UNIVERSITI PUTRA MALAYSIA

A NEW SCHEME FOR REDUCTION OF PEAK-TO-A VERAGE POWER RATIO IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

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By

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Chairman: **Professor Borhanuddin Mohd Ali, Ph.D.**

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Orthogonal Frequency Division Multiplexing (OFDM) is an attractive modulation method for channels with a non-flat frequency response, as it saves the need for complex equalizers. However, its main disadvantage is the high peak-to-average power ratio (PAPR) of the output signal, which may take values within a range that is proportional to the number of carriers in the system. As a result, a linear behavior of the system over a large dynamic range is needed and therefore the efficiency of the output amplifier is reduced. Many methods have been proposed to reduce the PAPR of the OFDM signal, among them a clipping technique which has been focused and investigated.

OFDM signal, among them a clipping technique which has been focused and investigated.

This thesis proposes a new scheme to reduce the PAPR. We name it Off technique. Further the effects of clipping scheme as well as the new scheme on the OFDM system performance in terms of Bit Error Rate (BER) and PAPR reduction is investigated. The results obtained indicate that both parameters, i.e. the reduction in PAPR and BER of this scheme were worse than those of the Clipping Scheme. In conclusion, results indicate that Off Technique does not offer a better solution to PAPR reduction in the OFDM system.

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

SKIM BARU PENGURANGAN NISBAH KUASA PUNCAK-KE-PURATA DALAM OFDM

Oleh

AHMED MUSTAFA H. MELAD

Jun 2003

Pengerusi: **Profesor Borhanuddin Mohd Ali**

Fakulti: **Kejuruteraan**

Pemultipleksan Pembahagian Frekuensi Ortogonal (OFDM) adalah merupakan satu kaedah pemodulatan bagi saluran yang mempunyai respon frekuensi bukan-rata, kerana ia tidak memerlukan penyama-penyama(equalisers) yang kompleks. Walau bagaimanapun, kelemahannya yang utama adalah nisbah kuasa puncak-ke-purata (PAPR) yang tinggi dalam isyarat keluaran, yang mempunyai nilai dalam satu julat yang berkadaran dengan bilangan pembawa dalam sistem itu. Hasilnya, sifat lefarus sistem tersebut dalam satu julat dinamik yang besar adalah diperlukan dan oleh kerana itu, kecekapan pembesar keluaran menjadi berkurangan. Banyak kaedah telah dicadangkan untuk mengurangkan PAPR dari isyarat OFDM, antaranya, teknik pemotongan (clipping) yang telah diberi perhatian dan dikaji dalam tesis ini.

Selami dari ini, pemotongan dan skim baru itu ke atas prestasi sistem OFDM dari segi Kadar Ralat Bit (BER) dan pengurangan PAPR. Dikaji-Hasil yang didapati menunjukkan bahawa kedua-dua parameter, iaitu pengurangan PAPR dan BER, adalah lebih buruk dalam skim ini berbanding Skim Pemotongan. Sebagai kesimpulan, keputusan-keputusan menunjukkan bahawa Teknik Tutup tidak menawarkan penyelesaian yang lebih baik untuk mengurangkan PAPR dalam sistem OFDM.

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DECLARATION

I hereby declare that the thesis is based on my original work except for the quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Ahmed Mustafa H. Melad

Date:

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LIST OF ABBREVIATIONS

DS-CDMA	Direct Sequence Code Division Multiplexing Access
DMT	Discrete Multi Tone
ADSL	Asymmetric Digital Subscriber Line
DAB	Digital Video Broadcasting
LAN	Local Area Network
WLAN	Wireless Local Area Network
4G	Fourth Generation
DFT	Discrete Fourier Transform
QAM	Quadrature Amplitude Modulation
BPSK	Binary Phase Shift Keying
TDMA/TDD	Time Division Multiplexing Access
PAPR	Peak-to-Average Power ratio
BER	Bit Error rate
A/D-D/A converters	Digital-to-Analogue; Analogue-to-Digital
CF	Crest Factor
RF	Radio Frequency
SNR	Signal-to-Noise Ratio
PPC	Peak Power Clipping
VDSL	Very-high Digital Subscriber Line
HPA	High power amplifier
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference

ICI	Inter Carrier Interference
MCM	Multi Carrier Modulation
CDF	Cumulative Density Function
FEC	Forward Error Correction
OBO	Out Back Off
SC	Signal Carrier
BPF	Band Pass Filter
PER	Packet Error Rate

CHAPTER 1

INTRODUCTION

1.1 Background

Recently, there have been emerging demands for high-rate data transmission such as digital audio and video broadcasting, and multimedia communication in wireless environment. Therefore, it is expected that a commercial wireless network will be an available for high-rate communications in the near future. Orthogonal frequency division multiplexing (OFDM) is believed to be a possible candidate for high-rate data transmission in wireline and wireless communication since it exhibits robustness over frequency selective fading. The robustness is due to the fact that each subcarrier of OFDM systems has relatively narrow bandwidth compared with the coherent bandwidth of channel [1, 2 and 3]. Therefore, OFDM system doesn't need to adopt complex RAKE receiver which is an essential demodulator in direct sequence code division multiple access (DS-CDMA) system [4, 5] since each subcarrier signal of OFDM system eventually experience flat fading.

In the real world, OFDM has been adopted in various wireline and wireless applications as follows:

1- In wire line systems, OFDM, under the name of Discrete Multi-Tone (DMT), was adopted as an efficient technology for asymmetric digital subcarrier line

(ADSL) for its easy implementation, high performance, and low cost [6, 7]. The ADSL was first proposed in [8, 9], and supports a service of delivering high-rate half-duplex data to residential telephone customers with existing copper lines. Since server channel attenuation, inter-symbol interference, crosstalk, and impulse noise occur in an ADSL channel environment, an efficient modulation scheme is required in ADSL system, which results in the utilization of OFDM techniques.

2- For wireless systems, OFDM was proposed as multi-carrier modulation scheme in digital audio broadcasting (DAB) by the European telecommunication standards institute (ETSI) [10, 11]. The DAB systems provide reliable and rugged reception of high-quality audio services, including multimedia service, to mobile, portable and fixed receiver.

While present communication system are primarily designed for one specific application, such as speech on mobile telephone or high-data rate in wireless local area network LAN, the next generation of WBMCS is expected to provide its users with customer premises services that have information rates exceeding 2Mbps. Most WLAN systems currently use the IEEE802.11b standard, which provides a maximum data rate of 11 Mbps [12]. Supporting such a large data rates with sufficient robustness to radio channel impairmrnts, requires careful choosing of modulation techniques. The most suitable modulation choice seems to be orthogonal frequency division multiplexing OFDM. Newer WLAN standards such as IEEE802.11a [13] and HiperLAN2 [14, 15] are based on OFDM technology and provides a much higher data rate of 54 Mbps. However systems of the near future will require WLANs with data rates of greater than

100 Mbps, and so there is a need to further improve the spectral efficiency and data capacity of OFDM systems in WLAN applications. In response to this need, OFDM systems have been proposed to provide broadband communication at a reasonable cost.

OFDM can be seen as either a modulation technique or multiplexing technique. One of the main reasons to use OFDM is to increase the robustness against frequency selective fading or narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of the subcarriers will be affected.

1.2 Orthogonal Frequency Division Multiplexing (OFDM)

The name 'OFDM' is derived from the fact that the digital data is sent using many carriers, each of a different frequency (Frequency Division Multiplexing) and these carriers are orthogonal to each other.

1.2.1 Basic of OFDM

OFDM is an alternative wireless modulation technology to CDMA. It has the potential to surpass the capacity of CDMA systems and provide the wireless access method for 4G systems. It is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multipath environments. It transmits data by using a large number of narrow bandwidth carriers. These carriers are regularly spaced in frequency, forming a block of spectrum. The frequency spacing and time synchronization of the carriers is chosen in such a way that the carriers are orthogonal, meaning that they do not cause interference to each other. This is despite the carriers overlapping each other in the frequency domain. The comparison of the parallel transmission scheme with a single high rate data transmission is shown in Table 1.1. T_S is the symbol time, N number of subcarriers.

Table 1.1: Comparison of Parallel and Serial Transmission Schemes [16].

Transmission method	**Parallel**	**Serial**
Symbol time	Ts	Ts/N
Rate	1/Ts	N/Ts
Total BW required	2*N/Ts + N*0.1/Ts (Assume Guard band = 0.1/Ts)	2*N/Ts
Susceptibility to ISI	Less	More

From Table 1.1, shows that the major disadvantages of the parallel transmission scheme are that is bandwidth inefficient and that several modulators and demodulator blocks are required.

In OFDM, these problems are overcome by

1- Using orthogonal sub-carriers instead of widely spaced sub-carriers (i.e., carriers with guard band between them).

2- Using IFFT and FFT algorithms for implementing the modulation and demodulation operations.

1.2.2 History of OFDM

The origins of OFDM development started in the late 1950's [17] with the introduction of Frequency Division Multiplexing (FDM) for data communications. In 1966 Chang patented the structure of OFDM [18] and published [19], the concept of using orthogonal overlapping multi-tone signals for data communications. In 1971 Weinstein [20] introduced the idea of using a Discrete Fourier Transform (DFT) for implementation of the generation and reception of OFDM signals, eliminating the requirement of banks for analog subcarrier oscillators. This presented an opportunity for an easy implementation of OFDM, especially with the use of Fast Fourier Transforms (FFT), which was an efficient implementation of the DFT. Recently the advances in integrated circuit technology have made the implementation of OFDM cost effective. The reliance on DSP prevented the wide spread use of OFDM during the early development of OFDM. It wasn't until the late 1980's that work began on the development of OFDM for commercial use, with the introduction of the Digital Audio Broadcasting (DAB) system. Development of the European HiperLAN2 standard was started in 1995, with the standard of HiperLAN2 being defined in June1999. HiperLAN2 pushes performance of WLAN systems, allowing a data rate of up to 54 Mbps [21]. HiperLAN2 uses 48 data and 4 pilot subcarriers in a 16 MHZ channel, with 2 MHz on either side of the signal to allow out of band roll off. User allocation was achieved by using TDM, and subcarriers were allocated using a range of modulation schemes, from BPSK up to 64-QAM, depending on the link quality.

Forward Error Correction was used to compensate for frequency selective fading. Since the physical layer of HiperLAN2 is very similar to the IEEE802.11a standard these examples are applicable to both standards.

Table 1.2 Summary of Characteristics of IEE802.11b, IEEE802.11a and HiperLAN2. Derived From [21].

Standard	802.11b	802.11a	HipeLAN2
Spectrum	2.4 GHz	5.2GHz	5.2GHz
Modulation Technique	DSSS	OFDM	OFDM
~ Max physical rate	11Mbps	54Mbps	54Mbps
~ Max data rate, layer3	5Mbps	32Mbps	32Mbps
Medium access control	CSMA/CA	Add Hoc	TDMA/TDD
Connectivity	Connectivity less	Connectivity less	Connectivity orientated