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Performance Comparison of μ −Law and Exponential Companding Algorithms in OFDM System

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ABSTRACT : *Orthogonal Frequency division multiplexing (OFDM) is a very attractive technique in wireless communications which provides robustness to channel fading and immunity to impulse interference. Despite of its advantages, one of the major drawbacks of OFDM system is very high peak-to-average power ratio (PAPR). Among the various PAPR reduction techniques, companding appears attractive for its simplicity and effectiveness. In this paper, comparison of companding algorithm such as μ-law and exponential based on the bit error rate and signal to noise ratio is evaluated.*

Keywords -*Companding, OFDM, PAPR, Complementary cumulative distribution function.*

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has good ability to support high data rates for wide area coverage, robustness to multipath fading, immunity to intercarrier interference. However one of the major drawbacks of OFDM signal is its large envelope fluctuation, likely resulting in large peak-to average power ratio (PAPR), these may causes problems such as inter modulation, spectral spreading and change in signal constellation.

Some of the methods proposed in literature [1] to reduce the PAPR of OFDM signals include several techniques such as amplitude clipping [2], tone reservation (TR), and coding, selective mapping [4], partial transmitting [5]. In optimal companding coefficient is determined to enlarge small OFDM signals along with PAPR reduction. In exponential companding OFDM signals are transformed into uniformly distributed signals.
The idea behind these methods is that by clipping the peaks of OFDM signal which is the simplest technique but it causes additional clipping noise and out-of-band interference (OBI) which degrades the system performance. But in μ-law companding [5], 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 [6] technique namely exponential companding has been developed [7].

II. COMPANDING ALGORITHM

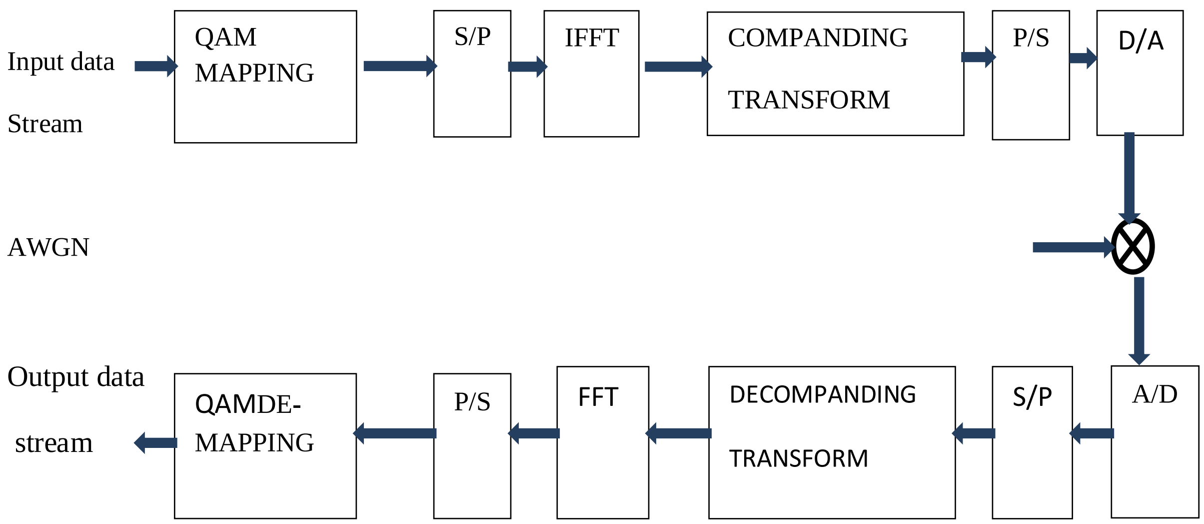

Fig.1.Block diagram of OFDM system with Companding transform

A companding system shown in Fig.1. Compresses the signal at input and expands the signal at output in order to keep the signal level above the noise level during processing. At the output, the original input signal is then restored by a simple attenuation. Companding increases the SNR when the input signal is low and therefore reduces the effect of a system's noise source.

2.1μ −Law Companding Algorithm

A simple but effective companding technique to reduce the peak-to-average power ratio of OFDM signal is evaluated in this paper. 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 [5].

AQAM-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. Suppose N is even and $s_k = a_k - jb_k$ the output of IDFT is

$$S(N) = 1/\sqrt{n}\sum_{k=1}^{\frac{N}{2}-1}\left(a_k \cos\frac{2\pi kn}{N} + b_k \sin\frac{2\pi kn}{N}\right) \quad \text{n=0, 1,…..N-1} \qquad (2)$$

Thus OFDM signal possesses a similar property with speech signal. The μ − law companding technique can then be introduced. The samples of OFDM signal *s(n)* are companded before it is converted into analog waveform. The signal after companding is given by

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

The degree of companding depends upon factor μ .A is normalization constant, after D/A conversion the signal is transmitted through channel. At the receiver end, received signal first converted into digital form, the sampling result is:

$$s(n) = s_c(n) + q(n) + w(n) \qquad (4)$$

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

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

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

2.2 Exponential Companding Algorithm

A nonlinear companding algorithm, called "exponential companding", developed to reduce the high Peak-to-Average Power Ratio (PAPR) of Orthogonal Frequency Division Multiplexing (OFDM) signals. Exponential companding technique adjusts both large and small signals and can keep the average power at the same level. By transforming the original OFDM signals into uniformly distributed signals, the exponential companding schemes can effectively reduce PAPR for different modulation formats and sub-carrier sizes [7].

Let $|t_n|^d$ be the d^{th} power of the amplitude of companded signal, have a uniform distribution in the interval [0,∝]. The exponent∝ is called the *degree* of a specific exponential companding scheme the CDF of $|t_n|^d$ is simply

$$F_{|t_n|^d}(x) = \frac{x}{\alpha}, 0 \le x \le \propto \qquad (6)$$

The amplitude of the$|t_n|$ of companded signal has following CDF

$$F_{|t_n|}(x) = \frac{x^d}{\propto}, 0 \le x \le \sqrt[d]{\propto} \qquad (7)$$

The inverse function of $t_{|n|}(x)$

$$F_{|t_n|}^{-1}(x) = \sqrt[d]{\propto x}\ , 0 \le x \le 1 \quad (8)$$

On the other hand, given that $h(x)$is a strictly monotonic\ increasing function, we have,

$$F_{|s_n|}(x) = F_{|t_n|}\big(h(x)\big), 0 \le h^{-1}(\sqrt[d]{\propto}) \quad (9)$$

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

$$h(x) = sgn(x)F_{|t_n|}^{-1})(F_{|s_n|}(x)) \quad (10)$$

$$= sgn(x)^{d}\sqrt[d]{\propto [1 - \exp(\frac{-|s_n|^2}{\sigma^2})} \quad (11)$$

Where sgn(x) is sign function. The positive constant ∝determines the average power of output signals. In order to keep the input and output signals at the same average power level, we let

$$\propto = (\frac{E[|s_n|^2]}{E[\sqrt[d]{1-\exp\left(\frac{-|s_n|^2}{\sigma^2}\right)}]^2}) \quad (12)$$

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

$$h^{-1}(x) = sgn(x)\sqrt{-\sigma^{2\log_e(1-\frac{x^d}{\propto})}} \quad (13)$$

Non-linear companding transform is an effective technique in reducing the PAPR of OFDM signals. In addition, the schemes based on companding technique have low implementation complexity and no constraint on modulation format and sub-carrier size.

III. PERFORMANCE SIMULATION

The waveform of OFDM signal before companding is plotted in figure.2.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

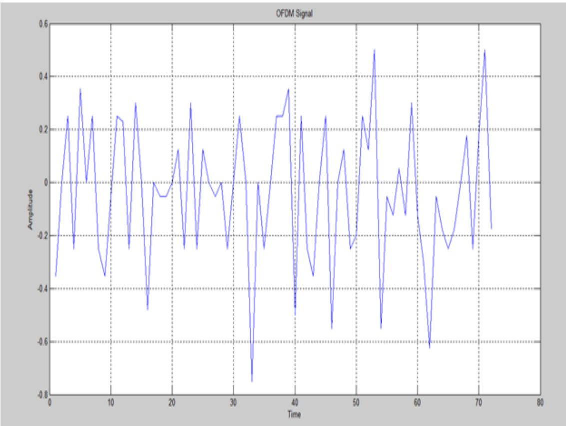

Fig.2. OFDM signal

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.3. Bit Error rate of No companded OFDM signal is compared with the μ − law companded signal

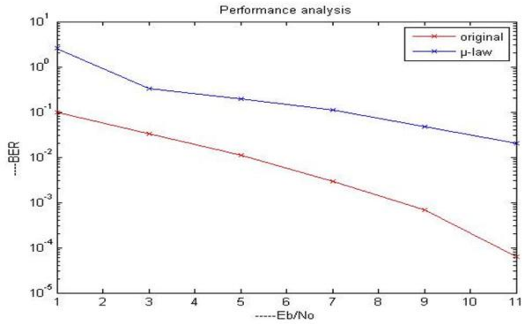

Fig.3. simulation result of BER vs. SNR

The simulation results of The BER vs. SNR are plotted in Fig.4. Bit Error rate of No companded OFDM signal is compared with the Exponential companded signal.

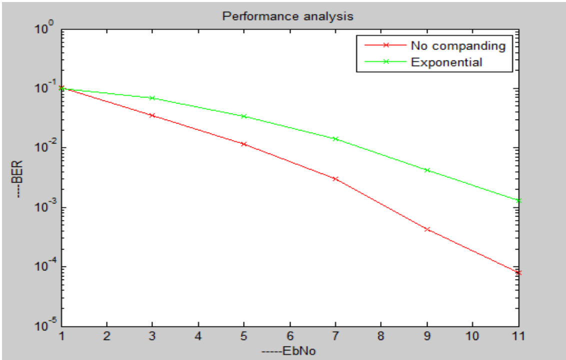

Fig 4: simulation result of No companding & Exponential companding Technique

Table.1.BER of original signal & Exponential companded signal

Sr. no	SNR	BER Original	BER μ −Law	BER Exponential
1	3	$10^{-1.5}$	$10^{0.5}$	$10^{-1.2}$
2	5	$10^{-1.9}$	$10^{0.7}$	$10^{-1.5}$
3	7	$10^{-2.7}$	$10^{0.9}$	$10^{-1.7}$
4	9	$10^{-3.2}$	10^{-1}	$10^{-2.4}$

IV. CONCLUSION

In this paper, comparison of μ-law & Exponential companding algorithm based on the bit error rate and signal to noise ratio is evaluated .It is observed that Exponential companding scheme shows better improvement in BER as compared with μ −law companding scheme.

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