Implementation of Selected Mapping and Clipping for PAPR Reduction in OFDM Communication Systems

Haris P. A, Sen Jose

Abstract-In the recent times, Orthogonal Frequency Division Multiplexing (OFDM) has been under intense research for broadband wireless transmission due to its robustness against multi-path fading. In this paper, a joint selected mapping and clipping method is proposed to reduce the peak-to-average ratio of OFDM signal. Here cyclically shifted mapping data is used to generate a set of data blocks which represent the original information. This will increase the data rate when compared with the conventional SLM technique. Then clipping operation has done to reduce the PAPR further. Simulation results show that the proposed scheme may obtain significant PAPR reduction while maintaining good performance in the BER compared to other methods.

Keywords- (OFDM), SLM, PAPR, BER.

I.INTRODUCTION

In recent years, need for high speed data transmission has increased with the rapid growth in digital wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) is the most popular and widely used method for data transmission in the area of high speed communication systems. But the major disadvantage of OFDM systems is the non-linear distortion caused due to high peak-to-average power ratio (PAPR) of the transmitted signal. OFDM consists of large number of independent subcarriers, as a result of which the amplitude of such a signal can have high peak values. A large PAPR ratio brings disadvantages like an increased complexity of the analog-to-digital (A/D) and digital-to-analog (D/A) converters and a reduced efficiency of the RF power amplifier. OFDM [1, 2] is used in many applications owing to its robustness to frequency selective fading or narrowband interference, high bandwidth efficiency and efficient implementation. This technique has found many applications in digital audio broadcasting (DAB) systems, digital video broadcasting terrestrial TV (DVB-T) systems, wireless local area networks (WLAN), broadband wireless access (BWA) networks and ultra-wideband systems. Moreover, it is expected to be the standard for the Fourth Generation (4G) cellular system. The carriers used to transmit the data in OFDM systems are orthogonal to each other. This will provide a lot of advantages over other systems. By dividing the channel into narrowband flat fading sub channels, OFDM is more resistant to frequency selective fading than single carrier systems are.

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OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation functions. Since the transmitter side of the OFDM system is modeled with the ifft block, the major drawback of this system is its high peak-to-average power ratio (PAPR). Linear power amplifiers are used at the transmitter to amplify the data for transmission. The high PAPR will shift the operating point of the amplifier to the saturation region which leads to in-band distortion and out-band radiation. Also an important constraint in applications like wireless mobile communications is its power consumption. Power amplifiers with wider linear range require more power. But it is very difficult to deliver that much power from an internal power source in such devices. An easy way to overcome this constraint is to reduce the PAPR. Various techniques have been proposed to reduce PAPR, which can be categorized into three. First, there are signal distortion techniques, such as clipping, peak windowing, and peak cancellation which reduce the peak amplitudes simply by nonlinearly distorting the OFDM signal at or around the peaks. Second, there are coding techniques that use a special code set that excludes OFDM symbols with a large PAPR ratio. The third technique scrambles each OFDM symbol with different scrambling sequences and selecting the sequence that gives the smallest PAPR ratio. Partial transmit sequence (PTS) [3], selected mapping (SLM) [4, 5], interleaving and some other techniques are used in this category. As an alternative approach, the combined effect of clipping and selected mapping techniques is utilized to reduce PAPR with less compromise in the BER performance is proposed here. The simulation results show that the proposed design has better performance compared with the individual techniques.

The organization of this paper is as follows. Section 2 presents the PAPR problem in OFDM systems. Clipping and selected mapping techniques are introduced in section 3 and section 4. In section 5, a PAPR reduction scheme by combing Clipping and selected mapping is proposed. Simulation results are reported in section 6 and conclusions are presented in 7.

II.OFDM SYSTEM MODEL

In this section, we review the basic of OFDM transmitter and the PAPAR definition [6]. Consider an OFDM consisting of N subcarriers. Let a block of N symbol $X = \{X_k, k = 0, 1,. . . N\text{-}1\}$ is formed with each symbol modulating one of a set of subcarriers $\{f_k, k = 0, 1,. . . N\text{-}1\}$, 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,

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

PAPR defines a relationship between the maximum signal power to the average signal power in the pass band. In general, the PAPR of OFDM signals x(t) is defined as the ratio period between the maximum instantaneous power and its average power during an OFDM symbol.

$$PAPR=\frac{\max[|x(t)|^2]}{1/(NT)\int_0^{NT}|x(t)|^2\,dt} \qquad (2)$$

Reducing the max x(t) is the principle goal of PAPR reduction techniques. In practice, most systems deal with a discrete-time signal, therefore, we have to sample the continuous-time signal x(t).

To better approximate the PAPR of continuous-time OFDM signals, the OFDM signals samples are obtained by L times oversampling. By sampling x (t) defined in Eq. (1), at frequency $f_s = L/T$, where L is the oversampling factor, the discrete-time OFDM symbol can be written as,

$$x(n)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1}X_k e^{j\frac{2\pi}{NL}kn}, 0\le n\le NL-1 \qquad (3)$$

Eq. (2) can be implemented by using a length (NL) IFFT operation. The new input vector X is extended from original X by using the so-called zero-padding scheme, i.e. by inserting L-1N zeros in the middle of X. The PAPR [7] computed form the L-times oversampled time domain OFDM signal samples can be defined as,

$$PAPR[x(n)]=10\log\frac{\max[|x(n)|^2]}{E[|x(n)|^2]} \qquad (4)$$

However, the PAPR does not increase significantly after L=4. In order to avoid aliasing the out-of-band distortion into the data bearing tones and in order to accurately describe the PAPR an oversampling factor L≥4 is required.

III.SELECTED MAPPING (SLM)

The SLM technique is developed from the idea of symbol scrambling. In this technique, a set of candidate signals are generated to represent the same information, the signal with lowest PAPR is selected and transmitted. The information about the selection of these candidate signals need to be explicitly transmitted along with the selected signal as side information. Selected mapping needs to transmit the information to the receiver, about the selected signal, as side information. If there is an error in the received side information, then it is very difficult for the receiver to recover the information from the transmitted selected signal. That is the reason why a strong protection against transmission errors is needed regarding side information. Once the receiver has these side information then the decoding process is very simple. SLM can be employed for larger number of sub-carriers with moderate complexity. The technique uses codes only for PAPR reduction and does not include error correction capabilities of codes. The complexity is increased due to the multiple numbers of IFFT operations. The need for transfer of side information to the receiver without any margin for transmission errors is very crucial under the fading channels. Under such noisy channels, the side information is distorted to result in BER degradation in the OFDM systems. Hence, the side information affected the system performance and its bandwidth efficiency.

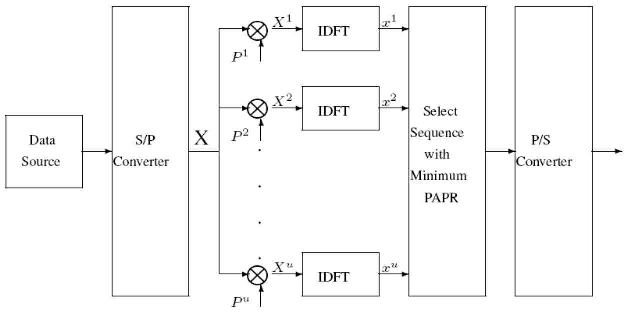

Figure 1. Transmitter Block Diagram with SLM technique.

The transmitter side [8] of an OFDM system with SLM technique is shown in figure 1. In the SLM technique, a set of U different, distinct sequences $P^{(u)}=[P_0^u,P_1^u,......,P_{N-1}^u]^T$ with $P_n^{(u)}=e^{j\varphi_n^{(u)}}$, $\varphi_n^{(u)}\in[0,2\pi)$, n=0,1,….N-1, u=1,2,…,U must be defined. At first, the input information is divided into OFDM data block X, which consists of N symbols, by the serial-to parallel (S/P) conversion and then data block X is multiplied carrier wise with each one of the U different phase sequences $P^{(u)}$, resulting in a set of U different OFDM data blocks $X^{(u)}=[X_0^{(u)},X_1^{(u)},....X_{N-1}^{(u)}]^T$ where $X_n^{(u)}=X_n.P_n^{(u)}$ n=0,1,….N-1, u=1,2,…,U. Then all U alternative data blocks are transformed into time domain to get transmit OFDM symbol $x^{(u)}$ = IDFT{$X^{(u)}$}. The sequence with minimum PAPR is selected for transmission. The receiver block diagram is shown in figure 2.

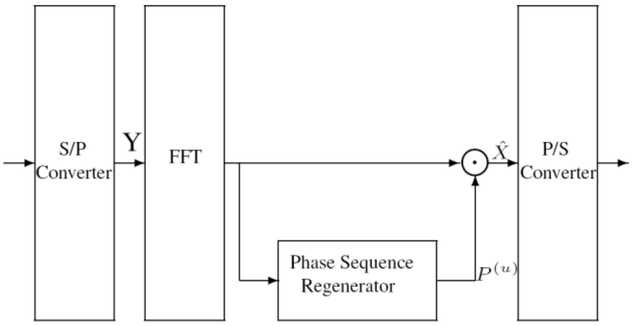

Figure 2. Receiver Block Diagram.

To recover the data sequence X at the receiver, SLM needs to transmit the information on the selected phase sequence as side information , which results in some loss of transmission efficiency. If each phase sequence $P_n^{(u)}$ is generated as the cyclically shifted version of the previous sequence, the information needed to transmit will be less to reconstruct the data. The BER performance will not be affected due to the presence of this technique because the original information is transformed into a different sequence and we can rebuild the information from the selected phase sequence itself.

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IV.CLIPPING

The simplest approach for reducing the PAPR of OFDM signals is clipping [9, 10, 11]. But this technique comes under the distortion based category. In this technique, the high amplitude peaks of the signal are clipped to a predetermined threshold value which limits the peak envelope of the input signal. Since the clipping is done on the actual information itself, there is a possibility to loose the data. So there will be a trade-off between the clipping and the BER performance. Let x[n] denote the pass band signal and $x_c[n]$ denote the clipped version of x[n],which can be expressed as

$$x_c[n] = \begin{cases} -A & x[n] \le -A \\ x[n] & |x[n]| < A \\ A & x[n] > A \end{cases}$$

Where A is the pre-specified clipping level.

This technique has some drawbacks which causes in band signal distortion, resulting in Bit Error Rate performance degradation. It also causes out-of-band radiation, which imposes out-of-band interference signals to adjacent channels. This out-of-band radiation can be reduced by filtering. This filtering of the clipped signal leads to the peak regrowth. That means the signal after filtering operation may exceed the clipping level specified for the clipping operation.

V.PROPOSED SCHEME

An OFDM system has been implemented with the hybrid scheme of selected mapping and clipping as the Peak-to average power ratio reduction technique. In the selected mapping technique, a set of data are used to generate the new data blocks which represents the original information. Then a clipping block has appended for further reduction of PAPR. The block diagram for the proposed design is shown in figure 3.

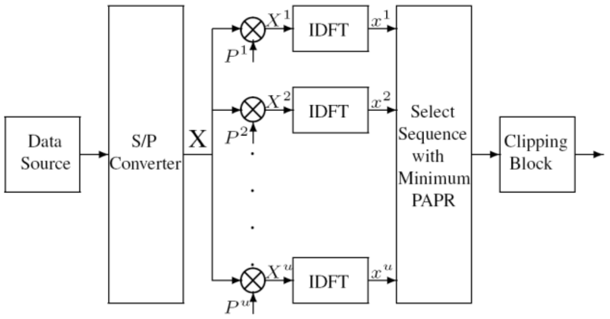

Figure 3. Block Diagram of the Proposed Design.

P^1, P^2, P^3...are used to generate the new set of information data. At the receiver side, the original information is reconstructed by using these new set of data known as phase rotating vector. So we have to transmit these data to the receiver along with the information data. This will reduce the efficiency of the system. So here cyclically shifted version of one data is used to generate the new information sequence. Thereby the data rate can be improved. The information from the data source is multiplied with the locally generated data and ifft of each data is taken. Then the PAPR of each data is calculated and the data with minimum PAPR is selected for transmission. The clipping operation is done on this sequence to reduce the PAPR further. But we cannot clip the signal after a particular threshold value which will make the reconstruction more difficult.

The main idea for combining the two methods is relaying on the observation that the overall performance in PAPR reduction will increase by using these two different types of signal processing. SLM performs linear transformation by rotating the vectors from the frequency-domain signal, and the clipping operation performs a non-linear transformation represented by signal limitation to a given threshold.

By using this technique the PAPR can be mitigated and the operating point of the linear amplifier which is used at the transmitter side can be kept in the linear dynamic range itself. This will avoid the shifting of the operating point to the saturation region by which the orthogonality can be maintained.

VI.RESULTS AND DISCUSSION

In this section, Matlab simulations are used to evaluate the peak-to-average ratio reduction capability and bit error rate of the proposed scheme. The channel is corrupted by an additive while Gaussian noise (AWGN). In simulation, an OFDM system is considered with subcarrier N=64 and QPSK modulation is used for encoding the information.

We can evaluate the performance of the proposed scheme using cumulative distribution of PAPR of OFDM signal. The cumulative distribution function (CDF) is the most regularly used parameters, which is used to measure the efficiency of and PAPR technique.

However, 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 CCDF of the PAPR of the data block is desired to compare outputs of proposed scheme to various reduction techniques.

The complementary cumulative distribution function (CCDF) of the PAPR for the proposed scheme and the individual techniques are plotted in figure 4. It is clear from the plot that the PAPR of the OFDM system is reduced evidently and we can keep the operating point in the linear range itself. From Fig. 5 we can see that with probability of 10^{-2}, PAR of the original signal is more than 8.9dB, while for a system with clipping and SLM, the PAR is reduced approximately to 8.6dB and 6.7dB respectively. And the proposed method has PAR of 4.7dB with a probability of 10^{-2}. From the figure, we notice that the CCDF curve has nearly 4.2dB improvement for the proposed system, compared to the conventional OFDM system at a probability of 10^{-2}. But we cannot reduce the PAPR without looking into the Bit Error Rate performance. Here the BER performance is also calculated for the proposed design and it is shown in fig. 4.

It is obvious from the figure that the proposed system maintains the BER performance so close to the conventional OFDM system. At the same time it serves an important role to reduce the PAPR considerably.

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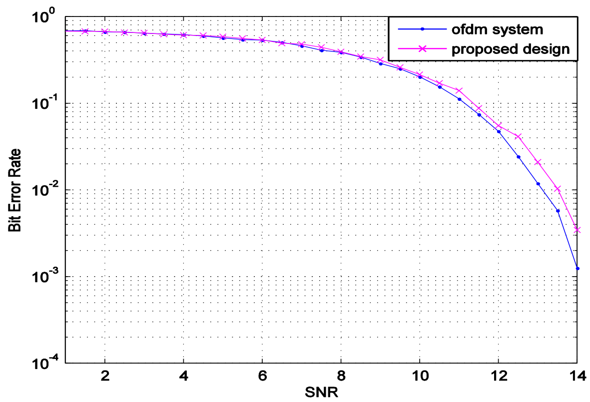

Figure 4. CCDFs of PAPR of proposed technique with the individual techniques

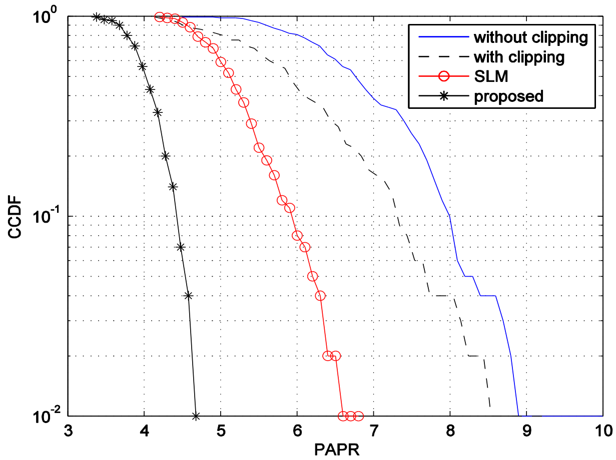

Figure 5. BER of the proposed technique for QPSK modulation, N = 64

VII.CONCLUSION

In this paper we proposed an alternative PAPR reduction technique based on combination of a selected mapping method with the clipping method. We have used selected mapping technique followed by the clipping operation. The simulation results show that the hybrid scheme brings higher PAPR reduction than the component methods. And we got an affordable BER performance for the proposed design compared with the conventional OFDM system.

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