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PEAK TO AVERAGE POWER RATIO REDUCTION USING THE CLIPPING TECHNIQUE IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEM

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By

WAN HAFIZA WAN HASSAN

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To my dearest mother …

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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May 2006

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The demand for high-speed mobile wireless communications is rapidly growing. The orthogonal frequency division multiplexing (OFDM) technology promises to be a key technique for achieving the high data capacity and spectral efficiency requirements for wireless communication systems of the near future. With its natural resistance to multipath fading and its capability to support extremely high data rates, OFDM is a major candidate for a fourth generation system.

Despite many advantages of OFDM, it has two major drawbacks which are high peak to average power ratio (PAPR) and synchronization problem. A high PAPR causes saturation in power amplifiers, leading to intermodulation products among the sub carriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR by means of PAPR reduction schemes.

Clipping has been identified as the simplest yet effective technique of PAPR reduction. However, we have found out that clipping has resulted in the degradation of BER and enhanced the growth of out of band radiation leading to the degradation of the OFDM overall performance.

As a solution, we have proposed an enhanced OFDM system with the objectives of reducing the high PAPR values while minimizing the effects of clipping. The convolutional coding scheme is incorporated into the proposed system as a forward error control (FEC) scheme to improve the performance of BER in OFDM system. Besides, oversampled IFFT and digital filtering techniques are introduced into the system to minimize the out of band radiation (OOBR).

In this thesis, we have shown that the proposed system has significantly enhanced the BER performance and minimized the OOBR. However, there are a few trade-offs which affected the overall performance. Hence, we have identified the optimum designed parameters which have resulted in a maximum PAPR reduction and OOBR suppression capability of 9 dB and 52 dB respectively at the cut-off BER of 10^{-4}. In comparison to the existing proposed systems, our proposed system can be considered as one of the optimum system as it offers good PAPR reduction as well as OOBR suppression and comparable BER performance at the lowest value of SNR.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENGURANGAN KADAR KUASA PUNCAK KEPADA KUASA PURATA DENGAN TEKNIK PEMOTONGAN DALAM SISTEM PEMULTIPLEKSAN PEMBAHAGIAN FREKUENSI ORTOGONAL

Oleh

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Mei 2006

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Permintaaan untuk sistem komunikasi wayarles yang berkelajuan tinggi sedang meningkat naik dewasa ini. Teknologi OFDM berupaya menjadi teknik asa untuk mencapai keperluan kapasiti data dan keberkesanan spektrum yang tinggi. Dengan kekuatan semulajadi untuk menentang saluran fading pelbagai dan kemampuannya untuk menampung data yang berkadar sangat tinggi , sistem OFDM telah menjadi calon utama untuk sistem generasi ke-empat.

Terdapat dua masalah utama dalam sistem OFDM iaitu kadar kuasa puncak kepada kuasa purata (PAPR) yang tinggi dan juga masalah penyelarasan. Puncak dalam sampul isyarat yang tinggi akan menyebabkan ketepuan pada penguat kuasa dan seterusnya akan mengakibatkan produk intermodulasi antara sub-pembawa dan gangguan pada tenaga di luar jalur. Oleh yang demikian, teknik pengurangan puncak yang tinggi disyorkan untuk mengatasi masalah yang dinyatakan.

Teknik pemotongan telah dikenal pasti sebagai teknik yang paling senang dan berkesan dalam mengurangkan nilar PAPR yang tinggi. Namun demikian, kami mendapati teknik pemotongan ini telah mengakibatkan penurunan prestasi kadar ralat bit (BER) dan menggalakkan penumbuhan radiasi di luar jaluran yang akhirnya akan merendahkan prestasi keseluruhan sistem OFDM.

Sebagai jalan penyelesaian, kami mencadangkan satu sistem OFDM yang dipertingkatkan dengan objektif untuk mengurangkan nilai PAPR yang tinggi sambil mengurangkan kesan-kesan dari teknik pemotongan. Skim pengekodan konvulasi telah dicadangkan sebagai skim untuk mengawal kadar supaya nilai BER dapat dikurangkan di dalam sistem OFDM. Disamping itu, teknik pensampelan IFFT yang terlampau dan penapisan digital telah juga diperkenalkan untuk meminimumkan radiasi di luar jaluran.

Kami telah membuktikan bahawa sistem yang kami cadangkan telah berjaya meningkatkan prestasi BER dan mengurangkan radiasi di luar jaluran Namun begitu, terdapat beberapa faktor timbal balik yang memberi kesan kepada prestasi keseluruhan sistem OFDM. Justeru itu, kami telah mengenal pasti nilai optimum bagi setiap parameter dan hasilnya pengurangan nilai puncak sebanyak 9 dB telah dicapai dan radiasi diluar jaluran telah dikurangkan sebanyak 52 dB pada nilai kadar ralat bit 10^{-4}. Dibandingkan dengan sistem-sistem yang dicadangkan sebelum ini, ternyata sistem kami telah menunjukkan prestasi yang optimum dengan keupayaan mengurangkan nilai puncak kuasa dan radiasi di luar jaluran yang berkesan pada kadar ralat bit yang setanding dengan sistem-sistem yang lain pada nilai SNR yang paling rendah.

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
ADSL	Asymmetric Digital Subscriber Line
AM	Amplitude Modulation
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BIBO	Bounded Input Bounded Output
CDMA	Code Division Multiple Access.
DAB	Digital Audio Broadcast
DAC	Digital to Analog Converter
dB	Decibel
DMT	Dicrete Multiple Tone
DSL	Digital Subsriber Line
DSP	Digital Signal Processing
DVB-T	Terrestial Digital Video Broadcast
ETSI	European Telecommunication Standard
FDM	Frequency Division Multiplex
FEC	Forward Error Control Scheme
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FM	Frequency Modulation

FM	Frequency Modulation
GSTN	General Switched Telephone Network
HYPERLAN2	High Performance Local Area Network 2
ICI	Inter-carrier Interference.
IDFT	Inverse Dicrete Fourier Transform
IEEE	Institute of Electrical and Electronic Engineers
IFFT	Inverse Fast Fourier transform
IIR	Infinite Impulse response
IMT2000	International Mobile Telecommunications-2000
ISI	Intersymbol Interference
LAN	Local Area Network
LP	Linear Programming
MMAC	Mobile Multimedia Access Communication
OFDM	Orthogonal Frequency Division Multiplexing
OOBR	Out of Band Radiation
PAPR	Peak to Average Power Ratio
PSK	Phase Shift Key
PTS	Partial transmit Sequence
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Key
RMS	Root Mean Square
SFN	Single Frequency Network
SLM	Selective Mapping

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SNR	Signal to Noise Ratio
TI	Tone Injection.
TR	Tone Reservation
UMTS	Universal Mobile Telecommunication System.
W-CDMA	Wideband-CDMA

CHAPTER 1

INTRODUCTION

1.0 Background

Dreams are fast becoming reality in the world of mobile technology. As mobile radio systems evolved, the first generation analog mobile cellular systems soon had insufficient capacity to handle rapidly growing demand for mobile cellular services. As a solution, the second generation (2G) cellular communication systems were developed to increase the limited capacity of the first generation analog cellular mobile systems. Despite of offering voice telephony, these 2G systems are limited by very low bit transmission rates (9.6 kbps and 14.4 kbps) and incompatible global standards which are not suitable to cater the internet and other multimedia services [1-3].

Up to this stage, the mobile communication technology again faced with a new challenge of transferring multimedia and internet applications over digital mobile radio link. The emerging of the third generation (3G) mobile communication systems has met the challenge of transferring those demands. These 3G systems which are called as International Telecommunications-2000 (IMT-2000) or Universal Mobile Telecommunications System (UMTS) employed wideband-code division multiple access system (W-CDMA) and CDMA-2000 system.

Compared to the first and second generation mobile systems, the 3G system is capable of supporting global services with a high bit rate of 2 Mbps, high quality and higher terminal mobility. The higher data rate of 3G systems have opened the route for supporting a wide range of services and multimedia applications including voice communications, mobile videophones and fast internet access.

To date, 3G wireless networks are rolling out almost all over the world. Interest in streaming media and other high-speed wireless data applications are growing. To ensure wireless networks can meet future users demand and remain competitive for years to come, operators and manufacturers are now planning for the fourth generation (4G) mobile communication systems. These systems which are expected to have a wider bandwidth with bit rates of up to 100 Mbps able to support interactive multimedia services, teleconferencing and wireless. Other reasons for 4G systems include obtaining global mobility and service portability at a low cost. In comparison to 3G, 4G systems will be entirely packet-switched networks with all digital elements and have a tight network security [4].

Two different types of multi-carrier modulations have become candidates for 4G via the multi-carrier CDMA and orthogonal frequency division multiplexing (OFDM). The growing use of streaming media and other high-speed applications may allow OFDM based solutions to beat W-CDMA in the race for 4G dominance as reported in [6], CDMA technology on which current 3G networks are employed would not be able to support the greater bandwidth as the trend in broadband data towards wider channels.

However, CDMA still has a long way to evolve and it will be several years before vendors must switch to OFDM.

In future, OFDM technology is expected to be the key to cut down on the multipath distortion inherent in single-carrier cellular networks, leading toward greater spectral efficiency and ultimately broadband speeds unthinkable on today's networks [6]. As the technology's name implies, OFDM splits a single-carrier signal into multiple signals, dividing the transmitted data among them.

OFDM has a solution to this multipath distortion problem by dividing one extremely "fast" signal into numerous "slow" signals, each spaced apart at precise frequencies. While each of those individual sub-carriers is subject to the same multipath distortion faced by a single-carrier transmission, the data is traveling slowly enough that the effects of the distortion become negligible. The numerous slow transmissions are then all collected at the receiver and recombined to form one high-speed transmission.

Based on the above discussion, there is no doubt that OFDM has a very bright future in mobile communications system for years to come. Hence, in this thesis, an investigation into OFDM has been made and ways to improve the overall performance of OFDM system are experimented.

1.1 Motivation and Problem Statement

High peak to average power ratio (PAPR) has been recognized as one of the major practical problems in OFDM system apart from synchronization problem. This problem results from the nature of the OFDM itself where N sub-carriers are added to form one OFDM signal. When N sub-carriers are added in phase, the peak magnitude would have a value of N and results in peak power that is N times the average power. The average might be quite low due to destructive interference between the sub-carriers as some of them are added out of phase.

The problem of high peak amplitude excursions is most severe at the transmitter output due to its nonlinear component such as power amplifier. When the signal is applied to a transmitter which contains nonlinear power amplifier it could cause the degradation of transmitted OFDM symbols including spectral spreading, intermodulation, and changing the signal constellation.

One way to avoid such nonlinear distortion is to force the transmitter components to work in their linear region. For example, the digital to analog converter must have enough bits to accommodate the peaks and more importantly, the power amplifier must remain linear over an amplitude range that includes the peak amplitudes. This leads to both high cost and high power consumption which it is not an efficient solution especially for wireless communication systems [18].

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A better solution to this PAPR problem is by reducing the PAPR of the transmitted signal with some manipulations of the OFDM signal itself. This approach has encouraged many researchers to propose a variety of techniques for PAPR reduction. These varieties of techniques are classified into four types including coding, signal distortion, phase rotation and tone techniques. Among all the techniques, clipping which is one type of signal distortion technique has been identified as the simplest yet a very effective technique. However, clipping has caused the degradation of bit error rate (BER) and enhanced the growth of out of band radiation which resulted in the degradation of the overall performance of OFDM system.

Hence, it is needed to come out with an enhanced clipping technique to reduce the high PAPR and minimize the problems caused by clipping in order to improve the overall OFDM system performance.

1.2 Research Aim and Objectives

The aim of this research is to reduce the high PAPR by means of enhanced clipping technique while trying to minimize the effects of clipping. In order to achieve this aim, the following objectives have been set:

1. To identify the main problems encountered by OFDM system.
2. To analyze and compare the existing techniques of PAPR reduction schemes.
3. To study and verify the effects of clipping technique.