REDUCING PAPR AND CHANNEL EQUALISATION IN OFDM

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Abstract - *OFDM is a multicarrier modulation technique which is used in broadband wireless communication system. The main drawback of the OFDM system is the High Peak to Average power ratio (PAPR). It is the ratio of maximum power of the signal to its average power. Many techniques have been developed to lower the values of PAPR. Some among them are Amplitude Clipping, Filtering, Selective Mapping (SLM), Tone Reservation etc. Each techniques have its own advantages and disadvantages. In the proposed method we uses a moving average filter and a Stationary Wavelet Transform (SWT). Moving average filter averages the signal frame by frame using a threshold thereby we can filters the peak signals and using SWT we can once again reduces the PAPR. SWT consist of an approximation part and a detailed part. At the same time machine learning is also used to reduce PAPR it consists of a feed forward neural network. In the proposed system, the combination of moving average filter and stationary wavelet transform gives a greater reduction in PAPR as compared to other conventional techniques. Here channel estimation and channel equalisation are also performed to reduce the interference due to fading.*

Key Words: OFDM, Interleaver, Moving Average Filter, Stationary Wavelet Transform (SWT), Channel estimation, Channel Equalisation

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing(OFDM) is a high speed communication technology for 4G and 5G telecommunication standards which includes digital radio broadcasting digital terrestrial television(DTT), wireless local area networks(WLANs), etc. The main principle of OFDM is to divides the data band into many narrow band sub channels. It is the one of the widely used multicarrier modulation technique for high speed data transmission. It is popular because it has several advantages such as high spectral efficiency, robustness to channel fading, immunity to channel interferences, efficient bandwidth utilization etc. However a major drawback of OFDM is high Peak To Average Power Ratio(PAPR). The high PAPR signals are highly undesirable since large magnitude spikes cause non-linear distortion when passed through the power amplifier prior to transmission which affects the performance and efficiency of Power Amplifier. High peak-to-average power ratio (PAPR) problem limits its wide adoption in some communication devices. For example, while OFDM is applied in downlink transmissions of mobile communication standards, it is not preferred in uplink transmissions due to PAPR limitation. High PAPR leads power amplifiers to operate in the saturation region expending large system power and induces bit error ratio (BER) degradation due to smearing of signals. In the literature, different PAPR reduction techniques exist and may be applied before or after OFDM modulation.

Several techniques are available for reducing PAPR they are Interleaved OFDM, Tone Injection(TI), Tone Reservation(TR), Selective Mapping(SLM), Partial Transmit Sequence(PTS, active constellation extension (ACE)) and Signal Distortion techniques. Signal Distortion techniques are Companding, Peak Windowing, Clipping and Filtering and Peak Cancellation. The companding destroys the orthogonality of OFDM subcarriers and the signals cannot recoverable at the receiver. Clipping is one of the simplest method for application and it did not require any receiver side processing, but it distorts the signal and decreases the BER of the system. TI, TR, and ACE do not distort the signal, but these methods cause energy increases of the transmitted signal. SLM neither cause any distortion in the signal nor causes any energy increases in the signal. But its application is more complex than the others methods. ICF is attractive because it is simple to implement and it does not require a predefined clipping ratio.

Companding is the foremost PAPR reduction scheme that explicitly imposes uniform distribution probability density function (PDF) constraint unto the Rayleigh PDF of the conventional OFDM signal amplitudes. However, companding destroys the orthogonality of the subcarriers, unfairly expands the low amplitude signals or compresses the larger amplitude signals - due to amplitude distortion, these increase noise overhead and lead to poor BER performance.

The fundamental principle of OFDM is to split the available bandwidth into multiple sub-carriers. As the number of sub-carriers increases, it gets more immune to frequency selective fading, and data rates are also increasing. However, number of sub-carriers cannot be increased arbitrarily because it increases the complex architecture of the system and symbol durations that make transmission more sensitive to the time incoherence of the channel.

1.1 OFDM System Design

An OFDM use overlap signals to divide the frequency selective channel into a number of narrow band flat fading sub channel. The FFT encodes the block of symbol. By spacing the subcarrier at the increase of symbol time, the sub-channels can be made orthogonal. The multipath fading can be nullified by making longer symbol period of sub-channel as compared to multipath delay spread and the effect of fading and interference can be decreased by deactivating signals having high noise and interference. The OFDM modulation technique is generated through Fast Fourier Transforms (FFTs) and inverse FFTs in the transmitter and receiver sections of the radio. One of the benefits of OFDM is its immunity to adverse effects of multipath propagation with respect to inter-symbol interference in a channel. And it is also spectrally efficient because the channels are overlapped and contiguous. In this system input data are FEC coded by using the convolution code and the diversity gain is obtained by interleaving the coded bit stream. After a group of channel bits are grouped together the constellation points are mapped. The data is serial which is represented by complex numbers then Mapping Technique such as pilot mapped is used. A serial to parallel converter is used and IFFT is applied on the complex parallel data.

Then transformed data are grouped as per the need of transmission sub-carriers. In every block of data cyclic prefix is inserted providing guard interval and the data is multiplexed in serial fashion. OFDM data are modulated and then digital data is converted to analog by using a DAC. And at the receiver side performs the down conversion of the signal and convert the signal from analog to digital by using ADC. Synchronization is also needed during the down conversion of the signal. Then the signal is convert to frequency domain by using a FFT and suitable de-modulation techniques. At last the original signal is received by using the FEC coding and Decoding.

2. RELATED WORKS

In the literature, PAPR reduction methods of different types are exist and can be applied before or after OFDM modulation [4].The two families of post-modulation PAPR reduction schemes contains companding and clipping [4]–[7]. In adaptive clipping technique, the number of the highest peaks in the signal is calculated first then decision is taken to whether the signal is clip or not. ie, first the signals are checked for the highest amplitude, then adaptive clipping is more helpful when there are so many peaks in the signals. Clipping the signals would leads to loss of signal and high error rate. But adaptive clipping first checks for the number of peaks and then decision is taken to whether clip or not to clip. If clipping is to be performed then at what level the signal is to be clipped so that there is no considerably loss of signal is calculated. Then the signal is clipped in such a way so as to maintain low PAPR in the signal. After the highest peak in the ofdm signal is calculated, then 10% of that value is measured. If the number of the signals under the 10% of the maximum value is less than 5% in terms of number of peaks then the signal is clipped. The clipping must be 10% of the highest amplitude. Here some information is lost due to clipping but the PAPR is maintained as a good level.

Companding destroys the orthogonality of OFDM subcarriers and this leads to signals to be unrecoverable at the receiver. In companding technique, the small signals are enlarged while compressing the large signals results increase in the immunity of small signals from noise. Clipping does not require any receiver-side processing, unlike companding. Exponential companding technique namely non-linear companding technique overcome the problem of increases of average power. This technique adjust both small and large signal without bias so that it is able to offer better performance in terms of PAPR reduction. Iterative clipping and filtering (ICF) technique can overcome the disadvantages of the conventional ICF PAPR reduction technique [6]. ICF is attractive because it is simple to implement, achieves better power amplifier efficiency and can be designed to achieve good BER performances [9]–[11]. After the introduction of clipping and filtering by [6], many studies [3], [4], [8]–[10], [12], [13] have been done as an ideal post-multicarrier modulation PAPR reduction method for OFDM systems.

In ICF method PAPR is reduced by clipping without setting thresholds[1]. In this method the signal amplitude peaks can be made to approach a uniform distribution, thereby PAPR problem can also be eliminated. Instead of converting the PDFs by using different companding transforms, here the design restricted to the mean amplitude distribution. For example, we first estimate the mean amplitude of OFDM signals, then clip all other amplitudes higher than the mean amplitude called Method 1.But this led to high in-band distortion which adversely impacted the BER performance when there are many subcarriers exhibiting the characteristic amplitudes higher than the mean amplitude. Since the BER is greatly degraded, another method is introduced that can improve the BER at the expense of the PAPR. Here the mean amplitude is scaled up so that the number of clipped signals is reduced thus reducing the in-band distortion called Method 2. After comparing both the PAPR performances of Method 2 with the original signal observed that Method 2 reduced the PAPR of unclipped OFDM signal much better and in terms of the BER, Method 2 achieved 3.4dB gain over Method 1.

Based on these two methods, the PAPR problem can be completely eliminated by using two simple steps, which leads to a third method called Method 3, the first step is determine the signal amplitudes below the mean and scale them up using the approach in Method 2, to transform these lower energy signals to equal or higher amplitudes as the mean signals. Then second method is to determine the amplitudes distributed above the mean, then clip the excess and this achieves the complete PAPR reduction to 0dB. However, to reduce the number of iterations involved in the ICF method, we apply the Lagrange multiplier (LM) optimization technique to reduce the distortion noise.

A multicarrier signal is the sum of many independent signals modulated onto sub channels of equal bandwidth. Let us denote collection of all data symbols X_n, $n = 0, 1, \ldots, N-1$, as a vector X=[x0,x1,x2,...x(N-1)]^T that will be termed a data block. The complex baseband representation of a multicarrier signal consisting of N subcarriers is given by

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

Δf is subcarrier spacing and NT denotes useful data block period. OFDM signals are orthogonal ,Δf = 1/NT

PAPR

PAPR may be define as square of peak amplitude to the ratio of square of peak rms value. Mathematically it is defined as:

$$PAPR = \frac{|X|peak^2}{xrms^2}$$

$$PAPR = \frac{\max_{0 \le t < NT} |x(t)|^2}{\frac{1}{NT}\int_0^{NT} |x(t)|^2\, dt}$$

It is one of the problem in OFDM system. The input symbol of IFFT posses a uniform power spectrum but the output of IFFT may result a non uniform or spiky power spectrum.

3. PROPOSED SYSTEM

In transmitter section, the input signal is provided to an interleaver where the mixing up of signal is done. Coding is typically combined with interleaving in order to mitigate the effect of error burst. Then the signal is modulated by using QAM modulator and the signal is converted from serial to parallel by using serial to parallel converter and again it is amplitude modulated. Here the IFFT is performed with the signal and signal converted from parallel to serial. Cyclic prefix is added in order to provide a guard interval. The ISI can be completely removed when the length of the guard interval is larger than the duration of channel impulse response. By using the moving average filter and the stationary wavelet transform the PAPR of the OFDM signal can be reduced. At the same time machine learning also performed to reduce the PAPR. This consist of a feed forward neural network where a set of OFDM signals and its corresponding PAPR signals are trained. Then the output of both of them are transferred to the channel thereby it is transmitted to the receiver.

In receiver section, the cyclic prefix is removed and FFT is performed. Then parallel signal is converted to serial. For removing the interference here we use channel estimation and channel quantization. Then the modulated signal is demodulated. Decoding and de-interleaving have to be performed.

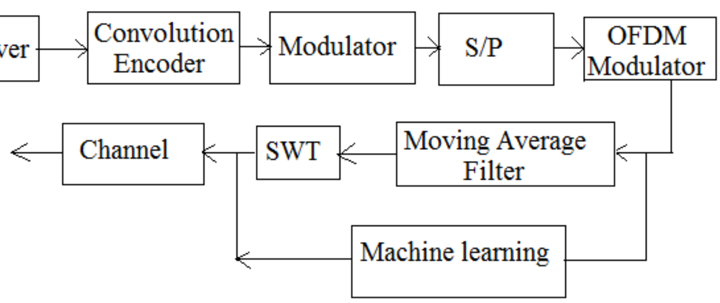

Fig-1: OFDM Transmitter Section

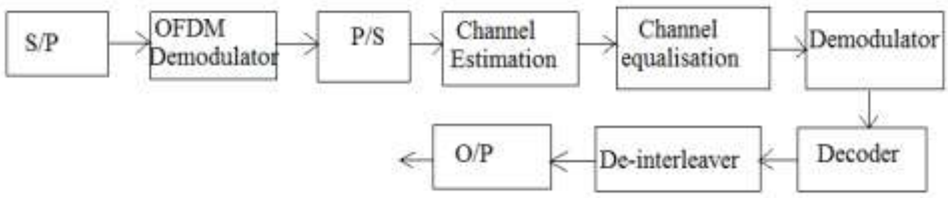

Fig-2: OFDM Receiver Section

Moving Average filter

The moving average filter is a simple low pass frequency impulse response filter. It is used for regulating an array of signal. It takes a frame or a set of samples of input at a time and takes the average of those input, then produce a single output point. The smoothness of output increases with increase in length of the filter.

Wavelet Transform

The advantage of Wavelet analysis over Fourier analysis, as it allows a time-frequency representation domain, allowing optimal resolution and flexibility. Wavelet analysis can provide a better time-frequency localization which can also result in improved flexibility. Here we use Stationary Wavelet Transform. It has two part approximation part and detailed part and it apply high and low pass filters to the data at each level.

Channel Estimation

In all communication the signal goes through a medium(called channel) and the signal get distorted or various noise is added to the signal goes through the channel. To properly decode the received signal without much errors are to remove the distortion and noise applied by the channel from the received signal. For this first figure out the characteristics of the channel that the signal goes through. This process to characterise the channel is called channel estimation.

The main steps for channel estimation is that

1) Set a mathematical model to correlate the transmitted signal and the received signal using channel matrix.
2) Transmit a known signal (reference signal) and the detect received signal.
3) By comparing the transmitted signal and the received signal, we can figure out each elements of channel matrix

Channel Equalisation

The channel equalisation is always carried out after the channel estimation. The goal of equalisation is to mitigate the effects of ISI. It is a process of reducing amplitude, frequency, and phase distortion in a channel with the intent of improving transmission performance. The basic operation of channel equalisation is to inverse the effect of channel.

CCDF

The PAPR is calculated by using Complementary Cumulative Distribution Function(CCDF). The CCDF of PAPR is the probability that the PAPR is greater than a certain value PAPR0 ie, Pr {PAPR>PAPR0}. Figure 3 shows the CCDF of PAPR for the proposed SWT method.

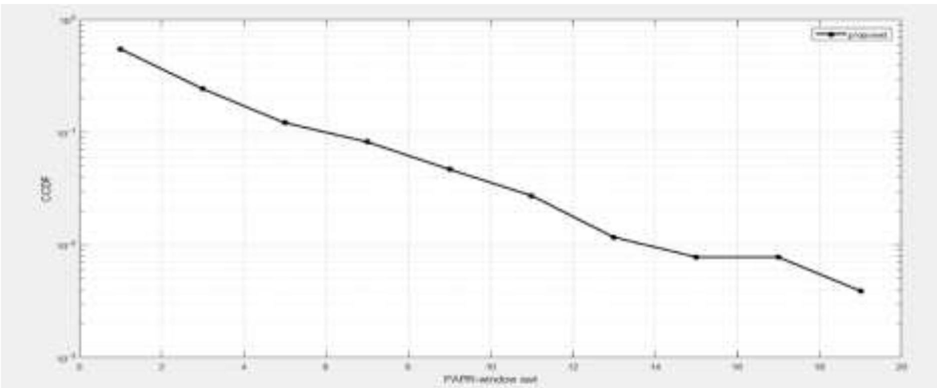

Fig-3: CCDF of PAPR for SWT

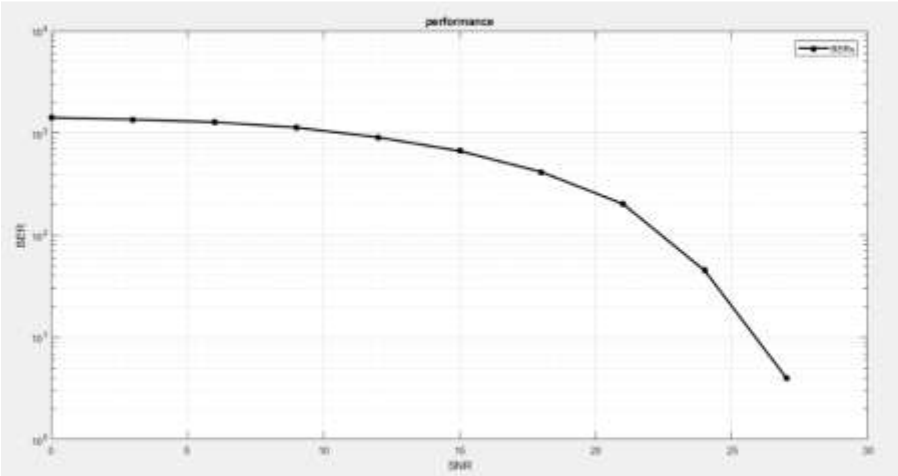

Fig-4: BER vise SNR of proposed method

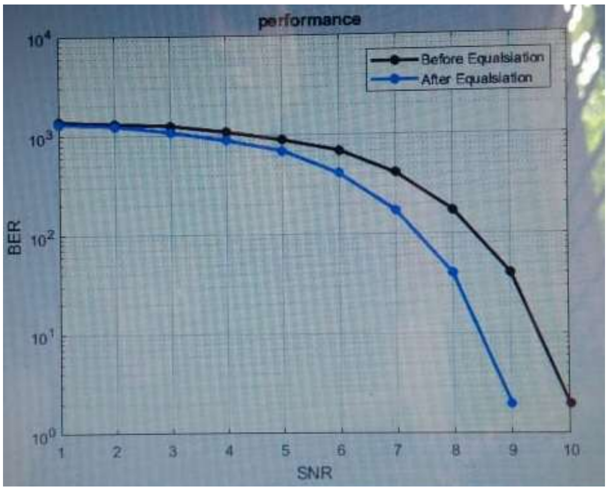

Fig-4: Shows the BER vise SNR of proposed system

The figure 4 shows the BER vise SNR performance of the proposed system. The graph represents the BER vise SNR before and after the equalization. From graph it is clear that after equalization Bit Error Ratio become much better than before equalization compared with SNR.

3. CONCLUSIONS

The OFDM techniques helps to divide the total bandwidth into many narrow sub-channels and sends data in parallel. High spectral efficiency, immunity to impulse interference and, frequency selective fading without having powerful channel equalizer are some of the advantages of OFDM. But one of the major drawbacks of the OFDM system is high PAPR. OFDM signal have a lot of independently modulated subcarriers, which are created the problem of PAPR. In the proposed system, we use a moving average filter to average the signal frame by frame and a Stationary Wavelet Transform also helps to reduces the peak power. The combination of moving average filter and stationary wavelet transform gives a greater reduction in PAPR as compared to other conventional techniques. Machine learning is also performed simultaneously consists of a feed forward neural network. And at the receiver side channel estimation and equalisation are provided for reducing the interferences.

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