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Algorithm to Improve the Performance of OFDM based WLAN Systems

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ABSTRACT

In this paper we propose a new form of adaptive modulation which has the ability of using the higher order modulation schemes such as 256-QAM and 128-QAM at low SNR values in order to enhance the data rate without degrading the SER performance especially at low SNR values. This new form of adaptive modulation is combined together with the power control and the PAPR clipping and filtering technique to produce a new algorithm. This algorithm is called MPC (adaptive Modulation, Power control and Clipping), which is not aim only to reduce the PAPR, but also to enhance the data rate of OFDM based WLAN systems.

Keywords: Adaptive Modulation, Clipping, PAPR, MPC, CCDF, IEEE 802.11g.

1. INTRODUCTION

The basic premise of a multicarrier modulation scheme is to break a wideband channel into multiple parallel, typically, orthogonal narrowband channels. OFDM has many well documented advantages including resistance to multipath fading and high data rates]. OFDM is an effective transmission technique for high data rate transmission in impulse noise and multipath fading environments. OFDM has been employed in diverse wired and wireless applications. For instance, in digital audio and video broadcasting, digital subscriber lines using discrete multitone, the wireless LAN systems, such as, IEEE 802:11, HIPERLAN and MMAC, wireless broadband services [6] and also is a strong candidate for next generation cellular systems. One of the limitations of using OFDM is the high peak-to average power ratio (PAPR) of the transmitted signal. A large PAPR leads to disadvantages such as increased complexity of the analog to digital converter (A/D) and reduced efficiency of the radio frequency (RF) amplifier.

If power amplifiers are not operated with large linear power back-offs, it is impossible to keep the out-of-band power below imposed limits. This leads to very inefficient amplification, expensive transmitters and causing inter modulation among the subcarriers and undesired out of-band radiation. The Analog to Digital converters and Digital to Analog converters are also required to have a wide dynamic range which increases complexity. The PAPR reduction techniques are therefore of great importance for OFDM systems. To reduce the PAPR different techniques were proposed. These techniques can be categorized into the following, clipping and filtering, coding, phasing, scrambling, interleaving, and companding. Coding is the most widely used technique. Selective mapping has been used to reduce PAPR. However this resulted in a loss of data during decoding. Partial transmit sequence (PTS) is another method that is based on scrambling. Compared to the previous method, this method is more effective. In the PTS scheme, sub-carriers are partitioned into many blocks and each block is multiplied by a constant phase factor (codes). But this greatly reduces the number of carriers. PAPR reduction is achieved by deliberately introducing a limited number of errors to the forward-error correction (FEC) encoded input bits. This approach suffers receiver performance degradation. Each of these above mentioned solutions had some problems that are yet to be solved.

The clipping signal scheme is relatively simpler than others. The performance of the clipping scheme is superior to that of the windowing signal scheme in OFDM system, because the windowing technique distorts all signals, but the clipping technique distorts small portion signal where the peak power exceeds the maximum permitted power. The simple concept behind this is to clip the power peaks that go beyond a predetermined level. Clipping has been thought to introduce error. But it actually depends on careful selection of clipping level. This paper will focus on the clipping signal technique and it will propose a simple method to recover the clipped part of the original OFDM signal to improve the SER performance. The remainder of the paper is organized as follows. Section 2 presents the simulation model. Section 3 presents the simulation results.

2. SIMULATION MODEL

The OFDM system model used in this work is shown in Figure 1, a digital nonlinearity is introduced at the transmitter and an equalization block at the receiver.

The proposed method to improve the SER performance by copying the clipped OFDM signal as shown in figure 1 is performed after the clipping process.

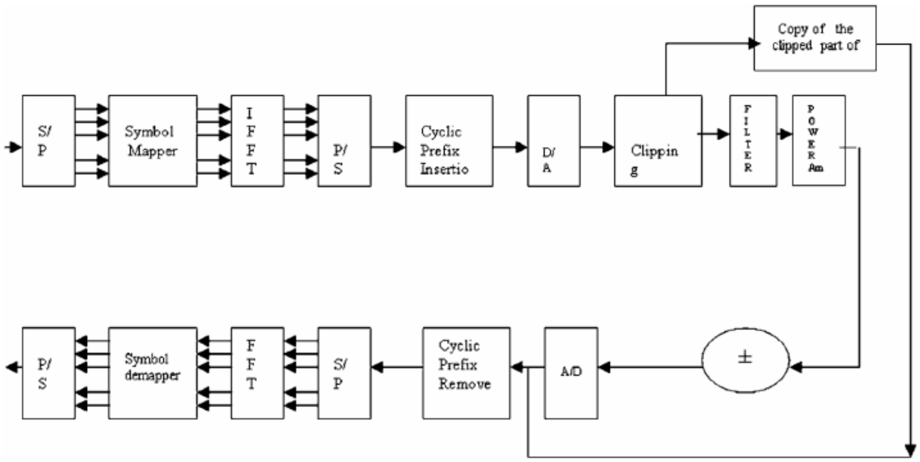

Fig. 1: OFDM System Block Diagram and the Proposed Solution

Deliberate clipping might be the simplest method to reduce PAPR. This method limits the samples' amplitudes of the input OFDM signal to a predetermined value. If the digital OFDM signals are clipped directly, the resulting clipping noise will all fall in-band and cannot be reduced by filtering. To address this aliasing problem, in this simulation, the OFDM signal is oversampled by a factor of 8. Then, the real valued bandpass samples, x, were clipped at amplitude A as follows:

$$Y = \begin{cases} -A, \ if \ \ x < -A \\ x, \ if \ \ -A \le x \ge A \\ A, \ if \ x > A \end{cases} \tag{2}$$

Although the PAPR is moderately high for OFDM, high magnitude peaks occur relatively rarely and most of the transmitted power is concentrated in signals of low amplitude. Therefore, the statistical distribution of the PAPR should be taken into account. PAPR is independent of modulation used.

One way to avoid nonlinear distortion is to operate the amplifier in its linear region. Unfortunately such solution is not power efficient and thus not suitable for battery operated wireless communication applications.

Minimizing the PAPR before power amplifier allows a higher average power to be transmitted for a fixed peak power, improving the overall signal to noise ratio at the receiver. It is therefore important to minimize the PAPR. The recovering process will be performed at the receiver side after A/D converter to avoid any reduction in the efficiency of the analog-to digital. The PAPR of a continuous-time OFDM signal cannot be computed accurately by sampling the signal at Nyquist rate. Hence over sampling is essential to produce accurate PAPR estimates. As mentioned before discrete time domain OFDM signal in this simulation is oversampled by a factor of 8. The variation of the envelope of a multi-carrier signal can be defined by the peak to average power ratio (PAPR) which is given by:

$$PAPR = \frac{MAX\{|\, x(t)^2\, |\}}{E\{|\, x(t)^2\, |\}} \tag{3}$$

At the transmitter side, the invertible clipping method reduces the amplitude dynamics, and thus the PAPR of the signal that has to be amplified. This result is presented in Complementary Cumulative Distribution Function (CCDF) a term which is defined as follows:

$$\text{CCDF (PAPR(x))} = \text{Prob (PAPR(x)} > \text{PAPR0)} \tag{4}$$

This function represents the probability that the PAPR of the OFDM signal exceeds the threshold PAPR0. This invertible clipping method allows reducing the PAPR of the OFDM signal. The implementation of deliberate clipping is quite simple and effective in PAPR reduction, but larger clipping ratio results in the severe SER performance degradation. Unfortunately, clipping generates a spectral regrowth (the so called spectral shoulders) on the spectrum of output signal, widening its frequency support. Thus, parasitic frequencies appear in the adjacent channels. Filtering after clipping is therefore compulsory to limit this spectral regrowth and, finally, to assure a good system performance. A cyclic prefix (CP) is then appended to minimize interblock interference and aid the frequency domain equalizer at the receiver. Digital-to analog (D/A) conversion and analog filtering are performed.

The clipping process is characterized by the clipping ratio (CR), defined as the ratio between the clipping threshold and the root-mean square (rms) level of the OFDM signal. However, Clipping is a nonlinear process that leads to distortion.

Without filtering, clipping causes out-of-band radiation. Digital filtering is present to control out-of-band radiation.

$$CR = \frac{CL}{\text{rms level}} \quad (5)$$

Where CL is the Clipping Level and CR is the Clipping Ratio.

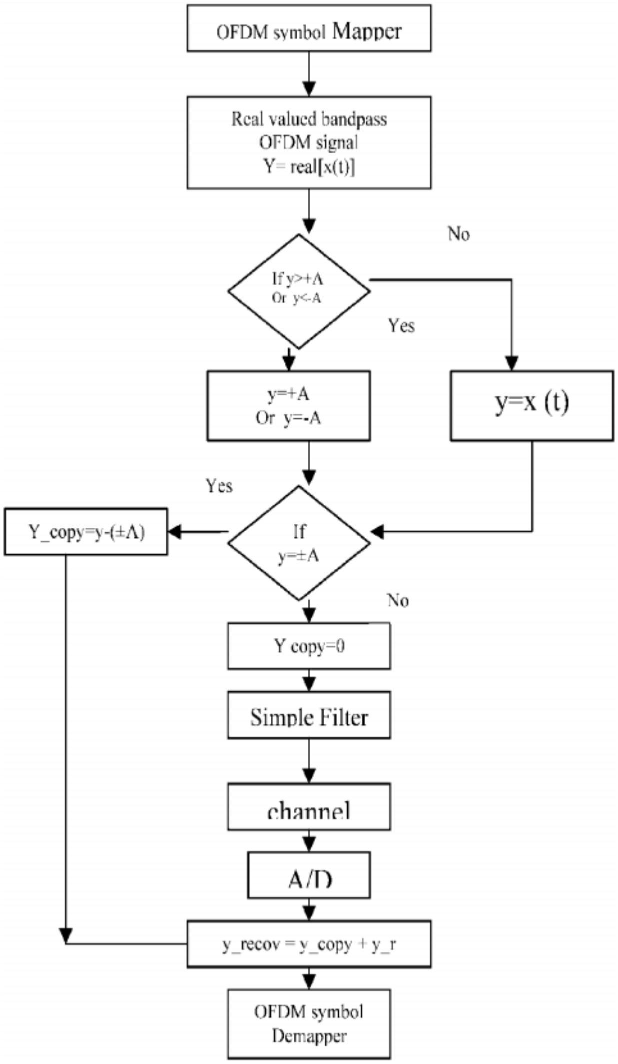

Fig. 3: The Proposed Method to Recover the Clipped OFDM Signal

To understand the proposed method of recovering the original signal, figure 3 illustrates the details of copying the clipped part of the OFDM signal and then using it to recover the original signal at the receiver side.

3. RESULTS AND DISCUSSION

When using the clipping scheme, the phase information of the signal is completely transmitted, and the amplitude of the signal is clipped if the power of the signal exceeds the maximum permitted power. If using ideal power control to counteract the influence of wireless channel in systems and not considering other factors (such as frequency set-off), the received signal amplitude also shows as the same as the original signal plus to AWGN. Although PAPR is very large for OFDM especially for large number of subcarriers as in this simulation, high magnitude peaks occur relatively rarely and most of the transmitted power is concentrated in signals of low amplitude.

It is important to choose the CR carefully to get a good reduction in the PAPR without degrade the performance of SER. But with this proposed method of recovering the clipped part of the original signal, it is possible to clip the signal hardly or in other word using small CR without degrading the SER performance.

The most important thing that should be considered in this proposed recovering method is appropriate choosing of the CR value. In this proposed method, a low Clipping Ratio (CR) will achieve a significant PAPR reduction, and improve the SER performance, but the price is increasing in the amount of the copied signal which is in fact a redundancy in the transmitted data.

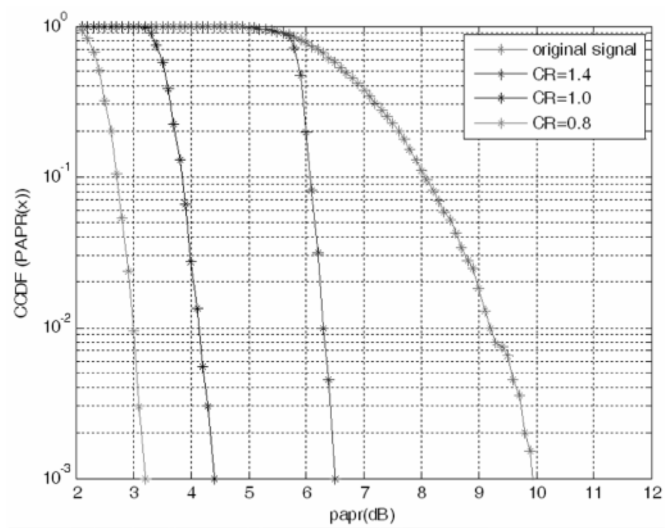

Fig: CCDF of PAPR for Normal and Clipped OFDM Signal at Different CR with 16-QAM

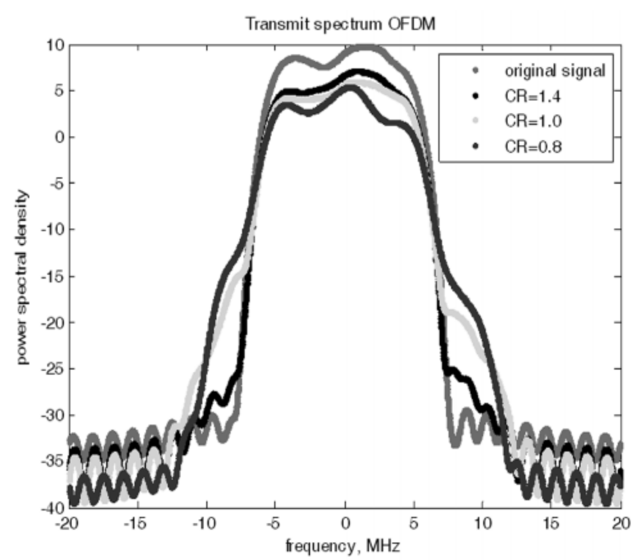

Fig: Spectrum of Clipped OFDM Signal

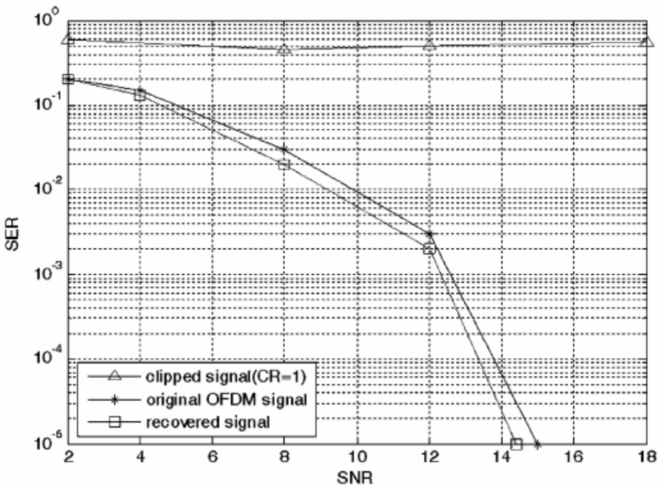

Fig. SER Performance of Clipped and Recovered OFDM Signals

4. PERFORMANCE OF IEEE802.11G

This paper tries to improve the overall performance of IEEE802.11g which is an amendment of Legacy standard, 802.11a and 802.11b, using OFDM in 2.4 GHz frequency band. To achieve this mission this paper suggests two models with numerous modes to use the clipping technique to control the adaptive modulation. The proposed adaptive modulation (AM) to be used in this simulation is totally different form the conventional AM.

The OFDM signal will be clipped hardly when using low order modulation scheme in model to give chance to the high order modulation schemes to be used at low SNR values. The appropriate choosing of clipping ratio is very important to keep the SER at acceptance value.

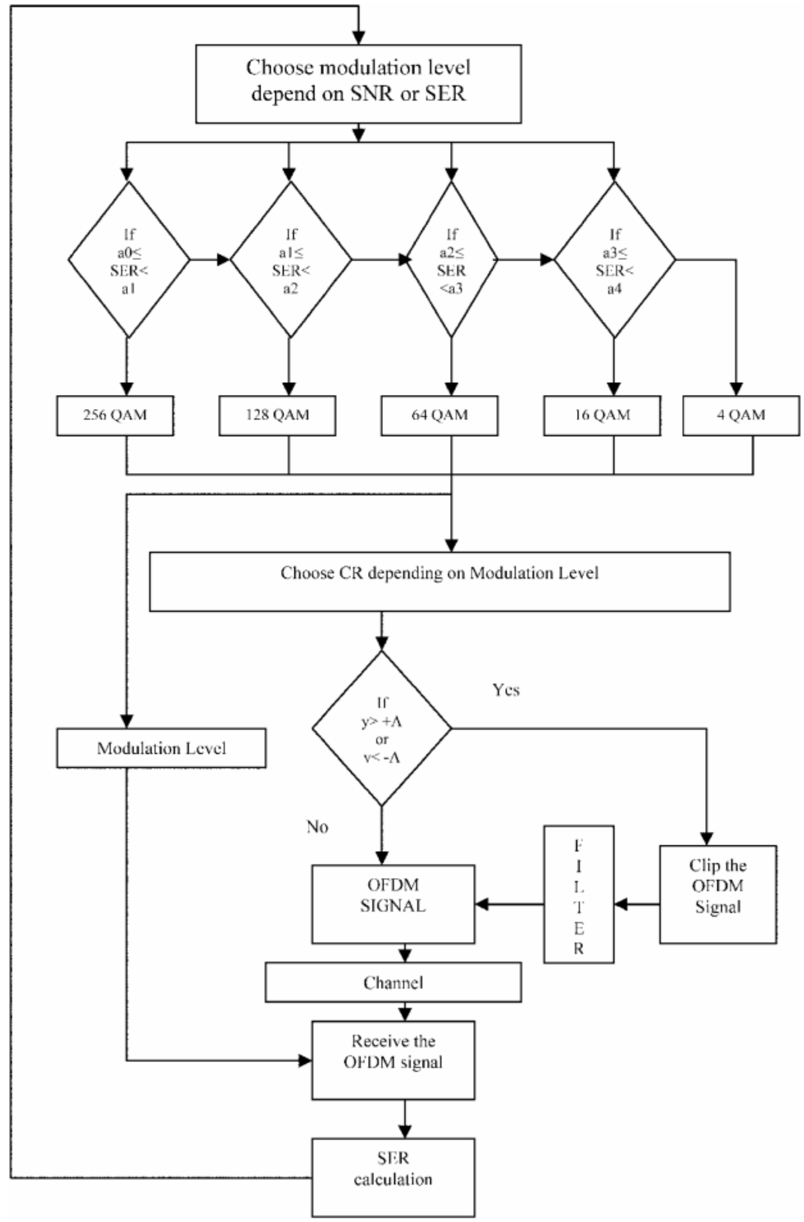

Fig: Proposed Model

Table
Simulation Parameters

Parameters	*Values*
Modulation scheme (mapping scheme)	4QAM, 16QAM, 64QAM, 128QAM, 256QAM
Channel bandwidth(MHZ)	20MHz
FFT Size(NFFT)	64
Number of data subcarriers	48
Useful symbol duration Tu	4ms
Carrier spacing 1/ Tu	312.5KHz
Carrier frequency f_c	2.4GHz
Guard Time	800ns
Channel coding	None
Channel model	AWGN

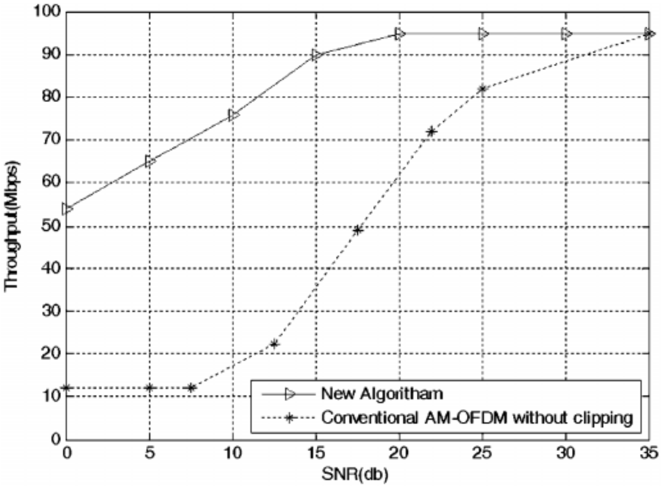

Fig. Throughput of IEEE802.11g

5. CONCLUSION

The numerical results show the ability of this method to eliminate the clipping noise and improve the SER performance compared to the conventional clipped signal and even better than the SER performance of unclipped OFDM system. It is possible to use low CR with this proposed method to get efficient PAPR reduction. But it is important to make appropriate selecting of the CR to minimize the amount of the transmitted copies of the clipped parts of the original OFDM signal to avoid wasting the valuable bandwidth. The analysis and numerical results show that the proposed models can provide improved performance in SER, reduce PAPR, and enhance the throughput of IEEE802.11g-OFDM system.

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