Log-Periodic Antenna for Wireless Communication

A project report submitted in partial fulfillment

of the requirements for the degree of

Bachelor of Technology

in

Electronics & Communication Engineering

By

Shreya Jaiswal - 21BEC1141
Blessy Abraham- 21BEC1271
Tamanna - 21BEC1644

School of Electronics Engineering,
Vellore Institute of Technology Chennai, Vandalur-Kelambakkam Road,
Chennai - 600127, India.

November 2024

Declaration

I hereby declare that the report titled "**Log Periodic Antenna for Wireless Communication**" submitted by me to the School of Electronics Engineering, Vellore Institute of Technology, Chennai in partial fulfillment of the requirements for the award of **Bachelor of Technology** in **Electronics and Communication Engineering** is a bona-fide record of the work carried out by me under the supervision of ***Dr Richards Joe Stanislaus*** .

I further declare that the work reported in this report, has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma of this institute or of any other institute or University.

Sign:

Name & Reg. No.: Shreya Jaiswal (21BEC1141)

Date: 20 November,2024

Sign:

Name & Reg. No.: Blessy Abraham (21BEC1271)

Date: 20 November,2024

Sign:

Name & Reg. No.: Tamanna (21BEC1644)

Date: 20 November,2024

School of Electronics Engineering

Certificate

This is to certify that the project report titled **Log-Periodic Antenna for Wireless Communication** submitted by **Shreya Jaiswal (21BEC1141), Blessy Abraham(21BEC1271),Tamanna(21BEC1644)** to Vellore Institute of Technology Chennai, in partial fulfillment of the requirement for the award of the degree of **Bachelor of Technology** in **Electronics and Communication Engineering** is a bona-fide work carried out under my supervision. The project report fulfills the requirements as per the regulations of this University and in my opinion meets the necessary standards for submission. The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma and the same is certified.

Supervisor		**Head of the Department**	
Signature:	....	Signature:	....
Name:	....	Name:	....
Date:		Date:	

Examiner

Signature: ....

Name: ....

Date:

(Seal of the School)

Abstract

Log-periodic dipole array antennas have a wide bandwidth, with high gain and moderate cost, cutting them out for all kinds of wireless communication applications. This report discusses various aspects of LPDA antenna design and performance characteristics with a focus on their suitability for wireless communication systems. The requirement for high-performance compact antennas becomes increasingly important for emerging wireless technologies such as 5G and beyond. The issue of miniaturization without sacrificing functionality in terms of the antenna becomes a matter of considerable importance. Traditional LPDA designs tend to be bulkier and less space-efficient with linear elements in the form of a dipole, relegating them to less-demanding small-scale systems.

This brings out an innovative way of overcoming this limitation, substituting the linear dipoles with Euclidean line elements, thereby reducing their physical size while maintaining broad bandwidth, high gain, and operational efficiency. The new design ensures optimal performance across a wide frequency range while making easier integration into compact wireless devices, such as mobile phones, IoT gadgets, and other portable communication systems. Next-generation wireless communication systems with desirable high performance and miniaturization hence provide an opportunity for design innovation and expansion of LPDA applications in meeting the rapidly growing demand of modern wireless networks.

The study demonstrates the possibility of using LPDA antennas for incorporation into smaller portable devices without compromising the functionality of such systems, with the physical footprint of the antenna reduced. With excellent advantages in terms of compactness, cost-effectiveness, and scalability, the design of the LPDA antennas allows the same to cater to the growing demands of next-generation wireless communication systems. While LPDA antennas unlock the true potential of rapidly advancing wireless technologies by miniaturizing designs and helping in improved performance, their effects will certainly be felt through the extensively changing landscape of LPDA implementation.

Acknowledgement

We wish to express our sincere thanks and deep sense of gratitude to our project guide, Dr. Richards Joe Stanislaus, Professor, School of Electronics Engineering, for his consistent encouragement and valuable guidance offered to us in a pleasant manner throughout the course of the project work.

We are extremely grateful to Dr. Ravishankar A, Dean Dr. Reena Monica, Associate Dean (Academics) & Dr. John Sahaya Rani Alex, Associate Dean (Research) of the School of Electronics Engineering, VIT Chennai, for extending the facilities of the School towards our project and for his unstinting support.

We express our thanks to our Head of the Department Dr. Mohanaprasad K for his support throughout the course of this project.

We also take this opportunity to thank all the faculty of the School for their support and their wisdom imparted to us throughout the course.

We thank our parents, family, and friends for bearing with us throughout the course of our project and for the opportunity they provided us in undergoing this course in such a prestigious institution.

Contents

List of Figures

Chapter 1

Introduction

LPDA antennas are well-known for good performance in a wide range of wireless communication applications. LPDAs are particularly suited to multi-band scenarios demanding reliable, consistent impedance characteristics over a host of frequency bands. With this characteristic, LPDAs have become an important tool in broadcasting, telecommunications, spectrum research, and signal monitoring. Their ability to efficiently operate over a wide frequency range, together with high front-to-back ratio, makes LPDAs ideal for applications requiring long-range, directional signals with minimal interference from unwanted directions.

With the advancements in wireless communication systems, the integration of high-performance antennas into smaller devices is posing a challenge. Compact and efficient antenna designs that support high-rate data flows, low latency, and various communication environments should be integrated within portable and embedded systems. Such an ever-growing demand has arisen to design solutions maintaining the wideband and directive properties of LPDAs but with smaller dimensions to better integrate with the modern wireless technologies.

It is in this context that this report presents the novel solution resolving the problem mentioned above: it proposes replacing linear dipoles conventionally used in the designs of LPDAs with the Euclidean line elements. The configuration of the elements of the antenna into a more compact shape reduces the overall physical size of the proposed design without compromising on the essential performance metrics like frequency range, return loss, and front-to-back ratio. This design approach will pave the way to incorporate LPDA antennas into much smaller and much more efficient systems of wireless communication without ever having to forfeit their core functionality.

The objective of this paper is to illustrate the possibility of such a new design in LPDA, demonstrating how the use of rectangular Euclidean elements will benefit the application of Log-Periodic Dipole Arrays in wireless communication technologies through its optimized size reduction versus performance optimization. This design opens up the possibility for wide applicability of LPDA antennas in modern wireless communication networks towards solving a key challenge of miniaturization facing modern electronics.

Literature Survey

2.1 Wideband Planar Log-Periodic Antenna

In this research study a small planar wideband microstrip antenna with seven dipole components and a log-periodic design is shown. It operates in the frequency range of 500–700 MHz and has dimensions of 268 x 145 x 3 mm. The antenna, which is constructed on a FR-4 substrate, has remarkable performance metrics, such as pure linear polarization with an axial ratio below 1 dB, impedance matching better than -10 dB throughout the working bandwidth, and a maximum gain of 4.5 dB at the central frequency (600 MHz). Its adaptability makes it a cost-effective substitute for traditional Yagi-Uda TV antennas and makes it appropriate for point-to-point communications, WLAN applications, and miniature sensors. Its outstanding directional qualities, uniform gain over the spectrum, and small size and low weight.

2.2 The Effects of the Trapezoidal Dipole Array Elements on Planar Log Periodic Antenna

In this research work an innovative method for designing antennas for high-frequency applications is provided by, which examines a planar log periodic antenna with trapezoidal dipole array elements. By using trapezoidal dipole forms rather than traditional straight dipoles, the main innovation allows for a large reduction in arm length without sacrificing performance. Achieving remarkable performance parameters, such as optimal VSWR throughout the operating bandwidth and high average gain throughout the majority of the operational bandwidth, the antenna was created utilizing Rogers substrate material and simulated using CST Microwave Studio. Key parameters including aperture angle, scaling factor, and spacing factor are carefully considered during the design process. Iterative simulations are run to maximize the trapezoidal dimensions.

Even though the coaxial cable feed portion is responsible for a few minor discrepancies, the final antenna prototype shows good agreement between simulated and measured findings. The study comes to the conclusion that this modest design, with its well-defined radiation patterns and lower size, is appropriate for both military and civilian uses, especially where performance needs to be maintained while smaller form factors are needed. Log periodic antenna technology has advanced significantly with the successful application of the trapezoidal element design, providing a more portable option for contemporary communication systems.

2.3 Band Rejection Methods for Planar Log-Periodic Antennas

This research investigates sophisticated band rejection techniques for a multi-octave wideband planar log-periodic antenna, which is essential for applications that need to minimize interference at particular frequencies, especially 6 GHz. The first method, known as aperture rejection, reduces gain in the targeted band by more than 25 dB by carefully eliminating some resonant teeth from the antenna's construction.

In order to improve the antenna's efficacy in rejecting undesired frequencies while preserving its broad capabilities, the second way incorporates a dual-band filter directly into the antenna design, attaining a rejection level higher than 30 dB. In order to achieve an impressive rejection level of more than 55 dB, the authors also suggest a combination strategy that makes use of both aperture rejection and the integrated filter.

Through thorough theoretical analysis and experimental validation, the work highlights the efficacy of these strategies, demonstrating excellent agreement between measured and projected results. By providing workable ideas for enhancing wideband antenna performance in settings with strict frequency rejection requirements, this research makes a substantial contribution to the field of antenna design.

2.4 Planar Channelized Log-Periodic Antenna

Log-periodic antennas for CMB measurements are a development of a series of very significant previous research work. Single-frequency dual polarization antennas, as discovered by Myers et al, were primarily derived for astronomical measurements but had limited sensitivity. The basic log-periodic antenna design was born from Isbell's 1960 work, whereas Gans, Kajfez and Rumsey further developed the field in tapered microstrip baluns. Work by Rauscher on channelizing filters and that by Filipovic on hyper-hemispherical lenses with high dielectric constants were significant works that furnished the insights for patterns in antenna radiation. The progression from relatively simple planar antenna structures to multi-frequency designs was indeed evolutionary because of the driving interests that sought to enhance CMB measurements, as innovations channeled their focus into different requirements for improved channelization and integration techniques for better measurement capabilities.

2.5 Wedge-Shaped Dual Planar Log-Periodic Antenna with Enhanced Directivity for WiMAX Applications

However, the literature on LPAs has pointed out that those can provide good unidirectional radiation patterns along with wide bandwidth and therefore can be of great use to the contemporary communication systems like WiMAX. Several studies have proved that LPAs are of adaptive nature and consist of variable-sized elements as dipoles, which provides them with frequency-independent behavior. However, conventional LPAs also suffer from the problem of being unable to meet the requirements in spite of the high directivity as well as performance. Recent progresses have mainly been focused on the optimization of LPA configurations including design, as well as the development of double-arm structures together with new feeding circuits giving increased directivity but not complicating the fabrication process. Some such notable works include optimization techniques by Azarmanesh et al., and Yang and Kildal with regard to variable design parameters, thus ensuring high essence of radiation characteristics for modern applications. Such findings led to the proposed dual planar LPA with wedge shape, aimed at overcoming the demerits of such conventional designs and ensuring efficient operation with high performance in broadband wireless communication systems.

2.6 Design and Development of a Compact Dual CP Eight Band Planar Log Periodic Antenna for RF Energy Harvesting through Ambient Sources

The RF energy harvesting antenna literature comprises the different designs targeted at optimizing performance over multiple frequency bands. Previous studies have analyzed microstrip patch, spiral, cross dipole, and loop antennas but frequently failed to offer optimum efficiency and bandwidth. It is also worth mentioning that log-periodic antennas, which belong to the class of frequency-independent antennas, have proven to be solutions that would most apparently help RF energy harvesters independently of the frequency range of the emission source. Compared with other types, these antennas tend to capture a higher percentage of ambient energy and can thus be used in applications where compactness and efficiency are crucial. Top-class development has focused on feeding methods that enhance impedance matching and gain. The log periodic antenna has also earned itself a place as one of the best solutions.

2.7 A Small Planar Log-Periodic Koch-Dipole Antenna (LPKDA)

The paper refers to a lot of literature that has greatly contributed towards the development of an antenna design, especially concerning log-periodic dipole antennas. Campbell et al. 1977 discuss the stripline LPDAs design with attention paid to their aspect in construction and operational conditions which will build a point for understanding broader applications of LPDAs. Carrel (1961) provides fundamental design requirements that form the basis for the log-periodic antennas' operation, putting prominence on element spacing and length variations for a wideband performance.

Finally, Butson and Thompson (1976) discuss gain calculations for LPDAs; in these works are methodologies on how to predict the LPDAs' performance with different configurations. These foundation works have demonstrated the historical development of designing antennas and the continued search for better efficiency and compactness. Therefore, the incorporation of Koch dipole elements in a log-periodic structure, as is proposed in this paper, draws on prior precedent but addresses the requirement for more compact and less heavy antennas without compromising performance, hence contributing to advancements in wireless communication technologies.

2.8 Micro-Coaxial Fed 18 to 110 GHz Planar Log-Periodic Antennas With RF Transitions

Previous efforts in wideband planar antennas operating in the millimeter-wave spectrum were based on high fabrication technologies that allow the development of very small aperture features and back-end passive devices. Most of these antennas have been fabricated using bolometers or photodetectors at the feed, thus resolving problems of integration as well as the low-loss feed lines. However, this limited them to receive-only operation and resulted in loss of phase information, making them impractical for most communication, radar, and electronic warfare applications. One notable attempt at a directly RF-fed millimeter-wave log-periodic antenna was presented previously, designed in an end-fire mode on a GaAs substrate, but it achieved only 13.4% bandwidth-significantly lower than what is typically expected from frequency independent antennas. In fact, with the development of the PolyStrata 3-D surface micromachining fabrication process, the first breakthrough took place-generating the reliably mass-produced various passive millimeter devices on an integrated chip with smallest integral features. PolyStrata also has a significant advantage over other rectangular coaxial fabrication techniques in that it is possible to insert dielectric straps to hold the inner conductor, which, in turn, enables the process to obtain much greater instantaneous operational bandwidth. Moreover, this process also has other advantages over the microstrip lines such as negligible losses, higher packing density, less cross-talk, and 3D stacking capability. Cross-over realization is also very simple, while dispersion-free performance is virtually achievable up to submillimeter wave frequencies.

Chapter 3

Methodology

3.1 Log Periodic Dipole Antenna Array

Definition

An LPDA is a unidirectional antenna with wideband frequency response; it is often used in applications that require frequency agility and high directivity. It is basically made up of an array of dipole elements arranged in a logarithmic periodic pattern for operation over broad bandwidths with quite uniform performance. The LPDA is a linearly polarized passive antenna and does not need any external power for it to work but relies on the power transmitted through or received on its input terminals. Due to the directional nature of an LPDA antenna, it focuses the radio wave in one direction; hence, it has a greater gain to one end than an omnidirectional antenna. It is primarily employed in broadcasting of television and radio, communications, and signal monitoring, where wide frequencies and directional radiation are required.

3.1.1 Element Configuration and design

In fact, the original LPDA configuration had 10 dipole elements , in direct balancing of antenna size, manufacturing feasibility, and performance requirements. This gave enough degrees of freedom for a good impedance match across the 2.175–6.825 GHz range and provided better gain through constructive interference in radiated signals. Other analyses highlighted additional deficiencies: lesser stability in gain, lesser smoothness in bandwidth, and radiation efficiency at critical frequencies.

The dipole elements were thus optimized to 12 elements. This optimization significantly improved the matching of the bandwidth, besides enhancing radiation efficiency and gain stability. The gain was uniformly maintained along the frequency range at 6–10 dB. The added elements reduced the mutual coupling with destructive interference, ensuring superior performance across most applications, including WiFi at 2.4 GHz, Bluetooth, and 5G mid-band at 3.5 GHz. The configuration also remained practical, albeit slightly larger, for mass manufacture and deployment.

3.1.2 Key parameters

LPDA antenna performance is highly dependent on a number of important parameters. These were tested in detail over several values to establish their impact on bandwidth, gain stability, impedance matching, and overall radiation efficiency.

Scaling Factor (τ)

The scaling factor τ determines geometric progression in the lengths of dipole element and has direct relationships with bandwidth, gain consistency, and input impedance. Choosing the appropriate value for τ ensures that transitions are smooth across frequencies and sets a minimum in performance variation.
The values to be considered here are 0.865, 0.9, 0.918, 0.935, and 0.957.
Lower τ values give a narrower bandwidth, but maybe better impedance matching at other frequencies. Higher τ values give broader bandwidth, but probably at the cost of somewhat less invariant

Spacing Factor (σ)

The spacing factor controls the spacing between the neighboring dipole elements. This factor influences mutual coupling, relative phases and the general efficiency in radiation pattern.
Measured Values: 0.157, 0.16, and 0.165.
Reduction in spacing reduces mutual coupling but will increase spacing and thus negatively impact endfire radiation efficiency. The aim was to be optimal in the optimization in finding that balance between destructive interference and the endfire radiation efficiency.

Maximum Element Length (L_max)

L_max: This is the largest dipole element within the array and, consequently, will determine the lower limit of frequency for the antenna. This will also affect the physical size and impedance matching of the antenna.
Values Evaluated: 64 mm, 70 mm, 72 mm, 75 mm, 83 mm.
Smaller lengths ensure compactness but tend to fail at lower frequencies. The bigger the length, the more performance is enhanced at low frequencies, but the higher the physical size.

Width of Element dipole elements (W_max)

Width element radiation efficiency and impedance transformation mainly depends on the W_max which decides on stable performance within the entire frequency range. A suitable width ensures that the whole system gives stable performance all along the frequencies. - Tested Values: Ranges from 9mm to 12mm.
Further increases in mismatch impedance are obtained with narrower widths, but wider elements enhance radiation characteristics but may increase mutual coupling further.

3.2 Substrate Material Selection

The substrate material is the characteristic that will determine the high-frequency performance of the LPDA antenna. This is due to its impact on dielectric losses, radiation efficiency, and general bandwidth. As such, the selected substrates, FR4 and Roger RO4003C, must be evaluated in terms of suitability for the 2-7 GHz frequency range.

FR4 Substrate

FR4 is cost-effective and a commonly used material with satisfactory performance at lower frequencies. It was modelled to assess its influence on the LPDA antenna's behavior.

Properties:

- Dielectric constant (εr): approximately 4.4
- Loss tangent: relatively high, meaning a higher signal loss, especially at the higher frequency limits.

Simulation Observations:

- The Bandwidth performance was still acceptable in the lower end but reduced immensely at the higher frequencies due to increased loss.
- Stability and radiation efficiency were moderately affected, especially for frequencies higher than 5 GHz.

Roger RO4003C Substrate

Roger RO4003C, a high-end substrate material with excellent dielectric properties, was also simulated to check performance.

Properties:

- Dielectric constant (εr): 3.38, thereby having low signal distortion.
- Loss tangent: Low, hence offering tremendous radiation efficiency throughout the *frequency band.*

Observations from the Simulations:

- Provided excellent high-frequency performance with gain stability as well as the degree of radiation within the range of 2–7 GHz.
- Possesses highly reduced signal loss compared to FR4, particularly at higher frequencies, and therefore signifies improved general performance

3.3 Electromagnetic Simulation

Electromagnetic simulation was one of the significant elements of LPDA design process toward verification and refinement of the chosen parameters toward optimal performance. This phase utilized ANSYS HFSS, an industry leader in high-frequency electromagnetic analysis. The simulation capabilities offered with the desired visual output enabled fairly rigorous metrics on the performance of the design and derived the optimal parameters.

3.3.1 Simulation Setup

In ANSYS HFSS, an LPDA antenna model was prepared with direct precise boundary conditions and a refined mesh with high accuracy on the simulation. The tool supported very detailed analysis of critical metrics in the 2–7 GHz frequency range. The steps during the simulation process included:

- Geometry : defined by modeling all the 12 dipole antenna elements with the chosen parameters, including τ, σ, Lmax and Wmax.
- Boundary Conditions:Radiation boundaries were used to simulate how the antenna interacts with free space.
- Adaptive meshing : has been utilized to get the high-resolution result around the critical regions of the antenna.

3.3.2 Key Performance Metrics and Graphical Analysis

1. Return Loss (S11):

The S11 parameter was measured to determine how well the impedance matches up within the frequency range.

- The graph showed the variation of return loss across the range, with the goal of maintaining values below -10 dB, indicating minimal signal reflection and effective power transfer.
- Design values were fined iteratively based on the graph:
  For example, the changes in τ and L_max ensured good operation at low-frequency ranges and changes in σ had corrected the return loss at middle frequency range.

2. Gain and Radiation Pattern (3D Polar Plot):

- The gain of the antenna was noticed via the feature 3D polar plot, which represents the radiation intensity in all directions.
- Simulations also validated a flat gain of 6–10 dB over the frequency band.
- The gain plot revealed guidance on how design parameters such as spacing (σ) and element width (W_max) affect directional radiation efficiency. Optimization was performed to improve front-to-back ratio and reduce sidelobe levels.

3. Bandwidth Performance:

- In the antenna's bandwidth, checking the range for which return loss remained below -10 dB validated the antenna's bandwidth.
- Iterative simulations fit τ to obtain smooth variations of impedance throughout the band for complete frequency content coverage.

3.3.3 Simulation-Driven Design Refinement

Every simulation graph consisted of actionable insights that informed design adjustments:

- S11 curves pinpointed frequencies requiring better impedance matching, prompting scaling factor fine-tuning.
- Gain plots show that spacing changes would enhance endfire radiation and reduce back lobes.
- A bandwidth analysis was performed to identify those areas where the element sizes required further improvement for uniform performance.

The use of ANSYS HFSS enabled the accurate visualization and validation of the LPDA design ensuring the final configuration met all the performance criteria.

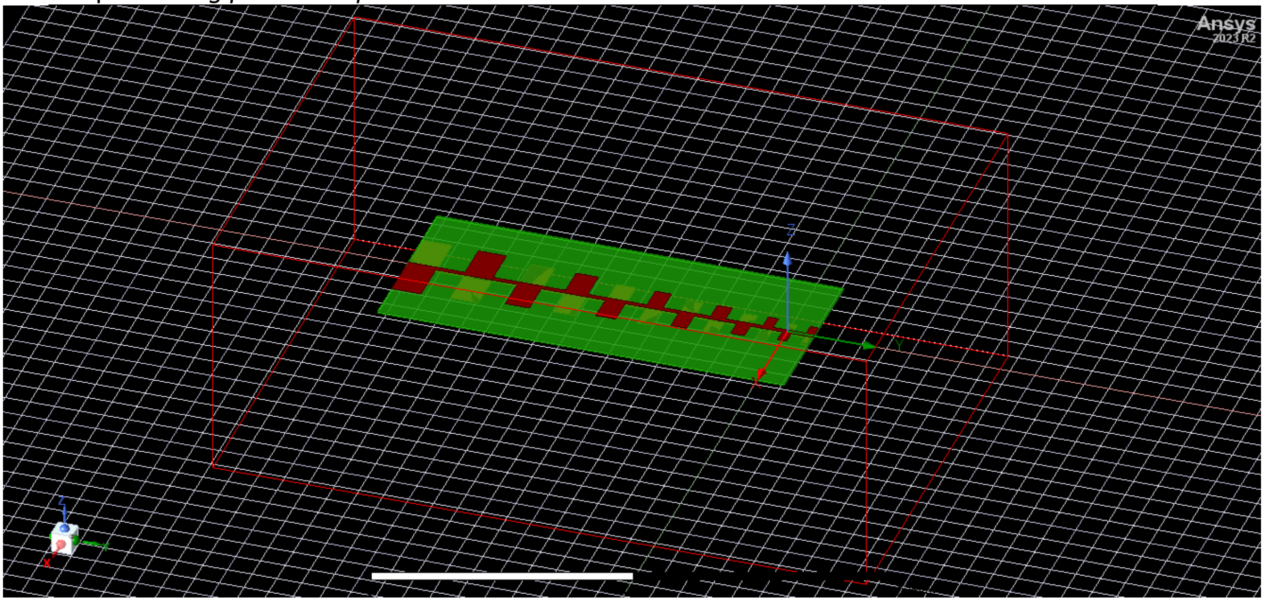

Figure 1: Design of LPDA in Ansys

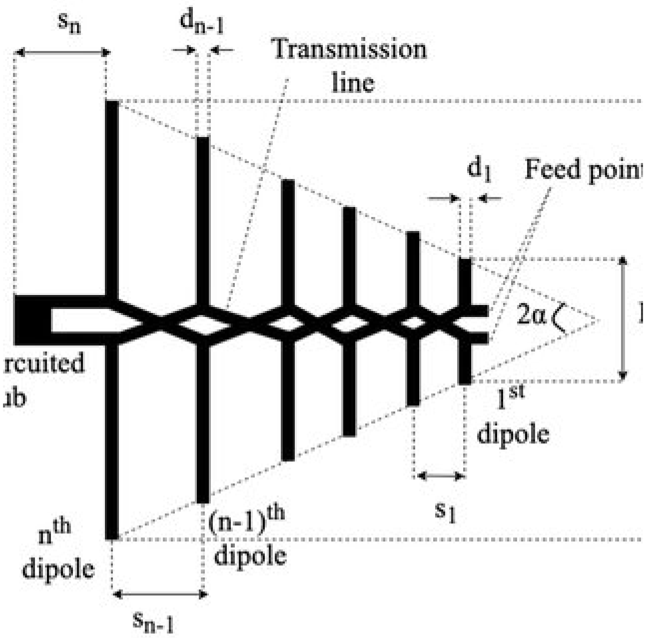

Figure 2: A conventional LPDA geometry

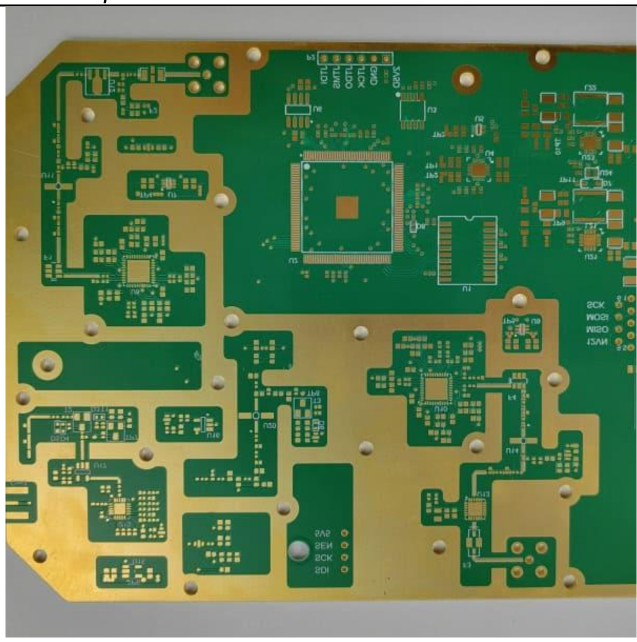

Figure 3: Rogers RO4003c Substrate

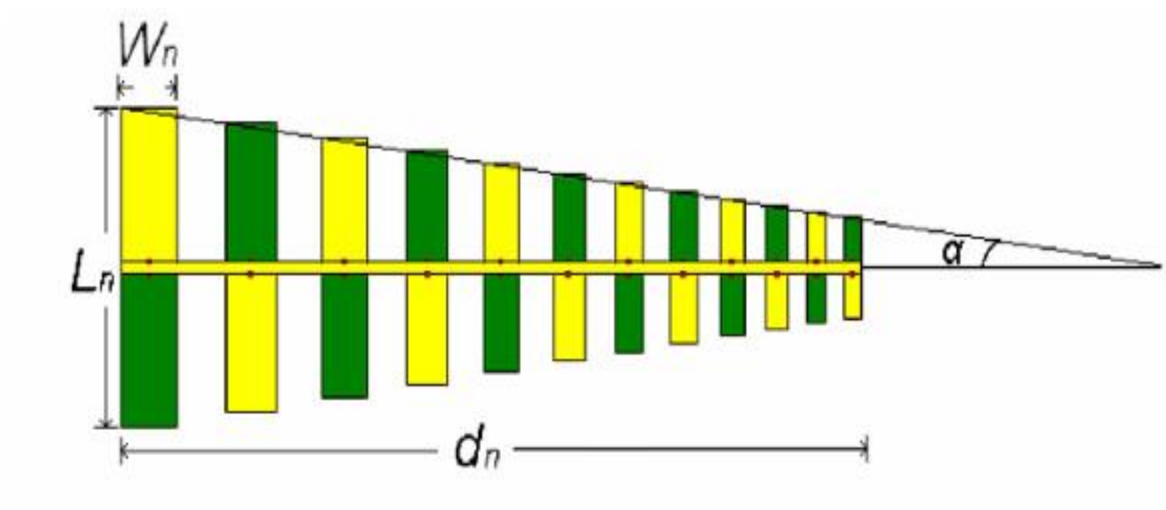

Figure 4: Schematic of the Euclidean log-periodic antenna design

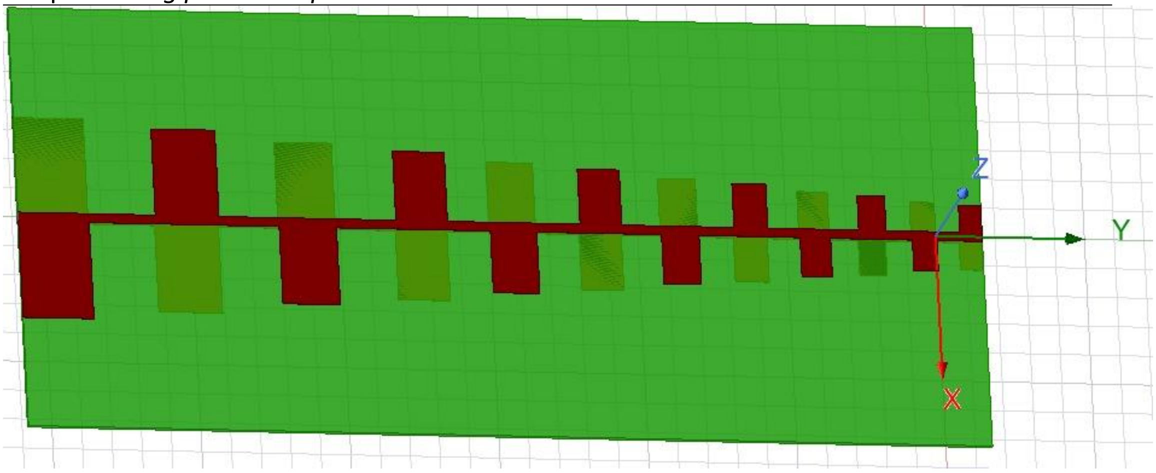

Figure 5: Mirroring of the schematic in Ansys

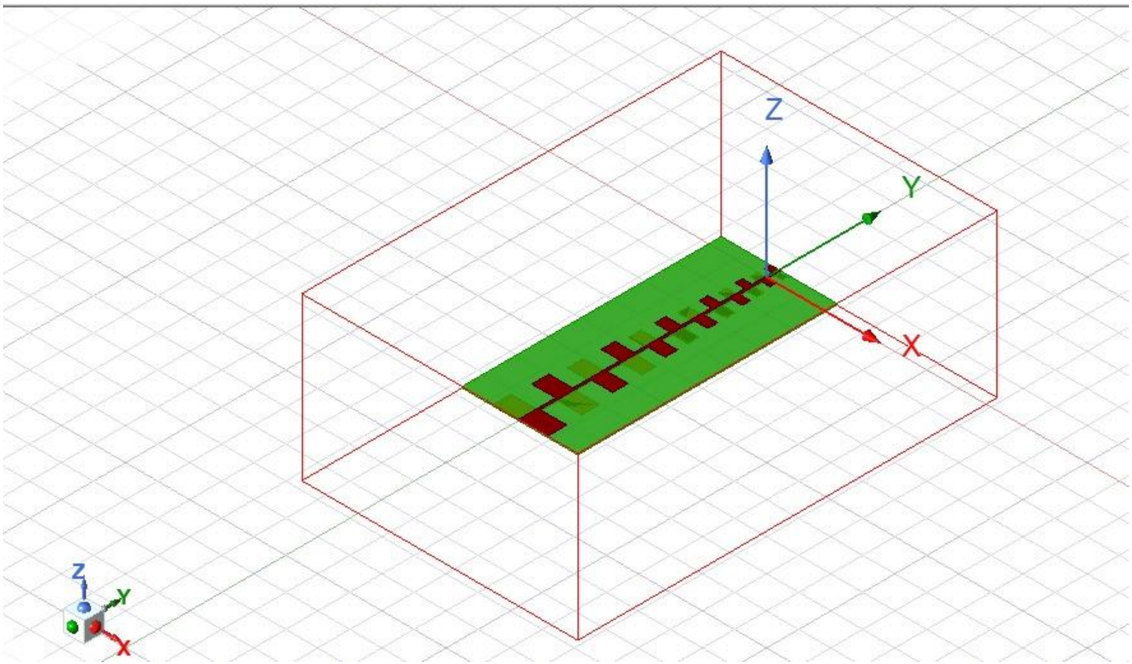

Figure 6: Radiation box of the design

3.4 Performance Optimization

Parametric sweeps were used to obtain progressive refinement of the significant parameters so that the performance optimization was obtained. The returns were achieved for S11, gain stability, and radiation pattern across the bandwidth of operation by systematically varying the values of scaling factor (τ), spacing factor (σ), and number of elements (N). It has optimized the performance on the substrate chosen.

3.4.1 Parametric optimization

Scaling Factor (τ):

- A τ parameter sweep from 0.865 to 0.95 was carried out over both FR4 and Roger RO4003C substrates.
- τ effects on the return loss S11 and gain were then simulated for a frequency of interest:
- Smaller τ values gave rise to sharper bandwidth transitions and introduced small impedance mismatches at localized regions, observable through the S11 plots.
- Higher τ values ensured better bandwidth flatness but resulted in gain ripples at higher frequencies.
- The optimal value of τ at 0.95 was found which minimizes the S11 across the band and stabilizes the gain 3D polar plots.

Spacing Factor (σ):

- The σ was chosen to be synthesized at 0.15, 0.16, and 0.165 in order to observe the impact on radiation pattern and mutual coupling.
- 3D polar gain plots showed;
- Lower σ values increased mutual coupling that enhanced destructive interference and produced sidelobes.
- Larger values of σ decreased mutual coupling but worsened endfire radiation efficiency.
- The spacing factor was optimized at 0.16, with a best compromise between clean radiation patterns and minimal sidelobe levels.

Number of Elements (N):

Simulated two configurations for elements 10 through 12 to analyze how N impacts gain and impedance matching. The goal was to find an increased N resulted in an increased number of elements such that: Increased number of elements led to increased gain and wider bandwidth, as shown by 3D polar plots S11 decreased throughout the frequency range as a result of smoother impedance transition.

An optimum value of 12 elements yielded stable performance without having to increase physical size or complexity excessively.

3.4.2 Final Design Parameters

After evaluating multiple parameter combinations and observing simulation outputs (S11 plots and 3D polar gain plots), the following optimized values were chosen:

- Scaling Factor (τ): 0.957.
- Spacing Factor (σ): 0.16.
- Maximum Element Length (L_max):83 mm.
- Number of Elements (N):12.
- substrate : Roger RO4003C

These values gave the best results with a stable gain of 6–10 dB, S11 below -10 dB across the 2–7 GHz range, and efficient directional radiation patterns, making the antenna suitable for its intended applications.

3.4.3 Simulation and Modeling

Once all key design parameters have been established, the design proceeds to the simulation phase. Using software tools such as HFSS, CST Microwave Studio, or FEKO, the electromagnetic behavior of the antenna is simulated. This includes the radiation patterns and gain performance at different frequencies.

This involves impedance matching, allowing an antenna to efficiently both transmit and receive signals, minimizing signal reflection.
The design is optimized for a minimum size while being highly efficient in wideband performance.

This phase finalises the design so that it should reach the point of physical fabrication process such that the devised antenna would surely meet the specification required in real-world operation.

3.4.4 Prototyping Fabrication and Testing

If the simulated results are promising, then it is an LPDA ready to be fabricated into a hardware version. This includes:

Fabrication of the antenna based on the simulation design.
The prototype is tested in a controlled environment for assessing some of the key performance metrics, such as bandwidth, gain, radiation patterns, and impedance matching. Such measurements thus confine the antenna design to those derived from design expectations.
Stability testing of the antenna under different conditions, say temperature and humidity, on how it performs in the real world.

3.4.5 Special feature of the design:

Log-Periodic Dipole Antennas (LPDAs) offer several features that are considered to make them highly effective and versatile for modern wireless communication systems. Their main advantages are: wideband operation, because they can cover a broad range of frequencies, so LPDAs are widely used in 5G and satellite communications, broadband systems that need multi-band transmission. LPDAs also offer high directional gain, making signal energy concentrated in a specific direction enable long-distance communication with minimal interference. It is particularly indispensable for systems where signal clarity over distance is critical. Their scalability and flexibility make them applicable to small, portable devices, like mobile phones, as well as to large, complex systems, such as base stations or satellite links, for widespread application.

Constant impedance is a very important feature that ensures efficient power transfer and minimum reflection loss with good signal integrity over a wide range of frequencies. This results in good performance for high-speed data transmitting environments. LPDAs also exhibit wide frequency stability with stable gain and radiation patterns, which is an essential requirement for dynamic and high-speed communication systems. Even though their overall performance is phenomenal, LPDAs are designed in a compact form factor, in order to be very suitable for use in space-limited environments such as in mobile devices or aerospace applications. They also come relatively easy to integrate into complex systems, be it standalone or a larger communication setup, thus making them versatile between civilian and military uses.

LPDAs are famous for being stable and reliable, capable of withstanding harsh environmental conditions, and therefore very important for applications outside and mission-critical, such as defense systems or satellite communication. These synthesized features-widespread working, high directional gain, scalability, impedance, stability, compactness, simplicity of integration, and reliability-make LPDAs a flexible and efficient and reliable solution for modern wireless communication systems.

Chapter 4

Results and Discussions

Objective

From the experimental analysis the S11 parameter graph shows a dip below -10 dB across multiple frequency points within the 2.5 GHz to 5.3 GHz range. This indicates that the aerial has an amp right resistance check over this frequency run consequent inch prompt radiation and nominal force expression. The S-parameter Effectiveness demonstrates that the LPDA Layout achieves broadband characteristics which is essential for Uses requiring consistent Effectiveness over a wide frequency spectrum. Hence this LPDA plan is well-suited for radio force change Uses appropriate to its wideband capabilities which enable prompt force change over aggregate frequencies. This feature is especially useful for systems that use wireless power transmission . It enables the antenna to work over a wide frequency range which promotes flexibility and Adaptability to different working environments. In gain the down face coefficient (indicated away the s-parameter dips) ensures that normal force is applied which allows for the use of a pitch of 1 inch which increases productivity. Further, the Layout employs Rogers R4003C (dielectric constant=3.3) substrates that promote reliable high frequency performance making LPDA favourable for WPT Applications that require a wide range of frequency response sustained over extended periods.

4.1 Results and Comparison

The LPDA antenna was tested at some critical frequencies critical to modern wireless communication applications. The results from simulation were such that S11 has never been greater than -10 dB for any of the essential frequencies-the impedance matching could be perfectly achieved without considerable reflections of signal.

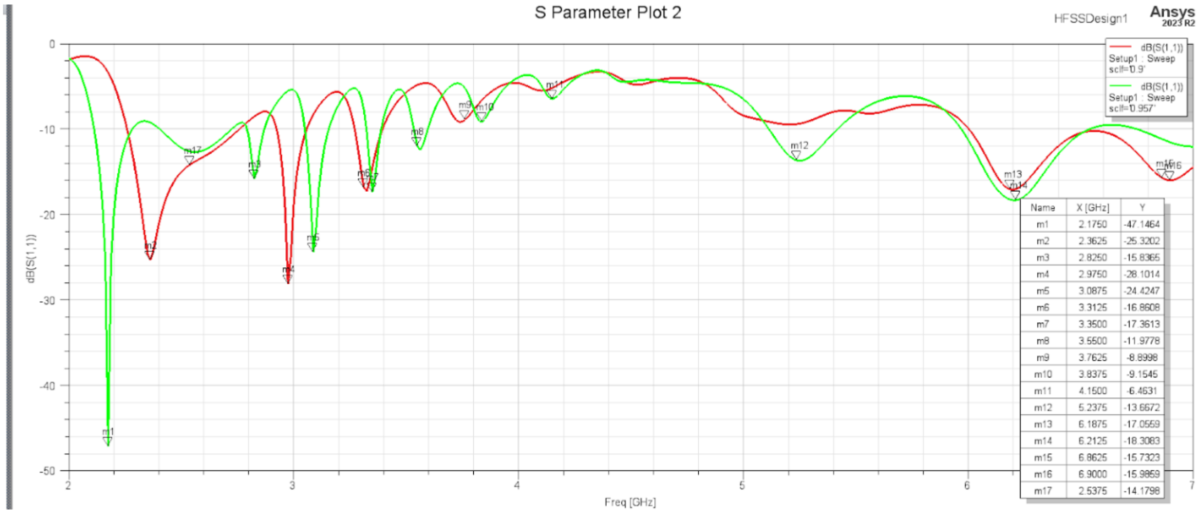

Figure 7: Scaling factor analysis using S11 parameter

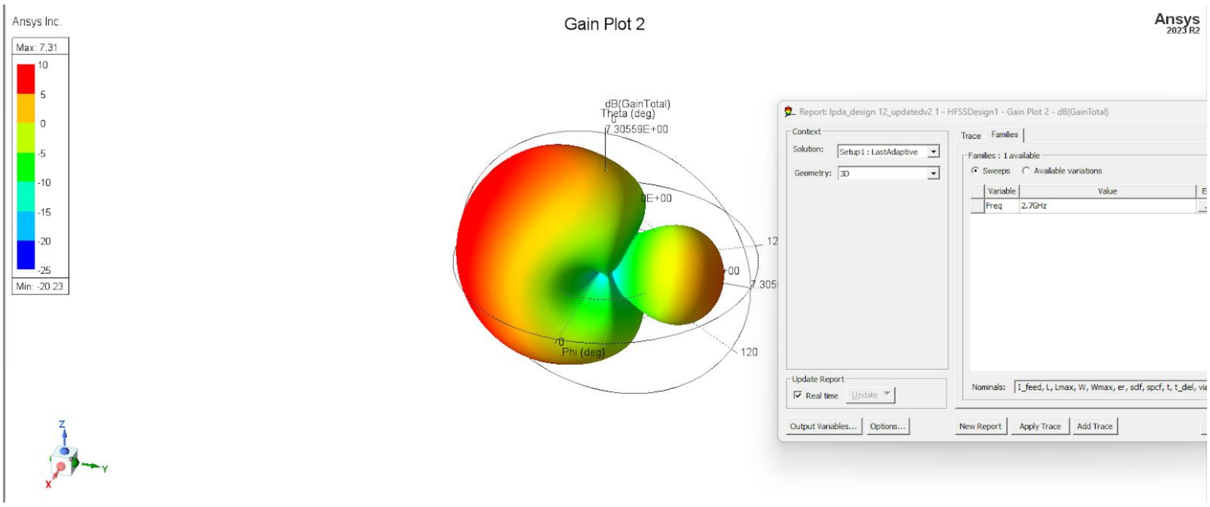

Figure 8 : Gain plot

4.1.1 Key Frequency Performance

1. 2.4 GHz (WIFI/Bluetooth)
    - S11 Value: -47.15 dB (m1).
    - Application: This frequency is widely used for WiFi (802.11b/g/n) and Bluetooth communication, supporting robust data transmission over short to medium ranges.
      The exceptionally low S11 value ensures efficient power transfer, making the antenna highly suitable for these applications.

2. 3.5 GHz (5G Mid-Band)

- S11 Value: -11.97 dB (m8).
- Application: This frequency is part of the 5G mid-band spectrum, offering a balance between coverage and capacity.
- The achieved S11 value ensures reliable performance for next-generation cellular networks and broadband communication.

3. 5.3 GHz (Wi-Fi)

- S11 Value-13.67 dB (m12).
- Application: This frequency is part of the 5 GHz Wi-Fi band (802.11ac/ax), commonly used for high-speed data transmission with reduced interference compared to the 2.4 GHz band.
- The antenna's performance at this frequency supports efficient and stable wireless communication in dense environments.

4.1.2 Other Frequencies in the Range

- 2.175 GHz (m1): S11 = -47.15 dB, demonstrating exceptional impedance matching.
- 6.825 GHz (m15):S11 = -15.75 dB, validating strong performance at the higher end of the operational frequency range.

These results confirm the antenna's capability to operate effectively across the 2–7 GHz range, catering to a wide variety of wireless communication applications such as WiFi, Bluetooth, 5G, and other RF systems

4.1.3 Gain Plot when Lmax=83 mm(Optimised results)

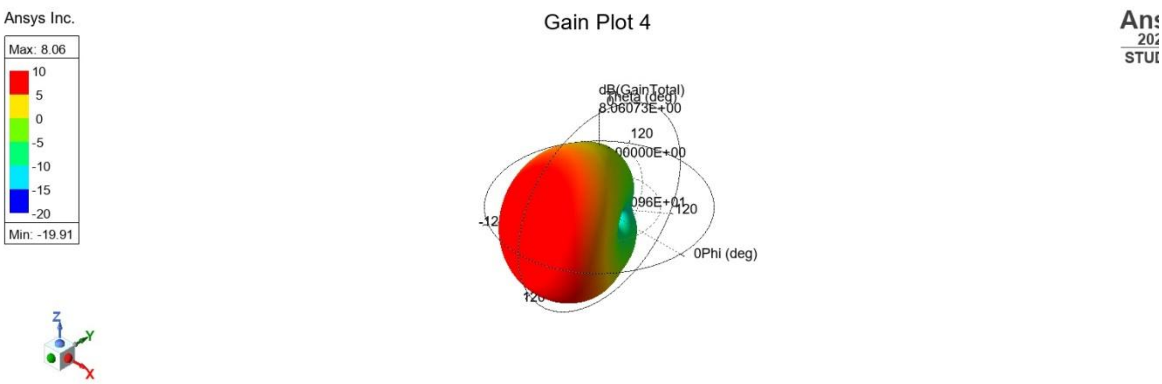

Figure 9: Gain Plot at frequency= 2.7 GHz

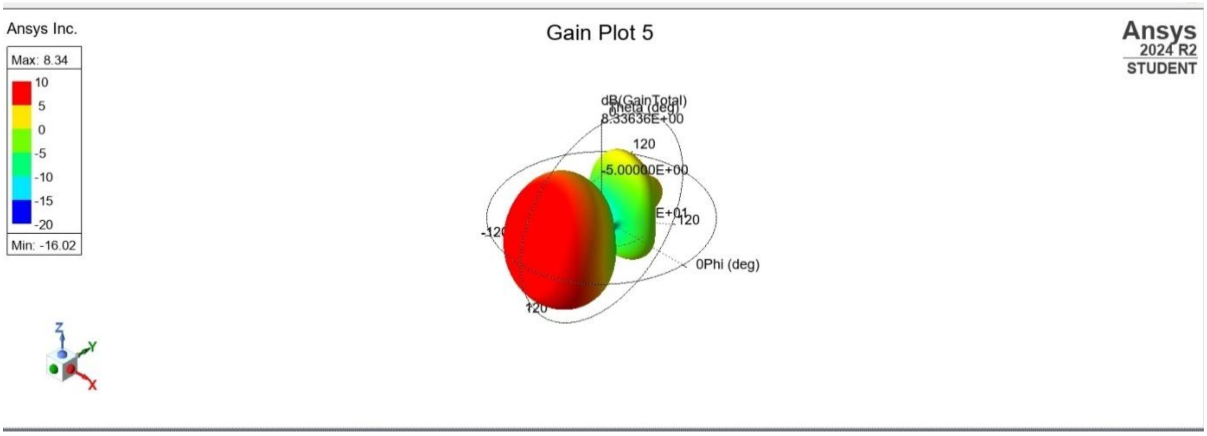

Figure 10: Gain Plot at frequency= 3 GHz

Name	X [GHz]	Y
m1	2.1750	-47.1464
m2	2.3625	-25.3202
m3	2.8250	-15.8365
m4	2.9750	-28.1014
m5	3.0875	-24.4247
m6	3.3125	-16.8608
m7	3.3500	-17.3613
m8	3.5500	-11.9778
m9	3.7625	-8.8998
m10	3.8375	-9.1545
m11	4.1500	-6.4631
m12	5.2375	-13.6672
m13	6.1875	-17.0559
m14	6.2125	-18.3083
m15	6.8625	-15.7323
m16	6.9000	-15.9859
m17	2.5375	-14.1798

Figure 11 : Frequency Vs S11 Parameter values (Optimized <-10dB for max frequencies)

4.1.5 Graph at Lmax=70 mm(for comparison purpose)

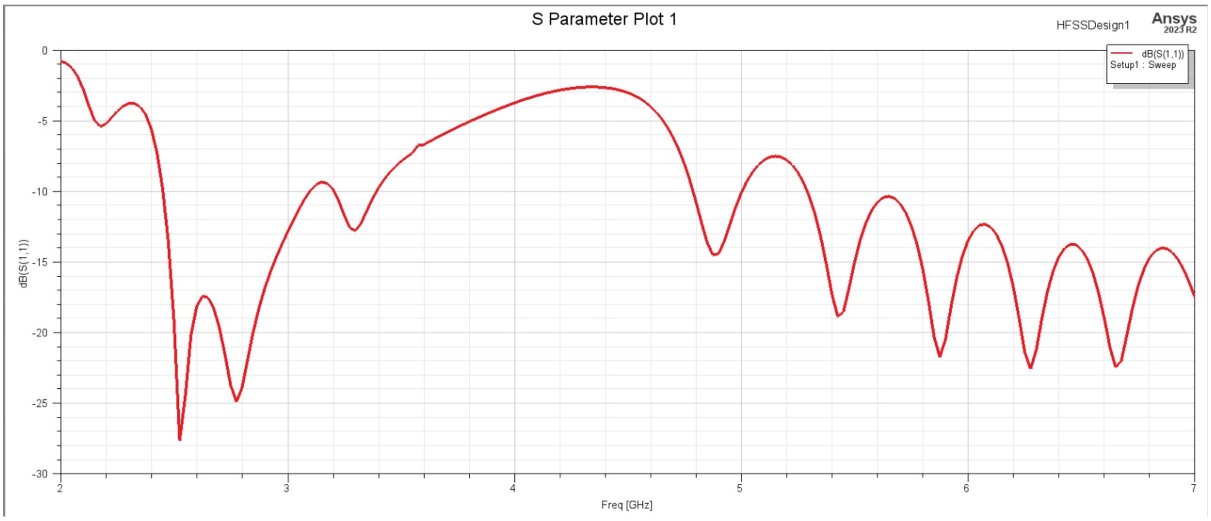

Figure 12: S Parameter Plot at scaling factor=0.918

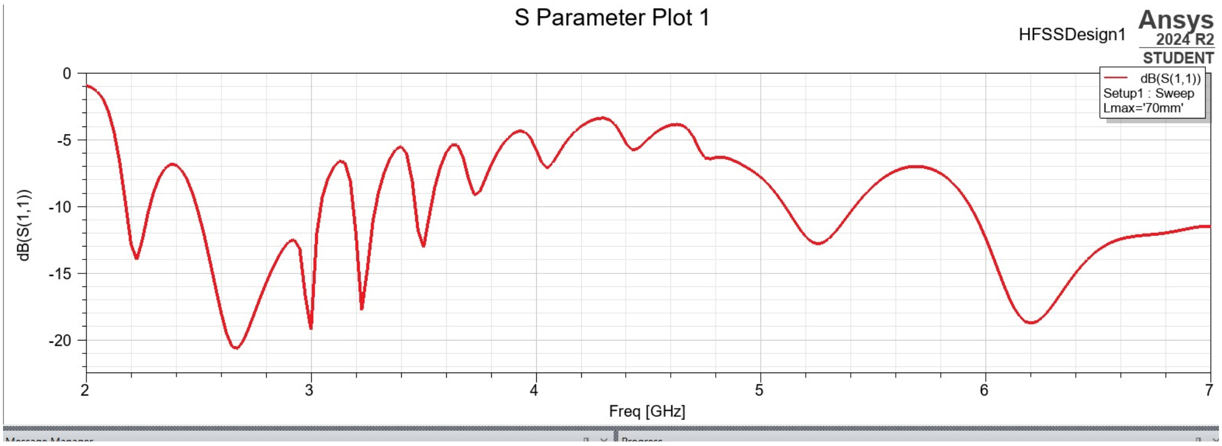

Figure 13: S Parameter Plot at scaling factor=0.957

4.1.5 Comparison of Yagi uda and LPDA for wireless communication

In comparison, Yagi-Uda antennas and Log-Periodic Dipole Antennas (LPDAs) have significant differences mainly based on bandwidth, design complexity, and suitability for application in wireless communication systems. Yagi-Uda antennas are used to design narrowband operation, which means they operate efficiently only in a very short range of a limited number of frequencies. They have high gain in one direction so are used to provide focused signal strength over long distances for television reception, point-to-point communication, and satellite dishes. Yagi-Uda antennas have a simpler design using fewer elements; therefore they are usually smaller, cost-effective, and easier to manufacture. Their performance is best suited for fixed installations and scenarios with a narrow and predictable frequency range.

In contrast, LPDAs are broadband antennas that can work efficiently over a wide frequency spectrum. Because their design has a group of elements in the logarithmic pattern, this always translates into constant gain for several frequencies. They are thus typically used in systems requiring broadband communication, as in the case of 5G networks ,satellite communication systems, and radar systems . LPDAs are more complex and larger than Yagi-Uda antennas since they must have more elements in order to obtain their wideband characteristics. Complexity increases cost; however, impedance matching and stable performance over a wide range of frequencies result, which is fundamentally important for high-performance systems. LPDAs are also more durable and reliable in harsh environments, making them a preferred choice

In general, Yagi-Uda antennas are best suited to high-gain narrow band applications, particularly those requiring compactness and cost-effectiveness. LPDAs are optimal for applications that require wideband performance and flexibility as well as consistent signal quality over multiple frequency ranges. The choice between the two depends on specific system requirements, including frequency range, environmental conditions, and cost constraints.

Summary of Key Differences:

Feature	**Yagi-Uda Antenna**	**LPDA (Log-Periodic Dipole Antenna)**
Bandwidth	Narrowband	Wideband
Gain	High gain in a specific direction	High gain across a broad frequency range
Directionality	Highly directional	Directional, but more versatile across frequencies
Size	Compact and simple	Larger, more complex
Impedance Matching	Narrowband matching	Better matching across wideband
Design Complexity	Simple	More complex
Environmental Robustness	Good for fixed, outdoor applications	More durable, ideal for harsh conditions
Cost	Generally cheaper	More expensive due to complexity
Applications	TV, radio, long-range point-to-point comm	5G, satellite, military, radar, wideband systems

4.1.6 Future scope and Recommendations

Deployment of LPDA in Wideband and Multi-band Communication Systems:

- LPDAs are better suited to 5G as well as other novel wireless systems requiring myriad frequency bands to be supported within those communication systems and high data processing.

- Their wideband characteristics would benefit the concept of dynamic spectrum access and multimodal communications distinctly, which forms the central theme of next-generation mobile networks. Advance Materials and Miniaturization:

- More advanced materials like composites and nanomaterials will need to be researched in order to miniaturize LPDAs in mobile devices. Furthermore, innovative applications in material science could lead to the design of LPDAs that are compact in size without performance degradation integral for the integration of the device in more compact form factors like smartphones or even IoT devices.

- New manufacturing technologies such as additive manufacturing or 3D printing should make the production of LPDAs less expensive.

- Economies of scale can allow LPDAs to be a better alternative for consumer electronics and mass-market applications.

- Develop Enhanced Environmental Robustness for Aerospace and Military Applications

- LPDAs will be optimized for military, aerospace, and satellite communication applications.

- As research in weather-resistant materials and designs continue to advance with the capability of withstanding extreme temperatures, humidity, and EMI, its application continues to expand into more critical communication systems.

- Further testing and validation in realistic scenarios like autonomous vehicles, smart cities, and industrial IoT networks to fine-tune the design and performance. These new technologies rely very much on high-data-rate, low-latency communication, and LPDAs could have a significant role to play in achieving those performance targets.

- Hybrid antenna solutions may potentially see applications in next-generation wireless systems where LPDAs are used in combination with other types of antennas such as microstrip antennas or parabolic reflectors to achieve optimum performance in broadband and point-to-point communication scenarios.

- Further study of these requirements can position LPDAs at the heart of the next generation in wireless communication system evolution, providing reliable, high-performance solutions for a broad spectrum of applications from the commercial to the mission-critical industries.

4.1.7 Other Applications of LPDA

Log-Periodic Dipole Antennas (LPDAs) are handy for the widest range of applications in most industries due to their outstanding wideband performance, high directional gain, and consistent radiation characteristics. The impotence that LPDAs give off is especially deep in wireless communication systems like 5G networks and Wi-Fi by virtue of their multi-band support with considerable performance reliability over a wide frequency range

Their usage for the reception and transmission of signals over long distances makes them appropriate for applications in satellite communications, in which they are used in ground stations and VSAT systems. LPDAs are extensively used in radar, including weather radar, surveillance by armed forces, and air traffic control, in all of which broad frequency coverage and high gain help in the proper detection and tracking of objects. In addition, LPDAs are integrated into broadcasting , both television and radio, since they guarantee the stable reception of signals over several channels.

Log-Periodic Dipole Antennas (LPDAs) are highly versatile and capable of serving a wide range of applications across different industries, especially in wireless communication systems that require **wide bandwidth**, **high gain**, and **consistent performance** across multiple frequencies. Here are some of the key applications of LPDAs

LPDAs also find application in military and defense systems, especially in electronic warfare and signal intelligence (SIGINT) and radars systems, all which require their wideband functionality to intercept and analyze many of these signals. The antennas are also crucial in wireless sensor networks and IoT systems as well, since their broad frequency cover and large gain support a long-distance transfer of data and communication across several nodes of sensors. The LPDAs are widely used in test and measurement equipment, where they are used to assess the performance of other antennas and wireless devices.

The LPDAs used are for the scientific R&D environments, radio astronomy, scientific studies, and remote sensing. These antennas provide reliable and wideband signal reception for applications in experimental environments. Furthermore, LPDAs also play an important role in point-to-point communication systems such as backhaul links for wireless, cellular infrastructure, and so on since they are required for the high-capacity long distance communication between towers and devices.

LPDAs find huge applications in the area of aerospace , mainly in satellite communication and navigation systems, both in spacecraft and in aircraft communication. Their high-performance characteristics give them the values that are inestimable during the exploration of space for data transmission from satellites on Earth, and they also use them in military aviation for good, strong communication systems in field environments.

Conclusion and Future Scope

LPDA antennas constitute a wideband, high-gain, impedance stable, and a directional antenna solution for modern wireless communication systems. Cellular networks to IoT, the suite of advantages they provide pertains to the arena where the basic needs are always broad frequency coverage and reliable signal transmission. LPDAs are suitable for future wireless technologies because they can be used efficiently within a wide range of frequencies and their compact design allows them to fit otherwise space-limited devices without sacrificing performance.

Future prospects for LPDA antennas are bright. As the demand for smaller, more efficient antennas increases, better materials and fabrication techniques can miniaturize further, without sacrificing performance. Potentially with metamaterials and advanced composites, LPDAs can provide more bandwidth, gain, and directivity in environments such as even more diverse wireless. Adaptation and tunable designs for LPDAs would allow for the variation of antenna performance over different network conditions to achieve real-time efficiency and coverage.

LPDs will continue to support wireless communication networks that will be supported by 5G, IoT, and future technologies with high data rates, low latency, and very high-density deployments. In addition to this, further innovations in beamforming and MIMO technologies will be added on the LPDAs to support complex communication environments. All in all, these ongoing design enhancements in LPDAs are guaranteed to make them continue to play an important role and represent the new future for global connectivity in next-generation wireless networks.

Bibliography

[1] E. M. K. Reddy and R. Bhaskar, “Design of novel free space log periodic array antenna to enhance the gain at the frequency range of 35 MHz to 60 MHz and compared with the dipole antenna,” *AIP Conference Proceedings*, vol. 3150, p. 030002, Jan. 2024, doi: 10.1063/5.0228627.

[2] A. A. Gheethan, D. E. Anagnostou, and ECE Department, South Dakota School of Mines & Technology, Rapid City, SD, 57701, “Reduced size Planar Log-Periodic Dipole Arrays (LPDAs) using rectangular meander line elements,” journal-article, 2008.

[3] “The Evolution of Antenna Technology: Yagi–Uda, helix, and log-periodic antennas.,” *IEEE Journals & Magazine | IEEE Xplore*, Oct. 01, 2024. https://ieeexplore.ieee.org/abstract/document/10623293

[4] “The Evolution of Antenna Technology: Yagi–Uda, helix, and log-periodic antennas.,” *IEEE Journals & Magazine | IEEE Xplore*, Oct. 01, 2024. https://ieeexplore.ieee.org/abstract/document/10623293

[5] S. S. Gültekin and M. Yerlikaya, “Enhanced Gain Dual-Port Compact Printed Meandered Log-Periodic Monopole Array Antenna Design with Octagonal-Ring Shaped FSS for Broadband 28 GHz Applications,” *Arabian Journal for Science and Engineering*, Jun. 2024, doi: 10.1007/s13369-024-09256-3.

[6] “volume | PIER Journals.” https://www.jpier.org/PIERC/pier.php?paper=23042004

[7] V. Sorathiya *et al.*, “Graphene-Based Log-Periodic Dipole Antenna-Shaped MIMO antenna structure for the terahertz frequency spectrum,” *Arabian Journal for Science and Engineering*, vol. 49, no. 5, pp. 6391–6404, Sep. 2023, doi: 10.1007/s13369-023-08235-4.

[8] C. Im, S. Youn, T. H. Lim, and H. Choo, “Design of a compact log periodic dipole array antenna for broadband and High-Power beam synthesis using superposition,” *Journal of Electromagnetic Engineering and Science*, vol. 24, no. 3, pp. 234–242, May 2024, doi: 10.26866/jees.2024.3.r.224.

[9] “Miniature Planar Log Periodic Dipole Array antenna for IEMI Detection Application,” *IEEE Journals & Magazine | IEEE Xplore*, Oct. 01, 2024. https://ieeexplore.ieee.org/abstract/document/10605071

[10] “An ultrawideband H-Plane monopulse Log-Periodic antenna for jamming signal finding,” *IEEE Journals & Magazine | IEEE Xplore*, Sep. 01, 2024. https://ieeexplore.ieee.org/abstract/document/10577594

[11] “The design of Log-Periodic Dipole Array (LPDA) antenna for 5G application using SIW technology,” *IEEE Conference Publication | IEEE Xplore*, May 12, 2024. https://ieeexplore.ieee.org/abstract/document/10576329

[12] “High gain arrow shaped Log-Periodic Dipole Array antenna for 5G applications,” *IEEE Conference Publication | IEEE Xplore*, Jul. 12, 2024. https://ieeexplore.ieee.org/abstract/document/10692165

[13] “RF circuit analysis of UWB Planar Log Periodic antenna for 5G communications using theory of characteristic modes,” *IEEE Journals & Magazine | IEEE Xplore*, Aug. 01, 2024. https://ieeexplore.ieee.org/abstract/document/10525207

[14] M. A. Saeed and A. O. Nwajana, “A review of beamforming microstrip patch antenna array for future 5G/6G networks,” *Frontiers in Mechanical Engineering*, vol. 9, Feb. 2024, doi: 10.3389/fmech.2023.1288171.

[15] “Ultrawideband Transmit-Reflect-Array antenna for 6G communication,” *IEEE Journals & Magazine | IEEE Xplore*. https://ieeexplore.ieee.org/abstract/document/10584263

Biodata

Name: Shreya Jaiswal
Mobile No.: 8004910875
E-mail: shreya.jaiswal2021b@vitstudent.ac.in
Permanent Address: 359/4/A Nirmal Nagar Colony Pili Kothi Kydganj Prayagraj,Uttar Pradesh

Name: Blessy Abraham
Mobile No.: 8770343642
E-mail: blessy.abraham2021b@vitstudent.ac.in
Permanent Address: Plot no 16/33 Ispat Nagar ,Risali , Bhilai ,Chhattisgrah .

Name: Tamanna
Mobile No.: 9078988227
E-mail: tamanna.2021@vitstudent.ac.in
Permanent Address: New AG Colony, Nayapalli, Bhubaneswar, Odisha 751012