Reduction in PAPR of OFDM Signals Using Hybrid Technique

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***Abstract*—A major drawback of orthogonal frequency division multiplexing is the high peak-to-average power ratio of the transmitted signal. PTS and SLM are the well known distortionless PAPR reduction techniques. In this paper, hybrid of these two schemes is done. In SLM different phase rotations are used while in PTS different combinations of phase rotations are used. In the proposed technique, different phase rotations as well as different combinations of these phase rotations are used. Simulation results show that the new scheme can achieve higher PAPR reduction but with increased complexity compared to conventional PTS scheme.**

Keywords-Orthogonal frequency division multiplexing (OFDM), peak-to-average power ratio (PAPR), Partial transmit sequence (PTS), Selected Mapping(SLM) .

I. INTRODUCTION

The advent of 4G wireless systems has created many research opportunities. The expectations from 4G are high in terms of data rates, spectral efficiency, mobility and integration. Orthogonal Frequency Division Multiplexing (OFDM) is proving to be a possible multiple access technology to be used in 4G. But OFDM comes with its own challenges like high Peak to Average Power Ratio, linearity concerns and phase noise. The high PAPR introduces inter modulation distortion and undesired out-of-band radiation due to the nonlinearity of the high power amplifier (HPA). The distortion causes degradation of the bit error rate (BER) and high adjacent channel interference, respectively. Therefore, it is desirable to reduce the PAPR of an OFDM signal.

To date, various schemes attempting to reduce the PAPR have appeared in the literature. The more common schemes include clipping and filtering [1], block coding [2], tone reservation and injection [3], Active constellation Extension(ACE) technique [4], Selected mapping (SLM) scheme[5],[6], and Partial transmit sequence (PTS) schemes[7]–[11]. Of these schemes, the SLM and PTS scheme have been considered the most attractive schemes due to its high PAPR reduction performance without incurring additional signal distortion. This paper proposes a solution to reduce Peak to Average Ratio by using Hybrid technique which is combination of these two techniques. Simulation results show that the proposed PAPR reduction scheme can significantly reduce PAPR over the ordinary PTS scheme. MATLAB was used to generate the code of this technique.

The rest of the paper is organized as follows. Section II describes about PAPR. In Section III, a conventional SLM and PTS schemes are described. A new PAPR reduction scheme is proposed in Section IV. In Section V, simulation results are given in order to compare the PAPR reduction performance of the proposed scheme with the conventional PTS scheme. Finally, we present conclusions in Section VI.

II. PEAK-TO-AVERAGE POWER RATIO

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

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

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

$$\text{PAPR} = \frac{\max_{0\le t<NT} [x(t)]^2}{1/_{NT} \cdot \int_0^{NT} [x(t)]^2 dt} \qquad (2)$$

In principle, PAPR reduction techniques are concerned with reducing max x(t). However, since most systems employ discrete-time signals, the amplitude of samples of x(t) is dealt with in many of the PAPR reduction techniques. Since symbol spaced sampling of

(1) sometimes misses some of the signal peaks and results in optimistic results for the PAPR, signal samples are obtained by oversampling (1) by a factor of L to approximate the true PAPR better. The L -times oversampled time-domain samples are obtained by an LN - point inverse discrete Fourier transform (IDFT) of the data block with zero-padding. It was shown in [12] that L= 4 is sufficient to capture the peaks.

III. CONVENTIONAL SCHEMES

A. Selected Mapping Technique

In the SLM technique, the transmitter generates a set of sufficiently different candidate data blocks, all representing the same information as the original data block, and selects the most favorable for transmission [5, 6]. A block diagram of the SLM technique is shown in figure 1.

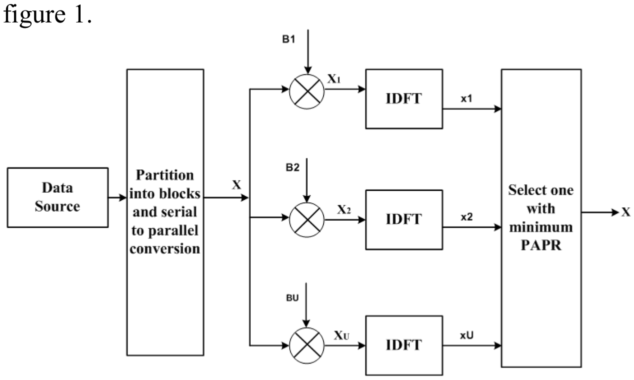

Figure 1. Block diagram of SLM scheme[5].

Each data block is multiplied by U different phase sequences, each of length N, $\mathbf{B}^{(u)} = [b_{u,0}, b_{u,1}, \dots, b_{u,N-1}]^T$, $u = 1, 2, \dots, U$, resulting in U modified data blocks. To include the unmodified data block in the set of modified data blocks, we set $\mathbf{B}^{(1)}$ as the all-one vector of length N. Let us denote the modified data block for the u^{th} phase sequence $\mathbf{X}^{(u)} = [X_0 b_{u,0}, X_1 b_{u,1}, \dots, X_{N-1} b_{u,N-1}]^T$, $u = 1, 2, \dots, U$. After applying SLM to $\mathbf{X}$, the multicarrier signal becomes

$$X^{(u)}(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \; b_{u,n} . e^{j2\pi n \Delta f t} \quad , 0 \le t < NT \qquad (3)$$

Where u = 1,2,…..U.

Among the modified data blocks $\mathbf{X}^{(u)}$, $u = 1, 2, \dots, U$, the one with the lowest PAPR is selected for transmission. Information about the selected phase sequence should be transmitted to the receiver as side information. At the receiver, the reverse operation is performed to recover the original data block. For implementation, the SLM technique needs U IDFT operations, and the number of required side information bits is $\lfloor \log_2 U \rfloor$ for each data block. This approach is applicable with all types of modulation and any number of subcarriers. The amount of PAPR reduction for SLM depends on the number of phase sequences U and the design of the phase sequences.

B. Partial Transmit Sequence Technique

In the PTS technique, an input data block of N symbols is partitioned into disjoint subblocks. The subcarriers in each subblock are weighted by a phase factor for that subblock. The phase factors are selected such that the PAPR of the combined signal is minimized.

Figure 2 shows the block diagram of the PTS technique. In the ordinary PTS technique [7] input data block X is partitioned into M disjoint subblocks $\mathbf{X}_m = [X_{m,0}, X_{m,1}, \dots, X_{m,N-1}]^{\mathrm{T}}$, $m = 1, 2, \dots, M$, such that $\sum_{m=1}^{M} X_m = X$ and the subblocks are combined to minimize the PAPR in the time domain. The L-times oversampled time domain signal of $\mathbf{X}m$, $m = 1, 2, \dots, M$, is denoted as $\mathbf{x}_m = [x_{m,0}, x_{m,1}, \dots, x_{m,NL-1}]^{\mathrm{T}}$. $\mathbf{x}_m$, $m = 1, 2, \dots, M$, is obtained by taking an IDFT of length NL on $\mathbf{X}_m$ concatenated with $(L - 1)N$ zeros. These are called the partial transmit sequences. Complex phase factors, $b_m = e^{j\phi m}$, Where $m = 1, 2, \dots, M$, are introduced to combine the PTS. The set of phase factors is denoted as a vector b = $[b_1, b_2, \dots, b_M]^{\mathrm{T}}$. The time domain signal after combining is given by

$$X'(\mathrm{b}) = \sum_{m=1}^{M} b_m . X_m \qquad (4)$$

Where $\mathbf{x}'(\mathrm{b}) = [x_0'(\mathrm{b}), x_1'(\mathrm{b}). \dots x_{NL-1}'(\mathrm{b})]^T$. The objective is to find the set of phase factors that minimizes the PAPR. Minimization of PAPR is related to the minimization of $\max_{0 \le k \le NL-1} [x'_k(b)]$. In general, the selection of the phase factors is limited to a set with a finite number of elements to reduce the search complexity. The set of allowed phase factors is written as

$$P = \{e^{j2\pi l/W} \mid l = 0, 1, \dots, W-1\} \qquad (5)$$

Where W is the number of allowed phase factors. In addition, we can set $b_1 = 1$ without any loss of performance. So, we should perform an exhaustive search for $(M - 1)$ phase factors. Hence, W^{M-1} sets of phase factors are searched to find the optimum set of phase factors. The search complexity increases with the number of subblocks M. PTS needs M IDFT operations for each datablock, and the number of required side information bits is $\lfloor \log 2 W^{M-1} \rfloor$, where $\lfloor y \rfloor$ denotes the exponentially smallest integer that does not exceed y. The amount of PAPR reduction depends on the number of subblocks M and the number of allowed phase factors W. Another factor that may affect the PAPR reduction performance in PTS is the subblock partitioning, which is the method of division of the subcarriers into multiple disjoint subblocks.

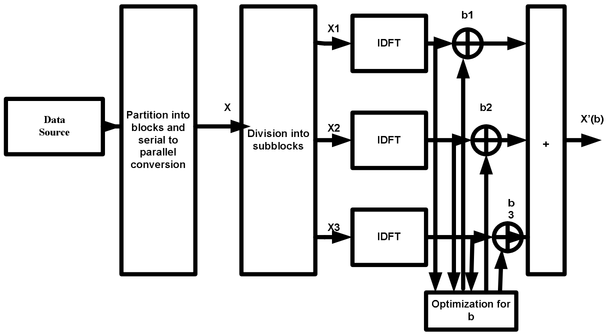

Figure 2. Block diagram of PTS scheme [7].

There are three kinds of subblock partitioning schemes: adjacent, interleaved, and pseudo-random partitioning. Here, we show a simple example of the PTS technique for an OFDM system with eight subcarriers that are divided into four subblocks.

The phase factors are selected in $P = \{\pm 1\}$. Figure 3 shows the adjacent subblock partitioning for a data block **X** of length 8. The original data block **X** has a PAPR of 7.5 dB. There are 8 (= 2^{4-1}) ways to combine the subblocks with fixed $b1 = 1$. Among them $[b1, b2, b3, b4]^T = [1, -1, -1, -1]^T$ achieves the lowest PAPR. The modified data block will be X' = $\sum_{m=1}^{M} b_m . X_m$ = [1, –1, –1, 1, –1, 1, 1, 1]^T whose PAPR is 6.3 dB, resulting in a 1.2 dB reduction. In this case, the number of required IDFT operations is 4 and the amount of side information is 3 bits. The side information must be transmitted to the receiver to recover the original data block. One way to do this is to transmit these side information bits with a separate channel other than the data channel. However this results in a data rate loss.

IV. Hybrid Technique

An ordinary PTS technique uses the binary weighting factors (1,-1). But it uses different combination of these two weighting factors. For Ex: if there are four phase factors then different possible combinations will be $2^4 = 16$. Those are [-1-1-1-1, -1-1-11, -1-11-1, -1-111, -11-1-1, -11-11, -111-1, -1111, 1-1-1-1, 1-1-11, 1-11-1, 1-111, 11-1-1, 11-11, 111-1, 1111]. PTS technique selects the one among all these combinations which gives minimum PAPR. While ordinary SLM technique uses different phase rotations. It multiplies same data block with different phase rotations and selects the one which is having minimum PAPR. In the proposed technique we use different phase rotations as well as different possible combinations of these phase rotations. So for four phase factors now we have 256 different combinations instead of 16 and if we take 8 phase factors we have 4096 possible combinations instead of 256. So this technique provides us a wide choice of different combinations for selecting the one which is having minimum PAPR. But here careful selection of phase change is important. If we take random values of phase shift we did not get the desired reduction in PAPR. Here set of phase factors remains same. Also there is no increase in number of IFFT blocks. But this method gives significant PAPR reduction compare to ordinary PTS technique, as the number of possible combinations for choosing the best combination for phase factors are increased. This results in increased search complexity and also in simulation time.

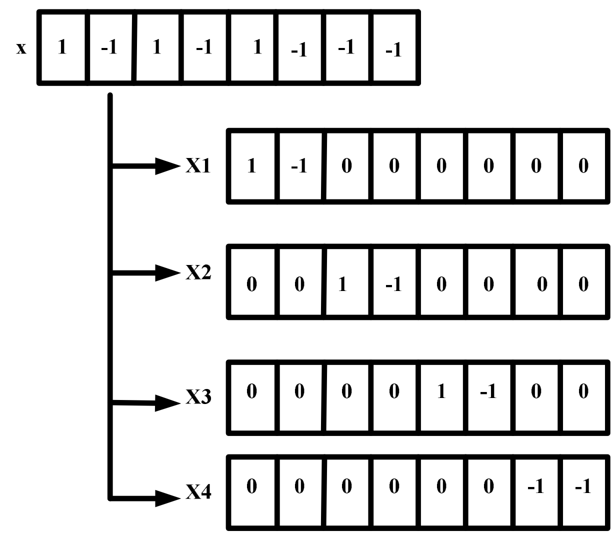

Figure 3. An example of adjacent subblock partitioning in PTS

V. Simulation Results

In this section, we have simulated Hybrid technique using MATLAB code for various phase factors and compare the result with conventional PTS scheme. Here we used QPSK modulation system. Also we have observed the effect on various parameters by increasing the number of phase shifts. Thus to summarize, various parameters are described in the table I.

Figure 4 Shows the effect on PAPR reduction when weighting factors are increased from 2 to 4 by keeping phase factors 4. Here combinations of phase factors are increased from 16 to 256. It is observed that PAPR is 8.64 dB using Hybrid scheme and 9.9 dB using conventional PTS scheme. Thus the improvement in PAPR reduction is 1.26 dB. Figure 5 shows that when we increase the no. phase shifts more we get more PAPR reduction. Here we kept weighting factors 8 for 8 phase factors. Thus possible combinations of phase factors are increased from 256 to 4096 and we get 2.25dB more PAPR reduction compare to ordinary PTS scheme. Figure 6 shows that careful selection of phase change is important. If we take random values of phase shift we did not get the desired reduction in PAPR.

TABLE I. PERFORMANCE ANALYSIS OF TWO TECHNIQUES

PAPR Reduction Technique	PTS	Modified PTS	PTS	Modified PTS
Phase factors	4		8	
Weighting factors	2	4	2	8
No. of Iterations	16	256	256	4096
Simulation Time In Minutes	0.5	1.5	3	30
PAPR in dB	9.9	8.64	8.99	6.74
Difference in PAPR	1.26		2.25	

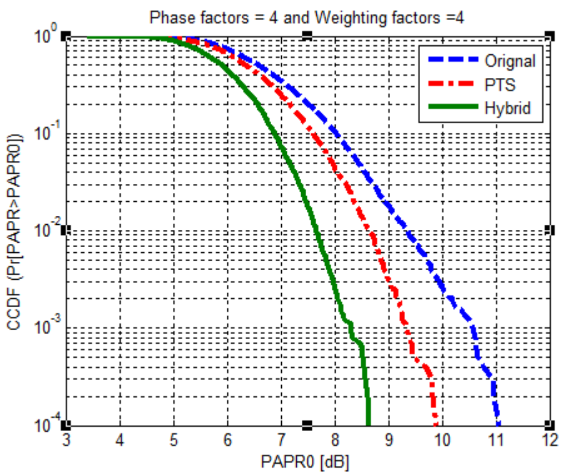

Figure 4. Comparison of two schemes for phase factors 4.

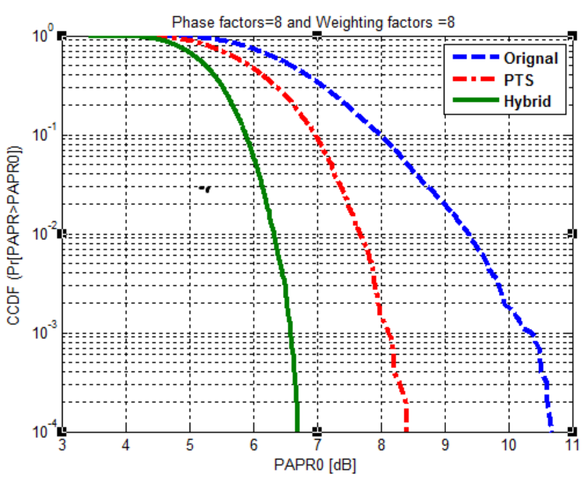

Figure 5. Comparison of two schemes for phase factor 8.

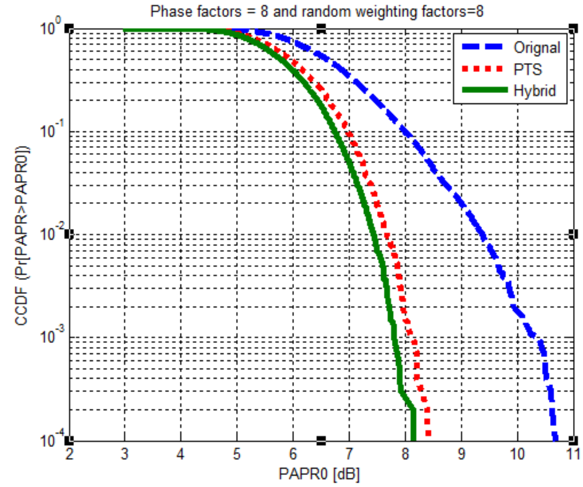

Figure 6. Comparison of two schemes for random weighting factors.

VI. CONCLUSION AND FUTUREWORK

The results presented in this paper for Hybrid scheme shows that there is improvement in PAPR reduction as compared to ordinary PTS technique. The effect of increasing phase shift is observed on various parameters and it is found that with the increase in phase shift PAPR reduction increases at the cost of increase in search complexity. Also the careful selection of phase shift is necessary. Here in this paper QPSK is used, but in future this can also be performed with MPSK.

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