ISSN: 2584-0495 Vol. 2, Issue 8, pp. 1131-1139

International Journal of Microsystems and IoT

ISSN: (Online) Journal homepage: https://www.ijmit.org

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Cite as: Namdeo, S. K., Patidar, M., Shreyaskumar Patel, S., Jain, A., Mandloi, D. S., Paranjpe, P., & Nagar, S. (2024). Genetic Algorithm (GA) Approach for Side Lobe Level-Reduction (SLL-R) and Enhanced Directivity in Wireless Communication. International Journal of Microsystems and IoT, 2(8), 1131-1139. https://doi.org/10.5281/zenodo.13729305

Published online: 20 August 2024

DOI: https://doi.org/10.5281/zenodo.13729305

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ISSN: 2584-0495; Vol. 2, Issue 8, pp. 1131-1139; DOI: https://doi.org/10.5281/zenodo.13729305

Genetic Algorithm (GA) Approach for Side Lobe Level-Reduction (SLL-R) and Enhanced Directivity in Wireless Communication

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ABSTRACT

The present investigation investigates the optimization of smart antenna systems, specifically the reduction of side lobe levels (SLL) using Genetic Algorithm (GA) techniques. The study assesses the radiation pattern performance of a ten-element antenna array with fixed 8 cm spacing and 2 amps of current. Variations in the number of elements (4, 6, and 8) are explored to determine how they affect SLL and directivity. Furthermore, the simulation analysis looks into directivity and SLL at larger currents (10, 15, and 20 amps). The analysis aim to increase understanding and performance of smart antenna technology, particularly in wireless communication applications. The result evaluated by MatlabR2024a tool.

KEYWORDS

Smart antenna system (SAS), Side lobe level reduction (SLL-R), Genetic algorithm (GA), Directivity, Radiation pattern, Wireless technology.

1. INTRODUCTION

The use of Artificial Intelligence (AI) and Machine Learning (ML) technologies in smart antenna systems is an innovative approach to enhancing wireless communication networks [1, 2]. The sophisticated antenna configuration modification in these systems allows for real-time optimization of signal transmission and reception. AI-ML algorithms enable smart antennas to reduce interference, improve system performance, and dynamically adjust their beam patterns [3, 4]. The incorporation of AI-ML technology enhances the flexibility, effectiveness, and stability of smart antenna systems inside wireless communication networks [5, 6]. AI-ML-powered smart antennas are essential for optimizing spectrum utilization, enhancing network performance, and improving user experiences for a range of wireless communication applications [7]. They accomplish this by turning on user localization, adaptive beamforming, dynamic spectrum management, self-optimization, and interference reduction.

Wireless technology is essential in smart antenna systems for increasing efficiency, adaptability, and overall performance. Smart antenna systems employ wireless communication technologies to increase signal transmission and reception in a wide range of applications, including cellular networks, Wi-Fi, satellite communications, and others [8]. Wireless technology enables smart antenna systems to employ improved beamforming and beam steering techniques. Smart antennas may direct transmission and reception in specified directions by adjusting the phase and amplitude of signals from various antenna parts, increasing signal strength, reducing interference, and improving system capacity. Wireless technology makes it simpler to install adaptive antenna arrays in smart antenna systems.

These arrays actively adjust their beam patterns and properties in response to ambient factors such as user position, movement, and interference. Wireless communication protocols feature feedback systems, which allow antenna designs to be modified in real time, thereby improving performance [9, 10].

MIMO (Multiple Input Multiple Output) Systems: MIMO technology employs advanced antenna systems to deliver high data speeds and stable communication connectivity. MIMO systems transmit and receive signals via many antennas, utilizing spatial diversity and multipath propagation to improve signal quality, eliminate fading, and increase system capacity. To boost performance, wireless protocols such as 4G LTE and 5G NR make use of MIMO [11].

1.1 Objectives of the proposed work

- To analyse the performance of the antenna radiation pattern when ten elements with a fixed spacing of 8 cm and a current of 2 amps
- To analyse the effects of SSL and the directivity of varying the number of elements 4, 6, and 8.
- To check the directivity and SLL for raised current at the value of 10 amp., 15 amp., or 20 amp.

The rest of the paper, as shown below, In Sect. 2, we introduce the smart antenna system. In Sect. 3, we explore the existing work and literature review related to the proposed work and its motivation. Section 4 discusses side-Lobe-Level reduction in smart antenna systems, and Section 5 explores the genetic algorithms (GA) for smart antenna systems. In Sect. 7, we discussed the performance of the proposed work after the conclusion and references.

2. SMART ANTENNA SYSTEM

Consider a sleek, modern smart antenna system mounted atop a high-tech skyscraper. The antenna is a sophisticated array composed of multiple narrow, cylindrical parts equally spaced in a circular pattern, indicating its ability to dynamically direct and focus radio waves for improved signal reception and transmission [12].

In the foreground, there is a control unit with a digital display that displays real-time data and controls, as well as intelligent functions such as beamforming, DoA estimates, and adaptive signal processing [13]. The background depicts a bustling cityscape, emphasizing the antenna's importance in urban communication networks by increasing broadband connectivity and allowing advanced wireless communication technologies. Fig. 1 showed the smart antenna system.

Fig.1 Smart antenna system

3. LITERATURE REVIEW

The efficiency and performance of smart antenna systems are greatly increased by the application of genetic algorithms, or GAs. By mimicking the process of natural selection, GAs resolve complex optimization problems including adaptive array pattern synthesis, direction of arrival (DOA) predictions, and beamforming. In smart antenna systems, GAs improve the emission pattern of the antenna array to maximize signal reception quality while reducing interference and noise. This is achieved by altering parts of the antenna, such as their weights and phases, which raises the spectral efficiency and signal-to-noise ratio (SNR). Moreover, GAs provide optimal performance in settings involving dynamic wireless communication by adapting to changing user needs and setups [14].

Bo Liu et al.'s work "An Efficient Method for Antenna Design Optimization Based on Evolutionary Computation and Machine Learning Techniques" looks into new approaches to antenna design optimization that combine evolutionary computation (EC) with machine learning (ML). Recognizing the computational difficulties of electromagnetic simulations in antenna design, the study presents a surrogate model assisted differential evolution method for antenna synthesis (SADEA). This method increases optimization efficiency by employing a Gaussian Process surrogate model to estimate candidate design performance, reducing the need for computationally demanding simulations. The proposed new surrogate model-aware evolutionary search technique enables successful global optimization while addressing the challenges associated with high-dimensional optimization problems often encountered in antenna design [15].

Prerna Saxena and Ashwin Kothari's publication "Ant Lion Optimization algorithm to control side lobe level and null depths in linear antenna arrays" introduces the antenna and electromagnetics world to the Ant Lion Optimization (ALO) technique. The study demonstrates how well ALO works for side lobe level (SLL) suppression and null placement optimization of linear antenna arrays, two critical functions for reducing interference and enhancing signal quality in wireless communications. ALO emphasizes how little it needs to change in terms of parameters and adaptive mechanisms. By contrasting ALO with traditional uniform arrays and other metaheuristic techniques, the study demonstrates improved performance in array pattern optimization, highlighting ALO's potential for antenna design and other electromagnetic difficulties [16].

The paper "A Novel Adaptive Beamforming with Reduced Side Lobe Level Using GSA" by Abhinav Sharma and Sanjay Mathur presents an innovative approach to adaptive beamforming (ABF) for uniform linear arrays (ULAs) utilizing the Gravitational Search Algorithm (GSA). This work aims to direct the main beam towards the desired signal while placing nulls towards interfering signals, thereby reducing the side lobe level (SLL), a critical requirement for minimizing the spread of radiated power and avoiding interference. The authors explore the capability of GSA to optimize a multi-objective fitness function, demonstrating its effectiveness through MATLAB simulations across various scenarios involving different numbers of interference signals at varied power levels. This study is pivotal as it showcases GSA's potential for achieving faster convergence rates and more accurate beam steering with reduced SLL compared to conventional ABF techniques like the minimum variance distortion less response (MVDR) and other heuristic algorithms [17].

In order to improve the performance of linear dispersion codes (LDCs) for transmit antenna selection (TAS), a novel approach to linear antenna synthesis is presented in the paper "A Novel Linear Antenna Synthesis for Linear Dispersion Codes Based on an Innovative HYBRID Genetic Algorithm" by Jinpeng Wang et al. This study focuses on beam pattern shaping, main-lobe width management, and side-lobe level reduction to solve the optimization problem of non-uniformly spaced and linear arrays. The proposed method utilizes a hybrid genetic algorithm (GA), which combines specific enhancements with the benefits of traditional GAs to tackle the unique challenges of antenna array synthesis. With this new approach, the building of antenna arrays may be improved to maximize a well-defined cost function through the use of crossover, elitism, mutation, and selection procedures. Simulation results demonstrate the effectiveness of this hybrid GA in enhancing the performance of antenna arrays, particularly in side-lobe level attenuation and beam pattern improvement [18].

This work proposes a novel strategy to enhance the performance of Uniform Linear Array (ULA)-based Spectrum Sensing (SS) approaches in Cognitive Radio (CR) systems using Side Lobe Level Reduction (SLLR) beamforming. The inherent issues with ULAs, such as high Side Lobe Levels (SLLs) and low realized array gains, significantly reduce the signal detection capabilities of CR receivers. The proposed method addresses these drawbacks by applying SLLR beamforming to the receiving ULA, which greatly boosts the array's gain while maintaining the original Half Power Beam Width (HPBW). This change significantly boosts the system's detection capability by increasing the received Signal-to-Noise Ratio (SNR) and Signal-to-Interference plus Noise Ratio (SINR) [19].

In addition to highlighting the benefits of their spectrum efficiency, this research investigates how Multiple Input–Multiple Output (MIMO) techniques might enhance data rate applications. Antenna selection, which is relevant when implementing MIMO because it calls for several antennas, which can be challenging, is one technique to make this requirement simpler. Two novel antenna selection techniques are presented in this paper: an adaptive genetic algorithm (AGA) and a firefly algorithm in conjunction with LTE scheduling. The research also examines an adaptive spectrum matching (ASM) optimization strategy. The study addresses the features, benefits, performance metrics, and limitations of various antenna selection systems and compares them to confirm the effectiveness of the techniques. It also points up gaps in the study [20].

The study introduces the Eisenstein actual antenna array, a novel fractal antenna design that provides multiband and wideband operation while avoiding grating lobes. For improved performance, its boundary contour is fractal. Array thinning addresses the problems of a high Side-Lobe Level (SLL) and large element count by effectively reducing the number of active elements to minimize SLL without sacrificing directivity through the use of a genetic algorithm (GA) optimization. Additionally, the array uses the Least Mean Square (LMS) technique for adaptive beamforming. MATLAB simulations demonstrate the improved performance of the proposed GA-LMS thinning array, emphasizing its potential as a versatile and efficient solution for complex wireless systems and showcasing its advantages in multiband, wideband, small, and economical [21].

4. SIDE-LOBE REDUCTION IN SAS

Side lobe reduction is an important element of smart antenna systems because it increases system performance by directing the main radiation beam in the desired direction while minimizing radiation in the opposite directions. Beamforming Algorithms: Smart antenna systems employ advanced beamforming algorithms to steer the primary beam in the desired direction while minimizing side lobes.

- Traditional Beamforming
- Adaptive Beamforming
- Hybrid Beamforming
- Sparse Beamforming

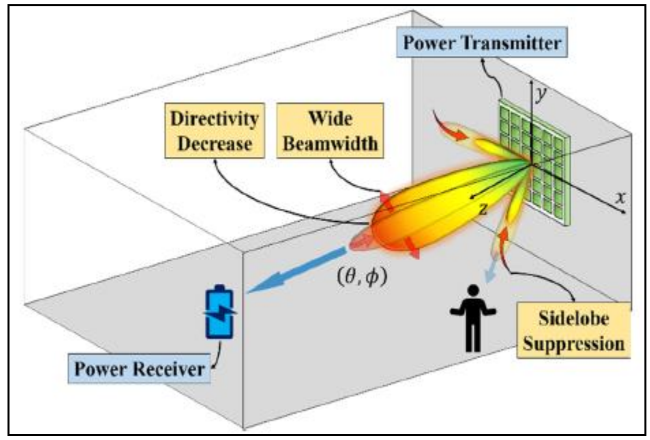

Fig. 2 SL-suppression beam-forming considering beam-width and directivity

Array Geometry Optimization: The physical arrangement of antenna elements in an array has a significant impact on side lobe levels. Smart antenna systems can reduce side lobes while enhancing main lobe directionality by carefully selecting array geometry and element spacing. Non-uniform element spacing and tapered array architectures are popular strategies for reducing side lobes [22, 23].

Null steering is a technique that directs nulls or deep minima in an antenna's radiation pattern toward sources of interference or noise, suppressing side lobes in those directions. Smart antenna systems can utilize adaptive nulling algorithms to dynamically change antenna weights, directing nulls towards interfering signals, lowering side lobe levels, and improving signal quality [24].

Spatial Filtering: Spatial filtering techniques are used in smart antenna systems to suppress signals from directions other than the primary beam while retaining signals from the desired direction [25]. By applying spatial filters to received signals, smart antennas can reduce contributions from spatially correlated interference sources, resulting in lower side lobe levels and a greater signal-to-interference ratio [26, 27].

5. GENETIC ALGORITHMS

Using Genetic Algorithms (GAs) for side lobe reduction in smart antenna systems comprises changing the antenna array's geometry and/or weight coefficients to reduce side lobe levels while maintaining or improving main lobe performance. The steps of a Genetic Algorithm (GA) are bellow [28].

Start → Initialization → Evaluation → Selection → Crossover → Mutation →Replacement →Termination →Result Analysis →Implementation.

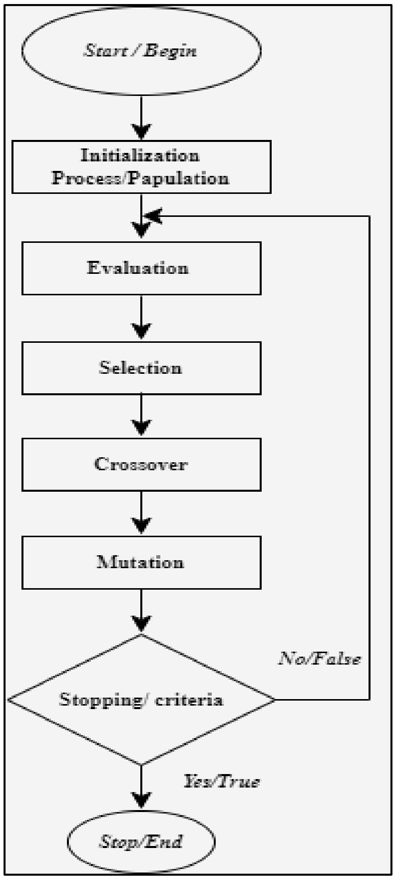

Fig.3 Flowchart of the standard genetic algorithm

Several antenna elements combined with signal processing algorithms make up a smart antenna system, which is a collection of antenna technologies intended to improve wireless communication transmission and reception. By constantly altering their patterns, these systems can focus more signal strength toward the intended users and away from potential sources of interference. Smart antenna systems are applied in a wide range of fields, including radar systems (improving detection efficiency and decreasing clutter), cellular networks (improving 4G and 5G performance), and wireless local area networks (WLANs). As a result of their improved coverage, data speed, and user experience, the upcoming generation of wireless communication technologies are anticipated to gain a great deal from development and application [29, 30]. The novel approach for the economically viable synthesis of the QCA circuit with multi-output Boolean functions with an arbitrary number of inputs is based on the Genetic Algorithm (GA) [31-33]. The QCA has the ability to provide advantages such as perform the high device density low or ultra-power consumption and compatibility with new transistor less nano technologies [34, 35].

6. PERFORMANCE OF PROPOSED WORK

The performance and efficiency of smart antenna systems are greatly enhanced by the use of genetic algorithms, or GAs. By mimicking the process of natural selection, GAs address complex optimization problems like adaptive array pattern synthesis, direction of arrival (DOA) estimations, and beamforming. In smart antenna systems, GAs improves the antenna array's emission pattern to maximize signal reception quality while reducing noise and interference. Signal-to-noise ratio (SNR) and spectral efficiency are raised by doing this by adjusting parameters like the weights and phases of antenna elements. Moreover, GAs adjusts to shifting configurations and user requirements, providing optimal performance in dynamic wireless communication scenarios. This adaptability increases the system's capacity and coverage while also protecting against multipath fading and co-channel interference. Overall, GAs help to design more efficient, dependable, and flexible smart antenna systems that meet the increasing demands of modern wireless communication networks.

Array Geometry Optimisation: The physical arrangement of antenna elements in the array has a significant impact on side lobe levels. Smart antenna systems can minimize side lobes while enhancing main lobe directionality by carefully selecting array geometry and element spacing. Non-uniform element spacing and tapered array topologies are common strategies for reducing side lobes. Changes in an antenna array system's element count, spacing, phase difference between elements, and current can all have an impact on the system's Side Lobe Level (SSL) and Directivity. A comparison of SLL-R techniques in antenna arrays is shown in the table 1.

Table. 1 Comparisons table for side lobe level reduction (SLL-R)

Figure numbers	Number of element	current of elements	Spacing between two element (cm)	Frequency	Phase between element	SSL (dB)	Directivity
			Change the spacing between elements				
Fig.1	10	2 amp	10.0cm	2×10^9	30^0	-8.6027	16.334
Fig. 2			12.0cm			-0.01014	15.6538
Fig. 3			14.0cm			-8.2315	16.1818
			Change the phases between elements				
Fig. 4	10	2 amp	8.0cm	2×10^9	45^0	-9.5538	15.5418
Fig. 5					90^0	-10.2751	15.7697
Fig. 6					180^0	-0.00054	15.1198
			Change the number of elements				
Fig. 7	4	2 amp	8.0cm	2×10^9	45^0	-0.00037	11.7449
Fig. 8	6					-11.8348	13.6495
Fig. 9	8					-12.7988	15.0178
			Change the current of elements				
Fig. 10	10	10amp	8.0cm	2×10^9	45^0	-12.9823	15.9069
Fig. 11		15amp				-8.6345	14.7144
Fig. 12		20amp				-10.722	15.8305

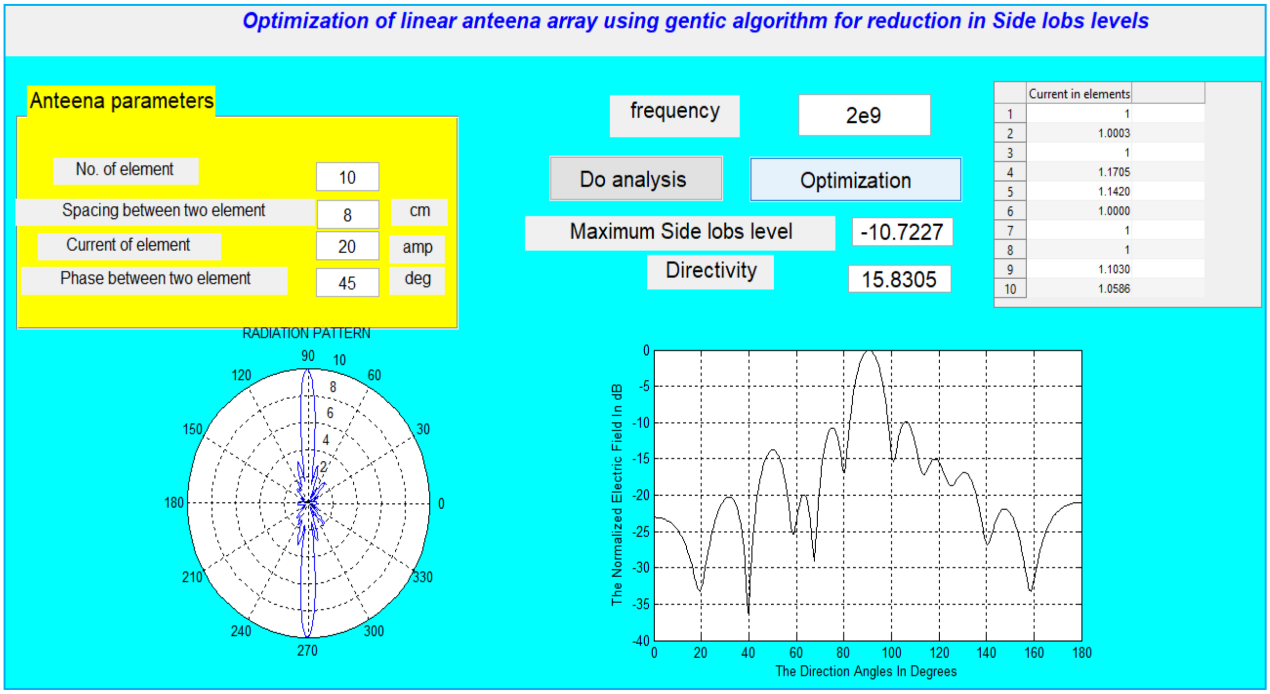

Fig. 4 Matlab GUI for analysis of SLL using GA

6.1 Change the spacing between elements

Fig. 5 to Fig. 7 analyse a 10-element array with three different element spacings (10 cm, 12 cm, and 14 cm). The array is maintained at 2 amps of continuous current, $2x10^9$ Hz of frequency, and 30° of phase difference. As the separation increases, SSL marginally improves (becomes more negative, which is better), but directivity also increases (the focus of the antenna beam sharpens).

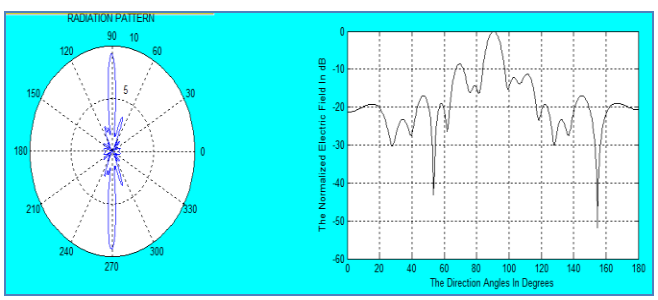

Fig. 5 Change the spacing between elements (10 cm/ 2 amp/ Ø=30^0)

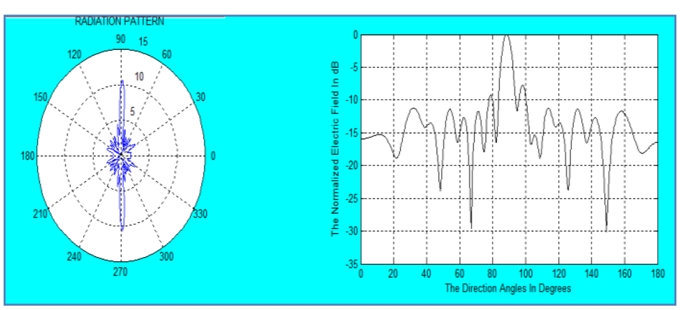

Fig. 6 Change the spacing between elements (12 cm/ 2 amp/ Ø=30^0)

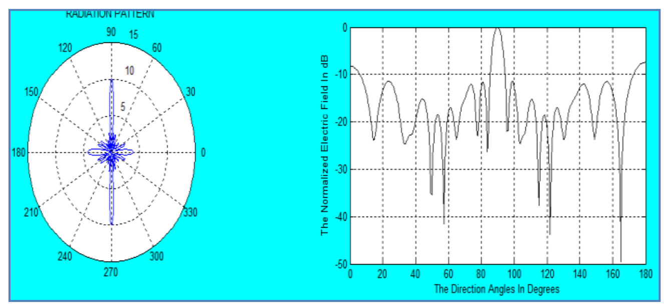

Fig. 7 Change the spacing between elements (14 cm/ 2 amp/ Ø=30^0)

6.2 Change the phases between elements

Fig. 8 to Fig. 10 show an array of ten elements with fixed 8-cm spacing and a current of two amps, but with different phase differences (45°, 90°, and 180°) between the components. While a 180° phase difference yields the lowest Directivity, a 90° phase difference provides the greatest SSL reduction.

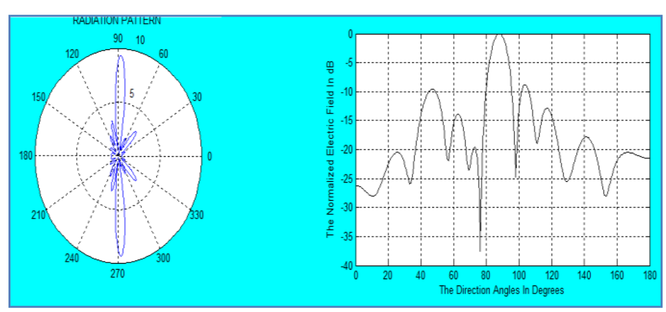

Fig. 8 Change the phases between elements (8 cm/ 2 amp/ Ø=35^0)

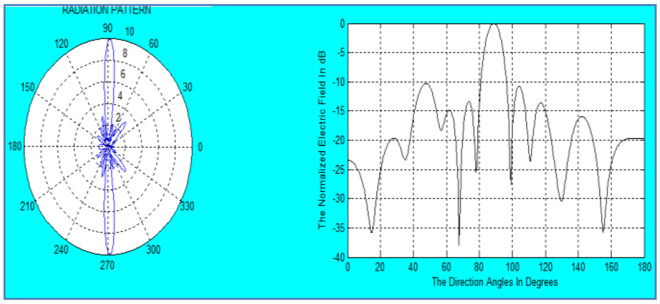

Fig. 9 Change the phases between elements (8 cm/ 2 amp/ Ø=90^0)

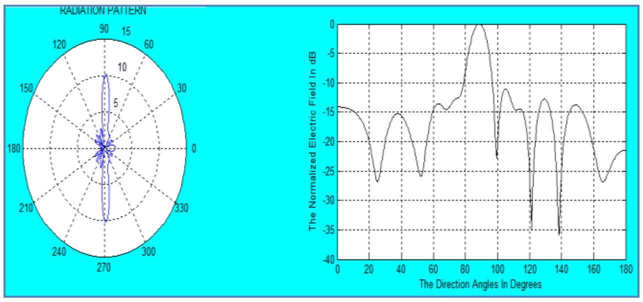

Fig. 10 Change the phases between elements (8 cm/ 2 amp/ Ø=180^0)

6.3 Change the number of elements

The effects of varying the number of elements (4, 6, and 8) on SSL and Directivity are displayed in Fig. 11 to Fig. 13, with a constant 8-cm spacing, 2 amps of current, and a 45° phase difference. Directivity rises and SSL falls as the number of elements grows.

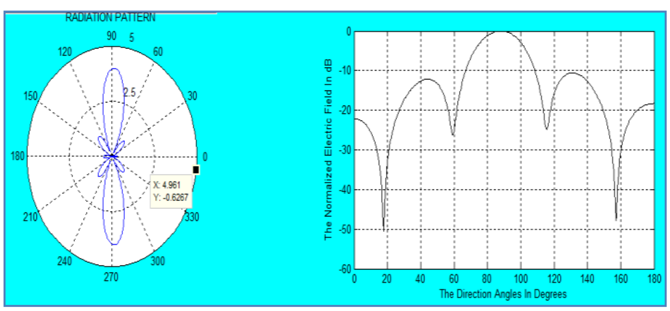

Fig. 11 Change the number of elements (Element=4, 8 cm/ 2 amp/ Ø=45^0)

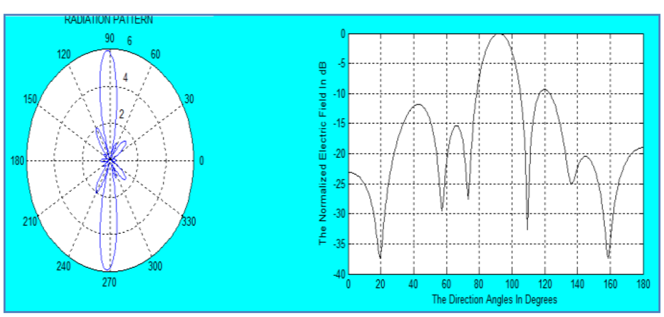

Fig. 12 Change the number of elements (Element=6, 8 cm/ 2 amp/ Ø=45^0)

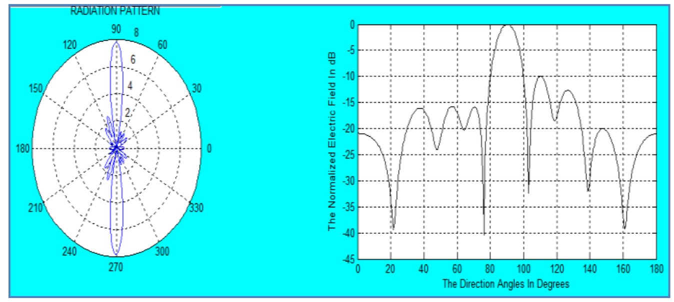

Fig. 13 Change the number of elements (Element=8, 8 cm/ 2 amp/ Ø=45^0)

6.4 Change the current of elements

Fig. 14 to Fig. 16 illustrate how SSL and Directivity vary with current (10 amp, 15 amp, and 20 amp) in an array of 10 components spaced 8 cm apart with a 45° phase difference. When current is raised, SSL lowers dramatically and directivity increases.

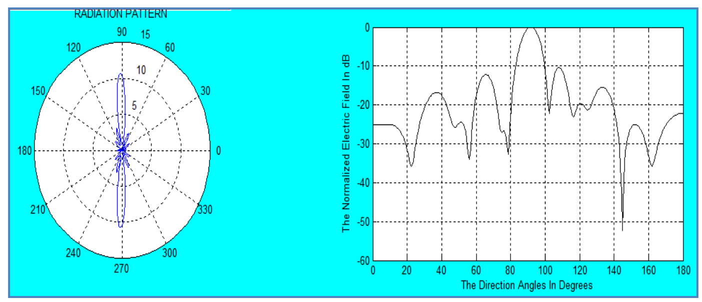

Fig. 14 Change the current of elements (Element=10, 8 cm/ 10 amp/ Ø=45^0)

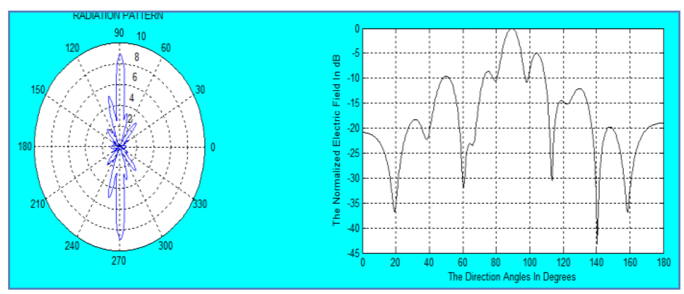

Fig. 15 Change the current of elements (Element=10, 8 cm/ 15 amp/ Ø=45^0)

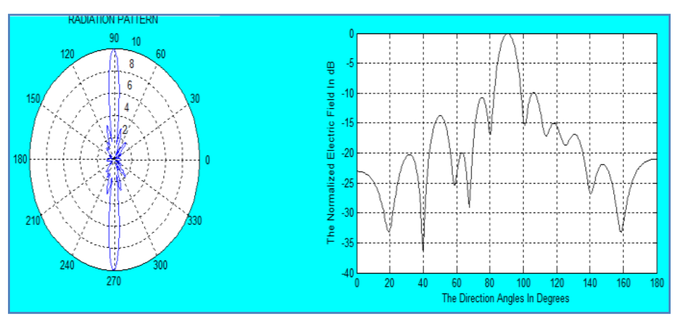

Fig. 16 Change the current of elements (Element=10, 8 cm/ 20 amp/ Ø=45^0)

Overall, the data indicates that by varying various physical and electrical parameters of an antenna array, one may tailor the balance between SSL and Directivity to fit certain objectives, such as stronger directivity or fewer side lobes, which are normally undesired in radiation patterns.

7. CONCLUSION

In conclusion, the use of genetic algorithms, or GAs, greatly improves the performance and efficiency of smart antenna systems. Adaptive array pattern synthesis and direction of arrival calculations are two complex difficulties that GAs tackles with the help of natural selection. This enhancement leads to increased spectral efficiency, a greater signal-to-noise ratio, and better signal reception quality. Furthermore, GAs provides dynamic wireless communication circumstances that improve coverage, system capacity, and interference resilience. Furthermore, careful array architecture and element spacing decrease side lobes and enhance the directionality of the primary lobe. Smart antenna systems that are more flexible, dependable, and efficient are created by employing a comprehensive approach in order to meet the ever-increasing requirements of contemporary wireless communication networks.

REFERENCES

1. Salim, E. K, Awatef, B., & et al. (2024). Integration of artificial intelligence (AI) with sensor networks: Trends, challenges, and future directions, Journal of King Saud University - Computer and Information Sciences, 36(1). https://doi.org/10.1016/j.jksuci.2023.101892
2. Rozhnovskyi, M., & Rozhnovska, I. (2023). Application of artificial intelligence method in adaptive antenna system. Radiotekhnika, 4(215), 77–85. https://doi.org/10.30837/rt.2023.4.215.08
3. Mohammad, M. K., Sazzad, H., & et al. (2022). A review on machine learning and deep learning for various antenna design applications,Heliyon, 8(4). https://doi.org/10.1016/j.heliyon.2022.e09317
4. Brilhante, D., Manjarres, J.C., Moreira R., & et al. (2023). A Literature Survey on AI-Aided Beamforming and Beam Management for 5G and 6G Systems. Sensors, 23(9):4359. https://doi.org/10.3390/s23094359
5. Shahjalal, M., Kim, W., & et al. (2023). Enabling technologies for AI empowered 6G massive radio access networks, ICT Express, 9(3), 341-355. https://doi.org/10.1016/j.icte.2022.07.002
6. Rawat, A., Yadav, R.N., & Shrivastava, S.C. (2012). Neural network applications in smart antenna arrays: A review, AEU - International Journal of Electronics and Communications, 66(11), 903-912. https://doi.org/10.1016/j.aeue.2012.03.012
7. Akhtar, M.W., Hassan, S.A., Ghaffar, R. & et al. (2020). The shift to 6G communications: vision and requirements. Hum. Cent. Comput. Inf. Sci. 10, 53. https://doi.org/10.1186/s13673-020-00258-2
8. ChienHsiang, W., Chin-Feng, L., & et al. (2022). A survey on improving the wireless communication with adaptive antenna selection by intelligent method, Computer Communications, 181, 374-403. https://doi.org/10.1016/j.comcom.2021.10.034
9. Mishra, R. & et al. (2023). Advances in MIMO Antenna Design for 5G: A Comprehensive Review, Sensors, 149(6329). https://doi.org/10.3390/s23146329
10. Singh, M. J. (2013). Advances in Antenna Technology for Wireless Handheld Devices. International Journal of Antennas and Propagation, Hindawi Publishing Corporation. 1687-5869. https://doi.org/10.1155/2013/838364
11. Anchidin, L., Lavric, A., Mutescu, P. M., Petrariu, A. I., & Popa, V. (2023). The Design and Development of a Microstrip Antenna for Internet of Things Applications. Sensors (Basel), 23(3):1062. https://doi.org/10.3390/s23031062
12. Vincenzo, I., Floriano D. R., & et al. (2018) Smart Antenna Systems Model Simulation Design for 5G Wireless Network Systems. Array Pattern Optimization. DOI: 10.5772/intechopen.79933
13. Naga P.M. (2015). Adaptive Based Beamforming for Direction-of-Arrival (DOA) EstimationCVR Journal of Science and Technology, 9, 37-43. https://doi.org/10.32377/cvrjst0908
14. Lema, G. G., Hailu, D. H. & Wuneh, T. B. (2019). SLL attenuation-based thinned antenna design for next-generation communications. J Wireless Com Network, 225. https://doi.org/10.1186/s13638-019-1547-5
15. Liu, B., Aliakbarian, H., Ma, Z., Vandenbosch, G. A. E., Gielen, G., & Excell, P. (2014). An Efficient Method for Antenna Design Optimization Based on Evolutionary Computation and Machine Learning Techniques. IEEE Transactions on Antennas and Propagation, 62(1), 7–18. https://doi.org/10.1109/tap.2013.2283605
16. Saxena, P., & Kothari, A. (2016). Ant Lion Optimization algorithm to control side lobe level and null depths in linear antenna arrays. AEU - International Journal of Electronics and Communications, 70(9), 1339–1349. https://doi.org/10.1016/j.aeue.2016.07.008
17. Sharma, A. & Mathur, S. (2018), "A novel adaptive beamforming with reduced side lobe level using GSA", COMPEL - The international journal for computation and mathematics in electrical and electronic engineering, 37(6), 2263-2278. https://doi.org/10.1108/COMPEL-07-2017-0311
18. Wang, J., Zhengpeng, Y., Tarun, M., Sanders, B. L., & Nianyu Z. (2019). A Novel Linear Antenna Synthesis for Linear Dispersion Codes Based on an Innovative HYBRID Genetic Algorithm, Symmetry 11(9): 1176. https://doi.org/10.3390/sym11091176
19. Hager, S. Fouda, & et al. (2022). A highly efficient approach for performance enhancement of multiple antenna elements based spectrum sensing techniques using side lobe level reduction, Alexandria Engineering Journal, 61(8), 5983-5999. https://doi.org/10.1016/j.aej.2021.11.028
20. Sindhwani, N., & et al. (2023). Comparative Analysis of Optimization Algorithms for Antenna Selection in MIMO Systems. In: Chakravarthy, V., Bhateja, V., Flores Fuentes, W., Anguera, J., Vasavi, K.P. (eds) Advances in Signal Processing, Embedded Systems and IoT . Lecture Notes in Electrical Engineering, 992. Springer, Singapore. https://doi.org/10.1007/978-981-19-8865-3_54
21. El-Khamy, S. E., El-Sayed H. F. & Eltrass, A. S. (2022). Synthesis of Wideband Thinned Eisenstein Fractile Antenna Arrays With Adaptive Beamforming Capability and Reduced Side-Lobes, IEEE Access, 10, 122486-122500. https://doi.org/10.1109/ACCESS.2022.3223104
22. Albagory, Y., & Alraddady, F. (2022). An Efficient Adaptive and Steep-Convergent Sidelobes Simultaneous Reduction Algorithm for Massive Linear Arrays, Electronics. 11(2):170. https://doi.org/10.3390/electronics11020170
23. Albagory, Y. & Alraddady, F. (2021). An Efficient Approach for Sidelobe Level Reduction Based on Recursive Sequential Damping. Symmetry. 13(3):480. https://doi.org/10.3390/sym13030480
24. Chien, S. F., & et al. (2024). Null Steering of Adaptive Beamforming Using Linear Constraint Minimum Variance Assisted by Particle Swarm Optimization, Dynamic Mutated Artificial Immune System, and Gravitational Search Algorithm. https://doi.org/10.1155/2014/724639
25. Ali, E., Ismail, M., Nordin, R. & et al. (2017). Beamforming techniques for massive MIMO systems in 5G: overview, classification, and trends for future research. Frontiers Inf Technol Electronic Eng. 18, 753–772. https://doi.org/10.1631/FITEE.1601817
26. Yadav, R., Moghe, P. & et al. (2023). Performance Analysis of Side Lobe Reduction for Smart Antenna Systems Using Genetic Algorithms (GA). IEEEXplore 14th International Conference on Computing Communication and Networking Technologies (ICCCNT), Delhi, India, 1-5. https://doi.org/10.1109/ICCCNT56998.2023.10306796
27. Patidar, M. Bhardwaj, G. & et al. (2022). An Empirical Study and Simulation Analysis of the MAC Layer Model Using the AWGN Channel on WiMAX Technology, 2022 IEEEXplore 2nd International Conference on Technological Advancements in Computational Sciences (ICTACS), Tashkent, Uzbekistan, 658-662. https://doi.org/10.1109/ICTACS56270.2022.9988033
28. Yang, Y., Jain, R. and et al. (2012). Solving "Antenna Array Thinning Problem" Using Genetic Algorithm, Applied Computational Intelligence and Soft Computing, Hindawi Publishing Corporation. https://doi.org/10.1155/2012/946398
29. Patel, S. (2021). Enhancing Image Quality in Wireless Transmission through Compression and De-noising Filters. In International Journal of

Trend in Scientific Research and Development 5(3) 1318–1323. IJTSRD. https://doi.org/10.5281/zenodo.11195294

30. Patel. S. (2022). Performance Analysis of Acoustic Echo Cancellation using Adaptive Filter Algorithms with Rician Fading Channel. In International Journal of Trend in Scientific Research and Development 6(2) 1541–1547. IJTSRD. https://doi.org/10.5281/zenodo.11195267

31. Pramanik, A.K., Mahalat, M.H., Pal, J. & et al. (2023) Cost-effective synthesis of QCA logic circuit using genetic algorithm. J Supercomput 79, 3850–3877. https://doi.org/10.1007/s11227-022-04757-0

32. Patidar, M., Jain, A., Patidar, K. & et al. (2024). An ultra-dense and cost-efficient coplanar RAM cell design in quantum-dot cellular automata technology. J Supercomput 80, 6989–7027. https://doi.org/10.1007/s11227-023-05722-1

33. Patidar, M., & Gupta, N. (2022). An ultra-efficient design and optimized energy dissipation of reversible computing circuits in QCA technology using zone partitioning method. Int. j. inf. tecnol. 14, 1483–1493. https://doi.org/10.1007/s41870-021-00775-y

34. Sharma D.K & et al. (2023). An efficient design and demonstration of fault-effects in full-adder circuits based on quantum-dot computing circuits, Materials Today: Proceedings, 2214-7853. https://doi.org/10.1016/j.matpr.2023.03.374

35. Patidar, M. & et al. (2024). Efficient Design of Half-Adders and EXOR Gates for Energy-Efficient Quantum Computing with Delay Analysis Using Quantum-Dot Cellular Automata Technology. In: Al-Turjman, F. (eds) The Smart IoT Blueprint: Engineering a Connected Future. AIoTSS 2024. Advances in Science, Technology & Innovation. Springer, Cham. https://doi.org/10.1007/978-3-031-63103-0_22

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