukil have been proposed an application of autocorrelation proprieties used in spreading codes given by low autocorrelation binary sequences are very important for communication applications and it is difficult to find binary sequences with low aperiodic autocorrelations. In this paper, a theorem has been proved to show that there is finite number of possible energy levels, spaced at an equal interval of 4, for the binary sequence of a particular length. Two more theorems are proved to derive the theoretical minimum energy level of a binary sequence of even and odd length of N to be N/2 and N−1/2 respectively, making the merit factor equal to N and N (N−1)/2 respectively.

II. NUMERICAL BACKGROUND AND ANALYSIS

A. Walsh code:

Definition: The Walsh code is a linear code which maps binary bits of length n to binary code words .The code words has length N=2n:Further these codes are mutually orthogonal.

Numerical analysis: A Hadamard matrix H of order n is an n x n matrix of 1s and -1s in which HHT = nxIn. (In is the n x n identity matrix.) For Walsh codes, we use a Hadamard matrix of the order 2^n.The rows of the matrix of order constitute the Walsh codes which encodes n bit sequences. Now, instead of 1 and -1 consider 1 and 0.Hence when N=1, 2….etc then the respective Walsh matrices are

$$W_1 = [0], \qquad W_2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}, \qquad W_4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix} \quad \text{and} \quad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

The Walsh code for each string of length n has a hamming distance of 2^{n-1}: Further, the Distance or the Distance between any two Walsh codes is also 2^{n-1}. Walsh codes are mutually orthogonal to each other.

B. Auto-Correlation:

Auto Correlation Function (ACF) is a measure of the similarity between a spreading code $\{b_n\}$ and its time shifted replica. For a code sequence $\{b_n\}$, it is mathematically expressed as:

$$A(k) = \sum_{n=1}^{N} b_n b_{n+k}$$

Ideally, this autocorrelation function should be impulsive type i.e. peak value at zero time shifts and zero values at all other shifts. This is required at receiver side to differentiate the desired user from other users producing ISI.

Numerical analysis for minimum autocorrelation:

Let us take a known spreading code S of length N and T is the transpose of the matrix S which is represented as:

$$S = [Y_1, Y_2, \ldots Y_{N-1}, Y_N]^T \quad \ldots\ldots(1)$$

Hence we get S after dispreading operation for autocorrelation as

$$\begin{bmatrix} Y_1 & Y_2 \ldots\ldots & Y_N \\ 0 & Y_1 \ldots\ldots & Y_{N-1} \\ . & . & . \\ . & . & . \\ . & . & . \\ 0 & 0 \ldots\ldots & Y_1 \end{bmatrix} * \begin{bmatrix} Y_1 \\ Y_2 \\ . \\ . \\ . \\ Y_N \end{bmatrix}$$

$G=|S^T \cdot L^T \cdot S|$ ………………………………………………… (2)

Here N-1zero Eigen values are getting and in order to minimize G the convex optimization method in LPP is used i.e.

Minimize $G=| S^T \cdot L^T \cdot S |$ ……….. (3)

Such that $S^T . S=1$

Hence by using dual optimization problem results

$Z= S^T . L^T . S +V (1- S^T . S)$.. (4)

Where V is the Eigen value of the Eigen vector and S is Eigen vector of Z.

***C.Cross-correlation*:**

Cross-correlation is the degree of agreement between two different spreading code sequences $\{b_n\}$ and $\{c_n\}$ mathematically it is expressed as:

$$C(k) = \sum_{n=1}^{N} b_n c_{n+k}$$

Cross-correlation function (CCF) actually indicates the correlation between the desired code sequence and the undesired ones at the receiver. Therefore, in order to reduce the effect of MAI at the receiver, the cross-correlation value must be zero at all time shifts.

Numerical analysis for minimum cross correlation:

Similarly like autocorrelation, mathematical analysis of cross correlation property is generally used to reduce MAI in the channel and the cross correlation there are two codes to be taken. Let us take a known spreading code S of length N which is represented as:

$S = [X_1, X_2, ... X_{N-1}, X_N]^T$ ……………………………………….(5)

Where T is the transpose of the matrix S and another spreading code S_2 minimizes the total magnitude of crossc correlation with all shift of Y.

Hence we get $S\&S_2$ after dispreading operation for cross correlation as

$$\begin{bmatrix} Y_1 & Y_2 \ldots\ldots & Y_N \\ 0 & Y_1 \ldots\ldots & Y_{N-1} \\ . & . & . \\ . & . & . \\ . & . & . \\ 0 & 0 \ldots\ldots & Y_1 \end{bmatrix} * \begin{bmatrix} X_1 \\ X_2 \\ . \\ . \\ . \\ X_N \end{bmatrix}$$

In order to minimize G the convex optimization method in LPP is used i.e.

Minimize $G=|S_2^T \cdot L^T \cdot S |$ ……….. (6)

Such that $S^T . S=1$

The magnitude of cross correlation is minimized take the value of s as that minimizes the square of G so the equivalent value of Z be

$Z= (S_2^T . L^T . S) .(S_2^T . L^T . S)^T + V (1- S^T . S)$.. (7)

***D.Numerical analysis of minimum correlation*:**

Where G the convex function can written in to a single minimization function H
min H= minG(autocorrelation)+ minG(cross correlation)
$= k(S^T \cdot L^T \cdot S) + (1-k) (S_2^T . L^T . S) .(S_2^T . L^T . S)^T$ …………………………………… (8)

Where the value of k is in between 0 to1 i.e. $0 \le k \le 1$ is the weight variable. Now the dual problem is formulated as
$M = S^T \cdot S(k L^T + (1-k) S_2^T . L^T . S_2 .L) + V (1- S^T . S)$.. (9)

In order to minimize M we have to take the derivative of M w.r.to S and equate to zero and finally we get
$O= k L^T + (1-k) S_2^T . L^T .S_2 .L$ .... (10)
Finally, it has been found that the eigenvector of a symmetric rank one matrix O and it has one positive Eigen value and N-1 zero Eigen values which provides the minimum correlation spreading sequence. Any spreading code of length N can provide N-1 number of minimum correlation spreading codes. Here, the generated N-1 numbers of codes which are eigenvectors of zero Eigen-value of the matrix O are orthogonal to each other. Hence it is desirable to have a code family consisting of spreading codes which possess both impulsive ACF and all zero CCF characteristics [5-6]. But unfortunately no such code family exist which possess both the required characteristics simultaneously.

E. Algorithm for proposed code:

Step1: Input a known sequence (s) of spreading code having binary bits of maximum length N taken randomly or any column of Walsh matrix of N length sequence except the first column which contain all zero element.

Step2: Construct a matrix L_1 of size NXN whose first row of N sequence generated from the above step by transposing the column in to row and all other N-1 rows are generated by circular shift of previous row by one bit shift .

Step3: Construct another matrix L_2 of size NXN by taking all element equal to one (unit matrix).

Step4 : Perform multiplication of matrix L_2 with each column vector of L_1 obtained a matrix L_{21} of size NX1.Thus N number of NX1 column vectors are formed .

Step5: Arrange all column vectors to generate the matrix Y and then take the transpose of that matrix to form a new matrix Y_1.

Step6 : Evaluate $O_i=K L_2^T+(1-K)Y_{ri} Y_{1ci}$ Where $0\le K \le 1$,K is a scalar quantity here I takes the value from 1 to N generate N no of NXN symmetric matrix.

Step7: Take the Eigen value and Eigen vector of O_i matrix.

Step8: For each matrix of O produce (N-1) no of zero Eigen values and one nonzero Eigen values. The corresponding Eigen vectors of N-1 no of zero Eigen values are mutually orthogonal to each other.

Step9: Finally for N length code generate N (N-1) number of distinct orthogonal code.

Step10: The rows of the matrix O will provide the members of the proposed code sequence.

III. SIMULATION AND RESULTS

The performance of the proposed code has depended upon large number of code generation, autocorrelation & cross correlation property which reduces MAI, ISI & analysis of BER performance of different number of users.

A. Performance based on number of codes:

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For all NXN number of matrix value N (N-1) no of zero Eigen values and N no of non zero Eigen values which gives the orthogonality property of the codes. Comparison of number of spreading codes shown below

Number of distinct code members			
Walsh (N)	Orthogonal Gold (N*N-1)	Orthogonal small set Kasami (√N*N-1)	Proposed OMCSC (N*N-1)
4	12	6	12
16	240	60	240
64	4032	504	4032
256	65280	4080	65280

From the above table we conclude that as number of users increases number of codes are also increases .By comparing the number of spreading codes of proposed code with different existing codes the number of distinct code members increases and it is more in case of both orthogonal GOLD code and proposed code .Walsh code has less number of distinct code members.

*B. **Performance based on autocorrelation property of codes**.*

The average magnitude of autocorrelation property of the proposed code is used to reduce ISI effect. The performance of autocorrelation of the proposed code is analyzed by MATLAB program as shown in fig 1(a) graph. It gives an impulsive peak at zero time shifts. Then the performance of autocorrelation of proposed code is compared with other known spreading codes like Walsh code, PN sequence, orthogonal Gold code, small set kasami code. In this thesis comparison of average magnitude of autocorrelation of different spreading codes with proposed code is shown by 1(b) graph.

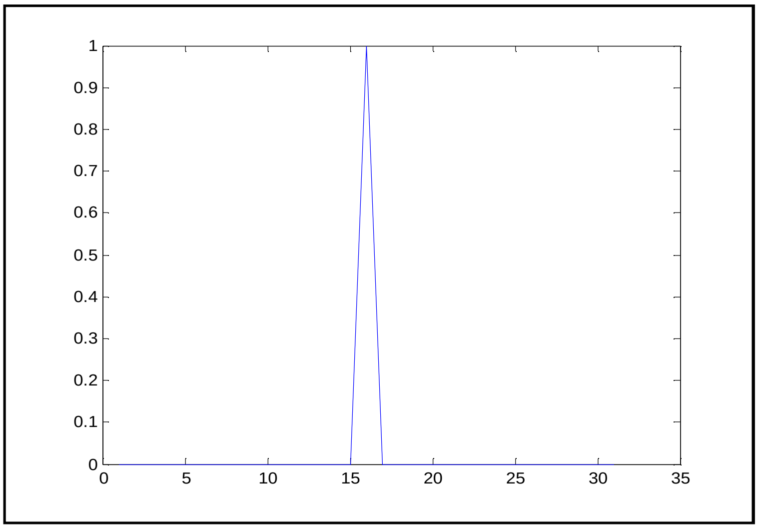

Fig1 (a) average magnitude of autocorrelation of proposed code

The average magnitude of autocorrelation vs. number of shift gives an impulsive peak at zero time shift i.e. maximum value at zero and side lobs give minimum as compared to others i.e. zero. Hence from the figure 1(b) the autocorrelation of proposed code gives good result then other existing spreading codes.

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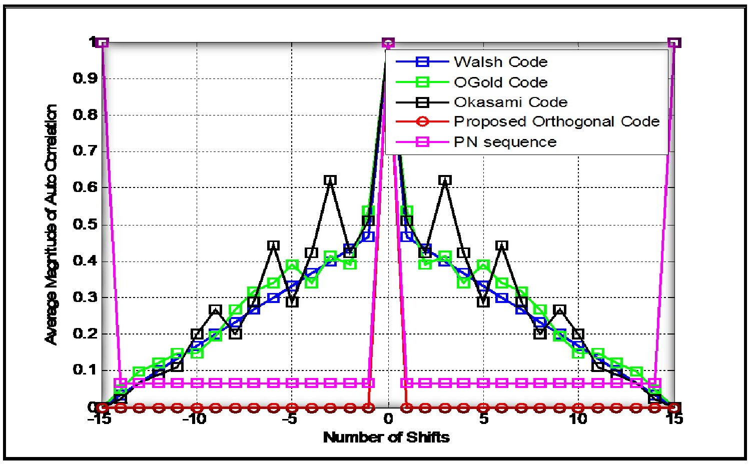

Fig1 (b) Average magnitude of autocorrelation vs. number of shift

C. Performance analysis based on cross correlation:

In order to reduce the effect of MAI at the receiver, the cross-correlation value must be zero at all time shifts. If the cross correlation is less, then more users will be able to communicate in the system and spreading codes are near orthogonal.

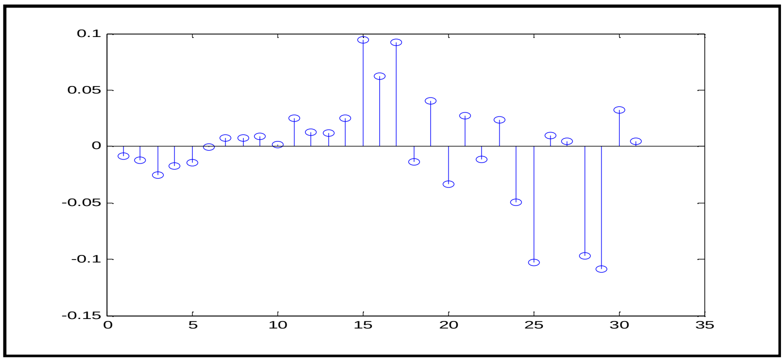

Fig 2(a) average magnitude of cross correlation

So from the cross correlation performance graph of spreading codes results near orthogonal spreading codes with zero cross correlation value at all time shift shown in fig 2(a).

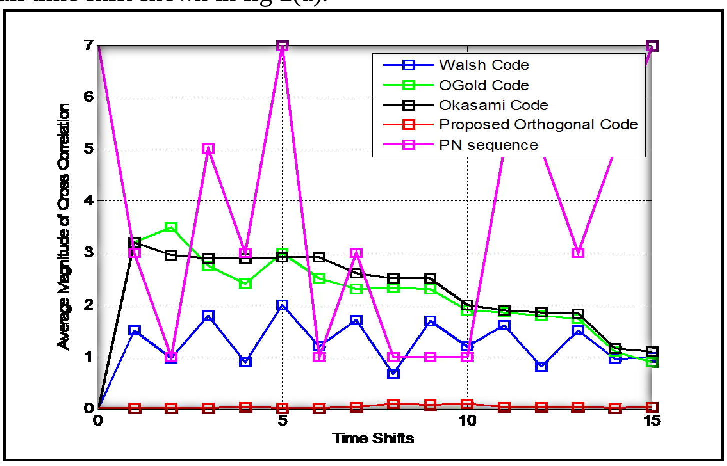

Fig2 (b). Average magnitude of cross correlation vs. number of shift

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Hence comparison of cross correlation values of proposed code with other existing code shown in fig 2(b) gives good result then other existing spreading codes. Here after analyse the average magnitude of cross correlation with number of shifts of different codes we get minimum cross correlation value i.e. approximately zero cross correlation value at all time shift of proposed code then the other existing code.

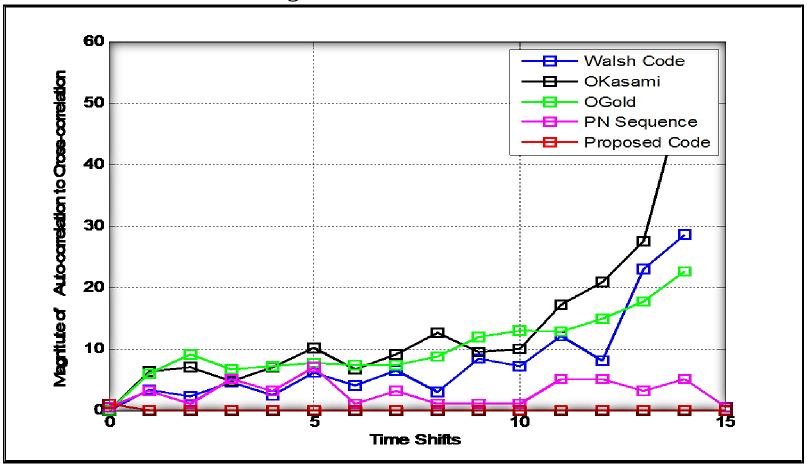

Fig2(c) Average magnitude of auto correlation to cross correlation vs. Number of shift

D.Performance analysis based on Bit Error Rate (BER):

The spreading code that provides least BER has been considered as the most efficient one. Thus BER can be thought of as a very important tool in evaluating the performance of any spreading code in a spread spectrum communication system For this purpose, SIMULINK-based downlink CDMA system model has been used and BER tool is used in MATLAB to get the best result for different number of users like two user, six user, eight user, ten user, twelve user and in figure3(a), 3(b), 4, 5, 6, 7.Here the simulation deals with synchronous transmission, decorrelator receiver and code length is 16.

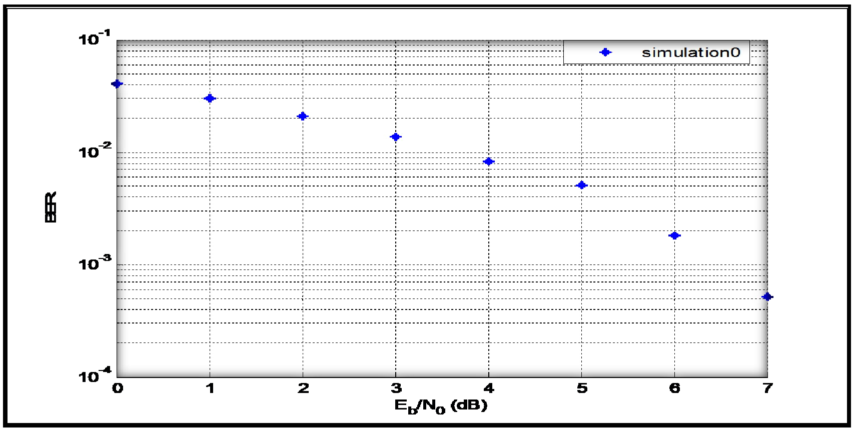

Fig 3 (a) simulation graph for two users

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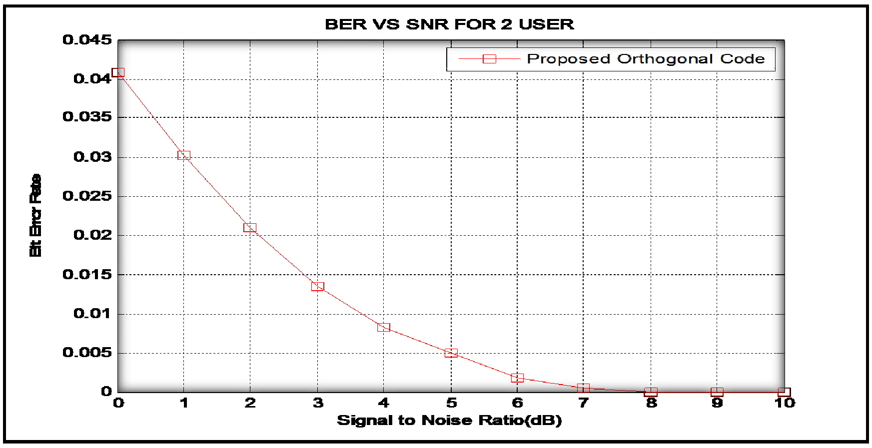

Fig 3(b) BER VS. SNR for two users

In case of fig 3 (a) and 3(b) the bit error rate decreases with increase of signal to noise ratio value hence the system capacity increases for two users.

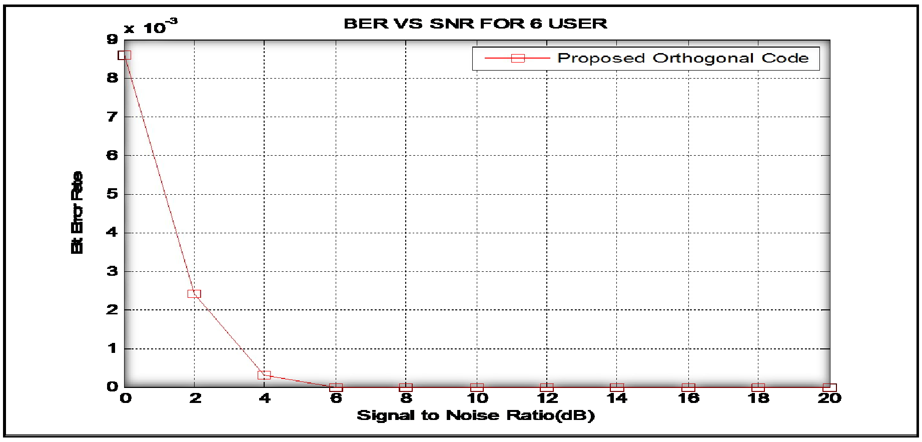

Fig4 BER VS.SNR for six users

Simulation analysis of six users in fig 4 uses the system simultaneously and gives minimum values of BER at maximum value of SNR.

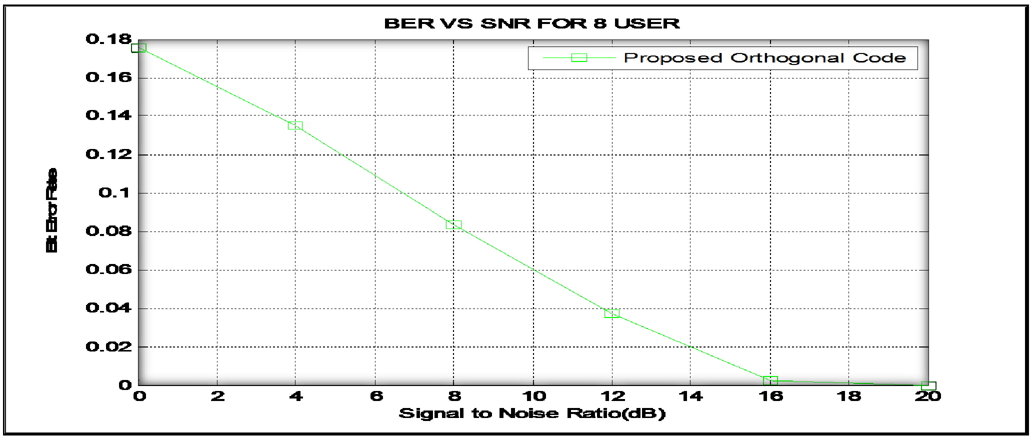

Fig5 BER VS SNR for eight users

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Similarly in fig5, 6& 7 gives same result hence we conclude that as number of user increases better is the BER performance and more is the system capacity because bit error rate is a function of signal to noise ratio.

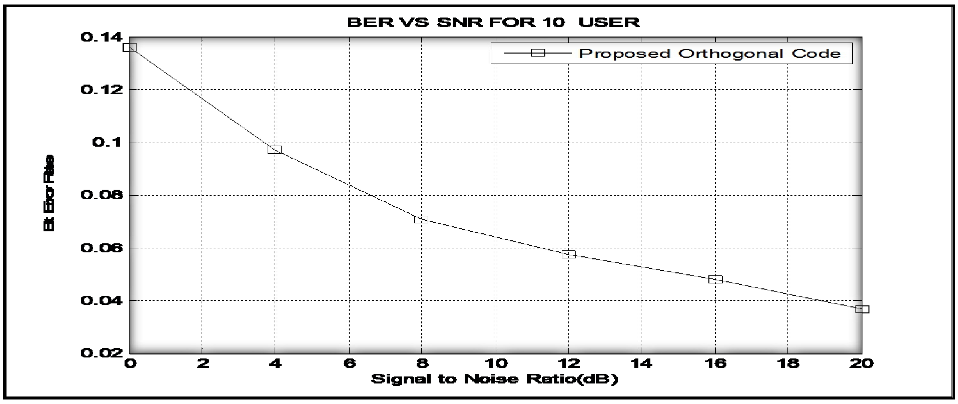

Fig 6 BER VS.SNR for 10 users

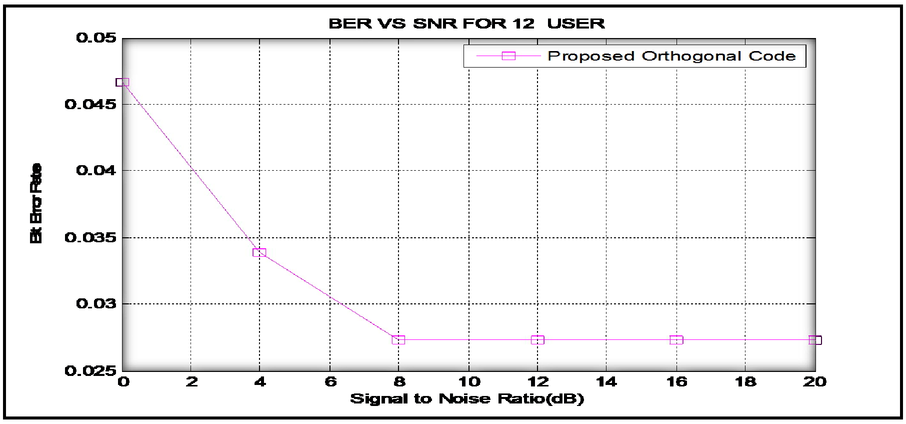

Fig7 BER VS.SNR for 12 users

E. Comparisons based on proposed code with other existing code by different users:

In fig.8,9 & 10 the BER of proposed code is compared with Walsh code, orthogonal small set Kasami code & orthogonal Gold code which is a function of signal to noise ratio for 8 user,10&12 user case. Here from the figure the proposed code have better BER performance then the other existing codes. Hence CDMA system capacity increases.

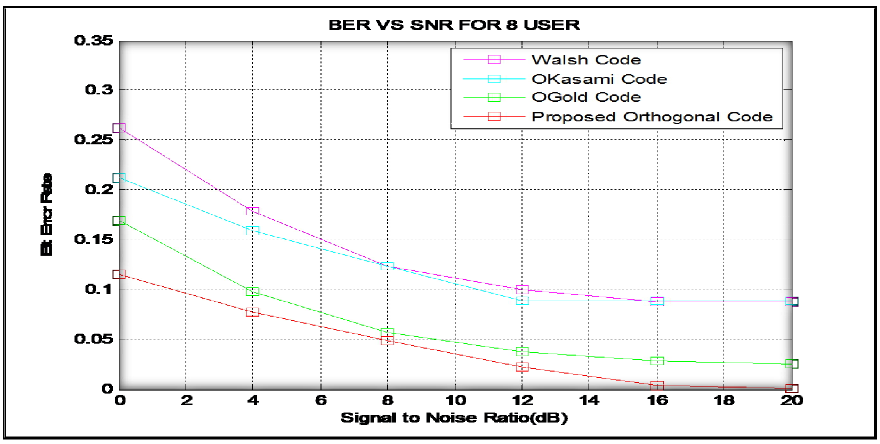

Fig8

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In fig8 from the graph the proposed code has better BER performance in comparison to other existing codes. Orthogonal Gold code has improved BER performance then Walsh code and Kasami code but worst then proposed code. Hence Walsh code has less BER performance than others.

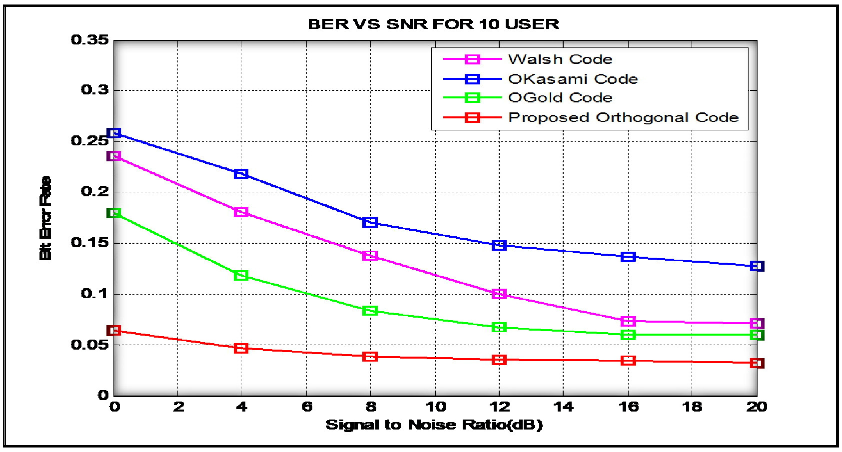

Fig9

Here in fig9 BER performance of Orthogonal Kasami code is less than others and proposed code gives better performance than existing codes.

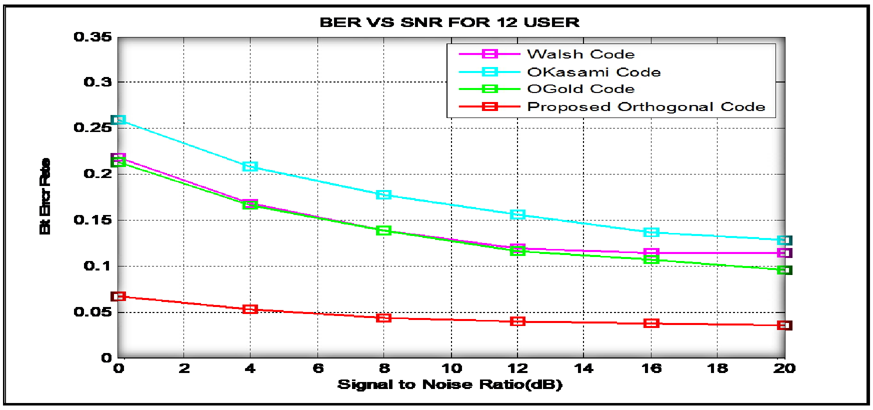

Fig10

In fig10 BER performance of orthogonal kasami code is worst than other codes. Orthogonal GOLD code and Walsh code has approximately same BER performance and the proposed code gives better performance than other existing codes. Hence as the number of user's increases the BER performance also improved more and more and the system capacity also increases.

IV. CONCLUSION AND FUTURE WORK

The simulation result, mathematical analysis proposed algorithm is implemented by using Matlab7.10 has been proposed in this thesis generate near orthogonal minimum correlation spreading code for CDMA system. The performance result of the proposed code depends upon availability of more number of codes, minimum cross correlation and impulsive peak autocorrelation and minimum BER value. Here by using the above factors and by using a given code of length N the proposed code generates N(N-1) number of distinct codes then the other existing codes. by comparing the BER performance value of different users with other existing orthogonal spreading codes which gives better performance then other. Hence considering the above facts it can be conclude that the proposed code gives a unexpected performance then other existing codes in all respect and gives a optimum solution for future CDMA communication system.

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The future woks that has to be done is

- As synchronous CDMA system is used in this thesis, a hope is generated to implement these methods in asynchronous CDMA system.
- Future work on study the average power ratio of CDMA system.
- Here in this thesis fixed length is used so it gives a scope for variable length to generate large number of spreading codes and reduce the effect of ISI &MAI.
- It also extended for design of multiple level orthogonal codes and its hardware implementation.
- It also gives a scope for generation of spreading codes for multicarrier DS-CDMA system.

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