# Wide Bandwidth and Small Size LPDA Antenna

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*Abstract*— **In this paper, a wideband log periodic dipole antenna (LPDA) with small size is proposed. The arms of the dipole are in the shape of a second order fractal, which makes each dipole element to resonate in more than one frequency. This results in a LPDA antenna whose size can be greatly reduced. The proposed antenna has a substrate size of $90 \times 60$ mm$^2$ and operates over 2-8 GHz bandwidth with VSWR< 2. The antenna has stable pattern over the frequency range.**

***Key words- LPDA antenna; fractal; wide bandwidth***

## I. INTRODUCTION

The log-periodic dipole array (LPDA) antenna was the first frequency independent antenna that immediately after its conception made a huge impact on both commercial and military applications throughout the world. A log-periodic antenna is defined as a structure whose electrical properties vary periodically with the logarithm of frequency. If an antenna is realized such that within each period its performance changes within bandwidth-defined conditions then multi decade operation can be obtained. To produce the required performance, similar mathematical relationships must be applied to the antenna's structural parameters.

The LPDA antenna consists of two in-plane sets of crisscrossed monopoles whose lengths and separations are related via the growth rate $\sigma$. The alternating feeding's is required to achieve the backward end-fire radiation in the direction of the small dipole pairs. The currents on the consecutive monopoles in the transmission line region are in the opposite direction, thus contributing little to the overall radiation.

The LPDA antenna, which is a simple antenna structure, has reasonable gain, narrow beam and constant input resistance over a wide impedance bandwidth. This antenna is used in versatile applications such as feed for reflector antennas, lens and signal detection. Based on the application, the shape of the radiating elements could be cylindrical dipole [1], printed dipole [2, 3] or other kinds of shape [4]. Due to low cost, light in weight, and simple to design, printed LPDA antennas are well in demand.

The LPDA antenna size is proportional to the antenna bandwidth, increases in size as bandwidth increases, making limitation in the antenna design. The lateral size of the LPDA is determined by the lowest operating frequency. In certain applications due to limit in space, the antenna size should be reduced.

Various techniques to foreshorten the dipole have been considered by many researches and great achievements have been made. The printed LPDA has been paid close attention in recent years. The initial work on printed LPDA antennas is that reported in [5] and since that work, a few papers have been published on reducing the lateral size of such antennas. In [6], using meandered lines a reduced size printed LPDA antenna is reported, achieving 26% size reduction with low return loss and high F/B over 1.8-4.2 GHz. A small planar log periodic Koch-dipole antenna (LPDKA) is reported in [2] resulting in some 12% size reduction. An improved fractal tree log-periodic dipole antenna resulting in a lateral size reduction of up to 39% operating over 0.4-1.5 GHz with good VSWR but with degraded pattern over the lower frequencies is given [3]. In [7] a rectangular patch loaded dipole LPDA design, reducing the size of the planar LPDA up to 30% with good VSWR and low cross polarization performance over 2-5 GHz is reported. Microstrip dipole antenna with top loading that uses T shaped dipole arms, covering 2.3-8 GHz bandwidth, with 50% size reduction in antenna width for singular T shape arms and 54% for dual T shaped antenna is given in [8]. In wire antennas at low frequencies, size reduction can be achieved through top loading technique. In [9] theoretical impedance variation of such antenna is given. In most of these works the size reduction takes place over a limited bandwidth.

In this paper, a wideband, covering 2-8 GHz bandwidth, log periodic dipole antenna (LPDA) with small size is proposed. The arms of the dipole are in the shape of a second order fractal, which makes each dipole to resonate in more than one frequency. This results in a LPDA antenna whose size can be greatly reduced. The proposed antenna has a substrate size of $90 \times 60$ mm$^2$. The antenna has stable pattern over the frequency range. Simulation results on VSWR and radiation pattern at the various frequencies over the band are provided via software package HFSS.

## II. ANTENNA DESIGN

In the LPDA printed antenna the radiating elements are printed on the two sides of a dielectric substrate board. Along the center line is a pair of strips that are used as the connection line and are fed at the end of the shortest element through a coaxial feed line. LPDA is composed of N parallel dipoles. In the first stage, a straight strip LPDA is designed. This is the reference antenna. Table I gives the dimension of a 9 straight element simple LPDA on a substrate of 90 mm × 120 mm [8].

TABLE I. DIMENSION OF A 9 STRAIGHT ELEMENT SIMPLE LPDA (IN MM)

| *N* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* |
|---|---|---|---|---|---|---|---|---|---|
| $L_n$ | *16.7* | *20.44* | *24.92* | *30.4* | *37.07* | *45.21* | *55.13* | *67.24* | *82* |
| $R_n$ | *5.6* | *11.97* | *19* | *27.714* | *38.93* | *52.493* | *69.032* | *89.204* | *113.804* |
| $D_n$ | *5.6* | *6.37* | *7.03* | *8.714* | *11.216* | *13.563* | *16.54* | *20.172* | *24.6* |

Figure 1 shows The LPDA structure with straight strip elements. The straight arms of the LPDA are then replaced by the proposed fractal elements. The typical fractal that would replace the simple dipole is the second order Koch fractal which makes each dipole to resonate in more than one frequency. Higher-order versions of the Koch curve are generated by simply repeating the iterative process until the desired resolution is achieved. The first four iterations of the Koch curve are shown in Fig. 2.

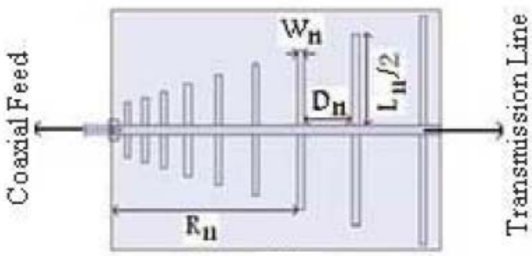
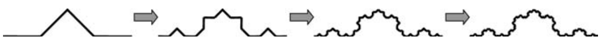



Fig. 1. The LPDA structure with Straight strip elements.[8]



Iteration 1 Iteration 2 Iteration 3 Iteration 4

Fig. 2. The first four stages in the generation of the standard Koch fractal

Following an optimization of the size of the antenna, the proposed antenna has a substrate size of $90 \times 60$ mm$^2$ while that of the straight dipole LPDA has a size of $120\times90$ mm$^2$ **[8].** Figure 3 shows the proposed printed fractal dipole LPDA antenna. The properties of this antenna are shown in Table II.

In Table II, σ is an antenna intrinsic property, *n* refers to the dipole number *n*=1,2,3,…(the number of elements that we have used in this antenna is 10) and $wt_n$ is nth element width. The optimum number for $\sigma$ achieved for this antenna is 0.8. The substrate height is 1.5 mm. The size of the susbtrate for the LPDA antenna with fractal elements shows some 25% size reduction in length and 33.34% size reduction in width.

$$\sigma = \frac{wt_n}{wt_{n+1}} \tag{1}$$

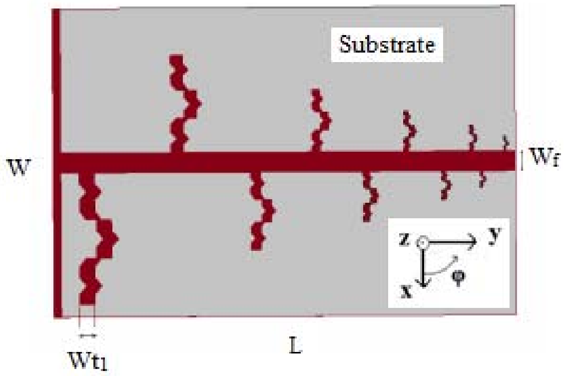



Fig. 3. LPDA antenna with second order fractal arms

TABLE II. ANTENNA PROPERTIES AND PARAMETERS (MM)

| $Wt_1$ | σ | ε |
|---|---|---|
| 3 | 0.8 | 2.5 |
| $W_f$ | L | W |
| 3.85 | 90 | 60 |

## III. RESULTS

Figure 4 shows the VSWR of the printed log periodic dipole antenna with second order fractal elements. The impedance bandwidth of the fractal LPDA for a VSWR ≤ 2.0 is between 2-8 GHz. The simulated results are obtained by HFSS software package.

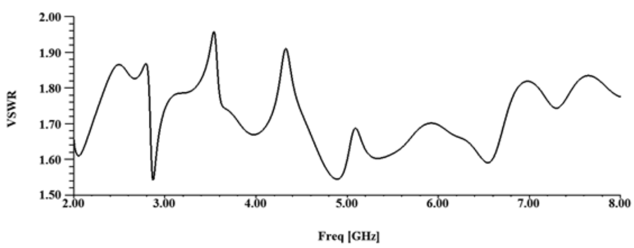



Fig. 4. VSWR varaition of the proposed LPDA antenna with fractal arms

Figure 5 shows the radiated pattern of the proposed antenna at frequencies of 2, 4, 6 and 8 GHz. It can be seen that the radiation pattern is stable over various frequencies within the band.

Figure 6 shows the measured peak gain of the LPDA antenna for various frequencies for the purposed antenna. Results show that, on average, the fractal elements give a high gain of 5.8 dBi over the 2-8 GHz bandwidth.

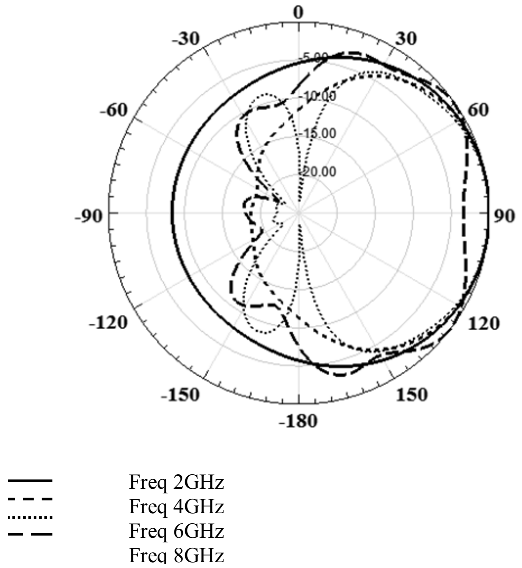



Fig. 5. Radiated pattern in phi=90 at frequencies of 2, 4, 6 and 8GHz

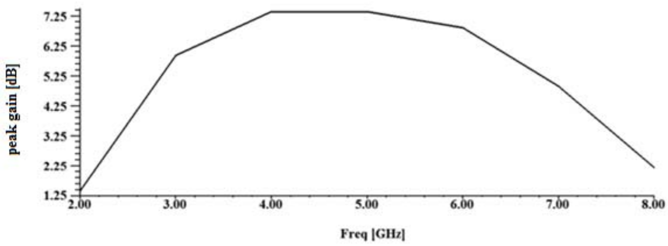



Fig. 6. Variation of peak gain over 2-8 GHz range.

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