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A New PAPR Reduction Scheme: CWPTS (Combined Weighting and PTS)

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***Abstract*—One of the serious problems in any wireless communication system using multi carrier modulation technique like Orthogonal Frequency Division Multiplexing (OFDM) is its Peak to Average Power Ratio (PAPR). It limits the transmission power due to the limitation of dynamic range of Analog to Digital Converter and Digital to Analog Converter (ADC/DAC) and power amplifiers at the transmitter, which in turn sets the limit over maximum achievable rate. This issue is especially important for mobile terminals to sustain longer battery life time. Therefore reducing PAPR can be regarded as an important issue to realize efficient and affordable mobile communication services. In this paper we present methods for reduction of PAPR in multi-carrier OFDM through the joint use of weighting, and Partial Transmit Sequence (PTS). Afterwards, we numerically discuss the PAPR characteristics using the complementary cumulative distribution function (CCDF) of the PAPR. The simulation results show that the combined weighting-PTS scheme (CWPTS) has a better PAPR and BER performances than PTS.**

Keywords—CCDF; OFDM; PAPR; PTS; Weighting

I. INTRODUCTION

Multi-carrier transmission, also known as Orthogonal Frequency Division Multiplexing (OFDM) or Discrete Multi-Tone (DMT), is a technique with a long history that has recently seen rising popularity in wireless and wire line application. The recent interest in this technique is mainly due to the recent advantage in digital signal processing technology and semiconductor technology. International standards making use of OFDM for high speed wireless communications are already established or being established by IEEE802.11, IEEE802.16, IEEE802.20 and European Telecommunications Standards Institute (ETSI) Broadcast Radio Access Network (BRAN) committees . For wireless application, an OFDM based system can be of interest because it provides greater immunity to multi-path fading and impulse noise eliminates the need of equalizers, while efficient hardware implementation can be realized using Fast Fourier Transform (FFT) techniques.

Despite of its advantage, one of the major drawbacks of OFDM is the high PAPR value of the transmitted signals. This problem comes from the nature of the modulation itself, where multiple sub-carriers are added together to form the signal to be transmitted. Usually, the systems are constrained to a limited peak power due to the limitation of the dynamic range over which the transmitter amplifier operates linearly. In OFDM systems, the PAPR is a random variable. Therefore it is important to search on the characteristics of the PAPR including its distribution and reduction in order to utilize the technical features of the OFDM. One of the characteristics of the PAPR is its distribution. Often it can be expressed in terms of Complementary Cumulative Distribution Function (CCDF) [1]. Numbers of techniques have been proposed in the literature for reducing the PAPR in OFDM systems. In this paper we propose a method for reducing PAPR using combined weighting and Partial Transmit Sequences techniques (CWP).

The paper is organized as follow: first we investigate the PAPR in OFDM systems in section 2 and then we describe the weighted OFDM signal scheme in section 3 and PTS technique in section 4. In section 5 we describe our proposal method to reduce both PAPR and BER in an OFDM transmission. Finally, we present our simulation results and conclusion.

II. PAPR OF AN OFDM SIGNAL

One of the new problems emerging in OFDM systems is the so-called Peak to Average Power Ratio (PAPR) problem. The input symbol stream of the IFFT should possess a uniform power spectrum, but the output of the IFFT may result in a non-uniform or spiky power spectrum. Most of transmission energy would be allocated for a few instead of the majority subcarriers. This problem can be quantified as the PAPR measure. It causes many problems in the OFDM system at the transmitting end.

In general, the PAPR of OFDM signals is defined as the ratio between the maximum instantaneous power and its average power. The PAPR of the discrete time sequences typically determines 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. 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. -times oversampled time-domain samples are LN point IFFT of the data block with (L-1)N zero-padding.

The definitions of N frequency domain signals in OFDM are $\{X_n, n=0, 1, 2 \ldots N-1\}$. These N signals construct 1 OFDM block. A set of N sub-carriers, i.e. $\{f_n, n=0, 1, 2 \ldots N-1\}$, is used for these signals in the OFDM. The N sub-carriers are chosen to be orthogonal, i.e., $f_n= n\Delta f$ in frequency domain where $\Delta f =1/NT$ and T is the OFDM time domain signal duration. The OFDM signal is expressed as [2]:

$$X(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\Pi f_n t}; 0 \le t \le T \quad (1)$$

The PAPR is defined by [2]:

$$PAPR = \frac{\max |x(t|^2}{E[|x(t)|^2]} \quad (2)$$

where E[.] denotes expectation. In some blocks of OFDM signals, large PAPR happens since the structure of the given symbols may cause this peak. High PAPR is a serious issue in RF analog circuits, particularly in a high power amplifier (HPA). Nonlinearity of HPA causes inter-carrier interferences (ICI) and thus out-of-band radiation. Accordingly, the BER performance is degraded.

III. A WEIGHTED OFDM SIGNAL SCHEME FOR PAPR REDUCTION OF OFDM SIGNALS

A PAPR reduction scheme based on a weighted OFDM signal is proposed in [3] to reduce the PAPR without distortion in removing the weight at the receiver side. This method is motivated by a circular convolution process, i.e., the modulated OFDM signal is convoluted with a certain kind of bandlimited signal for smoothing the peak of the OFDM signal before the HPA. In this weighted OFDM method with modified weight, the time duration needed to transmit the weighted OFDM signal is the same as the time duration for the original OFDM signal. Moreover, the original discrete data can be recovered completely at the receiver side with additional 2N complex multiplications of computational complexity without extra cost in transmission.

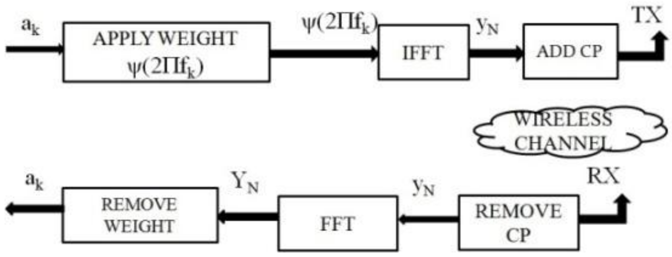

Fig 1: Simplified block diagram for an OFDM system with weighting scheme

The simplified block diagram for an OFDM system with the weighted scheme[3] is shown in Fig. 1. The modulated data stream is carried on the multicarriers by the IFFT, and the convolution block reduces the PAPR of signal, which is corresponding to the weight block of the weighted OFDM signal scheme, as shown in Fig. 1. In the following block, the cyclic prefix is added before the HPA. The modified weight with a positive constant α is [3]:

$$\varphi_\alpha(x) = \frac{1-\sin c(x)}{\Pi^2 x^2} + \frac{\alpha}{\log N} \quad (3)$$

where α is a shift parameter, and log N is obtained by experiment.

IV. PAPR REDUCTION USING PTS

In the PTS scheme[4] as shown in figure 2, the input symbol sequence is partitioned into a number of disjoint symbol subsequences. IFFT is then applied to each symbol subsequence and the resulting signal subsequences are summed after being multiplied by a set of distinct rotating vectors. Next the PAPR is computed for each resulting sequence and then the signal sequence with the minimum PAPR is transmitted. As the number of subcarriers and the order of modulation are increased, reducing the computational complexity becomes more important than decreasing redundancy.

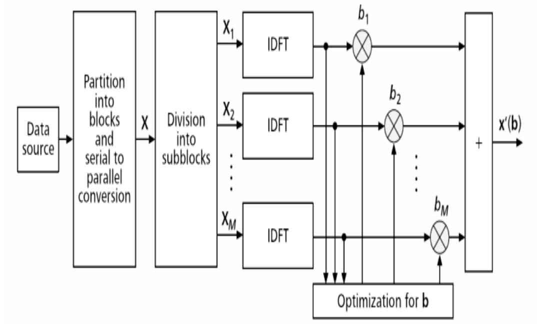

Fig 2 Block diagram of PTS technique

A. PTS Scheme with New Phase Sequence

A new phase sequence is proposed in [5], in order to decrease computational complexity of the conventional PTS technique.

The new phase sequence is based on the generation of N random values from the possible phase factors {1 -1}, if we consider the number of allowed phase factor W=2. Therefore the new phase sequence can be constructed as follows:

$$\hat{b} = \begin{bmatrix} b_{1,1}, b_{1,2} \ldots b_{1,N} \\ \ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots \\ b_{v,1}, b_{v,2} \ldots b_{v,N} \end{bmatrix} \quad (4)$$

Where *N* is number of subcarriers and *V* is number of sub blocks partitioning.

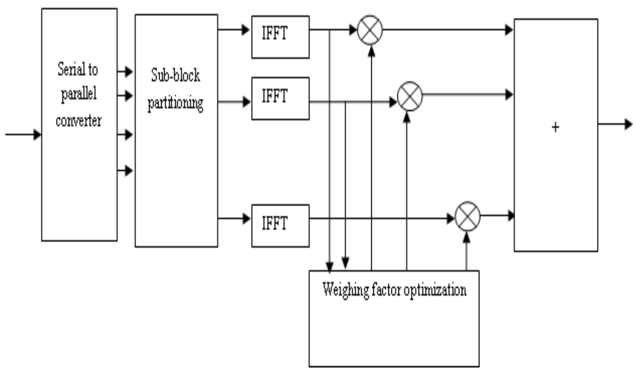

Fig 3: Block diagram of PTS technique with new phase sequence

In (4), *N* random phase sequence is generated periodically *V* times. The new phase sequence matrix has N different random values. For the new phase sequence format, the way to find the optimum phase factor will be different. In this case, first *N* different random phase sequence is generated and this is continued *V* times according to (4), hence the optimum phase factor is each row of this matrix. But for finding the optimum phase factor, matrix in (4) should be randomly generated several times. We constrain the number of times that the matrix would be generated to be the same as in C-PTS for fair comparison. Hence for the case of *W=2* and *V=4*, C-PTS has 8 iterations and therefore (4) should be generated 8 times. In this case we have 8 possibilities, because the first bit is fixed, {1,1,1}, {1,1,-1}, {1,-1,1}, {1,-1,-1},{-1,1,1},{-1,-1,1},{-1,1,-1},{-1,-1,-1}. Optimum phase factor will be chosen from these 8 phase sequences. In our proposed method, because there are N different random phase factors, to search for the optimum phase sequence it requires N8 iterations which is not practical. But here, we only apply the same iteration as was applied in C-PTS and later it will be shown through simulations, that good PAPR performance is achieved, and it is also possible to have less iteration while keeping the PAPR performance same as C-PTS but with reduced complexity.

V. PROPOSED METHOD

The block diagram of the proposed system combining weighting and PTS techniques is shown in figure 4.

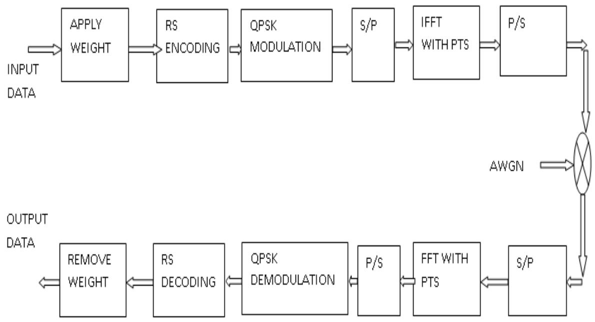

Fig 4 Proposed method

Here coding scheme used is Reed Solomon(RS) codes. Initially weight is added to discrete data and this weighted data is given to RS encoder and the encoded data is the given to modulator. The serial data is converted to parallel data. After serial to parallel conversion PTS technique is carried out. Here modified PTS technique is employed. PTS scheme involves transmitting only a part of the data of varying sub-carrier with low PAPR, which covers all the information to be sent in the signal as a whole.

The matrix in (4) can be extended as follows [5]:

$$\hat{b} = \begin{bmatrix} b_{1,1} \ldots\ldots\ldots\ldots b_{1,N}\,. \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ b_{v,1} \ldots\ldots\ldots\ldots b_{v,N} \\ b_{v+1,1} \ldots\ldots\ldots b_{v+1,N} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ b_{p,1} \ldots\ldots\ldots\ldots b_{p,N} \end{bmatrix} \quad (5)$$

where *P* is the number of iterations that should be set in accordance with the number of iterations of the C-PTS. The value of *P* can be calculated as follows [5]:

$$P = DW^{V-1} \quad (6)$$

where *D* is coefficient that can be specified based on the PAPR reduction and complexity and *DN* is amount that is specified by user. Value of *P* explicitly depends on the number of subblocks *V* if assuming the number of allowed phase factor is constant. The optimum phase sequence of (5) can be derived by successive search of phase sequence based on the value derived from (6) and then multiplied with input signal. Next the PAPR is computed for each resulting sequence and then the signal sequence with the minimum PAPR is transmitted. Here AWGN is added to it. In the receiver section the reverse process is carried out.

A. RS CODES

The coding scheme in the proposed method is RS encoding and decoding. In coding theory, Reed–Solomon (RS) codes are non-binary cyclic error-correcting codes invented by Irving S. Reed and Gustave Solomon. They described a systematic way of building codes that could detect and correct multiple random symbol errors. By adding t check symbols to the data, an RS code can detect any combination of up to t erroneous symbols, or correct up to $\lfloor t/2 \rfloor$ symbols. As an erasure code, it can correct up to t known erasures, or it can detect and correct combinations of errors and erasures. Furthermore, RS codes are suitable as multiple-burst bit-error correcting codes, since a sequence of $b + 1$ consecutive bit errors can affect at most two symbols of size b. The choice of t is up to the designer of the code, and may be selected within wide limits.

B. MODULATION

Here PSK modulation is employed. PSK is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases, each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal such a system is termed coherent.

VI. SIMULATION RESULTS

The analysis has been carried out using MATLAB 7.11. The modulation used is QPSK. The performance evaluation is done in terms of complementary cumulative distribution function.

TABLE I
SIMULATION PARAMETERS

Parameter	**Value**
Modulation	QPSK
Number of subblocks V	4
Oversampling factor L	1,4
Allowed phase factors W	4
User defined variable D	1 or 2
Channel	AWGN

Figure 5 shows CCDF of weighted OFDM system alone for α=0.03 and N=128.

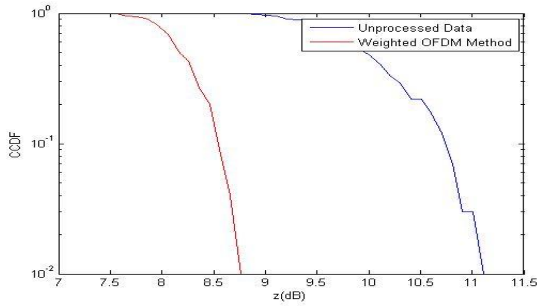

Fig 5 CCDF of weighted OFDM system

Fig 6 shows CCDF of weighted OFDM system for different values of α such as 0.05, 0.15 and 0.8. It can be concluded that for lower values of α PAPR reduction is better. Hence lower values of α is chosen for simulation.

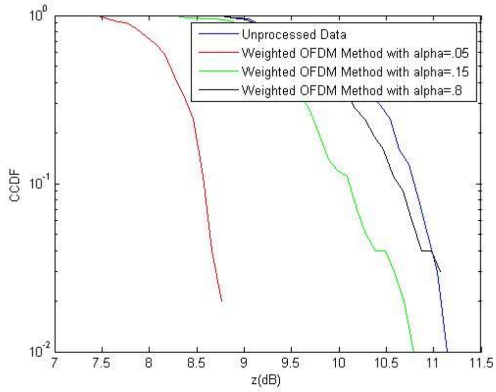

Fig 6 CCDF of weighted OFDM system for different values of α

Fig 7 compares the proposed combined weighting and PTS technique (CWP) with weighted OFDM signal scheme, PTS technique and clipping for CCDFs over AWGN channel. As shown in the figure, the CCDF of proposed CWP scheme is superior.

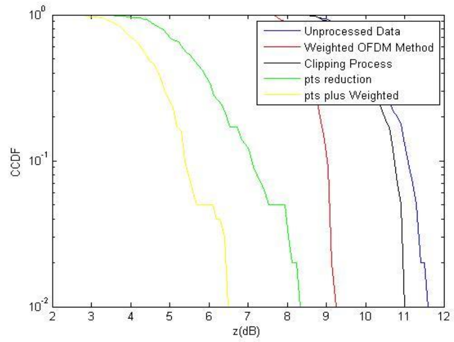

Fig 7 CCDF of proposed system

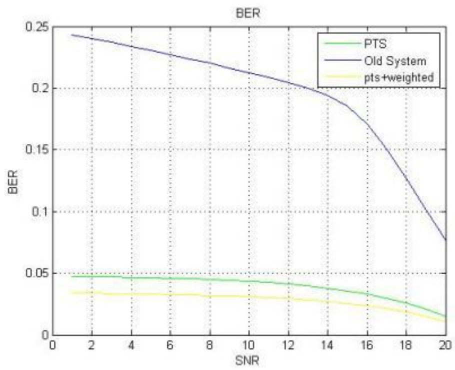

Fig 8 BER of proposed system

Fig 8 shows the BER performance of the proposed system. It can be concluded from the figure that the proposed CWP system has better performance.

VII. CONCLUSION

This paper discusses a new PAPR reduction method by combining weighting and PTS technique(CWPTS). Simulation results shows that the proposed system has better PAPR reduction when compared with other PAPR reduction techniques such as weighting, PTS and clipping. It has been shown that the proposed method is an effective way to reduce the PAPR of an OFDM signal. Also the BER performance is improved compared with existing method. The proposed scheme becomes more suitable for high data rate OFDM systems. The proposed method can be applied in recent wireless communications systems such as WiMAX and long term evolution (LTE).

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