# A Comparative Study between CMA Evolution Strategies and Particle Swarm Optimization for Antenna Applications

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Nature-inspired optimization techniques have been at the forefront of research within electromagnetics due to their unique properties as global optimization algorithms. These algorithms are stochastic techniques which direct the optimizer towards the most likely position based on previously tested points. The biggest question for current researchers in this area is which algorithm performs the fastest, provides the best solution, and offers robust convergence for a variety of different function topologies. Within the domain of nature-inspired optimization techniques, the Covariance Matrix Adaptation (CMA) Evolution Strategies (ES) and the Particle Swarm Optimization (PSO) techniques have transpired due to their rapid convergence for many electromagnetics optimization problems.

The CMA-ES technique is based upon the evolution of a population of individuals, capitalizing on the ideas of *survival of the fittest*, recombination, and mutation, and this version of ES has only been recently introduced to the antenna engineering community. This algorithm has certain similarities in comparison to the standard Genetic Algorithms, however the selection and recombination operators have some key differences. On the other hand, the PSO technique is well-established within the electromagnetics community, and its simple algorithm exploits both social and cognitive processes that have been observed in nature for swarms of bees searching for food. This study aims to clarify the advantages and disadvantages of each algorithm, as well as compare their convergence on a number of different benchmark problems within electromagnetics. We begin our study with a comparison on the convergence for resource-limited mathematical benchmark problems in order to qualify each algorithm's strengths and weaknesses for optimization problems well known in the literature. Next, several antenna design problems are optimized, including some antenna arrays, dual-polarized stacked patch designs, and reconfigurable antennas for cognitive radio applications.

The novelty of this work can be found in several aspects. First, it presents a timely comparison between two algorithms which have been claimed to be robust and fast for antenna design problems, and therefore a comparison is imminent in order to determine the most appropriate for handling a given antenna design problem. Next, many of the antenna applications discussed herein provide a general framework for the application of these nature-inspired optimization techniques to some various antenna design problems which are occuring more frequently. Lastly, our comparison between the algorithms hopes to shed light on possible ways to improve these techniques.