DEPARTMENT OF ELECTRICAL ENGINEERING
PHD DISSERTATION DEFENSE

Development and Application of Genetic Programming in the Design and Optimization of Ultra-Wideband 3D Metamaterials

Speaker: Jennifer Rayno
Date: Thursday, February 18, 2016
Time: 9:30am – 11:30am
Location: Holmes Hall 389

Abstract
Metamaterials are materials with engineered characteristics and unique properties not naturally available, such as artificial magnetic conductors (AMC). Limitation of present AMC designs is related to their narrowband and high frequency operation, in GHz range. For many commercial and military applications, however, it is desired to design such materials in lower MHz band and with ultra-wideband (UWB) performance. In addition, typical 2D AMCs are designed by trial and error, often based on combination of layers of existing designs, and lossy materials are used to achieve broadband performance. There is no methodology that exists for designing true-3D metamaterials with broadband characteristics in the MHz band. This research uses genetic programming (GP) to automatically and efficiently explore the utilization of 3D design space to develop materials with the desired low frequency and broadband characteristics. Genetic programing is a genetically based evolutionary process that creates and modifies new geometries to achieve final designs that meet desired specifications. In this dissertation, GP software is developed and used to synthesize 3D, compact, UWB AMC ground planes, with a focus on achieving a lower frequency response and without using lossy or expensive magnetic materials. Full-wave electromagnetic simulation software (HFSS) is used to evaluate these designs. To accelerate the design process, GP is hybridized with a low-level optimizer, where GP creates and modifies topologies at the upper level while at the lower level each design is optimized separate from GP. The code is further parallelized to speed up the computations. Simulation results for nine AMC ground plane examples meeting the specifications (225-450 MHz, compact) with thicknesses ranging from $\lambda o/11$ to $\lambda o/16$ are presented to illustrate variety of successful topologies achieved by GP software while requiring only a set of design specifications. This research thus provides an efficient design methodology for electromagnetic devices and systems, when augmented with suitable design algorithms, it could be used to design 3D metamaterials in general, antennas, and antenna array systems. Results from this research specifically fill a significant need of designing lower frequency UWB AMC ground planes without the use of heavy and/or expensive magnetic materials typically used in the MHz range.