Log Periodic Dipole Array Antenna for Television and FM broadcasting

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***Abstract*— A simple Log Periodic Dipole Array (L.P.D.A) antenna for Very High Frequency (V.H.F) applications is discussed in this paper. The antenna is fed by line feeding technique. A printed LPD has several dipoles connected together by several non radiating transmission lines, each of which are placed at finite distance from each other. The dimension of the largest dipole depends upon the lowest frequency of operation. This paper presents the design and simulation of a Log Periodic Dipole Array antenna for 50 MHz using an electromagnetic simulator CADFEKO. Various antenna parameters like Return loss, VSWR, Input Impedance, Gain etc of the designed antenna are observed. The results show that the designed wideband antenna is well suited for very high frequency applications like Television and FM broadcasting.**

***Index Terms*—Printed Log Periodic Dipole Array, Transmission line, CADFEKO.**

I. INTRODUCTION

A Log Periodic Dipole Array antenna is a frequency independent printed antenna and was introduced in 1950s through the works of Carrel [1] and Isabel [2]. The name Log Periodic is derived because of the uniform spacing between the resonant frequencies of antennas in a log periodic scale. Such antennas were mainly used for the design of receivers in colour television due to its wideband characteristics. The bandwidth of such an antenna depends on the precision in manufacturing the smallest element in the array and the size of largest element in the array [3]. Log Periodic Dipole Array antenna consist of an array of linear dipoles (Driven Elements) each of different length and spacing between them and are fed by a distributed system causing all the elements in the array to radiate by itself. The length of each of the element goes on increasing starting from the feed point of the array and each element is fed using a balanced transmission line and is designed to have a 180 degree phase difference with the neighbouring elements causing an endfire radiation pattern and tuning of frequency without much affecting its operations [4]. For a particular frequency of operation all the array elements will not be in the active region and as the frequency changes the array elements in the active region undergo a transition [5]. When the frequency is low, the large antenna elements are said to be active but as the frequency increases the active region moves towards the shorter elements. All the dipole elements radiate at some particular frequencies unlike a Yagi Uda antenna. The bandwidth of operation depends upon the number of dipole elements present in the array [6]. Since modern communication systems require small size antennas hence the number of dipoles should be less. Hence a compromise has to be made between bandwidth and size of a Log Periodic Dipole Array.

Even though printed antennas have several advantages like small size, light weight, easy fabrication etc they also have various drawbacks like less efficiency, narrow bandwidth, high level of cross polarisation, high input impedance etc when used in wireless communication systems [7]. LPDA is a type of printed antenna that has various advantages like excellent gain [8], low cost, compact size that allows the antenna to be used for very high frequency applications (30MHz-300 MHz). One drawback associated with Log Periodic Dipole Array antenna is that for lowest operating frequencies the dipole element may become too long [9].

Designing a feeding network is the most important part of a Log Periodic Dipole Array antenna. A feeding network is composed of 2 sections. One is the printed dipoles and the other is the external feeding structure. In CADFEKO the external feeding is modelled as a port which is placed at the middle of the dipole thereby achieving wideband impedance matching [10]. This can also be achieved using an infinite Balun [11] obtained by passing 2 coaxial cables as feed through any of the antenna beams. Though this method may improve the radiation pattern but the antennas realized using coaxial cables may experience some difficulties in realization and may degrade the characteristics of the antenna [12].

The printed Log Periodic Dipole antenna may also operate in the ultrawideband (UWB) frequencies using Orthogonal Frequency Division Multiplexing (OFDM) schemes thereby providing high directivity, low cross polarization and end fire radiation characteristics over a large frequency range [13]. But since the size and number of dipoles would turn out to be very large, hence it is very difficult to design a LPDA operating in UWB range.

The analysis of LPDA is done by using a transmission line approach. Welter [14] found out the current distribution of antenna elements by solving the wave equation in cylindrical coordinates. But at microwave frequencies the wire antennas may bent that result in back radiation and side lobes. So we replace the wire antennas by a printed dipole antenna [15]. The antenna discussed here consists of an array of 12 dipoles which are connected together by 11 transmission lines through a boom. Each transmission line has its associated impedance and length. Section II discusses the proposed antenna design while section III analyses the results and shows a parametric study on the number of dipoles on various antenna parameters and the paper ends with a conclusion in section IV.

II. ANTENNA DESIGN

There are three important parameters while designing a Log Periodic Dipole Array antenna- Scale Factor, Spacing Factor and the apex angle defined by equations 1-3. Equations 4-7 represent the various parameters used while designing a LPDA [1-2].

Scale Factor,

$$\tau = \frac{W_{n+1}}{W_n} = \frac{L_{n+1}}{L_n} = \frac{d_{n,n+1}}{d_{n-1,n}} \quad (1)$$

Spacing Factor

$$\sigma = \frac{d_{n,n-1}}{2L_{n-1}} = \frac{S_{n+1}}{4L_n} = \frac{1-\tau}{4\tan\alpha} \quad (2)$$

Enclosed angle

$$\alpha = 2\tan^{-1}\left[\frac{1-\tau}{4\sigma}\right] \quad (3)$$

Element Length

$$l_n = \frac{\tau}{n-1} \quad (4)$$

Number of elements in the array

$$n = 1 + \left[\frac{\ln(F_h) - \ln(F_l)}{\ln\left(\frac{1}{\tau}\right)}\right] \quad (5)$$

Length of last dipole

$$L_{last} = \frac{c}{2f_l} \quad (6)$$

Distance between dipole

$$S_n = \frac{L_n}{2\tan\alpha} \quad (7)$$

Where

W_n - Width of nth element

L_n - Length of nth element

$d_{n,n+1}$ - Distance between elements n and n+1

F_h - Highest Frequency of dipole in active region (MHz)

F_l - Lowest Frequency of dipole in active region (MHz)

The Log Periodic Dipole Array antenna used in this work is designed with τ =0.93, σ =0.7 and n =12. The scale factor should be such that its value is always less than one. The apex angle α should not be too small or too large, since it affects the bandwidth of the antenna. As the frequency increases the spacing factor decreases. This design methodology is based on the mutual coupling between the array elements. Later it was found that this method has some drawbacks but the basic procedure still remains the same.

Fig 1 shows the basic structure of a Log Periodic Dipole Array antenna designed using CADFEKO. For a compact LPDA the value of α should be high (small value of τ) which results in small number of dipole elements and less number of elements in the active region. Such a design causes large variation in the input impedance due to small transition between active and inactive elements in the array.

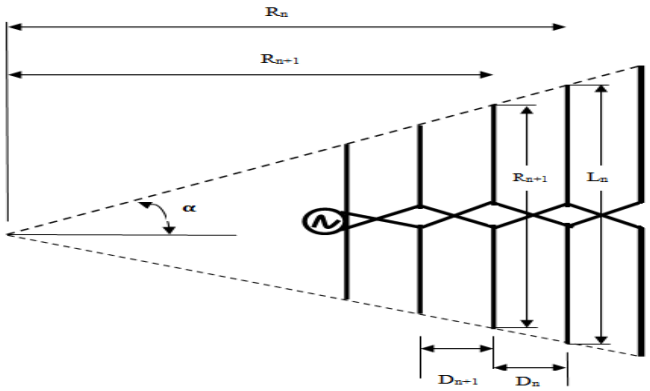


Figure 1 Antenna geometry

Fig 2 shows the 3 regions present in a Log Periodic Dipole Array antenna based on the wavelength of operation- Transmission line region, Active region and Stop region.

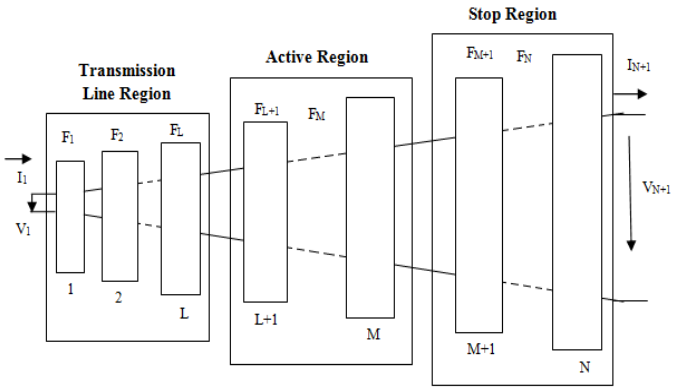


Figure 2 Regions of operation of a Log Periodic Dipole Array antenna

In transmission line region the size of the element is less than the operating wavelength hence the dipoles present in these regions do not radiate. However in the active region the size of the element is equal to the wavelength so the elements in these regions would radiate. Since there is a 180^0 phase shift between elements in active region and stop region hence, elements in stop region would not radiate any waves.

The smallest cutoff frequency of Log Periodic Dipole Array antenna depends upon the resonant frequency of the largest element when its length is half the wavelength of operation. Similarly the largest cutoff wavelength depends on the resonant frequency of the smallest element.

Fig 3 shows the 3-D view of the designed antenna using CADFEKO software

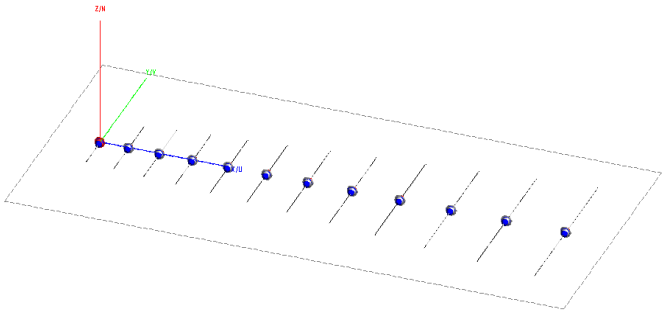


Figure 3 Antenna design using CADFEKO

III. RESULTS AND DISCUSSION

The proposed antenna is simulated using CADFEKO and various parameters such as Return loss, VSWR, Gain, Input impedance etc are observed.

Fig 4 shows the return loss of the Log Periodic Dipole Array antenna that operates at a frequency of 49 MHz.

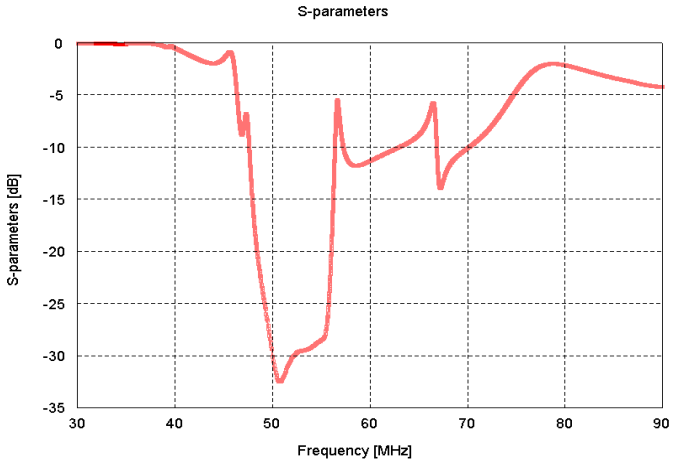
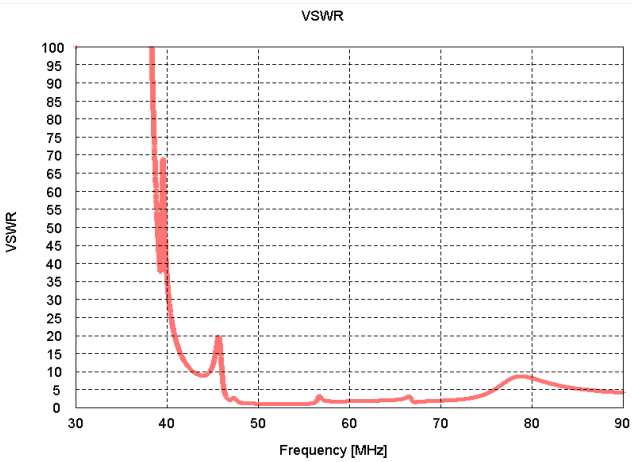


Figure 4 Return loss of the antenna

The bandwidth of the antenna is measured from the return loss curve. The LPDA resonates<-10 dB at a lower frequency band of 50.5 MHz with a return loss of -32 dB and impedance bandwidth of 8.97 MHz , at a middle frequency band of 58 MHz with a return loss of -12 dB and impedance bandwidth of 6.5 MHz, at an upper frequency band of 67 MHz with a return loss of -14 dB and impedance bandwidth of 3.81 MHz

VSWR of the Log Periodic Dipole Array antenna is less than 2 for all the frequencies above 50 MHz and is shown in fig 5 thereby providing a good impedance matching. Fig 6 shows the 3D plot of gain (in dB) of the Log Periodic Dipole Array antenna at 50 MHz. The observed gain at resonant frequency of the proposed antenna is 9.3 dB which is shown in fig 6.



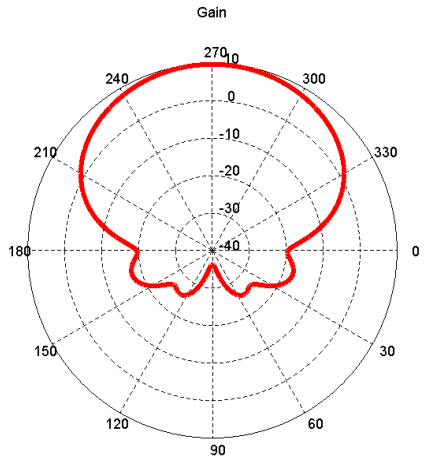
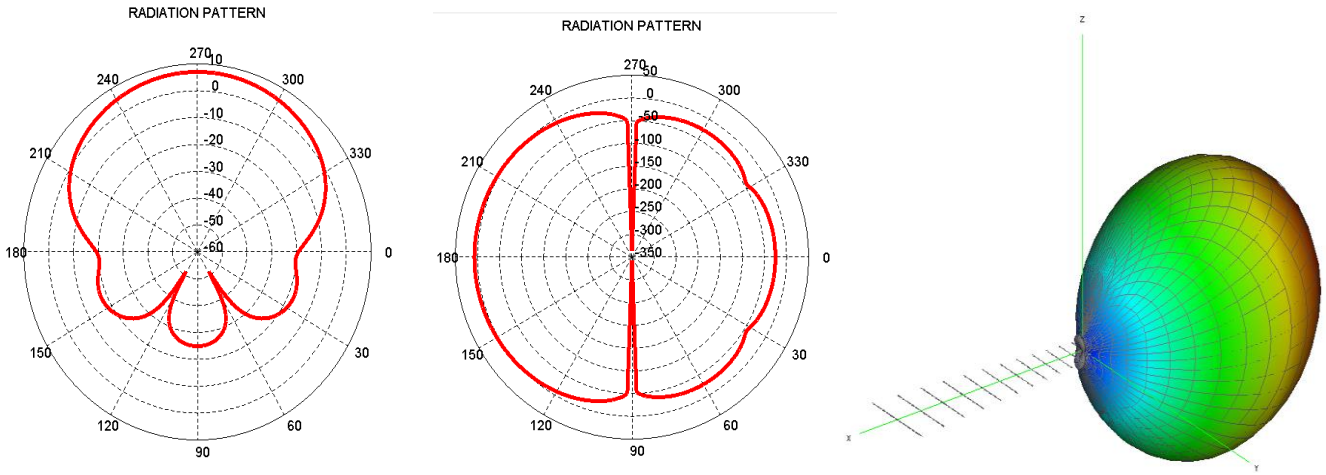


Figure 5 VSWR of the antenna

Figure 6. 3-D plot of gain of the antenna

The radiation pattern plot of the Log Periodic Dipole Array antenna in E plane (XZ) and H plane (YZ) at 50 MHz is plotted in fig 7 a) and 7b)) and fig 7c) shows a 3 dimensional view of the pattern.



(a) (b) (c)

Figure 7. a) Radiation pattern in XZ plane b) Radiation pattern in YZ plane c) 3D view of Radiation pattern at 50 MHz

Fig 8 plots the impedance graph of the Log Periodic Dipole Array antenna. It is observed that the input impedance of the LPDA at centre frequency of 50 MHz is 56 Ω which is very close to 50Ω. Hence good impedance matching is achieved and maximum power is transferred.

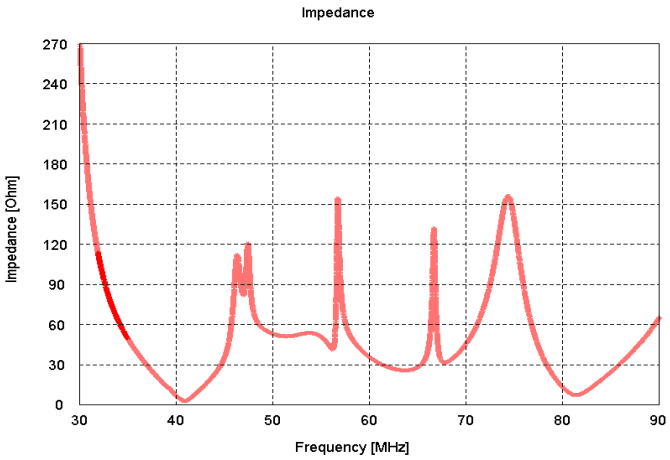


Figure 8. Impedance plot of the antenna

Current distribution plot at 50 MHz is illustrated in fig 9. Most of the radiation fields are concentrated near the active regions of the dipole array while the transmission line region and stop region receives very less currents. The arrows represent the direction of flow of the currents from the feeding point.

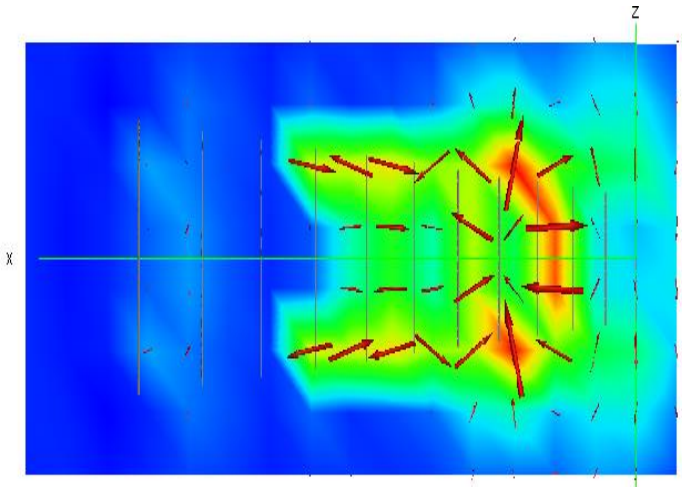


Figure 9. Current distribution of the antenna at 50 MHz

IV. Conclusion

A printed Log Periodic Dipole Array antenna operating in the Very High Frequency Band (30-300 MHz) has been designed and simulated using CADFEKO. In this paper a simple low profile LPDA antenna fed by an array of dipole elements has been discussed. Effect of these dipole elements on various antenna parameters like return loss, impedance, VSWR, gain etc are observed and evaluated. The designed antenna radiates efficiently at VHF frequencies making it an ideal candidate for Television and FM broadcasting..

REFERENCES

[1] R. L.Carrel, “The design of log periodic dipole antenna”, IRE International Convention Rec. , pp. 61–75, 1961.

[2] D. E. Isbelll, “Log-Periodic Dipole Arrays”, IEEE Transaction on Antennas Propagation vol. 8 Issue: 3, pp. 260-267, May 1960.

[3] J. Mruk, M. Uhm, and D. Filipovic, “Dual-wideband log-periodic antennas,” in Proc. IEEE AP-S. Int. Symposium, Jul. 2008, pp. 1–4.

[4] V. R. Lakshmi and G.S.N. Raju, “A novel miniaturized log periodic antenna,” Int. Journal. of Scientific & Eng. Research, vol. 3, no. 2, 2012.

[5] Hamid, M. R., P. S. Hall, and P. Gardner, “Wideband reconfigurable log periodic patch array," Progress In Electromagnetics Research C , Vol. 52, pp 123-138, 2013.

[6] Gheethan, A. A. and D. E. Anagnostou, “The design of reconfigurable planar log-periodic dipole array using switching elements," IEEE Antennas and Propagation Society International Symposium 2009.

[7] S. Lin, S. Luan, Y. D. Wang, X. Luo, X. Han, X. Q. Zhang, Y. Tian, and X. Y. Zhang, “A printed log-periodic tree-dipole antenna (PLPTDA),” Progress In Electromagnetics Research M, vol. 21, pp. 19-32, 2011.

[8] P. C. Butson and G. T. Thompson, "A note on the calculation of the gain of log-periodic dipole antennas", IEEE Trans. Antennas Propagation vol. 24, pp. 105-106, January 1976.

[9] S. H. Kim, J. H. Choi, J. W. Baik, and Y. S. Kim, "CPW-fed log-periodic dumb-bell slot antenna array, "Electron. Lett., vol. 42, no. 8, pp. 436–438, Apr. 2006.

[10] M. K. A. Rahim, M. N. A. Karim, F. Zubir, O. Ayop, and N. A. Samsuri, "Second iteration fractal Koch planar log periodic antenna design," Microwave Optical Tech. Letters vol. 53, no. 8, 2011.

[11] M. M. Tajdini and M. Shahabadi, "Wideband planar log-periodic antenna," in Proceedings of Int. Workshop on Antenna Technology-IWAT'07, Mar.2007, pp. 331–334.

[12] D. E. Anagnostou, J. Papapolymerou, M. M. Tentzeris, and C. G. Christodoulou, "A printed log-periodic Koch-dipole array (LPKDA)," IEEE Antennas Wireless Propagation Letters vol. 7, 2008.

[13] S. Y. Chen, P. H. Wang, and P. Hsu, "Uniplanar log-periodic slot antenna fed by a CPW for UWB applications, "IEEE Antennas Wireless Propagation Letters vol. 5, no. 1, pp. 256–259, Dec. 2006

[14] J. Welter, "Solution of Maxwell's Equations for Log Periodic Dipole Antenna", IEEE Trans. Antennas Propagation vol. AP-18, pp. 734–741, Nov. 1970.

[15] Zhong Chen, Austin, TX, Foegelle, M .Harrington, T. **"**Analysis of log periodic dipole array antennas for site validation and radiated emissions testing**"** IEEE Transaction on Antennas and Propagation Vol 2 02 Aug 1999 pp. 618-623