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CHAIRHOLDER PROFILES

Christian B. Schlegel
Canada Research Chair in High-Capacity Digital Communications
University of Alberta
Tier 2 - January 1, 2002

Achievements:
Published close to 100 research papers, a popular research book entitled *Trellis Coding* (1997), and an invited chapter contribution to the *Encyclopedia in Telecommunications*; two more research books in production; has given many invited research seminars and Institute of Electrical and Electronic Engineers (IEEE) workshops; senior member of the IEEE Information Theory and Communication Societies.

Research Involves: Study of fundamental limits of communication systems, high-capacity, limit-achieving algorithms, and their implementations in hardware

Research Relevance: Findings will help build intellectual talent in Canada that is needed to develop new and innovative wireless technologies, and assist Canadian industries to adopt the new high-capacity capabilities by developing them in a manner which is readily transferable out of the lab

Coming to Canada from: University of Utah, U.S.

ACHIEVING HIGH-CAPACITY WIRELESS COMMUNICATIONS

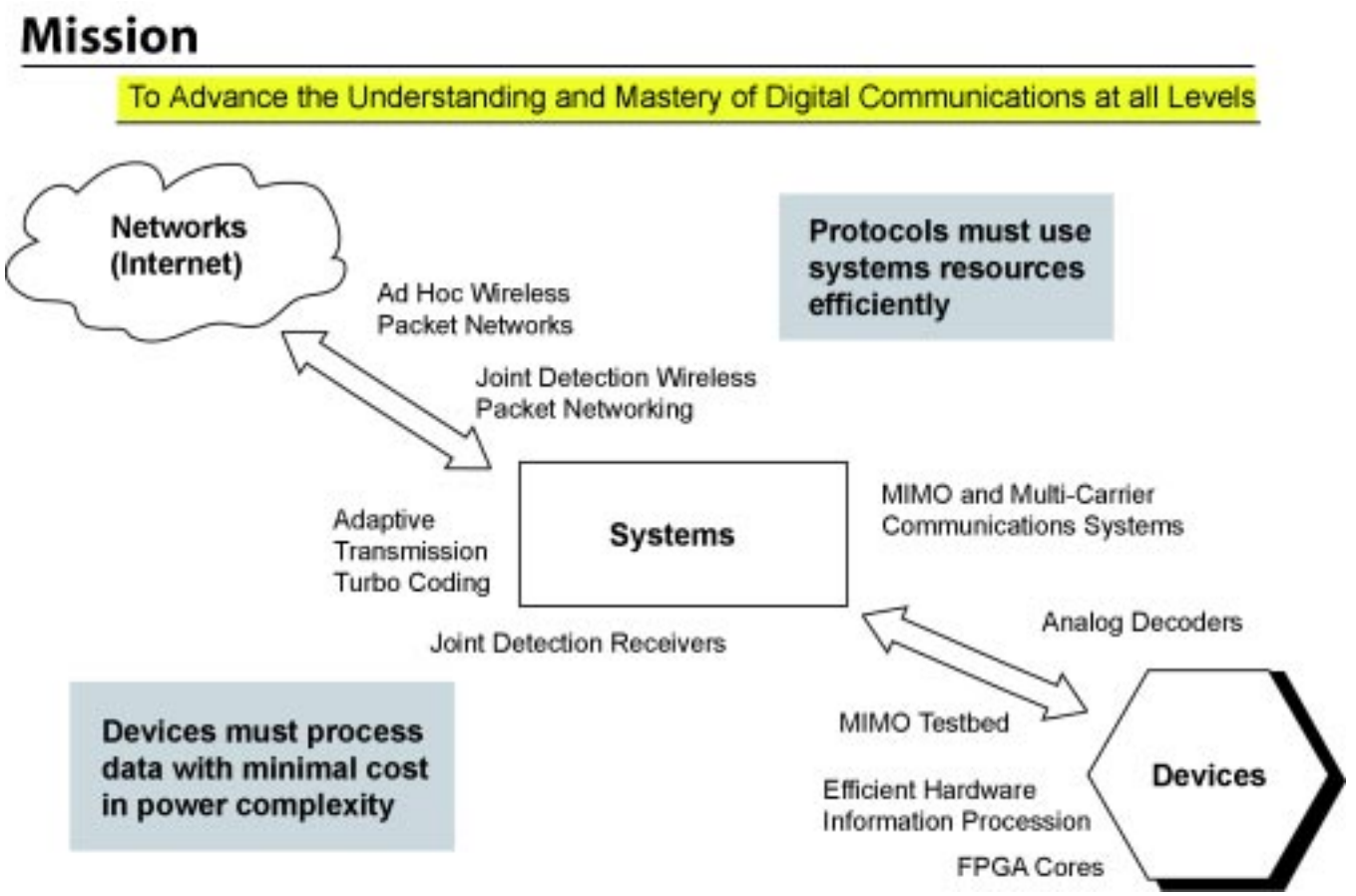
The growth of wireless communications over the past two decades has been nothing less than astounding. Furthermore, it is expected that wireless technology will continue to grow at this phenomenal rate. New and unexpected applications, such as wireless full-immersion virtual reality, may only be a few years away. With the gigantic data rates that such applications require, it will be essential to build digital data links which fully harness a channel's capacity.

Sophisticated theories prove that the capacity of wireless networks is essentially unlimited, but that very complex signal encoding and decoding methods, combined with complex transmitter and receiver systems, are required to harness this capacity. The success of future high-data rate information systems depends on a number of emerging core technologies at the frontier of digital communications research and development.

Dr Christian B. Schlegel is an internationally recognized expert in the theory and practice of digital communications systems design, analysis and implementation. The central focus of his

research as Canada Research Chair in High-Capacity Reliable Digital Communications will be on highly advanced, digital modulation, demodulation, coding and decoding methods, with the ultimate aim to build higher capacity wireless networks. He will work on error control coding technology (which renders an unreliable channel useable by avoiding transmission errors through the introduction of controlled redundancy), multiple antenna systems (required to increase data rates beyond current limits), interference control and mitigation technologies (addressing the serious problems of interference), high-speed, low complexity VLSI implementations (required to operate a data link), and analog circuit implementation of digital error control decoders.

Dr Schlegel's Chair will establish a High-Capacity Digital Communications Centre at the University of Alberta. The centre will provide a flexible and rapid design, prototyping and testing capability for new ideas in wireless communications research, and will benefit local and national industry through research results, highly trained human resources and access to experimentation facilities.



DR CHRISTIAN SCHLEGEL

HIGH-CAPACITY DIGITAL COMMUNICATIONS LABORATORY

iCORE Professor
Electrical and Computer Engineering
University of Alberta

Dr Christian Schlegel is an iCORE Professor of High-Capacity Digital Communications, a position he holds in the department of electrical and computer engineering at the University of Alberta. iCORE has committed $350,000 per year for five years for a total of $1.75 million dollars to develop this research group at the University of Alberta.

EXECUTIVE SUMMARY

The primary focus of the High-Capacity Digital Communications (HCDC) Laboratory is the efficient transmission of digital data through real-world communications channels, in particular, wireless data links. Each such link has an inherent capacity, which forms a limit on the maximum rate at which digital data can be transmitted reliably over the link. Achieving these limits, and thus optimally harnessing a channel's inherent information carrying potential, is the goal of the projects of the HCDC Laboratory.

The channel to which most attention is presently given is the multiple antenna, a special form of a multiple-input multiple-output (MIMO) channel, which consists of antenna arrays at both the transmitter and the receiver instead of single antennas. It is known that this channel can, under favorable conditions, increase the capacity of a data link by a factor equal to the minimum number of antenna elements at the receiver or the transmitter.

During the 2002/2003 fiscal year the HCDC team designed and constructed a prototype MIMO channel measurement system and conducted initial channel measurements which confirm theoretical expectations as well as results obtained by other laboratories. This system is currently being enhanced for real-time operations as well as full portability.

On the analog decoder research side, the design of a medium-sized product code analog subthreshold CMOS decoder has been completed and will enter the production phase this summer and testing later in the year. Initial measurements and projections based on simulations confirm that analog technology has the potential to outperform digital decoders by two orders of magnitude in power consumption and space requirements, and thus can challenge current digital designs and possible displace them in the future. Current efforts of HCDC members are to prove feasibility with real input and output circuitry. The HCDC laboratory has also generated 30 technical publications which are currently at various stages in the publication process. Most of these publications target capacity approaching communications systems for multiple access communications, MIMO channels, or random access packet networking.

During this phase the HCDC laboratory has expanded its team by hiring seven new students and a VHDL design engineer, Mr. Robert Hang. Furthermore a new University of Alberta faculty member, Dr Stephen Bates, will join the department this fall and will be an associate member of the HCDC laboratory. Dr Bates specializes in packet traffic theory and has also extensive industry experience, where he was involved in building 10 Gigabit Ethernet prototypes. Professor Schlegel has been appointed General Chair for the IEEE Communication Theory Workshop 2005, and Technical Program Chair for the 2005 International Symposium on Information Theory.

RESEARCH PROGRAM OVERVIEW

The focus of activities of the High-Capacity Digital Communications (HCDC) Laboratory, created by iCORE Professor Schlegel under iCORE funding, is the efficient transmission of digital data through a variety of currently popular transmission channels, most notably wireless channels. The goal is to transmit digital data with the least amount of resources, in terms of energy and bandwidth, and with the maximum amount of reliability. The laboratory's name, "high capacity," pertains to the capacity limits which were theoretically established by Claude Shannon in 1948, and which give each channel a maximum rate at which reliable communication is theoretically possible. Achieving this rate has been the research and development focus of many scientists and engineers over the past half century.

Among a large number of modern signal processing methods, error control coding is the single most important technique which allows communications engineers to approach this elusive limit. The main focus of our projects is consequently the efficient and judicious application of error control coding and supporting signal processing techniques to achieve a channel's inherent data carrying potential, that is, approach or achieve the capacity limit.

This question arises in a sense anew with each new channel that is being considered. The HCDC focuses on some novel channels as well as on more traditional transmission channels. Most important among those is the multiple antenna channel, which uses several transmit and receive antennas, also generically termed a multiple-input multiple-output (MIMO) channel. The promise of using multiple antennas is that of multiplying the channel's information carrying capacity by the numbers of antennas employed, without any additional requirement of bandwidth or power. This MIMO channel is currently a hot research topic for future ultra high-data rate applications as diverse as wireless localarea networks, cellular systems, ad-hoc wireless packet networks and even satellite systems.

Last year, the laboratory embarked on the design and construction of a hardware test platform which allows the researchers to measure the channel, evaluate its capacity potential, and test and implement transmission technologies of future applications. This effort is led by Professor Schlegel with the help of a hardware engineer, Paul Goud, who acts as the laboratory director and coordinates the design efforts of the various members of the laboratory. A first prototype implementation became operational in early 2003, and initial test channel measurements have been conducted which confirm theoretical results, as well as measurements conducted by a research team at Brigham Young University. This system is currently being enhanced to enable it to operate in real-time on a portable platform. Demonstrations to industry are planned for July in Calgary, and for August in Salt Lake City, Utah, to the first industrial partner, L3 Communications.

Research into efficient iterative receiver structures for code-division multiple access (CDMA) channels and MIMO channels has led to a number of academic publications, and the current theory and system designs have matured to a point where potential implementations are being discussed. Two new graduate students who concentrated on efficient packet communication at a number of research levels, have started to study packet traffic and system impacts of wireless networks equipped with future highly efficient joint receivers. Research work on turbo coding also forms a considerable portion of HCDC activities and Professor Schlegel's research monograph, *Trellis and Turbo Coding*, is nearing completion and a first draft has been handed into the publisher, IEEE/Wiley. Future extensions of these activities will include issues of channel acquisition and tracking and its efficient integration into iterative receivers. A concerted effort is under way together with extended team members to address each major aspect of complete high-capacity digital communications systems and networks.

Research efforts in the area of implementation of digital signal processing in analog VLSI

technology have gained speed with the completion of the design of a subthreshold CMOS analog message passing decoder for a medium-size product code. The design is currently submitted to Canadian Microelectronics Corporation (CMC) for fabrication in 0.25µm CMOS technology. Successful demonstration that this decoder operates close to the theoretically expected performance would demonstrate that analog processing technology has the potential to displace digital technology with circuits which are two orders of magnitude more power and space efficient. Prior to this chip, small analog decoders have been demonstrated to function according to expectations. If this larger chip also meets expectations, the viability of analog circuits to implement the large error control decoders required by future high-capacity communication systems will be demonstrated, and the team will then focus on the efficient design of interfacing circuitry, which currently consumes over 95 percent of the power of the chip.

An invention disclosure for the implementation of low-voltage alternate circuit for the computations modules of such analog processors has been filed with the university patent office. This contribution would allow designers to lower the supply voltage of chip to below one volt and thus achieve further power efficiency and other design gains.

Achievements over Past Year

The following is a list of achievements over the past 12 months.

1. Completion of the hardware MIMO channel measurement prototype and successful initial MIMO channel measurements which confirm expectations of both the MIMO channel potential as well as the system performance. A second project engineer has been hired to supervise and conduct the VHDL design for the measurement system as well as the future communications system testbed. The radio frequency (RF) designs for up/down conversion have been completed by the Calgary based RF company SignalCraft. The completed RF designs have been thoroughly tested and found to be of very high quality.

2. Special dual-polarized patch antennas have been designed by the North Carolina State University partners and are currently being used to study the effects on MIMO capacity of polarization diversity in a highly scattered indoor transmission environment. Two initial conference publications on these measurements have been submitted and are accepted for publication and presentation.

Electro-magnetics professor C. Furse from the University of Utah has been invited for a visit and a potential link is being explored to feed our results into the design of future antennas for mobile handsets using MIMO technology.

3. Theoretical research in the areas of joint detection for CDMA channels, joint detection and integrated channel estimation for MIMO systems, and signaling strategies in random access wireless packet communication systems have been investigated on the theoretical plain, and a number of publications have been generated by Dr Schlegel and his graduate students dispersing these results. Major contributions include the design of a novel random access packet system, use of a joint detector at the receiver, and the complete analysis of iterative receivers for CDMA with low-complexity interference cancellation front-ends. While some major questions still remain unsolved, iterative receivers using linear front-end processing are now completely understood.

4. The design and thorough analysis of an analog product code decoder in CMOS technology has been completed and pipelined for implementation and later testing. Several research papers on the design, novel analysis techniques based on importance sampling, and interface issues with decoder have been submitted and are in various stages of publication. This cosupervised project with Professor V. Gaudet has expanded through the hire of three new graduate students focusing on this new technology.

The HCDC webpage has been completely redesigned and is currently undergoing testing for completeness and ease of use. It is located at the University of Alberta web address www.ualberta.ca/hcdc.

Dr Schlegel has been appointed General Chair of the 2005 Communication Theory Workshop to be held in June 2005 in Park City, Utah, and as Technical Program Director of the prestigious International

Symposium on Information Theory, to be held in the fall of 2005 in Adelaide, Australia.

Objectives for Next Year
The objectives for next year are as follows.

1. Expansion of the current measurement testbed into the real-time version supervised by Mr Robert Hang, and demonstration thereof to local and US industry. To our best knowledge, such real-time MIMO measurement equipment is currently not available at any academic institution, where measurements are usually performed with off-line equipment after data collection.

The key innovation in this project is a novel low signal-to-noise ratio timing acquisition and tracking algorithm, which forms a vital function for future high-capacity communications systems.

2. Simulation, theoretical analysis, and implementation of a novel frequency compensation algorithm developed by HCDC members. This is a critical component for robust packet transmission systems.

3. Expansion of the hardware test-platform to make it ready for the implementation of novel communications systems and testing with real data communications in circuit and packet switched mode. The exact formulation of next year's goals will be debated at a late May brainstorming session with participation of Utah team members. The current hardware testbed effort will be channeled into two parallel research efforts: i) dealing with the issue of multiple joint access using concurrent but completely asynchronous transmissions of data packets, and, ii) the expansion of the MIMO channel measurement testbed into a MIMO communications prototype testbed using layering techniques.

4. Complete characterization of the analog product decoder, construction of an adequate measurment setup, and dissemination of results. If the processing core behaves as expected, the design focus will shift towards the efficient interface design. Industry contacts will be pursued and Mr Christopher Winstead, the senior PhD student on this project, is expected to graduate with these results. A new PhD student, Mr Golam Mostafa, has been hired and will pursue the question of efficient interface technologies, possibly in conjunction with the iCORE group of Professor Haslett in Calgary, who specialize in analog RF technology.

5. On the MIMO channel side it is planned to study various acquisition and channel tracking methods, primarily using iterative decoding methods, for their suitability to achieve the channel capacity and their implementability in hardware. A particular focus will be given to mobile channels with rapidly time-varying characteristics in an effort to prove viability of MIMO technology for mobile applications. A primary direction of thrust will be the spread pilot embedding method pioneered by our extended team member Dr Farhang. After theoretical studies concerning channel estimation and tracking in conjunction with our colleagues at the University of Utah have come to a completion, the implementation of a pilot embedded channel estimation system will be considered. Embedded pilot channel estimation essentially forms a direct and logical extension of our current MIMO channel measurement signaling.

6. Completion of the team's theoretical studies on near-capacity communications over multiple access channels using CDMA and the effective use of error control codes in such systems is expected during this and possibly the next phase. This will then open the possibility to implement such receiver structures in future testbed implementations.

7. Recently initiated studies in the area of efficient packet transmission systems using advanced joint receivers is expected to generate guidelines and results for highly efficient packet structures as well as communications protocols. Future implementations of high-density packet test networks is currently being discussed among the different team members.

8. With the arrival of Dr Bates as new member of the HCDC, the team will have one more FPGA hardware expert on board, and potential new directions that are being contemplated are the extension of high-capacity transmission systems to wireline channels, such as Ethernet.

RESEARCH TEAM

As of May 2003, the following are the team members of the HCDC Laboratory, which represents two groups: leadership team which comprises the permanent members of the research team and the extended team, which comprises members with limited-time association such as graduate students and academic visitors.

TEAM LEADER	AWARDS
Christian Schlegel	Canada Research Chair in High-Capacity Digital Communications
ASSOCIATE MEMBER	**TITLE**
Witold Kryzmień	Professor, supervision of lab engineers, advisory role, joint supervison of PhDs
Vincent Gaudet 50% with Dr Beaulieu	Professor, Specialty in Analog VSLI and Signal Processing
Robert Hang	VHDL Design Director
OTHER TEAM MEMBERS	**TITLE/TOPIC**
Lance Perez	Academic Visitor, University of Nebraska; FPGA Turbo Coding Algorithms
Alex Grant	Academic Visitor, University of South Australia; Multiple User Communications
Gianluca Lazzi	Joint Project, North Carolina State University; Dual-polarized Patch Antenna
Behrouz Farhang	Joint Project, University of Utah; Efficient Channel Estimation Procedures
Zhenning Shi	Joint Project, University of Utah; Joint Detection for Linear Multiple Access Channels
Zachary Bagley	Partner; Principal Engineer, L3 Communications, Utah; Iterative Filters for Receivers
Shayne Messerly	Joint Project (p/t); Hardware Design of the MIMO Receiver

PHD STUDENTS	TOPIC
Sheryl Howard	Efficient Coded Modulation using Iterative Receiver Principles
Christopher Winstead	Analog Decoder Implementations; First CMOS Analog Error Control Decoder
Sumeeth Nagarai	Wireless MAC Protocols
Roland Kempter	Capacity Limits of Random Packet Multiple Access, Joint Detection at the Receiver
Vishwa Rajaman	High-efficiency Hardware Implementations of Digital Data Processing Algorithms
Golam Mostafa	Analog Processing

UNDERGRADUATES	TOPIC
Mimi Yiu	FPGA Test Setup, Analog Hamming Decoder Implementation
Nicholas Lauzon	Channel Measurements of Multiple Antenna Transmission

COLLABORATIONS

The HCDC maintains strong academic partnerships as well as liaisons to industry. Currently, the following partners are actively contributing to the program:

L3 Communications, Salt Lake City, Utah
This company has had a long-standing liaison with Dr Schlegel and is currently supporting hardware-oriented research efforts by funding Mr Zack Bagley and Mr Shayne Messerly. Both engineers have developed VLSI systems for the transmission and reception stages of our hardware testbed. This cooperation is expected to continue next year. Mrs Bagley and Messerly will continue with their work of implementing an iterative layering processor in FPGA to be used to separate the data streams in our MIMO systems testbed. L3 communications will contribute to this project by purchasing an additional FPGA hardware test platform for $US 16,500 to be used by the Utah group.

North Carolina State University (NCSU)
Joint US NSF funding with NCSU is currently in place with the principal investigators, Dr Brian Hughes and Dr Gianlucca Lazzi. The topic of this joint research work is efficient space-time coding systems. The funding currently supports students at NCSU and Utah. Cooperation on the hardware testbed by duplicating the setup at NCSU have been discussed, but are currently on hold.

University of Utah
A cooperative link exists with the University of Utah where Dr Schlegel works with Dr Behrouz Farhang on the design of efficient and rapid equalization methods for multiple antenna systems. Drs Farhang and Schlegel jointly supervise two Utah PhD students and a postdoctoral research fellow in this project. Additionally, the team is talking to the Utah electromagnetics group about antenna designs for future hand-held terminals which could exploit MIMO capacities.

FUNDING

The University of Alberta provided $75,000 in start-up funding and $469,000 in kind for construction of the laboratory. Alberta Science and Research Authority (ASRA) contributed $125,000 as a separate research and infrastructure grant, in addition to the $329,400 from iCORE funding.

Federal funding included $100,000 from Dr Schlegel's five-year CRC, accompanied by $125,000 as the CFI component of the CRC chair. An NSERC strategic grant, held jointly with Dr Krzymień, who is a member of TRLabs, and Drs Beaulieu, Tellambura, and Fair, provides HCDC with a further $40,000. A four year NSERC Discovery Grant has an annual installment of $31,100 and is held by the Chair.

Cooperation with L3 Communications is continuing with potential funding in the future. Currently L3 Communications funds a partner laboratory in Utah at $150,000/annum.

INTELLECTUAL PROPERTY

A patent on the low-voltage implementation of analog processing nodes has been filed with the university patent office and is currently under consideration for patent application. The technology of analog processing can gain around two orders of magnitude in both size and power efficiency, and thus could become fairly important in future portable communications devices.

Negotiations are currently held to clear IP issues regarding our cooperation with L3 communications in anticipation of intellectual property resulting from our joint work on MIMO receiver technology.

Patents

1. Q. Shen, W.A. Krzymień, "Closed-loop power control scheme for wireless communication systems," US Patent No. 6 529 709 granted 4 March 2003 (assigned to TRLabs).
2. W.A. Krzymień, S. Sun, "Spread spectrum time-division multiple access communication scheme," US Patent No. 6 493 334 granted 10 Dec 2002 (assigned to TRLabs).

PUBLICATIONS

Journal Publications

1. C. Winstead, J. Dai, S. Yu, C. Myers, R. Harrison, and C. Schlegel, "CMOS Analog MAP Decoder for (8,4) Hamming Code," IEEE *Journal of Solid State Circuits*. (In Press).
2. C. Schlegel and A. Grant, "Differential Space-Time Turbo Codes," IEEE *Transactions on Information Theory* (In Press).
3. V. Gaudet and G. Gulak, "A 13.3Mbps 0.35um CMOS Analog Turbo Decoder IC with a Configurable Interleaver," (In Press).
4. V. Gaudet and A. Rapley, "Iterative Decoding Using Stochastic Computation," *Electronics Letters*, vol. 39, no. 3, February 2003, pp. 299-301.
5. Z. Shi and C. Schlegel, "Spreading Code Construction for CDMA," IEEE *Communications Letters*, January 2003, pp. 4-6.
6. H. Zhu, B. Farhang-Boroujeny, and C. Schlegel, "Pilot Embedding forJoint Channel Estimation and Data Detection in MIMO Communication Systems," IEEE *Communications Letters*, January 2003, pp. 30-32.
7. V. Gaudet, R. Gaudet, and G. Gulak, "Programmable Interleaver Design for Analog Iterative Decoders," IEEE *Transactions on Circuits and Systems II - Analog and Digital Signal Processing*, vol. 49, no. 7, July 2002, pp. 457-464.

Conference Papers

1. D. Haley, C. Winstead, A. Grant, and C. Schlegel, "An Analog LDPC Codec Core," International Symposium on Turbo Codes, Brest, France, September, 2003. (In Press)
2. A. Rapley, C. Winstead, V. C. Gaudet, and C. Schlegel, "Stochastic Circuits for Iterative Decoding," International Symposium on Turbo Codes, Brest, France, September 2003. (In Press).
3. C. Winstead, N. Nguyen, C. Schlegel, and V.C. Gaudet, "Low-voltage CMOS Circuits for Analog Decoders," International Symposium on Turbo Codes, Brest, France, September 2003. (In Press).
4. C. Schlegel and Z. Shi, "Turbo Performance of a Low-Complexity CDMA Iterative Multiuser Detector," International Symposium on Turbo Codes, Brest, France, September 2003. (In Press).
5. P. Goud Jr, C. Schlegel, R. Hang, W. Krzymieñ, Z. Bagley, S. Messerly, M. Nham, W. Rajamani, "Indoor MIMO Channel Measurements Using Dual Polarized Patch Antennas," IEEE PACRIM '03, August 28-30, Victoria, BC, Canada. (In Press).
6. P. Goud Jr, C. Schlegel, R. Hang, W. Krzymieñ, Z. Bagley, S. Messerly, P. Watkins, V. Rajamani, "MIMO Channel Measurements for an Indoor Office Environment," IEEE Wireless Conference 2003, July 7-9, Calgary, AB, Canada. (In Press).
7. C. Winstead and C. Schlegel, "Importance Sampling for SPICE-level Verification of Analog Decoders," ISIT 2003, Yokohama, June 2003, p.103
8. C. Winstead, C. Schlegel, and V. C. Gaudet, "Analog Iterative Decoding of Error Control Codes," Canadian Conference on Electrical and Computer Engineering, Montreal, QC, Canada, May 2003, pp.1539-1542
9. B. Farhang-Boroujeny and C. Schlegel, "Efficient Multicarrier Realization of Full-Rate Space-Time orthogonal block-coded systems," Proc. ICC'03, May 11-15, Anchorage, AK, USA, pp. 2267 -2271.
10. P. Kota and C. Schlegel, "A Wireless Packet Multiple Access Method Exploiting Joint Detection," Proc. ICC'03, May 11-15, Anchorage, AK, USA.
11. C. Schlegel and Z. Shi, "Performance and Complexity of CDMA Iterative Multiuser Detection," Proc. of ITW 2003, Paris, France, pp. 111-114.
12. C. Winstead and C. Schlegel, "Analog Decoding of Product Codes," ISIT 2002, June 30-July 5, Lausanne, Switzerland.
13. Z. Shi and C. Schlegel, "Asymptotic Iterative Multiuser Detection of Random Coded CDMA," ISIT 2002, June 30-July 5, Lausanne, Switzerland.

14. S. Howard, C. Schlegel, L. Perez, F. Jiang, "Differential Turbo Coded Modulation Over Unsychronized Channels," Proc. of International Conference on Wireless and Optical Communications (WOC 2002), July 17-19, Banff, AB, Canada, pp. 96-101.
15. C. Schlegel and Z. Bagley, "MIMO Channel and Space-Time Coding," invited Tutorial, IASTED International Conference on Wireless and Optical Communications (WOC 2002), July 17-19, Banff, AB, Canada.
16. H. Zhu, Z. Shi, B. Farhang-Boroujeny, and C. Schlegel, "An Efficient Statistical Approach for Calculation of MIMO Channels," IASTED International Conference on Wireless and Optical Communications (WOC 2002), July 17-19, Banff, AB, Canada.
17. J. Dai et. al., "Cell Library for Automatic Synthesis of Analog Error Control Decoders," ISCAS 2002, May 26-29, Scottsdale, Arizona.
18. Yu et. al, "An Analog Decoder for (8,4) Hamming Code with Serial Input Interface," submitted to ISCAS 2002 May 26-29, Scottsdale, Arizona.13.
19. C. Schlegel and L. Perez, "Turbo Coding: Principles and Applications," invited Tutorial, ICC 2002, April 28-May 2, New York, NY, USA.
20. Z. Shi and C. Schlegel, "Design of Serially Concatenated Coded CDMA System," ICC 2002, April 28-May 2, New York, NY, USA.
21. Y. Saouter, V. Gaudet, and C. Berrou, "Degenerated Turbo Codes for High Rate and Throughput Concatenated Schemes," accepted for the 3rd International Symposium on Turbo Codes and Related Topics, Brest, France, September 2003.
22. D. Gnaedig, E. Boutillon, M. Jezequel, V. Gaudet, and G. Gulak, "On Multiple Slice Turbo Codes," accepted for the 3rd International Symposium on Turbo Codes and Related Topics, Brest, France, September 2003.(In Press).
23. D. Gnaedig, E. Boutillon, M. Jezequel, G. Gulak, and V. Gaudet, "Turbo Codes Roulettes," accepted for the 19e Colloque GRETSI sur le traitement du signal et des images, Paris, France, September 2003.(In Press).
24. D. Mazzarese, and W.A. Krzymieñ, "High Throughput Downlink Cellular Packet Data Access with Multiple Antennas and Multiuser Diversity," VTC 2003. The 57th IEEE Semiannual, vol. 2, April 22-25, pp. 1079 -1083.
25. G.G. Messier, and W.A. Krzymieñ, "A Coloured Gaussian Model for CDMA Forward Link In-Cell Interference," VTC 2003-Spring, The 57th IEEE Semiannual, Jeju, Korea, vol. 3, April 22-25, pp. 2052 -2056.
26. R.Novak, and W.A. Krzymieñ, "SS-OFDM-F/TA system packet size and structure for high mobility cellular environments," VTC 2003-Spring. The 57th IEEE Semiannual, Jeju, Korea, vol. 2, April 22 - 25, pp. 1438 -1444.
27. K.W. Ang, and W.A. Krzymieñ, "Performance of the Multi-Stage Variable Group Hybrid Interference Cancellation Scheme with Timing and Phase Errors," in the Proc. of VTC2003-Spring, Jeju, Korea, April 22 - 25, paper S08C_04, 5 IEEE formatted pages.
28. V. Gaudet and G. Gulak, "A 13.3Mbps 0.35um CMOS Analog Turbo Decoder IC with a Configurable Interleaver," 2003 IEEE International Solid-State Circuits Conference Digest of Technical Papers, 484, February 2003, pp. 148-149.
29. G.G. Messier, and W.A. Krzymieñ, "Improved Forward Link Error Correction for CDMA Systems with Space Time Transmit Diversity," in the Proc. IEEE Globecom'02, Taipei, Taiwan, vol. 1, no. 17-21, pp. 992 -996.
30. R. Novak, and W.A. Krzymieñ, "An adaptive spread spectrum OFDM packet data system with two dimensional radio resource allocation: Performance in low-mobility environments," in the Proc. IEEE WPMC'02, Honolulu, Hawaii, USA, October 2002, pp. 163-167.
31. R.C. Elliott, and W.A. Krzymieñ, "Scheduling algorithms for the cdma2000 packet data evolution," in the Proc. 2002 IEEE Semi-Annual Vehicular Technology Conference, Sept. 2002, Vancouver, BC, Canada, VTC 2002-Fall, 2002 IEEE 56th, vol. 1, no. 24-28 Sept. 2002, pp. 304 -310.

32. G.G. Messier, and W.A. Krzymieñ, "Improving convolutional and turbo code performance on the CDMA forward link," in the Proc. IEEE International Symposium on Spread Spectrum Techniques & Applications, Prague, Czech Republic, September 2002, pp. 29-33.
33. R. Tanner, and W.A. Krzymieñ, "A comparison of fading channel state prediction techniques," in the Proc. International Conferrence on Wireless Communications (Wireless'02), Calgary, AB, Canada, July 2002, pp. 312-317.
34. G. Li, I.J. Fair, and W.A. Krzymieñ, "Low density parity check codes for space-time wireless transmission," ibid., pp. 76-82.
35. G.G. Messier, and W.A. Krzymieñ, "Improving convolutional code performance on the CDMA forward link," in the Proc. of Virginia Tech. Symp. on Wireless Personal Comm., Blacksburg, Virginia, USA, June 2002, pp. 163-167.
36. C. H. Rentel, W.A. Krzymieñ, B. Darian, V. Vanghi, and R. Elliott, "Comparative forward link data channel performance evaluation of HDR and 1XREME systems," in the Proc. 2002 IEEE Semi-Annual Vehicular Technology Conference (VTC2002-Spring), Birmingham, Alabama, USA, May 2002, pp. 160-164.

Workshops

1. D. Haley, C. Winstead, C. Schlegel, and A. Grant, "Architectures for error control in analog subthreshold CMOS," Australian Communication Theory Workshop, 2003.
2. V. Gaudet, "Towards 1Gbps: analog iterative decoding," Analog Decoding Workshop, Munich, Germany, June 2002.
3. C. Winstead, J. Die, S. Yu, R. Harrison, C.J. Myers, and C. Schlegel, "Interfacing and Mixed-Signal Design for Analog Decoders," Proc. of Analog Decoding Workshop, Munich, June 2002.