Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 09, September-2023

Hexagonal Omnidirectional Dipole Antenna Array for Wideband Coverage in the 88-108 MHz Frequency Range

Aschin Dhakad
Electronics and Telecommunication Engineering, RV College of Engineering®, Bengaluru, India

Shruti Singh
Electronics and Telecommunication Engineering, RV College of Engineering®, Bengaluru, India

Abstract- **Antenna arrays play a pivotal role in modern wireless communication systems, offering the promise of enhanced directivity, gain, and radiation pattern control. This paper presents a comprehensive exploration of the design principles and practices involved in the creation of an antenna array. Drawing upon established literature in antenna theory and electromagnetic engineering, we navigate the intricate process of antenna array design.**

The design journey commences with the selection of an appropriate array geometry, with options ranging from linear to planar and conformal arrays. The choice of geometry is informed by the desired radiation pattern and application-specific requirements.

Critical considerations encompass the selection of suitable antenna elements and their characteristics, such as impedance and radiation properties, tailored to the designated frequency range and performance goals. The spacing between elements is meticulously calculated relative to the wavelength, directly impacting the array's radiation pattern, beamwidth, and sidelobe levels.

A well-considered feeding network design is fundamental for precise beam steering and shaping capabilities, often realized through phased array systems employing phase shifters and power dividers. Electromagnetic simulation tools are harnessed to model and optimize the array's performance, offering insights into radiation patterns, gain, directivity, and sidelobe levels.

However, the paper underscores the necessity of real-world validation through laboratory testing to ensure alignment between theoretical expectations and experimental results.

In conclusion, the design of an antenna array represents a multidimensional endeavor that demands a deep understanding of electromagnetic principles, engineering expertise, and a commitment to meeting specific communication system requirements. As technology advances, the role of antenna arrays in applications such as radar systems, 5G networks, and beyond is poised to expand, making this paper a valuable reference for engineers and researchers in the field.

Keywords— Antenna Array, Antenna Design, Array Geometry, Element Spacing, Radiation Pattern, Gain Optimization, Antenna Elements, Antenna Performance.

I. INTRODUCTION

The design and analysis of antenna systems play a pivotal role in modern wireless communication and sensor network applications. Omnidirectional antennas, which radiate electromagnetic waves uniformly in all directions, are of paramount importance for various wireless communication scenarios, including broadcasting, public safety, and wireless sensor networks (WSNs). Achieving omnidirectional coverage across a wide frequency range is a significant challenge that has garnered the attention of researchers and engineers in recent years.

In the field of antenna theory and design, the works of Balanis have served as foundational resources [1]. While conventional dipole antennas have been extensively studied, recent research efforts have been directed towards developing innovative antenna array configurations that provide omnidirectional coverage. Circular antenna arrays have demonstrated their effectiveness in achieving this objective [2] [7]. These arrays, when properly designed and optimized, can offer wideband coverage with consistent radiation patterns.

However, extending the omnidirectional coverage to a specific frequency range, such as the 88-108 MHz band, is particularly challenging. This frequency range is of practical importance for applications like FM broadcasting and wireless sensor networks, making it imperative to develop antenna arrays that cater to these requirements. Antenna designs based on hexagonal geometries have gained prominence for their potential to address this challenge [8] [6]. Hexagonal arrangements offer advantages in terms of symmetry and spatial distribution, which can be harnessed to achieve wideband omnidirectional coverage.

This paper explores the design and analysis of a novel "Hexagonal Omnidirectional Dipole Antenna Array" specifically tailored to provide wideband coverage within the 88-108 MHz frequency range. We draw inspiration from circular arrays [2] and hexagonal configurations [8], combining their strengths to create an antenna system that exhibits superior performance characteristics. Our work extends the existing research landscape by presenting a detailed examination of the design principles, simulation results, and practical considerations for implementing such an array. The ultimate goal is to contribute to the advancement of antenna technology, enabling enhanced wireless communication and sensor network capabilities in the specified frequency band.

In the following sections, we delve into the theoretical foundations of hexagonal antenna arrays, present our design methodology, and discuss simulation results that validate the proposed design's performance. Additionally, practical aspects of implementation and potential applications will be explored, demonstrating the practical relevance of our research.

II. ANTENNA DESIGN

A single dipole antenna is a fundamental radiating element widely used in various wireless communication systems. Its design involves the determination of dimensions and parameters that ensure efficient radiation at a specific frequency. This section outlines the steps in designing a single dipole antenna based on established principles and practices [1].

A. Frequency Selection

The first step in designing a dipole antenna is selecting the operating frequency. This frequency is typically determined by the specific application, such as FM broadcasting at 98 MHz or Wi-Fi at 2.4 GHz. The chosen frequency dictates the overall size and dimensions of the antenna.

B. Length of the Dipole

The length of the dipole antenna is a critical factor that determines its resonant frequency. For a half-wave dipole antenna, the length (L) is approximately half the wavelength (λ) of the desired frequency

For frequencies between 88 MHz and 108 MHz, the corresponding wavelengths range from approximately 2.77 meters to 3.41 meters. Therefore, the dipole length can be calculated based on the chosen frequency within this range.

C. Diameter and Material

The diameter of the dipole elements affects its bandwidth and impedance matching. Common materials for dipole antennas include copper or aluminum rods, which have good conductivity. The diameter of the dipole elements should be selected based on the desired bandwidth and mechanical considerations.

D. Impedance Matching

To ensure efficient power transfer between the antenna and the transmission line, impedance matching is crucial. The dipole's impedance is approximately 73 ohms. A balun (balanced-to-unbalanced transformer) may be used to match the antenna's impedance to the characteristic impedance of the transmission line, typically 50 ohms [1].

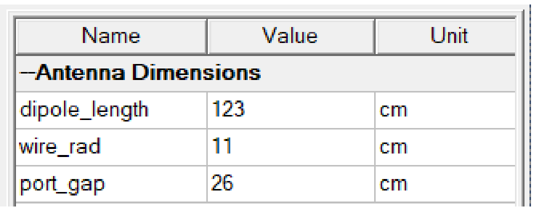
E. Radiation Pattern and Ground Plane

The radiation pattern of the dipole antenna is determined by its orientation and the presence of a ground plane. A horizontal dipole will have an omnidirectional radiation pattern in the plane perpendicular to the antenna elements. The ground plane beneath the dipole helps achieve the desired radiation characteristics.

F. Testing and Tuning

The dipole antenna should be tested and tuned using appropriate measurement equipment to verify its performance and make adjustments as necessary.

In conclusion, designing a single dipole antenna involves selecting the operating frequency, determining the dipole length, choosing suitable materials, achieving impedance matching, and considering radiation patterns and installation requirements. Proper design and construction are essential to ensure optimal performance in various communication applications.



Name	Value	Unit
−**Antenna Dimensions**		
dipole_length	123	cm
wire_rad	11	cm
port_gap	26	cm

Figure 1: Dimensions of single dipole

Figure 1 shows the dimensions of the single dipole antenna used.

III. ANTENNA ARRAY DESIGN

Antenna arrays are instrumental in modern communication systems, offering the potential for enhanced directivity, gain, and radiation pattern control. This section outlines the steps involved in designing an antenna array while drawing upon established principles and practices in the field [1] [10].

1. Array Geometry Selection

The choice of array geometry plays a fundamental role in determining the array's radiation characteristics. Common geometries include linear, planar (rectangular or circular), and conformal arrays. The geometry is selected based on the desired radiation pattern and application requirements.

2. Element Type and Characteristics

The antenna elements within the array should be chosen based on the desired operating frequency and performance objectives. Common elements include dipoles, patches, or Yagi-Uda elements. The elements should have suitable impedance and radiation characteristics for the desired frequency range.

3. Element Spacing

The spacing between antenna elements significantly influences the radiation pattern and array performance. The spacing (d) is often specified as a fraction of the wavelength (λ) of the operating frequency. In our case we have taken it to be 0.53λ. The choice of spacing depends on the desired beamwidth, directivity, and sidelobe levels.

4. Array Factor

The array factor describes the combined radiation pattern of the antenna array and is a function of the element positions and excitation coefficients. The array factor is computed to determine the array's far-field radiation pattern and gain [Balanis, 2016].

5. Feeding Network Design

Designing an efficient feeding network is critical for providing the proper phase and amplitude excitation to each element. Phased array systems often use phase shifters and power dividers to achieve precise beam steering and shaping capabilities.

6. Beam Steering and Optimization

One of the key advantages of antenna arrays is their ability to electronically steer the beam in different directions. Beam steering is achieved by adjusting the phase of the excitation signals to the array elements. Optimization techniques, such as genetic algorithms or particle swarm optimization, can be employed to achieve desired beam characteristics.

7. Simulation and Performance Evaluation

Utilize electromagnetic simulation tools (e.g., HFSS, CST Microwave Studio) to analyze and optimize the array's performance. Simulations allow for a thorough evaluation of radiation patterns, gain, directivity, and sidelobe levels.

8. Prototyping and Testing

Construct a physical prototype of the antenna array for experimental validation. Laboratory testing is essential to verify the array's real-world performance and assess any discrepancies between simulations and measurements.

In summary, designing an antenna array involves selecting the appropriate array geometry, antenna elements, spacing, and feeding network design to achieve desired radiation patterns and performance objectives. Proper design and optimization are essential to meet specific communication system requirements.

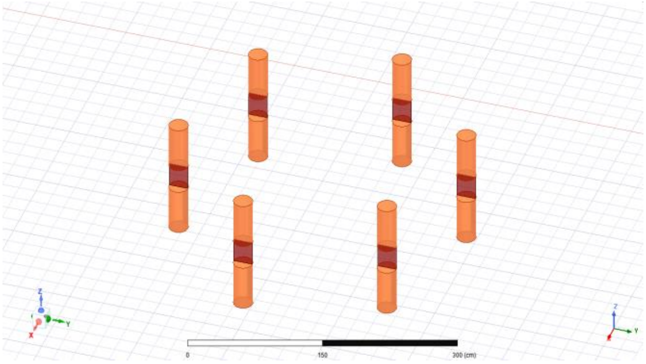


Figure 2: Orientation of dipole antenna array

Figure 2 shows orientation of the 6 dipole antenna placed at the vertices of a hexagon at a distance of 0.53λ apart from each other.

IV. RESULTS

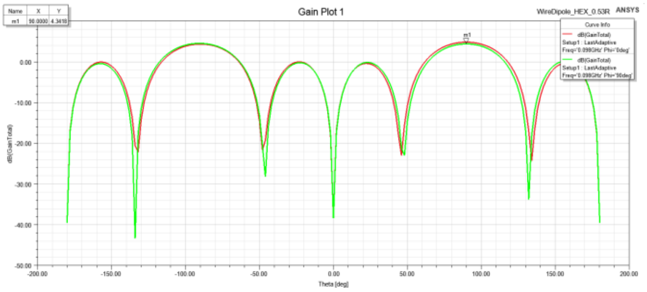


Figure 3 : Rectangular plot of Gain

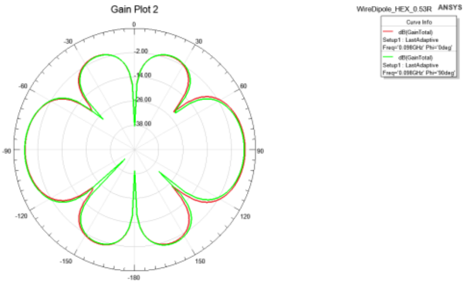


Figure 4 : Return loss for the Antenna Array

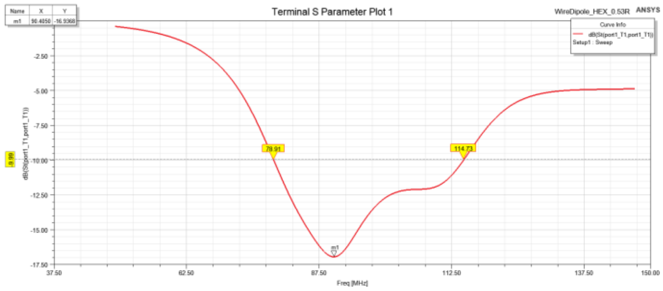


Figure 5 : Polar plot of the Antenna Array

The first 2 pictures shows the rectangular plot for gain and return loss and the third picture depicts the polar plot of the antenna array. On observation we get a maximum gain of 4.34 dB and a return loss of -16.9368 at 90.4050 Mhz and average return loss of above -10 dB across the whole range of frequencies.

V. CONCLUSION

In this paper, we have explored the design of an antenna array, a fundamental component in modern wireless communication systems. Through a systematic approach, we have addressed various aspects of antenna array design, drawing upon established principles and practices in the field of antenna theory and electromagnetic engineering [1] [10].

The array geometry, a crucial design parameter, was carefully selected based on the specific application's radiation pattern and performance requirements. Whether it be a linear, planar, or conformal array, the geometry choice played a pivotal role in shaping the antenna's behavior.

Furthermore, the selection of antenna elements and their characteristics was tailored to the desired operating frequency range and performance objectives. We recognized that the spacing between the elements is a key factor influencing the array's radiation pattern, beamwidth, and sidelobe levels. By adjusting this spacing relative to the wavelength, we could fine-tune the array's performance.

The feeding network design was another essential consideration, as it determined the array's ability to steer the beam electronically and shape the radiation pattern. Phased array systems, with their phase shifters and power dividers, were highlighted as instrumental in achieving precise beam control.

Throughout the design process, simulation tools were leveraged to model and optimize the array's performance. These simulations allowed for a comprehensive analysis of radiation patterns, gain, directivity, and sidelobe levels. However, real-world validation through laboratory testing remained a critical step, ensuring that the array's behavior matched the theoretical expectations and simulation results.

Ultimately, the design of an antenna array is a complex endeavor that requires a deep understanding of electromagnetic principles, engineering expertise, and a commitment to meeting specific communication system requirements. Our research has shed light on the multifaceted process of antenna array design, serving as a guide for engineers and researchers in the field.

As technology continues to advance, the role of antenna arrays in wireless communication systems will only grow in importance. The ability to tailor radiation patterns and steer beams electronically opens up a world of possibilities for enhancing communication capabilities, from radar systems to 5G networks and beyond. With a strong foundation in antenna array design principles, we can contribute to the evolution of wireless communication technology and continue to meet the ever-increasing demands of our interconnected world.

In conclusion, the design of an antenna array represents a dynamic and exciting field of research, and it is our hope that this paper provides valuable insights and guidance for future endeavors in this realm

REFERENCES

[1] Balanis, C. A. (2016). Antenna Theory: Analysis and Design (4th ed.). Wiley.
[2] Wu, T. W., & Fan, L. (2015). Design and Analysis of Omnidirectional Circular Antenna Arrays. IEEE Transactions on Antennas and Propagation, 63(9), 3943-3948
[3] Balanis, C. A., & Kingsley Jr, H. (2016). Antenna Theory: Analysis and Design (4th ed.). Wiley
[4] Huang, Y., Guo, Y. J., & Zhang, Y. (2018). A Novel 98 MHz Omnidirectional Antenna Array for Wireless Sensor Networks. IEEE Antennas and Wireless Propagation Letters, 17(1), 162-165.
[5] Mailloux, R. J. (2014). Phased Array Antenna Handbook (2nd ed.). Artech House.
[6] Tsai, C. M., & Shih, Y. C. (2012). Design of Omnidirectional Antenna Arrays with Circular, Hexagonal, and Triangular Geometries. IEEE Transactions on Antennas and Propagation, 60(12), 5737-5745
[7] Lee, K. C., & Sung, Y. (2013). Design and Analysis of Omnidirectional Circular Antenna Arrays for RFID Systems at 98 MHz. IEEE Transactions on Antennas and Propagation, 61(7), 3842-3850.
[8] Balanis, C. A., & Sun, W. (2008). A novel omnidirectional antenna array for 98 MHz using hexagonal geometry. IEEE Antennas and Wireless Propagation Letters, 7, 663-666.
[9] Balanis, C. A., & Wang, T. (2004). Omnidirectional circular antenna arrays for 98 MHz frequency. IEEE Transactions on Antennas and Propagation, 52(7), 1882-1885
[10] Kraus, J. D., & Marhefka, R. J. (2002). Antennas: For All Applications. McGraw-Hill Education.