Research Experiences for Undergraduates (REU) Site:
Bringing Us Together, Improving Communications and Lives
Examples of possible research projects

Research Project: Basic Research on Phase-Change Autonomous and Reconfigurable Antennas
REU Faculty Research Mentor: Dr. Dimitris E. Anagnostou

Background

Novel materials play an important role in reconfigurable antennas and RF front ends. Lately, phase-change materials have attracted the interest of researchers. These materials can be resistive or conductive and can be actuated using non-contact methods such as heat or laser. The antennas will have sensors on their structure to provide indications whether the antenna is working as anticipated or not. When the sensor feedback exceeds specific limits (to be determined experimentally), the antenna shall make autonomous corrections for the particular mishap. As an example, an antenna array with excessive flexing may radiate a main beam that is tilted. A feedback system, consisting of strain gauge sensors and phase shifters, will be implemented to correct the beam steering of the antenna array. A similar example is the correction of a radiated antenna pattern due to a failed or damaged antenna element by implementing appropriate phase shifting on the remaining working elements.

In addition, reconfigurable antennas may be used to reduce the number of antennas necessary for a particular system function. Further, they can also be designed to serve more complex roles. Some examples include their use as programmable control elements with feedback to increase throughput, reductions in errors and noise, security improvements, and use as reconfigurable hardware to extend the lifetime of an entire system.

REU Student Research

In this project, REU student(s) will work to implement autonomous reconfigurable antennas. To do this research, students will first get familiar with CAD design tools for antennas and microwave filters (e.g., IE3D and ADS). Then, students will research which properties can be improved if phase-change materials are used in different parts of each design. For example, traditional microstrip antennas with ground planes as well as more novel coplanar folded slot dipoles and dipole arrays will be investigated. The reconfigurable antennas and filters that will be developed are expected to have improved capabilities (e.g., return loss, number of radiating frequencies, polarizations, etc). The faculty mentor will be involved with the development of new architectures for reconfigurable antennas and with the design, fabrication and measurement of such antennas and their expansion into larger array structures. The students will become familiar with and trained to use anechoic chambers, vector network analyzers, spectrum analyzers, and wideband oscilloscopes. The faculty mentor and graduate students will assist and guide the undergraduate students as needed. An emphasis will be given to translating measured results into meaningful concepts that facilitate a deeper comprehension by the students of more complicated electromagnetic topics as preparation for their futures. This work will then be combined and translated into autonomous reconfigurable antenna arrays that can alter their behavior to compensate for external changes and conditions (e.g., damage or flexing).

This work will provide students with the background needed to work on emerging applications such as software defined / cognitive radio, multiple-in multiple-out (MIMO) systems, multifunction consumer wireless devices, and high performance phased arrays and radars. All these emerging applications are of paramount importance for the US economy and security. Furthermore, this research will enhance the support of currently-funded research projects that are of interest to DARPA as well as NSF. The faculty research mentor has extensive experience with reconfigurable antenna design, fabrication, and measurements (has built a dedicated platform) as well as with their wireless control.

Research Project: Collaborative Unmanned Teams
REU Faculty Research Mentor: Dr. Randy C. Hoover

Background

The South Dakota School of Mines and Technology (SDSM&T) has a long history of unmanned systems development and deployment on our campus. Specific examples of such history include an unmanned aerial vehicle (UAV) team that has been extremely successful over the years competing in the International Aerial Robotics Competition (IARC), an unmanned ground vehicle (UGV) team that has been extremely successful over the years competing in the IEEE robotics competition and has recently increased their involvement in the Intelligent Ground Vehicle Competition (IGVC), and the newly developed (as of a year and a half) autonomous underwater vehicle (AUV) team that has been continuously making strides toward successful completion of a truly unique system design.

The tradition of unmanned systems at SDSM&T has been targeted towards highly individualized challenges that were resolved with individualized solutions. However, current research trends suggest that more of a cooperative collaboration between unmanned systems is a must for future deployment. Specific examples of such collaborative efforts are automated traffic monitoring and re-routing, accurate navigation and mapping of remote and/or isolated environments, and automated search and rescue operations. The application of collaborative unmanned systems is virtually endless for commercial entities, Homeland Security, Department of Defense, Department of Transportation as well as many planned NASA missions.

REU Student Research

A recently funded NASA proposal has developed the infrastructure necessary for collaboration between UAVs and UGVs in terms of communication protocol, user interface, and hardware architecture. The next stage of the project (and the focus for two REU students working with current graduate students) is to develop efficient localization strategies in global positioning system (GPS) denied environments for the UAV/UGV team. Two such environments include urban terrain post disaster and/or dense vegetation for search and rescue. Using multiple UAVs/UGVs, terrain traversal and localization of the team can be accomplished via visual feedback mechanisms amongst each individual vehicle.

Research Project: Printed Antennas with Resistive Loading
REU Faculty Research Mentor: Dr. Thomas P. Montoya

Background

In recent years, two areas of research that have sparked considerable interest are printed (direct-write) electronics and nanotechnology. The proposed research project falls at the interface of these areas. A longstanding research focus of the Faculty Research Mentor is on the design and development of resistively-loaded antennas on flexible and rigid substrates using printed electronics fabrication techniques using surface mount devices, resistive inks, and highly conductive nano-inks. In many conferences and journal papers, the Faculty Research Mentor has presented work on conductive, "Altshuler"-type, resistively-loaded, conductive Vee, and resistively-loaded Vee (see Figure 1) monopole antennas. Some were fabricated with highly-conductive nano-inks and discrete surface mount resistors on flexible substrates; others were fabricated using a combination of milled copper traces and traces formed with resistive inks on rigid microwave laminate substrates. The printed portions of the antennas were fabricated using an Optomec Maskless Mesoscale Material Deposition ($M^3D^®$) system and/or the nScrypt 600-3Dn-HP material deposition system. These systems are in the Direct Write Laboratory (DWL) in the Tech Development Laboratory (TDL) located at SDSM&T.

Printed (direct-write) electronics fabrication technologies have significant potential advantages over standard fabrication techniques. Many antennas with desirable characteristics have found limited applications, due to being excessively difficult, expensive, and/or time consuming to fabricate. Other antennas have found widespread application, but could be more economically produced and/or improved by the use of direct-write fabrication. Also, constructing arrays of antennas and/or their integration with other microwave circuits/components can be more feasible/economical using these fabrication techniques.

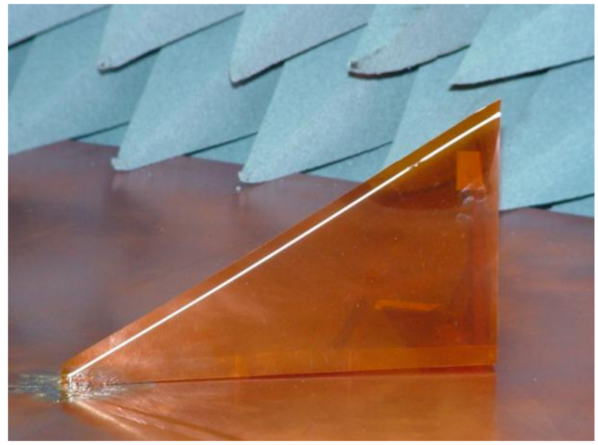

Figure 1 Vee monopole with discrete 249 Ω resistor.

REU Student Research

The student(s) will work under the direction of the Faculty Mentor on designing, fabricating, and testing resistively-loaded antennas, e.g., planar spirals. Students will be exposed to and trained in hands-on research that combines antenna design, construction (including using printed/direct-write fabrication systems), and measurements in the facilities of SDSM&T. As part of this work, the student(s) will also learn how to use a vector network analyzer to perform *S*-parameter, input impedance, radiation pattern, and gain measurements on the antennas.

Research Project: Staircased Thin Wire Antennas

REU Faculty Research Mentor: Dr. Thomas P. Montoya

Background

An ongoing research focus of the Faculty Research Mentor is on using the finite-difference time-domain (FDTD) method to accurately model staircases, i.e., repeated right angle bends, in thin ($a << \Delta s$) cylindrical wire antennas. Example structures are shown in Figure 2. The FDTD method provides time-stepping numerical solutions to electromagnetic problems using problem models based on discretizing Maxwell's equations in both time (time steps) and space (cells). To characterize of the effect of staircasing, the change produced in the apparent velocity of wave propagation for FDTD models of a staircased wire dipole antennas (Figure 2 right) is examined and compared to experimental results of staircased wire monopole antennas (Figure 2 left). As discovered in earlier work, an FDTD model which simply sets electric field components to zero within the wire does not yield accurate results, i.e., the apparent velocity of propagation was too slow. Moreover, results became progressively worse when multiple FDTD spatial cells were used per staircase (Δs). A key component in this research is to have accurate experimental results for a variety of staircased wire monopole antennas in order to assess the performance and accuracy of the FDTD models.

REU Student Research

The REU student(s) will work on designing, fabricating, and testing a variety (e.g., different wire diameters) of staircased wire monopole antennas. Students will be exposed to hands-on research that combines antenna design, construction, and test measurements at the facilities of SDSM&T. As part of this work, the student(s) will learn how to use a vector network analyzer to perform *S*-parameter and input impedance measurements on the antennas.

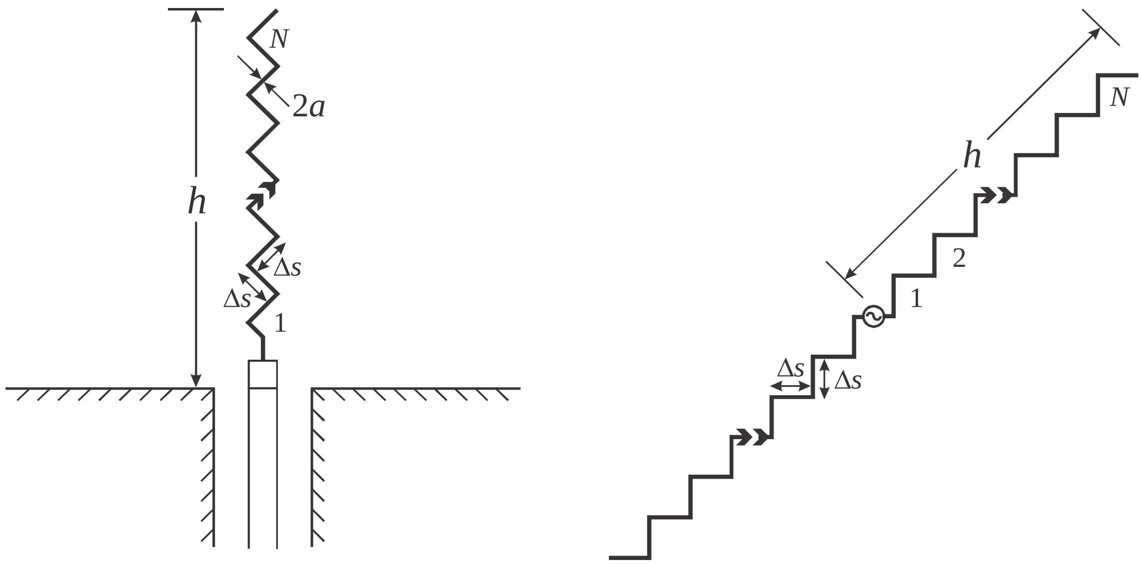

Figure 2 Staircased experimental monopole (left) and FDTD dipole (right) antennas.

Research Project: Fractal Analysis of Bio-Medical Imagery
REU Faculty Research Mentor: Dr. Charles R. Tolle

Background

Even though communication bandwidth continues to grow with time, it remains a large bottleneck for advancing imagery-based applications. One such application is biomedical imagery. Biomedical imagery is complex, structurally heterogeneous, and difficult to quantify. In addition, the resolution of these images grows faster than communication bandwidth. To date, these images rely on pixelized, verbal, or visual description methods, which limit the ability to predict and understand the mechanisms behind changes or growth formation. Increasingly, attention is being paid to quantify pixelized, verbal and visual descriptions into numerical values so that empirical models might be developed that track and predict tumor/tissue growth. Moreover, by reducing imagery down to a model – significant transmission bandwidth can be saved when storing and transmitting data.

These models need numerical based quantification methods that can fully describe changes in tumor/tissue structure and thereby relate fundamentally to growth models. Such newly proposed growth models can then be compared and contrasted with existing or proposed analytical models to: 1) elucidate the mechanisms underlying tumor/tissue formation; 2) investigate the dynamics of these complex systems; and 3) provide a conceptual framework for future model and experimental work. To this end, a software program entitled MAPPER is being developed to generate a topographical mapping over sub-regions of a tumor/tissue via the fractal statistics known as fractal dimension, lacunarity, and connectivity. It is hypothesized that tumor/tissue growth characteristics can be tracked by analyzing changes in these topographical maps. In order to speed the quantification process, the software program was designed for a distributed architecture using multiple hardware and system configurations via a secure network protocol. A graphical user interface (GUI) was developed to facilitate interaction among scientists from the key disciplines of microbiology and applied mathematics. The software program was developed as a diagnostic tool for assessing the mechanisms of biofilm structure, and has been evaluated using microscopic biofilms and synthetic biofilm images. The program has also been used to parse general imagery into regions of interest for additional human analysis for features of interest (http://www.hpcnet.org/tolle/fractals).

REU Student Research

This research project is made up of two parts. In the first part, the REU student(s) will focus on the development of a new fast lacunarity and connectivity estimation methods based on KD trees under the guidance of the Faculty Mentor. The second part will focus on extending MAPPER to read and analyze 2D and 3D DICOM image files. DICOM image files are the standard data format for medical imagery. Once DICOM images can be loaded into MAPPER, imagery provided by the Paul Strickland Scanner Center, part of the Mount Vernon Hospital, Northwood, Middlesex, United Kingdom will be analyzed.

Research Project: Renewable Energy Resources and their Integration into Smart Grid
REU Faculty Research Mentor: Dr. Yucheng Zhang

Background

Renewable energy resources and smart grid are the trends in power engineering nowadays. In the past decade, various renewable energy technologies have developed rapidly around world. Some examples are wind power, solar power, fuel cell, and energy storage systems. These renewable energy resources can be integrated into the developing smart grid via power electronics devices to reduce the consumption of traditional nonrenewable energy resources like coal and natural gas. Also, the developing smart grid applies modern communication technology to increase the efficiency, robustness, controllability, and protection of power systems. According to the reports from the National Renewable Energy Laboratory and the Department of Energy, the target ratio of renewable energy resources is 80% by 2030 in United States. This research will investigate the technology of various renewable energy resources and develop power electronics components to integrate these resources into smart grid in a high-efficiency way.

REU Student Research

The REU student(s) chosen for this project will design appropriate power electronics devices to realize power conversion between renewable energy resources and the smart grid, and develop power modules (wind and solar modules) on a lab scale. These power modules will be integrated to form a microgrid, which can be operate in standalone mode or integrated mode with an utility. The REU student(s) will be supervised by the faculty research mentor and work with graduate students in the research lab to finish these projects. The United States needs a large number of power engineers in the next few decades for the reconstruction of existing power grids. This project provides opportunities to REU students to gain knowledge in the reconstruction process.

Research Project: Wireless Communications and Networking
REU Research Mentor: Dr. Yanxiao Zhao

Background

Wireless technologies have significant impacts on all aspects of our daily lives and are fundamentally changing the way we acquire and transfer information. The past decade has seen their rapid proliferation, in which they are being widely used in energy, health care, education, public safety and consumer electronics. To facilitate those applications, a variety of wireless networks have been developing dramatically such as cognitive radio networks, wireless sensor networks and wireless mesh networks. As the revolution in wireless technologies unfolds, however, various new challenges arise. For example, the demand for spectrum from new applications is increasing exponentially, while the existing spectrum is depleting rapidly. This leads to "spectrum scarcity". So, how to use the limited spectrum efficiently is one crucial issue in wireless technologies. The Faculty Research Mentor has extensive experience with algorithm design, performance analysis and experimental implementation in wireless communications and networking.

One specific research areas is cognitive radio network, in which dynamic frequency allocation is used. Specifically, secondary users are allowed to opportunistically share spectrum bands with primary users. Cognitive radio network is emerging as a promising solution to solve the spectrum scarcity and thus improve the spectrum utilization. There are several challenging issues in cognitive radio networks including spectrum sensing, spectrum sharing, etc.

REU Student Research

The students will be exposed to the concepts of wireless communication and networking. They will learn to design novel algorithms or protocols in wireless networking after understanding existing state-of-the-art algorithms. Besides theoretical analysis, students will have opportunities to work on setting up a cognitive radio platform. The hands-on experiments will be based on GNU radio and Universal Software Radio Peripheral (USRP) boards. The goal is to implement advanced approaches on spectrum sensing, spectrum sharing and others with GNU radio and USRP boards.