Alberta Informatics Circle of Research Inc

iRadio Laboratory Annual Report

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1. EXECUTIVE SUMMARY

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, by high DC 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 ("green"). The mission of the Intelligent RF Radio Laboratory (iRadio Lab) is the development of 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.

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 iRadio Lab in the University of Calgary's ICT building (ICT 302) 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 A Block of the Engineering building (ENA 5), used for printed circuit boards fabrication and prototyping, being used by graduate students and researchers. The iRadio Lab facilities are supported by a number of computer aided design (CAD) based software, 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 and wireless communications industries and government R&D agencies. iRadio Lab has close formal collaborations with several national and international academic institutions, industry partners and government agencies..

The innovative and applications-oriented R&D activities being carried out at iRadio Lab have led to thirty six referred published and accepted journal papers, twenty eight refereed conference papers, three US patent applications and a publication of a book. Twenty keynotes and invited talks were given by iRadio Lab researchers in international conferences and leading research institutions and Universities. A team of five graduate students from iRadio Lab qualified for the finals of Software Defined Radio Challenge 2009/2010, an international competition, which is organized yearly by the SDR Forum.

During its fifth year, iRadio Lab was successful in securing substantial funding: $295K from the Natural Sciences and Engineering Research Council of Canada (NSERC), $63K from TRLabs, and $75 from industry. These monies supplement the $300K, $200K, and $150K yearly averages provided by iCORE, the Canada Research Chairs (CRC) Program and the University of Calgary, respectively, over a 5-year period. In addition, in-kind contributions and equipment donations and loans in the amount of about $215K from industrial partners and $100K of in-kind contributions from the University of Calgary have been obtained during the reporting period.

2. RESEARCH PROGRAM OVERVIEW

The research Team

There are many people affiliated with iRadio Lab, they include faculty members, research staff, students, support staff, visiting and adjunct researchers and industry collaborators. The head count of the iRadio Lab personnel affiliated directly with the University of Calgary currently includes two faculty members, two technical support staff, one administrative support staff, one lab manager, one research assistant, two postdoctoral fellows, one visiting scholar, and eighteen graduate students.

Research Partners

This laboratory has been mainly funded by joint sponsorship from iCORE, CRC, NSERC and the Canada Foundation for Innovation (CFI). Formal academic collaborations are maintained with Canadian and international universities in the area of device and system level modeling, power amplifier design and optimization, and software defined radio (SDR) based transceivers. In addition, close collaborations have been made with major leading national and international companies and agencies in the following areas:

i. semi-conductor technology (Freescale Semiconductor, Nitronex, RFHIC, Cree);

ii. wireless and satellite communications infrastructure (Nortel, Ericsson, Nanowave Technologies, the Canadian Space Agency, Powerwave Technologies, NXP);

iii. digital electronics, digital signal processing (DSP) and CAD software (Analog Devices, Altera, Xilinx, Agilent Technologies, Lyrtech, Canadian Microelectronic Corporation, Agilent Technologies)

Major Research Directions

The scope of this iCORE/CRC research program is related to the development of intelligent RF radio systems for emerging wireless and satellite communications. The main goal is the development of software-defined high-performance and environmentally friendly transceivers. This multidisciplinary research calls for broad knowledge in the fields of DSP and mixed signal technology, RF and microwave technology, and communications systems, including the implementation and manufacturing processes in the respective fields. The ongoing research activities span over the following research directions that were identified in the original research proposal.

Modeling Technology: The development of device, circuit and system models is essential for the design and optimization of the RF front end. Behaviour modeling is a key element for system level analysis of radio systems, as well as in predistortion and pre- or post-equalization applications.

Green RF Electronics: The power amplifier (PA) is the most critical and expensive subsystem in all RF wireless systems, as its performance dictates the overall performance of the transmitter, in terms of linearity and power efficiency. Accordingly, the development of power-efficient PA modules used in advanced transceiver architectures is essential for any high-performance and environmentally friendly (green) transceiver design in hybrid and/or integrated technologies.

DSP for Communications: The advances in transceiver architectures call for a RF/DSP co-design approach, in order to ensure desired functionality and optimal system level performance. This includes impairment pre-compensation and architecture dependant signal processing and conditioning

Software Defined Radio: The design of multi-band, multi-mode transmitters is an important element for the development of truly SDR based transmitters for the infrastructure of ubiquitous networks. The use of multi-antenna

radio architectures will further improve system performance, mainly in terms of capacity, coverage and service availability.

Adaptive and Reconfigurable Receivers: This is the counterpart of the multi-band transmitter required for software-defined high-performance transceivers. New architectures are considered critical for the development and deployment of multi-frequency, multi-standard communications systems

All the activities already carried out by iRadio Lab, as well as those planned, are in line with the aforementioned research directions. These projects all serve the intention of the original research proposal (submitted to iCORE and CRC), which was aimed at the development and advancement of knowledge and know-how related to the design of intelligent and reconfigurable RF front ends for multi-standard broadband communication systems. The optimization of power-added efficiency, due mainly to the reduction of DC power consumption of RF radios, is one of the objectives of the research program as initially stated in the chair proposal; and, since it may favourably impact the environment, this research thrust is being branded as green RF electronics, to better reflect its importance to the nontechnical person and to society at large.

3. RESEARCH PROJECTS

The research program is being conducted along the aforementioned five major research tracks. The achievements related to each of these five projects are reported and evaluated, in light of the initial main goals relevant to this project.

Microwave and Radio frequency Devices, Circuits and Systems Characterization and Modeling

The primary objectives of this research project cover the accurate characterization and modeling of RF and microwave active devices, circuits and systems.

Over the last year, the emerging gallium nitride (GaN) technology for power HEMT (high electron mobility transistor) transistors was the main focus of our research activities in the area of device characterization and modeling. This technology is expected to have great potential for future wireless communications infrastructure by achieving wideband operation with very high power efficiency and acceptable linearity performance. Nonlinear models dedicated to switching-mode power amplifier (SMPA) design have been developed. A straightforward and time-efficient design methodology for SMPAs was proposed using the switch based equivalent circuit model. This model was found to be accurate enough to predict the performance of the transistor in the power back-off region as well as in the saturation region. Experimental load-pull data based models are also being considered for the modeling of GaN transistors to be used in the design of continuously driven PAs. The activities carried out within this area have been performed in close collaboration with academic (ETS – École de Technologie Supérieure, Université du Québec) and industrial partners (NRC and Nitronex).

At the system level, it has been found that the current metrics used for behavioural model performance assessment are not accurate enough, since they fail to effectively quantify a key component (memory effects) of the behaviour of the system being modeled. Consequently, and as a continuation of the work achieved last year on the extraction of the static nonlinearity in power amplifiers / transmitters exhibiting memory effects, an innovative approach for model validation was proposed. This includes new metrics and methods that can efficiently quantify the accuracy of the behavioural model in mimicking both the static nonlinearity and the memory effects exhibited by the device under test.
In addition, a new class of low computational complexity behavioural models for power amplifiers / transmitters exhibiting strong memory effects have been proposed. These models, namely the Hammerstein – Winner oriented box models, lead to better performances with up to a 50% reduction in the number of parameters when compared to the state-of-the-art behavioural models. The activities carried out within this area have been performed in close collaboration with an industrial partner, Powerwave Technologies and Agilent Technologies.

Within the NSERC collaborative research and development grant project supported by Canadian Space Agency dealing with the design of digitally driven multi-input Doherty PAs, results were obtained for individual characterization of the carrier and peaking amplifiers while they are operating within the Doherty load modulation mechanism. This offers a unique in-depth observation of the behaviour of Doherty amplifier. This characterization approach is being directly used for innovative behavioural modeling applications of Doherty PAs and will lead to the development and the prototyping of high-performance digitally driven Doherty PAs.

Green RF Power Amplification Systems

The objective of this research project is the design of advanced multi-branch power amplification architectures that will achieve high performances in terms of power efficiency, linearity and bandwidth, in order to be used with highly demanding applications, such the 4th generation and beyond (4G+) standards. In continuation of work done in previous years on the development of the highly efficient amplifier design, the analysis and design methods were further advanced, in order to achieve even higher performances for different applications and a variety of standards. In particular, when targeting the design of class F and inverse class F PAs for 4G applications, new techniques to reduce the losses in the matching networks were developed, analyzed and validated. As a result, a state-of-the-art PA achieving 75% power added efficiency (PAE) at 2.45 GHz was developed and prototyped. In addition, a current mode class D achieving PAE of 70% was designed and prototyped at 2.425 GHz for use in 4G wireless transmitters with dual-branch Cartesian architectures, such as delta-sigma based transmitters. The activities carried out within this area are supported through an NSERC strategic project grant and have been performed in close collaboration with industrial partners (Nitronex and Cree).

The designed PA prototypes were tested with new advanced transmitter architectures using an out phasing technique to improve the efficiency versus linearity trade-off in the power back-off region. Indeed, a reverse MM-LINC (mode-multiplexing linear amplification with nonlinear components) technique was proposed, simulated, implemented and tested for 3G applications. The measurement results showed that the proposed architecture is capable of achieving a good linearity versus efficiency trade-off without requiring high pre-processing computational complexity, in comparison to the most commonly used linearization techniques, mainly digital predistortion. This characteristic makes the proposed approach a good candidate for mobile and broadband applications

The optimization of Doherty PAs to improve their linearity and/or efficiency was thoroughly studied over the past year. This led to the design of an improved Doherty PA that has superior linearity performance while maintaining excellent PAE performance. The linearization of the designed prototype using a digital predistortion technique led to the best trade-off in terms of linearity and efficiency that has been reported in the open literature for Doherty PAs driven by up to 60 MHz WCDMA (wideband code division multiple access) signals. The activities carried out within this project are supported through an NSERC collaborative research development grant and have been performed in close collaboration with the Canadian Space Agency (CSA).

Advanced Adaptive Digital Signal Processing Algorithms for Wireless Transceivers

This research project targets the development of advanced adaptive signal processing techniques for performance improvement of wireless transceivers. This can be divided into three tracks: nonlinearity compensation, impairment compensation and architecture dependant signal processing.

For nonlinearity compensation, several algorithms have been developed for base station and mobile terminal transmitters driven by WCDMA or/and LTE (Long Term Evolution) signals. These algorithms are mainly related to the cancellation of memory effects exhibited by RF PAs / transmitters. Results obtained illustrate the ability of the developed approaches to improve the convergence behaviour of predistortion algorithms using behaviour or artificial neural networks based models. Critical issues related to the computational complexity of digital predistortion systems have been considered in the predistorter's identification and implementation steps. Excellent linearization capabilities

have been achieved for highly nonlinear Doherty transmitters over a 60 MHz The implementation of memory compensation algorithm within the FPGA (field-programmable gate array) platform was completed and similar results were obtained when using commercial instruments, such as arbitrary waveform generators and vector spectrum analyzers

A new algorithm to compensate for in-phase/quadrature (I/Q) imbalance in direct conversion transmitters that does not require any specific training sequence or the use of an ideal I/Q imbalance-free demodulator in the feedback loop was developed and validated. Architecture dependant digital signal processing (DSP) is another area of investigation. Signal processing algorithms are being developed to provide the required and optimized driving signals synthesized in the DSP module of the considered innovative multi-branch and multi-input multi-output (MIMO) transmitter architectures.

The activities carried out within this project are supported through an NSERC collaborative research and development (CRD) and strategic grants and have been performed in close collaboration with industrial partners.

Multi-Band, Multi-Mode and Multi-Antenna SDR-Based Transmitters

This research project mainly focuses on the development of software defined radio (SDR) based transceivers that are able to adapt to multiple communication standards using the same hardware platform. The intention for the hardware platform can be targeted for multi-band, multi-standard, and multi-antenna applications that can be quickly controlled through the ease of software reconfigurability. In the context of a reconfigurable baseband transmitter platform, we proposed a multi-standard, multi-mode SDR based transmitters which incorporate a dual band PA, based on the high efficiency Doherty amplifier and channel selective digital predistortion system for the linearization purpose and the amplifier design has been fabricated and tested. A new dual band predistortion methodology has already been established and will be implemented in FPGA based DSP platform. A similar RF-DPD platform has been developed, which is under investigation in order to make it suitable for dual band application in repeaters.

In addition to the development of SDR based transceivers, we also investigated the potential application of SDR radios for public safety distress signal applications where the target was the establishment of SDR based cooperative network that can address a broad set of civilian safety services and the demonstration of the network's usefulness in safety distress applications. This was related to the 3rd international Annual Smart Radio student challenge where our team won first prize, as well as best design prize. We proposed a complete network and terminal based solution for establishing a SDR based cognitive network at the disaster scene that can maintain a database of rescuers' geolocations and coordinate the rescue operation within the network. Since determination of geolocations of the rescuers has a vital role in setting up the proposed network hence a considerable efforts are focused on the solution of the wireless location problem and mitigation of the issues surrounding it, such as the multipath problem. A proof of concept validation emulating the networks fixed and mobiles nodes was realized using standard RF instrument, Tx/Rx evaluation boards and software such as MATLAB.

The fully digital transmitter project allows for the adaptability and reconfigurability of several communication standards driven by a SDR interface. The heart of the digital transmitter is a delta sigma architecture with parallel processing to improve signal processing speed. We have extended upon the fully digital transmitter project to include enhancements such as support for a wider signal bandwidths, and selection of carrier frequencies up to 5 GHz. These improvements allow the prototype to interoperate with current wireless standards as well as the next generation of high speed wireless communication protocols such as WiMAX, and LTE.

The study on the performance improvement of the multiple-input multiple-output (MIMO) transmitter based on our recently proposed multi-cell processing technique, Cross-Over digital predistortion (CO-DPD), has been continued and a patent has been filed recently. It was shown and validated that CO-DPD technique can compensate for the transmitter's nonlinearities and the nonlinear RF crosstalk. Also, the cross-over multi-cell model has been extended for forward modeling of the MIMO nonlinear system and it has been shown that the new model can better predict the nonlinear behaviour of the MIMO system. The overall effects of the nonlinear and linear RF crosstalk and the

transmitter's nonlinearities on the Bit-Error-Rate (BER) performance of the MIMO system had been studied. The simulation results showed that the effects of RF nonlinearities at the transmitter need to be assessed carefully; otherwise, it would degrade the overall performance of the system. Extending the idea of using multi-cell processing technique for the nonlinearities' compensation of multi-band and multi-carrier RF transmitter is under investigation. The initial results show that using the multi-cell processing technique can significantly reduce the minimum required sampling rates of the analog-to-digital (ADC) and digital-to-analog (DAC) without performance degradation of the nonlinearities compensation.
In the context of developing simplified MIMO receiver, we proposed a new multiple-input single branch MIMO receiver using time-multiplexed technique. Initial test on the proposed technique was conducted and the results prove the functionality of the architecture. Developing a post-compensation technique to compensate for any gain and phase distortion as a result of using single branch receiver is under investigation.

Adaptive and Tuneable Receivers

Along with the multi-band transmitter project reported in the previous section, the design and prototyping of multi-band receivers continues to be carried out, as in previous years.

This project focuses on the development of multi-band and tuneable receivers. For this purpose, reconfigurable hardware is needed for the baseband processing block and the RF front-end. In this context, a reconfigurable baseband receiver was designed previously in an SDR reconfigurable platform. On the RF front-end side, a new topology based on de-interleaving and sub-sampling of the RF signal, was also previously developed in order to digitize and directly acquire the baseband signal, as closely as possible, from the receiving antenna.
In the past year, the linearity and signal quality of the de-interleaving and sub-sampling multi-standard receiver architecture was optimized using a very broadband (12 GHz) track-and-hold (T&H) circuit interfaced with an FPGA based platform, where a post processing algorithm was implemented. The reconfigurable receiver was tested and validated with different types of modulated signals (EDGE – Enhanced Data rates for GSM Evolution; CDMA – code division multiple access; and, WiMAX).

A new ultra-wideband signal down-conversion topology using passive six-port network has been also investigated. The use of only passive components not only reduces the power consumption in the receiver side and therefore increases the battery life in mobile communications. It also allows for the design of ultra-wide band receiver, which can be used for multi-standard and multi-carrier frequencies. This topology was implemented and validated with simple modulation techniques such as BPSK, QPSK, 8-PSK, 16-QAM. It is anticipated that in the next year, more effective processing algorithms will be proposed to improve the performance of this receiver for more complex modulation technique to handle OFDM and CDMA modulated signals.
The activities carried out within this project are supported through an NSERC discovery grant and iCORE funds.

4. OBJECTIVES FOR NEXT YEAR

The objectives of the next year are in line with the research directions of the chair's original proposal. These objectives are subdivided according to the research tracks and projects identified in the overview of the research program.

Modeling Track

As a continuation of our efforts in the modeling area, a robust model validation technique will be extended to handle MIMO and broadband multi-frequency radio systems. This is foreseen as a strategic path for the development of behavioural models and, consequently, nonlinearity compensation algorithms that will cover MIMO and multi-frequency applications. Commercial test equipment presently does not support such wide bandwidths; accordingly, custom measurement setups and techniques need to be developed. State-of-the-art behavioural models will be

augmented to take into account additional nonlinearity sources triggered by the wideband drive signals. The behavioural modeling of the designed multi-band PAs driven by multi-standard signals will also be initiated.

At the transistor level, the study of GaN devices will be continued through intensive measurements and modeling activities in collaboration with LACIME Laboratory at ETS, The National Research Council (NRC), Canadian Space Agency (CSA). Several devices provided by industrial partners who are developing GaN-based transistors, such as Cree, Nitronex and NRC, have been procured. The main objective is the development of a full-fledged model of GaN transistors suitable for continuously driven, as well as switching-mode, PA design.

Power Amplifiers Track

During the past year, we focused on the design of high-efficiency RF switching mode PAs for wireless communication applications with a carrier frequency in the range of 2-3 GHz. Matching network topologies were developed that optimized matching network architectures that reduced the power losses in the transmission lines. This results in efficiency improvement of the PA, in order to reach state-of-the-art performances. In the next period, we will focus on extending this knowledge to satellite and wireless personal area networks that work at millimetre wave (mm-wave) frequencies and wider bandwidths up to few hundred MHz. Working at higher frequencies is expected to be challenging in terms of fabrication and implementation technologies, as well as device and physical phenomena limitations.

It is also anticipated that work will begin on the implementation of a multi-mode digital Doherty transmitter for wireless personal area network applications at mm-wave frequencies. Contrary to conventional transmitters, the multi-mode Doherty transmitter uses different modes of operation. The selected mode varies as a function of the instantaneous power of the input signal. The choice of the modes and their thresholds of operation will be studied and optimized, in order to improve the linearity and efficiency of Doherty amplifiers without requiring complex pre-processing algorithms.

DSP for Wireless Communications Track

Our recent research activities on digital predistortion (DPD) will be extended for both baseband and RF technologies. On the baseband side, 60 MHz of instantaneous correction bandwidth will be targeted as a first step and then broaden to up to 100 MHz. This activity will be carried out in conjunction with the wideband characterization of RF PA / transmitter systems. The implementation of the predistortion function will create several challenges, and the developed low complexity predistortion functions are expected to play an important role in enabling the implementation of the wideband DPD systems. The development of innovative RF-digital and RF-analog predistortion systems that compensate for memory effects will be pursued over the next year. This will lead to the experimental validation and prototyping of RF-digital and RF-analog predistortion systems that are able to compensate for memory effects. This technology can be used on RF amplifiers and repeaters driven by RF signals where there is no access to a baseband signal.

The work on the linearization of PAs and transmitters under wideband (60 MHz and more) drive signals will be pursued. The main limitation observed so far is mainly due to the wide bandwidth of the observation path. Accordingly, a particular interest will be given to sub-band processing techniques in order to broaden the observation window maintaining acceptable dynamic range and signal quality.

One of the major challenges to achieving maximum performance from MIMO transceivers is the ability to maintain acceptable levels of impairments and nonlinearity that occur due to the unavoidable implementation imperfection in the MIMO chipset design process. A new multi-cell digital predistortion processing algorithm is under development for compensation of the nonlinearities and distortions as the results of nonlinear behaviour of the transmitter. When dealing with multi-carrier signals, distortions as the result of nonlinear behaviour of RF transmitter can be classified as intra-band and inter-band distortions.

For the multi-input single-branch MIMO receiver, the proposed topology shows remarkable performance in comparison to the conventional multi-branch MIMO receivers. However, time-multiplexing the multiple signals introduces extra distortions into the system which results in additional losses at the final BER performance. The idea of using post-compensation algorithms to compensate for these distortions is under investigation.

SDR Transmitters Track

The study and investigation of true digitally based transmitter architecture that allows for the communication signal to be kept in a digital binary format as close as possible to the antenna will be continued and intensified. In the past year, significant research efforts were expended on tackling the implementation issues in delta-sigma modulators for GHz ranges; however, the designed proof-of-concept prototype still needs further improvement at both the signal processing and hardware stages in order to increase the bandwidth, to improve the quality of the signal and to enhance the power efficiency of the entire transmitter.

Implementation and validation of wider band delta-sigma modulators for GHz frequency applications was made possible with parallel processing topology and high-speed multiplexers. However, the performance obtained in terms of power efficiency was relatively low. We intend to study, design and test a new delta-sigma architecture based on multilevel quantization. The architecture was briefly investigated, and preliminary results showed its potential to achieve high efficiency. The implementation of this architecture will require a special design of the RF part, especially the PA. It is anticipated that some time will be allocated to the design and optimization of a switching-mode PA suitable for multilevel quantization delta-sigma modulators

Adaptive and Tuneable Receivers Track

In order to offer an effective solution for the design of adaptive and tuneable receivers, the main challenge that has to be addressed is the implementation of a low-cost ultra-wideband receiver with minimum impairments in the down-converter. An approach that consists of using a passive multi-port network with circuit pre-calibration will be adopted. It is anticipated that this architecture will reduces the cost and power consumption by replacing the mixer with a passive six-port circuit and avoiding image rejection filters, which are hard to design and integrate. Power detectors are used at the outputs of the six-port circuit to extract the baseband envelopes of the RF signals. The baseband signals are then converted to analog using high-speed analog-to-digital converters. Digital signals with bandwidth of up to few hundred MHz will be targeted.

5. RESEARCH TEAM MEMBERS AND CONTRIBUTIONS

Faculty		
Name	Role / Topic	Awards / Special Info
Dr. Fadhel Ghannouchi	Team Leader, Director of iRadio Lab, iCORE Professor in Intelligent RF Radio Technology, and (Tier 1) Canada Research Chair. Research interests are in the areas of microwave instrumentation, modeling of microwave devices and communications systems, design and linearization of RF amplifiers and SDR and multi-band radio systems.	Professor Ghannouchi selected as IEEE-MTT-S Distinguished Microwave Lecturer (DML) for the three year period 2009-2011. Dr. Ghannouchi was inducted as a Fellow of the Canadian Academy of Engineering (July 09). Dr. Ghannouchi selected as a finalist for an ASTech award (October 09) Member of the International Advisory Board of the Gigahertz Research Centre, Sweden (2007-present)

		Dr. Ghannouchi received the APEGGA Summit Award : the Alberta Ingenuity Fund Research Excellence Award in Calgary on April 23, 2009
Dr. Mohamed Helaoui	iCORE associate and assistant professor Research interests are in the areas of RF and wireless communications, signal processing for ultra-wideband receivers.	Dr. Helaoui received a start-up research grant from The ECE department and the Schulich school of Engineering Began July 2009

Visiting Professor / Researcher		
Name	Role / Topic	Awards / Special Info
Dr. Smita Tiwari (October 09 - present)	Visiting Researcher Research interests: wireless and satellite geolocation	

Visiting Speakers		
Name	Topic	Special Info
Dr. Smita Tiwari	Position Estimation of Wireless Devices and their Sources of Error	September 23 2009

Research Associates / Assistants		
Name	Role / Topic	Awards / Special Info
Andrew Kwan	Research Associate	
Farzaneh Taringou	Research Assistant Behavioural modeling of communication transceivers	
Meenakshi Rawat	Research Assistant Neural network modeling of radio systems	Worked as a engineer for two years as an Officer of Hindustan Petroleum Corporation, India
Fermin Esparza Alfero	Research Assistant Wireless location and modeling	
Luc Devocht	Research Assistant All-digital transmitter implementation on a FPGA platform	

Postdoctoral Fellows

Name	Role / Topic	Awards / Special Info
Dr. Mohamed Helaoui	All-digital transmitter design	Graduated from University of Calgary
Dr. Oualid Hammi	Behavioural modeling of communication systems	Graduated from University of Calgary
Dr. Mohammad Hashmi	RF and microwave instrumentation	Graduated from Cardiff University, UK.
Dr. Souheil Bensmida	Load-pull measurement and device characterization	Graduated from University of telecom Paris, France
Dr. Sung Chan Jung	High efficiency Doherty power amplifier design	Graduated from Seoul University, South Korea
Dr. Anwar Jarndal	GaN device modeling	Graduated from Kassel University, Germany

Ph.D. Students		
Name	Role / Topic	Awards / Special Info
Seyed Aidin Bassam	MIMO transceivers for 4G wireless communication systems	
Pouya Aflaki	GaN Based PA design with application to polar transmitters	University award
Walid Saber El-Deeb	Design and implementation of RF waveform measurement system	Holds an international graduate scholarship from the Egyptian Government
Mohamed Mostageer	OFDM/LINC transmitter design	Associate, École Polytechnique de Montréal Currently holds an international graduate scholarship from the Egyptian Government. Graduated in August 2009
Sonia Bouajina	Behavioural modeling of RF power amplifiers with memory effects	Associate, École Nationale d'Ingenieurs de Tunis, Tunisia. Co-supervised by Dr. M. Jaidane. Graduated in January 2010
Afef Hargel	Memory-Polynomial Based models for RF transmitters linearization	Associate, Faculté des sciences, University of Tunis, Tunisia Co-supervised by Dr. A. Gharsallah
Mohammed Mojtaba Ebrahimi	Multi-band transceiver design	Co-supervised with Dr. Helaoui
Karun Rawat	Multi-standard SDR Transmitters	
Saeed Rezaei Nazifi	Generic analog linearization systems	
Mehdi Vejdani Amiri	MIMO radio systems	
Fahmi Elsayed	All-digital transmitter	Co-supervised with Dr Helaoui
Dhikra Saffar	MIMO behavioural modelling	Associate, Faculté des sciences, University of Tunis, Tunisia Co-supervised by Dr. A. Gharsallah
Ramzi Darraji	Multi-mode amplifiers	

Chokri Jbeli	Behavioural Modeling Wireless Transmitters	Associate, Faculté des sciences, University of Tunis, Tunisia Co-supervised by Dr. A. Gharsallah

M.Sc. Candidates		
Name	Role / Topic	Awards / Special Info
Andrew Kwan	Implementation of baseband digital predistortion techniques on a DSP / FPGA platform	Co-supervised by Dr. M. Smith. Graduated December 2009
Meenakshi Rawat	Neural network modeling of radio systems	Joined iRadio Lab as a student on September 2008
Levent Erdogan	Use of microwave energy in tar sands applications	Associate, École Polytechnique de Montréal Co-supervised by Dr. C. Akyel
Mayada Younes	Memory effect analysis and modeling	
Shubhrajit Bhattacharjee	Wireless Channel Modeling	Co-Supervised by Dr H. Lueng

Other Team Members (associates, undergraduate students, support staff)		
Oualid Hammi	Lab Manager	
Christopher Simon	Technical support	
Tibor Bata	Technical support to students for printed circuit board (PCB) fabrication and instrumentation	
Ivana D'Adamo	Administrative support to Dr. Ghannouchi and the iRadio Lab team	

6. COLLABORATIONS

Participants	Nature of Collaboration
National Collaborations	
École Polytechnique de Montréal: Dr. K. Wu Dr. R. Malhame Dr. A. Cevdet	Collaboration with the Poly-Grames Research Center (Dr. K. Wu) concerns access to advanced printed circuit board (PCB) fabrication facilities by the iRadio Lab team. Moreover, three graduate students from École Polytechnique de Montréal are currently supervised by Dr. Ghannouchi.
Université de Québec: Dr. A. Kouki	The ongoing theme of collaboration is related to LINC-based amplifiers and GaN transistors modeling.
International Collaborations	
Aachen University, Germany Dr. R. Negra	The ongoing collaboration is related to the modeling og GaN Tranistors and the design of switching mode Pas and Transmitters'
Université de Tunis (ENIT, FST, Sup'COM) , Tunisia: Dr. A. Ghazel (Sup'Com) Dr. M. Jaidane (ENIT)	The ongoing themes of collaboration are related to behaviour modeling of nonlinear systems, implementation of digital predistortion (DPD) technology using DSP/FPGA modules and the design of multi-standard receivers using RF subsampling techniques. Several joint papers have been published that report the

Dr. A. Gharsallah (FST)	results obtained so far. Dr. Ghannouchi is co-supervising the work of two Ph.D. candidates and one Master student.
Université de Bordeaux, France: Dr. E. Kerhervé Y. Deval	Collaboration with the IXL Laboratory of the Université de Bordeaux to study, analyze and assess the suitability of integrated multi-band RF power amplifiers. During this past year, one graduate student from Université de Bordeaux spent two terms at iRadio lab.
Ningbo University of China, China: Prof. T. Liu	Collaboration was initiated this year. Ongoing research activities are related to the modeling and compensation of memory effects in RF power amplifiers.
Amirkabir University, Iran: Prof. A. Mohammadi	Collaboration was initiated this year. Ongoing research activities on six-port receivers and MIMO wireless systems.
Industrial Collaborations	
TRLabs, Canada: Dr. R. Davis	The collaboration with TRLabs is mainly concerned with the development of an antenna selection algorithm for MIMO systems and RF front-end design for MIMO radio systems.
Canadian Space Agency, Canada: Mr. G. Brassard Mr. T. Pellerin	In the frame of a NSERC Collaborative Research and Development (CRD) grant (2007-2009), the objective of this collaboration is the development of GaN-based innovative Doherty power amplifiers intended for the Canadian Space Agency's quicksat program.
Focus Microwaves, Canada: Dr. C. Tsironis Dr Z. Ouardirhi	Focus Microwaves is sponsoring the ongoing NSERC Collaborative Research and Development (CRD) grant (2007-2009) and providing privileged technical support for our activities related to the load-pull characterization of active devices.
Nanowave Technologies, Canada: Dr. A. Rahal	Dr. Ghannouchi has been collaborating with Nanowave Technologies since 2006, within an 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.
Ericsson, Canada: P. Olanders	The collaboration with Ericsson was initiated last year. Ericsson is currently supporting an NSERC strategic grant application related to the development of millimtre-wave multi-mode Doherty PAs.
Powerwave Technologies, USA: B. Vassilakis Dr. N. Braithwaite	The collaboration with Powerwave Technologies was initiated last year. This collaboration is aimed at the modeling and linearization of Powerwave's commercial power amplifiers.
Freescale Semiconductor, USA: J. Wood	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.
Nitronex, USA: P. Rajagopal B. Therrien	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.
Altera, USA	Altera is providing iRadio Lab with FPGA boards from their university program.
Analog Devices, USA	Analog Devices is providing iRadio Lab with DSP boards and circuits from their university program.
MathWorks, USA	MathWorks provided iRadio Lab free software licences for special tool boxes needed to build the SDR platform in the context of SDR challenge 2008.
Agilent Technologies, USA	The collaboration is related to the wideband characterisation and modeling of Wireless Transmitters

7. GRADUATES

- Postdoctoral Fellows

Name	Degree	Research Topic	Current Position
Renato Negra	Ph.D.	Switching-mode power amplifiers	Presently Assistant Professor, Aachen University, Germany
Souheil Bensmida	Ph.D.	Characterization of RF transistors	Presently Research Associate, Bristol University, UK
Sung-Chan Jung	Ph.D.	Doherty power amplifiers	Presently Research Professor, Sungkyunkwan University, Korea
Mohamed Helaoui	Ph.D.	All-digital transmitter design	Presently Assistant Professor, University of Calgary
Anwar Jarndal	Ph.D.	GaN device modeling	Presently Assistant Professor, Hodeidah University, Yemen

- Ph.D. Candidates

Name	Degree	Research Topic	Current Position
Mohamed Mostageer	Ph.D.	OFDM/LINC transmitter design	Postdoctoral Fellow, Ecole Polytechnique
Sonia Bouajina	Ph.D.	Behavioural modeling of RF power amplifiers with memory effects	Assistant Professor, University of Tunis

- M.Sc. Candidates

Name	Degree	Research Topic	Current Position
Andrew Kwan	M.Sc.	Implementation of baseband digital predistortion techniques on a DSP / FPGA platform	Research associate, iRadio Lab, University of Calgary
Karun Rawat	M.Sc.	dual band RF directional couplers	Ph.D. Student, iRadio Lab

8. INTELLECTUAL PROPERTY

Patents and Patent applications:

1. F. M. Ghannouchi, M. Helaoui, S. Hatami, and R. Negra, "All-Digital Multi-standard Transmitter Architecture using Sigma-Delta Modulators", PCT patent WO/2009/055897, May 2009
2. Hammi, and F. M. Ghannouchi, “Nonlinear Behavior Models for Static and Dynamic Nonlinearity Modeling and Compensation and Methods for Use Thereof in Wireless Communication Systems”, US provisional patent application 61/228887, filed July 27, 2009.
3. S. A. Bassam, F. M. Ghannouchi and M. Helaoui, "Processing Cells for Multi-input Multi-output Systems ", US provisional patent application, filed May 14, 2009

Refereed Journal Publications:

1. A. Jarndal, P. Aflaki, L. Degachi, A. Birafane, A. B. Kouki, R. Negra and F. Ghannouchi, "Large-Signal Model for Algan/Gan Hemts Suitable for Rf Switching-Mode Power Amplifiers Design," Solid State Electronics, 2010 accepted.
2. M. Younes, O. Hammi, A. Kwan and F. M. Ghannouchi, "An Accurate Complexity-Reduced “Plume” Model for Behavioral Modeling and Digital Predistortion of Rf Power Amplifiers," IEEE Transactions on Industrial Electronics, 2010 accepted.
3. M. S. Hashmi, P. J. Tasker and F. M. Ghannouchi, "Transistor Device Optimization for Rf Power Amplifier Employing Rapid Envelope Load-Pull System," International Journal of Microwave and Optical Technology (IJMOT), 2010 Accepted.
4. Mohammadi and F. M. Ghannouchi, "Five-Port Microwave Receiver Architectures and Applications," IEEE Communications Magazine, 2010 accepted.
5. F. M. Ghannouchi, "Power Amplifier and Software Defined Radio Systems," IEEE Circuits and Systems Magazine, 2010 accepted.
6. S.-C. Jung, R. Negra and F. M. Ghannouchi, "Analysis of Miniaturized 3 Db Branch-Line Hybrid Couplers," Microwave and Optical Technology Letters, 2010 Accepted.
7. S. S.-. Bouajina, O. Hammi, M. Jaidane-Saidane and F. M. Ghannouchi, "Experimental Approach for Robust Identification of Rf Power Amplifier Behavioral Models Using Polynomial Structures," IET Microwaves, Antennas & Propagation, 2010 accepted.
8. K. Rawat, M. Rawat and F. M. Ghannouchi, "Compensating I-Q Imperfections in Hybrid Rf/Digital Predistortion with Adapted Look up Table Implemented in Fpga," IEEE Transactions on Circuits and Systems II, 2010 accepted.
9. F. Taringou, O. Hammi, B. Srinivasan, R. Malhame and F. M. Ghannouchi, "Behavior Modeling of Wideband Rf Transmitters Using Hammerstein-Wiener Models," IET Circuits, Devices & Systems, 2010 accepted.
10. O. Hammi, M. Younes, A. Kwan, M. Smith and F. M. Ghannouchi, "Performance-Driven Dimension Estimation of Memory Polynomial Behavioural Models for Wireless Transmitters and Power Amplifiers.," Progress in Electromagnetics Research (PIER-C), 2010 accepted.
11. M. M. Ebrahimi, F. M. Ghannouchi and M. Helaoui, "Analytical Approach to Optimize the Efficiency of Switching Mode PAs Loaded with Semi-Distributed Matching Networks," IET Microwaves, Antennas and Propagation, 2010 accepted.
12. W. S. El-Deeb, M. S. Hashmi, F. M. Ghannouchi, N. Boulejfene and S. Bensmida, "Thru-Less Calibration Algorithm and Measurement System for on-Wafer Large-Signal Characterization of Microwave Devices," IET Microwaves, Antennas and Propagation, Vol. 2010 accepted.
13. W. S. El-Deeb, N. Boulejfen and F. M. Ghannouchi, "A Multi-Port Measurement System for Complex Distortion Measurements of Nonlinear Microwave Systems,," IEEE Transaction on Instrumentation and Measurement, Vol. 59: Issue 5, pp. 1406-1413, May 2010.
14. M. S. Hashmi, Z. S. Rogojan, R. S. Nazifi and F. Ghannouchi, "A Broadband Dual-Inflection Point Rf Predistortion Linearizere Using Backward Reflection Topology," Progress in Electromagnetics Research C, Vol. 13, pp. 121-1342010.
15. M. S. Hashmi, Z. S. Rogojan and F. M. Ghannouchi, "A Flexible Dual-Inflection Point Rf Predistortion Linearizer for Microwave Power Amplifiers," Progress in Electromagnetics Research C, Vol. 13, pp. 1-182010.

16. W. S. El-Deeb, S. Bensmida, N. Boulejfen and F. M. Ghannouchi, "An Impedance and Power Flow Measurement System Suitable for on-Wafer Microwave Device Large Signal Characterization " International Journal of RF and Microwave Computer-Aided Engineering Journal, Vol. 20: Issue 3, pp. 306-312, February 2010.
17. M. Rawat, K. Rawat and F. M. Ghannouchi, "Adaptive Digital Predistortion of Wireless Power Amplifiers/Transmitters Using Dynamic Real-Valued Focused Time Delay Line Neural Networks," IEEE Transactions on Microwave Theory and Techniques, Vol. 58: Issue 1, pp. 95-104, January 2010.
18. M. Helaoui and F. M. Ghannouchi, "Linearization of Power Amplifiers Using the Reverse Mm-Linc Technique," IEEE Transactions on Circuits and Systems II: Express Briefs, Vol. 57: Issue 1, pp. 6-10, January 2010.
19. M. S. Hashmi, A. L. Clarke, J. Lees, M. Helaoui, P. J. Taskar and F. M. Ghannouchi, "Agile Harmonic Envelope Load-Pull System Enabling Reliable and Rapid Device Characterization," IOP Journal of Measurement Science and Technology, Vol. 21: Issue 055109, pp. 1-9, April 2010.
20. W. S. El-Deeb, N. Boulejfen and F. M. Ghannouchi, "A Multi-Port Measurement System for Complex Distortion Measurements of Nonlinear Microwave Systems,," IEEE Transaction on Instrumentation and Measurement, 2009 accepted.
21. W. S. El-Deeb, S. Bensmida, N. Boulejfen and F. M. Ghannouchi, "An Impedance and Power Flow Measurement System Suitable for on-Wafer Microwave Device Large Signal Characterization " International Journal of RF and Microwave Computer-Aided Engineering Journal, 2009 accepted.
22. Birafane, M. El-Asmar, A. B. Kouki, M. Helaoui and F. M. Ghannouchi, "Comprehensive Analysis of Linc Power Amplifiers from Efficiency and Linearity Perspectives," IEEE Microwave Magazine, 2009 accepted.
23. N. Boulejfen, A. Harguem, O. Hammi, F. M. Ghannouchi and A. Gharsallah, "Analytical Prediction of Spectral Regrowth and Correlated and Uncorrelated Distortion in Multicarrier Wirless Transmitters Exhibiting Memory Effects," IET Microwaves, Antennas & Propagation, 2009 accepted.
24. S. A. Bassam, S. Boumaiza and F. M. Ghannouchi, "Block-Wise Estimation of and Compensation for I/Q Imbalance in Direct-Conversion Transmitters," IEEE Transactions on Signal Processing, Vol. 57: Issue 12, pp. 4970-4973, December 2009.
25. F. M. Ghannouchi and O. Hammi, "Behavioural Modeling and Predistortion," IEEE Microwave Magazine, Vol. 10: Issue 7, pp. 52-64, December 2009.
26. K. Rawat and F.M.Ghannouchi, "A Design Methodology for Miniaturized Power Dividers Using Periodically Loaded Slow Wave Structure with Dual-Band Applications," IEEE Transactions on Microwave Theory and Techniques, Vol. 57: Issue 12, pp. 3380-3388, December 2009.
27. P. Aflaki, R. Negra and F. M. Ghannouchi, "Dedicated Large-Signal Gan Hemt Model for Switching-Mode Circuit Analysis and Design," IEEE Microwave and Wireless Components Letter, Vol. 19: Issue 11, pp. 740-742, November 2009.
28. S. A. Bassam, M. Helaoui and F. M. Ghannouchi, "De-Interleaved Subsampling Architecture for Homodyne Receivers," Progress In Electromagnetics Research C, Vol. 10, pp. 231-241, October 2009.
29. S.-C. Jung, K.-H. Lim, H.-C. Park, R. Negra, M.-S. Kim, F. M. Ghannouchi and Y. Yang, "A Load Network for Doherty Amplifiers Using an Optimized Impedance Transformer," Microwave and Optical Technology Letters, Vol. 51: Issue 10, pp. 2502-2504, October 2009.
30. S.-C. Jung, O. Hammi and F. M. Ghannouchi, "Design Optimization and Dpd Linearization of Gan-Based Unsymmetrical Doherty Power Amplifiers for 3g Multicarrier Applications," IEEE Transactions on Microwave Theory and Techniques, Vol. 57: Issue 9, pp. 2105-2113, September 2009.
31. P. Aflaki, R. Negra and F. M. Ghannouchi, "Enhanced Architecture for Microwave Currentmode Class-D Amplifiers Applied to the Design of an S-Band Gan-Based Power Amplifier," IET Microwaves, Antennas & Propagation, Vol. 3: Issue 6, pp. 997-1006, September 2009.
32. Kwan, M. Helaoui, S. Boumaiza, M. Smith and F. Ghannouchi, "Wireless Communications Transmitter Performance Enhancement Using Advanced Signal Processing Algorithms Running in a Hybrid Dsp/Fpga Platform," Journal of Signal Processing Systems, Vol. 56: Issue 2, pp. 187-198, September 2009.
33. O. Hammi and F. M. Ghannouchi, "Twin Nonlinear Two-Box Models for Power Amplifiers and Transmitters Exhibiting Memory Effects with Application to Digital Predistortion," IEEE Microwave and Wireless Components Letters, Vol. 19: Issue 8, pp. 530-532, August 2009.
34. R. Barrak, A. Ghazel and F. Ghannouchi, "Optimized Multistandard Rf Subsampling Receiver Architecture," IEEE Transactions on Wireless Communications, Vol. 8: Issue 6, pp. 2901-2909, June 2009.

35. M. Younes, O. Hammi and F. M. Ghannouchi, "Algorithm for Model Dimensions Estimation of Memory Polynomial-Based Rf Transmitters / Power Amplifiers Behavioral Models," International Journal of Microwave and Optical Technology, Vol. 4: Issue 4, pp. 242-247, July 2009.
36. S. A. Bassam, M. Helaoui and F. M. Ghannouchi, "Crossover Digital Predistorter for the Compensation of Crosstalk and Nonlinearity in Mimo Transmitters," IEEE Transactions on Microwave Theory and Techniques, Vol. 57: Issue 5, pp. 1119-1128, May 2009.

Refereed Conference Proceedings:

1. W. S. El-Deeb, M. S. Hashmi, N. Boulejfen and F. M. Ghannouchi, "Relative Waveform Measurement Technique for the Characterization of Multiport Microwave Devices," in IEEE AP-S International Symposium on Antennas and Propagation and USNC/CNC/URSI Meeting, Toronto, Ontario, 11-17 July 2010 accepted.
2. P. Aflaki, R. Negra and F. M. Ghannouchi, "Dual-Band Hybrid Balun Structure Using Transmission-Lines and Lumped Component Resonators," in International Microwave Symposium (IMS2010), Anaheim, California, 23-28 May 2010 accepted.
3. F. M. Ghannouchi, F. Taringou and O. Hammi, "A Dual Branch Hammerstein-Wiener Architecture for Behavior Modeling of Wideband Rf Transmitters," in IMS2010, Anaheim, California, 23-28 May 2010 accepted.
4. S. Tiwari, R. Darraji, S. A. Bassam, A. Kwan, K. Rawat, M. Rawat, M. Fattouche and F. M. Ghannouchi, "Practical Result of Wireless Indoor Position Estimation by Using Hybrid Tdoa/Rss Algorithm," in 23rd Canadian Conference on Electrical and Computer Engineering (CCECE2010), Calgary, Alberta, 2 - 5 May 2010 accepted.
5. S. A. Bassam, M. Helaoui and F. M. Ghannouchi, "Ber Performance Assesment of Linearized Mimo Transmitters in Prescence of Rf Crosstalk," in IEEE Radio and Wireless Symposium (RWS'2010), New Orleans, LA, USA, 10-14 January 2010 accepted.
6. W. S. El-Deeb, M. S. Hashmi, N. Boulejfen and F. M. Ghannouchi, "Dynamic Am-Am and Am-Pm Characterization of Mimo Rf Power Amplifiers Using Mta-Based Multiport Measurement Setup," in INMMIC 2010 (Integrated Nonlinear Microwave and Millimeter-Wave Circuit), Goteborg, Sweeden, April 26-27, 2010 2010 accepted.
7. Kwan, O. Hammi, M. Helaoui and F. M. Ghannouchi, "High Performance Wideband Digital Predistortion Platform for 3g+ Applications with Better Than 55dbc over 40 Mhz Bandwidth," in IMS2010, Anaheim, California, 23-28 May 2010 accepted.
8. M. S. Hashmi and F. M. Ghannouchi, "Recent Advances in the Load Synthesis Approaches for Characterization of Microwave Devices Employed in Power Amplifier Design," in 2010 IEEE AP-S International Symposium on Antennas and Propagation 2010 USNC/CNC/URSI Meeting , Toronto, Ontario, 11-17 July 2010 accepted.
9. R. Negra, D. Kalim, D. Erguvan and F. M. Ghannouchi, "On the Design of Broadband/Multiband Highly Efficient Power Amplifiers," in 12th International Symposium on Microwave and Optical Technology (ISMOT'2009), New Delhi, India, 16-19 December 2009 accepted.
10. Jebali, N. Boulejfen, A. Gharsallah and F. M. Ghannouchi, "Performance Assessment of Rf Power Amplifier Memory Polynomial Models under Different Signal Statistics," in 16th IEEE International Conference on Electronics, Circuits, and Systems (ICECS'2009), Yasmine Hammamet, Tunisia, 13-16 December 2009 accepted.
11. S. A. Bassam, M. M. Ebrahimi, A. Kwan, M. Helaoui, M. P. Aflaki, O. Hammi and F. M. Ghannouchi, "A Generic Architecture for Smart Multi-Standard Software Defined Radio Systems," in Software Defined Radio Technical Conference, Washington DC, USA, pp. 1-6, 1-4 December 2009
12. O. Hammi and F. M. Ghannouchi, "Comparitive Study of Recent Advances in Power Amplification Devices and Circuits for Wireless Communication Infrastructure," in 16th IEEE International Conference on Electronics, Circuits, and Systems (ICECS'2009), Yasmine Hammamet, Tunisia, pp. 379-382, 13-16 December 2009.
13. S.-C. Jung, R. Negra and F. M. Ghannouchi, "A Minaturized Double-Stage 3 Db Broadband Branch-Line Hybrid Coupler Using Distributed Capacitors," in 2009 Asia-Pacific Microwave Conference (APMC'2009), Singapore, pp. 1323-1326, 7-10 December 2009 2009.
14. M. M. Ebrahimi, M. Helaoui and F. M. Ghannouchi, "Trading-Off Stability for Efficiency in Designing Switching-Mode Gan Pas for Wimax Applications," in 2009 Asia-Pacific Microwave Conference (APMC'2009), Singapore, pp. 2348-2351, 7-10 December 2009 2009.
15. Jarndal, P. Aflaki, L. Degachi, A. Birafane, A. Kouki, R. Negra and F. M. Ghannouchi, "On the Large-Signal Modeling of Algan/Gan Hemts for Rf Switching-Mode Power Amplifiers Design," in 2009 Asia-Pacific Microwave Conference (APMC'2009), Singapore, pp. 2356-2359, 7-10 December 2009.

16. P. Aflaki, R. Negra and F. M. Ghannouchi, "Intrinsic Capacitances Effects on the Accuracy of the Large-Signal Switch-Based Gan Device Model," in 2009 Asia-Pacific Microwave Conference (APMC'2009), Singapore, Vol. , pp. 281-284, 7-10 December 2009.
17. M. M. Ebrahimi, M. Helaoui and F. M. Ghannouchi, "Efficiency Enhancment of a Wimax Switching Mode Gan Power Amplifier through Layout Optimization of Ditributed Harmonic Matching Networks.," in European Microwave Conference 2009, EuMC 2009, Rome, Italy pp. 1732-1735, September 29- October 1, 2009 2009.
18. M. M. Ebrahimi, M. Helaoui and F. M. Ghannouchi, "Efficiency Enhancement of a Wimax Switching Mode Gan Power Amplifier through Layout Optimization of Distributed Harmonic Matching Networks," in European Microwave Integrated Ciruits Conference 2009, EuMIC2009, Rome, Italy, pp. 379-382, September 28-29, 2009 2009.
19. F. M. Ghannouchi, "An S Band Rf Digital Linearizer for Twtas and Sspas," in European Conference on Circuit Theory and Design (ECCTD'2009), Antalya, Turkey, pp. 735-738, August 23-27 2009.
20. M. El-Asmar, A. Birafane, A. B. Kouki and F. M. Ghannouchi, "Investigation of Chireix Pa Performances by Testing One Branch Variable Load Amplifier," in International Conference on Advances in Computational Tools for Engineering Applications (ACTEA'2009), Zouk Mosbeh, Lebanon, pp. 279-283, 15-17 July 2009.
21. F. M. Ghannouchi, M. M. Ebrahimi and M. Helaoui, "Inverse Class F Power Amplifier for Wimax Applications with 74% Efficiency at 2.45 Ghz," in IEEE International Conference on Communications Workshops, Dresden, Germany, pp. 1-5, 14-18 June 2009.
22. S. A. Bassam, M. Helaoui and F. M. Ghannouchi, "De-Interleaved Direct Down-Conversion Receiver for Sdr Applications," in IEEE MTT-S International Microwave Symposium Digest (IMS'2009), Boston, MA, USA, pp. 1661-1664, 7-12 June 2009.
23. O. Hammi, S. Carichner, B. Vassilakis and F. M. Ghannouchi, "Effects of Crest Factor Reduction on the Predistortion Performance for Multi-Carrier 3g Rf Power Amplifiers," in IEEE MTT-S International Microwave Symposium Digest (IMS'2009), Boston, MA, USA, pp. 1085-1088, 7-12 June 2009.
24. K. Rawat and F. M. Ghannouchi, "Design of Reduced Size Power Divider for Lower Rf Band Using Periodically Loaded Slow Wave Structure," in IEEE MTT-S International Microwave Symposium Digest (IMS'2009), Boston, MA, USA, pp. 613-616, 7-12 June 2009.
25. W. S. El-Deeb, N. Boulejfen and F. M. Ghannouchi, "An Automated Multiport Measurement System for Linear and Non-Linear Characterization of N-Port Microwave Devices," in IEEE Instrumentation and Measurement Technology Conference (I2MTC'2009), Singapore, pp. 1211-1214, 5-7 May 2009.
26. O. Hammi and F. M. Ghannouchi, "Efficiency Optimization of Wcdma Driven Two-Way Doherty Power Amplifiers over Wide Power Range," in Canadian Conference on Electrical and Computer Engineering (CCECE'2009), St. John's, NL, Canada, pp. 1217-1220, 3-6 May, 2009 2009.
27. S. A. Bassam, M. E. Kalantari, S. Boumaiza and F. M. Ghannouchi, "On the Usage of Receive Antenna Subset Selection Algorithm in Dstbc Based Mimo Systems," in IEEE 10th Annual Wireless and Microwave Technology Conference (WAMICON'2009), Clearwater, FL, USA, pp. 1-4, 20-21 April 2009.
28. K. Rawat, O. Hammi and F. M. Ghannouchi, "Investigating Effects of Quadrature Imperfection of Vector Multiplier in Implementing Rf/Digital Predistortion," in IEEE 10th Annual Wireless and Microwave Technology Conference (WAMICON'2009), Clearwater, FL, USA, pp. 1-4, 20-21 April 2009.

Books and Chapters

Six-Port Techniques with Microwave and Wireless Applications, F.M. Ghannouchi and A. Mohammadi, Editor Artech House: (2009)

Special/Invited Presentations

1. F. M. Ghannouchi, “RF Front-ends for Software Defined and Cognitive Radio Solutions,” a keynote talk in IEEE MTT-S International Workshop, Aveiro, Portugal, February 22-23, 2010.
2. F. M. Ghannouchi, “Advanced RF power amplifier,” an invited talk, IEEE Radio and wireless symposium, January 10-14 2010, New Orleans , LA.
3. F. M. Ghannouchi, “Modeling and Design of Wireless Transmitters for Software Defined Radio Applications,” an invited talk, Universite de Lille I (IEMN), December 9 2009, Lille, France
4. F. M. Ghannouchi, “Modeling and Design of Wireless Transmitters for Software Defined Radio Applications,” an invited talk, Universite Paris EST (ESIEE), December 8 2009, Paris, France

5. F. M. Ghannouchi, “Software defined radio for 4G applications,” an invited talk, SDR workshop, University of Quebec (ETS), December 7 2009, Montreal, Canada.
6. O. Hammi, “Behavioural modeling and predistortion techniques,” an invited talk, Microwave Exhibition and Workshops 2009, November 25-27 2009, Yokohama, Japan.
7. F. M. Ghannouchi, “Technology Convergence and Software Define Radio,” an invited keynote talk, University of Bordeaux, November 17 2009, Bordeaux, France.
8. F. M. Ghannouchi, “Technology Convergence and Software Define Radio,” an invited keynote talk, Mediterranean Microwave Symposium (MMS 2009), November 16 2009, Tangiers, Morocco.
9. F. M. Ghannouchi, “Behavioural Modeling and Amplifier’s Linearization,” an invited talk, Chalmers University, November 11 2009, Goteborg, Sweden.
10. M. Helaoui, “Green RF Amplifiers for Wireless Communication Systems,” an invited talk, the ACAMP Cleantech 2009 seminar, September 28 2009, Edmonton, Canada
11. F. M. Ghannouchi, “Software Defined Radio Systems,” an invited talk, Dalhousie University, September 24 2009, Halifax, Canada
12. F. M. Ghannouchi, “Advanced Transmitters for Software Defined Radio Systems,” an invited talk, Sebanci University, August 25 2009, Istanbul, Turkey
13. F. M. Ghannouchi, “Advanced Transmitters for Software Defined Radio Systems,” an invited talk, Hacettepe University, August 27 2009, Ankara, Turkey
14. F. M. Ghannouchi, “Modeling Technology for Wireless Systems,” a keynote talk, The 21st IASTED International Conference on Modelling and Simulation, July 15-17 2009, Banff, Canada
15. F. M. Ghannouchi, “Advanced Transmitters for Software Defined Radio (SDR) Applications,” an invited talk, University of Berlin, June 15 2009, Berlin, Germany
16. F. M. Ghannouchi, “Advanced Transmitters for Software Defined Radio (SDR) Applications,” an invited talk, University of Dresden, June 16 2009, Dresden, Germany
17. F. M. Ghannouchi, “Advanced Transmitters for Software Defined Radio (SDR) Applications,” an invited talk, Telecom Paris, June 17 2009, Paris, France
18. F. M. Ghannouchi, “SDR based Power amplifiers for wireless and satellite Communications,” an invited talk, Analog Devices, May 20 2009, Greensboro, NC
19. F. M. Ghannouchi, “SDR based Power amplifiers for wireless and satellite Communications,” an invited talk, Freescale, May 18 2009, Tempe, Az
20. F. M. Ghannouchi, “SDR based Power amplifiers for wireless and satellite Communications,” an invited talk, Nanyang Technological University, May 7 2009, Singapore

Seminars

iRadio Lab continues to organize biweekly seminars where graduate students and research staff present and discuss the latest results of their work. Abstracts of these seminars may be found at http://iradio.ucalgary.ca/seminars/lab_seminars .

10. OUTREACH

The community outreach activities of iRadio Lab included:

- iRadio Lab students selected for the finals in SDR Challenge 2009-2010 (http://www.radiochallenge.org), Washington, DC, April, 2009.
- CBC News published an article on iRadio Labs’ efforts on the development of energy-saving radio systems being conducted at iRadio Lab.
- iRadio lab will be attending a the 2010 International Microwave Symposium and Exhibition in Anaheim, CA (http://www.ims2010.org/) where will be showcasing a hardware-software solutions developed to reduce the energy consumption of wireless radio terminals.

11. FINANCIAL REPORTS

1. ICORE Revenues/Expenses

The annual financial statement will be sent directly to iCORE by the Financial Services of the University of Calgary.

2. Funding Sources

The funding sources report lists all of our active funding sources. The provided spreadsheet for this purpose was updated to reflect the cash and in-kind funds obtained in this year. This spreadsheet is attached with this report.

Funding Sources:

- iCORE
- Alberta Government (ASRA, other)
- University of Calgary (cash)
- University of Calgary (in-kind)
- Industry (cash)
- Industry (in-kind)
- Canada Research Chair
- Canada Foundation for Innovation
- Natural Sciences and Engineering Research Council of Canada
- Other Federal Government
- Other Government

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