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AN EFFICIENT TECHNIQUE FOR REDUCING PAPR OF OFDM SYSTEM IN THE PRESENCE OF NONLINEAR HIGH POWER AMPLIFIER

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Abstract—Peak to Average Power Ratio (PAPR) is one of the serious problems in any wireless communication system using multi carrier modulation technique like OFDM, which reduces the efficiency of the transmit high power amplifier. In this paper, proposed scheme will be introduced that combine interleaving method with peak windowing. Simulation results show that our technique simultaneously decrease Bit Error Rate (BER), reduce the PAPR by 3.5 dB and improve out-of-band radiation, in presence of nonlinear power amplifier model.

1. INTRODUCTION

OFDM [1, 2] is a multicarrier modulation where it is split a high-rate datastream into a number of lower rate stream that are transmitted simultaneously over a number of subcarriers. Because the symbol duration increases for the lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Intersymbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol. International standards making used for OFDM in high-speed wireless communications are already established or being established by IEEE 802.11, IEEE 802.16, IEEE 802.20, and European Telecommunications Standards Institute (ETSI) Broadcast Radio Access Network (BRAN) committees [3, 4].

For wireless applications, an OFDM-based system can be of interest because it provides greater immunity to multi-path fading and impulse noise, and eliminates the need for equalizers, while efficient hardware implementation can be realized using Fast Fourier transform (FFT) techniques [5, 6].

The basic concept of OFDM is to divide the total bandwidth into several narrow band sub-channels, which are transmitted in parallel. Because, the symbol duration of each sub channel is made relatively larger than the delay spread it would minimize the ISI effect. Moreover, it is spectrally more efficient technique than a conventional single carrier modulation technique.

OFDM has several properties, which make it an attractive modulation scheme for high speed transmission links. However, one major difficulty is its PAPR.

High PAPR has been recognized as one of the major practical problem involving OFDM modulation. This problem results from the nature of the modulation itself, where multiple subcarriers/sinusoids are added together to form the signal to be transmitted. Usually, the systems are constrained to a limited peak power due to the limitation of the dynamic range over which the transmitter amplifier operates linearly.

Several researchers have proposed schemes for reducing peak amplitude, such as clipping [7], coding [8], interleaving [9], Active Constellation Extension (ACE) [10], partial transmit sequences [11], Turbo Coded OFDM [12].

In this paper, an efficient technique will be suggested to reduce the PAPR by making combination between the interleaving and peak windowing methods in presence of nonlinear power amplifier model.

The paper is organized as follows: In Section 2, the PAPR in OFDM is introduced, and the principles of interleaving and windowing method are investigated. Section 3 proposed technique will be introduced. Section 4, simulation results will be made. Section 5, conclusions will be done.

2. PAPR IN OFDM SYSTEM

If we consider N modulated data symbols from a particular signalling constellation, $X_k = (X_0, X_1, \ldots, X_{N-1})$, over a time interval [0, T], the OFDM symbol can be written as

$$x(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi k f_0 t} \tag{1}$$

where: $f_0 = 1/T$.

Replacing $t = nT_b$, where $T_b = T/N$, we arrive at the discrete time version given by:

$$x_n = \sum_{k=0}^{N-1} X_k e^{j2\pi kn/N} \tag{2}$$

The PAPR of the signal, $x(t)$, is then given as the ratio of the peak instantaneous power to the average power, written as:

$$PAPR = \max_{o \leq t \leq T} \frac{|x(t)|^2}{E\left[|x(t)|^2\right]} \tag{3}$$

where $E[\cdot]$ is the expectation operator.

If N is large enough, based on the central limit theorem, the real and imaginary parts of $x(t)$ have Gaussian distribution and its envelope will follow a Rayleigh distribution. This implies a large PAPR. Equivalently, we can think of this as N sinusoids adding constructively to give a PAPR as large as N.

2.1. Peak Windowing

The basic idea of peak windowing is to multiply the envelop of OFDM signal with a window function. Therefore,

$$\tilde{x}_E(t) = x_E(t) \cdot f(t) \tag{4}$$

where

$$x_E(t) = |x(t)|\,.$$

$$f(t) = 1 - \sum \alpha \cdot w(t - t').$$

$w(t)$: is the window function.

t': denotes the position of a local maximum of the envelop $x_E(t)$.

α: attenuation constant.

When the amplitude of envelop amplitude of the OFDM signal exceeds a threshold, a window function is applied to the envelop of the OFDM signal to eliminate the peak amplitude. windowing results in a smooth signal. The peak window is given by:

$$w(t) = 0.5 - 0.5\cos(2\pi t/T) \quad 0 \leq t \leq T \tag{5}$$

2.2. Interleaving

In this approach k interleavers are used at the transmitter. These interleavers produce K permuted frames of the input data sequence. These permutations can be done either before or after the modulation (mapping). The minimum PAPR frame of all the K frames is selected for transmission. The identity of the corresponding interleaver is also sent to the receiver as side information.

3. PROPOSED TECHNIQUE

In this paper we combine the interleaving and windowing methods as shown in Fig. 1.

First, the interleaving approach is used and the signal with lowest PAPR is then passed through windowing method. The intention to combine these two methods is to obtain signal with lower PAPR than in the case of interleaving method and with lower bit error rate in the case of windowing method.

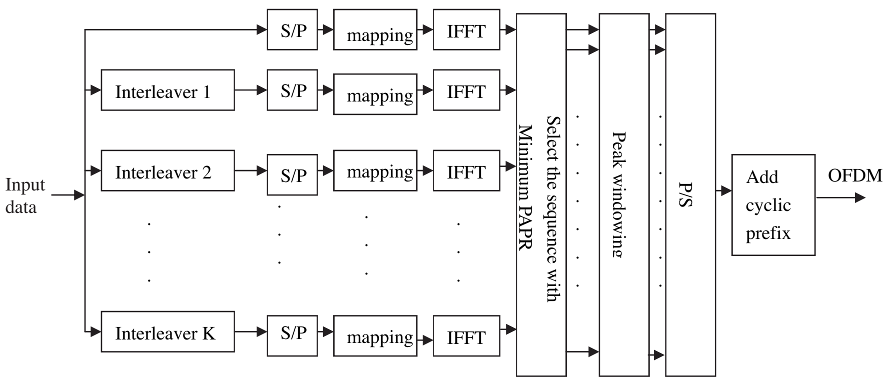


Figure 1. OFDM system with proposed technique for PAPR reduction.

4. SIMULATION RESULTS

Computer simulations are used to clarify the peak power reduction capability and the BER performance with the proposed technique. This simulated system employs an OFDM signal with $N = 256$, 512, and 1024 subcarriers using QPSK, 16 QAM, and 64 QAM. The high power amplifier (HPA) is Rapp's solid state power amplifier model (SSPA) [13, 14] with the characteristic

$$v_{out} = \frac{v_{in}}{\left(1 + \left(\frac{|v_{in}|}{v_{sat}}\right)^{2p}\right)^{1/2p}} \tag{6}$$

where v_{in}, v_{out} are respectively the complex input and complex output signals and v_{sat} is the output saturation level. The parameter p, often called "knee factor", controls the smoothness of the characteristic.

The BER performance was evaluated in Additive White Gaussian Noise (AWGN) channels. In the peak windowing method, a window is applied to a region there exist large peaks. The window function is multiplied with the signal in such a way that the signal peaks fall in the center of the window while the signal samples with lower amplitudes align themselves with the large amplitude segment of the window function. In this paper, the hanning window will be used as a window function.

In the Interleaving method, $k = 8$ is used where the number of stages only influence on the Complementary Cumulative Distribution Function (CCDF) of the PAPR. In the following, BER and CCDF performances will be investigated.

4.1. CCDF Performance

PAPR statistics are given in terms of the CCDF. The CCDF shows the probability of an OFDM frame exceeding a given PAPR,

$$CCDF(PAPR(x)) = Pr(PAPR(x) > PAPR_0).$$

Figure 2 show the performance of interleaving and windowing method each alone.

The interleaving and windowing methods give improvement by 2.7 dB and 1 dB, respectively for the probability of 10^{-3}.

The proposed technique gives better result than each method alone.

Figures 3(a) and (b) demonstrate the performance improvement over a conventional OFDM system of the proposed scheme. At the probability of 10^{-3} the PAPR is almost 3.5 dB smaller than in

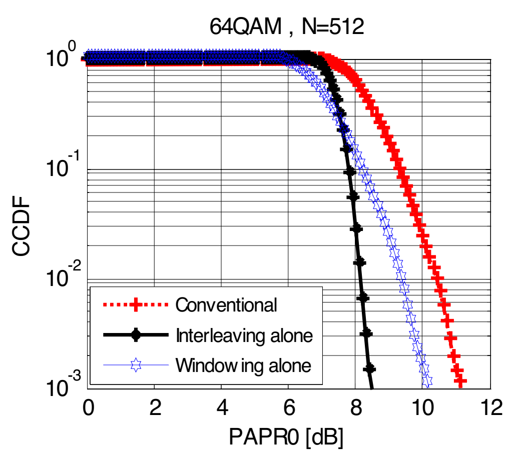
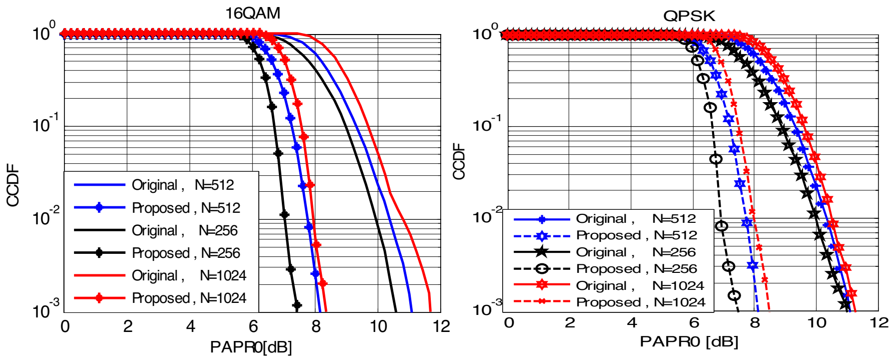
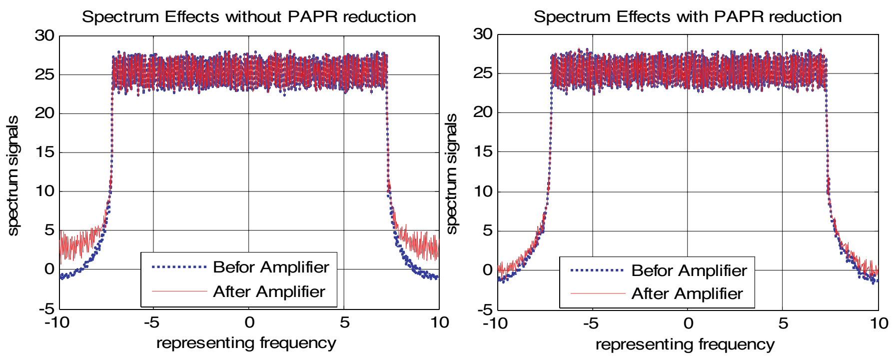


Figure 2. CCDF of PAPR for interleaving and windowing.



(a) 16QAM (b) QPSK

Figure 3. CCDF of PAPR with the proposed technique.



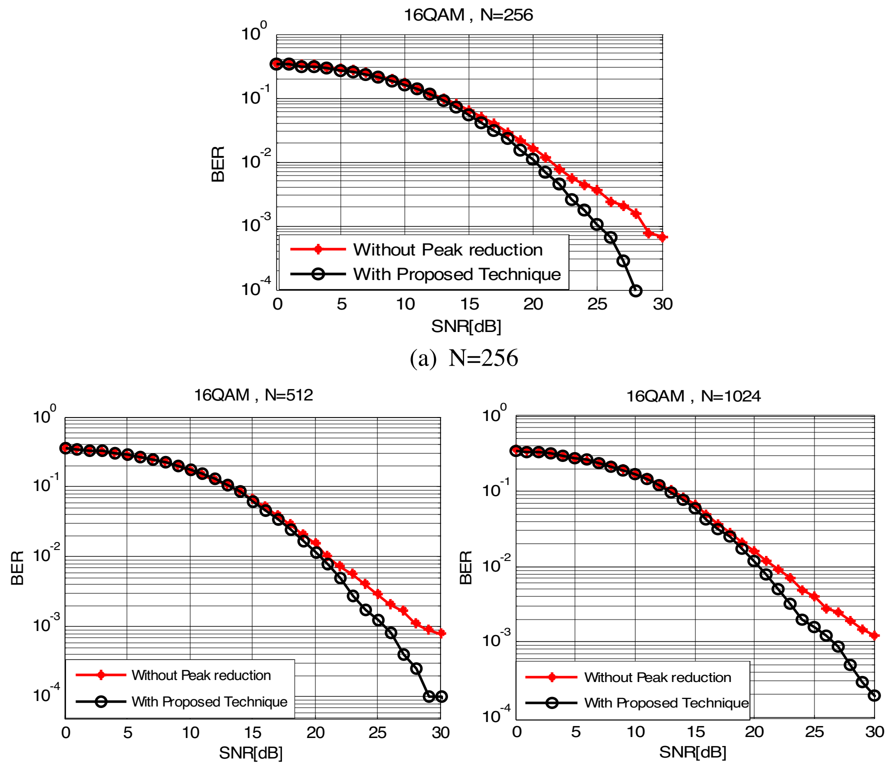
(a) Without PAPR reduction (b) With PAPR

Figure 4. Spectrum of an OFDM signal after passing through an SSPA.

modulator without PAPR reduction, where the same number of frame will be sent for each modulation.

4.2. Spectrum Effect

Figures 4(a) and (b) show the signal spectrum before and after passing through SSPA model for conventional OFDM system and OFDM system with PAPR reduction method. The spectrum with proposed technique is generated only in the usable frequency band, and the results confirm that the proposed technique can remove the components out of the system frequency band. The significant spectral leakage will interfere with the adjacent channel transmission.



(a) N=256

(b) N=512

(c) N=1024

Figure 5. Bit error performance in an AWGN channel.

4.3. BER Performance

The error performances of OFDM systems over the AWGN channel are given by the BER curves in Figs. 5(a), (b), and (c) where $N = 256$, $N = 512$, and $N = 1024$ respectively. The results with 16 QAM show that the required SNR for BER $= 10^{-2}$ is almost the same. We see that the SNR required for the BER $= 10^{-3}$ is improved by 3 dB, 3.5 dB, and 5 dB, for $N = 256$, $N = 512$, and $N = 1024$, respectively.

5. CONCLUSIONS

In this paper, proposed technique for PAPR reduction of OFDM signals had been suggested. This technique combines two basic PAPR reduction methods interleaving and windowing methods. The main advantage of the proposed combination reduce PAPR, decrease the BER over conventional techniques, and improve the spectrum efficiency, where the proposed technique is evaluated in presence of nonlinear power amplifier.

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