

國立交通大學

電信工程學系

碩士論文

正交分頻多工存取系統上傳連結之干擾消  
除方法

Interference Cancellation Schemes of  
OFDMA Up-Link System

研究生：陳啟豪

指導教授：紀翔峰

中華民國九十五年十月

# 正交分頻多工存取系統上傳連結之干擾消除方法


研究生： 陳啓豪

指導教授：紀翔峰 博士

國立交通大學

電信工程學系碩士班

## 摘要



近來正交分頻多工存取系統(OFDMA)已經吸引廣泛的注目，由於當此系統提供可靠的多工存取同時也提供了極佳的頻譜效益和能對抗多路徑傳輸之影響。然而載波頻率偏差(CFO)發生在正交分頻多工存取系統當中，會破壞子載波之間的正交性進而產生子載波之間干擾(ICI)和多用戶存取干擾(MAI)；子載波之間干擾以及多用戶存取干擾會使系統的表現下降。在此篇論文當中，作者將提出兩種干擾消除方法:區塊平行干擾消除(Block Parallel Interference Cancellation)和區塊連續干擾消除(Block Successive Interference Cancellation)來解決載波頻率偏差在正交分頻多工存取系統之上連結問題。此兩方法皆是使用在區塊正交分頻多工系統上。在模擬結果可知，此兩方法皆是多級干擾消除架構而能夠有效的壓抑子載波之間干擾和多用戶存取干擾。再者可以利用 Trench 演算法來搭配實現 Toeplitz 反矩陣進而只需要  $O(3n^2)$ 的運算量。良好的系統表現和合理的運算量將使這兩個方案在系統實現上更具吸引力。

# Interference Cancellation Schemes of OFDMA

## Up-Link System

Student: Chi-Hau Chen    Advisor: Dr. Hsiang-Feng Chi

Department of Communication Engineering

National Chiao Tung University

### Abstract

The technique of Orthogonal Frequency Division Multiple Access (OFDMA) had caused much attention recently because of the excellent bandwidth efficiency and the ability of combating multi-path effects while providing reliable multiple access capability. The Carrier Frequency Offsets (CFOs) in the OFDMA system destroys the orthogonality among the subcarriers and results in the, Inter-Carrier Interference (ICI) and the Multiple Access Interference (MAI). Without proper resolution, the ICI and the MAI will degrade the system performance. In this thesis, we present two interference cancellation schemes: Block Parallel Interference Cancellation (BPIC) and Block Successive Interference Cancellation (BSIC), to solve the CFOs problem in the OFDMA uplink receiver. These two schemes are based on the block based OFDMA system. The simulation results show that the proposed methods can effectively suppress the ICI and the MUI by using multistage cancellation. In addition, we make use of the Trench algorithm to save the computation complexity of the Toeplitz matrix inversion required in the proposed algorithms, The Trench algorithm needs only  $O(3n^2)$ . Good performance and reasonable computation requirement of the proposed algorithm are attractive in the practical system implementation.

## 誌謝

光陰似箭，短短兩年碩士班的研究生涯，以此論文之告成，即將劃上句號。在這兩年裡，首當感謝指導教授 紀翔峰老師於研究以及論文上給予充分且詳實的指導與教誨鼓勵，老師嚴謹認真的研究態度以及鼓勵學生的用心，令學生受益匪淺。

其次感謝交通大學電信系教授 黃家齊老師和 謝世福老師擔任口試委員的指導與建議，在此也表現由衷的感謝。

衷心的感謝實驗室的俊傑學長和喆祥學長，給予研究上的指導，給予學弟們許多的幫助，也感謝實驗室的夥伴們這兩年來的陪伴相隨，一起走過這艱苦的研究生涯，互相幫助扶持才能成就順利的碩士生涯，也共同度過許多快樂的時光，更有了難忘的回憶，謝謝你們。

最後，要特別感謝我的父母以、家人還有女友，感謝父母的辛苦栽培以及默默付出，使得我得以全心投入學業。再次衷心的謝謝以上諸位，由於你們的幫忙，此論文得以完成，衷心感謝。

僅以此篇論文獻給對我付出關心的你們。

民國九十五年十月

研究生陳啓豪謹識於交通大學

# INTERFERENCE CANCELLATION SCHEMES OF OFDMA UP-LINK SYSTEM

## -TABLE OF CONTENTS-

<b>1</b>	<b>Introduction .....</b>	<b>1</b>
1.1	Motivation .....	3
1.2	Organization .....	3
1.3	Overview of the OFDM System .....	4
1.3.1	OFDM signal characteristics .....	5
1.3.2	Guard interval and Cyclic Prefix .....	8
1.4	Overview of the OFDMA System .....	11
1.4.1	Architectures of the OFDMA System .....	12
1.4.2	The OFDMA Signal Model of the Proposed Architecture .....	16
<b>2</b>	<b>The Carrier Offset Problem in the OFDMA System .....</b>	<b>20</b>
2.1	Carrier Frequency Offset of OFDM system .....	20
2.2	Methods of Reducing Interference due to Carrier Frequency Offset in OFDM System .....	24
2.3	Carrier Frequency Offset of OFDMA System .....	26
2.4	Methods of Reducing Interference due to Carrier Frequency Offset in OFDMA System .....	31
<b>3</b>	<b>Block Based Carriers Frequency Offset Cancellation Schemes .....</b>	<b>35</b>
3.1	Block Parallel Interference Cancellation .....	37

3.2	Block Successive Interference Cancellation .....	39
3.3	Computation to Inversion of Toeplitz Matrix .....	43
3.3.1	Toeplitz matrix .....	43
3.3.2	Trench algorithm .....	44
<b>4</b>	<b>Computer Simulations and Observations .....</b>	<b>46</b>
4.1	Ideal Inversion .....	46
4.1.1	Vary CFO Sets ,fix SNR .....	46
4.1.2	Vary SNR ,fix CFO Sets .....	50
4.2	Inversion with Trench Algorithm .....	52
4.2.1	Vary CFO Sets ,fix SNR .....	53
4.2.2	Vary SNR ,fix CFO Sets .....	55
4.2.3	Multistage Iteration .....	57
<b>5</b>	<b>Conclusion and Future Work .....</b>	<b>58</b>
5.1	Conclusion .....	58
5.2	Future Work .....	59
<b>6</b>	<b>Reference .....</b>	<b>60</b>

# LIST OF FIGURES

## Chapter 1

Figure 1.3.0.1	Spectrum of FDM and OFDM .....	4
Figure 1.3.1.1	OFDM signal concept .....	5
Figure 1.3.1.2	Structure of discrete-time OFDM modulation system .....	6
Figure 1.3.1.3	Structure of discrete-time OFDM demodulation system ....	6
Figure 1.3.2.1	Silence Guard interval .....	7
Figure 1.3.2.2	ICI caused by silent guard interval with delay spread .....	7
Figure 1.3.2.3	Structure of complete OFDM signal with guard interval ....	8
Figure 1.3.2.4	(a) OFDM Transmitter (b) OFDM Receiver .....	8
Figure 1.4.1.1	(a) Transmitters and channels in uplink of OFDMA (b) Receiver of based station (single user based) .....	13
Figure 1.4.1.2	Block diagram of filter bank OFDMA system .....	14
Figure 1.4.1.3	Block diagram of uplink proposed OFDM system .....	16
Figure 1.4.2.1	Block diagram of depermutation and its mathematical expression .....	19

## Chapter 2

Figure 2.1.1	Carrier frequency offset between TX and RX .....	20
Figure 2.1.2	Amplitude of interference to difference carrier frequency offset .....	22
Figure 2.1.3	(a) The image of interference matrix in OFDM (b) The mesh of interference matrix in OFDM .....	24
Figure 2.2.1	Windowing to reduce sensitivity to frequency offset .....	25
Figure 2.3.1	Concept of CFO in OFDMA uplink .....	26
Figure 2.3.2	Simplified OFDMA uplink system with CFOs .....	27

Figure 2.3.3	Image of interference matrix in OFDMA system .....	29
Figure 2.3.4	Mesh of amplitude to interference matrix in OFDMA system .....	30
Figure 2.4.1	Block diagram of successive interference cancellation in OFDMA system .....	32

### Chapter 3

Figure 3.0.1	Concept of conventional multistage detection (two stages type) .....	35
Figure 3.0.2	Receiver at the base station of OFDMA uplinkv .....	36
Figure 3.1.1	Block diagram of block parallel interference cancellation..	38
Figure 3.2.1	Block diagram of BSIC the first iteration .....	40
Figure 3.2.2	Block diagram of block successive interference cancellation .....	41

### Chapter 4

Figure 4.1.1.1	Symbol Error Rate to varying CFO sets, U=4, Rayleigh fading channel tapes=4 .....	47
Figure 4.1.1.1	Symbol Error Rate to varying CFO sets, U=U, Rayleigh fading channel tapes=4 .....	48
Figure 4.1.2.1	Symbol Error Rate to SNR(dB), U=4, CFO=[ 60 20 70 10], Rayleigh fading channel tapes=4 .....	50
Figure 4.1.2.2	Symbol Error Rate to SNR(dB), U=8, CFO=[40 20 70 10 65 25 75 15], Rayleigh fading channel tapes=4 .....	51
Figure 4.2.0	MMSE to different CFO, Trench Algorithm block size 8 by 8 .....	52
Figure 4.2.1.1	Comparison Trench algorithm and ideal inversion, Symbol Error Rate to varying CFO sets, U=4, varying CFO sets,	



	Rayleigh fading channel tapes=4 .....	53
Figure 4.2.1.2	Comparison Trench algorithm and ideal inversion, Symbol Error Rate to varying CFO sets, U=8, varying CFO sets, Rayleigh fading channel tapes=4 .....	54
Figure 4.2.2.1	Comparison Trench algorithm and ideal inversion, Symbol Error Rate to SNR (dB) sets, U=8, CFO=[ 40 -50 60 -50], Rayleigh fading channel tapes=4 .....	55
Figure 4.2.2.2	Comparison Trench algorithm and ideal inversion, Symbol Error Rate to SNR (dB) sets, U=8, CFO=[ 20 -50 60 -55 40 -50 60 -25 ], Rayleigh fading channel tapes=4 .....	56
Figure 4.2.3.1	Performance of iteration in second stage, Symbol Error Rate to SNR, U=4, CFO=[60 20 70 10], Rayleigh fading channel, tapes=4 .....	57

