MITIGATING INTER-CARRIER INTERFERENCE IN ORTHOGONAL FREQUENCY DIVSION MULTIPLEXING SYSTEM USING SCALED ALPHA PULSE SHAPING TECHNIQUE

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Dedicated, in thankful appreciation for support, encouragement and understandings to my beloved mother, father, brothers and sisters.

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique for broadband wireless communication system, especially in fourth-generation (4G) applications. However, a special problem in OFDM is its vulnerability to frequency offset errors due to which the orthogonality is destroyed that results in Inter-Carrier Interference (ICI). ICI causes power leakage among subcarriers, thus degrading overall system performance. ICI is severe and often difficult to remove because the properties of additive noise vary for different carriers. Pulse shaping is among the techniques used to reduce ICI effect. In this thesis, a new pulse shape namely, Scale Alpha for ICI mitigation in OFDM system is proposed. The pulse is modelled and simulated using Matlab software. The pulse performance in reducing ICI is compared to the Franks pulse which is also known as the best pulse among Nyquist pulses. Impulse response, eye diagram, and ICI power reduction performances have also been carried out. The result shows 76.93 dB of ICI reduction compared to the Franks pulse when alpha is equal to 1. This advantage of new Scale Alpha pulse can be applied in the applications of wireless model system especially in 4G applications.

ABSTRAK

Frekuensi Ortogon Pembahagi Multipleks (OFDM) adalah teknik yang menjaminkan untuk sistem komunikasi tanpa wayar jalur lebar terutama di dalam aplikasi generasi keempat (4G). Walau bagaimanapun, masalah yang khusus di dalam OFDM ialah kerintangannya terhadap kesalahan frekuensi imbangi kerananya yang keortogonan ini hancur akibat campur tangan Gangguan Antara Pembawa (ICI). ICI menyebabkan kebocoran kuasa di kalangan sub-pembawa sehingga menjatuhkan prestasi sistem. ICI adalah tidak bagus dan sukar untuk dibuang kerana sifat-sifat bunyi tambahan bagi pembawa yang berbeza. Pembentukan denyut nadi ini adalah antara teknik yang digunakan untuk mengurangkan kesan ICI. Dalam projek ini, kami mencadangkan satu bentuk denyut nadi baru iaitu skala alpha untuk mengurangkan ICI dalam sistem OFDM. Denyut nadi ini dimodelkan dan diselakukan menggunakan Matlab. Keputusan dan perbincangan dibuat untuk menganalisis bentuk denyut nadi baru dalam pengurangan ICI dengan membandingkannya dengan denyut Franks yang juga dikenali sebagai denyut yang terbaik di antara denyut Nyquist dari segi prestasi balas impuls, gambarajah mata dan pengurangan ICI. Keputusan menunjukkan 76.93dB ICI pengurangan berbanding dengan nadi Frank apabila alpha yang digunakan adalah 1. Kelebihan denyut baru Skala Alfa boleh di aplikasikan dalam sistem tanpa wayar terutamanya dalam generasi keempat (4G).

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LIST OF SYMBOLS

α	-	alpha
T	-	period
T_u	-	time spacing
Π	-	pi
f_c	-	carrier frequency
N	-	subcarrier number
$1/T$	-	frequency spacing
θ	-	phase error
Δf	-	carrier frequency offset
S_m	-	transmitted symbol
f	-	frequency
β	-	beta
N	-	number of subcarrier
s	-	scale

LIST OF ABBREVIATIONS

3GPP	-	3^{rd} Generation Partnership Project
4G	-	Fourth-generation
ADSL	-	Asymmetric Digital Subscriber Line
AMPS	-	Advanced Mobile Phone System
AUC	-	Aunthentication Centre
AWGN	-	Additive White Gaussian Noise
BEM	-	Basic Expansion Model
BER	-	Bit Error Rate
CDMA	-	Code Division Multiple Access
CFO	-	Carrier Frequency Offset
COFDM	-	Coded Orthogonal Frequency Division Multiplexing
CP	-	Cyclic prefix
DAB	-	Digital Audio Broadcasting
DFT	-	Discrete Fourier Transform
DMT	-	Discrete Multi Tone
DVB	-	Digital Video Broadcasting
GSM	-	Global System for Mobile Communication
HFC	-	Hybrid Fiber Control
HiperLAN2	-	High performance Local Area Network
HLR	-	Home Location Register
HSDPA	-	High-speed Downlink Packet Access

ICI	-	Inter-carrier Interference
IEEE 802.11	-	IEEE wireless LAN protocol
IMT-2000	-	International Mobile Telecommunication 2000
Mbps	-	Mega Bit per second
MB	-	Mega Byte
MHz	-	Mega Hertz
MIMO	-	Multiple Input Multiple Output
MSC	-	Mobile Switching Centre
NMT	-	Nordic Mobile Telephone
OFDM	-	Orthogonal Frequency Division Multiplexing
PDC	-	Personal Digital Communication
SFO	-	Sampling Frequency Offset
SIR	-	Signal to Interference ratio
SNR	-	Signal to Noise ratio
TACS	-	Total Access Communication System
UMTS	-	Universal Mobile Telephone System
Wi-Bro	-	Wireless Broadband
Wi-Fi	-	Wireless Fidelity
WiMAX	-	Worldwide Interoperability for Microwave Access

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CHAPTER 1

INTRODUCTION

1.1 Project Background

In the last few years, multicarrier transmission techniques such as orthogonal frequency division multiplexing (OFDM) have emerged as the leading candidate for higher-data-rate transmission. Historically, these techniques have been applied to applications where time-selectivity can be effectively ignored [1]. OFDM applications on multicarrier systems for high speed channels have become increasingly important. Signal transmission is normally accompanied by loss of orthogonality of subcarriers resulting in inter-carrier interference (ICI). When ICI is not present, the channel matrix is diagonal (orthogonal), and hence channel estimation can be achieved by matrix inversion. Under this condition, channel equalization is uncomplicated. In the presence of ICI, the channel is no longer diagonal and channel estimation becomes a severe problem. ICI creates an off-diagonal in the channel coefficient [2], making channel equalization, which is associated with inversion of a channel matrix to be very complex [1].

OFDM techniques have been applied to situations where time-selectivity can be effectively ignored. However, the need for high speed transmission has made it critical to overcome the loss of orthogonality in OFDM subcarriers in order to reduce ICI which creates an off-diagonal channel matrix. In this way, the accuracy of channel estimation and equalization can be enhanced. ICI can be reduced using methods such as complexity reduction and basis expansion model (BEM). A direct method of eliminating ICI is through the use of pulse shaping to reduce out-of-band emissions and to minimize the sensitivity of the transmitted signal to interference and synchronization errors. This implies a process of identifying transmit and receive pulses, which have values close to eigen functions of the channel and thus approximately diagonalizing the channel matrix.

In order to identify such pulses, one needs to know the relationship between the channel spread and the pulse parameters. This information can be obtained if the channel is assumed to introduce some uncertainty (randomness) to the transmitted pulses. Conventional Heisenberg uncertainty principle defines Gaussian pulse as optimal. This study proposes a method of overcoming ICI in OFDM system using a novel eigen structure based on the uncertainty principle of affine groups. The eigen function of the derived eigen structure can provide approximate eigen pulses for very dispersive channel and can be used to eliminate off-diagonal elements of the channel matrix. This idea can also provide an insight to the way in which appropriate BEM can be used for ICI suppression. Multiple input multiple output (MIMO) OFDM requires training before optimal ICI estimation and equalization. Training process is an issue which will be defined and discussed in subsequent sections.

1.2 Problem Statement

ICI creates an off-diagonal channel matrix which is not desired as it affects the accuracy of channel estimation and equalization. To solve this problem, methods such as complexity reduction and the use of basis expansion model (BEM) have been considered. However, a direct method of eliminating ICI would be the use of pulse shaping on the transmitted signal to reduce emissions from adjacent bands and interference due to synchronization errors. The pulse shaping process provides a way of finding transmit and receive pulses, which can closely approximate the channel eigen functions so that the channel matrix can be altered to a form which can be considered diagonal.

Implementation of OFDM experiences several problems. These problems are (a) difficulties in synchronization, (b) interference due to phase noise. For proper synchronization, correct sampling of the incoming received signal is important. Without correct sampling of the incoming received signal, it will not be possible for the fast Fourier transform process at the receiver to recover the received data from the carriers correctly. Interference due to phase noise is normally caused by the receiver local oscillator which introduces phase noise to OFDM received signal. Common Phase Error (CPE) and ICI are two unwanted effects of the phase noise. CPE is a result of the rotation of the signal constellation while ICI introduces problems akin to additive Gaussian noise. ICI is severe and often difficult to remove because the properties of additive noise vary for different carriers.

1.3 Objectives

The objectives of this research are:

i) To propose a new pulse shaping method named scale alpha for wireless OFDM system.

ii) To model the mathematical expression of the proposed pulse shaping method in Matlab environment.

iii) To analyze the proposed scale alpha pulse has an optimum shape (having clear eye diagrams) which reduces ICI and enhances the performance of OFDM system.

1.4 Scope of Work

The scopes of work are listed as follows:

i) Matlab software is used to model the mathematical expression for new pulse shaping technique called the scale alpha pulse.

ii) The optimum value of alpha will be determined to reduce inter-carrier interference (ICI) of OFDM signal.

iii) The new pulse impulse response performance is compared to Franks, Raised Cosine and Double Jump pulse.

iv) Performance analysis of the new pulse shape, particularly regarding two parameters that are inter-carrier interference (ICI) power reduction and eye diagrams are carried out.

1.5 Thesis Outlines

The thesis consists of five chapters. The background and objectives of the project are presented in Chapter 1 and will be used to address all the research questions.

Chapter 2 presents the basic principle of OFDM used in fourth generation (4G) wireless system. In this chapter a proposed modified version of OFDM is also reviewed and described. A comparison is made between the proposed method of overcoming ICI with those which have been suggested by previous researchers. In this chapter, various methods of improving the performance of the OFDM are suggested after viewing the system model pros and cons. It is also felt necessary to discuss an overview of the wireless telecommunication systems, especially 1G, 2G, 3G and 4G to assist in the understanding of problems associated with the implementation of OFDM for wireless system.

Chapter 3 describes the methodology of system model design. The model system flow would be explained in this chapter. It would explain the design process (via simulation coding) adhered to from start to finish. Through system simulation, the transmission and receiving process of the proposed OFDM (from input data until the measurement component) is explained step by step. Design of system model has been implemented using Matlab software. Matlab software used in the simulation of the overall project is explained. The parameter provided by this software is revealed.

The results and discussions are presented in Chapter 4. This chapter discusses design, simulation and analysis of data. This is the most crucial chapter in this thesis, because from there it is possible to predict and determine through analytical calculations, which of the model systems is more accurate and gives the desired advantages. Analysis of data and creation of graphs illustrates three parameters, which are ICI power reduction, impulse response performance and eye diagrams.

Chapter 5 presents the conclusions derived from the overall project. This final chapter answers whether the project has successfully accomplished the project objectives spelt out. This chapter briefly suggests further research works which can be carried out with the hope that further improvement can be suggested for the proposed system model.

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