Review paper 1.docx

by Vit Chennai

Submission date: 19-Nov-2024 03:39PM (UTC+0530)
Submission ID: 2524913472
File name: Review_paper_1.docx (917.38K)
Word count: 1904
Character count: 11653

Log Periodic Antenna for Wireless Communication

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Abstract-The demand for high-performance wireless communication systems has raised a call for the design of antennas capable of handling ultra-wide bandwidth, high gain, and consistency over a wide range of operating environments. LPDAs promise to fill the gap because they are scalable and have wideband characteristics, delivering reliable high-performance results across a variety of applications. The present report investigates the application possibilities of LPDAs for communication over wireless media, their capacity to support efficient signal propagation throughout extended frequency ranges, and how they can be utilised in applications that require both high data rates as well as low latency due to their wide operating bandwidth and high directional gain. The technical discussion of LPDAs would focus on the following: important design considerations, which are compact form factors, high-efficiency materials, and stable performance over wide frequency spectrums. For this reason, LPDAs will continue to be the key and flexible solution in the advancement of applications in wireless communication systems, ranging from consumer electronics to infrastructure for large-scale applications.

1 Introduction

Log-Periodic Dipole Antennas have emerged to the forefront in antenna design as an effective means of attaining these objectives. LPDAs have a broad frequency range, high gain, and consistent radiation patterns, which make them suitable for several wireless applications-from high-speed data transmission to IoT networks.

The logarithmic form of the LPDAs ensures broad spectrum impedance and performance, making them suitable for environments needing ultra-wideband operation. Their high efficiency, compactness, and ability to support multiple users with minimal interference makes them very suitable for modern wireless systems. In this report the problem of LPDAs, their potentiality and their performance in wireless communication has been discussed especially over the 2-7 GHz frequency range and how LPDAs would enable future communication networks to cope with its demands.
Here, we aim for moderate to maximum gain across the operating frequency range 2-7 GHZ.

The Key objective of our research are :-
Design and Optimization: To design LPDA which should have high value of gain and minimum reflection coefficient, less than −10 dB, over the frequency range of 2-7GHz, by managing the size of the antenna without degrading its performance, particularly at low frequencies.
Cost Effective Alternative: To provide a low-cost, lightweight, and compact substitute. we have employed RO4003C (dielectric constant=3.38) due to the following reasons:-

Low Dielectric Loss: Suitable for high frequency applications, results in low loss of the signal.
Thermal Stability: Performance is achieved under temperature change when CTE(coefficient of thermal expansion) is low.
Low Cost: Its compatibility with conventional PCB techniques, high performance at a reduced cost.

Broad Frequency Support- The technology gives very good frequency support across a broad spectrum because it is low-loss over a large range of frequencies.The RO4003C is well suited for LPDAs in testing, radar, and telecommunication applications that provide a reliable, high-performance broadband coverage.

Experimental Verification- To ensure that the design meets gain, impedance matching, and radiation stability performance requirements over the specified frequency range by making simulations and experimental measurements.

2 Design and Optimization

In the design methodology of the Log-Periodic Dipole Array (LPDA), several key parameters—scaling factor, spacing factor, apex angle, and the number of dipoles—are essential to achieve optimal performance across a wide frequency range.

The scaling factor (τ) determines the ratio between the lengths of consecutive dipoles in the array. The value of τ is selected to control the array physical length and frequency ,its values typically ranges between 0.7 and 0.9 to ensure proper element scaling across the target frequencies. The spacing factor (σ) is a different important parametric quantity that determines the space between adjacent dipoles, it is defined by the ratio of the spacing (Sn) between two consecutive dipoles to the length of the nth dipole and expressed as $\sigma = Sn/ Sn+1$ .Choosing an appropriate value for σ ensures that the elements are positioned to maintain consistent effectiveness across operational frequency range.The apex angle (α) or the angle formed by the extended lines of each dipole element converging at a common apex influences the array beam width and directivity ,given by $2\cdot\arctan(1-\tau/2\ \sigma)$ .This angle is carefully chosen to optimise the radiation layout and minimise side lobes.Finally the number of dipoles (N) required in the LPDA layout depends on the desired frequency range and the scaling factor.A larger number of dipoles improves the array bandwidth and gain but it also increases the overall size.These parameters collectively define the LPDA layout providing a balance between frequency coverage directivity and physical size to achieve effective and efficient wideband.

Increasing the number of dipoles means more dipoles available to resonate at multiple frequencies allowing the LPDA to maintain a consistent gain at a wide range of frequencies. This is good for wireless power transmission Uses which run astatine disparate frequencies. Also more dipoles help in better radiation layout control . Smaller helps in minimising size of antenna but may lead to narrow bandwidth & decrease in gain because the effective aperture of antenna is reduced leading to reduced signal reception. Length of largest dipole (Lmax) determines the lowest operating frequency of the LPDA for this layout Lmax values between 64 mm and 90 mm were checked to achieve resonance at lower target frequencies ensuring sufficient gain for WPT uses at 2.3 GHz, 2.5 GHz and 2.7 GHz. ,3.5 GHz, 5.23 GHz.. Selecting an appropriate Lmax enables the antenna to operate effectively across a wide frequency range covering multiple WPT-relevant frequencies while optimising gain and productivity for energy transfer.

After iterating these various parameters we optimised our layout with no of elements to 12, scaling factor to 0.9 and length of largest element to 83mm. The optimised LPDA plan offers 6–10 decibel wireless power transmission . This reliable gain improves efficient power transfer at various frequencies making it well-suited for diverse wireless power transmission (WPT) uses. This Adjustability makes it an excellent choice for multi-frequency WPT setups that serve IoT devices, industrial sensors, consumer electronics and medical devices.

3 Result and Comparison

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 (WPT) 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 (WPT). 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=3.38) 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.

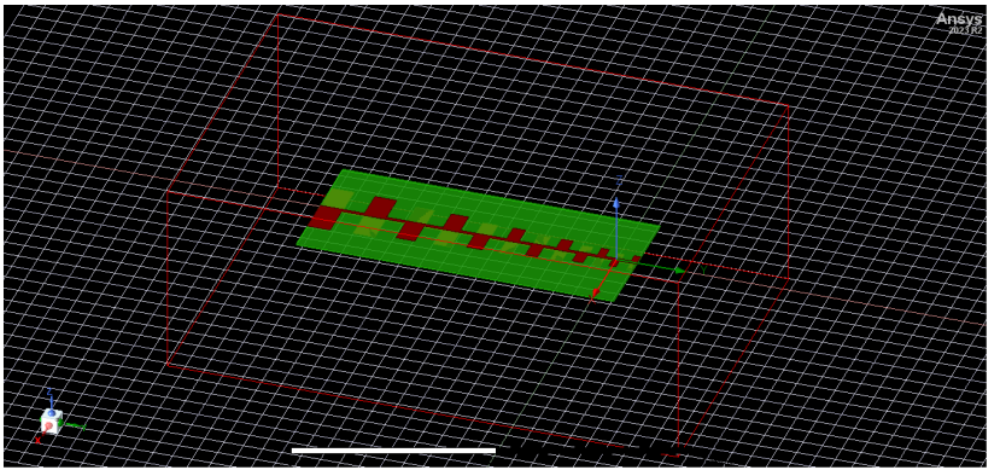

Figure 1: Design of LPDA in Ansys

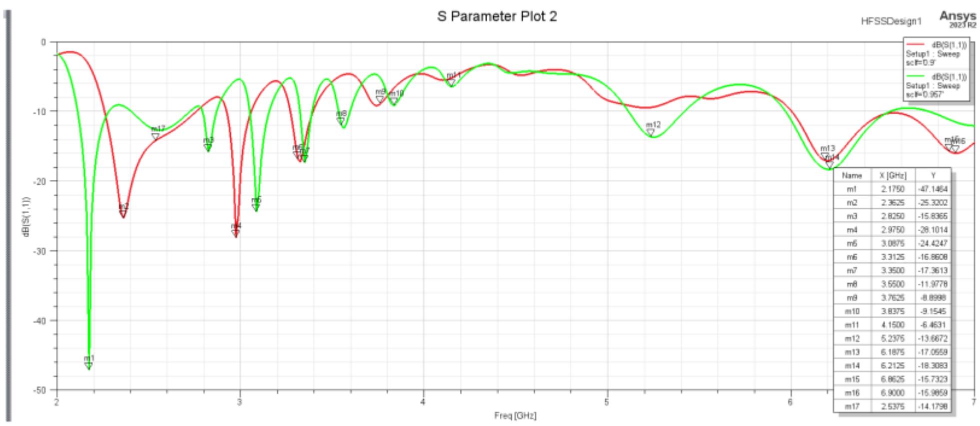

Figure 2: S11 parameter at Lmax = 83mm and scaling factor = 0.9 and 0.957

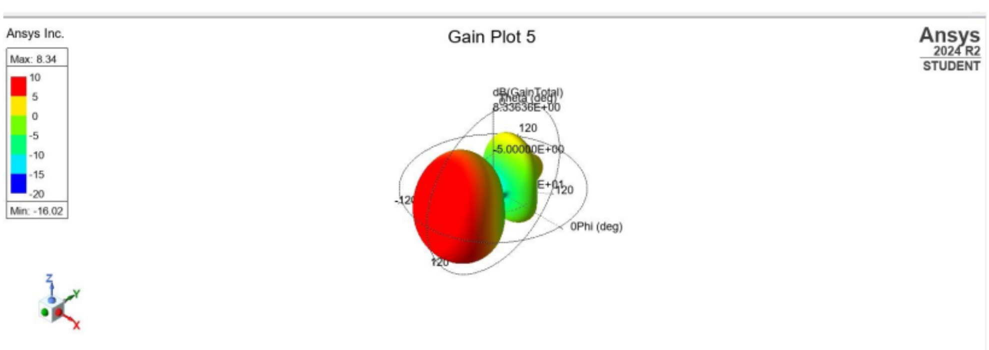

Figure 3 : Gain plot at 3 Ghz

4 Conclusion

The LPAs are very effective for the modern wireless communications system as they are broadband-capable, stable impedance, and versatile in designing. All these attributes make the selection of LPAs apt for various wireless applications including cellular networks to IoT systems. The ability of LPAs to operate over extended frequency ranges with consistent performance and directional gain makes them adapt to varied wireless technologies where efficiency and flexibility are dramatically required. With these benefits, LPAs are bound to play significant roles in filling the technology needs of the future-generation wireless networks in terms of reliable high-capacity and high-density wireless deployment.

Wideband Capacity: The LPDAs have efficient operation over a very broad frequency range and are hence suitable for wide varieties of wireless communication applications.
High Gain and Directivity: Its directional characteristics give it a high gain and assure effective signal transmission as the path loss is overcome.
Compact Design: It supports integration into dense device arrays with high-density deployments.
Stable Impedance: LPDAs maintain stable impedance over their operating range and therefore make network integration easier and reduce signal loss considerably.

In conclusion, the wideband capability, high gain, and compact design of LPDAs make them a versatile and efficient solution for the really vast area of wireless communication systems, with reliable performance and scalability to be presented in future generations of wireless networks.

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