SDR-Boston
Boston SDR User Group

New England Workshop on Software Defined Radio
Friday, 11 May 2012
Agenda

MathWorks
NATIONAL INSTRUMENTS

REGISTRATION

8:30 **Check-In and Continental Breakfast**

PROGRAM

9:00 **Mathworks Tutorial - Using MATLAB® and Simulink® with USRP® Hardware**

Mike McLernon, Ethem Sozer, Mukesh Chugh, Mathworks

The USRP® is a highly popular hardware platform for SDR teaching, research, and rapid prototyping. MATLAB® and Simulink® are popular software platforms for DSP and communications design, development, and rapid prototyping. Why not use the three together? In this tutorial, we will present three models to highlight the usage of these three products together to design communication systems. The first model highlights their usage to design a generic QPSK receiver that can perform soup-to-nuts demodulation and decoding on a stream of IQ samples. The second model will show how these tools can determine the SSID of a nearby WiFi access point. Finally, if your applications require more speed than a host computer can provide, the third model will show how you can generate HDL code for an algorithm and target it to the available FPGA area of your N-series USRP®.

10:00 Break (Posters, Demos and Coffee)

10:30 **Modular FPGA-Based Software Defined Radio for CubeSats**

Alexander M. Wyglinski, Associate Professor, Worcester Polytechnic Institute

In this presentation, we describe an adaptive digital communication system using field programmable gate array (FPGA) technology. This system adapts the Universal Software Radio Peripheral (USRP) to better suit the space and power limitations of the CubeSat satellite form factor and the Space Plug-and-Play Avionics (SPA) protocol. The result is a highly-adaptive, plug and play software-defined radio (SDR) that is easily incorporated into any CubeSat design.

11:00 **Reusable and Portable Waveform IP for FPGA-Based Hardware Platforms**

Erich Whitney, Lead Engineer, The MITRE Corporation

MITRE has developed a methodology for the design and deployment of reusable waveform IP. The methodology supports the piecewise reuse of components between waveforms and enables portability of waveform components between hardware platforms. It has been applied to the development several different waveforms spanning a variety of applications including communications, RADAR, and navigation. This presentation explains the key aspects of our methodology from component design through waveform deployment, illustrating the process through specific examples.

11:30 **Software Defined Wireless Communication – Beyond the RF Spectrum**

Michael Rahaim, PhD Candidate, Boston University

Visible Light Communication (VLC) uses the visible light spectrum as a medium for data transfer. This topic has gained recent interest due to increasing congestion in the RF spectrum, improvements in emerging solid state lighting, and ubiquity of lighting systems in indoor environments. We have demonstrated a Software Defined VLC solution implementing an illumination quality optical front end to adapt an SDR platform to the VLC channel. Using signal processing blocks from the GNU Radio toolset, we have implemented a VLC system in which our optical front end converts low frequency (5-10MHz) USRP output signals to optical intensity modulated signals on the visible light medium. This method provides an opportunity for the wide range of open source RF signal processing blocks to be utilized in testing and analysis of low data rate VLC channels.

12:00 Lunch, Posters and Demos

1:30 **Keynote - Software Radio -- Past, Present, and the [Near] Future**

Matt Ettus is a core contributor to the GNU Radio project, a free framework for Software Radio, and is the creator of the Universal Software Radio Peripheral (USRP). In 2004, Matt founded Ettus Research to develop, support and commercialize the USRP family of products. Ettus Research was acquired by National Instruments in 2010, and Matt continues as its president.

In the past he has designed Bluetooth chips, GPS systems, and high performance microprocessors. Before that, Matt received BSEE and BSCS degrees from Washington University and an MSECE degree from Carnegie-Mellon University. He is based in Mountain View, CA.

Software Radio has come a long way in the last 15 years. This talk will cover where we've come from, where we are, and where we're going, from the personal perspective of the speaker. We'll discuss what has and has not worked, what challenges remain ahead. Specific topics will include:

- Challenges in hardware for Software Radio, and a discussion of the state of the art in RF frontends and data converters
- The evolution of the various processing paradigms used in software radio (GPP, GPU, DSP, and FPGA)
- What problems we thought would be solved by now
- The basic economics of software radios in volume production

2:30 Break – Posters, Demos and Coffee

3:00 **Graphical System Design with Software Defined Radio (SDR) Platforms**

Amee Christian, National Instruments

Software Defined Radio (SDR) provides an affordable and flexible way to prototype new algorithms faster, thereby shortening time to results. A graphical system design approach for RF and communications unifies intuitive graphical software and SDR hardware for designing, prototyping and deploying systems that extend from low-cost to high performance. This session discusses a broad set of LabVIEW-based SDR applications spanning from cognitive radio research to GPS simulation and MIMO communication. This presentation will highlight the platforms, approaches and best practices used to rapidly develop real-world wireless prototypes. We also discuss how low-cost SDR hardware, such as the USRP transceiver, and graphical system design software can serve as a learning tool to get engineers and students up and running on basic RF fundamentals and complex topics such as a RF system design.

3:30 **Cognitive Radio in Medical and Vehicular Wireless Network Applications**

Rahman Doost, PhD Candidate, Northeastern University

Cognitive radio technology is envisaged to solve the spectrum scarcity problem through enabling dynamic spectrum access on the underutilized statically allocated spectrum, hence increasing the capacity of wireless networks. As the concept is maturing, new areas for utilization of such technology are emerging. Wireless Medical Telemetry and Vehicular Wireless Networks are two application area examples for the adoption of cognitive radios.Wireless Medical Telemetry Systems (WMTS) currently operate on the FCC designated bands for transmitting critical patient health information to distant receivers within hospitals. Deploying cognitive radio in these systems will overcome the intermittent interference that these devices currently experience from digital TV transmission in neighboring channels. Also Cognitive Radio enabled vehicles will be able to use additional spectrum outside of the IEEE 802.11p standard specified 5.9 GHz to enable new classes of user-end applications, e.g. in-car entertainment systems or enhanced emergency responder abilities. In this talk, we highlight some key research problems related to these areas and provide solutions to those problems based on some real-world measurements performed on the target frequency ranges for these applications.

POSTERS

iSCISM: Interference Sensing and Coexistence in the ISM Band (Joseph Baylon)
Non-WiFi interference signals in the 2.4 GHz Industrial, Scientific, and Medical (ISM) band cause performance degradation in WiFi systems by increasing the bit error rate and decreasing throughput. iSCISM seeks to alleviate the effects of interferers by first identifying interferers in a WiFi system and then applying interferer-specific mitigation schemes. Bluetooth and microwave oven signals are two of the most prominent sources of interference in the ISM band, and thus iSCISM has focused on identifying the presence of these interferers and mitigating them accordingly. A test platform was created in MATLAB to simulate 802.11g WiFi transmissions and the effects of interferers on throughput. An algorithm for locating transmission peaks was developed for extracting information from interference signals. Several machine learning classification algorithms were tested for identification accuracy and computational cost based on the data extracted. It was found that naive-Bayes produces accurate identification results with the least computational cost and thus serves as iSCISM's method for classifying interferers. Interference mitigation techniques were also simulated. Rate adaptation was chosen as the mitigation scheme for Bluetooth interferers, and timed-transmission was chosen to mitigate the effects of microwave emissions. Throughput improvements have been demonstrated for both Bluetooth and Microwave oven interferers. The WiFi testbench and iSCISM system will be implemented on a software-defined radio platform for further testing.

Development of Hardware for SDVLC Links (Kevin Tien)
This project entails the development of hardware for a unidirectional end-to-end visible light communications link designed to interface with a software-defined radio framework enabled by the USRP2 radio module and the GNURadio software toolkit. The primary aim is to outline the creation of proof-of-concept circuit topologies that will allow further research into complex modulation schemes, linear power efficient LED drivers, and multiple output diversity receivers. The use case for such devices will be as dual purpose lighting elements and communications elements. Thus, the circuit performance will be at a scale appropriate for practical use with respect to lighting output and power consumption. The use of a software-defined paradigm allows for rapid reconfigurability of modulation schemes for initial testing. In addition, offloading complex tasks such as modulation, coherent detection, and error-correction to software allows for more focus on hardware robustness. Currently, a prototype 1 Mbps link at a scale appropriate for localized home lighting has been achieved.

Practical Considerations for Spectrally Agile Multicarrier Waveforms employing Modulated Filterbanks (Amit Sail)
In this research project, we present the design of non-contiguous orthogonal frequency division multiplexing (NC-OFDM) employing modulated filter banks (MFBs) and predictive algorithm. Multicarrier modulation (MCM) techniques, such as NC-OFDM, often overcomes inter-symbol interference (ISI) by attaching a cyclic prefix (CP) at the start of each symbol, which is designed to capture the dispersive effects of the channel. The length of the CP must be greater than or equal to the channel impulse response in order for this mechanism to function properly. Consequently, ISI is reduced within an MCM-based system at an expense of symbol expansion and additional transmission overhead. To combat the effects of out-of-band (OOB) interference generated by NC-OFDM, MFBs are used to suppress the OOB emissions. However, most MFBs are constructed using finite impulse response (FIR) filters, which negatively impact the performance of the CP with respect to OOB interference reduction. Thus, we proposed an approach employing infinite impulse response (IIR) prototype filters for the MFB implementation to counteract the channel lengthening effects within the NC-OFDM transmission. We also, propose an algorithm which will predict the usage of any particular band of frequency at some particular time so that the transmitter can use that band of frequency at that particular time without sensing the channel.

Cosine Modulated Filter bank Multicarrier Modulation for Spectrally Agile Waveform Design (Harika Velamala)
In this research project, we implement a novel filter bank multicarrier modulation (FBMC) transceiver using software defined radio (SDR), using cosine modulated filter banks based on a lowpass prototype. FBMCs employ a series of bandpass filters called analysis and synthesis filters - at the transmitter and receiver in order to filter the collection of subcarriers being transmitted simultaneously in parallel frequencies. The novel aspect of this research is that a wireless transceiver based on non-contiguous FBMC is being used to design spectrally agile waveforms for dynamic spectrum access as opposed to the more popular NC-OFDM. Better spectral containment and bandwidth efficiency, combined with lack of cyclic prefix processing make it a viable alternative for NC-OFDM. To enable the efficient creation of filter banks, cosine modulated filter banks are used, where all the filters are frequency shifted versions of a lowpass prototype. Consequently, a lowpass prototype was designed for the proposed multicarrier implementation. Obtaining the required attenuation for the lowpass prototype filter in an actual hardware implementation was a challenge due to various reasons such as dropped packets occurring within the SDR hardware and the channel interference occurring nearby. A linear phase FIR filter was found to give the best results after several experimental trials were conducted. A working model of the FBMC transmitter with four

distinct center frequencies has been developed in the Simulink for use with the SDR hardware. The principles of polyphase representation and paraunitary perfect reconstruction filter banks are being considered to improve upon the filter design.

Software and Mechanical Beam-Forming for Jamming-Resilient Communications (Triet Vo-Huu)
Wireless networks have an increasing impact on the today's cyberphysical infrastructure with applications in various areas such as smart-grids, transportation networks, navigation, structural health monitoring, and implantable devices. Their resiliency to malicious behavior becomes an important requirement not only for military services, but also for civilian and commercial applications. In this work, we build a prototype that combines mechanical beam-forming and software radio signal processing techniques to achieve mitigation of jammers at unprecedented levels of robustness. Our mechanical beam-forming uses a custom-designed two-elements antenna capable of rotation and element-separation adjustment that can create flexible and dynamic radiation patterns. We use an iterative antenna-autoconfiguration algorithm for signal identification, which can bring the jammer to the nulls of the pattern to weaken the jammer signal's strength while putting the user node to the lobes to gain the user's signal power. The custom-designed antenna is built using analog-controlled servos which provide fine-grain mechanical control and overcome the typical saturation and limited dynamic range problems that make digital anti-jamming impractical against strong jammers. Our mechanical beam-forming approach is able to reduce the jammer power up to 28dB. To go beyond this limit, the second stage of our prototype uses the digital cancellation technique to improve the efficiency of the system. By employing several techniques of frequency offset estimation, phase estimation and channel gain estimation, our prototype can sustain the communication in the presence of a strong variable-power jammer up to 48dB without requirement of training signals and preknown location of nodes. Our adaptive algorithm for cancellation is able to deal with the multipath problem in a slow-fading channel, which enables our prototype to work efficiently in both outdoor and indoor narrow-band communications.

Heterogeneous Reconfigurable Architecture for SDR (Leandro Becker)
The growing complexity of new communication protocols together with the need to reduce the energy consumption of the communication devices are current challenges for SDR architectures. Reconfigurable computing using coarse-grained approaches is a good candidate for solving such issues, as it provides high performance and low power consumption. The present work proposes a heterogeneous reconfigurable architecture for SDR that uses a Network-on-Chip (NoC) to enhance the internal communication infrastructure and hardware accelerators to speed DSP-related algorithms. The proposed architecture is basically composed of a RF interface, hardware accelerators, a control block, and a high speed communication interface with the host. To validate the proposed architecture we developed an FPGA prototype using the GNU Radio as host. Our preliminary results show that the proposed solution presents a significant improvement in the total performance of the system in terms of CPU usage and latency when comparing with the off-the-shelf USRP2.

CRUSH: Cognitive Radio Universal Software Hardware (George Eichinger)
The FPGA is an integral component of a software defined radio (SDR), which provides the needed reconfigurability for dynamically adapting its transceiver and data processing functions. The current state of the art in SDR design relies on complete processing of the raw samples at the host computer, thereby impacting time critical tasks. Instead, we propose to move the processing closer to the front-end by interfacing an external FPGA board with the SDR. Our architecture, called CRUSH, is composed of a Xilinx ML605 FPGA Development Board connected to an Ettus Research USRP N210 through an HDL framework, with a custom interface to allow flexible transfer data between them and independent programming capability on the two devices. Our test scenario for spectrum sensing, a key step in determining channel availability before transmission in dynamic spectrum access networks, indicates significant benefits: CRUSH can implement FFTs at 100x improvement, and can perform a complete sensing cycle 10x faster than legacy SDRs for large FFT sizes that enable wideband sensing. By potentially reducing the load on the host, and allowing a powerful FPGA extension for off the shelf devices, CRUSH will enable advances in both protocol design and radio hardware.

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