UNC CHARLOTTE

Electrical and Computer Engineering

The William States Lee College of Engineering

Newsletter 2014-2015

Professor and Chair

Dear Colleagues:

Greetings from UNC Charlotte! It is my pleasure to share with you some of the exciting news and accomplishments of faculty and students of the Department of Electrical and Computer Engineering (ECE) of The William States Lee College of Engineering from 2014-15. This year, ECE continued its enrollment growth with an over 10% increase in undergraduate enrollment and a 7.5% increase in graduate enrollment. In fall 2015, total student enrollment in ECE exceeded 800 for the first time, with 520 undergraduates and 285 graduate students, approximately.

ECE faculty, which is currently comprised of 30 tenured and tenure-track faculty and 4 non-tenure track faculty, made many notable accomplishments in 2014-15. A total of 84 journal and 157 conference papers were published by ECE faculty this year. ECE faculty were awarded approximately $3.67 million of external research funds in 2014-15. These include a Phase-II award from DoE's Sunshot initiative, funds from the NSF, DoE, DoD, the NC Coastal Studies Institute, as well as from private funding agencies. Some of these funds were instrumental in boosting new research in the areas of power electronics, renewable energy systems, and the Smart Grid. The NSF I/UCRC on Metamaterials and the I/UCRC on Sustainably Integrated Buildings and Sites were also very successful this year. In addition, new activities were spawned in the areas of brain-implantable cyber-physical systems, power line modeling, wireless sensor systems, power systems resiliency, and others.

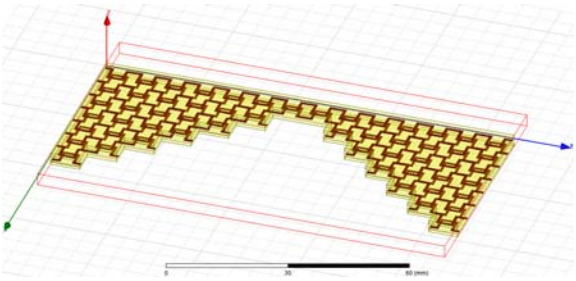
ECE faculty continued the development of new state of the art research facilities. Notable additions this year include the new Photovoltaic Research Laboratory and the Flexible Energy Systems Laboratory. In addition, ECE initiated the development of a new Audio-Video Media Laboratory and we are in the final stages of completing a neutron irradiation and probe system for in-situ monitoring and the study of neutron-irradiated materials and devices using Raman spectroscopy.

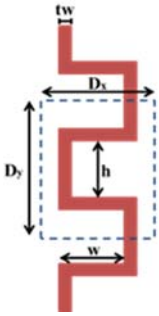
Some of the exciting accomplishments of ECE faculty are included below. I hope you enjoy reading about them.

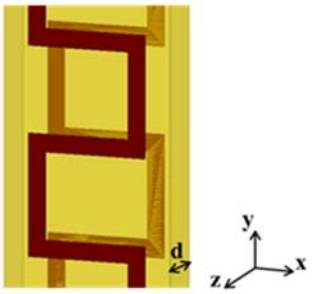
Top Stories

Metamaterials Research

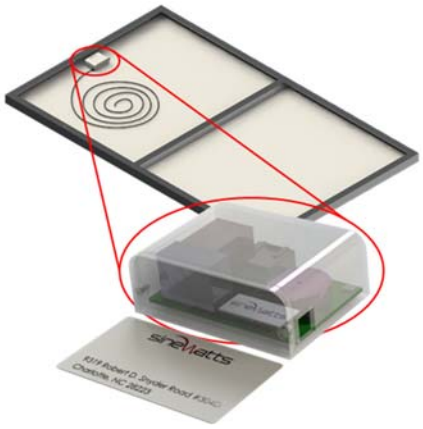
Metamaterials have properties that go beyond those of naturally occurring materials. They are typically composed of periodic arrays of conducting structures or meta-atoms as shown below. The geometry of these shapes behave like a resonant electrical circuit at certain frequencies and unusual permittivity and permeability values can be realized at resonance. Many applications arise from this, including improved antenna design and improved imaging systems. Through the NSF Center for Metamaterial, ECE researchers Drs. Michael Fiddy, Ryan Adams, and Tom Weldon and their students are studying novel patterns of meta-atoms to develop components and devices useful for manipulating microwaves. Dr. Adams has received funding from Raytheon to use metamaterials to make tunable and conformal antennas. He has created a phased array antenna that is electrically small overall, and that is capable of realizing near horizon or endfire radiation patterns from a planar 64 element array. He has used so-called non-Foster circuits associated with each meta-atom of the metamaterial array to compensate for the large imaginary part of the input impedance. To do this he uses phase shifters that incorporate couplers and varactor diodes in conjunction with a three stage amplifier. The integration and test of this unique antenna will be done in-house at UNC Charlotte.







Single Silicon Integrated Circuit Photovoltaic (PV) Inverter



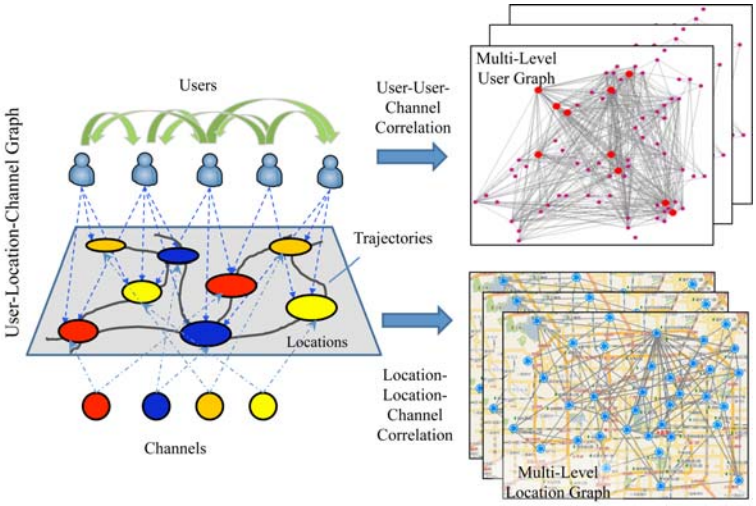
ECE faculty Drs. Babak Parkhideh, Rob Cox and Johan Enslin, together with a UNC Charlotte-EPIC incubated startup, SineWatts Inc., have started work on DOE's Phase-II Sunshot Incubator project. The team is developing a demonstrable prototype in real-life operating conditions. The SineWatts Inverter Molecule™ product is transforming the PV power plant on multiple dimensions: (1) dramatic miniaturization –5x to 10x – of the PV inverter to allow panel-mounted inverter hardware; (2) drastic component count reduction – 20x to 50x – by complete silicon integration and (3) guaranteed short-term capacity availability of the PV plant utilizing detailed panel level diagnostics and prognostics. As part of a SunShot Phase I awarded project, the SineWatts/UNC Charlotte team demonstrated that state-of-the art silicon switches allow the SineWatts Inverter Molecule™ architecture to achieve 5x miniaturization and 100% siliconization. The resulting distributed inverter system provides unprecedented total volume and component count reduction, while achieving a 70% reduction in installed cost.

So far, more than 16 research assistants including two post-doctoral fellows, 10 graduate students and four undergraduate students have contributed to the development of the technology as part of their

research, thesis or dissertation work. Through this collaboration, UNC Charlotte students have received several awards including a Best Paper Award at IEEE ECCE Conference, ARPA-E Summit Student Travel Award, ECE Outstanding Graduate Research Award, and UNC Charlotte Best Master's Thesis Award. Currently, SineWatts is preparing its first off-site demonstration of the technology and the prototypes are being tested at UNC Charlotte PV Integration Laboratory (PiL). This state-of-the-art testing facility is equipped with a canopy mounted 21kW reconfigurable solar PV system and advanced equipment for power electronics hardware development.

Accelerating Spectrum Access in Cognitive Radio Networks via Social Analysis of Secondary Users

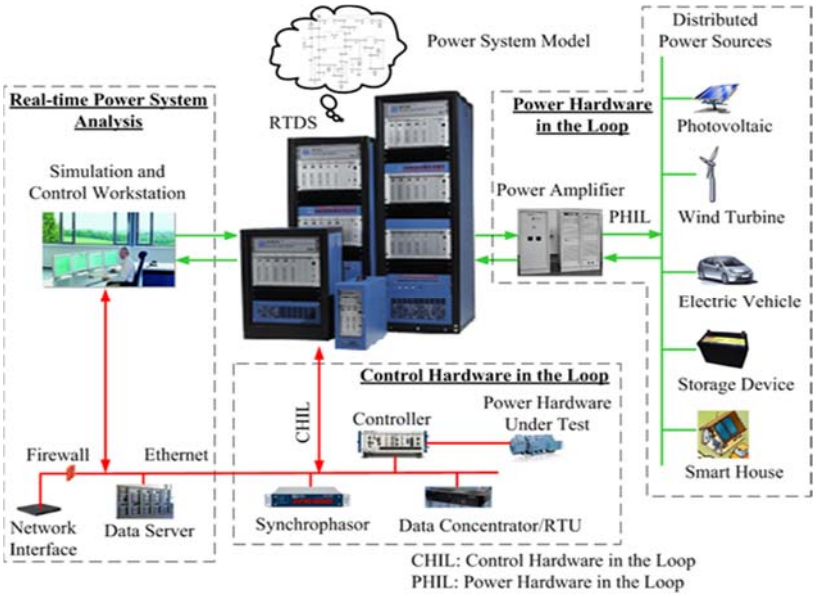
Dr. Jiang Xie of ECE and a team of experts from ECE, Computer Science and Sociology are looking to design, analyze, and evaluate fast and efficient spectrum access schemes for cognitive radio networks without a common control channel. Cognitive radio technology is a promising technology to overcome the imbalance between the increase in the spectrum access demand and the inefficiency in the spectrum usage by allowing dynamic spectrum access. Additional information about cognitive radio users (or secondary users) can help accelerate spectrum access, but due to practical constraints, such information is extremely difficult to obtain. The investigators analyze the time, location, and spectrum-dependent social patterns of secondary users and incorporate social analysis to enhance spectrum access efficiency.



This interdisciplinary research is potentially transformative as it will help generate innovative techniques to numerous applications of the cognitive radio technology, e.g., public safety networks, cognitive mesh networks, and emerging technologies with dynamic spectrum access, e.g., vehicular networks and mobile health. This research promises to enhance the understanding of social interactions of mobile users in wireless networks.

Real-Time Studies in Next-Generation Power Grid Infrastructure

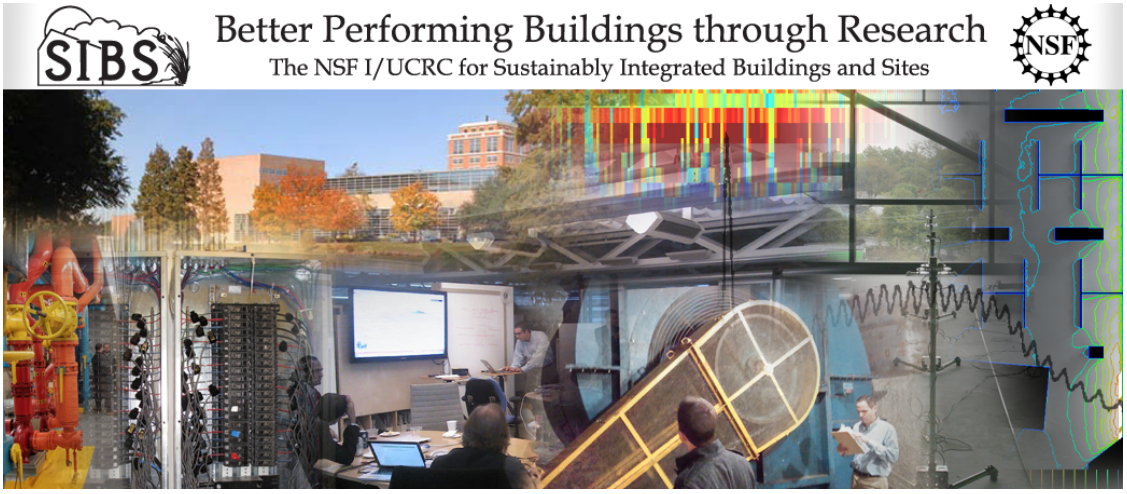
The Duke Energy Smart Grid Laboratory, funded by the Duke Foundation and UNC Charlotte, supports real-time simulation, modeling and analysis of the power grid. Several research projects have been conducted in the lab in the last 3 years. Drs. Johan Enslin, Sukumar Kamalasadan, and Valentina Cecchi are leading several research efforts in the Duke Energy Smart Grid Lab that include: (1) device functionality testing, (2) system integration and testing, (3) real-time power system studies, and (4) education and training.



The real-time simulation platform assists faculty and students in modeling the power grid as an integrated system of systems and analyzing the capability of the grid of transforming into next-generation sustainable power and energy infrastructure. Three Real Time Digital Simulator (RTDS) that were purchased with funds received from the NSF are used as the backbone for real-time analysis of smart grid functions such as renewable energy and grid interface, advanced sensing and measurements, control and communication technologies and advanced infrastructure development.

Drs. Kamalasadan and Enslin have also received funding from Duke Energy to work on an Energy Storage control project. In this project, multiple energy storage control functions that make the grid more stable with the interconnection of renewable energy systems such as PV farms are designed. A typical power distribution feeder is utilized for evaluation and analysis. Dr. Kamalasadan has also received funding from National Science Foundation for three years to study optimization and control of power grids in the presence of renewable energy integration. The study is expected to pave new ways to control and optimize grid integrated renewable energy resources to improve system stability, reliability and efficiency. Recently the group won the best paper award from IEEE Industry Application Society on this effort. Research based on this work has been published at IEEE flagship conferences and transactions. Drs. Kamalasadan, Chowdhury, Manjrekar, Cecchi and Enslin also won an industry sponsored project from Southern California Edison (SCE) to evaluate and model the power grid with real-time simulators. The goal of the project is to develop models of the power grid that can be interconnected for hardware-in-the-loop simulations.

The Center for Sustainably Integrated Buildings and Sites



Buildings have a major impact on the natural environment. They consume nearly half of the energy produced in the United States and are correspondingly responsible for nearly half of carbon emissions. Buildings also account for roughly 10% of US water consumption, and produce significant waste during

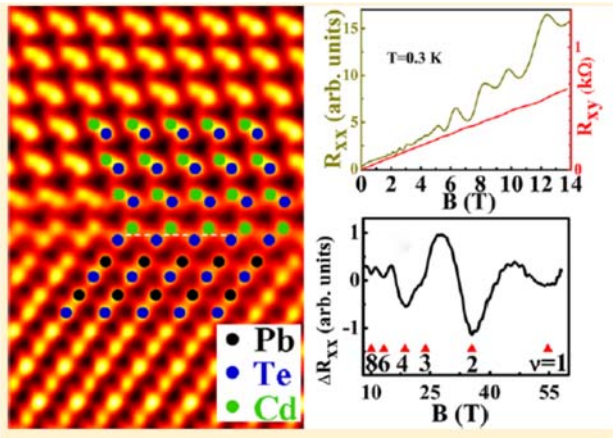
both construction and operation. The Industry / University Cooperative Research Center for Sustainably Integrated Buildings and Sites (SIBS) was conceived to help address these issues.

As a part of the NSF's network of Industry/University Cooperative Research Centers (I/UCRCs), SIBS brings together university researchers and interested industry supporters. The center's advisory board has determined that projects should focus on activities in the following four primary areas: (a) Analytics for improved energy, water, and waste performance, (b) Rapid improvements in building automation system utilization for improved energy performance and indoor environmental quality, (c) Systems integration for improved energy and water performance, and (d) Case study analysis of existing buildings.

Much of the work performed by the center and its researchers focuses on case studies in existing buildings and how these case studies can ultimately improve design and operations. In one recent project, the team studied a zero-net energy (ZNE) retail bank in south Florida. During design, engineers had determined that the facility's photovoltaic (PV) panels would provide more energy annually than would be consumed. Despite significant technology investments for both improved generation and efficiency, the building still consumed far more than it produced. The SIBS research team ultimately determined the root causes of these issues, and created a technology decision tree that would help owners and engineers to make more informed technology decisions. Other example projects focus on determining appropriate value schemes for analytics and developing models for human comfort in the indoor environment.

In addition to its activities with its participating member companies, SIBS also focuses on other activities. Recently, UNCC SIBS researchers have been participating with Envision Charlotte, a non-profit organization focused on making Charlotte a more sustainable city. SIBS researchers have been working closely with Envision on a number of activities, several of which have received attention from major national news outlets. A recent article by Politico Magazine highlights some of this activity.

Quantum Oscillations Observed in a Novel Semiconductor Heterostructure PbTe/CdTe

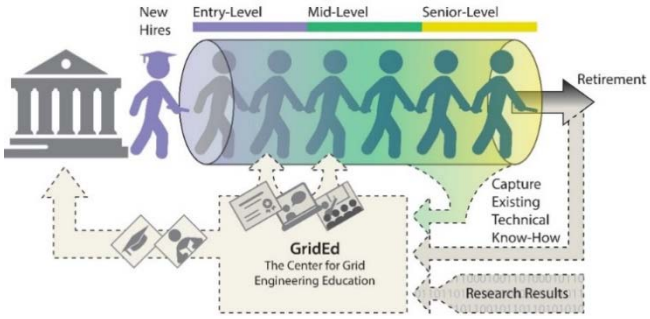


Dr. Yong Zhang, Bissell Distinguished Professor of ECE, in collaboration with scientist at Sandia Labs and Zhejiang University, reported (in Nano Lett) quantum oscillations of a high mobility 2DEG at the interface of a unusual semiconductor heterostructure (RS)PbTe-(ZB)CdTe that relies on a new mechanism - a mismatch in the bonding configurations of the valence electrons at the interface. This 2DEG system is a new candidate of topologic insulators. Other research activities of his group include 2D materials, IR detection, nanostructures, and fundamental semiconductor physics. Recently, he proposed a new model (in PRB) that unifies the concepts of "shallow" and "deep" impurities in semiconductors

The Center for Advanced Power Engineering Research (CAPER)

Power Engineering at UNC Charlotte has a brand new **research mechanism. UNC** Charlotte is one of three founding universities of a new industry-university collaborative called the Center for Advanced Power Engineering Research (CAPER). This center was established in 2014 as a membership driven consortium among three regional universities, namely UNC Charlotte, Clemson, and NC State, and several industry partners to spur the development of a comprehensive and integrated methodology for grid modernization. The main mission of the center, directed by Dr. Johan Enslin of ECE, is to develop and demonstrate grid modernization technologies and enhance the educational experience for students in electric power engineering. With an aging infrastructure, rising demands for cleaner electricity and extreme weather conditions, the nation's utilities are working to meet these operational and planning challenges while maintaining a resilient and reliable grid. As a collaborative effort, CAPER will develop research and demonstrate advanced technologies to meet the operational and expansion needs under uncertainties with an increased penetration of distributed renewable generation.

The Center for Grid Engineering Education (GridEd)

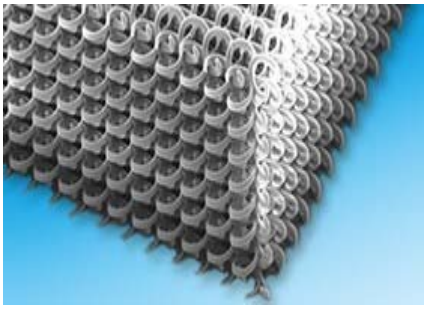


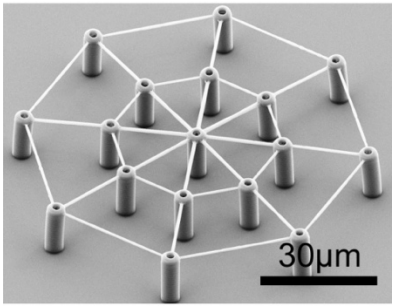
In 2013, the Department of Energy awarded a five-year, $6.4 million project to a university-industry consortium led by the Electric Power Research Institute (EPRI) under a new initiative known as Grid Engineering for Accelerated Renewable Energy Deployment (GEARED) within the SunShot program. UNC Charlotte was selected as one of four original partner universities in the collaborative project because of the presence of the Energy Production & Infrastructure Center (EPIC) on its campus as well as its growing reputation as having a strong power engineering program in the southeast. The consortium called the Center for Grid Engineering Education, or GridEd, also includes Georgia Tech, Clarkson University, University of Puerto Rico Mayaguez, EPRI, 14 electric utility partners, and one Independent System Operator covering 22 states. The objective of the initiative is to develop, train and empower new and continuing education students not only to become competent and well-informed engineers but also to participate and influence major technological, social, and policy decisions that address critical global challenges of the future electric grid. The UNC Charlotte team is led by ECE Professor Dr. Badrul Chowdhury.

Inverse Scattering

Dr. Mike Fiddy's group has partnered with the Army Research Office to explore how methods developed to image strongly scattering structures, such as buried or hidden objects, can also be applied to improve the design of materials with customize electromagnetic properties. The group is working on a project entitled "Development of Inverse Scattering – Structure Synthesis Methods: subwavelength scale imaging – metamaterial design ". ARO is funding the work both through the NSF Industry/University Collaborative Research Center for Metamaterials as well as through a Defense-University Research Instrumentation Program (DURIP) grant of $524k. The research is focused on the further development of nonlinear inverse scattering algorithms which can be used both for imaging, as well as the design of subwavelength-featured/structured materials, frequently referred to as metamaterials.

Inverse scattering methods have been developed for the recovery of high resolution and quantitative information about scattering targets. The group observed a significant dependence of the measured (or simulated) far field on subwavelength sized features within penetrable scattering targets that strongly scatter. The same algorithms can be used to calculate scattering structures that lead to desired scattering properties. This includes the possibility of designing a "complimentary" scattering metamaterial which can execute physically the inverse scattering process. The current project addresses the question of how to develop more accurate and efficient algorithms to image with higher resolution (sub-wavelength) and, correspondingly, model composite structures exhibiting low or negative refractive index for high resolution remote imaging. The Army Research Office hopes the work will lead to a new technology breakthrough. The DURIP grant is for the purchase of a Nanoscribe. This is a 3D printing system which can write features down to 100nm in size in various (doped) polymers or fabricate a nano-mold. This instrument is ideal for fashioning infrared metamaterials and metamaterial-based structures with unusual optical properties. Examples of such structures are shown below.





Other News

- **Dr. Cecchi receives new NSF award on *Adaptive Determination of Transmission Network Models for Optimized Use of Existing Transmission and Distribution Assets***
- **Drs. Joshi, Adams, and Fiddy receive new NSF award on *Fault-Tolerant Brain Implantable Cyber-Physical System***

- **Dr. J. Enslin received *2014 Charlotte Business Journal Energy Leadership Award***
- **Dr. Cox received the 2014 IEEE Region 3 *Joseph M. Biedenbach Outstanding Engineering Educator Award*, awarded at IEEE Southeastcon 2014.**
- **Dr. Conrad was elected to serve in the *IEEE Board of Directors,* 2016-2017.**
- **ECE Professor Dr. Aba Ebong developed a new *Photovoltaic Technology Research Laboratory* for teaching the science and engineering of solar energy.**
- **ECE doctoral student Kathryn Smith won the 2015 *NSF Graduate Research Fellowship*.**
- **ECE welcomes Dr. Tao Han, new faculty specializing in Internet of Things and Green Communications**
- **ECE welcomes Dr. Courtney Smith, new faculty specializing in diversity in engineering education.**