IJSTA
International Journal of Scientific and Technical Advancements
ISSN: 2454-1532

Performance Comparison of Various PAPR Reduction Techniques in OFDM

Rasmeet Kour[1], Sameru Sharma[2], Harinder Dhingra[3]
[1]ECE Department, GCET Jammu, J&K, India-180004
[2]ECE Department, GCET Jammu, J&K, India-180004
[3]ECE Department, GCET Jammu, J&K, India-180004
[#]Rasmeet.kour@live.com: sameru33@gmail.com : dhingra_h@yahoo.com

Abstract—This This paper portrays critical issue of high PAPR in high speed communication system using Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a special subset of Multicarrier communications, which is based on the principle of transmitting simultaneously many narrow- band orthogonal frequencies, often called OFDM subcarriers or subcarriers. It transmits the large amount of data over radio waves but, the summation of data in time domain OFDM signal results in high PAPR which is the major shortcoming of OFDM system. This high PAPR creates the requirement of PA (Power Amplifier) to be linear in its wide dynamic range and PA's efficiency is a dependent factor of its linear dynamic range which decreases as the range increases.

Various techniques have been recommended to reduce PAPR in OFDM. But there is a hidden cost that has to be paid in terms of payload data rate reduction to reduce high PAPR. This paper enlightens few reduction techniques (Clipping and Filtering, Selective Mapping, Golay codes) of PAPR, Huffman coding and their comparative study.

Keywords — Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Clipping and Filtering, Selective Mapping, Golay Complementary Codes

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has come to the forefront of technology in the field of Wireless communication systems due to its intrinsic robustness against multipath fading channels [1]. OFDM is a multicarrier modulation technique transmitting large data over radio waves. While sending high rate DataStream, it splits it into number of lower rate streams which are transmitted over a number of subcarriers in parallel. In a decade, OFDM has emerged as the standard of choice in a number of important high data applications. It finds its application widely being used in Digital Television Broadcasting (such as the digital ATV Terrestrial Broadcasting), European Digital Audio Broadcasting (DAB) and Digital Video Broadcasting Terrestrial (DVB-T), Wireless Asynchronous Transfer Mode (WATM).) [2], [3]

It is based on the principle of transmitting simultaneously many narrow- band orthogonal frequencies, often also called OFDM subcarriers or subcarriers. [1], [4]. The number of subcarriers is often noted by N. These frequencies are orthogonal to each other which eliminate the interference between channels. OFDM uses the spectrum much more efficiently by spacing the channels more closely together. The mathematical and diagrammatical representation of OFDM in time–domain model is:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X[k] e^{j2\pi kt/T}$$

Where:

X(t)	- Continuous time baseband OFDM symbol
N	- Number of Subcarriers
f	- Subcarrier spacing
T	- OFDM symbol period ($T = 1/f$)
X[k]	- Digitally modulated data symbol

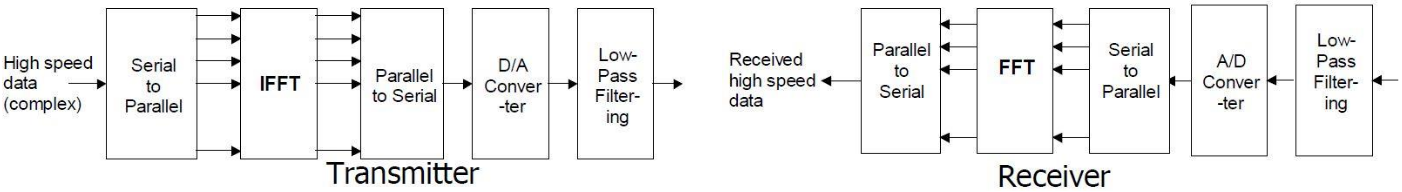

Fig.1. Baseband OFDM System

Rasmeet Kour, Sameru Sharma, and Harinder Dhingra, "Performance comparison of various PAPR reduction techniques in OFDM," *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 131-136, 2018.

II. PAPR - PROBLEM AND REDUCTION REQUIREMENT

OFDM is very effective and proficient technique in the field of high speed multi-carrier data transmission. However, OFDM has a drawback too in the sense that it shows high PAPR (Peak to Average Power Ratio) due to the time-domain superposition of many data subcarriers, and thus the subsequent time domain signal exhibits the Rayleigh-like characteristics and large time–domain amplitude variations [5]. The output in OFDM is superposition of multiple subcarriers which may cause some instantaneous power output to increase and thus become far higher than the mean power of the system. It requires high power amplifiers (HPA) to transmit signals with high PAPR [6]. These types of PA's are low efficiency with high cost and, also can lead to nonlinear power amplifiers, if the peak power is too high.

PAPR: In simple, PAPR can be defined as the ratio between the maximum power and the average power, and is defined by the equation below:

$$PAPR = \frac{P_{peak}}{P_{average}} = MAX\, [\,|X_n|^2] / E\,[\,|X_n|^2]$$

The transmitted OFDM signal is the real part of the complex signal

$$S(t) = \sum_{i=0}^{n-1} c_i(t) e^{2j\pi f_i t} \qquad (1)$$

Where f_i is the frequency of the *i*th carrier, $c_i(t)$ is constant over a symbol period of duration T.

To maintain orthogonality, the carrier frequencies are related by

$$f_i = f_0 + i\Delta f \qquad (2)$$

f_0 is the smallest carrier frequency and Δf is the integer multiple of the OFDM symbol rate.

Let $c_i(t)$ in eq.(1) takes the value c_i over a given symbol period, then the corresponding OFDM signal is denoted by $S_c(t)$ and can be expressed as

$$S_c(t) = \sum_{i=0}^{n-1} c_i e^{2j\pi f_i t} \qquad (3)$$

Instantaneous envelope power associated with signal is given as

$$P_c(t) = |S_c(t)|^2 = S_c(t).S_c^*(t) \qquad (4)$$

Also the average power of C can be expressed as

$$\frac{1}{T}\int_0^T P_c(t)\,dt = \|c\|^2 = \sum_{k=0}^{n-1} |c_k|^2$$

Where,

$$\|c\|^2 = \sum_{k=0}^{n-1} |c_k|^2 \qquad (5)$$

$$\text{PAPR}(c) = \frac{\max_{0\le t\le T} P_c(t)}{P_{av}} \qquad (6)$$

We would like to design codes C such that $PAPR\,(C) = \max_{C\in c} PAPR\,(c)$ are small. So ideally it is usually required that the percentage of code words with high PAPR be an order of magnitude less than the probability of decoding error.

III. PAPR REDUCTION TECHNIQUES

A variety of techniques have been proposed to reduce PAPR in the past few years and are classified mainly into two groups - *signal scrambling techniques* and *signal distortion techniques* which are given below [7]:

A) Signal Scrambling Techniques:

- Block Coding Techniques
- Block Coding Scheme with Error Correction
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Huffman coding

B) Signal Distortion Techniques:

- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier
- Clipping and Filtering

In order to decrease PAPR various Scrambling techniques have been proposed. These techniques involve scrambling of the codes to decrease the PAPR. Signal scrambling techniques with side information introduces redundancy and thus does not result in operative throughput. On the other hand the signal distortion techniques reduce high peaks directly by distorting the signal before amplification. But they introduce both In-band and Out-of-band interference and intricacy to the system.

A. CLIPPING AND FILTERING – SIGNAL DISTORTION TECHNIQUE FOR REDUCING PAPR IN OFDM

Clipping and Filtering is the simplest method for reducing the PAPR of the OFDM signal. The basic idea is to clip the signal at the transmitter to the desired level. Clipping is the nonlinear process and causes in-band noise distortion, which bases

Rasmeet Kour, Sameru Sharma, and Harinder Dhingra, "Performance comparison of various PAPR reduction techniques in OFDM," *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 131-136, 2018.

degradation in the performance of OFDM. However, the clipping introduces signal distortion but this unwanted effect can be curbed by low pass filtering of clipped signal that unfortunately further increases the PAPR.

A method [8] called repeated clipping and filtering that is based on *K*-times repetition of the clipping and filtering process. Therefore both PAPR and adjacent spectral emissions are reduced, although the PAPR reduction is far from simple clipping case. But the major downside of this method is its high complexity. For each frequency domain filtering, two FFT calculations are necessary. A method named simplified clipping and filtering with bounded distortion (SCAFBD) gives almost the same PAPR reduction as repeated clipping and filtering, but the complexity is significantly reduced. Only 3 FFT's are required for the PAPR reduction equivalent to iterative method using arbitrary *K*.

B. METHOD DESCRIPTION

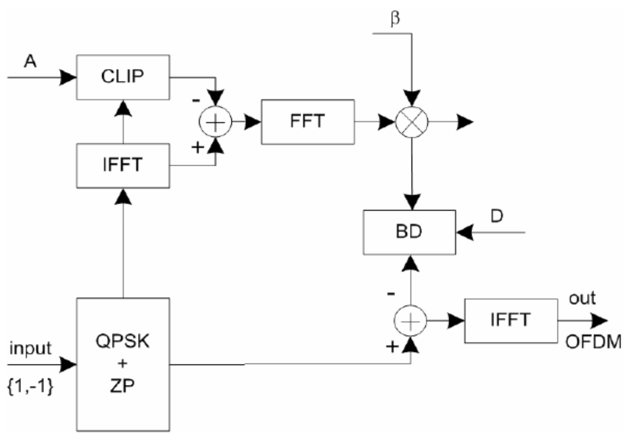

Fig.2. Block diagram for SCAFBD

Firstly the input data are mapped according to the selected constellation (QPSK). Then, Z zero subcarriers are inserted to zero-pad the signal. Resulting data are transformed using IFFT into time domain. Subsequently, the signal is clipped to level *A*. The error signal is computed as the difference between the original and clipped signal. This error signal is transformed back into frequency domain by using FFT and multiplied by the constant β, corresponding chosen number of clipping and filtering stages. The modified error signal in the frequency domain is then passed through the block ensuring the distortion bounding (limitation of I (real) and Q (imaginary) part of the error signal separately to value *D*).

For the simulation [9], the OFDM signal with 64 data subcarriers modulated by the QPSK has been used. The signal is 3-times oversampled by zero-padding, normalized to 0dB in the time domain and clipped to A=3dB. The constant β is set as the equivalent to 3-times repetition of clipping and filtering process. The distortion bound is derived using constant D=10.

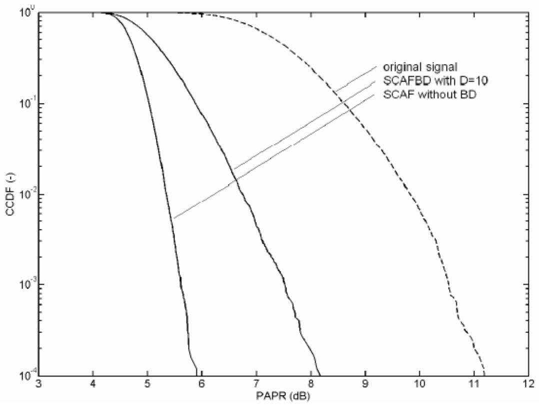

Fig.3. CCDF function for PAPR

C. SELECTIVE MAPPING TECHNIQUE

In SLM technique [10], firstly U independent vectors are generated. Each of these containing N random phase symbols in order to improve the PAPR of the symbol block that is to be transmitted. Each of these vectors is used to modify the phases of the complex baseband information symbols in order to randomize the phases in the block around the unit-circle. Therefore, this process produces U new sets of phase-modified symbol $X.S^1, X.S^2, \dots\dots X.S^U$. all the new symbols carry the same original information as X, but each with a different phase-mask. After passing each of the U modified symbols through the IFFT process, the symbol with the best PAPR performance will then be selected for transmission. Although PAPR reductions of several dBs can be achieved by using this method but this method invokes the IFFT operation U times per OFDM-block. Due to this, the system complexity significantly increases and hence power consumption and time latency.

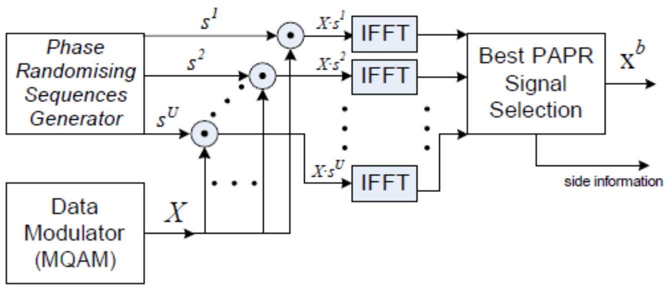

Fig4. Transmitter Scheme for SLM

A novel method *Post-IFFT Amplitude Transforming (PIAT)* has been proposed which applies the randomizing procedure directly in the power spectrum and then generates a corresponding amplitude coefficient sequence for the time domain signal. By doing this, multiple IFFT units and huge amount of searching and computational process can be avoided and thus reducing system complexity.

Rasmeet Kour, Sameru Sharma, and Harinder Dhingra, "Performance comparison of various PAPR reduction techniques in OFDM," *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 131-136, 2018.

ISSN: 2454-1532

D. HUFFMAN CODING TECHNIQUE

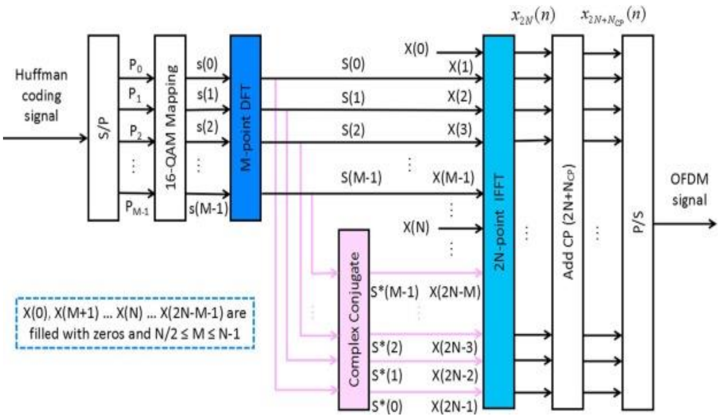

Fig.5. Block diagram for Huffman Coding in OFDM

Huffman Coding technique can be used to reduce PAPR. Huffman coding technique is based on the idea that it assigns fewer bits to the frequently occurring symbols and assigns more bits to the seldom occurring symbols so that it results in the better compression of the signal [11]. An important feature of this technique is that it can pack together the codes of variable length. When bit streams are rearranged among symbols, the probability of repeating the same symbols are eliminated, so these are not added during the coherent addition of multicarrier signals and thus the undesired high peaks are prevented to occur. Huffman coding can be used in the OFDM system as shown in figure 5 above. The input data stream is converted from serial to parallel among M symbols , while M=$^{2\ n}$, which is Huffman encoded yielding a serial bit stream, that is again converted to parallel among M symbols. It is then mapped using 16-QAM modulation and finally the OFDM composite time signal is produced through the IFFT stage. When applied to the OFDM signal, the Huffman encoding will cause the PAPR to be reduced.

E. GOLAY COMPLEMENTARY CODES

In 1949, Marcel J. E. Golay introduced Golay complementary Codes. The error detection and error correction capability of Golay codes are being used for reducing high PAPR
These complimentary sequences have the property that sum of their autocorrelation functions vanishes at all delays other than zero. Golay Complementary sequence can be very effective and efficient technique to reduce PAPR to close to 3 dB for small number of subcarriers but on the contrary has the disadvantage of decreasing the transmission rate significantly for a large number of subcarriers. Each member of Golay complementary pair is called a Golay complementary sequence [12].

IV. OVERALL COMPARISON BETWEEN REDUCTION TECHNIQUES

PARAMETERS / REDUCTION TECHNIQUE	CLIPPING AND FILTERING	SELECTIVE MAPPING	GOLAY COMPLEMNTARY CODES	Huffman Coding
DISTORTION LESS	NO	YES	YES	YES
POWER INCREASE	NO	NO	NO	NO
RATE LOSS	NO	YES	YES	NO
COMPLEXITY	YES	YES	YES	YES
PAPR REDUCTION	HIGH	MEDIUM	HIGH	MEDIUM

V. CONCLUSION

While selecting PAPR reduction technique, various factors have to be considered which includes PAPR reduction capacity, Power increase in transmit signal, BER increase at the receiver, loss in data rate, computational complexity increase and so on. The method for PAPR reduction in OFDM signal by the time domain clipping with bounded distortion and SLM provides good PAPR reduction and increase signal noise immunity. When compared with the ordinary SLM technique the PIAT technique is able to achieve huge complexity reductions while at the same time has a better overall PAPR reduction ability than the SLM technique. Use of Huffman coding results in transmitting the data at high rates due to its lossless data compression. Using Golay Complementary codes can be very effective and efficient technique to reduce PAPR to close to 3 dB for small number of subcarriers but on the contrary has the disadvantage of decreasing the transmission rate significantly for a large number of subcarriers. Therefore the PAPR reduction techniques should be carefully chosen according to various system requirements.
.

REFERENCES

[1] Nee, R. V. and R. Prasad, *OFDM for Wireless Multimedia Communications*, ArtechHouse Publishers, Norwood, MA, January 2000
[2] Liu, P., "*A new peak to average power ratio reduction schemes for OFDM system*," Master dissertation, 2004
[3] Min, K.-S., M.-S. Kim, C.-K. Park, and M. D. Vu, "Design for PCS antenna based on WiBro-MIMO," *Progress In Electromagnetic Research Letters*, Vol. 1, 77–83, 2008
[4] E. Telatar, "*Capacity of multi-antenna Gaussian channels*," European Transactions on Telecommunications, vol. 10, no 3, Dec 1999
[5] S. Muller, R. Bauml, R. Fischer, and J. Huber, "OFDM with reduced peak-to-average power ratio by multiple signal representation", Annals of Telecommunications, vol. 53, pp. 58–67, February 1997

[6] A. Ghassemi and T. A. Gulliver, .Fractional Selective mapping using Decimation in time IFFT/FFT, Publication in WCNC 2008 Proceedings IEEE, pp. 543-547

[7] KUANG Yu-jun, TENG Yong, "*A new symbol synchronization scheme for cyclic prefix based systems*," The Journal of China Universities of Posts and telecommunications

[8] Josef Urban, ''*PAPR Reduction in OFDM system by simplified Clipping and Filtering with Bounded Distortion"*, Doctoral Degree Programme (2), FEEC BUT

[9] Josef Urban, ''*PAPR Reduction in OFDM system by simplified Clipping and Filtering with Bounded Distortion"*, Doctoral Degree Programme (2), FEEC BUT

[10] Lin Yang and Emad Alsusa, ''Novel Low-Complexity Post-IFFT PAPR Reduction Technique by Utilising Amplitude Transforming for OFDM Systems", Microwave & Communication Systems Engineering Group, School of Electrical and Electronics Engineering,The University of Manchester, Manchester M60 1QD,England, United Kingdom

[11] Ashraf A. Eltholth, et al., "Peak-to-Average Power Ratio Reduction in OFDM Systems using Huffman Coding", World Academy of Science, Engineering and Technology, Vol.43, pp. 266-270, 2008.

[12] Stefan H.Muller and Johannes B. Huber, .A Comparison of Peak Power Reduction Schemes for OFDM., In Proc. of The IEEE Global Telecommunications conference GLOBECOM. 97, Phonix, Arizona, USA, pp.1-5, Nov. 1997

ISSN: 2454-1532

Rasmeet Kour, Sameru Sharma, and Harinder Dhingra, "Performance comparison of various PAPR reduction techniques in OFDM," *International Journal of Scientific and Technical Advancements*, Volume 4, Issue 1, pp. 131-136, 2018.