A WEIGHTED OFDM SCHEME WITH HADAMARD TRANSFORM AND WINDOWING TECHNIQUES FOR PAPR REDUCTION

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***Abstract*— In Orthogonal Frequency Division Multiplexing (OFDM) transmission technique, data is transmitted simultaneously over multiple carrier frequencies that are equally spaced. If correct time windowing is used at the receiver, the transmitted multiple carriers can be demodulated orthogonally. The method has been proposed for a lot of radio systems. It has high spectral efficiency and inherent resistance to dispersion in the propagation channel. OFDM is one of the most promising solutions for obtaining high data rate transmission in frequency selective fading radio channels. Irrespective of many positive aspects of OFDM, potentially high peak-to-average power ratio (PAPR) values is one of the noticeable limitation. Through this work, we are suggesting a method to reduce the value of PAPR through clipping and windowing technique which is easy to implement. This technique clips the OFDM signal to a predefined without data distortion in removing weight at the receiver side , by using a band limited signal & each clipping noise sample is multiplied by a window function. In the proposed scheme, thorough comparative study will be done to ensure that the BER performance and CCDF is much better compared to the existing clipping and filtering method. MATLAB toolbox will be used for the simulation study.**

***Keywords*— CCDF, HPA, OFDM, ICI, BER, PAPR**

I. INTRODUCTION

Mobile communications have become widely popular among consumers. New demands and new ways have emerged to extend the mobile concept. Multiple access schemes are one of the solutions which can solve the problem of limited radio spectrum. This is achieved by sharing the spectrum among multiple users. Multicarrier Modulation (MCM) is the technique of transmitting data by dividing the input data streams into many bit streams. These sub streams are used to modulate different carriers. In a classical MCM system, the total signal frequency band will be divided into N independent, non overlapping frequency subchannels. Each subchannel is revamped with a separate symbol and then these are frequency multiplexed. To eliminate interchannel interference spectral overlap of channels is avoided. In OFDM, the frequency spectrum of the individual carriers overlap in the frequency domain.But the signals are received without adjacent carrier interference. The carriers are chosen to be mathematically orthogonal to achieve this.

The measurement of a waveform which is obtained by dividing the peak power of the waveform from the average power is called crest factor or peak-to-average power ratio [9]. The main drawback of OFDM is its high PAPR. Through PAPR reduction the efficiency of high power amplifiers could be improved and nonlinear distortion noise caused by the HPA [24] could also be significantly reduced. Multicarrier system consists of separately modulated subcarriers. These subcarriers have different amplitudes and phases. In the frequency domain the subcarriers are present in different spectra and are transmitted at the same time. When those are added up, the instantaneous peak power will be bigger than the average power of the signal. So MCM has high PAPR than single carrier communication system. PAPR reduction is a must because when PAPR is lower, higher will be the efficiency of high power amplifiers [24] and analog to digital converters. This will reduce the power consumption as power saving is directly proportional to the average output power. Modulation techniques with low crest factor can transmit more bits per second. So crest factors have to be reduced. Also by spectral efficiency can be increased and system will be more energy efficient. High PAPR will badly affect the BER performance of the system. The average input power must be reduced, otherwise signal distortion will occur causing out of band spectral regrowth. PAPR should be reduced without bandwidth expansion, BER performance degradation, additional power, spectral

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spillage etc. Various approaches have been suggested to reduce the PAPR such as clipping[1][2][3], coding schemes[4], nonlinear companding transforms, Tone Reservation (TR) and Tone Injection(TI), Partial Transmission Sequence (PTS)[6], constellation shaping[16], and Selective Mapping (SLM)[5]. Among all these techniques, PTS is acknowleged to be the appropriate method for PAPR reduction scheme but it has high data processing complexity. In clipping data missing occurs. By using efficient coding techniques, PAPR can be reduced and enhanced BER performance can be obtained. But these techniques does not attempt to give better SNR. By combining window and Hadamard transform PAPR can be reduced without data missing and with better SNR.

The remainder of this paper is organized as: Section II focuses on the system model and description. The simulation parameters and simulation results are presented in Section III and section IV respectively and the paper is concluded in Section V.

II. SYSTEM MODEL

In peak windowing technique, the unwanted portion of the signal is removed. Clipping is one such type. But this introduces self interference. The technique of peak windowing attempt to give better PAPR reduction with better spectral properties. In peak windowing method large signal peak is multiplied with a specific window function. Different window functions exists, which are; Gaussian shaped window, cosine window, Kaiser, Hamming window etc.The OFDM signal is multiplied with these windows before transmission. The spectrum resulted wil be a convolution of the original OFDM spectrum with the spectrum of the applied window.

The simplified block diagram of a weighted OFDM system with Hadamard transform and Hanning window is shown in Fig.1. The block diagram consists of a mapper, modulator, serial to parallel converter, IFFT, cyclic prefix adder, channel, synchroniser, FFT, parallel to serial converter, demodulator and demapper. Binary data is inputted to the system. In the proposed method the data given has been added with weight and is passed through digital to analog mapping for modulation. The modulation technique used is BPSK.. It is a more robust modulation scheme compared to the QPSK technique. In BPSK modulation, it is easy in the receiver to recover the original bits. Only two decision points are desired to fetch the original binary information, also wide coverage area can be achieved from the base station. This modulated signal is then converted into parallel signal by signal to parallel converter. Then this is Hadamard transformed. The data is then performed the IFFT operation. The IFFT block converts the frequency domain signal to time domain signal for each subcarrier. It is then multiplied by Hanning window function. This windowed signal is transmitted through the channel. The signal is decoded with the help of inverse Hadamard transform at the receiver after FFT operation.

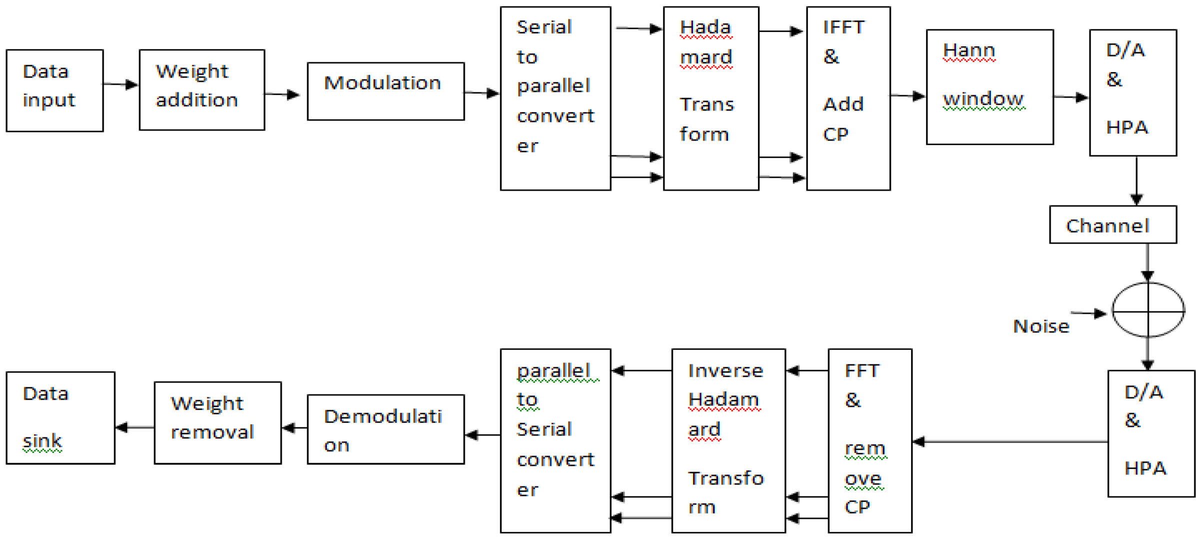

Fig.1:Block diagram of proposed system

The system description in detail is as follows:

Consider the OFDM signal as

$$P_N(t) = q\, e^{j2\pi f_q t} \qquad (1)$$

The weight is derived from an acceptable band limited signal with no zero on the real line. The discrete weight signal is (p). A new OFDM signal is formed with this weighted discrete data which is,

$$R_N(t) = {}_q\boldsymbol{\varphi}(2\pi f_q)\, e^{\, j2\pi f_q t} \qquad (2)$$

To increase the BER performance modified weight is used,which is,

$$\boldsymbol{\varphi}_\alpha(p) = \boldsymbol{\varphi}(p) + \alpha/\log N \qquad (3)$$

Therefore the OFDM signal with modified weight is

$$S_N(t) = 1/\sqrt{N} \sum a_q\, \boldsymbol{\varphi}_\alpha(2\pi f_q)\, e^{\, j2\pi f_q t} \qquad (4)$$

PAPR for a signal p (t) is defined as,

$$\text{PAPR }(S_N) = \frac{\max|S_N(t)|^2}{E|S_N(t)|^2} \qquad (5)$$

The main advantage of using weighted OFDM is that original signal can be recovered at the receiver without any distortion on removing the weight.

We are using orthogonal hadamard code for spreading. It performs the following operations such as orthogonal, linear, symmetric on 2^m real numbers. In a group of Hadamard codes all codes are orthogonal to each other. The code length is defined as the size of the matrix. The main purpose of using Hadamard codes is that it provides orthogonality among different users . By orthogonality it means, the cross correlation between different codes will be zero and the original data can be recovered without any data loss, using inverse of the Hadamard transform. Even though weighted OFDM with Hadamard transform can offer many advantages, it has a major limitation of data loss while reducing the PAPR .To solve this problem windowing technique can be used. A window function is a mathematical function. It has no value outside of some chosen interval ie., zero valued. The window should be as narrow band as possible, also should not be lengthy in the time domain because various signal samples will get affected, which make an rise in bit error rate (BER). The loss in signal to noise ratio (SNR) due to signal distortion can also be reduced. A threshold peak is set, if a signal peak exceeds this value that peak is windowed. Windowing gives better spectral efficiency than clipping because of the smooth peak. The Hanning window uses cosine functions to provide a smooth truncation and aliasing is very low. It touches zero at both ends, eliminating all discontinuities.

III. SIMULATION PARAMETERS

The simulation is set up for Weighted OFDM with Hadamard transform and Hanning window system in matlab for the following simulation parameters.

- Channel bandwidth = 5 MHz
- No: of subcarriers = 128
- Symbol duration = 160 µs
- Guard interval = 40 µs
- Total block length = 200 µs
- Modulation scheme = BPSK
- FFT size = 128
- Clipping ratio = 0.8,1.2,1.6
- Cyclic Prefix duration = 40 µs

Simulation set up for weighted OFDM signal

- No: of subcarriers = 128,256,1024
- FFT size = 128,256,1024
- Channel = White Gaussian channel
- Modulation scheme = BPSK

Simulation set up for weighted OFDM with Hadamard and Hanning window

- No: of subcarriers = 128,256,1024
- Windowing method = Hann peak window
- Spreading Code = Hadamard code

IV. SIMULATION RESULTS

The performance analysis of weighted OFDM system with Hadamard transform combined with Hanning window based on the BER and spectral efficiency is analyzed using MATLAB R2013a. A comparative study is carried out by plotting various CCDF plots. Effectiveness of the simulated system is studied using the following graphical analysis.

- BER
- CCDF

Communication system toolbox can be used for these simulations. In our work we are going to compare the performance of our work with other methods.

It is inspected that PAPR and BER of the weighted OFDM system is much better than that of the unprocessed data. For the same CCDF, the PAPR of the weighted OFDM is improved with 3dB difference.

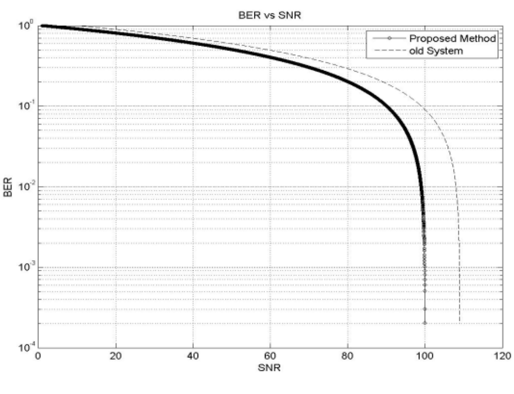

Fig.2:BER comparison of weighted OFDM and unprocessed data

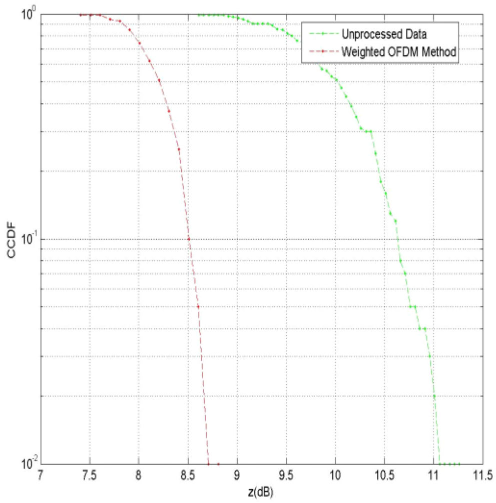

Fig.3:CCDF of unprocessed data and weighted OFDM

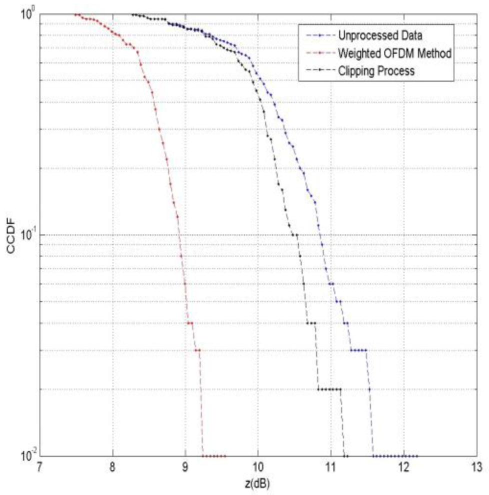

Fig.4: CCDF comparison of unprocessed data ,weighted OFDM and clipping

Change in PAPR is analysed with changing the number of subcarriers. This result shows that, as the number of subcarriers increases PAPR performance also also improves. It was analysed that when number of subcarriers increases the PAPR reduces. It was deduced from the plot that for N=1024 PAPR value is 0.6dB lesser than that from N=128.

PAPR comparison is also done for different values of clipping ratio (CR).We can see that when clipping ratio reduces,PAPR value also reduces. For clipping ratio, CR=0.8 PAPR is lesser than that of CR=1.6. PAPR reduction is also studied using Hadamard transform and Hanning window. In the proposed scheme, we have combined windowing with weighted OFDM.The results obtained shows that, in the combined process 5% of reduction in PAPR is seen, where as in methods like clipping and filtering it was around 2% and for weighted OFDM it was 2.7%.

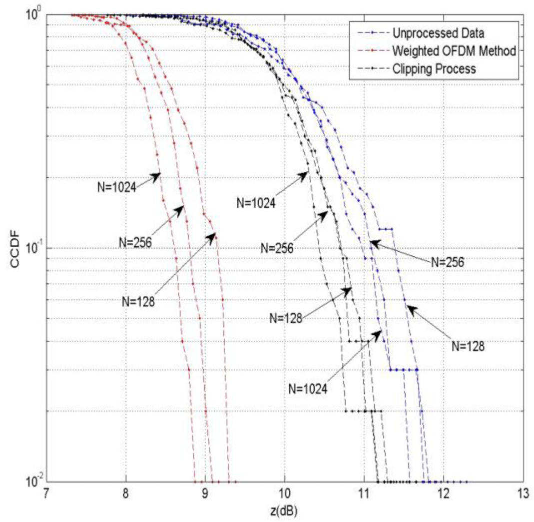

Fig.5: CCDF comparison for different values of N

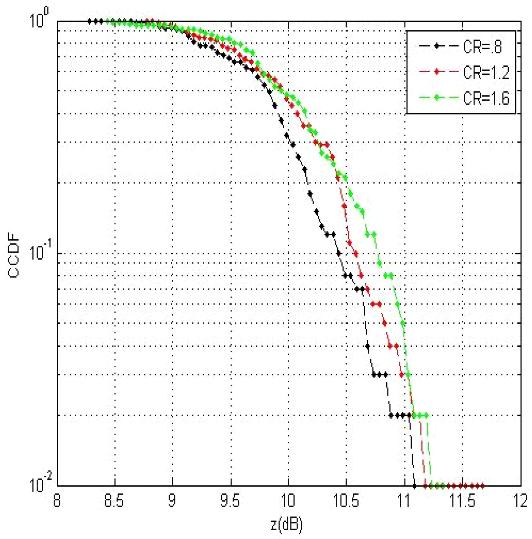

Fig.6: CCDF comparison for different clipping ratios

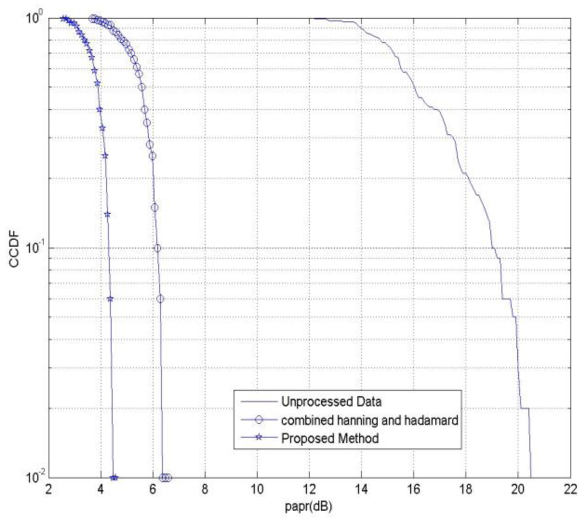

Fig.7: CCDF comparison of weighted OFDM with Hadamard transform and Hanning window

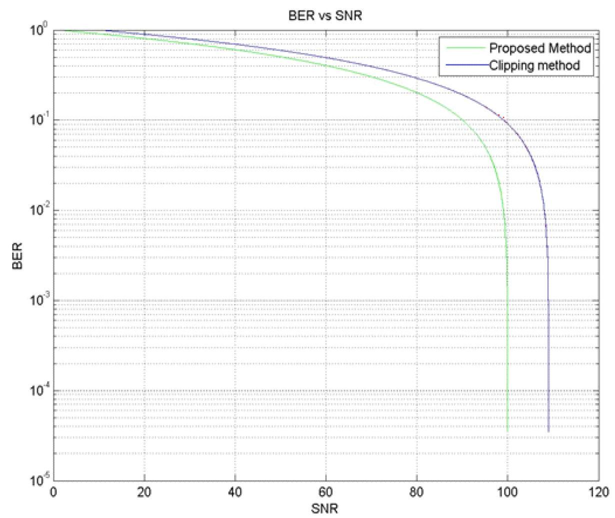

Fig.8:BER comparison of proposed system with clipping method

Table.1 PAPR comparison of different techniques

Techniques used	**PAPR of original OFDM signal (dB)**	**After applying the technique (dB)**	**Amount of reduction (dB)**
Clipped signal	16.4544	15.7450	0.7144
Hadamard transform	16.4544	12.147	4.3074
Hanning window	16.4544	5.8722	13.3062
Proposed system	16.4544	4.8946	14.2838

V. CONCLUSION

A PAPR reduction scheme considering a weighted OFDM signal with Hadamard transform and Hanning window has been suggested to make a reduction in the PAPR. It has been accomplished without data distortion in the removal of weight at the receiver side with better BER performance and without data loss. To reduce the peak value, the signal is multiplied by a certain banlimited signal. We considered a weighted discrete data as a weighted OFDM signal, which is interpreted on the same time interval as the original OFDM signal. It is shown that the C&F method is having higher PAPR than that of weighted OFDM method , and the BER performance is improved compared with. To reduce the data loss a windowing technique has been used. The window used is Hann peak window. So only the unwanted high peaks are reduced. Hadamard transform is also used, in order to reduce the data loss. The contrast in PAPR is examined and compared with the help of CCDF curves. After adding the clipping process, once again CCDF is compared with PAPR for weighted OFDM and unprocessed signal. Here even though there is an improvement in PAPR, CCDF curves shows that weighted OFDM method is better than clipping process.

The use of Hadamard transform helped to recover the original data.Hanning window helped to remove the unwanted peaks, so that data loss can be avoided to certain limit. This feature also gave better BER performance. From the comparisons made it can be understood that PAPR reduction of the recommended system is better than the other methods. In our work, PAPR reduction scheme is analyzed with clipping and weighted OFDM with Hadamard transform and window technique. Based on the results we recommend weighted OFDM scheme with Hadamard transform and Hanning window method for better PAPR.

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