

Adaptive Hybrid PAPR Reduction in OFDM System

Osama A. Omer, *Member, IACSIT* and Ahmed Abdel-Reheem

Abstract—High Peak to Average Power Ratio (PAPR) is still one of the most important challenges in Orthogonal Frequency Division Multiplexing (OFDM) system. In this paper, we propose a novel scheme based on Selected Mapping (SLM) technique for PAPR reduction in OFDM system. The proposed scheme is an adaptive hybrid scheme, which is based on the SLM technique and multiple transformation techniques. In the proposed scheme, instead of using only Discrete Fourier Transform (DFT) in OFDM system, we suggest to use Discrete Sine Transform (DST) and Discrete Cosine Transform (DCT) as well to get the lowest PAPR. In addition, the multiplied phase in the SLM is adapted to reduce the PAPR to an acceptable low PAPR level. Simulation results show that the proposed scheme technique can reduce the PAPR to about 4 dB in case of 256 sub-carriers and in case of 512 sub-carriers at clipping probability of 10^{-3} .

Index Terms—OFDM, PAPR reduction, DCT, DST, adaptive scheme.

I. INTRODUCTION

In the recent years Orthogonal Frequency Division Multiplexing (OFDM) technology has become a key technology for future communication systems and are currently attracting intensive attention in wireless communications and wire communications to meet the advancement that have been done in the multimedia technology and broadband services. OFDMA-based systems are able to execute high data rates, can exploit with multipath propagation, provide robustness against frequency selective fading or narrowband interference, OFDM is a very promising choice for future mobile communication systems. OFDMA has been used in IEEE 802.16, Wimax, 3GPP Long Term Evolution (LTE) downlink, and advanced Long Term Evolution [1].

Multicarrier modulation is a technique that provides high data rates and the orthogonality in OFDM system indicates that there is a mathematical relationship between the frequencies of the carriers in the system. On the other hand, in FDM system, the carriers are spaced apart with guard bands in such a way that guard bands are introduced between the different carriers in the frequency domain, which results in lowering spectrum efficiency [2].

However, there are still some challenging issues remain unresolved in the design of the OFDM systems. High Peak-to-Average Power Ratio (PAPR) of transmitted OFDM signals is one of the most important challenges [3, 4].

An OFDM signal consists of a number of independently

modulated sub-carriers, which can give a large peak-to-average power (PAP) ratio when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power [2]. High PAPR in OFDM system leads to the use of High Power Amplifier (HPA) with a large dynamic range, but these amplifiers are very expensive and represent the major cost component of the OFDM system. HPA usually operates in its linear region or near the saturation region to achieve the maximum output power efficiency. Moreover, high PAPR makes the amplifiers to work in non-linear regions and increase the Bit Error Rate (BER). Large PAPR leads to in band distortion and spectral spreading. Therefore, if we reduce the PAPR that is not only reducing complexity of A/D and D/A converters but also increasing the transmit power, thus, for same range improving received SNR, or for the same SNR improving range and reduce the cost of the OFDM system.

There are several developed techniques to reduce the PAPR in OFDM systems [5-14] including clipping [7], companding [8,9], Partial Transmit Sequence (PTS) [10], Selected Mapping (SLM) [11], coding [12], and trigonometric transforms [13], for recent review see [5].

Among these techniques, selected mapping (SLM) has paid more attention in the last decade due to its simplicity and efficiency [11], [15]-[18]. Recently, signal transformation has been combined with SLM [19], where the discrete cosine transform is incorporated with the conventional SLM scheme. Even if this modification resulted in PAPR reduction in the OFDM signal, it suffers from two main shortcomings. The first, it used DCT as a pre-coding followed by IDFT-based OFDM, however, IDFT-based OFDM is not always the best in sense of PAPR among the other OFDM schemes. The second, it uses constant phase in the SLM scheme.

Therefore, we propose to overcome these shortcomings by incorporating multiple OFDM schemes in the SLM technique. Instead of using only Discrete Fourier Transform (DFT) in OFDM system, we suggest using Discrete Cosine Transform (DCT) and Discrete Sine Transform (DST) as well and select the lowest PAPR from output of these multiple Transformers. Moreover, the multiplied phase in the SLM stage is adapted to get the lowest PAPR.

This paper is organized as follows: Section 2 describes the PAPR problem. Section 3 presents the related schemes. In Section 4 we present the proposed adaptive hybrid system model for PAPR reduction, and Section 5 presents simulation results. follow.

II. SYSTEM DESCRIPTION

A. Problem Description

A multicarrier signal is the sum of many independent signals modulated onto sub channels of equal bandwidth. Let

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Osama A. Omer is with the Electrical Engineering Department, Aswan Faculty of Engineering, Aswan University, Aswan, Egypt (e-mail: omer.osama@gmail.com).

Ahmed Abdel Reheem is with Egypt Telecommunication, Aswan Egypt (e-mail: ahmed@ieee.org).

us denote the collection of all data symbols, X_n , where $n = 0, 1, \dots, N-1$, as vector

$$X = [X_0, X_1, \dots, X_{N-1}]^T$$

That will be termed a data block. The complex baseband representation of a multicarrier signal consisting of N subcarriers is given by

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \cdot e^{j2\pi n \Delta f t}, 0 \leq t \leq N \quad (1)$$

Where $j = \sqrt{-1}$, Δf is the subcarrier spacing, and N denote the useful data block period in OFDM the subcarrier which are chosen to be orthogonal. The PAPR of the transmit signal is defined as

$$PAPR\{x[n]\} = \frac{\max_{0 \leq t \leq N-1} [|x[n]|^2]}{E[|X[n]|^2]} \quad (2)$$

B. The Effect of OFDM on PAPR

The main problem in the OFDM system it that it increases the PAPR as shown in Fig. 1. This figure shows that the OFDM increases the PAPR more than 5dB, in case of using 4 QAM modulation with number of subcarriers equals 512 carriers.

III. RELATED CONVENTIONAL OFDM SYSTEMS

A. Selected Mapping Scheme (SLM)

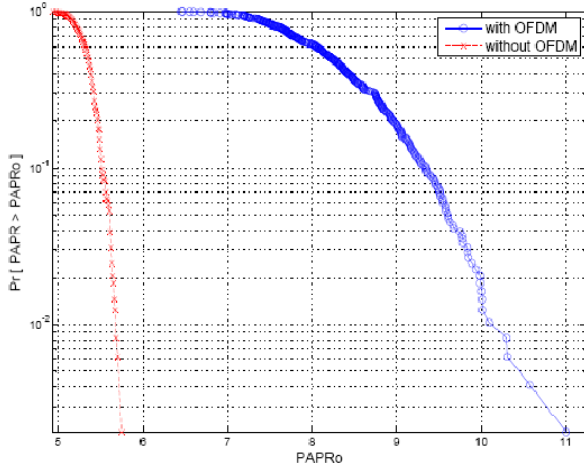


Fig. 1. Performance with OFDM and without OFDM system.

Selective mapping (SLM) approaches have been proposed by Bauml [11]. This method is used to minimize of peak to average transmit power of multicarrier transmission system with selected mapping. A complete set of candidate signal is generated signifying the same information in selected mapping, and then concerning the most favorable signal is selected as consider to PAPR and transmitted. In the SLM, the input data structure is multiplied by random series and then the resulting series with the lowest PAPR is chosen for transmission. To allow the receiver to recover the original data to the multiplying sequence is sent as 'side information', as shown in Fig. 2. The good side of selected mapping

method is that it doesn't eliminate the peaks, and can handle any number of subcarriers. However, the main drawback of this method is the overhead of side information that requires to be transmitted to the receiver of the system in order to recover information.

B. DFT-Based OFDM

In the conventional OFDM systems, digital modulation and demodulations is realized with the inverse DFT (IDFT) and DFT, respectively [14]. OFDM employs N separate subcarrier to transmit data instead of one main carrier. Input data is grouped in to a block of N bits, where $N = N_s \times N_n$ where N_s is the number of independent data symbols and N_n is the number of bits used to represent a symbol for each subcarrier. In order to maintain orthogonality between the sub-carriers, they are required to be spaced apart by an integer multiple of the subcarrier symbol rate R_s . The subcarrier symbol rate is related to overall coded bit rate R_c of the entire system by $R_s = R_c / N$. The output signal of an OFDM can be written as

$$X(t) = \sum_{n=0}^{N_s-1} C_K e^{2\pi(n-\frac{N_s}{2})\frac{t}{T_s}} \quad (3)$$

where C_K the complex representations of the subcarrier symbols and T_s are is the symbol period.

C. DCT-Based OFDM

The complex exponential function set is not the only orthogonal basis that can be used to construct baseband multicarrier signals. A single set of cosinusoidal functions can be used as an orthogonal basis to implement the OFDM scheme, and this scheme can be synthesized using a discrete cosine transform (DCT) [21]. Hence, it is denoted as DCT-OFDM. The output signal of a DCT based OFDM system can be written as

$$X(t) = \sqrt{\frac{2}{N_s}} \sum_{n=0}^{N_s-1} d_n B_n \cos\left(\frac{n\pi t}{T_s}\right) \quad (4)$$

where $d_0, d_1 \dots d_{N_s-1}$ are N_s independent data symbols obtained from a modulation constellation, and

$$B_n = \begin{cases} \frac{1}{\sqrt{2}}, & n = 0 \\ 1, & n = 1, 2, \dots, N_s - 1 \end{cases} \quad (5)$$

D. DST-Based OFDM

The complex exponential function set is not the only orthogonal basis that can be used to construct baseband multicarrier signals. A single set of Sinusoidal functions is also used as an orthogonal basis to implement the OFDM scheme, and this scheme can be synthesized using a discrete cosine transform (DST). Hence, it is denoted as DST-OFDM scheme. The output signal of a DST based OFDM system is written as

$$X(t) = \sqrt{\frac{2}{N_s}} \sum_{n=0}^{N_s-1} d_n B_n \sin\left(\frac{n\pi t}{T_s}\right) \quad (6)$$

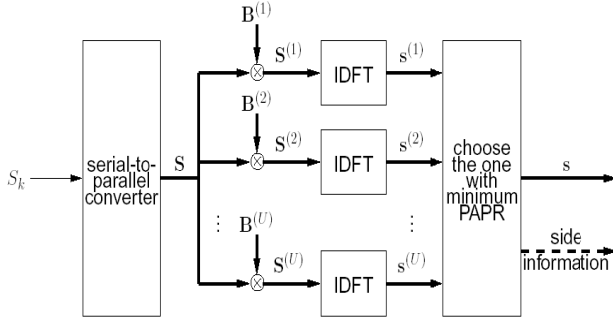


Fig. 2. Block diagram of the SLM technique[11].

IV. THE ADAPTIVE HYPRID SCHEME

The main idea of the proposed scheme is adaptively change the phase and to select among the IDFT, DCT and DST techniques to get the lowest PAPR. Where we use adaptive algorithm with maximum number of phase sequence equals 16 phases, below we shall describe the main steps of the proposed scheme.

Like SLM technique, the input data structure is multiplied by random phase series. Unlike the conventional SLM scheme, the proposed scheme selects among IDFT, IDCT and IDST to get the lowest PAPR. Moreover, the multiplied phases are changed adaptively if the PAPR is higher than pre-determined value. Finally, the transmitter sent the data block, which have minimum PAPR.

The proposed scheme is described as follows: first we design the target PAPR value (threshold PAPR). Second, partition the data into blocks (X) and generates four phases and each data block is multiplied by a phase sequence (B1, B2, B3, B4). Third, calculate the IDFT, IDCT and IDST for every block (X1, X2, X3, X4). Fourth, measure PAPR for each block, select the lowest PAPR and compare it with threshold PAPR. If the PAPR lower than or equal than threshold PAPR, then the transmitter send the data block, which have minimum PAPR. Otherwise, change the phase sequences (B1, B2, B3, B4) and again do the previous steps for each data block. The maximum number of phase sequences is 16 phases. So we get the target PAPR with 4 phases or higher phases with maximum 16 phases. Figure 3 shows the block diagram for the proposed scheme.

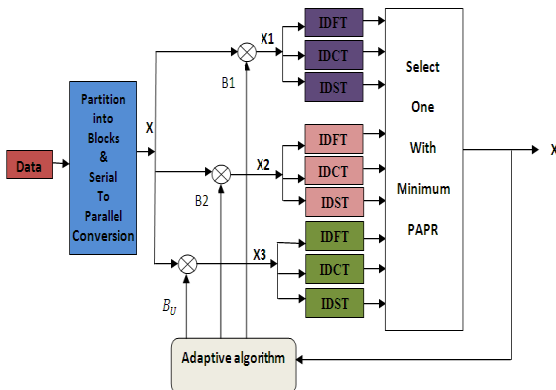


Fig. 3. The block diagram of proposed scheme.

V. SIMULATION RESULTS

A. Simulation Setup

The simulations results presented in this paper are obtained using MATLAB software to estimate the PAPR reduction capability with our proposed scheme. In this simulation, we compared the results of the proposed scheme with that of the conventional OFDM and conventional SLM techniques. The simulation parameters are tabulated in Table I

TABLE I. SIMULATION PARAMETERS

Parameter	Value
DATA source	Random data
Channel coding	Without coding
FFT Length	64, 256, 512
Modulation	4 QAM
No. OFDM blocks	10,000 block
clipping probability	10^{-3}
No. phases Sequences	4 to 16 phases

B. PAPR Comparison

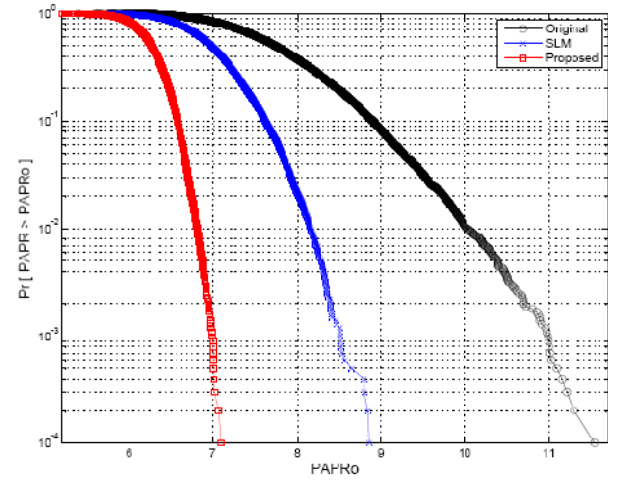


Fig. 4. PAPR of OFDM Original, Conventional SLM and our Proposal for N=256.

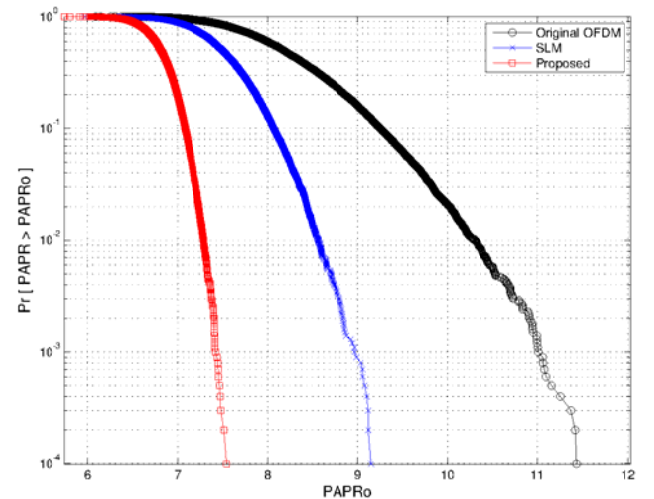


Fig. 5. PAPR of OFDM Original, Conventional SLM and our Proposal for N=512

Fig. 4 shows the CCDF comparisons of conventional OFDM, conventional SLM and the proposed scheme. Based on the simulation results, in case of $N = 256$ at clipping probability of 10^{-3} , the PAPR reduction of 1.7 dBs is

achieved by the proposed scheme compared to SLM-based OFDM system with conventional OFDM, and the PAPR reduction of 4.4 dBs is achieved by the proposed scheme compared to conventional OFDM system.

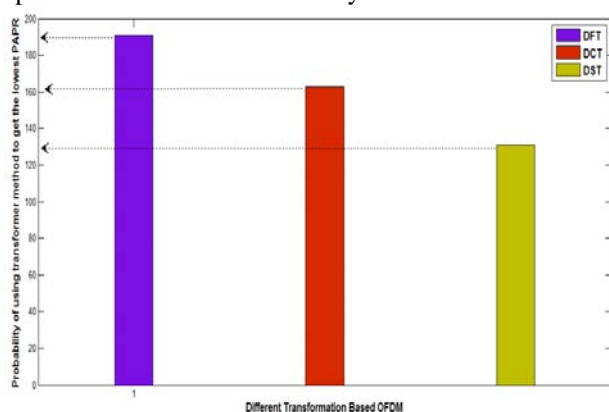


Fig. 6. Probability of using basis function to get the lowest PAPR.

As the PAPR depends on the number of carriers, we present another example for the PAPR comparison in Fig. 5, where the number of carriers equals 512. From this figure, we can see that, the PAPR reduction of 1.7 dB is achieved by using SLM-based OFDM compared to conventional OFDM. While we PAPR gain of 4 dBs is achieved by using the proposed scheme compared to the conventional OFDM, at clipping probability of 10⁻³.

To show the efficiency of using hybrid basis function rather than single basis function, the probability of obtaining the lowest PAPR for each of the basis functions is shown in Fig. 6. From this figure, we can see that none of these functions can give the lowest PAPR for all blocks.

VI. CONCLUSION

In this paper, we proposed a PAPR reduction scheme that depends on SLM with adaptive phase. The proposed scheme adaptively selects among IDFT-, IDCT- and IDST-based OFDM and adaptively change phase to get the lowest PAPR. The proposed scheme achieved PAPR reduction up to 4 dBs in case of 256 sub-carriers and in case of 512 sub-carriers at clipping probability of 10⁻³ compared to conventional SLM technique.

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Osama A. Omer Received his B.Eng. and M.Eng. degrees in electrical engineering from South Valley University, Aswan, Egypt, in 2000 and 2004 respectively. He received his Ph.D. degree from Tokyo University of Agriculture and Technology in 2009. He is now assistant professor at Aswan University. He spent the summer internship 2008 in Nokia/Tokyo research center. His interests include image/video super resolution and image/video compression.