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Research Paper

MC CDMA Paper Reduction Using Discrete Wavelet Transform and Companding on Rayleigh Fading Channel

Engineering

KEYWORDS : PAPR, DWT, CCDF, Companding

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ABSTRACT

High Peak to Average Power Ratio (PAPR) of the transmitted signal is a serious problem in multicarrier modulation systems. In this paper reduction of PAPR of the Multicarrier Code Division Multiple Access (MC CDMA) signals are done using Discrete Wavelet Transform (DWT) and Companding on Rayleigh fading channel with AWGN noise. It is analyzed and implemented using MATLAB. Simulation results for different modulation techniques and using both Mu-law & A-law of companding are analyzed by evaluating complementary cumulative distribution function (CCDF) & PAPR which shows the substantial reduction in PAPR of the MC CDMA signal.

INTRODUCTION

In broadband wireless communications high bit rate transmission is required for high quality communications. The most important objective of fourth generation systems is to take care of the severe Inter Symbol Interference (ISI) resulting from high data rates. MC CDMA system is the combination of Orthogonal Frequency Division Multiplexing (OFDM) and Code Division Multiple Access (CDMA) and reaps the benefits of both the techniques. In MC CDMA, data symbols consisting of modulated bits are spread by Walsh codes and then mapped into subcarriers of an MC CDMA modem data symbol which is spread across frequency domain (Jiang, 2010). MC CDMA is a very attractive technique for high speed data transmission over multipath fading channels.

The PAPR problem is one of the most important issues for developing multicarrier transmission systems. MC CDMA is widely used in broadband networks such as Long Term Evaluation (LTE) and broadband communication networks. However, MC CDMA systems have the inherent problem of a high PAPR, which causes poor power efficiency or serious performance degradation in the transmitted signal. This brings disadvantages like complexity of ADC and DAC, reduced power efficiency, and high Bit Error Rate (BER), consumption of more power. High power amplifiers are required which results in increased cost component. Thus, if we reduce PAPR, we shall obtain reduced complexity of Analog to Digital Converter (ADC) and Digital to Analog Converters (DAC), improved signal to noise ratio and Bit Error Rate (BER) (Han & Lee, 2005).

In this paper we had calculated and reduced the PAPR for the existing MCCDMA system by using PSK and QAM as modulation techniques and also using A-law and Mu law both for companding. The final performance analysis is done between CCDF & PAPR.

MC CDMA SYSTEM & PAPR CALCULATION:

To calculate the PAPR of an MC CDMA signal, we used Pseudo noise (PN) code spreading code sequence. In the proposed scheme, in the first step the input data is feeded to spreader and QAM mapper for very high bit rate transmission (Zhang, Donfeng & Wang, 2007). After being modulated by PSK and QAM it is spreaded using Pseudo noise (PN) code then it undergoes serial to parallel conversion. It is further processed with the IFFT block where it gets converted into discrete time domain signal. After this the cyclic prefix (CP) will be added which will add as guard band for the signal and it will be immediately removed after the RF down-conversion stage. So, CP is just a purely overload. Then, companding is performed using A law and Mu law. After this signal is transmitted on a Rayleigh fading channel with AWGN. At the receiver end the original data will be obtained by performing the process opposite at transmitter (Sarala & Venkateswarlu, 2011). The block diagram of both transmitter & receiver are shown in Figure (1).

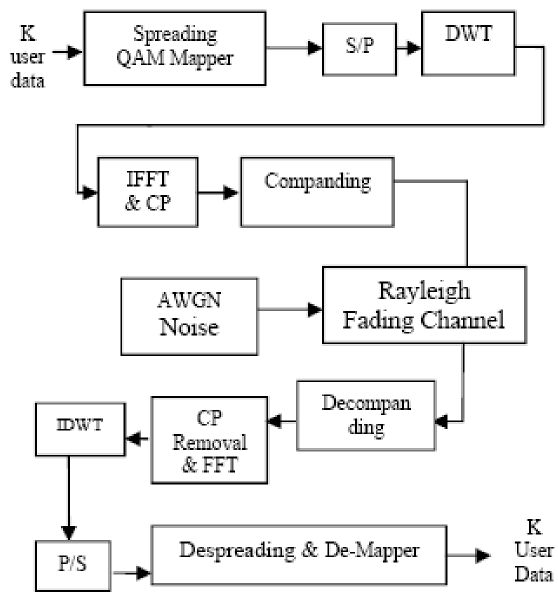

Figure 1: Block diagram of MCCDMA transmitter and receiver.

We have calculated PAPR using modulation techniques such as PSK, 8 QAM, 16 QAM and 64 QAM on Rayleigh fading channel with AWGN noise & the simulation results are shown between CCDF & PAPR value of each user using DWT & companding and are compared with original MCCDMA.

A. PAPR

OFDM signal has large peak to average ratio (PAPR) which severely limits its applications, and as long as basic operation of OFDM-CDMA is identical to OFDM system, this undesirable property remains. When in time domain, all the N subcarriers are added up constructively, they produce a peak power that is N times greater than the average power of the signal. PAPR can be defined as the ratio between instantaneous power and the average power of multicarrier signal. The PAPR is calculated by the following equation:

$$PAPR = \frac{p_{peak}}{p_{average}} = 10\log_{10}\frac{\max\left[|s(t)|^2\right]}{E\left[|s(t)|^2\right]} \qquad (2)$$

Where ppeak represents output peak power, paverage means output average power, [E /s(t)/2]denotes the expected value.

B. Cumulative Distribution Function

As PAPR is a random variable, an adequate statistic is needed to characterize it. The cumulative distribution function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency on any PAPR technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

The CDF of the amplitude of a sample signal is given by

$$F(z) = 1 - \exp(z) \tag{3}$$

The CCDF of the PAPR of the data block is desired & is given by

$$\begin{aligned} P(PAPR > z) &= 1 - P(PAPR \le z) \\ &= 1 - F(z)^N \end{aligned} \tag{4}$$

C. The Rayleigh Fading

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components (Paul & Linnartz, 2001). If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed. Calling this random variable R, it will have a probability density function:

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \ge 0 \tag{6}$$

where $\Omega = E(R^{2)}$.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number.

D. AWGN Noise

An AWGN channel adds white Gaussian noise to the signal that passes through it. The relative power of noise in an AWGN channel is typically described by the Signal-to-noise ratio (SNR) per sample, ratio of bit energy to noise power spectral density (Eb/No)and Ratio of symbol energy to noise power spectral density (Es/No)

E. Discrete Wavelet Transform

The wavelet transform is a kind of technique derived from Fourier Transform wherein the localization provides very efficient characteristics. The property of the wavelet functions along with localization of frequency main characteristic of the wavelet transform is to provide side lobes of much lower magnitude than of Fourier Transforms (Sarala & Venkateswarlu, 2011). This is a very important reason to have used wavelet bases to modulate symbols in Multi Carrier Modulation systems. The wavelet packet functions wk (t) (n _ Z+) is followed by the recursive functions:

$$w_{2k}(t) = \sqrt{2} \sum_{n \in Z_+} h(n)\, w_k(2t - n) \tag{7}$$

$$w_{2k+1}(t) = \sqrt{2} \sum_{n \in Z_+} g(n)\, w_k(2t - n)$$

Where h (n) and g (n) = (-1) k h (L-L-1-n) stand for a pair of quadrature mirror filters (QMFs) of length L. The discrete wavelet transform (DWT) is a type of batch processing, which analyzes a finite length time domain signal by breaking up the initial domain in two parts: the detail and approximation information. The DWT property is only few coefficients of DWT dominates the representation.

F. Companding

The companding transformation is applied at the transmitter after IFFT block in order to attenuate the high peaks and amplify low amplitude of the MC CDMA signal, thus decreasing the PAPR. At the receiver, the decompanding process is applied by using the inverse companding function prior to FFT block in order to recover the original MC CDMA signal.For the discrete MC CDMA signal, the signal is companded using A law and Mu (Mu) law both.

SIMULATION RESULTS

Original MC CDMA, MC CDMA with DWT & A law companding and MC CDMA with DWT and Mu law companding systems are implemented using MATLAB with the following specifications: number of symbols are 512, IFFT size is 128, and number of subcarriers are 64, spreading code is Pseudo noise (PN) codes and modulation technique used are Phase Shift Keying (PSK) and 8 Quadrature amplitude modulation (QAM),16 QAM and 64 QAM. We can evaluate 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. The simulation results are shown below:

The various results are as follows: For PSK, we get PAPR value of 3.9161 using A law companding but Mu law we get its value 3.7449.

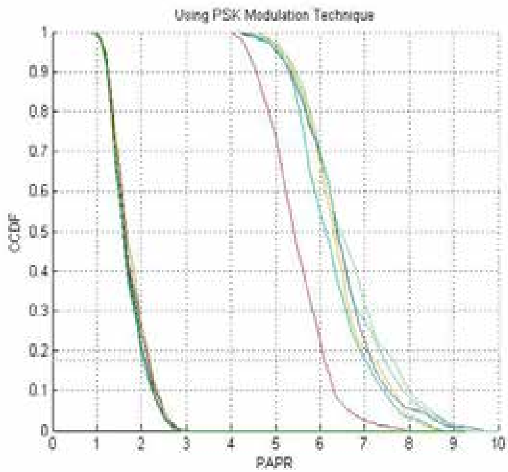

Figure 2: MC CDMA with DWT and A law Companding for PSK Modulation.

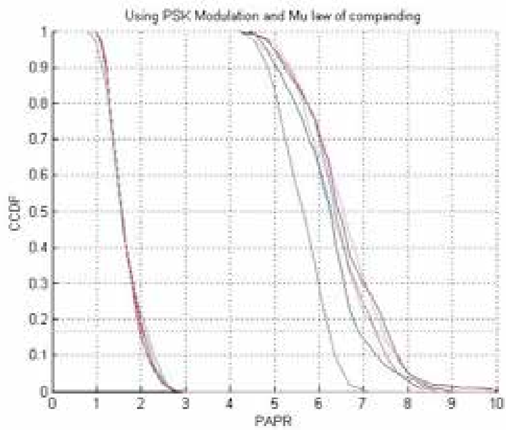

Figure 3: MC CDMA with DWT and Mu law Companding for PSK Modulation.

Similarly, for 8 QAM PAPR value is 3.9628 while with Mu law it is 3.8967. For 16 QAM, the PAPR calculated by A law is 3.9527 but with Mu law its value is 3.7706. On applying 64 QAM, we get PAPR value of 3.9083 with A law while with Mu law again we get reduced value that is 3.7404. Hence, from this we conclude that companding using Mu law gives more accurate results instead of using A law.

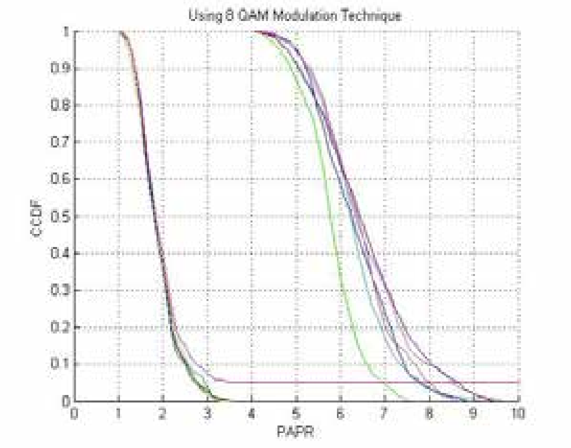

Figure 4: MC CDMA with DWT and A law Companding for 8 QAM Modulation.

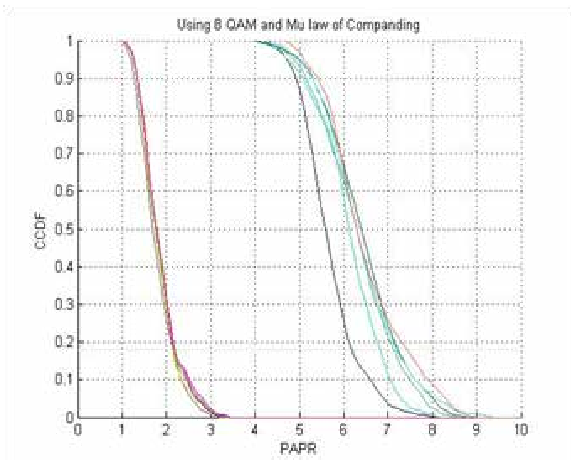

Figure 5: MC CDMA with DWT and Mu law Companding for 8 QAM Modulation.

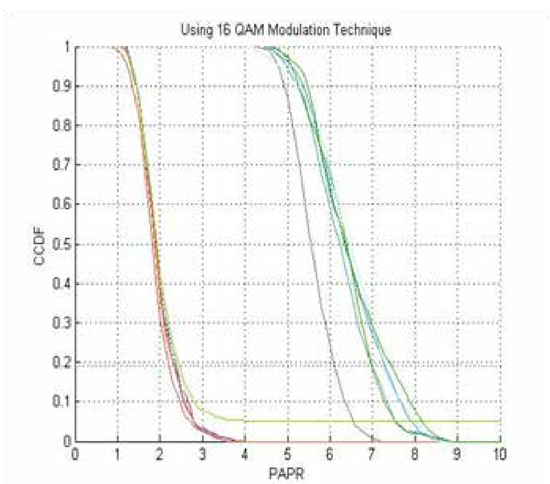

Figure 6: MC CDMA with DWT and A law Companding for 16 QAM Modulation.

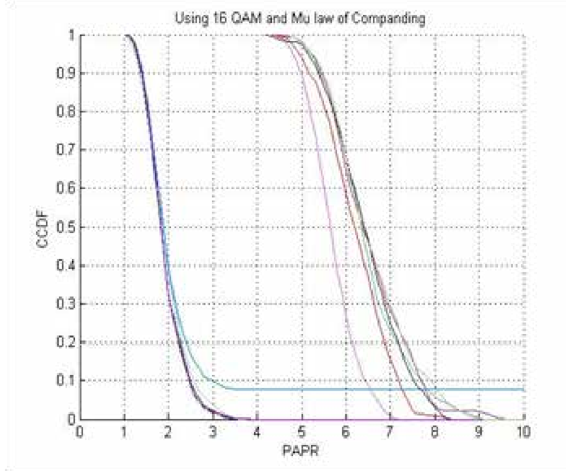

Figure 7: MC CDMA with DWT and Mu law Companding for 16 QAM Modulation.

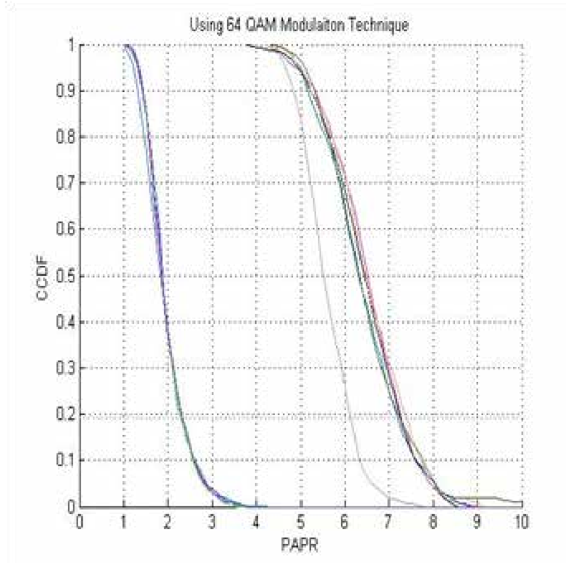

Figure 8: MC CDMA with DWT and A law Companding for 64 QAM Modulation.

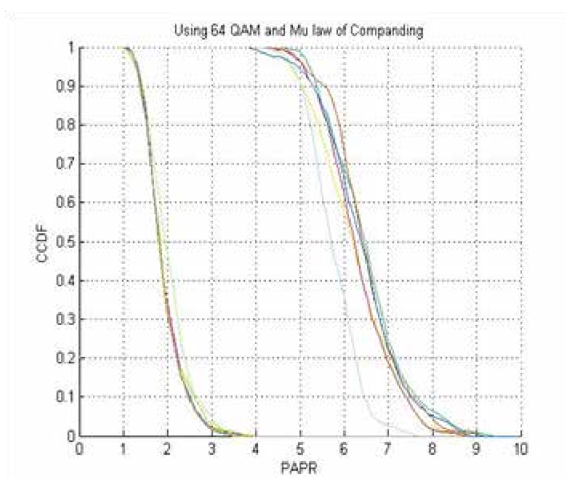

Figure 9: MC CDMA with DWT and Mu law Companding for 64 QAM Modulation.

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In above graphs, we find that the different number of users having PAPR values lying between 6.88 to 9 while the results compared with DWT and companded data shows the great reduction in PAPR value in range of 3 to 3.99.

CONCLUSIONS:

MC CDMA is used to combat channel distortion, and improves the spectral efficiency, high data rate, robust against multipath fading. MC-CDMA is an important multiple access candidate for 4G wireless communication system. The transmitted signal of an MC-CDMA system exhibits a very high peak-to-average power ratio (PAPR) when large numbers of sub-carriers are used. Therefore amplifier should be operated in large linear ranges to avoid non-linear distortion. This leads to very inefficient amplification and very expensive transmission. In this paper we have reduced the PAPR for various numbers of users and thus system performance gets improved.

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