REVIEW OF PAPR REDUCTION IN OFDM SYSTEM USING ACTIVE CONSTELLATION EXTENSION

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Abstract- The main problem of using OFDM system is high peak to average power ratio (PAPR). There are various methods available to reduce PAPR, some of them are distortion less and some methods cause distortion in original signal. Due to distortion actual data may get lost. Reducing PAPR by active constellation extension is one of the best method available. In this method, constellation points which contribute to high PAPR are extended. We can reduce the PAPR very effectively without disturbing the original signal & there is no need to send side information. This paper present algorithms to reduce PAPR using active constellation extension.

Keywords- OFDM; PAPR reduction; ACE; FFT; IFFT, constellation shaping, ISI

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing is a multi-carrier system. In this a single carrier is divided into number of sub-carriers. These sub-carriers are orthogonal to each other, this helps to reduce ISI effect and full bandwidth is utilized. OFDM is of great interest by researchers and research laboratories all over the world because it gives high data rate.

A. Major advantages of OFDM systems are:
- High spectral efficiency due to nearly rectangular frequency spectrum for high numbers of sub-carriers.
- Simple digital realization by using the FFT operation.
- Less complex receivers due to the avoidance of ISI with a sufficiently long cyclic prefix.
- Different modulation schemes can be used on individual sub-carriers which are adapted to the transmission conditions on each sub-carrier.

Due to above advantages it has already been accepted for the new wireless local area network standards IEEE 802.11a, High Performance LAN type 2 (HIPERLAN/2) and Mobile Multimedia Access Communication (MMAC) Systems. Also, it is expected to be used for wireless broadband multimedia communications.

But the major problem in OFDM system is high PAPR (peak to average power ratio). Due to orthogonal nature of sub-carriers, the magnitude of sub-carriers causes high peaks in magnitude. These peaks higher than the bandwidth of the filter, so the information present in the peaks may get lost. All the time it is not possible to change the bandwidth range of filter. So this PAPR problem of OFDM has been studied considerably and a number of techniques have been developed to reduce it.

Coding leads to satisfactory results, but it reduces the useful data rate, which is undesirable. SLM and PTS require side information. Clipping will cause loss of data. In active constellation extension, we extending the constellation points to reduce the peaks. In this paper new algorithm for ACE is discussed which is less complex as compare to other algorithms and gives satisfactory results

II. PAPR PROBLEM IN OFDM

- PAPR is generally used to characterize the envelope fluctuation of the OFDM signal and it is defined as the ratio of the maximum instantaneous power to its average power.

- Let the data block of length N be represented by a vector \( X = [X_0, X_1, \ldots, X_{N-1}]^T \). Duration of any symbol \( X_k \) in the set \( X \) is \( T \) and represents one of the sub-carriers \( \{f_n, n = 0, 1, \ldots, N-1\} \) set. As the \( N \) sub-carriers chosen to transmit the signal are orthogonal to each other, so we can have \( f_0 = 0, \Delta f = 1/NT \) and \( NT \) is the duration of the OFDM data block \( X \). The complex data block for the OFDM signal to be transmitted is given by \( X \). The PAPR of the transmitted signal is defined as

\[
x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi f_n t}, \quad 0 \leq t \leq NT,
\]

The PAPR of the transmitted signal is defined as

\[
PAPR = \frac{\max_{0 \leq t \leq NT} |x(t)|^2}{\frac{1}{NT} \int_0^{NT} |x(t)|^2 dt}
\]

Reducing the max \( |x(t)| \) is the principle goal of PAPR reduction techniques.
Effect of reduced PAPR in OFDM system –

Initially when original signal is transmitted without reducing PAPR, peaks are generated which are greater than normalized amplitude A (shown in blue color in above figure). The data present in these peaks may get lost.

In order to reduce data loss, if the same signal is transmitted using any scrambling technique to reduce PAPR, peaks gets reduced (shown in red color in above figure) and loss of data can be prevented.

III. ALGORITHM TO REDUCE PAPR USING ACTIVE CONSTELLATION EXTENSION

PROPOSED BLOCK DIAGRAM:

- Peak power reduction in this scheme is based on a simple metric calculation for the input symbols.
- Steps to reduce PAPR using this algorithm are as follows:

  i. The complex data symbol block \( a = (a_0, a_1, \ldots, a_{N-1}) \) is passed through an N-point IFFT to obtain the discrete time-domain samples to be transmitted.

  ii. The transmitted signal samples can be written as:

\[
b_m = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} a_m e^{j 2 \pi n m / N}
\]

Where,

\( a = a_0, \ldots, a_{N-1} \)

\( m = \) OFDM symbol index

\( a_m = \) data symbol transmitted over m th subcarrier

iii. With a large number of subcarriers the time-domain samples at the IFFT output can be modeled as truncated Gaussian random variables with zero mean. Thus, most of the magnitudes will be small (close to zero), but a very small percentage of them will have a very large magnitude. This results in the problem of PAPR from which multicarrier systems suffer considerably.

iv. The continuous-time PAPR can be approximated by employing the IFFT of the zero-padded input data sequence of length \( LN \), where \( L \) denotes the oversampling rate. Here in this case, we only investigated the case \( L = 1 \).

v. Constellation shaping consists of modifying the transmitted data symbol values without affecting the minimum distance and consequently the system bit error rate (BER).

vi. A metric is computed for each input data symbol which measures how this symbol contributes to the IFFT output samples with large values. More specifically, the metric indicates how much the peak values of the time-domain signal can be reduced by pre-distorting the symbol at hand without reducing minimum distance.

vii. The symbol metrics involve the magnitudes of the output signal samples \( s(n) = |b_n| \) and an appropriate measure of the angle between the output sample \( |b_n| \) and the contribution of symbol \( a_m \) to it, which is

\[ a_m e^{j \theta_m} \]

viii. The angle measure used in this algorithm is:

\[ f(n,m) = -\cos \theta_m \]

where, \( \theta_m \) is the angle between \( a_m e^{j \theta_m} \) and \( b_n \).

ix. Once the metric is computed for all input symbols of the block, the symbols are sequentially predistorted in the decreasing order of their metrics. The procedure stops when the peak power at the IFFT output stops decreasing.
The proposed algorithm involves five steps and can be summarized as follows:
1. Obtain the output sequence b via IFFT of the input data symbol block \( a = (a_0, a_1, \ldots, a_{N-1}). \)
2. For each sample \( b_n \) of the output sequence define a weighting function \( w(n) \), which is an increasing monotone function of its power.
3. For each input data symbol \( a_m \) compute the decision metric:
   \[
   \mu_m = \sum_{n=0}^{2^q-1} f^* (n, m) w(n),
   \]
   where, \( p \) & \( q \) are design parameters (with \( p \) odd)
4. \( \hat{B}_n = b_n + \frac{1}{\sqrt{N}} \sum_{k \in g} a_k e^{j2\pi m k / N} \), output as
5. 

IV. SIMULATION RESULTS

The performance of the proposed scheme for QPSK signaling is given.
In simulations, we considered the complex baseband representation of the OFDM signal and we used \( N = 256 \) subcarriers. The results are obtained by averaging over \( 10^6 \) randomly generated OFDM symbols.

The proposed scheme was applied when the PAPR is greater than 6 dB and the averaging is performed over all trials.

The design parameters \( p \) and \( q \) were taken as 1 and 6, respectively. Note that in PAPR calculation, the ratio of the peak power to the initial average power (before the application of the reduction algorithm) was taken into consideration.

The scaling values and the number of symbols to be modified were determined. Then, the results were presented as the Complementary Cumulative Distribution Function (CCDF) defined as

\[
\text{CCDF ( PAPR (b))} = \Pr \left( \text{PAPR (b)} > \gamma \right)
\]
which indicates the probability that the PAPR of a symbol block exceeds the threshold level \( \gamma^2 \).

- Figure (2) shows the change in the peak power as a function of the number of expanded data symbols with the expansion factor \( \alpha \) as parameter (solid-line curves).
- It also shows (dashed curves) the increase of the average signal power. We can see that the number of symbol pre-distortions which reduce the peak power is a function of the expansion factor.
- As can be seen on this figure, the optimum number of pre-distorted symbols is on the order of 20 for \( \alpha = 2 \) and on the order of 50 for \( \alpha = 1.3 \). The figure also shows that the largest peak power reduction is achieved for \( \alpha = 1.6 \) and 25 data symbols pre-distorted.
- For all values of \( \alpha \), the results indicate a reduction of the peak power by approx. 1.5 dB.

Figure (2): PAPR and average power vs. number of modified symbols for different scaling factors [2]

Fig. (3) shows the CCDF of the proposed scheme using the optimum \( \alpha \) and \( K \) parameters. The solid-line curve corresponds to conventional OFDM without any compensation and the dotted curve corresponds to the PAPR reduction technique proposed. These curves indicate that the improvement is on the order of 2.2 dB at the probability of \( 10^{-3} \) and of 2.7 dB at the probability of \( 10^{-5} \).

**FIG (3) : CCDF OF PAPR FOR CONVENTIONAL OFDM, AND THE PROPOSED SCHEME[2]**
CONCLUSION

In order to improve the performance of OFDM system, we discussed a algorithm to reduce the PAPR. Various results obtained from this algorithm are observed. These results are compared with the results got from other techniques. After comparison we came to know that the active constellation extension is one of the best technique to reduce PAPR. PAPR can be reduced upto 3 dB without distorting original data. We achieved our objectives through this method. It is simple and very effective method. If we could select more symbols at a time then rate of PAPR reduction also increases.

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