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Minimization of PAPR in OFDM Using SFBC and MIMO

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ABSTRACT

Peak-to-Average Power Ratio (PAPR) reduction is one of the main key factors in orthogonal frequency division multiplexing (OFDM) systems. From the various existing PAPR reduction techniques, Neural Network (NN) has been one of the efficient and powerful techniques in reducing the PAPR due to its good generalization properties with flexible modeling and learning capabilities. In this paper, we propose a new method that uses NNs trained on the active constellation extension (ACE) signals to reduce the PAPR of OFDM signals. It employs a receiver NN unit, at the OFDM receiver side for achieving significant bit error rate (BER) improvement with low computational complexity. To reduce the time complexity SFBC (Space frequency block coding) block is used in NN and multiple input and multiple output (MIMO) technique is introduced.

INTRODUCTION

To moderate the occurrence of OFDM signals with large peak power, various PAPR reduction methods have been proposed such as the active constellation extension (ACE) technique. The ACE scheme reduces the PAPR with low bit error rate (BER) by iterative time domain signal clipping and frequency domain constellation point extensions. Improved data rate is achieved compared with other PAPR reduction techniques.

A.Ofdm And Its Orthogonal Property:

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. It has developed into a popular method which is used in applications such as Digital Video Broadcasting (DVB), efficient broadband internet access, wireless networks, and mobile communications.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions without complex filters. By means of Channel equalization it is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal.

The orthogonally requires that the sub-carrier spacing is $\Delta_f = \frac{k}{T_U}$ Hertz, where T_U seconds is the useful symbol duration at the receiver side, and k is a positive integer, which is equal to 1. With N sub-carriers, the total pass band bandwidth $B \approx N \cdot \Delta f$ (Hz). The orthogonality also allows high spectral efficiency, at a total symbol rate near the Nyquist for the equivalent baseband signal (i.e. near half the Nyquist rate for the double-side band physical pass band signal). Almost the whole available frequency band can be utilized.

B. PAPR Problem:

One of the new problems emerging in OFDM systems is called Peak to Average Power Ratio (PAPR) problem. Then the input symbol stream for IFFT should have a uniform power spectrum, but the output of the

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IFFT may be resulted in a non-uniform or spiky power spectrum. Most of transmission energy would be distributed for a less instead of the many subcarriers. This problem can be identified as the PAPR measure and it cause many problems in the OFDM system at the transmitting end.

C. Effect of PAPR:

A major obstacle is that the OFDM signal exhibits a very high Peak to Average Power Ratio (PAPR).Therefore, RF power amplifiers should be operated in a linear region. Then, the signal peaks get into a non-linear region of the power amplifier, which cause signal distortion. Then the signal distortion produces inter modulation among the subcarriers and out of the band radiation. Where the power amplifiers should be operating with a large power back off. On the other hand, it leads to very inadequate amplification and expensive transmitters. Thus, it is highly difficult to reduce the PAPR.

The large peaks cause saturation in power amplifiers, which leads to inter modulation products among the subcarriers and disturbing out of band energy. It is desirable to reduce the PAPR, to reduce the PAPR, many techniques have been proposed such as clipping, Tone Reservation, coding, peak windowing and Tone Injection. But, most of the methods are not desirable to achieve a large reduction in PAPR with the desiration of low complexity and without performance degradation and without transmitter receiver symbol handshake. Complexity is increased in the analog to digital and digital to analog converter.

II. Modules:

- Active constellation extension (ACE) technique
- The time frequency neural network (TFNN)
- Proposed scheme

A. Active Constellation Extension (Ace) Technique Using Sfbc With Mimo:

In the ACE scheme, the PAPR is reduced through *L* number of iterative processing between the time and frequency domain. The signal peaks are reduced by clipping the signals with magnitudes exceeding a certain target peak level in time domain and BER degradation is avoided in frequency domain by limiting the movement of the constellation points due to clipping to only acceptable extension directions

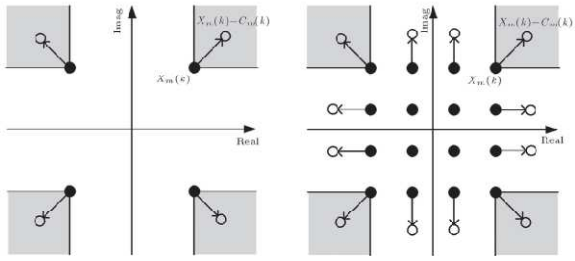


Fig. 1: PAPR reduction using constellation extension for QPSK and 16-QAM modulation

PAPR problem can be formulated as follows

$$\min_{C} \| \mathbf{x} + \mathbf{Q}^H \mathbf{C} \|^2$$
$$C_k = 0 \quad \text{for } k \notin I_a,$$

where **C** is the extension vector, $I_a$is the index of active sub channels reducing PAPR, and $C_k$is a component of **C** that is equal to zero for k _∈Ia.

In the ACE technique SFBC block is used to set for real and imaginary terms of the signal. MIMO system is obtained by placing more than one antenna at the transmitting side and the receiver side. Thus by multiple antennas in the transmission and reception leads to transmit the high data rate.

B. The Time Frequency Neural Network (TFNN):

A neural network is a extremely parallel system contained of many highly interconnected, interacting processing elements (also called nodes or neurons) based on neurobiological models of the brain. These systems act as non-linear and non-parametric function that learn to map inputs to outputs as a non-linear, multi-dimensional surface to fit general nonlinear, multivariate functions. Neural networks exhibit many advantageous properties for solving complex problems.

In this scheme a simple NN unit is added next to the clipping block and the BER performance improvement is obtained with the help of NN unit present at the receiver.

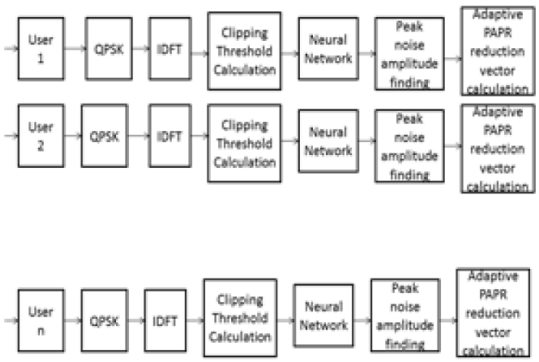


Fig. 2: General neural network

The Basic testing (steps) procedure of NN

1. Obtain time domain OFDM signal x.
2. Obtain the time domain TXNN signal xTXNN.

The training procedure of the TFNN technique is as follows:

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

2) Train and construct real and imaginary TNN modules, ModTNN Re and ModTNN Im. The real and imaginary parts constructions.

3) Obtain training input and desired signals for frequency domain processing: The frequency domain TNN signal TXNN is obtained by applying DFT to the time domain TNN output. The frequency domain ACE signal is obtained by applying DFT. It is used as the training input signal and 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, Re,1q, ModFNN Im,1q, ModFNN Re,2q , ModFNN Im,2q, ModFNN Re,3q , ModFNN Im,3q, ModFNN Re,4q , ModFNN Im,4q, 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.

C. Proposed Scheme

The Fourier Transform:

The Fourier transform allows us to relate events in time domain and in frequency domain also. There are many version of the Fourier transform and the choice to use that depends on the particular circumstances of the work. The conventional transform relates to continuous signals which are not limited to in either time or frequency domains. Then signal processing is made easy if the signals are sampled. By sampling the signals with an infinite spectrum, which leads to aliasing. The process of signals that are not time limited can lead to problems with storage space. To avoid this, the majority of signal processing uses a version of the discrete Fourier transform (DFT). The DFT is a variant on the normal transform in which the signals are sampled in both time and the frequency domains. By using the time waveform must repeated and it leads to a frequency spectrum that repeats in the frequency domain.

The fast Fourier transform (FFT) is merely a rapid mathematical method for computer applications of DFT. The process of transforming from the time domain representation to the frequency domain representation uses the Fourier transform itself, whereas the reverse process uses the inverse Fourier transform.

Mathematical Description of OFDM:

- The Fourier transform
- The use of Fast Fourier Transform in OFDM
- By using the guard interval and its implementation

In the proposed scheme, the FNN unit is removed and an additional simple NN unit is employed at the receiver side. Reduction of complexity is realized by using a single time domain NN unit for PAPR reduction and BER performance improvement is achieved through the time domain NN unit at the receiver. The transmitter NN (TXNN) and the receiver NN (RXNN) are based on the multilayer feed forward network with two layers and two neurons per layer with triangular activation function.

Qam Modulator:

The motivation for QAM comes from the fact that a signal occupies twice the bandwidth of the message from which it is derived. This is considered wasteful of the resources. And the QAM restores the balance by replacing two independent DSBSC and is derived from message #1 and message #2, in the same spectrum space as one DSBSC and the bandwidth is removed.

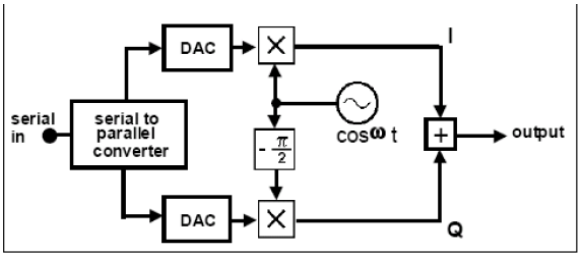


Fig. 3: QAM transmitter

The two paths to the adder are typically referred to as the 'I' (in phase), and 'Q' (quadrature), arms is not used for multiplexing two independent messages. Given an input binary sequence (message) at the rate of n bit/s. then two sequences may be obtained by splitting the bit stream into two paths at the rate of each of n/2 bit/s. This is a serial-to-parallel conversion. Because of the halved rate the bits in the I and Q paths are stretched to twice the input sequence bit clock time period. Then the two messages are combined at the receiver that uses a QAM-type demodulator. The two bit streams could have typically be band limited and/or pulse shaped before reaching the modulator.

Qam Demodulator:

The QAM receiver follows the similar principles to those at the transmitter, and is illustrated in the block diagram. It is idealized because it assumes the incoming signal has its two DSBSC indeed in phase quadrature.

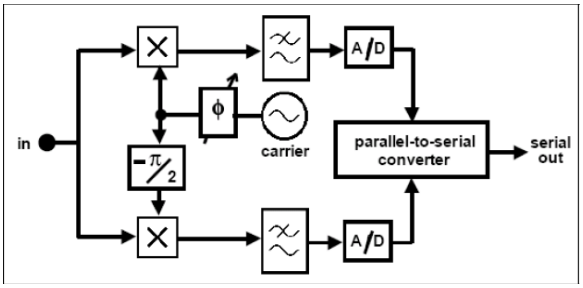


Fig. 4: QAM receiver

The parallel-to-serial (PS) converter block performs the following operations:

1. Regenerates the bit clock from the incoming data.
2. Regenerates a digital waveform from both the analog outputs of the I and Q arms.
3. Re-combines the I and Q signals will produce the outputs of a serial data stream.

Rayleigh And Rician Channels:

In the existing system, flat fading channel is used which tends to occur fading in the signals. To overcome this Rayleigh and Rician channels are used in the proposed scheme.

Reflection, diffraction tends to occur in the Rayleigh channel which reduces the fading considerably. Rician channel is used to send the high data over the channel.

III. Complexity Analysis:

The number of complex multiplications and additions due to the use of FFT modules, real multiplications and additions due to the use of NN modules, and the feasible region check operations. It is assumed that the number of complex multiplications and additions required of the N point FFT modules are (N/2) $\log_2(N)$ and N $\log_2(N)$, respectively. Furthermore, the NN modules based on the multilayer feed forward network with two layers and two neurons per layer require 8N real multiplications and 6N real additions. In the ACE scheme, L iterative processing of N point IFFT computation is required for time domain clipping and additional L iterative processing of N point FFT computation is required for frequency domain constellation extension. In addition,

LN feasible region check operations are required to enforce acceptable extension constraint. In the TFNN scheme, one N point IFFT computation is required for TNN processing and one N point FFT computation is required for FNN processing. In addition, 2 NN computations are required for the real and imaginary TNN processing and 8 NN computations are required for the real and imaginary FNN processing. Also, N feasible region check operations are required to enforce acceptable extension constraint. As for the proposed scheme, only one N point IFFT computation is required for TXNN processing. Furthermore, 2 NN computations are required for the real and imaginary TXNN processing and additional 2 NN computations are required for the real and imaginary RXNN processing. However, no feasible region check operation is needed in the proposed scheme.

A. PAPR Performance:

The CCDF of the PAPR was used to evaluate the PAPR reduction performance of the proposed scheme compared to other schemes. It was observed that the ACE scheme, TFNN scheme, and the proposed NN scheme can significantly reduce the PAPR compared to the original OFDM signal for both QPSK and 16-QAM constellations.

B. BER Performance:

It show the BER performances of the original OFDM system, the ACE scheme, the TFNN scheme, and the proposed NN scheme in the Rayleigh fading channel with QPSK and 16-QAM, respectively. The channel is assumed to be quasi-static frequency selective and perfect channel estimation is considered. It can be observed that the ACE and NN based methods achieve BER improvement over the original OFDM signal due to the constellation extension, resulting in increased margin and lower error rates. Furthermore, the TFNN and the proposed NN schemes show better BER performance compared to the ACE scheme, demonstrating robust frequency domain processing. performance is observed compared to the ACE scheme with BER = 1× 10−2 when E_b/N_0 = 20 dB. The performance improvement is due to the more concentrated symbol energy in the frequency domain constellations compared to the ACE method. Finally, the proposed NN scheme shows superior BER performance results compared to other PAPR reduction methods with BER = 3.5×10−4 when Eb/N0 = 20 dB. The reason for the significant BER performance improvement of the proposed NN method compared to other methods, in the 16-QAM case, is that the RXNN at the receiver side is able to successfully map the received TXNN transformed OFDM signal into the transmitted original OFDM signal increasing the 16-QAM demodulator performance.

Simulation Results For Ber:

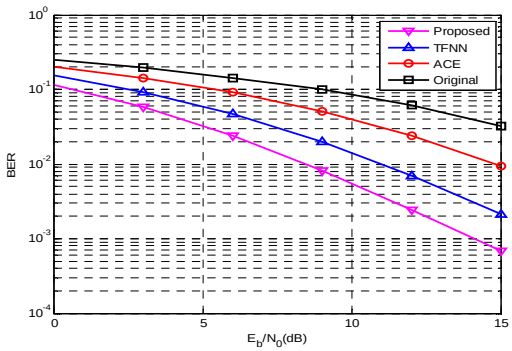
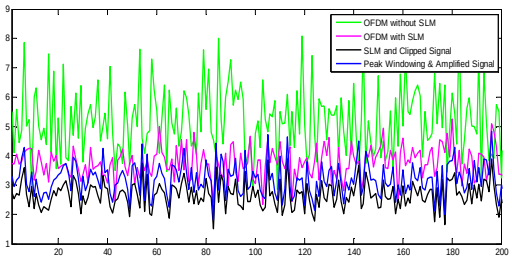
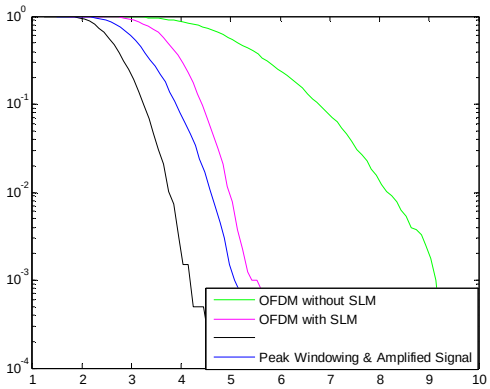


Fig. 5: BER performance for original OFDM, ACE, TFNN, and the proposed method with N = 128, L = 20, and QPSK in the Rayleigh fading channel.

IV. Future Enhancement:

Selective Mapping (SLM) trained by the NN is used in the future for getting better results in PAPR. Using SLM the time complexity of the system is also reduced to certain extent. The simulation results for the SLM scheme is given below.





Conclusion:

In this paper, we have proposed ACE PAPR reduction method based on the transmitter NN and receiver NN with low computational complexity using SFBC and MIMO. 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 Rayleigh fading channel with QAM modulation. The TFNN scheme was marginally better than the ACE scheme in the BER performance for high E_b/N_0 values. 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.

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