PAPR Reduction using Clipping with FEC Coding in OFDM System

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Abstract

Orthigonal Frequency Division Multiplexing (OFDM) is a promising technique for next generation wireless communication system. It is an efficient method of data transmission and find its application where high data rate is required at low latency and better spectral efficiency. One of the challenging issue for OFDM is its high Peak to Average Power Ratio (PAPR). Drawback of high PAPR is that dynamic range of power amplifier and D to A convertor during the transmission and reception of signal is higher. As a result, total cost of the system increases with reduced efficiency. In this paper, we proposed combination of clipping technique with FEC coding to reduce PAPR in OFDM systems. Performance evaluation is carried out in terms of CCDF(Complementary Cumulative Density Function) and BER(Bit Error Rate).
Keywords – OFDM, PAPR, FEC coding, Clipping, CCDF.

1. Introduction

Wireless communication is continous growing field and there are several researches in this area. The major research is focus on speed and accuracy. OFDM is one of attractive technique for high speed wireless communication systems. It offers high spectral efficiency, robustness to channel fading, immunity to intersymbol interference, uniform average spectral density, capacity to handle very strong echoes and less non linear distortion.[1,2]

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 mean power remains low. So OFDM systems suffer from serious problem of high PAPR. To transmit signals with such high PAPR, it requires power amplifier with very high power scope. These kind of power amplifier are very expensive and have low efficiency. If peak power is too high, it could be out of scope of linear power amplifier. This gives rise to non linear distortion thus resulting in performance degradation. To overcome PAPR effects for OFDM signals , there are a no. of proposed PAPR reduction techniques such as amplitude clipping, partial transmit sequence, selective mapping, subcarriers power adjustment, tone reservation, tone injection.[5,6] However all the proposed methods have some limitations. In this paper, we propose a clipping technique with FEC coding to reduce PAPR reduction in OFDM system. This paper is organised as follows : In section II, concept of OFDM is introduced. Section III explains the PAPR of OFDM system . Proposed method is explained in section IV. Simulation results and discussions are given in section V. Finaly we will conclude in section VI.

2. OFDM

OFDM is a special form of multicarrier (MC). The concept of MC transmission was first explicitly proposed by Chang in 1966 [2]. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the bandwidth into many carrier,each one is modulated by a low rate data stream. In term of multiple access technique, OFDM is similar to FDMA(Frequency Division Multiple Access), in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers.

The ofdm symbol can be expressed as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j 2\pi k f_0 t} \quad , \quad 0 \le t \le T$$

where X_k(k=0,1,…,N-1) is input data symbol, T is symbol period, N is no. of subcarriers, $f_0$is frequency spacing.

3. PAPR of OFDM system

An important limitation of OFDM is that it suffers from a high Peak-to-Average Power Ratio (PAPR) resulting from the coherent sum of several carriers. This forces the power amplifier to have a large input backoff and operate inefficiently in its linear region to avoid intermodulation products. High PAPR also affects D/A converters negatively and may lower the range of transmission. The PAPR of OFDM is defined as the ratio between the maximum power to the average power. The PAPR of the OFDM signal X(t) is defined as

$$PAPR = \frac{P_{peak}}{P_{average}} = \frac{\max[|x_n|^2]}{E[|x_n|^2]}$$

where x_n = An OFDM signal after IFFT (Inverse Fast Fourier transform)
E[.] = Expectation operator, it is an average power.

Performance of the PAPR reduction techniques can be evaluate using Complementary Cumulative Distribution Function(CCDF). It helps to measure the probability that the PAPR of a certain data blocks exceeds the given threshold. CCDF of a given data can be calculated by:-

CDF = ∫PDF & CCDF = [1 – CDF]

Mathematically, it can be explained as follows:-

P(PAPR > z) = 1-P(PAPR ≤ z)
=1-$F(z)^N$
=1-$(1 - exp(-z))^N$

Here F(z) represent the CDF(Cumulative Density Function).

4. Proposed method

In this section we are proposing clipping technique with FEC coding to reduce PAPR within OFDM system.

Clipping technique

Amplitude clipping is simplest approach to reduce PAPR. In this technique, initially a threshold value of amplitude is set and any subcarrier have more amplitude compared to threshold is clipped. This pseudo maximum amplitude in this approach is referred to as clipping level. It works on the idea of reducing large peaks by non linearly distorting the signal. The maximum power allowed is decided by system specification, generally by linear region of power amplifier.

Mathematically it can be expressed as-

$$x(y) = y, \ |y| \leq A$$

$$x(y) = Ae^{j\Phi(y)}, \ |y| > A$$

where x(y) is amplitude value after clipping, A is threshold value set by user and y is initial value of signal.
Clipping ratio(CR) defined as-

$$CR = \frac{A}{\sigma}$$

where σ is rms value of signal y. Since clipping is non linear process which introduces in band noise and out of band radiation as a result of which system performance is degraded. So to improve system performance we introduces FEC coding with this clipping approach.

FEC(Forward Error Correcting) coding

Convolution type FEC (Forward Error Correcting) coding has been used with clipping. Convolutional codes work on bit or symbol streams of arbitrary length. It is run length type code where k input data bits leads to n bits of output codeword bits. Input depends not only on current set of k input bits but also on past input bits. The no. of bits which affect current output code is called Constraint length and denoted by K.

where K = code memory + k.

Convolution encoding has been done using Trellis structure. Trellis is a more compact expression of convolution coding and can be generated by merging the nodes with the same label. Decoding has been done using Viterbi decoder algorithm. This decoder uses two metrics : the branch metric (BM) and the path metric (PM). The branch metric is a measure of the "distance" between what was transmitted and what was received, and is defined for each arc in the trellis. The path metric is a value associated with a state in the trellis (i.e., a value associated with each node).

The block diagram for Clipping without coding and Clipping with coding are as follows-

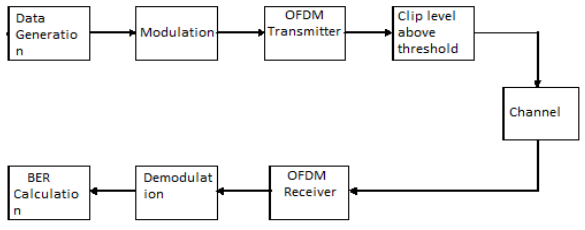

Figure1. Block diagram for clipping without coding.

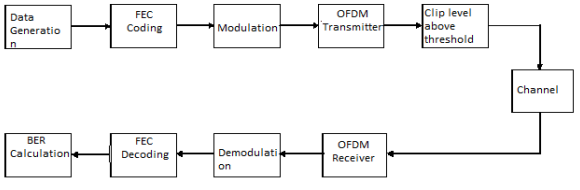

Figure 2. Block diagram for clipping with coding.

5. Simulation Results

The analysis of clipping with coding and clipping without coding has been done using MATLAB. The simulation parameters considered for this analysis is summarized in table 1.

Table 1. Simulation parameters

S. No.	Parameters	Value
1.	FFT size	64
2.	Length of Cyclic prefix	16
3.	Modulation	QAM
4.	SNR range	0 to18 db
5.	FEC code	Convolution
6.	CR	.9

Simulation results for above parameters are as follows –

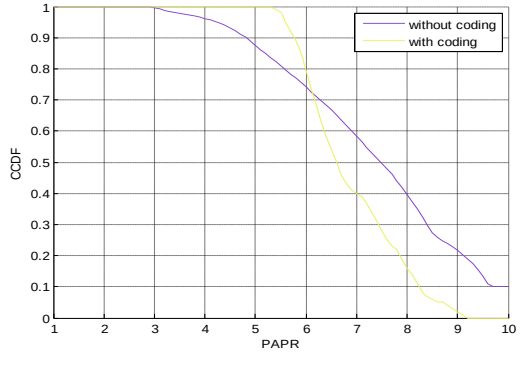

Figure 3. CCDF curve for PAPR reduction using clipping with coding and without coding

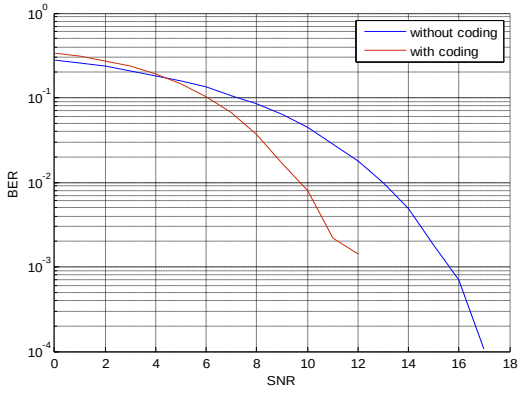

Figure 4. BER curve using clipping with FEC coding and without FEC coding

Both the graphs indicate that performance is improving using clipping with FEC coding. Almost 3db gain is achieved.

6. Conclusion

OFDM systems have generic problem of high PAPR. Drawback of high PAPR is dynamic range of power amplifier and D/A convertor which increases its cost. Hence we apply reduction techniques to reduce PAPR. This paper analyzed clipping technique with FEC coding. Since clipping is distortion technique and degrades bit error rate performance of system. But by using FEC coding with clipping, this approach not only reducing the PAPR of the OFDM system but also improving the BER performance.

7. References

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