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PAPR Reduction in OFDM System using DWT with Non linear High Power Amplifier

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Abstract- *High Peak to Average Power Ratio (PAPR) of the transmitted signal is a major problem in Orthogonal Frequency Division Multiplexing (OFDM) which induces the degradation of bit error rate (BER) leading to a significant loss in the transmission power efficiency. Simulation results of the proposed technique shows a prominent reduction of 1.63 dB in PAPR. In this paper, we have investigated the performance of DWT-OFDM against conventional FFT-OFDM in terms of PAPR and BER (Bit Error Rate) in the system.*

Keywords- ***DWT, FFT, HPA, OFDM, PAPR.***

I. INTRODUCTION

OFDM has largely been accepted for the new wireless local area network standards IEEE 802.11a. In July 1998, the IEEE standardization group decided to select OFDM as the basis for their new 5-GHz standard, targeting a range of data stream from 6 up to 54 Mbps. It is an attractive technique in multicarrier transmission system, where a single datastream is transmitted over a number of low rate subcarriers. In 4G wireless communication systems, bandwidth is a precious commodity, and service providers are continuously met with the challenge of accommodating more users within a limited allocated bandwidth. To increase data rates of wireless communication with higher performance, OFDM is used, but there is a major disadvantage associated with OFDM i.e. its high peak to average power ratio which causes nonlinear distortion in the transmitted OFDM signal when it is passed through a nonlinear HPA. A wavelet approach is implemented for the reduction of PAPR and computational complexity.

An alternative to the conventional orthogonal frequency division multiplexing (OFDM) scheme is to exploit the self and mutual orthogonal properties of wavelet packet basis function for multiplexing purposes. These systems are known as discrete wavelet transform based OFDM (DWT-OFDM) systems. Simulations are carried out to select the best wavelet packet basis function to reduce PAPR.

Each sub-carrier in an Orthogonal Frequency Division Multiplexing (OFDM) system is modulated in amplitude and phase by the data bits. The process of combining different subcarriers to form a composite time-domain signal is achieved using Fast Fourier Transform (FFT) and Inverse FFT (IFFT) operations. Modulation techniques typically used are binary phase shift keying, Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM), 16-QAM, 64-QAM etc.

The problem generally faced in the design of a communications system over a wireless link is to deal with multi-path fading, which causes a prominent degradation in terms of both the reliability of the link and the data rate as well. This research work proposes the DWT Technique in anticipation that this system should have reduced PAPR compared to the existing conventional systems. This paper is organized as follows. The section I gives a brief introduction to OFDM Systems. FFT based OFDM System will be discussed in section II. In section III, DWT based OFDM System will be discussed. Section IV will give the idea about non–linearity HPA model and Simulation results are provided in Section V and section VI contain the conclusion.

II. FFT-BASED OFDM SYSTEMS

Fig.1 shows the block diagram of Fast Fourier Transform (FFT) based OFDM transceiver. The input digital data provided by data generator, is processed by M-ary QPSK modulator to map the data stream with N subcarriers. After mapping, the data stream is converted into parallel form using serial to parallel converter. This lower data rate parallel steam is modulated by Inverse Fast Fourier Transform (IFFT) block [14]. IFFT block also converts the domain of input data (i.e., frequency to time). The output of IFFT is given by,

$$x(t) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X(K) e^{j2\pi kt/N} \qquad \ldots(1)$$

Where $x(t)$ is a sequence in discrete time domain, $X(K)$ are complex numbers in discrete frequency domain and N is number of parallel data streams. Now cyclic prefix is added to the output of IFFT block for minimizing the effect of both the Inter Symbol Interference (ISI) and Intercarrier Interference (ICI). It is usually 25% of the last part of the original OFDM symbol and this data is transmitted though AWGN channel. At the receiver side, the process is reversed to obtain and decoded data. First, we remove the cyclic prefix and processed in the Fast Fourier Transform (FFT) block. The output of FFT in frequency domain is given by,

$$X(K) = \sum_{t=0}^{N-1} x(t) e^{-j2\pi kt/N} \qquad (2)$$

After FFT, the signal is converted back to parallel form and demodulated to get the transmitted signal back. The PAPR of an OFDM signal, is to be

$$PAPR = \frac{\max|x(t)|^2}{E[|x(t)|^2]} \qquad (3)$$

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Where $\max|x(t)|^2$ is the peak signal power and $E[|x(t)|^2]$ is the average signal power.

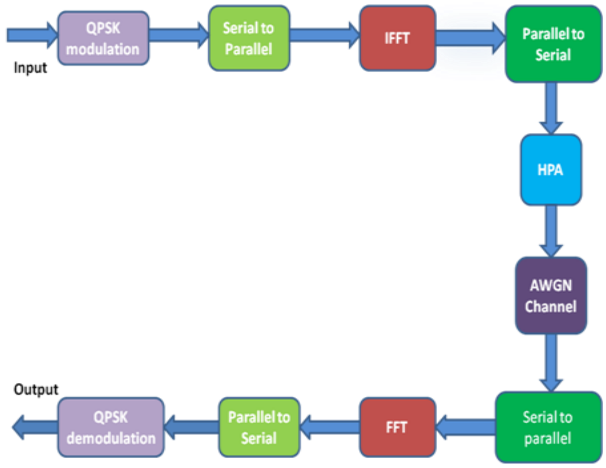

Fig.1. FFT-Based OFDM System

According to Central Limit Theorem, *x(t)* is approximately independently and identically distributed. Hence, when N is large the complex Gaussian random variables with zero mean and variance $\sigma^2 = E[|X_n|^2]/2$. According to parseval equality, the average power of x(t) is σ^2. The complementary cumulative distributed function (CCDF) of PAPR; i.e., the probability that PAPR exceeds a certain threshold $PAPR_0$ can be calculated as,

$$CCDF[PAPR(x(t))] = Pr(PAPR \succ PAPR_0)$$
$$= 1-(1-e^{-PAPR_0})^N \quad \dots (4)$$

The major advantage of the FFT based OFDM system is that they are immune to multipath fading. However, their major disadvantages are that the transmitted signal has a high Peak to Average Power Ratio (PAPR) and requiring linear transmitter circuitry. So to overcome the disadvantages of the FFT based OFDM systems, we prefer another technique i.e., Discrete Wavelet Transform (DWT) instead of FFT in the OFDM system [1,2].

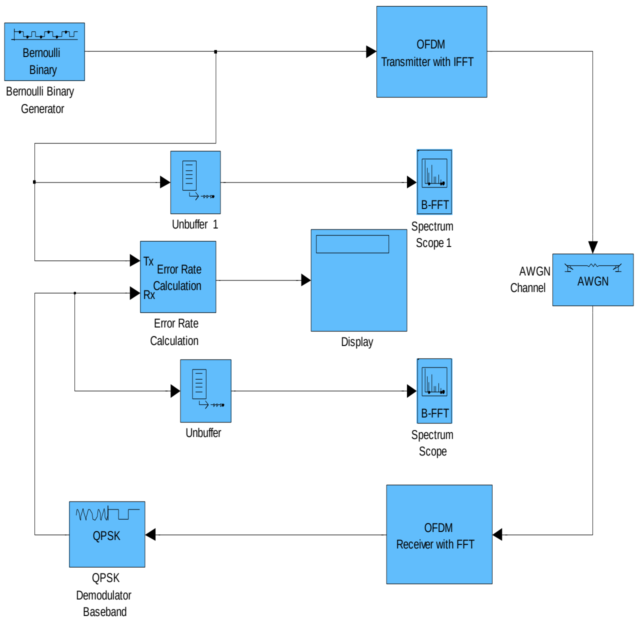

Fig.2 FFT-OFDM Simulink Model

III. DWT-BASED OFDM SYSTEMS

A wavelet, in the sense of the Discrete Wavelet Transform (DWT), is an orthogonal function which can be applied to a finite group of data. Functionally, it is very much like the Discrete Fourier Transform, in that the transforming function is orthogonal, a signal passed twice through the transformation is unchanged, and the input signal is assumed to be a set of discrete-time samples as shown in fig. 2. Both transforms are convolutions[14].

Whereas the basis function of the Fourier transform is a sinusoid, the wavelet basis is a set of functions which are defined by the equation,

$$\psi_{j,k}(t) = 2^{-j/2}\psi(2^{-j}t-k) \qquad (5)$$

where the orthogonality of these carriers relies on time location (k) and scale index (j).

The key point orthogonality is achieved by generating numbers of a wavelet family according to Eq. (6).

$$[\psi_{j,k}(t), \psi_{m,n}(t)] = \begin{cases} 1, & j = mk = n \\ 0, & otherwise \end{cases} \qquad (6)$$

DWT-OFDM symbol now can be considered as weighted sum of wavelet and scale carriers as expressed in Eq. (7). This is close to the Inverse Wavelet Transform (IDWT).

The wavelets together are a family of functions constructed from dilation and translation of the signal called the mother wavelet or signal function ψ(t). The Discrete Wavelet Transform (DWT) is represented by a function of a countable set of wavelet coefficients, which can be understood as individual wavelet functions localized in space [12,14].

$$S^u(t) = \sum_{j \le J}\sum_k w_{j,k}(t).\psi_{j,k}(t) + \sum_k a_{J,K}\,\phi_{J,K}(t) \qquad (7)$$

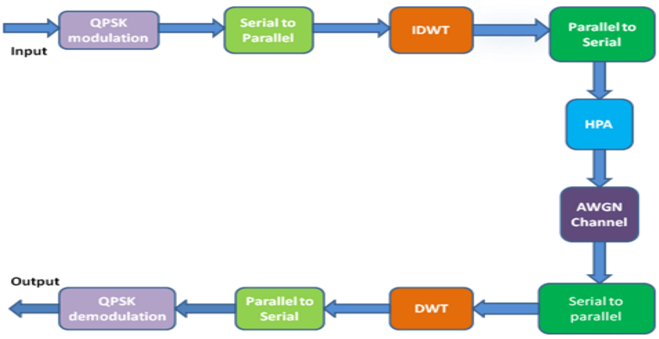

Fig.3. FFT-Based OFDM System

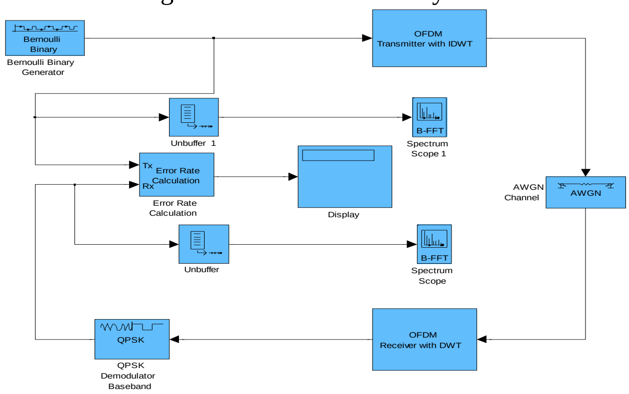

Fig.4 DWT-OFDM Simulink Model

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IV. NON LINEARITY HPA MODEL

In this section, we have described the memory less model for the nonlinear HPA. As we know that the non-linearity of the amplifier result in AM/AM and AM/PM distortions.
The modulated OFDM signal is represented by

$$s[t] = A[t]e^{j\theta[t]} \quad (8)$$

Where t is the time index before serial/parallel conversion, A[t] the amplitude of the transmit signal and θ [t] is the phase, the output signal of the HPA can be modeled as

$$s_{HPA}[t] = f(A[t]).e^{j\{\theta[t]+\varphi(A[t])\}} \quad (9)$$

$$s_{HPA}[t] = h[t].A[t].e^{\{\theta[t]+\varphi(A[t])\}}$$

and

$$\hat{S}_{HPA}[t] = \hat{h}[t].A[t].e^{j\{\theta[t]+\hat{\Phi}(A[t])\}} \quad (10)$$

where h [t] and Φ (A[t]) are usually called real-valued functions of AM/AM and AM/PM conversion, respectively, $\hat{h}[t]$ and $\hat{\Phi}(A[t])$ are amplitude and phase offset.

A. Solid State Power Amplifier (SSPA) Model

In this section, we described the memory less model for the nonlinear HPA. The AM/AM and AM/PM expressed as [8].

$$f(A[t]) = \frac{vA[t]}{\left(1+\left[\frac{vA[t]}{A_0}\right]^{2r}\right)^{\frac{1}{2r}}} \quad (11)$$

$$\Phi(A[t]) \approx 0,$$

Where $v \geq 0$ is the small signal gain, $A_0 \geq 0$ is the output saturating amplitude and $r \geq 0$ is a parameter to control the smoothness of the transition from the linear region to the saturation level. If *r* is ∞, then it is called Hard limiter. The hard limiter is defined as

$$f(A(t)) = |_{r\to\infty} = \begin{cases} vA(t) & \text{if } vA(t) \leq A_0 \\ A_0 & \text{otherwise} \end{cases} \quad (12)$$

B. Input back-off and Output-back-off

As mentioned earlier the amplifiers are operated in the linear region to avoid the non-linearity, this is called as input backing off, and the extent to which the amplifier is backed off from its maximum input is called as the input back off. It can be characterized by the input back-off (IBO) and output-back-off (OBO) [4].

$$IBO = 10\log_{10}\frac{P_{i,sat}}{\overline{P_i}} \quad (13)$$

And

$$OBO = 10\log_{10}\frac{P_{o,sat}}{\overline{P_o}} \quad (14)$$

Where $P_{i,\,sat}$ and $P_{o,\,sat}$ are the input and output saturation powers, $\overline{P_i}$ and $\overline{P_o}$ are the average power of the input and output signals.

V. SIMULATION RESULTS

In this section, we illustrate the simulation results conducted to examine the performance of the proposed method. The number of subcarriers are 256 and modulation used is QPSK mapping. The complementary cumulative distribution function (CCDF), which is a general method of performance estimation used in the PAPR value is larger than a specific value $PAPR_0$is given in equation (4).Table.1. summarizes the system parameters used in the simulation.

Table I. SimulationParameters

Parameters	Value
Modulation	QPSK
Number of data sub -carriers	256
Coding Technique	Gray coding
Bandwidth	5DHz
Number of FFT/DWT Points	256
HPA Model	SSPA
Number of controls smoothness HPA	r=2
IBO	6dB
Channel	AWGN

Figs. 5 (a), 5 (b) and 6 (a), 6 (b) show the simulation results for FFT-OFDM and DWT-OFDM respectively. The calculated PAPR of FFT-OFDM system is 6.8 and that of DWT-OFDM is 5.17, results of the proposed technique show a prominent reduction of 1.63 dB in PAPR. From the analysis and simulink design simulations we found that the designed DWT model is trustworthy leading to better performance of DWT-OFDM system.
Simulation results show that at the higher frequency ranges, the DWT method can achieve lower PAPR and signal to noise ratio gain than FFT method. This means that improvement in PAPR performance of DWT technique is better than in FFT based OFDM.

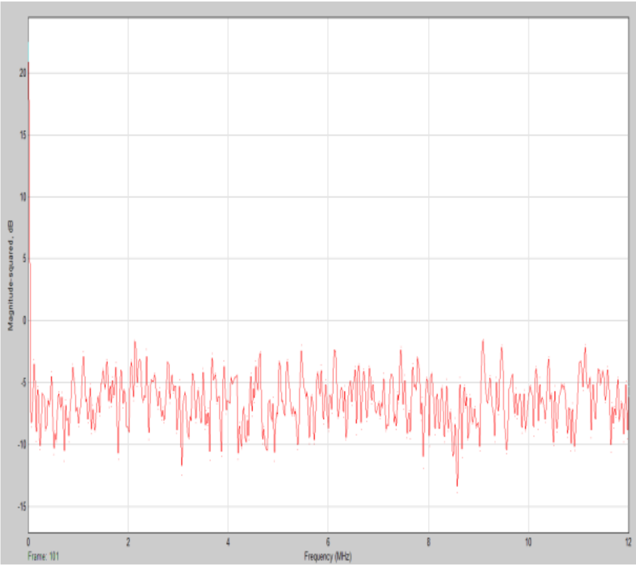

Fig 5 (a). FFT-OFDM Transmitted Waveform

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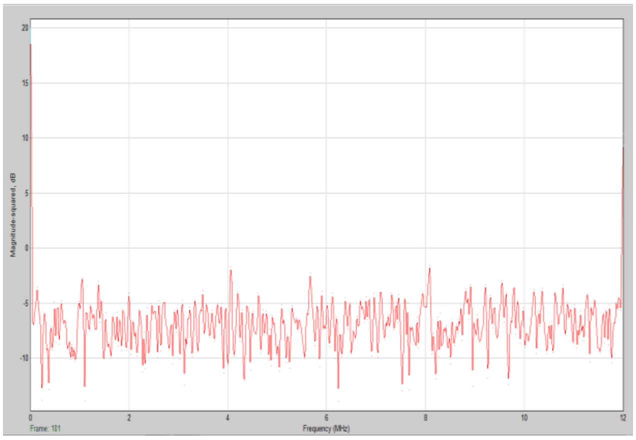

Fig 5 (b). FFT-OFDM Received Waveform

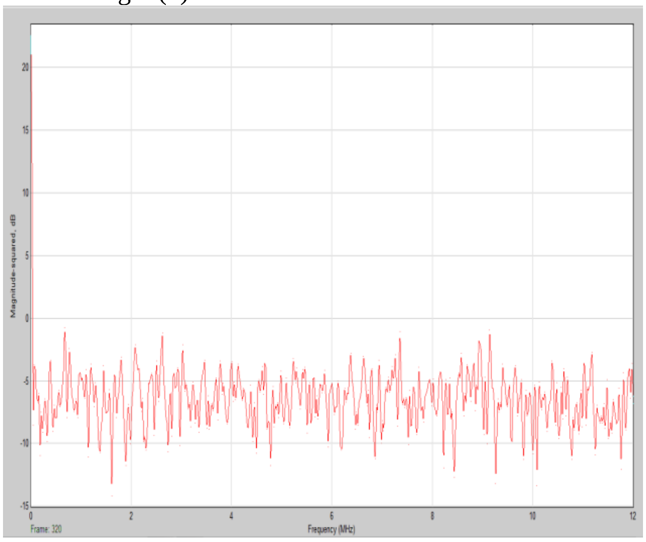

Fig 6 (a). DWT-OFDM Transmitted Waveform

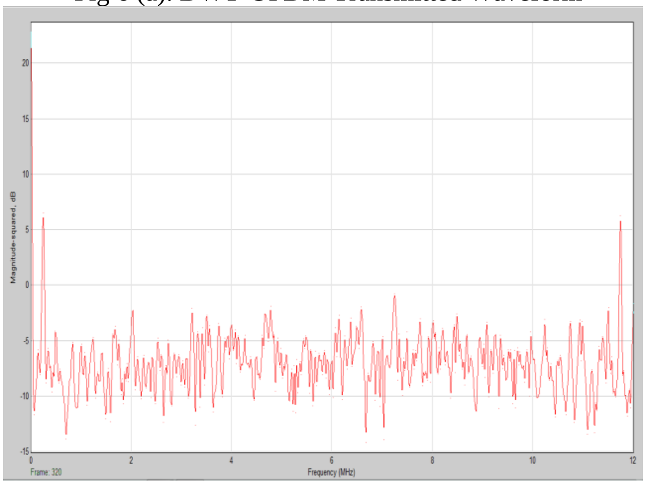

Fig 6 (b). DWT-OFDM Received Waveform

VI. CONCLUSION

This paper presents the Simulink simulation approaches for DWT-OFDM as an alternative substitution for the FFT-OFDM. The results show a prominent reduction of 1.63dB in PAPR of the DWT-OFDM system and hence improvement in BER performance as compared to the conventional technique.

VII. ACKNOWLEDGEMENTS

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