# Remote laboratory exercises and tutorials for spectrum-agile radio frequency systems


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***Abstract*— In this workshop, communications systems and wireless communications educators will experience and provide feedback on remote laboratory exercises and tutorials that employ an Internet-accessible, software-defined radio (SDR)-based testbed. The tutorials introduce and demonstrate concepts relevant to spectrum sharing, cognitive radio, and other radio / wireless communications applications that involve spectrum agility. Students run, modify, and / or configure code for cognitive engines or adaptive controllers that make real-time modifications to radio waveform parameters such as operating frequency, transmitting power, signal bandwidth, modulation, and error correction. The controllers make adaptations to optimize over-the-air operation in challenging signal environments. The resulting radio link performance is measured using an experiment management framework and can be visualized using a web interface that displays performance metrics as well as three-dimensional and two-dimensional waterfall plots. In the process of working through the exercises, students learn to use the above tools, which also enable them to design and perform original experiments. This workshop will be valuable for anyone teaching or studying wireless communications or using interactive remote laboratories and tutorials to teach technical concepts.**



***Keywords—remote laboratory, wireless communications, software-defined radio, cognitive radio, spectrum sharing***


## I. Goals of the Pre-Conference Workshop and how these goals align with the goals of FIE

This workshop will be valuable for anyone teaching or studying wireless communications or using interactive remote laboratories. The workshop aligns with the Innovative Practice and Research-to-Practice tracks of FIE. Specific goals include:

- Introduce educators to engaging remote laboratory exercises and instructional modules that employ an Internet-accessible, software-defined radio-based testbed to demonstrate introductory and advanced wireless communications concepts. In the exercises, students manually operate or program controllers to operate radio links in challenging signal environments, and monitor the performance of these links as transmission parameters are adapted.
- Demonstrate use of the tutorials to present advanced applications such as spectrum sharing and cognitive radio, which can be demonstrated to novice students and addressed through problem-solving remote laboratory exercises that include code development for advanced students and engineers in the workforce.
- Solicit feedback from workshop participants to improve the tutorials and underlying hardware and software infrastructure, and to ensure relevance and applicability of the tutorials across a wide range of institutions and curricula.

## *II.* Description of topics/subjects/content of the workshop

Participants will view and / or work through tutorials and exercises that include operation of radios using a web-based


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control interface and optionally work through additional tutorials that involve configuration and / or programming of autonomous radio controllers.

The student radio operators and / or autonomous controllers make adaptations to optimize over-the-air operation in challenging signal environments. Radio link performance is measured using an experiment management framework and visualized using a web interface that also displays radio spectrum plots. While working through the advanced exercises, students learn to use the tools to design and perform original experiments.

## III. References or explanations of the qualifications of presenters to lead this workshop.

The presenters have relevant technical and educational expertise. Students who developed the tutorial modules and exercises will also facilitate the workshop.

Carl Dietrich is a Research Associate Professor. From 2013-15, he was PI of an NSF REU site. He earned Ph.D., M.S., and B.S. degrees in Electrical Engineering. His interests include testing and evaluation of spectrum sharing radios and networks. He is a Sr. Member of IEEE, a member of ACM, ASEE, and IEEE HKN, and a professional engineer.

Richard Goff is an Associate Professor in Engineering Education. Prior to that, he was a Civil Service aircraft structural engineer for the Navy and a computer systems entrepreneur. He earned his B.S., M.S., and Ph.D. degrees in Aerospace Engineering. He was founding director of a Freshman Engineering Design Laboratory and former Director of an NSF I/UCRC. He has co-authored over 100 peer reviewed scholarly works. He is a member of the Academy of Teaching Excellence, ASME, and ASEE. His passion is creating engaging learning environments by bringing useful research results and industry practices into the classroom as well as using design research results to inform engineering practice.

## IV. Workshop Agenda

The agenda for the three-hour workshop is as follows:

*0:00-0:20* Introduction: motivation, goals, infrastructure, and overview of tutorials
*0:20-1:10* Hands-on time with interactive tutorial modules and exercises in which participants remotely control an over-the-air radio link and monitor its performance using a web application and standard web browser
*1:10-1:20* Break
*1:20-2:10* Demonstration of / participation in tutorial modules and exercises in which participants program or configure autonomous controllers for radios and monitor their performance (requires optional free software download and radio testbed account; access will be provided.)
*2:10-3:00* Discussion / feedback to improve tutorials

## V. Description of the anticipated audience and the maximum Preferred Number of People

The anticipated audience is faculty and graduate students who teach communications systems courses and / or have interest in remote laboratory experiences. To enable all participants to try some of the exercises, we request that attendance be limited to 20 participants.

## VI. Description of the take-away skill, knowledge or material that attendees will acquire

In this workshop, communications systems and wireless communications educators will:

- Experience and provide feedback on remote laboratory exercises and tutorials that employ an Internet-accessible, software-defined radio (SDR)-based testbed.
- Gain familiarity with software-defined radio, spectrum sharing, cognitive radio, and related concepts.
- Learn to use an experiment management framework to define and run experiments on the radio testbed.
- Learn to use a web interface to operate radios remotely and to display their performance metrics as well as three-dimensional and two-dimensional waterfall plots.
- Be given paper and / or soft copies of three or more tutorials, including hands-on exercises that they can use with their students in coordination with the testbed administrators.

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