Review Paper on Comparative study of various PAPR Reduction Techniques

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Abstract: Orthogonal Frequency Multiplexing (OFDM) has been increasingly used in modern wired and wireless communication systems due to its high data rate, immunity to noise and high frequency spectral efficiency. The major drawback in using OFDM technique is its high Peak to Average Power Ratio (PAPR). Within the existing PAPR reduction techniques, Selective Mapping is most popularly used Technique. In this paper, we discuss various PAPR reduction techniques. And find out that the signal scrambling techniques are having most advantages in terms of no out of band radiations and BER. But these techniques are more complex than others.

Keywords: Multi Carrier Modulation (MCM), Orthogonal frequency division multiplexing (OFDM), Peak to average power ratio (PAPR), Partial Transmit Sequence (PTS), Selective Mapping (SLM).

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is most widely used technique due to its capability of supporting high data rates. In OFDM based systems, a high data rate stream is broken down into several lower speed streams which are orthogonal or parallel to each other[7][12].

Due to this property, OFDM is widely used in high speed systems like Digital Subscriber Line (DSL), Digital Video Broadcasting (DVB) and wireless networks[3][12].

The main concept behind OFDM system is that the available bandwidth is divided among the various subcarriers. Due to the formation of subcarriers, the data rate of each carrier is reduced but overall data rate of system increases as more number of subcarriers can be used[7]. Example, in DSL communication 64 subcarriers are used whereas in DVB, 2048 subcarriers are used for video transmission. The major disadvantage in using the OFDM is the high value of PAPR. This means the difference in Peak power and average power is more. This difference increases if we increase the number of subcarriers. This high PAPR reduces the performance of High Power Amplifier (HPA) used for transmission due to the fact that amplifier is driven into saturation region if input power is increased beyond its linear range. This causes inter modulation and out of band modulation. This causes the system efficiency to degrade. So before using HPA, these high peaks need to be suppressed. To reduce this PAPR, there are many techniques used such as Source Coding, Scrambling Technique and Signal Distortion Techniques etc.[8].

This paper is organized as follows: Section I describes OFDM system. Section II describes PAPR in OFDM system. Section III describes PAPR reduction techniques. Section IV describes overall analysis of different techniques. Section V describes conclusion.

II. Papr in OFDM Signal

Let the input data block of length K be represented by block \( A_x = [A_1, A_2, A_3, ..., A_K] \). Thus OFDM symbol can be written as:

\[
x(s) = \sum_{k=1}^{K} A_x e^{j2\pi f_d k} \tag{1}
\]

Where X(s) is the OFDM symbol, \( A_x \) is the input data block and K is the number of symbols in input data block.
PAPR is defined as the ratio of Peak to Average Power. Mathematically PAPR can be defined as following:

\[
PAPR \{x(s)\} = \frac{\max [x(s)]^2}{E\{x(s)^2\}}
\]

(2)

Where \( x(s) \) is the original OFDM signal, \( \max [x(s)]^2 \) is the peak signal power, \( E\{x(s)^2\} \) is the average signal power and \( E[.] \) is the expectation operator.

III. PAPR Reduction Techniques

There are various techniques available for PAPR reduction in OFDM. These are described as follows:

A. Signal Scrambling Techniques:

Selected mapping (SLM) [2], Partial Transmit Sequence (PTS) [8], Tone Injection (TI) etc are Signal Scrambling Techniques.

Signal Scrambling Techniques are described as follows:

A.1. PTS Technique

In the PTS Technique, the input symbol sequence is partitioned into a number of disjoint symbol subsequences. IFFT is then applied to each symbol subsequence and the resulting signal subsequences are summed after being multiplied by a set of distinct rotating vectors.

Next the PAPR is computed for each resulting sequence and then the signal sequence with the minimum PAPR is transmitted. As the number of subcarriers and the order of modulation are increased, the system complexity is also increased to great extent thus making this technique more complex in implementation on hardware[8].

A.2. Selective Mapping

Selective Mapping is a useful technique to reduce PAPR in OFDM system, as this technique does not effects the system performance in terms of Bit Error Rate. The basic idea behind this technique is the phase rotation of the OFDM modulated data. After several rotations, the signal with low PAPR is selected[2].
Let the input data block be represented as
\[ A_K = [A_0, A_1, A_2, ..., A_{N-1}]^T \]  
(6)

And independent phase sequences are given by
\[ P^U = [p_0^U, p_1^U, ..., p_{N-1}^U]^T \]  
(7)

Where \( P^U \) is the phase sequence, \( U \) is the total no. of Phase sequences and \( T \) is the length of input data block.

After applying Phase rotation, IFFT is applied to obtain data block with different PAPR value and phase sequence \[2\].

\[ d^U = [d_0^U + d_1^U + ..., d_{N-1}^U]^T \]  
(8)

Where \( d^U \) is the OFDM symbol generated after IFFT operation. After this the stream with lowest PAPR is selected for transmission. CCDF is used for PAPR representation. CCDF of PAPR in SLM can be represented as

\[ P(\text{PAPR} > \text{PAPR}_0) = (1 - e^{-\text{PAPR}_0})^{\alpha N} U \]  
(9)

Where \( \alpha \) is the oversampling factor, \( N \) is no. of sub-carrier, \( U \) is total no. of independent phase sequences and \( \text{PAPR}_0 \) is the threshold value.

**A.3. Tone Injection**

Tone injection uses a set of equivalent constellation points for an original constellation to minimize the level of PAPR. It increases original constellation size and map several constellation points to extended constellation from each original constellation points. Since all elements mapped are useful for PAPR reduction.

There is no need for additional operation and no side information is required to transmit along with the original signal. This technique is based on summing a data block and time domain signal[13].

**B. Signal Distortion Techniques**

Clipping and Filtering ([2][10]), Peak cancellation, peak power suppression, companding etc. are signal distortion techniques.

**B.1. Peak Cancellation**

In this algorithm the amplitude and phase of peak is kept within constellation region which points to the data symbol to be transmitted. For example, to use this technique for QPSK constellation, it carries four regions to represent the four different value of QPSK symbol.
B.2. Peak Windowing

With this technique it is possible to remove larger peaks at the rate of a little amount of interference when large peaks arise infrequently. It mitigates PAPR at cost of increases BER (bit-error-rate) and out-of-bands radiation. In this method multiply large signal peak with a specific window such as Gaussian shaped window, Kaiser, cosine, and hamming window which results a spectrum of convolution of original OFDM spectrum with spectrum of window. The window size should be narrow otherwise it affects number of signal sample which cause increasing BER[9].

IV. Overall Analysis Of Various Techniques

<table>
<thead>
<tr>
<th>NAME OF SCHEME</th>
<th>DISTORTION LESS</th>
<th>POWER INCREASE</th>
<th>DATA RATE LOSS</th>
<th>BER IMPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTS</td>
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<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>SLM</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>TI</td>
<td>YES</td>
<td>YES</td>
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<td>YES</td>
</tr>
<tr>
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<td>NO</td>
<td>NO</td>
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<td>Companding</td>
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<td>NO</td>
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<tr>
<td>PW</td>
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</tbody>
</table>

V. Conclusion

In this paper, OFDM is studied and various PAPR reduction techniques are studied. These techniques are compared for different parameters. Here SLM is analyzed and it is found that this technique is better for PAPR reduction because this technique does not cause out-of-band radiations or degrades BER performance. The only drawback in using this Technique is that system becomes complex when phase sequence increases or number of subcarriers increases.

References