Optimal phase selection for PTS using GPW and RPW to reduce PAPR in OFDM systems

P.Elavarasan[1], G.Nagarajan[2]

Abstract

OFDM is a suitable candidate for high data rate transmission with forward error correction (FEC) methods over wireless channels and there is a growing need to quickly transmit information wirelessly and accurately. This paper proposes a new peak to average power ratio (PAPR) reduction technique. In wideband system each sub carrier is individually modulated according to channel state information. The proposed measured increases the system throughput while maintaining system performance under a desired condition. In order to obtain the optimum condition on partial transmit sequence (PTS) for PAPR reduction, a quite large calculation cost is demanded and thus it is impossible to obtain the optimum PTS in a short time. The PTS technique employs with grouping phase weighting (GPW) and recursive phase weighting (RPW). The proposed reduction method realizes both the advantages of GPW and RPW at the same time. Simulation results show that proposed method improves PAPR in OFDM system with drastic reduction in cost.

Keyword: OFDM, PAPR, PTS, GPW, RPW

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other [1]. One of the main advantages of OFDM its multi-path delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain. Also one other significant advantage is that the modulation and demodulation can be done using inverse fast fourier transform (IFFT) and fast fourier transform (FFT) operations, which are computationally efficient. In a single OFDM transmission all the subcarriers are synchronized to each other, restricting the transmission to digital modulation schemes [4,5]. OFDM is symbol based and can be thought of as a large number of low bit rate carriers transmitting in parallel. All these carriers transmitted using synchronized time and frequency, forming a single block of spectrum. This is to ensure that the orthogonal nature of the structure is maintained [3,4].Despite of OFDM advantages, it has a major potential drawback in the form of high Peak-to-Average Power Ratio (PAPR). The high PAPR has nonlinear nature in the transmitter and it degrades the power efficiency of the system. Owing to a large PAPR, the BER performance of an OFDM system becomes degraded.

II. Partial Transmit Sequence

A number of PAPR reduction schemes have been proposed in the literature, such as block coding [1,4]and nonlinear companding schemes [3,6,8], among which, partial transmit sequence (PTS) technique [6] is the most attractive scheme due to good system performance and no restriction of the number of the subcarriers[2]. However, the big issue of finding the optimal phase combina-

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tion for PTS sequence is complex and difficult when the number of subcarriers and the order of modulation are increased. To reduce the computational complexity, many extensions of PTS schemes have been proposed recently [7,8], such as adaptive PTS approach [9-10]. In this paper, proposed scheme provides novel solution to reduce the complexity while keeping the optimal combination of GRW and PRW to reduce the PAPR largely [11].

2.1 CONVENTIONAL PTS SCHEME

The Partial Transmit Sequences [12] is the distortionless method for the PAPR reduction. A simple block scheme of this method is shown in Fig. 1. The input data are mapped according to the chosen constellation and split into consecutive OFDM symbols. Each OFDM symbol is then partitioned into M distinct subblocks, each of them completed with zeros to the original symbol length

Partion into Blocks and S/P Conversion

Division into Subblocks

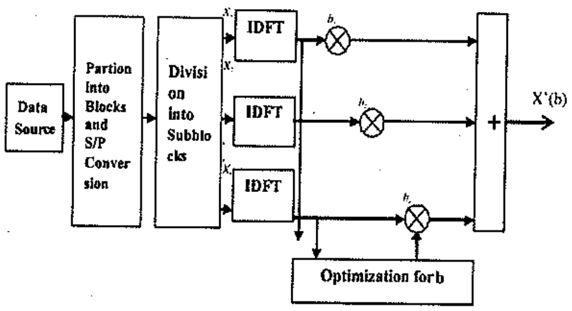


Fig. 1 Block diagram of PTS scheme.

Subsequently the Zero Padding (ZP) and the Inverse Fast Fourier Transform (IFFT) are performed on each subblock. After the IFFT, subblock outputs are multiplied by the vector of the so called complex rotation factors. The resulting OFDM symbol is calculated as a sum of all multiplied subblock outputs. The rotation factors are generated in the rotation factor generator block and their resulting vector is optimized in order to reduce the PAPR. The implementation is that, the possible values of complex rotation factors were limited to either +1 or -1 only in order to limit the search space for the optimization. For M subblocks, all 2M possible combinations of symbols 1 and-1 were tested for each OFDM symbol. The information about the rotation factors used for the multiplication in each OFDM symbol is necessary at the receiver for correct decoding. This information is called Side Information (SI). Throughout this paper, the transmission of the SI is not considered, and the SI is expected to be perfectly known at the receiver [13]. In the practical situation, the SI can be transmitted either through a special channel or by specified subcarriers excluded from data transmission [14].

2.2 THE PAPR OF A MULTICARRIER SIGNAL

A multicarrier signal is the sum of many independent signals modulated onto subchannels of equal bandwidth. Let us denote the collection of all data symbols Xn, n = 0, 1,…, N – 1, as a vector $X = [X_0, X_1 \ldots X_{N-1}]^T$ that will be termed a data block. The complex baseband representation of a multicarrier signal consisting of N subcarriers is given by

$$X(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{n-1} X_n e^{j2\pi n \Delta f t} \quad 0 \le t \le NT \qquad (2.1)$$

where, $j = \sqrt{-1}$, Δf is the subcarrier spacing, and *NT* denotes the useful data block period. In OFDM the subcarriers are chosen to be orthogonal (i.e., D*f* = 1/*NT*). The PAPR of the transmit signal is defined as

$$PAPR = \frac{\max_{0 \le n \le N-1} |x(n)|^2}{E\left[(|x(n)|^2)\right]} \qquad (2.2)$$

where, x(n) is the time domain OFDM signal sampled at symbol rate

2.3 THE CCDF OF THE PAPR

The cumulative distribution function (CDF) of the PAPR is one of the most frequently used performance measures for PAPR reduction techniques. In the literature, the complementary CDF (CCDF) is commonly used instead of the CDF itself. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold [15]. The CDF of the amplitude of a signal sample is given by

$$F(z) = 1 - \exp(z) \qquad (2.3)$$

The CCDF of the PAPR of a data block with Nyquist rate sampling is derived as

$$\begin{aligned} P(PAPR > z) &= 1 - P(PAPR \le z) \\ &= 1 - F(z)^N \\ &= 1 - (1 - \exp(-z))^N. \qquad (2.4) \end{aligned}$$

This expression assumes that the N time domain signal samples are mutually independent and uncorrelated. This is not true, however, when oversampling is applied [16].

III. Proposed PAPR Reduction Technique

In this section, formulation of searching sequences of PTS as a combinational optimization problem with some variables and constrains have been presented. An optimal combinational optimization scheme, which is derived from GPW and PRW, is proposed to achieve better PAPR reduction than that of earlier schemes with low number of trials. Accordingly, the objective of the PTS is to design an optimal phase factor for the subblock set that minimizes the PAPR. PTS significantly improves PAPR performance, but unfortunately, finding the optimal phase factors is a complex process. To reduce search complexity, search techniques have recently been proposed [15-20] because they can obtain the desirable PAPR reduction with low computational complexity. There are two advantages in PTS with GPW or/and RPW, i.e., lower computational complexity and the same performance in PAPR reduction compared with (O-PTS).

3.1 PROPOSED SCHEME TO REDUCE PAPR

The proposed scheme is based on GPW and RPW and search the optimal combination of phase factors for PTS with less number of iterations while keeping good PAPR reduction.

3.2 GROUPING PHASE WEIGHTING

The OFDM sequence is given in equation 3.1,

$$x' = \sum_{i=1}^{v} b_i x_i + \sum_{i=1}^{v_1} b_i x_i + \sum_{i=r+1}^{v_2} b_i x_i + \ldots\ldots + \sum_{i=v_{R-1}+1}^{v} b_i x_i$$

$$1 < r_1 < r_2 < \cdots T_R - V \qquad (3.1)$$

where, the value of r_i, i=1, 2 ,R-1 is the index of subblock.

It can be observed that all the subblocks can be split into several groups, and for each group, phase weighting process can be implemented by itself [21]. In this way, it can define that is the number of groups, subcandidate sequence from the k^{th} group and the number of subblocks in each group can be expressed by r_1, r_2-r_1, r_3-r_2, r_1 where must be bigger than one (because phase weighting factor for the first subblock is constant). By making use of the same set of phase weighting factors, these groups can implement their respective phase weighting processes and obtain their respective subcandidate sequences. Finally, subcandidate sequences from different groups can be combined by complex additions to achieve all the OFDM candidate sequences, and the one with the minimum PAPR is selected for transmitting. When the number of subblocks V=4, the set of phase weighting factors is {1,-1} (i.e.,W=2), the number of groups and there are two subblocks in the first group, so the four subblocks can be split into two groups: one includes the first two subblocks, and the other includes the rest ones[20]. It can be obtained by employing the phase weighting sequences, respectively

It can be seen that PTS with GPW and Original PTS (O-PTS) have the same OFDM candidate sequences. That is to say, PAPR reduction performance of proposed scheme is the same as that of O-PTS. As for computational complexity, each element in phase weighting sequence means that complex multiplications are needed. Thus, regarding each phase weighting sequence, the fewer elements it contains, the lower computational complexity can be needed for generating one candidate sequence [18-19]. If the proposed scheme is employed, six phase weighting sequences are generated and the number of elements in each sequence is two; but if O-PTS is adopted, eight phase weighting sequences are generated and the number of elements in each sequence is four of groups increasing, which will be examined by simulation results.

3.4 RECURSIVE PHASE WEIGHTING

As above mentioned, there are phase weighting sequences generated for obtaining candidate sequences. Consider all the phase weighting sequences, the relationship between phase weighting sequences if the following condition is satisfied. The set of allowed phase weighting factors is $e^{j(\frac{2\pi k}{w})}$, K=0,1…*W-1*It is worth mentioning that the given constraint conditions are with no loss of generality due to the fact that they are satisfied in the sets of phase weighting factors used for PTS in most literatures, [14–16].

3.5 COMBINATION OF GPW AND RPW

The PTS with GPW and RPW are summarized as follows: The input data sequence is partitioned into subblocks and the entire subblock sequences are divided into several groups, where for successfully performing RPW method the number of subblocks in each group must be bigger than one. Then, for each group, the RPW is implemented. However, when GPW and RPW are combined, the implementation of RPW is a little different from the circumstance that RPW is used solely [17]. But for other groups, because the first phase weighting factor is no longer constant, the only difference is the third step of RPW method. When the number of subblocks in one group is bigger than two, the modified step is that select any one from the two parts and split it into a number of troops, where phase weighting sequences with the same first phase weighting factor are in the same troop, and then continue the splitting of each troop into several smaller troops, where the sequences with the same second phase weighting factor are in the same troop. On the other hand, when one group includes two subblocks, the modified third step can be achieved by splitting twice the first splitting rule is that phase weighting sequences with the same first phase weighting factor are in the same troop, and then in terms of phase weighting factor for the second subblock, the second splitting can be accomplished, where the sequences with the opposite phase weighting factors for the second subblock are in the same troop. After RPW being implemented, subcandidate sequences in each group can be obtained. Finally, in terms of GPW, subcandidate sequences from different groups are combined and all the OFDM candidate sequences can be obtained.

IV. Simulation Results

In this section, extensive simulations are carried out to verify the performance of proposed schemes. The independent OFDM symbols which are randomly generated. Simulation parameters are given in Table. 1. The performance improvement of the proposed scheme is evaluated via simulation. Different scenarios have been investigated :(V,W)= (4,4), (4,3), (4,2), (3,3), (3,2) and (2, 2) in the order of computational complexity from low to high.

Table. 1 Simulation Parameters

Parameters	Details
Subcarrier	128,256,512&1024
No.of Subblock	4
Modulation	QPSK
Phase Set	4,3&2
Channel Used	Rayleigh Channel
Software Tool	MATLAB 7.9

For the proposed PTS scheme, QPSK modulation is applied for the conventional PTS for pseudo random partition. The Complementary Cumulative Distribution Function (CCDF), defined as the probability that the PAPR value is larger than a specific value $PAPR_0$, is generally used to evaluate the PAPR reduction performance for different schemes.

GPW and RPW can show their prime advantage in computational complexity reduction. Moreover, if GPW and RPW are combined, they further reduce the computational complexity. Moreover, for PTS with GPW, it can also be observed that if the number of subblocks is fixed, more computational complexity reduction can be obtained as the number of groups increasing. With the number of subblocks increasing, PTS with GPW can show its advantages in computational complexity reduction. As for PAPR reduction performance, the CCDF is usually used to evaluate and compare the performance of any PAPR reduction schemes.

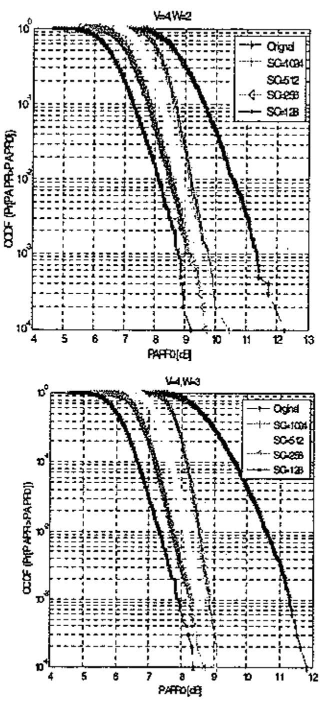
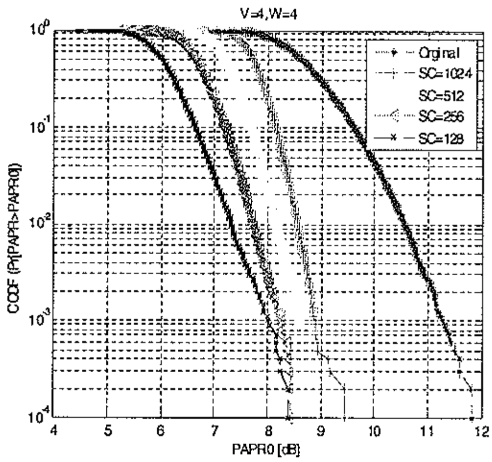
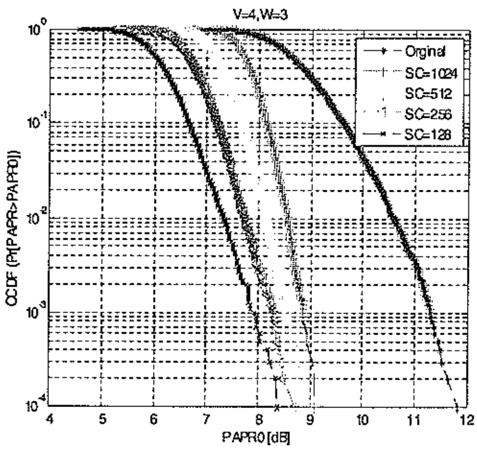


Fig. 2 Comparisons of PAPR reduction between proposed scheme and O-PTS (a) V=4, W=2 (b) V=4, W=3.

In Fig.2(a),(b) and Fig 3(a),the CCDF of PAPR are obtained by simulation, (V,W) = (4,4), (4,3), (4,2).Meanwhile, the proposed schemes make use of GPW and RPW to reduce computational complexity and have the same candidate sequences as O-PTS, therefore the proposed schemes also cause no change in the spectrum of original OFDM signals.It is clear that with increasing phase factor, the signal operates more in the linear region and hence decreases the amount of PAPR.

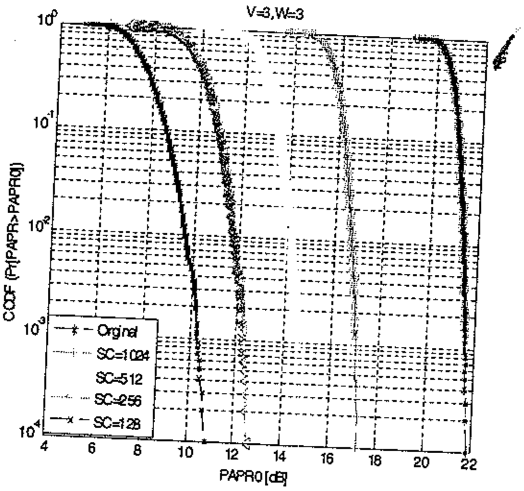


(a)

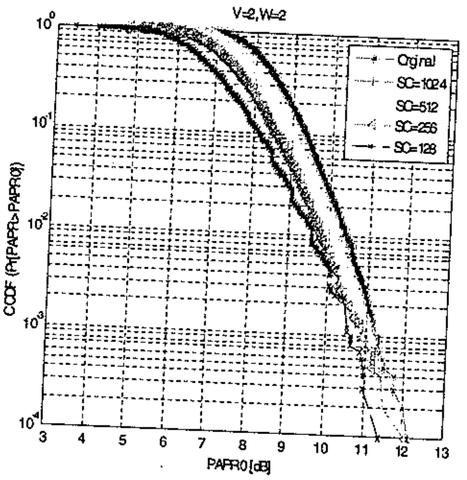


(b)

Fig. 3 Comparisons of PAPR reduction between proposed schemes and O-PTS



(a)



(b)

(a) V=4, W=4 (b) V=3, W=2

Fig. 4 Comparisons of PAPR reduction between proposed schemes and O-PTS

(a) V=3, W=2 (b) V=2, W=2.

Now only one value of GPW and RPW is used in Fig. 3(b) and Fig. 4(a). Since the distortion is going to different in each subcarrier, it is very difficult to reach a trade-off point of the amount of distortion that can be allowed in each modulation. It is found that the proposed PTS scheme, by applying the uniform phase factors, can achieve an improvement of 5 - 8 dB in PAPR reduction for different scenarios than the conventional PTS scheme with uniform phase factors. If a specific PAPR threshold is desired, the outage probability can be improved by a factor of 10dB. It is found that the proposed PTS scheme still outperforms the conventional PTS scheme with (V, W) = (3,3),(3, 2), (2,2) an improvement of (0.25 - 0.4) dB in PAPR reduction for different scenarios. The performance can be evaluated under the influence of the non-linear power amplifiers. The results are presented, works well for very low values GPW or/and RPW of SNR, yet it satisfy the target BER for almost all other subcarrier. Its performance decreases in Fig 4(b) due to limited in phase factor.

V. Conclusion

Multicarrier transmission is a very attractive technique for high-speed transmission over a dispersive communication channel. The PAPR problem is one of the important issues to be addressed in developing multicarrier transmission systems. The paper has proposed a modified PTS scheme by applying pre-determined uniform phase factors for PAPR reduction in OFDM systems. The two phase weighting methods with low computational complexity for PTS are proposed. The two methods focus on simplifying the computation for candidate sequences, resulting in computational complexity reduction. Moreover, the computational complexity can be further reduced when the two methods are combined. The analysis and simulation results show that, compared with O-PTS, the PTS using GPW or/and RPW can not only dramatically reduce computational complexity but also have the same PAPR reduction performance. It must be noted that the applied phase factors can be determined in advance based on system parameters, without increasing the computational complexity of the transmitter and receiver.

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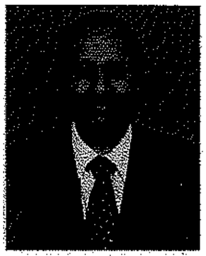

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