

Report on tracking of new knowledge

January 13, 2009

The project partners established an IPR Policy Committee consisting of technical experts and legal experts in September, 2006. This committee defines rules and guidelines for the reuse of existing knowledge (PEKH, Pre-Existing Know-How, Background) and the tracking of new knowledge generation (Knowledge, Foreground) in the project. The IPRs generated by the project will be evaluated by the IPR Policy Committee for patent filing or for exploitation. The actual patent filing itself will be performed by the partners involved. The ultimate goal of this activity is to build up and maintain a MASCOT IPR portfolio

IPR Policy Committee Members are:

- **Legal experts:** Horst Rode (FTW), Teemu Soininen (NOKIA), Ulf Johann (FhG-HHI), Roberta Melchiorre (PoliTo), Verena Dolovai (VUT), Matias Beck (ETHZ), Josep Civil (FBM-UPF), N.N. (UNICAL).
- **Technical experts:** Christoph Mecklenbräuker (FTW), Ari Hottinen (NOKIA), Martin Schubert (FhG-HHI), Giorgio Taricco (PoliTo), Gerald Matz (VUT), Helmut Bölcskei (ETHZ), Ezio Biglieri (FBM-UPF), Emanuele Viterbo (UNICAL).

New knowledge generated during 2007

1. Golden Space-Time Trellis Coded Modulation for high data rate transmission in 2x2 MIMO systems. In particular code design and optimization, performance evaluation in different channel conditions, reduced complexity decoding and VLSI implementation. Joint work by: Barbara Cerato, Yi Hong and Emanuele Viterbo.
2. Optimum receiver scheme and specific iterative decoding algorithm for space-time coded MIMO systems with imperfect channel state information at the receiver (obtained by pilot symbol insertion) and in the presence of perfect channel distribution information at the transmitter corresponding to separately correlated Rician fading channel. Joint work by: Giorgio Taricco, Giulio Coluccia, [JSAC 2007].

3. Throughput optimization for the optimum receiver scheme developed in [Taricco, Coluccia JSAC 2007] leading to a blind receiver design. Joint work by: Giulio Coluccia, Giorgio Taricco, [Communications Letters 2007].
4. Generalization of the optimum receiver concept developed in Ref. [Taricco, Coluccia JSAC 2007] to MIMO-OFDM transmission. Joint work by: Giorgio Taricco, Giulio Coluccia, Erwin Riegler, and Christoph Mecklenbräuer
5. Method for the asymptotic analysis of the ergodic capacity of a narrowband MIMO communication system affected by separately correlated Rician fading and narrowband interference including iterative covariance optimization algorithm. Joint work by: Giorgio Taricco, Erwin Riegler, [ISIT 2007]
6. Algorithm for the asymptotic derivation of the mutual information statistics of a narrowband MIMO communication system affected by separately correlated Rician fading and narrowband interference. Joint work by: Erwin Riegler, Giorgio Taricco, [Globecom 2007]
7. Algorithm for the derivation of the sum capacity and of the corresponding rate region for a narrowband multiuser MIMO communication channel affected by separately correlated Rician fading. Joint work by: Erwin Riegler, Giorgio Taricco, [Globecom 2007]
8. Method for analyzing the outage characteristics of correlated Ricean fading, coherent MIMO channels and establishment of the "critical rate" notion, below which communication at zero outage is possible. Joint work by Markus Gärtner and Helmut Bölcskei [ISIT 2007]
9. Method to establish the optimal diversity-multiplexing (DM) tradeoff of coherent time, frequency and time-frequency selective-fading MIMO channels and a code design criterion for DM-tradeoff optimality for these channels. Joint work by Pedro Coronel and Helmut Bölcskei [ISIT 2007].
10. Reference VLSI implementation of a programmable matrix decomposition architecture for MIMO communication systems and a detailed investigation of associated implementation trade-offs. Joint work by Christoph Studer, Patrick Blösch, Peter Friedli, and Andreas Burg [ACSSC 2007]
11. VLSI implementation of a reduced-complexity MIMO detector with close-to ML error rate performance. Joint work by Christian Hess, Markus Wenk, Andreas Burg, Peter Lüthi, Christoph Studer, Norbert Felber and Wolfgang Fichtner [GLSVLSI 2007]
12. VLSI Implementation of a High-Speed Iterative Sorted MMSE QR Decomposition based on Givens rotations providing the base for improved layered stream decoding. Joint work by P. Luethi, A. Burg, S. Haene, D. Perels, N. Felber, W. Fichtner [ISCAS 2007]
13. Space-Time Block Codes with reduced-complexity decoders for transmission in 2x2 and 4x2 MIMO systems. In particular: code design and optimization, and performance evaluation in different channel conditions. Joint work by: Ezio Biglieri, Yi Hong and Emanuele Viterbo.
14. Multiuser detection when the number of active users is unknown. In particular: Design of detectors optimized under different cost functions, dynamic models for users' activity and users' mobility, performance evaluation, and design of reduced-complexity receivers. Joint work by: Ezio Biglieri, Daniele Angelosante, Marco Lops, and Adria' Tauste Campo.

15. Neighbor detection in wireless ad hoc networks. In particular: Development of an algorithm, its analysis, and evaluation of its performance. Joint work by: Ezio Biglieri, Daniele Angelosante, and Marco Lops.
16. Method for low-complexity lattice reduction using Seysen's algorithm in MIMO detection and precoding. Joint work by Dominik Seethaler, Gerald Matz, and Franz Hlawatsch (ICASSP 2007)
17. VLSI implementation of Brun's lattice reduction for MIMO broadcast precoding. Joint work by Andreas burg, Dominik Seethaler, and Gerald Matz (ISCAS 2007)
18. Algorithm for flexible multi-user channel estimation in MIMO-OFDMA. Joint work by Peter Fertl and Gerald Matz (ICASSP 2007)
19. Method for joint data detection and channel estimation in MIMO-IDMA systems based on factor graphs. Joint work by Clemens Novak, Gerald Matz, and Franz Hlawatsch (ICASSP 2007 and ICC 2008).
20. Algorithm for low-complexity and full-diversity MIMO detection based on condition number thresholding. Joint work by J. Maurer and G. Matz (ICASSP 2007)

New Knowledge Generated During 2008

21. Channel estimation for MIMO-OFDM. In particular: Development of an algorithm, its analysis, and evaluation of its performance. Joint work by: Ezio Biglieri, Daniele Angelosante, and Marco Lops.
22. Low-complexity multiuser detectors for the estimate of transmitted data when the number of users is unknown. Joint work by: Ezio Biglieri, Daniele Angelosante, and Marco Lops.
23. Receiver estimating the identity, the transmitted data, and the received power of each user in multiuser systems when the number of active users is unknown. Joint work by: Ezio Biglieri, Daniele Angelosante, and Marco Lops.
24. Analysis of High and low-SNR regimes for stochastic networks. Joint work by: G. Alfano, A. Tulino, and M. Guillaud [ISITA 2008].
25. Scaling laws for large ad-hoc wireless networks with Wishart-Poisson fading. Joint work by: G. Alfano, M. Guillaud, and A. Tulino [ISSSTA 2008].
26. SINR estimation in random beamforming with noisy MIMO channel measurements. Joint work by: R. Tresch and M. Guillaud [ICC 2008].
27. Analysis of imperfect channel knowledge on cellular interference alignment. Joint work by: R. Tresch and M. Guillaud [submitted to LTE evolution workshop 2009].
28. Decoding of LDPC codes with binary vector messages and scalable complexity. Joint work by: G. Lechner, I. Land, and L. Rasmussen [Symposium on Turbo Codes and Related Topics 2008].
29. Optimization of binary LDPC codes for the q-ary symmetric channel with moderate q. Joint work by: G. Lechner and C. Weidmann [Symposium on Turbo Codes and Related Topics 2008].
30. Soft sphere decoder for an iterative receiver in time-varying MIMO channels. Joint work by C. Dumard, J. Jalden, and T. Zemen [EUSIPCO 2008].

31. High-SNR analysis of outage-limited communications with bursty and delay-limited information. Joint work by: S. Kittipiyakul, P. Elia, and T. Javidi [accepted at Transactions IT 2008].
32. Derivation of asymptotic ergodic capacity of a wideband MIMO communication system affected by separately correlated Rician fading. Algorithm to obtain the corresponding optimum input covariance matrix. Joint work by: Giorgio Taricco and Erwin Riegler [Globecom 2008].
33. Investigation of the asymptotic ergodic capacity region of a wideband multiuser MIMO communication channel affected by separately correlated Rician fading. Two algorithms to obtain the corresponding optimum transmit covariance matrices (for sum-rate and weighted sum-rate). Joint work by: Erwin Riegler and Giorgio Taricco [Globecom 2008].
34. Derivation of the error bound for the spectral optimization of the optimum OFDM MIMO receiver. Joint work by: Giulio Coluccia, Erwin Riegler, Christoph Mecklenbräuerl, and Giorgio Taricco [submitted to JSTSP 2008].
35. Analysis of the transmit covariance optimization algorithm of the narrowband MIMO communication system affected by separately correlated Rician fading and narrowband interference depending on the system parameters. Joint work by: Giorgio Taricco, Erwin Riegler [submitted to Transactions IT 2008].
36. Proof of asymptotic Gaussianity for the mutual information statistics of a narrowband MIMO communication system affected by separately correlated Rician fading and narrowband interference. Joint work by: Erwin Riegler, Giorgio Taricco [submitted to Transactions IT 2008].
37. To be defined
38. To be defined

VHDL Reference Designs (Deliverable D2.2.1)

Four algorithms have been selected for the VHDL reference designs. The following four algorithms are included in Deliverable D2.2.1:

1. **Sorted QR Decomposition** [P. Luethi, A. Burg, S. Haene, D. Perels, N. Felber, and W. Fichtner. VLSI implementation of a high-speed iterative sorted MMSE QR decomposition. In IEEE Int. Symp. on Circuits and Systems, pages 1421–1424, New Orleans, May 2007]
2. **Singular Value Decomposition** [C. Studer, P. Blösch, P. Friedli, and A. Burg. Matrix decomposition architecture for MIMO systems: Design and implementation trade-offs. In Proc. 41st Asilomar Conf. on Signals, Systems and Computers, Pacific Grove (CA), USA, Nov. 2007]
3. **Lattice-reduction aided precoding using Brun's algorithm** [A. P. Burg, D. Seethaler, and G. Matz. VLSI implementation of a lattice-reduction algorithm for multi-antenna broadcast precoding. In IEEE Int. Symp. on Circuits and Systems, pages 673–676, New Orleans, May 2007]



4. **425 Mbps K-BEST decoder for MIMO and Multi-User detection** [M. Wenk, M. Zellweger, A. P. Burg, N. Felber, and W. Fichtner. K-best MIMO detection VLSI architectures achieving up to 424 Mbps. In Proc. IEEE Int. Symp. on Circuits and Systems, pages 1151–1154, May 2006]

The dissemination level of Deliverable D2.2.1 is defined as “Confidential, only for members of the consortium (including the Commission Services)” in Table 2 of the MASCOT Technical Annex (see page 26 of AMENDMENT 2). The MASCOT Consortium Agreement defines the rules among the eight MASCOT partners in further detail:

- IPR and Ownership in Clause IV.3 on page 10 and
- Access Rights for Use: in Clause IV.4.4 on page 12.

Furthermore, the MASCOT Project Steering Committee agreed on 22.02.2008 that ETHZ will make the VHDL library of reference designs available to interested external parties on request. The reference designs can be licensed and ordered by accepting the MASCOT Reference Design License Agreement. After successful license application and license approval, the Integrated Systems Laboratory at the ETH Zurich, Switzerland, will contact the licensee and the reference designs will be made available to the licensee. ETHZ does not give any guarantees or liability. The VHDL library of reference designs will be provided with only minimal support.

Patent Applications

1. There were no patent applications during 2006
2. During 2007 there were three (3) patent applications (Applicant: Nokia)
3. During 2008 there were four (4) patent applications (Applicant: Nokia)
4. During 2009 there was one (1) patent application (Applicant: Nokia)

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