Low Complexity Adaptive Iterative Receivers for Layered Space-Time Coded and CDMA Systems

Chakree Teekapakvisit

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Telecommunications Research Group
School of Electrical and Information Engineering

The University of Sydney
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Abstract

In this thesis, we propose and investigate promising approaches for interference mitigation in multiple input multiple output (MIMO) and code division multiple access (CDMA) systems. Future wireless communication systems will have to achieve high spectral efficiencies in order to meet increasing demands for huge data rates in emerging Internet and multimedia services. Multiuser detection and space diversity techniques are the main principles, which enable efficient use of the available spectrum. The main limitation for the applicability of the techniques in these practical systems is the high complexity of the optimal receiver structures.

The research emphasis in this thesis is on the design of a low complexity interference suppression/cancellation algorithm. The most important result of our research is the novel design of interference cancellation receivers which are adaptive and iterative and which are of low computational complexity.

We propose various adaptive iterative receivers, based on a joint adaptive iterative detection and decoding algorithm. The proposed receiver can effectively suppress and cancel co-channel interference from the adjacent antennas in the MIMO system with a low computation complexity. The proposed adaptive detector, based on the adaptive least mean square (LMS) algorithm, is investigated and compared with the non-adaptive iterative receiver. Since the LMS algorithm has a slow convergence speed, a partially filtered gradient LMS (PFGLMS) algorithm, which has a faster convergence speed, is

proposed to improve the convergence speed of the system. The performance and computational complexity of this receiver are also considered.

To further reduce the computational complexity, we apply a frequency domain adaptation technique into the adaptive iterative receivers. The system performance and complexity are investigated. It shows that the computational complexity of the frequency domain based receiver is significantly lower than that of the time domain based receiver with the same system performance.

We also consider applications of MIMO techniques in CDMA systems, called MIMO-CDMA. In the MIMO-CDMA, the presence of the co-channel interference (CCI) from the adjacent antennas and multiple access interference (MAI) from other users significantly degrades the system performance. We propose an adaptive iterative receiver, which provides the capability to effectively suppress the interference and cancel the CCI from the adjacent antennas and the MAI from other users so as to improve the system performance. The proposed receiver structure is also based on a joint adaptive detection and decoding scheme. The adaptive detection scheme employs an adaptive normalized LMS algorithm operating in the time and frequency domain. We have investigated and compared their system performance and complexity. Moreover, the system performance is evaluated by using a semi-analytical approach and compared with the simulation results. The results show that there is an excellent agreement between the two approaches.

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Invaluable encouragement came from my discussions with my fellow colleagues at The University of Sydney. I am grateful to Dr. Tracy Tung who was a senior student when I first started my study. She encouraged and gave suggestions to me to continue my study during the early years. I am very grateful to my colleagues, Yang Tang, Agus Satoso for their help on many occasions to resolve problems and for discussion on various technical issues. I would like to thank all other colleagues in the Telecommunications Laboratory for making my stay at The University of Sydney a pleasant one.

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Statement of Originality

The novel research results reported in this thesis represent original work by the author. The present results depend on the numerous results from well known references as well as on results from the recent publications. None of the content of this thesis has been previously submitted for consideration for a degree or any qualification. Some results have been published, submitted or are in preparation for publication in technical journals or conference proceedings.

All the results presented in this thesis were achieved under the guidance and instruction of the thesis supervisor Professor Branka Vucetic. The results concerning adaptive iterative receiver structures were formulated in co-operation with Professor Branka Vucetic, Dr. Van D. Pham and Dr. Yonghui Li.

Chapter 3, “Time-domain Adaptive Iterative Receiver for coded MIMO systems” introduces the concept of applying a least mean square (LMS) and a partially filtered gradient LMS (PFGLMS) algorithm in an adaptive iterative receiver for a multi input multi output (MIMO) system. We propose and develop an adaptive iterative receiver based on the adaptive least mean square (LMS) algorithm operating in time domain. Because of the slow convergence speed of the LMS algorithm, the PFGLMS algorithm, which has a faster convergence speed, is applied in the LMS based adaptive iterative

receiver. The proposed adaptive iterative receiver is able to reduce the computational complexity and provide an acceptable system performance. The adaptive schemes, based on the LMS and PFGLMS algorithm, are proposed to as a means of achieving a low computational complexity receiver. A comparison of system performance and complexity is made with that of the non-adaptive iterative MMSE receiver. The results, analysis and conclusions are original contributions by the author. This material appeared in published papers [1] and [2].

Chapter 4, " Frequency Domain Adaptive Iterative Receiver for Space-Time Coded MIMO Systems" describes an original idea by the author. It consists of applying a frequency domain adaptive algorithm in the adaptive iterative receiver. The idea is to reduce the computational complexity of the system while presenting a satisfactory system performance by performing a convolution in the frequency domain. This significantly reduces the complexity compared to the time domain approach. The results show that the proposed receivers have the same performance as their counterparts operating in the time domain. The computational complexity of the proposed frequency domain receiver is up to 75% lower than that of the time domain approach.

Chapter 5, The " Time Domain Adaptive Iterative Receiver for the Layered Space-time Coded CDMA system" presents the proposed adaptive iterative receiver for the MIMO-CDMA system. The adaptive iterative receiver, based on an adaptive normalized LMS (NLMS) algorithm, is proposed. Although, the NLMS has been recognized for a number of years, it is the first time it is applied in adaptive iterative MIMO-CDMA receiver systems. The proposed receiver employs a suppression and cancellation technique to efficiently suppress and remove the co-channel interference (CCI) and multiple access interference (MAI) from the received signal. The system performance is evaluated by using a semi-analytical approach and comparing them to the simulation results. This investigation was inspired by discussion with Dr. Yonghui Li. The results show that the performance of the system approaches the single user's interference-free bound. The results, which are contributions by the author, were partly published in [3, 4].

Chapter 6, The " Frequency Domain Adaptive Iterative Receiver for Layered Space-time Coded CDMA system" describes a frequency domain adaptive iterative CDMA receiver. The receiver structure is modified from the time domain adaptive receiver (presented in Chapter 5) but operates in the frequency domain. The main advantage of the proposed receiver is a computational complexity reduction. Results of this research on the novel application of the adaptive algorithm of the frequency domain receiver appeared in [3, 4]. Publications that are a result of the research results of this thesis are listed below.

Publications

[1]C. Teekapakvisit, V. D. Pham, and B. Vucetic, "An Adaptive Iterative Receiver for Space-time coding MIMO Systems," *3rd Workshop on the Internet, Telecommunications and Signal Processing*, 2004.

[2]C. Teekapakvisit, V. D. Pham, and B. Vucetic, "An Adaptive Iterative Receiver for Space-time coding MIMO Systems," to be appeared in *Journal of Telecommunications and Information Technology (JTIT)*, vol. 1/2006, 2006.

[3]C. Teekapakvisit, Y. Li, V. D. Pham, and B. Vucetic, "Frequency domain adaptive iterative receiver for layered space-time coding CDMA systems," presented at Signal Processing and Its Applications, 2005. Proceedings of the Eighth International Symposium on, 2005.

[4]Teekapakvisit C, Li Yonghui, Pham V. D., and V. B., "Low Complexity Adaptive Iterative Receiver for Layered Space-time Coding CDMA Systems," *submitted to The Institute of Electronics, Information and Communication Engineering(IEICE), Japan*, 2006.

List of Acronyms

AWGN	additive white Gaussian noise
BER	bit error rate
BLAST	bell-laboratory layered space-time
CCI	co-channel interference
CDMA	code division multiple access
CIR	channel impulse response
CSI	channel state information
D-BLAST	diagonal BLAST
DLST	diagonally layered space-time
DS-CDMA	direct sequence CDMA
FDMA	frequency division multiple access
FIR	finite impulse respond
H-BLAST	horizontal BLAST
HLST	horizontally layered space time
i.i.d.	independent and identically distributed
ISI	interference symbol interference
LLR	log-likelihood ration
MAC	multiple access channel
MAI	multiple access interference
MAP	maximum a posteriori
MF	matched filter
MIMO	multiple input multiple output
ML	maximum likelihood
MMSE	minimum mean square error
OSIC	ordered successive interference canceller
PIC	parallel interference canceller
PN	pseudo-noise
SINR	signal to interference plus noise
SISO	single input single output
SM	spatial multiplexing
T-**BLAST**	threaded BLAST
TDMA	time division multiple access
V-BLAST	vertical BLAST
ZF	zero forcing