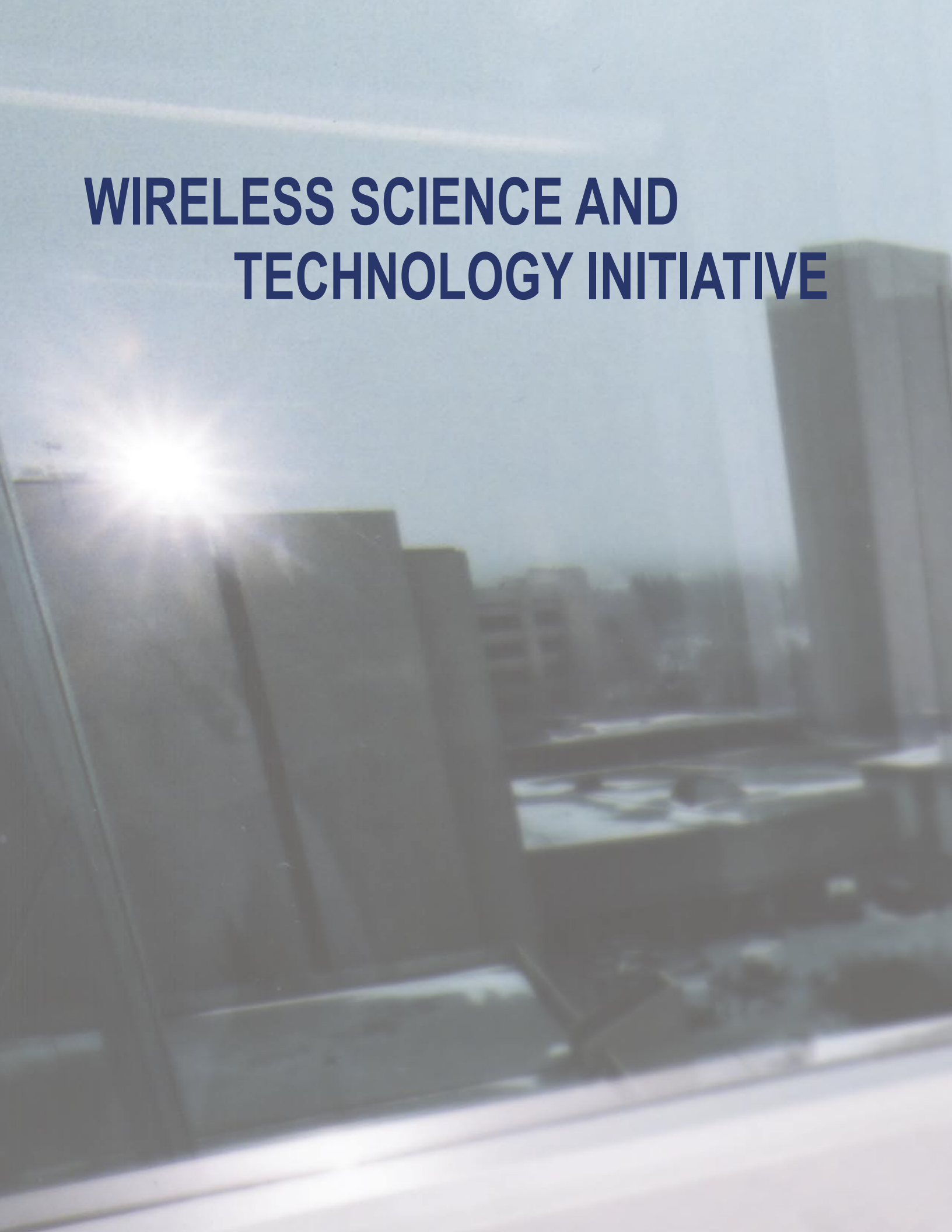

WIRELESS SCIENCE AND TECHNOLOGY INITIATIVE

JAMES W. HASLETT

TRLabs/iCORE/NSERC Industrial Research Chair
Department of Electrical and Computer Engineering, University of Calgary
http://www.enel.ucalgary.ca/People/Haslett/Haslett.htm

This five year Industrial Research Chair program, funded by TRLabs, iCORE and NSERC, is focused on developing, in conjunction with the TRLabs Wireless Research Center in Calgary, a sophisticated wireless RF Integrated circuit design and test capability, with Dr Jim Haslett as the group leader.

EXECUTIVE SUMMARY

After two years of operation, a very strong research team is in place, well trained in the art of sophisticated analog integrated circuit design for wireless communication systems. The team, consisting of 6 PhD and 7 MSc students, and two postdoctoral fellows, has won several national and international awards for the research work in the past year. During the reporting period, a new academic staff member has been hired as part of the chair program, and three new graduate students are currently being supervised or co-supervised by the new staff member.

The most notable achievements over the past 12 months relate to the first experimental demonstration of low power, small area on-chip RF filters using a new quality factor enhancement technique for monolithic passive components, and the successful design, fabrication and testing a novel patented new signal processing integrated circuit to facilitate long distance optical data communications without repeaters in the fiber optic system.

During the reporting period, integrated circuit fabrication grants of approximately $90,000 have been received, on a competitive basis, from the Canadian Microelectronics Corporation. In addition, IC design software and other infrastructure support amounting to over $1,000,000 dollars were received from the CMC to support the microelectronics program in Electrical and Computer Engineering. An NSERC equipment grant was received to add a laser cutter facility to our RF wafer prober, and that was installed in the summer of 2003. The research team held six NSERC scholarships with supplementary iCORE scholarships, and one postdoctoral fellow received an NSERC PDF, during the reporting period.

During the year, four journal papers and 11 conference papers have been published, while another 11 conference papers have been accepted for publication in the coming months. One patent has been filed, and another has been approved and is pending. Another journal paper is in the final stages of the review process and several others are in preparation.

In addition to expertise in RFIC design, several related projects have been initiated to exploit the expertise gained. We have initiated a project with the Foothills Hospital involving patient vital sign monitoring using ad hoc self-organizing sensor networks, as part of their new "Ward of the 21st Century". The project involves novel low power sensor designs, both discrete and integrated, and the design and application of a wireless networking environment for continuous patient monitoring. Another collaborative project with Dr Graham Jullien and Dr Karan Kaler involving non-invasive stimulation of neurons on chip is being discussed with a research group in the medical faculty at the University of Calgary.

RESEARCH PROGRAM OVERVIEW

The main thrust of the research program is to develop new and novel devices for the next generations of wireless products, of interest to the industrial sponsors of TRLabs, and to the wireless community in general.

The Wireless Science and Technology Initiative is targeted to contribute to the development of a critical mass of RF researchers in Alberta with a primary focus on the device and circuit aspects, in cooperation with researchers working on overall system aspects at the University of Calgary, in the TRLabs Wireless Research Centre in the Discovery Place Research Park adjacent to campus. It is envisaged that the enhanced wireless RF research activity will provide a focal point for the training of highly qualified personnel that the industry needs as it moves into the next generation of wireless systems.

James Haslett

The critical mass is also expected to attract excellent graduate students, visitors and postdoctoral fellows from around the world. At present 7 of the 14-team members hold prestigious scholarships or fellowships. Between three and five new applications to join the research group are received every day, from many countries.

To enhance the chair research program, an additional tenure track academic staff member was to be hired into Electrical Engineering, with research expertise in a related field. This was accomplished in January of 2004, and the second academic staff member is already supervising three graduate students.

Research is carried out on several fronts, as follows:

Development of General RF Integrated Circuit Design Expertise

The intention in the research proposal is to build a team of people with expertise in RF integrated circuit design. During the past two years, Dr Haslett's research group has successfully developed expertise in the design, fabrication and testing of RF wireless integrated circuit building blocks, in a variety of fabrication technologies, for RF transceiver applications in the 1 to 20 GHz frequency range. Since many of the team members were new, and since the successful design, fabrication and testing of state-of-the-art RF integrated circuits is very challenging, the first year involved a steep learning curve for many of the team members. The core group is now proficient in the design, modeling, layout, and testing of low noise amplifiers, mixers, voltage controlled oscillators, filters, and other transceiver building blocks in Silicon-Germanium (SiGe) BiCMOS and deep submicron CMOS technologies, and this expertise is being applied to several research projects as outlined below.

Realizing Fully Monolithic RF Transceivers in CMOS Fabrication Technology

The major challenge facing the wireless industry at present is to economically realize all required transceiver circuit functions on one silicon substrate (a monolithic realization), and to provide programmability to accommodate the various transmission standards encountered. This will reduce the cost of production very significantly, as well as miniaturizing the circuitry. Miniature low power circuits will open up the possibility of many new applications in the

biomedical and other areas. The research proposal outline a series of research tasks that would help move toward this goal, as follows:

- High Frequency Modeling of RF CMOS and Bipolar Transistors – developing lumped models of the transistors used is critical for hand analysis of RF analog circuits, in order to gain a physical understanding of the design tradeoffs involved in achieving performance goals.
- Active Tunable Inductors for RF Wireless Applications – on-chip passive elements are generally of poor quality (lossy), limiting the achievable performance of the monolithic circuits. One solution to this problem is to simulate the passive components with active (transistor) circuits, to achieve better performance.
- Quality Factor Enhancement of Passive on-chip Spiral Inductors – this is a slightly different approach to solving the lossy passive component problem, by using active circuits to enhance the passive components, as opposed to replacing them completely with active circuits.
- Noise in RF Wireless Devices and Circuits – electronic noise is the fundamental limiting factor in modern communications receivers, requiring a detailed understanding and clever design techniques to achieve performance objectives.

Integrated Optics and Optical Fiber Communication Systems

Analog RF IC design expertise is directly applicable to high-speed digital data communication circuits, and the chairholder intends to use the expertise to design circuits of interest to Nortel and other sponsors of TRLabs.

The Gigabit Radio RFIC Project

Staff Scientists at TRLabs have patented a novel new high data rate wireless local area network. The research proposal outlined an intention to integrate the remote terminals of the LAN, to demonstrate proof of concept.

All of the objectives of the chair proposal have been or are being met in a timely fashion. The details of the accomplishments in each of the areas are described in the “Research Projects” section that follows.

Jim Haslett and some research team members

RESEARCH PROJECTS

Realizing Fully Monolithic Transceivers in CMOS Fabrication Technology.

To assist industry in achieving this goal, the research group is working in several areas, as follows:

High Frequency Modeling of RF CMOS and Bipolar Transistors

A great deal of activity is currently ongoing in the industry to provide sophisticated computer-aided design models for both bipolar and MOS transistors. Dr Haslett's group has developed approximate analytic models for hand analysis of analog RF circuits, along with the development of a detailed understanding of current state-of-the-art computer-aided models such as the Berkley BSIM4 Model, and the RF Bipolar transistor model high frequency scattering parameters. Hand analysis is extremely useful for understanding functional dependence and behavior of small transistor count analog circuits in the wireless industry. During the next year, this modeling capability will be extended to much higher frequencies, up to 60 GHz.

Active Tunable Inductors for RF Wireless Applications

In the early stages of the research chair program, we developed a new tunable CMOS active inductor, which has independently tunable inductance and Quality factor. The work has been published and patented, and the research on this topic is essentially complete. We found that the circuit was suitable for lower frequency operation (up to 1GHz), but we have since developed better ways of achieving the same behavior at higher frequencies.

Quality Factor Enhancement of Passive on-chip Spiral Inductors

One of the major impediments to achieving fully monolithic low cost transceivers in the industry today relates to the poor quality factor of on chip passive components, and the worst of these is the spiral inductor. Researchers throughout the world have tried a myriad of solutions, but no real success has been achieved without expensive additional fabrication steps in the manufacturing process. Initial work by our group involved the development of a detailed understanding of the modeling and design issues involved, and a technique to optimize the design of these inductors using the accepted approach to fabrication was developed and published. However, only marginal improvements are achievable with this approach, and a more dramatic solution was needed.

During the past year, a solution involving the use of a flux compensating second inductor mutually coupled to the main component, and driven in such a way as to enhance the quality factor electronically, has been successfully demonstrated experimentally. The initial research won the $3000 CAD/Componentware prize at the annual CMC workshop and Texpo in Ottawa, in June 2003, and was subsequently published in a Special Issue of the *IEEE Transactions on Circuits and Systems*, October 2003. Very recently, a fully integrated 2.35GHz, 60 MHz bandwidth bandpass filter has been successfully designed, fabricated and tested by the research group. This is one of two important achievements in the chair program to date, as it is the first time such a fully integrated filter has been realized in any technology, without requiring RF chokes for dc biasing. This results in small chip area and low power (10 mW in the first generation design). This technique also has the significant advantage of not introducing distortion in the filter passband, unlike other negative resistance approaches that have been published in the past. A patent application has been filed through TRLabs. Detailed noise, distortion and stability analyses are being carried out, both theoretically and in simulation, and verified by measurement.

The success of this research now opens the door to a large amount of additional work. Means of tuning the enhanced inductance value are being explored, and a technique for self tuning the Q-factor of the enhanced inductors to overcome process variation must be achieved if the technique is to be commercially viable. Ways of improving distortion characteristics must also be explored. Many other researchers are also working on the monolithic filter problem. We have just filed a second patent application involving a low power differential version, and have a number of ideas for self tuning that will be explored in the near future.

Noise in RF Wireless Devices and Circuits

During the two-year period, we have engaged in extensive noise modeling of the behavior of all of our RF IC designs. In particular, we have theoretically described and experimentally verified the noise behavior of our transformer based Q-enhancement circuits. This modeling is currently being extended to Q-enhancement circuits published by others, and to our latest fully differential transformer based designs. We will use these results to predict and optimize noise figures of the monolithic filters that we are currently designing using the new enhancement techniques, and to compare the performance with the results of others.

Integrated Optics and Optical Fiber Communication Systems

This is the second area in which an important achievement has been made in the past year of the chair program. This project uses an RF logarithmic compression amplifier, along with a Hilbert Transformer and several other components, to reduce chromatic dispersion in optical fiber networks by generating a single-sideband modulated optical carrier. This will increase optical data transmission distance before repeaters are required, while providing a low cost solution compared to existing techniques. First and second generation compression amplifiers with 4 and 8 GHz bandwidth have been successfully designed, fabricated and tested in collaboration with Nortel Ottawa, first using the NT 25 bipolar fabrication process, and more recently using a 47 GHz f_T Silicon-Germanium bipolar process, made available to us by the Canadian Microelectronics Corporation, MOSIS and IBM Corporation. To our knowledge, these are the highest performance compression amplifiers published to date. The initial design won a National Award in June of 2002, and the details have been published in the *IEEE Journal of Solid State Circuits* and elsewhere (ISCAS 2004). A US patent on the log compression amplifier architecture is pending (31 claims allowed, February 2004).

The next challenge is to produce a monolithic Hilbert Transformer, and this project is currently underway. A design has been completed and submitted for fabrication, using the Q enhancement technique developed for the monolithic filters described above. If successful, this will be the first integrated circuit of its type, and the combination of the two circuits could lead to a commercial product.

The Gigabit Radio RFIC Project

A novel new architecture for a very high-speed wireless local area network (LAN) system has been designed by Dr Grant McGibney, a TR Labs Staff Scientist, and patents have been granted in April of 2004. The hostility of the wideband indoor radio channel imposes severe multipath and intersymbol interference (ISI) that must be overcome in order to send data successfully. Mitigation of these effects is accomplished in the new architecture by using digital signal processing (DSP) techniques to predistort/equalize transmitted data before/after passing through the wireless channel. To minimize the power consumption and complexity of the terminals, the DSP functionality is placed solely in the basestations of the network. The remote terminals are left as relatively simple devices consisting of a direct conversion receiver and simple comparators for analog/digital conversion.

The goal of this project as outlined in the original proposal was to produce a Radio Frequency Integrated Circuit (RFIC) which implements the functionality of a Gigabit Radio simple terminal. Initial research has concentrated on system planning, which involves a large number of tradeoffs in gain distribution, choice of receiver architecture, and the like. Research over the past year has concentrated on designing the RF low noise amplifier LNA), direct down conversion mixer, and voltage controlled oscillator (VCO) that will form part of the receiver frequency synthesizer. These projects push the technology to the limits. At this time we have a functional mixer circuit, and four successful VCO's have been tested recently. We are also currently testing a novel subsampling mixer/filter circuit that has been designed by one of the members of the research team.

OBJECTIVES FOR NEXT YEAR

We plan to continue to work in the monolithic RF filter area. A large amount of work still needs to be done, to characterize noise behavior, stability, self-tuning to overcome process and temperature variations, and reduce distortion.

Recent industry directions suggest that more and more of the future wireless transceiver components will be digital, eventually with A/D conversion occurring immediately after a Low Noise Amplifier attached to the antenna. We are evaluating subsampling and high-speed A/D conversion circuits in anticipation of moving in that direction.

We also plan to continue to work in the optical data transmission area. If our Hilbert Transformer is a success, we should be able to fully integrate a circuit that can be used with conventional optical transmission components to achieve very low cost, long range data transmission over fiber without repeaters (on the order of a few hundred kilometres).

We have identified a number of new opportunities that will make use of the expertise that we have developed over the past two years, without requiring massively expensive fabrication technologies.

We are beginning to work with self-organizing ad hoc wireless sensor networks, and have started a project with the foothills hospital in Calgary to help develop their hospital "Ward of the 21st Century." A postdoctoral fellow and two graduate students currently are working on various aspects of the networks, and we will use our previous sensor development experience

from our commercial oilfield instrumentation projects to develop new low power sensors for a variety of sensing parameters. In the case of the hospital, we will initially monitor patient temperature, blood oxygenation and pulse rate, transmitted wirelessly to central locations even when the patients move about.

A second project is being discussed with Gérard Lachapelle and Elizabeth Cannon in geomatics, to integrate miniature low power GPS receivers for several new applications.

We have initiated a collaborative project with Michal Okoniewski and Ron Johnston, relating to the use of RF switches to electronically reconfigure antennas and other microstripline elements. Initial results are promising, and a board level self-tuning impedance matcher has been designed and fabricated as proof of concept, with applications in wireless navigation and location as well as in spatially selective communications.

Another project is being developed in collaboration with Michal Okoniewski, involving RF MEMS for a variety of applications from self-configuring antenna systems to high quality RF wireless transceiver components. We have visited a Canadian Industrial firm to see whether we can set up a mutually beneficial collaboration in this area. This area holds great promise for the future, and we will continue to work in the area for the remainder of the chair term.

RESEARCH TEAM MEMBERS AND CONTRIBUTIONS

Team Leader

NAME	ROLE/TOPIC	AWARDS
Dr J.W. Haslett	iCORE Chair	APEGGA Excellence in Education Summit Award

Faculty Team Members

NAME	ROLE	AREA
Dr Sebastian Magierowski	Academic Staff Member	Theoretical and practical behavior of RF wireless transceiver building blocks
Majid Aghtar	Associate Member	Very high frequency modeling of CMOS transistors
Dr John McRory	TR Labs Scientist, Adjunct Professor, U of C	General RF designer
Dr Bob Davies	TR Labs Scientist, Adjunct Professor, U of C	Optical fiber communications system specialist
Dr Grant McGibney	TR Labs Scientist	Communicaions systems expert
Dr Hua Yan	iCORE Research Associate	Self-tuning impedance matching system
Dr Vijay Devabhaktuni	NSERC Postdoctoral Fellow	Self-organizing ad hoc wireless sensor system Carleton University Research Excellence Medal

PhD Students

TEAM MEMBER	ROLE/TOPIC	AWARDS
Chris Holdenried	RF integrated circuit design for optical data transmission systems.	NSERC PGS-B and iCORE scholarships IEEE Microwave Theory and Techniques graduate scholarship He has won one local, one national and one International award for his research work over the past two years
Holly Pekau	Sub sampling mixers and high-speed data conversion for RF transceivers, in addition to doing the system planning for the high data rate wireless LAN architecture.	NSERC PGS-B and iCORE scholarships $1500 US funds "outstanding student IC designer" award from Analog Devices Inc. in Wilmington, Mass., which was presented to her at the IEEE International Solid State Circuits Conference in San Fransisco, February 2004
Joshua Nakaska	High frequency bipolar transistor modeling, and frequency synthesizer design for high frequency wireless transceivers. He is one of the main researchers working on the high data rate wireless LAN.	NSERC PGS-B and iCORE scholarships
Rob Randall	Fully integrated high linearity CMOS Power Amplifiers. He has spent a considerable amount of time putting together an RF Load Pull facility at TRLabs, which is necessary for the measurement of his power amplifiers.	NSERC PGS-B and iCORE scholarships
Ahmed Youssef	Will decide on a PhD thesis topic shortly.	The Canadian Microelectronics Corporation (CMC) CAD/ Componentware Award (honourable mention)
Bogdan Georgescu	Transformer based Q-enhancement techniques for RF monolithic filter applications.	NSERC PGS-B and iCORE scholarships The Canadian Microelectronics Corporation (CMC) CAD/ Componentware Award (national award)

MSc Students

TEAM MEMBER	ROLE/TOPIC	AWARDS
Mike Lynch	17 GHZ mixer and LNA for the high data rate wireless LAN. He led our efforts, in conjunction with the Canadian Microelectronics Corporation, to use Flip-Chip technology for RF designs through Auburn University in the US.	NSERC PGS-A and iCORE scholarships
Jim Kulyk	Q-enhanced monolithic RF Filter Design. He has just achieved the first transformer based 3rd order Chebychev 2.4 GHz bandpass filter using a coupled resonator structure to achieve low power and small chip area, in 0.18um CMOS technology.	TR Labs scholarship
Damon Holmes	Novel techniques to realize high efficiency fully integrated CMOS RF Power Amplifiers.	NSERC PGS-A and iCORE scholarships
Ken Townsend	Low power CMOS RF transceiver building blocks for applications in wireless sensor networks.	NSERC PGS-A and iCORE scholarships NSERC PGS-B scholarship to begin September 2004
Cavell Li	Designing a simple, low power GPS receiver chain for the ad hoc wireless sensor networks, in CMOS technology.	
Michael Chen	Co-supervised with Dr Magierowski. Low phase noise RF CMOS VCO's.	
Steven Zhai	Co-supervised with Drs Magierowski, Nowicki. Low power medical sensors for the ad hoc wireless sensor network project with Foothills hospital.	
Adesh Garg	Co-supervised with Dr Graham Jullien. Adaptive filtering in the High Data Rate wireless LAN basestation.	NSERC PGS-A scholarship, taken up in Toronto

Others

TEAM MEMBER	ROLE/TOPIC
Majid Aghtar	Research assistant. High frequency bipolar and CMOS modeling areas.
Ian Steiner	Intern

COLLABORATIONS

PARTICIPANTS	NATURE OF COLLABORATION
PROVINCIAL	
TRLabs	TRLabs, as industrial sponsor of the chair program, provided an office to the chairholder, student offices, scholarships and computers, and access to a sophisticated RF test laboratory. A wire bonder was also provided on a full time basis. Staff scientists worked with the chairholder and the research group on an ongoing basis. Biweekly review meetings and an annual technology forum were held for the past two years.
Dr Graham Jullien	Dr Jullien's expertise is in advanced number systems and VLSI Implementations of DSP systems. We have co-supervised an Internship student for the past two years, working on a wireless base station. We are jointly co-supervising a student who has just completed the design and test of a Recursive Cellular Neural Network IC, which performs ultra low noise digital arithmetic using analog circuits. We are also beginning a joint collaboration with researchers from the medical faculty, in the area of neuron stimulation with non-contacting stimulus using embedded integrated circuits
Dr Michal Okoniewski	The collaboration with Dr Okoniewski involves self-configuring antenna systems and RF MEMS. We have designed and fabricated a self-tuning impedance matching system, working in the GHz range, that uses a genetic algorithm and a series of programmable switched tuning stubs in a transmission line to achieve the impedance match automatically. We plan to duplicate this system on chip at very high frequency, up to 60GHz. We are also mating MEMS high quality inductors designed by Dr Okoniewski's group with CMOS RF circuitry integrated the Chair's research group, to achieve low noise RF circuits.
Dr Vijay Devabhaktuni, RFIC Group, UofC, Dr John Conly, Lucy Reyes, Dave Hurd, Sonja Morrison, Andrea Robertson, Foothills Hospital and Faculty of Medicine, UofC	We are working on proof-of-concept of a wireless self-organizing sensor network for patient vital sign monitoring in the Foothills Hospital "Ward of the 21st Century." A prototype system for measuring patient temperature is working in our lab. If successful, many new research projects in the sensor area will be pursued.
Dr Ivars Finvers, SiWorks, Calgary	Dr Ivars Finvers is the director of Analog IC Design in this semicustom integrated circuit design house located adjacent to the university in the Research Park. He has co-supervised one of the PhD students for the past year. Another SiWorks employee, James Quan, is an MEng thesis-route student under the Chair's supervision
NATIONAL	
A. J. Bergsma, and R.D. Beards, Nortel Ottawa	Chris Holdenried, a PhD candidate, has been working with researchers at Nortel to design a wideband true logarithmic compression amplifier for optical fiber communications applications. The designs are successful, and the next project involves the design of an accompanying Hilbert Transformer
INDUSTRIAL	
Dalsa Semiconductor, Bromont Quebec, Dr Michal Okoniewski	We are exploring possible collaboration with Dalsa Semiconductor in Bromont, Quebec, on RF MEMS. Dr Okoniewski and the Chair visited Dalsa in April of 2004 to discuss the use of their MEMS facility for RF research work.

INTELLECTUAL PROPERTY

PATENTS FILED	CANADA	U.S.	OTHER
C. D. Holdenried, J.W. Haslett, J.G. McRory, and R.J. Davies, "Branch Logarithmic Amplifier and Logarithmic Amplifier Delay Circuitry," full US and Canadian Patents Filed, US file # 10/156,731, April 2002. 31 claims allowed December 2003, US patent pending.	X	X	
C.D. Holdenried, J.W. Haslett and J. McRory, "Fully Differential Transformer Based Q-Enhanced Inductor Circuit," US provisional patent filed March 2004.		X	
PATENTS ISSUED			
Holbert, Marvin L., Haslett, James W. , Smallwood, Robert E, and Trofimenkoff, Frederick N., "Subsurface Signal Transmitting Apparatus," US Patent # 6,672,383, Issued January 6th, 2004.		X	

FUNDING

James Haslett's Industry Chair is funded by iCORE ($200K/year), NSERC ($120K/year) and TRLabs ($120K/year cash and additional in-kind). Additional support is received from NSERC (~$120K/year). Haslett also works with the consortiums CMC ($300K/year) and Micronet (~$225/year) in conjunction with iCORE Chair Graham Jullien.

PUBLICATIONS

REFEREED JOURNAL PUBLICATIONS

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X. Ding, V. Devabhaktuni, B. Chattaraj, M. Yagoub, M. Deo, J. Xu, and Q.J. Zhang, "Neural network approaches to electromagnetic based modeling of passive components and their applications to high-frequency and high-speed nonlinear circuit optimization," IEEE Transactions on Microwave Theory and Techniques, vol. 52, January 2004. , pp. 436-449.

V. Devabhaktuni, M. Yagoub, B. Chattaraj, and Q.J. Zhang, "Advanced microwave modeling framework exploiting automatic model generation, knowledge neural networks, and space mapping," IEEE Transactions on Microwave Theory and Techniques, vol. 51, July 2003, pp. 1822-1833.

S. Magierowski and S. Zukotynski, "CMOS LC-Oscillator Phase Noise Analysis Using Nonlinear Models," accepted for publication in the *IEEE Transactions on Circuits and Systems I: Fundamental Theory and Applications*.

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Yeboah, J., G.A. Jullien and J.W. Haslett, "Recursive Cellular NonLinear Neural Networks for Ultra Low Noise Digital Arithmetic", *Proceedings of the 46th IEEE International Midwest Symposium on Circuits and Systems*, Cairo, Egypt, December 27-29, 2003.

C. Holdenried, M.W. Lynch and J.W. Haslett, "Modified CMOS Cherry Hooper Amplifiers with Source-Follower Feedback in a 0.35um Technology", *Proceedings of the European Solid State Circuits Conference,* Portugal, September 2003, Pages 553 - 556.

Lynch, M.W., C. Holdenried, J.W. Haslett, "A 17-GHz Direct Down-Conversion Mixer in a 47-GHz SiGe BiCMOS Process", *Proceedings of the Radio Frequency Integrated Circuit Symposium (Held in conjunction with the International Microwave Symposium*), Philadelphia PA June 2003, pp. 461-464.

Garg, A., I. Steiner, G.A. Jullien, J.W. Haslett and G.H. McGibney, "A High Speed Complex Adaptive Filter for an Asymmetric Wireless LAN Using a New Quantized Polynomial Representation", *Proceedings of the IEEE International Circuits and Systems Conference,* (ISCAS), Bangkok, Thailand,Volume: 2 , 25-28 May 2003, Pages:II-157 - II-160 vol.2.

B.A. Georgescu, J. Nakaska, R. Randall and J.W. Haslett, "A 0.18um CMOS Bluetooth Frequency Synthesizer for Integration With a Bluetooth SOC Reference Platform", *Proceedings of the3rd IEEE International Workshop on System-on-Chip*, Calgary, Alberta, July 2003, pp. 258-263.

Georgescu, B., J. Haslett and J. McRory, "Transformer Based Resonant Tank with Active Q-Enhancement", *Proceedings of the 15th International Conference on Wireless Communications*, Calgary, Alberta, conference *Proceedings*, July 2003, pp. 455-462.

Nakaska, J. and J.W. Haslett, "Integrated GHz Oscillators in a 47 GHz SiGe Process", *Proceedings of the15th International Conference on Wireless Communications*, Calgary, Alberta, July 2003., pp. 159-164.

TECHNOLOGY FORUM POSTERS

Nakaska, J., and J.W. Haslett, "RFIC Research at the University of Calgary", Poster presentation at the TRLabs Technology Forum, Calgary, Alberta, October 28-29, 2003.

Georgescu, B., and J.W. Haslett, "On-chip Spiral Inductor Q Enhancement Techniques", Poster presentation at the TRLabs Technology Forum, Calgary, Alberta, October 28-29, 2003.

REFEREED CONFERENCE PAPERS

C. Holdenried and J.W. Haslett, "A DC-6 GHz, 50 dB Dynamic Range, SiGe HBT True Logarithmic Amplifier", to be presented at the IEEE International Symposium on Circuits and Systems, Vancouver Canada, May 2004.

Vijay Devabhaktuni and James Haslett, "Introduction to Theory and Applications of Self Organizing Wireless Sensor Networks", accepted for presentation at the 14th International Conference on Wireless Communications, Calgary, Alberta, July 12-14, 2004.

Kenneth Townsend and James Haslett, "A Low-Power 900MHz Relaxation Voltage Controlled Oscillator in 0.18 um CMOS", accepted for presentation at the 14th International Conference on Wireless Communications, Calgary, Alberta, July 12-14, 2004.

Damon Holmes, Ronald Johnston and James Haslett, "A 2.4 GHz Switched-Mode Power Amplifier IC for Linearization", accepted for presentation at the 14th International Conference on Wireless Communications, Calgary, Alberta, July 12-14, 2004.

H. Pekau, J. Nakaska, J. Kulyk, G. McGibney, J. Haslett and J. McRory, "SOC Design of an IF Subsampling Terminal for a Gigabit Wireless LAN with Asymmetric Equalization", to be presented at the 2004 International Workshop on System-on-Chip, Banff, Alberta, July 2004.

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K. Iniewski, S. Magierowski, and M. Syrzycki, "Phase Locked Loop Gain Shaping for Gigahertz Operation," accepted for presentation at the IEEE International Symposium on Circuits and Systems, Vancouver Canada, May 2004.

S. Magierowski, K. Iniewski, and S. Zukotynski, "A Wideband LC-VCO with Enhanced PSRR for SoC Applications," accepted forpresentation at the IEEE International Symposium on Circuits and Systems, Vancouver, Canada, May 2004.

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