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PAPR Reduction of OFDM Signal with Improved Selected Mapping and Clipping Techniques

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ABSTRACT: OFDM is one of the proven multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non-linear distortion. This technique is used by almost all 3G wireless standard and above. The every technique has some pit fall. The one major shortcoming in the implementation of this system is the high peak-to-average power ratio of this system. There are several techniques has been identified by researcher to overcome this problem. Selected Mapping (SLM) and Clipping Techniques are promising techniques to reduce the PAPR for OFDM. Almost all PAPR reducing techniques are degrading the BER performance. In this Paper we used these techniques with Convolution code to improve BER. The performances of the system with and without the algorithm are also compared. The Channel considered is AWGN with QAM and BPSK modulation technique and code rate ½.

Keywords: OFDM, PAPR, SLM, BER, CCDF

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is widely used in modern wireless communication systems because of its high spectrum efficiency and low susceptibility to multi-path effects. It effectively combats the multipath fading channel and improves the bandwidth efficiency. At the same time, it also increases system capacity so as to provide a reliable transmission [1]. OFDM uses the principles of Frequency Division Multiplexing (FDM), but in much more controlled manner, allowing an improved spectral efficiency. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. These subcarriers are overlapped with each other. Because the symbol duration increases for lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter- symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol. Therefore, OFDM has been adapted to various standards, such as IEEE 802.11 a/g/n wireless local area networks (WLANs), IEEE 802.16 e/m mobile worldwide interoperability for microwave access (WiMAX), and 3GPP long term evolution (LTE). On the other hand, the major drawback of OFDM signal is its large peak-to-average power ratio (PAPR), which causes poor power efficiency or serious performance degradation to transmit power amplifier.

Therefore, the OFDM receiver's detection efficiency is very sensitive to the nonlinear devices used in its signal processing loop, such as Digital-to-Analog Converter (DAC) and High Power Amplifier (HPA), which may severely impair system performance due to induced spectral re-growth and detection efficiency degradation.

For example, most radio systems employ the HPA in the transmitter to obtain sufficient transmits power and the HPA is usually operated at or near the saturation region to achieve the maximum output power efficiency, and thus the memory-less nonlinear distortion due to high PAPR of the input signals will be introduced into the communication channels [8]. If the HPA is not operated in linear region with large power back-off, it is impossible to keep the out-of-band power. To reduce the PAPR, many techniques have been proposed. Such as clipping, coding, partial transmit sequence (PTS), selected mapping (SLM), interleaving, nonlinear companding transforms, hadamard transforms and other techniques etc [7].

These schemes can mainly be categorized into signal scrambling techniques, such as PTS, and signal distortion techniques such as clipping, companding techniques. Among those PAPR reduction methods, the simplest scheme is to use the clipping process [9]. However, using clipping processing causes both in-band distortion and out-of-band distortion and further causes an increasing of error bit rate of system. This Selected Mapping is one of the promising techniques due to its simplicity for implementation which introduces no distortion in the transmitted signal. This technique has one of the disadvantages of sending the extra Side Information (SI) index along with the transmitted OFDM signal.

II. PAPR PROBLEM OF OFDM SIGNAL

A. Continuous-time PAPR

In general, the PAPR of OFDM signals s(t) is defined as the ratio between the maximum instantaneous power and its average power

$$\mathrm{PAPR}[x(t)] = \frac{\max_{0 \le t \le NT}[|(x)|^2]}{P_{av}} \quad \ldots(1)$$

Where is P_{av} the average power of x(t) and it can be computed in the frequency domain because Inverse Fast Fourier Transform is a unitary transformation.

B. Discrete-time PAPR

The PAPR of the discrete time sequences typically deter mines the complexity of the digital circuitry in terms of the number of bits necessary to achieve a desired signal to quantization noise for both the digital operation and the DAC [2]. However, we are often more concerned with reducing the PAPR of the continuous-time signals in practice, since the cost and power dissipation of the analog components often dominate. To better approximate the PAPR of continuous-time OFDM signals, the OFDM signals samples are obtained by L times oversampling. L-times oversampled time-domain samples are LN-point IFFT of the data block with (L-1) N zero-padding. Therefore, the oversampled IFFT output can be expressed as

$$x[n] \triangleq \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi nk}{LN}} \quad , \quad 0 \le n \le LN \ 1 \quad \ldots(2)$$

The PAPR computed from the L-times over sampled time domain OFDM signal samples can be defined as

$$\mathrm{PAPR}\{x[n]\} = \frac{\max_{0 \le n \le NL-1}[|x[n]|^2]}{E[|x[n]|^2]} \quad \ldots(3)$$

Where E{.} denotes the expectation operator.

In OFDM transmission, complex data symbols are transmitted in many orthogonal sub channels, after inverse fast Fourier Transform (IFFT), the transmitted OFDM signal samples over one symbol interval can be written as

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k)\, e^{\frac{j2\pi kn}{N}}, n = 1,2,3,\ldots,N-1 \quad \ldots(4)$$

Where N is the number of subcarriers, X (k) is the data symbol transmitted over the k^{th} subcarrier. When the number of subcarriers is large and the input data symbols are independent and identically distributed random variables, the IFFT output signals which in the time domain, can be modeled as truncated Gaussian random variables with zero mean according to the central limit theorem. Thus, the power of the OFDM signal samples can be calculates as

$$p(t) = |x_n|^2$$

$$= \frac{1}{N} \sum_{i=0}^{N-1} \sum_{s=0}^{N-1} x_i x_s e^{\frac{j2\pi(i-s)n}{N}} \quad (5)$$

The PAPR of the time-domain samples can be defined as

$$PAPR = \frac{\max_{1 \le n \le N-1} |x(n)|^2}{E\{|x(n)|^2\}} \quad \ldots(6)$$

Generally, the output signals after IFFT are random because the input data samples are random. The highest PAPR occurs only when n (n<N) modulated signals have the same phase. In this case, the peak power would be the sum of the power of these signals. Since the PAPR is a random variable, in all literatures, Complementary Cumulative Distribution Function (CCDF) is the most common way to evaluate the statistic properties of PAPR by estimating the probability of PAPR when it exceeds a certain level $PAPR_0$. The CCDF of the PAPR is defined as

$$CCDF = P_r\{PAPR > PAPR_0\}$$

$$= (1 - e^{-PAPR_0})^N \ , PAPR_0 > 0 \quad \ldots(7)$$

This is the simulation of OFDM system to observe PAPR in it. So this is the basic explanation about PAPR and why it is reduce in OFDM system. Now there are different techniques has been proposed for the reducing PAPR in OFDM system.

III. PAPR REDUCTION TECHNIQUES

PAPR reduction techniques are classified into the different approaches: clipping technique, coding technique, probabilistic (scrambling) technique, adaptive pre-distortion technique, and DFT-spreading technique.

A. Clipping

The clipping approach is the simplest PAPR reduction scheme, which limits the maximum of transmit signal to a Pre-specified level [10]. In this scheme, the L-times oversampled discrete-time signal x'[m] is generated from the IFFT of Equation below

$$X'[k] = \begin{cases} X[k], for\ 0 \le k < \frac{N}{2}\ and\ NL - \frac{N}{2} < k < NL \\ 0, \quad elsewhere \end{cases} \quad \ldots(8)$$

and is then modulated with carrier frequency f_c to yield a pass-band signal $x^p[m]$.

Let x_c^p [m] denote the clipped version of $\mathbf{x^p[m]}$, which is expressed as

$$x_c^p[m] = \begin{cases} -A & x^p[m] \le -A \\ x^p[m] & |x^p[m]| < A \\ A & x^p[m] > A \end{cases} \quad \ldots(9)$$

Or

$$x_c^p[m] = \begin{cases} x^p[m] & if\ |x^p[m]| < A \\ \frac{x^p[m]}{|x^p[m]|} . A & Otherwise \end{cases} \quad \ldots(10)$$

where A is the pre-specified clipping level.

Note that Equation (10) can be applied to both baseband complex-valued signals and passband real-valued signals, while Equation (9) can be applied only to the pass-band signals. Let us define the clipping ratio (CR) as the clipping level normalized by the RMS value σ of OFDM signal, such that

$$CR = \frac{A}{\sigma} \quad (11)$$

B. Selective Mapping

Fig. 1 shows the block diagram of selective mapping (SLM) technique for PAPR reduction [6]. Here, the input data block X = [X[0], X[1], ...,X[N-1]] is multiplied with U different phase sequences $P^u = [P_0^u, P_1^u, \dots, P_{N-1}^u]^T$ where $P_v^u = e^{j\varphi_v^u}$ and $\varphi_v^u \in [2\pi)$ for v = 0,1, …, N-1 and u = 1,2,…u which produces a modified data block $X^u = [X^u[1], X^u[2], \dots, X^u[N-1]]^T$, among which the one $\tilde{X} = X^{\bar{u}}$ with the lowest PAPR is selected for transmission, as shown as

$$\bar{u} = \underset{u=1,2,\dots,U}{\operatorname{argmin}} \left(\underset{n=0,1,\dots,N-1}{\max} |x^u[n]| \right) \quad (12)$$

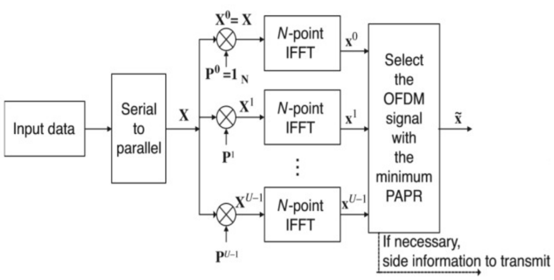

Fig. 1. Block diagram of selective mapping (SLM) technique for PAPR reduction.

In order for the receiver to be able to recover the original data block, the information about the selected phase sequence P^u should be transmitted as side information [5]. The implementation of SLM technique requires U IFFT operations. Furthermore, it requires $[\log_2 U]$ bits of side information for each data block where [x] denotes the greatest integer less than x.

IV. PROPOSED SCHEME

The Basic Idea of SLM to generate several OFDM symbols as candidates and then select the one with minimum PAPR reduction. In this Paper we explore SLM and Clipping techniques using convolutional codes. Convolutional codes [3] were proposed by P. Elias in 1995. It encodes *k* information bits in *N* bits which are not related to the current *k* bits but also related to the former $(L-1)_X N$ bits where is the L is the constraint length of the encoder. The candidate signals are generated using three methods. First is label insertion in which for each frame of data, the bits label d_i is inserted which is a sequence of m bits, i = 1,2,…*V*. Where after, the convolutional encoder generates a sequence V_i = 1,2,…*V*. [4].

V. SIMULATION RESULT

In our project data's are simulated by using MATLAB software, Fig. 2 plots the CCDFs of the PAPR for original symbols, modified symbols using Clipping and SLM technique, and modified symbols using our proposed method (for 1 and 2 iterations) involving filter optimization. From the Fig.2, it can be seen that both the Clipping and SLM technique can significantly reduce the PAPR using Convolutional Coding (CC). Fig. 3 plots the bit error rate curves of the original signal through an AWGN channel. Comparing the BER curves of our method with those of the Clipping and SLM technique with CC coding, it is observed that the signal to noise ratio (SNR) of SLM and Clipping is having same performance up to SNR 4 dB, after 4 clipping is better than SLM.

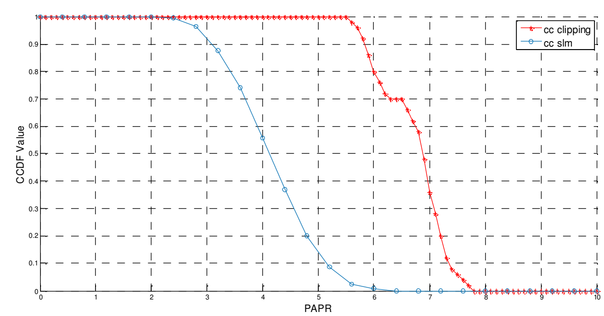

Fig. 2. CCDF Vs PAPR using CC Clipping and CC SLM.

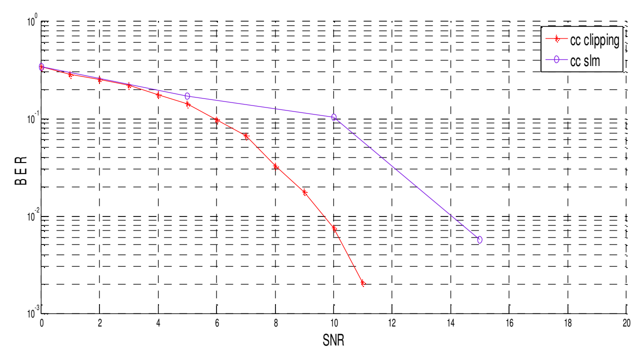

Fig. 3. BER Vs SNR using CC Clipping and CC SLM.

VI. CONCLUSION

This paper proposes a optimization technique to dynamically Reduce the PAPR of OFDM signal using Clipping and SLM methods using Convolution Code. It has been observed that this method has better PAPR and computational complexity reduction performances without the degradation of the BER. These results will help to design an efficient PAPR reduction in OFDM and will increase the efficiency of utilization of spectrum and provide large economic and social benefits.

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