PAPR Reduction using Companding and FEC Coding in OFDM System

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Abstract – The next generation of mobile wireless communication is based on OFDM technology. It is an efficient method of data transmission for high speed communication system. It provides high spectral efficiency, less vulnerability to echoes, low implementation complexity and resistance to non linear distortion. However, the main drawback of OFDM system is high PAPR of transmitted signals. OFDM consist of large no. Of independent subcarriers , as a result of which the amplitude of such a signal can have high peak values. Thus a power amplifier must be carefully manufactured to have a linear input output characteristics or to have large input output backoff. 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 transceiver increases with reduced efficiency. In this paper, we have used combination of companding technique with FEC coding to reduce PAPR within OFDM systems. Performance evaluation is carried out in terms of CCDF(Complementary Cumulative Distribution Function) & BER(Bit Error Rate).
Key words- Companding, Forward Error Correcting coding, Orthogonal Frequency Division Multiplexing, Peak to Average Power Ratio, CCDF, BER, D to A convertor.

I. Introduction

OFDM technique is one of the most attractive technique for 4th generation wireless communication. OFDM uses principle of FDM but in much more controlled manner, allowing an improved spectral efficiency. It also offers immune to multipath delay, low ISI(intersymbol interference), immunity to frequency selected fading and high power efficiency[2,3]. 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 system suffers from serious problem of high PAPR. To transmit signals with such high PAPR, the D to A convertor and power amplifier of the transmitter required large dynamic ranges to avoid amplitude clipping thus increasing both power consumption and component cost of the transceviers.To overcome PAPR effects for OFDM signals , there are a no. of proposed PAPR reduction techniques such as amplitude clipping[6], partial transmit sequence, selective mapping, subcarriers power adjustment[7], tone reservation, tone injection. However all the proposed methods have some limitations. In this paper, we propose a PAPR reduction technique using A law companding with FEC coding. 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.

II. OFDM

OFDM is a special form of multicarrier (MC). The concept of MC transmission was first explicitly proposed by Chang in 1966 [3]. 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

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \, e^{j2\pi k f_0 t} \quad , \quad 0 \le t \le T$$

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.

III. 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 convertors 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).

IV. Proposed method

In this section we are proposing companding technique with FEC coding to reduce PAPR within OFDM system. In companding the OFDM signal is compressed at transmitter and expand at receiver. Here we are using A law compander for this purpose. For a given input x the equation for A law compression is as follows:

$$F(x) = sgn(x)\{\frac{A|x|}{1+\ln(A)}, |x| < \frac{1}{A}$$

$$F(x) = sgn(x)\{\frac{1+\ln(A|x|)}{1+\ln(A)}, \quad \frac{1}{A} \le |x| \le 1$$

where A is the compression parameter. Decompression is simply the inverse of $F(x)$.

Convolution type FEC(Forward Error Correcting) coding has been used with companding. 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 diagrams for companding without coding and companding with coding are as follows –

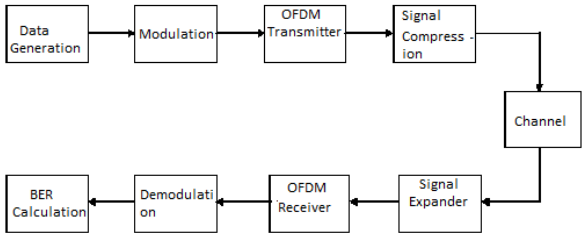

Figure 1 : Companding without coding

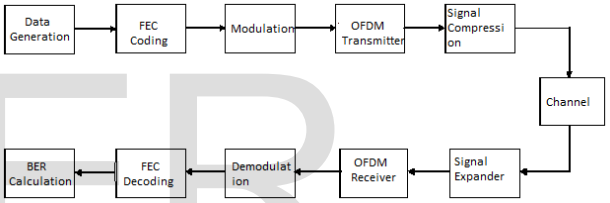

Figure 2 : Companding with coding

V. Simulation results

The analysis of companding with coding and companding 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.	Companding technique	A law with constant A=87.5

Simulation 1 :

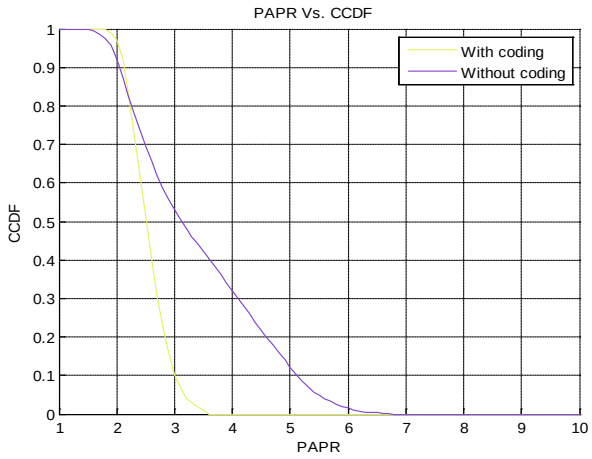

Figure 3

Figure 3 indicates that companding with coding technique gives an effective result for papr reduction which is almost 3db.

Simulation 2 :

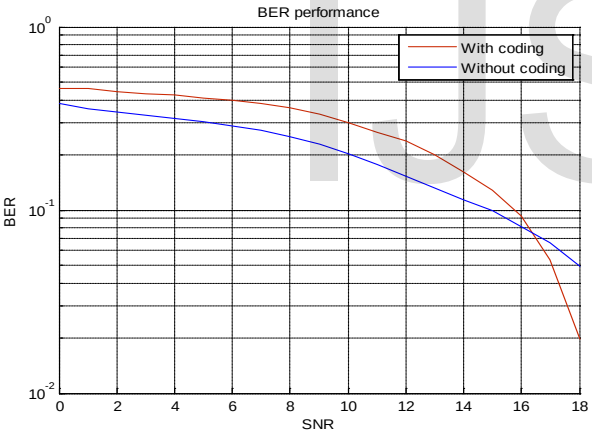

Figure 4

Figure 4 indicates that BER performance is improving for higher values of SNR.

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VI. 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 companding technique with FEC coding. Since companding is distortion technique and degrades bit error rate performance of system. But by using FEC coding with companding, this approach not only giving the effective results of PAPR reduction but also improving the BER performance.

VII. References

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