MC-CDMA PAPR Reduction using a Modified Exponential Companding Transform with Clipping

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Abstract

Multicarrier Code Division Multiple Access (MC-CDMA) system has the inherent problem of a high Peak to Average Power Ratio (PAPR), which results in nonlinear distortion at the High Power Amplifier (HPA) and consequently reduces power efficiency, performance degradation at the receiver. High PAPR causes lowers battery life, and requires HPAs. HPAs result in increased cost, reduced battery life, increased co-channel interference and Inter Symbol Interference (ISI). This paper analyzes a new idea that is combination of exponential companding transform and clipping concept to obtain a new Modified Exponential Companding with Clipping Transform(MECCT) technique for MC-CDMA PAPR reduction. This method evaluates performance analysis of MC-CDMA while considering linear companding and exponential companding (nonlinear) with the Additive White Gaussian Noise (AWGN) channel and is simulated using MATLAB. The simulation results show that the proposed algorithm reduces the PAPR by 2.0 dB, and are able to improve Bit Error Rate (BER), reduced Power Spectral density (PSD), and improvement in spectral bandwidth.

Index terms— MC-CDMA, PAPR, HPA, BER, MECCT

1 Introduction n recent years, Multicarrier Code Division Multiple

Access (MC-CDMA) system has been receiving wide spread interests for future wireless communications. Combining Orthogonal Frequency Division Multiplexing (OFDM) modulation and Code Division Multiple Access (CDMA), a new scheme is developed which reaps the benefits of both the techniques. A patented 4th Generation (4G) wireless technology like higher spectral efficiency, result in higher bit rates and multiple access capability, robustness in case of frequency selective channels. MCCDMA is a multiple access scheme used in Orthogonal Frequency Division Multiplexing (OFDM) telecommunication systems, allowing the system to support multiple users at the same time. The main idea of the MCCDMA system relies on transmission of data by dividing the high data rate stream into several low data rate subcarriers. MC-CDMA spreads each user in the frequency domain [1,2]. MC-CDMA modulation causes high Peak to Average Power Ratio (PAPR), which results in nonlinear distortion at the High Power amplifier (HPA) and consequently degradation of BER performance at the receiver. It requires a linear amplifier with a large dynamic range. However, this linear amplifier has poor power efficiency and is very expensive. Power efficiency is required for wireless and mobile communication as it provides adequate coverage area, saves power consumption and allows portable terminals etc. Hence, a better solution is to try to prevent the occurrence of interference by reducing the PAPR of the MC-CDMA transmitted signal. PAPR reduction results in reduction of cost and consumes less power, low BER, and improvement in spectral bandwidth by using few companding transform techniques. To reduce the PAPR of MC-CDMA system, many techniques are proposed [3].

This paper uses companding techniques for PAPR reduction. The companding transformation is applied at the transmitter to attenuate the high peaks and increase low amplitude of the MC-CDMA signal, before transmission. At the receiver, the de-companding method is applied through the inverse companding function in order to pick up the original signal. Companding systems are useful for reducing PAPR in MC-CDMA transmitted signal. Companding method describes compression in the transmitter and expansion in the receiver. Transmitter and receiver requires compander and expander [4].

This paper analyzes a modified exponential companding with clipping technique for PAPR reduction of MC-CDMA transmitted signals and compares with exponential and linear companding schemes, in terms of PSD, BER, and PAPR. The proposed companding technique reduces PAPR and minimizes Out of Band Interference (OBI) and also improves BER.

The rest of the paper is organized as follows: Section I describes MC CDMA system PAPR analysis. Section A describes proposed MC-CDMA system; in section B related works are discussed. In section C a newly introduced MECCT companding and decompanding algorithms are discussed. In section D II.

2 MC-CDMA PAPR Analysis

In MC-CDMA system, entire system bandwidth is divided into several orthogonal subcarriers with narrow bandwidth, and K user data symbols are modulated by Phase Shift Keying (PSK) and transmitted independently on subcarriers. In the MC-CDMA transmitter, a group of Nlog 2 M input bits are encoded into block of N c symbols x t (l = 0? N c -1), where symbol duration is T s (sec) and MC-CDMA-array modulation, is considered. These symbols are converted from serial to parallel (S/P) form and modulated using N c subcarriers whose frequencies are regularly spaced with Î?"f = (HZ) Where T s is the symbol period; N c is the number of subcarriers. Thus MC-CDMA signal x(t) for a block of duration N c T s (sec) may be represented as (1) Where x t represents the l th modulated data symbol and Î?"f represents the l th subcarrier frequency.

By discretizing x (t) in equation (**??**) at t= lT s (l = 0,?.,Nc-1) then the discrete MC-CDMA signal as given as

(2) Equation (**??**) is equivalent to N c point Inverse Fast FourierTransform (IFFT) of Nc symbols xl, followed by parallel-to-serial (P/S) converter. Thus, a fast implementation using IFFT may be employed, at the receiver, and subcarrier demodulation can be effectively implemented by Nc -point Fast Fourier Transform (FFT).

The transmitted MC-CDMA signals x(t) follow a Gaussian distribution when the number of subcarriers N c are large , resulting in high PAPR, the PAPR of continuous frequency domain MC-CDMA signals are generally defined as (3) From equation (3) it is observed that PAPR reduction of MC-CDMA signals is mainly obtained by decreasing the maximum instantaneous signal power (4) The values x m , m=0? Nc-1, are the time samples of an MCCDMA symbol.

The relation between Crest Factor (CF) and PAPR is given as (5) PAPR for MC-CDMA Up-link as represented as (6) The PAPR of an MC-CDMA down-link signal with k users and N c = L can be represented as **??**5, and 6]. Figure **??** shows MC-CDMA receiver with decompanding. At the receiver, the de-companding method is applied through the inverse companding function before CP removal and Fast Fourier Transform (FFT) block in order to pick up the original signal. The transmitted signal power is amplified by using HPA [7] The variation of the envelope of a multicarrier signal can be defined by Peak to Average Power Ratio (PAPR) , which is given as (LNST) was investigated. The authors proposed a LCT that has one -tone mapping of input and output transformed signal. The proposed scheme degrades Power Spectral Density (PSD), lower PAPR and BER than LNST [8]. Tao Jiang, et.al proposed a new nonlinear companding technique, called "exponential companding", to reduce PAPR of OFDM signals. The exponential companding scheme can offer better PAPR reduction, BER, and phase error performance, and less spectrum side lobes [9].

Earlier we proposed the technique for the use of DCT/DWT in combination with companding in order to achieve a very substantial reduction in PAPR of the MC CDMA signal. In this scheme, in the first step, the data is transformed by a Discrete Cosine Transform (DCT) or Discrete Wavelet Transform into new modified data. In the second step, this scheme also uses the companding technique further to reduce the PAPR of the MC CDMA signal. The DCT may reduce PAPR of an MC CDMA signal, but does not increase the BER of system. The proposed scheme uses the spreading codes for MC CDMA like Walsh codes, Gold codes, and Maximal length Pseudo Noise (PN) codes, in order to minimize the BER, and to reduce Multiple Access Interference (MAI) and has implemented the same proposed techniques to reduce the PAPR and PSD for MC CDMA system **??**3, and 4].

This paper analyzes a new idea that combines exponential companding transform and clipping concept to obtain a new Modified Exponential Companding with Clipping Transform (MECCT) for MC-CDMA PAPR reduction. This method evaluates performance analysis of MC-CDMA while considering linear companding and exponential companding. The proposed algorithm reduces the PAPR by 2.0 dB, and is able to improve Bit Error Rate (BER), Out-of Band Interference (OBI).

This paper first compares the PAPRs of MC-CDMA original, MC-CDMA with linear companding, MC-CDMA with exponential companding and a newly introduced MCCDMA with MECCT. Simulation results show that the PAPRs of MC-CDMA with MECCT system have low PAPR when compared with other companding based MC CDMA systems. The power spectral density of the resultant signal has 10 dB less in main and side lobes which minimize interference between signals when compared with the LCT based MC-CDMA system. The MECCT technique reduces PAPR, without degradation in BER performance.

3 c) Modified Exponential Companding with Clipping Transform

This new idea is a combination of clipping concept which has a value of threshold and exponential concept. It generates a new algorithm named as a Modified Exponential Companding with Clipping Transform (MECCT). The MECCT companding algorithm as given below:

Step1: Calculate threshold value at the transmitter is given by (??)? xn

2 is a variance of (standard deviation) 2 , â?"?x n â?"?is modulus of the MC-CDMA transmitted symbol, T 1 is the threshold value. Step2: (9) Step3:

(10)

Step4:

(11) When = and x n is in the form of ax n +jbx n At the receiver, the inverse companding transform operates on the received signal to obtain an estimation of the transmitted signal. The MECCT decompanding algorithm as given below:

Step1: Calculate threshold value at the receiver is given by (12) ? xn 2 is a variance of standard deviation, â?"?r n â?"? Is modulus of MC-CDMA received symbol, is the threshold value at the receiver.

Step 2 :

Step 3 : When= and r n is in the form of (14)

Step4 : The original received signal after decompanding

4 i. CCDF Performance

This paper evaluates the performance of PAPR using cumulative distribution of PAPR of MC-CDMA signal. The Complementary Cumulative Distribution Function (CCDF) is one of the most regularly used parameters, which is used to measure the efficiency of PAPR technique.

Figures **??**, 4, 5 show that, using MC-CDMA with MECCT technique and PN codes PAPR is reduced by 1.75dB, and 1.5 dB when compared with the original MC-CDMA (no companding), and MC-CDMA with linear and exponential companding techniques. If the numbers of subcarriers are doubled the PAPR is increased by 2.0 dB. Figures 6, 7, 8 show that, using MC-CDMA with Gold codes and MECCT technique PAPR is reduced by 2.5dB, and 2.0dB when compared with the original MC-CDMA (no companding), and MC-CDMA with linear and exponential companding techniques. If the numbers of symbols are increased, the PAPR is further reduced by 0.5 dB. 9, **??**0, **??**1, **??**2 show that, using MC-CDMA with Walsh codes and MECCT technique PAPR is reduced by 0.75dB, and 1.0dB when compared with the original MCCDMA (no companding), MC-CDMA with linear, and MCCDMA with exponential companding techniques. If the number of symbols is increased, the PAPR is further reduced by 0.5 dB. If the numbers of subcarriers are doubled, the PAPR is increased by 2.25 dB.

5 Figure 13 : Power Spectral Density comparison

The simulation results of Power Spectral Density (PSD) in figure **??**3 shows that the MECCT based MC-CDMA system has 10 dB less in lower side and main lobe when compared with the original MC-CDMA system, and MCCDMA with linear companding. MC-CDMA with exponential companding has less mean amplitude and system maintains constant main lobe bandwidth compared to other MC-CDMA systems.

6 Conclusions and Future Work

In this paper, a newly introduced MC-CDMA system using MECCT to reduce the PAPR about 2.0 dB for Gold codes and PN codes and 0.75 dB for Walsh codes, decrease the BER over linear companding technique, and improve the spectrum efficiency. This technique found that the MECCT based MC-CDMA has

Figure 1:

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d) Simulation Results

Original MC-CDMA, MC-CDMA with Linear, exponential, and newly introduced MECCT systems are implemented using MATLAB with the following specifications: number of symbols are 256, 512, 1024, 4096 symbols, IFFT size is 256, and number of

Figure 2:

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