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REVIEW OF ADAPTIVE LINEAR ANTENNA ARRAY PATTERN OPTIMIZATION

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ABSTRACT

The main aim of designing an adaptive antenna array is to steer the main beam in the directions of the desired signals and steering nulls in the directions of the interfering signals. The adaptive antenna system can provide a greater coverage area for each cell site, higher rejection of interference and cost-down benefit of equipment. The major area of interest in phased and adaptive arrays is their application to problems arising in radar and communication systems, where interference suppression and high reliability is required. Null control in an antenna arrays can be achieved with different techniques such as: Perturbation of elements position, phase control of each element, amplitude control of each element and combination of amplitude and phase controls of each element.

The objective function involved in the optimization process for the design of adaptive arrays is complex. The genetic algorithm (GA) emerged as a competent optimization algorithm for a wide range of complex cost functions. The uses of GAs have shown great potential in the solution of complex problems related to the design of antenna optimization and have been an extremely active area of research. This paper presents several applications of GA for adaptive antennas. This paper demonstrates the use of GA to adaptively control antenna characteristics. The example demonstrates that the GA can quickly places nulls in the sidelobes in the directions of the interfering signals by minimizing the total output power. This paper reviews adaptive linear antenna array optimization.

KEYWORDS: Adaptive Linear Array, Phase Array Antenna, Genetic Algorithm, Adaptive Nulling, Null Steering, Sidelobe Level Reduction, Pattern Nulling, Amplitude Perturbation, Phase Perturbation

INTRODUCTION

The study of Adaptive antenna systems is becoming the interest of engineers and researchers in the communication field. The need is first, in antenna theory, a single antenna cannot change the direction of its radiation pattern without mechanism. Nevertheless, the radiation pattern can be changed if the communication system has two or more antennas combined together (conventional arrays).

An adaptive antenna arrays differ from the conventional arrays in the sense that they are adaptive that is capable of adjusting their weights automatically so that it is able to control its own pattern. An adaptive antenna can offer an optimal radiation pattern for user.

Second, to weaken or even eliminate the effect of the unwanted signal to the wanted one and direction finding in severe interference environment, adaptive antennas have come into being in various applications such as military radar and communication satellite systems or commercial mobile communication systems with high reliability requirements. Adaptive antennas are extensively used in communication systems that are subject interference. They adjust their pattern automatically to the signal environment to improve signal reception and to reduce the interference.

Third, the increasing demand for communication services without a corresponding increase in RF spectrum allocation motivates the need for new techniques to improve spectrum utilization. Among the many alternatives taken the Adaptive Antenna approach shows real promise for increasing spectrum efficiency.

Fourth, the use of adaptive antenna arrays in mobile handsets can help eliminate co-channel interference and multi-access interference among other problems. These antennas are able to radiate power towards a desired angular sector, thus avoiding interference with undesired devices.

Fifth, a smart or adaptive antenna is one alternative for recovering desirable signals. A smart antenna adapts it's receive and/or transmit pattern characteristics in order to improve the antenna's performance [1].

Adaptive beamforming techniques are used to obtain the desired antenna radiation pattern by adjusting the antenna parameters such as position, phase and amplitude weights of the linear antenna array. Radiation pattern nulling optimization techniques are very important to suppress undesired interfering signals. Today a lot of research on antenna array is being carried out using various optimization techniques to improve nulling performance due to their robustness and easy adaptivity. Recently, the genetic algorithm has found more popularity to optimize the antenna radiation pattern [2, 3].

The rest of the paper is structured as follows: Section II discusses the array pattern nulling/ null steering techniques. Section III highlights the array pattern synthesis. Synthesizing methods are the process of choosing the antenna parameters to obtain desired radiation characteristics, such as the specific position of the nulls, the desired sidelobe level and beamwidth of antenna pattern. Sidelobe reduction and interference suppression can be obtained using the following technique. Section IV demonstrates the need of optimization and the application of GA.

Then, Section V describes the model of the radiation pattern which is suitable for optimal solution search. Section VI discuss the review of various optimization techniques for array pattern nulling .Section VII is the review of the general principles of genetic optimization and an application of genetic algorithm to control the adaptive antennas. Finally, some conclusions are summarized at the end.

ARRAY PATTERN NULLING/NULL STEERING TECHNIQUES

Since the output power consists of both the interference and desired signals, constraints must be applied to prevent the nulling of the desired signal. Pattern nulling techniques are very important to cancel undesired interference in the modern wireless communication that asks for higher quality and better efficiency.

There are five controls to shape the overall pattern of the antenna are geometrical configuration of the overall array, relative displacement between elements, excitation amplitude of individual elements, excitation phase of individual elements, and relative pattern of the individual elements. Null steering in phased and adaptive arrays may be achieved by controlling some of the array parameters such as the position only of the array elements, the amplitude only, the phase-only and the complex element weights (both the amplitude and the phase).

Techniques for designing antenna arrays can be divided into two main objectives: (1) finding the excitations, and (2) finding the position of antenna elements that obtain a set of trade-off solution between main beam width and the side lobe level.

There are several popular methods available to reduce the sidelobes in the antenna pattern. The most popular technique are to taper the amplitude using different window functions such as Kaiser or Dolph Chebyshev [1]. In tapering process the main task is to calculate an appropriate weights vector which can produce the narrow beam with minimum level of sidelobe. One drawback of amplitude tapering is beamwidth expanding. It means to gain lower amount of sidelobe we must accept the wider value of beamwidth.

- Phase tapering of input signals also is very popular way for antenna array radiation pattern optimization since in phased array the required controls are available at no extra cost. Phase manipulation of input signals into antenna elements is technically efficient way to form and shift the main beam in desired direction and also it can be used for null steering in order to mitigate the effect of interferers in the system. However, the problem for excitation phase-only and element position only array nulling techniques is inherently nonlinear and cannot be solved directly by an analytical method. By assuming that the phase perturbations are small, the nulling equations can be linearized [4], but it makes impossible to place nulls at symmetric location with respect to the main beam. In order to steer the nulls symmetrically with respect to the main beam, the methods based on nonlinear optimization techniques have been proposed, however, the resultant patterns of these methods have considerable pattern distortion because phase perturbations used are large [5]. It is also easier to control the main beam direction by controlling phase instead of controlling amplitude only.
- The most efficient method in order to both shifting the main beam and reducing the sidelobes is based on full amplitude/phase control of signal fed into array elements [6]. Interference suppression with the complex weights is the most efficient because it has greater degrees of freedom for the solution space. However, it is also the most expensive considering the cost of the both phase shifter and variable attenuator for each array element.
- Element space perturbation can be an alternative technique to improve the main beam power to sidelobe power ratio by taking the advantage of element position as a variable in the arrays. The nulls can be placed at symmetric direction with respect to the main beam by perturbing the element positions, so that the computational time is effectively halved. Also, because the phase shifters are used solely for steering the main beam, any change in the phase increment has no effect in the null steering results [7]. However it requires a mechanical driving system such as servomotors to place the desired locations of the array elements, so difficult to apply for real time application [8, 9]. Also, for the case of smart antennas, the position of the antenna elements is fixed so the relative displacement cannot be changed.
- Amplitude manipulation of excitation signals of the array elements basically help to improve the main beam power to sidelobe power ratio. The method of amplitude-only control utilizes an array of attenuators to adjust the element amplitudes. If the array elements have even symmetry about the centre of the array, both the number of attenuators required and the computational time are halved. It is easy to implement [10].
- However, from practical viewpoint, it is desirable that array elements be symmetrically situated and excited. When the array elements are symmetrically situated and excited, the amplitude-only and position-only nulling methods are not suitable to produce the array pattern having asymmetrical nulls with respect to the main beam. The asymmetrical nulls can be achieved by phase-only control. However, in this case, there is an unavoidable sidelobe level increase in the direction symmetrical to the nulling direction with respect to the main beam [11]. The asymmetrical nulls can easily be obtained with a higher nulling performance by controlling both the phase and position [12].

Almost adaptive algorithm possesses some of the characteristics- to steer the nulls in the desired interference directions, to steer the nulls in the given interference directions without affecting the main beam, to minimize the power of an interfering signal coming from any direction by putting a null in its direction, but none of them meets all the characteristics, as a result, they do not find the optimum weights to reject the interference at hand and cannot produce the closest pattern to the desired radiation pattern with specified properties.

ANTENNA ARRAY PATTERN SYNTHESIS

In array-pattern synthesis, the main concern is to find an appropriate weighting vector to yield the desired radiation pattern such as the specific position of the nulls, the desired sidelobe level and the beam width of antenna pattern, etc. The antenna array pattern synthesis is needed to improve the desired signal reception by steering nulls to the direction of interference and placing the main beam directed to the desired signal. The shape of the desired pattern can vary widely depending on the application.

Generally it can be classified into three categories. The first category requires that the antenna patterns possess nulls in desired directions. This property is widely used in smart antenna systems to eliminate the interference from specific noise directions. The Schelkunoff polynomial method is an effective approach to synthesize the null controlled patterns. The second category requires that the antenna patterns exhibit a desired distribution in the entire visible region, which is referred to as beam shaping. This property is widely used in the design of a sector beam pattern, which allows the antenna array to have a wider angular coverage. This is usually accomplished using the Fourier transform technique and the Woodward–Lawson method. The third category usually requires antenna patterns with narrow beams and low side lobes. This guarantees the radiating or receiving energy to be more focused in specific directions. Various techniques such as the binomial method, Dolph-Chebyshev method, and Taylor Line-Source are proposed to serve this purpose.

NEED OF OPTIMIZATION AND GENETIC ALGORITHM

Various algorithms are used to optimize antenna array. Analytical optimization methods have been developed for specific radiation pattern subject to only one restriction. But there are many possibilities to find the fit solution. Exhaustive checking of all possible phase-amplitude excitation is very difficult as these methods search for a single point using deterministic rules. During the last one decade, numerical methods are becoming popular to synthesize the patterns to meet the specifications demanded by the user.

Many researchers have worked on linear array optimization techniques. By properly choosing the element length, element spacing, feed current amplitude and feed current phase, the desired radiation pattern could be achieved such as directivity, maximum antenna gain in the desired direction and minimum in the undesired direction. It has a wide range of study from analytical method (Dolph, Chebyshev, Taylor, Elliot) [1] to numerical method (Powell, Conjugate gradient) and to optimization methods (Genetic Algorithm, Particle Swarm Optimization). Today a lot of research on antenna array is being carried out using various optimization techniques.

Among these techniques, the genetic algorithms (GA) have been widely used particularly for the synthesis of antenna arrays. Optimized selection for more complex synthesis cases- such as a radiation pattern with various main beams and one or more nulls in a given directions, of multiple parameters can be efficiently achieved using Genetic algorithm (GA). It was observed that as compared with analytical method GA has superior accuracy in null locating and maintaining the required null depths [13]. GAs acquires importance because they use random search methods, are robust and are capable of solving complicated and nonlinear search problems.

In literature there are many works related with the synthesis of antenna array using Genetic Algorithm [14-16]. D. Marcano et al., 1996 uses a combination of the Schelkunoff method and GA to locate the roots in the w plane and to obtain the complex excitation for a given and feasible radiation pattern, specified by various nulls and other points. In the second method [18] the GA is used to directly change the complex amplitude of each array element until the desired radiation pattern is obtained. The results obtained show the capability of this method to solve a complex synthesis antenna problem as well as good agreement between the desired and calculated radiation patterns.

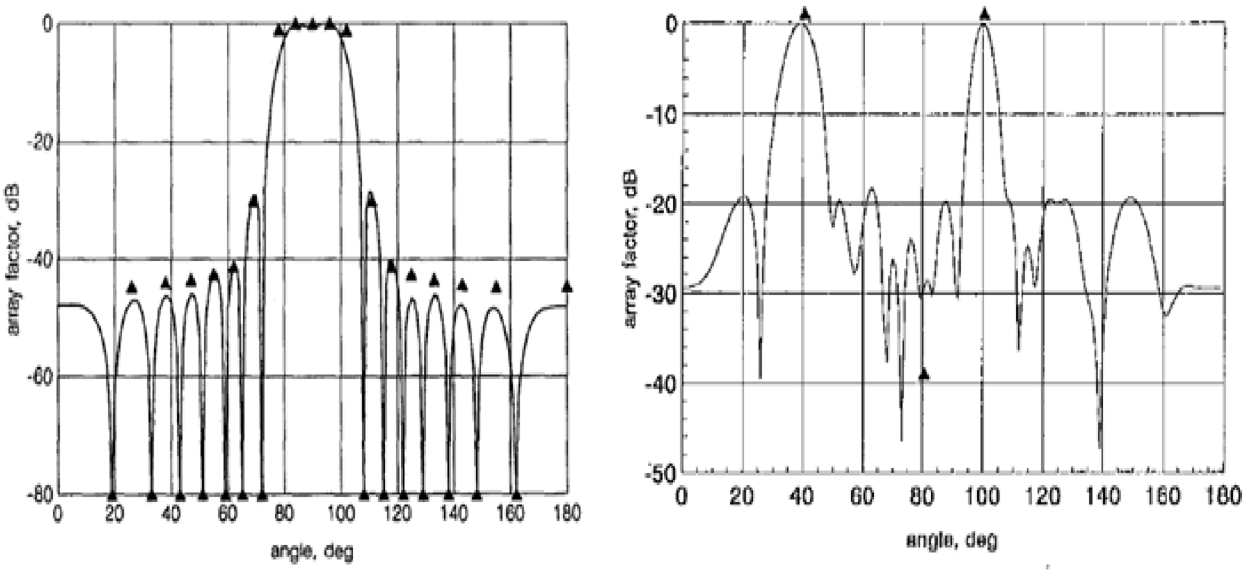

Figure 1: (a) Calculated (_)and Specified(▲) Radiation Pattern for a 19 Element Array[17] (b) The Calculated (_) and Desired (▲) Radiation Patterns with Two Beams and one Null for a 20-Element Linear Array [18]

Then in the third method, the constraint of sidelobe level reduction is introduced [19] by forcing it in the fitness function. The sidelobe level for 40-element array is less than that of the 30-element array because of imposing the same value of the directivity. As the number of the elements has increased, the sidelobe level has to decrease. However the values got still overtake the desired ones.

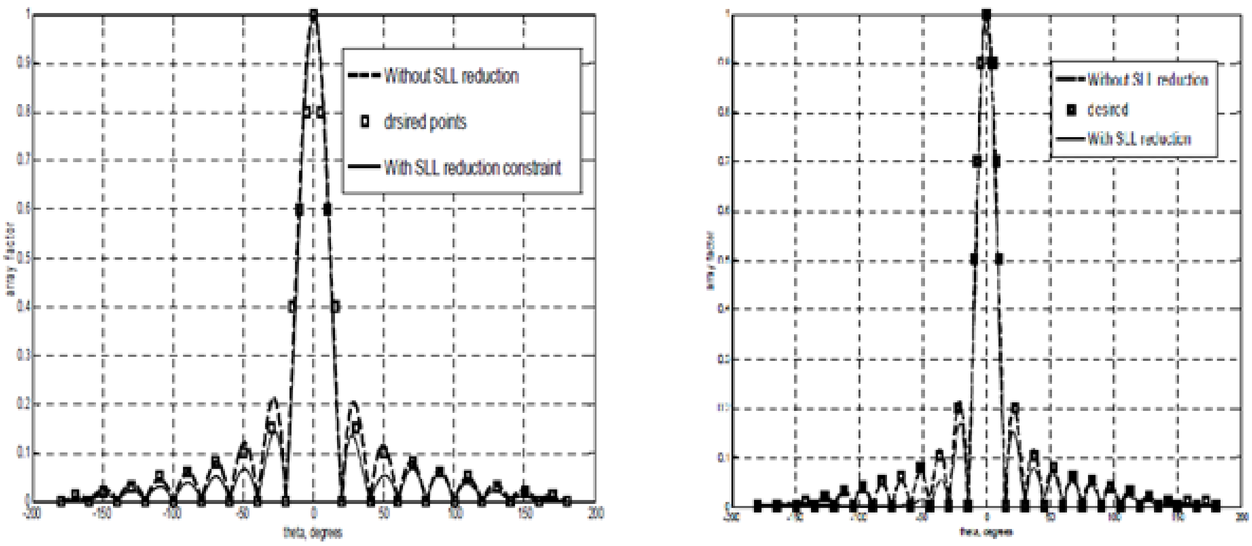

Figure 2: (a) The Reduced Sidelobe Level Radiation Pattern of the 30-Element Array Towards 0° (b) The Reduced Sidelobe Level Radiation Pattern of the 30-Element Array Towards 0°[19]

M. M, Dawoud et al., 1994 demonstrates its use in null steering in phased and adaptive array.

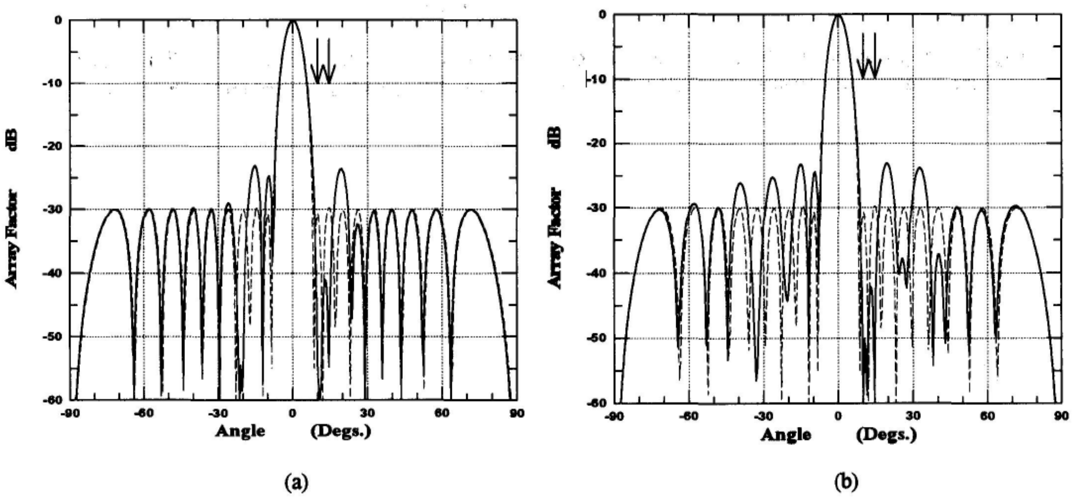

Figure 3: Array Pattern for a 20 Element 30 dB Chebyshev Array with Main Beam at 0° and Two Nulls Imposed at 10° and 14.5° Using Element Position Perturbations and Compared to the Initial Pattern (Dashed)

(a) Analytic Solution, (b) GA Solution [20]

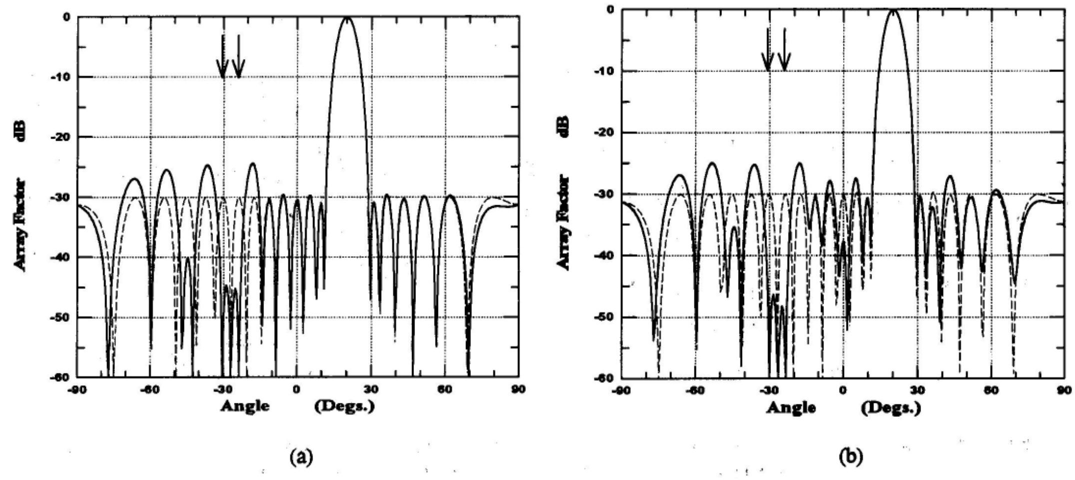

Figure 4: Array Pattern for a 20 Element 30 dB Chebyshev Array with Main Beam at 20°-and Two Nulls Imposed at -30.5° and -23.5° Using Element Position Perturbations and Compared to the Initial Pattern (Dashed)

(a) Analytic Solution, (b) GA Solution [20]

From the fig.3, 4 it is clearly shown that it is possible to steer the array nulls precisely to the required interference direction and can achieve any prescribed null depths.

Conventional GAs with binary coding and binary genetic operation are inconvenient and inefficient for array pattern synthesis problems to optimize real or complex numbers. Keen-Keong Yan and Yilong Lu, 1997 propose a simple and flexible GA for pattern synthesis of arbitrary arrays. This approach avoids coding and directly deals with real or complex weighting vectors so as to simplify software programming and to reduce CPU time. Using this approach, constraints on the phases and magnitudes of the complex coefficients can be easily imposed for practical implementation of digital phase shifters and digital attenuators.

Side lobe level reduction should be performed to avoid degradation of total power efficiency. Other methods deal with the null control to reduce the effects of interference and jamming. Interference suppression must be done to improve the signal to noise plus interference ratio (SINR). In the process of placing nulls at the interference locations, side lobe level increases with respect to the main beam. Shang Fei et al., 2006 aims to optimize both side lobe level and null depth.

Sidelobe reduction in the radiation pattern should be performed to avoid degradation of total power efficiency and the interference suppression must be done to improve the signal to noise plus interference ratio (SINR). It demonstrates that Double Population Genetic Algorithm (DGPA) has no limitation to frequency and avoids premature convergence compared with Chebyshev and Simple GA (SGA) method.

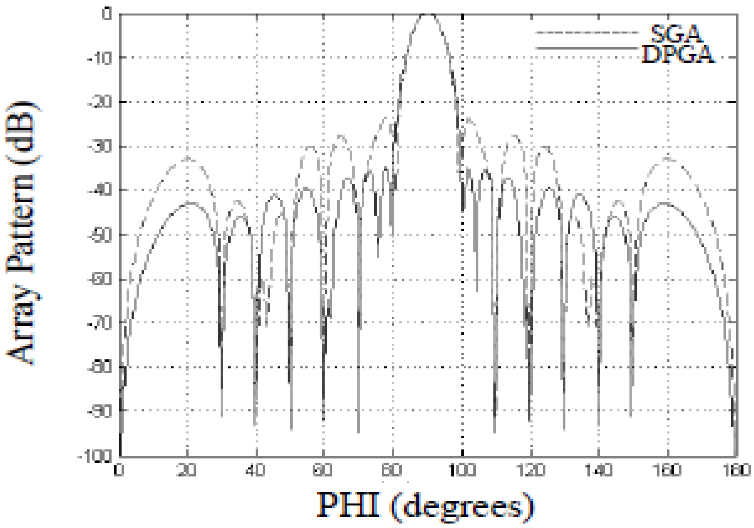

Figure 5: Synthesized Array Pattern by DGPA with Five Null and SGA Pattern [22]

Grating lobes are undesirable as they lead to reduced antenna gain and high interference levels compared to desired signal. M. M. Dawoud, 2002 demonstrates the possibility of reducing the level of these grating lobes by means of locating some array nulls within the grating lobe spatial directions using GA.

The synthesis problem discussed by T.S. Jeyali Laseetha et al., 2011 is to find the amplitude excitation of the antenna array elements that are optimum to provide radiation pattern with maximum reduction in sidelobe level. The best result of -48.9dB is obtained with reduced computational time and complexity.

Bipul Goswami et al., 2012 presented an approach of null control using Real-coded Genetic Algorithm (RGA) to determine an optimum set of current excitation weights of antenna elements and optimum inter-element spacing that satisfy the optimization goal to introduce deeper null/nulls to some desired direction and to suppress the relative SLL with respect to main beam with the constraint of a fixed first null beam width for a symmetric linear antenna array of isotropic elements.

A cost function is defined which keeps the nulls and maximum side lobes at lower levels. Null depths improve above -80dB and SLL has also been reduced by 3.90dB. Beam width between first null (BWFN) of initial and final radiation patterns remain approximately same.

Different pattern synthesis techniques are extensively studied to allow the placing of one or more nulls at specified jamming directions, null steering, reducing the sidelobe level and null depth, reducing the computational time, to simplify computing programming, fast convergence rate simultaneously avoidance of premature convergence.

MATHEMATICAL FORMULATION OF RADIATION PATTERN ARRAY FACTOR

For a linear array of 2N equispaced sensor elements, an interfering signal with a wavelength λ impinges on any two adjacent sensor elements n and n+1 by a distance d, and from a direction θ with respect to array normal [26].

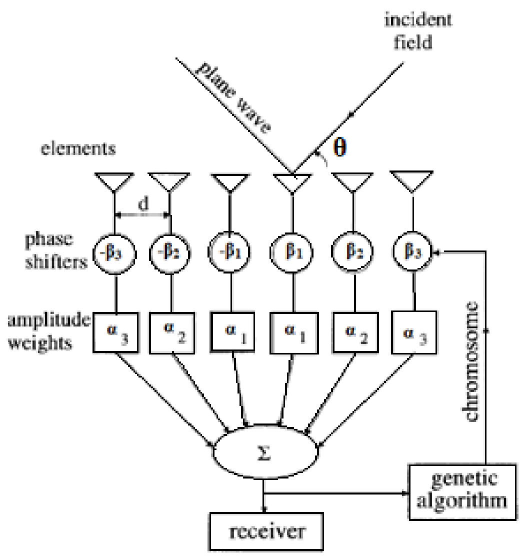

Figure 6: Phase Only Adaptive Linear Array [27]

The υ is the propagation speed of radio wave. Then, there is a time delay as follows:

$$\tau = \frac{d\sin\theta}{\upsilon} \tag{1}$$

The τ corresponds to a phase shift of $\frac{2\pi}{\lambda} d\sin\theta$

$$\psi = \frac{2\pi}{\lambda} d\sin\theta = kd\sin\theta \tag{2}$$

The adaptive array factor for far field is given by

$$AF(\theta) = \sum_{n=1}^{2N} w_n e^{j(n-1)\psi} \tag{3}$$

If the reference point is at the physical center of the array, the array factor becomes

$$AF(\theta) = \sum_{n=1}^{2N} w_n e^{j(n-N-0.5)\psi} = \sum_{n=1}^{2N} \alpha e^{j[(n-N-0.5)\psi+\beta_n]} \tag{4}$$

Where

2N= number of elements,

$w_n = \alpha e^{j\beta_n}$, complex array weights at element n,

α= amplitude weight for all elements,

β_n=phase shifter weight at element n,

ψ=kdsinθ, θ= an incidence angle of interfering signal or desired signal.

The array designer controls the array factor via the amplitude weights, the phase weights, and/or the element locations in order to meet performance specifications, such as sidelobe levels, beamwidth, nulls and bandwidth.

Suppose, if phase shifts are considered, so the amplitude weights are constant. And if the phase shifts are odd symmetry, the array factor can be written as [28]

$$AF(\theta) = 2\sum_{n=1}^{N} \cos[(n-0.5)\psi + \beta_n] \tag{5}$$

And in its normalized form

$$AF_n(\theta) = \frac{1}{N}\sum_{n=1}^{N} \cos[(n-0.5)\psi + \beta_n] \tag{6}$$

Given a desired transmitter called user1 at θ_1 direction and an interferer transmitter called user 2 at θ_2, now we have to find a set of phase shifters that will configure a linear antenna array in such a way that the main lobe is directed to user 1 while a null is presented to user 2.

The fitness consist of two functions: $F(\theta_1)$ which will attempt to maximize the value of the array factor for the direction of user1 = θ_1, while $F(\theta_2)$ must minimize the array factor for the direction of user2 = θ_2. The fitness function is deduced

$$F = F_1 - F_2 = |AF(\theta_1)|^2 - |AF(\theta_2)|^2$$

$$F = \left|\frac{1}{N}\sum_{n=1}^{N} \cos[(d-0.5)k\sin(\theta_1) + \beta_n]\right|^2 - \left|\frac{1}{N}\sum_{n=1}^{N} \cos[(d-0.5)k\sin(\theta_2) + \beta_n]\right|^2 \tag{7}$$

The optimization function to maintain the main beam direction and to impose null at the jamming direction is given by [29]-

$$F = \frac{F(u_s)}{\prod_{m=1}^{M} F(u_m)} \tag{8}$$

Where $F(u_m)$ is the value of the array factor at each of the desired null positions, $F(u_s)$ is the value in the main beam direction and M is the total nu. In evaluating F, the contribution from each $F(u_m)$ is limited to the desired design specification and the optimization process halted when all nulls were at or below this level.

The fitness function to minimize the peak side lobe level in the range outside the main beam and fixing multiple (M) nulls at the same time is given by[29]-

$$F = 20\log_{10}(AF(u) + \sum_{m=1}^{M} AF(u_m)) \tag{9}$$

Where $AF(u) = \sum_{n=1}^{N} a_n e^{jd_n(u-u_s)}$ is the value of the array factor without any null, where d_n is the distance from the array center to the nth element, $u = \beta\sin\theta$ and θ is the angle measure from the broadside, and $AF(u_m)$ is the value of the array factor with every précised null position.

VARIOUS OPTIMIZATION TECHNIQUES FOR ARRAY PATTERN SYNTHESIS

Many synthesis methods are concerned with suppressing the Side Lobe Level (SLL) while preserving the gain of the main beam [30]. M.M.Khodier et al., 2005 work on the field of antenna array analysis and design in which the relative position of the antenna elements has been optimized by the PSO technique to obtain minimum Side-Lobe Levels (SLL) and nulls towards the undesired directions to minimize the total output power.

The problem of forming nulls in the radiation pattern of an antenna array has been extensively studied in the literature. A method based on the modified touring ant colony optimization (MTACO) algorithm is presented by D. Karaboga et al., 2004 to steer the single, multiple and broadband nulls to the directions of interference by controlling both the amplitude and the phase of array elements. The maximum SLL, the null depth level and the dynamic range ratio are taken into account in the pattern synthesis. Simulation results for Chebyshev patterns with the imposed single, multiple and broad nulls are given to show the effectiveness of the proposed method.

A method for antenna pattern synthesis that suppresses multiple interfering narrow or wide band signals while receiving the desired signal by controlling only the phase using Sequential Quadratic programming (SQP) is discussed by M. Mouhamadou et al., 2006.

The problem of imposing nulls in arrays fed by Dolph-Chebychev excitations through element position perturbation is carried out by A.Recioui et al., 2010 based on the Taguchi method. The idea is to keep the trade-off directivity/sidelobe level within an allowable rate with the nulls constrained to be as deep as possible in the desired directions.

A simulated annealing technique is efficiently presented[35] for forming nulls to any prescribed directions by controlling only the amplitude of each array element while keeping the pattern as close as possible to initial pattern. The trade-off of the relative importance between the maximum sidelobe level and the null depth by changing the weighting factors is also apparently observed.

Due to increasing usage of the electromagnetic spectrum, there has also been considerable interest in synthesizing array patterns with broad nulls. The broad nulls are needed when the direction of arrival of the unwanted interference may vary slightly with time or may not known exactly, and where a comparatively sharp null would require for continuous steering for obtaining a reasonable value for the signal-to-noise ratio. A wide band jammer may be required to null an entire sector. This can be done by closely spaced nulls in the entire jammer. A method based on the tabu search algorithm is presented in [36] to steer the single, multiple and broad-band nulls to the direction of interference by the amplitude-only and also both the amplitude and the phase of each array element. The method of Tabu Search efficiently computes the design of uniform linear antenna array to generate a radiation pattern with minimum side lobe level at a fixed main beam width [37].

OPTIMIZATION OF ADAPTIVE LINEAR ARRAY ANTENNA PATTERN

A genetic algorithm have found extensive use in optimizing antenna array patterns because it is an efficient method to perform a search of a very large, discrete space of phase settings to achieve the minimum output power of the array. The array weights or beamforming network are optimized to create a desired array factor. The objective function involved in the optimization process for the design of adaptive arrays is complex. In the 1990s, the GA emerged as a competent optimization algorithm which has very wide applications. It works by emulating the natural process of evolution as a means of progressing towards the optimum. Recently, genetic algorithm proves to be very efficient for the pattern synthesis designs. The use of GA for phased array optimization is discussed in [38, 39]. C.Florens and Z.Raida, 1998 describes how GA can be applied to the control of adaptive antennas to find out in which situation they work better than gradient algorithm.

M.M.Dawoud et al., 1994 demonstrates the application of GA in null steering in phase and adaptive array. It has been shown that it is possible to steer the array nulls precisely to the required interference directions and to achieve any prescribed null depths.

R.L.Haupt, 1997, describes a new approach to adaptive phase only nulling with phased arrays. GA adjusts some of the least significant bits of the beam steering phase shifter settings in order to reduce the total output power from the array. The approach combines a GA with the hardware limitations of the array to place nulls in the directions of interference with small perturbations to the far field pattern. Using small adaptive phase values results in minor deviations in the beam steering direction. Various results are presented to show that GA is better than previous phase only adaptive algorithms. Limitations include, cannot place a null in a quantization lobe and interference sources at symmetric locations about the main beam cannot both be nulled.

M.A.Mangoud et al., 2003 studied the null steering for Dolph-Chebyshev and thinned antenna arrays using GA. It has been shown that thinned arrays can replace Chebyshev arrays to be used in switched beam antennas to get the steered nulls with the same pattern requirements.

Yong- Jun Lee et al. 2009 perform adaptive null steering by using GA which adjusts the amplitude and the phase of each radiating element. The cost function is derived to maximize the ratio between the power of the desired signal and that of the interference signal. Lowering the sidelobe levels requires an even phase shift about the center of the array, while nulling requires an odd phase shift. Since nulling is purpose so GA is coded to have the crossed sign odd phase shift. Then the null steering algorithm is coded with MATLAB using phase only in order to facilitate the realization. Both the single and two jammers showed the deep nulling capability over 80 dB, and small pattern distortions. The simulated results with MATLAB are verified through using CST’s MWS tool 3-dimensional electromagnetic simulator.

Md.Rajibur Rahman Khan et al., 2011 propose a null steering beamforming algorithm based on the GA to cancel interference in the wireless communication system. The method used to calculate the position perturbations of selected elements is based on minimization of the power at the null locations and power fluctuation in the main beam.

Wang Jiancheng et al., 2011 utilize GA to optimize element current amplitudes in obtaining the needed radiation pattern of adaptive linear array antenna under intensive interference environment. The synthesized array pattern has deep nulls steered in the interference direction and main beam directed towards the desired signal with the prescribed SLL of -30dB and null depth level of -80dB in the side lobe region at three interrupting directions respectively.

An adaptive GA has been used by I. Padmaja et al., 2012 in linear array to optimize the excitation levels of the elements resulting in a radiation pattern with minimum side lobe level and desired null position. This paper aims to optimize both the side lobe level and null depth. Examples demonstrate the effectiveness of GA for synthesizing single and double nulls with SLL of -20dB and null depth of -90dB.

M.A.El Cafsi et al., 2011 describe a new method for adaptive beamforming for a phased antenna arrays using GA. The algorithm can determine the values of phase excitation for each antenna to steer the main beam in specific direction.

A. Hammami et al., 2011 presents the application of a multiobjective optimisation GA for the synthesis of linear antenna arrays. The computer simulation results show that the amplitude-phase control, using the GA and -40dB

Chebyshev amplitude, is efficient for forming single and broad nulls imposed at the directions of interference and maximum main beam in the direction of the desired signal. The maximum SLL and the null depth are -30dB and 75dB repesctively.

Le Quang Thao et al., 2011 researches an efficient adaptive algorithm based on a GA which uses a limited number of bits of the beam steering phase shifters and a few least significant attenuator bits in amplitude weights. The phase shifter settings evolve until the antenna pattern has nulls in the direction of jammers and amplitude weights setting reduce the main beam. Using a few bits for nulling speeds convergence of the algorithm and limits pattern distortions.

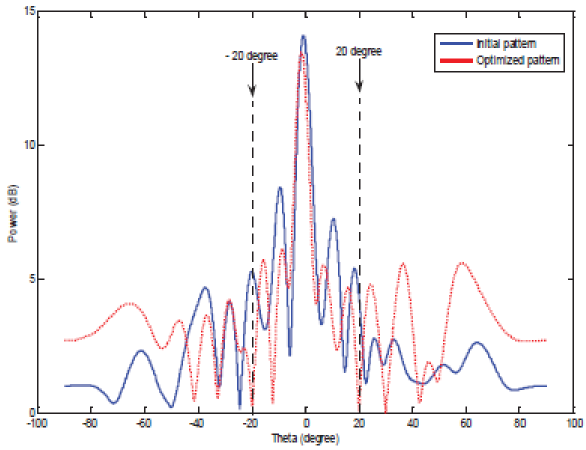

Figure 7: Null are Adaptively Placed at -20° and 20° [47]

Either real or complex weights vector without binary coding and decoding for crossover process can be used. When the multiple beam and null steering in different direction is required, the GA with complex weights always outperform than the GA with real chromosomes value. However, the result shows that for sidelobe cancellation and minimization, the GA with real chromosome has a better performance and also has a lower beamwidth penalty. In the other words, the GA with complex chromosome causes to wider the beam more than real chromosome GA algorithms. Therefore, careful choice of chromosome type is needed for different problem of beam pattern optimizations shown by Reza Abdolee et al., 2007.

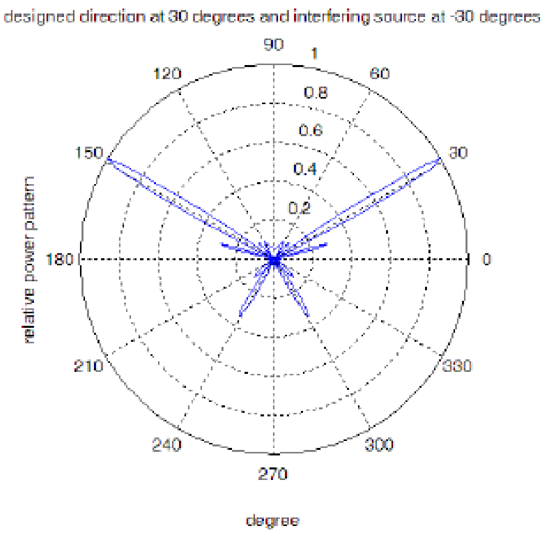

Figure 8: Radiation Pattern of Adaptive Antenna in Polar Co-Ordinates (Desired Signal from 30° and Interference Signal from -30°) [49]

A perturbation method consists of small perturbations in the element phases to obtain the optimal radiation pattern, which has got much attention. A search procedure based on the PSO algorithm is used in an adaptive linear array by C.H.Hsu et al., 2010 to obtain the required perturbations for the design of optimal radiation patterns which places null in the interfering direction and places maximum power pattern in the desired signal direction to the far-field pattern. Chao-Hsing Hsu, 2010 proposed PSO technique is also able to do the cancellation of multiple interferences for different incident directions.

Virgilio Zuniga et al., 2010 use the PSO technique to find the optimal radiation pattern of an adaptive antenna is proposed by calculating the phase shift weights of a linear antenna array, to maximize the power of the main lobe at the desired direction and keeping nulls at the direction of possible interferers.

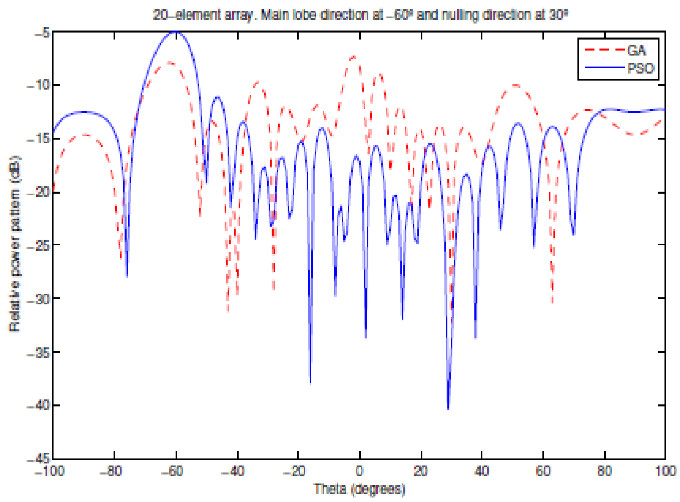

Figure 9: Radiation Pattern for Desired and Interfering Angles -60°, 30° [Virgilio Zuniga et al., 2010]

Multi-lobe beamforming and adaptive nulling of the pattern is achieved by controlling the phase of each array element [51].

A new GA method for array pattern synthesis with null steering is discussed by Yu-Bo Tian, 2005, Shang Fei et al., 2006, G.K.Mahanti et al., 2007, B.Kadri et al., 2010, Durbadal Mandal et al., 2011.

Table 1: References Categorized Under Subtopic

Topic	Reference
Array Synthesis	[10],[11],[15],[16],[17],[18],[19],[21],[22],[24],[30],[31],[44],[45],[46],[51],[55]
Adaptive Arrays	[20],[48]
Phased Arrays	[7],[9],[14],[23],[38],[39],[41],[45],[49],[50]
Element Perturbations	[7],[8],[9],[12],[13],[31],[52]
Amplitude Perturbations	[10],[35]
Phase Perturbations	[4],[5],[12],[26],[27],[28],[33],[51],[53],[54]
Complex Weight Perturbations	[6],[11],[32],[47],[53]
Sidelobe level reduction	[11],[15],[19],[21],[25],[31],[37],[44],[48]
Interference Suppression	[9],[14],[33],[43],[49]
Null Steering	[7],[9],[10],[13],[20],[22],[29],[34],[36],[38],[41],[42],[48]
Pattern Nulling	[4],[5],[6],[8],[12],[32],[35]
Adaptive pattern nulling	[26],[27],[28],[40],[43],[47],[50]

CONCLUSIONS

Adaptive arrays can automatically adjust the element weightings to null out interfering signals in their directions. Several challenges remain in the development of these adaptive systems. The techniques of placing nulls in the antenna patterns to suppress interference and maximizing their gain in the direction of desired signal has achieved considerable attention. The use of GA can adaptively control antenna characteristics. Problems of nulls symmetry about the main beam, slower GA convergence, cost and complexity for null steering designs are main issues. The techniques of null steering including controlling the complex weights (the amplitude and phase) the excitation amplitude only and phase-only, and the element position only have been extensively considered in the literature. A little modification on the evaluation function is adequate to fit in different assumptions and requirements of different problems.

REFERENCES

1. C.A.Balanis, “Antenna Theory: Analysis and Design, 3rd ed.”, John Willy & Sons Inc., New York, 2005.
2. R.L. Haupt, "An introduction to gentic algorthim for electromagnetic", IEEE Anten. Propag. Mag 37(2) pp7-15 April 1995.
3. R.L.Haupt and D.H.Werner, “Genetic Algorithms in Electromagnetics”, Wiley-Interscience, A John Wiley & Sons, Inc., USA, 2007.
4. H.Steyskal, “Simple method for pattern nulling by phase perturbation”, IEEE Transaction on Antennas and Propagation, vol.31, pp.163-166, 1983.
5. R. Shore, "Nulling a symmetric pattern location with phase-only weight control," IEEE Transactions on Antennas and Propagation, vol.32, no.5, pp. 530- 533, May 1984.
6. H. Steyskal, R. Shore and R. Haupt, "Methods for null control and their effects on the radiation pattern," IEEE Transactions on Antennas and Propagation, , vol.34, no.3, pp. 404- 409, Mar 1986.
7. T.H.Ismail and M.M.Dawoud, “Null steering in phased arrays by controlling the element positions', *IEEE Trans.*, AP-39, pp.1561-1566, 1991.
8. A.Tennant, M.M. Dawoud and A.P.Anderson, “Array pattern nulling by element position perturbations using a genetic algorithm," *Electronics Letters*, vol.30, no.3, pp.174-176, 3 Feb 1994.
9. Alphones and V. Passoupathi, "Null steering in phased arrays by positional perturbations: a genetic algorithm approach," IEEE International Symposium on Phased Array Systems and Technology, pp.203-207, 15-18 Oct 1996.
10. W.P.Liao and F.L.Chu, “Array Pattern Synthesis with null steering using genetic Algorithm by controlling the current amplitudes”, International Journal of Electronics, vol.86, pp.445-457, 1999.
11. Y.C.Chung and R. Haupt, “Low sidelobe pattern synthesis of spherical arrays using genetic algorithm”, Microwave and Optical Technology Letters, vol.32, n0.6, March 20 2002.
12. K.Guney and A.Akdagli, “Array pattern nulling by phase and position perturbations with the use of a modified Tabu Search Algorithm”, Turk journal of Elec Engg, vol.10, no.3. 2002.
13. P. Sattari and N. Hejazi, "Array pattern null steering using genetic algorithm by element position perturbations," IEEE Canadian Conference on Electrical and Computer Engineering, CCECE pp.000423-000428,4-7May2008.
14. D.I.Abu-Al-nadi, T.H.Ismail and M.J.Mismar, “Interference suppression by element position control of phased arrays using LM algorithm”, International journal of Electronics and Communications, AEU, vol.60, pp.151-158, 2006.

15. Xiang-Qian Che; Li Bian; , "Low-Side-Lobe Pattern Synthesis of Array Antennas by Genetic Algorithm," Wireless Communications, Networking and Mobile Computing, 2008. WiCOM '08. 4th International Conference on , vol., no., pp.1-4, 12-14 Oct. 2008.
16. V.Rajya Lakshmi and G.S.N.Raju, "Optimization of radiation patterns of array antennas", PIERS Proceedings, Suzhou, China, pp.1434-1438, 12-16 September 2011.
17. D. Marcano, M. Jiminez and O. Chang, "Synthesis of linear array using Schelkunoff's method and genetic algorithms," IEEE International Symposium on Antennas and Propagation Society, AP-S. Digest, vol.2, p.814-817 21-26 Jul 1996.
18. D.Marcano and F.Duran, "Synthesis of antenna arrays using genetic algorithm", IEEE Antennas and Propagation Magazine, vol.42, no.3, pp. 12-20, June 2000.
19. Abdelmadjid Recioui, Arab Azrar, Hamid Bentarzi, Mokrane Dehmas and Mouloud Chalal, "Synthesis of Linear Arrays with Sidelobe Level Reduction Constraint using Genetic Algorithms," International Journal Of Microwave And Optical Technology, vol. 3, no. 5, November 2008.
20. M.M. Dawoud, A. Tennant and A.P. Anderson, "Null Steering in Adaptive Arrays using a Genetic Algorithm," 24th European Microwave Conference, vol.2, pp.1108-1114, 5-9 Sept. 1994.
21. Keen-Keong Yan and Yilong Lu, "Sidelobe reduction in array-pattern synthesis using genetic algorithm", IEEE Transactions on Antennas and Propagation, vol.45, no.7, July 1997.
22. Shang Fei, Cai Ya-xing and Gao Ben-qing, "A New GA Method for Array Pattern Synthesis with Null Steering", IEEE 4th Asia-Pacific Conference on Environmental Electromagnetics, pp.490-494,1-4 Aug. 2006.
23. M.M.Dawoud, "Control of grating lobes in phased arrays using genetic algorithm", The 6th Saudi Engineering Conference, KFUPM, Dhahran, vol.4, pp. 187-, December 2002.
24. T.S.Jeyalilaseetha and R. Sukanesh, "Investigation on the performance of linear antenna array synthesis using genetic algorithm", Cyber Journals: Multidisciplinary Journals in Science and Technology, Journals of selected areas in telecommunications, JSAT, pp.60-66, May 2011.
25. Goswami and D. Mandal, "Introducing deeper nulls and reduction of Side Lobe Levels in a symmetric linear antenna array using genetic algorithm," IEEE 1st International Conference on Recent Advances in Information Technology (RAIT), pp.404-409, 15-17 March 2012.
26. Chao-Hsing Hsu, Wen-Jye Shyr and Chun-Hua Chen, "Adaptive Pattern Nulling Design of Linear Array Antenna by Phase-Only Perturbations Using Memetic Algorithms," IEEE First International Conference on Innovative Computing, Information and Control, ICICIC , vol.3, pp.308-311, Aug. 30 2006-Sept. 1 2006.
27. R. L. Haupt, "Phase-only adaptive nulling with a genetic algorithm," IEEE Transaction on Antennas Propagation, vol. 45, no. 6, pp. 1009-1015, Jun. 1997.
28. Virgilio Zuniga, Ahmet T. Erdogan and Tughrul Arslan, "Adaptive radiation pattern optimization for antenna arrays by phase perturbations using particle swarm optimization," IEEE NASA/ESA Conference on Adaptive Hardware and Systems (AHS), pp.209-214, 15-18 June 2010.
29. M.A. Mangoud, M. Aboul-Dahab and M. Sabry, "Optimum steering techniques for linear and planar antenna arrays using genetic algorithm," Proceedings of the Twentieth National Radio Science Conference, NRSC, pp. B7- 1-8, 18-20 March 2003.
30. Aritra Chowdhury, Ritwik Giri, Arnob Ghosh, Swagatam Das, Ajith Abraham and Vaclav Snasel, "Linear Antenna Array Synthesis using Fitness-Adaptive Differential Evolution Algorithm", IEEE Congress on Evolutionary Computation, CEC, pp.1-8, 18-23 July 2010.

31. Khodier, M.M.; Christodoulou, C.G., "Linear Array Geometry Synthesis with Minimum Sidelobe Level and Null Control Using Particle Swarm Optimization," IEEE Transactions on Antennas and Propagation, vol.53, no.8, pp. 2674- 2679, Aug. 2005.
32. Karaboga, K. Guney and A. Akdagli, “Antenna array pattern nulling by controlling both amplitude and phase using modified touring ant colony optimization algorithm,” International Journal of Electronics, vol.91, no.4, pp.241-251, April 2004.
33. M.Mouhamadou, P.Armand, P.Vaudon and M.Rammal; , "Interference Suppression of the Linear Antenna Arrays controlled by Phase with use of SQP Algorithm," Progress in Electromagnetics Research, PIER , vol.59, pp.251-265, 2006.
34. Recioui and H. Bentarzi, “Null steering of Dolph- Chebyshev arrays using Taguchi method”, WSEAS Transactions on Communications, vol.9, issue. 11, November 2010.
35. A.Akdagli and K.Guney, “Array pattern nulling using Simulated Annealing technique by controlling only the element amplitudes”, Research Gate.
36. K.Guney and A.Akdagli, “Null steering of linear antenna arrays using a modified Tabu Search Algorithm”, Progress in Electromagnetics Research, PIER, vol.33, pp.167-182, 2001.
37. L.Merad, F. Bendimerad and S.Meriah, “ Design of linear antenna arrays for sidelobe reduction using the Tabu search method”, The International Arab journal of Information Technology, vol.5, no.3, pp. 219-222, July 2008.
38. B.E. Stuckman and J.C. Hill, "Method of null steering in phased array antenna systems," IEEE Electronics Letters, vol.26, no.15, pp.1216-1218, 19 July 1990.
39. Randy L.Haupt, “Genetic algorithm application for phased Arrays”, ACES Journal, vol.21, no.3, Nov.2006.
40. C.Florens and Z.Raida, “Adaptive beamforming using genetic algorithm”, Radioengineering, vol.7, no.3, September 1998.
41. Yong-Jun Lee, Jong-Woo Seo, Jae-Kwon Ha and Dong-Chul Park , "Null steering of linear phased array antenna using genetic algorithm," IEEE Microwave Conference APMC Asia Pacific , pp.2726-2729, 7-10 Dec. 2009.
42. M.R.R. Khan and V. Tuzlukov, "Null steering beamforming for wireless communication system using genetic algorithm," IEEE International Conference on Microwave Technology & Computational Electromagnetics (ICMTCE), pp.289-292, 22-25 May 2011.
43. Wang Jiancheng, Qiu Hui and Chen Jianming; , "Optimizing Adaptive Linear Array Antenna Pattern Under Intensive Interference Environment Using Genetic Algorithm," International Conference on Intelligent Computation Technology and Automation (ICICTA), vol.1, pp.185-187, 28-29 March 2011.
44. Padmaja, N.Bala Subramanyam, N.Deepika Rani and G.Tirumala Rao, “Linear Array geometry Synthesis using genetic algorithm for optimum side lobe level and null”, International Journal of Advanced Research in Computer Science and Electronics Engineering, vol.1, no.3, May 2012.
45. M.A.El Cafsi, R.Ghayoula, H.Trabelsi and A.Gharsallah, “Phased uniform linear antenna array synthesis using genetic algorithm”, 11th Mediterranean Microwave Symposium (MMS), pp.67-72, 8-10 Sept.2011.
46. Hammami, R.Ghayoula and A.Gharsallah, "Antenna array synthesis with Chebyshev-Genetic Algorithm method," International Conference on Communications, Computing and Control Applications (CCCA), pp.1-4, 3-5 March 2011.
47. Le Quang Thao, Nguyen Ngoc Dinh and Dam Trung Thong, "Amplitude and phase adaptive nulling with a genetic algorithm for array antennas," IEEE 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC), pp.1887-1890, 8-10 Aug. 2011.

48. Reza Abdolee, Mohd Tamizi Ali, Tharek Abd Rahman, “Decimal genetic Algorithms for Null steering and Sidelobe Cancellation in switch beam smart antenna system”, International Journal of Computer Science and Security, vol.1,issue.3, pp. 19- 26, 2007.
49. Chao-Hsing Hsu, Wen-Jye Shyr and Kun-Huang Kuo, “Optimizing Multiple Interference Cancellations of Linear Phase Array Based on Particle Swarm Optimization ”, Journal of Information Hiding and Multimedia Signal Processing, Ubiquitous International,vol.1, no. 4, October 2010.
50. Chao-Hsing Hsu, Chun-Hua Chen, Wen-Jye Shyr, Kun-Huang Kuo, Yi-Nung Chung and Tsung-Chih Lin, "Optimizing Beam Pattern of Linear Adaptive Phase Array Antenna Based on Particle Swarm Optimization," IEEE Fourth International Conference on Genetic and Evolutionary Computing (ICGEC), pp.586-589, 13-15 Dec. 2010.
51. M.Mouhamadou, P.Armand, P.Vaudon and M.Rammal; , "Smart antenna array patterns synthesis: null steering and multi-user beamforming by phase control," Progress in Electromagnetics Research, PIER , vol.60, pp.95-106, 2006.
52. Yu-Bo Tian and Jian Qian, “Improve the performance of a linear array by changing the spaces among array elements in terms of genetic algorithm”, IEEE Transactions on Antennas and Propagation, vol.51, no.7, July 2005.
53. G.K.Mahanti, A.Chakrabarty and S.Das, “Phase-only and amplitude-phase synthesis of dual-pattern linear antenna arrays using floating-point genetic algorithms”, Progress in Electromagnetics Research, PIER, vol.68, pp.257-259, 2007.
54. B. Kadri, M. Boussahla and F.T. Bendimerad, “ Phase-only planar antenna array synthesis with fuzzy genetic algorithms”, International Journal of Computer Science Issues, IJCSI, vol.7, issue.1, no. 2, January 2010.
55. G.R.Hardel, N.T. Yallaparagada, D. Mandal and A.K.Bhattacharjee, "Introducing deeper nulls for time modulated linear symmetric antenna array using real coded genetic algorithm," *IEEE Symposium on Computers & Informatics (ISCI)*, pp.249-254, 20-23 March 2011.
56. Namrata Langhnoja, Ved Vyas Dwivedi, and Y P Kosta, ‘Beam Squint Analysis of Offset Microstrip Reflectarray and Feed’, International Journal of Electronics Engineering Research, pp 229-236, vol. II, no. II, 2010; http://www.ripublication.com/Volume/ijeerv2n2.htm