A Threshold Selected Mapping for PAPR Reduction in OFDM System

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Abstract— **Orthogonal frequency division multiplexing (OFDM) has become the most popular wireless communication technique due to its high speed data transmission. However, high peak to average power ratio (PAPR) is a major drawback of this technique. In fact, high PAPR is one of the most detrimental aspects in OFDM system, as it decreases the efficiency of power amplifier at transmitter. This paper discusses two PAPR reduction schemes, conventional selected mapping (SLM) scheme and a new threshold selected mapping (TSLM) to obtain PAPR reduction performance in OFDM system. In SLM scheme independent phase sequences are combined with the data for generating alternative signals as candidates and then select the one with the lowest PAPR for actual transmission, so as to reduce PAPR. In new TSLM scheme phase sequences are compared till threshold level. After this threshold level phase mapping is not useful for reducing PAPR. Simulation result shows that TSLM technique is a promising PAPR reduction technique for OFDM system and also observed that increasing the number of phase sequences, large PAPR reduction can be obtained.**

Keywords— **Orthogonal Frequency Division Multiplexing (OFDM), Peak To Average Power Ratio (PAPR), Selected Mapping (SLM), Threshold Selected Mapping (TSLM), Complementary Cumulative Distribution Function (CCDF).**

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is widely popular an attractive scheme for wireless communication due to its high-data-rate transmission [1]. OFDM systems can be easily implemented by employing the IFFT (Inverse Fast Fourier Transform) and FFT (Fast Fourier Transform) process in digital domain [4]. Over the last decade OFDM system has become popular in wireless communication due to its high spectral efficiency, robustness and easy implementation, but it also has some limitations such as the large variation in envelope of OFDM signal, which causes high Peak-to-Average- Power-Ratio (PAPR) [3]. When N signals are added with the same phase, they produce a peak power that is N times the average power which increased the complexity of the analogue to digital (A/D) and digital to analogue (D/A) converters, and reduced the efficiency of high-power amplifier (HPA). When OFDM signals with high PAPR are transmitted through a nonlinear device, such as HPA, a high peak signal generates out-of-band energy and in-band distortion. These degradations would seriously affect the performance of OFDM system [2]. A number of approaches have been proposed to deal with PAPR problem of OFDM system for improving its performance. These techniques include clipping and filtering, selected mapping, partial transmit sequence, tone reservation and tone insertion. These techniques can reduce PAPR of OFDM system but not be considered as sufficient. Therefore a new technique TSLM is carried out for efficient PAPR reduction in OFDM system. New TSLM scheme shows the effective and better PAPR reduction performance.

The paper is organized as follows: Section II introduces the briefly description of OFDM system and PAPR issue of OFDM system. Section III introduces the brief description about mapping. Section IV shows the basic SLM scheme for PAPR reduction. Section V shows the new TSLM scheme. Section VI shows the comparative simulations of PAPR reduction performance and section VII concludes this paper.

II. OFDM PAPR DESCRIPTION

Fig 1 shows the block diagram of an OFDM system [5]. In an OFDM system, the input data sequence is baseband modulated, using a digital modulation scheme such as BPSK, QPSK or QAM than converts the input data from a serial stream to parallel sets. Inverse Fast Fourier Transform (IFFT) is used to convert the frequency domain data set into samples of the corresponding time domain data. IFFT is useful for OFDM system because it generates samples of a waveform with orthogonal frequency components, then the parallel to serial block creates the OFDM signal by sequentially outputting the time domain samples. Digital to analogue converter and High-power amplifier (HPA) are applied to amplify the incoming data and then transmit it by radio channel. The receiver performs the inverse of the transmitter. First, the incoming analogue signals are converted into digital domain by the use of analogue to digital convert, then serial to parallel block converts a serial stream into parallel sets after that Fast Fourier Transform (FFT) is used to convert the time domain samples back into a frequency domain representation. Finally, the parallel to serial block converts this parallel data into a serial stream after that demodulation technique is applied to recover the original input data.

Let N denote the number of subcarriers used for parallel information transmission and let $X(k)$ $(0 \leq k \leq N-1)$ indicate the k^{th} complex modulated symbol in a block of N information symbols. The outputs of N-point Inverse Fast Fourier Transform of $X(k)$ are *denoted by* x_n and can be represented as

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) \ \exp\left(\frac{j.2\pi kn}{N}\right) \qquad (1)$$

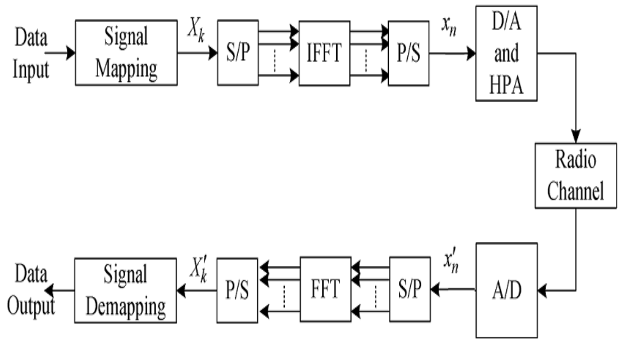

Fig. 1 Block Diagram of OFDM

The PAPR of discrete-time OFDM is defined as [6],

$$\mathrm{PAPR_s}(x_n) = 10.\log_{10} \frac{Max\ \{|xn|^2\}}{E[|xn|^2]} \,(\mathrm{dB}) \qquad (2)$$

Suppose that the input information symbols are statistically independent and identically distributed (i.i.d.). By the central limit theorem, as N increases ($N \geq 64$), the real and imaginary parts of x_n become i.i.d. Gaussian random variables with zero mean and variance σ^2 and the phase of the signal is uniform. The peak value of the signal that has Rayleigh distribution will exceed any values with nonzero probability. Thus the probability of the PAPR of the discrete signal exceeds a threshold z_0 is given by

$$\Pr(\mathrm{PAPR_s} \geq z_0) = 1 - (1 - \exp(-z_0))^N \qquad (3)$$

III. MAPPING

Mapping is the representations of information using spatial relationships of the data. In communication field mapping is a technique that conveys data by changing the phase of a given signal. In Mapping finite numbers of phases were used, each phase assigned by a unique pattern of binary digits such as QPSK uses four points on the constellation diagram, equal spaced around a circle. With four phases, QPSK can encode two bits per symbol. In this paper selected mapping technique were used. In selected mapping technique a selected phase rotation were used for the data representation.

IV. SELECTED MAPPING (SLM)

The Selected Mapping (SLM) technique is the most promising PAPR reduction technique of OFDM system. The first SLM scheme was introduced by Bauml, Fischer and Huber in 1996 [7].The basic idea of this technique is based on the phase rotation. The lowest PAPR signal will be selected for transmission from a number of different data blocks (independent phase sequences) that have the same information at the transmitter. Fig 2 shows a block diagram of SLM scheme [8]. U candidate sequence $x^{(u)} = [x_0^{(u)} + x_1^{(u)}, \ldots\ldots, x_{N-1}^{(u)}]^T$ of length N (u = 0, 1…, U-1) are generated by multiplying original input data X $[X_0, X_1, \ldots, X_{N-1}]^T$ component-wise with predetermined independent phase sequences $P^{(u)} = [P_0^{(u)}, P_1^{(u)}, \ldots\ldots, P_{N-1}^{(u)}]^T$ (u =0,1, U-1), Both the input data and phase sequences have the same length N (u = 0, 1…, U-1). Then IFFT is applied to each sequence, transforming the signal from frequency domain to time domain. As a result, the candidate sequence is given by

$$x^{(u)} = \mathrm{IFFT}\{X \otimes P^{(u)}\} \qquad (4)$$

in which $\otimes$ denote a component-wise multiplication. The last step is comparing the PAPR among the U candidate sequences $x^{(u)}$, the optimal mapped one $\hat{\mathbf{x}}$ with the lowest PAPR will be selected for transmission. That is,

$$\hat{\mathbf{x}} = \arg\min_{0 \leq u \leq U-1} [PAPR(x^{(u)})] \qquad (5)$$

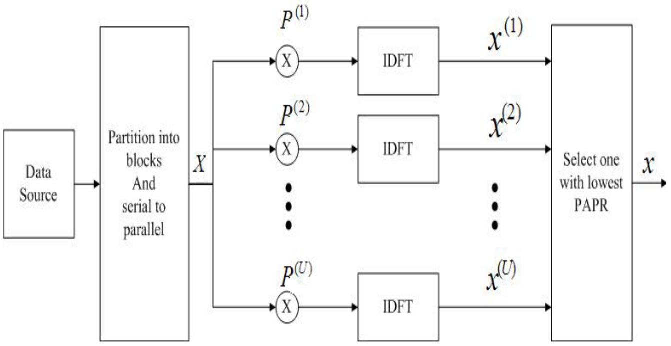

Fig. 2 Block Diagram of SLM

V. THRESHOLD SELECTED MAPPING (TSLM)

The threshold selected mapping (TSLM) is extended version of selected mapping (SLM). In TSLM the comparison of phase sequence till threshold level. After this threshold level phase mapping is not useful for reducing PAPR. The idea of thresholding the PAPR of a SLM system was first mentioned in [10]. From eq. (1), Let us assume that the average power of x_n is equal to 1, and Z_N is the independently and identically distributed (i.i.d) Rayleigh random variables. The probability density function of Z_N is given by [9],

$$f_{z_n}(Z) = 2Z \exp(^{-}z_0) \qquad (6)$$

Where, u = 0, 1, 2……., N-1

The maximum value of Z_N is equivalent to PAPR. If $Z_{max} = \max_{n = 0,1,\ldots\ldots N-1} Z_N$ then the cumulative distribution function (CDF) of Z_{max} and the probability of peak to average power ratio (PAPR) below threshold are given by [9],

$$\begin{aligned} F_{Z_{max}}(z_0) &= \Pr(Z_{max} < z_0) \\ &= \Pr(Z_0 < z_0).\ \Pr(Z_1 < z_0)\ldots\ldots..\ \Pr(Z_{N-1} < z_0) \\ \Pr(\mathrm{PAPR_s} \leq z_0) &= F_{Z_{max}}(z_0)^N = (1 - \exp(-z_0))^N \end{aligned} \qquad (7)$$

The complementary cumulative distribution function (CCDF) is used when PAPR value exceeds the threshold. To find the probability that PAPR of an OFDM signal exceeds the threshold z_0, assume the following complementary cumulative distribution function (CCDF) [9],

$$\begin{aligned} \bar{F}_{Z_{max}}(z) &= \Pr(Z_{max} > z_0) \\ &= 1 - \Pr(Z_{max} \leq z_0) \\ &= 1 - F_{Z_{max}}(z_0) \\ \Pr(\mathrm{PAPR_s} > z_0) &= 1 - (1 - \exp(-z_0))^N \end{aligned} \qquad (8)$$

In TSLM technique each data block will create U times phase sequences, if each mapping considered statistically independent, then CCDF of the Peak to Average Power Ratio (PAPR) in Threshold Selected Mapping (SLM) will be,

$$\Pr(\mathrm{PAPR}_s > z_0) = (1 - (1 - \exp(-z_0))^{N})^{U} \quad (9)$$

Where U is the number of phase sequences, *N* is the number of subcarriers, and $z_0$is threshold.

VI. SIMULATION RESULTS

The system parameters used for simulations are listed in Table I. In order to verify the performance of the SLM and TSLM technique for the reduction of PAPR MATLAB software has to be used. Comparative MATLAB simulation result of performance of PAPR reduction with SLM and TSLM scheme is shown in Fig 3 similar parameters have to be taken to calculate the PAPR for both schemes. The effect of increasing the phase sequences U and number of subcarriers *N* are shown in Fig 4 to Fig 8. Fig 9 shows the PAPR performance of TSLM scheme for the different values of subcarriers *N*. Table IIIII shows the final conclusion of all the simulation results.

TABLE I
SIMULATION PARAMETERS

Simulation Parameters	**Specifications**
Number of OFDM symbols	10000
Number of subcarriers (*N*)	64/128/256/512/1024
Number of phase sequences(U)	2/4/8/16
Modulation scheme	QPSK

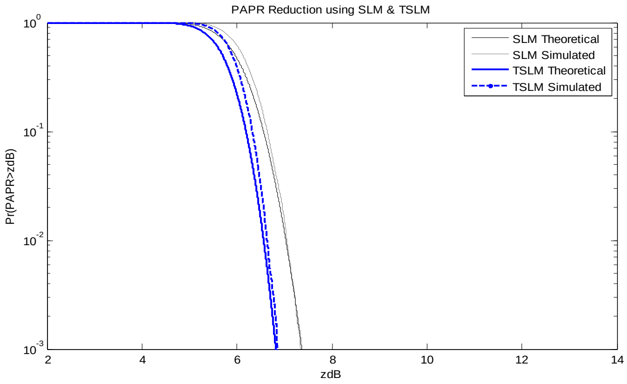

Fig. 3 PAPR CCDF of SLM and TSLM

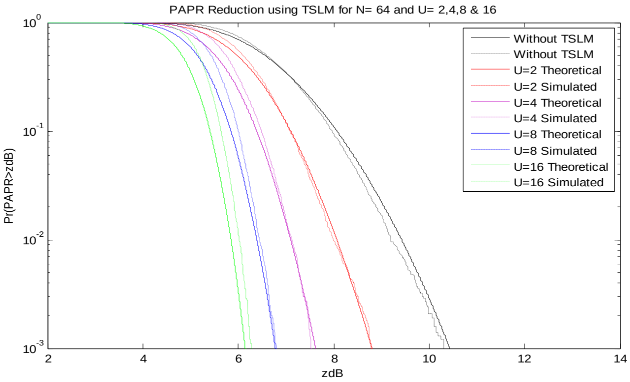

Fig. 4 PAPR CCDF of TSLM for *N* = 64 and U=2,4,8 & 16

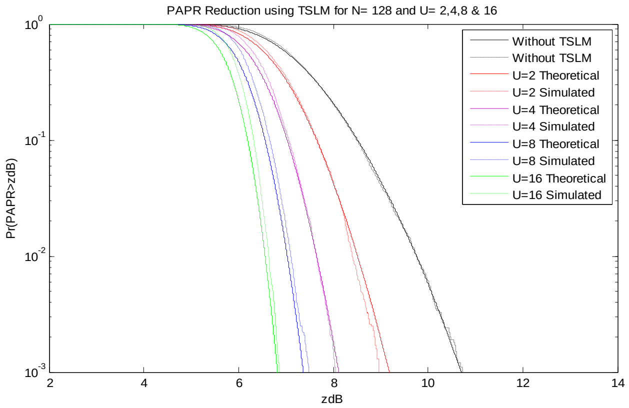

Fig. 5 PAPR CCDF of TSLM for *N* = 128 and U=2,4,8 & 16

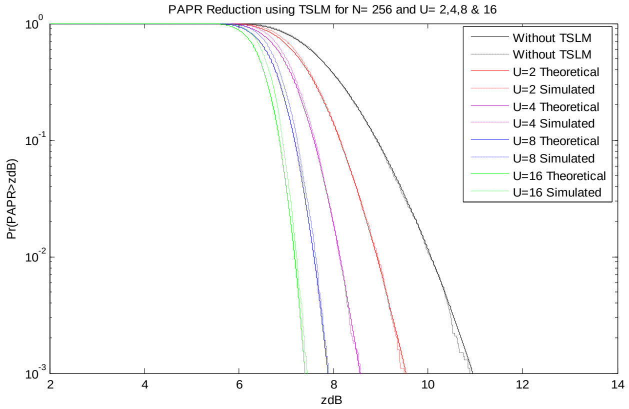

Fig. 6 PAPR CCDF of TSLM for *N* = 256 and U=2,4,8 & 16

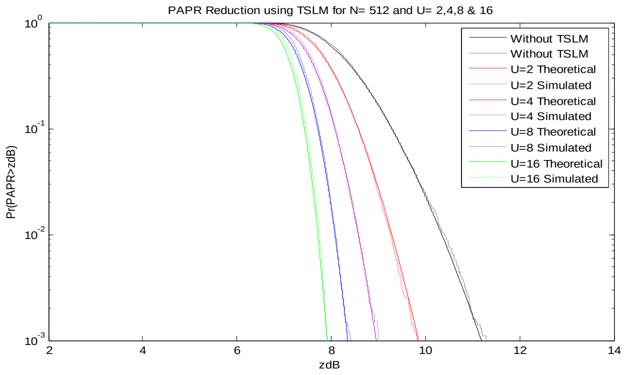

Fig. 7 PAPR CCDF of TSLM for *N* = 512 and U=2,4,8 & 16

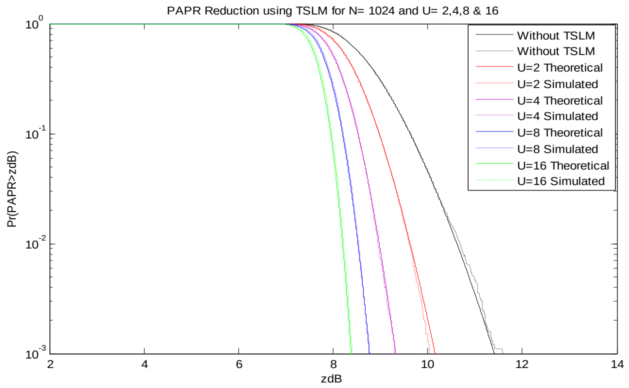

Fig. 8 PAPR CCDF of TSLM for *N* = 1024 and U=2,4,8 & 16

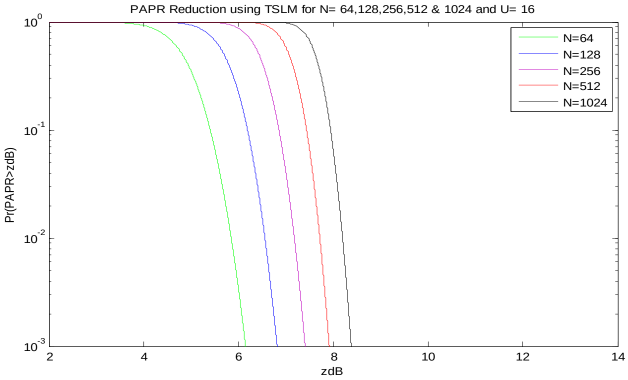

Fig. 9 PAPR CCDF of TSLM for N =64,128,256,512 & 1024 and U=16

TABLE II
PAPR AT 10^{-3} DB

PAPR (10^{-3} DB)					
	N = 64	N = 128	N = 256	N = 512	N = 1024
Without TSLM	10.4	10.7	11.0	11.2	11.4
U=2	8.7	9.1	9.5	9.9	10.2
U=4	7.5	8.1	8.5	9.0	9.3
U=8	6.8	7.3	7.9	8.3	8.6
U=16	**6.2**	6.9	7.4	7.9	8.4

Table II shows the PAPR Reduction at 10^{-3} dB corresponding to various phase sequences (U) for different number of subcarriers (N). As we can see from the table 2, best PAPR reduction can be obtained by setting the parameters, N = 64 and U=16.

VII. CONCLUSION

In this paper, we introduce a SLM and new TSLM technique for PAPR reduction for OFDM transmission. After the simulation result it is observed that TSLM technique provides better PAPR reduction performance as compared to SLM technique. It also concluded that increasing the number of phase sequences, large PAPR reduction can be obtained and as we increase the number of subcarriers PAPR also increased. For more efficient PAPR reduction, number of phase sequences should be large and number of subcarriers should be small.

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