IMPLEMENTATION OF PRINCIPAL COMPONENT ANALYSIS TECHNIQUE IN PEAK TO AVERAGE POWER RATIO

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UNIVERSITI SAINS MALAYSIA

2018

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by

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Thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Engineering (Electronic Engineering)

JUNE 2018

ACKNOWLEDGEMENT

I would like to dedicate my gratitude to my supervisor, Dr Aeizaal Azman bin Abd Wahab for his guidance towards completing this project. His support and as well as knowledge that have been given helped me in completing this project

Secondly, I am indebted to my loving mother for her encouragement and support towards completing this project. Without her endless love, I would never be able to continue doing what I am doing now.

Lastly, I would like to thank my friends for their support. They helped me throughout conducting this project and shared some thoughts and discussion with me.

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LIST OF ABBREVIATIONS

OFDM	: Orthogonal Frequency Division Multiplexing
PAPR	: Peak to Average Power Ratio
PCA	: Principal Component Analysis
PTS	: Partial Transmit Sequence
SLM	: Selective Mapping
QAM	: Quadrature Amplitude Modulation
ASK	: Amplitude Shift Keying
PSK	: Phase Shift Keying
BER	: Bit Error Rate

LIST OF SYMBOLS

N	:	Number of subcarriers
Δf	:	Frequency spacing
T	:	Symbol period
$\bar{P}$	:	Envelope power
P_{av}	:	Average power
D	:	Mean-centring data
Σ	:	Covariance matrix
P_r	:	Probability

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ABSTRACT

Wireless communication has become one of the most rapid technology evolvements in the world. Orthogonal Frequency Division Multiplexing (OFDM) has become the most efficient multi carrier modulation technique for achieving high data rate transmission in wireless communication. OFDM offers advantages such as immunity to selective fading, spectrum efficiency, and various more. Regardless of these beneficial advantages, the performance of OFDM is limited as Peak Power to Average Power Ratio (PAPR) is significantly high. This would reduce the performance of Power Amplifier (PA). Principle Component Analysis (PCA) technique is proposed to implement in the high PAPR as it identifies the directions of most variation in the data set and it reduces the data down into its basic component, dispossess any unnecessary parts. A novel framework using Principal Component Analysis in PAPR is studied. A simple framework using Covariance Matrix in Principal Component Analysis is developed in the PAPR. An evaluation of the overall performances is made using the proposed Principal Component Analysis scheme in PAPR in OFDM system. The project starts with initializing the parameter used in the OFDM system. The input data is generated randomly. Next, serial to parallel the subcarriers ready for the processing of IFFT. Then, the IFFT takes place. After that, PCA technique save the largest eigenvector and eigenvalue. Lastly, the optimal

transmitted signal with the lowest PAPR is chosen. It has been observed from the obtained results that PCA technique increased the value of PAPR even when it supressed the amplitude of the signal. When implementing PCA technique with clipping, PAPR is reduced significantly. It can be concluded that PCA technique alone do not reduced PAPR, but when combining with other methods, notable PAPR reduction can be achieved.

PELAKSANAAN ANALISIS KOMPONEN UTAMA DALAM PENGURANGAN NISBAH KUASA PUNCAK KE PURATA

ABSTRAK

Komunikasi tanpa wayar telah menjadi salah satu perkembangan teknologi yang paling pesat di dunia. Multipleksing Bahagian Frekuensi Ortogonal (OFDM) telah menjadi teknik modulasi pelbagai pembawa yang paling berkesan untuk mencapai penghantaran kadar data yang tinggi dalam komunikasi tanpa wayar. OFDM menawarkan kelebihan seperti imuniti untuk pudar terpilih, kecekapan spektrum, dan pelbagai lagi. Tanpa mengira kelebihan ini, prestasi OFDM adalah terhad disebabkan oleh Kuasa Puncak kepada Nisbah Kuasa Rata-Rata (PAPR) yang tinggi. Ini akan mengurangkan prestasi Power Amplifier (PA). Teknik Analisis Komponen Prinsip (PCA) dicadangkan untuk dilaksanakan pada PAPR yang tinggi kerana ia mengenal pasti petunjuk-petunjuk yang paling banyak variasi dalam set data dan ia mengurangkan data ke dalam komponen asasnya, melupuskan mana-mana bahagian yang tidak perlu. Rangka kerja baru menggunakan Analisis Komponen Utama dalam PAPR dipelajari. Rangka kerja mudah menggunakan Matriks Kovarians dalam Analisis Komponen Utama dibangunkan dalam PAPR. Penilaian terhadap prestasi keseluruhan dibuat menggunakan skim Analisis Komponen Utama yang dicadangkan dalam PAPR dalam sistem OFDM. Projek ini bermula dengan memulakan parameter yang digunakan dalam sistem OFDM. Data masukan dijana secara rawak. Seterusnya, bersiri selari dengan sub pembawa yang sedia untuk pemprosesan IFFT. Kemudian, IFFT berlaku. Selepas itu, teknik PCA memilih

vector eigen terbesar dan nilai eigen. Akhir sekali, isyarat penghantaran optimum dengan PAPR paling rendah dipilih. Ia telah diperhatikan dari hasil yang diperolehi bahawa teknik PCA meningkatkan nilai PAPR walaupun ia mengurangkan amplitud isyarat. Apabila melaksanakan teknik PCA dengan kliping, PAPR dapat dikurangkan dengan ketara. Ia dapat disimpulkan bahawa teknik PCA sahaja tidak mengurangkan PAPR, tetapi apabila menggabungkan dengan kaedah lain, pengurangan PAPR yang ketara dapat dicapai.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter, the background of this research is discussed briefly. The Orthogonal frequency division multiplexing (OFDM) is introduced clearly while the analysis of the problem in OFDM called as peak-to-average-power ratio (PAPR) are stated evidently. A solution is proposed to overcome high PAPR in OFDM system.

1.2 Research Background

The revolution of telecommunications has evolved dramatically, transforming wired communications to wireless communication system. Within recent years, the use of wireless communications has expanded remarkably worldwide, as more and more users are sending and receiving data and image applications. The early application of Frequency Division Multiplexing (FDM) is used which is the telegraphs. It carried low rate signal using a separate carrier frequency for each signal. Throughout time, the Orthogonal Frequency Division Multiplexing or commonly referred to as OFDM scheme is focused on the synthesis of band-limited orthogonal signals for multi-channel data transmission. New scheme of transmitting signals synchronously over a band-limited channel without inter-carrier interface (ICI) and inter-symbol interface (ISI) is also introduced [1]. The OFDM contradict from FDM as the multiple carriers or also known as subcarriers carry the flow of information, the subcarriers are orthogonal, and a guard interval is included to each symbol to decrease the channel delay spread and inter symbol interference.

The main technological development was introduced as the First Generation (1G) mobile phones from the previous generation was the use of multiple cell sites, and the ability to transfer calls from one site to the next as the user travelled between cells during a conversation. As the system expanded and neared capacity, the ability to reduce transmission power allowed new cells to be added, resulting in more, smaller cells and thus more capacity. Cell phones received their first major upgrade when they went from 1G to 2G. Wireless communication starts with the 2G such as Global System for Mobile communication (GSM), Code Division for Multiple Access (CDMA), General Packet Radio Service (GPRS), and Enhanced Data for GSM revolution (EDGE) networks and effectively took cell phones from analog to digital. The 2G telephone technology introduced call and text encryption, plus data services like SMS, picture messages, and MMS. As the use of 2G phones became more widespread and people began to use mobile phones in their daily lives, it became clear that demand for data services (such as access to the internet) was growing. Then 3G emerged as it assisted in faster data transmission speeds that is needed for multimedia support.

CDMA forms the base for the 3G communications, which have various wireless standards such as wideband CDMA (WCDMA), CDMA 2000 and high-speed down link (HSDPA) or uplink packet access (HSUPA). With the implementation of 4G, some 3G features are removed, such as the spread spectrum radio technology; others are added to higher bit rates due to smart antennas. The fourth generation of networks is called 4G, which was released in 2008. One of the main ways in which 4G differed technologically from 3G was in its elimination of circuit switching, instead employing an all-IP network. Thus, 4G ushered in a treatment of voice calls just like any other type of streaming audio media, utilizing packet switching over internet, long-term evolution (LTE) and worldwide interoperability for microwave access (WIMAX) and offer data rates from 100 -200 Mbps.

In IEEE 802.11b, Wireless Local Area Network (WLAN) reception is slowed down by multipath distortion that occurs when the receiving device is forced to wait until all reflection signals are received. The 802.11a standard solves this problem through a new multiplexing technique called Orthogonal frequency division multiplexing (OFDM). It is a scheme for digital multi-carrier modulation using many closely spaced subcarriers. Each of these subcarriers contains numbers of parallel data streams or channels and is modulated conventionally at a low symbol rate, which is expressed in bits/second. OFDM transmits bits at a slower rate in parallel, across several subcarriers instead of sending a long stream of data across a single channel [2]. By implementing OFDM, the multipath distortion problems that caused by the higher speed transmission in 802.11b is reduced while the data rate is increases.

Orthogonal Frequency Division Multiplexing (OFDM) is widely adopted in wireless communication fields such as terrestrial digital video broadcasting (DVB-T), WLAN and in 4G mobile communications. OFDM acted as multi-carrier modulation method to achieve high speed communication. It has seen as a robust signal processing attributable to its high spectral-efficiency [3]. Apart from that, other notable characteristics that

OFDM can offers are simpler channel equalization, resilience against Selective Fading, cost effective equalization process, better spectrum efficiency, and immunity to narrowband effects. OFDM is said to be the most promising candidate for flexible spectrum pooling in communication systems[4].

Whilst OFDM furnishes many advantages, there is still one disadvantage to its use which need to be addressed when considering its use. The most significant drawback is high peak-to-average-power ratio (PAPR). PAPR can be defined as the relationship between the maximum power of a sample in a transmit OFDM symbol and its average power[5]. The use of large number of subcarriers introduces high PAPR in OFDM systems. High PAPR occurs due to several sinusoids get added coherently in inverse fast Fourier transform (IFFT) at a particular instant[3]. The output envelope has a sudden growth and as a result, a very high peaks is constructed.

1.3 Problem Statement

As introduced earlier in research background section, it is apparent that OFDM is a multicarrier modulation technique that proved to be a superior solution against multipath propagation and is adopted in many contemporary communication protocols. However, one major issue that OFDM has is the high PAPR. PAPR occurs in a multicarrier system when the different sub-carriers are out of phase with each other. It is arisen during the pre-processing phase of the OFDM where the signals are enhanced and they add up constructively to produce peaks and deviate from average power. The output envelope to sudden rise when all points of the sinusoids achieve the maximum value simultaneously.

This will cause a peak in the output envelope and as a result, very high peaks will be structured.

The high PAPR feature will cause poor efficiency of power consumption, in band distortion, and spectral spreading when an OFDM signal is passed through a nonlinear power amplifier[6]. Nonlinear operation degrades the signal at the output of power amplifier and introduces Inter-Symbol Interference (ISI) in OFDM system[7]. In fact, the high PAPR is one of the most detrimental aspects in an OFDM system as it decreases the signal-to-quantization noise ratio (SQNR) of the analog-digital convertor (ADC) and digital-analog convertor (DAC) while degrading the efficiency of the power amplifier in the transmitter. A large PAPR would drive Power Amplifiers (PA) at the transmitter into saturation, producing additional interference among the subcarriers that degrades the Bit Error Rate (BER) performance and corrupts the spectrum of the signal. To avoid driving the PA into saturation, the average power of the signal may be reduced. However, this solution reduces the signal-to-noise and consequently, the BER performance. Therefore, it is preferable to solve the problem of high PAPR by reducing the peak power of the signal.

There has been active research in recent years in the area of pre-processing of OFDM signals for PAPR reduction. Some form of coding is employed but the additional redundancy of PAPR reduction coding causes a reduction in user data rate and most schemes also lack flexibility. Hence, a Principal Component Analysis (PCA) method is proposed as a solution in reduction of the PAPR. PCA can be considered as an efficient pre-processing technique by which the principle component gives the prominent data[8].

The advantage of utilizing PCA method are that principle component identifies the directions of most variation in the data set and it reduces the data down into its basic component, dispossess any unnecessary parts This research concentrates on how PCA method can be used in the reduction of PAPR. The application of MATLAB software is used for the simulations for the modulation techniques and the performance BER is observed.

1.4 Objectives

The objectives of the research is to propose a simple and cost-effective computational framework that can minimize the PAPR in OFDM system. The objectives of the project are:

i. To study a novel framework using Principal Component Analysis for PAPR of OFDM communication system.

ii. To develop a simple framework using Covariance Matrix in Principal Component Analysis in PAPR.

iii. To evaluate the overall performances of the proposed Principal Component Analysis scheme in PAPR of OFDM system.

1.5 Project Scope

The scope of this research is only limited on OFDM system. This research will focus on PAPR reduction using PCA technique. In accordance to attain the objectives of the project, studies on the PCA method is done through online references. Online references include journals, articles, and e-books. The result of this project is generated by simulation. The overall performance related to the PAPR of the proposed scheme will be investigated and analysed thoroughly. Two different size of modulation techniques, 16-QAM and 64-QAM will be used to evaluate the performance of the implemented technique of PCA. A total of four number of subcarriers of 64, 128, 256, and 512 are observed rigorously. The performances of the BER and the gain of PAPR will be analysed.

1.6 Thesis Structure

This thesis contains 5 chapters and it the thesis starts with chapter 1, the introductory chapter. It discusses the background information of OFDM system. An analysis of high PAPR issue in OFDM system with their comparative evaluation is stated, followed by the objectives, problem statement, and project scope. In chapter 2, literature review is discussed as it describes the mathematical analysis of proposed method PCA, PAPR and OFDM system.

Chapter 3 elaborates methodology of this project thoroughly, with clearly stated procedure. Later in chapter 4, the result obtained from the simulation of implementation PCA technique is shown and discussed in detail on how PCA can effects the high PAPR. Lastly, a conclusion is made in chapter 5 and some areas of further research is pointed as a recommendation of future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, relevant literature related to the reduction of PAPR in OFDM system is presented in detail. Orthogonal Frequency Division Multiplexing is emphasized and its associated problems is explained. OFDM give significant benefit in its robustness against multipath propagation. One of the utmost drawback of ODFM is that it provides high Peak-Average-to-Power Ratio or commonly known as PAPR. High PAPR signals are usually undesirable for it usually strains the analog circuitry. If a power amplifier (PA) has high PAPR, signals would require a large range of dynamic linearity from the analog circuits which usually results in expensive devices and high power consumption with lower efficiency where it operated with larger back-off to maintain linearity [9]. Apart from that, high PAPR will also causes additional interference, and induces bit error rate (BER) performance degradation [10]. These factors will reduce the system's efficiency as well as high cost of the system.

This chapter discussed the contribution being made by the significant literatures from numerous researchers for addressing the unsolved issues of PAPR. Several PAPR reduction schemes related in PAPR of OFDM system have been proposed in the literature, including signal predistortion techniques, coding techniques, and multiple signaling and probabilistic techniques [7]. Signal distortion techniques include clipping and filtering, peak windowing, companding, and peak cancellation. These techniques reduce the PAPR significantly, but they also introduce in-band and out-of-band distortion. Hence, a proposed method is introduced by using Principle Component Analysis (PCA) technique as a solution for this issue. PCA is used as a pre-processing step in the high PAPR by identifies the directions of most variation in the data set and it reduces the data down into its basic component. This chapter will elaborate more on PCA on how it can be used in PAPR.

2.2 Orthogonal frequency division multiplexing (OFDM)

Orthogonal frequency division multiplexing (OFDM) is a widely used modulation and multiplexing technology, which has become the basis of many telecommunications fields. The OFDM concept is based on spreading the data to be transmitted over a large number of carriers, each being modulated at a low rate. These sub-carriers or sub-channels divide the available bandwidth and are sufficiently separated in frequency or is known as frequency spacing so that they are orthogonal. The carriers are made orthogonal to each other by appropriately choosing the frequency spacing between them[11]. As the subcarriers are orthogonal, it ensures that the subcarriers do not interfere with each other, and at the same time, for higher system efficiency, they are packed densely in the spectrum without any frequency guard bands [12]. The frequency domain of an OFDM system is represented in the diagram below.

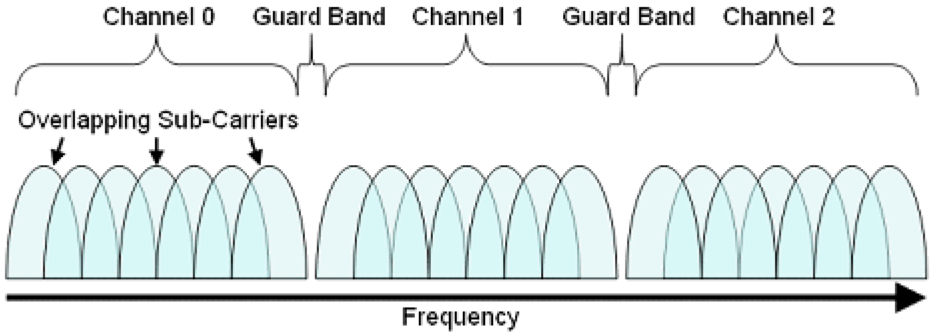

Figure 2. 1 Spectrum of an OFDM system

From Figure 2.1 above, there are seven sub-carriers for each individual channel. As the symbol rate increases as the channel bandwidth increases, this implementation allows for a greater data throughput than with an FDM system. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has a null at the centre frequency of each of the other carriers in the system. This results in no interference between the carriers, although their spectra overlap.

Each sub-channel's orthogonality in the OFDM system can be preserved through the staggered QAM technique[13]. However, the difficulty of sustaining orthogonality with an analog system emerges when a large number of subcarriers are required. The use of FFT technique to implement modulation and demodulation functions makes it computationally more efficient. OFDM systems have gained an increased interest during the last years. It is used in the European digital broadcast radio system, as well as in wired environment such as asymmetric digital subscriber lines (ADSL). This technique is used in digital subscriber lines (DSL) to provide high bit rate over a twisted-pair of wires

2.2.1 Evolution of OFDM

The idea for the implementation of OFDM systems evolved from the traditional Frequency Division Multiplexing (FDM) technique. From FDM, it evolved to Multicarrier Modulation (MCM) and then, Orthogonal Frequency Division Multiplexing.

2.2.1.1 Frequency Division Multiplexing

FDM technique is that in which a single channel is divided into various subchannels and each subchannel is modulated to separate symbol, after which it undergoes frequency multiplexing where each symbol is assigned different carrier frequencies in Figure 2.1.

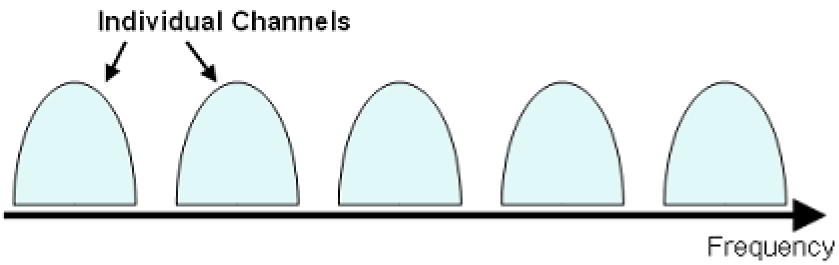

Figure 2. 2 Spectrum of an FDM system

Figure 2.1 shows the frequency domain of an FDM system. From the diagram that each channel operates a different carrier frequency and that these channels are bandlimited to operate within a defined bandwidth. These carrier systems are aligned such that they do not overlap with each other by inserting guard bits. Empty spectral regions which are placed in between sub carriers such that they do not overlap with each other with the help of filters at the receiver.

2.2.1.2 Multicarrier Modulation (MCM)

Multicarrier Modulation (MCM) is a form of FDM[14]. The basic principle of MCM is to split a high-rate data stream into a number of lower-rate streams that are transmitted simultaneously over a number of subcarriers[15]. OFDM is the most widely used form of MCM that plays an important role in today's mobile communication. In an MCM based communication system, the modulated carriers are summed for transmission, and must be separated in the receiver before demodulation.

2.2.1.3 Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is a multiplexing technique that subdivides the high-rate data stream into many parallel low-rate data streams which are modulated on orthogonal subcarriers [16]. OFDM offers the notion of single subcarrier modulation by using multiple subcarriers within the same single channel. Instead of conveying a high rate outflow of data with a single subcarrier, it utilizes a substantial number of parallel transmission of closely spaced orthogonal subcarriers. OFDM technique has been widely used for many of the latest wireless applications as well as telecommunication technologies such as DSL, Wi-Max, LTE and others due to its effective multicarrier modulations.

2.2.2 OFDM Features

The main features of a practical OFDM system are, some processing is done on the source data, such as coding for correcting errors, interleaving and mapping of bits onto symbols. An example of mapping used is QAM. Next, the symbols are modulated onto orthogonal sub-carriers. This is done by using IFFT. Moreover, orthogonality is maintained during channel transmission. This is achieved by adding a cyclic prefix to the OFDM frame to be sent. The cyclic prefix consists of the L last samples of the frame, which are copied and placed in the beginning of the frame. It must be longer than the channel impulse response. Apart from that, is synchronization as the introduced cyclic prefix can be used to detect the start of each frame. This is done by using the fact that the L first and last samples are the same and therefore correlated. This works under the assumption that one OFDM frame can be consider to be stationary. In addition, demodulation of the received signal by using FFT. Furthermore, channel equalization. The channel can be estimated either by using a training sequence or sending known so-called pilot symbols at predefined sub-carriers. Lastly, decoding and de-interleaving.

2.2.3 Advantages and Issues of OFDM

OFDM contribute numerous advantages for the technology of wireless communication system. Advantages of OFDM includes high spectral efficiency, robustness to the selective fading, immunity to inter-symbol interference(ISI), uniform average spectral density, capacity to handle very strong echoes, and lack of nonlinear distortion [17]. Moreover, it is implementation by fast Fourier transform (FFT), has low receiver complexity, high flexibility in terms of link adaption, and low complexity multiple access scheme[18].

Despite from the advantages contributed, OFDM has several drawbacks that needs to be consider. Some of the issues related to the wireless technologies are the high peak to average ratio (PAPR) and the sensitivity to phase noise and frequency offset [19]. Apart from that, other disadvantages of OFDM system are high synchronism accuracy, and