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A Novel Miniaturized Log Periodic Antenna

V. Rajya Lakshmi and G.S.N. Raju

Abstract- Log-Periodic Dipole Antenna (LPDA) is a common and important broadband antenna, due to its non-frequency dependent characteristic. However, in the conventional design, the physical size is restricted to the longest oscillator dipole with the lowest resonant frequency, which is quite large and constrains its application. To realize the antenna miniaturization, many methods, including loading technology, fractal technology, meandering line technology etc. have been used to reduce the size of antenna without reducing the antenna's performance. To achieve the purpose of miniaturization of the LPDA, this paper presents a novel structure of log-periodic antenna loaded with symmetrical meandering dipoles. The modeling and simulation of the above design is carried out using a 3D Electro- magnetic simulator WIPL-D microwave.

Index Terms - Log periodic dipole antenna, meandering, broadband antenna, WIPL-D microwave, fractal technology, miniaturization.

1 INTRODUCTION

In many applications, an antenna should operate over a wide range of frequencies. An antenna with this characteristic is called broadband antenna. Log periodic antenna can be one of the broadband antennas. Basic idea of log periodic antenna is using elements of varying lengths, which would resonate at different frequencies [1-4]. For any frequency within the design band, there are some elements, which are nearly half-wave length dimensions. The currents on these elements are large compared to the currents on the other elements. The elements with dimensions approximately half-wave lengths contribute most of the radiation so the region where these elements take place is called active region. As the frequency changes, the active region shifts from one group of elements to the next. The elements outside the active region act as parasitic elements. They do not contribute the radiation much.

2. MEANDERING TECHNOLOGY

The wireless revolution is creating a flood of new wireless devices that dramatically increase the availability of voice and data nearly anywhere in the world. In addition, applications in present-day mobile communication systems usually require smaller antenna size in order to meet the miniaturization requirements of mobile units. This revolution is significantly expanding the opportunity for smaller and better wireless communication terminals and it is also creating new performance demands for antennas. Thus, size reduction and bandwidth enhancement are becoming major design considerations for practical applications. For this reason, studies to achieve compact and broadband antennas have greatly increased [5-6].

- Rajya Lakshmi is pursuing her Ph.D in ECE Dept, Andhra University, Visakhapatnam..
  Email: rajeevani2005@yahoo.co.in.
- G.S.N.Raju is Professor, Dept.of ECE, Andhra University, Visakhapatnam. E mail: profrajugsn@gmail.com

To realize the antenna miniaturization, different methods like loading technology, fractal technology, meandering line technology etc. have been considered to reduce the size of antenna without reducing the antenna's performance. Loading technology needs to insert some components or networks in right place to change the current distribution of antenna and the electricity characteristic of antenna, which increases the complexity and cost, and reduces the antenna efficiency with extra energy loss. Space-filling property and self similarity make fractal antennas have many advantages [7] in constructing small-size antenna and broadband antenna. Meandering antenna also can have similar characteristic and even have better quality in some cases. Moreover, the construction of fractal antenna has comparative complexity. The antenna with meandering structure is relatively simple and low cost.

3. DESIGN OF LOG PERIODIC ANTENNA

The log periodic antenna described in Fig. 1, consists of parallel linear dipole elements of different lengths and spacings. The lengths of the dipole elements, the spacing from the virtual apex to the dipole elements, the wire radius of the dipole elements, the spacing between the quarter wave-length dipoles are proportional with the geometric scale factor, τ , which is always smaller than 1. A wedge of enclosed angle 2α bounds the dipole lengths [8-9]. The spacing factor, σ is defined as the distance between two dipole elements divided by the twice of the length of the larger dipole element. The relationship between the different parameters can be summarized as follows:

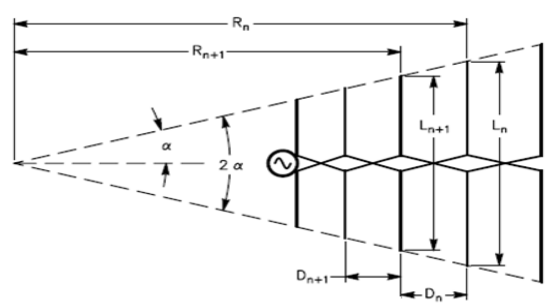

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Fig.1. Log periodic dipole antenna

$$\tau = \frac{R_{n+1}}{R_n} = \frac{D_{n+1}}{D_n} = \frac{L_{n+1}}{L_n} \qquad (1)$$

$$\sigma = \frac{1-\tau}{4\,tan\alpha} = \frac{D_n}{2L_n} \qquad (2)$$

Here,
τ = Geometric ratio and τ <1,
L = Length of the dipole,
R =Distance from apex to the dipole elements,
D =Spacing between the dipole elements.
σ=Spacing factor, which relates distance between two adjacent elements with the length of the larger element.
α =Half of the apex angle.

As the first step of the design procedure, fundamental design parameters τ and σ should be chosen for a given directivity. For a given directivity, the relative spacing, σ and the geometric ratio, τ can be related through the following Fig. 2:

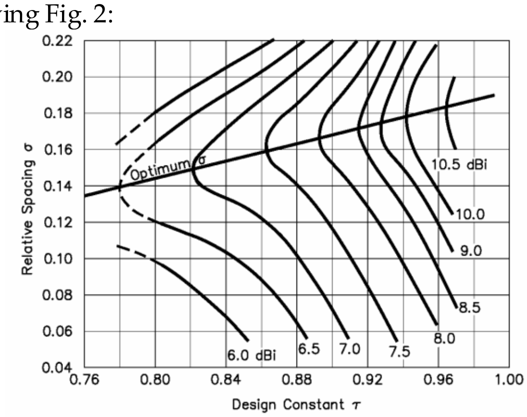

Fig. 2. LPDA gain as a function of τ and σ.

For a given directivity, corresponding σ and τ can be found. For a certain τ, if maximum directivity is desired, σ_{opt} should be chosen through the curves. Optimum σ in Fig .2 can be formulated as:

$$\sigma_{opt} = 0.258\,\tau - 0.066 \qquad (3)$$

and

$$\alpha = 2\tan^{-1}\left(\frac{1-\tau}{4\sigma}\right) \qquad (4)$$

After determining σ, τ and α, bandwidth of the system which determines the longest and the shortest dipole elements can be calculated. Active region bandwidth, Bar can be related with the fundamental design parameters by the following equation.

$$Bar = 1.1 + 7.7(1-\tau 2)\cot\alpha. \qquad (5)$$

In practice a slightly larger structure bandwidth, Bs is usually designed to reach the desired bandwidth, B. These bandwidths are related by:

$$Bs = B \times Bar = B(1.1 + 7.7(1-\tau 2)\cot\alpha \qquad (6)$$

Boom length of the structure is defined between the shortest dipole and longest dipole elements and is given by:

$$L = \frac{\lambda_{max}}{4}(1 - 1/Bs)\cot\alpha \qquad (7)$$

$$\lambda_{max} = 2\,L_{max} \qquad (8)$$

4. Design of Meandering LPDA

A Meandering Log-Periodic Dipole Antenna (LPDA) is designed to operate in frequency range of 1.2 to 2.5 GHz. In normal Log-Periodic Antenna, the longest horizontal length of the dipole is given by half of the maximum wavelength. Longest horizontal length of the dipole = λmax/2. In Meandering Log-Periodic Dipole Antenna, the horizontal length of a dipole element is designed to reduce the original length to 46% by using meandering technique. Longest horizontal length of the meandering dipole = (λmax/2)*0.46.A Log-Periodic Dipole Antenna is identified with Scaling factor τ and Spacing factor σ. Each dipole antenna is identified with dipole length (L), the diameter of the wire d, and the spacing between the dipoles D .In this paper, the Scaling factor τ =0.92 and the Spacing factor σ = 0.17. Radius of the feeding line is 10mm. Now according to the procedure, Wedge angle α = 6.15.While the bandwidth of the system determines the lengths of the shortest and longest elements of the structure, the width of the active region depends on the specific design. Bar = 1.50 Hz, Bs = 3.128 Hz, λmax =0.25, N=16. The dimensions of individual elements are listed in Table.1.

TABLE 1

DIMENSIONS OF THE DESIGNED LPDA.

Element(i)	Li(mm)	Ri – Ri-1 (mm)	di(mm)
1	125	40.19	4.5
2	115.625	37.17	4.16
3	106.95	34.31	3.85
4	98.93	31.80	3.56
5	91.511	29.42	3.29
6	84.64	27.21	3.04
7	78.299	25.17	2.81
8	72.42	23.21	2.60
9	66.99	21.54	2.41
10	61.97	19.92	2.23
11	57.322	18.43	2.06
12	53.02	17.05	1.90
13	49.04	15.77	1.76
14	45.36	14.58	1.63
15	41.96	13.49	1.51
16	38.81	-	1.39

L = Length of the i^{th} dipole element, R_i-R_{i-1} is the spacing between i^{th} and $(i-1)^{th}$ dipole element. d_i is the diameter of the i^{th} dipole element. The Folded Dipole is shown in the Fig. 3.

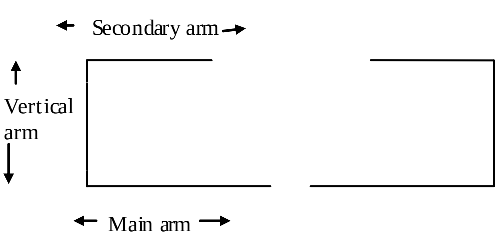

Fig. 3.Geometry of the meandering dipole

The longest horizontal length of a dipole element in meandering log-periodic dipole antenna = 125*0.46 = 57.5. All the 16 Dipole elements of the Log-Periodic antenna are converted into Folded Dipole elements. The dimension of each Folded Dipole element is given by the above ratios. The individual length of each dipole element is given in the table2.

TABLE 2

LENGTHS OF THE FOLDED DIPOLES

Element	Main arm(mm)	Vertical arm(mm)	Secondary arm(mm)
1	57.5	37.50	30.00
2	53.18	34.68	27.75
3	49.19	32.05	25.66
4	45.50	29.67	23.74
5	42.09	27.45	21.96
6	38.93	25.39	20.31
7	36.01	23.48	18.79
8	33.31	21.72	17.38
9	30.81	20.09	16.07
10	28.50	18.59	14.87
11	26.36	17.19	13.75
12	24.39	15.90	12.72
13	22.56	14.71	11.77
14	20.86	13.61	10.88
15	19.30	12.58	10.07
16	17.85	11.64	9.31

5. DESIGN WITH WIPL-D PRO

WIPL-D Microwave accurately simulates circuits that consist of built-in or user defined components. A distinguished feature of WIPL-D Microwave is that you can create your own components specified as composite metallic and dielectric structures [10]. Circuit simulation is based on the s-parameter representation of components. S-parameters of the 3D EM components are computed on-the-fly during circuit simulation. 3D EM solver is a frequency domain solver based on the method of moments. It enables to model structures of arbitrary shape using wires and plates as basic building blocks.

WIPL-D Microwave has intuitive visualization of circuits, 3D EM structures and simulation results. You can plot frequency response of the circuit: s-parameters, impedance and admittance parameters, voltages, currents, and power. Radiation pattern, near field and distribution of surface currents of an arbitrary 3D EM structure can be visualized by 2D and 3D graphs. In addition, you can overlay graphs from different projects to present several curves on the same diagram. The Meandering Log-Periodic Dipole Antenna is constructed with dimensions in table.1 and table.2 in WIPL-D 3D EM solver. The simulated Meandering log-periodic dipole antenna design is shown in Fig. 4.

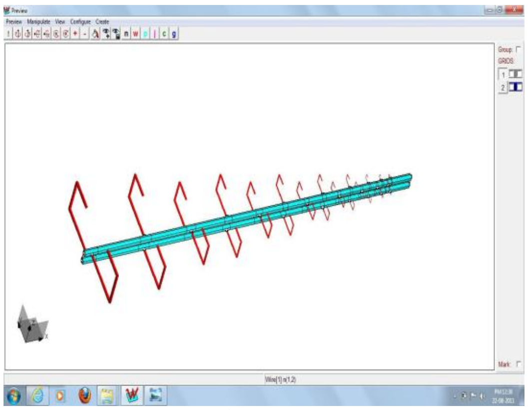

Fig. 4. Model of Log periodic antenna.

The Return Loss, VSWR are plotted against the frequency for the Meandering Log-Periodic Antenna constructed in WIPL-D. The Return Loss (S11) graph of the antenna from 1.2 GHz to 2.5 GHz is shown in the fig.5.The Voltage Standing Wave Ratio (VSWR) of the antenna from 1.2 GHz to 2.5 GHz is shown in the figure 6.

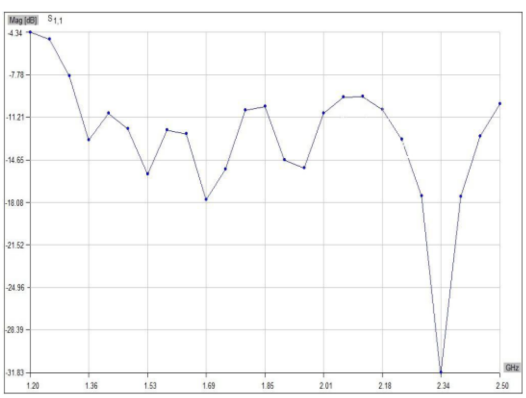

Fig. 5. Return loss of proposed antenna.

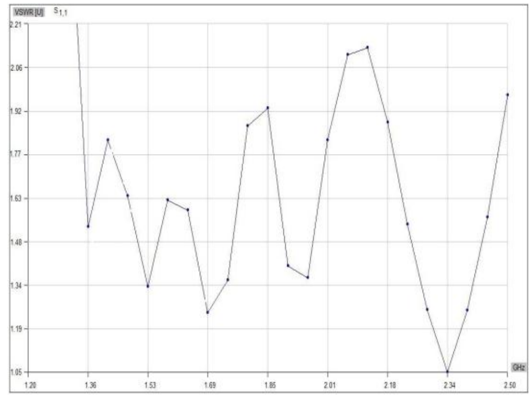

Fig. 6. VSWR of the simulated antenna.

From the figure 5, it can be seen that the return loss or S11 is less than -10dB for the frequency range from 1.4-2.5 GHz. From the figure 6, it is observed that the VSWR is less than 2 for the frequency range from 1.4-2.5GHz.The simulated gain 2-D radiation patterns in dB are shown in figures(7-10) within the frequency band 1.4GHz-2.5GHz at frequencies1.4, 1.6, 1.8, 2and 2.3GHz, respectively. Fig.11 represents the variation of gain with respect to frequency.

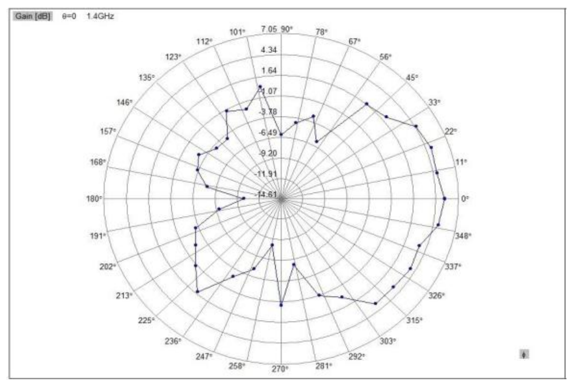

Fig. 7. Gain at 1.4GHz

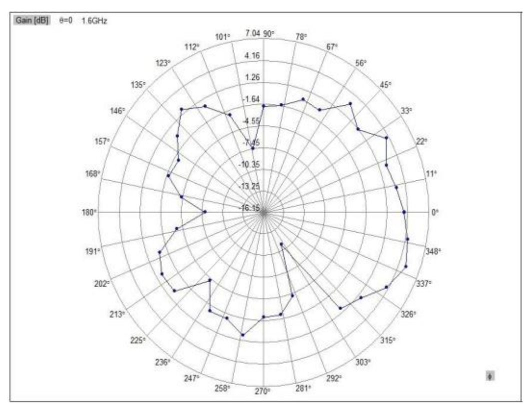

Fig. 8. Gain at 1.6GHz

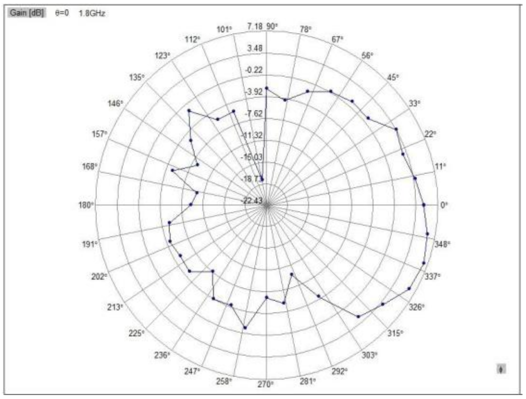

Fig. 9. Gain at 1.8GHz

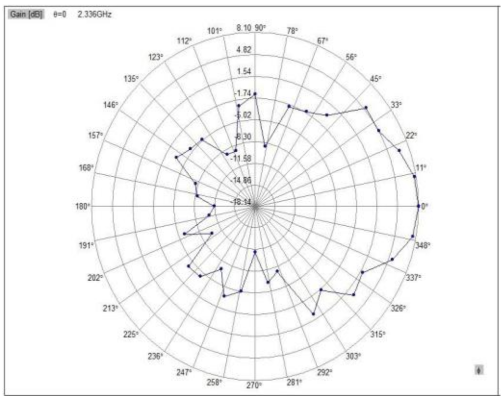

Fig. 10. Gain at 2.336GHz

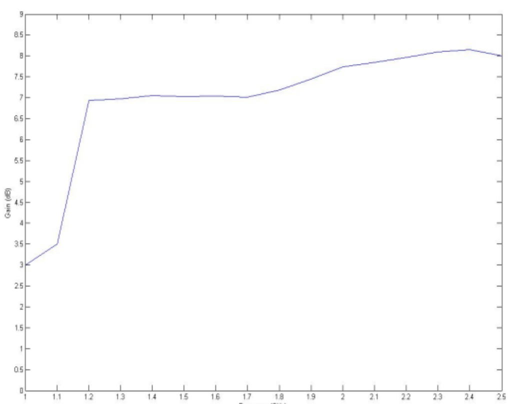

Fig. 11. Gain at different frequencies.

6. CONCLUSIONS

The paper presented a meandering method for the miniaturization of Log-Periodic Dipole Antenna in the frequency range from 1.2 GHz to 2.5 GHz. The radiation patterns at different frequencies are obtained using Electro Magnetic simulator software WIPL-D. The horizontal length of the meandering Log-Periodic Dipole Antenna is just 46% of the conventional Log-Periodic Dipole Antenna. The return loss is less than -10dB from 1.35 GHz to 2.5 GHz.

REFERENCES

[1] G.S.N.Raju, (2006) , *Antennas and Wave Propagation*, Pearson Education.

[2] Constantain. A.Balanis, (1982) *Antenna Theory Analysis and Design*, III Edn., Wiley-Interscience, A John Wiley & Sons Inc. Publication.

[3] John D.Kraus and Ronald J. Marhefka, (1997) *Antennas for all Applications*, Second Edn., Tata McGraw-Hill Publishing Company Ltd.

[4] Thomas A.Milligan(2005) *Modern Antenna Design*, 2nd Ed.,John Wiley & Sons, Inc., Hoboken, New Jersey.

[5] D.Misman, I.A Salmat & M F Abdul Kadir(2007), "*The effect Conductor line to meander Line antenna design*",Asia pacific conference on applied electromagnetics proceedings,Malaysia.

[6] Frank M.Caimi(2002) "*Meander Line Antennas*", Skycross, August

[7] Qiu Jinghui, Lin shu,Yang caitian,You qidi(2005), "*A Novel printed fractal log periodic dipole antenna*", 5th IEEE –Russia conference:MEMIA'.

[8] Banic,B & Hajach,P (2000) "*Design and simulation of properties of log-periodic dipole Antenna*", Radioelektronika, Bratislava, 12-16. pp. 108-109.

[9] R.R.Pantoja, A.R.Sapienza, & F.C.Medeiros Filho (1987)"*A Microwave printed planar Log-periodic Dipole array Antenna*",IEEE transactions on antennas and propagation, vol. ap-35, no. 10, october

[10] B.Kolundzija, J.S.Ognjanovic & T.K.Sakar, (2000) WIPL-D: *Electromagnetic Modeling of Composite Metallic and Dielectric Structures - Software and User's Manual*, Artech House Inc.