# 1 INTRODUCTION

The log periodic dipole antenna, hereafter referred to as LPDA antenna was invented in 1958 by Isbell [1], of the university of Illinois, United states of America. This antenna is a system of driven elements designed to operate over a wide range of frequencies. The LPDA antenna exhibits constant electrical characteristics (i.e. fairly constant gain, pattern and VSWR etc), over the designed frequency range. The basic concept guiding the operation of the LPDA antenna is that a gradually expanding periodic structure array, radiates most effectively when the array elements (dipoles) are near resonance, so that with frequency variation, the radiating or active region moves along the array.

Structurally speaking, the LPDA antenna consists of a sequence of dipoles with successively increasing lengths outwards from the feed point at apex as figure1 depicts. The feed lines cross over between adjacent elements, so as to give an $180^0$ phase reversal between any two adjacent elements. This is to ensure that the radiated fields from the resonant elements are in phase at the far field. The active or radiating region moves along the structure with changing frequency. The active region is comprised of dipole elements whose wavelengths are $\lambda/2$ at the resonant frequency and most of the antenna currents are concentrated within this region. The remaining elements of the array may then be classified as;
(i) Directors, being elements whose wavelengths are slightly less than $\lambda/2$ at the resonant frequency. (ii) Reflectors, comprised of elements whose elements are slightly greater than $\lambda/2$ at the resonant frequency. The directing and reflecting dipole elements of a LPDA antenna are referred to as parasitic elements. Consequent to the actions of the directors and reflectors, the LPDA antenna is directional in its radiating and receiving patterns. This means that it radiates or receives energy more in one direction than in others. In addition the phase reversal of currents in adjacent elements, ultimately results in highly directive beam emerging from the direction of the smallest element in the array.

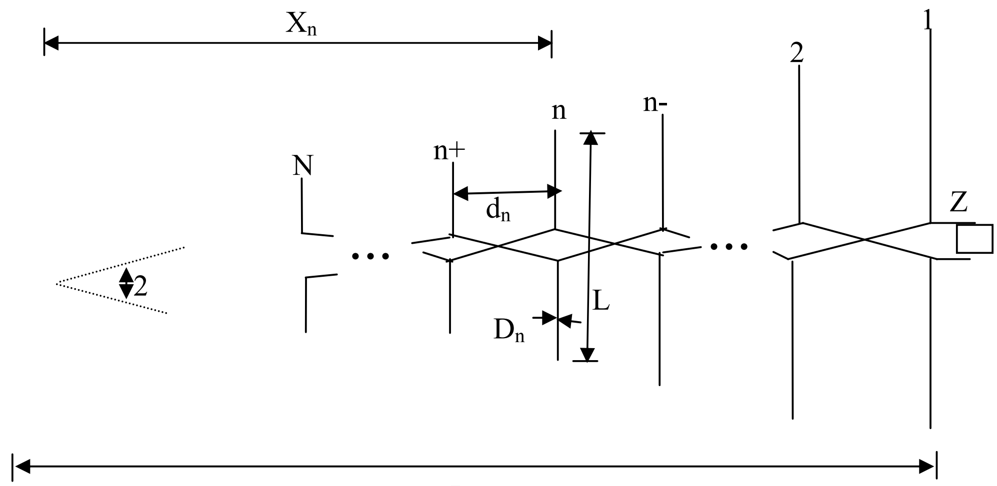


**Figure 1.1** The LPDA Antenna

The behaviour of the LPDA antenna is fairly well modelled, mathematically speaking. The elements are shortened by a factor $\tau$ as we move towards the source of excitation, where $\tau$ is known as the scaling factor and is one of the key parameters of the LPDA antenna. The scale factor is defined by

$\tau = L_{n+1}/L_n = d_{n+1}/d_n = D_{n+1}/D_n = X_{n+1}/X_n$ . . (1)

(Where $D_n$ is the diameter of the $n^{th}$ dipole element and $L_n$ is the length of the $n^{th}$ dipole element.) The scaling factor specifies the dimensional relationship between any two adjacent dipole elements. Another important parameter of the LPDA antenna is the space constant '$\sigma$', which is given by

$\sigma = d_n/2L_n = (1-\tau)/4\cot\alpha$ . . (2)

Where $\alpha$ is the apex angle and $d_n$ is the distance of the $n^{th}$ dipole element from the preceding element. This factor determines the antenna element density. It is an indication of how many dipole elements, a given antenna boom can accommodate. During designs, you may specify either the spacing factor or the apex angle, as they have the same effects on the LPDA Antenna performance. For this reason, the number of dipole elements N, which is another parameter of the LPDA Antenna is specified in terms of both the scaling factor and spacing constant and is given by

$N = 1 + \log(L1/LN)/\log(1/\tau)$. . (3)

$Z_o$ in ohms, is the impedance of the Antenna boom. This impedance is one of the parameters which must be specified during design and its effects on the performance characteristics of the LPDA Antenna is part of the subject of this dissertation. The boom-length L in meters is given as a function of spacing constant, scaling factor, and the longest and shortest dipole elements. This is mathematically expressed as $L = 2\sigma(L_1 - L_N)/(1-\tau)$ (4)
$L_1$ and $L_N$ are the longest and the shortest dipole elements respectively.

Carrel [2], published a simple design procedure for designing LPDA antennas. The only draw back to this procedure is that it neglects the effects of the boom-impedance and length to diameter ratio on the gain performance characteristics of the LPDA antennas. This though does not detract from the elegance and simplicity of this design technique.

Subsequent works by De vito and Stracca [3], [4], Peixeiro [5] and others have taken advantage of the availability of computers to numerically model the LPDA antenna, thereby introducing more accurate design curves. Despite the attractiveness and popularity of the LPDA antenna, much information is still lacking regarding its performance characteristics.

## 1.1 STATEMENT OF THE PROBLEM

The parametric curves giving the performance characteristics of the LPDA antennas, currently available in design books and other literature are those of Carrel [2], De vito and Stracca [3], [4], and Peixeiro [5]. Each of these researchers though having essentially the same objective, which is the design of a functional LPDA antenna, placed emphasis on different aspects of the design problems. Carrel [2], one of the many pioneer researchers of the LPDA antenna, though recognising the effects of the length to diameter ratio ($L_n/D_n$) and the boom-impedance ($Z_o$) on the gain performance of the LPDA antenna, took the view that these effects are negligibly small. Carrel's design curves therefore did not incorporate these effects.

De vito and Stracca [3], [4], on the other hand, considered Carrel's miscalculation of the gain a major problem and therefore sought to correct it. In looking at the problem, Peixeiro [5], was of the view that not only is carrel's gain prediction overly optimistic, his neglect of the effects of the length to diameter ratio and the boom-impedance on the performance characteristics of the LPDA antenna was unacceptable. His design curves therefore contained LPDA antenna performance characteristics for values of length to diameter ratio and boom-impedance. Butson and Thompson [6], also considered the incorrect gain values as given by Carrel [2], but differed with Peixeiro [5] as to the origin of the error.

The aim of this research is to take advantage of the immense computational capability inherent in the method of moments based Super Nec [7], to achieve the following:

(1) Extend the range of the parametric curves beyond those given by Peixeiro [5]. This is necessitated by the fact that the design curves as given by Peixeiro [5] are limiting in scope as it does not cover the range of scale factor $\tau$, below 0.7 and space $\sigma$, beyond the range of values between 0.05 and 0.22. This limitation of the parametric curves was also investigated by Bantin and Balmain [8]. Their research concentrated on different aspect of this problem though.
(2) Extend the range of investigation of the effect of length to diameter ratio, on the performance characteristics of the LPDA Antenna, beyond the range of values between 177 and 1000 and the effect of boom-impedance on the performance characteristics of the LPDA Antenna, beyond the range of values between 100 and 400Ω, as did Peixeiro [5].
(3) Find a means of minimising the number of element 'N' as a means of cost optimising LPDA antenna. The justification for minimising "N' is propelled by the need to keep the cost down as the number of elements and the boom-

length are the main cost determinants of the LPDA antenna, De vito and Stracca [3], [4]. This minimisation criterion is referred to in this dissertation as convergence and it will enable the Engineer to ascertain the minimum number of elements necessary for a LPDA antenna of given length and operating bandwidth, to yield acceptable performance with regards to its functions as a practical antenna. This aspect of investigation is unique to this dissertation. Despite the various aspects of investigations performed on the LPDA Antenna by all the researchers previously mentioned, non has tried to answer the question, what is the minimum dipole element density required for a LPDA Antenna of given length and operating bandwidth, to yield acceptable performance?

(4) Give cognisance to the effects of boom-length (L in meters) and operating bandwidth (B) on the gain performance characteristics of LPDA antennas by presenting parametric curves in terms of these parameters. This was not done by Peixeiro [5].

(5) Study the effects of boom-impedance ($Z_o$) and length to diameter ($L_n/D_n$) ratio on the gain performance of converged LPDA Antennas.

It is intended that these parametric curves of performance will broaden our perspective, extend the choices available to us and enable the use the minimisation of 'N' to make the design of LPDA antenna cost effective without degrading performance.

## 1.2 JUSTIFICATION

Justification for this research was founded on the basis that the situation as currently exists, is that some information regarding the performance attributes of the LPDA antennas is unavailable. Therefore an extension of the characterisation of the LPDA antenna will not be out of place, given the fact that there are missing information and the need of the practising engineer to have a tool to better optimise the performance of the LPDA antenna. The choice of Super Nec [7] as the simulation software is justified on the basis of it being a highly respected and tested program within the electromagnetic field. Super Nec [7] is based on (Nec2) which in turn is based on the method of moments [9] theoretically. Super Nec [7] when compared to Nec2 has the advantage of compatibility with Matlab, which makes it easy to visualise the output of simulation. This would have been difficult using Nec2.

## 1.3 APPROACH TO SOLVING THE PROBLEM

The investigations in this dissertation were performed in four stages. Firstly, in order to perform computational investigation of the LPDA antennas, measured impedance and VSWR are compared with theoretical predictions of them. Favourable comparison between the two sets of values will serve as a validation of the numerical model used in obtaining the theoretical results (ref. Chapter Two). Secondly, once the numerical model is validated, the generalised performance characteristics of the LPDA antenna for various lengths and operating bandwidths are then presented without cognisance to whether the Antenna is convergent or not [ref. Appendix A]. Thirdly, trends in the variation patterns of the average and standard deviation of the gain are used, as the basis for optimising LPDA antennas in terms of the number of element (N) [ref. Appendix A]. Thereafter, the performance characteristics of converged LPDA antennas are presented [ref. Appendix A]. Finally, the effects of length to diameter ratio and boom-impedance on the gain performance of convergent LPDA antennas are investigated and presented in form of parametric curves [ref. Appendix B and C].

In all, four hundred and ten LPDA antennas were investigated. The totality of these investigations is then presented in chapter 3, under the heading 'results'. The simulations were done such that, for any operating bandwidth, the number of frequency steps will be the same, to ensure same average values. In the same vain, for any boom-length and operating band-width, the number of element is doubled for each incremental step, starting with N = 4 where possible. This is to ensure uniformity.

## 1.4 LIMITATIONS OF THE RESEARCH

Due to time and other related constraints, the scope and range of parameters investigated are of necessity, not exhaustively extensive.

This research does not cover all varieties of Log Periodic Array Antennas, as there are an infinite number of such antennas. This research investigates LPDA Antennas within the bandwidth of 300MHz – 3GHz, [except for one of the built models where validation of Super Nec was the main aim], with boom lengths ranging from $0,5\lambda_{max}$ to $2\lambda_{max}$ (where $\lambda_{max}$ is the wavelength at the lowest operating frequency). The variations of these parameters are limited to ranges, which are of practical interest. The length to diameter ratio was investigated for range of values between 25 and 10000. This is because for length to diameter ratio value greater than 10000, the log periodicity of the antenna is no longer guaranteed Wo and Lee [10]. The boom impedance $Z_o$ is investigated for values ranging between 50Ω and 600Ω. This is to cover the range of characteristic impedance for both coaxial and two -wire transmission lines.

The boom lengths are chosen to be multiples of half the wavelength at the lowest frequency (in this instance 300 MHz). It is to be noted here that Super Nec [7] is not an infallible tool. It does have its own limitations and rules, which, if not well followed, can yield erroneous results. Finally, these investigations are limited to free space environment only. This means that the antennas are assumed not to have been electro-magnetically coupled to the earth or any nearby structure. This is an ideal situation.

## 1.5 DOCUMENT OVERVIEW

The aim of this Section is to briefly discuss the information covered in chapters two to four. The main purpose of each section is delineated as an argument for the dissertation.

Chapter Two is an introduction to the methodologies used in arriving at the final results. This chapter includes the process of validating the numerical model, the use of trends in variation patterns of the average and standard deviation of the gain as the basis for delineating LPDA antennas as convergent or sparse (i.e. for minimisation in terms of N).

Chapter three presents result of investigations starting with the extended parametric curves of gain as a function of boom-length and operating bandwidth for LPDA antennas irrespective of being convergent or sparse and ending with the effects of boom-impedance and length to diameter ratio on gains of convergent (optimized) LPDA antennas.

Chapter four concludes the research. An overview of the research was presented. Some examples on the applications of the research were presented. Finally concluding statements about the aims of the research and whether these aims were met was made.