ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 9, September 2013

SLL REDUCTION IN APERIODIC LINEAR ARRAY ANTENNA SYSTEM WITH SCAN ANGLES

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ABSTRACT: In modern wireless communication system one of the criteria is control over the antenna beam pattern. Antenna array provides better control over the beam pattern and provides flexibility of scanning in the required direction. The important parameter for consideration in array is spacing between elements. As the spacing between elements is increased beyond half wavelength, the steerability from broadside will significantly reduce due to appearance of grating lobe. In this paper a model of thinned aperiodic linear phased arrays is presented. Differential Evolution algorithm is used for synthesizing the performance of peak side lobe levels

Keywords: Antenna arrays, Differential Evolution algorithm, Driving point impedance, Scan angle, thinned aperiodic arrays.

I.INTRODUCTION

The traditional way of creating linear thinned array is by exciting a number of elements in a uniform spaced linear array. The first thinned array was created by removing elements randomly or by trial and error **Ошибка! Источник ссылки не найден.**, **Ошибка! Источник ссылки не найден.** . The problem with this arbitrary technique was poor side lobe suppression. This is due to the non-optimal locations of radiating elements. The recent work in thinned arrays made use of different optimization algorithms to remove elements in such a way to have minimum peak side lobe level. Most work on thinning arrays is concentrated only in optimizing an array with low side lobe levels at broadside. As these arrays are scanned a small angle away from broadside, grating lobe appears **Ошибка! Источник ссылки не найден.**, **Ошибка! Источник ссылки не найден.**. This paper presents a model of thinned aperiodic linear phased arrays for various scan angles. DE algorithm is used for synthesizing the performance of peak side lobe levels. The optimization process causes the perturbation added to each element in periodic array to create an aperiodic array.

II. ANTENNA ARRAY CONFIGURATION

For a single element antenna the dimension of element gives the aperture. For linear array, the aperture is decided by the distance between two farthest elements. With the help of antenna arrays pattern control and beam scanning are possible. A basic array geometry and coordinate system is shown in Fig. 1.

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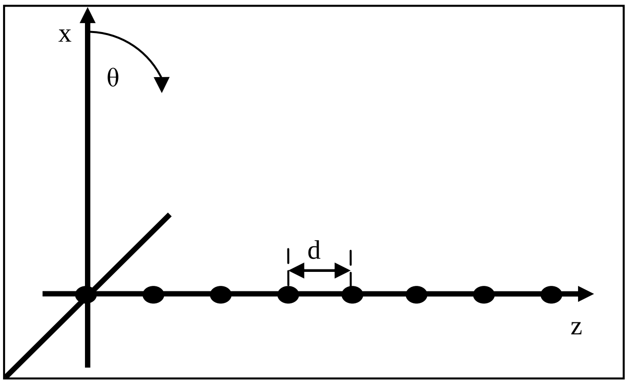

Fig. 1 Array geometry and coordinate system

N elements are arranged in a straight line along z-axis with uniform element spacing '*d*'. If the elements in the array are isotropic sources, then the radiation pattern of array is described by the array factor as **Ошибка! Источник ссылки не найден.**

$$AF(\theta) = \sum_{n=0}^{N-1} I_n e^{ik d_n (sin\theta - sin\,\theta_0)} \qquad (1)$$

Where AF is array factor, k is free space wave number, θ is the angle measured from broadside, θ_0 is the beam scan angle from broad side and I_n is the excitation current of n^{th} element in the array and d_n is distance of n^{th} element from origin. For uniform array

$$d_n = nd \qquad (2)$$

III. SCAN ANGLE

The maximum scan angle for uniform array without grating lobe is given by

$$\theta_{max} = sin^{-1}\left(\frac{\lambda}{d} - 1\right) \qquad (3)$$

Where θ_{max} is the maximum scan angle from broadside From Eq. (3), it can be seen that the scanning range is between 0^o and 90^o for element spacing d, between λ and $\lambda/2$.
Limited scan range is the drawback due to grating lobe appearance in modelling of uniform arrays.
To construct thinned periodic array with same aperture, the uniform spacing between array elements is selected beyond the half wavelength. The array has lesser elements in the given aperture so fewer phase shifters are required. But the steerability of the array is reduced.

IV. INCREASED STEERABILITY USING THINNED APERIODIC PHASED ARRAYS

The maximum scan angle in thinned periodic array is limited by grating lobe. These grating lobes are the result of superposition of the element patterns when the array is steered to an angle greater than that given by eq. (3). To overcome this, the element locations in periodic array can be perturbed in such a way so that the pattern from each element is in phase. After perturbation, the element locations are given as

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$$d_n = nd + \delta d_n$$

Where δd_n is the perturbation.

Fig. 2 shows the thinned aperiodic phased array (grey elements) obtained by adding a perturbation δd_n to the position of each element in the periodic array (black elements). An N element array require N separate positional perturbations. The solution space of this problem is very large, so we need optimization called Differential Evolution (DE).

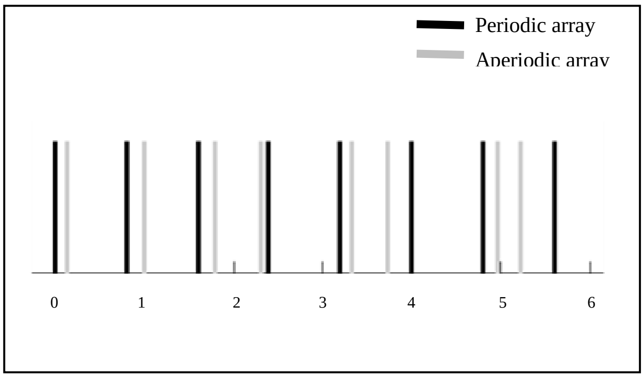

Fig. 2 The geometry of thinned aperiodic array (grey elements) created by adding perturbations to the thinned periodic array (black elements)

In this paper the optimization process is developed based on equation (4) for generating arrays that have radiation pattern with reduced grating lobe. The perturbation limits consider for aperiodic model is $-0.4\lambda \leq \delta d_n \leq +0.4\lambda$.

V. DIFFERENTIAL EVOLUTION

DE algorithm is a global search technique which was described in **Ошибка! Источник ссылки не найден.**, **Ошибка! Источник ссылки не найден.**.

DE notations used in this paper are

Ps = size of population, *t* = no. of generations, *F* = Mutation factor, *CR* = cross over rate, $X_{i\,(t)}$= target vector.

The initialization of population is done after lower and upper bound for parameters were specified. In D- dimensional search space, the initial population is given by

$$P_t = \{X_{1\,(t)}; X_{2\,(t)}; \ldots \ldots \ldots \ldots X_{P_S(t)}\} \qquad (4)$$

Where $X_{i\,(t)}$ is target vector and is given by

$$X_{i(t)} = [x_{i,1(t)}, x_{i,2(t)}, \ldots \ldots x_{i,D(t)}] \qquad (5)$$

After the initialization, the evaluation of the fitness of each population is done with the help of Fitness Function.

After fitness function evaluation, the best crossover solution is used by the mutant vector, given by

$$V_i = X_{best} + F.(X_{r1} - X_{r2}) for\ (i \neq r1 \neq r2) \qquad (6)$$

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Where $V_{i(t)}$ is mutant vector, X_{r1}, X_{r2} are random but mutually different members in the population. X_{best} is the individual vector that has the best fitness value in the current population and mutation factor $F \in [0, 2]$ controls the amplification of the differential variation$(X_{r1} - X_{r2})$.)
After mutation, each vector is crossed with a mutant vector to obtain the trial vector

$$U_{i\,(t)} = \left[u_{i,1(t)}, u_{i,2(t)}, \dots \dots u_{i,D(t)}\right]$$

$$u_{i,j} = \begin{cases} v_{i,j} & if\ \left(rand_j(0,1) \le CR\right) or \\ & (j = jrand) \\ x_{i,j} & otherwise \end{cases}$$

$$where\ \ j = 1,2, \dots, D$$

Where $rand_j$ (0,1) is uniform random number between 0 and 1, Cross over rate, $CR \in [0, 1]$ and $jrand$ is a randomly chosen index to ensure that the trial vector U_i is not a duplicate of X_i.
After crossover operation, the selection process is described as follows. The fitness value of each trial vector $f\left(U_{i(t)}\right)$of each generation is compared to that of its corresponding target vector $f\left(X_{i(t)}\right)$ of the present generation in the current population.
The operation is expressed as:

$$X_{i(t+1)} = \begin{cases} U_{i(t)}, & if f\left(U_{i(t)}\right) \le f(X_{i(t)}) \\ X_{i(t)}, & otherwise \end{cases}$$

The best solution $X_{Gbest\,(t)}$ among P_S individuals at current generation is given by

$$X_{Gbest\,(t)} = \min_{i \epsilon \{1,\dots,P_S\}} f\left(X_{i(t+1)}\right) \tag{7}$$

After the generation of new population, the processes mutation, crossover and selection are repeated until termination conditions are satisfied.

VI. OPTIMIZATION RESULTS

The optimization procedure above was performed on an eight element array with a uniform spacing of 0.8λ with uniform current excitation. From equation (3) it can be seen that a thinned periodic phased array with this spacing has a maximum scan angle of 14.5^0 from broad side without grating lobes. In this paper, we consider main beam steered to 60^0 from broadside for optimization. The fitness function is peak side lobe level. Fig. 3 shows the result of normalized array factor obtained after DE algorithm in comparison to that of periodic array when main beam steered to 60^0 from broadside. The DE algorithm reduces the grating lobes with pattern having maximum side lobe level of -9.634 dB. So, the optimized array having steerability 0^0 to 60^0 from broadside having maximum side lobe level is -9.634 dB. Table-1 shows the perturbation values after optimization and Table-2 shows the element locations of periodic array and optimized aperiodic array (λ). We increase the scan angle up to 90^0, there is no grating lobes appeared. Fig. 4 shows the maximum side lobe level for aperiodic array in comparison to periodic array when main beam steered up to 90^0 from broadside .so there is complete scan range of 90^0 from broadside.

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Table I: The perturbation values after optimization

Element Numbers	Perturbations(λ)
1	0.3035
2	-0.1167
3	-0.2040
4	-0.0012
5	-0.0830
6	-0.1864
7	-0.0336
8	-0.3727

Table II: Element locations of periodic array and aperiodic array

Element Numbers	ELEMENT LOCATIONS OF PERIODIC ARRAY(Λ)	ELEMENT LOCATIONS OF APERIODIC ARRAY (Λ)
1	0.0	0.3035
2	0.8	0.6833
3	1.6	1.3960
4	2.4	2.3988
5	3.2	3.2830
6	4.0	3.8136
7	4.8	4.7664
8	5.6	5.2273

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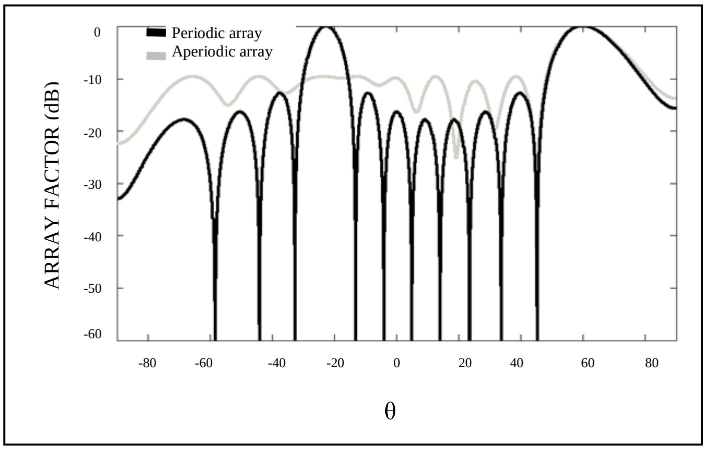

Fig. 3 Normalized array factors with N=8, d=0.8λ and main beam steered to 60^0

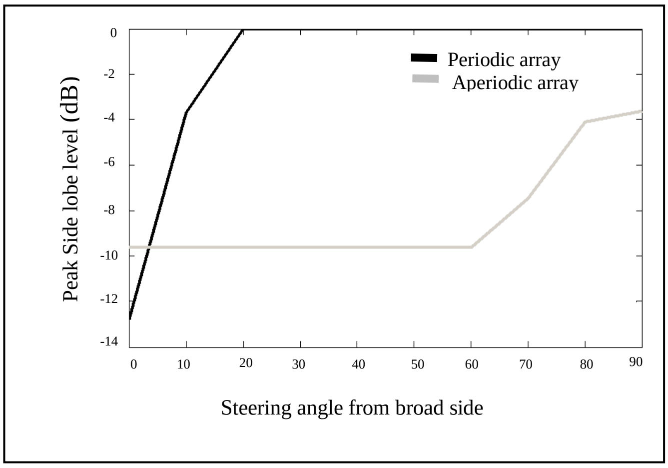

Fig. 4 Maximum sidelobe levels over different optimization values for N=8

VII. CONCLUSIONS

Using optimization technique the complete scan range of 90^0 from broad side can be achieved with SLL under specified limits. Varying the spacing between elements causes the change in mutual coupling environment, which has impact on the driving point impedance.

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