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An Overview of Performance Evaluation of MC-CDMA System

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Abstract : *MC-CDMA is one of the most promising technique for future mobile communication, since it offers high bit rate and high capacity transmission. It is actually the combination two efficient techniques such as Code division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) techniques. Consequently, it combines the benefits and limitation of both CDMA as well as OFDM techniques. MC-CDMA is an effective scheme that reduces the problems like spectral limitation and distortions due to multipath channels. The main limitation in MC-CDMA system is the high Peak to average power ratio (PAPR) which in turn reduces the system power efficiency. The studies shows that the use of efficient spreading codes with good correlation properties and PAPR reduction techniques, help to improve the system performance by reducing the PAPR. There are different PAPR reduction techniques such as signal scrambling techniques and signal distortion techniques, which will help to improve the system performance. However the technique should be chosen by considering the following factors such as, it should create only few harmful side effects such as in-band distortion, out-of band radiation, reduced BER degradation, low implementation complexity. This paper focusses on various problems and the possible solutions of MC-CDMA system.*

Keywords – *CDMA, MAI, MC-CDMA, MPI, MUI, OFDM, PAPR, ZCZ*

I. Introduction

In the contemporary world, the need of people to communicate and get connected with each other is increasing day by day. Hence the capacity of a wireless communication system has become critical. This problem can be resolved with the use multiple access schemes, that efficiently utilize the limited radio spectrum. The techniques such as Frequency division multiple access (FDMA) and Time division multiple access (TDMA), used by the 1G/2G technology are limited in either frequency or time slots. Hence the accommodation of large number of users becomes critical. The capacity of Code division multiple access (CDMA) technology used by the 2G/3G technology, is superior to that of FDMA and TDMA system since it assigns a pseudorandom code to each users instead of frequency and time slots [1]. However, CDMA system is interference limited. The Fig 1 shows the diagrammatic representation of various multiple access techniques.

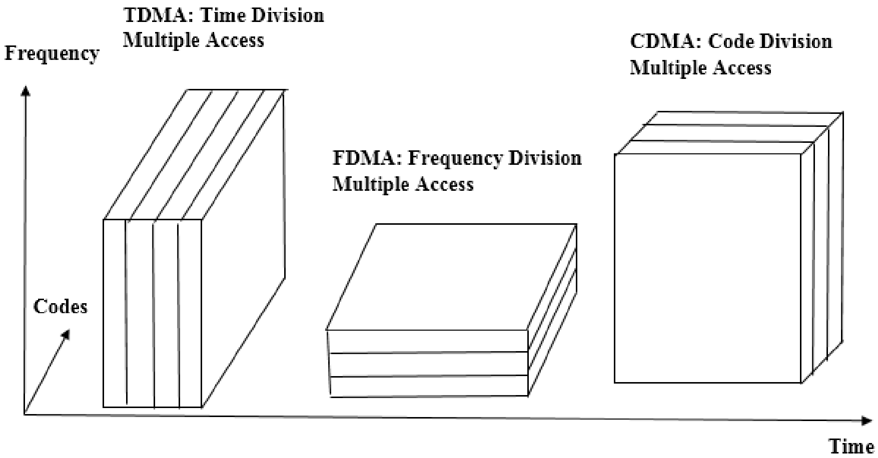

Figure 1: Multiple Access Techniques [1]

With the introduction of the new services such as multimedia, mobile internet access services, there is a need of a communication system with high spectral efficiency. High spectral efficiency can be achieved with the use of multicarrier techniques. Orthogonal frequency division multiplexing (OFDM) is one of the multicarrier technique that transmits high data rate streams into several low rate parallel subcarriers, which reduces the effect of inter symbol interference (ISI). Due to the overlapping of subcarriers, the spectral efficiency of the system is enhanced [2].

To achieve the objectives such as reduced ISI, resulting from high data rate transmission and to utilize the limited bandwidth in an efficient way, 4G technologies use a multiple access technique known as multi-carrier code division multiple access (MC-CDMA). This technique combines the advantage of both OFDM and CDMA techniques [3]. MC-CDMA scheme spreads the data symbols in frequency domain and transmitted on different subcarriers, which eliminates the chance of frequency selective fading and improves the bit error rate (BER) performance [2].

In a MC-CDMA scheme, each user is distinguished with respect to the degree of cross correlation between the spreading codes assigned to each user. The cross correlation properties of the spreading code assigned to each user results in multiple access interference (MAI). Hence the level of MAI is influenced by the spreading code assigned to each user. Hence codes used should have good correlation properties [4].

Like other multicarrier techniques, the OFDM part in an MC-CDMA structure will create peak to average power ratio (PAPR) that occurs in the system when several sub channels add in phase at the output of the transmitter [5]. As the PAPR increases, the power efficiency of the amplifier gets degrade, which causes the signal suffer from nonlinear distortion at the transmitter and degrades the BER performance of the system. The effect of high PAPR and Multiple access interference (MAI) can be reduced with the proper use of forward error coding (FEC) scheme with high coding gain [6].

The remainder of this paper is organized as: Section II describes about a brief idea of MC-CDMA system. Section III and IV focuses on the problems and possible solution of MC-CDMA system. Section V concludes the paper.

II. MC-CDMA System

The MC-CDMA scheme is a promising technology for future wireless communication systems. Future wireless communication requires a system supporting a large number of users, which can simultaneously provide high data rate. The MC-CDMA is a type of multiple access that utilize the benefits of both CDMA and OFDM schemes. The multi carrier part reduces the multipath fading and ISI, whereas the spread spectrum technology utilizes the limited spectrum in an efficient way. The high data rate transmission will make a resistive channel. The multi carrier part will overcome this problem by transmitting high data rate data into low rate parallel subcarriers. The overlapping of carriers provides high spectral efficiency.

Compared to the other multicarrier technique, in a MC-CDMA scheme the original data symbols are first spread with a pseudorandom sequence, followed by the modulation on different carriers. That is, in a MC-CDMA system the chips of same symbol are modulated on different carriers. Hence the spreading is said to be done in frequency domain. Compared to DS-CDMA, in MC-CDMA the codes that is used to distinguish each user are modulated in frequency domain, hence the need of complex rake receiver is avoided. The Fig 2[7] shows the block diagram of a MC-CDMA system.

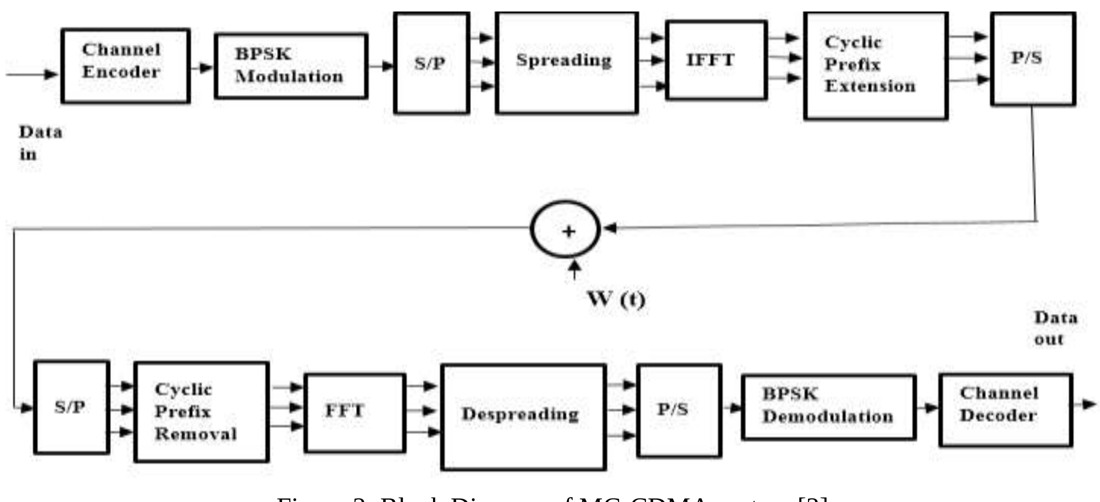

Figure 2: Block Diagram of MC-CDMA system [2]

The Fig 2 shows the block diagram of a MC-CDMA system in which the data sequence is first encoded and modulated with a suitable carrier. Here BPSK modulation is used as the modulation technique. The modulated outputs are then spreaded by a suitable spreading sequence in frequency domain and transmitted simultaneously on N_C parallel subcarriers. The number of subcarriers is kept equal to the spreading code length. These parallel subcarriers are orthogonal to each other and can be generated using inverse fast Fourier transform (IFFT). Similar to an OFDM system, the MC-CDMA system reduces the interference between the successive symbols by cyclically extending the FFT block with cyclic prefix of N_P samples. A parallel to serial converter (P/S) converts the parallel data into serial data stream. The signal is then transmitted through a channel having transfer function H_{ch} (f) and the signal received at the receiver is affected by additive white gaussian noise (AWGN) w(t) having power spectral density $N_0/2$. At the receiver, the serial data is first converted into parallel and then subjected to the cyclic prefix removal. This step is followed by the fast Fourier transform (FFT) of the received signal. Finally, the data is retrieved after demodulating and decoding the received signal.

The Fig 3 shows the BER comparison of Multicarrier DS CDMA scheme, MC-CDMA scheme with MMSEC, two subcarrier MT-CDMA scheme with 2 finger rake receiver and DS-CDMA scheme with 2 finger rake receiver. The figure clearly shows that MC-CDMA performs better than the other schemes.

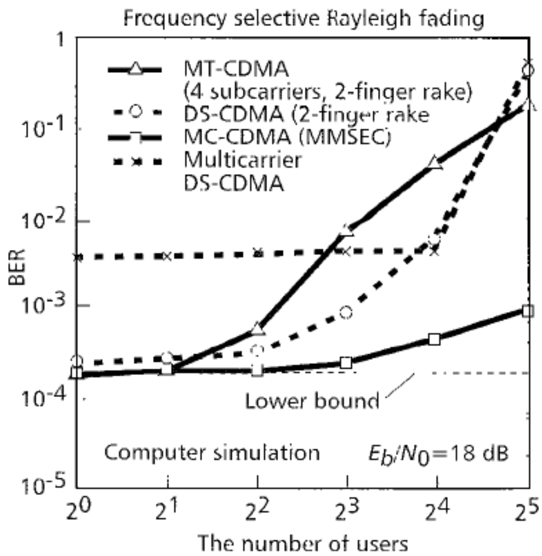

Figure 3: BER Comparison [16]

Compared to other multiple access schemes the main benefits of a MC-CDMA system includes high spectral efficiency, robustness to channel fading, flexible system design, high frequency diversity etc. However since MC-CDMA is a multi-carrier scheme, its performance is limited due to high PAPR, which occurs due to the combination of large number of independent subcarriers.

III. Problems in an MC-CDMA System

The important limiting factor in every communication system is the interference affecting the system. The MC-CDMA system is a combination of both CDMA and OFDM, hence it will have the drawbacks of both the schemes.

3.1. Interference affecting the system

The performance of a CDMA system will depend on the interference affecting the system, so that it is known as interference limited system. The interference affecting the system can be multi path interference (MPI) due to multi path delays and multiple access interference (MAI) due to multiple access delays. Both MPI and MAI cause self-interference as well as multi-user interference (MUI) that degrade the performance and capacity of CDMA systems [8]. The MPI occurs when the signal from the transmitter travels through two or more path to the receiver under the right condition. These two or more signal components will interfere resulting in MPI.

The MAI is one of the major factors that limits the performance and capacity of CDMA systems. It is actually the interference between the direct sequence users which occur due to the random time offset between the signals. Due to MAI, the design of orthogonal code waveforms becomes difficult.

3.2. Peak to average power ratio

The OFDM scheme used in a MC-CDMA system is capable of providing improved quality of service at high data rates. At high data rates single carriers are more susceptible to fading and multipath propagation, however multicarrier techniques eliminates the need for complex equalizers by maintaining high data rate transmission [9]. The OFDM scheme transforms a wideband channel in to a narrowband channel and the use of narrow band signals will reduces frequency selective multipath fading because narrow band signals are less sensitive to fading and inter symbol interference (ISI). However in a multicarrier system, at the output of the transmitter several subcarriers add in phase which creates high PAPR. The PAPR of a MC-CDMA signal x (t) is actually defined as the ratio of maximum power of a sample in a given OFDM symbol to the average power of that OFDM symbol. The PAPR is given by:

$$PAPR=\frac{\max[|x(t)|^2]}{E[|x(t)|^2]} \quad (1)$$

Due to high PAPR, the RF power amplifiers should be operated in a very large linear region, if not the signal peaks will move into a nonlinear region of the power amplifier which will result in signal distortion [10]. This signal distortion may result in intermodulation among the subcarriers. Hence power amplifiers should be operated with large back offs which may result in costly transmitter and poor amplification. Therefore it is essential to reduce the PAPR.

IV. Solutions to Reduce the Problems in a MC-CDMA System

The CDMA scheme used in a MC-CDMA system is interference limited. Therefore, the performance and capacity it can handle will depend on the interference affecting the system.

4.1. Interference cancellation techniques

The user capacity of a system is mainly limited due to the domination of interference affecting the system. There are several ways to improve the user capacity by using optimum detection, interference cancellation (IC) methods, or methods such as decorrelating receiver. The use of multi user algorithms improves the performance of the system, however the complexity increases exponentially with increase in the number of users and code length. In IC techniques, it attempts to remove the multiple user interference from each user's received signal prior to making data decisions. IC cancellation techniques can be mainly classified as serial or successive and parallel cancellation techniques. In serial cancellation techniques, 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 [17].

4.2. Use of efficient spreading sequence

The interferences such as MPI and MAI are closely related to the Auto-correlation function (ACF) and Cross-correlation function (CCF) of the spreading sequence used to spread the data sequence. Hence the use of spreading sequence with good correlation properties can replace the need of complicated interference cancellation techniques. The commonly used spreading sequences are Pseudo noise sequence, WH codes, ZCZ Codes, Gold codes etc.

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 sequence set that have ideal impulsive ACF and zero CCF can significantly reduce the interference affecting the system. But such ideal sequences are difficult to design. A set of spreading sequence known as zero correlation zone (ZCZ) sequence are defined to be a sequence set with zero correlation zone at out of phase state [8]. Hence, if the entire multi path and multiple access delays are within this zero correlation zone, then the use of ZCZ sequences in the system can effectively eliminate MPI and MAI. Both binary and ternary codes are a type of ZCZ code in which ternary ZCZ sequence have longer zero correlation zone and large family size. Hence the performance of the system using ternary ZCZ code is superior to the system using binary ZCZ code.

4.3. PAPR reduction techniques

Also compared to a CDMA system, the use of narrow band signals in an MC-CDMA system makes the system less sensitive to ISI and multipath fading. However, in a multi carrier system the transmitted signal exhibit high PAPR which reduces the efficiency of high power amplifier and degrades the system performance. Hence to improve the system performance, it is required to reduce the PAPR. There are different PAPR reduction techniques, which are mainly classified as signal scrambling techniques and signal distortion techniques [10].

Partial transmit sequence (PTS), selected mapping (SLM), Block coding techniques etc., are signal scrambling techniques and peak windowing, envelope scaling, peak reduction carrier etc., are signal distortion techniques. The table 1 shows the amount of PAPR reduction for different PAPR schemes [11].

Table 1: PAPR reduction for different PAPR schemes [11]

PAPR Scheme	**PAPR Reduction in dB**
Amplitude Clipping	2.0 to 3.0
Clipping and Filtering	3.9
Companding(MC-CDMA)	3.5 to 6.5
SLM (OFDM)	3.5
PTS (OFDM)	4.3
Block Coding	3.7
DCT	1.0
DWT	2.0

The PAPR reduction techniques should be selected by considering the following factors such as, it should create only few harmful side effects such as in-band distortion, out-of band radiation, reduced BER degradation, low implementation complexity etc. [10]. However, most of the PAPR reduction techniques reduces PAPR at the cost of loss in data rate, increases complexity and transmit signal power etc. Ref [12] shows that PTS is a special case of SLM and also the performance of system using PTS is superior to that of the one using SLM. However the use of both PTS and SLM increases the implementation complexity at the receiver.

The systems using an excellent coding technique can reduce PAPR and consequently improve the system performance in terms of BER. Ref [6] shows that by using efficient forward error coding (FEC) scheme having high coding gain such as Turbo code (TC) and Low density parity code (LDPC) provide better BER performance with reduced PAPR. The Fig 4 shows the BER comparison of a MC-CDMA system using turbo code, LDPC code, uncoded data, and convolutional code data with QAM modulation with AWGN channel [15].

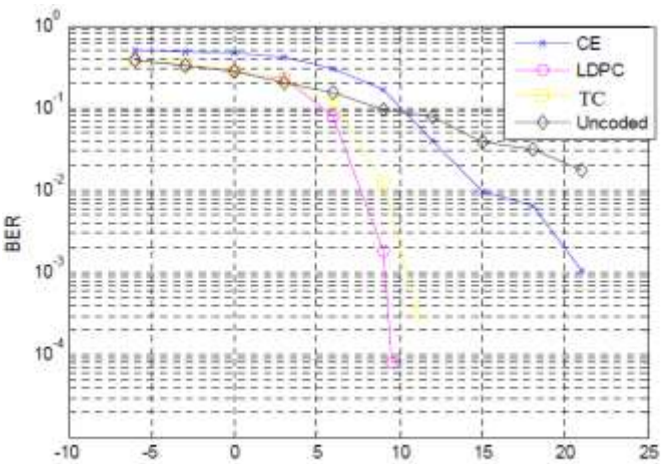

Figure 4: Coded MC-CDMA performance for Rayleigh Fading channel [15]

The Fig 4 clearly depicts that the LDPC coded MC-CDMA system behaves better than any other coded schemes. Hence the use of block coding technique with a code having high coding gain will help to reduce PAPR with low complexity.

V. Conclusion

In this paper, we have done a case study of the works done by various researchers on MC-CDMA system and it is observed that MC-CDMA suffers the benefits and limitation of both CDMA and OFDM scheme. The CDMA part makes the system interference limited and the OFDM part reduces the system performance due to high PAPR. However the use of efficient spreading sequences can reduce the interference affecting the system as well as the PAPR. The use of highly orthogonal codes such as WH code will makes the system interference free. Ref [8] proposes a code known as zero correlation zone (ZCZ) code which can effectively eliminate MPI and MAI if all the multipath delays and multiple access delays are inside the zero correlation zones. Most of the PAPR reduction techniques selected will reduce PAPR at the cost of loss in data rate, increase in BER and computational complexity. The systems using an excellent coding technique can reduce PAPR and consequently improve the system performance in terms of BER. Ref [6] shows that by using efficient forward error coding (FEC) scheme having high coding gain such as Turbo code (TC) and Low density parity code (LDPC) provide better BER performance with reduced PAPR.

References

[1] Ipatov, Valeri (2000). "Spread Spectrum and CDMA" *John Wiley & Sons, Ltd*.

[2] Madhvi J, Vrinda T, "Performance Analysis of MC-CDMA System", *IEEE 2012 RAIT Conference, pp-263-266.*

[3] S.Chatterjee,W.A.C.Fernando, .K.Wasantha, "Adaptive modulation based MC-CDMA systems for 4G wireless consumer application", *IEEE June 2003,pp-995-1002.*

[4] B.Sarala," Code Division Multiple Access transmission techniques for 3g and 4g wireless communication systems:A survey", *ACEEE 2011, Vol.05,No.02, pp-190-194.*

[5] Kiran Khurshid, Imtiaz Ahmed Khokhar, "Comparison survey of 4G competitors", *IEEE communication, August 2013, pp 1-7.*

[6] K Rasadurai, Parvathy S K, N Kumaratharan,"Performance enhancement of MC-CDMA system using LDPC codes", *2013 IEEE conference on Information & communication technologies, pp 78-82.*

[7] Heidi Steendam and Marc Moeneclaey, "Comparison of the sensitivities of MC-CDMA and MC-DS-CDMA to carrier frequency offset", *2000 IEEE, PP-166-173.*

[8] Suk-Hoon Noh, "On ZCZ Sequences and its Application to MC-DS-CDMA", *July 2005.*

[9] Zachaeus K. Adeyemo, Olumide O. Ajayi," Effect Of Subcarriers on Orthogonal Frequency Division Multiplexing at Different Mobile Speeds", *Journal of Theoretical and Applied Information Technology, 31st July 2011. Vol. 29 No.2.*

[10] ArunGangwar, Manushree Bhardwaj,"An Overview: Peak to Average Power Ratio in OFDM system & its Effect", *International Journal of Communication and Computer Technologies, Volume 01 – No.2, Issue: 02 Sept 2012, PP-22-25.*

[11] B. Sarala, D. S. Venkateswarulu, N. Bhandari," Overview of MC-CDMA PAPR Reduction Techniques", *International Journal of Distributed and Parallel Systems (IJDPS) Vol.3, No.2, March 2012, PP-193-206.*

[12] Md. Kislu Noman, Md. Mojahidul Islam, Md. ShafiulAzam, Nur Hossain Khan,"Comparative study between Selection Mapping Technique (SLM) and Partial Transmission Sequence (PTS) for PAPR reduction in OFDM signals", *IJARCCE, Vol. 2, Issue 11, November 2013, PP-4459-4463.*

[13] Nanthawan Ruangsurat, R.M.A.P. Rajathev, "An Investigation of Peak to Average Power Ratio in MC-CDMA Combined with Partial Transmit Sequence", *IEEE VTS 53rd, 2001, pp:761 – 765, vol.1.*

[14] Maryam Sabbaghian, YongjunKwak, BesmaSmida, VahidTarokh, "Near Shannon Limit and Low Peak to Average Power Ratio Turbo Block Coded OFDM", *IEEE Transactions on communications, vol. 59, no. 8, August 2011.*

[15] Aqiel N Alamaamory, HusamAbdhuldaem, "Performance evaluation and comparison between LDPC and Turbo coded MC-CDMA", *Journel of Engineering, Volume 18, April 2012*

[16] S. Hara and R. Prasad., "Overview of Multicarrier CDMA", *IEEE Communications Magazine, vol. 35, pp. 126–133, Dec.1997.*

[17] DariushDivsalar, Marvin K. Simon, Dan Raphaeli, "Improved Parallel Interference Cancellation for CDMA", *IEEE Transactions on Communications, Vol. 46, NO. 2, February 1998, PP. 258-268.*

[18] Gagandeep Kaur, Rajbir Kaur, "An Overview of PAPR Reduction Techniques for an MC-CDMA System", *IJARCET, Vol 1, Issue 4, June 2012, PP. 461-470.*

[19] Rohini S, Dr. Prof. Suriyakala C D "Performance Evaluation of MC-CDMA System – A Survey", *International Journal of Computer Science and Communication (IJCSC), Vol 6, Issue 2, April-Sep 2015.*