PAPR Analysis of FFT and Wavelet FDM System Using Clipping Technique

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***Abstract*—Orthogonal Frequency Division Multiplexing(OFDM) has been currently under intense research for wireless transmission due to its robustness against multipath fading. However, it has some limitations such as the Peak-to-average power ratio (PAPR), which restricts its use. It reduces the efficiency of the system. The aim of this paper is to analyze the performance of system over clipping technique. Wavelet based system is also suggested. Results of both systems are compared.**

Keywords—Fast Fourier Transform (FFT), Discrete Wavelet Transform (DWT), Clipping, Bit Error Rate (BER)

I. INTRODUCTION

An Orthogonal Frequency Division Multiplexing (OFDM) system is a multi-carrier system which utilizes a parallel processing technique allowing the simultaneous transmission of data on many closely spaced, orthogonal sub-carriers. Inverse Fast Fourier transform (IFFT) and fast Fourier transform (FFT) in a conventional OFDM system are used to multiplex the signals together and decode the signal at the receiver respectively. The system adds cyclic prefixes (CP) before transmitting the signal. The purpose of this is to increase the delay spread of the channel so that it becomes longer than the channel impulse response. The purpose of this is to minimize inter-symbol interference (ISI). However, the CP has the disadvantage of reducing the spectral containment of the channels. Wavelet transforms have been considered as alternative platforms for replacing IFFT and FFT [1], [2], [5], [6], [7]. By using the transform, the spectral containment of the channels is better since it does not use CP [1], [2], [5], [6]. One type of wavelet transform is namely as Discrete Wavelet Transform OFDM (DWT-OFDM). It employs Low Pass Filter (LPF) and High Pass Filter (HPF) operating as Quadrature Mirror Filters satisfying perfect reconstruction and orthonormal bases properties. The transform uses filter coefficients as approximate and detail in LPF and HPF respectively. The approximated coefficients is sometimesreferred to as scaling coefficients, whereas, the detailed is referred to wavelet coefficients [3]. Sometimes these two filters can be called sub-band coding. Since the signals are divided into sub-signals of low and high frequencies respectively.

The purpose of this paper is to perform simulation study on the FFT and wavelet based OFDM for Clipping as a PAPR reduction technique. This paper is divided into four main sections: section II will briefly explain conventional FFT-OFDM, section III will describe in detail the models for

DWT-OFDM, section IV will discuss the different channel models and section V will describe the simulation result of both transforms over MATLAB platform.

II. FOURIER-BASED OFDM (FFT-OFDM)

An OFDM transceiver system is shown in Fig. 1. The inverse and forward transform blocks are concerned in more attentions since they can be FFT-based or DWT-based OFDM. The system model for FFT-based OFDM will not be discussed in detail as it is well known in the literature. Thus, we merely present a brief description about it [4]. The data generator produces in random binary form. It is first being processed by a constellation mapping. BPSK modulator is used for this work to map the raw binary data to appropriate QAM symbols. These symbols are then input into the IFFT block. This involves taking N parallel streams of BPSK symbols (N being the number of sub-carriers used in the transmission of the data) and performing an IFFT operation on this parallel stream. The output in discrete time domain is as follows:

$$X_{m(t)} = \left\{ \sum_{i-\frac{Ns}{2}}^{\frac{Ns}{2}-1} \exp\left(j2\Pi\left(fc - \frac{i+0.5}{T} \right)(t-ts) \right) \right\},\ t \le T$$

$X_{m(i)} = 0$, t <ts and t >ts + T (1)

Where, $N_s$is the number of subcarriers, T is the symbol duration, and f_c is the carrier frequency [4]. At the receiver, theprocess is reversed to obtain the decoded data. The CP is removed to obtain the data in the discrete time domain and then processed to FFT for data recovery. The output of the FFT in the frequency domain is as follows:

$$U_{m(i)} = \mathrm{Re}\left\{ \sum_{i=\frac{Ns}{2}}^{\frac{Ns}{2}-1} s(t).\exp\left(-j2\Pi\left(fc - \frac{i+0.5}{T} \right) \right) \right\},$$

ts ≤ t ≤ ts+T (2)

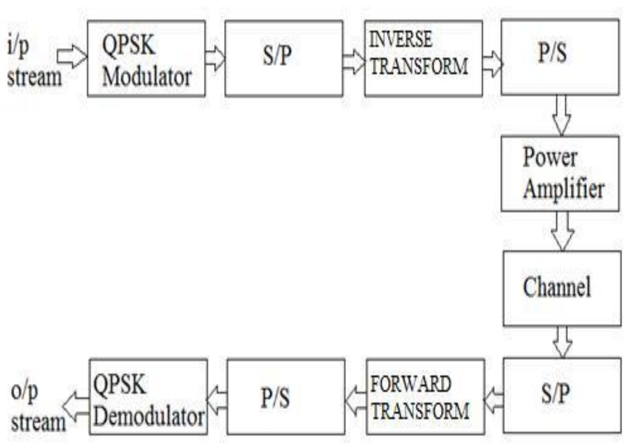

Figure 1 An OFDM transceiver with inverse and forward transform blocks

As the number of subcarriers increases, it reduces the bandwidth requirement and complexity of system. Orthogonality permits the proper demodulation of the symbol streams without the requirement of non-overlapping spectra. Another way of specifying the sub-carrier orthogonality condition is to require that each sub-carrier have exactly integer number of cycles in the interval T. As the data is concerned in the Power Spectral Density (PSD) form for frequency domain, maximum numbers of high peak amplitudes are reduced [5][7].

III. WAVELET-BASED OFDM (DWT-OFDM)

A wavelet is a waveform of effectively limited duration that has an average value of zero. The comparative difference between wavelets and sine waves, which are the basis of Fourier analysis is that sinusoids do not have limited duration, they extend from minus to plus infinity and where sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric. As the well-known technique of signal analysis Fourier analysis consists of breaking up a signal into sine waves of various frequencies, similarly, wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or mother) wavelet [10].

The Discrete Wavelet Transform (DWT) is used in a variety of signal processing applications, such as video compression, Internet communications compression, object recognition and numerical analysis[3]. The advantage of wavelet transform over other transforms such as Fourier transform is that it is discrete both in time as well as scale. The transform is implemented using filters. One filter of the analysis (wavelet transform) pair is a low-pass filter (LPF), while the other is a high-pass filter (HPF). Each filter has a down-sampler after it, to make the transform efficient[10]. The wavelet transform divides the signal into the approximation coefficients and detail coefficients as shown in figure 2.

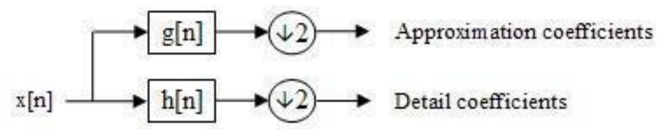

Figure 2 Block diagram of filter analysis

One of the advantages of using wavelet transform is that due to the overlapping nature of wavelet properties, the wavelet based OFDM does not need cyclic prefix to deal with delay spreads of the channel[7][8].

The wavelet functions forms a subspace orthogonal to the basis formed by the scaling function. The scaling and the wavelet function both satisfy some dilation equation.

$$\Phi(t) = \sum \Phi(2t-n).h(n)$$

If ø (t) should be orthonormal to its translated, then h[n] should satisfy the orthonormality condition.

$$\sum h[n].h[n-2m] = \partial m \text{ and}$$

$$\sum [-1]^n h[n] = 0$$

Given a sequence g[n] get searched, such that the function satisfying the **Dilation** equation.

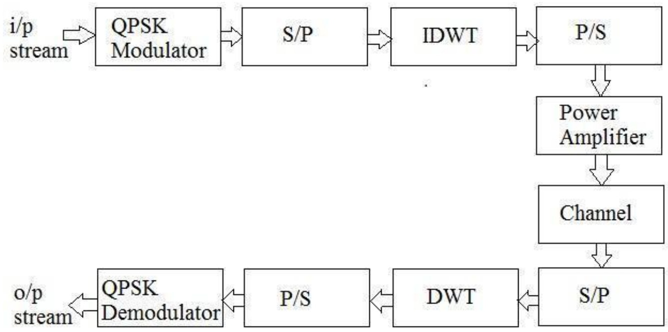

Figure 3 Wavelet based OFDM system

In wavelet decomposition process, both the detail and approximation coefficients can be split into a second level details and approximations. These two sets of coefficients are obtained by performing convolution between the input signals and wavelet filter coefficients. Decomposition process is repeated by a series of high-pass (HP) and low-pass (LP) filters until we obtain wavelet sequence that is orthogonal in nature [5]. The original signal is then reconstructed by performing the reverse operation of this decomposition. One thing about wavelet packet analysis that attracts communication system more is its accurate reconstruction using wavelet coefficients.

IV. SIMULATION RESULTS

Various parameters used for system are shown in table 1.The performance of FFT-OFDM and DWT-OFDM has beeninvestigated by means of computer simulation. Different wavelets are available for implementation of discrete wavelet transform. Haar, Daubechies, Symlet and Coiflet wavelets are considered for analyzing the response of system.

TABLE 1. SIMULATION PARAMETERS

Sr.no.	Parameters	Used Values for FFT	Used Values for DWT
1.	Number of bits per symbol	52	52
2.	Number of symbols	10000	10000
3.	FFT/ DWT size	64	-
4.	Number of sub-carriers	48	48
5.	SNR length	0:5:30	0:5:30
6.	Modulation type	BPSK	BPSK

A. Simulation results for FFT based system

The graphical results show the bit error rate probabilities of both the systems. Figure 4 shows the BER performance for FFT based OFDM system.

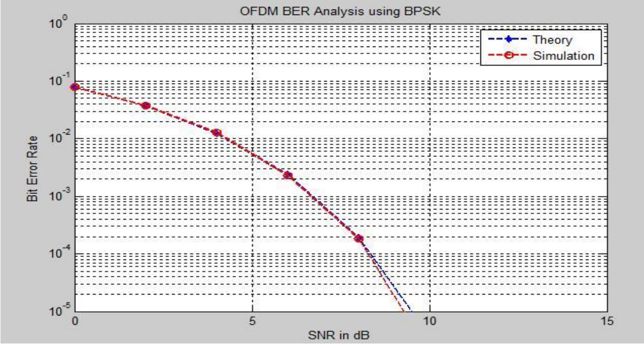

Figure4. BER analysis for FFT OFDM using AWGN channel

BER performance is observed for Theoretical value. It is compared with the simulated result. It is observed that result for both is much more similar. As number of symbols increases, it improve the quality performance.

In clipping method, the amplitude of generated OFDM signal is clipped for different threshold values and that resultant data is passed through system. For each threshold value, PAPR is calculated. So the result window is PAPR Vs Threshold value. As the threshold value increases, it increases the Mean square value of data. PAPR value and MSE are inversely proportional to each other. So that, as MSE increases, decrement in PAPR value and vice versa.

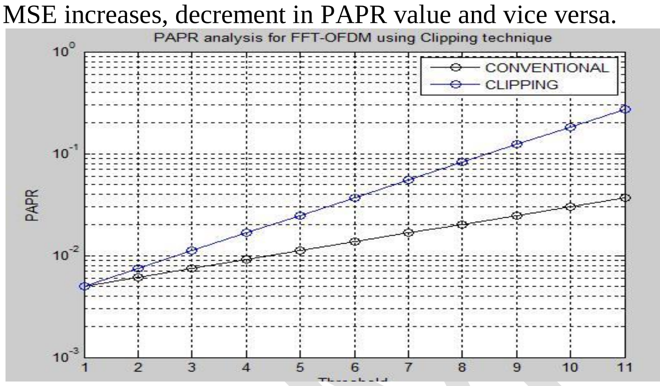

Figure 5. PAPR performance for FFT OFDM using Clipping technique

B. Simulation results for DWT based system

Wavelet family contains different types of wavelets. For the simplification we have considered Haar, Daubechies, Symlet and Coiflet wavelet functions. BER performances for these wavelets are shown in figure 6. Each wavelet has its own orthogonality property.

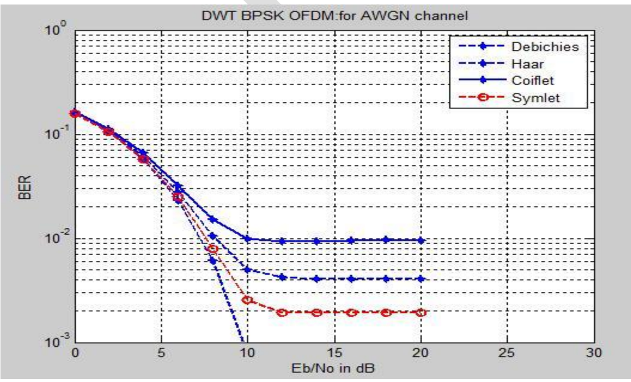

Figure6. BER performances for different wavelets

It is observed that performance for Haar wavelet is better than other wavelets. Coiflet gives the worst performance. Data is rotated for 7 times iterations. Number of iterations may vary, according to the requirement.

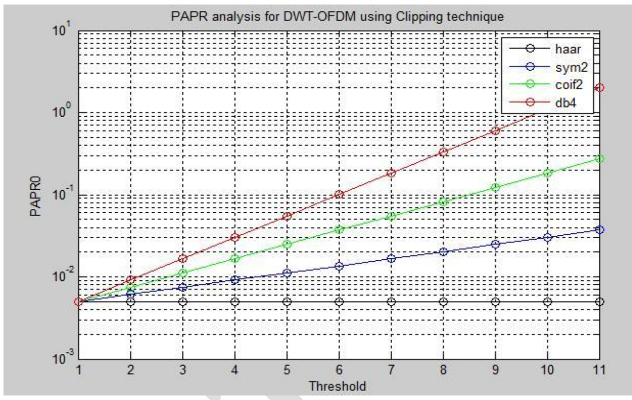

Figure7 PAPR performance using Clipping technique for different wavelets

In this case, as we have increase the number of iterations then also BER remain constant after particular value of SNR. If the result is compared with the FFT OFDM then, Haar wavelet gives the similar performance as simulated result of FFT-OFDM. But for other wavelets, BER value does not reach to 0 levels. Haar wavelet is more suitable for wavelet based system. For large number of data, clipping is suitable because operation is independent on length of original data. Because of clipping in amplitude, high peak interference is avoided. Haar wavelet gives the better performance than other wavelets. As threshold value increases, the PAPR value also goes on increasing. Daubechies wavelet has very large change in PAPR value.

V. CONCLUSION

PAPR performance is observed for both FFT and Wavelet based OFDM systems. In wavelet system, number of wavelets is used to observe the result. It is observed that, Wavelet gives the better performance than FFT system. For same input data, PAPR reduction is more in wavelet system. Clipping technique avoids the data loss. As amplitude decreases, peak power also decreases, which results decrease in PAPR. Wavelet function has its own orthogonality property, so circuit design using wavelet is also simple. Different types of the techniques are available for reduction of PAPR. In future, these techniques are also implementable using Wavelet system.

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