International Journal of Scientific & Engineering Research, Volume 5, Issue 2, February-2014 1627
ISSN 2229-5518

Non Linear Companding Transform for Peak to Average Power Ratio Reduction in Ofdm System

Deepender Gill, Garima Saini

Abstract— High Peak-to-average-power-ratio (PAPR) is a problem associated with OFDM systems. Various companding schemes are used to reduce the problem of PAPR in orthogonal frequency division multiplexing schemes. High PAPR drives the power amplifiers used at the transmitter's side into non-linear region and leads to high power dissipation in hand held devices. Signal companding is one of the widely used techniques to reduce high PAPR.

Index Terms— Orthogonal Frequency division Multiplexing(OFDM),Peak-to-average power ratio(PAPR), Non-linear Companding TransformCompanding(NCT),Quadrature Amplitude Modulatipon(QAM),Inverse Fast Fourier Transform(IFFT), High power amplifier(HPA),Complemetry Cumultive Distribution Function(CCDF).

---

1 INTRODUCTION

OFDM has many important properties due to which it has become one of the preferred techniques for the implementation of 4G (fourth generation mobile communication) systems. Multipath fading has little impact on OFDM and it provides high spectral efficiency which makes it a suitable technique for 4G systems [1]. Due to these properties OFDM has also been adopted by 3GPP LTE (Long Term Evolution) for downlink transmission. However this technique also suffers from some critical drawbacks such as high PAPR and ICI. High PAPR may further lead to undesired spectral regrowth. Due to this the High Power Amplifiers (HPA) required in the OFDM signal generation are need to be highly linear which is a difficult condition to meet. High PAPR may also lead to in-band-distortion across various subcarriers used in the process [2].This paper deals with the problem of high PAPR by using one of the companding methods to reduce the effect of high PAPR.The companding technique used is of non-linear nature and can redistribute the power in OFDM signal.

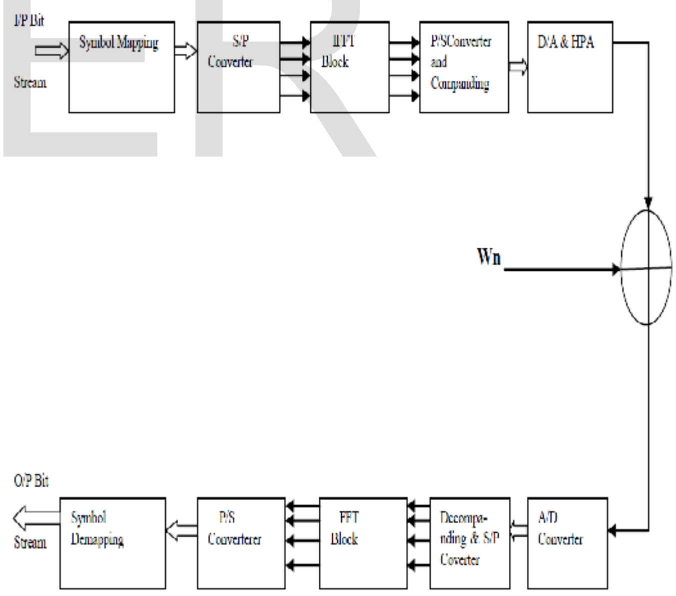


Fig.1 OFDM System Model [6]

2 OFDM System Model

The relationship between different sub-carriers in OFDM system must be carefully controlled to maintain the orthogonality property. For this reason, first the spectrum requirement is computed based upon the input data and the modulation scheme used [3].

Each sub-carrier to be produced is assigned some data to transmit. The required amplitude and phase is calculated based on the modulation scheme. The digital data stream in serial form is converted to parallel form using a serial to parallel convertor [4]. Inverse Fast Fourier Transform (IFFT) is used to convert back the required spectrum to its time domain signal as shown in Fig. 1. In most applications, an Inverse Fast Fourier Transform (IFFT) is used [5].

ISSN 2229-5518

The IFFT block performs the time domain transformation very efficiently and provides a simple way of ensuring that the carrier signals produced are orthogonal to each other. The output of the IFFT is provided as an input to the compander. The companded data is converted to analog form and transmitted after amplification through a high power amplifier (HPA).At the receiver side the data is converted back to digital form and applied to a decompander. This paper deals with the first four blocks of the OFDM system model. OFDM signal is generated and applied to the companding block. This companding block applies the non-linear companding function to the OFDM signal. The purpose of applying the companding function is to reduce the high value of PAPR.

Decomanpder performs the inverse process of compander. The output is again converted to parallel form and applied to FFT block. The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency domain spectrum. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal

3 Peak-to-Average-Power Ratio

The reason for high PAPR in OFDM systems is that in time domain, a multicarrier signal is the sum of many narrow-band signals. At some time instances, this sum is large and at other times it is small which means that the peak value of the signal is substantially larger than the average value[7].

The peak to average ratio for a signal x (t) may be defined as

PAPR$=\max[x(t)\,x^*(t)]/E[x(t)\,x^*(t)]$ ---------------------- (1)

In decibels PAPR may be expressed as

PAPR $_{dB}=10\log 10\,(PAPR)$ ------------------------------ (2)

In the presence of a large number of independently modulated sub-carriers in an OFDM system, the peak value of the signal can be very high as compared to the average value of the whole signal. This ratio of peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of the same phase produces a peak which is N times the average signal.The large amplitude variation results in increase in in-band noise and the Bit Error Rate (BER) [8].

Due to these inherent disadvantages of high PAPR it needs to be reduced before the OFDM signal is to be transmitted through the channel. Many techniques have been proposed in the literature to reduce high value of PAPR in OFDM signals. Block Coding, Selective Mapping and Partial Transmit Sequence are some of the techniques which may be used for the reduction of high PAPR in OFDM. But these techniques put some restrictions on various parameters used in the OFDM system such as frame format, constellation size etc [9]. The system designer has to work within these restrictions to use any of these techniques for the reduction of high PAPR. The another category of techniques used for PAPR reduction are based upon signal distortion before transmission of OFDM signal.Signal clipping and signal companding fall under this category. These signal distortion techniques have the advantage that they do not put any restrictions on the system parameters but use of these techniques also increases the Bit-Error-Rate (BER) and spectral regrowth. The clipping method is suitable only at low data rates and companding is suitable for high data rates.

Companding is a combination of compression and expansion [10]. The reverse process of companding is known as decompanding. For PAPR reduction in OFDM system companding is done at the transmitter side and the decomapnding is done at the receiver side. Companding is basically the process of making quantization levels unequal. In companding the quantization levels are kept very close for the small amplitude signals and larger spacing between quantization levels is used for high amplitude signals.

The Non-Linear Companding Transform (NCT) is suitable to be used in OFDM system due to it's advantages such as low complexity in implementation and good efficiency

4 Formulation of Companding-Transform

In this paper we have used non-linear companding transform technique for reducing the PAPR of OFDM signal. The companding function transforms the statistics of the amplitude of the signals into a uniform distribution.The companded signal has almost constant average power level which relieves the strict linearity requirements on the HPA(High Power Amplifiers) used in the process.

The companding function h(x) can transform the original OFDM signal $\mathbf{x_n}$ into a form which leads to the reuction of PAPR.The companded signal may be expressed as

$\mathbf{y_n}=h(x_n)$--------------(3)

$\mathbf{h(x)} = F_{|yn|}^{-1}[F_{|xn|}(x)].\ \mathrm{sgn}(x)$--------(4)

where $F_{|x|}(x)$ is the cumulative distribution function for the input signal x and may be given as

ISSN 2229-5518

$$\mathbf{F}_{|xn|}\ \mathbf{(x)} = 1-\exp(-x^2/\sigma^2)\text{-----------}(5)$$

By using these expressions the companding function may be derived as

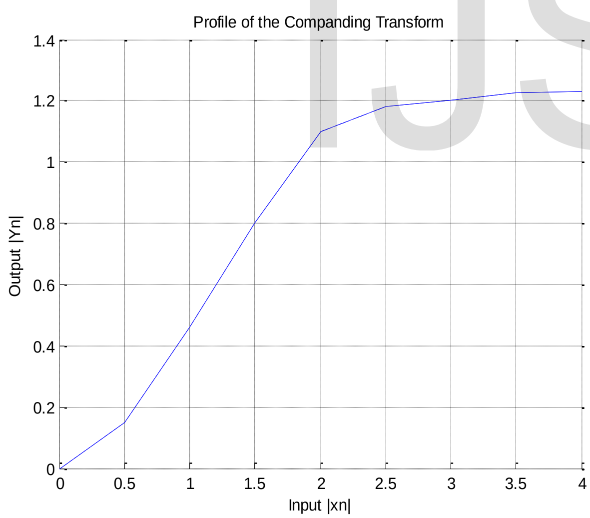
If $X_0 = p(mT)^{q+1}/(q+1)$

$$\mathbf{h(x)} = \begin{cases} [\{(q+1)/pT\}.(F_{|xn|}x))]^{1/(q+1)}.\mathrm{sgn}(x) & x \leq X_0 \\ (F_{|xn|}(x))/p(mT)^{q+1}.\ \mathrm{sgn}(x) & x > X_0 \end{cases} \text{-------}(6)$$

The proposed companding function h(x) has the ability to compress large amplitude signals and at the same time expand the small amplitude signals which is the primary requirement for PAPR reduction. The proposed function provides the flexibility and some adjustable parameters which can be changed to obtain different profiles for the companding transform.

4.1 Profile of the Comapnding Transform:

For values q=0.5,m=0.25



5 Simulation Results:

Simulation has been performed for OFDM system using following parameters

Modulation Type: 16QAM.

FFT length: 64.

Number of data points used for the purose of simulation: 6.4×10^5.

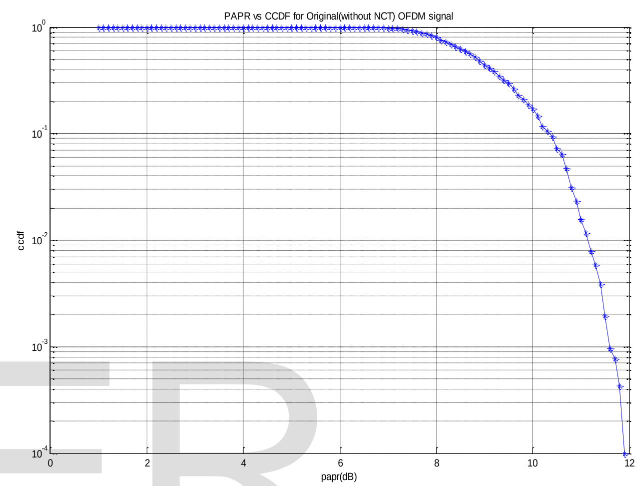
q=0.5

m=0.25

Graphs have been plotted for CCDF of the original OFDM signal(without NCT) and the companded OFDM signal.

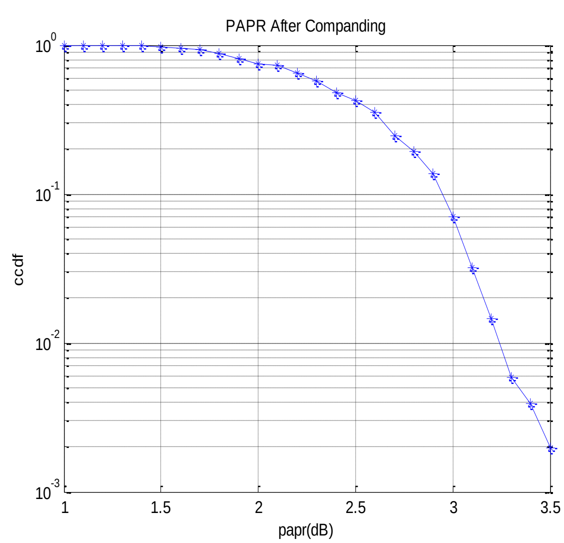
5.1PAPR vs CCDF Graph of Original OFDM (without NCT) signal:

The graph shows CCDF Vs PAPR for the original OFDM signal on which no companding function has been applied



5.2 PAPR vs CCDF Graph After Comapnding:

The graph shows the change in PAPR Vs CCDF graph for the OFDM signal on which the proposed companding transform has been applied



ISSN 2229-5518

6.Conclusion:

The proposed companding transform is able to reduce the PAPR of the OFDM signal by considerable extent. The companding transform is able to compress the large signal values simultaneously enhancing the small signal values. By choosing the value of companding transform parameters the value of PAPR can be reduced. The original OFDM signal is Gaussian distributed and the proposed NCT is able to transform this Gaussian distribution in such a way that reduces the PAPR value by a significant extent as can be observed from the simulation results.

REFERENCES

[1]Hongwei Yang, "A road to future broadband wireless access: MIMO-OFDM based air interface," IEEE Communications Magazine, Vol.43, No.1, pp. 53-60, 2005.

[2]Y.Wu, W. Y. Zou, "Orthogonal frequency division multiplexing: a multi-carrier modulation scheme," IEEE Transactions on Consumer Electronics, Vol. 41, No. 3, pp. 392–399, 1995.

[3]S. H. Han, J. H. Lee, "An overview of peak-to-average power ratio reduction techniques for multicarrier transmission," IEEE Wireless Communications Magazine, Vol 12, No.2, pp. 55-65, 2005.

[4]J. Hou, J. Ge, D. Zhai, and J. Li, "Peak-to-average power ratio reduction of OFDM signals with nonlinear companding scheme", IEEE Tranasctions on Broadcasting, Vol. 56, No. 2, pp. 258–262, 2010.

[5]T. Jiang and Y.Wu, "An overview: Peak-to-average power ratio reduction techniques for OFDM signals," IEEE Transactions on Broadcasting, Vol. 54, No. 2, pp. 257–268, 2008.

[6] X. B.Wang, T. T. Tjhung, and C. S. Ng, "Reduction of peak-to-average power ratio of OFDM system using a companding technique," IEEE Transactions on Broadcasting, Vol. 45, No. 3, pp. 303–307, 1999.

[7] D. Dardari, V. Tralli, and A. Vaccari, "A theoretical characterization of nonlinear distortion effects in OFDM systems," IEEE Transactions on Communication, Vol. 48, No. 4, pp. 1755–1764, 2000.

[8] P. Banelli and S. Cacopardi, "Theoretical analysis and performance of OFDM signals in nonlinear AWGN channels," IEEE Transactions on Communication, Vol. 48, No.2, pp. 430–441, 2000.

[9] A. Mattsson, G. Mendenhall, and T. Dittmer, "Reduction of peak-to-average power ratio of ofdm system using a companding technique," IEEE Transactions on Broadcasting, Vol. 45, No.6, pp. 418–419, 1999.

[10]S. A. Aburakhiya, E. F. Badran, D. A. E Mohamed, "Non-linear companding transform for reduction of peak-to-average power ratio of OFDM signal," IEEE Transactions on Broadcasting, Vol 55, No.1, pp 456-461, 2009.

[11].Y. Rahamatallah, N. Bouaynaya, S. Mohan, "On the performance of linear and non-linear companding transforms in OFDM systems," IEEE Wireless Telecommunication Symposium, pp.1-5, 2011.

[12]X. Huang, J. Lu, J.Zheng, K. B. Letaief, J. Gu, " Companding transform for reduction in peak-to-average power ratio of OFDM signals", IEEE Transactions on Wireless Communications, Vol. 03, No. 6, pp.2030-2039, 2004.

[13] Tao Jiang, Yang Yang, and Yong-Hua Song, " Exponential companding transform for PAPR reduction in OFDM systems", IEEE Transactions on Broadcasting, Vol. 51, No. 2, pp. 244-248, 2005.

[14] S. -S. Jeng, J. -M. Chen, "Implementation of low complexity companding technique for effiecient peak to average ratio reduction in orthogonal frequency division multiplexing systems", IEEE Transactions on Broadcating, Vol. 5, No. 2, pp. 154–162, 2011.

[15]S.-S.Jeng, J.-M. Chen , "Efficient PAPR reduction in OFDM systems based on a companding technique with trapezium distribution", IEEE Transactions on Broadcasting, Vol. 5, No. 2, pp. 291-298, 2011.