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Low-Complexity PAPR Reduction of OFDM Signals Using Partial Transmit Sequence (PTS)

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Abstract:- This paper present the low complexity PAPR reduction in the multi-carrier modulation scheme using partial transmit sequence. OFDM Suffers as the no of Subcarriers operating in the large dynamic range operates in the non-linear region of amplifier due to OFDM suffers the PAPR problem. Peak to Average Power Ratio (PAPR) is one of the serious problems in any wireless communication system using multi carrier modulation technique like OFDM, which reduces the efficiency of the transmit high power amplifier. In order to reduce PAPR, the sequence of input data is rearranged by the PTS for the reduction of PAPR. The results are performed using partial transmit sequence (PTS) technique for different route number which is most efficient technique for PAPR reduction when the number of subcarrier is large. Simulation also performed with different number of subcarrier for N=256 and 512. Comparative analysis is also presented for the different number of sub blocks with N=256 and N=512.

***Keywords:* Peak-to-Average power Ratio (PAPR), Orthogonal Frequency Division Multiplexing (OFDM), partial transmit sequence (PTS), complementary cumulative distribution function (CCDF).**

I. INTRODUCTION

In multi-carrier modulation, the most commonly used technique is Orthogonal Frequency Division Multiplexing (OFDM); it has recently become very popular in wireless communication. The performance of an orthogonal frequency division multiplexing (OFDM) system is degraded if the peak-to average power ratio (PAPR) is high. An OFDM system dynamic range is typically two or four times larger than a single carrier system increasing value of the dynamic range will lead to an increased cost, power consumption of transmitter amplifier and also lead to high peak to average power ratio (PAPR). This is one of the major drawbacks of OFDM system [1]. OFDM is a bandwidth efficient multicarrier modulation where the available spectrum is divided into subcarriers, with each subcarrier containing a low rate data stream. OFDM has gained a tremendous interest in recent years because of its robustness in the presence of severe multipath channel conditions with simple equalization, robustness against Inter-symbol Interference (ISI), multipath fading, in addition to its high spectral efficiency. However, the Peak-to-Average Power Ratio (PAPR) is a major drawback of multicarrier transmission system such as OFDM [3]. The OFDM has many advantage such as high bandwidth efficiency, robustness to the selective fading problem, use of small guard interval, and its ability to combat the ISI problem. So, simple channel equalization is needed instead of complex adaptive channel equalization. High PAPR has been recognized as one of the major practical problem involving OFDM modulation [1]. This problem results from the nature of the modulation itself, where multiple subcarriers/sinusoids are added together to form the signal to be transmitted [2]. To overcome above mentioned serious drawbacks, several solutions have been proposed, such as clipping with filtering [6], clipping [7], coding [8], interleaving [9], Active Constellation Extension (ACE) [10], Turbo Coded OFDM [11]. This paper presents the low complexity PAPR reduction in the multi-carrier modulation scheme using partial transmits sequence. In order to reduce PAPR, the sequence of input data is rearranged by the PTS for the reduction of PAPR. PAPR can be described by its complementary cumulative distribution function (CCDF). An effective PAPR reduction technique should be given the best trade-off between the capacity of PAPR reduction and transmission power, data rate loss, implementation complexity and Bit-Error-Ratio (BER) performance. The paper is organized as follows: In Section II, The OFDM system model is explained. In section III, the PAPR in OFDM is introduced.. Section IV, partial transmits sequence introduced and approach to PAPR reduction is described. Section V, experimental results will be explained and comparison is given. Section VI, conclusions will be make.

II. OFDM SYSTEM MODEL

The OFDM signal is expressed as a sum of the prototype pulses shifted in the time and frequency directions and multiplied by the data symbols [2]. An OFDM signal in baseband is defined as:

$$x(t) = \sum_{n=0}^{N-1} (a_n e^{j2\pi f_n t}\, w(t)) \quad 0 \le t \le T, \qquad (1)$$

where, a_n denotes the complex symbol modulating the n-th carrier, w(t) is the time window function defined in the interval [0,T], N is the number of subcarriers, and T is the duration of an OFDM symbol. Sub carriers are spaced Δf =1/T apart. Each subcarrier is located at:

$$f = \frac{n}{T}, \quad 0 < n < N-1 \qquad (2)$$

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In order to maintain the orthogonality between the OFDM symbols, the symbol duration and sub channel space must meet the condition TΔf = 1. In eq. (1) time-limited complex exponential signals $\{(e^{j2\pi f_n t})_{n=0}^{N-1}$ which represent the different subcarriers at $f = \frac{n}{T}$ in the OFDM signal.

III. PEAK-TO-AVERAGE RATIO (PAPR)

Peak-to-Average ratio describes the envelope fluctuation. The system should operate in the linear region. Large peaks cause saturation in the power amplifiers and amplifier saturation results in non-linear distortion. One particular problem with multicarrier is the large envelope fluctuation. This envelope variation is due to the superposition of multiple channels. PAPR has two main causes Inter modulation and Out-of-band radiation. The complex envelop of the OFDM signal, over T second interval is given by:

$$S(t) = A_c \sum_{n=0}^{N-1} w_n \varphi_n(t), \qquad 0 > t > T \tag{3}$$

A_c where is the carrier amplitude, and w_n is the element of N-elements parallel data vector and the orthogonal carriers are

$$\varphi_n(t) = e^{j2\pi f_n t} \tag{4}$$

The envelope dynamic of signal s(t) can be objectively measured using the parameter called Peak to Average Power Ratio (PAPR) defined as:

$$\text{PAPR}\{s(t)\} = \frac{\max\{|s(t)|^2\}}{E\{|s(t)|^2\}} \tag{5}$$

The PAPR of OFDM signal with N subcarriers sampled at symbol rate is upper-bounded by the value N. Statistically it is possible to characterize the PAPR distribution using its cumulative distribution function (CDF) or complementary cumulative distribution function (CCDF). For the case of OFDM, the following expression for the PAPR CCDF holds as

$$\Pr(\text{PAPR} > \gamma) = 1 - (1 - \exp(-\gamma))^N \tag{6}$$

In order to minimize the problems arising from the use of signals with high PAPR in communication transmitters with nonlinearities, several approaches can be successfully used. Each of them has its advantages and disadvantages. As the alternatives, it is possible to either use some of the linearization techniques or some form of the efficiency enhancement techniques.

IV. PARTIAL TRANSMITS SEQUENCE

In PTS approach, the input data block is partitioned into disjoint sub-blocks. The sub-carriers in each sub-block are weighted by phase rotations. The phase rotations are selected such that the PAPR is minimized [2]. At the receiver, the original data are recovered by applying inverse phase rotations. In the PTS technique, an input data block of K symbols is partitioned into disjoint sub-blocks. The subcarriers in each sub-block are weighted by a phase factor for that sub-block. The phase factors are selected such that the PAPR of the combined signal is minimized. In order to implement this idea, the input data block of K symbols is partitioned into M pair wise disjoint blocks X_k, k = 1, ..., M.

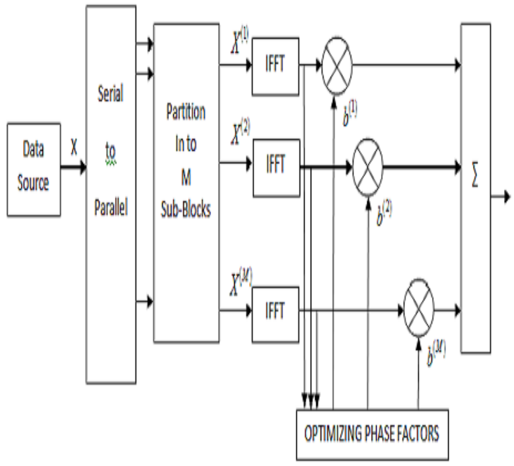

Fig. 1 Block diagram of PTS technique.

Mainly, the total number of subcarriers included in any one of these sub-blocks X_k is arbitrary, but sub-blocks of equal size have been found to be an appropriate choice. All sub carrier positions in X_k, which are already represented in another sub-block, are initialized to zero, so that $X = \sum_{k=1}^{M} X_k$.

Each sub-block is weighted by a set of rotation factors $b_k(u)$ where u = 1…..U , so that a modified subcarrier vector $\hat{X} = \sum_{k=1}^{M} X_k b_k(u)$ is obtained, which represents the same information as X, if the set $b_k(u)$ is known for each u and k. The phase factors are selected such that the PAR of the combined signal is minimized (Fig-3). Mathematically, it is expressed as:

$$\{b_1(u), b_2(u), \dots \dots, b_M(u)\} = \arg\min_u \left(\max_{0 \le n < N_{SL}-1} \left|\sum_{k=1}^{M} IDFT(X_k).\, b_k(u)\right|\right)$$

Where, $b_u(u) = e^{j\phi(u_k)}, \phi(u_k) \in (0, 2\pi)$

Resulting in the optimum transmit sequence

$$\hat{X}(u_{opt}) = \sum_{k=1}^{M} IDFT(X_k).\, b_k(u) \tag{7}$$

Where uopt is the phase vector that gives the greater reduction. Hence, U(M-1) is the amount of sets of phase factors that are evaluated to find the best case. The total

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complexity increases exponentially with the number of sub-blocks M. The receiver needs to know the set bk(u). Hence, an unambiguous representation of it must be transmitted to the receiver. As a consequence, the amount of bits as side information is $\lfloor log_2 U^{(M-1)} \rfloor$. Fig. 1 represents the block diagram of PTS algorithm.

V. EXPERIMENTAL RESULTS

In this experiment, Peak-to-Average power Ratio (PAPR) reduction technique based on signal scrambling in OFDM signal is explained based on complementary cumulative distribution function (CCDF). The PAPR reduction of the proposed scheme is examined by computer simulation using matlab 7.11.

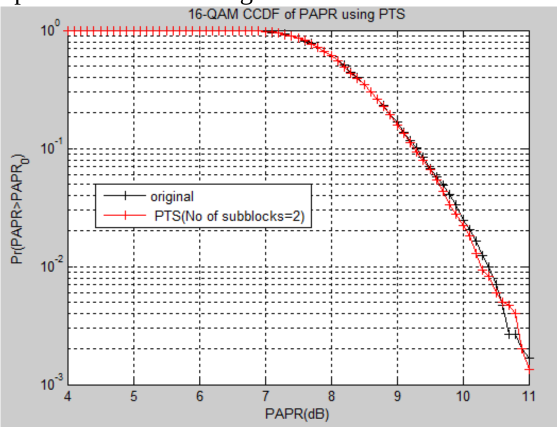

Fig. 2 CCDF of PAPR in Partial Transmit Sequence (PTS) technique versus original technique with M=2 sub blocks and Number of subcarriers N=512

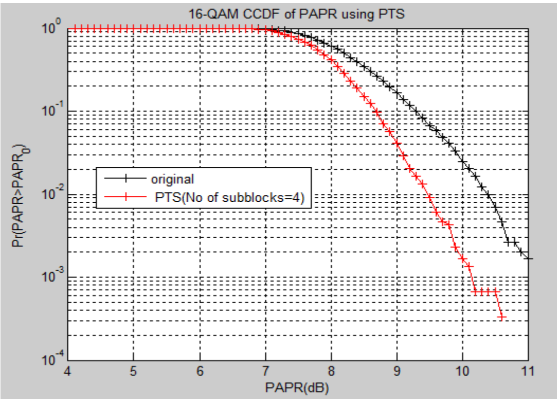

Fig. 3 CCDF of PAPR in Partial Transmit Sequence (PTS) technique versus original technique with M=4 sub blocks and Number of subcarriers N=512

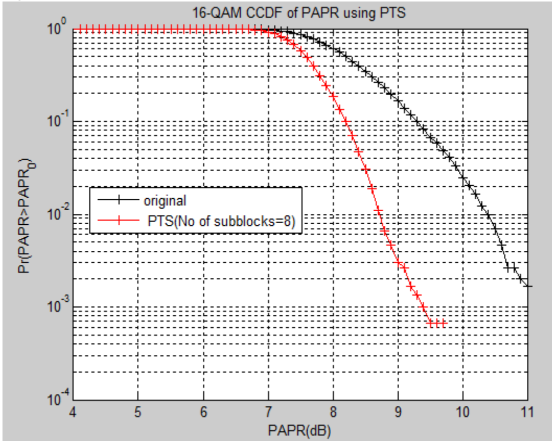

Fig. 4 CCDF of PAPR in Partial Transmit Sequence (PTS) technique versus original technique with M=8 sub blocks and Number of subcarriers N=512

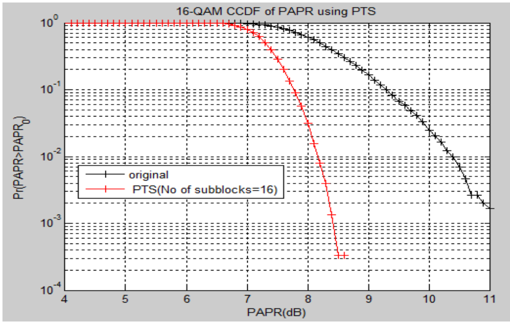

Fig. 5 CCDF of PAPR in Partial Transmit Sequence (PTS) technique versus original technique with M=16 sub blocks and Number of subcarriers N=512

In the simulation we consider an OFDM signal with N = 256 and 512 subcarriers, 16-QAM mapping, using Partial Transmits Sequence Technique. It has been investigated that the performance of proposed technique gives better results for 2, 4, 8, 16, sub-blocks and equivalent result for 32 sub-blocks. Fig. 2 shows the CCDF of PAPR using Partial Transmit Sequence (PTS) technique with M=2 sub blocks and Number of subcarriers N=512. Fig. 3 shows the CCDF of PAPR using Partial Transmit Sequence (PTS) technique with M=4 sub blocks and Number of subcarriers N=512. Fig. 4 shows the CCDF of PAPR using Partial Transmit Sequence (PTS) technique with M=8 sub blocks and Number of subcarriers N=512. Fig. 5 shows the CCDF of PAPR using Partial Transmit Sequence (PTS) technique with M=16 sub blocks and Number of subcarriers N=512. Fig. 6 shows the CCDF of PAPR using Partial Transmit Sequence (PTS) technique with M=32 sub blocks and Number of subcarriers N=512. Fig. 7 shows the comparison CCDF of PAPR using Partial Transmit Sequence (PTS) technique with different values of sub blocks and Number of subcarriers N=512.

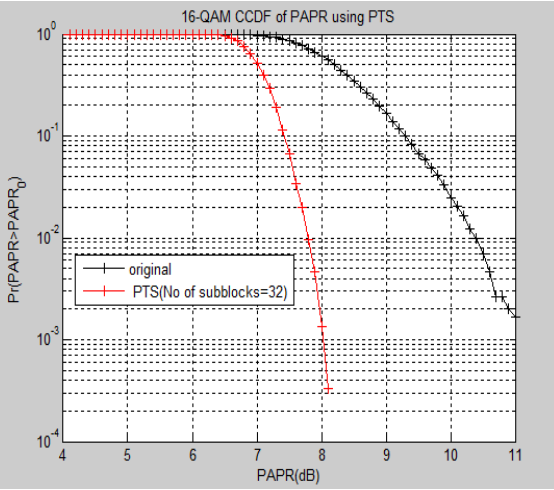

Fig. 6 CCDF of PAPR in Partial Transmit Sequence (PTS) technique versus original technique with M=4 sub blocks and Number of subcarriers N=512

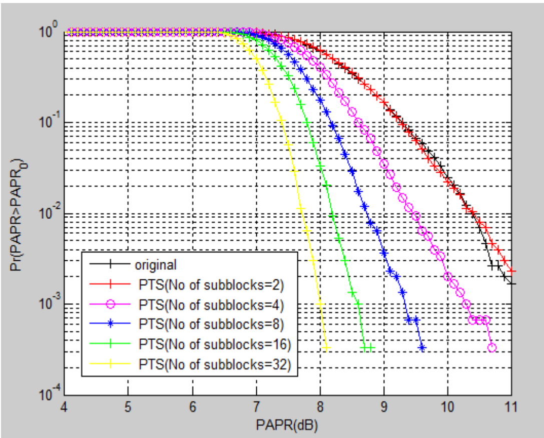

Fig. 7 Comparison of CCDF of PAPR in Partial Transmit Sequence (PTS) technique versus original technique with M=2, 4, 8, 16, 32 sub blocks and Number of subcarriers N=512

Fig. 8 shows the comparison CCDF of PAPR using Partial Transmit Sequence (PTS) technique with different values of sub blocks and Number of subcarriers N=256.

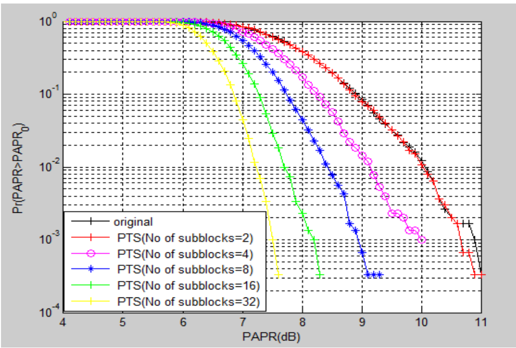

Fig. 8 Comparison of CCDF of PAPR in Partial Transmit Sequence (PTS) technique versus original technique with M=2, 4, 8, 16, 32 sub blocks and Number of subcarriers N=256

VI. CONCLUSIONS

This paper presents the low complexity PAPR reduction in the multi-carrier modulation scheme using partial transmits sequence. In order to reduce PAPR, the sequence of input data is rearranged by the PTS for the reduction of PAPR. PAPR can be described by its complementary cumulative distribution function (CCDF). An effective PAPR reduction technique should be given the best trade-off between the capacity of PAPR reduction and transmission power, data rate loss, implementation complexity and Bit-Error-Ratio (BER) performance. PAPR reduction concepts will be expanded for distortion less transmission and identifying the best alternatives in terms of performance increase. the complexity issues of the PAPR reduction technique is required, especially looking at ways of further reducing the complexity of the sphere decoder.

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