Evaluation of OFDM System and Implement PAPR Reduction Techniques in OFDM System

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Abstract—Although OFDM seems to be a solution to keep up with the demand of increasing data rates, it has some drawbacks. Sensitivity to high PAPR is the most significant of these drawbacks. The main objective of this paper was to investigate and document the effects of PAPR on the performance of OFDM based digital communications under different channel conditions. A step-by-step approach was adopted in order to achieve the objective of this paper. The first step is to provide a basic background on the principles of OFDM. The reasons for the PAPR and a theoretical analysis of these effects on OFDM systems are documented. The OFDM system has a high peak-to-average power ratio (PAPR) that can cause unwanted saturation in the power amplifiers, leading to in-band distortion and out-of-band radiation. To be able to observe the system behavior, the simulation results for different channel models are presented in graphical form. Next, the simulation results obtained in this work are compared to the simulation results reported in related studies.

Keywords—orthogonal frequency division multiplexing (OFDM), peak to average power ratio (PAPR), selected mapping (SLM), partial transmit sequence (PTS), inverse discrete Fourier transform (IDFT).

I. INTRODUCTION

OFDM was introduced in the 1950s but was first implemented in the 1960s. It was originally developed from the multi-carrier modulation techniques used in high frequency military radios. A patent for OFDM was granted in the 1970s. However, when OFDM was first introduced, it was not very popular because of the cost and complexity of large arrays of sinusoidal generators and coherence demodulators. The actual widespread use of OFDM started after the inverse discrete Fourier transform (IDFT) and discrete Fourier transform (IDFT) made the OFDM implementation possible without the use of large number of sinusoidal generators. OFDM was accepted as a wireless local area network (WLAN) standard in September 1999, but actually it was not the first IEEE physical standard for WLANs.
II. DESIGN ISSUE

The OFDM technique divides the total bandwidth into many narrow sub-channels and sends data in parallel. It has various advantages, such as high spectral efficiency, immunity to impulse interference and, frequency selective fading without having powerful channel equalizer. But one of the major drawbacks of the OFDM system is high PAPR. OFDM signal consists of lot of independent modulated subcarriers, which are created the problem of PAPR. It is impossible to send this high peak amplitude signals to the transmitter without reducing peaks. So we have to reduce high peak amplitude of the signals before transmitting. PAPR Reduction Techniques PAPR reduction techniques are classified into the different approaches: There have been many new approaches developed during the last few years. Several PAPR reduction techniques have been proposed in the literature. These techniques are divided into two groups. These are signal scrambling techniques and signal distortion techniques. The signal scrambling techniques work with side information which minimized the effective throughput since they commence redundancy. Signal distortion techniques introduce band interference and system complexity also. Signal distortion techniques minimize high peak dramatically by distorting signal before amplification.

a. Amplitude Clipping and Filtering

The simplest technique for PAPR reduction may be amplitude clipping. Amplitude clipping limits the peak envelop of the input signal to a predetermined value,

\[ B(x) = \begin{cases} x & |x| \leq A \\ A e^{i \varphi(x)} & |x| > A \end{cases} \]

Where \( \varphi(x) \) is the phase of \( x \) and \( A \) is the cutting threshold. The noise caused by amplitude clipping falls both in-band and out-of-band. In-band distortion cannot be reduced by filtering and results in an error performance degradation, while out-of-band radiation reduces the spectral efficiency.

Filtering the out of- band distortion after clipping cause some peak re growth and to avoid this undesirable effect, repeated

b. Proposed Modified Selected Mapping Technique

Selective Mapping (SLM) approaches have been proposed by Bauml in 1965 [13]. This method is used for minimization of peak to average transmit power of multicarrier transmission system with selected mapping. A complete set of candidate signal is generated signifying the same information in selected mapping, and then concerning the most favorable signal is selected as consider to PAPR and transmitted. In the SLM, the input data structure is multiplied by random series and resultant series with the lowest PAPR is chosen for transmission. To allow the receiver to recover the original data to the multiplying sequence can be sent as ‘side information’.

One of the preliminary probabilistic methods is SLM method for reducing the PAPR problem. The good side of selected mapping method is that it doesn’t eliminate the peaks, and can handle any number of subcarriers. The drawback of this method is the overhead of side information that requires to be transmitted to the receiver of the system in order to recover information.

Figure 3 shows the block diagram of selective mapping (SLM) technique for PAPR reduction. Here, the input data block \( X = [X[0], X[1], X[2], \ldots, X[N-1]] \) is multiplied with \( U \) different phase sequences \( p^u = [p_0^u, p_1^u, \ldots, p_{N-1}^u] \) where \( p_v^u = e^{j \varphi_v^u} \) and \( \varphi_v^u \in [0,2\pi] \) for \( v=0,1,\ldots,N-1 \) and \( u=1,2,\ldots,U \), which produce a modified data block \( X_u = [X_u[0], X_u[1], \ldots, X_u[N-1]] \) after which the indices of the \( X_u \) with the lowest PAPR are selected for transmission.
Figure 3 Block diagram of selective mapping (SLM) technique for PAPR reduction.

In order for the receiver to be able to recover the original data block, the information (index u) about the selected phase sequence Pu should be transmitted as a side information. The implementation of SLM technique requires \( U \) IFFT operations. Furthermore, it requires \([\log_2 U]\) bits of side information for each data block where \([x]\) denotes the greatest integer less than \(x\).

c. Proposed Modified Partial Transmit Sequence Technique

The partial transmit sequence (PTS) technique partitions an input data block of \(N\) symbols into \(V\) disjoint sub blocks as follows:

\[
X = \{X^0, X^1X^2, \ldots, X^{v-1}\}\]

Where \(X^i\) are the sub blocks that are consecutively located and also are of equal size. Unlike the SLM technique in which scrambling is applied to all subcarriers, scrambling (rotating its phase independently) is applied to each sub block in the PTS technique (see Figure 7.19). Then each partitioned sub block is multiplied by a corresponding complex phase factor \(b^v = e^{j\theta_v}\), \(v = 1, 2, \ldots; V\), subsequently taking its IFFT to yield

\[
x = IFFT\left\{\sum_{v=1}^{V} b^v x^v\right\} = \sum_{v=1}^{V} b^v \cdot IFFT\{X^v\} = \sum_{v=1}^{V} b^v x^v
\]

Where \(\{x^v\}\) is referred to as a partial transmit sequence (PTS). The phase vector is chosen so that the PAPR can be minimized, which is shown as

\[
(b^1, \ldots, b^V) = \arg \min \left[\max_{n} \sum_{v=1}^{V} b^v x^v[n]\right]
\]

Then, the corresponding time-domain signal with the lowest PAPR vector can be expressed as

\[
x = \sum_{v=1}^{V} b^v x^v
\]

In general, the selection of the phase factors \(\{b^v\}_{v=1}^{V}\) is limited to a set of elements to reduce the search complexity. As the set of allowed phase factors is \(b = \{e^{j\theta_i} / i = 0, 1, \ldots, W-1\}\), \(W^v\) sets of phase factors should be searched to find the optimum set of phase vectors. Therefore, the search complexity increases exponentially with the number of sub blocks. The PTS technique requires \(V\) IFFT operations for each data block and \(\log_2W^v\) bits of side information. The PAPR performance of the PTS technique is affected by not only the number of sub blocks, \(V\), and the number of the allowed phase factors, \(W\), but also the sub block partitioning. In fact, there are three different kinds of the sub block partitioning schemes: adjacent, interleaved, and pseudo-random. Among these, the pseudo-random one has been known to provide the best performance [18]. As discussed above, the PTS technique suffers from the complexity of searching for the optimum set of phase vector, especially when the number of sub blocks increases. In the literature, various schemes have been proposed to reduce this complexity.
III. SIMULATION STUDIES

SIMULATION RESULTS FOR OFDM WITH 16-QAM:
1) No. of bits transmitted = 960000
2) No. of Carriers: 64
3) coding used: Convolutional coding
4) Single frame size: 96 bits
5) Total no. of Frames: 10000
6) Modulation: 16-QAM
7) No. of Pilots: 4
8) Cyclic Extension: 25%(16)

In this part we explore Mat lab simulation results of discussed methods in the previous chapters, here most results represented as CCDF of PAPR which studied in We consider 1024 OFDM with 84 useful data subcarriers and 16 QAM modulations which is oversampled by 4 times. Pilot subcarriers are set as known value 1 in the whole simulations. The performance of the proposed modified PAPR Reduction techniques is evaluated by Complementary Cumulative Distribution Function (CCDF) of PAPR with respect to threshold PAPR0. The CCDF or Pr[PAPR > PAPR0] denotes the probability of the signals having a PAPR greater than threshold PAPR0. The CCDF of PAPR performance of the proposed technique is investigated by 16 subcarriers OFDM- system as shown in Figure.

Figure 5. Successive Results pertain to transmit symbols before IFFT using symbol rate sampling.
Figure 6. Successive Results pertain to receiver symbols after FFT using symbol rate sampling.

Figure 7. Successive peak Results pertain to Squared Absolute transmit symbols after IFFT showing peaks without PAPR suppression.

Figure 8. Successive peak Results pertain to transmit symbols after IFFT showing peaks without PAPR suppression.

Figure 9. The performance of OFDM PAPR with Without Reduction Amplitude Clipping.
IV. COMPARISON BETWEEN THREE PAPR REDUCTION TECHNIQUES

To make a fair comparison between the three PAPR reduction techniques PAPR at CCDF of 10-3 and 10-5 is listed in Table 1.

<table>
<thead>
<tr>
<th>Reduction Techniques</th>
<th>PAPR at CCDF of 10^{-3} (dB)</th>
<th>PAPR at CCDF of 10^{-5} (dB)</th>
<th>Difference of PAPR Reduction (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clipping Technique</td>
<td>8.94</td>
<td>11.1</td>
<td>2.94</td>
</tr>
<tr>
<td>Selected Mapping</td>
<td>9</td>
<td>10.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Partial Transmit Sequence</td>
<td>8.93</td>
<td>7.5</td>
<td>1.43</td>
</tr>
</tbody>
</table>

Table 2 gives the comparison on Performance measure of PAPR Reduction Technique.

<table>
<thead>
<tr>
<th>Name of schemes</th>
<th>Name of parameters</th>
<th>Distortion Less</th>
<th>Power Increase</th>
<th>Data rate Loss</th>
<th>Computational Complexity</th>
<th>Distortion Less</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude clipping</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Amplitude clipping</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Partial Transmit Sequence (PTS)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>M IFFT, WM-1complex vector sum</td>
<td>Side information extraction, inverse PTS</td>
<td></td>
</tr>
<tr>
<td>(SLM)</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>U IFFT</td>
<td>Side information extraction, inverse SLM</td>
<td></td>
</tr>
</tbody>
</table>
V. CONCLUSION

The high throughput OFDM signal high PAPR problems are solved by the proposed methods of Modified Interleaving technique, Modified Selected Mapping technique, Modified Partial Transmit Sequences technique and Modified Tone Reservation technique. The analysis based on varying the number of subcarriers, transmit antennas and users indicated that the proposed technique has the high PAPR reduction capability compared with the conventional techniques. This grade is achieved at the cost of slight decrease in the data rate and a negligible degradation in the bit error performance of the system. With the help of proposed Modified Interleaving, Selected Mapping, Partial Transmit Sequences techniques BER degradations performance is improved. Based on PAPR reduction performance comparison, Modified Tone Reservation provides the best result.

REFERENCES