REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
15-07-2009	Final Report	1-Jul-2005 - 30-Jun-2009

4. TITLE AND SUBTITLE
ARO Grant W911NF0510382 Final Report

Optimal Transmission Diversity for High-Speed Wireless Communication Systems Under Adverse Environment

5a. CONTRACT NUMBER
W911NF-05-1-0382

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
611102

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSOR/MONITOR'S ACRONYM(S)
ARO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
47584-NS.21

12. DISTRIBUTION AVAILIBILITY STATEMENT
Approved for public release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
High speed wireless mobile communication systems have become increasingly important in battlefield command/control and in sensor network systems for national defense and security. The project investigates advanced design of bandwidth efficient retransmission diversity in multi-input-multi-output (MIMO) wireless communication systems. We develop optimization techniques in (hybrid) ARQ and MIMO precoding for robust, progressive, adaptive, and scalable diversity. We focus on OFDM as the underlying broadband signal modulation.

15. SUBJECT TERMS
MIMO wireless, integrative transceivers, bandwidth efficiency.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Zhi Ding
U	U	U	SAR		19b. TELEPHONE NUMBER 530-752-4625

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Optimal Transmission Diversity for High-Speed Wireless Communication Systems Under Adverse Environment

PI: Z. Ding

Abstract

High speed wireless mobile communication systems have become increasingly important in battlefield command/control and in sensor network systems for national defense and security. The project investigates advanced design of bandwidth efficient retransmission diversity in multi-input-multi-output (MIMO) wireless communication systems. We develop optimization techniques in (hybrid) ARQ and MIMO precoding for robust, progressive, adaptive, and scalable diversity. We focus on OFDM as the underlying broadband signal modulation. We present new frameworks for the novel integration and optimization of bandwidth efficient and scalable ARQ protocols with robust precoding and other MIMO techniques in broadband OFDM wireless communication systems. We design bandwidth and power efficient transceiver technologies in full integration with new HARQ designs for the performance improvement of end user applications. Overall, our goal is to develop design methodologies of broadband wireless MIMO communication systems for military operations. The new techniques developed in this project can be applied in wireless networks for military operations to significantly improve performance with limited bandwidth and power resources encountered by defense units.

Contents

1 State of the Problem Studied

Hybrid ARQ (HARQ) has been well established as an effective mechanism for packet error protection in wireless communications. Given the tremendous capacity gains offered by MIMO diversity technologies in wireless communications, it is important to note that they have not been naturally integrated with the design of ARQ protocols. Mostly, MIMO transceiver design is done independently from the ARQ protocol considerations. Similarly, ARQ has also long been treated as a separate apparatus. In fact, most HARQ researches originate from the coding and single channel perspective. The full integration of ARQ protocols with different MIMO functionalities at the physical layer (PHY) has received little attention. This integration is critical in maintaining the remarkable PHY gains generated by recent advances of wireless antenna diversity techniques such as space-time coding. Indeed, while links using multiple antennas at both transmitter (Tx) and receiver (Rx) offer tremendous spectral efficiency and reliability improvement, a laissez faire attitude in designing the corresponding ARQ protocols could potentially undermine much of the PHY gains. Thus, as more and more mainstream products begin to adopt MIMO technologies in wireless LAN and other wireless systems, there is an urgent need to analyze and achieve the full potential benefit offered by integrating ARQ in MIMO wireless designs. Our project on efficient **integration of ARQ with broadband MIMO physical layer** is of great broad and practical importance.

The goal of this project is to develop and analyze bandwidth efficient **HARQ protocols** and corresponding integrated **MIMO transceivers** to fully capitalize on both the BER advantages of MIMO PHY against wireless channel fading **and** the scalable diversity of hybrid ARQ protocols.

More specifically, this project studied the following primary problems:

- To design optimum ARQ transmission precoders and protocols for different MIMO wireless communication systems.
- To develop integrated MIMO and broadband OFDM transceivers for HARQ wireless communications;
- To develop simple, scalable, rate-adaptive ARQ protocols for bandwidth efficient and high throughput MIMO wireless systems;
- To derive new and efficient channel estimation methods for broadband MIMO ARQ systems;
- To develop fast and low complexity joint MIMO multirate receivers for efficiently punctured ARQ;
- To design variable rate error protection codes for joint MIMO detection and integrated ARQ.

2 Project Accomplishment

This project represents a comprehensive effort targeting the design and analysis of resource efficient integrative transceivers and retransmission diversity in *broadband* multi-input-multi-output (MIMO) wireless communications. Focusing on MIMO-OFDM as the underlying broadband technology, we achieved our goal of optimizing and adapting ARQ (Automatic Repeat reQuest) protocols for MIMO wireless systems to achieve efficiency and scalability.

We presented new capacity analysis and transceiver optimization for progressive MIMO precoding to fully exploit the ARQ retransmission diversity. We proposed a class of simple remapping diversities as effective ARQ protocols and demonstrate their advantages in terms of low complexity transceivers and performance gains. We designed bandwidth and power efficient transceiver technologies in full integration with new scalable ARQ designs to significantly improve the performance of end user applications. We described new formulation of wireless MIMO channel estimation algorithms particularly tailored for bandwidth efficient and scalable hybrid ARQ protocols in future *broadband* wireless communication systems.

3 Detailed Summary of Most Important Results

3.1 Integrated ARQ Protocols in MIMO Wireless Communication Systems

In many wireless communication systems, the major figure of merit is the frame/packet error rates (FER) for high data rate users. To assure packet delivery, error control mechanisms are often introduced to the system. One popular form of error control transmits additional information only at the request of the receiver. This additional information is either a retransmission of the original packet, or a transmission of additional bits or symbols related to the packet, as illustrated in Fig. 1. This form of incremental error control is commonly known as the Automatic Repeat reQuest (ARQ) protocol.

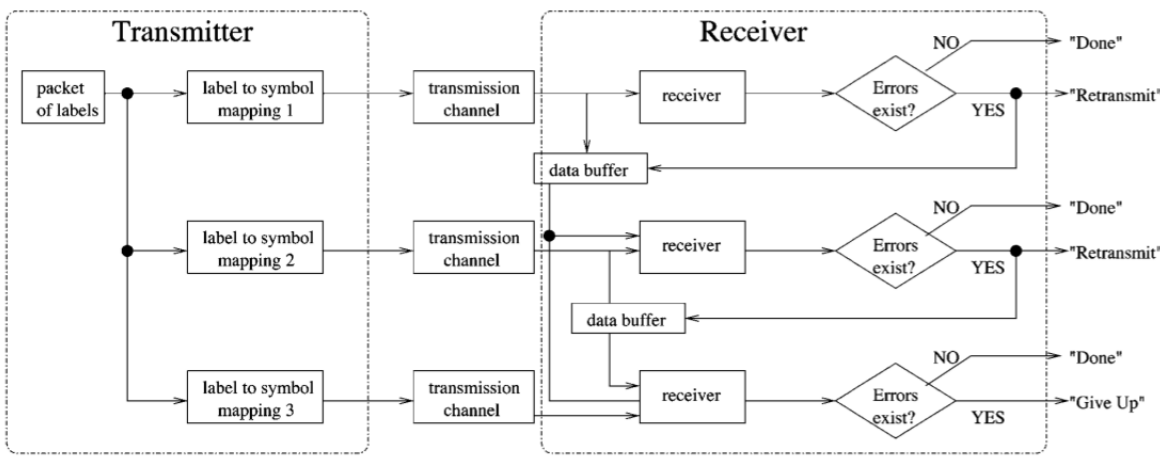

Figure 1: Diagram of ARQ protocol with mapping diversity.

Our goal is the development of diversity combining ARQ schemes that concentrate on the various features at the physical layer of communication systems.

One of primary contributions is a technique that implements a different bit-to-symbol mapping, when non-binary modulations are utilized, for each packet retransmission. We refer to this technique as symbol mapping diversity. The receiver performs a joint demapping of the M packet transmissions. When identical Gray mappings are used for retransmissions (in AWGN only channels), the performance of the joint receiver is equivalent to that of demapping a single transmission with M times SNR increase. Adapting the mapping can alleviate the smaller Euclidean distances between symbols in previous transmissions. The optimizations are performed offline, with the resulting mappings stored into memory at both the transmitter and receiver. Thus, the overall complexity of mapping diversity is almost negligible since joint demapping is hardly more expensive than single transmission demapping. The BER upper bounds produced from optimized mappings indicate dramatic improvements in BER when compared to identical retransmissions.

In previous works, we have investigated the integration of ARQ within OFDM communication systems. We also proposed a new hybrid automatic repeat request (ARQ) approach to enhance receiver performance for communication systems employing forward error-correction codes in frequency-selective fading environments. This new approach involves a simple modification to the traditional turbo equalizer by combining multiple ARQ transmissions via integrated channel equalization. This modification leads to better computational efficiency, better exploitation of channel diversity, better channel-estimation ability, and improved performance (frame-error rates) when concatenated with an outer code.

In [Sam06], we studied retransmission diversity in the context of multiple-input, multiple-output (MIMO) flat-fading systems. Through the use of symbol mapping diversity, considerable gains in performance are achievable. Sphere decoding has been recently proposed for low-complexity maximum likelihood (ML) decoding of MIMO transmissions. Our MIMO ARQ protocol modifies the sphere decoder to jointly process multiple transmissions made using mapping diversity. To maintain low decoding complexity, we propose a new efficient method for enumerating potential symbol candidates. Hybridization of retransmissions is also proposed, where retransmitted symbols are mixed with other original symbols. Distinct precoding for retransmission is suggested to enhance the diversity among all transmissions when they experience the same MIMO channel. Simulation results validate the performance and complexity improvements produced by the new joint sphere decoder and mapping diversity.

Another important MIMO ARQ protocol design problem is the optimal precoder design for packet retransmissions in Multi-Input Multi-Output (MIMO) systems. The basic problem formulation of ARQ precoding optimization is shown with a joint receiver in Fig. 2.

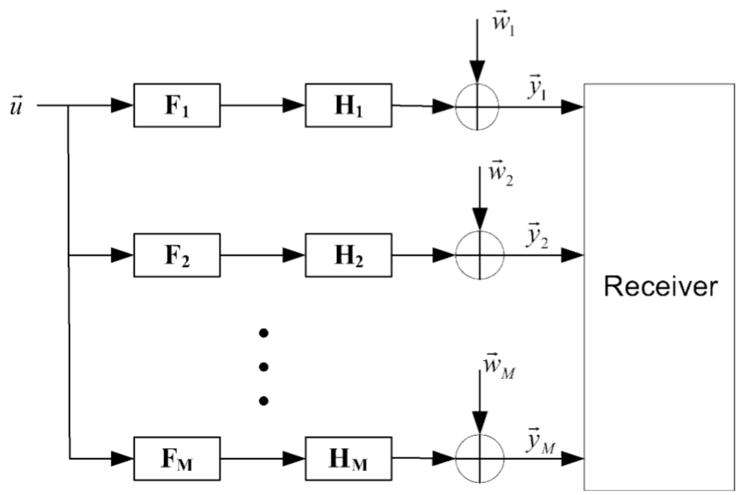

Figure 2: Progressive ARQ precoder integration in MIMO wireless systems.

[Sun06a] investigates the optimal linear precoder design for packet retransmissions in Multi-Input Multi-Output (MIMO) systems. To fully utilize the time diversity provided by ARQ, we derive a sequence of successive optimal linear ARQ precoders for flat fading MIMO channels, which minimize the Mean Square Error (MSE) between the transmitted data and the joint receiver output. The optimization is subject to an overall transmit power constraint. This progressive linear ARQ precoder combines the appropriate power loading and the optimal pairing of channel matrix singular values in the current retransmission with previous transmissions. This optimal pairing is a special feature unique to our sequential ARQ precoding approach. Simulation results demonstrate the effectiveness of this optimized ARQ precoding in reducing symbol MSE and detection bit error rate, as shown in

Fig. 3.

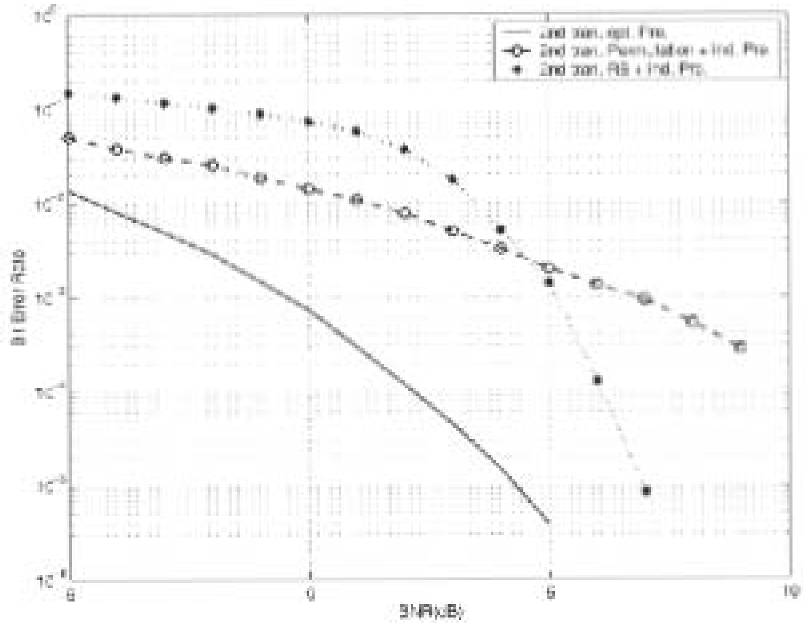

Figure 3: BER performance improvement of optimal sequential precoding compared with joint type-II hybrid ARQ by using ReedSolomon code and individually optimized precoding.

In [Sun06b], we investigated the design of robust precoders for ARQ packet retransmissions in Multi-Input Multi-Output (MIMO) systems under channel uncertainty. In practice, it is common for transmitters to only have imperfect Channel State Information (CSI). More specifically the channel uncertainty is characterized by the Frobenius norm between the actual and estimated channel. Given a known bound on the channel knowledge error, our objective is to sequentially design the robust precoder for each (re)-transmission that minimizes the Mean Square Error (MSE) for the worst case channel within CSI error bound. This min-max problem is solved by Lagrangian optimization. The robust precoders are proposed in this paper with simulation results demonstrating the worst case performance gain.

In [Sun06c], we investigate the design of optimal linear transceiver for Multi-Input-Multi-Output (MIMO) systems under channel mean feedback. We consider the case in which the receiver has perfect channel knowledge while the transmitter has only mean and variance information of the channel coefficients. We aim to minimize the mean square error of symbol detection by jointly designing the transmitter linear precoder and the receiver linear decoder. We present the optimal transceiver structure for any rank of channel mean matrix together with the sufficient and necessary conditions for optimal power loading. Furthermore, we provide a numerical optimal power loading strategy using water-filling principle, as well as one suboptimal solution based on Jensen's Inequality.

In [Sun07], we investigate the problem of progressive transceiver design for integrated multi-input multi-output (MIMO) systems with automatic repeat request (ARQ) capability. We consider a generic MIMO transceiver architecture that utilizes a linear transmission precoder and a linear decoder followed by decision feedback interference cancellation at the receiver. To be consistent with ARQ, our goal is to progressively design the optimal transmission precoder and receiver feedback system to jointly minimize the mean square error (MSE) under the assumption of perfect feedback. We consider both zero-forcing and minimum MSE (MMSE) decoder as joint ARQ receivers. Unlike in single transmission design, joint ARQ receivers cannot change previous precoders. Here, we propose an approach to design the precoder and receiver which improves the system performance successively over each retransmission to achieve MSE performance close to the known lower bound.

In [Sun07] and [Sun08], we investigated the design of linear precoders for ARQ packet retransmissions in Multi-Input Multi-Output (MIMO) systems. We consider transmitter precoder design based on partial MIMO channel information in the form of their covariance feedback. Our objective is to maximize the ergodic mutual information provided by multiple (re)transmissions of a packet subject to transmission power constraint. We propose a set of near-optimal successive linear ARQ precoders for flat fading MIMO channels. This progressive linear ARQ precoder combines the appropriate power loading and the reverse-order pairing of singular values in the current retransmission with previous transmissions. This reverse-order pairing is a special feature unique to our sequential ARQ precoding approach with demonstrated performance gains.

Sam06 H. Samra and Z. Ding, "New MIMO ARQ Protocols and Joint Detection via Sphere Decoding," IEEE Transactions on Signal Processing, vol. 54, no.2, pp. 473-482, Feb. 2006.

Sun06a H. Sun, J. Manton, and Z. Ding, "Progressive Linear Precoder Optimization for MIMO Packet Retransmissions Exploiting Channel Covariance Information", IEEE Journal on Selected Areas in Communications, Vol. 24, no.3, pp. 448-456, March 2006.

Sun06b H. Sun and Z. Ding, "Robust precoder design for MIMO packet retransmissions over imperfectly known flat-fading channels", Proc. IEEE International Conf. on Communications, Istanbul, Turkey, 2006.

Sun06c Haitong Sun, and Zhi Ding, "Optimal Linear Transceiver Design for Mimo Flat Fading Channels Exploiting Channel Mean Feedback", IEEE Global Telecommunications Conference, Nov., 2006.

Sun07 H. Sun and Z. Ding, "Iterative Transceiver Design for MIMO ARQ Retransmissions With Decision Feedback Detection" IEEE Transactions on Signal Processing, vol. 55, pp. 3405-3416, July 2007.

Sun08 H. Sun, Z. Shi, C. Zhao, J. H. Manton, and Z. Ding, "Progressive Linear Precoder Optimization for MIMO Packet Retransmissions Exploiting Channel Covariance Information", *IEEE Transactions on Communications,* Volume: 55, Issue: 5, page(s): 818-827, May 2008.

3.2 Blind Channel Estimation under Space-time coded modulations

Space-time block coded (STBC) transmission has recently been established as an efficient method to enhance wireless communication performance over quasi-static fading channels. Often, the success of STBC requires accurate channel knowledge at the receiver side.

In [Amm06], we present a channel estimation approach that does not require training data to estimate the unknown channel. We establish that under real space-time coded transmission, then the channel is identifiable up to a scalar ambiguity under some mild and verifiable identifiability conditions. We develop simple algorithms to identify the unknown space-time channel matrix for STBC transmission. We also developed the a semiblind algorithm for space-time coding when channel estimation ambiguity can remain.

To improve reliability of channel estimation at the receiver, in [Amm07] we present a semiblind channel estimation method for linear STBC without the usual code orthogonality condition. We provide a set of identification conditions that are mostly verifiable a priori in terms of code parameters and antenna array configuration. We also present a simple channel estimation algorithm. As the results in Fig. 4 shows, the semiblind channel estimates under 16QAM and Rayleigh channel generate near optimum decoding performance as those under perfect channel knowledge.

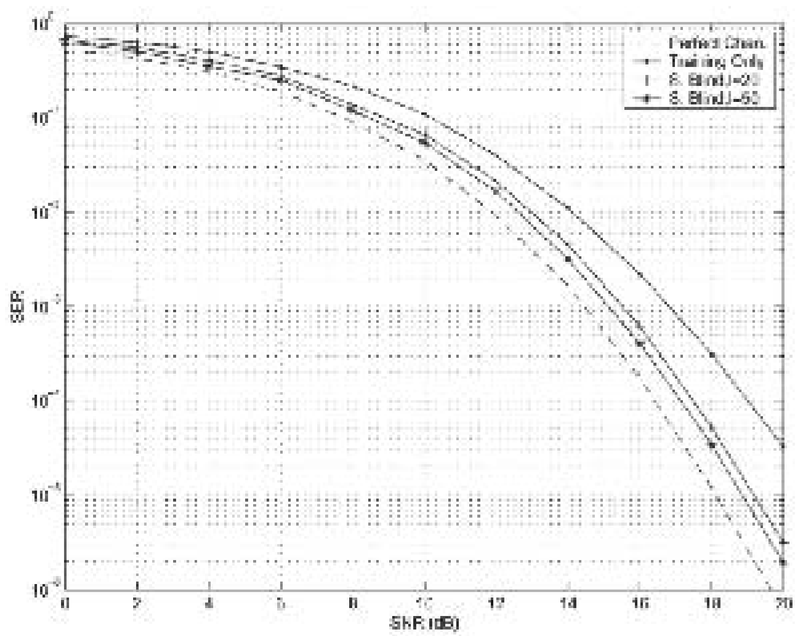

Figure 4: Decoded symbol error rate (SER) using the exact and the estimated channels under (Rayleigh channel) and three Rx antennas.

Also in [Muh09], we presented a new approach to blind equalization for generalized orthogonal space-time block codes. Our method takes the form of linear programming (LP) and is globally convergent. We exploit the implicit structure of orthogonal space-time block codes to cast the problem as linear programming that can be solved efficiently. Unlike several known methods, the proposed technique is applicable to many full-rate orthogonal space time codes such as the popular Alamouti code. Our algorithm allows receiver detection of full diversity codes without channel knowledge with detection performance comparable to the optimum maximum-likelihood (ML) detection.

Amm06 N. Ammar and Z. Ding, "Channel Identifiability under Space-Time Coded Modulations without Training", IEEE Transactions on Wireless Communications. Vol. 5, no. 5, pp. 1003-1013, May 2006.

Amm07 N. Ammar and Z. Ding, "Blind Channel Identifiability for Generic Linear Space-Time Block Codes", IEEE Transactions on Signal Processing, Vol. 55, no. 1, pp. 202-217, Jan. 2007.

Muh09 Muhammad, Zia; Chen Meng,; Ding, Zhi; "Blind detection of high rate orthogonal space-time block codes IEEE International Conference on Acoustics, Speech and Signal Processing, 19-24 April 2009, Page(s):2745 - 2748.

3.3 Novel Bi-Directional Channel Estimation for Wireless Communications

We were the first to develop a novel scheme for forward channel estimation by wireless base-stations. It represents an effective forward channel identification method in duplex wireless mobile communications. By letting the mobile receiver send a fraction of the received data back to the base station, both forward and reverse channel identification can be achieved at the base transmitter. In this

[Don06], we extend this bent-pine feedback approach to accommodate fractionally spaced sampling and to utilize known pulse shape for better performance. We demonstrate that the new method requires minor modification on the system structure. Furthermore, with the fractionally spaced channel output, we can use the known information such as the pulse shaping filter and anti-aliasing filter to improve the channel identification and significantly reduce the needed data sample size.

Transmission precoding in MIMO wireless systems can significantly improve system capacity and diversity gain. The effectiveness of MIMO precoding depends critically on accurate knowledge of channel state information available to the transmitter. In [Don06a], we describe a novel method for the feedback of downlink channel estimation from an end user unit. Instead of letting the mobile receivers first identify and then send back the downlink channel parameters, a receiver returns portions of its received data back to the base station for channel identification. The base-station can then utilize all the channel information to design channel-aware downlink precoders. The basic principle for an OFDM multicarrier system is illustrated in Fig. 5. In [Don06b], we show how this can be directly applied to MIMO transmitters and to transmitters with precoders against channel distortions.

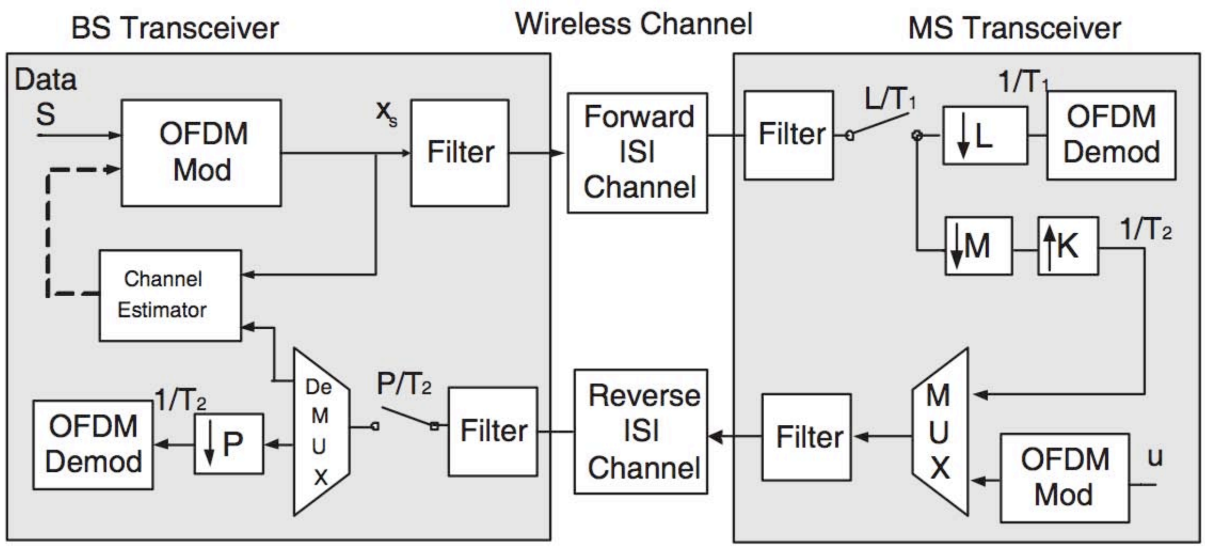

Figure 5: An OFDM system utilizing the proposed (decimated) feedback.

In [Don08], we developed an effective method for time domain channel estimation of wireless orthogonal frequency division multiplexing (OFDM) system. Relying on a bent-pipe mechanism, the mobile receiver sends a fraction of the received data back to the base station which can then estimate both the forward link and reserve link channel impulse responses. Given knowledge on the forward link channel response, the resource rich base station can employ effective adaptive modulation schemes to increase OFDM system capacity. In this work, closed-form expressions for channel estimation Cramer Rao lower bound are derived for the feedback system. Impact of feedback parameters on channel estimation performance is discussed through Cramer Rao bound analysis and simulation. Identifiability issues associated with power loaded multicarrier systems are also addressed. Simulation results on the proposed feedback channel estimation scheme are shown.

In [Don09], we investigate transmission precoding in MIMO wireless systems as an effective technique to improve system capacity and diversity gain. In general, the effectiveness of MIMO precoding depends critically on the knowledge of channel state information available at the transmitter. In this work we describe a novel method for the downlink channel estimation based on a novel feedback mechanism. To minimize processing need at mobile units, the receiver in this new framework returns a fraction of its received data back for the base-station to extract downlink channel information in the form of a quadratic channel product. The base-station can then utilize the quadratic channel product to design channel-aware downlink precoders. This bandwidth efficient feedback scheme applies to both flat fading and frequency selective MIMO channels.

Don06a X. Dong and Z. Ding, "Channel Estimation and bit loading in wireless multicarrier systems based on decimated signal feedback", Proc. IEEE International Conf. on Communications, Istanbul, Turkey, 2006.

Don06b Xiaofei Dong and Zhi Ding, "Downlink MIMO Channel Estimation for Transmission Precoding" IEEE Global Telecommunications Conference, San Francisco, Nov., 2006.

Don08 X. Dong, Z. Ding, and S. Dasgupta, "Performance Analysis of a Forward Link Channel Estimation Method for Wireless Multicarrier Systems," IEEE Transactions on Wireless Communications,, 7(8): 3026-3035, August 2008.

Don09 Xiaofei Dong and Z. Ding, "Wireless Channel Estimation for Linear MIMO Transmission Precoding" IEEE Transactions on Communications, Volume 57, Issue 4, April 2009 Page(s):1151 - 1161

3.4 Signaling and Channel Estimation in bandwidth efficient ARQ systems

In [Rob06], we developed a novel ARQ retransmission scheme that is bandwidth efficient and yet still achieves full diversity. In order to facilitate low complexity joint detection of STBC from multiple ARQ transmissions, we stress the application of orthogonal space time block codes. More specifically, we demonstrate our basic concept using the well known orthogonal Alamouti code which has the advantages of low decoding complexity and full diversity. The motivation behind our new ARQ-STBC integration is straightforward. Typically, ARQ requires a full retransmission when a packet detection ends in error. Often times the channel fading is not severe enough to require a full retransmission, thus some symbols are transmitted unnecessarily. In fact, most of the time, a moderate amount of SNR increase or diversity gain can lower the number of errors within a packet such that the full packet can be correctly received after error correction. We take advantage of that fact and only retransmit half of the packet. We refer to this partial retransmission as PARQ. Our principle of partial retransmission is shown in Fig. 6. As shown in Fig. 7, at half of the retransmission bandwidth, the novel ARQ retransmission achieves nearly the same performance as the full ARQ retransmission.

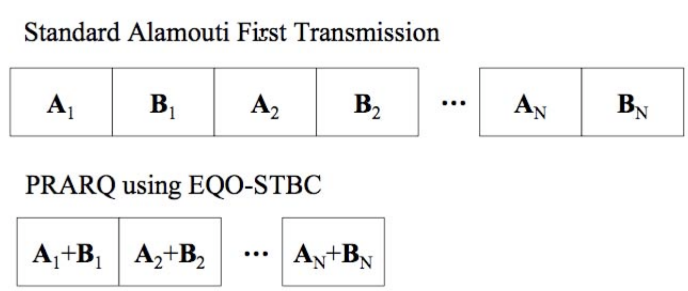

Figure 6: The bandwidth efficient PARQ retransmission illustration.

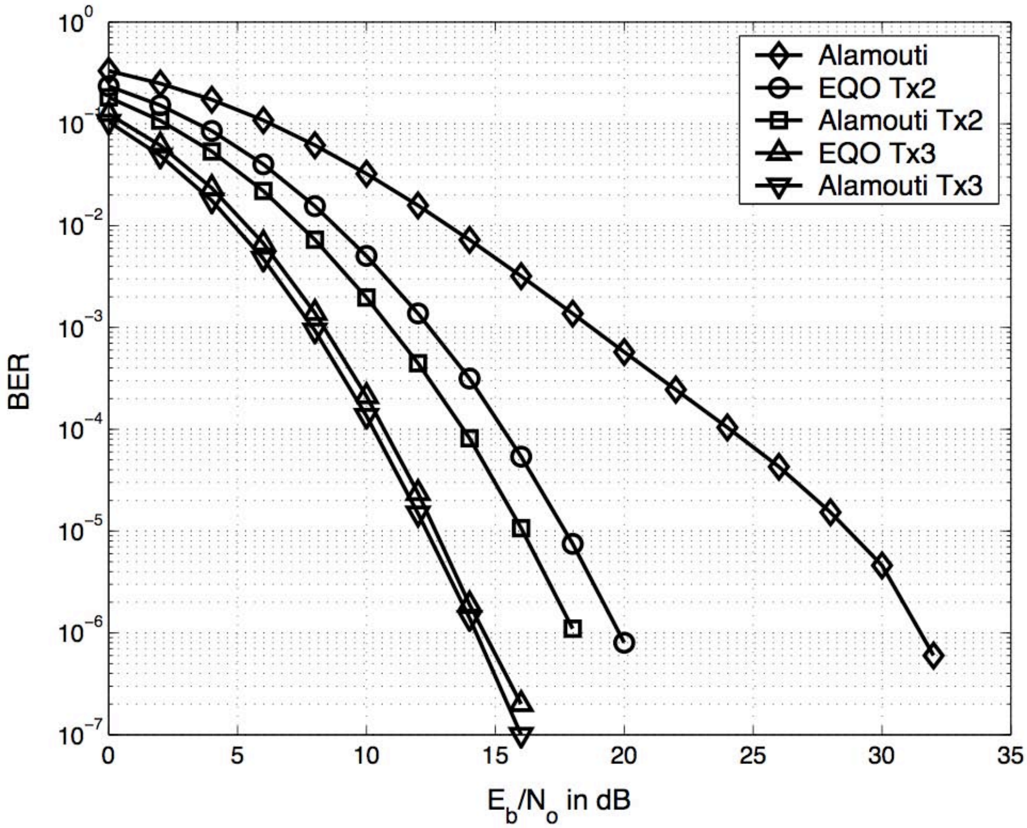

Figure 7: PARQ performance in comparison with naive retransmission.

We also developed a new symbol punctured ARQ system to preserve wireless channel bandwidth. In [Rob07], we study channel estimation and equalization for a class of bandwidth efficient automatic repeat request (ARQ) systems. In these systems, retransmissions achieve bandwidth efficiency through symbol-wise downsampling. Unlike a standard ARQ scheme, in which an erroneous packet is fully repeated, more sophisticated hybrid ARQ systems retransmit a recoded data packet. However, many of these ARQ schemes do not consider the integration of ARQ protocols with receiver signal processing such as channel estimation and signal detection. In this work, we present a joint multichannel estimation algorithm that exploits the structure of a symbol-wise downsampled ARQ equipped network. We show that this new method can improve the identifiability conditions for channel estimation as well as the overall system performance.

The design of the joint ARQ receiver for bandwidth efficient MIMO system is studied in [Muh08]. In this work, we develop a joint ARQ receiver design for channel estimation and equalization under bandwidth efficient automatic repeat request (ARQ) in Multiple-input multiple-output (MIMO) system. Our retransmission proposal improves bandwidth efficiency by sending a partial response of the original data sequence and by potentially omitting training sequence. To estimate unknown channels and to detect the transmitted data, our design of joint ARQ receivers can implement semiblind channel estimation and joint detection based on multiple transmissions. We demonstrate bandwidth savings without significant performance loss. We also propose a low complexity joint ARQ equalizer that minimizes the mean square error and provides a good design trade-off between performance and complexity.

Rob06 J. Roberson and Z. Ding, “Integration of hybrid ARQ and space-time coding through embedded quasi-orthogonal block codes" , Proc. IEEE Conference on Information Sciences and Systems, Princeton, NJ, March. 2006.

Rob07 J. Roberson, X. Dong, and Z. Ding, "Channel Estimation and Equalization Techniques in Downsampled ARQ Systems" , IEEE Transactions on Signal Processing, Volume 55, Issue 5, Page(s):2251 - 2262, May 2007.

Muh08 M. Zia and Z Ding, "Joint ARQ Receiver Design for Bandwidth Efficient MIMO Systems", 2008 IEEE Global Telecommunications Conference, Nov. 30 2008-Dec. 4 2008.

3.5 Other Relevant Published Works

3.5.1 OFDM Receiver Design under Wireless Channels with Long Multipath Delay Spread

In [Kam08], we consider channel shortening in OFDM wireless systems when the order of a channel impulse response exceeds the length of the cyclic prefix (CP). This problem leads to significant performance degradation due to interblock interference (IBI). This paper proposes a blind-channel shortening method in which the equalizer parameter vector is formed by the noise subspace of the received signal correlation matrix so that the output power is maximized. The proposed method can not only shorten the effective channel impulse response to within the CP length but also maximize the output signal-to-interference- and-noise ratio while eliminating the IBI. We point out that the performance depends on the choice of a decision delay and propose a simple method for determining the appropriate delay.We propose both a batch algorithm and an adaptive algorithm and show by simulation that they are superior to the conventional algorithms.

3.5.2 Robust Algorithms for Wireless Source Localization

In [Men08], we study the problem of wireless source localization in a distributed wireless sensor network. We propose a novel approach to the source localization and tracking problem in wireless sensor networks. By applying minimax approximation and semidefinite relaxation, we transform the traditionally nonlinear and non-convex problem into convex optimization problems for two different source localization models involving measured distance and received signal strength. Based on the problem transformation, we develop a fast low-complexity semidefinite programming (SDP) algorithm for two different source localization models. Our algorithm can either be used to estimate the source location or be used to initialize the original non-convex maximum likelihood algorithm.

In [Hua09], we investigate the design of MIMO linear precoders for multiuser broadcast channels under signal leakage constraints. This power leakage constraints reflect both an important security consideration and the need for interference suppression at receivers. Defining a convex optimization problem, we propose two sequential semi-definite program algorithms. In principle, our algorithms exploit both spatial diversity and multiuser diversity to enhance the overall system performance. The resulting MIMO precoded transmission demonstrates superior performance over time-division multiplexed multiuser transmission in conjunction with the traditional space-time transmission.

In [Bas08a], we consider a heterogeneous multiuser OFDM wireless network serving both QoS constrained high-priority users and best-effort users. We investigate resource allocation to maximize the total network utility by specifying two different utility functions for the two user classes. Our strategy is to first maximize the number of satisfied high-priority users before allocating the remaining resource among the best-effort users. Our results show significant improvement of overall user satisfaction among both user classes.

Furthermore, in [Bas08b], we consider a heterogeneous multiuser OFDMA wireless network serving both QoS-constrained high-priority users and best-effort users. We propose several efficient algorithms for subcarrier/cluster and power allocation. Our strategy is to maximize the total network utility of the best-effort user while satisfying the high-priority users. We define the best-effort user utility function in two different ways and propose two different novel, efficient and optimal cluster allocation algorithms. We also propose an efficient and optimal power allocation algorithm based on the modification of existing algorithms.

In [Men09], we presented a quadratic programming algorithm for fast blind equalization and signal separation. By introducing a special non-mean-square error (MSE) objective function, we reformulate fractionally spaced blind equalization into an equivalent quadratic programming problem. Based on a clear geometric interpretation and a formal proof, we show that a perfect equalization solution is obtained at every local optimum of the quadratic program. Because blind source separation is, by nature and mathematically, a closely related problem, we also generalize the algorithm for blind signal separation. We show that by enforcing source orthogonalization through successive processing, the quadratic programming approach can be applied effectively. Moreover, the quadratic program is easily generalizable to incorporate additional practical conditions, such as jamming suppression constraints.

Kam08 H. Kameyama, T. Miyajima, and Z. Ding, ‘ ‘Perfect Blind Channel Shortening for Multicarrier Systems”, *IEEE Transactions on Circuits and Systems,* Volume: 55, Issue: 3, page(s): 851-860, April 2008.

Men08 C. Meng, Z. Ding, and S. Dasgupta, “A Semidefinite Programming Approach to Source Localization in Wireless Sensor Networks”, *IEEE Signal Processing Letters*, Volume 15, 2008, Page(s):253 - 256.

Men09 C. Meng, J. Tuqan, and Z. Ding, “ A Quadratic Programming Approach to Blind Equalization and Signal Separation” IEEE Transactions on Signal Processing, 57(6): 2232-2244, June 2009.

Hua09 Huang, River; Zhi Ding,; “Precoder design for MIMO broadcast channels with power leakage constraints,” IEEE International Conference on Acoustics, Speech and Signal Processing, 19-24 April 2009, Page(s): 2385 - 2388.

Bas08a S. Al Bashar, Z. Ding, and Y. Li, “QOS aware resource allocation for heterogeneous multiuser OFDM wireless networks”, *Proc. IEEE Workshop on Signal Processing Advances in Wireless Communications*, 6-9 July 2008, Page(s):535 - 539.

Bas08b S. Bashar and Z Ding, “Efficient Algorithms for Resource Allocation in Heterogeneous OFDMA Networks”, 2008 IEEE Global Telecommunications Conference, Nov. 30 2008-Dec. 4 2008.

Dru06 T. A. Drumright and Z. Ding, “QAM Constellation Classification Based on Statistical Sampling for Distortive Channels”, IEEE Transactions on Signal Processing, Vol.54, No.5, pp. 1575-1586, May 2006.

Eva06 Ashley A. Evans, S. J. Ben Yoo, and Zhi Ding, “Space-Time Coded Modulation and Detection in Coherent Freespace Optical Communications”, IEEE Global Telecommunications Conference, Nov., 2006.

4 Awards

Former graduate research assistant, Dr. Haitong Sun, previously supported under the project support, received the Anil Jain Memorial Prize for the 2006-07 Best PhD Dissertation in the Department of Electrical and Computer Engineering, UC Davis.

5 Bibliography

Journal Papers

Sam06 H. Samra and Z. Ding, "New MIMO ARQ Protocols and Joint Detection via Sphere Decoding," IEEE Transactions on Signal Processing, vol. 54, no.2, pp. 473-482, Feb. 2006.

Sun06a H. Sun, J. Manton, and Z. Ding, "Progressive Linear Precoder Optimization for MIMO Packet Retransmissions Exploiting Channel Covariance Information", IEEE Journal on Selected Areas in Communications, Vol. 24, no.3, pp. 448-456, March 2006.

Dru06 T. A. Drumright and Z. Ding, "QAM Constellation Classification Based on Statistical Sampling for Distortive Channels", IEEE Transactions on Signal Processing, Vol.54, No.5, pp. 1575-1586, May 2006.

Amm06 N. Ammar and Z. Ding, "Channel Identifiability under Space-Time Coded Modulations without Training", IEEE Transactions on Wireless Communications. Vol. 5, no. 5, pp. 1003-1013, May 2006.

Amm07 N. Ammar and Z. Ding, "Blind Channel Identifiability for Generic Linear Space-Time Block Codes", IEEE Transactions on Signal Processing, Vol. 55, no. 1, pp. 202-217, Jan. 2007.

Rob07 J. Roberson, X. Dong, and Z. Ding, "Channel Estimation and Equalization Techniques in Downsampled ARQ Systems" , IEEE Transactions on Signal Processing, Volume 55, Issue 5, Page(s):2251 - 2262, May 2007.

Sun07 H. Sun and Z. Ding, "Iterative Transceiver Design for MIMO ARQ Retransmissions With Decision Feedback Detection" IEEE Transactions on Signal Processing, vol. 55, pp. 3405-3416, July 2007.

Sun08 H. Sun, Z. Shi, C. Zhao, J. H. Manton, and Z. Ding, "Progressive Linear Precoder Optimization for MIMO Packet Retransmissions Exploiting Channel Covariance Information", *IEEE Transactions on Communications,* Volume: 55, Issue: 5, page(s): 818-827, May 2008.

Kam08 H. Kameyama, T. Miyajima, and Z. Ding, ' 'Perfect Blind Channel Shortening for Multicarrier Systems", *IEEE Transactions on Circuits and Systems,* Volume: 55, Issue: 3, page(s): 851-860, April 2008.

Men08 C. Meng, Z. Ding, and S. Dasgupta, "A Semidefinite Programming Approach to Source Localization in Wireless Sensor Networks", *IEEE Signal Processing Letters*, Volume 15, 2008, Page(s):253 - 256.

Don08 X. Dong, Z. Ding, and S. Dasgupta, "Performance Analysis of a Forward Link Channel Estimation Method for Wireless Multicarrier Systems," IEEE Transactions on Wireless Communications,, 7(8): 3026-3035, August 2008.

Don09 Xiaofei Dong and Z. Ding, "Wireless Channel Estimation for Linear MIMO Transmission Precoding" IEEE Transactions on Communications, Volume 57, Issue 4, April 2009 Page(s):1151 - 1161

Men09 C. Meng, J. Tuqan, and Z. Ding, " A Quadratic Programming Approach to Blind Equalization and Signal Separation" IEEE Transactions on Signal Processing, 57(6): 2232-2244, June 2009.

Conference Papers

Sun06b H. Sun and Z. Ding, "Robust precoder design for MIMO packet retransmissions over imperfectly known flat-fading channels", Proc. IEEE International Conf. on Communications, Istanbul, Turkey, 2006.

Sun06c Haitong Sun, and Zhi Ding, "Optimal Linear Transceiver Design for Mimo Flat Fading Channels Exploiting Channel Mean Feedback", IEEE Global Telecommunications Conference, Nov., 2006.

Rob06 J. Roberson and Z. Ding, "Integration of hybrid ARQ and space-time coding through embedded quasi-orthogonal block codes" , Proc. IEEE Conference on Information Sciences and Systems, Princeton, NJ, March. 2006.

Don06a X. Dong and Z. Ding, "Channel Estimation and bit loading in wireless multicarrier systems based on decimated signal feedback", Proc. IEEE International Conf. on Communications, Istanbul, Turkey, 2006.

Don06b Xiaofei Dong and Zhi Ding, "Downlink MIMO Channel Estimation for Transmission Precoding" IEEE Global Telecommunications Conference, San Francisco, Nov., 2006.

Eva06 Ashley A. Evans, S. J. Ben Yoo, and Zhi Ding, "Space-Time Coded Modulation and Detection in Coherent Freespace Optical Communications", IEEE Global Telecommunications Conference, Nov., 2006.

Kaz07 T. Kazemi and Z. Ding, "Scalable MIMO ARQ Retransmission using Differential Space-Time Block Codes," *Proc. Military Communications Conference*, 29-31 October 2007.

Hua09 Huang, River; Zhi Ding,; "Precoder design for MIMO broadcast channels with power leakage constraints," IEEE International Conference on Acoustics, Speech and Signal Processing, 19-24 April 2009, Page(s): 2385 - 2388.

Muh08 M. Zia and Z Ding, "Joint ARQ Receiver Design for Bandwidth Efficient MIMO Systems", 2008 IEEE Global Telecommunications Conference, Nov. 30 2008-Dec. 4 2008.

Bas08a S. Al Bashar, Z. Ding, and Y. Li, "QOS aware resource allocation for heterogeneous multiuser OFDM wireless networks", *Proc. IEEE Workshop on Signal Processing Advances in Wireless Communications*, 6-9 July 2008, Page(s):535 - 539.

Bas08b S. Bashar and Z Ding, "Efficient Algorithms for Resource Allocation in Heterogeneous OFDMA Networks", 2008 IEEE Global Telecommunications Conference, Nov. 30 2008-Dec. 4 2008.

Muh09 Muhammad, Zia; Chen Meng,; Ding, Zhi; "Blind detection of high rate orthogonal space-time block codes IEEE International Conference on Acoustics, Speech and Signal Processing, 19-24 April 2009, Page(s):2745 - 2748.