5th Annual

New England Workshop on Software Defined Radio (NEWSDR 2015)

Friday, 22 May 2015

Worcester Polytechnic Institute | Rubin Campus Center

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Welcome

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The 2015 New England Workshop on Software Defined Radio (NEWSDR) is the fifth installment of an annual series of workshops organized by the Boston SDR User Group (SDR-Boston).

The previous NEWSDR events were held at Boston University (Saturday 1 October 2011), Northeastern University (Friday 11 May 2012), Worcester Polytechnic Institute (Friday 17 May 2013), and Boston University (Friday 6 June 2014). This year, we are very excited about having Worcester Polytechnic Institute (WPI) generously serving as the host institution for NEWSDR 2015; the Odeum of the Rubin Campus Center is a fantastic venue for this event!

The goal of this series of workshops is to provide a forum through which individuals working on SDR-related projects in the New England area can get together in order to collaborate and introduce SDR concepts to those interested in furthering their knowledge of SDR capabilities and available resources.

Following on the success of these workshops, this year's NEWSDR event offers a chance for presenting the latest developments in SDR and Cognitive Radio research by individuals from academia, industry, and government in the New England area, as well as from across the Nation. In addition to providing an opportunity for researchers in this area to network and interact on issues relating to SDR and Cognitive Radios, NEWSDR 2015 will include:

- Keynote Presentations on the latest in SDR
- Poster Presentations with Short "Elevator-Pitch" Oral Presentations
- Technology demonstrations
- Hands-On Tutorials
- Free parking / breakfast / coffee / lunch included with advanced registration

During this event, we would like to encourage all of you to engage in conversation with your fellow attendees, exchange ideas, and talk about your latest findings with respect to SDR. We hope that you will find NEWSDR 2015 a productive event to expand your knowledge and horizons regarding SDR technology, and we would like to wish you a very positive and rewarding workshop!

Agenda

8:00AM-8:15AM	**Welcome and Introduction**
8:15AM-9:00AM	**Invited Presentation:** *Professor Miriam Leeser, Northeastern University*
9:00AM-9:30AM	**"Elevator Pitch" Oral Presentations of Poster Presenters**
9:30AM-11:15AM	**Coffee, Networking Break, Poster Presentations, Sponsor Exhibits and Demos**
11:15AM-12:00PM	**Invited Presentation:** *Professor Mieczyslaw Kokar, Northeastern University*
12:00PM-1:00PM	**Lunch**
1:00PM-2:00PM	**Keynote Presentation:** *Professor fred harris, San Diego State University*
2:00PM-2:30PM	**Coffee, Networking Break, Poster Presentations, Sponsor Exhibits and Demos**
2:30PM-3:15PM	**Short Course I** Learning Software Defined Radio using MATLAB, Simulink, and the RTL-SDR" *Bob Stewart, MathWorks*
3:15PM-4:00PM	**Short Course II** FPGA Acceleration with RF NoC *Jonathon Pendlum, Ettus Research*
4:00PM-4:10PM	**Closing Remarks and Adjournment**

Keynote & Invited Speakers

fredric j harris holds the Signal Processing Chair of the Communication Systems and Signal Processing Institute at San Diego State University where since 1967 He has taught courses in Digital Signal Processing and Communication Systems. He holds 20 patents on digital receiver and DSP technology and lecture throughout the world on DSP applications. He consults for organizations requiring high performance, cost effective DSP solutions. He is an adjunct member of the IDA-Princeton Center for Communications Research. He has written over 200 journal and conference papers, the most well known being his 1978 paper "On the use of Windows for Harmonic Analysis with the Discrete Fourier Transform". He is the author of the book Multirate Signal Processing for Communication Systems and he has contributed to a number of other books on DSP applications including the "Source Coding" chapter in Bernard Sklar's 1988 book, Digital Communications and the "Multirate FIR Filters for Interpolation and Resampling" and the "Time Domain Signal Processing with the DFT" chapters in Doug Elliot's 1987 book Handbook of Digital Signal Processing, and "A most Efficient Digital Filter: The Two-Path Recursive All-Pass Filter" and the "Ultra Low Phase Noise DSP Oscillator" Chapters in Rick Lyons 2012 second edition book Streamlining Digital Signal Processing. In 1990 and 1991 he was the Technical and then the General Chair of the Asilomar Conference on Signals, Systems, and Computers and was Technical Chair of the 2003 Software Defined Radio Conference and of the 2006 Wireless Personal Multimedia Conference. He then, became a Fellow of the IEEE in 2003, cited for contributions of DSP to communications systems. In 2006 He received the Software Defined Radio Forum's "Industry Achievement Award". His 2006 paper and again his 2011 paper at the SDR conference were selected for the best paper award as were his paper at the Autotestcon-2011 conference and his paper at WPMC-2022. He served as the Editor-in-Chief of the Elsevier DSP Journal. He is a traditional absent-minded professor who drives secretaries and editors to distraction by requesting strictly lower case letters to spell his name. For amusement, he roams the world collecting old toys and slide-rules and riding old railways.

Miriam Leeser received her BS degree in electrical engineering from Cornell University, and Diploma and PhD degrees in computer science from Cambridge University in England. She was an assistant professor in Cornell University's Department of Electrical Engineering before coming to Northeastern, where she is head of the Reconfigurable Computing Laboratory, director of the Center for Communications and Digital Signal Processing, and a member of the Computer Engineering research group. Her research includes using heterogeneous architectures for signal and image processing applications as well as implementing computer arithmetic and verifying critical applications. She is a senior member of the IEEE and of the ACM.

Mieczyslaw Kokar technical research interests include Information Fusion, Software Engineering, Ontology-Based Computing, and Modeling Languages. In particular, he is interested in higher-level information fusion and situation awareness, ontology-based software radios, the specification and design of self-controlling software using the control theory metaphor, ontology development, ontological annotation of information, logical reasoning about OWL annotated information, consistency checking, formalization of the UML language, consistency checking of UML models vs. UML Metamodel and of UML Metamodel vs. MOF. Dr. Kokar teaches various graduate courses in software engineering, formal methods and artificial intelligence. He has an M.S. and a Ph.D. in computer systems engineering from Wroclaw University of Technology, Poland. He is a senior member of the IEEE and member of the ACM.

Short Courses

Low Cost SDR First Principles Design using MATLAB, Simulink and the RTL-SDR

Bob Stewart (MathWorks), Dale Atkinson, Kenneth Barlee, Louise Crockett (University of Strathclyde)

Abstract – In this short course, we will present examples and information from the pre-release edition of the new 11 chapter, 620 page textbook "Software Defined Radio using MATLAB & Simulink and the RTL-SDR" (for publication and release June 2015). This new free textbook (will be available as a free PDF download along with more than 200 MATLAB and Simulink teaching and development examples) will take users from the first principles of DSP and SDR using MATLAB and Simulink to receive and process off-air RF signals using the sub $20 RTL-SDR.

We will show live examples at the poster suitable for teaching and learning for both students and the professional engineer – ranging from the simple real-time design of AM and FM receivers, to complete QPSK receivers featuring complete DSP receiver design and including first principles synchronization and timing control. The short course will outline how the RTL-SDR can be used for education of SDR and DSP enable radio principles in both undergraduate, graduate classes, and provide an excellent low cost platform for capstone projects.

Pre-print draft copies of the 600 page book will be available for inspection to delegates at the NEWSDR poster and in exchange for an email address and answering one simple DSP question a USB drive featuring the book PDF and more than 200 RTL-SDR and related examples will be shipped on at release time in later June 2015.

FPGA Acceleration with RF NoC

Jonathon Pendlum (Ettus Research)

Abstract – RFNoC (RF Network on Chip), a new framework for Ettus third generation devices (X300 & E300) that aims to make FPGA acceleration in SDRs more easily accessible. In this short course, I will cover some background on FPGAs and their use in SDR, the motivation and design of RFNoC, and conclude with a few live demos.

Poster Presentations

Ziria: Domain-Specific Language for PHY Programming

Radunovic Bozidar (Microsoft Research), Gordon Stewart, Mahanth Gowda, Geoffrey Mainland, Dimitrios Vytiniotis, Cristina Luengo Agullo

Abstract – Software-defined radio (SDR) brings the flexibility of software to wireless protocol design, promising an ideal platform for innovation and rapid protocol deployment. However, implementing modern wireless protocols on existing SDR platforms often requires careful hand-tuning of low-level code, which can undermine the advantages of software. Ziria is a new domain-specific language (DSL) that offers programming abstractions suitable for wireless physical (PHY) layer tasks while emphasizing the pipeline reconfiguration aspects of PHY programming. The Ziria compiler implements a rich set of specialized optimizations, such as lookup table generation and pipeline fusion. We also offer a novel - due to pipeline reconfiguration - algorithm to optimize the data widths of computations in Ziria pipelines. We demonstrate the programming flexibility of Ziria and the performance of the generated code through a detailed evaluation of a line-rate Ziria WiFi 802.11a/g implementation that is on par and in many cases outperforms a hand-tuned state-of-the-art C++ implementation on commodity CPUs.

Bi-Directional Transceiver Implementation with Optimal Parameter Selection

Benjamin Drozdenko (Northeastern University), Ramanathan Subramanian, Kaushik Chowdhury, Miriam Leeser

Abstract – Software defined radio (SDR) transitions the communication signal processing chain from a rigid hardware platform to a user-controlled paradigm, allowing unprecedented levels of flexibility in parameter settings. However, programming and operating such SDRs have typically required deep knowledge of the operating environment and intricate tuning of existing code, which adds delay and overhead to the network design. In this work, we describe a bi-directional transceiver implemented in MATLAB that runs on the USRP platform and allows automated, optimal selection of the parameters of the various processing blocks associated with a DBPSK physical layer. Further, we provide detailed information on how to create a real-time design wherein the same SDR switches between transmitter and receiver functions, using standard tools like the MATLAB Coder and MEX to speed up the processing steps. Our results reveal that link latency and packet reception accuracy are greatly improved through our approach, making it a viable first step towards protocol design within an easily accessible MATLAB environment.

Micro Transceiver System: Compact Software Defined Radio Implementation

Jonathan Peck (SRC, Inc.)

Abstract – The Micro Transceiver system is a small software defined radio that can be used for multiple applications. This flexible and modular hardware platform is suitable for direction finding, spectrum monitoring, voice, and data communications. The major components of the system include a RF module, DSP module, and an enclosure. This hardware platform leverages recent advances in compact transceiver design and is able to leverage future advances in this area through a modular approach to software defined radio. To reduce the size of these major components the Micro Transceiver utilizes system on chips that combine the typical functionality of multiple discrete chips into a single small package. The RF module utilizes multiple integrated transceivers which allow 4 RF channels to access the spectrum anywhere between 70 MHz to 6 GHz. Each of the RF channels includes a LNA and a filter bank in addition to the integrated transceivers that can be configured for either transmit or receive. A single DSP module can support two RF modules with a total 8 RF channels and multiple DSP modules can be connected together using a high speed connection to support more RF channels. The interface between the RF and DSP module uses a FPGA mezzanine connector (FMC) that follows the VITA-57 standard. This allows various off the shelf modules to be connected to the system. DSP module uses a FPGA SoC that includes hardware support for floating-point arithmetic in both the processor and FPGA fabric which can reduce software development time. In addition to the FPGA SoC the DSP module also includes a microcontroller to allow for low power operation on a battery and software defined security features. Various interfaces are provided on the enclosure to allow for integration of common peripherals for SDRs including high power amplifiers (HPAs), smart antennas, precision GPS modules, and

precision oscillators. Ethernet and USB are provided as interfaces to allow for both programming and user control from a PC.

Software Defined Radio-Based Signal Generator

Ruolin Zhou (Western New England University), Matthew Dore, Jonathan Downing

Abstract – There is tremendous interest in the world of wireless communications and RF for a single platform suitable for multiple applications, including wireless communications, radar, and other RF. To develop a single platform capable of implementing each of these applications, we propose a software defined radio (SDR) based signal generator employing Ettus USRP hardware. The USRP RF front-end allows for a flexible, upgradeable, and inexpensive hardware platform to implement the RF signal generator. The USRP works in conjunction with multiple interchangeable daughterboards to allow for operation at a wide variety of frequency bands. The signal generator platform consists of single-carrier and multi-carrier signals, which are produced and controlled from a graphical-user-interface input window. Within the single-carrier signal generator, various modulations are available including ASK, FSK, BPSK, QPSK, 8-PSK, 16-QAM, and LFM. Within the multi-carrier signal generator, the user may select either overlay or hybrid overlay/underlay operation, allowing the user to assign weightings to individual sub-carriers of the multi-carrier. To avoid harmful interference, or to block or disturb an external user's signal, weightings can be assigned to individual sub-carriers to lower or raise transmission power of the signal generator, respectively. Specifically, this control ensures there is no harmful interference to the external user's signal as the signal generator underlays the external signal within its interference tolerance. The control also allows for the signal generator to increase power to individual sub-carriers to disturb or block an external user's signal. The platform implements many desirable functions, realizes coexistence between the signal generator user and other external users via one waveform, and provides a base for wireless communications, radar, navigation, cognitive radio development, and other RF research.

Full Duplex 802.11a-Compliant Transceiver with Split Functionalities

Rahman Doost (Northeastern Univeristy), Ben Drozdenko, Kaushik Chowdhury, Miriam Leeser

Abstract – Software-defined radio (SDR) transitions the communication signal processing chain from a rigid hardware platform to a user-controlled paradigm, allowing unprecedented levels of flexibility in parameter settings. However, performing the most common SDR operations in software is usually less efficient than a hardware implementation. For this reason, modern-day real-time bi-directional communications systems may be difficult to model using only a typical computer processor. Instead, some components of the communication system would be more advantageously implemented using FPGA. In this work, we design a full duplex 802.11a-compliant transceiver with split functionalities between a processor and reconfigurable hardware for handling the most time-consuming operations. We implement our design using the Xilinx Zynq-7000 series ZC706 System-on-Chip (SoC) and the AD-FMCOMMS3-EBZ RF transceiver. We experiment using GNU radio and the MathWorks Communications System Toolbox Xilinx Zynq-Based Radio Hardware Support Package for interfacing with the radio. We describe the PHY and MAC system components, and propose which would be best implemented on either the RISC-architecture ARM-based processing system (PS) or the programmable logic (PL). Our initial results reveal that frame detection and digital self-interference cancellation can potentially be expedited through PL, whereas control operations such as frame header decoding and MAC state transitions are best suited for PS. Moreover, our design involves only unidirectional data flows from the front-end, through FPGA fabric and towards the ARM processor for the receiver, and vice versa for the transmitter and hence avoids any back and forth data exchange between the FPGA and ARM. Our design takes the first step towards a zynq-based SDR research platform for full duplex protocol design with an easily accessible environment. We envisage a parametrized design for the FPGA blocks comprising of matched filters and correlators that are programmable through software and hence could easily switch gears to support various wireless standard with rapid prototyping through MATLAB or GNU radio.

Geophysical Radio Remote Sensing with Software Defined Radio

Juha Vierinen (MIT)

Abstract – We describe recent advances with software defined radio and geophysical radio remote sensing. We describe two different geophysical radio remote sensing experiments that can be done with minimal hardware: 1) spread spectrum continuous pseudorandom coded ionospheric HF radar that can be used to

measure ionospheric electron density using a few milliwatts of effective radiated power, and 2) a FM radio passive radar that can be used to measure ionospheric irregularities produced by geomagnetic storms. We describe the signal processing theory related with these two experiments, example hardware configuration, and results obtained with these experiments.

LTE SIB1 Recovery with Two Antennas

Ying-On Yan (MathWorks), Mike McLernon

Abstract – Most modern communication standards support the use of multiple antennas to improve system performance. It is important for communication system designers to be able to prototype and analyze algorithms quickly based on actual signals transmitted and received by radios with multiple antennas. We demonstrate a 2x2 MIMO communication scenario by transmitting and receiving an LTE signal via USRP B210 radios. The LTE signal is generated in MATLAB and sent to the transmitter radio directly. MATLAB receives the signal via another radio and performs carrier frequency correction, frame synchronization, LTE cell search procedure, channel estimation, and orthogonal space-frequency block code decoding. At the end, the SIB1 field, the first of the System Information Blocks in the LTE standard, is recovered and the CRC is verified. This demonstration serves as a starting point for communication engineers who want to get hands-on experience with MIMO transmission for the LTE standard.

LTE MIMO Transmission and Reception using MATLAB and Analog Device FMCOMMS based Zynq Radio

Mukesh Chugh (MathWorks)

Abstract – Using Zynq-Based Radio Support Package and LTE System Toolbox(TM) generate a multi-antenna LTE transmission for simultaneous transmit and receive on a single radio. An image file is encoded and packed into a radio frame for transmission, and subsequently decoded on reception. Prototype your radio algorithms quickly on Zynq platform using HDL Coder(TM). Generate HDL code from your radio designs in Simulink automatically to customize programming logic of the Xilinx Zynq radio.

Extending VOLK to ARM SIMD Instructions

Nathan West (Oklahoma State University/U.S. Naval Research Laboratory), Douglas Geiger, George Scheets

Abstract – We extend GNU Radio's Vector Optimized Library of Kernels (VOLK) to use ARM SIMD instructions by creating optimized signal processing routines in NEON with both compiler intrinsic functions and hand-tuned assembly where appropriate. We use source analysis and disassembly to determine when hand-tuned assembly is required for optimization. Finally, profiling results using ARM Cortex-A9 processors are presented that demonstrate our performance improvements.

Low Cost SDR First Principles Design using MATLAB, Simulink and the RTL-SDR

Bob Stewart (MathWorks), Dale Atkinson, Kenneth Barlee, Louise Crockett

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Cognitive Radio-Based LEO Satellite Solutions for Rain Fading in Ka-Band

Paulo Ferreira (WPI), Alexander M. Wyglinski

Abstract – Low orbit satellite (LEO) have been a good alternative for global coverage communications infrastructure. The increase of user number and applications that require high bandwidth demands usage at Ka-band, where the spectrum is more available. However, at this frequency band the signal attenuation due to rain fading is very high. Given the dynamic change in the fading level of the line of sight between a mobile ground station and the natural LEO orbit, a cognitive radio-based can be used improve the link performance in terms of bit error rate using prediction algorithms.

AD9361 Filter Design Wizard

Di Pu (Analog Devices), Tim Harder

Abstract – The AD9361 Filter Design Wizard is a small MATLAB App, which can be used to design transmitter and receiver FIR filters, which take into account the magnitude and phase response from other analog and digital stages in the filter chain. This tool provides not only a general purpose low pass filter designer, but also magnitude and phase equalization for other stages in the signal path. With this wizard, users can perform the following tasks:

1. Choose correct digital filters to use for receive and transmit.
2. Design the programmable FIR filters, get the filter coefficients and save them in a .ftr file, which can be directly loaded into the hardware.
3. Examine the independent response of each filter, and the composite response of all the filters, including both digital and analog filters.

Along with the AD9361 Filter Design Wizard, we will conduct an LTE demo on a latest SDR platform - PicoZed, and see how AD9361 Filter Design Wizard improves the RF performance of this platform.

NMR and MR Imaging Experiments using Software Defined Radio

Chris Hasselwander (Vanderbilt University Institute of Imaging Sciences), Chris Hasselwander, Zhipeng Cao, William A Grissom

Abstract – Conventional commercial MR spectrometers are often limited in configurability, portability, scalability and cost. This has led several researchers to build lower-cost, smaller and more customizable architectures in-house. One such approach is a software-defined radio (SDR) architecture, comprising high-speed A/D and D/A converters, an FPGA to perform high-bandwidth digital mixing and filtering, and a USB or Ethernet link to a PC for real-time data transfer. SDR's have several strengths, including high-bandwidth direct RF signal synthesis and digitization with high bit depth, high configurability and low cost. In this work we describe NMR and MR imaging experiments using the commercially-available Ettus Research USRP1 SDR (Ettus Research, Santa Clara, CA, USA), which retails for around $700 USD. The work was motivated by the need for a low-cost spectrometer for teaching an MR engineering course, and for a transmitter that could generate adiabatic pulses with large frequency sweeps for Bloch-Siegert shift-based RF encoding experiments on a 0.5 Tesla Oxford Maran scanner (Resonance Instruments, Witney, UK).

Supporting Waveform and Terminal Development with an FPGA-Based Software Defined Radio

Matthew Zimmerman (MITRE Corporation)

Abstract – High-rate communication waveforms are getting increasingly complex leading to more complicated waveform specifications. Without a clear, unambiguous specification, terminal developers interpret the specification differently, increasing interoperability risk and cost. Furthermore, a complex specification will reduce overall competition, as many vendors may not be willing to compete without a full understanding of the specification. Because of this, MITRE has set up the Reference Implementation Lab (RIL) to develop a reference waveform implementation and deploy it on a Software Defined Radio (SDR). The SDR uses multiple FPGAs to achieve data rates up to 550 Mbps. This provides a Government-Owned Technical Baseline for developing and validating the waveform specification and provides test artifacts to support vendors

throughout the terminal acquisition process from early verification to final interoperability testing. These test artifacts increase vendor competition, as more vendors are able to develop terminals, and increase terminal interoperability by verifying the vendor's implementation against the RIL's golden reference. In 2014 & 2015, the RIL was used as part of a terminal acquisition program supporting multiple vendors' terminal development efforts. The testing methodologies performed by the RIL were able to support vendor development throughout the process and independently verify across all vendors on behalf of the government. Approved for Public Release; Distribution Unlimited. Case Number 15-1509. NOTICE: This technical data was produced for the U.S. Government under Contract No. FA8702-15-C-0001, and is subject to the Rights in Technical Data-Noncommercial Items Clause (DFARS) 252.227-7013 (NOV 1995).

Channel Modeling of Decode-and-Forward Relaying Vehicular Networks

Bengi Aygun (WPI), Alexander M. Wyglinski

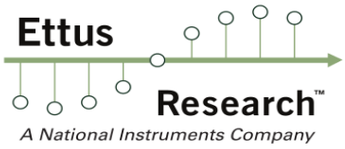
We propose a statistical channel model for decode-and-forward relaying vehicular ad hoc networks (VANETs) with single-input-single-output (SISO) antennas. The proposed model uses a sum-of-sinusoids (SoS) Rician model, which is derived for highway scenarios with line-of-sight (LOS) components, time varying conditions and multipath excess delay. Since the time delay differences between multipath components are considered in this work as opposed to previous studies, the power of channel impulse response is conserved. One of the advantages of the proposed channel model is that it does not depend on parameters such as distance and angle between vehicles, which changes continuously in a highway transmission environment. Using the proposed channel model, we analyze the relay network capacity of a VANET operating in highway traffic conditions. The results show that, the proposed channel model has higher performance relative to previous studies since the model contains the effect of time delay between multipath components.

Notes

NEWSDR 2015 was made possible by generous contributions from our sponsors.

MathWorks is the leading developer of mathematical computing software. Engineers and scientists worldwide rely on its products to accelerate the pace of discovery, innovation, and development.

Since 1976, National Instruments has equipped engineers and scientists with tools that accelerate productivity, innovation, and discovery. NI's graphical system design approach provides an integrated software and hardware platform that simplifies development of any system that needs measurement and control. Engineers and scientists use this platform from design to production in multiple industries, advanced research, and academia. The company's long-term vision and focus on improving society through its technology has led to strong, consistent company growth and success of its customers, employees, suppliers, and shareholders.



Ettus Research™, a National Instruments (NI) company since 2010, is the world's leading supplier of software defined radio platforms, including the Universal Software Radio Peripheral (USRP™) family of products. With a low overall system price, expansive capabilities, and software availability, USRP products are used by thousands of engineers worldwide and remain the top choice in software defined radio hardware for algorithm development, exploration, and prototyping.

MediaTek is a pioneering fabless semiconductor company, and a market leader in cutting-edge systems on a chip for wireless communications, HDTV, DVD and Blu-ray. MediaTek created the world's first octa-core smartphone platform with LTE and our CorePilot technology released the full power of multi-core mobile processors. MediaTek [TSE:2454] is headquartered in Taiwan and has offices worldwide.

The Wireless Innovation Laboratory (WI Lab) is an internationally renowned research facility founded in July 2007 by Professor Alexander M. Wyglinski at Worcester Polytechnic Institute that conducts both fundamental and applied research in order to solve technically challenging issues involving wireless spectrum, data transmission, communication systems and networking, and security. WI Lab has had extensive experience working with industry and government sponsors on both fundamental and applied research projects, yielding successful outcomes that often exceed the expected value-add these projects bring to the sponsors.

A community within the New England area that possesses members from academia, industry, and government who are involved in the design and implementation of software-defined radio (SDR) technology in order to advance the current state-of-the-art in wireless communication systems and networks.