OPTIMAL SIDE LOBE REDUCTION OF LINEAR NON-UNIFORM ARRAY USING GENETIC ALGORITHM

P.M. Mainkar#1, Shailesh.S.Ghule#2, Onkar.S.Ghate#3, Radharaman.N.Ojha#4
Department of Electronics and Tele-communication, Maharashtra Institute of Technology
Pune, Maharashtra,India.
[1]prakash.mainkar@mitpune.edu.in
[2]shailesh.engg10@yahoo.com
[3]Onkarghate2011@rediffmail.com
[4]radharaman167@live.com

***Abstract*-The Smart Antenna Techniques in future wireless system is expected to have a significant impact on the efficient utilization of the spectrum, the minimization of the cost of establishing new wireless network, the optimization of service quality and realization of transparent operation across multi technology wireless network .This paper present brief account on smart antenna (SA) system.SA system can place nulls in the direction of interferers by adaptive updating of weights linked to each antenna element.SA system thus cancel out most of the co-channel interference resulting in better quality of reception. In this paper, we propose the use of Genetic Algorithm (GA) to perform the adaptation control of the system parameters under dynamically changing environments. The GA-based beam former has nearly optimal interference cancellation under dynamic conditions and make the output consistently close to the optimal one. Other advantages of the GA are its simplicity and fast convergence provided that the parameters are appropriately chosen, which makes it a practical algorithm for beam forming in smart antenna. Simulation results validate substantial performance improvements relative to other standard adaptive algorithms.**

***Keyword:* - Sidelobelevel, Aperture Efficiency, Optimization Symmetric linear antenna array, First null beam width (FNBW), Genetic algorithm (GA)**

I. INTRODUCTION

Side lobe is an important metric used in antenna arrays, and depends on the weight and positions in the array. A method of determining optimal side lobe minimizing weight is derived that holds for any linear array geometry, beam width, antenna type and scan angle. The positions are then optimized simultaneously with the optimal weight to determine minimum possible side lobe level in linear array

II. DESIGN EQUATION

The radiation pattern of an antenna array depends strongly on the weighting method and the geometry of array. Selection of weight has received extensive attention, primarily because the radiation pattern is linear function of the weights. However the array geometry has received relatively little attention even though it also strongly influences the radiation pattern. There are several array design variables which can be changed to achieve the overall array pattern design.

Array Design variables [4]:

- General array shape (linear,planar,circular).
- Element spacing.
- Element excitation amplitude.
- Element excitation phase.
- Pattern of array element.

The goal in antenna array geometry synthesis is to determine the physical layout of the array that produces the radiation pattern that is closest to the desired pattern. In this paper the design goal for a linear antenna array of isotropic elements covers suppression of SLL and restriction of the BWFN to its initial values as far as possible. This is done by designing the relative spacing between the elements, with a non-uniform excitation over the array aperture.

The rest of the paper is arranged as follows:- in section II, the general design equations for the non-uniformly excited linear antenna array are stated. Then in section III a brief introduction for Genetic Algorithm is presented. Numerical simulation result is presented in section IV. Finally the paper concludes with a summary of work in section V.

Geometrical configuration is a key factor in the design process of an antenna array. The linear antenna arrays are those in which the elements are positioned along a line and could have uniform separation or non uniform separation. Fig. 1 shows the general configuration of a uniform symmetric linear antenna array with *2N* elements placed along the *z*-axis and centered at the origin. If all the elements are assumed to be isotopic sources, then the radiation pattern of this array can be written in terms of its array factor only.

Referring to Fig.1,[1][4] the array factor, $AF(\theta, I)$, *I* □ □ for the linear antenna array in y-z plane may be written as (1) [1]:

$$AF(\theta, I) = 2\sum_{m=1}^{N} I_m \cos\left[\frac{(2m-1)}{2} \times kd\cos\theta\right] \qquad (1)$$

where *Im* denotes current excitation of the *m*th element $k = 2\pi/\lambda$, *d* is the distance between the elements of the uniform array, λ □ being the signal wave-length, and θ symbolize the zenith angle from the positive z axis to the orthogonal projection of the observation point P.

After defining the array factor, the next step in the design process is to formulate the objective function which is to be minimized. The objective function “Cost Function” □*CF*□ may be written as (2): [4][1][9]

$$CF = \frac{SLL1(initial)}{SLL1(current)} + \frac{SLL2(initial)}{SLL2(current)} + \sum_i |AF(\theta i)|\text{^}2 + |FNBW(initial) - FNBW(current)| - |\eta taper - 0.7156| \qquad (2)$$

$$\text{SLL1}_{\text{initial}} = 20\log_{10}\left(\frac{0.5 \times \left| \begin{array}{l} AF\left(\theta_{msl1_{initial}}, I_{initial}\right) \\ + AF\left(\theta_{msl2_{initial}}, I_{initial}\right) \end{array} \right|}{\left| AF\left(\theta_0, I_{initial}\right) \right|}\right) \qquad (2a)$$

$$\text{SLL1}_{\text{current}} = 20\log_{10}\left(\frac{0.5 \times \left| \begin{array}{l} AF\left(\theta_{msl1_{current}}, I_{m_{current}}\right) \\ + AF\left(\theta_{msl2_{current}}, I_{m_{current}}\right) \end{array} \right|}{\left| AF\left(\theta_0, I_{m_{current}}\right) \right|}\right) \qquad (2b)$$

Similarly same formulae for SLL2 initial and SLL2 current. FNBW is an angular width between the first nulls on either side of the main beam. θ is the angle where peak of the main lobe is attained in $\theta \in [0, \pi]$. $\theta_{msl1_{current}}$ is the angle where the maximum side lobe $\left(AF\left(\theta_{msl1_{current}}, I_{m_{current}}\right)\right)$ is attained in the lower band and $\theta_{msl2_{current}}$ is the angle where the maximum side lobe $\left(AF\left(\theta_{msl1_{current}}, I_{m_{current}}\right)\right)$ is attained in the lower band and $\theta_{msl1_{initial}}$ is the angle where the maximum side lobe $\left(AF\left(\theta_{msl1_{initial}}, I_{initial}\right)\right)$ is attained in the lower band and $\theta_{msl2_{initial}}$ is the angle where the maximum side lobe $\left(AF\left(\theta_{msl1_{initial}}, I_{initial}\right)\right)$ is attained in the upper band for the initial case. For the initial case inter element spacing is $\lambda/2$ and all the excitation coefficients $(I_{initial})$ are equal to 1. So the first and second term in (2) is the ratio of SLLs of initial case and current iteration. Second term is used to introduce nulls in each and every direction outside the main beam. Thus this term, in the present case is used to reduce side lobe level in each iteration. In (2) the two beam widths, FNBW*current and* FNBW *initial* basically refer to the computed first null beam width in radian for the non-uniform excitation case and for uniform excitation respectively.[9]

$$\eta_{\text{taper}} = \frac{\left(\sum_{n=1}^{N} |I_n|\right)^2}{N \cdot \sum I_n^2}$$

For a uniform amplitude distribution, excitation efficiency is equal to 1. If the first sidelobe level of about -18 dB gtaper is around 0.95 (-0.22 dB) , for first sidelobe value of -23 dB gtaper = 0.81 (-0.92 dB), and for first sidelobe level equal to -31.5 dB gtaper = 0.67 (-1.7 dB).[9]

The aperture efficiency value \1 shortens communication range. However, reduced side lobes increase the immunity to the interference sources. Therefore, antenna design engineer has to choose reasonable compromise between the side lobes level and the gain loss to satisfy the communication system requirements.[9]

Thus the third term of (2) restricts the spreading of the main beam as far as possible. As it is a minimization problem, minimization of *CF* means maximum reductions of SLL both in lower and upper bands. The forth term is aperture efficiency used for reduction of side lobe level. The evolutionary optimization techniques employed for optimizing the current excitation weights and the inter-element spacing, resulting in the minimization of *CF* and hence reduction in SLL is described in the next section.

III. SMART ANTENNA

A smart antenna system combines an antenna array with innovative algorithm to receive and transmit an adaptive, spatially sensitive manner such a configuration sensitive manner. Such a configuration dramatically enhances the capacity of a wireless link through a combination of diversity gain, array gain and interference suppression. Increased capacity translates to higher data rates for a given number of users for a given data rate per user in other words, such a system can automatically change the directionality of its radiation patterns in response to its signal environment .This can dramatically increase the performance characteristics(such as capacity) of a wireless system.[6]

The following are distinctions between the two major categories of smart antennas regarding the choices in Transmit strategy.[6]

- *Switched Beam*—a finite number of fixed, predefined patterns or combining strategies (sectors).
- *Adaptive Array*—an infinite number of patterns (scenario-based) that are adjusted in real time.

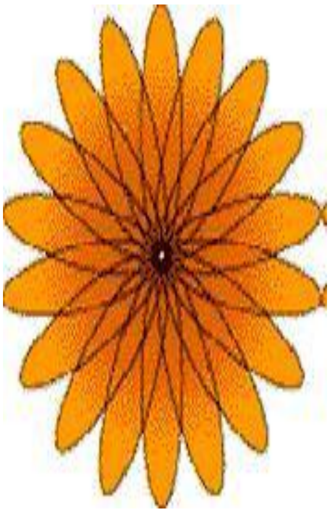

Fig 1.Switched beam Pattern

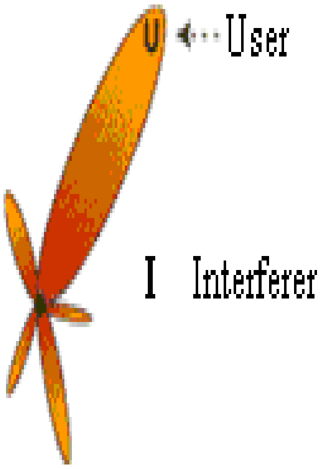

Fig 2.Adaptive beam pattern

IV. GENETIC ALGORITHM(GA)

The genetic algorithm (GA) is an optimization and search technique based on the principles of genetics and natural selection. A GA allows a population composed of many individuals to evolve under specified selection rules to a state that maximizes the "fitness" (i.e., minimizes the cost function).The method was developed by John Holland (1975) over the course of the 1960s and 1970s and finally popularized by one of his students, David Goldberg, who was able to solve a difficult problem involving the control of gas-pipeline transmission for his dissertation (Goldberg, 1989). Holland's original work was summarized in his book. He was the first to try to develop a theoretical basis for GAs through his schema theorem. The work of DeJong (1975) showed the usefulness of the GA for function optimization and made the first concerted effort to find optimized GA parameters. Goldberg has probably contributed the most fuel to the GA fire with his successful applications and excellent book (1989). Since then, many versions of evolutionary programming have been tried with varying degrees of success.[8]

Some of the advantages of a GA include that it

- Optimizes with continuous or discrete variables,
- Doesn't require derivative information,
- Simultaneously searches from a wide sampling of the cost surface,
- Deals with a large number of variables,
- Is well suited for parallel computers,
- Optimizes variables with extremely complex cost surfaces (they can jump out of a local minimum),
- Provides a list of optimum variables, not just a single solution,
- May encode the variables so that the optimization is done with the encoded variables, and
- Works with numerically generated data, experimental data, or analytical functions

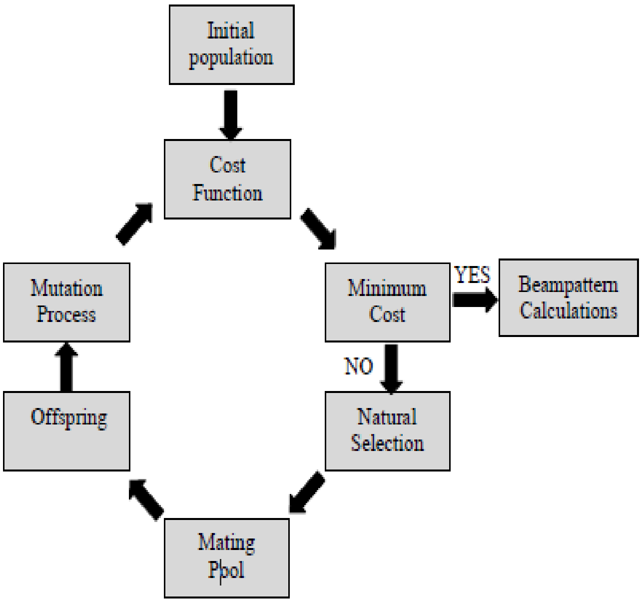

Fig 3.Flowchart of Genetic Algorithm

The important parameters of GA are:

- *Selection* – this is based on the fitness criterion to choose which chromosome from a population will go on to reproduce.
- *Reproduction* – the propagation of individuals from one generation to the next.
- *Crossover* – this operator exchanges genetic material which are the features of an optimization problem. Single point cross over is used here.
- *Mutation* – the modification of chromosomes for single individuals. Mutation does not permit the algorithm to get stuck at local minimum.
- *Stopping criteria* – the iteration stops when the maximum number of cycles is reached. The grand minimum CF and its corresponding chromosome string or the desired solution are finally obtained.

V. APPLICATION

Genetic algorithms have been used for difficult problems (such as NP-hard problems), for machine learning and also for evolving simple programs. They have been also used for some art, for evolving pictures and music. A few applications of GA are as follows:[8]

- Nonlinear dynamical systems–predicting, data analysis

- Robot trajectory planning
- Evolving LISP programs (genetic programming)
- Strategy planning
- Finding shape of protein molecules
- TSP and sequence scheduling
- Functions for creating images
- Combinatorial Optimization–set covering, traveling salesman (TSP), Sequence scheduling, routing, bin packing, graph coloring and partitioning.

VI. SIMULATION RESULT

This section gives the simulated result for various linear antenna array design obtained by GA technique. Three linear array structures are assumed, each maintaining a fixed spacing between the elements.

The parameters for the GA are set after many trial runs. It is found that the best results are obtained for an initial population of chromosomes. Maximum number of generation, Nm is limited to 400. For selection operation, the method of natural selection is chosen with a selection probability 0.3. Crossover is randomly selected dual points. Crossover ratio is 0.8. Mutation probability is 0.004. GA technique generates a set of normalized non-uniform current excitation weights for all sets of linear antenna array. Sets of linear array designs considered are of 12, 18, 24 elements. Table II shows the result for non-uniformly excited linear antenna array with uniform optimized spacing of between elements. Table I shows SLL values, 39dB beam width (3 dB BW) and FNBW values for all corresponding to uniformly excite linear antenna array structures. Table II shows two set of result for each of the set of 12, 18 and 24 element arrays.

SLL and FNBW for Uniform excitation $(I_{initial})$=1 with $\lambda/2$ Element Spacing Linear Antenna Array Sets. [1]

Table 1:---

Set No	No of Element	SLL (dB)	3dB BW(deg)	FNBW(deg)
I	12	-13.07	8	20
II	18	-13.33	8	16
III	24	-13.44	6	12

Table 2:--
SLL and FNBW for Optimal excitation coefficients and optimized Element Spacing Linear Antenna Array Sets.

Set No	Excitation weights for the array elements	Sp.(λ)	SLL(dB)	3dB BW (deg)	FNBW (deg)
I	0.9904317259085587; 0.8588940122119197; 0.638947834383311; 0.3990029200975745; 0.1990095883922436 4; 0.06895067874592087;	0.413916017421149 7	-46.91	18	50
II	0.9180014150207731; 0.8459886742186002; 0.7513018113737818; 0.6071494832032625; 0.4564072156738589 5; 0.3137614986268987; 0.19357353098773905; 0.10224113414516561; 0.03846653368914286;	0.399246536605698 9	-48.34	10	34
III	0.9233254296873952; 0.8843549999999687; 0.806845937500043; 0.7036263330077759; 0.582699125143945; 0.4592663629150593; 0.3390334375000066; 0.23629780364990438; 0.14914452148440205; 0.09126000000003387 ;0.0415571484374459; 0.020285410156304806	0.406932525634833 9	-59.16	8	32

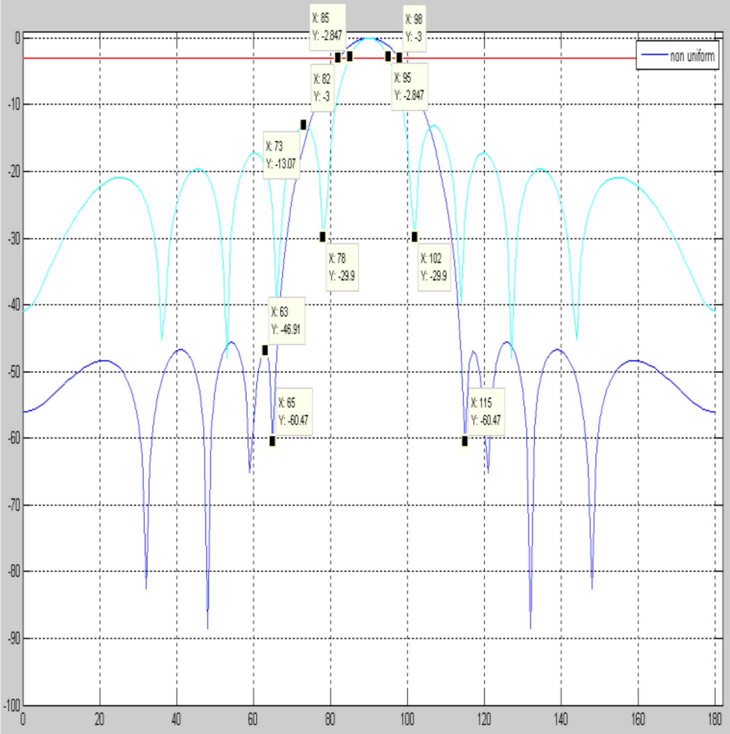

Fig 4. Optimal solution for 12 elements

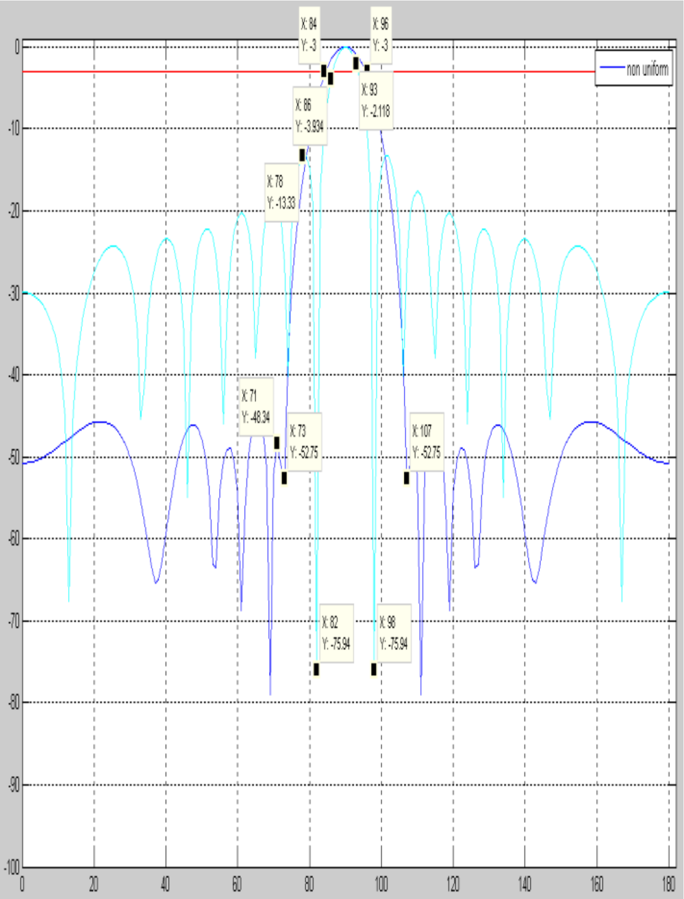

Fig 5. Optimal solution for 18 elements

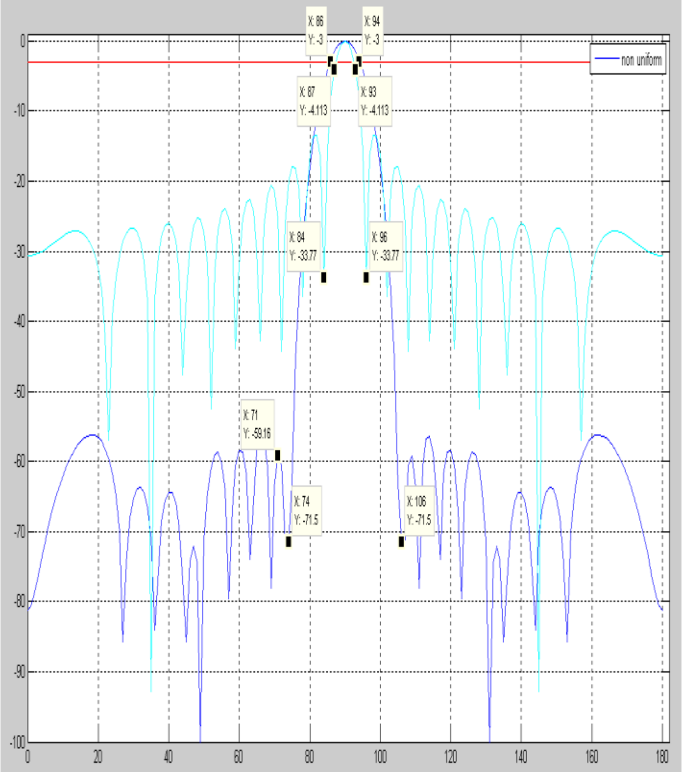

Fig 6 . Optimal solution for 24elements

VII. FUTURE SCOPE

Genetic algorithms can be applied to a wide range of problems which are NP (Nondeterministic ally Polynomial) complete. This means that if an enumerative search were to be carried out, it would take an exponential amount of Time.

VIII. CONCLUSION

In this paper, an optimal design for symmetric linear antenna array is found with uniform spacing and non – uniform excitation. Here extra factor is also included antenna aperture efficiency. Antenna aperture efficiency reduces side lobe level, but it also affects the parameter such as gain, coverage area. In order to optimize the side lobe level, FNBW is also affected i. e. Increases as side lobe level is decreases and also it depends on the spacing between elements.

So there is a tradeoff between SLL and FNBW. Here we successfully optimized spacing between elements with excitation coefficients with sacrifice of directivity. Hence Genetic Algorithm gives optimal solution for optimizing any antenna array design problem.

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