A Comparative Study of EP, GAs and PSO in Subsurface Inverse Profiling of Sectored Dielectric Elliptical-Cylindrical Objects

Maryam Hajebi[1] and Ahmad Hoorfar*[2]
(1) Dept. of Electrical Engineering, Amirkabir University of Technology, Tehran, Iran
(2) Antenna Research Laboratory, ECE Dept. Villanova University, Villanova, PA 19085

Inverse profiling of objects buried in a lossy dielectric medium is of importance in such widely used applications as medical imaging, geophysical survey, archaeology, nondestructive testing, and mine detection, to name a few. As an electromagnetic inverse scattering problem, subsurface imaging is rather challenging to solve due to its ill-posedness, non-uniqueness, and non-linearity, particularly in cases of high contrast objects and/or when multiple scattering effects are not negligible. Various iterative nonlinear inverse approaches exists where the problem is recast as searching for the minimum of a suitable cost function. The corresponding techniques for solving these types of minimization problems can be categorized in two main classes of deterministic and stochastic optimization methods. Traditional deterministic methods are fast local search techniques and are preferable for the cost functions that do not have many local minima. However, in highly non-linear cases with cost functions consisting of a large number of local minima, these methods may lead to inaccurate results. Stochastic optimization techniques, on other hand, are able to find the global optimal solution irrespective of the problem's non-linearity, albeit at the cost of higher computational burden, which could limit their use in real-time applications. Nonetheless, in cases where finding an accurate result is vital or in dealing with high contrast objects, stochastic methods offer a more robust approach compared to deterministic methods.

In this work, we consider the inverse profiling of lossy dielectric cylindrical objects with elliptical cross-sections buried in a lossy dielectric half-space using three different nature-inspired optimization techniques, namely Evolutionary Programming (EP), Genetic Algorithms (GAs) and Particle Swarm Optimization (PSO). By considering a cylinder with sectored elliptical cross section, seven parameters are needed to completely define the object's shape, location and material. The first six parameters include the cylinder's center coordinate, minor/major semi-axis, tilt angle, and the object's relative permittivity and conductivity. The last parameter, sector angle of ellipse, which varies between 0° and 360°, permits reconstruction of a larger class of objects, including those with different wedge-shaped cross sections, as shown in Figure 1. We have performed detailed statistical comparisons among the algorithms using different configurations of the subsurface objects with various cross-sections. For comparison, we have used two different variations of EP: EP-GMO and EP-CMO which use Gaussian and Cauchy mutation operators, respectively. The results show that EP-CMO, which is well-suited for problems whose fitness functions possess a large number of local minima, significantly outperforms EP-GMO, GAs and PSO in majority of the subsurface profiling cases investigated. Detailed formulation of the problem together with various numerical examples and sensitivity analysis will be given in the presentation.

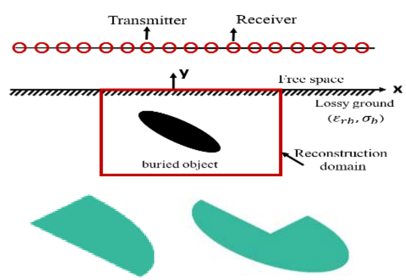

Fig. 1. Configuration of subsurface imaging problem (top); construction of two different target cross-sections by varying the sector-parameter (bottom).