Performance Analysis of SC-FDMA with Piecewise Linear Companding over Various Fading channels

Ajay Thammana¹, J.Ramesh², R.Uma Maheswari³

¹,²,³ Department of ECE. VIIT
Visakhapatnam, India

ajay.thammana@gmail.com, jramesh49@gmail.com, maheswaru.ramisetty@gmail.com

Abstract

Orthogonal FDM (OFDM) is an exciting method for typical applications those require huge degree of data rates. Because of the excessive PAPR, the complexity of HPA and in addition DAC moreover will growth. For the reduction of PAPR in OFDM several strategies are to be had. Among them Companding is an appealing low multifaceted way for the OFDM alerts PAPR diminishment. As of overdue, a Piecewise linear companding approach is prescribed going for limiting companding contortion. In this paper, an aggregate Piecewise linear companding (PLC) method and Discrete Fourier Transform (DFT) approach is relied upon to reduce PAPR of OFDM to a top notch extent. Simulation outcomes suggests approximately show off this new proposed method acquires noteworthy PAPR lower even as keeping up improved overall performance in the Bit Error Rate (BER) in comparison to piecewise linear companding approach without PSD overall performance degradation.

Key Words: Orthogonal FDM; Peak to Average Power Ratio;
1. Introduction

Orthogonal FDM is an adjustment arrangement that is being utilized by many of the latest wireless and additionally telecommunications standards. A substantial number of nearly dispersing sub-carrier signals those are orthogonal to each other are utilized to convey information on a several parallel information paths or channels. Significant preferences of OFDM is that the Receiver has low complexity, discovers applications which require high information rate applications, give invulnerability to ISI by utilizing cyclic prefix than single carrier systems, no requirement for utilizing bank of oscillators. It permits synchronous transmission of subcarriers over a typical channel, in this manner making effective utilization of accessible range, brings about high Spectral Efficiency. Because of its antagonistic advantages, it finds the applications in Digital Audio Broadcasting (DAB), IEEE 802.11(Wireless LAN), MBWA (IEEE802.20), DSL and ADSL Modems, DRM and Wireless Metropolitan Area Networks (WMAN) and in addition DVB-T.

A couple of systems are developed to address the problem of PAPR in OFDM signals [1,2]. In these techniques, companding plans secure thought in light of their versatility and straightforwardness. The possibility of μ-law companding framework was at first introduced in [3-6]. Later on, Exponential Companding (EC) was made in [7], which can upgrade diminishment of OFDM's PAPR by adjusting the scattering (conveyance) of OFDM signs while keeping normal power remains reliable. Starting late, another nonlinear companding strategy is proposed [8] which changes the Gaussian distribution motion into linear. This nonlinear companding system reduces the PAPR of OFDM signal to a weakness of high computational multifaceted nature. By then Two Piecewise Companding (TPWC) methodology proposed in [9] which pack broad signal amplitudes and develop minimal ones by using two particular piecewise limits. In all above companding systems, it diminishes PAPR by making companding curving. Starting late, a piecewise linear companding strategy was explored in [10] to lessen the reduction in companding distortion. The DFT Precoded structure (SC-FDMA) is better than anything diverse precoders in lessening PAPR and moreover it gives change in BER execution of the basic OFDM at the same BER [11].

In this, the paper is offevolved with the preface of the subject in zone 1. Portion 2 displays a problem or drawback of OFDM (i.e.) PAPR. Territory 3 offers signal preparing steps to realize a PAPR diminish by method for joining PLC Transform and DFT. MATLAB Simulated outcomes are introduced in area 4 ultimately the paper concluded in 5.
2. Problem in OFDM-PAPR

Predominantly, $M$ number of data symbols those are independent are going to be mapped by using available baseband modulation schemes. In a general sense, OFDM signal is described as the sum of these $M$ modulated symbols of independent nature. Thus oversampled OFDM symbols in time-domain

$$y_n = \frac{1}{\sqrt{ML}} \sum_{k=0}^{M-1} Y_k e^{j2\pi kn/ML}, \quad 0 \leq n \leq ML-1$$

(1)

Where time index ranging from $n = 0, 1, \ldots, LM-1$.

Usually, Up-sampling factor ($L>=4$) is used to precisely portray the PAPR. For ensuring the Nyquist criteria ($L-1)M$ zeros are infused in the centre of the OFDM signal of $M$ length vector, i.e.

$$Y_e = \begin{bmatrix} Y_0, Y_1, \ldots, Y_M, \ldots, 0, \ldots, 0, Y_M, \ldots, Y_{M-1} \end{bmatrix}^T$$

(2)

We can say that $y = \text{IFFT}_{LM} \{y_e\}$. By taking these into consideration, real and imaginary parts of the OFDM signal $|y_n|$, it approaches a Rayleigh distribution

$$f_{|y_n|}(y) = \frac{2y}{\sigma^2_y} e^{-\frac{y^2}{2\sigma^2_y}}, \quad y \geq 0.$$  

(3)

As from (3), now the CDF of $|y_n|$ is related as

$$F_{|y_n|}(y) = \text{Pr} \{ |y_n| \leq y \} = \int_0^y \frac{2y}{\sigma^2_y} e^{-\frac{y^2}{2\sigma^2_y}} dy = 1 - e^{-\frac{y^2}{2\sigma^2_y}}, \quad y \geq 0$$

(4)

With this the Peak to Average Power Ratio of OFDM is

$$\text{PAPR}_y = \frac{\max_{n \in [0,LM-1]} |y_n|^2}{E\left[|y_n|^2\right]}$$

(5)

It is necessary to consider the PAPR of OFDM system as an arbitrary variable and characterize the statistical depiction adapted by the Complementary CDF (CCDF), expressed as the likelihood that the PAPR of signal $(x)$ surpasses a relegated level

$$CCDF_{y_0}(y_0) = \text{Pr} \{ \text{PAPR}_y > y_0 \} = 1 - (1 - e^{-y_0})^N$$

(6)
The piecewise linear companding technique (PLC) is explained [9] in Fig. 1.

![Schematic of PLC Transform](image)

**Figure 1. Schematic of PLC Transform**

### 3. Suggested Strategy

In this section, a crossover companding strategy (DFT precoding OFDM with PLC) is proposed to diminish the Problem caught in OFDM sign by method for joining DFT and PLC. To start with the approaching information changed through making utilization of Discrete Fourier Transform, after which this changed over data is actualized as contribution to IFFT sign preparing module. The OFDM framework with proposed approach is demonstrated in Figure 2.

The proposed system processing steps are given below:

**Step 1:** The input sequence Y is applied to DFT Transform i.e. \( Z = HY \)

Here H is the DFT precoding Transform.

![Proposed method's Block diagram](image)

**Figure 2. Proposed method’s Block diagram (DFT Precoded OFDM with PLC Transform)**
Step-2: Applying Inverse FFT to DFT transformed output signal
\[ z = \text{ifft}(Z) \]
\[ z_n = \frac{1}{\sqrt{NL}} \sum_{k=0}^{N-1} Z_k e^{j2\pi kn/N}, \quad 0 \leq n \leq NL-1 \] (8)

Step-3: Now perform PLC transform to y, i.e. \( r(n) = C \{ z(n) \} \)
\[
\begin{align*}
  r(n) &= C \{ z(n) \} = \begin{cases} 
    z(n) & |z(n)| \leq A_j, \\
    mz(n) + A_k (1 - p) & A_j < |z(n)| \leq A_k, \\
    A_k \text{sgn}(z(n)) & |z(n)| > A_k
  \end{cases}
\end{align*}
\] (9)

This signal is passing through medium.

Step-4: Perform Inverse PLC transform to the signal received at Receiver section \( s(n) \), i.e \( z'(n) = C^{-1} \{ s(n) \} \)
\[
\begin{align*}
  z'(n) &= C^{-1} \{ s(n) \} = \begin{cases} 
    s(n) & |s(n)| \leq A_j, \\
    (s(n) + (p - 1)A_j)/p & (1 - p)A_j < |s(n)| \leq A_k, \\
    A_k \text{sgn}(s(n)) & |s(n)| > A_k
  \end{cases}
\end{align*}
\] (10)

Step-5: Now perform FFT to this signal \( z'(n) \) (i.e.) \( Z' = \text{fft}(z') \)

Step-6: Lastly do the IDFT to this signal.

4. Results

MATLAB simulated results are conferred to assess the execution of the proposed procedure with reference to the Peak to Average Power Ratio diminishment, BER and also PSD execution. In this number of subcarriers to be taken are 256 and the over-sampling factor should be 4 with reference to the specifications of WiMAX (IEEE 802.16). M-ary QAM (M=4, 16, 64, 256) is adopted as mapping strategy here.

This SSPA model is formulated by
\[
|y(t)| = \frac{|x(t)|}{1 + (\frac{|x(t)|}{Z_{sat}})^{2k}}^{1/2k}
\]

Where \( Z_{sat} \) is the saturation level and Knee factor \((k)=2\).

A. Reduction in PAPR Capabilities

The PAPR improved characteristics of the proposed method along with the existing systems are simulated by using CCDF
allowing 4-QAM, 16-QAM and 64-QAM are used as the mapping methodologies are depicted in the Figures 3 and 4.

![Figure 3](image1.png)

**Figure 3.** CCDF plot of proposed system along with conventional systems with 4-QAM, 16-QAM

![Figure 4](image2.png)

**Figure 4.** CCDF plot of proposed system along with conventional systems with 64-QAM

Table-1 tabulates the PAPR estimations for this proposed framework in comparison with existing systems over M-QAM (M=4, 16, 64, 256)
### TABLE I: improvement in PAPR by proposed system

<table>
<thead>
<tr>
<th></th>
<th>4-QAM</th>
<th>16-QAM</th>
<th>64-QAM</th>
<th>256-QAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFDM</td>
<td>9.40</td>
<td>8.01</td>
<td>7.73</td>
<td>8.24</td>
</tr>
<tr>
<td>OFDM along with PLC Transform (PAPRReset=4dB)</td>
<td>5.16</td>
<td>5.09</td>
<td>5.16</td>
<td>5.09</td>
</tr>
<tr>
<td>OFDM along with PLC Transform (PAPRReset=4.5dB)</td>
<td>5.49</td>
<td>5.41</td>
<td>5.47</td>
<td>5.46</td>
</tr>
<tr>
<td>OFDM along with PLC Transform (PAPRReset=5dB)</td>
<td>5.81</td>
<td>5.77</td>
<td>5.86</td>
<td>5.78</td>
</tr>
<tr>
<td>DFT Precoded OFDM with PLC (PAPRReset=4dB)</td>
<td>1.34</td>
<td>3.61</td>
<td>4.56</td>
<td>5.09</td>
</tr>
<tr>
<td>DFT Precoded OFDM with PLC (PAPRReset=4.5dB)</td>
<td>1.12</td>
<td>3.52</td>
<td>4.48</td>
<td>5.02</td>
</tr>
<tr>
<td>DFT Precoded OFDM with PLC (PAPRReset=5dB)</td>
<td>1.06</td>
<td>3.43</td>
<td>4.40</td>
<td>4.95</td>
</tr>
</tbody>
</table>

The worthwhile observations from these figures and Table is that the proposed strategy can draw great PAPR decrease as compared to existing methodology.

B. Improvement in Bit Error Rate Statistics

The proposed system’s improved BER performance be depicted here along with the available existing system over M-ary QAM (M=4, 16) under Additive WGN Channel and figured in Figure-5.

![Figure 5](image)

Figure 5. Proposed system’s Enhanced BER in comparison with existing system using 4-QAM and 16-QAM

From this, the loved comment is that the BER execution is enhanced with FOUR-QAM regulation, with the current proposed strategy.

Fig.6 delineates the BER execution with 4-QAM, 16QAM as mapping alongside SSPA going through an AWGN channel.
Figure 6. Proposed system’s Enhanced BER in comparison with existing system using 4-QAM and 16-QAM including Solid State Power Amplifier

Significant perception from these is that the BER execution of this proposed strategy with Solid State Power Amplifier is adequate as well.

Figure 7 delineate the Bit Error Rate execution of this proposed strategy under SUI channels, those are the Standardized Multi path fading channels as per Stanford University Interim.

(a) SUI-1 Channel
(b) SUI-2 Channel
Figure 7. Proposed system's Enhanced BER in comparison with existing system using 4-QAM under SUI

The worthwhile observations from the results obtained from Figure 7 that this proposed strategy enhances the BER improvement over SUI Channels

C. Improved PSD performance

The proposed system’s improved Power Spectral Density performance be depicted here along with the available existing system over M-ary QAM (M=4, 16, 64) and figured in Figures 8, 9.
5. Conclusion

In this paper, a new tactic is recommended to diminish the P to AP Ratio of OFDM and MATLAB simulated results stood out from the current PLC Transform framework. The value of PAPR is blurred by 4 dB while utilizing the preset (esteem) as 5 (in dB). The Bit Error Rate performance underneath an Additive Gaussian channel (AWGN) using 4-QAM is enhanced by 0.5dB and furthermore holding up a practically identical execution with 16-QAM additionally. This system also exhibits BER execution improvement over the present system under SUI channels additionally also. The change in BER execution and PAPR diminishment are refined without surrendering the PSD execution debasement.
References


