Comparison of PAPR reduction techniques in OFDM based Cognitive Radio

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Abstract
Cognitive Radio technology is a promising solution to utilize the licensed frequency band in opportunistically. OFDM is a multicarrier modulation scheme. It provides the number of benefits when it is implemented at the physical layer of the cognitive radio such as ease in spectrum sensing, reducing the Inter Symbol Interference, flexible in adapting to environmental conditions, provides interoperability with other wireless technologies and shaping the spectrum. Besides its pros, there are two drawbacks of the OFDM based cognitive radio system are high PAPR and high side lobe power radiation. High PAPR produces the interference with primary users and also induces the inter channel interference. In this paper various PAPR reduction techniques are analyzed and the comparison of them is also discussed.

Keyword: Cognitive Radio, OFDM, Peak-to-Average Power Ratio(PAPR), PTS, SLM

Introduction
The OFDM modulation scheme has been used in cognitive radio systems to solve the two major issues of cognitive radio system. First one is the inter symbol interference and second is the slow data rate transmission. In conventional cognitive radio systems data was transmitted over a single carrier of high data rate. But this modulation scheme changed the way of data transmission in cognitive radio networks[1]. In OFDM based cognitive radio systems data is transferred with multiple low rate carrier rather than single high rate carrier[2]. It promises the higher utilization of licensed frequency band in cognitive radio networks. In cognitive radio system, there are two major aspects one is sensing and second is error free data transmission[3].

The OFDM is the most widely used technology in wireless communication which has the potential to fulfill the requirements of the cognitive radio systems inherently or with some changes[4]. It provides various facilities such as reducing the inter symbol interference, increasing the data rate, ease in spectrum shaping and sensing. But, Peak-to-Average Power Ratio is the major problem of the orthogonal frequency division multiplexing based cognitive radio systems[5],[6]. OFDM systems consist of a large number of modulated subcarriers which have different phases and amplitudes. When these modulated subcarriers are combined coherently. Due to this, the power of the some signals might increase instantaneously which crosses the average power. High PAPR also degrades the performance of the system because it increases the Bit Error Rate(BER). The PAPR is computed by the following equation

\[
PAPR = \frac{\max(x^2(t))}{\text{mean}(x^2(t))}
\]

Where \(x(t)\) is the amplitude of the signal.

There are numbers of basic techniques to reduce the high PAPR are Selective Mapping, Partial Transform Sequence, Coding techniques, Clipping and Filtering technique. This technical paper has been divided into various sections. Section-I presents analysis of PAPR reduction techniques, Section-II describes the comparison of various PAPR reduction techniques by considering three parameters. Further, Section-III discusses the future work. Finally, the paper is concluded

Analysis of PAPR reduction techniques
PAPR reduction techniques are classified into two categories on basis of loss of information. Peak windowing, Clipping and filtering are the signal distortion techniques while Selective mapping, Partial Transmit Sequence, Tone Reservation and Tone ejection are the non signal distortion PAPR reduction techniques.

Clipping PAPR reduction
In clipping PAPR reduction technique high PAPR is reduced by cutting the amplitude of the modulated signal greater than the threshold value before the transmission at the transmitter end. It reduces the PAPR but it also produces the in-band radiation and out-band radiation. Out-band radiation can be reduced by performing the interpolation before the clipping and filtering after the clipping process[7]. This process is performed iteratively to reduce the high peak PAPR. But, filtering after the clipping may regrow the PAPR.
The advantage of clipping and filtering technique is that it does not require side information to send along with the data signal to the receiver and no operation is performed at the receiver to recover the original signal as well.

**Peak Windowing**

In Peak Windowing PAPR reduction technique modulated signal is multiplied with the co-efficient of the particular window. Window can be Kaiser, Gaussian, Hamming window etc[8]. But, it is difficult to select the appropriate window to reduce the high PAPR. Like clipping and filtering PAPR reduction technique, the side information is not needed to decode the data signal at the receiver end. Both the Clipping & Filtering and PEAK windowing PAPR reduction have advantage is that these techniques does not reduce the spectral efficiency.

**Coding Techniques**

In block coding technique the certain length of codes are used for encoding the original signal to reduce the PAPR and at receiving end by using these code words the original signal is recovered. But, the block coding approach is useful for short codes because it requires large computation.

**Selective Mapping**

Selective mapping is most widely used PAPR reduction technique. Firstly, the original modulated signal is passed through IFFT process. Then, the output of the IFFT process is multiplied by phase factor and the signal of having minimum PAPR value is chosen. Both phase factor and that signal which has smallest PAPR value is sent to the receiver[9].

It reduces the high PAPR but, its major weak point is that to send the side information to decode the signal at receiving end. Cause of this extra information spectral efficiency reduces.

**Partial transmit Sequence**

Partial transmit sequence is the extended version of SLM PAPR reduction technique. Unlike SLM technique, In PTS technique data signal is partitioned into m-sub parts and a different phase factor is chosen for each subpart[9]. Then each part is submitted to IFFT block which convert the frequency domain to time domain. After this, each sub portion is multiplied by a different phase factor and selects that phase factor for each subpart of the signal which has minimum PAPR value.

Phase factor can different for different subparts of the signal. By processing the signal in this manner the high PAPR value of the transmitted signal is reduced but it requires large number of computations to select the appropriate the phase factor for each subpart of the signal which has minimum PAPR value. Unlike SLM reduction technique it does not require side information to send to the receiver because of differential modulation

**Tone reservation**

High PAPR is reduced in this approach by using the set of reservation of tones. The amount of PAPR reduction is directly depends on the location of the reserved tones and the number of the reserved tones, amount of complexity and permitted power on the reserved tones[10]. It is additive approach to minimize the high PAPR in multicarrier modulation system. The merits of Tone Reservation are: it is less complex than other PAPR reduction techniques and no side information is transmitted along the original signal. Its major drawback is that it consumes the extra bandwidth which decreases the data rate.
Tone Injection
Tone Injection is also an additive approach for reducing the high PAPR. Unlike Tone Reservation approach it does not reduce the data rate. Tone Injection uses the set of corresponding constellation points for the original constellation size. The basic initiative is to increase the constellation size[7]. Then, each point in the original constellation can be mapped into number of equivalent constellation points that reduces the high PAPR of the transmitted signal. Problems with this technique is that an extra IFFT operation have to performed and also side information is required to decode the signal at the receiving end.

Comparison
Three parameters are considered to compare the PAPR reduction techniques as shown in table No-1.

<table>
<thead>
<tr>
<th>Name Of schemes</th>
<th>Distortion Less</th>
<th>Data Rate Loss</th>
<th>Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clipping &amp; Filtering</td>
<td>No</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>Peak Windowing</td>
<td>No</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>Coding</td>
<td>Yes</td>
<td>Yes</td>
<td>High</td>
</tr>
<tr>
<td>Selective Mapping</td>
<td>Yes</td>
<td>Yes</td>
<td>High</td>
</tr>
<tr>
<td>Partial Transmit Sequence</td>
<td>Yes</td>
<td>Yes</td>
<td>High</td>
</tr>
<tr>
<td>Tone reservation</td>
<td>Yes</td>
<td>Yes</td>
<td>High</td>
</tr>
<tr>
<td>Tone Injection</td>
<td>Yes</td>
<td>No</td>
<td>High</td>
</tr>
</tbody>
</table>

First parameter is distortion less, it means that the PAPR reduction technique distort the data which degrade the BER(bit error rate) performance. Second parameter shows which technique decreases the data transmission rate that effect the spectral efficiency. And third parameter defines the computational requirement to implement the PAPR reduction technique. The advantages of the Clipping and Peak Windowing PAPR reduction techniques are high data rate transmission and low computational complexity. But these techniques distort the transmitted signal. In Coding, Selective Mapping, Partial Transmit Sequence and Tone reservation PAPR reduction techniques signal does not distort but these techniques are highly complex and reduce the data transmission rate as well.

Conclusion
OFDM is a best promising modulation technique which provides the solution to numbers of problems. But the major problem high PAPR occurs when orthogonal frequency division multiplexing multicarrier modulation technique is implemented. As we have discussed the various PAPR reduction technique to handle this problem. Numbers of researcher have been working on OFDM based cognitive radio systems to combat the problems of high PAPR and high sidelobe power radiation. It is concluded by analyzing these techniques, for respective application we can choose different scheme such as non data distortion PAPR reduction technique should be used in transmitting important text information where we can’t tolerate distortion in data. In audio or video transmission we can compromise with the voice quality or video quality, data distortion techniques can be used which have high spectral efficiency and low computational requirement as well.

Future work
A hybrid technique can be designed to reduce the high PAPR. This novel technique can inherit the properties from the both data distortion and non data distortion technique. Also it can be a combination of two or more data distortion or non data distortion PAPR reduction techniques by inheriting the best feature of them.

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