The New Approach to Linear Antenna Array Synthesis Using Real Coded Genetic Algorithm

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ABSTRACT :

The Genetic algorithm optimization method is used in this project for the synthesis of antenna array radiation pattern in linear. The synthesis problem in this project discussed is to finding the weights of the antenna array elements that are optimum to provide the radiation pattern with maximum reduction in the sidelobe level. This technique proved its effectiveness in improving the performance of the antenna array. In this project synthesis of symmetric linear antenna arrays is described using Real coded Genetic Algorithm (GA). Genetic Algorithm has many advantages over other conventional optimization techniques. Real coded GA (RGA) is a high performance evolutionary optimization algorithm. It is used in this project to find optimum inter-element spacing and excitation coefficients for the symmetric linear antenna array in order to minimize the maximum relative sidelobe level (SLL) in the radiation pattern of the array for minimum possible First Null Beam width (BWFN) increment.

I. INTRODUCTION:

A lot of research works have been carried out for optimizing the radiation pattern of linear antenna array by reducing the SLL using different computational methods for the past few decades. Antenna Array is formed by assembly of radiating elements in an electrical or geometrical configuration. In most cases the elements are identical. Total field of the Array Antenna is calculated by vector addition of the fields radiated by each individual element. There are five controls in an array antenna that can be used to shape the pattern properly, they are, the geometrical configuration (linear, circular, rectangular, pherical etc.) of the overall array, relative displacement between elements, excitation amplitude of the individual elements, excitation phase of the individual elements, and relative pattern of the individual elements. In many communication applications it is required to design a highly directional antenna.

Array antennas have a high gain and directivity compared to an individual radiating element. A linear antenna array has all its elements placed along a straight line, with a uniform relative spacing between elements . 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. In this paper, for the optimization of such complex, highly non-linear, discontinuous, and non- differentiable array factors, one evolutionary optimization technique such as a Real coded Genetic Algorithm (RGA) is adopted.

II. DESIGN EQUATION:

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, the array factor, AF(θ , I) for the linear antenna array in y-z plane written as (1) :

$$AF(\theta, I) = 2 \sum_{m=1}^{N} I_m \cos\left[\frac{(2m-1)}{2} X k d \cos\theta\right] \quad (1)$$

where I_m denotes current excitation of the mth element, k = $2\pi/\lambda$; d is the distance between the elements of the uniform array, λ being the signal wave-length, and 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):

$$CF = \frac{SLL_{initial}}{SLL_{current}} + \sum_i |AF(\theta_i)|^2 + |BWFN_{initial} - BWFN_{current}| \quad (2)$$

Where,

$$SLL_{initial} = 20\log_{10}\left[\frac{0.5X|AF(\theta_{ms/1initial}, I_{initial}) + AF(\theta_{ms/2initial}, I_{initial})|}{|AF(\theta_0, I_{initial})|}\right] \quad (2a)$$

$$SLL_{current} = 20\log_{10}\left[\frac{0.5X|AF(\theta_{ms/1current}, I_{current}) + AF(\theta_{ms/2current}, I_{current})|}{|AF(\theta_0, I_{current})|}\right]$$

(2b)

$$\theta_i \in \{(0, \theta_{ms/1current}), (\theta_{ms/2current}, \pi)\}$$
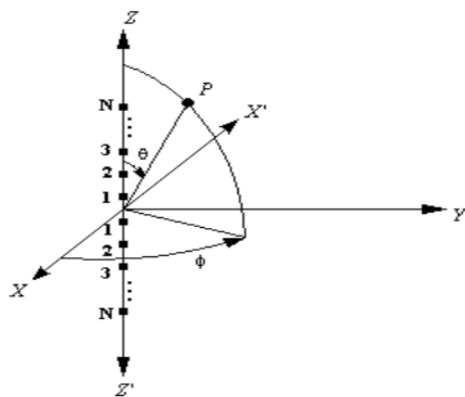
Fig. 1. Geometry of the 2N-element symmetric linear antenna array placed along the z-axis.

BWFN is the angular width between the first nulls on either side of the main beam.   is the angle where peak of the main lobe is attainedin

BWFN is the angular width between the first nulls on either side of the main beam. θ_0 is the angle where peak of the main lobe is attained in $\theta \in [0, \pi]$, $\theta_{ms/1current}$ is the angle where the maximum sidelobe $AF(\theta_{ms/1current}, I_{m\,current})$ is attained in the lower band and $\theta_{ms/2current}$ is the angle where the maximum sidelobe $AF(\theta_{ms/1current}, I_{m\,current})$ is attained in the upper band for the current iteration. Similarly, $\theta_{ms/1inital}$ is the angle where the maximum sidelobe $AF(\theta_{ms/1inital}, I_{inital})$ is attained in the lower band and

$\theta_{ms/2inital}$, is the angle where the maximum sidelobe $AF(\theta_{ms/1inital}, I_{inital})$ is attained in the upper band for the initial case. For the initial case inter element spacing is $\lambda \backslash 2$ and all the excitation coefficients $I_{initial}$ are equal to 1. So, the first term in (2) is the ratio of the SLLs of the initial case and the current iteration. The 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 sidelobe level in each iteration. In (2) the two beam widths, $BWFN_{initial}$ and $BWFN_{current}$ basically refer to the computed first null beamwidth in radian for the non-uniform excitation case and for uniform excitation respectively. 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 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. REAL CODED GENETIC ALGORITHM (RGA):

GA is mainly a probabilistic search technique, based on the principles of natural selection and evolution. At each generation it maintains a population of individuals where each individual is a coded form of a possible solution of the problem at hand and called chromosome. Chromosomes are constructed with genes of random values between (0, 1). Each chromosome is evaluated by a function known as fitness function, which is usually the cost function or the objective function of the corresponding optimization problem. Fig. 2. shows the steps to follow by the RGA to achieve Low SLL and many more thing for increasing the effectiveness of the linear antenna array.

Steps of RGA as implemented for optimization of spacing between the elements and current excitations are:

•Initialization of real chromosome strings of np population, each consisting of a set of excitations. Size of the set depends on the number of excitation elements in a particular array design.

•Decoding of strings and evaluation of CF of each string.
•Selection of elite strings in order of increasing CF values from the minimum value.
•Copying of the elite strings over the non-selected strings.
•Crossover and mutation to generate off-springs.
•Genetic cycle updating.
•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.
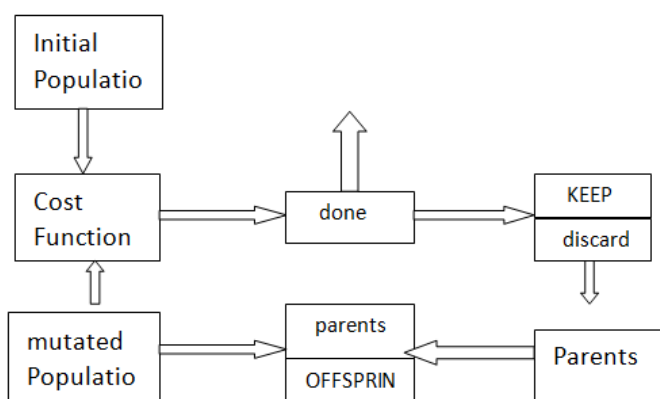

Fig 4.2. Genetic algorithm flowcharts

IV. NUMERICAL SIMULATION RESULTS ALGORITHM:

Generation of radiation patterns with Uniform Amplitude Distribution function:

The 24 elements $\lambda/2$ Uniform array has the SLL=-13 .21dB as shown in the fig.5.5 and the main lobe bottom beam width w=13o.Using the same number of antenna elements ,SLL reduction is performed by adjusting the shaping function parameters of Eq. 4.4 such that $\phi o=90o$ and w=13o.Fig 5.1,5.2,5.3 shows the original array pattern for n= 12,18,24.
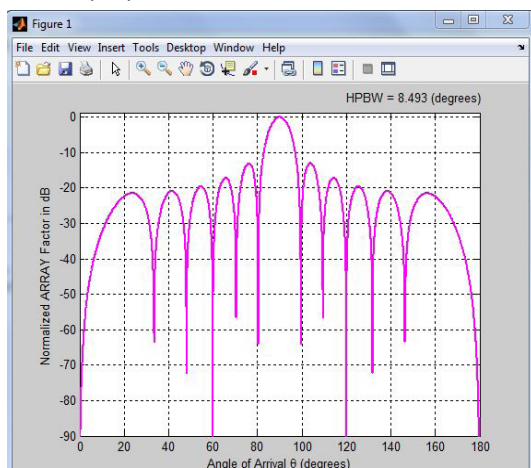
Fig 3 Original array pattern with 12 elements
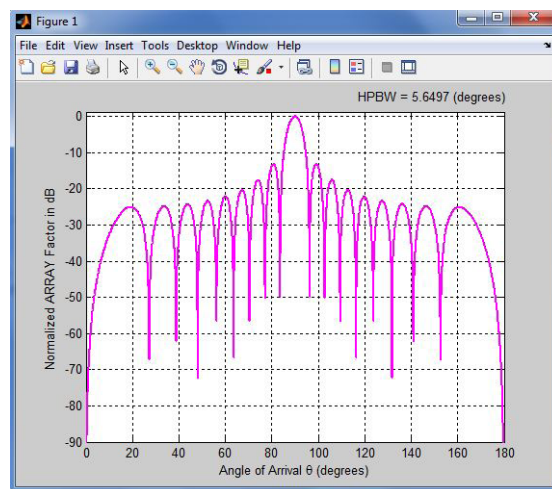
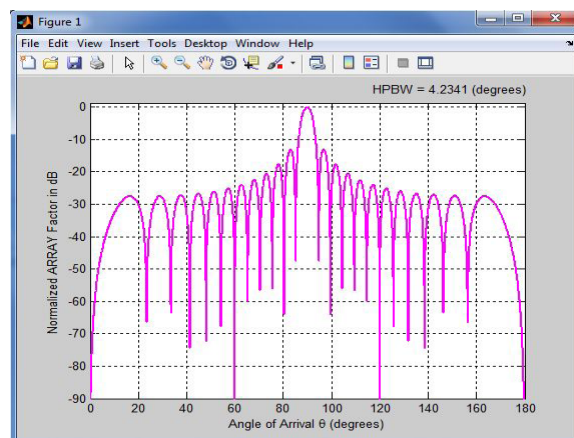**Fig 4 Original array pattern with 18 elements**

Fig 5 Original array pattern with 24 elements

Uniform array		Synthesised arrays using the Genetic Algorithm						
M=24		M=24		M=20	M=18	M=16	M=12	M=8
d=0.5λ		d=0.886λ		d=0.896λ	d=0.912λ	d=0.922λ	d=0.938λ	d=0.944λ
a1	1	a1	0.4401	0.1200	0.3189	0.2540	0.2630	0.0850
a2	1	a2	0.5880	0.2600	0.3579	0.4739	0.2816	0.0828
a3	1	a3	0.5788	0.2641	0.3685	0.4401	0.3189	0.1161
a4	1	a4	0.6483	0.3817	0.4403	0.5880	0.3579	0.1558
a5	1	a5	0.7758	0.5121	0.4310	0.5788	0.3685	
a6	1	a6	0.7796	0.6461	0.5265	0.6483	0.4403	
a7	1	a7	0.8879	0.7727	0.5701	0.7758		
a8	1	a8	0.8893	0.8030	0.6136	0.7796		
a9	1	a9	0.9230	0.9870	0.5650			
a10	1	a10	0.9656	0.9780				
a11	1	a11	0.9400					
a12	1	a12	0.9900					
SLL=-13.21dB		SLL=-32.02dB		SLL=-31.66dB	SLL=-26.77dB	SLL=-24.94dB	SLL=-18.75dB	SLL=-15.54dB
				Reduction of elements =16.66%	Reduction of elements =25%	Reduction of elements =33.33%	Reduction of elements =50%	Reduction of elements =66.66%

Table I:Element spacing, SLL and Excitation coefficients of the synthesised arrays using with 4,20,18,16,12 and 8 antenna elements, compared to the analytical 24-elements λ/2 uniform array

Excitation Coefficients	Synthesized arrays using Genetic Algorithm		
	M=40	M=32	M=28
	d=0.846λ	d=0.866λ	d=0.876λ
a1	0.2209	0.0850	0.2630
a2	0.1045	0.0828	0.2816
a3	0.2800	0.1161	0.3189
a4	0.1540	0.1558	0.3579
a5	0.1240	0.2880	0.3685
a6	0.1320	0.2538	0.4403
a7	0.2630	0.2540	0.4310
a8	0.2816	0.4739	0.5265
a9	0.3189	0.4401	0.5701
a10	0.3579	0.5880	0.6136
a11	0.3685	0.5788	0.5650
a12	0.4403	0.6483	0.6086
a13	0.4310	0.7758	0.7940
a14	0.5265	0.7796	0.7784
a15	0.5701	0.8879	
a16	0.6136	0.8893	
a17	0.5650		
a18	0.6086		
a19	0.7940		
a20	0.7784		
	SLL=-33.18dB	SLL=-32.88dB	SLL=-32.54Db

Table II: Excitation Coefficients for the synthesized antenna array with 40,32,28 elements using Genetic Algorithm

Synthesised radiation patterns using RGA for N=8,12,16,24,28,32,40 :

Genetic algorithm is applied to obtain the low side lobes of uniform linear antenna array of 8,12,16,18,20,24,28,32,40 elements. The array factor is calculated using eq. (1) and the fitness function is evaluated by the equation. The synthesized radiation pattern of 40 elements is shown in fig 8 and the side lobe level is -33.18dB.

The spacing between the elements is optimized using the genetic algorithm toolbox. The element spacing and corresponding excitation coefficients are shown in table II. The synthesized array patterns using genetic algorithm of 8,12,16,18,20,24,28,32,40 elements are shown in figures 6,7,8,9,10,11,12,13 respectively. The uniform array of 24 elements has the side lobe level of -13.21 dB is shown in the fig 7.The results are obtained using the MatLab simulator.
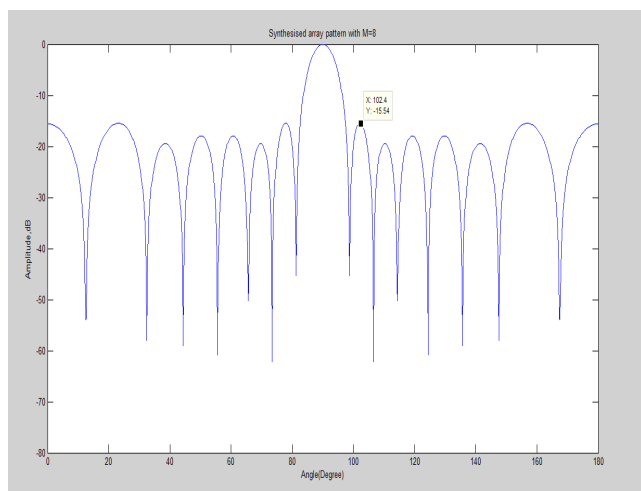
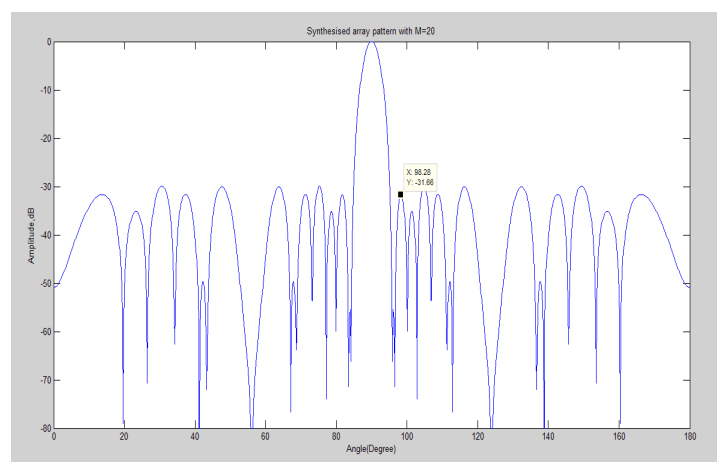Fig 6 The synthesized radiation pattern using GA with 8 elements

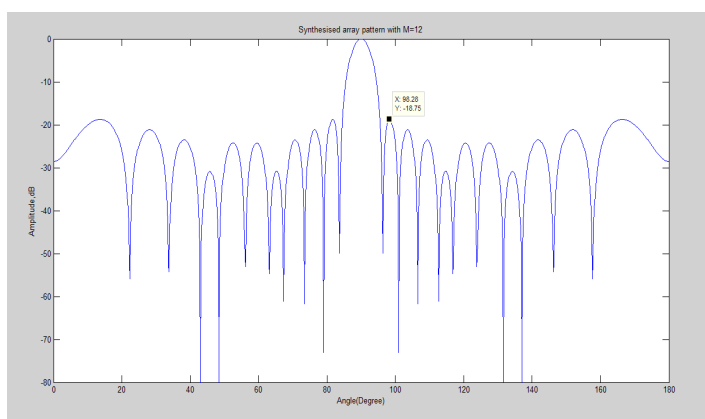Fig 7 The synthesized radiation pattern using GA with 12 elements

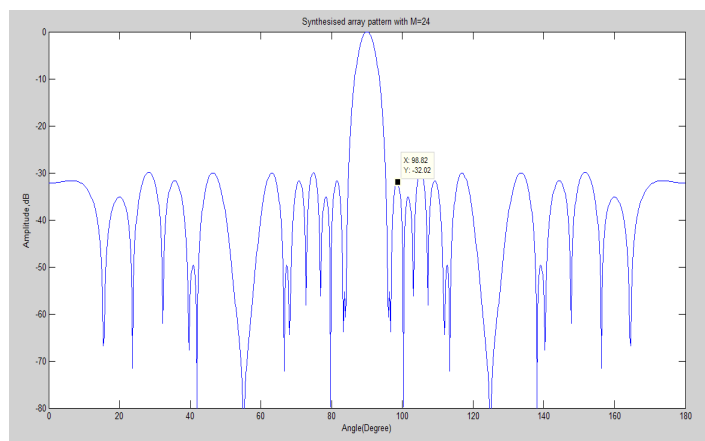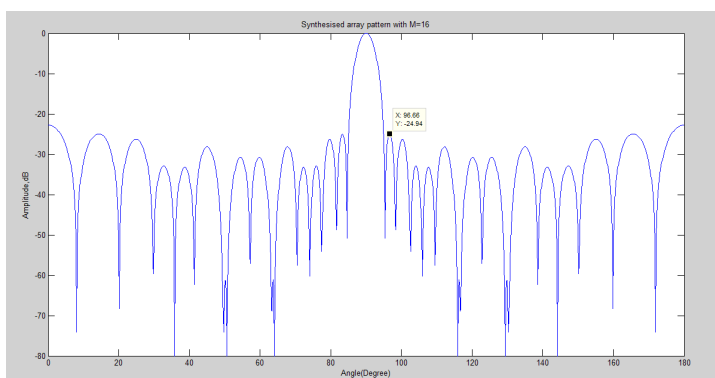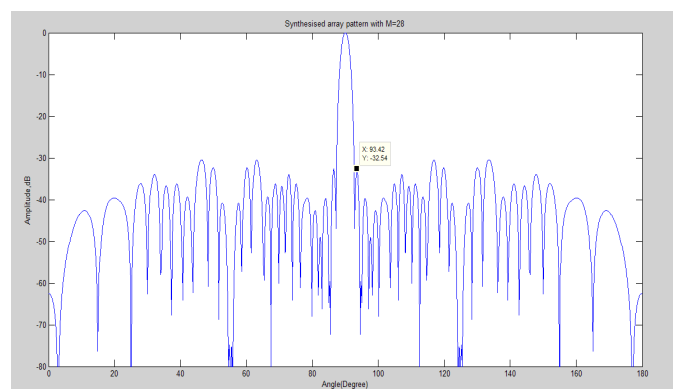Fig 8 The synthesized radiation pattern using GA with 16 elements

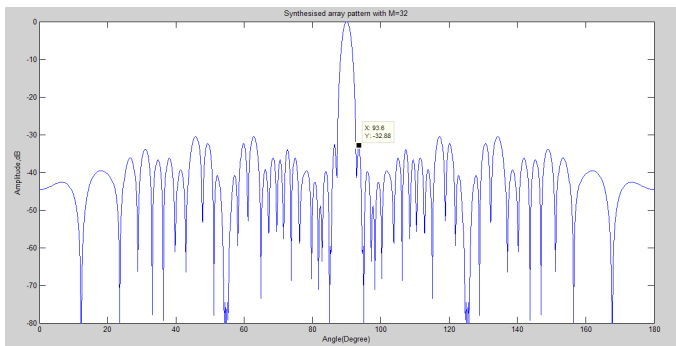Fig 9 The synthesized radiation pattern using GA with 20 elements

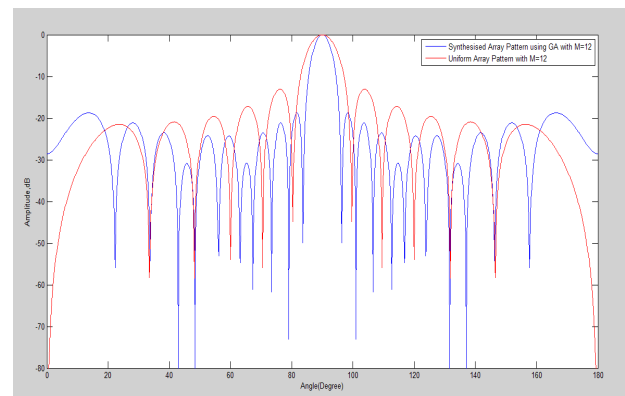Fig 10 The synthesized radiation pattern using GA with 24 elements

Fig 11 The synthesized radiation pattern using GA with 28 elements

Fig 12 The synthesized radiation pattern using GA with 32 elements

Fig 13 The synthesized radiation pattern using GA with 40 elements

Comparison of synthesized Radiation pattern (RGA) with Uniform excited antenna array for N=8,12,16,24,32,40 :

The corresponding synthesized patterns compared with the respective uniform array patterns are shown in the figures 14,15,16,17,18,19,20,21,22 respectively. The synthesized radiation pattern using genetic algorithm technique has more side lobe level than the conventional uniform array pattern is observed. The excitation coefficients and the spacing between the elements are shown in the tables I and II. The results are obtained using MatLab simulator.
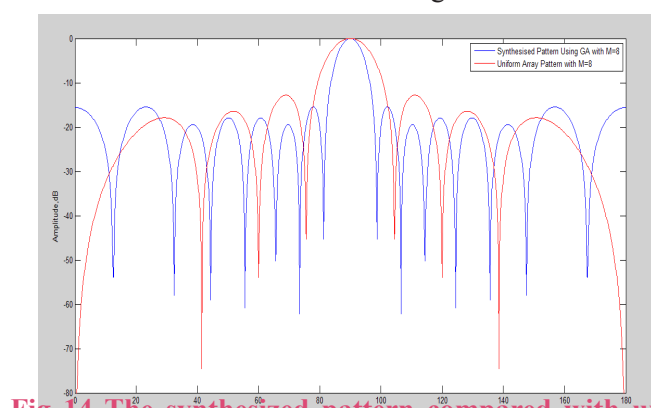

Fig 14 The synthesized pattern compared with uniform array pattern for M=8 elements
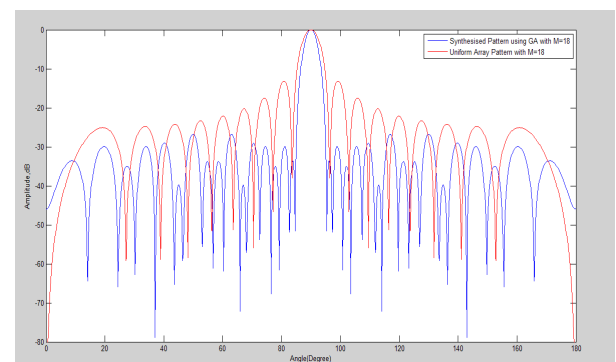

Fig 15 The synthesized pattern compared with uniform array pattern for M=12 elements
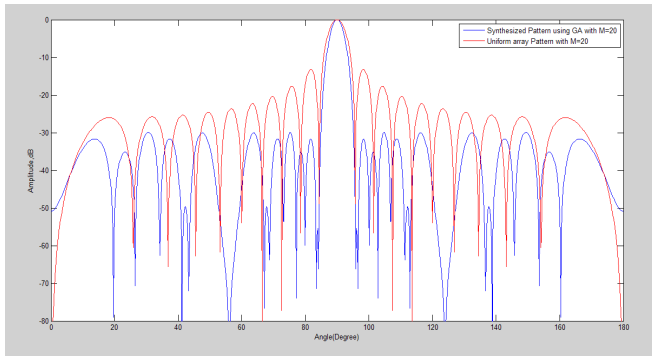

Fig 16 The synthesized pattern compared with uniform array pattern for M=16 elements

Fig 17 The synthesized pattern compared with uniform array pattern for M=18 elements

Fig 18 The synthesized pattern compared with uniform array pattern for M=20 elements.
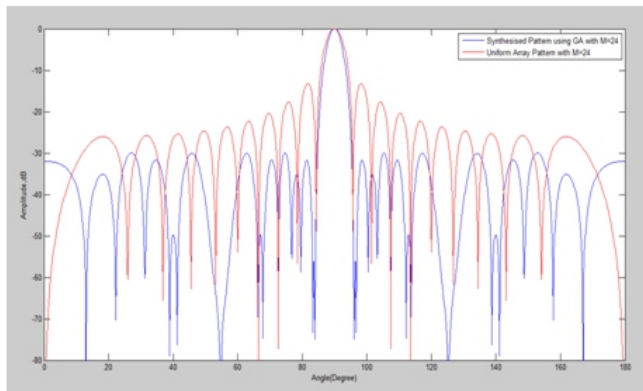

Fig 19 The synthesized pattern compared with uniform array pattern for M=24 elements.
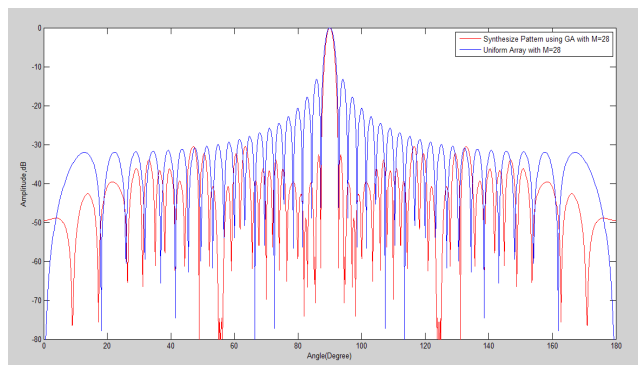

Fig 20 The synthesized pattern compared with uniform array pattern for M=28 elements
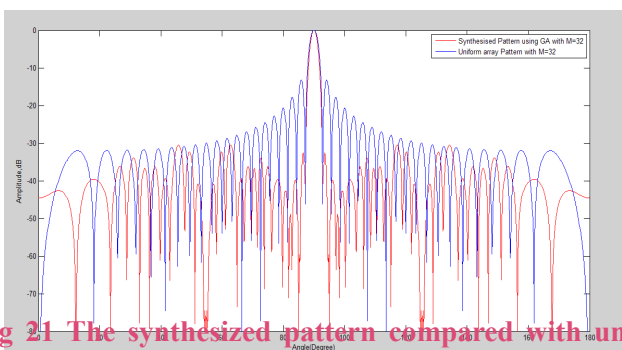

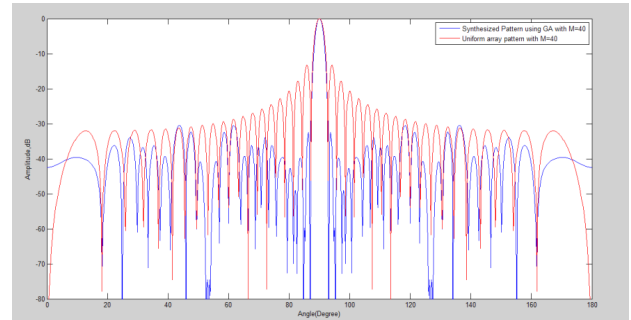**Fig 21 The synthesized pattern compared with uniform array pattern for M=32 elements**

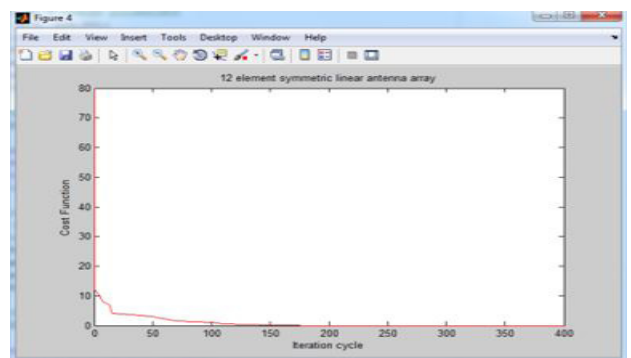**Fig 22 The synthesized pattern compared with uniform array pattern for M=40 elements**

Figure 23 Convergence Curve of RGA for 12 element symmetric linear antenna array with excitation coefficients and spacing
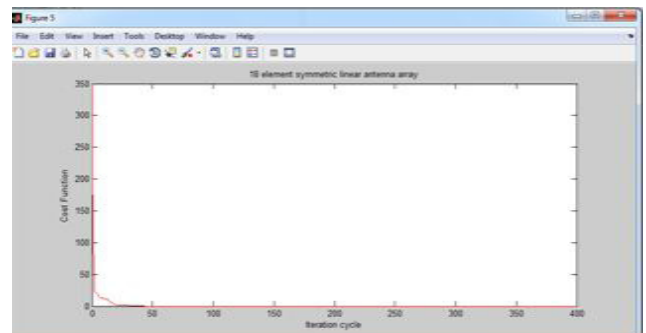

Fig. 24 Convergence Curve of RGA for 18 element symmetric linear antenna array with excitation coefficients and spacing.

V. CONCLUSION :

In this project, the various aspects of the antennas and antenna arrays are studied. The radiation pattern of antenna arrays has many aspects in order to obtain the desired pattern with minimum side lobe level. Genetic algorithms has been used for the optimization of arrays for this purpose and implemented in Matlab. The spacing between the antenna elements is optimized using Genetic Algorithm Tool box. The synthesis of linear antenna array using genetic algorithm to reduce the side lobe level is

performed. The excitation coefficients for different set of elements i.e.,40,32,28,24,20,18,16,12,8 are determined using genetic algorithm.The obtained coefficients are used to optimize the antenna radiation pattern.The synthesized radiation pattern is generated and the low side lobe level is obtained.The synthesized radiation pattern is compared with the conventional uniform antenna array to visualize the difference in the side lobe level obtained using genetic algorithm.

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