IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 12, July 2017)

PAPR Reduction using Hybridization of Weighted-OFDM and PTS

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Abstract –**OFDM is successfully used in many wireless digital communication system over multipath channels. One of the principle disadvantages of OFDM is the occurrence of high PAPR. OFDM signals are very sensitive to nonlinear effects due to the high PAPR, which leads to the power inefficiency in the RF section of the transmitter. This paper is focused on analyzing PAPR reduction by undertaking the hybridization of Weighted-OFDM and PTS (Partial Transmit Sequence). Performance evaluation is done using PAPR vs. CCDF graph.**

Keywords –**CCDF, OFDM, Weighted-OFDM, PAPR, PTS.**

I. Introduction

With the advent of new high data rate wireless applications, demand of the spectrum is rapidly increasing. Communications governmental and regulatory agencies impose regulations on spectrum usage, such as control of allocations and priorities, as well as its features. At this time, most of the prime spectrum has been assigned and it is difficult to find spectrum for the new wireless applications. It can be made available for either expands existing infrastructures or invent new services. Orthogonal Frequency Division Multiplexing (OFDM) is promising candidate for flexible spectrum pooling in communication systems.

For a long time, usage of OFDM in practical systems was limited. Main reasons for this limitation were the complexity of real time Fourier Transform and the linearity required in RF power amplifiers. However since 1990s, OFDM is used for wideband data communications over mobile radio FM channels, High-bit-rate Digital Subscriber Lines (HDSL, 1.6Mbps), Asymmetric Digital Subscriber Lines (ADSL, up to 6Mbps), Very-high-speed Digital Subscriber Lines (VDSL, 100Mbps), Digital Audio Broadcasting (DAB), and High Definition Television (HDTV) terrestrial broadcasting.

OFDM has many advantages over single carrier systems. The implementation complexity of OFDM is significantly lower than that of a single carrier system with equalizer. When the transmission bandwidth exceeds coherence bandwidth of the channel, resultant distortion may cause intersymbol interference (ISI) [1].

One of the challenges of the OFDM is high peak-to-average power ratio (PAPR). A high PAPR brings disadvantages like an increased complexity of the A/D and D/A converters and reduced efficiency of radio frequency (RF) power amplifier [2]. OFDM signal consists of a number of independent modulated subcarriers that leads to the problem of PAPR. If all subcarriers come with same phase, the peak power is N times the average power of the signal where N is the total number of symbols in an OFDM signal. Thus, it is not possible to send this high peak amplitude signals to the transmitter without reducing peaks. Because power amplifier used for the transmission has non-linear nature which causing inter-modulation and out-of-band radiation. The high peak of OFDM signal can be reduced in several ways.

PAPR can be described by its complementary cumulative distribution function. In this probabilistic approach certain schemes have been proposed by researchers. These include clipping method, coding and signal scrambling method. Although some techniques of PAPR reduction have been summarize, it is still indeed needed to give a comprehensive review including some motivations of PAPR reductions, to compare some typical methods of PAPR reduction through theoretical analysis and simulation results directly, and such as power saving [3, 4, 5, 6, 7].

The objective of this paper is to develop a PAPR reduction system using normal OFDM, PTS and a hybrid weighted OFDM-PTS approach along with comparative analysis of CCDF for above-mentioned schemes.

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II. Proposed Methodology

PAPR Reduction using PTS Method

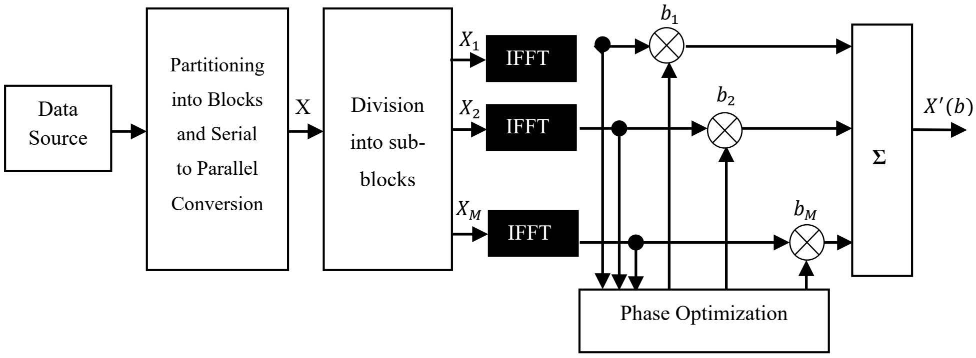

Figure 1: Block diagram of Partial Transmit Sequence method

In the PTS technique, input data block X is partitioned in M disjoint sub-blocks $X_m = [X_{m,0}, X_{m,1}, \ldots.. X_{m,N-1}]^T$, $m = 1,2,\ldots\ldots M$, such that $\sum_{m=1}^{M} X_m = X$ and the sub – blocks are combined to minimize the PAPR in the time domain. The L times oversampled time domain signal of X_m, $m = 1,2,\ldots\ldots M$, is obtained by taking the IFFT of length NL on X_m concatenated with $(L-1)N$ zeros. These are called the partial transmit sequences. Complex phase factors, $b_m = e^{j\emptyset m}, m = 1,2,\ldots\ldots M$ are introduced to combine the PTSs. The set of phase factors is denoted a vector $b = [b_1, b_2, \ldots\ldots. b_M]^T$. The time domain signal after combining is given by:

$$x'(b) = \sum_{m=1}^{M} b_m . x_m \quad (1)$$

Where $x'(b) = [x'_0(b), x'_1(b), \ldots\ldots. x'_{NL-1}(b)]^T$.

The objective is to find the set of phase factors that minimizes the PAPR. The optimum signal $x'(b)$ with the lowest PAPR is to be found out.

Both b and x can be shown in matrix form as follows:

$$b = \begin{bmatrix} b_1, b_1 \ldots.. b_1 \\ : \;\; : \ldots\ldots : \\ b_m, b_m \ldots.. b_m \end{bmatrix}_{(M\times N)} \quad (2)$$

$$x = \begin{bmatrix} x_{1,0}, x_{1,1} \ldots.. x_{1,NL-1} \\ : \;\; : \ldots\ldots : \\ x_{m,0}, x_{m,1} \ldots.. x_{m,NL-1} \end{bmatrix}_{(M\times NL)} \quad (3)$$

It should be noted that all the elements of each row of matrix b are of the same values in this method. In order to have exact PAPR calculation, at least 4 times over sampling is necessary. As the over sampling of x, add zeros to the vector, hence the number of phase sequence to multiply to matrix x will remain the same.

The PTS consist of several inverse fast Fourier transform (IFFT) operations and complicated calculations to obtain optimum phase sequence which results in increasing the computational complexity of PTS.

PAPR Reduction using Modified Weighted OFDM System

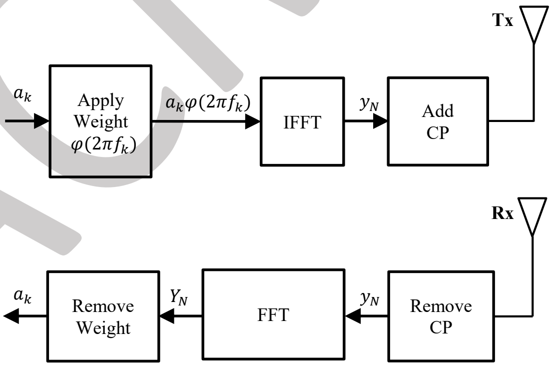

Figure 2: Block diagram for weighted OFDM method

The simplified block diagram for PAPR reduction with the weighted OFDM scheme is shown in Figure 2. Here, the weighted OFDM signal is provided, where the weight is derived from a suitable band-limited signal having no zero on the real line.

As described in Figure 2 the modulated data stream is carried on the multicarriers by the weight block of the proposed scheme. In the following block, the cyclic prefix is added.

A simple weighted OFDM signal y_N as:

$$y_N(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} a_k \varphi(2\pi f_k) e^{j2\pi f_k t}$$

$$0 \le t \le NT \quad (4)$$

The demerit of the weighted OFDM signal in equation (4) is the degradation of BER performance since the weight φ is nonuniform. To overcome this obstacle, a modified weight is considered with a positive constant α as follows:

$$\varphi_\alpha(x) = \varphi(x) + \alpha / \log N \quad (5)$$

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Where α is a shift parameter, and $\log N$ is obtained by experiment. Then, $\varphi = \varphi_0$. In the weighted OFDM signal in equation (4), the weight φ is replaced with φ_α for a suitable positive constant α to get the weighted OFDM signal, i.e., $z_N(t)$ as a transmitted signal, which is expressed as:

$$z_N(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} a_k \varphi_\alpha(2\pi f_k) e^{j2\pi f_k t} \quad 0 \le t \le NT \qquad (6)$$

In equation (5), weight $\varphi_\alpha(2\pi f_k)$ is imposed on the discrete data a_k, $k = 0, \dots N-1$, and an OFDM signal is formed with the weighted discrete data $\{a_k \varphi_\alpha(2\pi f_k)\}_{k=0}^{N-1}$ to get weighted OFDM signal z_N. Also the weighted OFDM signal z_N is transmitted for the same time duration $[0, NT]$ as the original OFDM signal.

It can be noticed that weight φ is positive on the real line; therefore, the modified weight φ_α is positive on the real line. Since $\varphi_\alpha(2\pi f_k) \neq 0$ for any $k = 0, \dots N-1$, the discrete data $\{a_k\}_{k=0}^{N-1}$ can be completely recovered. Then the PAPR of the modified weighted OFDM signal z_N is expressed as:

$$PAPR(z_N) = \frac{\max_{0 \le t \le NT} |z_N(t)|^2}{E(|z_N(t)|^2)} \qquad (7)$$

Hybrid Approach of PAPR Reduction using Modified Weighted OFDM with PTS Scheme

Figure 5 shows a hybrid scheme of PAPR reduction using modified weighted OFDM-PTS scheme. A weight is multiplied with the input data.

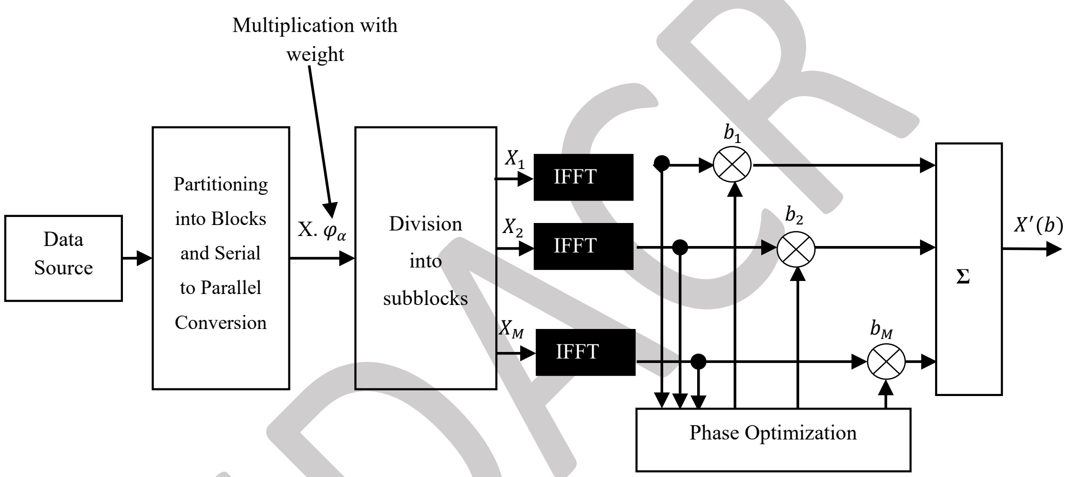

Figure 3: Block diagram of hybrid modified weighted OFDM-PTS scheme

III. Simulation and Results

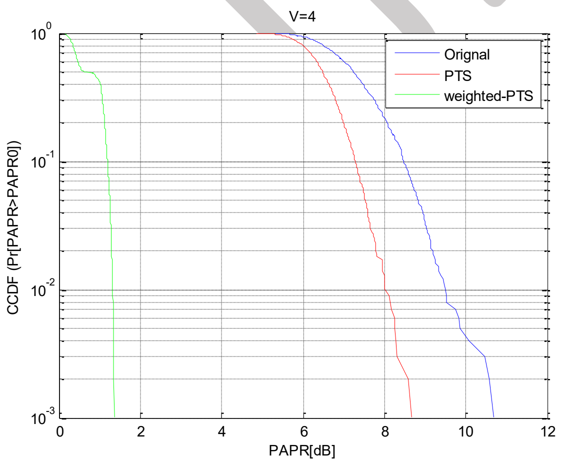

Figure 4: CCDF v/s PAPR calculation graph for original, PTS and hybrid weighted OFDM-PTS schemes

The above simulation result shows the comparative graph between CCDF and PAPR with FFT-128 for normal OFDM, PTS scheme and hybrid weighted OFDM-PTS. The X axis indicates the PAPR value and Y axis represents CCDF. It can be observed by above graph that the hybrid weighted OFDM-PTS outperforms other methods.

IV. Conclusion

The current status of the research is that OFDM appears to be a leading candidate for high performance wireless telecommunications. Although due to the fact that it reduces ISI and multipath distortion while giving a very high spectral efficiency, it also exhibits high PAPR that severely limits its popularity. However, no specific PAPR reduction technique is the best solution for the OFDM system. In this paper, the complementary-cumulative-distribution-function (CCDF) is plotted against the Peak-to-Average Power Ratio to understand the performance for different methods namely; normal OFDM, PTS and modified weighted OFDM-PTS. The simulation results indicate that,

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application of the algorithm results in significant reduction in the PAPR values. It was observed that the PAPR of hybrid weighted OFDM-PTS method is smaller than that of other methods.

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