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An Efficient PAPR Reduction Technique for OFDM

R. Deshpande[1*], DJ. Pete[2]

[1]Department of EXTC, University of Mumbai, Navi Mumbai, India
[2]Department of EXTC, Datta Meghe College of Engineering, Navi Mumbai, India
Corresponding Author: rohinide1@gmail.com

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Abstract— This Orthogonal Frequency Division Multiplexing (OFDM) is an efficient multiplexing & a bandwidth efficient modulation scheme in wireless communications.However, OFDM faces the high Peak-to Average Power Ratio (PAPR) problem that is a major drawback of this multicarrier system which leads to power inefficiency in the RF section of the transmitter.Thus, the OFDM signals with high PAPR could seriously be distorted by the non-linearity of the HPA, resulting in degradation of both spectral efficiency (SE) and energy efficiency (EE) performances. Our paper will review a few techniques to reduce the high PAPR to combat multipath fading and signal distortion which will facilitate better data transmission.

Keywords—PAPR, RF, OFDM, SE, EE

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a bandwidth efficient modulation scheme. It is a multicarrier system; it facilitates transmission of several low data rate streams in parallel form to be sent over the channel in a form of data blocks, which helps accommodate 'n' number of users.
Due to orthogonality property among the sub-carriers of an OFDM signal inter symbol interference (ISI) is eliminated. OFDM technique has been widely adapted in Digital Video Broadcasting, IEEE 802.16a standard and 4G mobile communications.

It has several advantages such as immunity against interferences, it is robust against multipath fading, and it facilitates single frequency networks and eliminates ISI. The basic principle of OFDM system is to split a number of high data rate streams to a number of low data rate streams that can be transmitted simultaneously over a number of sub-carriers. OFDM faces several challenges such as inter-symbol interference (ISI) due to multipath delay using guard interval would eliminate it, a major problem is its large Peak to Average Power ratio (PAPR) in to the power amplifier section of the transmitter which would have the effects as follows [1, 2]:

1) Spectral regrowth.
2) Lower spectral efficiency
3) Non-linear distortion

A number of the techniques have been devised to reduce the large PAPR; they are signal distortion techniques and signal scrambling techniques. An OFDM carrier signal is the sum number of orthogonal subcarriers independently modulated using some form of modulation technique; this composite baseband signal is used to modulate an RF carrier.

II. BASIC OFDM

A number of the techniques have been devised to reduce the large PAPR; they are signal distortion techniques and signal scrambling techniques. An OFDM carrier signal is the sum number of orthogonal subcarriers independently modulated using some form of modulation technique; this composite baseband signal is used to modulate an RF carrier. [3]

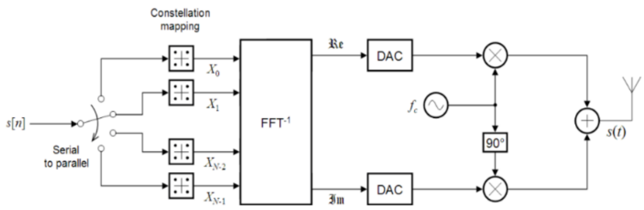

Fig.1 OFDM transmitter with IFFT and Modulators

As shown in Fig.1 is serial stream of binary digits, by inverse multiplexing, these are first demultiplexed in to N parallel streams and each one is mapped to a possibly complex symbol stream using some modulation constellation QAM, PSK etc. note that the constellations may be different so some streams may carry high data rate.

An inverse FFT is computed on each set of symbols giving a set of complex time domain samples. These samples are then quadrature mixed to pass band in the standard way. The real and imaginary components are first converted to the analog domain using digital to analog converter (DAC); these analog signals are then used to modulate cosine and sine waves at the transmitter carrier frequencies, f_c, respectively. These signals are then summed to give the transmission signal s (t) [3].

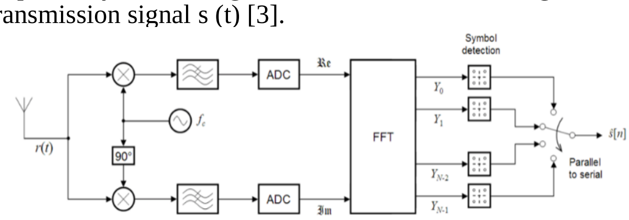

Fig.2. OFDM Receiver with FFT and demodulators

The receiver shown above picks up the signal r (t), which is the quadrature mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on $2f_c$, so low pass filters are used to reject these. The baseband signals are the sampled and digitized using analog to digital converters (ADC) and a forward FFT is used to convert back to the frequency domain. This returns ‘N Parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then recombined in to serial streams ŝ[n], which is an estimate of the original binary stream at the receiver.

The high PAPR is a point of concern of the RF section transmitter. The PAPR is defined as [3]:

$P_{peak}/P_{avg.} = 10\log_{10} \text{Max } [|x(t)|^2]/E[|x(t)|^2]$
Where,
P_{peak} = Peak o/p power
$P_{average}$= Average o/p power
x(t)=transmitted symbols
Ex(t)= expected value of transmitted symbols
X(k)= IFFT operation on modulated o/p symbol s

$$X(k)= 1/\sqrt{N} \sum_{k=0}^{N-1} X_k W_N^{nk}$$

The instantaneous output of the OFDM system has large fluctuations and hence the power amplifier and the DAC and ADC need to have large dynamic range. If this is not satisfied a series of undesirable interferences is encountered when thepeak signal goes in to the non-linear region of the transmitter which leads to high out of band distortions and abrupt intermodulation with a very a high Peak to average power ratio (PAPR).[7]

So, effective Peak to Average Power ratio (PAPR) reduction techniques need to be implemented [5]

III. OFDM BASEBAND SIGNAL GENERATION FLOWCHART

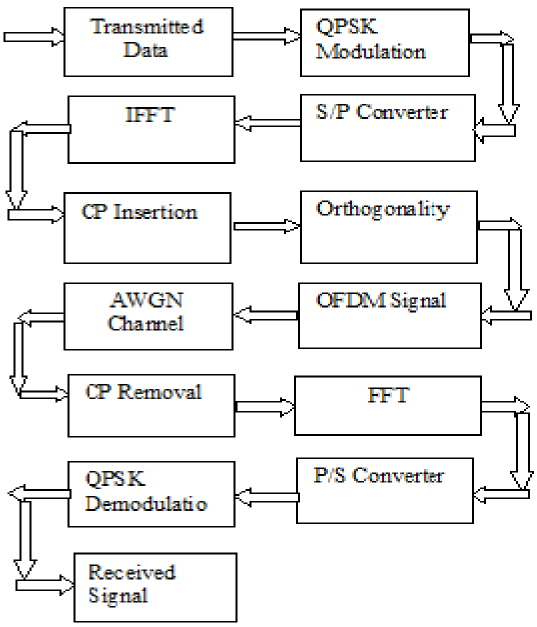

Fig.1 OFDM Baseband signal generation

Signal Distortion Techniques [3], [9]
1) Companding
2) Peak Windowing
3) Clipping and filtering
4) Peak Cancellation

Signal Scrambling Techniques [3], [9]
1) Interleaved OFDM
2) Tone Injection
3) Tone Reservation
4) Selective Mapping
5) Partial Transmit Sequence
6) Coding

Of which we will review a few of them to reduce PAPR, and try to simulate them and come to a conclusion with their results regarding relation between P(PAPR>z) vs. z for some threshold level [4].
N.B. z= threshold power of the amplifier

A. *Amplitude Clipping (Method I)*

The PAPR reduction method is to employ clipping in the time domain signal, the signal would appear as if it suffered a distortion just before transmission, by repeating clipping and filtering several times both high PAPR and out of band spectrum distortion can be avoided. In amplitude clipping we will be analyzing the OFDM signal and accordingly implement clipping at 70 percent of the maximum signal (z) so that maximum information can be maintained, but amplitude clipping will introduce in band distortion which can be eliminated by filtering, but out of band radiation is difficult to eliminate by filtering which leads to peak regrowth so we introduce an oversampling factor to bring the PAPR value to its lowest [7]10], [11]

A threshold level is assigned for the amplitude and sub-carriers containing amplitude more than the pre-determined threshold level is clipped or cleaned to fetch out an inferior PAPR rate.

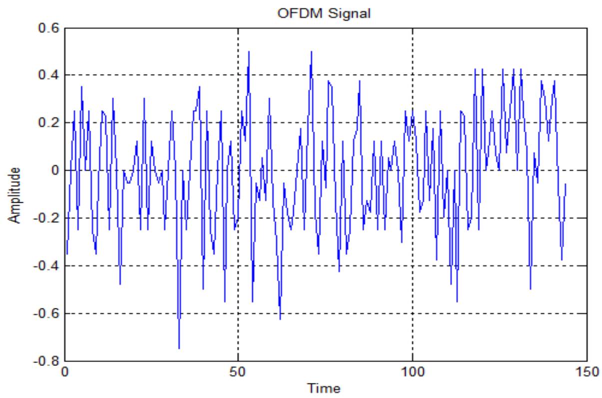

Fig.2 OFDM Signal

However, Amplitude clipping is a nonlinear process and it may create problems like linear in band distortion and out of band distortion.In band distortion affects the OFDM system by degrading the bit error rate (BER) and out of band distortion affects the spectral efficiency. Filtering after clipping can reduce out of band radiation to a maximum extent but also produces some peak regrowth in the filtered signal. Aliasing problem is faced by Clipping after filtering which can be reduced by adding zeroes in the original input called zero padding or oversampling

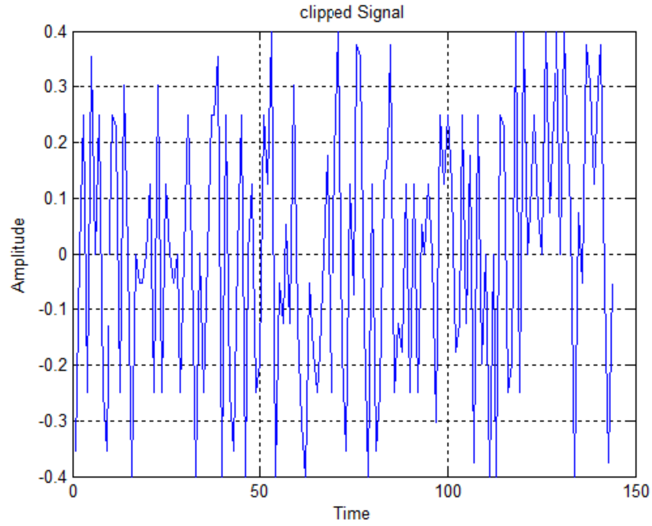

Fig.3. Clipped OFDM Signal

The difference in amplitude between the OFDM signal and that of the clipped signal itself indicates low and high power.

CCDF function of the Normal OFDM signal [4]

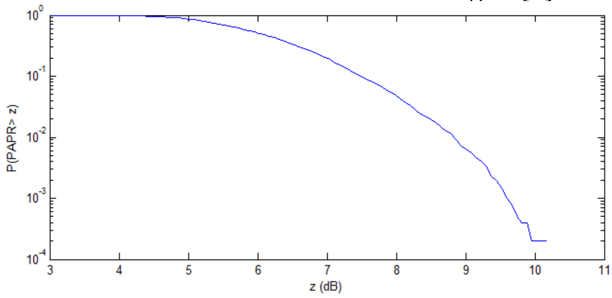

Fig.4 P (PAPR>.z) Vs. z of a normal OFDM Signal

Analysis of General Signal to show the Filtering Effect

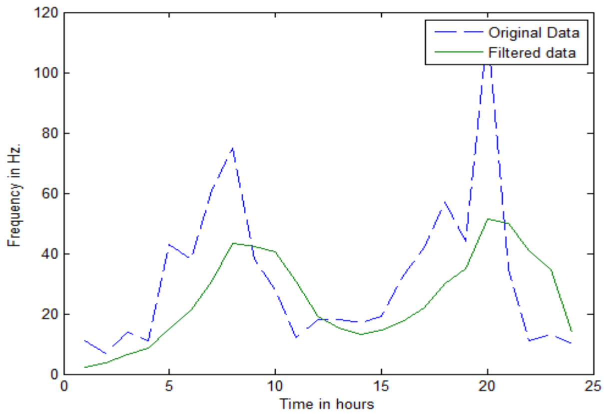

Fig.5 E.g. of a Low Pass filter showing filtering effect

Here we have considered the Moving average filter (LPF), it takes M samples of I/P at a time and takes the average of those M-samples and produces a single o/p, this filter, filters out unwanted noise [17]. We have used it to show how the filtered data has less frequency and is smoother than the original data, which states that an efficient PAPR cannot be achieved in an original signal without filtering [16, 17]. So, considering this only clipping or only filtering would not achieve the desired PAPR reduction but combining both would be another option for an efficient technique [7].

B. Amplitude Clipping and Filtering (Method II)

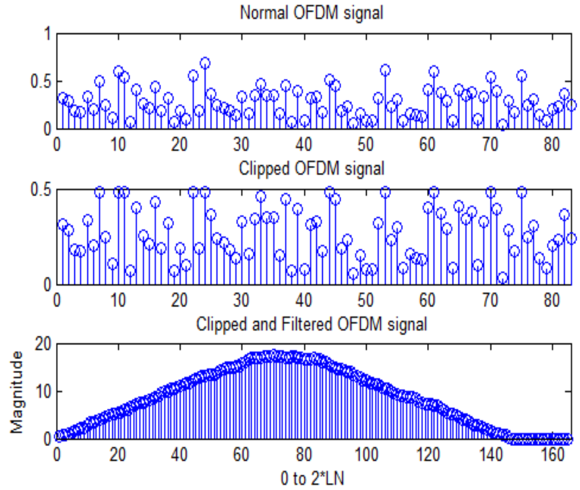

Fig.6. Amplitude clipping and filtering

Fig.6. shows the effect of clipping and filtering together, as discussed earlier clipping alone introduces in-band distortion and out of band distortion, this out of band distortion can be eliminated by filtering but in band distortion degrades the Bit Error Rate (BER) Performance. So, oversampling by taking longer IFFT can reduce the in-band distortion effect, as portion of the noise is reshaped outside of the signal band that can be removed later by filtering.

Parameters:
L (Oversampling factor) (1 to 1.5) =1.3
N (No. of transmitted Symbols) ^2 preferably (> 32) =64
M (Alphabet size) ^2 < N, preferably (<32) =16

PAPR of Original OFDM signal = 4.6882
PAPR of Clipped and filtered OFDM signal = 2.8079

Clipping with filtering gives BER degradation so a more effective PAPR Reduction technique needs to be looked upon.
Selective Mapping is one such technique which does not have power increase, is less complex and the BER does not degrade.

C. Selective Mapping (Method III)

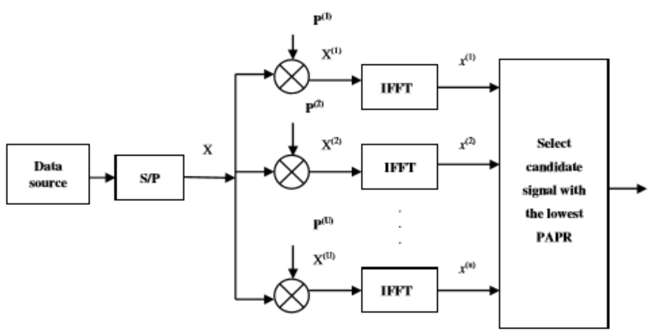

Fig.7 Block Diagram of Selective Mapping Scheme

In the SLM approach, statistically-independent phase sequences say, $P^{(u)} = [P_0^{(u)}, P_1^{(u)}, P_2^{(u)}......P_{N-1}^{(u)}]^T$ are generated, where $P_k^{(u)} = \exp(j\phi_k^{(u)}, \phi_k^{(u)} \epsilon [0,2\pi])$, k=0,1,2…. N-1, u=1,2,3…. U. [5], [6], [7], [10], [12].

Then the data block $X= \{X_0, X_1, X_2...X_{N-1}\}^T$ is multiplied component wise with each one of U different phase sequence $P^{(u)}$, resulting in a set of U different data blocks $X^u[X_0P_0^{(u)},X_1P_1^{(u),}X_2P_2^{(u)}....X_{N-1}P_{N-1}^{(u)}]^T$,u=1,2.3….U. [5],[6],[7],[10],[12].

Then, all U alternative data blocks are transformed in to time domain to get transmitted symbols x^u, u=1, 2, 3…U by IFFT, and are defined as candidate symbols. Finally, the one with the minimum PAPR is selected for transmitting [5], [6], [7], [10], and [12].

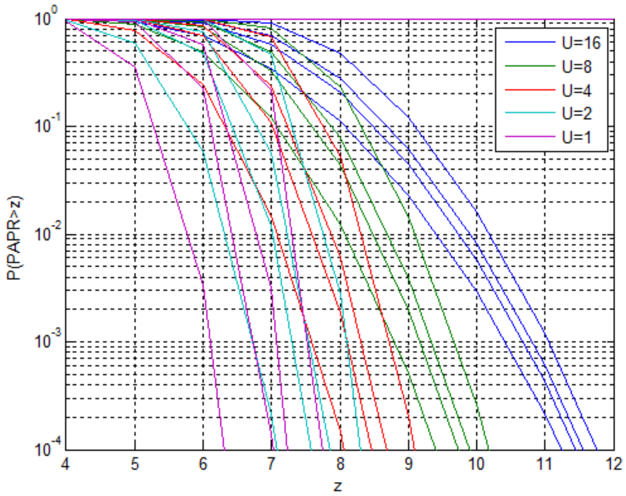

Fig.8 P(PAPR>z) Vs. z for N=64,128 and whenα=2.8 for N=64,128

TABLE I: ANALYSIS OF SLM SCHEME

z=6dB

		U=16	U=8	U=4	U=2	U=1
N=64	P(PAPR>z)	0.004	0.55	0.25	0.50	0.70
N=128	P(PAPR>z)	0.23	0.49	0.70	0.80	0.90
α=2.8N						
N=64	P(PAPR>z)	0.90	0.80	0.85	0.98	0.60
N=128	P(PAPR>z)	1.00	1.00	1.00	1.00	1.00

Table above shows the P(PAPR>z), the least this value the more are the chances of transmission, in our case N=64, U=16 and for α=2.8 N=64, U=1 have the least value of P(PAPR.>z), so these sequences are better for transmission.

VI. CONCLUSION

The main objective of the communication system designer is to transmit messages speedily as possible with least probability of error, fast communication is possible by

1) Reducing the time of each message but this can in turn increase the bandwidth of the signal.
2) Simultaneous transmission of several messages over a single physical channel. This process is also known as multiplexing.

By reviewing all the above PAPR reduction methods we can conclude as follows:

TABLE II
COMPARISON OF DIFFERENT PAPR REDUCTION TECHNIQUES

REDUCTION TECHNIQUES	Power Increase	Implementation Complexity	Bandwidth Expansion	BER Degradation
Clipping	No	Low	No	Yes
Coding	No	Low	Yes	No
PTS	No	High	Yes	No
SLM	No	Low	Yes	No
TR/TI	Yes	High	Yes	No

Comparison shows that Clipping and Selective Mapping are easy to implement and requires less power.

OFDM is a prospective candidate for 5G and can have the following features [2]:

1) **FBMC** Filtering each sub carrier individually.
2) **UFMC** does not use CP Insertion, sub-bands are filtered individually.
3) **GFDM** has better control over out of band emissions and controls peak to average power (PAPR).
4) **F-OFDM –** Filters each sub-band individually andservices are accommodated in the most suitable waveform and numerology.

VII. FUTURE WORK

To combine one or two techniques so that they can be used to develop a new technique or make an improvisation in the previous techniques which will facilitate maximum data transmission with an operational PAPR [14].

In our previous method, the threshold value of the Power amplifier was static and accordingly clipping was done, but in our future work we will try to keep the threshold value of the power amplifier dynamic depending on the peaks in the particular region and find an operational PAPR for which bit error rate (BER) will be minimum and a maximum of information can be reached, such a technique can well be termed as an efficient PAPR Reduction technique for an OFDM.

ACKNOWLEDGMENT

Above PAPR Reduction methods are general ones and we have tried to figure out the best suitable one to put a milestone for our future work. I sincerely appreciate the inspiration, support, motivation and guidance given by my Supervisor and to all those who have lent a helping hand for making this work, a success.

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