

# K. RAJ KUMAR

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## ACADEMICS

**Ph.D.** (Expected May 2009) in Electrical Engineering, UNIVERSITY OF SOUTHERN CALIFORNIA (USC), Los Angeles, USA.

- Advisor: Prof. Giuseppe Caire
- GPA: 3.97/4
- Research: Physical layer wireless communication, with a particular emphasis on coding and information theory (focussing on MIMO systems, cooperative/cognitive communications and other multi-user channels).
- Minor: Mathematics

**M.Sc.(Engg.)** (July 2005) in Electrical Communication Engineering, INDIAN INSTITUTE OF SCIENCE, Bangalore, India.

- Advisor: Prof. P. Vijay Kumar
- Thesis: Provided the first explicit construction of approximately universal Space-Time codes for the MIMO fading channel and the MIMO-ARQ channel.

**B.E.** (June 2003) in Electronics and Communication Engineering, UNIVERSITY OF MADRAS, India.

- Standing: First Class with Distinction

## HONOURS AND AWARDS

- Received the OAKLEY FELLOWSHIP from the Graduate School at USC for the 2007-08 academic year.
- Recipient of the 2006 BEST STUDENT PAPER AWARD from the Dept. of Electrical Engineering - Systems, University of Southern California.
- Recipient of the IISc INSTITUTE SCHOLARSHIP, provided by the Ministry of Human Resources Development (MHRD), Government of India, 2003-2005.

## AREAS OF INTEREST

- Cooperative communication networks: Information theory and coding
- MIMO systems: Space-Time codes and performance limits
- Cognitive Radio
- Network MIMO
- Analysis of low-power communication scenarios: Sensor networks, Femto-cells
- Low Complexity MIMO Receivers
- Quantum Information, Neurobiology and Genetics: Applications of Info. Theory

## RESEARCH SUMMARY

**Ph.D. Candidate, under the guidance of Prof. Giuseppe Caire, Dept. of EE - Systems, USC**

- **Cooperative communications:** Analyzed the outage behaviour of the dynamic decode and forward protocol for the single relay fading channel, and characterized the diversity-multiplexing tradeoff (DMT) for finite block-lengths. Designed DMT optimal coding schemes along with addressing practical issues such as relay error detection, resulting in codes operating within a fraction of a dB from outage probability.
- **Low complexity MIMO receivers:** Provided an analysis of the performance of linear MMSE and ZF receivers under consideration for the forthcoming IEEE 802.11n standard. Two types of asymptotic analysis: characterized the outage exponent (DMT) for high SNR using large deviation theory, and proposed a Gaussian approximation for the mutual information in the large antenna regime using random matrix theory.

- **Space-Time (ST) codes from algebraic lattices:** Constructed explicit ST codes derived from dense lattices and cyclic division algebras endowed with good packing and shaping properties, and moderate decoding complexity. Extended the methodology to construct codes with long block-lengths using trellis coded modulation. Performance in terms of error probability is among the current state of the art.
- **Correlated MIMO channels:** Analyzed the impact of correlation on the outage performance of ST codes over Rayleigh and Rician MIMO channels by characterizing the diversity-multiplexing tradeoff for arbitrary correlation structures.
- **Adaptive modulation for MIMO systems:** Investigated the use of adaptive coded modulation for the MIMO fading channel. Characterized the transmitter power allocation policies for discrete constellations (under both long-term and short-term power constraints) using the theory of mercury-waterfilling.
- **CSI feedback schemes for cellular uplink:** (Work in progress) We are currently working on the problem of designing short block-length codes designed for the application of CSI feedback over the cellular uplink channel.

**Visiting Research Scientist, Institute EURECOM,  
Sophia Antipolis, France (Aug. 2008)**

- **Cooperative wireless networks:** (Collaborative work with Prof. Petros Elia) We have been working on the area of cooperative wireless networks, and on the application of the recently proposed deterministic channel model to this scenario.

**M.Sc.(Engg.) Thesis, under the guidance of Prof. P. Vijay Kumar,  
Dept. of Electrical Communication Engg., Indian Institute of Science**

- **Explicit construction of approximately universal ST codes:** Settled the open problem of explicitly constructing ST codes that are high-SNR outage optimal for arbitrary fading statistics and arbitrary number of transmit/receive antennas. The proposed ST codes are derived from cyclic division algebras.
- **Codes for the MIMO feedback channel:** Provided a sufficient condition for a family of ST codes to be high SNR outage optimal over the MIMO-ARQ channel, and an explicit algebraic construction of codes meeting this criterion.

**PROFESSIONAL  
ACTIVITIES**

- Reviewer for the IEEE Transactions on Information Theory, IEEE Transactions on Communications, IEEE Transactions on Wireless Communication, Foundations and Trends in Communications and Information Theory, Eurasip Journal on Wireless Communication and Networking.
- Reviewer for several conferences including IEEE ISIT, ITW, PIMRC, GLOBECOM.
- Student member of the IEEE.

**TEACHING  
EXPERIENCE**

- Teaching assistant for the following courses:
- USC EE-364 (Probability & Statistics for Electrical Engineers)
    - Instructor: Prof. Keith Chugg (Fall 2005)
  - USC EE-562A (Random Processes in Engineering)
    - Instructor: Prof. Todd Brun (Spring 2006 and Spring 2007)
  - USC EE-562B (Advanced Topics in Random Processes)
    - Instructor: Prof. Robert A. Scholtz (Spring 2009)

**PUBLICATIONS**

**Journal Papers**

1. K. Raj Kumar and Giuseppe Caire, “Coding and Decoding for the Dynamic Decode and Forward Relay Protocol,” Accepted for publication in *IEEE Trans. Inform. Theory*. Available at <http://arxiv.org/abs/0801.2588>.
2. K. Raj Kumar and Giuseppe Caire, “Space-Time Codes from Structured Lattices,” Accepted for publication in *IEEE Trans. Inform. Theory*. Available at <http://arxiv.org/abs/0804.1811>.

3. Giuseppe Caire and K. Raj Kumar, "Information Theoretic Foundations of Adaptive Coded Modulation", Invited paper, *Proceedings of the IEEE* (Special issue on Adaptive Modulation/Transmission), Dec. 2007.
4. K. Raj Kumar, Giuseppe Caire and Aris L. Moustakas, "Asymptotic Performance of Linear Receivers in MIMO Fading Channels," Submitted to *IEEE Trans. Inform. Theory*, Oct. 2008. Available at: <http://arxiv.org/abs/0810.0883>.
5. Giuseppe Caire, Petros Elia and K. Raj Kumar, "Space-Time Coding: An Overview", Invited paper, *Journal of Communications Software and Systems (JCOMSS)*, Vol. 2, No. 3.
6. Sameer A. Pawar, K. Raj Kumar, Petros Elia, B.A. Sethuraman and P. Vijay Kumar, "Minimum-Delay Space-Time Codes Achieving the DMD Tradeoff of the MIMO-ARQ Channel," Accepted for publication in *IEEE Trans. Inform. Theory*.
7. Petros Elia, K. Raj Kumar, Sameer A. Pawar, P. Vijay Kumar and Hsiao-feng Lu, "Explicit, Minimum-Delay Space-Time Codes Achieving The Diversity-Multiplexing Gain Tradeoff", *IEEE Trans. Inform. Theory*, Vol. 52, No. 9, pp. 3869 - 3884, Sept. 2006.

#### Conference Papers

1. K. Raj Kumar and Giuseppe Caire, "Channel State Feedback over the MIMO-MAC," Submitted to *IEEE Int. Symp. on Inform. Theory (ISIT-09)*, Seoul, Jan. 2009.
2. Aris L. Moustakas, K. Raj Kumar and Giuseppe Caire, "Performance of MMSE MIMO Receivers: A Large N Analysis for Correlated Channels," Invited paper, *IEEE 69th Vehicular Technology Conference*, Barcelona, April 2009.
3. K. Raj Kumar and Giuseppe Caire, "Coding and Decoding for the Dynamic Decode and Forward Relay Protocol," *Proc. IEEE Int. Symp. Inform. Theory (ISIT-08)*, Toronto, Jul. 2008.
4. K. Raj Kumar and Giuseppe Caire, "Code Design for the Dynamic Decode and Forward Relay Protocol," *Proc. 45th Allerton Conf. on Communications, Control and Computing*, Illinois, Sept. 2007.
5. K. Raj Kumar, Giuseppe Caire and Aris L. Moustakas, "The Diversity-Multiplexing Tradeoff of Linear MIMO Receivers," *Proc. IEEE Inform. Theory Workshop (ITW-07)*, Lake Tahoe, Sep. 2007.
6. K. Raj Kumar and Giuseppe Caire, "Structured Lattice Space-Time Trellis Coded Modulation", *Proc. IEEE Int. Symp. Inform. Theory (ISIT - 2007)*, Nice, France, Jun. 2007.
7. K. Raj Kumar and Giuseppe Caire, "Outage Analysis and Code Design for Correlated MIMO Fading Channels", *Proc. IEEE Int. Symp. Inform. Theory (ISIT - 2007)*, Nice, France, Jun. 2007.
8. K. Raj Kumar and Giuseppe Caire, "Construction of Structured LaST Codes", *Proc. IEEE Int. Symp. Inform. Theory (ISIT - 2006)*, Seattle, July 2006.
9. S. A. Pawar, K. Raj Kumar, P. Elia, P. Vijay Kumar and B. A. Sethuraman, "Achieving the D-MG Tradeoff for all  $T \geq M$  as well as for the ARQ Channel", *Proc. IEEE Int. Symp. Inform. Theory (ISIT - 2005)*, Adelaide, Sept. 2005.

10. Petros Elia, K. Raj Kumar, Sameer A. Pawar, P. Vijay Kumar and Hsiao-feng Lu, "Explicit, Minimum-Delay Space-Time Codes Achieving The Diversity-Multiplexing Gain Tradeoff", *Proc. of IEEE Int. Symp. Inform. Theory (ISIT - 2005)*, Adelaide, Sept. 2005.
11. Hsiao-feng Lu, Petros Elia, K. Raj Kumar, Sameer A. Pawar, and P. Vijay Kumar, "Space-Time codes meeting the D-MG Tradeoff with low signaling complexity", *Proc. of the 39th Annual Conference on Information sciences and systems*, John Hopkins University, March 2005.
12. K. Raj Kumar, Sameer A. Pawar, Petros Elia, P. Vijay Kumar and Hsiao-feng Lu, "Two Generalizations of the Rank-Distance Space-Time Code", *Proc. National Conference on Communications (NCC-'05)*, India, Jan. 2005.
13. Sameer A. Pawar, K. Raj Kumar, Petros Elia, P. Vijay Kumar and Hsiao-feng Lu, "Space-Time Codes Optimal Under the Diversity-Multiplexing Gain Tradeoff", *Proc. National Conference on Communications (NCC-'05)*, Kharagpur, India, Jan. 2005.
14. Petros Elia, P. Vijay Kumar, Sameer A. Pawar, K. Raj Kumar, B. Sundar Rajan and Hsiao-feng Lu, "Diversity Multiplexing Tradeoff Analysis of a Few Algebraic Space-Time Constructions", *Proc. of the 42nd Allerton Conf. on Communications, Control and Computing*, Sept. 29 - Oct. 1, 2004.
15. P. Vijay Kumar, Petros Elia, Hsiao-feng Lu, Sameer A. Pawar, K. Raj Kumar, "On the Decoding and Diversity-Multiplexing Gain Tradeoff of a Recent Multilevel Construction of Space-Time Codes", *Proc. IEEE Int. Symp. Inform. Theory*, pp 128, June 27-July 2, 2004, Chicago.
16. Raj Kumar K., Srinivas S.R., N. Venkateswaran, "Automated Detection of Diabetic Retinopathy Using Image Processing", *Proc. of the International Congress on Biological & Medical Engg. (ICBME 2002)*, Singapore, Dec. 2002.

## REFERENCES

Prof. Giuseppe Caire (Ph.D. Advisor)  
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 Indian Institute of Science (On leave of absence from USC)  
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