DESIGN OPTIMIZATION OF LOG PERIODIC DIPOLE ANTENNA USING GENETIC ALGORITHM

Narinder Kaur[1],Munish Rattan[2]
Department of ECE
Guru Nanak Dev Engineering college, Ludhiana,India
Email: [1]04narinder.er@gmail.com ,[2]rattanmunish@gndec.ac.in

ABSTRACT

In this paper,design optimization of Log Periodic Dipole Antenna (LPDA) has been carried out using Genetic Algorithm. The design objectives of this work is maximization of gain and minimization of VSWR.This has been achieved by variations in geometrical parameters of log periodic dipole antenna like maximum length, minimum length,spacing factor (σ). The simulation results have attained gain from 6.04dB to 8.45dB and VSWR<1.5 on the operating frequencies from 300MHz to 400 MHz.

Key Words: *Optimization, Log periodic dipole Antenna,Gain and VSWR,Genetic Algorithm*

1. INTRODUCTION

The Log Periodic Dipole Antenna is one of the useful antenna among the frequency independendent antennas.It is used in many applications,ranging from HF to microwaves.Antenna components are proportional in size to each other and to the wavelength.Its geometry forces the antenna impedance and radiation properties to repeat periodically as the logarithm of frequency [1]. The LPDA is a coplanar linear array of unequal and unequally spaced parallel linear dipoles fed by twisted balanced transmission line.The characteristic impedance of the feeder transmission line and dipoles diameters are chosen by taking into consideration the required input resistance, the voltage standing wave ratio (VSWR) allowed, power handling capability[2]. The LPDA is a directional, wideband antenna whose performance is not affected by the frequency variation. Its characteristics remain nearly constant and it radiates with high gain at frequencies within the operational bandwidth. The use of ultrawideband high frequency structures can make the ground work for improvement of existing data link parameters. The log periodic dipole antenna can be a powerful solution for UWB communications systems[3]. Optimization techniques are used to either synthesize an antenna from given radiation characteristics or simply improve existing antenna designs. Genetic algorithms are very useful for finding optimum antenna designs that maximize or minimize certain radiation properties [4]. LPDA antenna's performance is optimized by varying the antenna's geometrical parameters for narrowband and broadband designs. In order to provide useful design data, further optimization is required, which should involve additional parameters and cover wider ranges of parameters [5].

Recently GA has been used for design optimization of LPDA antenna[6]. In that work Genetic algorithm is used to design LPDA antennas that provide a significantly larger bandwidth than conventional LPDA with the same size. Over the bandwidth of operation, GA optimized LPDA offers a size reduction of 2:1 relative to the conventional LPDA. In this work optimization of Gain and VSWR is done by varying geometrical parameters of LPDA antenna using GA. The parameters which are used in this work are maximum length, minimum length and spacing factor of LPDA. Here Gain and VSWR are calculated on different operating frequencies within the range of 300 MHz to 400 GHz. This paper is analyzing LPDA antenna theoretically and practically.

Section 2 describes geometry of LPDA. Section 3 presents design optimization of LPDA antenna at different operating frequencies

2. GEOMETRY OF LPDA

The LPDA antenna consists of a sequence of dipoles with successively increasing lengths outwards from the feed point at apex as Figure 1depicts. The feed lines cross over between adjacent elements, so as to give a 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 λ/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 λ/2 at the resonant frequency. (ii) Reflectors, comprised of elements whose elements are slightly greater than λ/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.

The elements are shortened by a factor τ as we move towards the source of excitation, where τ is known as the scaling factor and is one of the key parameters of the LPDA antenna. The scale factor is defined by

$$\tau = Ln+1/Ln = dn+1/dn = Dn+1/Dn = Xn+1/Xn \qquad (1)$$

(Where Dn is the diameter of the nth dipole element and Ln is the length of the nth 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 'σ', which is given by

$$\sigma = dn/2Ln = (1-\tau)/4\cot\alpha \qquad (2)$$

Where α is the apex angle and dn is the distance of the nth 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 we 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

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

Zo 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 are part of the subject of this paper. 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

$$L = 2\sigma(L1 - LN)/(1-\tau) \qquad (4)$$

L1 and LN are the longest and the shortest dipole elements respectively

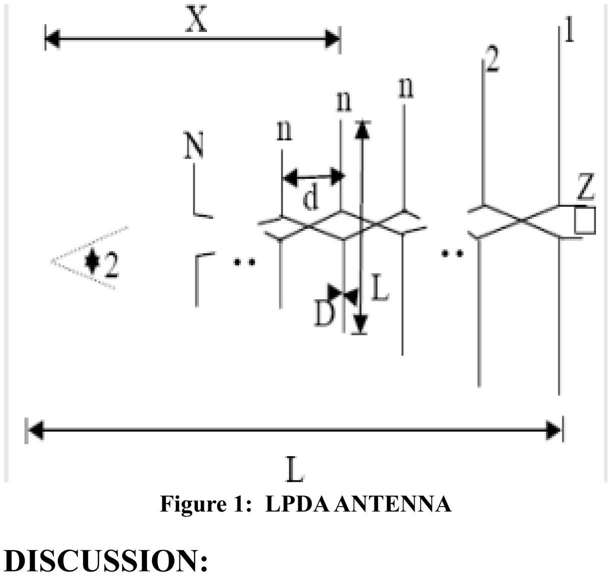


Figure 1: LPDA ANTENNA

3 SIMULATION RESULTS & DISCUSSION:

Different parameters are varied as specified below for the optimization of LPDA antenna:

1 The maximum length and spacing factor are the first and second parameters which are to be varied and other parameters are taken as fixed. Range of maximum length is 800-2000 mm for frequency 300 to 400 MHz. The spacing factor is varied between 60-300 mm for the frequency 300 to 400MHz with resolution of 1MHz. Further maximum length are to be varied between 850-1900 mm and spacing factor is varied as 40-250 mm. Antenna size gets reduced for higher frequencies so ranges are to be decided accordingly.

2. Third parameter which is to be varied is minimum length. The minimum length is to be varied in the range of 100-900 mm for the frequency range 300-400 MHz. Further minimum length is to be varied 700-1750 mm for same frequency with resolution of 1MHz. These ranges can be further reduced or changed for different frequencies.

In this paper 3 designs are discussed on different frequencies from 300 to 400 MHz.

In first case, simulation parameters have been taken as per Table 1. In this case the optimum value of Gain &VSWR have been obtained as 8.45 and 1.104 respectively. The optimum value of design variables have been found using GA. The other parameters have been set as per their default value in SuperNec [4]. The gain plot is shown in Figure 2

Table 1 Simulation Parameters at 300MHZ

Maximum length(mm)	Spacing Factor(mm)	Desired Gain	Desired VSWR
[800,2000,1]	[60,300,1]	3.0 dB	1.08
[500,1900,1]	[50,250,1]	3.3 dB	1.2

In second case, simulation parameters have been taken as per Table 2. The optimum value of Gain &VSWR has been obtained as 3.3 and 1.2 respectively.

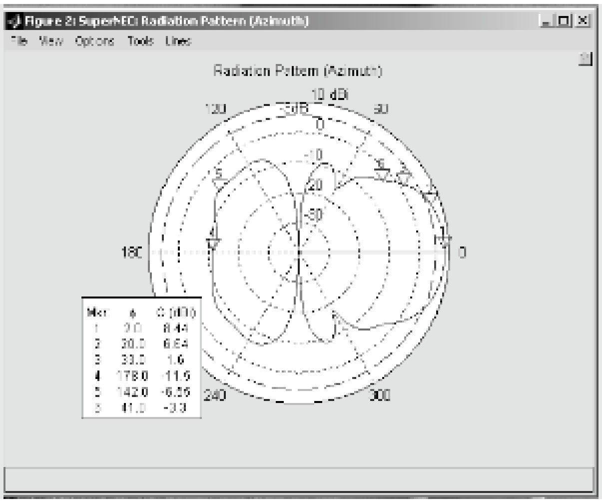
Table 2 Simulation Parameters at 300MHz

Minimum length(mm)	Spacing Factor(mm)	Desired Gain	Desired VSWR
[200,1000,1]	[60,300,1]	6.04dB	1.13
[100,900,1]	[40,250,1]	8.45dB	1.104

In Third case, the simulation parameters have been taken as per Table 3. The optimum value of Gain &VSWR has been obtained as 7.1 and 1.5 respectively. The gain plot is shown in Figure 3 .

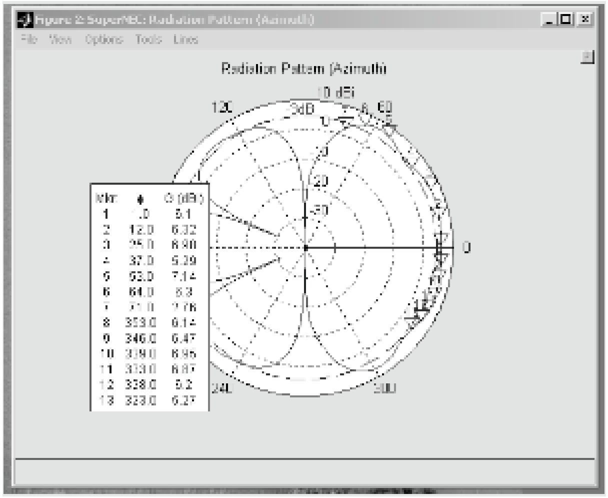
Table 3 Simulation Parameters at 300MHz

Maximum length(mm)	Minimum Length(mm)	Desired Gain	Desired VSWR
[800,2000,1]	[600,1800,1]	6.9dB	1.08
[850,1900,1]	[700,1750,1]	7.1 dB	1.5



Mkr	ϕ	G (dBi)
1	0.0	8.44
2	20.0	6.64
3	33.0	1.6
4	178.0	-11.6
5	142.0	-6.56
6	41.0	-3.3

Figure 2 : Radiation Pattern Corresponds to Table 1



Mkr	ϕ	G (dBi)
1	0.0	5.1
2	12.0	6.32
3	25.0	6.90
4	37.0	5.29
5	53.0	7.14
6	64.0	6.3
7	71.0	7.76
8	353.0	6.14
9	346.0	6.47
10	339.0	6.96
11	333.0	6.87
12	338.0	5.2
13	323.0	6.27

Figure 3: Radiation pattern corresponds to Table 3

4. CONCLUSION AND FUTURE SCOPE

In this paper optimization of LPDA antenna is discussed in detail. GA optimizer of Super NEC simulation is used for the optimization which is latest for the study of antennas in various applications. The performance of LPDA antenna is measured by calculating gain and VSWR at different frequencies. Promising results are obtained for various ranges of geometrical parameters of LPDA antenna. The average gain of LPDA improved from 7.1 to 8.45dB. An average VSWR of 1.104 over the frequency range 300 to 400 MHz has been achieved. It is concluded that optimization of LPDA antenna can be used for further research work because of its versatile applications in communication field. It is also concluded that LPDA antenna has a potential for many signals and applications yet to be explored. LPDA antenna can be designed for various dimensions and can be analyzed and further can be compared with theoretical results. LPDA antenna optimization can be further explored in detail where range of frequencies can be increased and Gain can further be maximized for particular applications. Further design of LPDA and other antennas can be optimized using latest evolutionary techniques like Biogeography based optimization, Ant colony optimization and Bacterial foraging optimization.

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