PAPR Reduction using DWT with Nonlinear Effects of HPA in OFDM system

Anjana Rani J K, Fatima Rasheed J, Haseen Bhanu H

Abstract— **In wireless communication systems, the design and analysis of an orthogonal frequency division multiplexing (OFDM) system is highly affected by the nonlinear effects of high power amplifier (HPA). The nonlinear effects of HPA reducing the OFDM system performance. OFDM signalling exhibits high peak-to-average power ratio (PAPR) which results in large sensitivity to nonlinear distortion created by the use of HPA at the end of wireless transmitter. In this paper we have investigated the nonlinear distortion effects in an OFDM system and the performance of DWT-OFDM against conventional FFT-OFDM in terms of PAPR and BER in the system. Simulation results of the proposed technique shows a prominent reduction of 2.6 dB in PAPR.**

Keywords— **HPA , OFDM and Nonlinear effects , DWT , FFT , 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 its performance is degraded by various factors that is very common in any wireless communication system [3]. However, one of the major problems associated with OFDM is the nonlinear distortion in the transmitted OFDM signal when it is passed through a nonlinear HPA. This nonlinear distortion causes serious in-band distortion as well as adjacent channel interference due to spectrum re-growth in the transmitted signal. The performance of wireless communication is highly related with the power amplifier.

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Nonlinearity in power amplifier response leads to nonlinear amplification of OFDM signal. The nonlinearity at the output of a PA was modeled as AM/AM (amplitude distortion which depends on the amplitude of the input). It presumed that the nonlinear noise at the receiver can be modeled as a complex Gaussian process uncorrelated with the input process and hence evaluated the OFDM system performance with nonlinear distortions in Additive White Gaussian Noise (AWGN) channels. To achieve maximum efficiency the power amplifier should be driven near the saturation region, but since the OFDM signal has high PAPR these power amplifiers will cross over to the nonlinear region causing serious in-band distortions as well as adjacent channel interference with spectrum re-growth in the transmitted signal. To minimize these nonlinear effects we have to reduce the PAPR and thereby increasing the OFDM system performance. 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.

This work proposes that the DWT Technique 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 SYSTEM

Fig.1 shows the block diagram of Fast Fourier Transform (FFT) based OFDM transceiver. The input digital data

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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 stream is modulated by Inverse Fast Fourier Transform (IFFT) block [4]. IFFT block also converts the domain of input data (i.e., frequency to time). The output of IFFT is given by,

$$x(t) = 1/\sqrt{N} \sum_{K=0}^{N-1} X(K) \exp(j2\pi kt/N) \quad (1)$$

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, whose duration is one fourth of the total OFDM symbol duration and this data is transmitted though AWGN channel. At the receiver side, the process is reversed to obtain the 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,

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

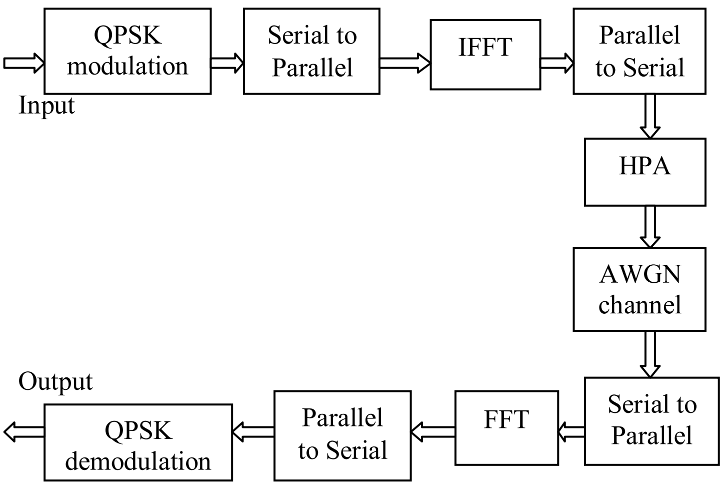

Fig.1. FFT- Based OFDM System

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,

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

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

The complementary cumulative distributed function (CCDF) of PAPR; i.e., the probability that PAPRo exceeds a certain threshold PAPR0 can be calculated as,

$$CCDF [PAPR(x(t))] = Pr(PAPR > PAPRo) \quad (4)$$

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 [5, 6].

II. DWT–BASED OFDM SYSTEM

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. Both transforms are convolutions [4]. 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,

$$\psi_{j,k(t)=2}^{-1/2}\, \psi(2^{-j} t-k) \quad (5)$$

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

DWT-OFDM symbol now can be considered as weighted sum of wavelet and scale carriers as expressed in Eq. (6). 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 $\psi(t)$. 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 [4,7].

$$Su(t)= \sum_{jsj} \sum k\, w_{j,k}(t),\ \Psi_{j.k}(t)+ \sum_k a_{j,k}\phi_{j,k}(t) \quad (6)$$

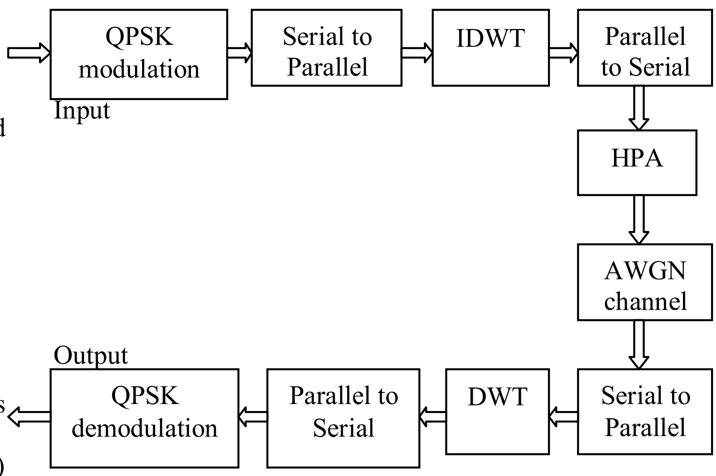

Fig.2. DWT- Based OFDM System

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III. 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,

$$S[t] = A[t] \exp(j\,\theta(t)) \quad (7)$$

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

$$S[t]= f(A[t]) \exp(j(\varnothing(t)+ \psi(A[t]))$$

$$S[t]= h[t]A[t]) \exp(\varnothing(t)+ \psi(A[t]) \quad (8)$$

Where h[t] and ψ(A[t]) are usually called real-valued functions of AM/AM and AM/PM conversion, respectively.

IV. SIMULATION RESULTS

In this section, numerical simulation results are presented to investigate the nonlinear effects of HPA and the performance of the proposed method. HPA nonlinearity may have bad influence on OFDM signals mainly on two aspects: (a). Out of-band distortion, which will cause the OFDM power spectrum distortion, i.e. the spectral spreading of the amplified signal and introduce adjacent channel interference (ACI). Requirements on ACI for RF systems are very strict especially for large number of subscribers; therefore, it is of great importance to decrease the out-of-band distortion. (b). In-band distortion, which may disturb the OFDM constellations. PSD is utilized to evaluate the effects of AM/AM distortions on OFDM signals. Fig.3 shows the distortion caused by AM/AM distortions. From Fig.3, it is clear that the AM/AM distortion has great influence on HPA power spectral density performance.

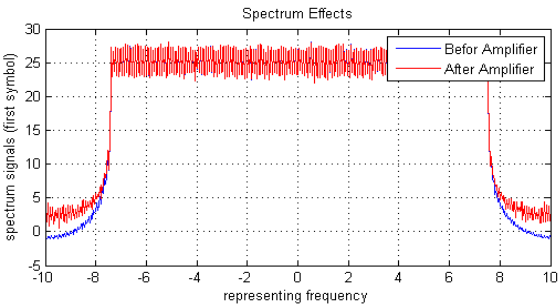

Fig.3. Power Spectrum of OFDM signal before and after amplifier.

Fig.4 demonstrates the comparison of idealized and practical AM/AM response of power amplifier at the RF transmitter side of OFDM system. From the input =1, nonlinearity starts for the high power amplifier. AM/AM distortions have distinct effects on OFDM signal constellations that shown in Fig.5. It is clear to see from simulation Fig.5 that the AM/AM distortion causes not only the dispersion but also the rotation of signal constellations which greatly degrade the performance of the OFDM system.

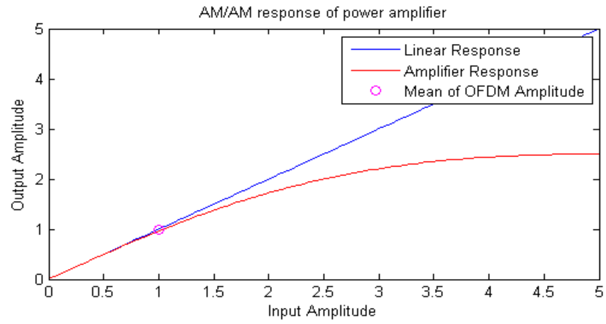

Fig.4. AM/AM Response of OFDM Signal

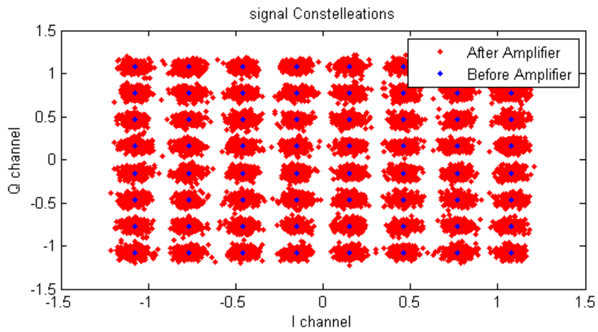

Fig.5. Signal Constellations

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 PAPR0 is given in equation (4).Fig 6 shows the PAPR of FFT- OFDM System and the DWT -OFDM System.

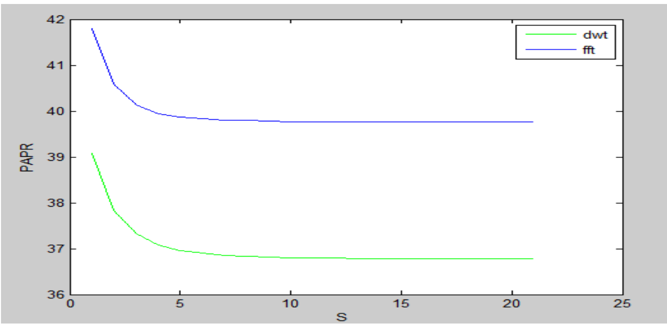

Fig.6. PAPR Comparison of FFT-OFDM and DWT-OFDM

Simulation result of the proposed technique shows a prominent reduction of 2.6 db. Fig 7 shows the Power Spectral Density of both FFT-OFDM and DWT-OFDM System.

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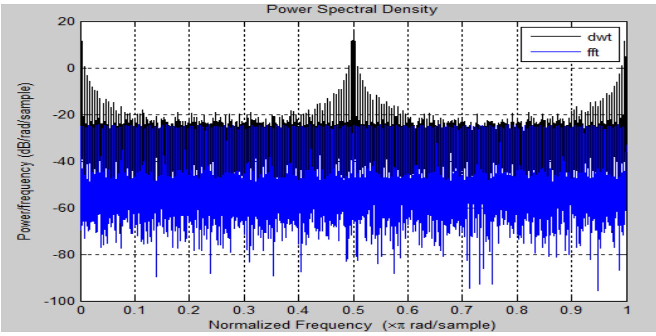

Fig.7. Power Spectral Density of FFT-OFDM and DWT-OFDM.

Fig.8 shows the BER comparison of both FFT- OFDM and DWT-OFDM System .It is clear to see that from Fig 8, greater performance is achieved in DWT-OFDM System.

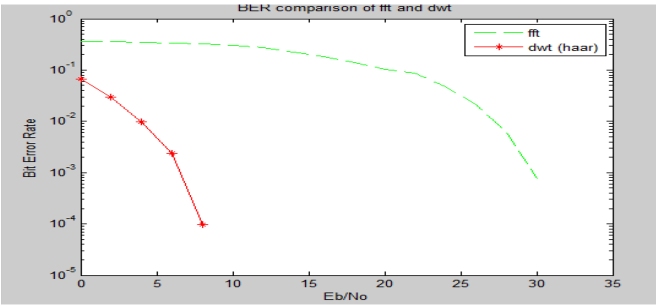

Fig.8. BER comparison of FFT-OFDM and DWT- OFDM System.

From the analysis and 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.

V. CONCLUSION

In this paper, we have highlighted the effects of nonlinearities in the power amplifier and PAPR Reduction using Wavelet method for performance improvements in OFDM System. So it is obvious from the simulation results that the performance of the OFDM system will be greatly degraded if we will not minimize the nonlinear effects of HPA. These nonlinear effects of HPA reducing the OFDM system performance. OFDM signalling exhibits high peak-to-average power ratio (PAPR) which results in large sensitivity to nonlinear distortion created by the use of HPA at the end of wireless transmitter. So this paper presents the simulation approaches for DWT-OFDM as an alternative substitution for the FFT-OFDM. The results show a prominent reduction of 2.6dB in PAPR of the DWT-OFDM system and hence improvement in BER performance as compared to the conventional technique.

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