Airy Function Based Papr Reduction Method for Ofdm Systems

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Abstract:*Orthogonal Frequency division multiplexing (OFDM) is widely used technique in modern day wireless communication systems which provides robustness to channel fading and immunity to impulse interference. Despite of its advantages, one of themajor drawbacks of OFDM system is very high peak-to-average power ratio (PAPR). Among the various PAPR reductiontechniques, companding appears attractive for its simplicity and effectiveness. In this paper novel compandingtechnique based on mathematical airy function is proposed which offers improved bit error rate, minimizes out-of-bandinterference and reduce PAPR effectively. Simulation results illustrates the performance of the system under Additive WhiteGaussian Noise (AWGN) and further evaluation is done for comparing the proposed companding technique with previoustechniques.*

Keywords:*OFDM, OBI, PAPR, Companding*

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has significant ability to support high data rates for wide area coverage, robustness to multipath fading, immunity to impulse interference [1,2]. However one of the major drawbacks of OFDM signal is its large envelope fluctuation, likely resulting in large peak-to average power ratio (PAPR), which distorts the signal if the transmitter contains the non-linear components such as power amplifiers and these may causes deficiencies such as intermodulation, spectral spreading and change in signal constellation. Minimizing PAPR allows higherAverage power to be transmitted for a fixed peak power and improving the overall signal to noise ratio at the receiver.

Some of the methods proposed in literature to reduce the PAPR of OFDM signals include several techniques such as amplitude clipping ,tone reservation(TR), active constellation extension(ACE) and coding [1,2][13], selective mapping [3], partialtransmitting [4]. In [5], optimal companding coefficient is determined to enlarge small OFDM signals along with PAPR reduction. In [6], non-linear companding scheme is described by a single valued function which allows to be transformed beforeamplification. In exponential companding OFDM signals are transformed into uniformly distributed.

The idea behind these methods is that by clipping the peaks [8] of OFDM signal which is the simplest technique but it causes additional clipping noise and out-of-bandinterference (OBI) which degrades the system performance. But in μ-law companding, the PAPR is reduced at the expense of increasing the average power. In order to overcome the problem of increase of average power and to have efficient PAPR reduction, a non-linear companding technique namely exponential companding has been developed. In this paper, a simple but effective novel new companding technique which uses the special airy function to reduce the peak-to-average power ratio of OFDM signal is proposed.

II. PEAK TO AVERAGE POWER RATIO (PAPR)

An OFDM signal can be expressed as

$$s(t)=\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1}S_k e^{j2\pi kt/NT},\quad t\in\left[0,NT\right] \tag{1}$$

Where S_k is the complex based band modulated symbol and N is the number of subcarriers

LetS^mbe the *m*-th OFDM symbol, then its PAPR is defined as

$$\mathbf{PAPR}_m=\frac{\left\|\mathbf{s}^{(m)}\right\|_\infty^2}{E\left[\left\|\mathbf{s}^{(m)}\right\|^2\right]/N} \tag{2}$$

The peak power occurs when modulated symbolsare added with the same phase. The effectiveness of aPAPR reduction technique is measured by thecomplementary cumulative distribution function (CCDF), which is the probability that PAPR exceedssome threshold [11, 12], i.e.

CCDF = Probability(PAPR >PAPRo)(3)

III. PROPOSED METHOD

In OFDM system, the ideal case is to reduce thePAPR to make the amplitude of the complex basebandsignal constant. Quantification of the OBIcaused by companding requires the knowledge of thepower spectral density (PSD) of the compandedsignal. Unfortunately analytical expression of thePSD is in general mathematically intractable, becauseof the nonlinear companding transform involved.Here we take an alternative approach to estimate theOBI. Let f (x) be a nonlinear compandingfunction,and x(t) = sin(wt) be the input to the compander. Thecompanded signal y(t) is:

$$y(t) = f[x(t)] = f[\sin(wt)] \tag{4}$$

We now propose a new companding technique using a smooth function, namely the airy special function. The companding function is as follows:

$$f(x) = \beta\, .sign\,(x).[airy\,(0\,) - airy\,(\alpha\,.\,x\,)] \tag{5}$$

Where airy(.) is the airy function of the first kind

$$\mathrm{Ai}(x)=\frac{1}{\pi}\int_0^\infty \cos\left(\tfrac{1}{3}t^3+xt\right)\,dt, \tag{6}$$

Where α isthe parameter that controls the degree ofcompanding β is the factor adjusting the averageoutput power of the compander to the same level asthe average input power:

$$\beta = \sqrt{\frac{E\left[|x|^2\right]}{E\left[|airy(0) - airy(\alpha|x|)|^2\right]}} \quad (7)$$

The de-companding function is the inverse of f(x):

$$f^{-1}(x) = \frac{1}{\alpha}.sign\,(x).airy^{-1}\left[airy\,(0) - \frac{|x|}{\beta}\right] \quad (8)$$

IV. EXPERIMENAL RESULTS

The spectrums of the uncompressed and compressedOFDM signals by the proposed scheme are illustratedin Fig.1.From the simulation results; it is observedthat the proposed algorithm produces OBI almost3dB lower than the exponential algorithm, 10dB lower than the μ-law. Fig.2 depicts the CCDF of thethreecompanding schemes. The new algorithm isroughly 1.5dB inferior to the exponential, butsurpasses the μ-law by 6dB. The BER vs. SNR isplotted in Fig.3 proposed algorithm has improved biterror rate compared with exponential and μ-lawalgorithms. The amount of improvement increases as SNR becomes more. One more observation from thesimulation is that unlike the exponential compandingwhose performance is found almost unchanged underdifferent degrees of companding, the new algorithmis flexible in adjusting its specifications simply bychanging the value of α in the companding function.

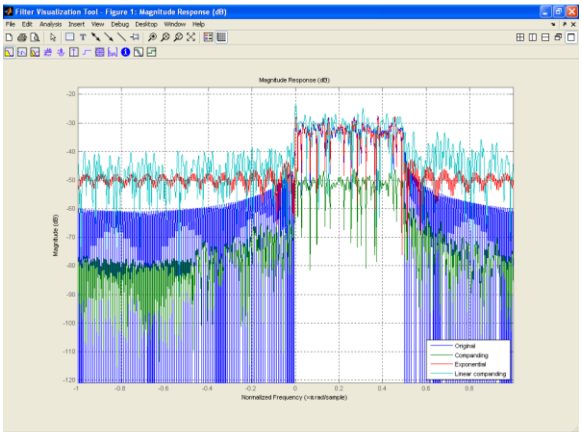

Figure 1:Power spectral density of original and compandedsignals (companded i/p power = 3dBm, α = 30)

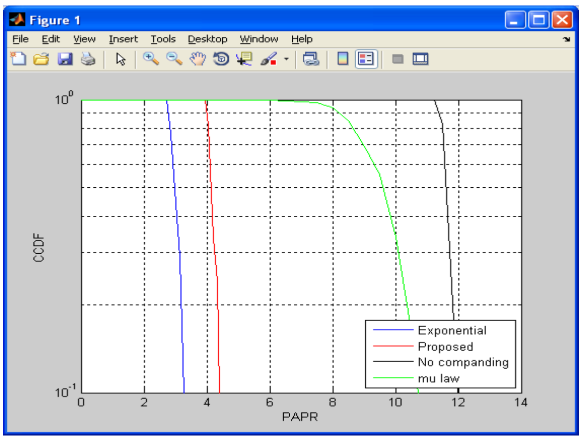

Figure 2: Complimentary Cumulative Distribution function oforiginal and companded signals companded i/p power =3dBm, α = 30)

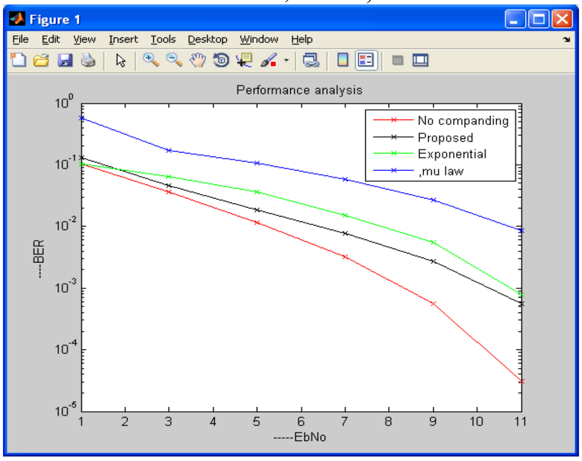

Figure3: BERVs SNR for original and companded signals inAWGN channel and Linear LDPC coding (companded i/ppower = 3dBm, α = 30)

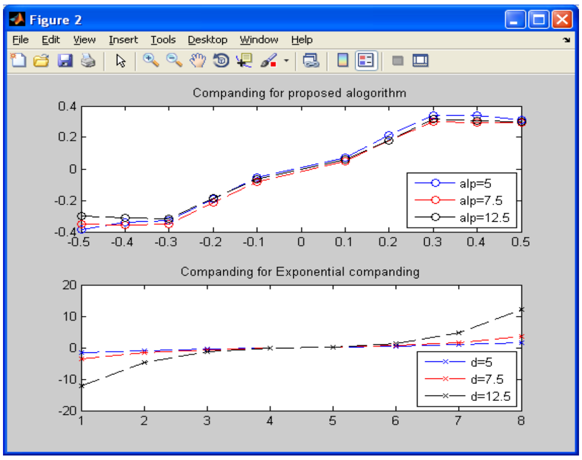

Figure 4: Comparative analysis between the proposed and the exponential companding transform

V. CONCLUSION

Anattractive and simpler companding algorithm is proposed toeffectively reduce PAPR problem in OrthogonalFrequency Division Multiplexing (OFDM) with mathematical airy function.Bycarefulselection of the control parameter α explained in thepaper, the PAPR reduction can be achieved in a betterway and the BER performance can be improved.Simulation results show, that the proposed algorithmoffers improved performance in terms of BER andOBI while reducing PAPR effectively compared withexponential and μ-law companding schemes.

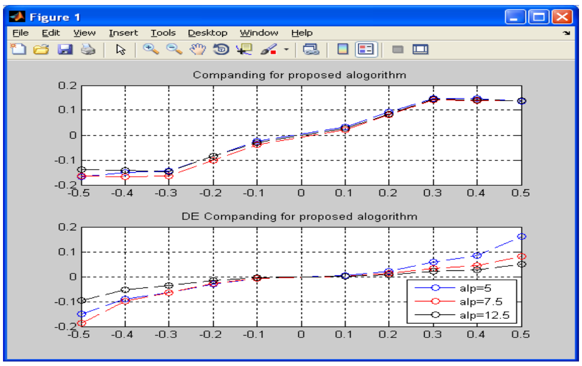

Figure 5: Proposed companding method analysis for companding and de-companding

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