# Simplified Levenberg-Marquardt Algorithm based PAPR Reduction for OFDM System with Neural Network

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***Abstract***— In recent years, OFDM is the key transmission technique in the communication system. This is because of the high channel estimation, strong against multipath fading and increased spectral efficiency. Because of the independently modulated subcarriers, the Peak to Average Power Ratio (PAPR) is very high in OFDM systems. Previously we use a number of PAPR reduction schemes using clipping, adding windows etc. But in these methods we cannot achieve the optimum reduction or the BER performance is high or the system is very complex. On considering the BER performance and system complexity we employ a new method based on the Neural Network (NN). In this new method we achieve significant PAPR reduction with great BER improvement and complexity reduction. In the simulations we seen that the PAPR reduction and BER performance are very good.

***Keywords***-*OFDM,PAPR,Neural Network.*

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## I. INTRODUCTION

The basic principle of OFDM is to split a high-rate datastream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers [1]. Because the symbol duration increases for the lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath extended to avoid intercarrier interference.

Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak to average power ratio of this system. A large PAPR increases the complexity of the analog to digital and digital to analog converter and reduces the efficiency of the radio frequency (RF) power amplifier. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. This has a harmful effect on the battery lifetime. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value.

There are a number of techniques to deal with the problem of PAPR. Some of them are amplitude clipping, clipping and filtering, coding, partial transmit sequence (PTS), selected mapping (SLM) and interleaving. These techniques achieve PAPR reduction at the expense of transmit signal power increase, bit error rate (BER) increase, data rate loss, computational complexity increase, and so on.

Presence of large number of independently modulated sub- carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal. The major disadvantages of a high PAPR are-

- Increased complexity in the analog to digital and digital to analog converter.
- Reduction is efficiency of RF amplifiers.

From references [2] and [4], we select the advantages of the method Active Constellation Extension (ACE). The method includes iterative time domain clipping and frequency domain constellation point extensions. From the previous methodologies we see that ACE has a main drawback, the slow convergence and complexity. To avoid these disadvantages, methods [7], [3] and [8] are employed. From the analysis of these ideas we seen that, they are not effective or they are limited in a single class.

In [5], [9] and [10] new methods using the advantages of neural networks (NN) are introduced. On the analysis of these approaches we seen that, they have a number of advantages over the ACE scheme. But still the complexity is high. From the NN approaches explained above, [5] has an efficient performance over the other two methods. The methodology uses a TFNN scheme. We see that it reduces the number of Fast Fourier transforms (FFT), complex additions and complex multiplications compared to the ACE scheme. In addition to the above parameters, it has a number of unique parameters are present. This is because of the neural network approach. Here a number of Neural Networks, Real additions and Real multiplications are present. One disadvantage of this method is that more number of neural networks, and thereby the number of real additions and multiplications.

Our aim is to reduce the number of NNs and reduce the number of real additions and multiplications. The complexity of the neural network is also considered.

## II. OFDM SYSTEM

Let frequency domain data symbol vector for an OFDM system with N subcarriers and oversampling rate of J with (J-1)*N zeros in the middle be represented as

$$X = [X_0, X_1, \dots, X_{N/2-1}, 0, \dots, 0, X_{N/2}, \dots, X_{N-1}]^T, \qquad (1)$$

Where $X_k$ is the quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM) modulated data symbol of $k^{th}$ subcarrier. The $n^{th}$ oversampled time domain OFDM signal is expressed as

$$x_n = \frac{1}{\sqrt{JN}} \sum_{k=0}^{JN-1} X_k e^{j2\pi\frac{nk}{JN}}, n = 0, 1, \dots, JN-1 \quad , \qquad (2)$$

Where N is the number of subcarriers. Equation (2) can be expressed as

$$x = Q^H X, \qquad (3)$$

Where Q is the inverse discrete Fourier transform (IDFT) of size JN×JN with elements $q_{n,k} = (\frac{1}{JN})^{1/2} e^{j2\pi nk/JN}$ and $Q^H$denotes the Hermitian of Q. The PAPR of the transmitted OFDM signal is defined as

$$PAPR = \frac{\max_{0 \le n \le JN-1} \{|x_n|^2\}}{E\,[|x_n|^2]} \qquad (4)$$

Where E[ ] denotes the expectation factor. The complementary cumulative distribution function (CCDF) of the PAPR of an OFDM signal is generally used to evaluate the performance of a PAPR reduction scheme. The CCDF of the PAPR for a given clip level $PAPR_0$ is defined as

$$CCDF_{PAPR} = \Pr(PAPR > PAPR_0) \qquad (5)$$

For the OFDM system with Gaussian time domain signal, the CCDF of the PAPR can be expressed as

$$CCDF_{PAPR} = 1 - (1 - e^{PAPR_0})^N \qquad (6)$$

Where N is the number of subcarriers.

## III. PROPOSED TECHNIQUE

In the proposed scheme we employ the Active Constellation Extension (ACE) with the Neural Network method. Here we use the OFDM signal as the training input and the ACE signal as the desired signal. The neural network train the OFDM signal with the ACE signal using the Levinson-Marquardt algorithm.

### *A. ACE Scheme*

ACE uses non-bijective constellations to reduce the PAR by appropriately encoding the data symbols [2]. The idea is easily explained in the case of flat-power OFDM with QPSK modulation in each sub-channel. For an individual channel, there are four possible constellation points, which lie in each quadrant in the complex plane and are equidistant from the real and imaginary axes. Assuming white Gaussian noise, the maximum-likelihood decision regions are the four quadrants bounded by the axes, and thus a received data symbol is assigned according to the quadrant in which the symbol is observed.

Because only one of the four constellation points can be transmitted at a time, errors occur when noise translates the received sample into one of the other three quadrants. Any point that is farther from the decision boundaries than the nominal constellation point (in the proper quadrant) will offer increased margin, which guarantees a lower error rate (assuming white Gaussian noise). We can therefore allow modification of constellation points within the quarter-plane outside of the nominal constellation point with no degradation in performance. This principle is illustrated in Fig 1, where the shaded region represents the region of increased margin for the data symbol in the first quadrant.

For an OFDM system, the effect of moving into the shaded region is to add additional co-sinusoidal and/or sinusoidal signals at the particular sub-channels frequency to the transmitted signal. If adjusted intelligently, a combination of these additional signals can be used to partially cancel time-domain peaks in the transmitted OFDM signal.

### B. *Proposed Scheme*

In the proposed scheme we employ two simple NNs at the transmitter and the receiver side. The block diagram is shown in figure 2.

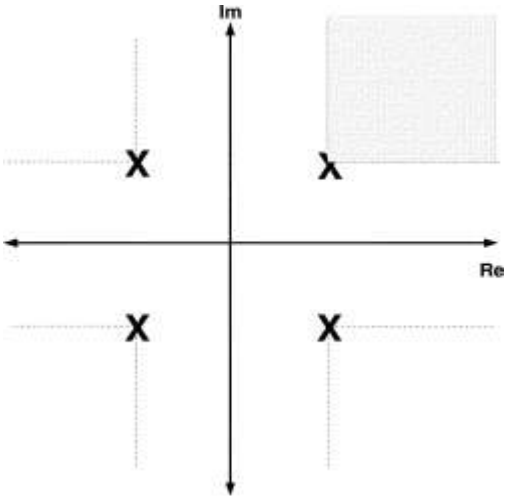


Fig. 1. Depiction of active channel extension with QPSK encoding. The shaded region represents the extension region for the first-quadrant data symbol.

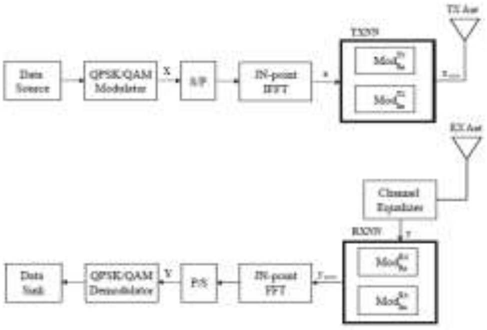


Fig. 2. Block Diagram of the Proposed Scheme

The PAPR reduction is achieved through the NN at the transmitter and the BER improvement is realized through the time domain NN unit at the receiver. The proposed transmitter NN (TXNN) and the receiver NN (RXNN) are based on the multilayer feedforward network with two layers and two neurons per layer with triangular activation function.

The training procedure for the transmitter and receiver section is described below.

- Obtain the time domain OFDM signal x as the training signal and the time domain ACE signal $x_{ACE}$ as the desired signal for the TXNN.
- Separate the real and imaginary part of the training input and the desired signals to construct the real and imaginary TXNN modules.
- Obtain training input and desired signals for RXNN: The time domain TXNN signal $x_{TXNN}$ is used as the training input signal to the RXNN and the time domain OFDM signal x is used as the training desired signal.
- Train and construct real and imaginary RXNN modules to be applied at the receiver side.

## IV. SIMULATION RESULTS

In this section, the proposed NN algorithm was evaluated based on the PAPR reduction and the BER performance. Also we calculate the PAPR of each case numerically and compare them for the efficiency of the proposed method and algorithm.

The parameters used for the generation of OFDM signals are;

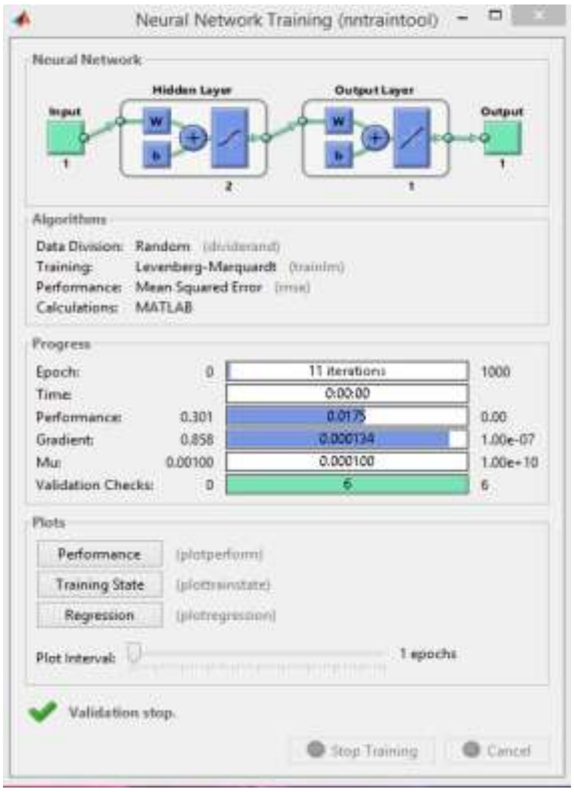
- No of Carriers: 64
- Single frame size: 96 bits
- Total no. of Frames: 100
- Modulation: 16-QAM
- No. of Pilots: 4
- Cyclic Extension: 25

### A. *Neural Network*

For the OFDM transmission and reception, here we use a new method, Neural Network. This is a new method in the field of OFDM technique. The main advantage of this method is that the complexity is reduced.

To realize the NN (Neural Network) method we use the following functions:

*net = newff(I1,O1,2);*



Data Division: Random (dividerand)
Training: Levenberg-Marquardt (trainlm)
Performance: Mean Squared Error (mse)
Calculations: MATLAB

| | | | |
|---|---|---|---|
| Epoch: | 0 | 11 iterations | 1000 |
| Time: | | 0:00:00 | |
| Performance: | 0.301 | 0.0175 | 0.00 |
| Gradient: | 0.858 | 0.000134 | 1.00e-07 |
| Mu: | 0.00100 | 0.000100 | 1.00e+10 |
| Validation Checks: | 0 | 6 | 6 |

Performance (plotperform)
Training State (plottrainstate)
Regression (plotregression)
Plot Interval: 1 epochs

✓ Validation stop.

Fig. 3. Neural Network Training.

```
net1=train(net,I1,O1);
y1=sim(net1,I1);
net2 = newff(I2,O2,2);
net3=train(net2,I2,O2);
y2=sim(net3,I2);
z= complex(y1,y2);
z1= abs(z);
```

This will find the real and imaginary parts of the transmitted signal and combined the output to get the complex valued output. The training tool is shown in the figure 3.

### *B. PAPR performance and comparison*

PAPR of original signal in dB: 17.4151
PAPR of ACE scheme in dB: 2.0582
PAPR of proposed scheme in dB: 9.2575

From the data we seen that the PAPR of a normal OFDM signal is 17.4151 dB. When we apply the ACE scheme, it will greatly reduce. From the output, the PAPR of the ACE scheme is only 2.0582 dB. The main disadvantage of this method is that the circuit is very complex.

To avoid the complexity of the ACE scheme we use the PAPR reduction method with Neural Network. The PAPAR of the NN method is 9.2575 dB which is greater than the ACE scheme. But when compared to the original OFDM method it is very low. The circuit is very simpler when compared to the ACE scheme. Thus a NN scheme with more reduced PAPR is a good objective for the future.

The CCDF of the PAPR was used to evaluate the PAPR reduction of the proposed scheme in comparison with the other schemes.

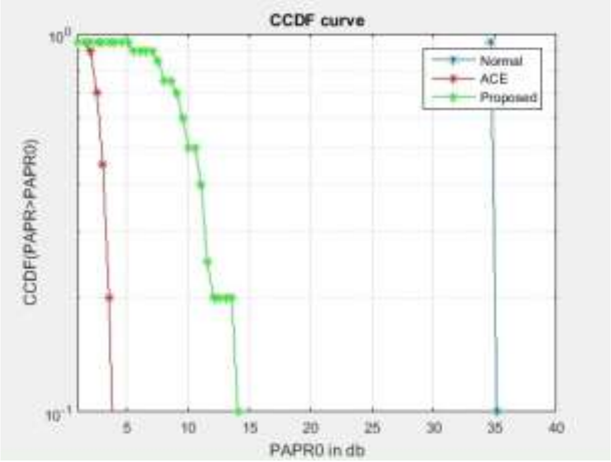


Fig. 4. CCDFs of the PAPR for original OFDM, ACE, and the proposed method with QPSK modulation

The CCDF of the proposed scheme for QPSK is shown in the figure 4.

### *C. BER Performance*

Figure 5 show the BER performance of the original OFDM signal, the ACE signal and the proposed method in the AWGN channel with QPSK modulation. The channel is assumed to be Quasi-static frequency selective and perfect channel estimation is considered. It can be observed from the figure 5 that the NN method achieve BER improvement over the original OFDM signal due to the constellation extension, resulting in increased margin and lower error rates.

## V. CONCLUSION

In this study, a novel ACE PAPR reduction method based on the transmitter NN and receiver NN with low computational complexity is proposed. From the simulation results, it was observed that the BER performance of the conventional ACE scheme is very poor than that of the original OFDM signal in AWGN channel with QPSK modulation.

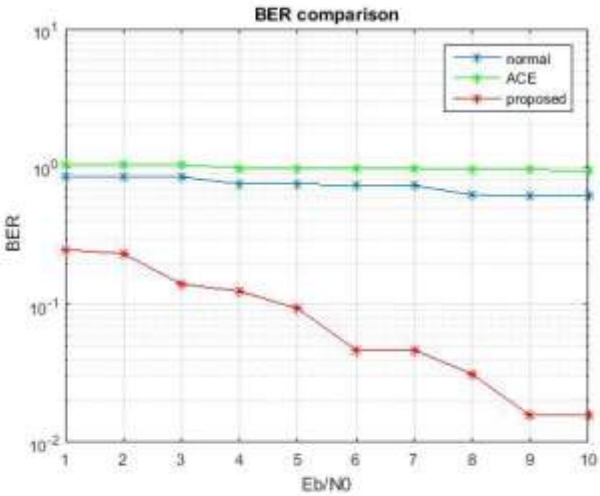


Fig. 5. BER performance for original OFDM, ACE signal and the proposed

However, the proposed scheme was shown to achieve a significant improvement in BER performance with similar PAPR reduction capacity compared to other ACE based techniques with lower complexity. In future we try to reduce the PAPR by selecting the Rayleigh fading channel and the QAM modulation techniques. In our proposed method we select the original OFDM signal as the trained signal. Instead of the original OFDM signal with high PAPR we select a PAPR reduced signal for the future analysis.

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