PAPR Reduction by PTS & SLM Techniques Using M-2-M Mapping

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Abstract - Orthogonal Frequency Division Multiplexing (OFDM) is most commonly preferred in digital communication for high data rate transmission. OFDM system has a main shortcoming of high peak to average power ratio (PAPR) value [1]. As survey and studied in literatures PTS and SLM are the most suitable methods to overcome the problem of high PAPR. . Major limitation of this scheme is PAPR. In this paper, new algorithms are proposed by mapping of phase rotation factor, by the mapping of M-ary data points to the 2M constellation points of 2M-ary modulation scheme using two phase rotation factors (1, j), and hence it is known as “M-2M Mapping” scheme.With this property, the proposedalgorithms can reduce half of the computational complexity compared with the conventional algorithms. Simulations results demonstrate thatthe proposed algorithmcan provide significantcomputational complexity reductionwith good performance.

Keywords—Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), M-2M Mapping, Selected Mapping (SLM), Partial Transmit Sequences (PTS).

I. INTRODUCTION

OFDM (Orthogonal Frequency Division Multiplexing) is now a days widely used for wireless applications since it provides high data rate and also improvesthe spectral efficiency [1]. OFDM is a multicarrier digital communication technique in which the all available bandwidth is divided into many small streams of low data rate and then they are modulated with various different sub-carriers. One of the main shortcoming of OFDM is high PAPR (peak to average power ratio) [5]. To overcome this problem and to obtain efficient output power, generally the high power amplifier (HPA) is set to near the saturation region. The high PAPR mainly causes nonlinearity in the amplifier behavior. Due to this it works in the linear portion with large head-room and this tends to very inefficient amplification. So, it is customary to reduce the PAPR for making the system with less losses. The detailed analysis is given in the next sections.

OFDM signal generated by an N point Inverse Fast Fourier Transform (IFFT) in the transmitter, and the Fast Fourier Transform (FFT) can beused at the receiver to reform the signal. Now if the input complex-valued data of N subcarriers as: $X_N = X_K, K = 0,1,2 \ldots\ldots N-1$ is used to form with each of the symbol modulating the corresponding subcarrier from a set of opted orthogonal set, the discrete-time OFDM symbol can be written as:

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

Where; X_K is the symbol carried by the K^{th}sub-carrier, L is the oversampling factor. An OFDM signal contains an “N” number of independently modulated subcarriers,which can be given a very large PAPR when added up coherently.

Further, one can also define PAPR for continuous time and discrete-time signals [6]. For a continuous-time OFDM signal, it can be definedat an instant as the ratio of the maximum power to the average power as:

$$PAPR\,[s(t)] = \frac{t \in \max_{[0,T_s]} |s(t)|^2}{E\{|s(t)|^2\}}$$

Where s (t) is the time-continuous type OFDM signal & in case of a discrete-time type signal, sampling is generally placed at a rate of Nyquist-rate to estimate true PAPR. But these samples which are taken here need not to becompulsorily overlapped with the time-continuous signal’s peaks. To accurately estimate of PAPR, one need to perform oversampling of given OFDM signal. PAPR with oversampling factor L is given as [6];

$$PAPR[oversampling] = \max_{k \in [0,NL]} \frac{|x(k/L)|^2}{E\{|x(k/L)|^2\}}$$

Where,E [.] denotes the expected value, basically shows average power of the signal and x (k/L) are samples of the OFDM signal with oversampling and defined as:

$$x[k/L] = \sum_{n=0}^{N-1} s_n e^{i2\pi kn/N}$$

Where k=0, 1,……, LN-1. For the value L=1, the samples are called Nyquist-rate samples. PAPR with rate of Nyquist-rate sampling is:

$$PAPR[Nyquist - sampling] = \max_{k \in [0,NL]} \frac{|x(k/l)|^2}{E\{|x(l)|^2\}}$$

The rest of this paper is presented as follows. In Section II illustration of various PAPR reduction techniques. In Section III theoretically comparison of different PAPR reduction techniques including the advantages and disadvantages of these techniques are given. The next part concludes and give the briefs about the future possibilities to this work for implementations.

Statistically it can be possible to characterize the PAPR using Complementary Cumulative Distribution Function (CCDF). CCDF is a most common type of way to evaluate the PAPR by estimating the probability of PAPR, when this exceeds a particular level. The CCDF equation of the PAPR of OFDM signals with small subcarriers is written as:

$$CCDF = P(PAPR > PAPR_0) = 1 - (1 - exp(PAPR_0))^N$$

This equation is interpreted as the probability that thePAPR of a block symbol exceeds some threshold level$PAPR_O$.

PAPR is a measure of the envelope variations of a multicarrier signal and is used as FOM or figure of merit. Since OFDM signal consists of a number of independent modulated symbols, the sum of independently modulated subcarriers may have large amplitude fluctuations which causes in a large PAPR.

II. EFFECTS OF PAPR

As PAPR increases it results in the following effects [21]:

• Large dynamic range of the D/A and A/D converters will be required; if it is not increased then the peak values could be clipped, results in signal distortion.

• If A/D and D/A converters with large working ranges are taken, quantization noise will also increase and performance will degrade.

• Furthermore, the selection of power amplifier and up-converters will also be crucial when PAPR problem occurs. The working range of Power amplifier & up converters is required, so that the nonlinear distortion would not be introduced which results in decreasing the power efficiency of Power amplifier.

III. PAPR REDUCTION TECHNIQUES

PAPR reduction techniques can be mainly divided into two types. These are signal scrambling techniques and signal distortion techniques [24].

The signal scrambling techniques are classified as:

- Block Coding Techniques
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

The Signal Distortion Techniques are classified as:

- Peak Windowing
- Envelope Scaling
- Clipping

IV. PROPOSED PAPR REDUCTION TECHNIQUES

It has been in literature that PTS and SLM are the two better techniques, which can be used for reduction of high PAPR. Since in most of the literature they are used for getting good results, also without affecting the other parameters. In this paper we are proposing a new method for both PTS and SLM, by the introduction of a new mapping scheme, which do not requires SI information.

In this paper we are proposing a new mapping scheme for PTS as well as SLM which basically maps M-ary data points to the 2M constellation points of 2M-ary modulation scheme using two phase rotation factors (1, j), and hence it is known as "M-2M Mapping" scheme. Mainly we have made changes in the S/P & P/S conversion blocks. The proposed mapping scheme completely eliminates the requirement of SI, like MPSM-PTS [28].

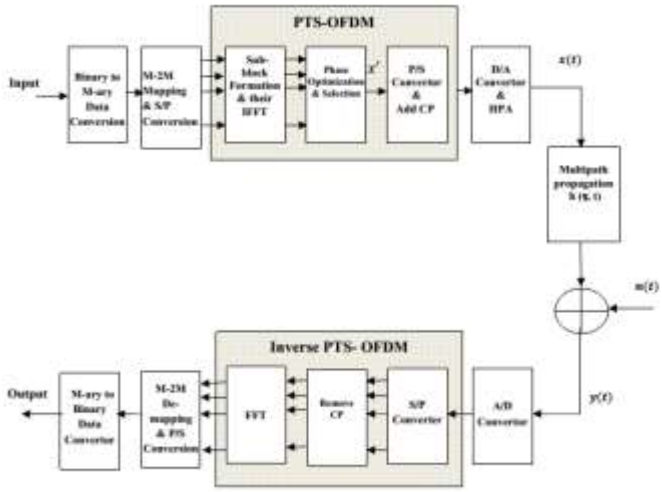

Fig. 1: Proposed system model for PTS-OFDM

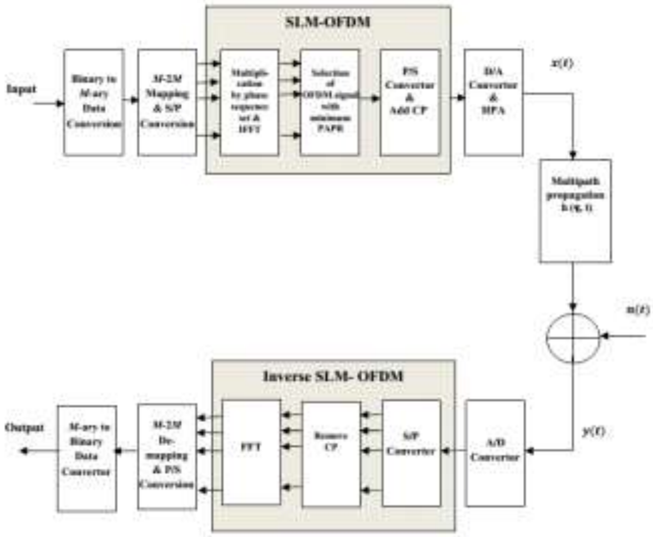

Fig. 2: Proposed system model for SLM-OFDM

Selective Mapping

It is natural to apply SLM to each of the M antennas in MIMO-OFDM individually, a procedure called individual SLM (ISLM). For each of the parallel OFDM frames the optimum phase modification out of the possible (not necessarily the same for the parallel systems) is individually selected. Now, MV IFFT operations and Mlog2 V bits of side information are required. Since the worst PAPR does not exceed the threshold if all individual PAPR stay below the threshold, and the individual PAPR are distributed according to (5), we can obtain equation as:

$$\Pr(PAPR > PAPR_0) = 1 - (1 - (1 - (1 - e^{-PAPR_0})^N)^V)^M$$

Partial Transmit Sequence

In the ordinary PTS algorithm for OFDM system, the input symbol sequence X is partitioned into D disjoint symbol subsequences, therefore;

$$X = \sum_{d=0}^{D-1} X^{(d)}$$

Then, the sub-blocks X(d) are transformed into D time-domain partial transmit sequences by IFFT operations. These partial sequences are independently rotated by phase factor sequences;

$$q^{(d)} = [b_0^{(d)}, b_1^{(d)}, \ldots, b_{N-1}^{(d)}] \ldots (1 \le d \le D) \quad \&$$

$$b_N^{(d)} \in \left\{ e^{\frac{j2\pi k}{W}\ at\ k=0,1,\ldots,W-1} \right\},$$

Where; W is the number of allowed phase factors. Hence, W^{D-1} sets of phase factors are searched to find the optimum set of phase factors. The search complexity increases exponentially with the number of sub-blocks D. Next the PAPR is computed for each resulting sequence and then the signal sequence with the minimum PAPR is transmitted. This phase rotation factor is altered in our scheme mapping of M-ary data points to the 2M constellation points of 2M-ary modulation scheme using two phase rotation factors (1, j), and hence it is known as "M-2M Mapping" scheme.

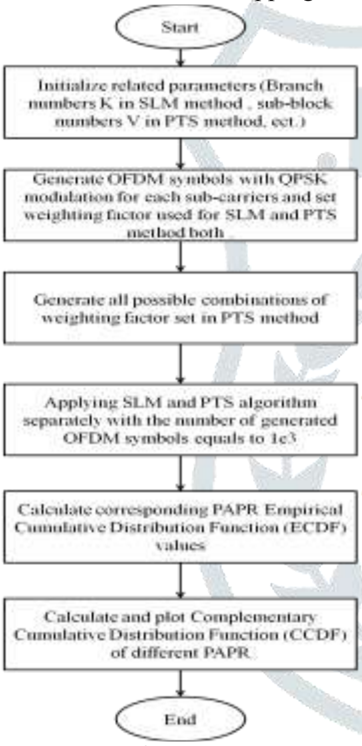

Figure 3: Comparison of PAPR reduction performances between SLM and PTS method.

V. SIMULATION RESULTS

In this we have simulated PTS and SLM system model for the 1, 00, 00 OFDM symbols out of 1, 00,000 in accordance with our proposed M-2M mapping schemes.

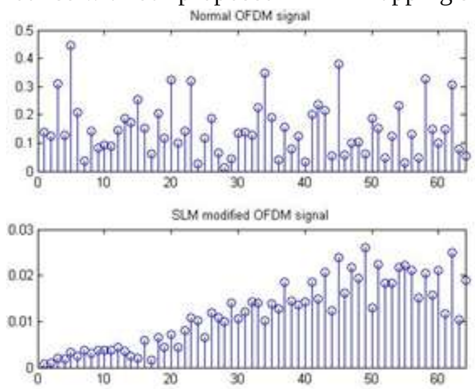

Figure 4: PAPR comparison of Proposed SLM with original OFDM

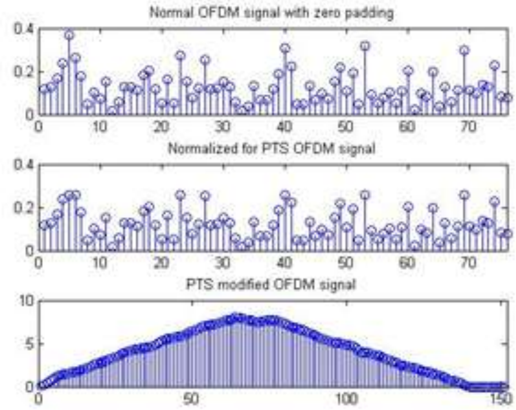

Figure 5: PAPR comparison of Proposed PTS with Original OFDM

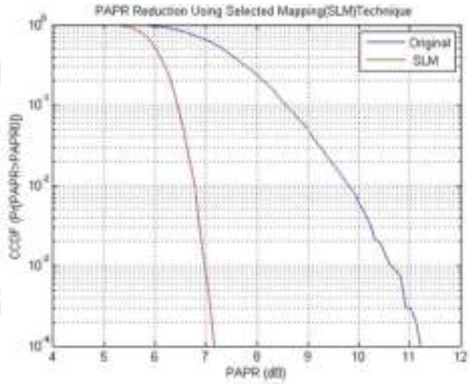

Figure 6: PAPR vs CCDF using Proposed SLM technique

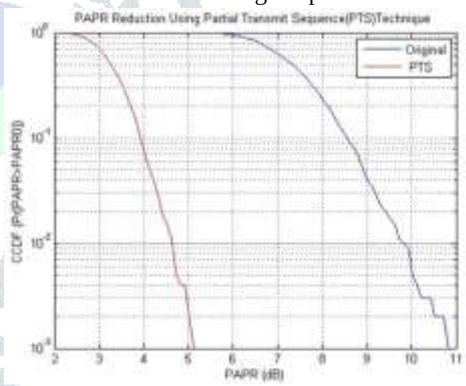

Figure 7: PAPR vs CCDF using Proposed PTS technique

SIMULATION RESULTS SUMMARY

PAPR of normal OFDM= 17.9218

PAPR of SLM modified OFDM= 7.2089

PAPR after PTS modified OFDM= 5.27401

Hence, PTS technique provides 26.8 % more reduction in PAPR than SLM.

VI. CONCLUSION

OFDM is the efficient modulation technique for multi-carrier transmission and high data rate transmission and it is also spectrally efficient. Majorlimitation of this scheme isPAPR. In this paper, new algorithms are proposed by mapping of phase rotation factor, by the mapping of M-ary data points to the 2M constellation points of 2M-ary modulation scheme using two phase rotation factors (1, j), and hence it is known as "M-2M Mapping" scheme.With this property, the proposedalgorithms can reduce half of the computationalcomplexity compared with the conventionalalgorithms. Simulation results demonstrate that the proposed algorithmcan provide significant computational complexity reductionwith good performance. An improvement of 60 % reduction in PAPR for SLM compared to original OFDM & 71% for PTS techniques using proposed scheme.

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