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Optimization of Linear Antenna Array Using Big Bang Crunch Algorithm for Reduction in Side Lobe Levels

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***Abstract*— The basic property of an antenna is to transmit and receive energy signal in one/all direction. This fundamental property is directivity. This paper employs big bang crunch algorithm optimization method for the synthesis 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. Optimization is done using MATLAB. Big bang crunch algorithm is used which enables search in broader space along randomly generated directions to produce new generations. This improves the performance greatly to achieve the maximum reduction in side lobe level with minimum function calls.**

***Keywords*—Antenna array, BB-BC, cost function.**

I. INTRODUCTION

With the advent of technology and recent developments in communication, wireless communication has reached to new level. Recent updates in wireless communication were not possible without application of smart antennas. Use of smart antennas is one of the vital characteristic that has led to third and fourth generation standard developments. However, smart antenna theory always driven by the Antenna array and so do the wireless communication. With antenna pattern synthesis there comes speed and robustness to the existing system thereby improving transmission parameters [3]. Along with this radio wave propagation is a matter of research that accounts to faster and reliable transmission, since wireless is generated from the roots of radio communication. Radio communication was first came into existence in December, 1901 when Guglielmo Marconi successfully received the first transatlantic radio message [1]. The message under radio communication was letter 'S' which is considered as the most significant approach in developments of radio communication. With this, a reform came in the field of communication. Message packet has been directed in every possible manner to yield promising output. Furthermore, wireless communication has been developed with the research and development in field of signal communication, electronics, information theory and coding, antenna array synthesis etc. However at the path led by Marconi, there is a lot to explore for more improved wireless transmission. The antenna array for wireless communication was first initiated in decade of 1940 [2]. This was the prominent development as it has enabled antenna structure to receive transmit information from any direction without any structure movement. Moreover, now antenna systems could receive the energy from the wanted direction while rejecting energy or information signal from all other direction that are basically contributing to noise. Now, the antenna arrays could be used to mitigate intentional interference or unintentional interference directed toward the communication system. Intentional interference here refers to jamming while unintentional interference refers to radiation from other source that is not meant for the system in communication. With more research in the field to optimize and improvise the antenna array performance, there came adaptive antenna concept. These antenna arrays were capable of adapting signal radiations pattern as per the environment factors they are operating in, a one more milestone in wireless communication. Because of all tremendous advancements wireless communication resulting with updates in antenna array , numerical computing, optimization of the element positions in an antenna array (for various situations) is now up to the mark and is referred as smart Antennas. Smart antenna systems basically act as the switched beam type; communicate directionally by forming specific antenna beam patterns thereby selecting one of the weighted combinations of antenna outputs with the greatest output power in the remote user's channel [4]. But the transmission reception is not 100 percent here as there dominates noise, circuit power, and other environmental factors. So , when a smart antenna directs its main lobe with enhanced gain in the direction of the user (information intended receiver), it forms side lobes as well thereby segregating the gain in areas of minimum gain in direction away from the main lobe gain. Thus, to yield maximum gain in transmission, side lobe level needs to be as minimum as it can be. For this purpose, the concept of different switched beam and adaptive smart antenna systems is taken that controls the lobes and nulls with varying degrees of accuracy and flexibility [5,7]. Traditional methods for these are used in general synthesis but if the radiation pattern has increased number of constraints then other numerical methods are used. For solution employed on large arrays , the problem is more critical and the solution space is very large so exhaustive checking of all possible phase-amplitude excitations and/or element positions is very difficult for the methods based on deterministic rules. So, for faster and efficient calculations, we prefer use of BB-BC. The most important benefit of using BB-BC is that it can be used efficiently where traditional methods becomes complex and with fast convergence [6]. Pattern generated using this method can be integrated much better than that by using the traditional method and other optimization techniques for

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the more element number or pattern in the form of the function, and when the more complex the more obvious, the superior of the genetic algorithm performance. However, there is a long way to go and research will contribute entirely for new upgrades in it. The primary objective of this thesis is to study the effect of linear array antenna on to communication channel and then the optimization of a linear array antenna using BB-BC for side lobe level reduction thereby improving the communication.

II. ANTENNA ARRAY

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,

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

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 beam forming. 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 the geometry of the element and array excitation. But side lobe reduction in the radiation pattern should be performed to avoid degradation of total power efficiency. Side lobe reduction can be obtained using the following techniques: 1) amplitude only control 2) phase only control 3) position only control and 4) complex weights (both amplitude and phase control). The process of choosing the antenna 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 by Stone who proposed binomial distribution, Dolph[13] the Dolph-Chebyshev amplitude distribution, Taylor[14], Elliot, Villeneuve Hansen and Woodyard[15], Bayliss laid[16] 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 electromagnetic problems due to their robustness and easy adaptively. In this paper, it is assumed that the array is uniform, where all the antenna elements are identical and equally spaced. The design criterion considered here is to minimize the side lobe level at a fixed main beam width. Hence the synthesis problem is, finding the weights of current in each array element that are optimum to provide the radiation pattern with maximum reduction in the side lobe level.

III. OPTIMIZATION USING BB-BC

The big bang crunch (BB-BC) optimization [12] method is based on two main steps. The first step is the Big bang phase where candidate solutions are randomly distributed over the search apace 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.

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.

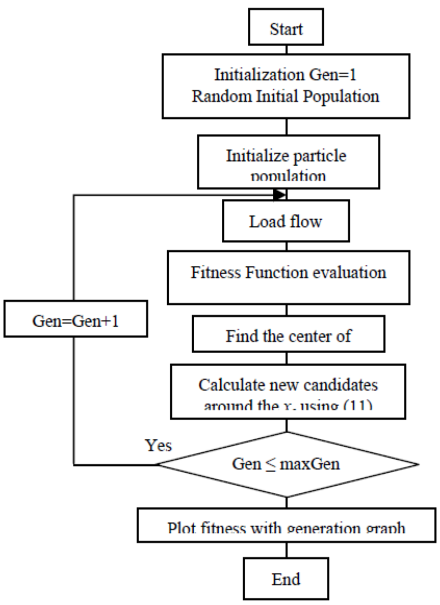

Fig.1 Flow chart of BB-BC [12]

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IV. SIMULATION RESULTS

The following parameters' are used for the system development in MATLAB,

S. No.	Parameter	Value
1	Frequency of operation	2.4 GHz
2	Type of antenna array	Broadside
3	No. of element	5,10
4	Output parameter	Directivity and side lobe level

The simulation results of optimize and without optimize is shown below,

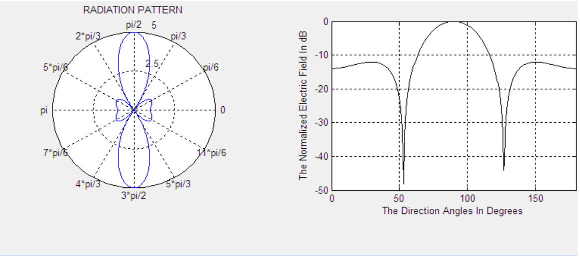

Fig 2: Beam pattern without optimization 5 elements

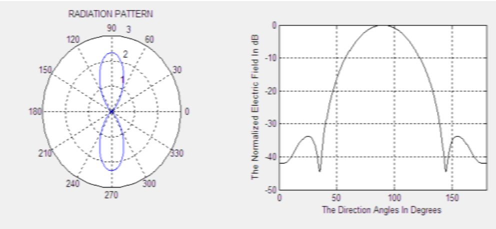

Fig 3: Beam pattern with optimization 5 elements

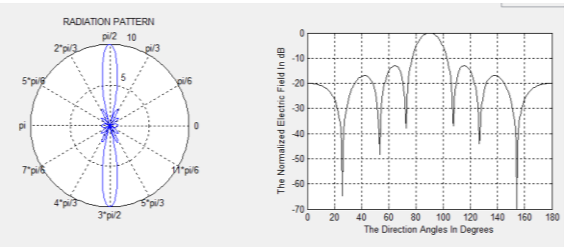

Fig 4: Beam pattern without optimization for 10 elements

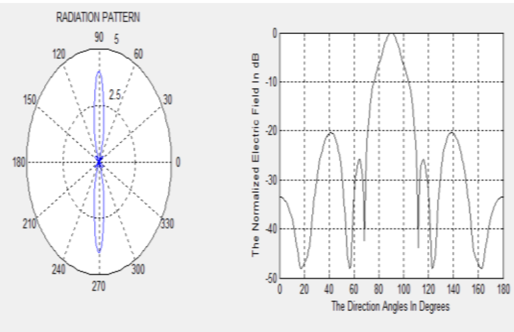

Fig 5: Beam pattern wit optimization for 10 elements

V. CONCLUSION

In this paper, Big bang crunch algorithm [12] 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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