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Adaptive offset dividing and squaring technique for PAPR Reduction in OFDM System

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Abstract

Orthogonal frequency division multiplexing (OFDM) is a multicarrier communication system. It is widely used in modern broadband communication system due its spectral efficiency, Immunity from frequency selective fading and easy implementation. However, the OFDM systems suffer from a severe problem called high value of peak to average power ratio (PAPR) which negate all the features of multicarrier modulation technique. This paper propose a new technique for peak-to-average power ratio (PAPR) reduction in orthogonal frequency division multiplexing (OFDM) System, named adaptive offset dividing & Squaring Technique. The proposed technique changes the statistical distribution of the OFDM output signal from Rayleigh distribution to Gaussian like distribution, this change in statistical distribution contributes to reduction in peak to average power ratio of OFDM signal. The proposed technique is based on 16-QAM OFDM system with 16 sub carriers and up to 1.5 dB PAPR reduction can be achieved with least bit error rate degradation at signal to noise ratio of 10 dB. The proposed technique is adaptive where PAPR reduction and BER response can be adjustable as per system requirement.

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1. Introduction

The Orthogonal frequency division multiplexing (OFDM) has been invented to serve the high data requirements of the modern communication systems. This multicarrier modulation technique is robust to frequency selective fading of a signal. It is also characterized by features such as easy implementation by fast Fourier transform (FFT) & inverse fast Fourier transform (IFFT), low Complexity in receiver design and highly adaptive to radio link conditions. All these features make this system favorable option for wideband communication systems and 4G cellular systems for next generation communication networks [1]. Despite all the favorable features in OFDM system for implementation in communication systems, it encounters a noticeable problem of high peak to average power ratio (PAPR). This PAPR problem has been topic of research from many decades among researchers because such high PAPR becomes huge obstruction to harvest all the features of OFDM system for the implementation of high speed broadband communication systems [1] [2].

OFDM symbols having high PAPR value get clipped by D/A converter or power amplifier and such clipping may cause loss of information by way of distortion of the signal which leads to in band noise and out of band radiation. In band noise leads to loss of orthogonality pattern and out of band radiation causes inter-carrier interference and its combined effect is poor BER response of the system [3] [4].

The solution to above problem can be resolved by conventional methods like using high range linear amplifiers and D/A converters. However, such kind of conventional solutions are expensive and power inefficient for battery powered tiny communication devices [5]. Hence, lot of research work is in progress to obtain low values of PAPR by application of various techniques which are broadly classified as distortion based and distortion less techniques. The PAPR reduction by time domain signal processing has provided easy option for system implementation. The proposed technique processes OFDM symbol elements in time domain when they are discrete and before they are fed to D/A converter [6].

This paper proposes adaptive offset dividing and squaring technique, a modified and optimized technique based on time domain statistical control for PAPR reduction in OFDM s in OFDM system [6] and adaptive square-rooting companding technique [7]. In this technique, individual complex elements of the OFDM symbol are processed without any change in phase. This technique is adaptive to a logical condition and applied to specific individual elements of the OFDM symbol, which have magnitude levels more than the set threshold. This operation results in low PAPR and improved BER performance when compared to Time domain statistical control for PAPR reduction in OFDM system technique. This paper analyzes the proposed technique from the point of view of effect on statistical distribution of the signal, PAPR reduction with different threshold levels and BER performance.

This paper is configured as follows: Section 2 elaborates OFDM signal generation, PAPR calculations and statistical properties of OFDM signal. Section 3 presents proposed adaptive offset dividing and squaring technique for PAPR reduction in OFDM systems. Section 4 and 5 presents simulation results and conclusion respectively.

2. Conventional OFDM System and PAPR

In OFDM system, input data stream is converted to decimal numbers and then such decimal numbers are modulated with M-ary QAM and converted to discrete form by IFFT operation at the transmitter side. IFFT operation produces orthogonal data subcarriers. The time domain complex OFDM signal is given as,

$$x_n = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X_k \, e^{\frac{j2\pi n}{N}k} \qquad 0 \le n \le N-1 \tag{1}$$

where x_n, is the nth OFDM output signal X_k is the kth data modulated symbol in OFDM frequency domain and N is the no of subcarriers.

The PAPR of OFDM symbol in dB is calculated by equation

$$PAPR = 10log_{10} \left\{ \frac{P_{peak}}{P_{average}} \right\} \tag{2}$$

Where P_{peak} and $P_{average}$ are the peak and average powers of output of output OFDM symbol, respectively and they are computed as,

$$P_{peak} = \max |x_n|^2 \tag{3}$$

And

$$P_{average} = \frac{1}{N} \sum_{n=0}^{N-1} |x_n|^2 \tag{4}$$

The complex valued data modulated symbols, are considered as independent identically distributed (i.i.d) random variables because the modulation is memory less process treating the data individually. In the OFDM system, the summation of these i.i.d. variables is performed by the IFFT. Hence according to central limit theorem, IFFT changes the statistical distribution of the proposed signals to complex Gaussian distribution. Also, according to Parseval's theorem, the IFFT operation does not alter the total average power of the processed signals [8].

3. Adaptive offset dividing and squaring technique for PAPR reduction

The proposed technique implementation is shown in Fig.1. By using this technique, original OFDM signal amplitudes $\boldsymbol{x_n}$ which exceed threshold, are processed by (5) and (6) before they are fed to D/A converter and power amplifier. The adaptive approach helps in targeting high values of $\boldsymbol{x_n}$, which not only reduces overall dynamic range of OFDM symbols but also helps in reducing distortion of the signal and hence helps in achieving least degradation in BER performance.

$$x'_n = [x_n/2]^2 \, e^{j\emptyset n} \qquad \text{for } x_n \ge \text{Threshold} \tag{5}$$

$$x'_n = x_n \, e^{j\emptyset n} \qquad \text{for } x_n \le \text{Threshold} \tag{6}$$

x'_n Is the new OFDM signal and $\emptyset_n$ is the phase of x_n. In this technique, only the amplitudes of individual elements in OFDM symbols are changed but the phases remain unaffected. The side information is generated for receiver to indentify OFDM signal amplitudes which are processed by proposed technique at the transmitter side to regenerate transmitted signal at the receiver side.

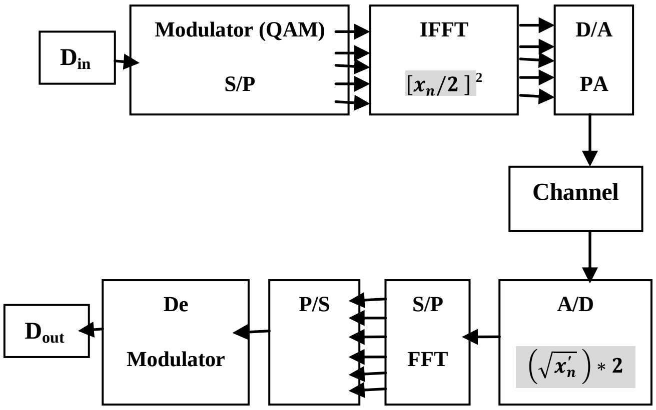

Fig.1-Block diagram of proposed technique

4. Simulation results

To demonstrate the PAPR reduction capability with different threshold levels and BER performance of the adaptive offset dividing and squaring technique, 16 sub carriers and 64-QAM modulation scheme is used in this work. For simulation results, the same set of randomly generated data is used to analyze the performance of the proposed technique. A complementary cumulative distribution function $CCDF = Prob\{PAPR > PAPR_0\}$ is used to represent the PAPR in terms of probability of occurrence of PAPR values greater than the specific PAPR value under consideration on x-axis.

Fig.2 shows the change in statistical distribution of the OFDM signal amplitude before and after the application of proposed technique. A Rayleigh distribution in Fig.2 (a) changes to Gaussian like distribution as seen in Fig.2 (b).

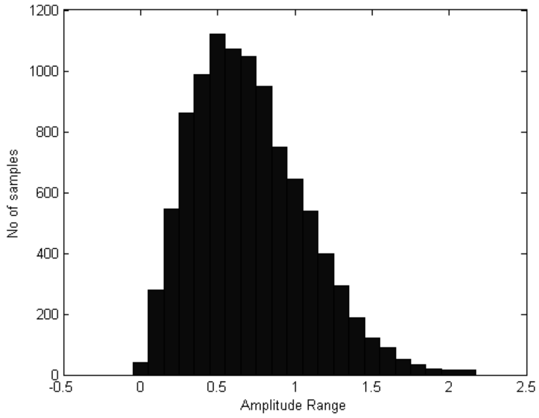

Fig.2 (a) Rayleigh distribution

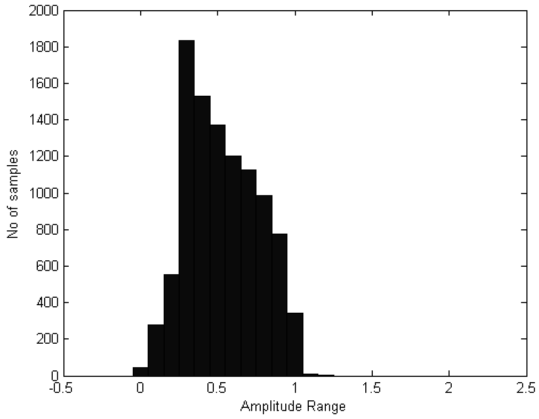

Fig.2 (b) Gaussian like distribution

Fig.3 shows the PAPR reduction capability before and after application of the proposed technique with different threshold levels. The PAPR measures at different probabilities of occurrence can be extracted from the CCDF curve for both conventional OFDM and the proposed technique. From Fig.3, it can be noticed that PAPR obtained by proposed technique is reduced by 5.5 dB for threshold level of 0.5 and by 1.5 dB at threshold level of 1.

The amount of PAPR reduction by application of proposed technique is computed by,

$$\Delta PAPR = PAPR - PAPR'$$

Where $PAPR'$ is the PAPR of proposed technique and PAPR is that of conventional OFDM system. For this system, $PAPR'$ at threshold of 0.5 is 3 dB, at threshold of 1, it is 7 dB and for conventional OFDM, it is 8.5 dB. Therefore, $\Delta PAPR$ are 5.5 dB and 1.5 dB respectively for the two threshold values.

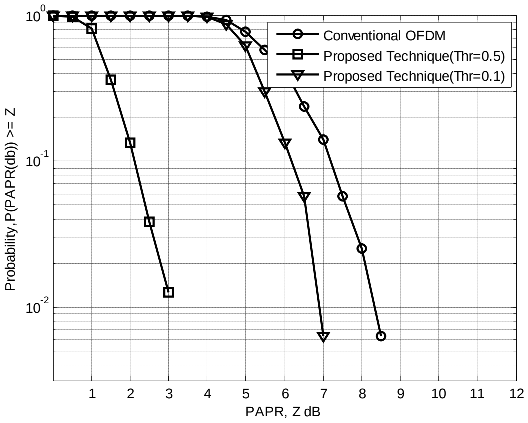

Fig. 3 CCDF plot of PAPR for proposed technique

Fig.4 presents the BER performance of the proposed technique and conventional OFDM over an AWGN channel. The proposed technique uses two threshold levels of 0.5 and 1 to evaluate the error performance. For this, complex form of AWGN noise signal is generated by MATLAB with different $(E_b \backslash N_0)$ ratio and added to the OFDM signal to evaluate the performance. Fig.4 shows error performance of the proposed technique and conventional OFDM. From the graph, it is noticed that for threshold level of 0.5, BER is 10^{-4} at $(E_b \backslash N_0)$ of 10 dB. This is mainly due to the fact that large number of amplitudes of OFDM signal undergoes the operation suggested by the proposed technique, which causes more distortion of the signal. In contrast, at threshold level of 1, less number of amplitudes of

OFDM signal undergoes the operation suggested by the proposed technique, which causes less distortion of the signal and hence results in BER of 10^{-4} at 10 dB which is better than that of conventional OFDM system which is 10^{-4} at $E_b \backslash N_0$ of 12 dB.

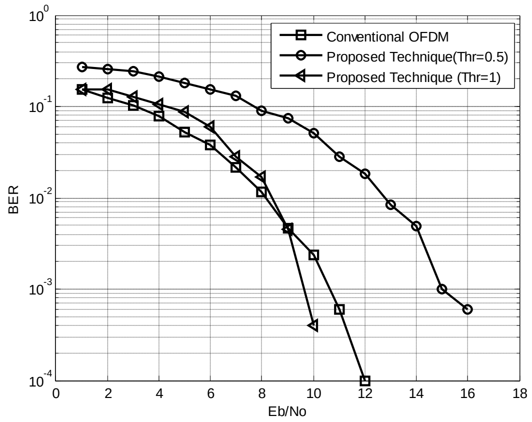

Fig.4 Bit error rate plot for proposed technique

The effect of the proposed technique on the power spectral density (PSD) of the signal is plotted in fig.5. The figure is plotted for one block of OFDM signal with 16 sub carriers. From fig.5, it is clear that level of out of band energy is 15 dB above in proposed technique than that of conventional OFDM.

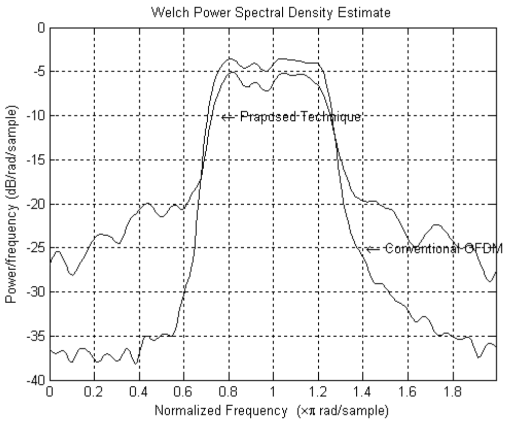

Fig.5 PSD plot for basic OFDM and proposed technique

Fig.6 shows the CCDF plot of adaptive square-rooting technique (ASRT) which shows PAPR reduction capability with different threshold values. This threshold value selected by calculating the PAPR value for each OFDM symbol of the OFDM signal where as in proposed technique threshold value is set by calculating the amplitude value of the OFDM signal, though both techniques are adaptive to logical condition but they differ in determining the threshold value for the reduction of PAPR value [3].

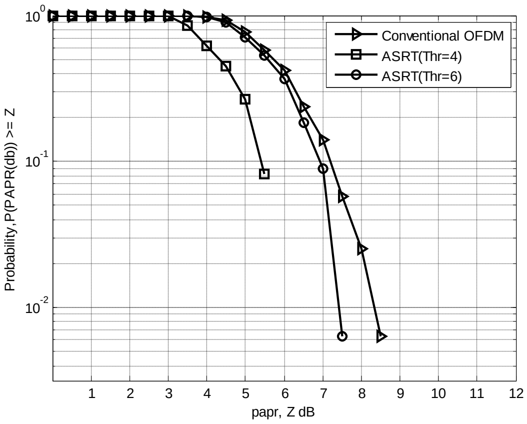

Fig.6 CCDF plot of PAPR for ASRT

From figure 6 we can notice that adaptive square-rooting tech can reduce PAPR by 3 dB at PAPR threshold value of 4 dB and by 1 dB at PAPR threshold value of 6 dB. The proposed technique provides PAPR value reduction by 1.5 dB which is minimum reduction and maximum reduction by 5.5 dB. So from PAPR reduction point of view proposed technique provide better PAPR value reduction.

Figure 7 shows the BER response of adaptive square-rooting technique (ASRT) for different values of PAPR threshold values.

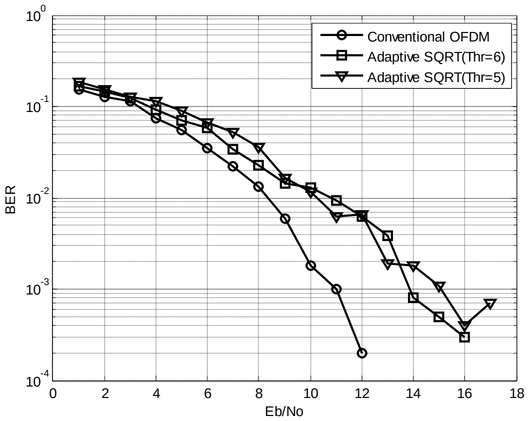

Fig.7 BER plot for ASRT

From figure 7 it can be notice that for PAPR threshold values of 4 dB and 6 dB error rates are nearby to 10^{-4} at 15dB and 16 dB values of E_b/N_0 respectively which are more than conventional OFDM error rate. In contrast the proposed technique provide better error rate response at 10 dB value of E_b/N_0 value which indicate proposed technique provide much better BER response if compared to adaptive square- rooting technique.

From figure 6 and figure 7 we can quickly summarize that proposed technique better in terms of PAPR reduction and error rate performance.

5. Conclusion

The proposed technique exploits statistical distribution conversion technique to reduce the signal peaks by adaptive approach. Such logical approach helps in suppression of high amplitudes with least signal distortion. It provides a scope for designing the system for a pre-decided and desirable PAPR level. Though it introduces distortion in the OFDM signal, but still is capable in achieving significant peak to average power ratio reduction with least error rate.

6. References

[1]. R.Van Nee, R. Prasad Publication by Artech House“OFDM for wireless Multimedia Communications” e-book.

[2]. S. H. Han And J. H. Lee, “An Overview of Peak-to-Average Power Ratio Reduction Techniques for Multicarrier Transmission,” IEEE Wireless Comm., Vol. 12, April, 2005, pp. 56-65

[3]. H.Ochiai and H. Imai, “Performance of the deliberate clipping with adaptive symbol selection for strictly band-limited OFDM systems,” *IEEE J. Select Areas. Comm.*, vol. 18, no.11, pp. 2270–2277, Nov.2000

[4]. Xiao Huang Et Al, “Reduction of Peak-to-Average Power Ratio of OFDM Signals with Companding Transform,” Elect. Lett Vol. 37, April 2001, pp. 506-507

[5]. Elena Costa, et al, “Impact of Amplifier Nonlinearities on OFDM Transmission System Performance,” IEEE Comm. Lett., Vol. 3, Feb.1999, pp. 37-39

[6]. Wisam F. Al-Azzo, Borhanuddin M. Ali, Sabira Khatun and Syed M.Bilfagit, “Time domain statistical control for PAPR reduction in OFDM system” proc IEEE APCC 2007, Bangkok, Thailand, 2007.pp 141-144.

[7]. Wisam F. Al-Azzo and Borhanuddin Mohd. Ali , “Adaptive Square-Rooting Companding Technique for PAPR Reduction in OFDM Systems”, world academy of science, engineering and technology

[8]. J.G. Proakis, Digital Communications, Mc-Graw Hill, 2010.