Analysis of PAPR Reduction in Alternative OFDM using Conventional SLM and Class-III SLM Methods

[1] C.Kumar, [2] A.manimegalai, [3]B.Renuka

[1] Assistant Professor, [2]Professor, [3]PG Student

[1]Department of ECE, [1]Ganadhipathy Tulsi's Jain Engineering College, Vellore, India.

***Abstract* - In several wireless communication systems and standards, Orthogonal Frequency Division Multiplexing (OFDM) is used widely due to its high spectral efficiency, high data rate, multipath delay spread tolerance, power efficiency, robustness to multipath fading channels and immunity to the frequency selective fading channels. However, the main challenge for OFDM system implementation is high PAPR, which results from large envelope fluctuation in OFDM signals. In this paper, we present an analysis of PAPR reduction using class III SLM and conventional SLM methods for 4G wireless networks. Simulation results shows that class III SLM method provides a better PAPR reduction than conventional SLM method especially at high data rates.**

***Index Terms* - Class-III selected mapping (SLM), Orthogonal frequency division multiplexing (OFDM), Peak-to average power ratio (PAPR), Conventional selected mapping.**

I. INTRODUCTION

The high speed wireless applications are in high demand, increasing day by day. Only low rate data services are available for mobile applications at present. However, there is a demand for high data rates for multimedia applications. OFDM is a unique form of multicarrier modulation scheme, which divides the whole frequency selective fading channel into various orthogonal narrowband flat-fading sub channels, in which high-bit-rate data stream is transmitted in parallel over a number of lower data rate subcarrier.

A main problem associated with OFDM is its large peak to-average power-ratio (PAPR) that makes system functioning more sensitive to distortion introduced from nonlinear devices such as power amplifiers (PAs). In an attempt to decrease the nonlinear distortion caused by the PAs, numerous techniques have been proposed that can reduce the PAPR of the OFDM signal earlier it enters a PA.

When OFDM signals with large PAPR pass through nonlinear high power amplifier, they experience in-band distortion & out-of-band radiation. OFDM signals with their high peak-to-average power ratios (PAPRs) require high linear amplifiers. Otherwise, performance degradation happens and out-of-band power requirement will be improved.

The OFDM receiver's detection efficiency is more sensitive to the nonlinear devices used in its signal processing loop, such as Digital-to-Analog Converter (DAC) & High Power Amplifier (HPA), which may severely impair system performance because of, induced spectral re-growth & detection efficiency degradation. most radio systems employ the HPA in the transmitter to obtain enough transmits power and the HPA is usually operated at or near the saturation region to achieve the highest output power efficiency, thus the memory-less nonlinear distortion due to high PAPR of the input signals can be introduced into the communication channels. When the HPA is not operated in linear region with large power back-off, it is not possible to keep the out-of-band power less than the specified limits. This situation leads to very inefficient amplification and costly transmitters [8]. Therefore, it is important and necessary to reduce PAPR in order to make use of the technical features of the OFDM.

Many PAPR reduction techniques are proposed for OFDM systems such as clipping, tone reservation, peak windowing, filtering, selected mapping (SLM) [4], constellation shaping, partial transmit sequence (PTS) [7], and adaptive all-pass filters [8]. Among these methods, the SLM method is an attractive and efficient technique, since it can achieve fine PAPR reduction without signal distortion. Recently, a Low-complexity SLM scheme, called Class-III SLM method , was proposed, which provides a better PAPR reduction compared to conventional SLM method[9]. Thus in this paper, analysis of PAPR reduction using class III SLM scheme and conventional SLM scheme is made.

The rest of this paper is ordered as follows. We briefly describe the Conventional-SLM method in Section III. In Section IV, the class- III SLM method is described in detail. The simulation results are given in Section V, followed by conclusions in Section VI.

II. RELATED WORK

OFDM systems, including clipping, coding, selected mapping, partial transmit sequences and tone reservation (TR). Although the TR method provides the lowest complexity of all distortion less methods so far, it is achieved at the expense of bandwidth efficiency [2]. Traditional SLM schemes have better bandwidth efficiency, but require a bank of inverse fast Fourier transforms (IFFTs) to generate candidate signals, resulting in a dramatic increase in computational complexity. To overcome this drawback, a low-complexity method in which the IFFTs are replaced by conversion vectors obtained by taking the IFFT of the phase rotation vectors is proposed. Unfortunately, for most of the conversion vectors proposed, the elements of the equivalent phase rotation vectors do not have the same magnitude, leading to significant degradation in bit error rate (BER) performance [9]. Three novel low-complexity SLM schemes are proposed in [5], where the IFFT blocks were changed by conversion vectors. We primarily claim that conversion vectors should be specified in the form of perfect sequences. 3 novel classes of perfect sequences are then introduced, each comprising certain base vectors & their cyclically shifted equivalents. These sequences are after utilized as the basis for three low-complexity SLM schemes. Reviews and analysis of different OFDM PAPR reduction techniques, based on computational complexity, bandwidth expansion, spectral spillage and performance are mentioned in [8].

The alternative symbol sequences are also generated by multiplying the data in the binary expression by the binary phase sequences prior to mapping to quadrature amplitude modulation (QAM) symbols [7]. SLM Method does not need to reserve bits for the transmission of side information, ensuing in the increase of the data rate. Its key idea is that different phase rotation sequences are multiplied by their equivalent phase offsets at the transmitter is mentioned in [6]. To decrease the complexity of C-SLM, the real & imaginary parts of the OFDM signals are treated separately. The even and odd sequences of the real & imaginary parts are obtained using the Fourier transform properties is proposed in [10] .

III. OVERVIEW OF CONVENTIONAL SLM METHOD

The total data stream is divided into different blocks of N symbols each. Each block is multiplied with U different phase factors to generate U modified blocks prior giving to IFFT block. Each modified block is given to different IFFT block to produce OFDM symbols. Finally PAPR is calculated for each modified block and select the block which is having minimum PAPR ratio [6]. This technique can reduce PAPR considerably. But this technique will increase circuit complexity since it contains several IFFT calculations [6].

The input data block $X=\{X(K),K=0,1,\ldots N-1\}$ is encoded into two vectors X_1 and X_2,

$$X_1 = [X(0),-X^*(1),\ldots,X(N-2),-X^*(N-1)],$$
$$X_2 = [X(1),X^*(0),\ldots,X(N-1),X^*(N-2)] \quad (1)$$

Where, X(K) is modulated by a given signal constellation ,

N is the number of sub-carriers & $(.)^*$ denotes the complex conjugate operation.

After inverse fast Fourier transform (IFFT) operation, the time domain signal is $x_1=[x_i(0), x_i(1),\ldots, x_i(JN-1)]$

$$x_i(n)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_i(k)\, e^{\frac{j2\pi kn}{jN}} \quad (2)$$

Where, i=1,2,3...and n=0,1,..,JN-1. The oversampling J factor is an integer.

For the P-SLM scheme, U different phase offsets $\{e^{\frac{j2\pi u}{U}}$,u=0,1,…U-1}are generated for the U phase rotation sequences P^u .When these alternative vectors are transformed into time domain signals & via IFFT operation, the optimal signals and with the minimum PAPR are sent to the receiver.

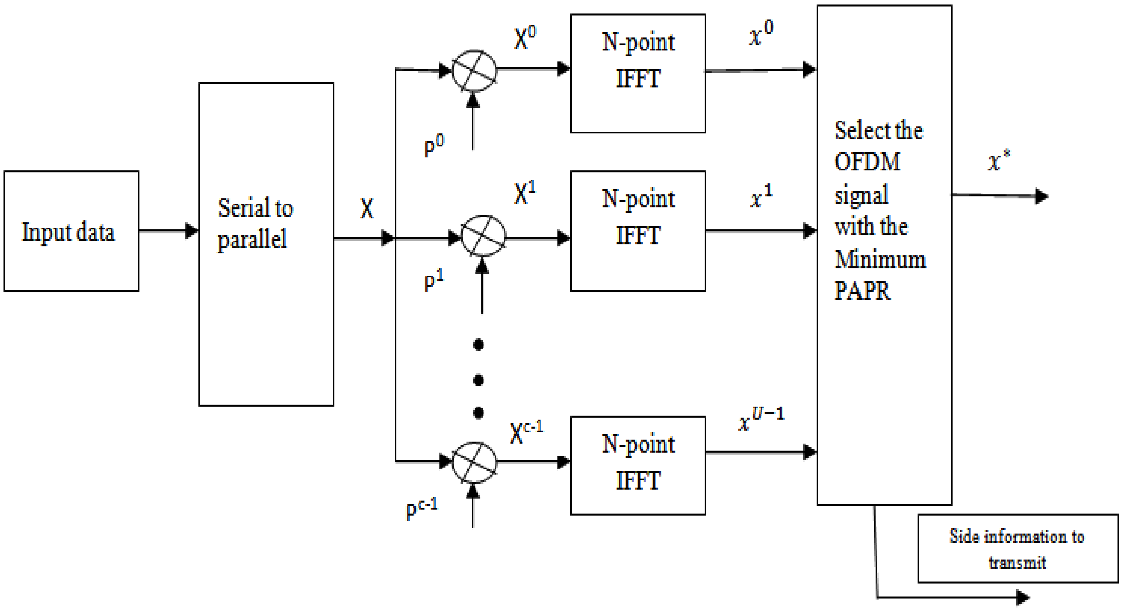

Fig.1. Block diagram of the conventional SLM Method.

IV. OVERVIEW OF CLASS III SLM METHOD

A less-complexity SLM scheme, called Class-III SLM scheme, was proposed, which performs only one inverse fast Fourier transform (IFFT) to produce alternative OFDM signal sequences. By randomly selecting the cyclic shift and rotation values, Class-III SLM scheme can generate up to N^3 alternative OFDM signal sequences, where N is the IFFT size. However, all N^3 alternative OFDM signal sequences do not achieve good PAPR reduction performances. Therefore, an efficient selection method of good rotation & cyclic shift values is needed, which results in good PAPR reduction performance.

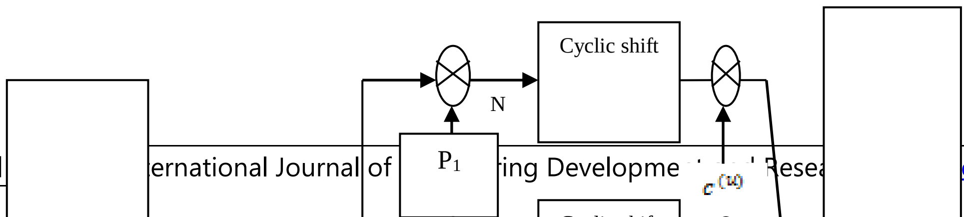

Fig. 2. Block diagram of the Class III-SLM Method

Fig. 2 shows a block diagram of Class-III SLM scheme. It requires only one inverse fast Fourier transform (IFFT) to generate the entire alternative OFDM signal sequences. The input symbol sequence $x=[x_0,x_1,x_2,\cdots,xN]$ to the IFFT module is generally modulated by M-ary phase-shift keying (MPSK) or M-ary quadrature amplitude modulation(M-QAM), where N is the IFFT size & $N\geq 4$. The OFDM signal sequence $X==[x_0, x_1,\ldots, x_{N-1}]$ is obtained by N-point IFFT of X and then, altered by N-point circular convolution (denoted by $\otimes$ N). The i^{th} sequence of four generated sequences is cyclically right shifted by $0\leq\tau_i^{(u)}$ I <N/4 and rotated by multiplying (u) I $\in\{\pm 1,\pm J\}$, where$1\leq i\leq 4$ and u is the index of alternative OFDM signal sequence. Note that without loss of generality, we can set $\tau^{(u)}{}_1=0$and $c^{(u)}{}_1=1$. By summing the resulting four sequences, the u^{th} alternative OFDM signal sequence s(u) are generated and the one with the lowest PAPR is transmitted.

Optimal cyclic shift values selection method for Class-III SLM scheme is done. Also, a good additional alternative OFDM signal sequences selection method by using proper rotation values is done.

The magnitude of the correlation R_{st} (m) between the s^{th} and t^{th} alternative OFDM signal sequences is calculated as

$$|R_{ST}(m)|=\left|E\{x_n{}^{(s)} x_{n+m}{}^{(t)*}\}\right| \quad (3)$$

The phase sequences with low variance of correlation (VC) in SLM scheme give good PAPR reduction performance. VC is defined as

$$VC = \left(\sum_{0\leq s<t\leq U-1} Var\{|R_{st}(m)|^2\}_{m=0}^{N-1}\right)/\binom{U}{2} \quad (4)$$

Where, Var $\{\cdot\}$ denotes the variance. Low VC means that alternative OFDM signal sequences are less correlated. Since the conventional SLM scheme shows fine PAPR reduction performance while alternative OFDM signal sequences are low correlated, VC can be a good criterion for PAPR decrease by Class-III SLM scheme. Based on VC, we derive the optimal condition for cyclic shift values of Class-III SLM.

The maximum number of optimal alternative OFDM signal sequences is n/8. However, it may be necessary to generate more alternative OFDM signal sequences by sacrificing the optimality. For good PAPR reduction performance, Let us consider a case of generating n/4 alternative OFDM signal sequences and n/8 optimal alternative OFDM signal sequences without rotation values can be generated. However, by adjusting the rotation values for these n/8 optimal alternative OFDM signal sequences, good additional n/8 alternative OFDM signal sequences can be generated. Note that the same cyclic shift values in table ii are used for the first n/8 optimal sequences and the second additional n/8 sequences. For example, to generate total n/4 alternative OFDM signal sequences, the rotation values $c(u)_1 = 1$, $c(u)_2 = -1$, $c(u)_3 = j$, and $c(u)_4 = -j$ are multiplied to each of the n/8 optimal alternative OFDM signal sequence cases to generate additional n/8 sequences. Let $c(u)\ i = e^{j\theta}(u)i$, and if we use $\theta(u)\ i = (i - 1)(\pm\pi/2)$ or $(i - 1)\pi$ for the second n/8 alternative OFDM signal sequences, the PAPR reduction performances of the first n/8 and the second n/8 sequences are the same because the second n/8 sequences are just cyclic-shifted version of the first n/8 optimal sequences in time domain. Therefore, to generate good additional alternative OFDM signal sequences, we need to use the rotation values which do not have linear relation as above. Consequently, total 4n/8 good alternative OFDM signal sequences can be generated by multiplying the rotation values $\{c(u)\ 1 , c(u)\ 2 , c(u)\ 3 , c(u)\ 4 \} = \{1, j,-j,-1\}, \{1,-j, j, -1\}, \{1,-1, j,-j\}, \{1,-1,-j, j\}$ to each of the n/8 optimal**.**

V. SIMULATION RESULTS

In this section, simulations results have been given to evaluate the ability of the proposed scheme of PAPR reduction.Figs.2 and 3 shows the complementary cumulative distribution functions (CCDF) of the PAPR obtained by the conventional SLM and Class-III SLM methods.Fig.5 shows the comparative graph plotted between the results obtained from the conventional SLM and Class-III SLM methods.

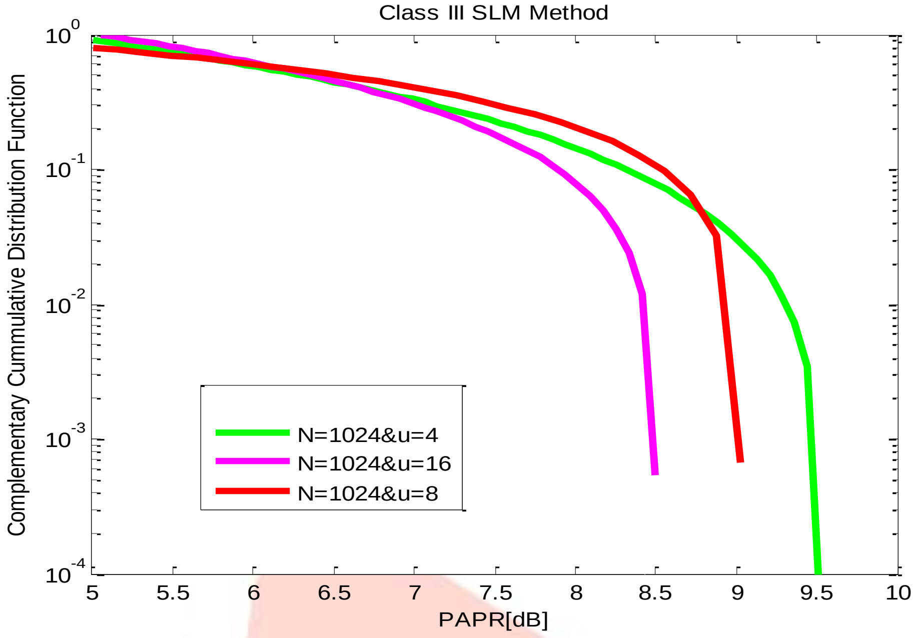

Fig. 3. PAPR's CCDF using Class IIISLM method

Figure 3 shows the CCDF as a function of PAPR distribution when class III SLM method is used with N=1024 numbers of subcarrier and for different number of symbol selection i.e. N=1024 & U=4, 8, 16.

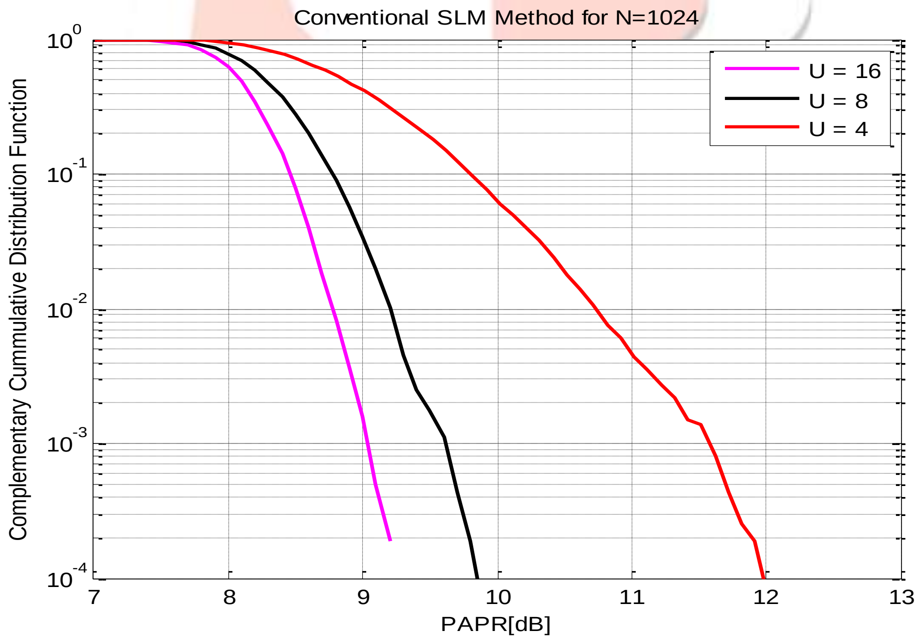

Fig. 4. PAPR's CCDF using Conventional SLM method for N=1024

Figure 4 shows the CCDF as a function of PAPR distribution when Conventional SLM method is used with N=1024 numbers of subcarrier and for different number of symbol selection.i.e.U=4,8,16.

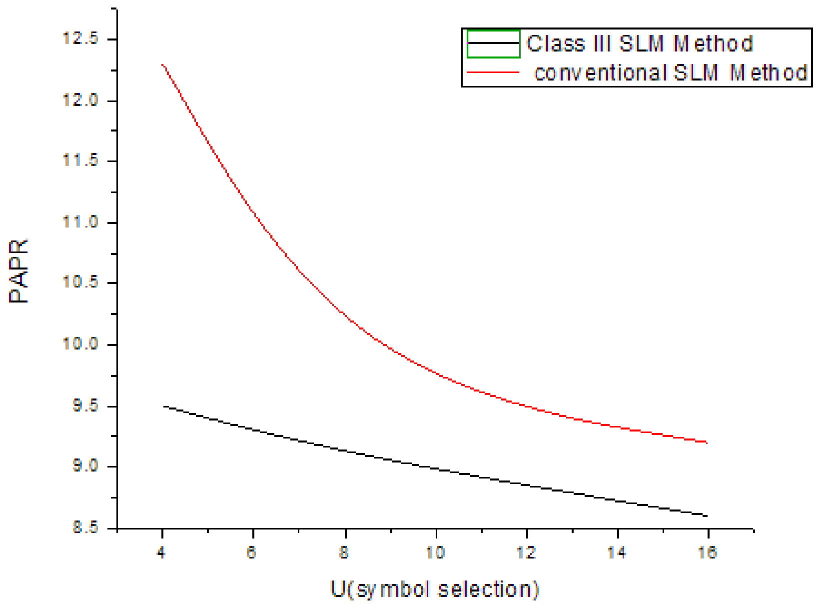

Fig. 5. Comparison Graph using Conventional SLM and Class III SLM Methods for N=1024 with different U values

VI. CONCLUSION

OFDM is a very attractive method for wireless communications due to its spectrum efficiency and channel robustness. One of the serious drawbacks of OFDM systems is that the transmit signal can exhibit a very high PAPR when the input sequences are highly correlated. Simulation results shows that class III SLM method provides a better PAPR reduction than conventional SLM method especially at high data rates. The above comparison graph illustrates us that the PAPR for N=1024 and different symbol selection U = {4, 8, 16} values, that the class III SLM method has optimal reduction in PAPR values especially for high rate dates.

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