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COMBINED INTERLEAVING AND COMPANDING FOR PAPR REDUCTION IN OFDM SYSTEMS

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ABSTRACT - Peak to Average power Ratio (PAPR) is one of the serious problem in any wireless communication systems using multicarrier modulation technique as OFDM which reduces the efficiency of transmit high power amplifier. In this paper, proposed scheme will be introduced, which combines interleaving technique and companding technique to reduce PAPR. This scheme will be compared with the system that uses other technique for reduction which is the clipping technique. By using proposed scheme, the PAPR of OFDM signal can be reduced by 6.8 dB over the original system, i.e., without PAPR reduction. Also, SNR decreases by more than 5 dB for Bit Error Rate (BER) of 10−3 over the original system. Moreover, the proposed scheme gives improvement more than 4.5 dB for BER of 10−3 over the system that uses clipping. All these systems will be evaluated in the presence of nonlinear power amplifier.

Keywords— **PAPR, OFDM, Companding**

I. INTRODUCTION

International standards used for OFDM in high speed wireless communications have already been established are being established by IEEE 802.11, IEEE 802.16, IEEE 802.20, and European Telecommunications Standards Institute (ETSI) Broadcast Radio Access Network (BRAN) committees. OFDM is a multicarrier modulation where it is split a high rate data stream into a number of lower rate data streams that are transmitted simultaneously over a number of subcarriers. Because the symbol duration increase for the lower rate parallel subcarriers, the retrieve amount of dispersion in the time caused by multipath delay spread is decreased. Inter symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol. Moreover, OFDM provides greater immunity to multi path fading and impulse noise, and reduces the complexity of equalizers, while efficient hardware implementation can be realized using Fast Fourier Transform (FFT) techniques. In despite of its advantages, there is a serious problem, PAPR. This problem comes from the nature of the modulation itself, where multiple carriers 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 dynamic range over which the transmitter amplifier operates linearly. Several researchers have proposed schemes for reducing peak amplitude, such as clipping, coding, Active Constellation Extension (ACE), partial transmit sequences, and turbo coded OFDM.

In this paper. Proposed scheme will be presented to reduce the be evaluated under the eff ect of AWGN. PAPR by combining the interleaving and companding methods. This scheme will be compared with the original system and the system that uses clipping method for reduction. All these systems will be studied in the presence of nonlinear power amplifier. Moreover, all these systems will be evaluated under the effect of AWGN.

II. PAPR IN OFDM SYSTEMS

If we consider N modulated data symbols from a particular signaling constellation, Xk = (X0, X1….. XN−1), over a time interval [0, T], the OFDM symbol can be written as

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

Where $f_0 = 1/T$

Replacing t=n. Tb, where Tb = T/N, the discreate time version can be given by

$$X_n = \sum_{K=0}^{N-1} X_k e^{j2\pi kn/N} \quad (2)$$

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

$$PAPR = \max_{0 \le t \le T} \frac{X(t)2}{E[X(t)2]} \quad (3)$$

In practice, the occurrence of these large PAPR requires in efficient hardware design and implementations and also aff ects bit error rate during signal transmission. The first problem of in efficient hardware design will be discussed. The PAPR ratio is a measure of the dynamic range in OFDM signals. Thus high PAPR induces a high dynamic range which describes high variability in the signal range. The large PAPR leavels increase the implementation complexity (the number of quantization bits) of the A/D and the D/A converters such that large peaks can be represented with good precision. To avoid any loss of information, these large dynamic ranges must be compensated by the hardware such as A/D and D/A converters through hardware design. Because high PAPR signals

Generally exhibit high energy concentrations over small portions of the signal, the designing of hardware to compensate for only a small fraction of the signal leads to inefficiency in design and implementation costs. Another problem which Another problem which is experienced by OFDM signals that have high PAPR involves the development of non-linear distortions. High power amplifiers used at the transmitters only perform eff ectively when signals passing through the amplifier are within the dynamic range, catered by the amplifiers. When amplifiers limit the transfer of large induced peak powers in signals, amplifiers then forced to operate in the non linear regions creating non linear distoritions. These non-linear distortions are a major problem that causes out of band radiation which influences BER. The ideal condition is that the power amplifier is intuitively recoverable to their original form. Once distortions are nonlinear, the changing in signals is no longer predictable or recoverable.

III. PROPOSED TECHNIQUE

The principles of the used techniques which are companding and interleaving will be studied in the following

A. Companding Technique

The compander consists of compressor and expander. The compressor is a simple logarithm computation. The reverse computation of a compressor is called an expander. In this paper, the compression at the transmit and after the IFFT process and expansion at the receiver end prior to FFT process are used.

There are two types of companders that are used here which are described these two types are µlaw and A law companders.

B. µ-law companding

The µ-law compander employs the logarithmic function at the transmitting side

In general a µ law compression characteristic

$$y = \frac{V \log_e(1+\mu|x|)}{\log_e(1+\mu)} sgn(x) \quad (4)$$

where µ is the µ-law parameter of the compander, where x : input signal

V: maximum value of the signal x.
µ: parameter controls the amount of compression.

The maximum value of output y is the same maximum of input x is equal to V.

For normalized input signal with lxl ≤ 1, the characteristic becomes

$$y = \frac{\log(1+\mu|x|)}{\log(1+\mu)} sgn(x) \quad (5)$$

The µ law expander is the inverse of the compresser

C. A law Companding

The characteristics of this compander is given by

$$Y = \begin{cases} \frac{1+\ln A|x|}{1+\ln A} sgn(x) & \frac{1}{A} \le |x| \le 1 \\ \frac{A|x|}{1+\ln A} sgn(x) & 0 \le |x| \le \frac{1}{A} \end{cases} \quad (6)$$

A: parameter controls the amount of compression

The compression characteristics are shown below in the figure. µ-law compander characteristics and A-Law compander characteristics (fig 1)

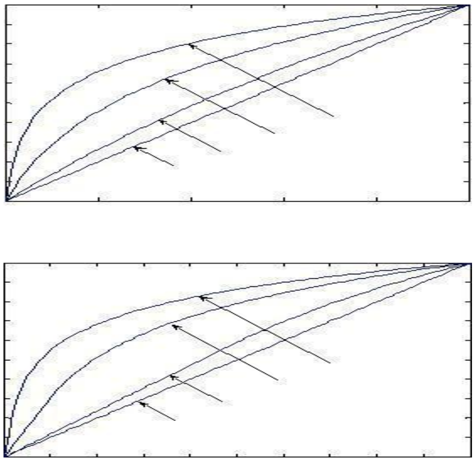

Fig.1 µ-law compander characteristics,
A-Law compander characteristics

IV. INTERLEAVING TECHNIQUE

The detailed descriptions of interleaver are found in the proposed 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 side information.

The main idea of the proposed scheme is to use a combination of two appropriate methods. One is the distortionless technique using data interleaving; the other is the distortion technique using companding as shown in Figure 2. First, the interleaving approach is used and the signal with lowest PAPR passes through companding technique. The intention to combine these two methods is to obtain signal with lower PAPR than in the case of interleaving method and with lower BER in the case of companding technique. We try to compensate the disadvantages of the two, complexity and distorition.

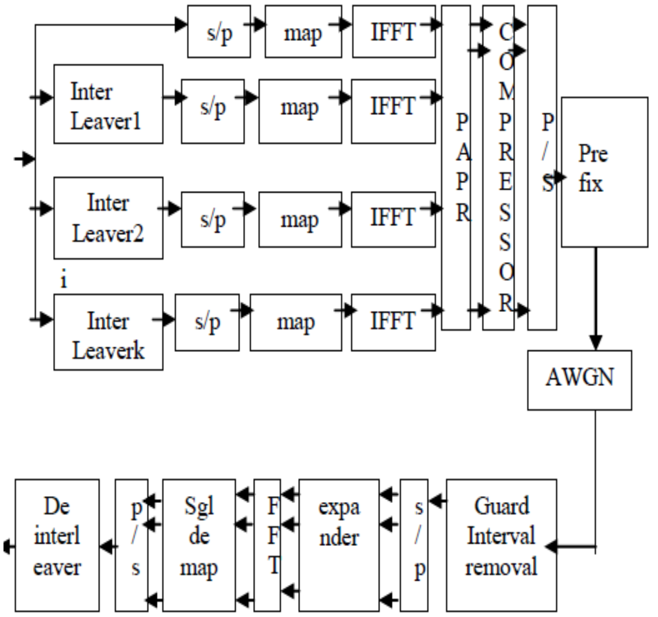

Fig 2. Ofdm System with Proposed Technique For Papr Reduction

V. SIMULATION RESULTS:

Computer simulations are used to clarify the peak power reduction capability. This simulated system employs an OFDM signal with N = 1024, N = 512, N = 256 sub carriers using 16 QAM. The High Power Amplifier (HPA) is Rapp's solid state power amplifier model.

$$v_{out} = \frac{v_{in}}{(1 + (\frac{|v_{in}|}{v_{sat}})^{2p})} \quad (7)$$

Where Vin, Vout are the complex input and output signals, respectively. vsat is the output saturation level. The parameter p, often called "knee factor", controls the smoothness of the characteristic.

The input back-off (IBO) with respect to the saturation values can be defined as,

$$IBO = 10\log_{10}\{\frac{V^2 sat}{E[|Vin|]}\} \quad (8)$$

In this paper, a rapp model HPA is assumed with knee factor p = 2, IBO = 3.5 dB. The BER performance will be evaluated under the effect of Additive White Gaussian Noise (AWGN).

To clarify the effect of peak reduction, CCDF is defined as a complementary function in the following, CCDF and BER performance will be studied. The CDF is (Cumulative Distribution Function).

A. CCDF performance

PAPRstatistic is 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) > PAPRo).

Figure 3 shows the CDF performance of the proposed scheme of the proposed scheme over original system for different values of μ, 16 QAM and N = 256. With the proposed method, peak power at CCDF = 10−3 is reduced by about 4.9 dB, 6.8 dB and 8 dB as compared to the case of original system, for μ = 2, μ = 13, and μ = 64 respectively.

The value for μ = 13 and k = 8 interleaver is chosen to compensate the disadvantages of the two techniques, the complexity and sitortion .

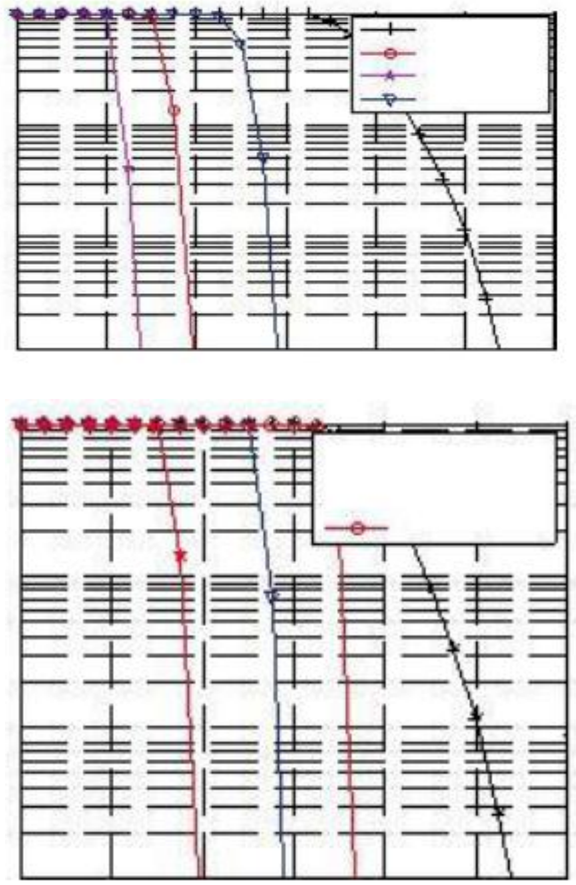

Fig 3 CCDF of PAPR with the proposed system for different μ

B. BER performance

BER performance vs. SNR over AWGN where N=256, N=512, and N=1024, respectively. SNR that is required for BER of 10−3 is improved by 5 dB, 6 dB, and 6.5 dB, for N = 256, N = 512, and N = 1024, respectively, by using μ = 13 and k = 8 interleaver. Figure 7 shows the effect of different values of μ on the proposed system. Irrespective of the better results which comes from the higher value of μ on CCDF performance, BER becomes worst. Thus, we must compromise between these performances. Therefore µ equal to 13 is chosen in the paper.

The figure 4 shown the BER performance of the proposed

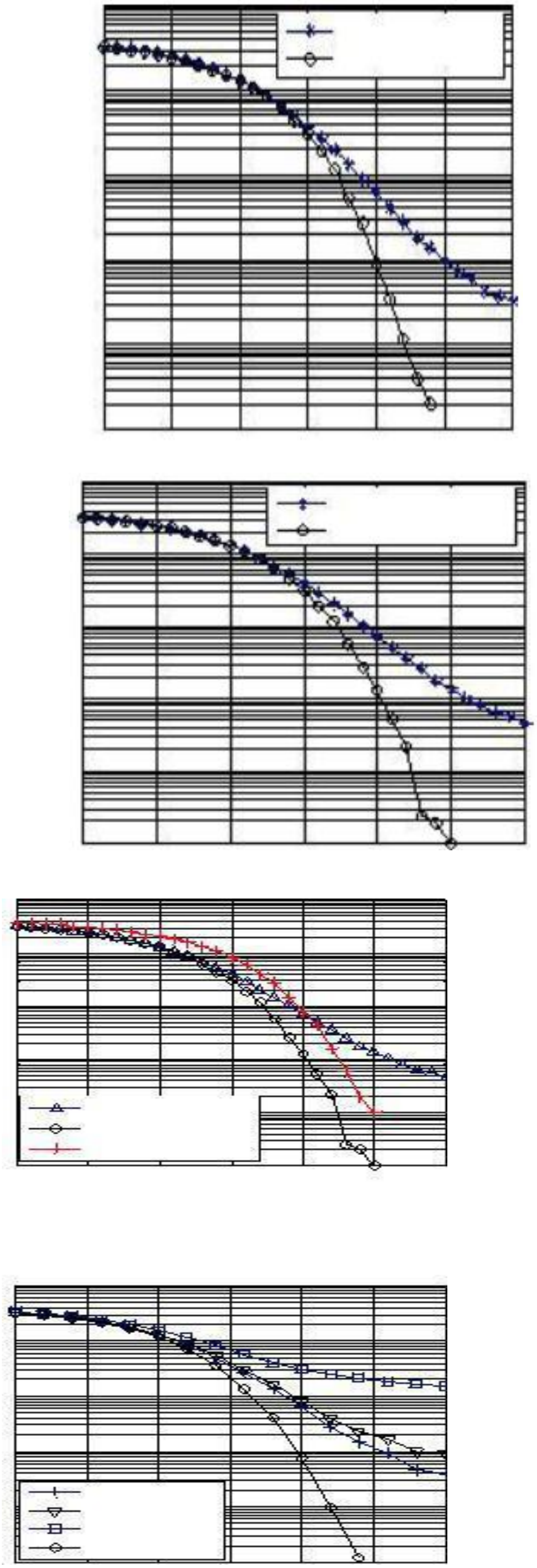

Fig.4. BER vs SNR(dB)

Technique for µ = 13 is compared with that of the clipping technique for different CR, where the proposed technique reduces the BER more than 4.5 dB over clipping technique. This improvement that is seen in BER in proposed system which includes the amplifier is just another way of visualizing the PAPR reduction. The PAPR reduction that is archieved means our amplifier is operating more in its linear region , which means many errors related to clipping from saturation region of power amplifier are not seen. In other words, the dominant effect that is causing the errors is the amplifier and not AWGN.

VI. CONCLUSIONS

In this paper, proposed technique for PAPR reduction of OFDM signals had been introduced. This technique combines two basic PAPR reduction techniques which are interleaving and companding methods. The companding technique uses the µ-law or A-law with suitable values of µ or A, which gives better performance, where the µ-law and A-law reduce dynamics range of the signal. By using this scheme, the PAPR improves by 6.8 dB at CCDF = 10^{-3} over the original system. Moreover, the proposed method gives improvement more than 2 dB at probability of 10^{-3} over the system that uses clipping for PAPR reduction. Also, SNR decreases by more than 5 dB for BER of 10^{-3}. All these systems will be evaluated in the presence of nonlinear power amplifier.

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