AN EFFECTIVE APPROACH TO REDUCE PAPR AND IMPROVED OBI IN OFDM SYSTEM USING ICTF

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Abstract

OFDM is widely used in wireless communication due to its multiple carrier uses. There are some considerable drawbacks in OFDM system which degrades the performance of OFDM system. One of the most drawback is its high PAPR. PAPR reduction in OFDM modulation scheme attains attention because of its high application ability. Tremendous work carried out in literature to solve the issue of PAPR but none can meet the desired result. Iterative companding transform and filtering is implemented in this work which achieves reliable trade-off between PAPR reduction and BER performance. Low OUT-OF-BAND interference is another significant approach of proposed work. Simulation results show good performance and reliable efficiency over traditional state of methods.

Keywords: ICTF, PAPR, BER, OUT-OF-BAND interference.

1. INTRODUCTION

OFDM is also known as parallel transmission system. OFDM is known as multiplexing/modulation scheme and it acts on the “orthogonality principle”. With the help of more number of sub-carriers the high data signal is divided into small chunks and transmitted in parallel fashion.

OFDM offers high data and supports advance applications. Inter-modulation among sub-carriers and undesired Out-of-Band Interference (OBI) are the resultant of PAPR. PAPR is produced due to high nonlinear distortions. Due to this type of nonlinear distortions power requirement increased to an enormously high level.

PAPR presence has been area of concern in OFDM and vast amount of research has been carried out using different techniques like Clipping and Filtering (CF), Tone Reservation (TR), Companding Transform (CT), etc. But none of the above techniques succeed in achieving the desired result. Clipping and filtering technique architecture is easy to implement and desired complex system.

In the paper, enlightened by the iterative filtering approach in ICF method, an Iterative CT and Filtering (ICTF) technique is proposed for reducing the PAPR of OFDM signal. By using an iterative procedure, ICTF can obtain a significant PAPR reduction as well as an improved BER performance simultaneously. Moreover, to tackle with the OBI issue, a frequency-domain filtering is adopted for minimizing the out-of-band spectral regrowth. In addition, when compared to classic ICF method, ICTF dramatically decreases the number of required iterations to obtain a desired PAPR with lower
computation complexity. Specifically, it is shown that the ICTF without de-compressing operation at the receiver offers a good BER performance.

2. PROPOSED METHOD

(A) DESCRIPTION OF PROPOSED METHOD

International telecom union for radio frequencies (ITU-RF) has approved the bit error rate (BER) as performance evaluation parameter to get desired statistics of the signal. In OFDM, BER is gradually declined due to companding distortion and the sudden declination in BER performance is due to signal attenuation factor which compresses the original symbols. Minimization of OBI is another prominent factor to be considered and to successfully handle the problem of OBI a frequency-domain filtering is utilized in the latter stage. The proposed method is compared with the ICF for more convenience. And it is shown that the complexity of proposed ICTF is less than ICF due to less iterations.

Figure 1: Iterative companding and transform technique and its mechanism

Here two constants \( S_1 \) and \( S_2 \) are used to switch the single and multiple operations in respective iteration level. If \( S_1 \) value is set to 1, then OFDM symbol \( X \in C^{IN} \) is given as input to ICTF at the iteration, \( M=1 \) and these iterations are processed based on symbol-by-symbol process. In case, if both \( S_1 \) and \( S_2 \) are set to 2, then in that stage both companding and ICTF are used for the same ODFM symbol. In last iteration both constants values are set to 1 again to get the output as \( \tilde{X}^m \in C^{IN} \) respectively. Assume \( c^m \in C^{IN} \) and \( \tilde{c}^m \in C^{IN} \) represented the frequency-domain OFDM symbol at \( m \)th iterative level (before and after filtering process).

The proposed method ICTF for the reduction of PAPR is shown in figure area as follows

Figure 2: Proposed block diagram

The proposed method intends to decrease the PAPR impact and achieves improved OBI performance. The presence companding noise and channel noise results in companding distortion. Finally BER analysis is carried out using companding distortion. Two
companding transform techniques is initialized by linear (LST) companding transform technique and non linear companding scheme (TPCW).

(i) Linear symmetrical transform (LST)

Linear symmetrical transform (LST) is a companding transform profile and its respective companding transform function is as follows

\[ f(x) = (k|x| + b) \cdot \text{sgn}(x) \quad (1) \]

The above equation is composed of sign function and two parameters. These parameters are used to specify companding profile. PAPR reduction and improved BER is achieved by selecting the parameters in linear regions of companding profile. Average power alternation is concerned area in companding transform and by using \( k^2 + \sqrt{\pi} \cdot \frac{kb}{\sigma} + \frac{b^2}{\sigma^2} = 1 \) is used to maintain the average power in unchanged form. The decompanding function is notated as follows

\[ f^{-1}(x) = \frac{|x| - b}{k} \cdot \text{sgn}(x) \quad (2) \]

The PAPR and the transform gain \( G \) is defined as the ratio of the PAPR of original symbol to that of the compounded symbol are as follows

\[ \text{PAPR}_{LST}(dB) = 10\log \max_{n \in [0, N-1]} \left| \frac{1}{\sqrt{N-1}} \sum_{n=0}^{N-1} |y_n|^2 \right| \]

\[ = 20\log \left( \frac{k \cdot V + b}{\sigma} \right) \quad (3) \]

\[ G_{LST}(dB) = 10\log \frac{\text{PAPR}_{orig}}{\text{PAPR}_{LST}} \]

\[ = 20\log \left( \frac{V}{k \cdot V + b} \right) \quad (4) \]

(ii) Two-Piecewise Companding (TPWC)

There are four classified companding transform profiles in both linear and non-linear way. Linear Nonsymmetrical Transform (LNST) has achieved best results in terms of PAPR reduction and BER performance over remaining companding transform profiles. The companding function is as follows

\[ f(x) = \begin{cases} \frac{1}{u_1} |x| \cdot \text{sgn}(x), & |x| \leq v \\ \frac{1}{u_2} (|x| - s) \cdot \text{sgn}(x), & |x| > u_1v \end{cases} \quad (4) \]

For \( u_1 > 1, 0 < u_2 < 1, s = (u_1 - u_2)v > 0, and 0 \leq v \leq V \) is the cutoff point with \( V = \max_{0 \leq \lambda < 1} \left| x_n \right| \) with maximum value \( V = \max_{0 \leq \lambda < 1} \left| x_n \right| \)

The decompanding function of TPWC is given by

\[ f^{-1}(x) = \begin{cases} \frac{1}{u_1} |x| \cdot \text{sgn}(x), & |x| \leq u_1v \\ \frac{1}{u_2} (|x| - s) \cdot \text{sgn}(x), & |x| > u_1v \end{cases} \quad (5) \]

The relationship between \( \lambda, u_1, u_2 \) is carried out using above notations and three sets of parameters are shown in following Table.

### Table 1

<table>
<thead>
<tr>
<th>( \lambda )</th>
<th>1.20</th>
<th>1.60</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>( u_1 )</td>
<td>1.143</td>
<td>1.041</td>
<td>1.009</td>
</tr>
<tr>
<td>( u_2 )</td>
<td>0.13</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td>( v )</td>
<td>1.2\sigma</td>
<td>1.6\sigma</td>
<td>2.0\sigma</td>
</tr>
<tr>
<td>( s )</td>
<td>1.216\sigma</td>
<td>1.457\sigma</td>
<td>1.738\sigma</td>
</tr>
</tbody>
</table>

For a single TPWC-CT approach, Its achievable PAPR is given by

\[ \text{PAPR}_{TPWC}(dB) = 20\log \frac{u_2V + s}{\sigma} \quad (6) \]
The corresponding transform gain $G$ is written by

$$G_{TPWC}(dB) = 20\log \frac{V}{u_2V + s} \quad (7)$$

(B) COMPANDING DISTORTION ANALYSIS

(i) Companding noise

The BER performance in ICTF procedure is investigated. Based on Bussgang theorem for real and complex Gaussian Signal, the companded signal can be approximately decomposed into two parts: the attenuated signal component and companding noise, $\rho_n$, i.e. $y_n = SAF \times x_n + \rho_n$. Thus, the transmitted symbol with ‘m’ iterations using ICTF can be approximately decomposed as $x_n^m = SAF^m \times x_n + \rho_n$.

(ii) Channel noise

Improved BER is achieved even in the absence of decompanding operation at receiver end. The necessary theoretical analysis as follows;

(a) ICTF-LST

At receiver end, When decompanding operation is performed and if $m=1$ (Iteration 1) the received signal is as follows

$$\hat{x}_n = f^{-1}(f(x_n) + \omega_n) = x_n + \omega_n/k \quad (8)$$

Where, $\omega_n =$ channel noise

If number of iterations increased then it results in noise,

$$e_n^m = |\omega_n/k^m| \quad (9)$$

As a result, it is preferable to abandon the decompanding at the receiver. It is noteworthy that this is quite advantageous for practical OFDM systems.

(b) ICTF-TPWC

ICTF-TPWC analysis is carried out in same way as ICTF-LST. Assuming that $m$ iterative decompanding operations are performed at the receiver, the recovery error is approximately given by

$$e_n^m = \left\{ \begin{array}{ll} |\omega_n/u_1^m|, & ne\phi_1(v) \\ |\omega_n/u_2^m|, & ne\phi_2(v) \end{array} \right. \quad (10)$$

3. RESULTS AND ANALYSIS

Assume that, the number of subcarriers is $N=128$ using quaternary phase shift keying (QPSK) or 16 Quadrature amplitude modulation (16-QAM). Over sampling $j=4$ is used in proposed work to accurate PAPR estimation. BER performance is analyzed in both the AWGN channel and multipath fading channels (RACIAN and SUI) are applied. A CP with length of $1/4$ symbols is inserted to control ICF.

ICTF achieves better PAPR reduction (6.57dB PAPR reduction is achieved) over traditional CT techniques and ICF.

The impact of PAPR reduction technique on OFDM system is observed using BER and OBI.

Figure 3: Transform profiles of LST, classic LNST, and TPWC
Figure 4: Theoretical transform Gain in PAPR

Figure 5: CCDF statistics of OFDM symbol for different PAPR-reduction schemes (N=1024, QPSK, and the over-sampling ratio J=4)

Figure 6: Performance analysis of PAPR reduction approaches under AWGN channel (N=128, QPSK)

Figure 7: Performance analysis of PAPR reduction approaches under AWGN channel (N=128, 16-QAM)

Figure 8: Performance analysis of PAPR reduction approaches under Rician channel environment (N=128, QPSK)
ICTF is proposed successfully and obtained reduced PAPR is shown theoretically as well as with simulation. ICTF is an equipped approach has ability to reduce PAPR and improved BER performance. Both AWGN channel and SUI channel for reliability and efficiency. ICTF achieves good results over conventional techniques. The proposed ICTF technique not only obtains significant PAPR reduction with improved BER and OBI performance, but also dramatically decreases the iterations number. The same work is done with the very less number of iteration so its complexity is also very less. In addition, ICTF procedure can also be extended to other well known linear and nonlinear companding profiles.

REFERENCES


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