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PAPR Reduction Techniques With Conventional Hybrid SLM-PTS Schemes For OFDM Systems

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is considered to be a promising technique for high data rate wireless communications. However, OFDM faces the Peak-to-Average Power Ratio (PAPR) problem that is a major drawback of multicarrier transmission system which leads to power inefficiency of high power amplifier (HPA) and it also demands the large dynamic range digital to analog converter (DAC) at the transmitter. This paper present different PAPR reduction techniques with conventional hybrid SLM-PTS technique and concludes with an overall comparison of these techniques. Simulation shows that the PAPR problem reduced as the route number increases. The PAPR reduction capability of those techniques is demonstrated by presenting simulation results of PAPR.

I. Introduction

In wireless communication systems, the orthogonal frequency division multiplexing (OFDM) technique is a widely popular and attractive scheme for high-data-rate transmission because it can cope with frequency-selective fading channel. The modulators and demodulators of OFDM systems can be simply implemented by employing inverse fast Fourier transform (IFFT) and FFT to make the overall system efficient and effective. Nowadays, it has been adopted as a powerfully potential candidate for next-generation mobile communications systems [3]. In a basic communication system, the data are modulated onto a single carrier frequency. The available bandwidth is then totally occupied by each symbol. This kind of system can lead to inter-symbol-interference (ISI) in case of frequency selective channel [4]. The basic idea of OFDM is to divide the available spectrum into several orthogonal sub channels so that each narrow band sub channel experiences almost flat fading. OFDM is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments. Many research centers in the world have specialized teams working in the optimization of OFDM systems. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-carriers are transmitted in parallel. These carriers divide the available transmission bandwidth. The separation of the subcarriers is such that there is a very compact spectral utilization. With OFDM, it is possible to have overlapping sub channels in the frequency domain, thus increasing the transmission rate. The attraction of OFDM is mainly because of its way of handling the multipath interference at the receiver. Multipath phenomenon generates frequency selective fading and Inter symbol interference (ISI). OFDM technology is one of the most attractive candidates for fourth generation (4G) wireless communication. It effectively combats the multipath fading channel and improves the bandwidth efficiency. At the same time, it also increases system capacity so as to provide a reliable transmission [3]. OFDM uses the principles of Frequency Division Multiplexing (FDM) but in much more controlled manner, allowing an improved spectral efficiency. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. These subcarriers are overlapped with each other. Because the symbol duration increases for lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter-symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol. The basic block diagram of OFDM system is shown in figure 1.

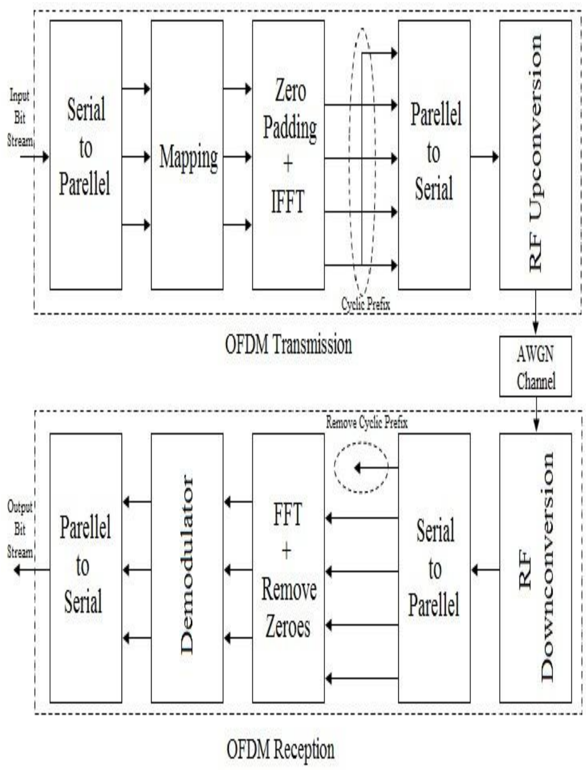

Figure 1: *OFDM block diagram.*

OFDM, orthogonal frequency division multiplex is a rather different format for modulation to that used for more traditional forms of transmission. It utilizes many carriers together to provide many advantages over simpler modulation formats. But the major problem one faces while implementing this system is the high peak – to – average power ratio of this system. A large PAPR increases the complexity of digital to analog converter (DAC) and reduces the efficiency of the radio frequency (RF) power amplifier.

II. PAPR IN OFDM

OFDM signal exhibits a very high PAPR, which is due to the summation of sinc waves and non-constant envelope. Therefore, RF power amplifiers have to be operated in a very large linear region. Otherwise, the signal peaks get into non-linear region causing signal distortion. This signal distortion introduces inter modulation among the subcarriers and out-of-band radiation [5]. PAPR is a very important situation in the communication system because it has big effects on the transmitted signal. Low PAPR makes the transmit power amplifier works efficiently, on the other hand, the high PAPR makes the signal peaks move into the non-linear region of the RF power amplifier which reduces the efficiency of the RF power amplifier. In addition, high PAPR requires a high-resolution DAC at the transmitter, high-resolution analog to digital converter (ADC) at the receiver [5]. Any non-linearity in the signal will cause distortion such as inter-carrier interference (ICI) and inter symbol interference (ISI).

The Cumulative Distribution Function (CDF) is used to measure the efficiency of any PAPR reduction technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold [2]. By implementing the Central Limit Theorem for a multicarrier signal with a large number of sub-carriers, the real and imaginary part of the time domain signals have a mean of zero and a variance of 0.5 and thus follow a Gaussian distribution. So Rayleigh distribution is followed for the amplitude of the multicarrier signal, where as a central chi-square distribution with two degrees of freedom is followed for the power distribution of the system.

III. PAPR REDUCTION TECHNIQUES

Over the years, different solutions have been proposed to combat this high PAPR problem. The first solution, in the history of OFDM, was proposed by Greenstein, about ten years after the discovery, although addressing the same basic issue; these solutions differ greatly in the specific approach taken. Furthermore, different researchers do not entirely agree on the impact of the high signal peaks on the system performance. Several PAPR reduction techniques have been proposed in the literature. These techniques are divided into two groups - signal scrambling techniques and signal distortion techniques. Here, we are discussing about SLM, PTS and its combinational methods.

1. Selective Level Mapping (SLM)

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 . A block diagram of the SLM technique is shown in Fig. 2.

Each data block is multiplied by *U* different phase sequences, resulting in *U* modified data blocks. Among the modified data blocks, 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.

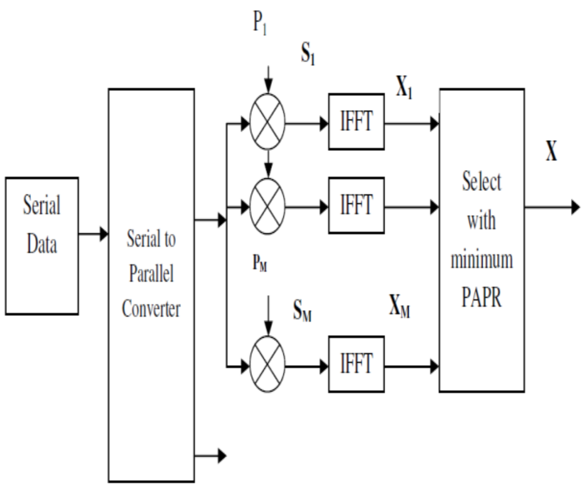

Figure 2: *PAPR reduction using SLM method*

At the receiver, the reverse operation is performed to recover the original data block. For implementation, the SLM technique needs *U* IDFT operations. 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. Figure 3 shows the flowchart of the SLM method.

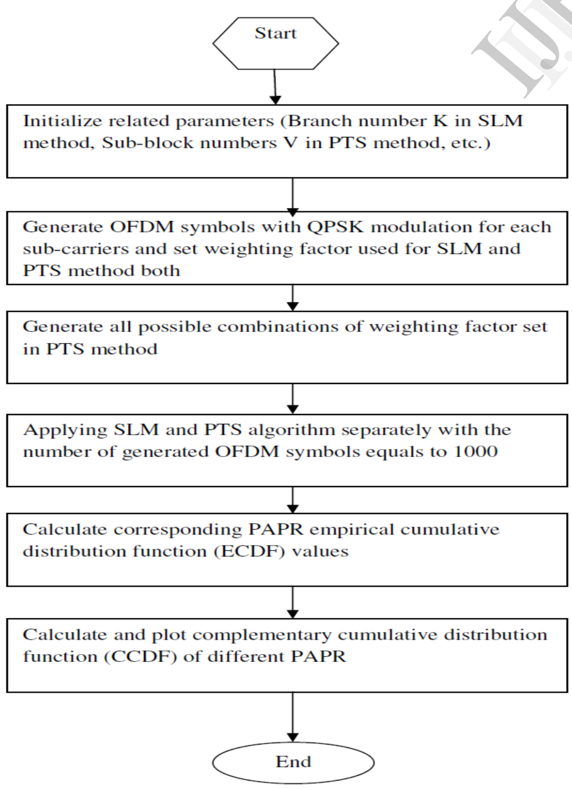

Figure 3: *Flowchart for SLM method.*

Figure 4 shows the CCDF of PAPR for OFDM with 2 and 4 phase sequence SLM.

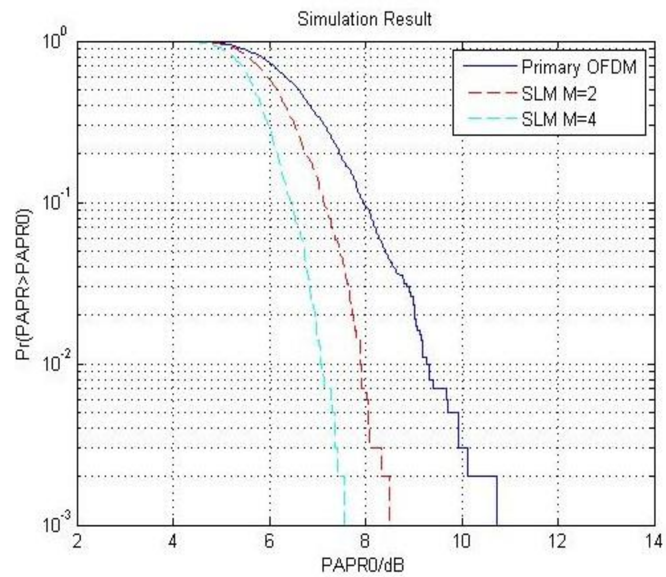

Figure 4: *CCDF of PAPR with Different set of phase vectors (Elapsed time is 0.576960 seconds)*

Figure 5 shows the CCDF of PAPR for OFDM with 8 and 12 phase sequence SLM. Figure 6 shows the CCDF of PAPR for OFDM with 16 and 24 phase sequence SLM.

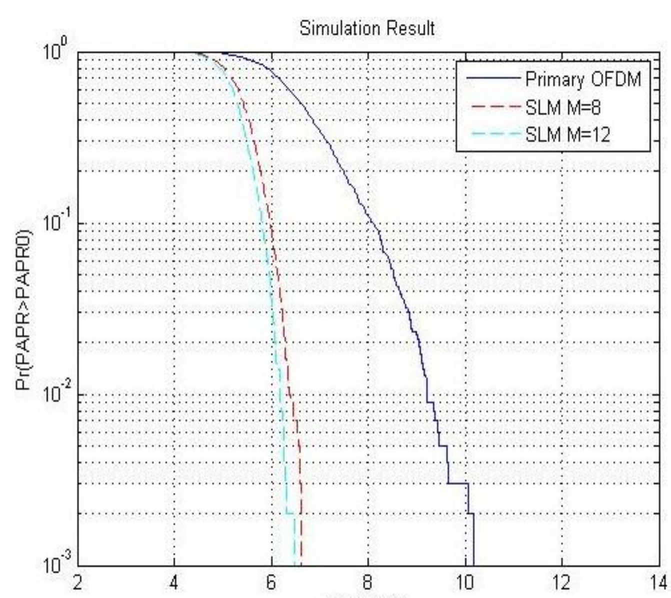

Figure 5: *CCDF of PAPR with Different set of phase vectors (Elapsed time is 0.865826seconds.)*

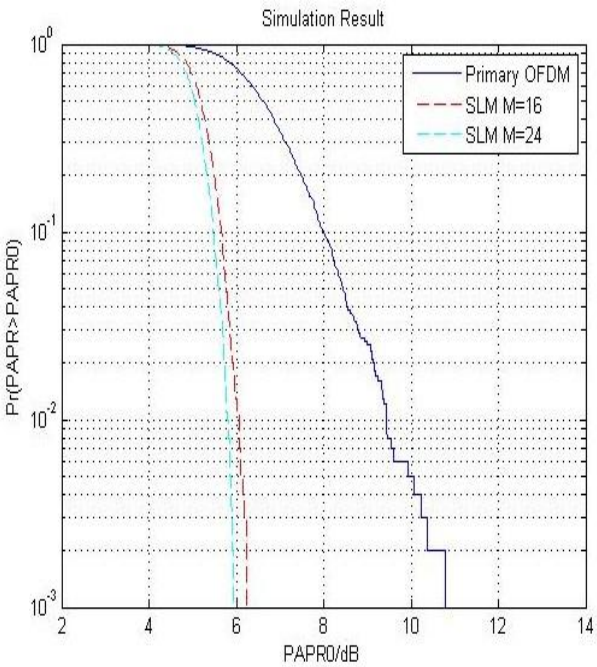

Figure 6: *CCDF of PAPR with Different set of phase vectors (Elapsed time is 1.268421seconds.)*

Figure 7 shows the CCDF of PAPR for SLM method (8 phase sequence) with BPSK and 16-QAM modulation technique. From this fig. 7, it can be seen that BPSK has better PAPR reduction performance as compared to 16-QAM method.

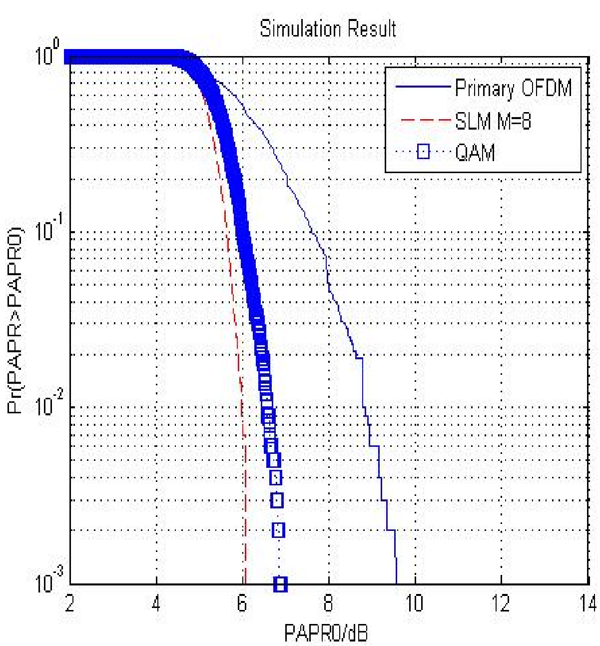

Figure 7: *CCDF of PAPR for SLM with QAM.*

2. Partial Transmit Sequence (PTS)

PTS method is a distortion less phase optimization scheme which provides reduction of PAPR with a small amount of redundancy. The input data is divided into number of disjoint sub blocks and they are weighted by a set of phase factors to create a set of candidate signals. Finally the candidate signal with the lowest PAPR with the help of threshold is chosen for transmission. A block diagram of the PTS technique is shown in Figure 8.

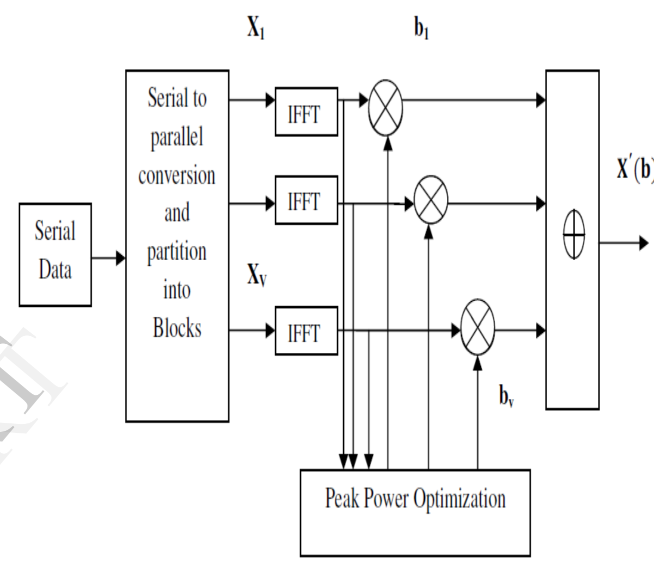

Figure 8: *PAPR reduction using PTS technique*

The objective here is to optimally combine the sub blocks to obtain the time domain OFDM signals with the lowest PAPR. The search complexity for an optimum set of the phase factors increases exponentially with the number of sub blocks. Figure 9 shows the CCDF of PAPR for OFDM with 4 phase sequence PTS. From fig. 9, it can be seen that the maximum value of PAPR for OFDM system without any PAPR reduction technique is 10.8 dB but PAPR value of OFDM with PTS method cannot exceed 9 dB.

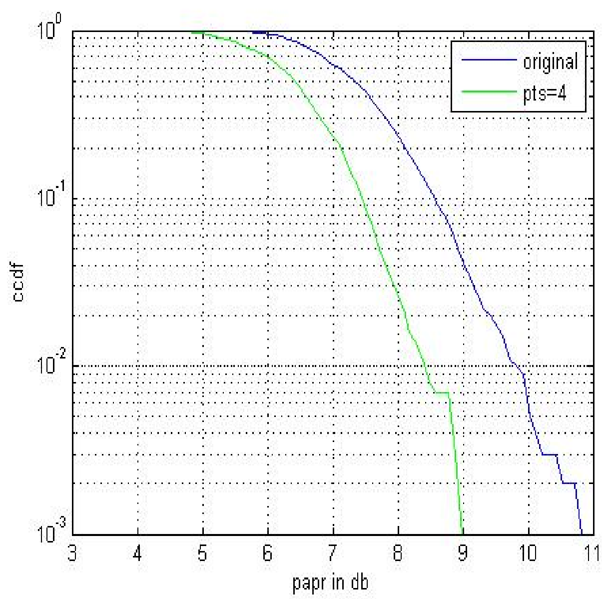

Figure 9: *CCDF of PAPR for PTS technique*

3. Conventional SLM-PTS hybrid method

The block diagram of the conventional SLM-PTS hybrid method (CH method) is shown in Fig. 10.

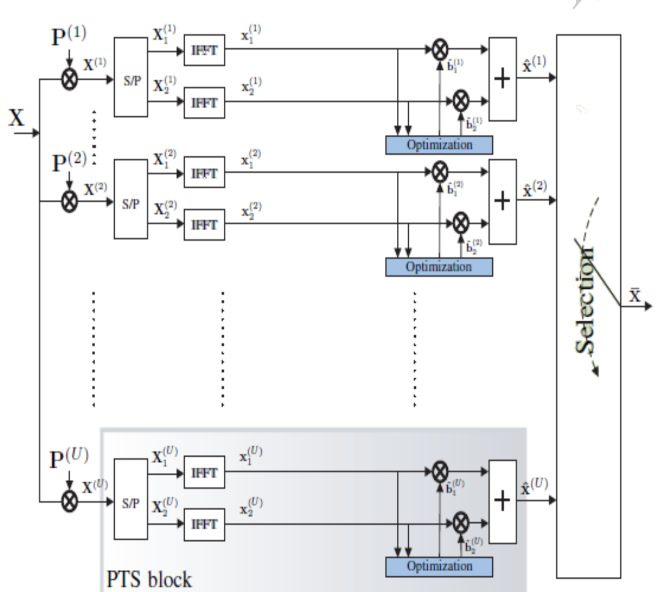

Figure 10: *Conventional SLM-PTS hybrid method*

The original OFDM symbol is multiplied with the U phase rotation sequences, and then each of the new OFDM symbols is partitioned into V pair wise disjoint sub-blocks. Those OFDM sub-block values are calculated by each optimization of PTS blocks [1]. For simplicity and without loss of generality, V = 2 is always considered in this paper. Each signal with the lowest PAPR value is selected by each optimization block. Figure 11 shows the CCDF of PAPR for OFDM with SLM-PTS hybrid method**.**

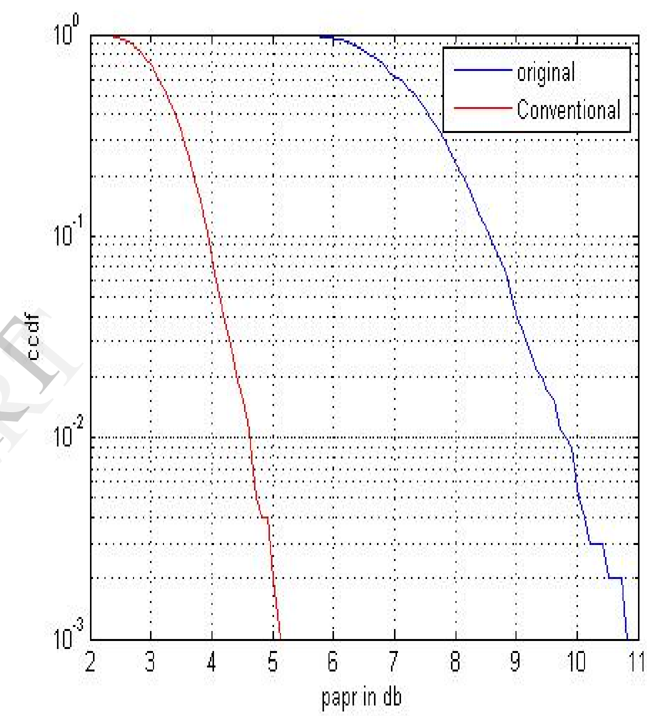

Figure 11: *CCDF of PAPF for SLM-PTS hybrid method.*

Table 1 shows the comparison of all discussed methods. From this table, it can be seen that CH method provides more PAPR reduction as compared to simple SLM or PTS method. The CH method has many advantages as compared to simple SLM and PTS method.

Table 1: Comparison of PAPR Reduction Techniques

Parameters	SLM method		PTS method	CH method
	BPSK	QAM		
Implementation complexity	LOW	LOW	High	High
BW reduction	No	Yes	Yes	No
Distortion less	Yes	Yes	Yes	Yes
Data Loss	Yes	Yes	Yes	No
Power increases	No	No	No	No
Reduced data rate	Yes	No	Yes	No
PAPR reduction (%)	40	30	20	55

IV. Conclusion & Future Work:

The study of PAPR reduction methods like SLM, PTS and CH method is done. The CH method has given the best PAPR reduction. In general, the PAPR reduction performance becomes better as the number of phase sequences increases in CH scheme, but the CH scheme has high computational complexity because of the increase of the number of IFFT. Therefore, future work is to find the powerful algorithms for CH method which will improve the PAPR reduction performance without increasing the number of IFFT operations.

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