Minimization of Side Lobe Level and Side Band Radiation of a Uniformly Excited Linear Antenna Array using Artificial Bee Colony Algorithm

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***Abstract*—This project focuses on optimizing antenna arrays, crucial for enhancing communication system performance. Sidelobe minimization is targeted using an artificial bee colony (ABC) algorithm. Inspired by honeybee foraging, this algorithm employs employed, onlooker, and scout bees to explore and find the global optimum. The fitness function, sidelobe level, is derived from the antenna array factor, dependent on element weights and positions. Smart antennas, categorized as adaptive and phased array types, adapt radiation patterns to enhance wireless communication. Optimization techniques like genetic algorithms and particle swarm optimization are also explored. ABC optimization, efficient and robust, has been utilized to optimize antenna weights and positions, effectively reducing sidelobe levels, enhancing directivity, and gain. This research underscores the significance of smart antennas and optimization techniques in communication systems, offering promising avenues for improved performance.**

I. INTRODUCTION

Antennas are essential for strong communication systems. We aim to make them even better by reducing unwanted radiation, called sidelobe levels. Our solution is the artificial bee colony (ABC) algorithm, inspired by bees' search for nectar. It uses three types of "bees" to find the best antenna setup. Smart antennas, which adapt their signals, are very useful in wireless communication. We're exploring different ways to optimize them, like genetic algorithms and particle swarm optimization. ABC stands out for its efficiency and ability to cut sidelobes, improving antenna performance. This report dives into smart antennas and how ABC can make them even smarter.

II. LITERATURE

The paper presents a novel approach to optimize the inter-element spacing and excitation amplitudes of the antenna array to achieve a desired radiation pattern with reduced side lobe level and sideband radiation. The effectiveness of the proposed method is demonstrated through simulations. The radiation pattern of an antenna array is influenced by factors such as the inter-element spacing and excitation amplitudes. Side lobe level and sideband radiation are undesirable characteristics that can degrade the performance of an antenna array by causing interference and reducing signal quality.

Drawing inspiration from the foraging behavior of honeybees, ABC adeptly balances exploration and exploitation, efficiently probing the solution space to find near-optimal solutions. ABC's resilience to handle the complexities of antenna optimization, such as non-linearities and noise in measurement data, ensures reliable performance enhancements in real-world scenarios.

III. DESIGN EQUATIONS

A. Antenna Array Factor (AF):

The antenna array factor represents the radiation pattern of the antenna array. It is calculated using the following formula:

$$AF(\theta) = \sum_{n=1}^{N} w(n) \cdot e^{i \cdot 2\pi d(n-1)\sin(\theta)}$$

Where:

- AF(θ) is the antenna array factor as a function of θ
- w_n are the weights assigned to each antenna element.
- d is the distance between adjacent antenna elements.
- N is the total number of antenna elements.
- j is the imaginary unit.
- θ angle at which the radiation pattern is calculated.

This equation calculates the complex phasor representing the contribution of each antenna element to the total radiation pattern at a given angle θ. The weights wn determine the magnitude and phase of each element's contribution.

B. Side Lobe Level (SLL):

The side lobe level represents the level of undesired radiation in the antenna pattern. It is calculated using the following formula:

$SLL = -20 \log10(\max(AF_{main\ lobe})$

Where:

- $AF_{main\ lobe}$ is the magnitude of the main lobe of the antenna array factor.

This equation quantifies the level of side lobes by finding the maximum value of the main lobe in the radiation pattern and converting it to decibels.

C. Fitness Function:

The fitness function plays a crucial role in the optimization process of the antenna array. It serves as the metric for evaluating the performance of each antenna configuration during the artificial bee colony (ABC) optimization algorithm. It is calculated by:

Fitness Function = AF (max SLL) / AF (main lobe)

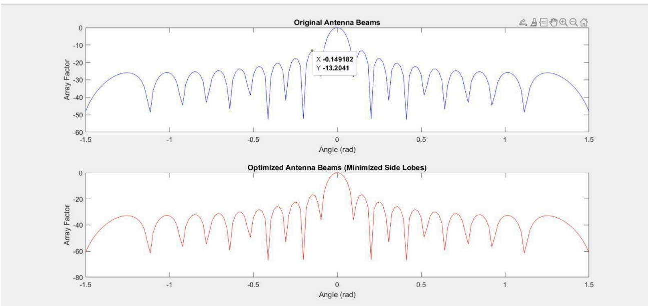
Based on the calculated SLL and maximum sidelobe value, the fitness function assigns a fitness score to the antenna configuration. Lower values of SLL and maximum sidelobe indicate better antenna performance..

As a result, the fitness function guides the ABC algorithm towards converging on optimal excitation amplitudes for the antenna elements.

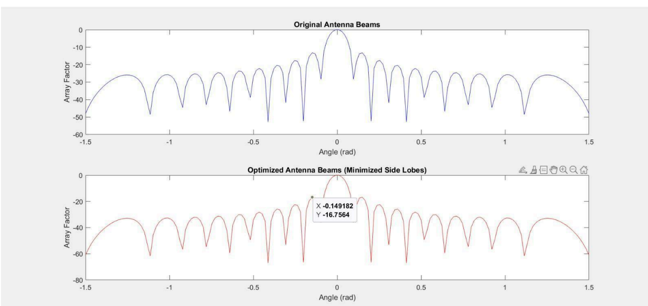
The number of iterations, colony size, and limit are set to 100, 250, and 20, respectively. The optimization process revolves around iteratively adjusting the excitation amplitudes of individual antenna elements. Each antenna configuration is represented by a vector of excitation amplitudes, encapsulating the specific weight assigned to each element.

This representation enables a systematic exploration of the solution space. The goal is to identify the optimal configuration that not only maximizes the directivity of the main lobe but also minimizes sidelobes, enhancing the overall performance of the antenna array.

IV. SIMULATION RESULTS



Simulation: Original AF = -13.20



Simulation: Optimized AF = -16.75

The simulation illustrates how the antenna's radiation pattern changes as the excitation amplitudes are optimized using the ABC algorithm.

Array Factor (AF) against the angle (θ) in radians. The x-axis represents the angle (θ) ranging from $-\pi/2$ to $\pi/2$, covering the angular range of the radiation pattern. The y-axis denotes the normalized Array Factor (AF), where the amplitude values are normalized to the maximum amplitude.

Through the optimization process, the inter-element spacing of 0.5λ and the excitation phase of 90° remained fixed, ensuring a focused exploration of the solution space primarily driven by excitation amplitude adjustments.

Comparison between the original and optimized antenna beams revealed a noticeable decrease in side lobes and an increase in the main lobe's sharpness, indicative of improved antenna performance. In addition to the analysis presented, a table detailing the optimized excitation amplitudes for each antenna element is provided as well.

Element	Optimized Excitation Amplitude
a1	0.7776
a2	0.3426
a3	0.2621
a4	0.9067
a5	0.0200
a6	0.0022
a7	0.2944
a8	0.8408
a9	0.4179
a10	0.5581
a11	0.7458
a12	0.2870
a13	0.9153
a14	0.4524
a15	0.9131
a16	0.4695
a17	0.7445
a18	0.9812
a19	0.6442
a20	0.2284

Table: Optimized Values for Amplitude Excitation

IV. CONCLUSION AND FUTURE ASPECTS

For our project, we focused on optimizing excitation amplitude values by implementing an ABC classification system within a linear array using MATLAB. We aimed to minimize side-lobe level (SLL) and achieve optimal amplitude and spacing within the array. This approach not only enhances signal clarity but also improves overall system efficiency. Our implementation on MATLAB allowed for efficient analysis and testing of various configurations, ultimately leading to a refined design that maximizes performance in real-world applications.

Moving forward, potential avenues for further exploration include:

- Experimenting with alternative optimization algorithms to enhance antenna array performance.
- Investigating methods for dynamic adaptation of antenna arrays to varying environmental conditions.
- Conducting real-world validation of optimized antenna designs to assess practical efficacy.
- Exploring multi-objective optimization approaches to address additional performance criteria.
- Integrating optimization techniques with smart antenna technology to achieve synergistic improvements in system performance.

These future directions hold promise for advancing antenna design and optimization, contributing to the continued evolution of communication systems

INDIVIDUAL CONTRIBUTIONS

Aaesha Akram:

Explored Array Factor calculation, optimization of the excitation amplitude, and decrement of side lobe level.

Anvita Pandit:

Worked on algorithm optimization, documentation of procedure, key concepts utilized and analysis of results.

Priyanka Vanama:

Handled implementation of algorithm, visualization and data interpretation tasks and documentation.

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