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Performance Comparison of Companding Algorithm in OFDM

Malhari Kutwal[1], A.N. Jadhav[2]

Assistant Professor, E &TC, D.Y.Patil Technical Campus, Talsande, Kolhapur, India[1]

Associate Professor, Electronics Department, D.Y. Patil College of Engineering & Tech. Kolhapur, India [2]

Abstract: Orthogonal Frequency Division Multiplexing is most promising technology for high data rate wireless communication. High peak-to-average power ration is major disadvantage of Orthogonal Frequency Division Multiplexing system.[1],[2]. This paper analyses bit error rate performance by using companding algorithm µ-law, Exponential and companding using Airy Function.

Keywords: Companding, Orthogonal Frequency Division Multiplexing, Peak-to-average power ratio.

I. Introduction

Orthogonal Frequency Division Multiplexing is a multicarrier transmission technique, it divides avaible spectrum into many carriers. OFDM uses spectrum much more efficiently by spacing the channels much closer to each other. This system has better properties such as high spectral efficiency, robustness to channel fading, immunity to interference. There are some obstacles in OFDM system. A major problem is that OFDM signal exhibits a very high peak to average power ratio (PAPR). These large peaks cause saturation in power amplifiers, intermodulation amongst subcarriers, increases out of band interference. Therefore it is necessary to reduce PAPR.

To reduce the peak to average power ratio several technique have been proposed such as clipping [3], [4], coding, peak windowing, tone reservation[6],. But most of these technique are unable to achieve simultaneous a large reduction in peak to average power ratio with low complexity. Among all these techniques the simplest solution is to clip transmitted signal when its amplitude exceeds a desired threshold. Clipping highly non-linear process however, it produces significant out of band interference (OBI). A good remedy for out of band interference is called companding. The technique 'soft' compress, rather than 'hard' clips, the signal peaks causes far less out of band interference. The method was first proposed in, which employed in classical μ law transform and showed effective. Since then many different companding transform with better performance have been published. This paper organized as follows: section 2, presents companding algorithms such as µ law, Exponential, Companding using airy function. In section three these algorithms compared with non-companded signal. We use Bit error rate as a comparison parameter for companding algorithm. In section four we conclude.

II. Companding Algorithm

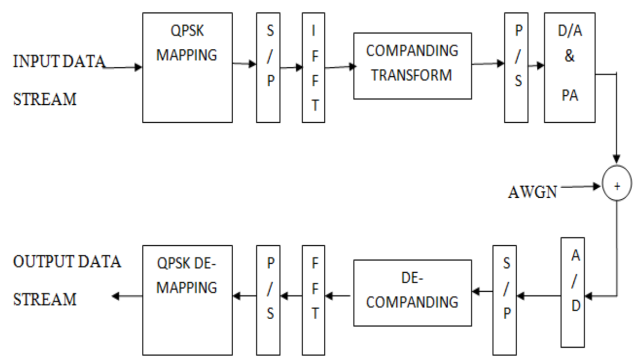

Fig.1. Block diagram of OFDM system with Companding transform

A. *µ-Law Companding*

µ −Law is a simple but effective companding technique to reduce the peak-to-average power ratio of OFDM signal is. The idea comes from the use of companding in speech processing. Since OFDM signal is similar to speech signal in the sense that large signals only occur very infrequently, the same companding technique might be used to improve OFDM transmission performance [7],[8].

A QAM-OFDM system diagram is shown in Figure .1. The incoming bit stream is packed into x bits per symbol to form a complex number S_k where x is determined by the QAM signal constellation. For a real sequence output at the IDFT, the complex input to the IDFT has Hermitian symmetry and is constrained as follows

$$S_{N-K} = S_k \qquad (1)$$

Where k=0, 1, 2……… (N/2)-1, and S(0)=0.

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Suppose N is even and$S_k = a_k - jb_k$, the output of IDFT is

$$S(n) = 1/\sqrt{N}\sum_{k=1}^{\frac{N}{2}-1}(a_k cos\frac{2\pi kn}{N} + b_k sin\frac{2\pi kn}{N}) \quad (2)$$

n=0, 1,2…………………,N-1
The µ law companding technique can be then introduced. The samples of OFDM signal s(n) are companded before it is converted into analog waveform.
The signal after companding is given by

$$S_c(n) = \frac{Asgn\,(s(n))In[1+\mu\left|\frac{s(n)}{A}\right|}{In(1+\mu)} \quad (3)$$

A is normalization constant, after D/A conversion the signal transmitted through channel. At the receiver end, received signal first converted into digital form, the sampling result is

$$s(n) = S_c(n) + q(n) + w(n) \quad (4)$$

Where q is analog to digital conversion error and w is AWGN channel factor.
The expanded signal can be approximated as :

$$S'(n) \approx s(n) + \frac{[q(n)+w(n)]AB}{\mu} + S(n)[q(n) + w(n)]B \quad (5)$$

Here we recover the original data, expanded samples $S'(n)$ are send to FFT block.

B. Exponential Companding

Exponential companding technique adjusts both large and small signals and can keep the average power at the same level[9]. By transforming the original OFDM signal into uniformly distributed signals, the exponential companding schemes can effectively reduce peak to average power ratio for different modulation subcarriers [9].Companding equation can be given as: Let $|t_n|^d$ the d^{th} power of amplitude of companded signal, have a uniform distribution in the interval [0,∝]. The exponent ∝ is called degree of specific exponential companding scheme. The CDF of $|t_n|^d$ is simply

$$F_{|t_n|^d} = \frac{x}{\propto}, 0 \leq x \leq \propto \quad (6)$$

Considering the phase of the input signals, the companding function $h(x)$ is given by,

$$h(x) = sgn(x)F_{|t_n|}^{-1}(F_{|s_n|}(x)) \quad (7)$$

$$= sgn(x)\sqrt[d]{\propto [1 - \exp(\frac{-x^2}{\sigma^2})} \quad (8)$$

Where sgn(x) is the sign function. The positive constant ∝ determines the average power of output signals.

$$\propto = (\frac{E[|s_n|^2]}{E[\sqrt[d]{\propto[1-\exp(\frac{-|s_n|^2}{\sigma^2})]^2}})^{\frac{d}{2}} \quad (9)$$

At the receiver side, the inverse function $h(x)$ of is used in decompanding operation,

$$h^{-1}(x) = sgn(x)\sqrt{-\sigma^2 log_e(1 - \frac{x^d}{\alpha})} \quad (10)$$

C. Companding Using Airy Function
Companding algorithm using airy function [10] is explained below; the companding function is as follows:

$$f(x) = \beta \cdot sign(x) \cdot [airy(0) - airy(\alpha \cdot |x|)] \quad (11)$$

Where airy (·) is the airy function of first kind.∝ is the parameter that controls the degree of companding and β is factor adjusting the average input power.
The de-companding function is the inverse of $f(x)$

$$f^{-1}(x) = \frac{1}{\propto} \cdot sign(x) \cdot airy^{-1}[airy(0) - \frac{|x|}{\beta}] \quad (12)$$

III. Performance simulation

The OFDM system used in the simulation consists of 64 QAM-modulated data points. The size of the FFT/IFFT is 256, meaning a 4× oversampling. Given the compander input power is 3dBm
The parameters used to check the performance are bit error rate (BER), signal to noise ratio (SNR) are discussed below. The simulation results of The BER vs. SNR are plotted in Fig.2. Bit Error rate of No companded OFDM signal is compared with the $\mu -$ law companded signal.

TABLE I
SNR vs. BER MU-LAW COMPANDED & NON-COMPANDED

Sr.no.	SNR	BER (non-companded)	BER (µ-law companded)
1	1	0.09	2.54
2	3	0.03	0.33
3	5	0.01	0.19
4	7	0.002	0.10
5	9	0.006	0.04

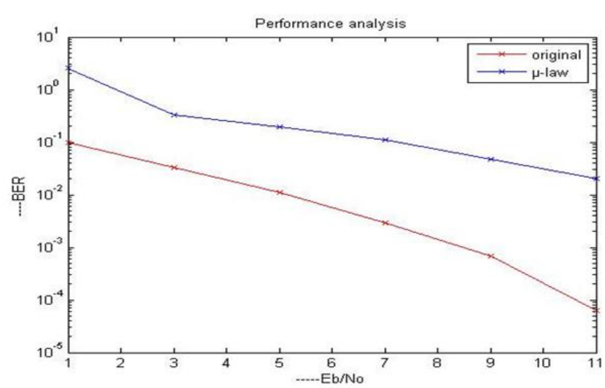

Fig.2. simulation result of BER vs SNR

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The simulation results of The BER vs. SNR are plotted in Fig.3. Bit Error rate of No companded OFDM signal is compared with the Exponential companded signal and companding using airy function.

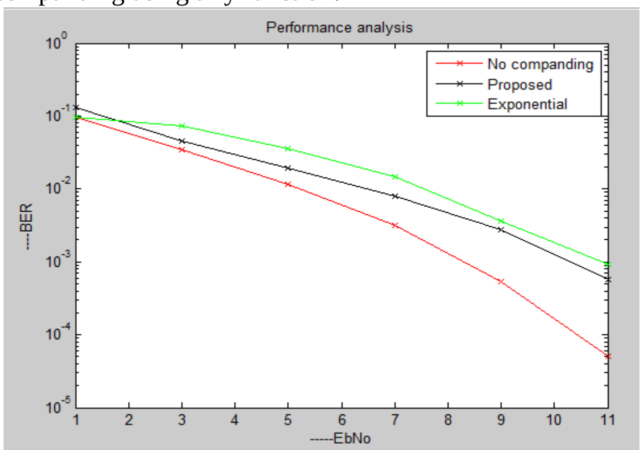

Fig 3. Simulation results of Exponential Companding and companding using airy function.

TABLE 2.
SNR vs. BER of Exponential companded signal and companding using airy function

S.No	SNR	BER (non-companded)	BER (Exponential companded)	BER using airy function
1	1	0.09	0.09	0.1
2	3	0.03	0.06	0.04
3	5	0.01	0.03	0.01
4	7	0.002	0.01	0.007
5	9	0.006	0.003	0.002

IV. CONCLUSION

In this paper, performance of companding algorithms such as μ −law & Exponential, companding using airy function algorithm is evaluated based on bit error rate and signal to noise ratio. Exponential companding scheme adjust both large and small peaks and airy function minimizes out of band interference thus we can minimize bit error rate of the system. It is observed that to reach BER of the required SNR for companding using airy function algorithm implies better improvement than μ law and Exponential scheme. As BER is decreased automatically PAPR of the OFDM signal will reduce.

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BIOGRAPHIES

Mr. Malhari V. Kutwal completed BE from Terna College of Engineering Osmanabd in 2009 and doing M.E. ETC in D.Y. Patil College of Engineering, Kolhapur and presently working as a Assistant Professor in D.Y. Patil Technical Campus, Talsande, Kolhapur. His research interest in Mobile Communication.

Mr. A.N. Jadhav received BE in Electronics from D.Y. Patil College of Engineering & Technology, Kolhapur in 1991, ME degree in Electronics from walchand College of Engineering Sangli in 1997,(Ph.D. Scholar). He is currently working as Associate Professor and HOD in D.Y. Patil College of Engineering & Technology, Kolhapur. He is a LM of ISTE. His 33 international and 19 national research papers are published.