

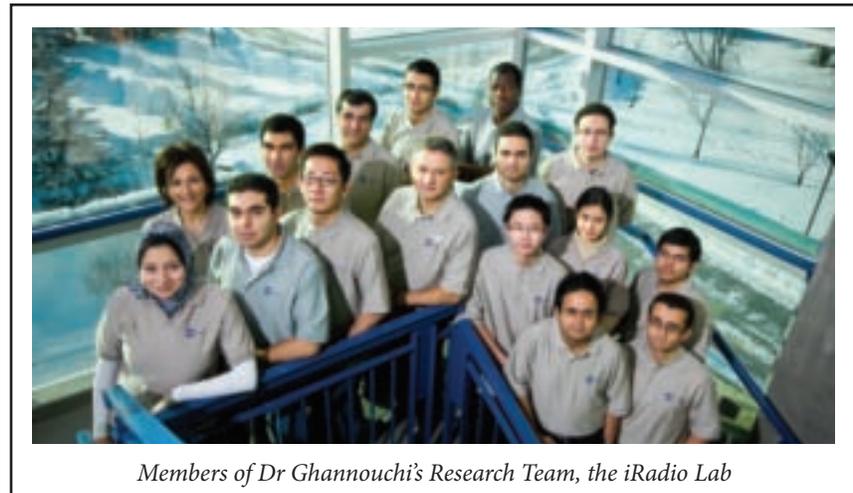
Networks and Wireless Communications



Intelligent RF Radio Technology

The trends in communication networks are toward ubiquitous, distributed, and cooperative networks, which will also be required to support the large demand for mobility and high-throughput specifications within the environment of multi-standard communications. This adds up to severe linearity requirements for wireless and satellite communications' mobile and fixed terminals accompanied, in most cases, with high direct current power consumption resulting in very low power efficiency. Accordingly, future radio systems will need to be designed to meet all the aforementioned critical capabilities, as well as to be less energy hungry and more environmental friendly, or "green." The mission of the Intelligent RF Radio Laboratory (iRadio Lab) is to develop new knowledge and innovative enabling technologies pertinent to intelligent and green radio systems and related applications that are valuable to our partners and sponsors and to train highly qualified personnel in radio frequency (RF) and wireless communications science and technology.

This laboratory is devoted to advanced research and development (R&D) activities relevant to intelligent and green RF radio technolo-



Members of Dr Ghannouchi's Research Team, the iRadio Lab

gies applicable to broadband wireless and satellite communication systems. The research program of iRadio Lab is concerned with RF and microwave devices, circuits and systems; adaptive digital signal processing (DSP); modeling of device and systems; linearization and hardware impairment compensation concepts; multiple-input multiple-output (MIMO) systems; software-hardware implementation and integration issues; and other related applications.

The iRadio Lab was founded in May 2005 and it is already staffed with more than twenty graduate students and talented researchers, recruited worldwide. The main space dedicated to the iRadio Lab in the University of Calgary's ICT building is being used as

offices for graduate students and research staff, as well as the main instrumentation, simulation, and design area. An auxiliary space in the Engineering building, used for printed circuit boards fabrication and circuit prototyping, was recently completed; and, the development of the fabrication process is under way. The iRadio Lab facilities are supported by a number of computer aided design (CAD) based software tools, test benches, and rapid prototyping setups.

Leading-edge research, development, testing, validation, and evaluation of new concepts and architectures relevant to software-defined and software-enabled RF radio activities are being conducted in collaboration with the RF

Dr Fadhel Ghannouchi

and wireless communications industries and government R&D agencies. Despite its recent creation, the iRadio Lab has succeeded in the initiation of close formal collaborations with several national and international academic institutions, industry partners, and government agencies. Ten non-disclosure agreements to access proprietary information and technologies have been signed to support these collaborations.

The innovative and applications-oriented R&D activities being carried out at iRadio Lab have led to more than fifty refereed journal and conference papers, a Patent Cooperation Treaty (PCT) patent application, a US patent application, and two provisional patent applications. One distinguished speaker has been invited to give a public talk at the University of Calgary. Graduate students from iRadio Lab won second and third places in a worldwide competition on the design of highly efficient power amplifiers, which took place in June 2007 in Hawaii at the International Microwave Symposium (IMS 2007). These designed green RF amplifiers achieved a benchmark, in terms of power-added efficiency of over 80%. In addition, a team of six iRadio Lab graduate students qualified for the finals of the Software Defined Radio Challenge 2008, an international competition, taking place in Washington in November 2008. The iRadio Lab team is the only Canadian and non-US team among the six selected teams.

In 2008, iRadio Lab has been successful in securing substantial funding: \$165K from the Natural Sciences and Engineering Research Council of Canada (NSERC), \$63K from TRILabs, and \$135K from industry. These monies supplement the \$30K, \$20K, and \$120K yearly averages provided by iCORE, the Canada Research Chairs (CRC) Program and the University of Calgary, respectively, over a five-year period. In addition, in-kind contributions and equipment donations and loans in the amount of about \$120K from Industry partners and \$100K of in-kind contributions from the University of Calgary have been obtained during the reporting period ⑦



Location: University of Calgary

Department: Electrical and Computer Engineering

Team Members: 30

Website: <http://www.iradio.ucalgary.ca>

Biography: Dr Fadhel Ghannouchi has been an iCORE chair since 2005. He received his BEng in 1983, his MSc in 1984, and his PhD in 1987 from the University of, Montréal, Quebec. He is a professor, researcher, and engineer.

As a CEO, he guided the development of an innovative line of products for the satellite communications market., which is now manufactured by Mitec Telecom and sold worldwide. Dr Ghannouchi is a recognized member of a network of influential people in academia, as well as in the RF, microwave, digital signal processing, wireless and satellite communications sectors in Canada, the US, Japan, and Europe. He has provided consulting services to a number of microwave and wireless communications companies ⑦

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COLLABORATIONS

<i>Participants</i>	<i>Nature of Collaboration</i>
National Collaborations	
<p>École Polytechnique Montréal Dr K. Wu Dr R. Malhame Dr A. Cevdet</p>	<p>Collaboration with the Poly-Grames Research Center (Dr K. Wu) concerns the access to advanced printed circuit board (PCB) fabrication facilities by the iRadio Lab team. Moreover, three graduate students from École Polytechnique Montréal are currently supervised by Dr Ghannouchi.</p>
<p>Focus Microwaves, Canada Dr C. Tsironis</p>	<p>Focus Microwaves is sponsoring the ongoing NSERC Collaborative Research and Development Grant (CRD) (2007-2009) and providing privileged technical support for our activities related to the load-pull characterization of active devices. (Lead contact person: Dr F. Ghannouchi)</p>
<p>Nanowave Technologies, Canada Dr A. Rahal</p>	<p>Dr Ghannouchi has been collaborating with Nanowave Technologies since 2006, within a NSERC CRD project. The ongoing collaboration involves an NSERC strategic research project related to the development of GaN based switching-mode amplifiers for satellite and avionic applications. (Lead contact person: Dr F. Ghannouchi).</p>
<p>Nortel Networks, Canada T. Dashin</p>	<p>The collaboration with Nortel Networks, Calgary Division, was initiated last year. Nortel Networks is currently supporting an NSERC strategic project related to the development of GaN based switching-mode power amplifiers. (Lead contact person: Dr F. Ghannouchi)</p>
<p>Rockwell Collins, Government Systems, USA Dr G. Hegazi</p>	<p>Collaboration on LINC transmitter design. (Lead contact person: Dr F. Ghannouchi)</p>
<p>Powerwave Technologies, USA B. Vassilakis</p>	<p>The collaboration with Powerwave Technologies was initiated last year. This collaboration is aimed at the modeling and linearization of Powerwave's commercial power amplifiers. (Lead contact person: Dr F. Ghannouchi)</p>
<p>Freescale, USA J. Wood</p>	<p>Freescale is providing LDMOS-based devices and high-efficiency PA evaluation boards of their products to be used as devices under test for the ongoing research topic related to the design of high-efficiency Doherty power amplifiers. (Lead contact person: Dr Boumaiza)</p>
<p>Nitronex Corporation, USA P. Rajagopal</p>	<p>The collaboration with Nitronex was initiated last year. It covers the support of an NSERC strategic grant, as well as privileged access to Nitronex's GaN device technology. (Lead contact person: Dr Ghannouchi)</p>

RFHIC Corporation, Korea	RFHIC, Korea is providing the iRadio Lab with privileged access to their GaN transistor products for characterization, modeling and application to the design of wideband RF power amplifiers. (Lead contact person: Dr Boumaiza)
Altera, USA	Altera Corporation is providing the iRadio Lab with FPGA boards from their university program. (Lead contact person: Dr F. Ghannouchi)
Analog Devices, USA	Analog Devices is providing the iRadio Lab with DSP boards and circuits from their university program. (Lead contact person: Dr F. Ghannouchi)
Industry Collaborations	
TRLabs, Canada Dr R. Davis	Concerns the development of an antenna selection algorithm for MIMO systems and RF front-end design for MIMO radio systems (Lead contact person: Dr Ghannouchi)
Canadian Space Agency, Canada Mr. G. Brassard	In the frame of a NSERC Collaborative Research and Development Grant (CRD) (2007-2009), this collaboration aims at the development of GaN based innovative Doherty power amplifiers intended for CSA's quiksat program. The ongoing collaboration covered the co-supervision of a master thesis of a CSA engineer (Lead contact person: Dr Ghannouchi)
Focus Microwaves, Canada Dr C. Tsironis	Focus Microwaves is sponsoring the ongoing NSERC Collaborative Research and Development Grant (CRD) (2007-2009), and providing privileged technical support for activities related to the load-pull characterization of active devices (Lead contact person: Dr Ghannouchi)
Nanowave Technologies, Canada Dr A. Rahal	Collaborating with Nanowave Technologies since 2006 within a NSERC CRD project, the ongoing collaboration involves an NSERC strategic research project related to the development of GaN based switching mode amplifiers for satellite and avionic applications. (Lead contact person: Dr Ghannouchi)
Nortel Networks, Canada T. Dashin	Initiated this year, Nortel's technical staff assisted with the two-day course organized by the iRadio Lab. Recently, Nortel Networks supported an NSERC strategic grant application (Lead contact person: Dr Ghannouchi)
Agilent Technologies, USA A. Amini	This work concerns the co-simulation and optimization of WiMAX transmitters within Agilent's Advanced Design System (ADS) software. For this purpose, privileged access to Agilent's ADS WiMAX library was granted to the iRadio Lab (Lead contact person: Dr Boumaiza)

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INTELLECTUAL PROPERTY

<i>Applicants</i>	<i>Title/Name</i>	<i>Status</i>
Applied for through UTI this year	Mode-Multiplexing LINC Transmitters for Wireless Transmitters	US provisional patent application, Feb. 2008
Applied for this year	All-Digital Multi-standard Transmitter Architecture using Sigma-Delta Modulators	PCT patent application, Feb. 2008
Applied for this year through UTI	Methods and Apparatuses for Providing Digital Baseband Predistortion	US patent application, Dec. 2007
Applied for this year	Multi-standard Transmitter using Sigma-Delta Modulator	US provisional patent application, Nov. 2007
US patent # 7,035,345, April 2006.	“Adaptive Predistortion Device and Method Using Digital Receiver”	Granted

