



PEAK TO AVERAGE POWER RATIO REDUCTION IN OFDM SYSTEM USING ROBUST ESTIMATOR

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a spectrally efficient multicarrier modulation technique for high speed data transmission over multipath fading channels. High Peak-to-Average Power Ratio (PAPR), which leads to power inefficiency in the RF portion of the transmitter, is a major drawback of OFDM. Lots of PAPR reduction techniques are proposed in literatures in last two decades. For instance, amplitude clipping, companding, coding, partial transmit sequence, selected mapping (SLM), interleaving, etc. This paper introduced an improved PAPR reduction scheme using robust estimator or trimmed mean. A truncated mean or trimmed mean is a statistical measure of central tendency, much like the mean and median. It involves the calculation of the mean after discarding given parts of probability distribution or sample at the high and low end, and typically discarding an equal amount of both. The trimmed mean is a useful estimator because it is less sensitive to outliers than the mean but will still give a reasonable estimate of central tendency or mean for many statistical models. Furthermore, there is no need for side information, and no loss in terms of data rate. Simulation results show that more than 1.2 dB reduction in the PAPR value can be achieved using the proposed method.

Keywords: *Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Trimmed Mean.*

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a multicarrier technique for high-speed data transmission. It's considered an important technique for wireless communications due to many advantages such as robustness in frequency-selective fading channels, high spectral efficiency, immunity to inter-symbol interference, and so on.

OFDM uses the Inverse Fast Fourier Transform (IFFT) operation to generate a large number of sub-channels that are orthogonal [1]. A cyclic prefix is added in the time domain that simplifies equalization and also eliminates *interblock interference* (IBI). OFDM is a widely used communication technique in broadband access applications requiring high data rates. It is already used in different WLAN standards (HIPERLAN 2, IEEE 802.11a), ADSL and digital video broadcasting (DVB) [2]. An OFDM signal is basically a bundle of narrowband carriers transmitted in parallel at different frequencies from the same source. In fact, this modulation scheme is often termed "multi-carrier" as opposed to

conventional "single carrier" schemes. Each individual carrier, commonly called a sub-carrier, transmits information by modulating the phase and possibly the amplitude of the sub-carrier over the symbol duration [1]. One of the major drawbacks of any OFDM system, which is often an obstacle to its use, is the fact that the signal has a non-constant envelope, i.e. it exhibits peaks whose power strongly exceeds the mean power: the signal is said to have a high PAPR. In this paper we proposed a simple approach using robust estimator or trimmed mean [3].

2. PAPR OF OFDM SYSTEM

An OFDM symbol consists of N sub-carriers by the frequency spacing of Δf . The total bandwidth B will be divided into N equally spaced sub-carriers with all sub-carriers are orthogonal to each other within a time interval of length $T = \frac{1}{\Delta f}$. Each sub-carrier can be modulated independently with complex modulation symbol $X_{m,n}$, where m is a time index and n is a sub-carrier index.

The m -th OFDM block period can be described as :

$$x_m(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_{m,n} g_n(t - mT) \quad (1)$$

Where, $g_n(t)$ is defined through,

$$g_n(t) = \begin{cases} \exp(j2\pi\Delta f t), 0 \leq t \leq T \\ 0, \text{else} \end{cases} \quad (2)$$

Where $g_n(t)$ is a rectangular pulse applied to each subcarrier [4]. The total continuous time signal $x(t)$ consisting of all the OFDM block is given by ,

$$x(t) = \frac{1}{\sqrt{N}} \sum_{m=0}^{\infty} \sum_{n=0}^{N-1} X_{m,n} g_n(t - mT) \quad (3)$$

Consider a single OFDM symbol ($m=0$) without loss of generality. This can be shown because there is no overlap between different OFDM symbols.

Since $m=0$, $X_{m,n}$ can be replaced by X_n . Then, the ofdm signal can be described as follows,

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi\Delta f t} \quad (4)$$

For an OFDM signal with N subcarriers, the PAPR can be defined as

$$PAPR = \frac{\max |x(t)|^2}{E|x(t)|^2} \quad (6)$$

In particular, a baseband OFDM signal with N subchannels has

$$PAPR_{\max} = 10 \log_{10} N \quad (7)$$

From the central limit theorem, it follows that for large values of N ($N > 64$), the real and imaginary values of $x(t)$ become Gaussian distributed. Therefore the amplitude of the OFDM signal has a Rayleigh distribution, with a cumulative distribution given by

$$F(z) = 1 - e^{-z} \quad (8)$$

The probability that the PAPR is below some threshold level can be written as

$$P(PAPR \leq z) = (1 - e^{-z})^N \quad (9)$$

In fact, the complementary cumulative distribution

function (CCDF) of PAPR of an OFDM is usually used, and can be expressed as

$$P(PAPR > z) = 1 - (1 - e^{-z})^N \quad (10)$$

3. THE PROPOSED METHOD

The most important measure of central tendency, and one of the basic building blocks of all statistical analysis, is the arithmetic mean, or simply mean. The mean may often be confused with the median, mode or range. The mean is the arithmetic average of a set of values, or distribution; however, for skewed distributions, the mean is not necessarily the same as the middle value (median), or the most likely (mode). The standard mathematical definition of the mean can be given by

$$\bar{X} = \frac{\sum_{i=1}^n x_i}{n} \quad (11)$$

A truncated mean or trimmed mean is a statistical measure of central tendency, much like the mean and median. It involves the calculation of the mean after discarding given parts of probability distribution or sample at the high and low end, and typically discarding an equal amount of both. The trimmed mean is a useful estimator because it is less sensitive to outliers than the mean but will still give a reasonable estimate of central tendency or mean for many statistical models. While a wide range of robust estimators have been proposed in the past [5], the trimmed mean is intuitively appealing because of their computational simplicity and good theoretical properties [6]. It should be noted that for all of the investigated distributions, we always applied symmetric trimming, removing 20% of the observations from each tail of groups set of scores. Since this rule is well established [7]. Let

$$X_{(1)j} \leq X_{(2)j} \leq X_{(3)j} \leq \dots X_{(n_j)j} \quad (12)$$

represent the ordered observations associated with the j th group. When trimming let

$$g_j = \lfloor \gamma_s n_j \rfloor \quad (13)$$

where γ_s represent the proportion of observations that are to be trimmed in tail of the distribution. For most statistical applications, γ_s lies between 5 to 25 percent of the end discarded. The effective sample size for the j -th group becomes

$$h_j = n_j - 2g_j \quad (14)$$

And thus the j -th sample trimmed mean is

$$\bar{X}_{tj} = \frac{1}{h_j} \sum_{i=g_j+1}^{n_j-g_j} X_{(i)j} \quad (15)$$

From equation (6), we will replace the arithmetic mean, $E|x(t)|^2$ with the trimmed mean using equation (15).

4. SIMULATION AND RESULTS

In this work, computer simulation is implemented to evaluate the performance of the proposed method. The OFDM system was modeled using MATLAB to allow various parameters of the system to be varied and tested. Table 1 shows the values of parameters were used in the simulation model. A simple AWGN channel is used as channel model. Two set number of subcarrier ($N=256$ and $N=2048$) were tested with five, ten and twenty percent of trimming percentage. The simulation results will be presented as the (CCDF) of the PAPR of the OFDM signals.

Table 1 : Simulation Parameters

Parameters	Values
Modulation scheme	QPSK, 16 QAM
Oversampling Factor	4
No. of Subcarrier	256 and 2048
Data Block Size	16
FFT size	64
T_{FFT}	$3.2\mu s$

Table 2 : PAPR Comparison for Overall result

N	Modulation	Original OFDM	5%	10%	20%
256	QPSK	9.843	9.249	9.38	9.802
256	16QAM	9.429	9.194	9.482	9.502
2048	QPSK	10.53	9.516	9.418	9.277
2048	16QAM	9.815	8.837	9.159	9.314

Full comparison of 99.9 percentile PAPR for different modulation formats is given in Table 2. We can see that 16 QAM has lower PAPR than QPSK consistently for both $N=256$ and $N=2048$ for conventional OFDM system. For trimmed mean technique, QPSK has the highest reduction in PAPR value by 1.253 dB for 20% trimming percentage and number of subcarrier 2048, while PAPR reduction of 16 QAM is around 0.501dB. Figure 1 and 2 show the comparison of trimmed mean method on the PAPR when using 20% trimming percentage 2048 number of subcarrier.

From the simulation results, it is proven that the new technique has significantly reduced the PAPR for high data rate systems. This improvement in the systems performance have been maintained even when different combination modulation scheme and number of subcarrier were used.

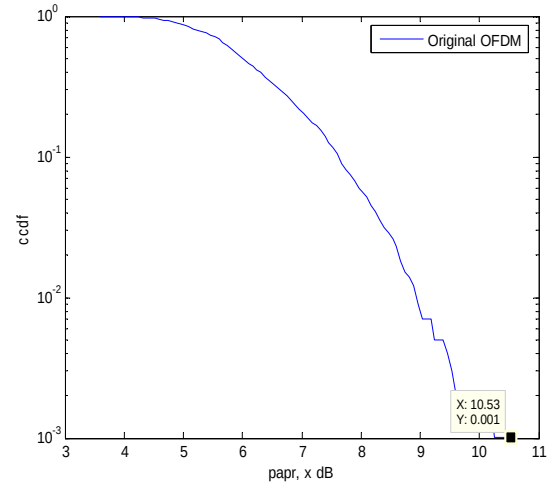


Figure 1 : CCDF of PAPR for original OFDM Using QPSK Modulation Scheme

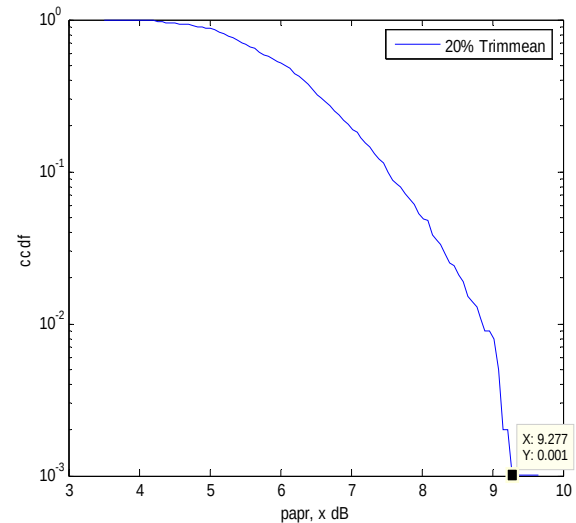


Figure 2: CCDF of PAPR for 20% trimming percentage using QPSK Modulation

5. CONCLUSION

A new PAPR reduction method for the OFDM system by trimmed mean has been proposed and investigated. This was achieved by replacing the conventional arithmetic mean formula in the PAPR calculation formula with the new robust estimator known as trimmed mean. This process involves the calculation of the mean after discarding given parts

of probability distribution or sample at the high and low end, and typically discarding an equal amount of both. The proposed method is suitable for OFDM applications that are sensitive to spectral efficiency and noise, since it allows reduction in PAPR value. For QPSK OFDM system with $N=2048$ data sub-carriers, more than 1.2 dB reduction in PAPR value was achieved. Furthermore the new method is compatible to be used with other modulation scheme such as 16 QAM and from the result is shows a reduction of 0.9 dB of PAPR value and it is slightly lower than QPSK mapping scheme.

REFERENCES:

- [1] R. V. Nee and R. Prasad, "OFDM for Wireless Multimedia Communications," Artech House, 2000.
- [2] "Broadband Radio Access Network (BRAN); High Performance Radio Local Area Network (HIPERLAN) Type 2; Requirements and Architecture for Wireless Broadband Access," TR101031, 1999.
- [3] S.H. Han and J. H. Lee, "An Overview of Peak-To-Average Power Ratio Reduction Techniques For Multicarrier Transmission," *IEEE Wireless Comm.*, Vol. 12, No. 2, April 2005, pp. 56-65.
- [4] Rohling H., "Broadband OFDM Radio Transmission For Multimedia Applications," *IEEE Proceedings*, Vol. 87, pp. 1778-1788, 1999.
- [5] Gross, A. M., "Confidence Interval Robustness With Long Tailed Symmetric Distributions", *Journal of The American Statistical Association*, 1976, pp. 409-416.
- [6] Wilcox, R.R., "ANOVA: A Paradigm for Low Power and Misleading Measures of Effect size?", *Review of Educational Research*, 1995, pp. 51-77.
- [7] Wilcox, R.R., "A One-Way Random Effects Model for Trimmed Means", *Psychometrika*, 1994, pp. 289-306.