Performance Enhancement of Broadside Linear Antenna Array Using Big Bang Crunch Algorithm

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Abstract—the big bang crunch algorithm optimization [15] method is used in the reduction in side lobe levels of broadside linear antenna array. In this paper optimum value of current of each antenna element is determined which produces radiation pattern with minimum side lobe level. Big bang crunch algorithm is used, which enables search in broader space along randomly generated directions to produce new generations. This improves the performance significantly to attain the maximum reduction in side lobe level with minimum function calls. By using this approach, the reduction in side lobe level occurred in the range between -30 dB to -35dB.

*Keywords:*Side lobe level, Big bang crunch, linear antenna array, Array factor

I. INTRODUCTION

In many communication systems, point to point communication is used, for this highly directive beam of radiation is required. By arranging several dipoles in the form of an array or other antenna elements this can be achieved. Consider a linear array of *n* isotropic elements of equal amplitude and separated by distance *d.* The total field *E* at a far field point P in the given direction φ is given by,

$$E = 1 + e^{j\psi} + e^{2j\psi} + e^{3j\psi} + \cdots \dots \dots \dots \dots \dots + e^{(n-1)j\psi} \quad \dots.1$$

Where, Ψ is the total phase difference of the fields from adjacent sources. It is given by;

$$\psi = 2\pi \left(\frac{d}{\lambda}\right) cos\phi + \alpha$$

One method to achieve a highly directional beam is to use adaptive beamforming.Adaptive beam forming is an adaptive signal processing technique in which an array of antenna is exploited to achieve maximum reception in a look direction in which the signal of interest is present, while signal of same frequency from other directions which are not desired (signal of not interest) are rejected.

The characteristics of the antenna array can be controlled by thegeometry of the element and array excitation. But side lobereduction in the radiation pattern should be performed to avoid degradation of total power efficiency. Side lobereduction can be obtained using thefollowing techniques: 1) amplitude only control 2) phase onlycontrol 3) position only control and 4) complex weights (bothamplitude and phase control). The processofchoosingtheantenna parameters to obtain desired radiation characteristics, such as the specific position of the nulls, the desired side lobe level and beam width of antenna pattern is known as pattern synthesis. Analytical studies byStone who proposed binominal distribution, Dolph the Dolph-Chebyshev [5] amplitude distribution, Taylor [20], Elliot, VilleneuveHansen and Wood yard [12], Bayliss [13] laid the strong foundation on antenna array synthesis. Today a lot of research on antenna array is being carried out using various optimization techniques, to solve electromagneticproblems due to their robustness and easy adaptively.

II. BIG BANG CRUNCH OPTIMIZATION

The big bang crunch (BB-BC) optimization [15] method is based on two main steps. The first step is the Big bang phase where candidate solutions are randomly distributed over the search space and the next step is the Big Crunch where a contractions procedure calculates a center of mass for the population. The initial Big bang population is randomly generated over the search space just like the other evolutionary search algorithms. All subsequent Big bang phases are randomly distributed about the center of mass or the best fit individual in a similar fashion. In the working principle of this evolutionary method is explained as to transform a convergent solution to a chaotic state which is a new set of solutions. The procedure of the BB-BC optimization is given in the table below.

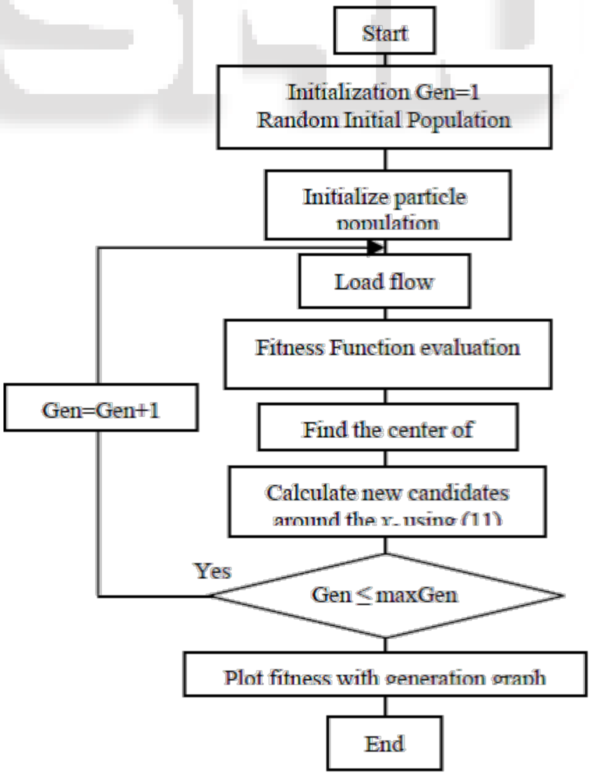

Fig. 1: Flowchart of Big Bang crunch [Optimization Algorithm [15]

Step 1 (Big bang phase)

An initial generation on N candidates is generated randomly in the search space.

Step 2

The cost function values of all the candidate solutions are computed.

Step 3 (Big crunch phase)

The center of mass is calculated. Either the best fit individual or the center of mass is chosen as the point of Big Bang Phase.

Step 4

New candidates are calculated around the new point calculated in step 3 by adding or subtracting a random number whose value decreases as the iterations elapse.

Step 5

Return to step 2 until stopping criteria has been met.

III. UNIFORM LINEAR ANTENNAARRAY

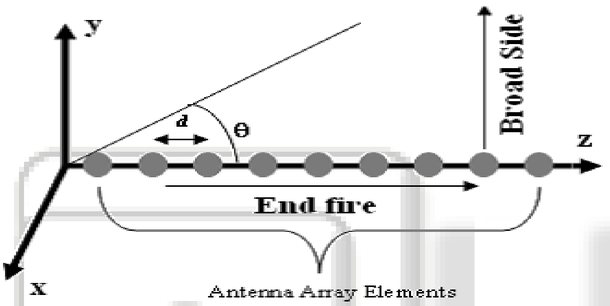

Fig. 2: Linear antenna array

In linear antenna array, all the antenna elements are arranged ina single line with equal spacing between them. In Fig 2 it is shown that the antenna elements are arranged withuniformly spacing, in a straight line along the z-axis, and N isthe total number of elements in the antenna array with thephysical separation distance as d, and the wave number of thecarrier signal is $k = 2\pi/\lambda$. When kd is equal to π (or $d = \lambda/2$)

Thephase shift between the elements experienced by the plane waveis $kd\cos\theta$. Weights can be applied to the individual antennasignals before the array factor (AF) is formed to control thedirection of the main beam. This correspondsto a multiple-input-single-output (MISO) system. The total AF is just the sum of the individual signals, given by the

$$AF = \sum_{n=1}^{N} E_n = \sum_{n=1}^{N} {e_n}^{jk}$$

Where $E_n = {e_n}^{jK}$and $K = (nkd\cos\theta + \beta_n)$ is the phase difference. βn is the phase angle. Final simplification of this equation is by conversion to phasor notation. Only the magnitude of the AF in any direction is important, the absolute phase has no bearing on the transmitted or received signal. Therefore, only the relative phases of the individual antenna signals are important in calculating the AF. Any signal component that is common to all of the antennas has no effect on the magnitude of the AF.

IV. RESULTS AND DISCUSSION

Consider an array of antenna consisting of N number ofelements. It is assumed that the antenna elements are symmetricabout the center of the linear array as shown in fig 3.

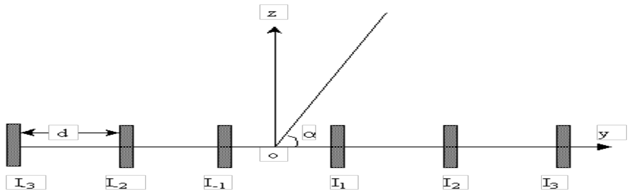

Fig.3: Uniform linear antenna array

The far field array factor ofthis array with an even number of isotropic elements (2N) canbe expressed as

$$AF(\theta) = 2\sum_{n-1}^{N} a_n \cos(a\,\pi/\lambda\, d_n \sin\theta) \;\ldots\ldots\ldots\ldots(2)$$

Where $a_n$is amplitudeof amplitude of n^{th} element, θ is the angle from broadside and d_n is the distance between position of n^{th} element and array center .The main objective of this work is to find an appropriate set of required element amplitudes and that achieves interference suppression with maximum side lobe level reduction and narrow main beam width. To find a set of values which produces the array pattern, the algorithm is used to minimize fitness function.

The fitness function associated with this array is the maximum Side Lobe Level of its associated radiation field pattern to be minimized.

The general form of the fitness function is given by

$$Fitness = Max(20\log 10(|E(\theta)|)/(\max|E(\theta_0)|))$$

$$\text{Max}\,|E(\theta_0)| = |E(\theta)|\quad, -\pi/2 \le \theta \le \pi/2$$

Where, $E(\theta)$ is array factor.

In this paper, it is assumed that the array is uniform, where allthe antenna elements are identical and equally spaced. Thedesign criterion considered here is to minimize the sidelobe level at a fixed main beam width. Hence the synthesisproblem is, finding the weights of current in each array element that are optimum to provide theradiation pattern with maximum reduction in the sidelobe level.

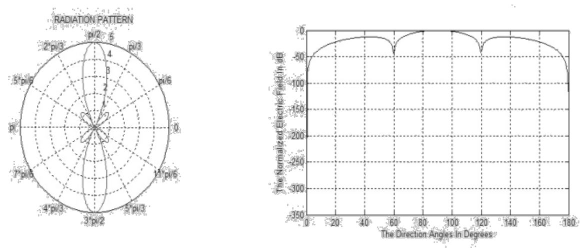

Fig. 4: Un-optimized Radiation pattern having side lobe level

Technical Specifications:-

1) Number of elements(N)- 5
2) Spacing between elements(in cm)- 5

3) Excitation current in element(amp)- 1
4) Phase among elements(in radian)- 0
5) Operating Frequency (in GHz)- 2.4

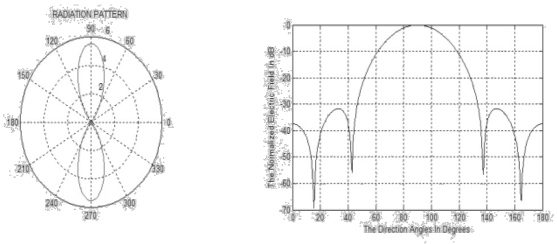

Fig. 5: optimized Radiation pattern using Genetic Algorithm having side lobe level

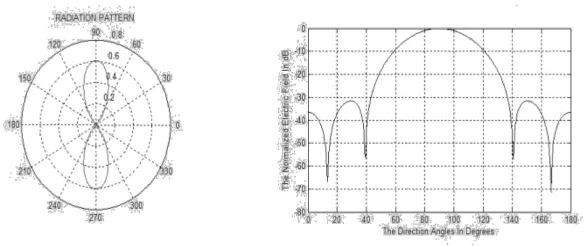

Fig. 6: optimized Radiation pattern using Big Bang Crunch having side lobe level

V. CONCLUSION

In this paper, Big bang crunch algorithm [15] Optimization method offers a significant means to attain maximum reduction in side lobe level relative to the main beam in the range of-30dB to -35dB. In this work, the optimization of radiation pattern is compared with the genetic algorithm. In comparison, the BB-BC gives better reduction in side lobe levels as compared to genetic algorithm. In addition, the number of calls for iteration significantly lowers in big bang crunch method as compare to genetic algorithm.

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