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PERFORMANCE IMPROVEMENT OF OFDM SYSTEM USING PAPR REDUCTION

Mohit Pant[1] and Dhiiraj Nitnawwre[2]

[1]Electronics & Communication Institute of Engineering & Technology, DAVV, Indore, INDIA
E-mail: ermohitpant@gmail.com
[2]Electronics& Communication Institute of Engineering & Technology, DAVV, Indore,INDIA
E-mail: dhiirajnitnawwre@gmail.com

ABSTRACT

Orthogonal frequency division multiplexing (OFDM) signals have a generic problem of high peak to average power ratio (PAPR) which is defined as the ratio of the peak power to the average power of the OFDM signal. The drawback of the high PAPR is that the dynamic range of the power amplifier and digital-to-analog converter during the transmission and reception of the signal is higher. As a result, the total cost of the transceiver increases, with reduced efficiency. In this paper, we proposed a method to improve the performance of OFDM System by reduction of Peak-to-Average Power Ratio (PAPR). In this paper, we have combine phasing scheme with companding technique to reduce the PAPR within OFDM systems. Companding OFDM symbols prior to transmission using the μ-Law can significantly improve PAPR reduction. Several authors have proposed schemes for reducing peak amplitude, such as clipping, partial transmit sequence, and selective mapping [1], subcarrier power adjustment [3], linear combination [6]. Here we discussed combining both companding with phasing schemes to improve PAPR reduction. Complementary Cumulative Distributed Function of PAPR reduction techniques is also presented

Keywords: PAPR; OFDM; Power amplfier; D/A converter; QAM; Companding; CCDF

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is known to be an efficient technique for high-bit-rate transmission systems such as digital audio broadcasting (DAB), digital video broadcasting (DVB), and digital subscriber lines (xDSL) systems, because it offers high spectral efficiency, robustness to channel fading, immunity to impulse interference, and the capability to handle frequency-selective fading without resorting to complex channel equalization schemes [1,6]. An OFDM signal is a sum of several individual signals modulated over a group of orthogonal subcarriers with equal bandwidths. Therefore, when added up coherently, the OFDM signal has large peak, while the mean power remains low. PAPR is the ratio of the maximum power to the average power of a given signal. By dividing the total bandwidth into a number of overlapped sub-channels, the spectral efficiency of an OFDM signal is increased significantly. However, a major drawback of an OFDM signal is the Gaussian-distributed amplitude of the time domain waveform that causes a high peak-to-average power ratio (PAPR). Whenever high PAPR occurs, the D/A converter and power amplifier of the transmitter require large dynamic ranges to avoid amplitude clipping, thus increasing both power consumption and component cost of the transceiver. PAPR reduction can be achieved by modifying OFDM signal characteristics in time or frequency domain at the transmitter. If information about these changes is transmitted to the receiver, it can reverse the operation, and demodulate the data correctly. Several researchers have proposed schemes for reducing peak amplitude, such as as clipping, partial transmit sequence, and selective mapping [1], subcarrier power adjustment [3], linear combination [6].

Most of these algorithms possess a high computational complexity, especially for a large number of subcarriers. In this paper, we propose a method, which tries to reduce the PAPR by making combination between sub-carrier phase adjustment technique and companding of the time domain OFDM signals. This paper is organized as follows. In section II, the PAPR reduction techniques in OFDM is introduced, and the principles of some specific algorithms for PAPR reduction of the OFDM signals are investigated. Section III introduces the proposed technique. Section 4 presents the transmitter. The detailed simulation results and discussion are given in section V. Finally we will conclude in section VI.

1.1. PAPR Problem of OFDM Signals

An OFDM signal consists of N data symbols transmitted over N distinct subcarriers. Let $X = \{X_k, k = 0,1,\ldots, N\text{-}1\}$ be a block of N symbols formed by each symbol modulating one of a set of subcarriers $\{f_k, k = 0,1,\ldots,N\text{-}1\}$ The N subcarriers are chosen to be orthogonal, that is,

$f_k = k\Delta f$, where $\Delta f = 1/NT$ and T is the original symbol period. Therefore, the complex baseband OFDM signal can be written as:

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi f_k t}\ ;\ 0 \le t \le NT \qquad (1)$$

To better approximate the PAPR of continuous-time OFDM signals, the OFDM signals samples oversampled by a factor of L. By sampling, $x(t)$ defined in Equation (1), at frequency $f_s = L/T$, where L is the oversampling factor, the discrete-time OFDM symbol can be given by:

$$x(n) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{\frac{j\pi}{NL}} kn\ ;\ 0 \le n \le NL-1 \qquad (2)$$

Now, the Peak to Average Power Ratio of this transmitted signal can be calculated from equation given below [1] [2]

$$PAPR(x) = 10\log_{10}\left(\frac{\max|x(n)|^2}{E[x(n)|^2]}\right) \qquad (3)$$

1.2. Complementary Cumulative Distributed Function (CCDF)

In the modern telecommunication world CCDF measurements prove as one of the precious tool. The CCDF plots offer a comprehensive analysis of signal power peaks. It is a statistical technique that provides the amount of time, a signal spends above any given power level CCDF of a given data can be calculated by:-

$$CDF = \int PDF \ \ \& \ CCDF = [1 - CDF]$$

Mathematically, it can be explained as follows,

$$P(\text{PAPR} > z) = 1 - P(\text{PAPR} \le z)$$
$$= 1 - F(z)^N = 1 - (1\text{-}\exp(-z))N$$

Here $F(z)$ represent the CDF

2. PAPR REDUCTION TECHNIQUES

PAPR reduction techniques can be broadly categorized into deterministic and probabilistic approaches. Deterministic approaches guarantee that the PAPR of an OFDM signal does not exceed a predefined threshold, whereas the probabilistic approaches minimize the probability that the PAPR of an OFDM signal exceeds a predefined threshold [1]. There are several solutions proposed in the literature that could be employed by the system. Most of these algorithms possess a high computational complexity, especially for a large number of subcarriers. Some of the reduction techniques will be discussed in the following sections.

2.1. Clipping Technique

2In this approach, we can perform time-domain based clipping or frequency-domain based coding. The simplest approach for PAPR reduction is to deliberately clip the amplitude of the signal to a predefined value before amplification. However, there are several drawbacks of thisapproach, such as signal distortion and spectral re-growth. Hence simple clipping is not enough, we have to use coding techniques that are applied to OFDM signals in order to find technique works well only when the number of subcarriers is small, because at higher at higher subcarriers, the clipping ratio is to be very low which will lead to more distortion. [3,6]

2.3. Subcarrier Phase Adjustment

This technique involves computing subcarrier phase adjustments that leads to the coherent cancellation of subcarriers, thus reducing the PAPR with low computational complexity. Moreover, the computed phase adjustments consist of a discrete set of values in (0,2Π), resulting in lower transmission overhead. Knowing that the PAPR is large when the subcarriers sum together coherently, it is possible to reduce the PAPR by adjusting the phase of subcarrier k at time instant n by adding a phase offset $\beta n,k$. [2]

2.4. Linear Combination

This is a new technique, based on modifying the time domain signal after taking IFFT, such that the resulting PAPR is reduced. Using this algorithm, the maximum and minimum of the time domain signal is replaced by the linear combination of them. In this method, peak of the signal will be reduced while the average is kept constant. This method will require transmission of some extra information from transmitter to the receiver. [3]

2.5. Phasing Schemes for PAPR Reduction

Several phasing schemes have been developed for producing lower PAPR in multicarrier transmissions. These are now briefly described.

2.5.1. Newmann Phasing Scheme

Newmann phases [6] are varied in a quadratic fashion as shown in (3). [7]

$$\theta k = \frac{(k-1)^2}{N} \qquad (3)$$

Here N is the number of subcarriers and k is the index of the particular subcarrier.

2.6. Companding Technique

In companding the OFDM signal is compressed at the transmitter and expanded at the receiver. Compression is performed according to the well known μ-Law viz

$$y = V\frac{\log\left(1+\mu\frac{x}{y}\right)}{\log(1+\mu)} \qquad (4)$$

where V is the peak amplitude of the signal, and x is the instantaneous amplitude of the input signal. Decompression is simply the inverse of y. Compression improves the quantization resolution of small amplitude signals at the cost of lowering the resolution of large signals. This also introduces quantization noise, however, the effect of the quantization noise due to reduction in resolution of the peaks is relatively small as the peaks occur less frequently. The compression algorithm as described by (4) amplifies the signals of lower amplitude with the peaks remaining unchanged. [4]

3. PROPOSED TECHNIQUE

In this section we are proposing a new technique which comprises of the subcarrier phase adjustment technique which is a frequency based reduction followed by companding the resulting time domain sequence to further reduce the resulting PAPR.

3.1. Algorithm

- Let Xk be the modulated signal sequence.
- We convert this into time domain by taking the IFFT and calculate the PAPR_Initial of the original sequence.
- We apply the subcarrier phase reduction technique on X_k
- We calculate the PAPR Final of this transformed signal and then calculate Reduction in PAPR by calculatingPAPR Final - PAPR Initial.

3.2. Algorithm

- Let Xk be the modulated signal sequence.
- We convert this into time domain by taking the IFFT and calculate the PAPR_Initial of the original sequence.
- We take the IFFT to convert the resulting signal into time domain and then apply companding technique as shown in Figure 1
- We calculate the PAPR Final of this transformedsignal and then calculate Reduction in PAPR by alculating PAPR Final - PAPR Initial.

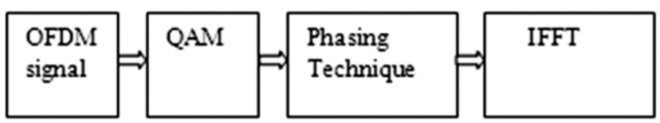

Figure 1: Transmitter Design for Phasing Technique

4. TRANSMITTER DESIGN

PAPR reduction algorithms are implemented in the transceiver designed using the following steps & specifications. The transceiver block is shown in Fig 1and Fig. 2 The main blocks of the transceiver are IFFT, FFT, QAM modulator and demodulator with QAM to output the complex envelope. PAPR reduction block in transmitter side is tested with the mentioned techniques.

- Generation of OFDM signal
- Quadrature Amplitude Modulation
- IFFT Block for each sub carrier.
- PAPR Calculation before implementing
- PAPR Reduction Block
- Firstly, Subcarrier Phase adjustment then Companding
- Reduced PAPR Calculation

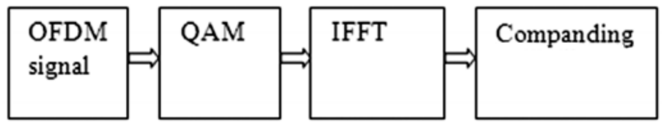

Figure 2: Transmitter Design for Companding Technique

5. SIMULATION RESULTS

Matlab codes are used to clarify the peak power reduction capability and the improvement of PAPR reduction This simulated system employs an OFDM signal with sub carriers using 8- ary QAM. The simulated wave forms for some specific algorithms and their analysis and comparisons are listed out in the following.

Analysis of Subcarrier Phase Adjustment Technique

From Figure 3, observation shows high PAPR occur in the original signal, The reduction in PAPR when only newmann is considered is about 3.5 dB. Interestingly,it is observed that OFDM with random phases reduction of PAPR of about 1 dB.

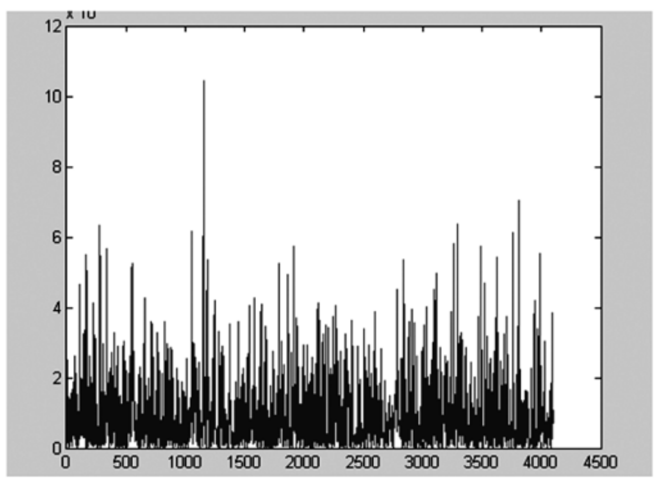

Figure 3: Original Signal

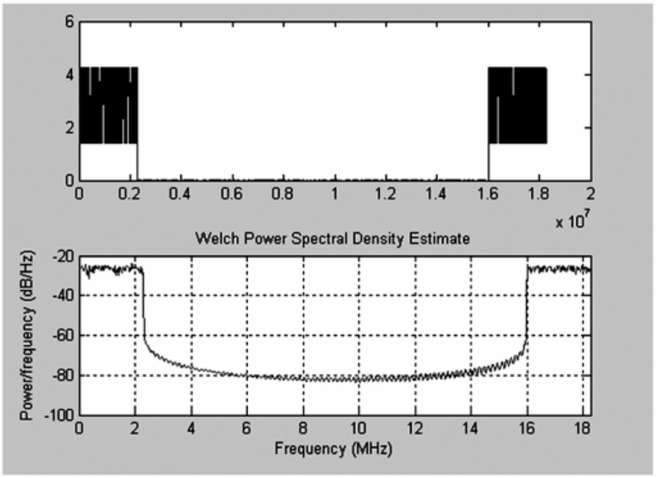

Figure 4: Frequency Response of Signal Carrier

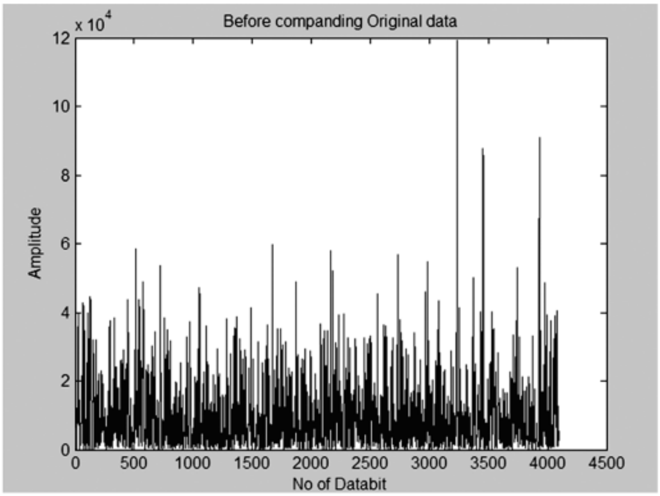

Figure 5: Before Companding Original Data Companding

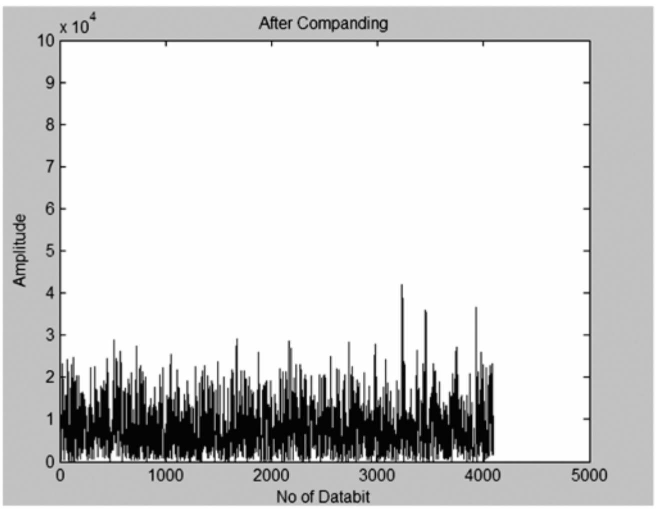

Figure 6: Transformed OFDM Signal After Applying

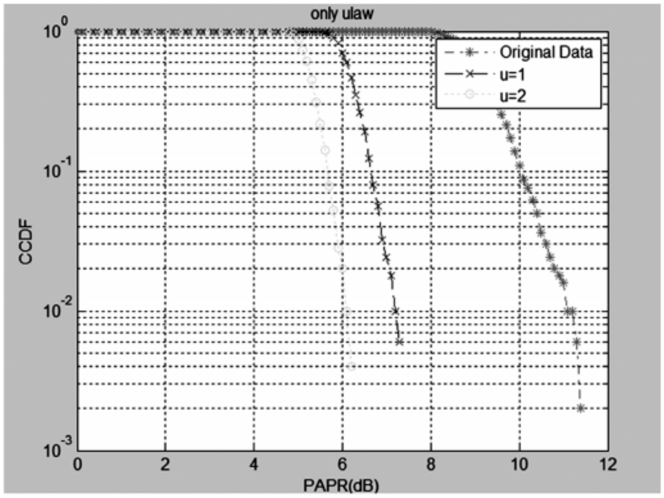

Figure 7: CCDF Plot of Companding Technique

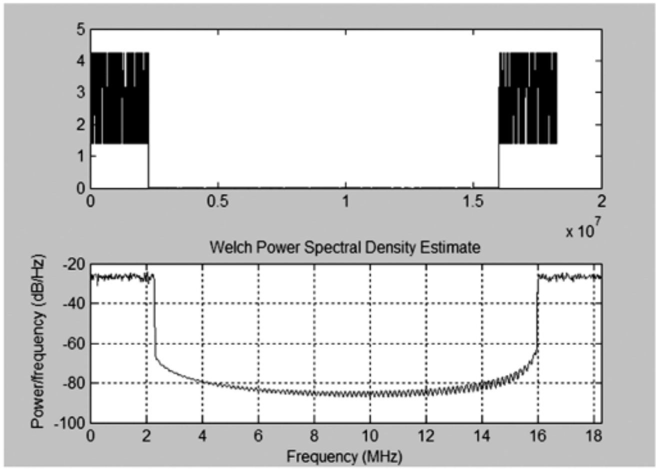

Figure 8: Frequency Response of Signal Carrier

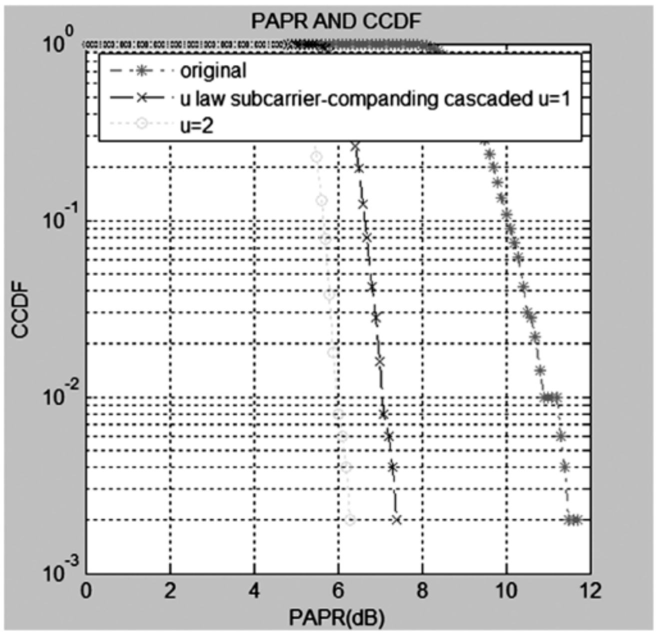

Figure 9: CCDF Plot of Combining Subcarrier Phase Adjustment and Companding Technique

Figure 5 and Figure 6 shows the signal before and after applying companding technique

Figure 7 shows the CCDF performance of *a c* om-panding algorithm for PAPR reduction. The values of the companding factor, *u*, for the companding procedure of the second step were fixed to 1 and 2. With this com-panding method, the peak power at CCDF = 10^{-2} is reduced by 4.7 dB 5.7 dB when compared with the case of original system.

Figure 8 shows the frequency response of the carrier signal

Figure 9 shows the CCDF performance of Combining Subcarrier Phase Adjust & Companding The values of the companding factor, *u*, for the companding procedure of the second step were fixed to 1 and 2. With this companding method, the peak power at CCDF = 10^{-2} is reduced by 4.1dB and 4.8dB when compared with the case of original system.

Table 1
Subcarrier Phase Adjustment Technique

S.No	*Technique*	*PAPR Reduction*
1	Subcarrier Phase Adjustment	3.4dB

Table 2
Companding Technique

S.No	*Technique*	*PAPR Reduction*
1	Companding	For companding factor,u = 1 4.1dB at CCDF = 10^{-2} For companding factor,u = 1 4.8dB at CCDF = 10^{-2}

Table 3
Combining Subcarrier Phase Adjust & Companding Technique

S.No	Technique	PAPR Reduction
1	Combining Subcarrier Phase Adjust& Companding	For companding factor,u = 1 4.7dB at CCDF =10^{-2} For companding factor,u = 1 5.7dB at CCDF = 10^{-2}

6. CONCLUSION

OFDM signals have a generic problem of high PAPR. The drawback of the high PAPR is the dynamic range of the Power Amplifiers & D/A Converters which increases its cost. Hence we apply reduction technique to reduce the PAPR. This paper analyzed companding and subcarrier phase adjustment. All these technique were implemented in Matlab Analyzing the above technique, we proposed an technique by combining the subcarrier phase adjustment and companding technique. Tested Matlab result shows that, the proposed method exhibits significant improvement in PAPR reduction than the earlier studies.

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