



Overview of PAPR Minimization Method

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Abstract: Orthogonal Frequency Division Multiplexing is widely utilized in digital communication for higher data rate transmission. Large peak to average power ratio (PAPR) is the main shortcoming of OFDM system [2]. This paper is mainly aimed on review of distinguish PAPR minimization method & a comparative analysis of the distinguish methods are studied given in literature has been given here. It also presents a review of the distinguish commonly used PAPR minimization method & the detailing of the same in this area based on references. Finding of this paper is that the Partial Transmit Sequences (PTS) method is the most effective method for PAPR minimization as per the literatures.

Keywords: OFDM, PAPR, HPAs, CCDF, PTS.

I. INTRODUCTION

Recently OFDM (Orthogonal Frequency Division Multiplexing) is widely used for wireless applications since it provides high data rate & also improves the spectral efficiency [3]. OFDM is a multicarrier digital communication technique in which the all available bandwidth is distributed into many small streams of low data rate & then they are modulated with distinguish sub-carriers. One of the main cons of OFDM is high PAPR (peak to average power ratio) [6]. To remove this & to attain maximize output power, normally the high power amplifier (HPA) is maintained at the saturation region. Orthogonal frequency division multiplexing is the desirable technique to achieve higher speed in data rates & better spectrum efficiency.

In OFDM [1] first higher data stream has been divided into lower streams of data & after modulation these data streams are together transmitted by orthogonal subcarriers. One of the major challenges in OFDM system is high Peak to average power Ratio (PAPR), which produced nonlinear distortion & degrades system performance. As a consequence of increased value of PAPR, HPA starts operating in nonlinear region, hence transmitted data became distorted.

To overcome the issue of high PAPR & improve the system performance, number of techniques has been proposed in various literatures [2]. One of the simple approaches is clipping technique [3], in which PAPR has been diminished by clipping the higher peaks of the signal.

This technique sometimes encounters with in-band & out-band interference. Some of the other techniques, which also use same kind of mechanism, are clipping & filtering, peak windowing, peak cancellation etc.

In another approach i.e. coding techniques, where selection of the appropriate codeword to minimize PAPR significantly, has been proposed [4][5][6][7]. There OFDM signal generated by an N point Inverse Fast

Fourier Transform (IFFT) in the transmitter, & the Fast Fourier Transform (FFT) can be used at the receiver to reform the signal. Now if the input complex-valued data of N subcarriers as: $X_N = X_K, K = 0, 1, 2, \dots, N - 1$ is used to form with each of the symbol modulating the corresponding subcarrier from a set of opted orthogonal set, the discrete-time OFDM symbol can be written as:

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi}{NL}kn}, 0 \leq n \leq NL - 1$$

Where; X_K is the symbol carried by the K^{th} sub-carrier, L is the oversampling factor. An OFDM signal contains an "N" number of independently modulated subcarriers, which can be given a very large PAPR when added up coherently.

For a CT-OFDM signal, it is defined at an instant as the ratio of the maximum power to the average power as:

$$PAPR [s(t)] = \frac{t \in \max_{[0, T_s]} |s(t)|^2}{E\{|s(t)|^2\}}$$

Where s (t) is the time-continuous type OFDM signal & in case of a discrete-time type signal, sampling is generally placed at a rate of Nyquist-rate to estimate true PAPR. But these samples which are taken here need not to be



compulsorily overlapped with the time-continuous signal's peaks. To accurately estimate of PAPR, one need to perform oversampling of given OFDM signal. PAPR with oversampling factor L is given as [6];

$$PAPR[\text{oversampling}] = \max_{k \in [0, NL]} \frac{|x(k/L)|^2}{E\{|x(k/L)|^2\}}$$

Where, E [.] denotes the expected value, basically shows average power of the signal & x (k/L) are samples of the OFDM signal with oversampling & defined as:

$$x[k/L] = \sum_{n=0}^{N-1} s_n e^{i2\pi kn/N}$$

Where k=0, 1,....., LN-1. For the value L=1, the samples are called Nyquist-rate samples. PAPR with rate of Nyquist-rate sampling is:

$$PAPR[\text{Nyquist - sampling}] = \max_{k \in [0, NL]} \frac{|x(k/l)|^2}{E\{|x(l)|^2\}}$$

The rest of this paper is presented as follows. In Section II illustration of distinguish PAPR minimization method. In Section III theoretically comparison of distinguish PAPR minimization method including the advantages & disadvantages of these method are given.

The next part concludes & give the briefs about the future possibilities to this work for implementations. Statistically it can be possible to characterize the PAPR using Complementary Cumulative Distribution Function (CCDF). CCDF is a most common type of way to evaluate the PAPR by estimating the probability of PAPR, when this exceeds a particular level. The CCDF equation of the PAPR of OFDM signals with small subcarriers is written as:

$$CCDF = P(PAPR > PAPR_0) = 1 - (1 - \exp(-PAPR_0))^N$$

This equation is interpreted as the probability that the PAPR of a block symbol exceeds some threshold level $PAPR_0$.

PAPR is a measure of the envelope variations of a multicarrier signal and is used as FOM or figure of merit. Since OFDM signal consists of a number of independent modulated symbols, the sum of independently modulated subcarriers may have large amplitude fluctuations which causes in a large PAPR.

II. EFFECTS OF PAPR

As PAPR increases it results in the following effects [21]:

- Large dynamic range of the D/A and A/D converters will be required; if it is not increased then the peak values could be clipped, results in signal distortion.
- If A/D and D/A converters with large working ranges are taken, quantization noise will also increase and performance will degrade.
- Furthermore, the selection of power amplifier and up-converters will also be crucial when PAPR problem occurs. The working range of Power amplifier & up converters is required, so that the nonlinear distortion would not be introduced which results in decreasing the power efficiency of Power amplifier.

III. PAPR MINIMIZATION METHOD

Mainly PAPR minimization techniques are subdivided into two categories, methods which cause distortions & which does not cause distortions. Depending upon the method & its implementations, further they are minutely subdivided into categories named with their working principle. Some of them are listed below;

The signal scrambling techniques are classified as:

- Block Coding Techniques
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

The Signal Distortion Techniques are classified as :

- Peak Windowing
- Envelope Scaling
- Clipping

A. Clipping

Amplitude clipping is a basic method to minimize PAPR. It clips the amplitude of a signal outside the specified region. This insert in-band & out-of-band distortion both. Out-of-band distortion minimizes spectral efficiency of the transmission, & in-band distortion introduces the error performance [9].

$$A(y) = \begin{cases} y, & y \leq C \\ C, & y > C \end{cases}$$

Where C is the clipping level.



B. Selective Mapping (SLM)

In this technique, distinguish data blocks are generated while the information of the blocks is same as that of the original data block. These blocks are combined with distinguish phase sequences & then transformation is performed with IFFT. Out of these signals, the signal with least PAPR is chosen [8].

Procedure for SLM technique is:

- Each of the data segment is multiplied by V distinguish phase factors, each of length N, $B_v = [b_{v,0}, b_{v,1}, \dots, b_{v,N-1}]^T$, where $v=0, 1, 2, \dots, V-1$.
- After combining the phase factors with the data block, we obtain $X^v = [X_0 b_{v,0}, X_1 b_{v,1}, \dots, X_{N-1} b_{v,N-1}]^T$ ($v=0, 1, \dots, V-1$).
- Out of these data blocks X ($v= 0, 1, \dots, V-1$), only one block with the least PAPR is chosen for transmission.

SLM technique provides sufficient minimization in PAPR. Increase in number of phase factors, more combinations are generated which increase the number of iterations causes more PAPR minimization [8].

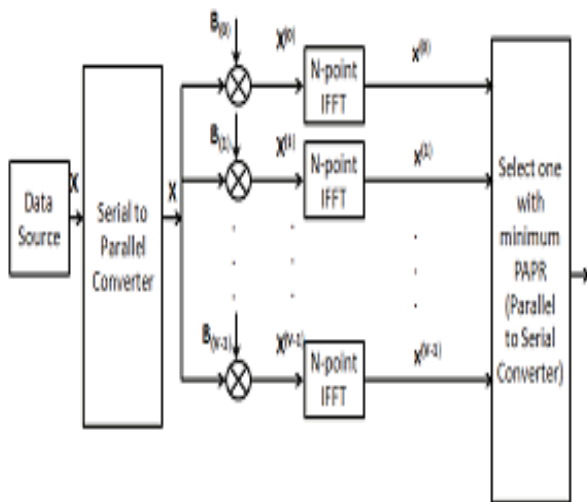


Fig. 1. Block Diagram of SLM Technique

C. Partial Transmit Sequence (PTS)

In this, one data source is divided into many sub data blocks. Each partition has a number of sub-carriers. These sub-carriers are combined with distinguish possible combinations of the phases. Out of all these combinations, combined signal with the minimum PAPR can be obtained.

Procedure for PTS technique is:

- Input block Y is divided into P disjoint sub-blocks $Y_p = [Y_{p,0}, Y_{p,1}, \dots, Y_{p,N-1}]^T$, $p=1, 2, \dots, P$.

- IFFT is performed on the sub-blocks & time domain signal is obtained.
- The phase factors $b = \{ b_p = e^{j\theta_p}, p=0, 1, \dots, P-1 \}$ are combined with the time domain signal & the least PAPR of the combined signal is opted.

This technique is highly complex to search such phase factors which gives the minimum PAPR. Another It also has side information extra overhead of these phase factors which is to be transmitted to the receiver side.

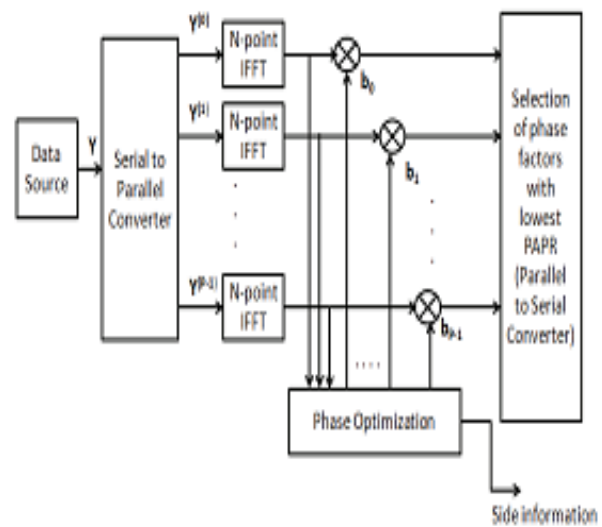


Fig. 2. Block Diagram of PTS Technique

D. Tone Reservation (TR)

Tone reservation basically deals with reserving a number of tones to produce a signal that can reduce peak-power. It has limited reserved sub-carriers which are not used for transmission. These kind of reserved sub-carriers are termed as the reserved tones. Mathematically,

$$X = I + T \tag{6}$$

The receiver only needs to be aware of the positions of these tones & ignore them. Here I is the information signal, T is the additive signal selected so that the PAPR of x is minimized. It is less complex; at the receiver end, no separate processing is needed. Also, there is no need to transmit the tones information additional to the data signal. But the same time signal power requirement increases as power is required for reservation of tones.

IV. COMPARATIVE ANALYSIS OF DISTINGUISH PAPR MINIMIZATION METHOD

Table 1 gives the comparative analysis of distinguish important PAPR minimization method as studied for available literatures for several references;



| Parameters | Clipping | PTS | SLM | TR/TI |
|---------------------------|-------------------------------|--|--|--|
| PAPR Reduction | Least PAPR reduction | Better than clipping and SLM | Better than clipping | Better than clipping |
| Computation Complexity | Low complexity | High complexity in computation | High complexity in computation | High complexity in computation |
| Bandwidth Expansion | No | Yes | Yes | Yes |
| Power increase | No | No | No | Yes |
| Data rate loss | No | Yes | Yes | TR- Yes TI- No |
| Distortion- less | No | Yes | Yes | Yes |
| BER Degradation | Yes | No | No | No |
| Processing at Transmitter | Amplitude clipping, filtering | P-IFFTs | V-IFFTs | TR: To find the reserved sub-carriers, IFFTs TI: To search for greatest point in time, IFFTs, modification of tones |
| Processing at Receiver | None | Inverse PTS, side information separation from the received data | Inverse SLM, side information separation from the received data | TR: Discard the reserved sub-carriers with no data TI: Modulo-D operation |
| Other factors | SNR Degradation | More iterations give a better solution. Better reduction capability with more complexity | More iterations give a better solution. Better reduction capability with more complexity | - |

Table 1 Comparison of distinguish PAPR minimization method

V. CONCLUSION

OFDM is one of the best available modulation technique for multi-carrier & high data rate transmission & also spectrally efficient. Major limitation of this scheme is PAPR. This paper presents a brief review of distinguish PAPR minimization methods with their performance comparisons. In this paper, we have aimed on mainly PTS. Because PTS outperforms all other methods. All other methods introduce some losses. Basic PTS requires Side Information for detection, which again causes low data rate. Hence, from this discussion we can conclude that a PTS method which does not requires SI, should be developed. It can be done through introduction of mapping schemes. These are the finding of this paper.

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