

**REQUIRED COVER PAGE**

**APPLICATION FOR FACULTY RESEARCH GRANT**

**\*\*All questions must be completed to be considered for grant award.**

<b>Choose one:</b> <input type="checkbox"/> Creative <input type="checkbox"/> Research	<b>Date of Last FRG Award</b> (Semester and Year awarded): _____
	<b>Date of ATU Faculty Appointment</b> (Semester and Year): _____

1. Project Title: Constrained Higher Order Statistics Based Multiuser Detection  
2. Name of Principal Investigator/Project Director: PING LIU  
3. School (abbrev): ATU 4. Department: Electrical Engineering  
5. Campus Mail Address: Electrical Engineering 6. PI/PD Campus Phone: 479 498 6046  
7. Amount Requested: \$ 1000 8. Total Cost of Project: \$ 1000  
9. Does this project involve: \_\_\_\_\_ 10. Duration of Project: 1 Year

**Yes No**

- ☐ ☒ human subjects?  
☐ ☒ animals/animal care facility?  
☐ ☒ radioactive materials?  
☐ ☒ hazardous materials?  
☐ ☒ biological agents or toxins restricted by the USA Patriot Act?  
☐ ☒ copyright or patent potential?  
☐ ☒ utilization of space **not** currently available to the PI/PD?  
☐ ☒ the purchase of equipment/instrumentation/software currently **available** to the PI/PD?

**NOTE:** If the answer is "yes" to any of the above questions, the investigator must attach appropriate documentation of approval or justification for use/purchase.

**SIGNATURES**

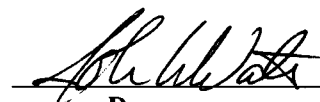
**Department Contribution** (if applicable): \$ \_\_\_\_\_

Account Number: \_\_\_\_\_

 10/13/04  
Chairperson Date

**School Contribution** (if applicable): \$ \_\_\_\_\_

Account Number: \_\_\_\_\_

 10-13-04  
Dean Date

**This Section to be completed by the Office of Academic Affairs**

FSBA Committee Award Recommendation: Yes \_\_\_\_\_ No \_\_\_\_\_  
FSBA Committee Proposal Rank: \_\_\_\_\_ of \_\_\_\_\_ Total Proposals.  
Recommendation of VPAA: Yes \_\_\_\_\_ No \_\_\_\_\_  
Recommendation of President: Yes \_\_\_\_\_ No \_\_\_\_\_  
Award Date: \_\_\_\_\_

**PROPOSED BUDGET  
FACULTY RESEARCH GRANT**  
(include budget categories as appropriate)

1.	Graduate assistant stipend	\$ _____
	Fringe benefits @ .4% (4/10 percent) of graduate assistant stipend	_____
2.	Non-work study stipend	_____
	Fringe benefits @ .4% (4/10 percent) of non-work study stipend	_____
3.	*Supplies (please list items to be purchased and estimated price per item including taxes and shipping, if appropriate):	
	Item No. 1 (e.g., software)	Estimated Price _____
	Item No. 2 (e.g., copying costs)	Estimated Price _____
	Item No. 3	Estimated Price _____
	(additional lines as needed)	
	Total estimated supplies	_____
4.	Travel (please list travel expenditures by date and estimated costs):	
	Travel No. 1 <i>SPAWC 2005</i>	Estimated Price <i>\$1000. ✓</i>
	Travel No. 2	Estimated Price _____
	Travel No. 3	Estimated Price _____
	(additional lines as needed)	
	Total estimated travel	_____
5.	*Capital Outlay (please list items to be purchased and estimated price per item including taxes and shipping, if appropriate):	
	Item No. 1	Estimated Price _____
	Item No. 2	Estimated Price _____
	Item No. 3	Estimated Price _____
	(additional lines as needed)	
	Total estimated capital outlay	_____
	<b>TOTAL PROPOSED BUDGET</b>	<b>\$ <i>1000. ✓</i></b>

\*Items purchased under \$2,500 (including taxes and shipping) are considered supply items. Capital Outlay items are those which cost \$2,500 or more (including taxes and shipping). Please contact the Purchasing Office for questionable items.

# Constrained Higher Order Statistics Based Multiuser Detection

*Ping Liu*

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## Abstract

In this project, we will investigate higher order statistics (HOS) based approaches to blind multiuser detection in an uplink CDMA system in the presence of unknown multipath channels. Since system information is embedded in the statistics of the received data vector, it is thus possible to retrieve them from the received data and then construct optimal receiver to detect the desired symbols. To remove user ambiguity and guarantee detection of desired user's symbols, some constraints on the receivers are imposed, resulting in constrained HOS based multiuser detection. Existing approaches in this category have shown some limitations. First, the convergence problem remains largely open. Second, most approaches consider detection of only one user at one time, which might be inefficient for uplink communications. In this project, we will develop globally convergent approach to detect either one user's symbol or all users' symbols simultaneously. Performance analysis in terms of convergence, channel estimation mean-squared-error, detector's bit-error-rate will be studied. Extensive simulations involving different communication scenario will be conducted to verify the proposed approaches.

## I. OBJECTIVE

The research goal is summarized into the following two aspects:

- For detection of a single user, we will try to solve the convergence problem by proposing new constraints and deriving closed-form solution for our proposed approach.
- Then we will consider detection of all users simultaneously by applying cross-cumulant properties among different users' symbols.

## II. SIGNIFICANCE

In the field of multiuser detection, considerable recent research has been focused on higher order statistics (HOS) based solutions, since second-order statistics (SOS) criteria in most cases do not suffice for the complete separation of the sources due to the existence of a unitary matrix ambiguity. The HOS approaches can be divided into two categories. One is to consider only the user of interest, such as in downlink CDMA systems. With the given spreading codes of the desired user, the detector is forced to satisfy a set of linear constraints such that the signals of only the desired user is detected [5], [7], [6], [8], [9], [5], [10]. The other one is to design a bank of detectors to recover all user's signals, such as in base stations. In the second category, to ensure that each detector detect the signals of a distinct user, multistage successive cancellation (MSC) [1] or a Gram-Schmidt orthogonalization on the detectors [3] are implemented.

However, existing approaches have shown some disadvantages. In the first category, [8] exhibits local minima and inability to optimally combine signal components from different paths. The approaches [9], [5] are batch iterative algorithms based on a batch processing of a block of data. Their global convergence has not been established analytically. Our previously developed CMA-based method [7], [10] requires proper initialization for the constraint vector. In the second category, the MSC approach [1] might suffer from error accumulation in the final solution, due to imperfect subtraction of the detected signals in previous stages, while the Gram-Schmidt orthogonalization [3] performed at each step imposes some computational complexity. At the

end of detection, the user ambiguity due to the position rotation is still unavoidable in those approaches. Motivated by the facts, we plan to develop new schemes for detecting either one or all users at the same time. Convergence issues will be mainly tackled in our research.

## REFERENCES

- [1] C-Y. Chi and C-H. Chen, "Cumulant-based inverse filter criteria for MIMO blind deconvolution: properties, algorithms, and application to DS/CDMA systems in multipath", *IEEE Trans. Signal Processing*, vol. 49, no. 7, pp. 1282-1299, July 2001.
- [2] A. Mansour and N. Ohnishi, "Multichannel blind separation of sources algorithm based on cross-cumulant and the Levenberg-Marquardt method", *IEEE Trans. Signal Processing*, vol. 47, pp. 3172-3175, Nov. 1999.
- [3] C. B. Papadias, "Globally convergent blind source separation based on a multiuser kurtosis maximization Criterion," *IEEE Trans. Signal Processing*, vol. 48, pp. 3508-3519, Dec. 2000.
- [4] A. Touzni and I. Fijalkow, M. G. Larimore and J. R. Treichler, "A globally convergent approach for blind MIMO adaptive deconvolution," *IEEE Trans. Signal Processing*, vol. 49, pp. 1166-1177, Jun. 2001.
- [5] J. Tugnait and T. Li, "Blind detection of asynchronous CDMA signals in multipath channels using code-constrained inverse filter criterion", *IEEE Trans. on Signal Processing*, vol. 49, no. 7, pp. 1300-1309, July 2001.
- [6] Z. Xu and P. Liu, "Kurtosis based maximization/minimization approach to blind equalization for DS/CDMA systems in unknown multipath", *Proc. of IEEE Intl. Conf. on Acoustics, Speech, and Signal Proc. (ICASSP'02)*, vol. III, pp. 2585-2588, Orlando, Florida, May 13-17, 2002.
- [7] Z. Xu and P. Liu, "Constrained CMA-Based multiuser detection under unknown multipath", *Proc. of 12th IEEE International Symposium on Personal Indoor and Mobile Radio Communication (PIMRC'01)*, pp. A21-25, San Diego, CA, September 30-October 3, 2001.
- [8] L. Li and H. Fan, "Blind CDMA detection and equalization using linearly constrained CMA", *Proc. of IEEE Intl. Conf. on Acoustics, Speech, and Signal Proc. (ICASSP'00)*, vol. 5, pp. 2905-8, June 2000.
- [9] J. Tugnait and T. Li, "Blind asynchronous multiuser CDMA receivers for ISI channels using code-aided CMA", *IEEE Journal on Selected Areas in Communications*, vol. 19, no. 8, pp. 1520-1530, August 2001.
- [10] P. Liu and Z. Xu, "A globally convergent CMA-based approach to blind multiuser detection, " *Proc. of 36th Asilomar Conf. On Signals, Systems, and Computers (Asilomar'02)*, Nov. 3-6, 2002.

# Ping Liu

Electrical Engineering  
Arkansas Tech University  
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## EDUCATION

**University of California, Riverside** 1999-2004  
**Ph.D.**, Electrical Engineering, March 2004  
Dissertation: Code-Aided Multiuser Detection for Multiple Access Wireless Communication Systems  
Advisor: Zhengyuan Xu

**Nanyang Technology University, Singapore** 1997-1999  
**M. Eng.**, Electrical and Electronic Engineering, March 1999

**Sichuan University, Chengdu, China** 1986-1993  
**M. Sc.**, Electrical Engineering, July 1993  
**B. Sc.**, Electrical Engineering, July 1990

## RESEARCH EXPERIENCE

**University of California, Riverside, CA** 07/2000-Present  
*Research Assistant, Department of Electrical Engineering*

- ◆ (Founded by UCR Academic Senate Research) Proposed several novel multiuser detection schemes, under a set of code-aided constraints, for CDMA systems in the presence of unknown channels, based on second-order and fourth-order statistics of the received signal and spreading codes of the desired user.
- ◆ (Founded by NSF) Proposed a power of  $R$  technique for multiuser detection in a CDMA system. The proposed approach is superior to the subspace method in terms of channel estimation, and significantly outperforms the MOE receiver in terms of detection performance.
- ◆ (Founded by NSF) Proposed blind multiuser detection schemes for long-code CDMA system by employing spatial diversity. Analyzed channel MSE and detection BER jointly.
- ◆ (Founded by ARL) Designed multiuser detection schemes for ultra-wideband (UWB) communication systems by converting a nonlinear pulse position modulated UWB system model into a linear form and then applying some advanced signal processing techniques.
- ◆ Designed blind channel equalization schemes for TDMA systems by exploring spatial characteristics of input constellations, and incorporating the information into optimization criterion to achieve significant performance gain.

## TEACHING EXPERIENCE

**University of California, Riverside, CA** 09/1999-08/2003  
*Teaching Assistant, Electrical Engineering*

- ◆ Instructed labs, graded assignments, prepared solution sets for the following undergraduate courses: *Engineering Circuit Analysis I, Engineering Circuit Analysis II, Electronic Circuits, Introduction to Communication Systems, Logic Design, Signals and Systems, and Computer Vision.*
- ◆ Participated in the Teaching Assistant Development Program (TADP) at University of California, Riverside, which addresses issues including teaching and learning style, teaching assistant's role and responsibility, and grading techniques. Obtained TADP certificate upon completing all required workshops.

## **PUBLICATIONS**

### **Journal Papers (Published/Accepted):**

1. Z. Xu, P. Liu and J. Tang, "A subspace approach to blind multiuser detection for ultra-wideband communication systems," Accepted with minor revision by *EURASIP Journal on Applied Signal Processing, special issue on UWB*.
2. Z. Xu, J. Tang, and P. Liu "Multiuser channel estimation for ultra-wideband systems using up to the second order statistics," Accepted by *EURASIP Journal on Applied Signal Processing, special issue on UWB*.
3. Z. Xu, P. Liu and X. Wang, "Blind multiuser detection: from MOE to subspace methods," *IEEE Trans. Signal Processing*, vol. 52, no. 2, pp. 510-524, Feb. 2004.
4. Z. Xu, P. Liu and M. D. Zoltowski, "Diversity assisted channel estimation and multiuser detection for downlink CDMA with long spreading codes," *IEEE Trans. Signal Processing*, vol. 52, no. 1, pp.190-201, Jan. 2004.
5. Z. Xu and P. Liu, "Blind multiuser detection by kurtosis maximization/minimization," *IEEE Signal Processing Letters*, vol. 11, no. 1, pp. 1-4, Jan. 2004.
6. Z. Xu and P. Liu, "Code constrained blind detection of CDMA signals in multipath channels," *IEEE Signal Processing Letters*, vol. 9, no. 12, pp. 389-392, December 2002.
7. Lin Zhen Yong and Liu Ping, "Structural attribute feature code representation and recognition of multifont printed Chinese characters", *International Journal of Pattern Recognition and Artificial Intelligence*, vol.15, (no.2), March 2001, pp.287-309.

### **Conference Papers:**

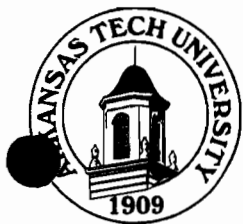
1. P. Liu and Z. Xu, "Temporal diversity assisted blind channel estimation for downlink long-code CDMA systems," accepted by ICASSP'04.
2. P. Liu, Z. Xu and J. Tang, "Subspace multiuser receivers for UWB communication systems," *Proc. of IEEE Conf. on Ultra Wideband Systems and Technologies*, Reston, Virginia, November 16-19, 2003.
3. P. Liu, Z. Xu and J. Tang, "Minimum variance multiuser detection for impulse radio UWB systems," *Proc. of IEEE Conf. on Ultra Wideband Systems and Technologies*, Reston, Virginia, November 16-19, 2003.
4. P. Liu and Z. Xu, "Blind adaptive multiuser detection for uplink long-code CDMA systems," *Proc. of IEEE Workshop on Statistical Signal Processing*, pp. 329-332, St. Louis, Missouri, 2003.
5. P. Liu and Z. Xu, "Linear multiuser detection for uplink long-code CDMA systems," *Proc. Of IEEE Intl. Conf. On Acoustics, Speech, and Signal Proc. (ICASSP'03)*, Hong Kong, April 6-10, 2003.
6. P. Liu and Z. Xu, "A globally convergent CMA-based approach to blind multiuser detection," *Proc. of 36th Asilomar Conf. On Signals, Systems, and Computers (Asilomar'02)*, Pacific Grove, CA, November 3-6, 2002.
7. P. Liu and Z. Xu, "Channel estimation and multiuser detection for long-code CDMA," *Proc. Of 36<sup>th</sup> Asilomar Conf. On Signals, Systems, and Computers (Asilomar'02)*, Pacific Grove, CA, November 3-6, 2002.
8. Z. Xu, P. Liu and X. Wang, "Towards closing the gap between MOE and subspace methods," *Proc. of 36th Asilomar Conf. On Signals, Systems, and Computers (Asilomar'02)*, Pacific Grove, CA, November 3-6, 2002.
9. Z. Xu and P. Liu, "Kurtosis based maximization/minimization approach to blind equalization for DS/CDMA systems in unknown multipath," *Proc. of IEEE Intl. Conf. On Acoustics, Speech, and Signal Proc. (ICASSP'02)*, Orlando, Florida, May 13-17, 2002.
10. P. Liu and Z. Xu, "Correlation matching in channel estimation for multirate DS/CDMA," *Proc. of IEEE Intl. Conf. On Acoustics, Speech, and Signal Proc. (ICASSP'02)*, Orlando, Florida, May 13-17, 2002.
11. Z. Xu and P. Liu, "Code constrained CMA-based multirate multiuser detection," *Proc. of 35th Asilomar Conf. On Signals, Systems, and Computers (Asilomar'01)*, Pacific Grove, CA, November 5-7, 2001 (invited).
12. Z. Xu and P. Liu, "Constrained CMA-based multiuser detection under unknown multipath," *Proc. Of 12th IEEE International Symposium on Personal Indoor and Mobile Radio Communication (PIMRC'01)*, pp. A21-25, San Diego, CA, September 30-October 3, 2001.
13. P. Liu and Z. Xu, "Convergence analysis of a new blind equalization algorithm with M-ary PSK channel inputs," *Proc. of IEEE Intl. Conf. on Acoustics, Speech, and Signal Proc. (ICASSP'01)*, vol.

- IV, pp. 2529-2532, Salt Lake City, Utah, May 7-11, 2001.
14. Z. Xu and P. Liu, "Demodulation of amplitude modulated signals in the presence of multipath, " Proc. of 10<sup>th</sup> IEEE Workshop on Statistical Signal and Array Processing (SSAP'00), pp. 33-37, Pocono Manor, Pennsylvania, August 14-16, 2000.
  15. Z. Xu and P. Liu, "New criteria for blind equalization of M-PSK signals, " Proc. of 10th IEEE Workshop on Statistical Signal and Array Processing (SSAP'00), pp. 692-696, Pocono Manor, Pennsylvania, August 14-16, 2000.
  16. Ping Liu and Zhen Yong Lin, "Recognition of off-line Chinese character via a structural method, " Proceedings of JCIS'98, Durham, USA.
  17. Zhen Yong Lin and Ping Liu, "An index search pre-classification scheme for Chinese characters, " Proceedings of JCIS'98, Durham, USA.

#### **PROFESSIONAL AFFILIATION AND ACTIVITIES**

- ◆ Student member of IEEE, since 2000.
- ◆ Reviewer for *IEEE Transactions on Signal Processing*, *IEEE Transactions on Communications*, *IEEE Transactions on Wireless Communications*, *IEEE Transactions on Vehicular Technology*, and *IEEE Communication Letters*.





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November 5, 2004

Dr. Ping Liu  
Research Scientist  
Arkansas Tech University  
Center for Energy Studies, Room 155  
Russellville, AR 72801

Dear Dr. Liu:

Congratulations! Academic Affairs is pleased to announce your application for the Spring, 2005 Faculty Research Grant has been recommended by the Faculty Salary, Benefits, and Awards Committee. Based on this recommendation, Academic Affairs has approved the \$1,000 budget for your research of Constrained Higher Order Statistics Based Multiuser Detection. Requisitions regarding the grant will be processed through your Dean's office and should be expended by June 30, 2004.

Your research on this project is sure to not only benefit your department, but Arkansas Tech University as a whole. We wish you success with this endeavor.

Sincerely,

A handwritten signature in cursive script, which appears to read "Jack Hamm".

Jack Hamm  
Vice President for Academic Affairs

Copy: Dr. Stephen Kline  
Dr. John Watson  
File