Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) in Engineering Electromagnetics: Let Darwin and the Bees Design your Antennas

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Overview: Antenna designers are constantly challenged with the temptation to search for optimum solutions for complex electromagnetic device designs. The ever increasing advances in computational power have fueled this temptation. The well-known brute force design methodologies are systematically being replaced by the state-of-the-art optimization techniques. The ability of using numerical methods to accurately and efficiently characterizing the relative quality of a particular design has excited the EM engineers to apply stochastic global evolutionary optimizers (EO). EO techniques have been applied with growing applications to the design of electromagnetic systems of increasing complexity. The recent popularity experienced by EO methods is not unique to the field of electromagnetics; in fact, EO techniques have been successfully applied to problems in fields ranging from engineering to economics and artificial intelligence. Among various EO techniques, Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) have attracted considerable attention. These schemes are finding popularity within electromagnetic community as design tools and problem solvers because of their versatility and ability to optimize in complex multimodal search spaces applied to non-differentiable cost functions.

GA: Relying on Darwin's original thoughts, it has been argued that life in this world in all its diverse and amazing forms was evolved by natural selection and natural adaptation processes controlled by the survivability of the fittest species. With this acceptance has come the temptation that perhaps one might be able to utilize nature's "selection and adaptation implementation engine" and apply it to the solution of engineering problems via the applications of Genetic Algorithms (GAs). In a few words, the machinery of Genetic Algorithms utilizes an optimization methodology which allows a global search of the cost surface via the mechanism of the statistical random processes dictated by the Darwinian evolutionary concept (Y. Rahmat-Samii and E. Michielssen, *Electromagnetic Optimization by Genetic Algorithms*, John Wiley, 1999). In this course, some of the key features of GA's are summarized in an innovative and illustrative fashion and then they are applied to facilitate the optimum design of a class of electromagnetic and antenna structures.

PSO: Relying on the social behavior of swarm of bees, fish and other animals, the concept of the Particle Swarm Optimization (PSO), new to the electromagnetics community, has been developed. The PSO is a robust stochastic evolutionary computation technique based on the movement and intelligence of swarms looking for the most fertile feeding location. The PSO technique was introduced into EM applications recently by *Robinson* and *Rahmat-Samii* (Particle Swarm Optimization in Electromagnetics, IEEE Transactions on Antennas and Propagation, vol. 52, no. 2, February 2004). PSO's foundation is based on the principle that each solution can be represented as a particle (agent) in a swarm. Each agent has a position and velocity vector and each position coordinate represents a parameter value. Thus for an n-dimensional optimization, each agent will have a position in n-dimensional space that represents a solution. Like GA or any optimization techniques, PSO also requires a fitness evaluation function that takes the agent's position and assigns to it a fitness value. The position with the best fitness value in the entire run is called the global best. Each agent also keeps track of its best fitness value. The location of this value is called its personal best. Each agent is initialized with a random position and random velocity. The velocity in each of n dimensions is accelerated toward the global best and its own personal best to ultimately converge to the desired solution. In this course, some of the key features of PSO are presented in an innovative and illustrative fashion and then they are applied to facilitate the optimum design of a class of electromagnetic and antenna structures.

Applications: One of the aims of this course is to provide the participant with an up to date body of knowledge on the applications of GA and PSO techniques to the synthesis and optimization of electromagnetic systems. Specifically, this course will focus on: **(a)** engineering introduction to Genetic Algorithms by reviewing simple GAs and their standard terminology and operators (populations, parents, children, chromosome, selection, crossover, and mutation), **(b)** engineering introduction to Particle Swarm Optimization by reviewing terminology and operators (agent, local best, global best, velocity, etc.), **(c)** demonstration of potential applications of GA's and PSO's to a variety of electromagnetic engineering designs including microstrip antennas, multi-band and wideband antennas, synthesis of non-planar radar absorbing materials for RCS

applications, Luneburg lens antenna design, array antennas, synthesis of reflector and horn antennas, design of electromagnetic bandgap (EBG) structures, etc, and **(d)** assessment of the advantages and the limitations of the techniques.

Yahya Rahmat-Samii is a Distinguished Professor and former chairman of Electrical Engineering Department at the University of California, Los Angeles (UCLA). Before joining UCLA, he was a Senior Research Scientist at NASA's Jet Propulsion Laboratory/California Institute of Technology. Dr. Rahmat-Samii was the 1995 President of IEEE Antennas and Propagation Society and was appointed an IEEE Distinguished Lecturer and presented lectures internationally. Dr. Rahmat-Samii was elected as a Fellow of IEEE in 1985 and a Fellow of IAE in 1986 and also served as the Vice President of AMTA. Dr. Rahmat-Samii was the 1984 recipient of the prestigious Henry Booker Award of USNC/URSI. Dr. Rahmat-Samii has authored and co-authored over 650 technical journal articles and conference papers and has written 18 book chapters and two books entitled, *Electromagnetic Optimization by Genetic Algorithms*, and *Impedance Boundary Conditions in Electromagnetics*. He is also the holder of several patents. His research contributions cover a diverse area of electromagnetics, antennas, satellite and personal communications, advanced material, modern measurement techniques, numerical and optimization techniques, etc (visit http://www.ee.ucla.edu/antlab). Dr. Rahmat-Samii has received numerous awards, including the 1992 and 1995 Wheeler Best Application Prize Paper Award for his papers published in the IEEE Antennas and Propagation Transactions, 1999 University of Illinois ECE Distinguished Alumni Award, IEEE Third Millennium Medal, and AMTA'2000 Distinguished Achievement Award. In 2001, Rahmat-Samii was the recipient of the Honorary Doctorate in Physics from the University of Santiago de Compostela, Spain. He is the winner of the 2005 International Union of Radio Science (URSI) Booker Gold Medal presented at the URSI General Assembly, New Delhi, India. Professor Rahmat-Samii is the designer of the IEEE AP-S logo.