

# Survey of Interference Mitigation Techniques and Correlation Properties of Spreading Codes for MC-CDMA System

Priyanka Raut<sup>1</sup>P.G. Student, Department of Electronics and Tele-communication Engineering, Rajiv Gandhi Institute of Technology  
Mumbai, India<sup>1</sup>

**ABSTRACT:**In this paper, we present extensive review on different Multiple Access Interference (MAI) cancellation schemes for Multi-Carrier Code Division Multiple Access-Orthogonal Frequency Division Multiplexing (MC-CDMA) for Next generation wireless communication systems. This paper starts with the detailed structure of MC-CDMA system, their requirements, and then proceeds to describe the Issues happen in MC-CDMA wireless communication systems by eliminating those issues with help of novel interference cancellation schemes Multiple Access Interference (MAI) is the major challenge in the MC-CDMA System due to Asynchronous Transmission and imperfect correlation property of the Orthogonal spreading codes after passing subcarriers through the multipath fading channel which tend to destroy the Orthogonality among the users and system performance is degraded. The goal of this paper is to highlights the various advanced interference cancellation schemes; various aspects influencing the proper selection of Spreading Codes through capacity and BW expansion improvement and made comprehensive comparison of all the schemes on the basis of their performance and fulfilments for future wireless communication based MC-CDMA-OFDM System.

**KEYWORDS:**Multicarrier Code Division Multiple Access (MC-CDMA), Multiple Access Interference (MAI), Intercarrier Interference (ICI), Intersymbol Interference (ISI)

## I. INTRODUCTION

Wireless communication is one of the most vibrant areas in the communication field today. While it has been a topic of study since the 1960s, the past decade has seen a surge of research activities in the area. This is due to a confluence of several factors. Such as tremendous increase in demands of connectivity, higher data rates, synchronous, and asynchronous data transmission, rapid introduction of new services and technologies. During recent year there has been significant improvement in the field of wireless communication 3G and 4G focusing on that demands. Beyond 3G, A 4G system will be able to provide a comprehensive IP solution where voice, data and streamed multimedia can be given to users at higher data rates than previous generations. The primary aim of future wireless communication system will not only be the overview of new technologies to cover the need for higher data rates and new services, but also the integration of existing technologies in a common platform [3].

4G technologies support multicarrier Modulation systems such as Orthogonal Frequency Division Multiplexing (OFDM), Multicarrier code division multiple access (MC-CDMA) both are the assuring challenger in Next generation wireless communication system due to robustness against the frequency selective fading channels and multipath fading channels. MC-CDMA is the combination of the OFDM signalling and CDMA systems. OFDM lowers ISI by prefixing the symbol with repetition of the end using Cyclic prefix (CP) and protect the OFDM signal from ISI. CDMA provides multiple access ability as well as spread each user signal over the frequency domain to reduce the impact of frequency selective fading. Combination has major advantage that it can lower the symbol [3].

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

Rate in each subcarrier so that longer symbol duration makes it easier to quasi-synchronize the transmissions. MC-CDMA is promising candidate and powerful multiple access technique. Due to the use of OFDM it is more robust to the ISI. However, Carrier Frequency Offset (CFO) tend to destroy the orthogonality between the users and lead to MAI. In MC-CDMA system transmitter transmits user data symbols that are spread using the given orthogonal spreading code and then modulates on different subcarriers. After passing through multipath fading channel, codes are no longer orthogonal at receiving end due to unmatched correlation properties of the spreading codes and Multiple Access Interference occurs [5].

There are number of techniques for capable of mitigating MAI like Multiusers detection, function of spreading sequence, Maximum ratio combining (MRC), Orthogonal restoring combining (ORC) Minimum mean square error combining (MMSEC), MMSEC requires higher evaluation of the system and due to this system complexity increases. In case of single users MRC gives better performance but if no.of users increases BER increases. MRC provides frequency diversity gain. Another way to mitigate MAI is succeeded by code strategy while keeping structure of MC-CDMA system is unchanged. For the realization of MUD perfect channel estimation is necessary. Multiuser more complicated and its accuracy degrades as the number of users increases, which will destroy the performance of the system. Suboptimum linear MUD techniques such as Minimum Mean Square Error (MMSE) techniques are explored. MMSE needs maximum Signal to Noise plus Interference Ratio (SINR), instead of minimization of the BER that is the objective of a good receiver [4-6].

In this paper, we analyse the interference mitigation problem for MC-CDMA systems for this select a set of good spreading codes keeping the transceiver construction simple and the computational burden low.

Outline of this paper is as follows: Section 2 describes MC-CDMA Transceiver structure with proper analysis. Section 3 and section 4 describes the different MAI cancellation techniques and types of sequence with comprehensive comparison of all on the basis of their performance and fulfilments for future wireless communication. Section 5 concludes finally.

## II. MC-CDMA SYSTEM MODEL WITH ANALYSIS

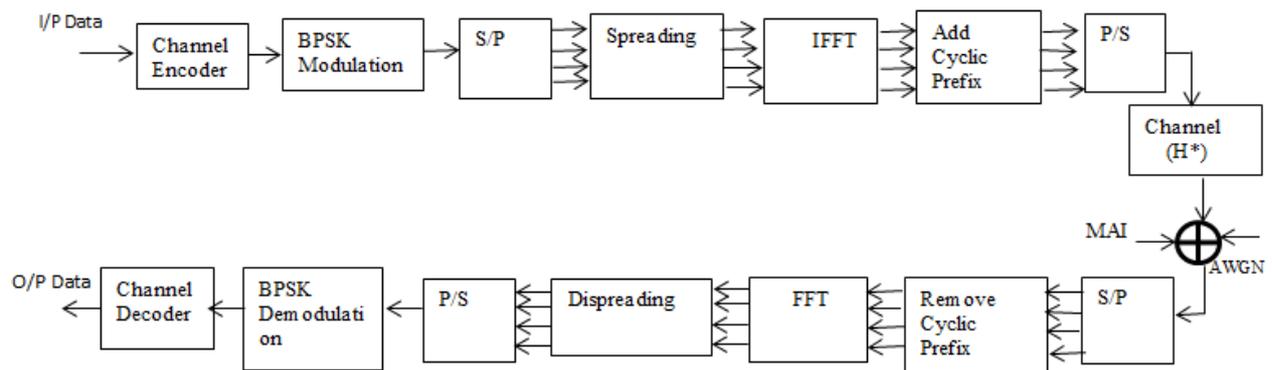


Fig.1 Shows Transceiver structure of MC-CDMA system in which the input data source is encoded and then modulated with carrier. By using suitable spreading sequence modulated data is spreaded in frequency domain and transmitted on parallel subcarriers using S/P converter.  $[N_c = G_{MC}]$ . Parallel subcarriers are generated using Inverse Fast Fourier Transform these are orthogonal to each other. MC-CDMA system lowers the interference between the consecutive symbols by cyclically extending the FFT block with cyclic prefix. After P/S signal is then transmitted through a channel and received at the receiver is affected by additive white Gaussian noise (AWGN). At the receiver, after S/P parallel data is subjected to the cyclic prefix removal followed by the fast Fourier transform (FFT) of the received signal. Finally, data is regained after demodulating and decoding the received signal. MC-CDMA system is divided into 2 parts one is time domain spreading and frequency domain spreading. Spreads the serial-to-parallel (S/P) converted data streams using a given spreading code, and then modulates it on different subcarrier with each data

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

stream that is time domain spreading. And spreads the original data stream using given spreading code and modulates it on different spreading code that is frequency domain spreading difference is that in frequency domain first spread the sequence and then modulates. And reverse process happens in time domain spreading.

Spreading in frequency domain with  $[N_c = G_{MC}]$ . Walsh Hadamard code is used because these are orthogonal to each other and perfect auto-correlation property.

The transmitted signal of the  $j^{th}$  user is written as

$$s_{MC}^j(t) = \sum_{i=-\infty}^{+\infty} \sum_{m=1}^{G_{MC}} a^j(i) C_m^j \cdot p_s(t - iT_s) \cdot \cos\{2\pi(f_0 + m\Delta f)t\} \quad (1)$$

Where,  $f = 1/T_s$  the subcarrier separation, and  $p_s(t)$  is the pulse waveform defined as:

$$p_s(t) = \begin{cases} 1 & (0 \leq t \leq T_s) \\ 0 & otherwise \end{cases} \quad (2)$$

At the receiving end receiver combines all the signals in frequency so after the serial-to-parallel conversion, the  $m^{th}$  subcarrier is multiplied by the gain  $q_m$  to combine the received signal energy scattered in the frequency domain and diminish the effect of fading.

The decision variable is given by

$$D^{j'} = \sum_{m=1}^{G_{MC}} q_m^{j'} y_m \quad (3)$$

$$\text{Where, } y_m = \sum_{j=1}^J z_m^j c_m^j a^j + n_m \quad (4)$$

Where,  $y_m$  and  $n_m$  are the complex baseband component of the received signal and the complex additive Gaussian noise at the  $m^{th}$  subcarrier,  $z_m^j$  is the complex envelop of the subcarrier  $m^{th}$  for the  $j^{th}$  user. And J is number of active user. Where,  $j = (1, 2, \dots, J)$ .

### III. RELATED WORK

In this chapter we will explore the ideas of various researchers about detection and prevention of different Interference cancellation techniques on Multicarrier Modulation systems such as MC-CDMA, OFDM systems.

S. Hara and R. Prasad, [1] discussed that, if the original symbol rate is high it occurs frequency selective fading, the signal needs to be first S/P-converted before spreading over the frequency domain the proper choice of the number, of subcarriers and the guard interval is important in order to increase the robustness against frequency selective fading.

K.Fazel and S. Kaiser [2] the basic principle of OFDM technique is to split the available spectrum into N number of sub-channel bandwidths and transmission of signal using orthogonal carriers through these sub-channels. OFDM converts the frequency selective channel to frequency flat channel so that it can completely eliminate Inter symbol interference (ISI). This is the major advantage of OFDM (which is multi carrier communication) over single carrier communication.

Y. Zhao and S.G. Haggman suggested that [4] In spite of a loss of bandwidth, the ICI self-cancellation scheme is a very simple way for suppressing ICI in OFDM system. Its main idea is to modulate one data symbol onto a group of subcarriers with predefined weighting coefficients. By doing so, the ICI components generated within a group can be "self-cancelled" each other.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

P. Castodi [5] proved that MC-CDMA is an important multiple access candidate for 4G wireless communication system. During asynchronous transmission, multiple access interference (MAI) is a major challenge for MC-CDMA and significantly affects their performance have studied spreading sequence, MLS Detector, Frequency-Domain Oversampling and slow frequency hopping MAI reduction algorithms and compare that algorithms for multicarrier transmission, all which have the potential to reduce MAI at the cost of loss in data rate, increase in BER, transmit signal power and computational complexity.

S. Verdu [6] have suggested Multiuser detection (MUD) or related signal processing algorithms to mitigate MAI. Due to heavy processing load number of users increases. Moreover, the channel information is needed for the application of the MUD scheme so channel estimation plays important role. Their complexity is high, and this imposes a computational burden on the receiver.

E.Geraniotis [7] suggested Slow Frequency hopping algorithm involve changing or hopping carrier frequency in every predetermined time interval For slow frequency hopping (SFH), the predetermined time interval is restricted to any values that are much larger than one symbol duration. SFH has been successfully implemented in DS-SS as way to reduce the MAI during synchronous transmission this technique is referred to as frequency hopping MC-CDMA (FH/MC-CDMA). However, to clearly represent the nature of hopping and to confusion, this technique is also referred to as group subcarrier frequency (GSFH/MC-CDMA). In GSFH/MC-CDMA has been implemented under synchronous condition. It was found that GSFH/MC-CDMA can increase capacity of system and outperform MC-CDMA in a tap delay line corrected channel. The problem for GSFH/MC-CDMA, however, is the condition of group hopping, which is found to be unnecessary which put constraint on the total bandwidth to be multiples of  $N$  subcarrier frequency. Therefore new MCCDMA based on SFH is proposed; this new system referred to as Individual subcarrier frequency MC-CDMA (ISFH/MC-CDMA).

Lu, H.-Y and Suk-Hoon Noh [8-9] have suggested serial or successive and parallel cancellation techniques, in serial cancellation the interference caused by the remaining users is removed from each user in succession. However in order to achieve this, a specific geometric power distribution must be assigned to each user. Another disadvantage of this scheme is that there is a delay in accomplishing the interference cancellation of all users in the system. In parallel processing the interference produced by the remaining users accessing the channel is simultaneously removed from each user. By using optimum detection techniques and IC techniques users capacity is also increases or methods such as decor relating receiver. And also proposed the Walsh Hadamard codes, zero correlation zone (ZCZ) The WH codes are mutually orthogonal codes used to spread the data sequences in a CDMA system. These sequences have zero cross-correlation when the codes are synchronous, but when asynchronous, their cross-correlation is very much dependent on the particular pair of codes used, some will have cross-correlation zero while others will have a very high correlation. WH codes are created using Hadamard matrix. The spreading sequenced that have ideal impulsive ACF and zero CCF can significantly reduce the interference affecting the system. But the drawback is difficult to design such ideal sequence.

## IV. MAI MITIGATION TECHNIQUES AND TYPES OF SEQUECES

There are number of MAI mitigation techniques are used like Multiusers detection, function of spreading sequence, Maximum ratio combining (MRC), Orthogonal restoring combining (ORC) Minimum mean square error combining (MMSEC), in this section these techniques and types of sequence are analyse with its advantages and disadvantages.

### A. MULTIUSER DETECTOR (MUD)

The basic idea behind multiuser detection was to take into account all the information of all the users simultaneously and give the decision according to maximum likelihood criterion over one bit period. The very purpose of multiuser detection is to find out different ways to process outputs of matched filters so that the transmitted bit can be detected accurately. The basic operation of multiuser detection algorithm is to drop out effect of interference on each user data bit and jointly detect the data bits. In MUD MAI term is used as useful information to detect the received bits correctly. For the realization of MUD perfect channel estimation is necessary. Multiuser more complicated and its accuracy degrades as the number of users increases, which will destroy the performance of the system. MUD provides good BER in comparison with single user detector but AWGN is low. Due to increasing number of users complexity increases but

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

it eliminates all types of interferences. For reducing the complexity, different types of detector have been developed such as Minimum mean square error detector (MMSE) and Subtractive interference cancellation (SIC). Parallel interference cancellation. MUD is similar to diversity technique in communication [6].

### **B. MINIMUM MEAN SQUARE ERROR COMBINING (MMSEC)**

It's a type of Suboptimum linear multiuser detection technique. It evaluates the mean square error between evaluated bit and received bit. Eliminate background noise as well as MAI but it requires the higher computation and due to this system complexity increases. For MUD Perfect channel estimation about the subcarriers is necessary for the achievement of the channel state estimation (CSI). And MMSEC demands for simple realization it claims for signal to noise plus interference ratio without reducing BER performance. It provides better performance than Equal Gain Combining but provides worse performance than ORC-MRC [4].

Gain  $q_m^{k'}$  is given by

$$q_m^{k'} = c_m^{k'} z_m^* / (J|z_m|^2 + N_m) \quad (5)$$

Where,  $N_0$  is the noise power.

### **C. ORTHOGONALITY RESTORING COMBINING-MAXIMUM RATIO COMBINING(ORC-MRC)**

Orthogonality Restoring Combining is diminishes the effect of channel phase shift and channel amplitude fading. Low rate data streams tend to be multiplied by high gains, and the noise components are amplified at weaker subcarriers. Noise amplification degenerate the BER performance of the system.

gain  $q_m$  is given by,

$$q_m^{k'} = c_m^{k'} z_m^* / |z_m|^2 \quad (6)$$

where,  $z_m^k$  is the complex envelop of the m-th subcarrier for the  $k^{th}$  user.

Maximum ratio combining is the diversity combining technique. To suppress the effect of MAI and acquire the frequency diversity gain and improves SNR by enrolling with the M element sequences multiplied by the weighted factor and proportional to signal amplitude. The gain for maximum ratio combining is given by,

$$q_m^{k'} = c_m^{k'} z_m^{k'*} \quad (7)$$

Maximum ratio combining quite improves BER performance if one user using frequency allocation at the time system. But if number of user's increases system degrades the performance [15]. In case of ORC offers MAI-free performance. it demands more no. of gain vectors for lower SNR. But if ORC is used along with the MRC it provides better performance. By using reconstruction detection algorithm ORC evaluates the transmitted sequence (symbol). And MRC evaluates the candidate of transmitted sequence (Symbol) after suppression of interference from MUD and formulate the decision variable from correlation output of filtered signal. If decision for further users is accurate then BER provides better performance [1].

### **A. PN SEQUENCE**

Pseudo random Noise Sequence is a binary sequence which though deterministically generated by a circuit or an algorithm appears to be statistically random like in the case of a fair coin flipping. PN sequences are generated by combining outputs of feedback shift registers. Some of the properties are as follows: PN sequences are deterministic and periodic in nature. The same pattern repeats after some duration. PN sequence is used in MC-CDMA system because it spreads the bandwidth of baseband modulated signal to the much larger bandwidth before transmission to distinguish between different users by allocating unique PN sequences to them. It must be deterministic and random to a

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

listener without prior knowledge of the code, the cross-correlation between any two codes must be small, and the code must have a long period[8].

## B. GOLD SEQUENCE

In order to construct PN sequence having smaller cross correlation can add preferred pair of m-sequence to make gold sequence. One of a family of pseudo-noise codes that exhibits minimal, well defined, cross-correlation levels with all other members of the family. This property is often exploited in CDMA spread spectrum systems. A Gold code is normally generated through modulo-2 addition of two PN codes of equal length. Distinct members of a Gold code family are determined by the chip (bit) offset of one code relative to the other. Preferred pairs of PN codes, which exhibit optimal performance, have been thoroughly studied and documented. A balanced Gold code is one in which the number of ones exceeds the number of zeros by one, a trait shared by all m sequences. Gold developed new sequences with better cross correlation properties called Gold sequences[7-8].

## C. WALSH HADAMARD SEQUENCE

Walsh code is called Hadamard Transform. These are error correcting orthogonal codes. Important property is that they are orthogonal to each other's and does not have to pay the attention of auto-correlation property of the spreading code. But cross correlation between different Walsh codes are not zero so it cannot be users for simultaneous transmission. Walsh codes are the backbone of the CDMA One and cdma2000 cellular systems, and are used to support the individual channels used simultaneously within a cell [8].

## D. KASAMI SEQUENCE

It's a binary sequence and has good auto correlation property. Generation of Kasami sequence is same like generation of Gold sequence It creates a maximum length sequence a (n) a periodic sequence and period is  $2^N - 1$  N is even integer. Large set of maximum correlation value is same as like Gold sequence. There are two groups of Kasami Sequences one is the small set number of sequence is  $2^{n/2}$ . And another is large set with number of sequence is  $2^{n/2} (2^n + 1)$ [7 - 1].

## IV. CHARACTERISTICS ADVANTAGES OF SPREAD SPECTRUM AND ORTHOGONAL SEQUENCE

It obtain a secure communication improves interference rejection, hide signal by transmitting it at low power thus making it difficult for unintended listener to detect in presence of background noise.

Resistance to Interference and Jamming (Jam resistance): Intentional or unintentional interference and jamming signals are rejected because they do not contain the spread-spectrum key. Only the desired signal, which has the key, will be seen at the receiver when the despreading is done.

Low Probability of intercept (LPI): Since undesired users do not have the key used to spread the original signal, those users cannot decode received sequence without the proper key, the spread-spectrum signal appears as noise or as an interferer.

Resistance to Fading (Multipath Effects): Wireless channels often include multiple-path propagation in which the signal has more than one path from the transmitter to the receiver. Such multipath can be caused by atmospheric reflection

or refraction, and by reflection from the ground or from objects such as buildings. The reflected path (R) can interfere with the direct path (D) in a phenomenon called fading. Because the despreading process synchronizes to signal D, signal R is rejected even though it contains the same key.

To permit Multiple Accesses: Spread spectrum can also be used as another method for implementing multiple accesses.

Advantages: Narrow-band interference rejection,  
Simple one tap equalization,

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 11, November 2016

Higher flexibility and higher spectral efficiency  
Provides the robustness against the multipath fading channels

A channel-access scheme is based on a multiplexing method that allows several data streams or signals to share the same

## V.CONCLUSION

In this paper we have done an extensive study of MC-CDMA system and Interference cancellation techniques with proper selection of spreading code for better performance of the system. Every system has its drawbacks and advantages some has computation problem but has an improved BER; some has complex but has good data rates.

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 we observe that it has low power spectral density, privacy is more, and overall good performance.

## REFERENCES

- [1] S. Hara and R. Prasad, "Design and performance of multicarrier CDMA system in frequency selective Rayleigh fading channels," *IEEE Transactions on Vehicular Technology*, vol. 48, no. 5, pp.1584-1595, Sep. 1999.
- [2] K.Fazel and S. Kaiser, "Multi-Carrier and Spread Spectrum System," Second Edition, *John Wiley and Sons*, 2008.
- [3] N. Yee, J-P.Linnartz and G. Fettweis, "Multicarrier CDMA in Indoor Wireless Radio Networks," *Proc. of IEEE PIMRC'93*, Yokohama, Japan Sept. 1993, pp.109-13.
- [4] Y. Zhao and S.-G. Haggman, "Intercarrier interference self-cancellationscheme for ofdm mobile communication systems," *IEEE Transactions on Communications*, vol. 49, pp. 1185-1191, July 2001
- [5] P. Castodi, *Multiuser detection in CDMA mobile terminal* Boston Artech House.2002
- [6] S. Verdu, *Multiuser Detection*. Cambridge, U.K.: Cambridge Univ.Press,
- [7] E.Geraniotis, "Coherent hybrid ds-ss-spectrum multiple-access communication", selected area in communication, *IEEE Journal*, vol., Sept.1985.
- [8] Lu, H.Y, "A family of minimum mean square error multiuser detectors for three-domain spread multi-carrier direct sequence-code division multiple access", *Communications, IET*, vol. 6, no. 6, pp. 587 - 598, 2012 .
- [9] S.H. Noh, D.S. Kim, and H.Y. Song, "Performance of MC-DS-CDMA using zczsequences (in Korean)", *JCCI 2005*, 2005.
- [10] R.van Nee and R. Prasad, *OFDM for Wireless Multimedia Communication*, Bartech house, 2000
- [11] R. Gold, "Maximal recursive sequences with 3-valued recursive crosscorrelation functions", *IEEE Transactions on Information Theory*, pp. 154-156, January 1968
- [12] Deepak Kedia, Dr.ManojDuhana, Prof. S.L. Maskara, "Evaluation of Correlation Properties of Orthogonal Spreading Codes for CDMA Wireless Mobile Communication", 978-1-4244-4791- 6/10/\$25.00, 2010 IEEE
- [13] H. Chenggao, N. Suehiro, T. Hashimoto., "A systematic framework for the construction of optimal complete complementary codes," *IEEE Trans. Inf. Theory*, vol. 57, no. 9, pp. 6033-6042, Sept. 2011.
- [14] S. M. Alamouti, "A simple transmit diversity technique for wireless communications," *IEEE Journal on Selected Areas in Communication*, vol. 16, no. 8, pp. 1451-1458, Oct. 1998.
- [15] G.Senthilkumar, R.Amutha, "Capacity Enhancement of MCCDMA Systems through MAI Cancellation Using Switched Interleaving Technique and Correlation Reconstruction based MRC with Diversity Gain" *International Journal of Soft Computing & Engineering*, ISSN: 2231-2307, Volume-4, Issue-1, March 2014