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Research Article

Evaluation of OFDM system in terms of PAPR and BER using PAPR Reduction Techniques: Windowing and Clipping

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ABSTRACT

The issue of transferring signals in a non-intrusive and efficient manner is highly intriguing. Consequently, the utilisation of the Orthogonal Frequency Division Multiplexing (OFDM) transmission technology is employed due to its enhanced resilience against multipath fading and its ability to achieve better efficiency compared to alternative wireless communication methods. Although the PAPR issue offers certain benefits, it poses undesirable consequences for OFDM, leading to a significant decrease in data transmission rate. Consequently, the mitigation of peak-to-average power ratio (PAPR) issues leads to an improvement in the quality of service. The reduction of PAPR can be achieved by the implementation of clipping and windowing techniques. These approaches arrange the signal into discrete levels of similar magnitude and apply clipping to minimise the bit error rate (BER), resulting in a drop in PAPR. The proposed approach is implemented using the MATLAB software.

1. INTRODUCTION

The growing use of mobile phones and other communication devices, such as personal digital assistants (PDAs) and small-sized telephones, has led to a higher need for strong wireless communication coverage. In order to fulfil the aforementioned requirements, many multicarrier frameworks such as code division multiplexing (CDM), temporal division multiplexing (TDM), and frequency division multiplexing (FDM) are suggested. Although the solutions were assessed in high-data-rate scenarios, the multicarrier frameworks were incapable of adjusting to multi-way blurring and signal reduction. The Orthogonal Frequency Division Multiplexing (OFDM) is a recently introduced technique that aims to resolve the aforementioned issues associated with the multi-carrier system [1].

Contrarily, the novel approach utilises restricted band sub transporters rather than a solitary wideband carrier transmission. OFDM allows for high data transmission speeds while simultaneously offering strong protection against multi-path interference. When comparing to single transporter systems, each subcarrier in OFDM receives the minimum amount of bandwidth, and the subcarriers are mutually perpendicular to each other [2]. The fundamental concept underlying OFDM is to partition a data stream with a high rate into several streams with lower rates, which are sent simultaneously over numerous subcarriers. Although extensively utilised for computerised sound telecommunications, advanced video broadcasting, and long-distance transmission, this technology does have certain limitations. These include challenges with time and frequency synchronisation, peak to average power ratio, carrier frequency offset, and station estimation [3].

The main issue with this construction is in the ratio between crest and normal power, which diminishes the high information rate. When all subcarriers have equal stage and abundance and reach the receiver side, the signal envelope expands, resulting in an instantaneous rise in the percentage of crest to normal power. Consequently, the power enhancer operates in the immersion area, leading to a reduction in the efficiency of the framework [4]. Several solutions to this problem have been proposed, which may be categorised into three distinct groups. Signal distortion mechanisms, diverse signalling and probabilistic techniques, and coding systems all possess inherent limits. The signal distortion method provides a significant reduction in PAPR by utilising clipping and windowing techniques [5]. Because clipping restricts the greatest peak of the transmitted signal to a predetermined level, it results in out-of-band radiation, in-band signal distortion, and worse BER

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performance. When a high peak surpasses the threshold set by the window function, the window function is multiplied by the high peak to determine its weight. The Cosine, Hamming, Hanning, Kaiser, and Gaussian Windows are among the most frequently used window functions. The issue here is that it would require more iterations to get the signal's peak level down to the required level. Therefore, it is essential to create a framework that successfully clips the appropriate regions to lessen the PAPR problem. The PAPR problem is what causes the OFDM system to degrade [6].
In addition to the non-linear challenge of developing the PAPR problem, another circumstance arises when the receiver employs FFT to transfer the signal from the time domain to the frequency domain. This FFT also incorporates many signalling components that lead to fluctuations in amplitude and deviations from linearity. The main focus of this study was to reduce the occurrence of errors in the transmission of signals by employing a clipping technique that is based on a discretization and interdependency approach. Additionally, it aimed to prevent the emission of unwanted signals outside the desired frequency range by using a windowing strategy based on an optimal threshold-based method [7].

2. RELATED WORK

By utilising a shift in signal through a precise mapping and clipping process, [8] provide a methodology that decreases the PAPR problem. The procedure's working standard required that the duplicated information signal be transmitted through the clipping element in order to reduce pinnacle control. The signal with the lowest top to normal power proportion will then be used for transmission at that time. The main disadvantage of this component is that it would take a lot of time to finish the process, which causes a rise in bit error rate. In [9] discussed the construction of the horrifyingly precoded-based OFDM while also planning a unique precoder. Low pass channel use was reduced in an OFDM-based architecture. The main problem with the OFDM architecture was that the subcarriers would include free stage and that the OFDM signal would exhibit a high strong range because of its tendency to resemble White Gaussian noise. The frightfully precoded techniques had a major drawback in that it took more time to compute. To address the PAPR issue, [10] introduced superposition coding as a different strategy in an OFDM-based framework. A parallel to serial transformation square, superposition coding, CP evaluation, serial to parallel change, DFT activity, and a new transmitter and collector structure were all necessary for the novel technique. Stage coefficients were extracted and evaluated by this subcarrier bunch using a SIC finder. The main drawback of this component is its highly calculative multidimensional character [11].

3. PAPR MITIGATION THROUGH CLIPPING AND WINDOWING

By using the OFDM approach, transmission from one end to the other end offers strong resistance to multipath fading and boosts the overall effectiveness of the wireless communication system [12]. However, the PAPR issue has caused a reduction in data rate, which has left the transmission region unable. This framework is designed to keep the transmitted signal linear and lower the bit error rate, which lowers PAPR. The signal that has to be modulated will first be routed through a QAM modulator, where it will be phase-shifted by 90 degrees and organised orthogonally [13-14]. The QAM modulator output is sent via an inverse fast Fourier transform, which converts the signal from the frequency domain to the time domain. To maintain signal orthogonality, it is then transmitted to the clipping process. The CAIM algorithm does this. The CAIM method distributes the signals at equal discrete intervals, minimising the loss of mutual signal threshold dependency while decreasing the BER. Although the BER of this clipped signal will be low, it should now exhibit an orthogonal character for PAPR reduction. This is not fully-fledged clipping since local optima occur, thus it is required to use a windowing approach that would enable the task by taking into account values outside of the region to Zero and reaching global optima [15].

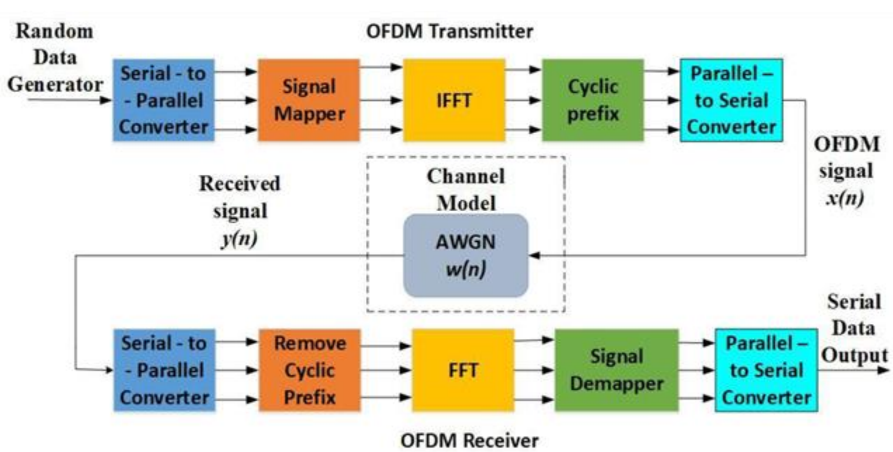

Fig.1. Block Diagram of OFDM

Only the Planck-taper window, which uses mathematical expressions to organise signals at equal intervals, can achieve this effectuality while preserving linearity and positioning the signal by preventing it from exceeding the limit. As a result, the signal on the receiver side, which the DAC transformed into analogue, has gained linearity and is now on the transmission channel, where the addition of noise can do so with poor quality [16]. The technique is briefly described below, and Figure 1 shows the overall block diagram of the OFDM approach using the suggested way. Consider a random signal Ii that is modulated using QAM in such a way that the signal is made stronger and is also phase-shifted at a right angle. The amplitude and phase are both modulated, causing OFDM to behave improperly orthogonally. The modulated signal is then sent to IFFT for the inverse fast Fourier transform, which is used to translate the signal from the frequency domain to the time domain [17].
The examination of PAPR performance in an OFDM system is comparable to that of an OFDM system with a single antenna. The total system PARP is defined as the sum of the PAPRs of all transmit antennas. The following equation(1) represents the PARP in OFDM signals and N is the number of subcarriers.

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} e^{\frac{j2\Pi kn}{N}}$$

$$PAPR = \frac{Max\left|x(n)\right|^2}{E\left[\left|x(n)\right|^2\right]}$$

Clipping method : Clipping methods are used to decrease PAPR by restricting the peak amplitude value of the OFDM signals to the threshold value [18-20]. Clipping methods can be defined mathematically as

$$C(x) = \left\{ \begin{matrix} x; |x| \le C_l \\ C_l e^{j\Phi}; |x| \ge C_l \end{matrix} \right\}$$

where C(x), Ө, Cl, and x are clipped signal, phase of x, clipping level, and input signal, respectively. Clipping changes the PAPR, which may be represented as

$$PAPR = \frac{C_l^2}{E\left[\left|C(x)\right|^2\right]}$$

Amplitudes exceeding a certain threshold are cut, and information is lost. Clipping creates in-band distortion and out-of-band radiation due to its nonlinear functioning. BER performance is degraded due to in-band distortion.

Windowing Method: Windowing is the process of multiplying a signal by a finite length window with an amplitude that varies gradually towards zero at the edges[18-20]. We studied two windows in this paper : Hamming window and Hanning window.

$$W_{HM} = 0.54 + 0.46\,\mathrm{Cos}\left(\frac{2\Pi n}{N} - 1\right); 0 \le n \le N-1$$

$$W_{HN} = 0.5 + 0.5\,\mathrm{Cos}\left(\frac{2\Pi n}{N} - 1\right); 0 \le n \le N-1$$

4. RESULTS

The simulated outcomes for the suggested technique are detailed in this section. By taking into account the transmitter part, receiver section, frame size, modulation technique, number of Pilots, and cycle extension employed as simulation factors, the suggested approach is realized on the working platform of MATLAB. All of the simulation parameters utilized in the suggested technique are listed in Table 1.

Table I. SIMULATION PARAMETERS

Parameter	Description
Modulation scheme	QAM
Cyclic extension	25%
number of subcarriers	1024
Oversampling rate	4
Bit per symbol	4
FFT size	512
Number of OFDM block	20000
Clipping levels	0.2, 0.4, 0.6, 0.8
Channel	AWGN
Window function	Hamming, Hanning

The results indicated in Figure 2 show the performance of the OFDM system when clipping procedures are used as well as when reduction techniques are not used. When the clipping approach is used, the PAPR is reduced. At CCDF=10-4, the original OFDM signal gives PAPR of 11.6dB, but when the clipping method applied it gives 8.3dB. Figure 3 shows the PAPR analysis for various clipping levels. Clipping techniques minimise the PAPR significantly by allocating a minimal amount of clipping level.

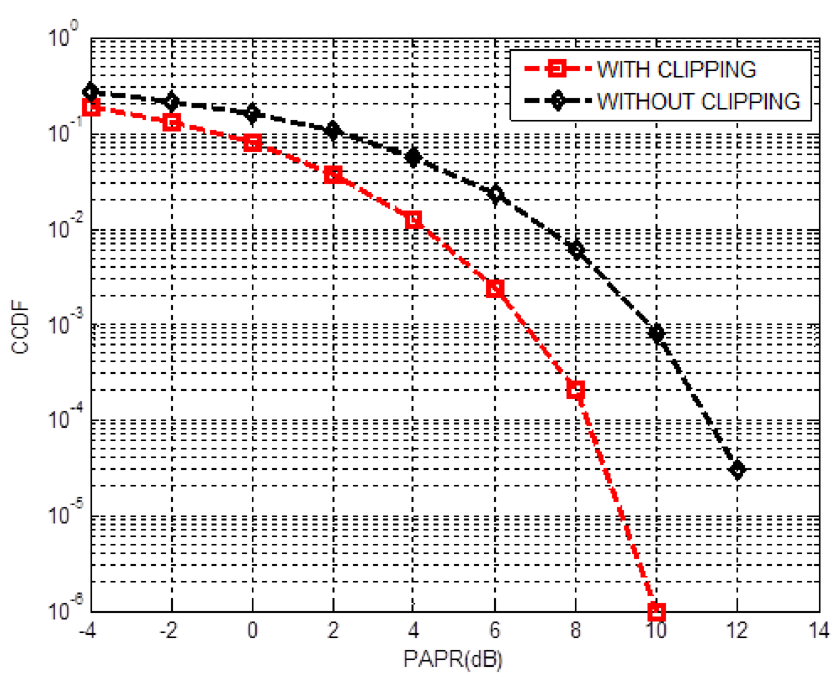

Fig.2. PAPR for without and with clipping method

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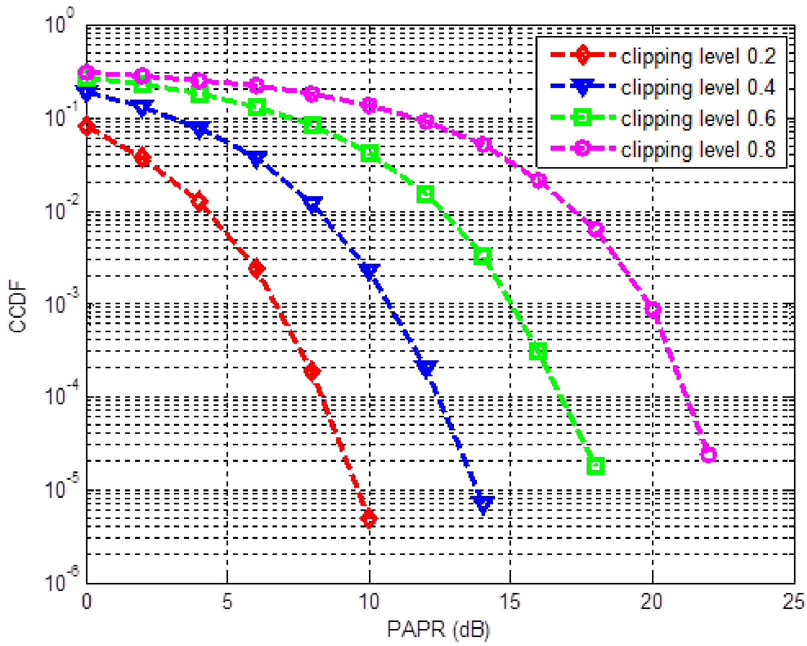

Fig.3. PAPR for various clipping levels

Figure 4 represents the BER analysis for various clipping levels. As the clipping level increases the SNR increases. Lower clipping threshold values gives better BER performance. Clipping method provides better BER performance significantly by allocating a minimal amount of clipping level.

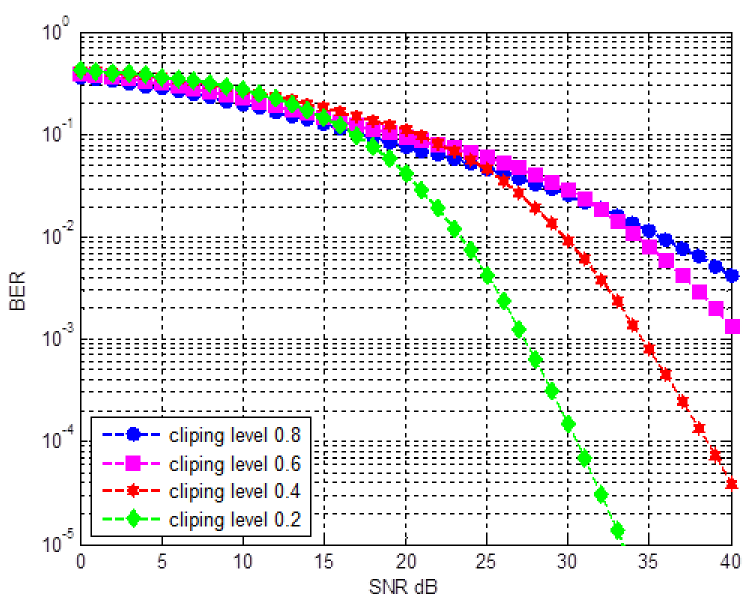

Fig.4. BER vs SNR for various clipping levels

Peak windowing is the removal of larger peaks at the expense of higher BER and out-of-band radiation. It improves PAPR migration while also improving spectral characteristics. A large signal is multiplied by a certain window. The window size should be small; otherwise, it would impact the amount of signal samples, increasing the BER. Hamming and Hanning windowing has been examined to analyse the effectiveness of different forms of peak windowing on PAPR reduction. Hamming window provides the lower PAPR and better BER performance.

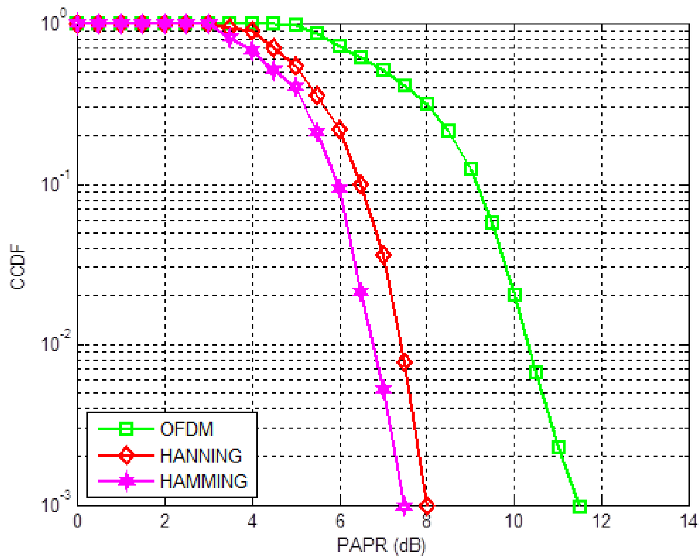

Fig.5. PAPR for various windows

5. CONCLUSION

This article primarily focuses on decreasing PAPR by lowering the BER and establishing linearity in transmitted signals via the use of a clipping technique and an interdependency approach, as well as preventing OoB radiation through the use of a windowing strategy. Although the orthogonality principle provides for the optimal utilisation of bandwidth, it does not preclude the system from having a high PAPR. Because of the low power efficiency in nonlinear power amplification, the high PAPR in OFDM is deteriorating. Clipping and peak windowing techniques were developed to increase the performance of the OFDM system in order to mitigate this disadvantage. The simulation results indicated that with a clipping threshold level of 0.2, there is an 8 dB decrease in PAPR and an 2.2dB reduction in PAPR when considering Hamming window. As a result, having an improved BER decreases the complexity of the OFDM system, makes implementation easier, and improves power consumption.

Conflicts of Interest

The author's affiliations, financial relationships, or personal interests do not present any conflicts in the research.

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