Bit Error Rate Improvement by using Active Constellation Extension and Neural Network in OFDM System

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Abstract – The demand for multimedia data services has grown up rapidly. One of the most promising multi-carrier system, Orthogonal Frequency Division Multiplexing (OFDM) form basis for all 4G wireless communication systems due to its large capacity to allow the number of subcarriers, high data rate and ubiquitous coverage with high mobility. OFDM is drastically affected by peak-to-average-power ratio (PAPR). In this paper, an effort has been made to analyze how well an OFDM system can perform when a signal, of various PAPR reduction techniques, is transmitted over Additive White Gaussian Noise (AWGN) channel using 16-QAM modulation technique. The performances of PAPR reduction schemes have been evaluated in terms of the bit error rate (BER). Simulation results reveal that, the OFDM system with Active constellation extension (ACE) and Neural Network (NN) schemes improve the BER performance and robust to high PAPR.

Index Terms – OFDM; PAPR; ACE; NN; BER.

1. INTRODUCTION

Wireless communications is the most important development of an era that has an extremely wide range of applications from TV remote to cellular phones. Wireless signals transmitted over the air usually experience frequency selective fading, i.e. different frequency components are faded by the channel differently. Complex equalization techniques are used to reduce the frequency-selective fading in single carrier (SC) systems. The frequency response of the equalizer is the inverse of frequency response of the channel, therefore, infinite numbers of equalizer taps are required. Signal noises can also be increased through the equalizer when a deep fade occurs. Therefore in conventional SC systems, even with the finest equalizer, a deep fade can still occur, which causes communication link failure.

In 1967 [1], first proposal to use parallel data transmission to minimize frequency selective fading channels was published, in which small numbers of sub-channels use carriers that fall within each deep-faded frequency band, error correcting codes can be used to recover the data along those corrupted sub-channels. Moreover in mid 1960s, the idea of using frequency division multiplexing and parallel data transmission was published [2]. In conventional parallel transmission, as shown in Fig.1.(a), the whole frequency band is shared by ten non-overlapping sub-channels which is not a bandwidth efficient transmission. In the 1960s, with the use of overlapping sub-channels spectral efficiency was improved, as shown in Fig.1.(b), which saves half of the spectrum as compared to conventional parallel transmission. At this stage, OFDM system came into existence, which is frequency multiplexing method that maintains orthogonality among sub-carriers.

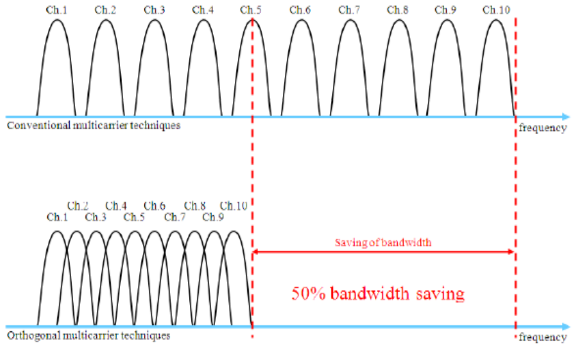

Figure 1.(a)Traditional non-overlapping MCM;(b) orthogonal MCM. [3]

It was considered for high density recording, high speed modems, as well as digital mobile communications, in 1980s. Finally in 1990s, it was utilized for wide band data communication over mobile radio Frequency modulation channels, wireless local area network IEEE802.11a/g standard, high bit rate digital subscriber lines, very high speed digital subscriber lines, digital audio broadcasting (DAB), asymmetric digital subscriber lines and high definition television (HDTV) terrestrial broadcasting [4].

In this paper, Section I describes the introduction to OFDM, Section II gives the details of OFDM system model, Section III describes ACE scheme, Section IV explains the NN technique, result of proposed technique is discussed in Section V and Section VI summarizes the discussion.

2. OFDM SYSTEM MODEL

A multicarrier signal is the summation of numerous independent signals modulated onto sub channels of equal bandwidth. 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

$$X = \left[X_0 \dots X_{\frac{N}{2}-1}\ 0 \dots 0\ X_{\frac{N}{2}} \dots X_{N-1}\right]^T \qquad (1)$$

where X_k is the quadrature phase shift keying or quadrature amplitude modulation (QAM) modulated data of kth subcarrier. The nth oversampled time domain OFDM signal is expressed as,

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

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 $q_{n,k} = (1/JN)^{\frac{1}{2}} e\string^(j2\pi nk/JN)$ and Q^H denotes the Hermitian of Q.

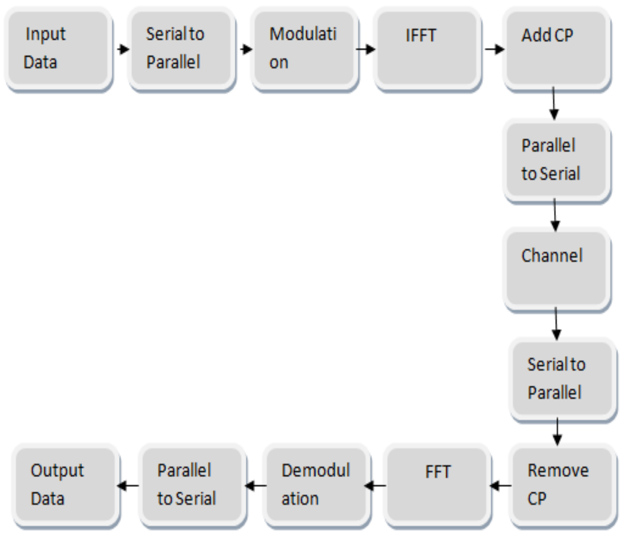

Figure 2 OFDM System

The PAPR of the transmitted OFDM signal is,

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

where E [.] denotes the expectation operator.

3. ACTIVE CONSTELLATION EXTENSION

The class of non-linear PAPR reduction methods is represented by approaches like active constellation extension (ACE), clipping, partial clipping, and signal compression. In 1999 a new method for PAR reduction using active (data-carrying) channels is presented which dynamically moves outer constellation points, within margin-preserving constraints, to minimize the peak magnitude [5]. This scheme simultaneously decreases the bit error rate slightly while substantially reducing the peak magnitude.

In this technique, some of the outer signal constellation points in the data block are dynamically extended towards the outer side of the original constellation such that the PAPR of the data block is reduced [6]. The main idea of this scheme is easily explained in the case of a multicarrier signal with QPSK modulation in each sub-carrier. This class of PAR reduction techniques called nonbijective constellations tries to alter or introduce new constellations to combat large signal peaks. Rather than assigning each symbol to a certain constellation point, the symbol can be mapped to a set of constellation points (this set can be finite or infinite).

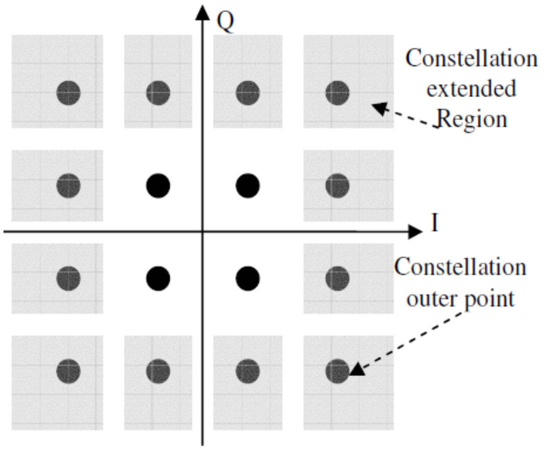

Figure 3 Active Constellation Extension with 16-QAM encoding

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). Thus, the PAPR problem can be formulated as follows [7],

$$\min_{C} ||x + Q^H C||^2 \qquad (5)$$

Subject to: $C_k = 0 \; for \; k \notin I_a$,

Where C is the extension vector, I_a is the index of active subchannels reducing PAPR, and C_k is a component of C that is equal to zero for $k \notin I_a$.

4. PROPOSED SCHEME

The proposed technique uses Neural Network (Levenberg-Marquardt (LM) backpropagation network) trained on the Active Constellation Extension (ACE) signal to reduce the PAPR of OFDM signal which results in significant bit error rate (BER) improvement with low computational complexity. In this scheme, the PAPR is reduced by the use of two stage neural network architecture based on time domain neural network (TNN) for time domain processing and frequency domain neural network (FNN) for frequency domain processing. Both TNN and FNN are based on the multilayer feedforward network [8] with two layers and two neurons per layer with triangular activation function. The TFNN is trained using the ACE signal as the desired signal with the Levenberg-Marguardt algorithm [9] as the learning algorithm.

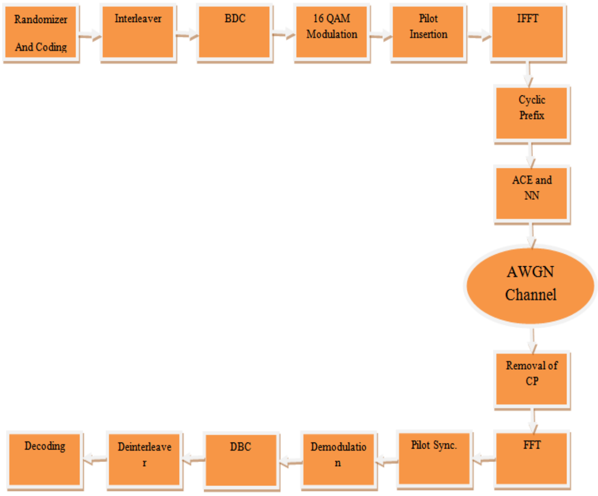

Figure 4 Block diagram of proposed technique with ACE and NN

The block diagram of proposed technique is shown in Fig. 4, in which ACE and NN are used at the transmitter side of OFDM system. The channel used here is AWGN channel. The training procedure for the TFNN technique is as follows [10].

1) Obtain training input and desired signals for time domain processing: The time domain OFDM signal x is used as the training input signal to the TNN. The time domain ACE signal x_{ACE} is used as the desired signal for neural weight adaptation process.

2) Train and construct real and imaginary TNN modules, $Mod^{TNN}{}_{Re}$ and $Mod^{TNN}{}_{Im}$: The real and imaginary parts of the training input and desired signals are separated to be used as independent training input and desired signals for two different TNN module constructions.

3) Obtain training input and desired signals for frequency domain processing: The frequency domain TNN signal **X**TNN is obtained by applying DFT to the time domain TNN output. The frequency domain ACE signal x_{ACE} is obtained by applying DFT to x_{ACE}. **X**TNN is used as the training input signal and X_{ACE} is used as the training desired signal for training FNN.

4) Separate the training input and desired signal into four constellation regions: The divided signals are used to construct eight independent FNN modules, $Mod^{FNN}{}_{Re,1q}$, $Mod^{FNN}{}_{Im,1q}$, $Mod^{FNN}{}_{Re,2q}$, $Mod^{FNN}{}_{Im,2q}$, $Mod^{FNN}{}_{Re,3q}$, $Mod^{FNN}{}_{Im,3q}$, $Mod^{FNN}{}_{Re,4q}$, $Mod^{FNN}{}_{Im,2q}$, corresponding to each four quadrants.

5) Train and construct real and imaginary FNN modules for four constellation regions.

6) TFNN architecture is completed based on the TNN and FNN modules from previous steps.

TABLE 1. SIMULATION PARAMETERS

Parameters	**Values**
OFDM subcarriers, N	64
Cyclic-prefix length	64
Modulation	16 QAM
FEC	Convolutional code
No. of Pilots	4
Noise	AWGN
SNR	0 to 25 db
Channel	AWGN

Bandwidth	20MHz

The simulation parameters used in proposed technique are shown in table 1. The OFDM functional structure with the proposed approach is simulated with Matlab.

5. SIMULATION RESULTS

In this section, we illustrate the performance of our proposed algorithm using computer simulations. Simulation results have been prepared to demonstrate the performance enhancement of an OFDM system using ACE with NN. In the simulations we use 16 QAM modulation technique on the subcarriers of OFDM system. The channel used here is AWGN.

TABLE 2. COMPARISION OF BER

SNR(dB)	BER of OFDM signal			
	Without any technique	With clipping	With ACE	With ACE and NN
0	0.5	0.5	0.5	0.5
5	0.25	0.5	0.3	0.3
10	0.1	0.5	0.15	0.1
15	0.009	0.5	0.05	0.01

In table 2, the BER of OFDM signal with clipping, ACE, NN and without any PAPR reduction technique is given in TABLE II, which shows that BER of OFDM signal with ACE and NN is better.

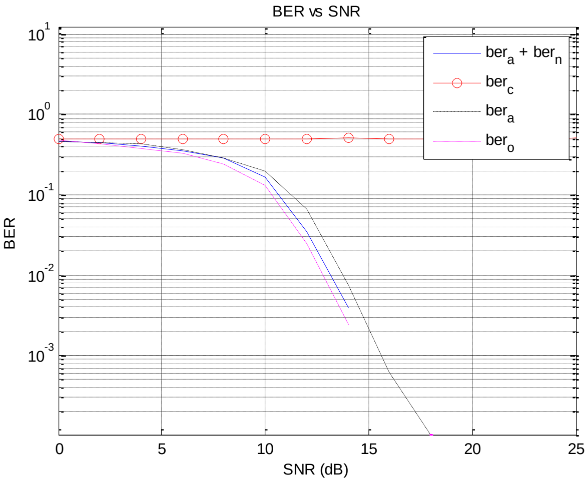

Figure 5 BER Vs. SNR graph

The BER performance of OFDM system with ACE and NN with varying SNR values for 16-QAM modulation under AWGN channel is evaluated. From the simulation result, it can be concluded that the OFDM signal with ACE and NN has better BER performance.

6. CONCLUSION AND FUTURE SCOPE

In this paper the BER performance of ACE and NN with OFDM system with respect to SNR for 16-QAM modulation under AWGN channel, for SNR 0 to 25 dB, is evaluated. From this, it can be concluded that proposed technique using Neural Network (Levenberg-Marquardt (LM) back propagation network) trained on the Active Constellation Extension (ACE) signal reduced the PAPR of OFDM signal which results in significant bit error rate (BER) improvement with low computational complexity.

To reduce the PAPR without any distortion Partial Transmit Sequence (PTS) scheme along with NN can be used to improve PAPR and BER performance, instead of ACE. PTS scheme transmits only part of data of varying sub-carrier which covers all the information to be sent in the signal as a whole, so there are less chances of data loss. Clipping based ACE (CB-ACE) can also be used for better PAPR performance.

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