Orthogonal Frequency Division Multiplexing (OFDM) system is a multicarrier system used to transfer data at high rates. This system offers advantages due to its high data rates and resistance to fading channels. However, one of the major problems associated with OFDM systems is the high Peak to Average Power Ratio (PAPR), which can lead to severe degradation in performance.

**I. INTRODUCTION**

Orthogonal frequency division multiplexing is a very attractive technique for the transmission of high-bit-rate data in wireless communication systems due to several advantages, such as better utilization of the available bandwidth and the ability to transmit multiple channels simultaneously. OFDM systems are widely used in wireless communication systems to increase data rates, but they suffer from the problem of high PAPR, which is a well-known signal processing topic in OFDM systems. This degradation problem occurs because OFDM signals are the sum of many narrowband signals. The high PAPR degrades the system's performance as it can cause inter-modulation and out-of-band radiation. To overcome this problem, the transmission amplifier must operate within its linear region to avoid spectral distortion and the degradation of Bit-error-rate (BER). Therefore, it is very essential to reduce the PAPR of OFDM signals.

**II. PEAK-TO-AVERAGE POWER RATIO**

Peak to average power ratio is a signal property that is calculated by dividing the peak power amplitude of the waveform by the RMS value of the waveform. This dimensionless quantity, referred to as the PAPR, is defined as follows:

\[
\text{PAPR} = \frac{\max(|S[n]|^2)}{\mathbb{E}[|S[n]|^2]} , \quad 0 \leq n \leq N-1
\]

Where \( S[n] \) represents the signal samples, \( \max(|S[n]|^2) \) denotes the maximum instantaneous power, and \( \mathbb{E}[|S[n]|^2] \) is the average power of the signal.

**III. PAPR REDUCTION METHOD**

PAPR reduction is a well-known signal processing technique used in multi-carrier transmission systems, and a large number of techniques have been proposed in the literature. These techniques include amplitude clipping and filtering, tone reservation (TR), coding, active constellation extension (ACE) and multiple signal representation methods such as selective transmission sequence (PTS) and selective mapping (SLM) [2].

**A. Selective Mapping (SLM)**

Selective mapping is based on the idea of generating multiple copies of the original signal through several series of codes. The copy of signal with the lowest PAPR is chosen for transmission. The side information (index of the
transmitted signal) is required at the receiver to recover the original signal. As the number of subcarrier increases, larger the set of codes required to obtain a required PAPR (5-6dB). High-computational complexity and need to transmit side-information have been criticized in the original SLM [5]. Many efficient variants have emerged recently.

In selected mapping method, firstly $M$ statistically independent sequences which represent the same information are generated, and next, the resulting $M$ statistically independent data blocks $s_m$ as in equation (2)

$$s_m = [S_m,0,S_m,1,...,S_m,N-1]T, \quad m=1,2,...,M$$  

(2)

then forwarded into IFFT operation simultaneously. Finally, at the receiving end, OFDM symbols:

$$x_m = [x=1, 2, 4, 4, 5, 6, 7, 8, 9,...,13]T$$

In discrete time-domain are acquired, and then the PAPR of these $M$ vectors are calculated separately. Eventually, the sequences $x_m$ with the smallest PAPR will be elected for final serial transmission. Fig.1 illustrates the basic structure of selected mapping method for suppressing the high PAPR.

This method can significantly improve the PAPR performance of OFDM system. The reasons behind that are: Data blocks $S_m=[S_m,0,S_m,1,...,S_m,N-1]T$, $m=1,2,...,M$ are statistical independent, assuming that for a single OFDM symbol, the CCDF probability of PAPR larger than a threshold is equals to $p[1]$. The general probability of PAPR larger than a threshold for $k$ OFDM symbols can be expressed as $pK$. It can be verified that the new probability obtained by SLM algorithm is much smaller compared to the former. Data blocks $S_m$ are obtained by multiplying the original sequence with $M$ uncorrelated sequence $P_m$. In the reality, all the elements of phase sequence $P1$ are set to 1 so as to make this branch sequence the original signal.

**B. Phase Transmit Sequence (PTS)**

In the PTS technique, an input data block of $N$ symbols is partitioned into various sub-blocks. The subcarrier in each sub-block are weighted by a phase factor for that sub-block. The phase factors are selected in such a way that the PAPR of the combined signal get minimize.

In conventional PTS approach, it is required to calculate the PAPR value at each step of the algorithm, which will introduce tremendous trials to achieve the optimum value of PAPR. Then after, to make the receiver to identify different phases, phase factor $b$ is required to send the receiver as sideband information (usually the first sub-block $b1$, is set to 1). The optimization is achieved by searching thoroughly for the best phase factor. Theoretically, $b=[b1, 2, ...]$ is a set of discrete values, and number of computation will be required for the OFDM system when this phase collection is very large.

![Fig. 1. Basic principles of selected mapping [4]](image1)

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![Fig. 2 Block diagram of PTS algorithm [4]](image2)

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Fig. 2 is the block diagram of PTS algorithm. At first, the data information in frequency domain $X$ is separated into $V$ non-overlapping sub-blocks and each sub-block has the same size $N$. Hence, we know that for every sub-block, it contains $N/V$ nonzero elements and set the rest part to zero. Each sub-block vector is given by:

$$\bar{X} = \sum_{v=1}^{V} b_v X_v$$  

(4)

where, $b_v = e^{j\theta_v} (\theta_v \in [0,2\pi]), \{v = 1,2,3,4, \ldots, V\}$

$b_v$, is a weighting factor been used for phase rotation. Time domain signal $X$ is obtained by applying IFFT operation on $\bar{X}$, that is:
\[ X = \text{IFFT}(\hat{X}) = \sum_{v=1}^{V} b_v \text{IFFT}(X_v) = \sum_{v=1}^{V} b_v X_v \]  
(5)

Select one suitable factor combination \( b = [b_1, b_2, ..., b_V] \) which makes the result optimum. The combination can be given by:

\[ b = [b_1, b_2, ..., b_V] = \arg\min_{(b_1, b_2, ..., b_V)} \left( \max_{1 \leq m \leq N} \left| \sum_{v=1}^{V} b_v X_v \right|^2 \right) \]  
(6)

In this way we can find the best \( b \) so as to optimize the PAPR performance. The additional cost we have to pay is the extra \( V-1 \) times IFFTs operation.

IV. SIMULATION RESULTS

The PAPR reduction performance is evaluated by the Cumulative Complementary Distributive Function (CCDF). In order to analyze the PAPR reduction of OFDM system we compared here both PTS and SLM technique, simulation has been performed using MATLAB 2013a. The number of sub-carriers employed is 64, number of OFDM symbols 10000, number of sub-band \( N=64 \), and oversampling factor \( L=4 \). In Figure 3, Based on the principles of PTS algorithm, it is apparent that the ability of PAPR reduction using SLM is affected by the route number \( M \) and subcarrier number \( N \). Therefore, simulation with values of \( M \) and \( N \) will be conducted.

![Fig. 3 Prediction Curve of PTS technique](image)

![Fig. 4 Performance of SLM Technique in OFDM system.](image)

![Fig. 5 Prediction Curve of SLM technique](image)

**Table 1. Observation Table for PTS Technique**

<table>
<thead>
<tr>
<th>Used Parameter</th>
<th>CCDF ((P_r))</th>
<th>Original OFDM</th>
<th>PTS-PAPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK Modulation with AWGN Channel</td>
<td>(10^{-1})</td>
<td>8.6 dB</td>
<td>4.0 dB</td>
</tr>
<tr>
<td></td>
<td>(10^{-2})</td>
<td>9.6 dB</td>
<td>4.5 dB</td>
</tr>
<tr>
<td></td>
<td>(10^{-3})</td>
<td>10.4 dB</td>
<td>5.1 dB</td>
</tr>
</tbody>
</table>

**Table 2. Observation Table for SLM Technique**

<table>
<thead>
<tr>
<th>Used Parameter</th>
<th>CCDF ((P_r))</th>
<th>Original OFDM</th>
<th>SLM-PAPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK Modulation with AWGN Channel</td>
<td>(10^{-1})</td>
<td>8.60 dB</td>
<td>6.45 dB</td>
</tr>
<tr>
<td></td>
<td>(10^{-2})</td>
<td>9.80 dB</td>
<td>6.70 dB</td>
</tr>
<tr>
<td></td>
<td>(10^{-3})</td>
<td>10.80 dB</td>
<td>7.00 dB</td>
</tr>
</tbody>
</table>
V. CONCLUSION

The CCDF of PAPR is obtained by MATLAB simulation. It can be clearly seen that the proposed PTS technique has better PAPR performance when compared to the original OFDM methods. It has been observed that the original signal has a high PAPR value of 10.4dB. The Partial Transmit Sequence technique (PTS) reduces the PAPR value to about 5.1dB. By regression analysis too, we can see that PTS results are much better than SLM technique. Value of $R^2$ is 0.999 for PTS and 0.998 for SLM.

REFERENCES


