# MODELLING AND SIMULATION OF LOG PERIODIC DIPOLE ANTENNA USING T-SHAPED TOP LOADINGS

[1]NEELIMA GOTTIMUKKALA, [2]R.ANJI NAIK, [3]Dr. S.SIVA LINGAM, [4]BODEKKA GARI SURENDRA

[1,2]Assistant Professor, [3]Professor [4]Student, Dept. of Electronics & Communication Engineering, Newton's Institute of Engineering, Macherla, Andhra Pradesh, India.

**Abstract**

The geometry of the log periodic structure is so chosen that electrical properties must repeat periodically with the logarithm of the frequency .It is a broad band antenna .The main intend of the project is to reduce the size of log periodic antenna. As the antenna size increases, it is difficult to integrate with planar circuits / RF circuits which increases complexity of the circuit. This antenna also occupies more area, consumes high power and cost. For best experience of the LPDA antenna, the gain lies between 7-12 db. Since LPDA's are combination of multiple λ/2 dipole elements, they're not feasible when the space for antenna is limited.

We used T-Shaped top loadings where the horizontal wires purpose is to increase the capacitance at the top of the antenna. The horizontal top load wire can increase radiated power by 2 to 4 times for a given base-current consequently, whereas T-Shaped antenna can radiate more power than a simple vertical monopole of the same height. While considering the vertical dipole the length of the pole is quite large when compared to applied T-Shaped top loadings. So, we employ T-Shaped top loading to obtain miniaturization of antenna. After studying different sized dipoles, the 0.9 kr dipole is chosen for the compact LPDA, because it is smallest in design that can maintain the same bandwidth as a conventional 1.6 kr dipole (Here r is the radius and k is the wave number).

The main objective of this project is to reduce the element size by using T-Shaped top loadings. The result obtained as individual dipole elements lengths are reduced to 55%.It offers unidirectional and bi-directional radiations and can be used for UHF/VHF/HF communications as well as TV reception.

**Keywords**: Log periodic dipole array; Compact antennas; Top loaded antennas; Altair HyperWorks FEKO.

## INTRODUCTION

A log-periodic antenna is also known as log-periodic array. It is a directional antenna designed to operate over a wide band of frequencies which was invented by John Dunlavy in 1952. It consists of a system of driven elements but all the elements in the system are not active on a single frequency of operation. Depending upon its design parameters, LPDA can be operated over a desired range of frequencies, high gain in terms of db and impedance measurement. The log periodic dipole antenna consists of several dipole elements which are of different lengths and different spacings.The length of the longest dipole component of a typical LPDA antenna ought to be adequate to half the wavelength at least operational frequency. From this property, it's not appropriate for applications that have some area limitations, like Aircraft and vehicle platforms. To use the LPDA antenna to those platforms, the antenna ought to be miniaturized. Several techniques were introduced, for miniaturization of LPDA antenna.

In pervious studies, Miniaturization of LPDA using ridged waveguide technique was reported. Koch shaped dipoles were implemented to reduce the size of the antenna upto 18% when compared to conventional log periodic dipole antenna. Reduced log periodic dipole antenna using cylindrical hat cover were reported to achieve size reduction upto 31%. Miniaturization of log-periodic dipole array antenna using triangular meander structure is implemented to reduce size upto 60% with overall gain of 6.69db. Design of a dual band electrically small, parasitic array antenna is implemented to observe dual bands and to reduce the antenna size evolve the elements are bent in rectangular shapes.

In this paper, a new compact log periodic dipole antenna is designed by replacing lambda/2 dipole elements with T- shaped top loadings to reduce the length of individual elements. The purpose of the horizontal wires is to increase the capacitance at the top of the antenna. Where as in vertical wire more current is required to charge and discharge the capacitance during the cycle of RF current. Thus these increased currents are responsible for effectively increase the antenna’s radiation resistance and radio power radiated by 2 to 4 times for a given base current. Thus, the T antenna can radiate more power when compared to simple vertical monopole of the same height.

The top-loading structure increases the radiation resistance, a circular arc for the T-shaped loading shape is used to maximize the antenna volume in the ‘kr’ sphere (‘k’ is the wave number and ‘r’ is the radius). A kr of 1.6, the electrical size of the dipole can be reduced with T-shaped top loading while maintaining an impedance bandwidth similar to that of the λ/2 dipole, which is still under the Wheeler-Chu limit. The smallest electrical size of a T-shaped top-loaded dipole with impedance bandwidth comparable to that of a λ/2 dipole is explored.

After selecting the T-shaped top loading dipole with the smallest size, six elements of differently defined T-shaped top loaded dipoles are combined to design a compact LPDA. FEKO HYPERWORKS ALTAIR is used for all simulations. The optimization of the compact LPDA is performed using a postfeko. Hence, a prototype of the compact LPDA antenna is fabricated and simulated for verification.

**DESIGN EQUATIONS**

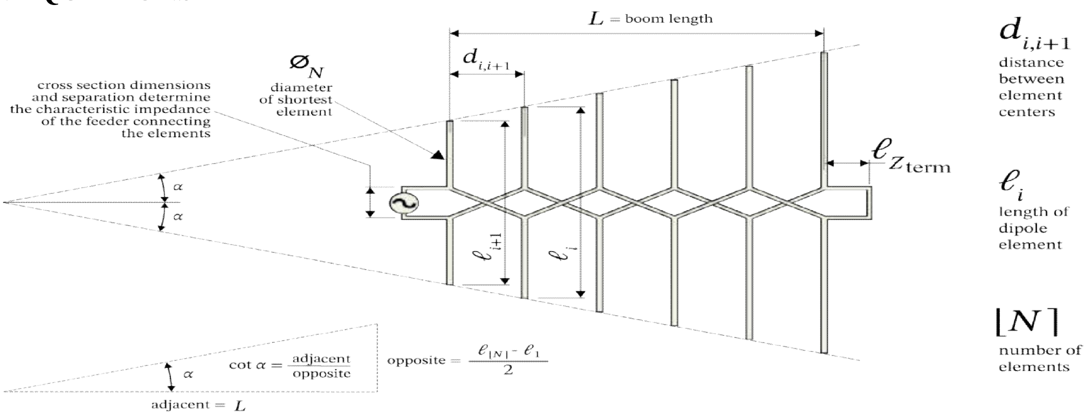



**Fig 1. Physical structure and dimensions of log periodic dipole antenna**

There are some formulas that describe the characteristics of the log periodic antenna. These can be used to calculate the lengths and spacings of the elements within the antenna.

Where, L is the length of elements, d is the distance between elements ,τ is the design constant, α is the angle of the line of the elements and σ is the relative spacing factor. Spacing factor is the ratio of the length of one element to its next longest element.

From the definition of the spacing factor □ it is possible to know the relationship between the sizes and spacing of the different elements.

$$\frac{1}{\tau} = \frac{l_{n+1}}{l_n} = \frac{R_{n+1}}{R_n} = \frac{d_{n+1}}{d_n}$$

The antenna features are grown by a constant geometric multiple. As a result of all these elements growing by a constant multiple then the logarithmic ratio will be constant. This is expressed in the formula below.

$$\log(\sigma) = \frac{\log(f_{n+1})}{\log(f_n)}$$

It is also possible to see the angle of the line of an element to the line drawn through the centre of an element using the formula or equation given below.

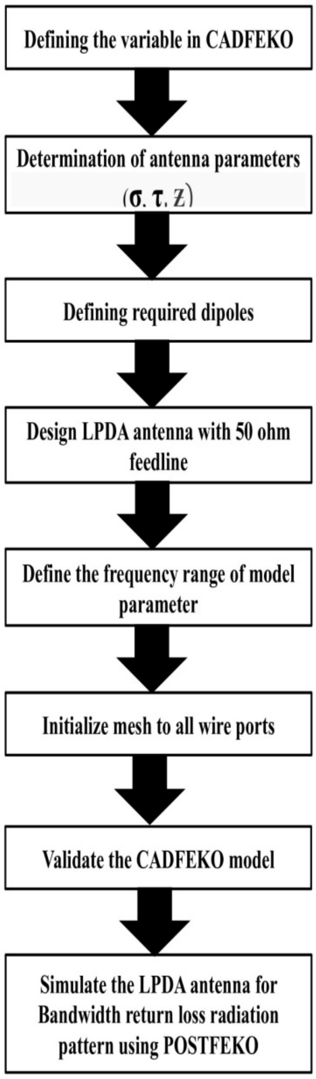
$$\cot(\alpha) = \frac{4\sigma}{1-\tau}$$

It is also possible to relate the distance between two elements and the length of each element using the angle that the element lengths form at the apex using the formula given below.

$$d_{x,y} = \frac{1}{2}(L_x - L_y)\cot(\alpha)$$

Thus, these are the basic formulas and equations which relate the basic parameters of log periodic dipole antenna.

**DESIGN METHODOLOGY**




The basic flow of performing a FEKO analysis consists of

1) Creating a geometry for the antenna in CADFEKO or EDIT FEKO.

2) construct a geometry to represent surrounding geometry i.e., creating a supporting structure for antenna in CADFEKO, EDITFEKO.

3)Apply Meshing to the Created Antenna and Surrounding Geometries (CADFEKO or EDIT FEKO).

4) Requesting Solution Types and Setting Antenna Parameters (CADFEKO or EDITFEKO)

5) Running the FEKO solver.

6) Simulate the LPDA antenna for Bandwidth return loss & radiation pattern using POSTFEKO.

**ANTENNA DESIGN AND SIMULATION RESULTS :**

Five dipoles are designed at 1 GHz, with T-top loadings at different electrical sizes, kr,as shown in Fig. 2. The electrical size is controlled by the radius, r, and the wave number, k, is fixed at frequency of 1 GHz. The simulated S11 graphs of different-sized dipole antennas with -30dB characteristics are shown in Fig. 3. As the kr gets smaller, however the -30-dB impedance bandwidth of the dipole gets smaller. But the electrical size of the dipole is reduced the antenna facing issue from poor impedance mismatch due to low radiation resistance for its small antenna size. The center dipole segment of each dipole element in an LPDA is reduced to 55% of its original length Fig. 3 shows a compact LPDA created with top-loaded dipoles, compared with a conventional λ/2-element LPDA. In both LPDAs, five elements are used and the feed of the LPDA is located at the smallest dipole element.

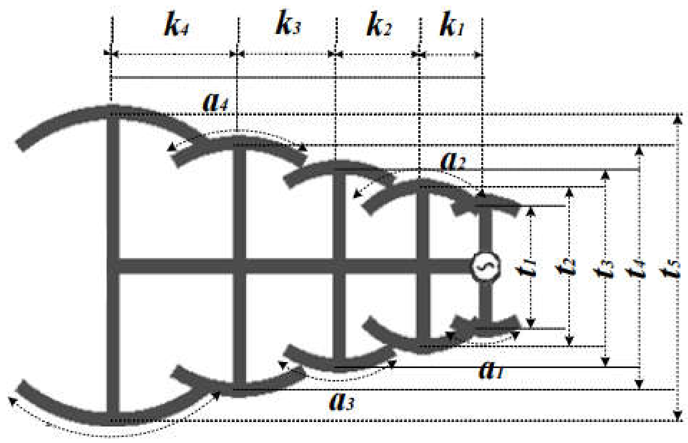



**Fig 2. Geometries and Dimensions of Compact LPDA**

Designing of LPDA using top loading with λ/2-element , with a geometric ratio τ of 0.8 and spacing factor σ of 0.148. After applying the geometric ratio and the spacing factor calculations in the length of the longest element that determines the starting frequency is chosen as 0.85 GHz, and the shortest element is designed to cover the ending frequency of 1.2 GHz. The designed conventional λ/2-element LPDA is then simulated with FEKO. Fig. 4 shows the simulated S11 of the conventional λ/2-element LPDA. The simulated -10-dB of s11 of the conventional λ/2-element LPDA is between 0.84 GHz and 1.2 GHz .

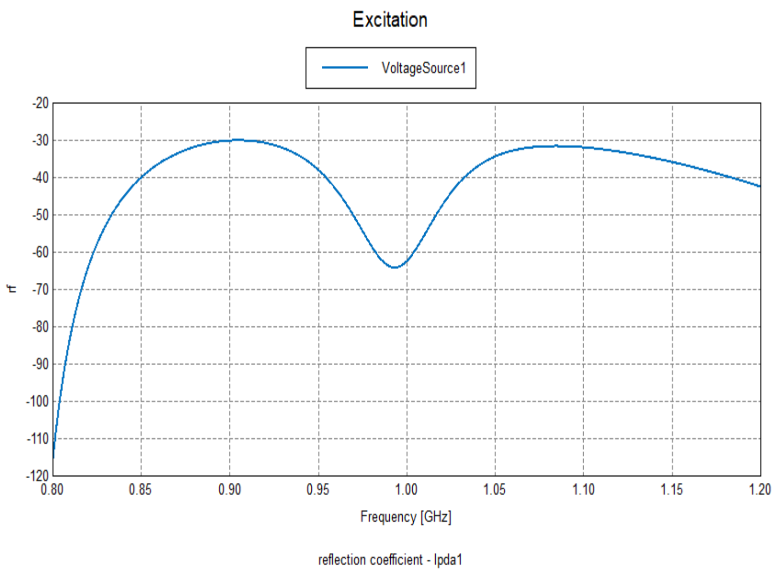



**Fig 3. Reflection coefficient of log periodic dipole antenna in dB**

A 50-Ω load is applied on the difference output port to terminate the differential function and two input sources that are 180 out-of-phase are combined to obtain correct results. Fig shows the comparison between the S11 of normal LPDA and S11 of the compact LPDA. The -30-dB reflection coefficient (87.3%, ranging from 0.82 GHz to 1.2 GHz) of the fabricated antenna has good agreement with that of the simulated one. Next, realized gain in the forward direction is measured. For the realized gain measurement below 1 GHz, two different dipole antennas that resonate at 0.84 GHz and 0.96 GHz, respectively, are used as reference antennas with gain of 45dB.

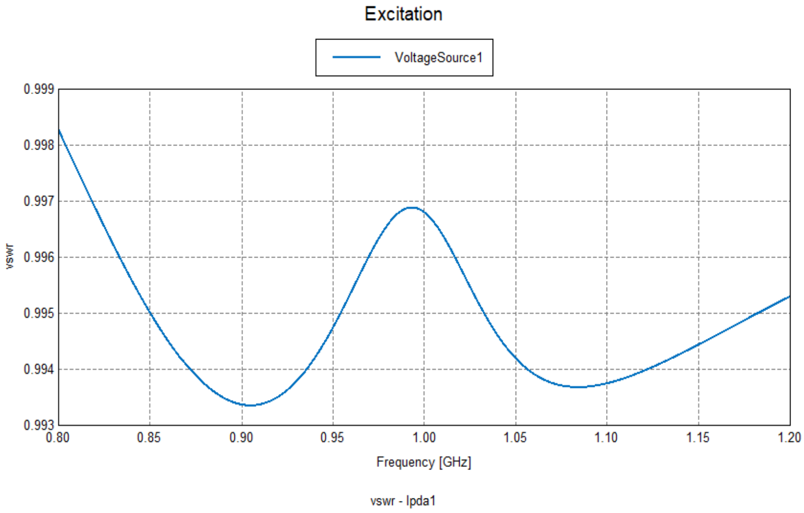
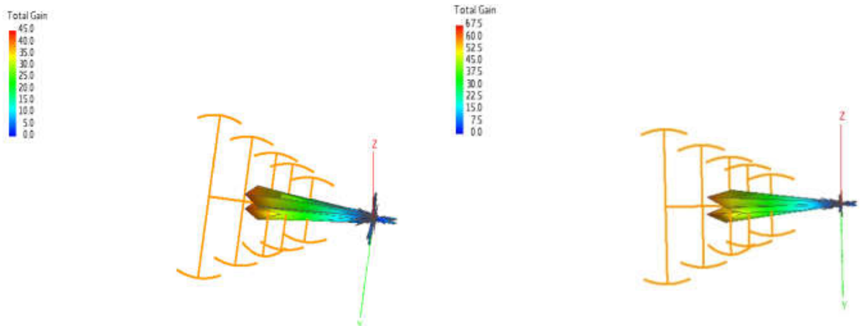



**Fig 4. VSWR of LPDA using T- shaped top loadings**

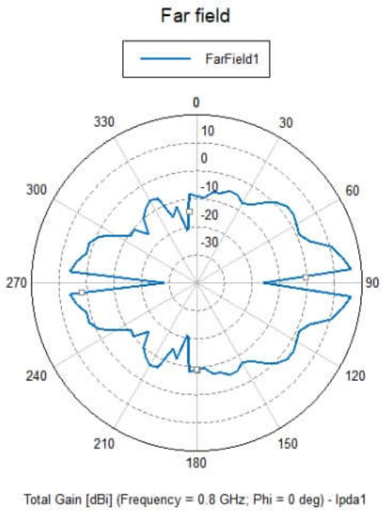
From Fig 5, we can observe that (a)The first frequency point is 0.84 GHz, the simulated forward realized gain is 45dB, (b)The second frequency point is 0.966 GHz, the simulated forward realized gain is 45 dB, (c)The third frequency point is 1.02 GHz with a simulated forward realized gain of 67.5 dB, (d)The last frequency point is 1.2 GHz, the simulated forward realized gain is 67.5 dB. Both (c) and (d) have more than 45 dB.

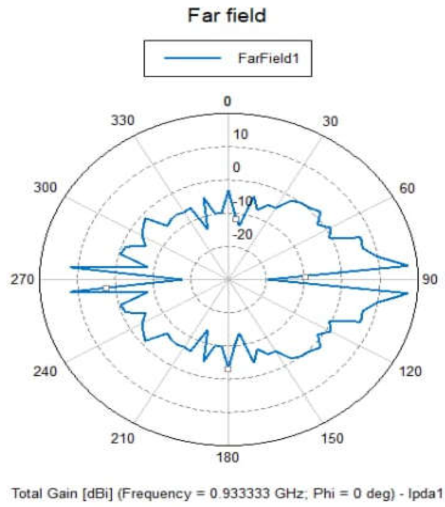



**(a)** **(b)**

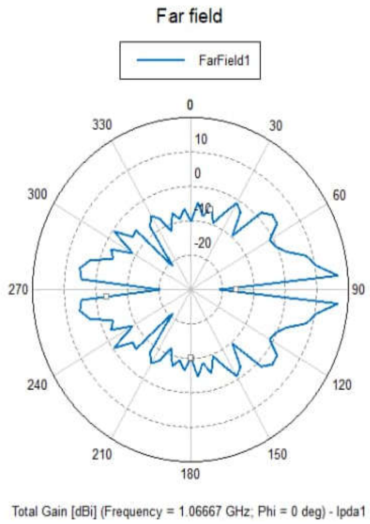
**Fig 5**. **Realized gain at frequencies (a)0.84 and 0.96 (b) 1.02 and 1.2**

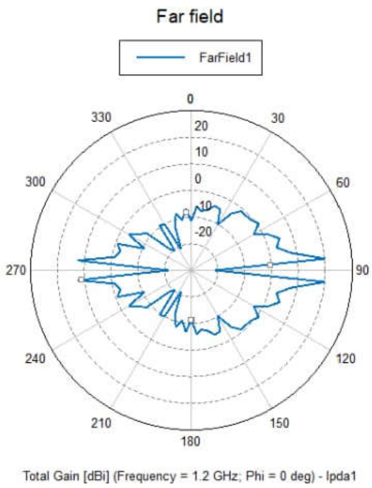
Fig. 6 shows the realized gain patterns at four different frequencies in both simulation and measurement in E-plane. These four frequencies are chosen evenly in the common frequency range of -30-dB impedance bandwidth in both simulation and measurement. The maximum realized gain in the cross polarization are -110 dB at 0.84 GHz, -30.3 dBi at 0.96 GHz, -60 dB at 1.02 GHz and -40dB at 1.02 GHz.




**(a) (b)**




**(c)** **(d)**

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**PARAMETERS OBTAINED FOR LPDA USING TOP-LOADINGS :**

The below table shows the parameters of the compact LPDA after simulated the model

| FREQUENCY | REFLECTION COEFFICIENT | VSWR | GAIN(dB) |
|---|---|---|---|
| 0.8GHZ | -110dB | 0.998 | 45 dB |
| 0.96GHZ | -30dB | 0.9935 | 45 dB |
| 1.03GHZ | -60dB | 0.997 | 67.5 dB |
| 1.2GHZ | -40dB | 0.995 | 67.5 dB |

## CONCLUSION

In this project we design a conventional log periodic dipole antenna and compact log periodic dipole array using T-shaped top loadings. After simulating these two antenna design we observed that conventional log periodic dipole antenna exhibits 6db gain and the size of the antenna is complex. While in LPDA using T-shape technique, small spacing factor leads to reduce the size of antenna. The compact LPDA has an overall average realized gain of 67.5 dbi while maintaining –30dB reflection coefficient from 0.82GHz to 1.2GHz in measurement. A method of decreasing the element size of a lambda/2 element LPDA is presented, using T-shaped top loadings. Individual dipole element lengths are reduced to 55%. The log-periodic dipole antenna with reliable bandwidth and gain estimates.

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