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RESEARCH ARTICLE

Performance Analysis of Peak to Average Power Ratio Reduction Techniques

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ABSTRACT- Orthogonal Frequency Division Multiplexing (OFDM) is considered to be a promising technique against the multipath fading channel for wireless communications. OFDM has many advantages, but one of the major drawback is large peak to average power ratio. The high peak to average power ratio increases the complexity of Analogue to Digital (A/D) and Digital to Analogue (D/A) converters and reduces the efficiency of RF High Power Amplifier (HPA). Several techniques have been proposed to reduce the PAPR in OFDM system, This paper gives overview on some of the popular PAPR reduction techniques such as clipping and filtering, partial transmit sequence(PTS), selected mapping(SLM), tone reservation, precoding that are proposed to overcome this problem.

Keywords- " Orthogonal Frequency Division Multiplexing (OFDM)"," partial transmit sequence (PTS)","selected mapping (SLM"), "peak to average power ratio (PAPR)", "High Power Amplifier (HPA)".

I. INTRODUCTION

With the increase of communications technology, there is a rapid increase in the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links. New modulation schemes are required to transfer the large amount of data which existing techniques cannot support. These techniques must be able to provide high data rate, allowable Bit Error Rate (BER), and maximum delay. so various multicarrier modulation techniques have been introduced. Orthogonal Frequency Division Multiplexing (OFDM) is one of them. OFDM has been used for Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) in Europe, and for Asymmetric Digital Subscriber Line (ADSL) high data rate wired links. Orthogonal Frequency Division Multiplexing (OFDM) is a digital transmission Method developed to meet the increasing demand for higher data rates in communications which can be used in both wired and wireless environments.

OFDM provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem is the high Peak to Average Power Ratio (PAPR) of this system. A large PAPR increases the complexity of the analog to digital and digital to analog converter and reduces the efficiency of the radiofrequency (RF) power amplifier. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate.

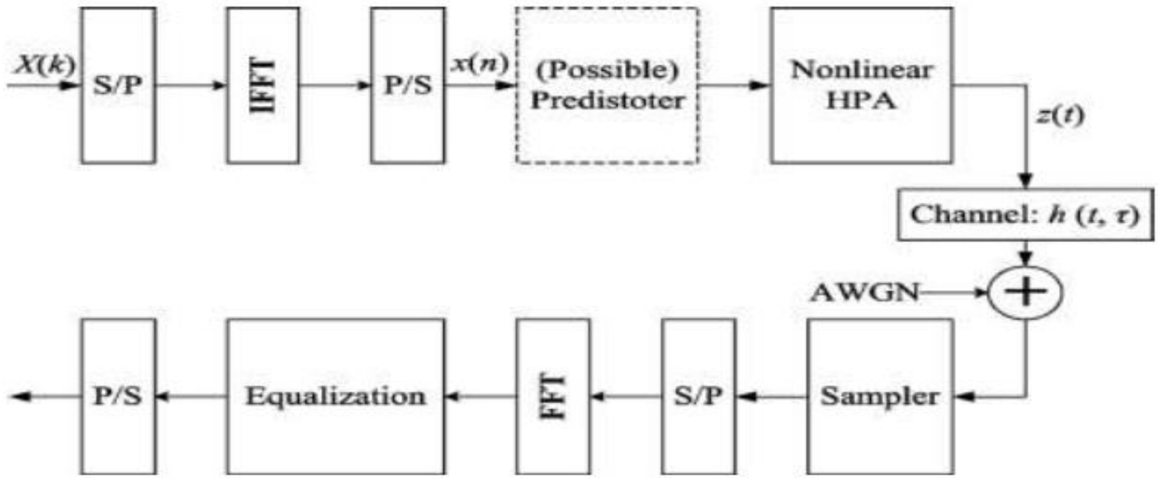

Fig 1. Basic principle of OFDM system

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. OFDM faces several challenges. The key challenges are ISI due to multipath-use guard interval, large peak to average ratio due to non linearity‟s of amplifier; phase noise problems of oscillator, need frequency offset correction in the receiver. Large peak-to-average power (PAP) ratio which distorts the signal if the transmitter contains nonlinear components such as power amplifiers (PAs).

Many PAPR reduction methods have been proposed. This paper presents some of the popular PAPR reduction techniques. Such as clipping and filtering, partial transmit sequence and selected mapping.

II. PEAK TO AVERAGE POWER RATIO

The PAPR is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. PAPR occurs when in a multicarrier system the different sub-carriers are out of phase with each other. Due to presence of large number of independently modulated subcarriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio.

The complex data block for the OFDM signal to be transmitted is given by

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{k=N-1} X_k \, e^{\frac{j2\pi n}{N}k} \ \ where\ n = 0,1 \dots \dots N-1 \qquad (1)$$

The PAPR is defined as:

$$PAPR = \frac{max[|x(n)|^2]}{E[|x(n)|^2]} \qquad (2)$$

Where $E[.]$ is expectation. Reducing $max[x(n)]$ is the principle goal of PAPR reduction techniques.

III. PAPR REDUCTION TECHNIQUES

A. *clipping and filtering*

Amplitude clipping is considered as the simplest technique which may be under taken for PAPR reduction in an OFDM system. A threshold value of the amplitude is set in this case to limit the peak envelope of the input signal. Signal having values higher than this pre-determined value are clipped and the rest are allowed to pass through un-disturbed.

$$B(X) = \begin{cases} x, & x \le |A| \\ Ae^{j\emptyset x} & x > |A| \end{cases}$$

where,

B(x) = the amplitude value after clipping.
x = the initial signal value.
A = the threshold set by the user for clipping the signal.

The problem in this case is that due to amplitude clipping distortion is observed in the system which can be viewed as another source of noise. This distortion falls in both in – band and out – of – band. Filtering cannot be implemented to reduce the in – band distortion and an error performance degradation is observed here. On the other hand spectral efficiency is hampered by out – of – band radiation. Out – of – band radiation can be reduced by filtering after clipping but this may result in some peak re – growth. A repeated filtering and clipping operation can be implemented to solve this problem. The desired amplitude level is only achieved after several iteration of this process.

B. *partial transmit sequence*

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

$$x'(b) = \sum_{m=1}^{M} b_m . x_m \qquad (3)$$

Where, $x'(b) = [x_0'(b), x_1'(b) \dots \dots x_{NL-1}'(b)]^T$, The objective is to find the set of phase factors that minimizes the PAPR. Minimization of PAPR is related to the minimization of $\max_{0 \le k \le \le NL-1} |x_k'(b)|$.

The PTS technique significantly reduces the PAPR, but unfortunately, finding the optimal phase factors has been a highly complex problem. In order to reduce the search complexity, the selection of the phase factors has been limited to a set of finite number of elements. The Exhaustive Search Algorithm (ESA) has been employed to find the best phase factor. However, the ESA requires an exhaustive search over all combinations of the allowed phase factors and has exponential search complexity with the number of sub blocks. To reduce the computational complexity, some simplified search techniques have been proposed such as the Iterative Flipping Algorithm (IFA). Although the IFA significantly reduces the search complexity, there has been some gap between its PAPR reduction performance and that of the ESA.

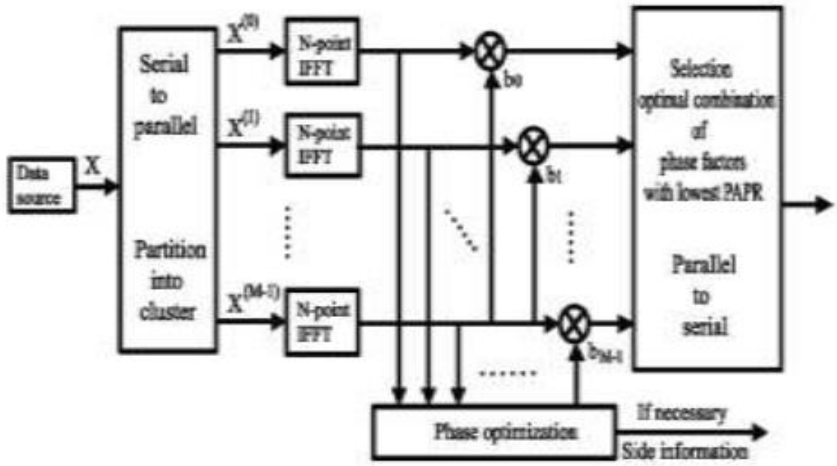

Fig 2. Block diagram of PTS technique

C. *selected mapping*

Selected Mapping (SLM) technique is the most promising reduction technique to reduce Peak to Average Power Ratio (PAPR) of Orthogonal Frequency Division Multiplexing (OFDM) system. Let us assume that the original input data X $[X_0, X_1 \dots \dots X_{N-1}]^T$ multiplied with independent phase sequences $P^{(U)} = [P_0^{(u)}, P_1^{(u)} \dots \dots P_{N-1}^{(u)}]^T (u = 0.1 \dots \dots U-1)$ where U is the number of phase sequences. Both the input data and phase sequences have the same length N $(u = 0.1 \dots \dots U-1)$ After multiplication, inverse fast Fourier transform (IFFT) will be applied on each sequence to convert the signal from frequency domain to the time domain. The result from multiplication will generate the data block of an OFDM system that has different time domain signals, with length of U, and different PAPR values, $X^{(u)} = [X_0^{(u)} + X_1^{(u)} + \dots + X_{N-1}^{(u)}]^T$. The last step is comparing the PAPR among the independent data blocks and the candidate $\hat{X}$ with the lowest PAPR will be selected for transmission. The following equation expresses the optimal candidate that has the lowest PAPR and selected for transmission,

$$\hat{X} = argmin_{0 \le u \le U} \left[PAPR\left(X^{(u)}\right) \right] \qquad (4)$$

Where argmin (·) represent the argument of its value is minimized.

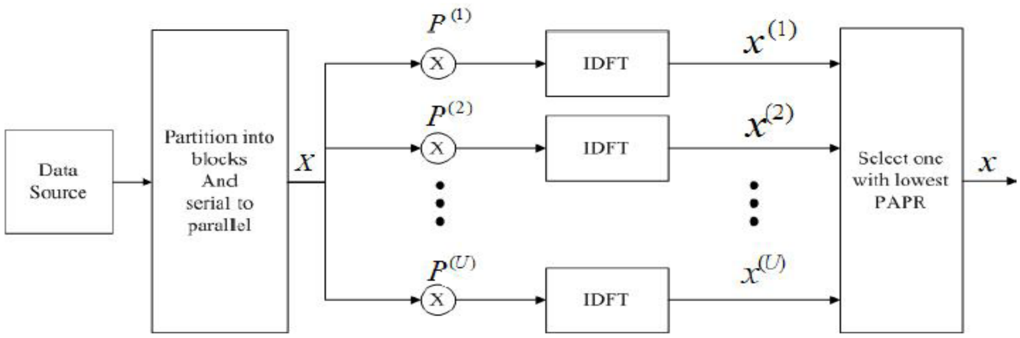

Fig 3. Block diagram of SLM techniqu

IV. RESULTS AND DISCUSSION

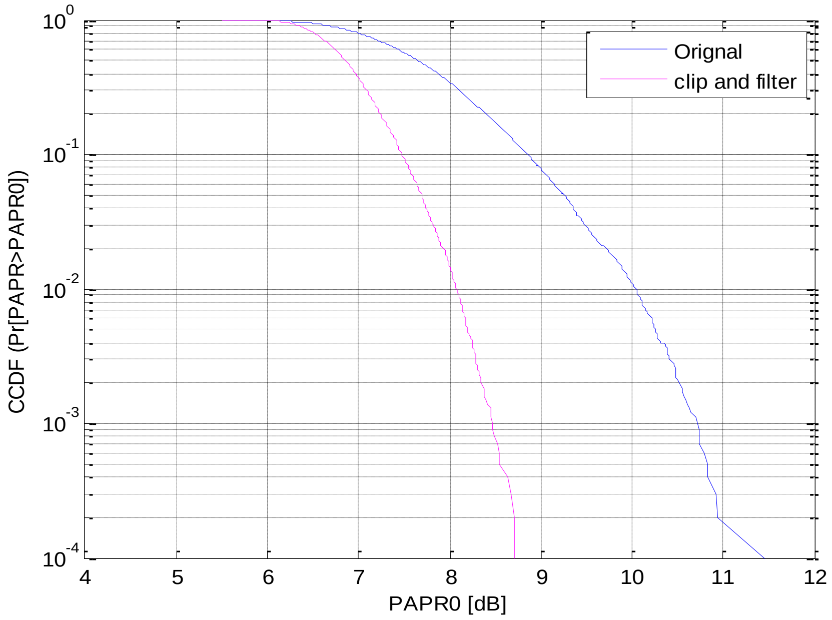

Fig 4. Reduced PAPR using clipping and filtering

Clipping and filtering technique can provide PAPR reduction upto 2.75 dB when applied to 64-subcarrier QPSK OFDM symbols.

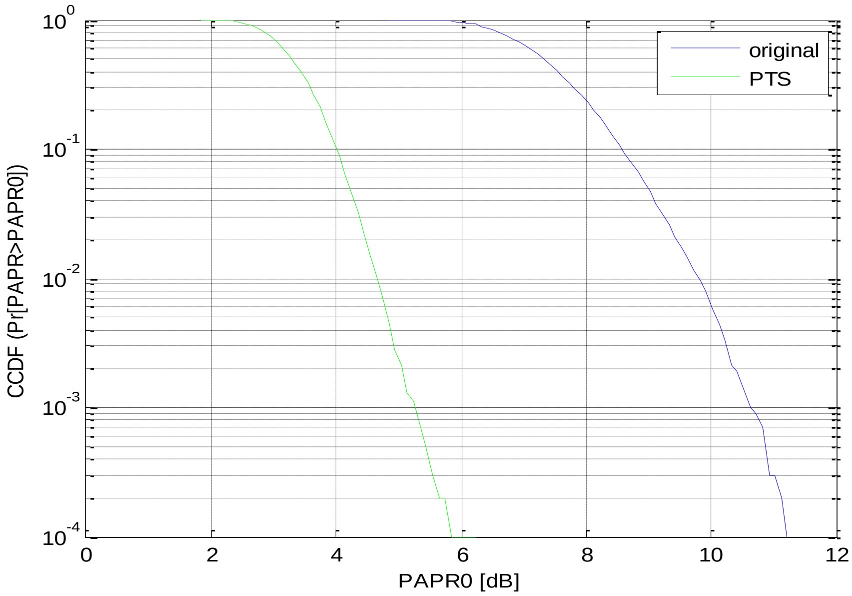

Fig 5. Reduced PAPR using partial transmit sequence

Partial transmit sequence technique can provide PAPR reduction up to 5.1 Db when applied to 64-subcarrier QPSK OFDM symbols.

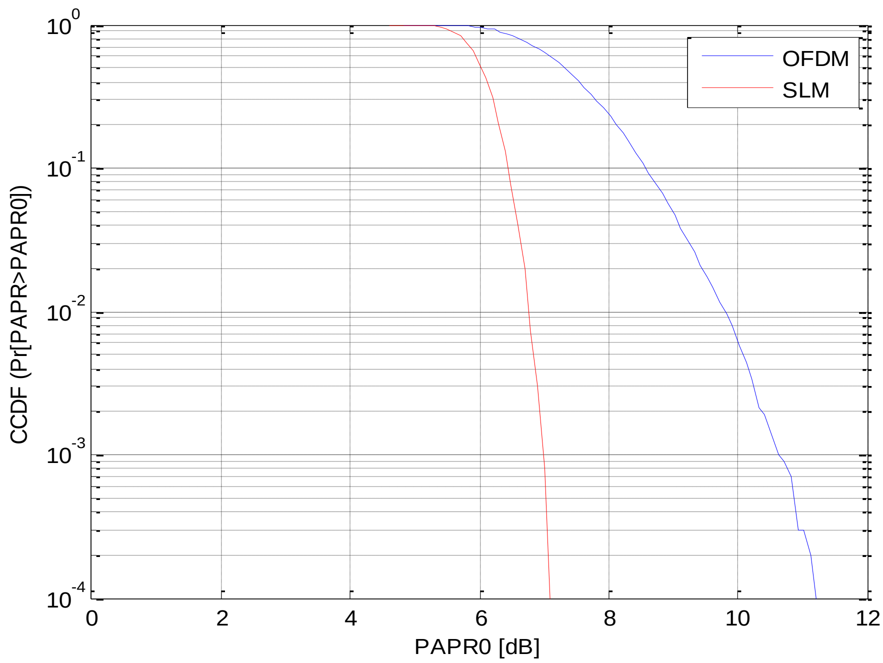

Fig 6. Reduced PAPR using SLM technique

Selected mapping technique can provide PAPR reduction up to 4.1 db when applied to 64-subcarrier QPSK OFDM symbols.

V. CONCLUSIONS

In this paper some PAPR reduction techniques for multicarrier transmission have been discussed. Many techniques to reduce the PAPR have been proposed all of which have the potential to provide substantial reduction in PAPR at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase and so on.

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