PAPR Reduction in WLAN-OFDM System Using Code Repetition Technique

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Abstract- Orthogonal Frequency Division Multiplexing (OFDM) is the best choice to achieve high data rate transmission in wireless environment. OFDM system shows many favorable property such as high spectral efficiency, robustness to channel fading and immunity to impulse interference. However, there are some obstacles in using OFDM in transmission system, which is in contrast to its advantages. One of the major drawbacks is a very high peak to average power ratio (PAPR) of the OFDM signals. Therefore this paper analyzes the capability of Code Repetition (CR) to reduce PAPR in WLAN/OFDM system. The analysis is on a network model designed by WLAN 802.11a standard using Matlab, a mathematical simulation software tool. The network model has been simulated in AWGN channel environment to investigate the behavior of PAPR and BER performance. The proposed technique to reduce PAPR in the WLAN/OFDM channel coding consists of two part; convolutional code and CR. Simulation model with different number of repetition has been analyzed and the results were compared with the conventional coded OFDM (COFDM). The simulation results show that the proposed technique based on CR reduces PAPR down to 5 dB compared to COFDM model.

Keywords
OFDM, PAPR, Wireless LAN802.11a, Code Repetition, Convolutional Code.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is one of the multi-carrier modulation (MCM) techniques that can reduce the Intersymbol Interference (ISI), delay spread of signal and increase the spectral efficiency of system. Due to the numerous advantages of this system, it has been successfully applied in wide variety of digital communications over the past several years and has been adapted to the wireless LAN standards [1].

However, an OFDM system dynamic range is typically two or four times larger than a single carrier system. Increasing value of the dynamic range will lead to an increased the cost, power consumption of transmitter amplifier and also lead to high peak to average power ratio (PAPR). This is one of the major drawbacks of OFDM system.

A serious problem of large PAPR presents when cheap and energy-efficient nonlinear power amplifiers are used. Frequent excursions into the nonlinear operating region contribute to the increment of BER and spectral regrowth outside the intended frequencies of operation. Therefore PAPR reduction techniques are required to overcome this problem.

There are several techniques have been proposed to reduce PAPR in OFDM system. From the literature, clipping is the simplest approach to reduce PAPR. However it results a significant in-band distortion and this technique requires filtering to overcome the weakness. Besides of using clipping and filtering, coding scheme get attention since it can handling both reducing PAPR and error correction at the same time. Therefore, this paper investigate the effectiveness of coding technique in reducing PAPR for OFDM system. In this method a combination of convolutional code and Code Repetition was developed.

This paper is divided into 6 sections. Section II, gives a brief overview of the fundamentals of PAPR in WLAN/OFDM system. In section III, Channel coding that had been used in this thesis are presented. This section briefly explains the encoding and decoding process of code repetition, which is the coding that had been proposed to reduce PAPR. Section IV gives the methodologies used for reducing PAPR. Section V discusses the results obtained in this research and an analysis and discussion of these results are carried out. Lastly, Section VI gives the conclusions of this research followed by possible extensions and addition as future work.

II. PEAK TO AVERAGE POWER RATIO (PAPR)

An OFDM signal is the sum of C_i complex random variables, each of it can be considered as a complex modulated signal at a different frequency. In some cases, all signal components can add up in phase and produce a large output and in some cases, they may cancel each other, producing zero output. Thus, the peak-to-average ratio (PAPR) of an OFDM system is very large.

In the transmitter front-end, a power amplifier with a wide linear range to include the peaks in the transmitted waveform is needed. Such amplifier not only consumes a large amount of power but also costly. DAC's and ADC's must also have a wide signal range to avoid clipping. The symbols that have a large PAPR are vulnerable to errors.

Peak to Average power Ratio is defined by Müller and Huber (1997) [7];

$$PAPR = \frac{\max|S_x(t)|^2}{\varepsilon\{|S_x(t)|^2\}} \quad t \in [0,T] \qquad (1)$$

where ε denotes the expectation and $S_x(t)$ is the OFDM transmitted signal. This expectation value is the value that we expect to measure most often if repeated measurements were made on the system. The PAPR also can be expressed in dB as in equation (2).

$$PAPR = 10\log\frac{\max|S_x(t)|^2}{\frac{|S_x(t)|^2}{N}} \text{ [dB]} \qquad (2)$$

$\max|S_x(t)|^2$ is the maximum power of the OFDM transmitted signal while $\frac{|S_x(t)|^2}{N}$ is the average power for N number of carriers.

III. CODE REPETITON (CR)

Code Repetition (CR) is one of the forward error correcting (FEC) codes that have a capability to detect and correct an error bit depends on the number of repetition, k. The encoding process of CR can be achieved by repeating each input bit k times depending on number of repetition. A block CR can be used to detect errors in a u-block,. As before, CR will send a few copies of a codeword whenever a codeword is to be sent. Then, it will produce a new block code in which every block is just k repetitions of one of the original codewords. If the original code is an r-block code, then the new code will be a u-block code where $u=rk$. There are still only 2^u codewords, but each block consists of r message digits and $(k-1)r$ check digits.

For example, where r=4, k=2, u=8, the codeword 1100 is in the original 4-block code. The 8-block code will have the codeword 11001100. One error in transmission will destroy the symmetry of the block, revealing the presence of an error. Let say the received word is 11001110 then we know an error occurred. There is no guarantee that two errors will be detected, since two errors might preserve symmetry. It is clear that repetition causes a decrease in efficiency. We send extra digits with no additional information. For k = 2, only single error can be detected but it does not have capability to correct the error bit. More errors can be detected by repeating the codewords more times. Sending k copies of a codeword enables detection of k-1 errors.

In the case of a binary code (using only 0 and 1), the possible received of codeword available using a u-block code is $2u$. For example in a 3-block binary code there are 8 possible codeword [000, 001, 010, 100, 011, 101, 110, 111]. Figure 1 shows the distance for each possible received codeword for 3 times repetition.

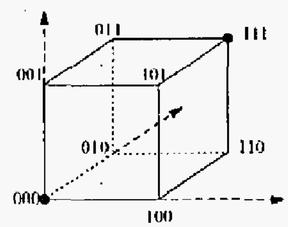

Figure 1. Distance between possible received codeword

The CR decoding process can be done using maximum likelihood by select the nearest neighbor of the received codeword. However, there is a simple way to do it than searching explicitly for the nearest neighbor. In this paper, decoding process is done by select the output bit based on the majority bits in the codewords. For example, if the received codewords is {101}, the majority bit is 1. Therefore the CR decoder will produce bit 1 as an output.

IV. OFDM WITH MODIFIED CR

The Matlab simulation model generates the corresponding OFDM transmission, simulates through the channel before attempts to recover input data and performs the analysis to determine the PAPR reduction and BER performance.

In this simulation model, the OFDM sub-carriers are modulated using BPSK modulation technique as a symbol mapper to the FFT point. The sub-carrier signals in OFDM were placed at indexed from –26 to +26 at 64 FFT point except at point 0, which is the direct current (DC) sub-carrier. Spacing between sub-carriers is 0.3125 MHz and total bandwidth for this system is 16.875 MHz. Basic parameters and system configuration used for the simulations are summarized in Table 4.1.

Table 1. OFDM parameters for Wireless LAN 802.11a standard

Parameter	Value
Sampling rate (f_s)	20 MHz
Total symbol duration (T_{total})	4.0 µsec
Number of data subcarrier (N_D)	48
Number of pilot subcarrier (N_P)	4
FFT point	64
Subcarrier spacing (Δf)	0.3125 MHz
Total BW (B)	16.875 MHz

There are seven models have been designed to be analyzed. Each designed model is differentiates at the channel coding part. The conventional COFDM is used as a reference model to be compared with proposed CR*k* models. The first model is the generation OFDM that represent a basic OFDM without any channel coding technique applied. This model is used to analyze the characteristic of PAPR in OFDM system based on Wireless LAN physical layer configuration. Second model is coded OFDM (COFDM). This model used convolutional codes as a channel coding with rate of ½ and constraint length equal to 7. It is used as a reference model in the analysis. The other 5 represent the proposed model with adaptation of code repetition, CR*k* on the COFDM model where *k*=3,4,5,6 and 7. The repetition, *k* is chosen to be greater than 3 to allow both error detection and correction. Table 4 shows the parameters for each model.

Table 2. Parameters for OFDM, COFDM and CR*k* simulation models

Model / PARAMETER	OFDM	COFDM	CR3	CR4	CR5	CR6	CR7
Total no. of subcarrier, N_s	52	52	52	52	52	52	52
Subcarrier spacing (MHz)	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125	0.3125
FFT point	64	64	64	64	64	64	64
Modulation Technique	BPSK	BPSK	BPSK	BPSK	BPSK	BPSK	BPSK
Coding	-	Conv. codes	Conv. Codes + CR. k=3	Conv. Codes + CR, k=4	Conv. Codes + CR, k=5	Conv. Codes + CR, k=6	Conv. Codes + CR, k=7

Figure 2 shows the proposed coded OFDM with additional Code Repetition (CR). This proposed scheme separate channel coding into two parts. They are convolutional codes and code repetition. The purpose of adapting CR before the symbol mapper is to produce codeword with low PAPR value. Therefore it will result in reduction of PAPR for OFDM transmitted signals. Beside of reducing PAPR, CR also capable to handle error correction and leads to BER improvement.

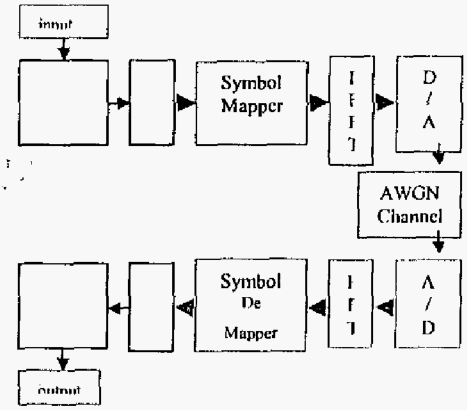

Figure 2. CR transceiver

Some modifications of conventional CR are needed to further reduce the PAPR. Output from CR encoder is chosen to have low PAPR value besides of choosing the maximum number of repetition to handle error correction. CR for this system can be generated by mapping input bit *k* times and toggle up the LSB bit. For example, for number of repetition, $k = 4$, conventional CR will produce output either (1111) if the input bit is 1 or (0000) if the input bit is 0. These codeword have a maximum PAPR value for 4 binary bits, as shown in Table 5.1 in section 5.2.1. Therefore CR will toggle up the LSB bit. Hence, it will produce output either (1110) or (0001). From the same table, it can be seen that these codeword have the lowest PAPR compared to the others. Table 4.3 shows PAPR value for each possible output from CR with different rate. The increment of *k* revealed the increase value of PAPR for CR output.

Decoding process for CR is done by toggle up the LSB bit and choosing the majority bits as the output. However, for even number of repetition (*k*= 4 and 6), it is possible to receive the same number of bit 1 and 0. Therefore, there is no majority bit. In this case, the LSB will be chosen as the output.

Table 3. PAPR for CR*k* output

Code rate, 1/*k*	Output from CR	PAPR (dB)
1/3	Bit 0 : 0 0 1 Bit 1 : 1 1 0	4.9802 4.9802
1/4	Bit 0 : 0 0 0 1 Bit 1 : 1 1 1 0	5.2450 5.2450
1/5	Bit 0 : 0 0 0 0 1 Bit 1 : 1 1 1 1 0	5.9321 5.9321
1/6	Bit 0 : 0 0 0 0 0 1 Bit 1 : 1 1 1 1 1 0	7.2700 7.2700
1/7	Bit 0 : 0 0 0 0 0 0 1 Bit 1 : 1 1 1 1 1 1 0	8.5387 8.5387

PAPR calculation is done at the end of the transmitter. In terms of BER performance, AWGN channel is inserted in Monte Carlo BER simulation.

V. RESULTS AND DISCUSSION

This part discussed all the results obtained. The Matlab simulated outcomes have been successfully carried out from the simulation model.

Several simulations had been done using 1000 random binary bit. The averaging results from those simulations are plotted in Figure 3.

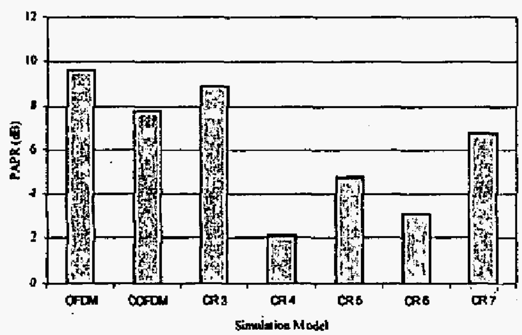

Figure 3. PAPR performance for all simulation models

The uncoded OFDM system is also shown in the graph for comparison. Basic OFDM without any coding technique gives PAPR value of 9.6114 dB while PAPR for COFDM is 7.7738dB. The reduction is approximately 2 dB with respect to the basic OFDM. From this simulation, model CR4 yield the optimal performance with 5 dB reductions regarding to COFDM. This results shows that the combination of bit and length of bit transmitted for CR4 is an appropriate combination to reduce PAPR in this system.

Figure 4 shows the BER performance of the all simulation models in an AWGN channel with ½ rate convolutional code with constraint length 7 and hard decision Viterbi decoding. The number of repetition, *k* contribute to the error correction capability of the system. Thus, the increment of repetition, *k* will decrease the BER performance. The graph in Figure 5.5 shows that the model with highest repetition number, CR7 gives the best BER performance.

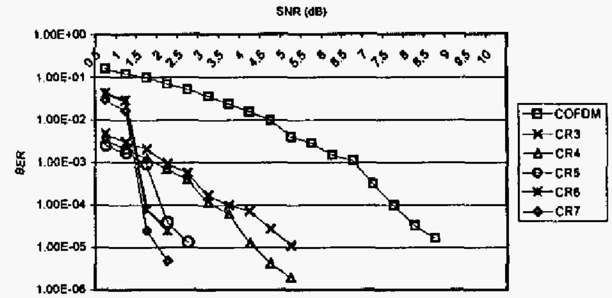

Figure 4. BER performance for all simulation models in AWGN channel

The improvement percentage of BER performance is calculated using formulation and gives 96% improvement regarding to COFDM model.

VI. CONCLUSION AND FUTURE WORKS

CR encoder and decoder has been designed based on the PAPR characteristic for different combination bits. The combination that gives low PAPR is considered to be the output for CR encoder. The COFDM system with CR were implement for code rate, r= 1/3, 1/4, 1/5, 1/6 and 1/7. In terms of PAPR reduction, model with r =1/4 gives an optimal performance with PAPR reduction is up to 5 dB. The other models with additional CR also reduced PAPR down to 3 dB with respect to the conventional COFDM. In general, the increases of repetition, *k* will reasonably increased the data rates and consequently increase the BER. Besides that, BER should be increased with the increment of PAPR. This is due to the frequent excursion into nonlinear operating region of power amplifier. However, this work assumed that the power amplifier operated in linear range. Therefore the results on BER do not totally follow the general principle. It has been found that BER performance increases with increasing number of repetition, *k*.

In general the proposed technique has achieved the objective to reduce PAPR and improve BER. The adaptation of CR to convolutional codes in WLAN/OFDM system had reduces PAPR with a simple encoding and decoding task.

In this paper, simulations studies have been carried out to investigate the reduction of PAPR using Code Repetition technique. From the results, it has been found that an addition of CR in WLAN/OFDM system decreases PAPR value up to 5 dB compared to COFDM system. However, this technique contributes to increase data rates k times from conventional COFDM. The increased data rates will somehow affect the bandwidth efficiency. Analysis on this drawback is a possible extension that can be made.

This paper evaluates the BER performance in AWGN channel, which is not the channel environment for wireless LAN. Indoor wireless channel should be designed with a time delay spread and multipath reflection of surrounding environment. Future works can be made to evaluate the performance of proposed model in indoor wireless channel. Beside that, the implementation of the proposed model on hardware can be done to evaluate the real performance of this system.

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