Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

# Pattern Synthesis Using Particle Swarm Optimization

S. KrishnaVeni[1], G.S.K. Gayatridevi[2]
[1]*Department of ECE, Dadi Institute of Engineering and Technology*
[2]*Dept of ECE, Malla Reddy Institute of Engineering and Technology*

**Abstract:** The main aim of this work is to generate the ramp shaped radiation pattern from an array of isotropic radiating elements using Particle Swarm Optimization. It is focused to realize the patterns, for meeting its demand and requirements in radar and satellite communication systems for tracking applications. There are many analytical methods available for beam shaping, but PSO acquires its significance importance and capable of solving complicated search problems. Results are obtained for finite ramp width by varying element number. All the results are simulated using matlab software. The simulated results are more close to the desired radiation patterns. The optimized data and radiation patterns are extremely useful for array designers. Any array can be designed for an application specific.

**Key words :** Antenna Array Synthesis, Beam Shaping, Ramp pattern, Particle Swarm Optimization.

## I. INTRODUCTION

Antennas are commonly employed to transmit energy to their far field region. Arrays offer the unique capability of electronic scanning of the main beam. By controlling the phase and amplitude excitation of each radiating element, the radiation beam direction and the shape of the beam radiated by the array can be dynamically controlled.

Most of these techniques have been carried out for equally spaced linear arrays and unequally spaced linear arrays. The shape of the desired pattern can vary widely depending on the application. Narrow beams are useful for point to point communication as well as high resolution radars. For wider angular coverage of mobile communication, flat-top or sector beams are preferred.

Many synthesis methods can be found in the literature to generate the desired beam shapes. The classical synthesis methods are Wood-ward Lawson and Fourier transform method. In Woodward method [1] the excitation coefficients are chosen such that its field strength is equal to the amplitude of the desired pattern at its corresponding sample point. The drawback of Woodward method is that it lacks control over the side lobe level in the tradeoff region of the entire pattern. Fourier transform method [2] is used to design the excitation distribution of either a continuous line source or a discrete array for a specified radiation pattern.

In the literature, there are many works related with the antenna array synthesis. The pattern synthesis technique proposed by [3] depends on the controlled location of zeros of pattern function in the complex pattern plane with the relative displacement of these zeros from real Sinθ axis. The locations are approximately constrained by known zero locations of fan or sector pattern.

Attempts has been made to develop a nonlinear phase function for the generation of $CSc^2$ patterns [6]. The pattern synthesis carriedout for equi- spaced linear arrays [4] has some control in the trade in region and also in the trade- off region. Also reported in [5] sum, difference and shaped beam synthesis using Poisson sum expansion of the array factor.

To avoid the complexity involved in conventional analytical synthesis techniques, today a lot of research on antenna array synthesis is being carried out using Evolutionary optimization techniques like Genetic algorithm(GA), Particle Swarm Optimization(PSO), Simulated Annealing(SA), Ant colony Optimization(ACO) and etc. The feeding network amplitudes and phases are optimized [7] using modified tabu search algorithm to obtain the desired shaped pattern.

From the above discussion, it is evident that no work is reported on realization of ramp patterns using optimization techniques. The main aim of this paper is to obtain the ramp patterns from an array of isotropic radiating elements using Particle Swarm Optimization. For fast scanning applications, the maximum of the array synthesis is based on control of the phase excitation of the elements. In addition to the above, proper amplitude excitation of the elements is used to control the beam width and sidelobe level. In the present work, both amplitude and phase excitations of elements are optimized to achieve the desired beam shape.

## II. PARTICLE SWARM OPTIMIZATION

Optimization is a process that finds the optimal solution among the alternativesfor any givenproblem.The Particle Swarm Optimizer (PSO) belongs to a special group of stochastic algorithms that is inspired by the stochastic phenomenon in nature[9].

In the present synthesis, amplitude and phase of each element are optimized to obtain the desiredbeams.It is explained in step by step manner.

**Step 1:** Select parameters to be optimized and define the fitness function.

The amplitude and phase of each element in the array are considered as parameters. The general form of the fitness function is given by

**Fitness function** = $min(w_1\, e_1 + w_2\, e_2)$

Each particle is represented as

$$X_i^k = [Ax_{i1}^k, Ax_{i2}^k, , \dots . Ax_{im}^k, \varphi x_{i(m+1)}^k, \varphi x_{i(m+2)}^k, \dots . \varphi x_{id}^k] \qquad (1)$$

Here m=d/2

Where $\varphi x$ and $Ax$ represents the parameters to be optimized and $\varphi x_{id}^k$ is the position of the $i^{th}$ particle with respect to $d^{th}$ dimension or it is value of $d^{th}$ optimized parameter in $i^{th}$ candidate solution. The number of such antenna configurations represents the population.

Here, it is represented as

$$pop^k = [X_1^k, X_2^k, X_3^k, \dots . X_n^k] \qquad (2)$$

$pop^k$ is the set of n particles in the swarm at iteration k.

**Step 2:** Generate velocities to all particles in the population randomly in the D-dimension space.

Particle velocity $V_i^k$ is the velocity of the particle *i* at iteration *k*. It can be described as

$$V_i^k = [Av_{i1}^k, Av_{i2}^k, \dots . Av_{im}^k, \varphi v_{i(m+1)}^k, \varphi v_{i(m+2)}^k, \dots . \varphi v_{id}^k] \qquad (3)$$

And velocity values are restricted to some minimum and maximum values, namely

$$V_i^k = [V_{min}, V_{max}] \text{ where } V_{min} = -V_{max} \qquad (4)$$

**Step 3:**Evaluate the fitness of each particle.

**Step 4:**Assign the obtained fitness value as Pbest of corresponding particle. The best position associated with the best fitness value of the particle i obtained so far is called particle best (Pbest).

**Step 5:**Sort all Pbest values. Best of all Pbest values becomes Gbest.

**Step 6:**Update particle's position and velocity using following equations.

$$V_{id}^k = w(k) * V_{id}^{k-1} + c1(k) * r1_{id}^k * \left(pb_{id}^{k-1} - X_{id}^{k-1}\right) + c2(k) * \left(1 - r1_{id}^k\right) * \left(gb_{id}^{k-1} - X_{id}^{k-1}\right)$$

$$if \quad V_{id}^k > V_{\max}^d \quad or \quad V_{id}^k < V_{min}^d \quad then \quad V_{id}^k = U(V_{min}^d, V_{max}^d) \qquad (5)$$

Position vector is updated as

$$X_{id}^k = r2_{id}^k * X_{id}^{k-1} + \left(1 - r2_{id}^k\right) * V_{id}^k \qquad (6)$$

The linearly decreasing inertia weight, w is given by

$$w(k) = \frac{w_0 * (w_0 - w_1) * K}{I} \qquad (7)$$

Here k= Search number

**Step 7 :**Evaluate the fitness of each particle at its new position and velocity

**Step 8:**If the fitness of the particle is better than Pbest, then replace Pbest with new fitness value.

 

**Step 9:** Best of all Pbest becomes current Gbest.
**Step 10:** Check for stopping criteria, if yes stop giving Gbest, optimal solution. Otherwise, go to **Step 6** and repeat the process.

Usually,termination occurs when the number of iterations reaches a pre- determined value. Table 1 shows the control parameters of PSO.

***Table 1.Parameter setup of PSO:***

| Parameter | Value |
|---|---|
| Swarm size | 40 |
| c1 and c2 | 2.05 |
| $w_0$ | 0.9 |
| $w_1$ | 0.4 |
| K | 0.729 |
| Maximum iterations | 2000 |

## III. FORMULATION

The linear array is the one of the most commonly used array structure owing to its simplicity and beam shaping property.

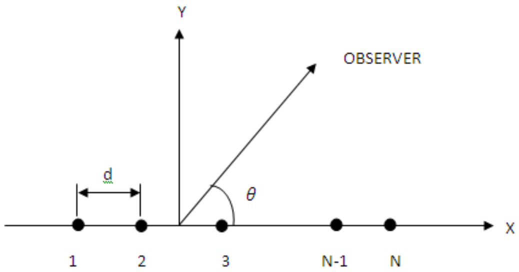


Fig.1. Linear array

Consider a linear array with 'N' isotropic elements spaced at a distance of half wavelength (λ/2), its far-field pattern is represented by

$$E(u) = 2\sum_{n=1}^{N/2} A(x_n)\, e^{j(kL(u-u_0)x_n+\varphi(x_n))} \quad (7)$$

Here
$A(x_n)$ = Amplitude excitation of $n^{th}$ element
$\phi(x_n)$ = Normalised phase excitation of $n^{th}$ element
$k = 2\pi/\lambda$
L= length of the array
$u = \sin\theta$
$u_0 = \sin\theta_0$
$\theta_0$ = scan angle
$x_n$ = Element position in the array.

A. Ishimaru (8) has suggested a spacing function, which is useful for odd and even number of elements in the array. It is given by

$$x_n = \left(\frac{2n-N-1}{N}\right)$$

 

In the synthesis, the main aim is that the beam shape should approach the optimization target in the shaped region.

**Initialization:**

To generate the desired pattern, limit the amplitudes of elements from 0 to 1 and phase values in between –π and π. Cost function determines the direction of evaluation and it has great influence on obtained optimal solution.

The desired ramp pattern is represented by

$$F(u) = \begin{cases} \frac{u}{u_0} & ; 0 \leq u \leq u_0 \\ 0 & ; \text{elsewhere} \end{cases} \quad (8)$$

Here $u_0$ =width of the finite ramp

This is sampled at fixed number of values of 'u'. At the same points the error between desired pattern and obtained pattern is evaluated.

The error in the main beam region is calculated as

$$E_1(u) = \begin{cases} E(u) - F(u) & ; 0 \leq u \leq u_0 \\ 0 & ; \text{elsewhere} \end{cases}$$

Least mean square error of the main beam region is $e_1 = \left[\frac{1}{Q}\sum_{i=1}^{Q}|E_1(u_i)|^2\right]^{\frac{1}{2}}$

Here 'Q' represents the number of sampling points in the main beam region.

The error in the sidelobe region is calculated as

$$E_2(u) = \begin{cases} E(u) - F(u) & ; 0 \leq u \leq u_0 \\ 0 & ; \text{elsewhere} \end{cases}$$

Least mean square error in the sidelobe region is $e_2 = \left[\frac{1}{S}\sum_{i=1}^{S}|E_2(u_i)|^2\right]^{\frac{1}{2}}$

Here 'S' represents the number of sampling points in the sidelobe region

***Cost function*** = $min(w_1\, e_1 + w_2\, e_2)$ **(9)**

Here $w_1$ and $w_2$ represents the weights of $e_1$ and $e_2$ respectively and it should be such that

$$\sum_{i=1}^{2} w_i = 1$$

## IV. SIMULATION RESULTS

Particle Swarm optimization is applied to obtain the ramp patterns from a linear array of isotropic elements. The spacing between the elements is set to λ/2. The array factor is calculated using equation (7) and the desired ramp pattern is evaluated by equation (8).The fitness function is evaluated by the equation(9).Table 2.2 shows the values of control parameters responsible for beam shaping. Results are obtained for ramp width ($u_0$) of 0.4 by varying number of elements. The excitations obtained through algorithm are used in the calculation of array factor and simulation results are plotted for N=20, 40 and 80 elements..

From the results obtained in the present work, the realized patterns are optimum and are very close to the desired ones with small ripples. Also it can be observed that all patterns are generated with lowest possible sidelobe levels.

 

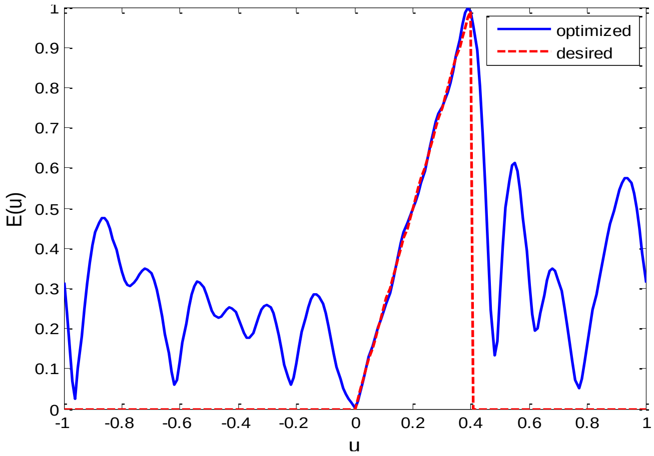


***Figure.2. Radiation pattern for N= 20 elements***

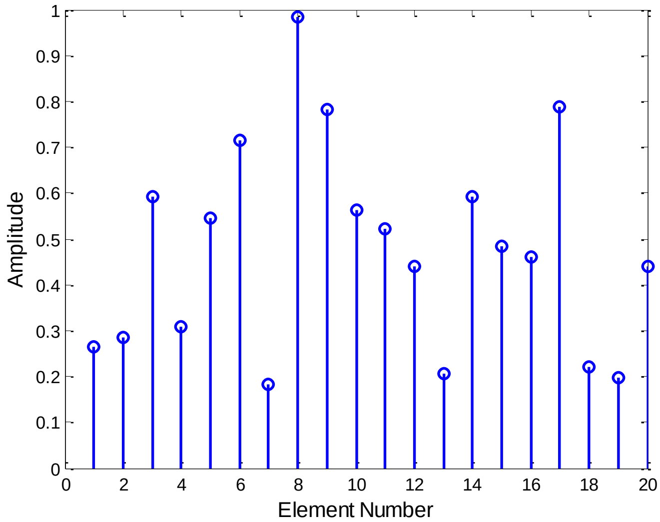


***Figure.3. Amplitude Distribution for N= 20 elements***

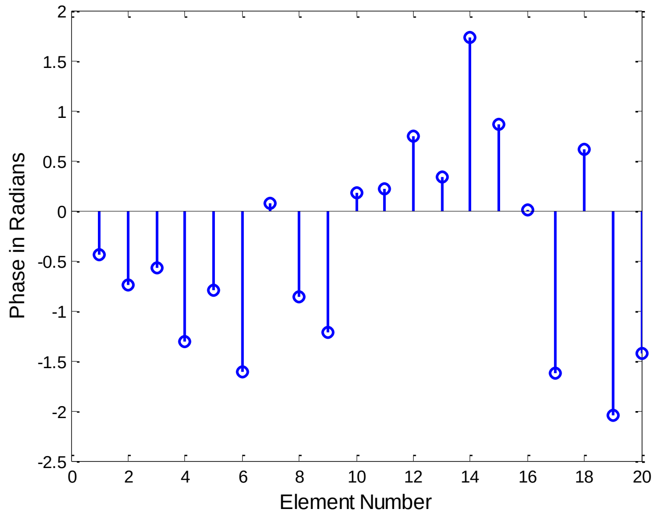


***Figure.4. Phase Distribution for N= 20 elements***

 

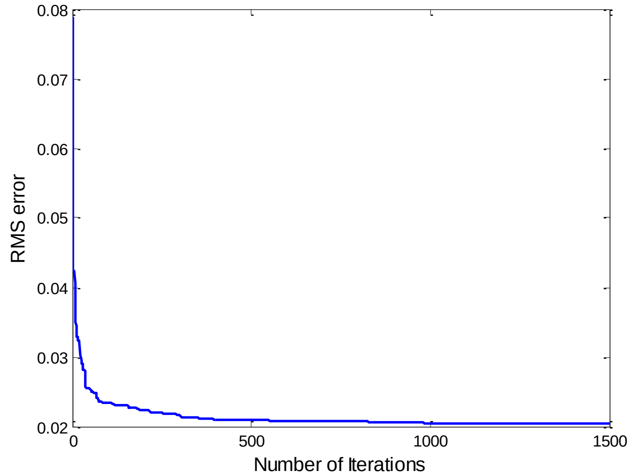


***Figure.5. Convergence plot of 20 elements***

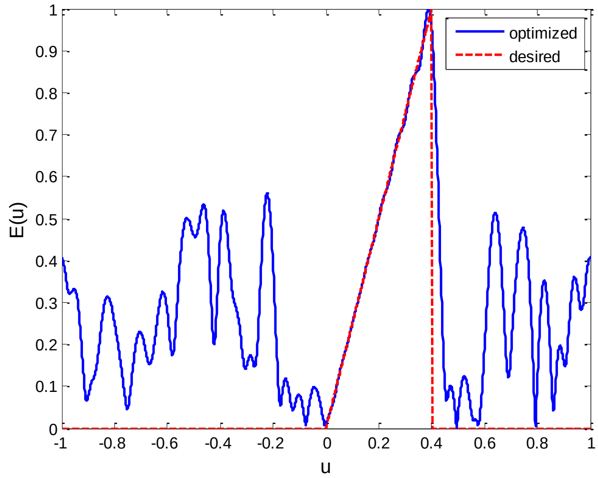


***Figure.6. Radiation pattern for N= 40 elements***

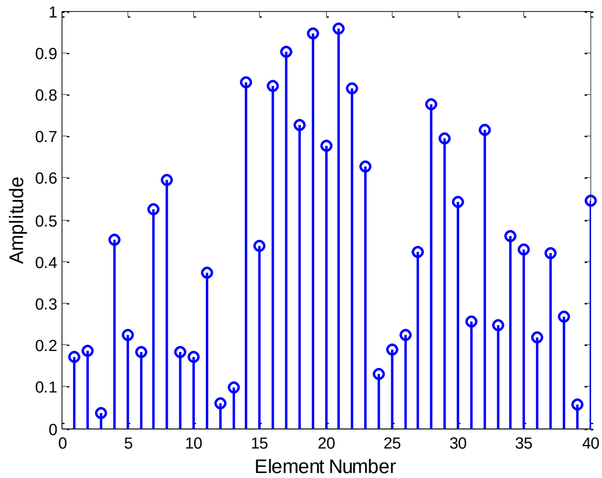


***Figure.7. Amplitude Distribution for N= 40 elements***

 

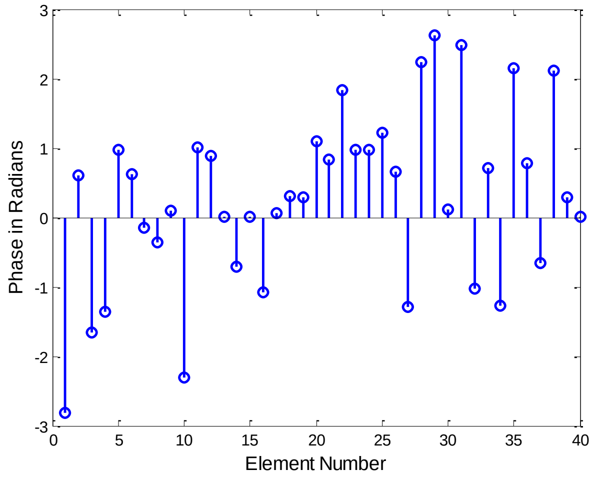


***Figure.8. Phase Distribution for N= 40 elements***

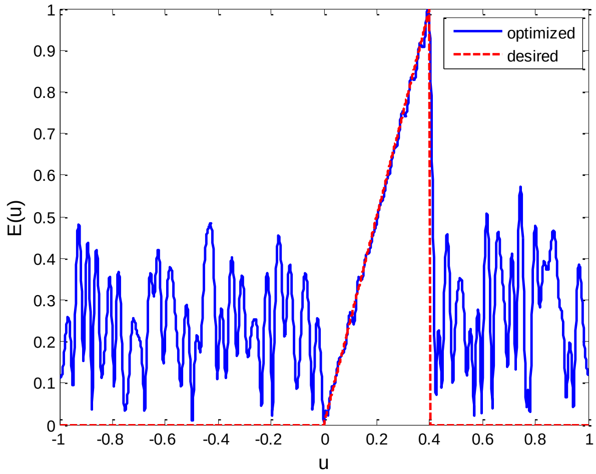


***Figure.9. Radiation pattern for N= 80 elements***

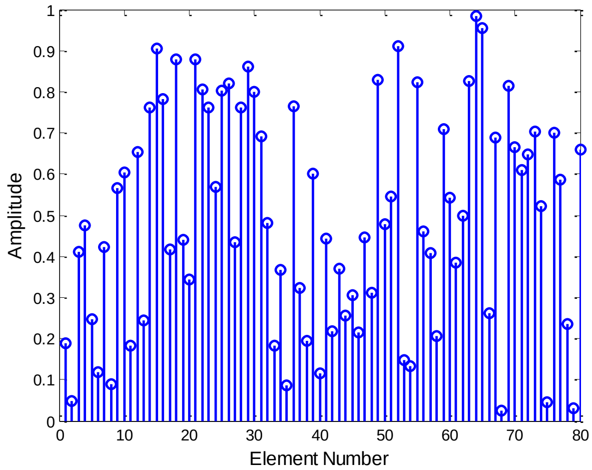


***Figure.10. Amplitude Distribution for N= 80 elements***

 

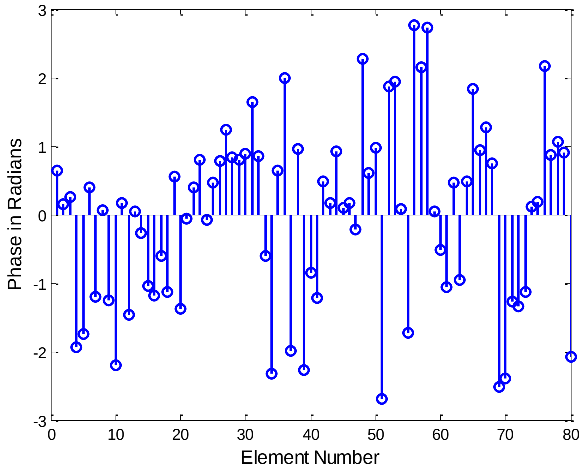


***Figure.11. Phase Distribution for N= 80 elements***

## V. CONCLUSION

The design of non-uniformly excited linear antenna array with uniform spacing for the generation of ramp pattern has been described using a Particle Swarm Optimization. It is evident from the results presented; the realized patterns are optimal and are very close to the desired ones with minute ripples. Also, it can be observed that, ripples in the trade-off region are also properly controlled. The generated patterns are very useful in point to point communication. The lowest side lobe levels reduce problems due to EMI. Although the present work is focused on array of isotropic radiating elements, it can be extended for practical radiating elements. This method is suitable for small and large arrays.

## REFERENCES

1. G. S. N. Raju (2005), "Antennas and wave propagation," Pearson Education,
2. C. A. Balanis (1997), "Antenna Theory Analysis and Design ,"2nd Edition, John Wiley & Sons Inc., New York,.
3. R. F. Hyneman and R. M. Johnson (1967) "A technique for the synthesis of shaped beam radiation patterns with approximately equal percentage ripple," IEEE Trans. Antennas and Propagation, vol. AP-15, pp. 736- 743.
4. R.S. Elliot and G.J. Stern (1984), "A new technique for shaped beam synthesis of equi-spaced arrays," IEEE Trans. Antennas and Propagation, Vol.AP-32, pp 1129-1133.
5. Homayoon Oraizi and MojtabaFallahpour (2011), "Sum, Difference and Shaped beam pattern synthesis by Non-Uniform spacing and Phase control," IEEE Transcations on Antennas and Propagation, vol.59, No.12, pp.4505-4511.
6. G.S.N.Raju and A. Chakraborty (1986), "Synthesis of non linear phase function for the Generation for $CSc^2$ patterns.," IEMA Journal, pp 37-38.
7. Akdagli, A. and K. Guney (2003), "Shaped-beam pattern synthesis of equally and unequally spaced linear antenna arrays using a modified tabu search algorithm," Microwave Opt. Technol. Lett.,Vol. 36, No. 1, pp 16-20,.
8. A. Ishimaru (1962), "Theory of unequally spaced arrays", IRE Transactions on Antennas and Propagation, Vol, AP-10, pp.691-702.
9. J. Kennedy and R. C. Eberhart, 1995, "Particle swarm optimization," IEEE Proc., Int. Conf. Neural Networks,Vol.4, pp. 1942–1948.