Chapter 16
Application of the Spiral Optimization Technique to Antenna Array Design

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ABSTRACT
Antenna arrays are considered as important type used in today’s long-distance communication. The design of such antenna depends on parameters and desired behavior performing the task. This chapter deals with the application of a new type of nature-inspired global optimization methodology in the design of an optimized planar antenna array which ensures minimum side lobes and high directivity, this new optimization method is Spiral optimization technique which is a population based iterative heuristic global optimization algorithm technique for multi-dimensional and multi-modal problems with the potential to implement constraints on the search domain. The optimization task results in a good suppression of the side lobe level for the different antenna configurations with several sorts of excitation: Amplitude only, phase only, both amplitude and phase. Besides, the directivity is not worse than that of the conventional uniform one.

MOTIVATION
Antenna array systems communicate directionally by forming patterns with the main beam in the direction of the desired user (Reciou and Azrar, 2007). When the antenna array directs its main lobe with enhanced gain in the direction of the user, it naturally forms side lobes and nulls or areas of medium and minimal gain respectively in directions away from the main lobe. Hence the level of the sidelobes needs to be as minimum as possible for the sake of interference reduction (Reciou and Azrar, 2007; Reciou et al., 2008).

Pattern synthesis techniques are, in general, based on the variations of the array parameters such as the element excitations (amplitude and/or phase) and positions of array elements. The characteristics of the desired pattern can vary depending on the required application. Some synthesis methods are
concerned with reducing the Sidelobe Level (SLL) while preserving the gain of the main beam (Elliot, 2003). Others deal with null control to eliminate the effects of interference and jamming. Other methods of controlling the array pattern use non-uniform excitation and phased arrays (Steysskal et al, 1986).

The method of controlling both amplitude and phase is the most effective since it has larger solution alternatives (Steysskal et al., 1986). However, it is also the most expensive considering the cost of the controllers used for phase shifters and variable attenuators. Moreover, when the number of elements in the array increases, the computational time to find the values of element amplitudes and phases will also increase. The amplitude-only control (Bevelacqua and Balanis, 2007; Monorchio et al., 2007) uses a set of variable attenuators to adjust the element amplitudes.

The problem of the phase-only and position-only nulling is generally nonlinear, and it cannot be solved by analytical methods without any approximation. In order to steer the nulls symmetrically with respect to the main beam, the methods based on nonlinear optimization techniques have been proposed (Shore, 1984; Haupt, 1997). However, the resultant patterns of these methods have considerable pattern distortion because the phase perturbations used are large. Phase-only null synthesizing (Shore, 1984; Haupt, 1997; Liao and Chu, 1997; Akdagli and Guney, 2004) is less complicated and attractive for the phased arrays since the required controls are available at no extra cost, but it still has common problems.

The element position control with the use of a mechanical driving system, such as servomotors, is an alternative way to create nulls in the radiation pattern (Haupt, 1997; Abu-Al-Nadi et al., 2006; Akdagli et al., 2002). In this case, the amplitudes and phases can be solely used for the pattern synthesis with the desired sidelobe level and main beam characteristics.

The Schelkunoff array polynomial method (Schelkunoff, 1943) has been used to synthesize the equispaced linear array pattern. In this method, the pattern synthesis problem is reduced to the determination of proper roots of the array polynomial for a desired pattern. From this the element excitations are determined. The works reported in literature considered large arrays based on various optimization techniques together with the Schelkunoff unit circle representation of the array polynomial for uniform linear array. A genetic algorithm has been used for the pattern synthesis by (Monorchio et. al., 2007). Optimized low sidelobe levels have been presented by (Yu et. al., 2004). The optimization has been performed for different beamwidth values and the tradeoff between the sidelobe level and the main beam examined. Another genetic algorithm based optimizer has been proposed by (Recioui et al., 2008) and the results have been compared with other techniques.

In this work, the spiral optimization method is used to optimize antenna array of isotropic elements to achieve a pattern with some desired null directions and minimum achievable sidelobe level. Many strategies are adopted by acting on different array element controls such as excitation amplitudes and phase along with position. The results are interesting and can be exploited in communication systems.

RELATED WORKS

Optimization techniques are classified into two classes: local and global optimizers. The distinction between local and global search of optimization techniques is that the local techniques produce results that are highly dependent on the starting point or initial guess, while the global methods are highly independent of the initial conditions (Recioui and Azzar, 2007). Though they possess the characteristic of being fast in convergence, local techniques have a direct dependence on the existence of at least the first derivative. In addition, they place constraints on the solution space such as differentiability and