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Nonlinear Commanding Transform Algorithm for Peak -To-Average Power Ratio Reduction Technique of OFDM Signal

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Abstract: *Orthogonal Frequency Division Multiplexing (OFDM) is digital multicarrier Modulation access system for high data rate transfer .But it has high PEAK To Average Power Ratio which increases complexity of A/D Converter and D/A Converters and lowers the efficiency of power amplifiers. In this paper Repeated Clipping and Filtering (RCF) distortion PAPR Reduction technique of an OFDM signal which is existing technique for reducing high Peak –to –Average Power of an OFDM signal. The basic idea of Repeated Clipping and Filtering(RCF) algorithm is to generate the anti-peak signal for Peak-to-Average Power Ratio (PAPR) reduction by projecting the clipping in-band noise into the feasible extension area while removing the Out-of-Band Interference (OBI), also called as Out-of-Band Distortion with filtering [3]. The Clipping and filtering method suffers from the three major problems like in-band distortion, out-of-band radiation & peak re-growth after digital to analog conversion [24].*

The Nonlinear Commanding Transform (NCT) distortion technique is proposed for reducing the high Peak –To –Average Power Ratio This proposed scheme reduces the PAPR by compressing the peak signals and expanding the small while maintaining average power constant selecting transform parameters Finally simulation results show that the proposed technique outperforms than Repeated Clipping and Filtering (RCF) technique in terms of low clipping ratio problem, peak re-growth ,out-of-band interference(OBI),PAPR reduction and BER Performance .

Keywords - *Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), Nonlinear Companding Transform (NCT), Repeated Clipping and filtering (RCF) algorithm Bit Error Rate (BER).*

I. INTRODUCTION

Orthogonal Frequency division multiplexing (OFDM) system provides high spectral efficiency, easy implementation with FET, greater immunity to multipath fading and impulse noise, good protection against co-channel interference and nonlinear distortion. Due to these advantages,OFDM system has popularly applied in wired and wireless communication system including Digital Video Broadcasting(DVB),Wireless Local Area Network(WLAN),World wide Interoperability for Microwave Access(WIMAX),3G and CDMA.OFDM system has one major disadvantage i.e. a very high Peak-To-Average Power Ratio at the transmitter .This high PAPR increases the complexity DAC and ADC Converters high peak signal generates out-of-band interference and in-band –distortion and also degrades system performance. To reduce this high PAPR, many schemes have been proposed in literature, which can be divided into two categories. The first category reduces high PAPR before multicarrier modulation, e.g. selective level mapping (SLM),partial transmit sequence(PTS) and coding known as signal scrambling techniques which have limitations on system performance such as the number of subcarriers, frame format and constellation type. The second category reduces high PAPR after multicarrier modulation such as clipping and filtering [3], companding transform [13] known as signal distortion techniques. Among which clipping and filtering is the simplest and most widely used for reducing the PAPR of OFDM signal. Nevertheless it causes clipping noise problem, peak re-growth and out-of- band interference (OBI) which makes nonlinear companding technique more suitable for high data rate applications. In this paper, a repeated clipping and filtering (RCF) is known as clipping based –active constellation algorithm is existing PAPR reduction technique which has a low clipping ratio problem..Furthermore, the piecewise nonlinear companding scheme has been also proposed to compared with the repeated clipping and filtering (RCF) for reducing PAPR .This proposed scheme transforms the Rayleigh distributed OFDM signal into a uniformly distributed signal and achieves better system performance with low BER than the RCF algorithm

II. OFDM SYSTEM AND PEAK-TO-AVERAGE POWER RATIO

Fig .1 shows OFDM system with Companding technique for PAPR reduction. Whole input bit stream is divided into many orthogonal subcarriers with narrow bandwidth and each symbols modulated by Qudurature Phase Shift Keying (QPSK) or QAM.

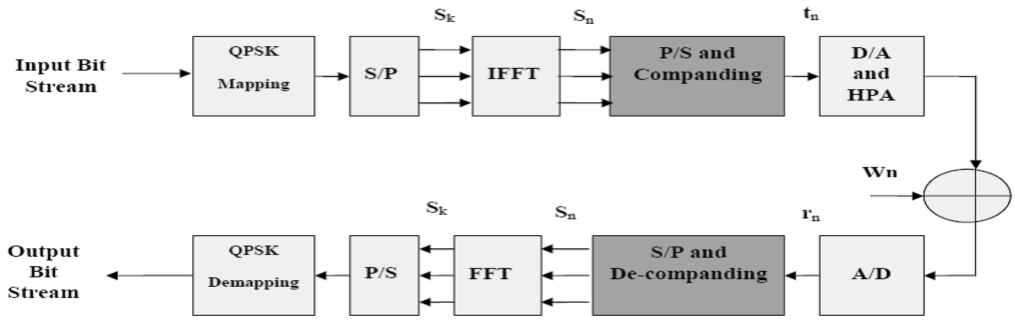

Fig.1 Block diagram of Companding of OFDM system

Let N denote the number of sub-carriers used for parallel information transmission and let S**k** (0 < k < N-1) the Kith complex modulated symbol in a block of N information symbols. The outputs Sn of the N-point Inverse Fast Fourier Transform(IFFT)of S_k are given by.

$$s_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} s_k \exp\left(\frac{j.2\pi kn}{N}\right) \qquad (1)$$

And the PAPR of OFDM signal in terms of power is in term of power is defined as

$$\text{PAPR} = 10 \log_{10} \max \{|Sn|^2\} / E[|Sn|^2] \text{ (dB)}$$

Where |Sn| returns the magnitude of Sn and E [.] denotes the expectation operation.

III REPEATED CLIPPING AND FILTERING (RCF) SCHEME

The repeated and filtering (RCF) also known as Clipping –Based Active Constellation Extension(CB-ACE) to generate the anti-peak signal for reducing the PEAK-to-Average Power Ratio by projecting the clipping noise into feasible in-band noise extension area while removing the out –of-band distortion with filtering

RCF involves switching between the time domain and the frequency domain which consists of Active Constellation Extension (ACE) constraint in the frequency domain and clipping Filtering in frequency domain. The RCF algorithm is first used to clip the peak amplitude of original OFDM signal. The clipping sample after the clipping the peak signal is given by

$$c_n^{(i)} = \begin{cases} (|x_n^{(i)}| - A)e^{j\theta_n}, & |x_n^{(i)}| > A \\ 0, & |x_n^{(i)}| \le A \end{cases} \qquad (2)$$

Where $c_n^{(i)}$ -Clipping Sample of the i^{it} iteration.

$x_n^{(i)}$ -Oversampled OFDM signal.

A –Predetermined Clipping Level θ_n –arg ($x_n^{(i)}$)

The target clipping ratio , is given by

$$\gamma = \frac{A^2}{E\{|x_n|^2\}} \qquad (3)$$

Where γ -Target clipping ratio

A-Predetermined Clipping Level

Xn –Oversampled OFDM signal

The clipping of the peak signal results In-band distortion and out-of-band distortion in the OFDM signal, The in –band distortion degrades the system performance and cannot be reduced, while out –of –band distortion can be reduced by filtering the clipping signal. The signal obtained after the clipping signal is given by

$$X^{(i+1)} = X^{(i)} + \mu\, \delta^{(i)} \qquad (4)$$

Where $\delta^{(i)}$ –Anti Peak Signal at the i^{th} iteration

μ -positive real number

The anti peak signal is given by the equation

$\delta^{(i)} = T^{(i)} C^{(i)}$ ________ (5)

Where $C^{(i)}$ =Anti- Peak signal
T = Transfer Matrix at the ith iteration
The transfer matrix at the i^{th} iteration is given by

$$\hat{T}^{(i)} = \hat{Q}^{*(i)} \hat{Q}^{(i)}$$ __________ (6)

Where $T^{(I)}$ =Transfer Matrix at the i^{th} iteration

$\hat{Q}^{*(i)}$ = Conjugate of Constellation Order $\hat{Q}^{(i)}$ = Constellation Order

Filtering eliminates the distortions caused by the clipping process, but it introduces peak re-growth at some of the peak signals of the OFDM signal. The peak re-growth can minimized by repeating the filtering process.

III NONLINEAR COMPANDING TRANSFORM (NCT) ALGORITHM

The Nonlinear Companding Transform [29] is also known as Exponential Companding Transform (ECT) based on speech processing. This scheme mainly focuses on compressing the large signals, while maintaining average power constant by properly choosing the transform Parameters.

Exponential Companding Transform can also eliminate the Out-of-Band Interference (OBI), which is a type of distortion caused by clipping the original OFDM signals. The other advantage of the companding transform is that, it can maintain a constant average power level. The proposed scheme can reduce the PAPR for different modulation formats and sub-carrier sizes without increasing the system complexity and signal bandwidth. The Exponential Companding Transform also causes less spectrum side-lobes. The companded signal obtained by using Nonlinear companding Transform

$$H(x) = sgn\,(x) \sqrt[d]{\alpha\left[1 - exp\left(-\frac{x^2}{\sigma^2}\right)\right]}$$ ___________ (7)

Where(x) –companded Signal
Sgn(x) –Sign Function
α – Average Power Output Signals
x –original OFDM signal
The average Power of the output signals is given by the equation

$$\alpha = \frac{E[|s_n|^2]}{E\left[\sqrt[d]{\left[1-exp\left(-\frac{|s_n|^2}{\sigma^2}\right)\right]}^2\right]}$$ _________ (8)

Where d –power of the amplitude of the companded signal.

VI SIMULATION RESULTS

A) PAPR Performance Of original OFDM Signal

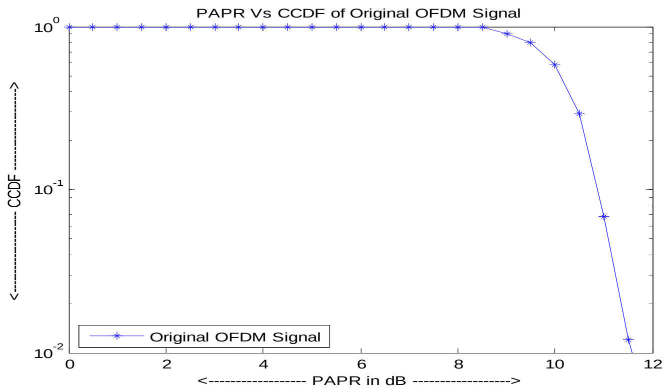

Fig-1-PAPR Vs CCDF of Original OFDM Signal

From fig -1 Peak-to-Average Power Ratio (PAPR) of the original Orthogonal Frequency Division Multiplexing (OFDM) signal is equal to 11.8 dB with a Complimentary Cumulative Distribution Function (CCDF) of 10-2 or 0.01.The Peak-to-Average Power Ratio (PAPR) of the original Orthogonal Frequency Division Multiplexing

(OFDM) signal is very high, which results to increase in the complexity of the Analog-to-Digital Convertors (ADCs) and Digital-to-Analog Convertors (DACs) and also reduces the efficiency of the power amplifiers.

B) PAPR Performance using RCF (CB-ACE) Algorithm

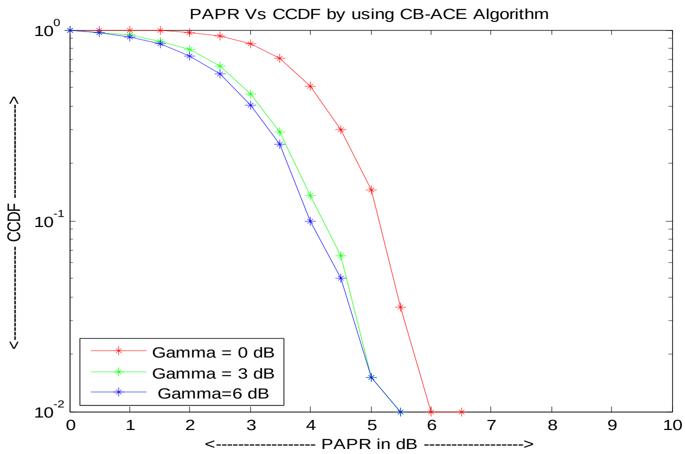

Figure-2 PAPR Vs CCDF For RCF Algorithm (For Different Target Ratios)

From Fig -2 the PAPR of the original OFDM signal obtained by using RCF algorithm is equal to 7.5dB, 6dB and 5.5 dB for different target clipping ratios of 0 dB, 3dB, 6dB respectively with a CCDF of 10^{-2} or 0.01 i.e. PAPR is increasing as the target clipping ratios is decreasing which results low clipping ratio problem, peak re-growth and out-band-interference.

C) PAPR Performance Of Nonlinear Companding Transform (NCT) Algorithm

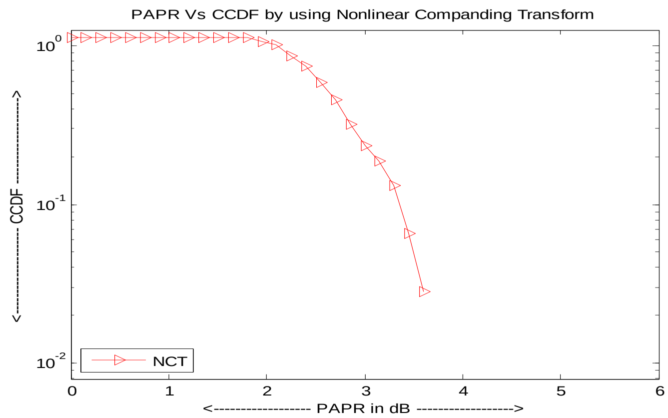

Fig-3 PAPR Vs CCDF using Nonlinear Companding Transform (NCT)

From fig-3 the Peak-to-Average Power Ratio (PAPR) of the Orthogonal Frequency Division Multiplexing (OFDM) signals obtained by using the Nonlinear Companding Transform is reduced to 3.5 dB with a Complimentary Cumulative Distribution Function (CCDF) of 10^{-2} or 0.01

Table 1 – Comparison of PAPR (in dB) and CCDF for different techniques

Different Techniques	PAPR (in dB)	CCDF
Original OFDM Signal	11.8	10^{-2} or 0.01
Repeated Clipping and Filtering Algorithm	7 (For $\gamma = 0$ dB) 6 (For $\gamma = 3$ dB) 5.5 ((For $\gamma = 6$ dB)	10^{-2} or 0.01
Nonlinear Companding Transform Algorithm	3.5 dB	10^{-2} or 0.01

From the table 1 the PAPR Of Original OFDM signal is reduced more(3.5 dB) by using Nonlinear Companding Transform (NCT) algorithm than the Repeated Clipping and Filtering Algorithm.

C) BER Performance of Original OFDM Signal

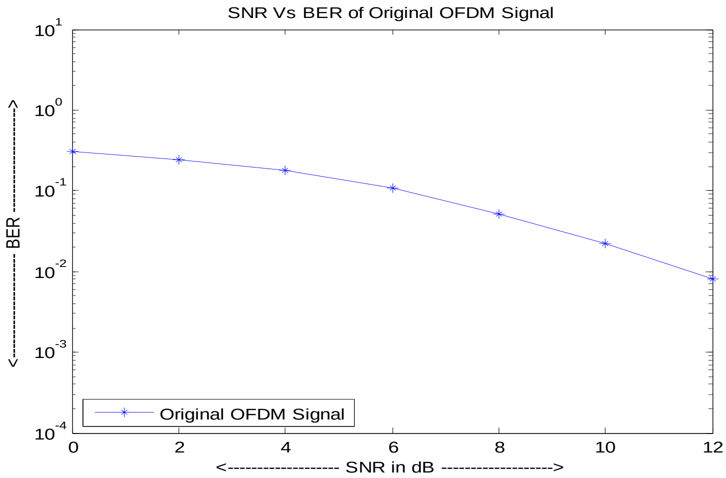

Fig-4 BER Vs SNR of original OFDM Signal

From fig-4 Signal-to-Noise Ratio (SNR) of the original Orthogonal Frequency Division Multiplexing (OFDM) signal is equal to 12 dB at a Bit Error Rate (BER) of 10^{-2} or 0.0

D) BER Performance of Repeated Clipping and Filtering (RCF) PAPR Reduction Technique

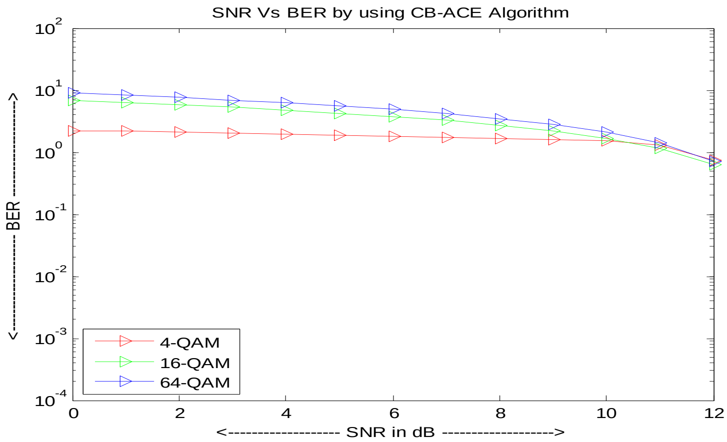

Fig-5 BER VS SNR using RCF

From fig-5 the Signal-to-Noise Ratio (SNR) of the Orthogonal Frequency Division Multiplexing (OFDM) signal obtained using the using RCF is equal to 12 dB at a Bit Error Rate (BER) of $10^{-0.2}$ for different constellation orders like 4-QAM,16-QAM and 16-QAM.

E) BER of Performance Original Using Nonlinear Companding Transform

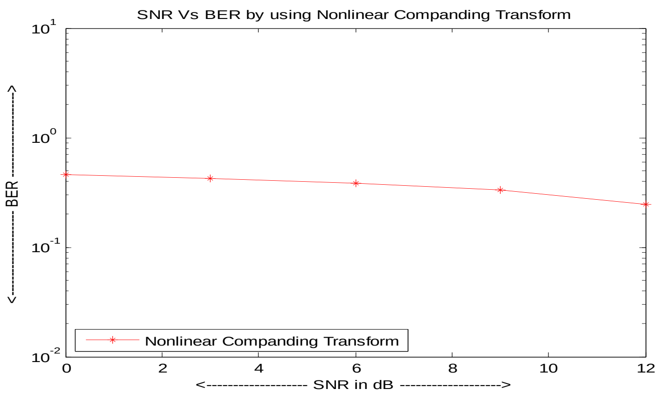

Fig- 6 BER VS SNR using NCT

From fig-6 the Signal-to-Noise Ratio (SNR) of the companded Orthogonal Frequency Division Multiplexing (OFDM) signals obtained by using the Nonlinear Companding Transform is equal to 12 dB at a Bit Error Rate (BER) of $10^{-0.6}$ for QPSK

Table 2 – Comparison of SNR (in dB) and BER for different techniques

Different Techniques	SNR (in dB)	BER
Original OFDM Signal	12	10^{-2}
Repeated Clipping and filtering Algorithm	12	$10^{-0.2}$
Nonlinear Companding Transform	12	$10^{-0.6}$

From the table 5.2, the Bit-Error Rate (BER) of the OFDM signal is drastically increased by using the PAPR reduction technique like Repeated Clipping and Filtering Algorithm , but the BER is slightly increased by using the Nonlinear Companding Transform, when compared with the original OFM signal

V CONCLUSION

The Repeated Clipping and Filtering Algorithm (RCF) reduce the high Peak-to-Average Power Ratio (PAPR) by clipping and filtering the original OFDM signal. The RCF Algorithm results to peak re-growth, Out-of-Band Interference (OBI), low clipping ratio problem, increase in the Bit Error Rate (BER) and decrease in the Signal-to-Noise Ratio (SNR).

The Nonlinear Companding Transform improves the Bit Error Rate (BER) and minimizes the Out-of-Band Interference (OBI) in the process of reducing the Peak-to-Average Power Ratio (PAPR) effectively by compressing the peak signals and expanding the small signals. Simulation results have shown that the proposed Nonlinear Companding Transform (NCT) algorithm could offer better performance in terms of PAPR reduction, Power spectrum and without increase Complexity Of system performance.

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