LOG PERIODIC DIPOLE ANTENNA WITH CURVED STRIP ELEMENTS

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***Abstract*— This paper presents a log periodic dipole antenna (LPDA) with straight or curved metallic strip elements. In the first part, the results of a straight and a curved cylindrical wire LPDA is presented. Then, results of straight and curved strip plate LPDA elements are provided. It is shown that the straight or curved wire or strip plates results in a VSWR <2 over 2-10GHz bandwidth, with the curved elements showing a smaller VSWR over most of the band. Variations of the gain with frequency for the above straight and curved elements shows that the curved elements give an improvement of around 2dB compared to that of the straight elements over most of the band. With provided curved metallic elements 20% size reduction compared to the original dipole element length. Simulation results on VSWR, E and H-plane radiation patterns and gain at various frequencies obtained via software package HFSS are provided. To confirm the accuracy of the results CST software package is also used.**

I. INTRODUCTION

Recently, a lot of attention has been paid to Ultra Wide Band (UWB) communications because their advantages make them attractive for consumer communications applications. A wide variety of antennas directional or non-directional are suitable for use in UWB applications [1-3].

The log-periodic dipole antenna is a popular directional antenna that is used successfully in many applications, ranging from HF to microwaves and recently for UWB [4, 5]. One important reason for such popularity has certainly been the straight forward design of such antennas, [3, 6-8]. Its characteristics remain nearly constant and it radiates with high gain at frequencies within the operational bandwidth. The forms of the radiating elements used in the LPDA structure could be cylindrical wire dipoles [9], printed dipoles [10, 11] or other kinds of shapes [12] in terms of different situations where the LPDA are applied. The LPDA consists of dipoles whose lengths and spacing are arranged in a log periodic manner. The lateral size of the LPDA is determined by the operating frequencies, and the longest radiation element is proportional to the lowest frequency.

With the development of large scale integrated circuit, antenna is required to be light, small and easy to make. In wire antennas at low frequencies, size reduction can be achieved through top loading technique. In [13] theoretical impedance variation of such antenna is given.

In this paper, a simple LPDA structure is presented that result in low VSWR over the 2-10GHz band with good gain performance over most of the frequencies in the band. The LPDA structure proposed uses curved cylindrical wire or strip plate elements to achieve the higher in gain. With provided curved metallic elements 20% size reduction compared to the original dipole element length. . Simulation results on VSWR, E and H-plane radiation patterns and gain at various frequencies obtained via software package HFSS are provided. To confirm the accuracy of the results CST software package is also used.

II. ANTENNA CONFIGURATION

The basic arrangement of a log-periodic dipole array excited by a two-wire line (antenna feeder) is shown in Fig. 1(a) along with the geometry-defining formulas. The array elements are dipole antennas excited with 180 phase shift and their length and distance decreases according to equ. (1), respectively. The two supporting booms act as a twin-line feeder. The required 180 phase shift is implemented by attaching the elements alternately to the first and second boom. LPDA is composed of N parallel dipoles. Its structural characteristic is such that each dipole's size and position are related to a constant τ called periodicity, which is less than 1 and is the ratio between successive elements:

$$T = \frac{R_n}{R_{N+1}} = \frac{D_n}{D_{N+1}} = \frac{L_N}{L_{N+1}} \qquad (1)$$

Where, n is the dipole's serial number, n =1, 2,..., N; R_n is the vertical distance from the antenna's virtual apex O to the dipole n, L_n is the length of the dipole n, D_n is the distance between two neighbouring dipoles. Sometimes, for the designing convenience, another parameter, σ, is introduced. σ is called the spacing factor and is defined as:

$$\sigma = \frac{D_n}{2L_{n+1}} \qquad (2)$$

Throughout this paper to have maximum gain from the antenna τ =0.82 and σ =0.15 is used.

As it will be shown in the next section, to increase the gain of the straight wire LPDA, Fig 1(a), one can replace the wires by curved wires, Fig. 1(b). As shown in Fig. 1(b), R'_n now shows the radius of circles with centre at O and L'_n are the arc lengths. With provided curved metallic elements 20% size reduction compared to the original dipole element length. To reduce the complexity of the curved wire elements one can use curved strip plates, Fig. 1(c).

Each of the curved elements is an arc from a circle whose radius is according to the following Formula

$$R'n = \left(\frac{2*180}{\alpha}\right)\left(\frac{L'_n}{2*3.14}\right) \quad (3)$$

Where R'_n is the radius of a circle for element n, L'_n is the arc length which is taken to be the same as the length of a straight element; Ln. Table 1 gives the dimension of a 9 element curved wire LPDA.

For the strip plates, the same arrangement as the curved wire LPDA is used, i.e. the width of the strips are chosen to be equal to diameter of the wires, the position of the strips are at the centre of the wires and the thickness of the plates are set at 2mm.

III. SIMULATED RESULTS

In the first stage, a straight wire LPDA is designed with the above described method. Then this straight LPDA is converted to a curved wire LPDA. To do this, the linear element positions Rn for the straight wire are changed to circular radiuses R'_n according to the Table I. Fig. 2(a) shows the VSWR of the wire log periodic dipole antenna with straight and curved elements. The impedance bandwidth of the LPDA is between 2-10GHz. The VSWR result shows that the curved wire elements results in a smaller VSWR over most of the band. These results were obtained by HFSS software package. A second powerful software package, CST, was also used to confirm the result of the curved wire LPDA. Comparison between the two results is quite good. Fig. 2(b) shows the VSWR of the LPDA with straight and curved strip elements obtained by HFSS and also the VSWR result of curved strip elements obtained via CST. Also shown is VSWR of curved wire element for comparison. Overall, this result shows that the curved wire or strips results in a lower VSWR as compared to the straight wire or strips. The results for the curved wire or strip LPDA are quite similar but construction of the strip LPDA is simpler.

Fig. 3 and 4 show the simulated E- and H-plane plane radiation patterns of the straight and the curved log periodic dipole antenna with HFSS and CST software at centre frequency, 5GHz. Good radiation patterns of antennas are noticed. Although not shown, the results of the patterns at the lower and upper end of the bandwidth, i.e. 3 and 8GHz were also obtained. At the lower frequencies, the curved elements show a narrower beam while at the upper and lower frequencies, and the curved elements has lower side lobe levels compared to the other element shapes. Overall, the curved elements provide, on average, a narrower main beam and lower side lobe levels over the 2-8 GHz band. Also a study of the cross polarization of the two antenna shapes shows that at the lower and higher frequencies the straight elements give a higher cross polar level compared to the other element shapes. Overall, the cross polar level is ≤ -15dB in the worst case.

Fig. 5 shows the simulated gain of the LPDA antenna for various frequencies for the straight and curved wire and strip elements obtained via HFSS. This shows that the curved elements give an improvement of around 2dB in gain compared to that of the straight elements over most of the band. The LPDA gain of the curved strip and wire element are almost the same.

TABLE I

Dimension of a 9 element straight and curved wire LPDA (in cm)

Straight wire Position, R_n	Radius of circle for Curved wire, R'_n	Radius of each wire, G_n
R_1=0.51	R'_1=2.32	G_1=0.35
R_2=1.122	R'_2=2.83	G_2=0.35
R_3=1.869	R'_3=3.45	G_3=0.35
R_4=2.78	R'_4=4.28	G_4=0.35
R_5=3.893	R'_5=5.14	G_5=0.35
R_6=5.25	R'_6=6.27	G_6=0.45
R_7=6.90	R'_7=7.64	G_7=0.45
R_8=8.92	R'_8=9.32	G_8=0.45
R_9=11.38	R'_9=11.38	G_9=0.45

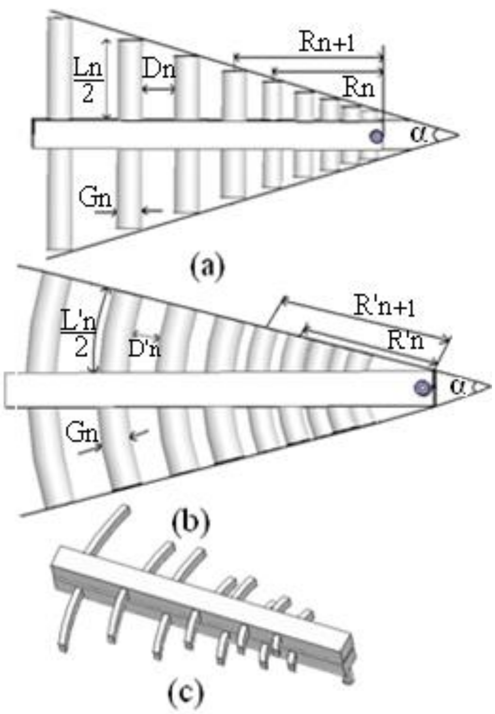

Fig. 1 The LPDA structure. (a) Straight cylindrical wire LPDA, (b) Curved wire LPDA, (c) Curved strip plates LPDA.

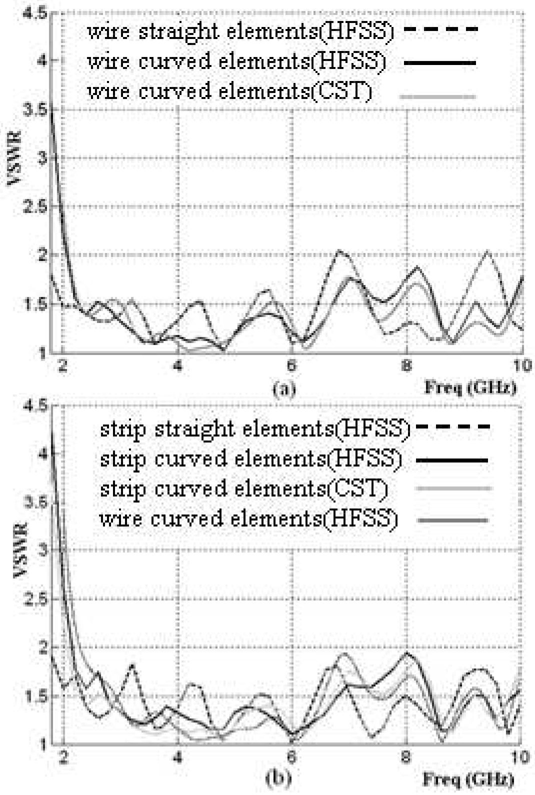

Fig. 2 shows the VSWR of the wire log periodic dipole antenna (LPDA) with straight and curved elements (a) and strips LPDA with straight and curved elements (b).

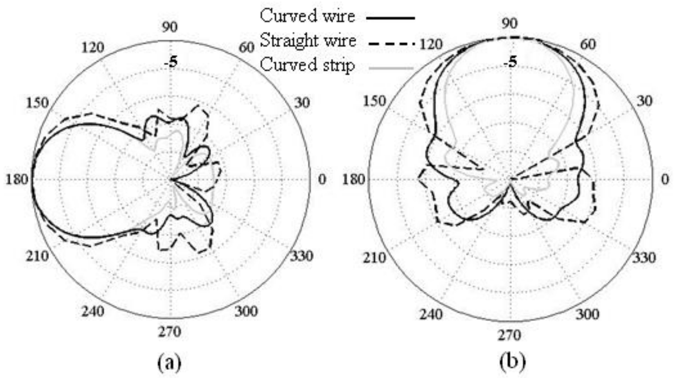

Fig. 3 (a) H-plane and (b) E-plane radiation pattern of the LPDA antenna Straight and curved elements with HFSS software at centre frequency.

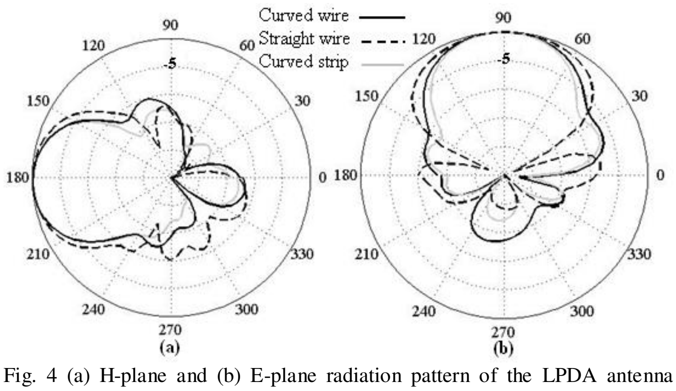

Fig. 4 (a) H-plane and (b) E-plane radiation pattern of the LPDA antenna Straight and curved elements with CST software at centre frequency.

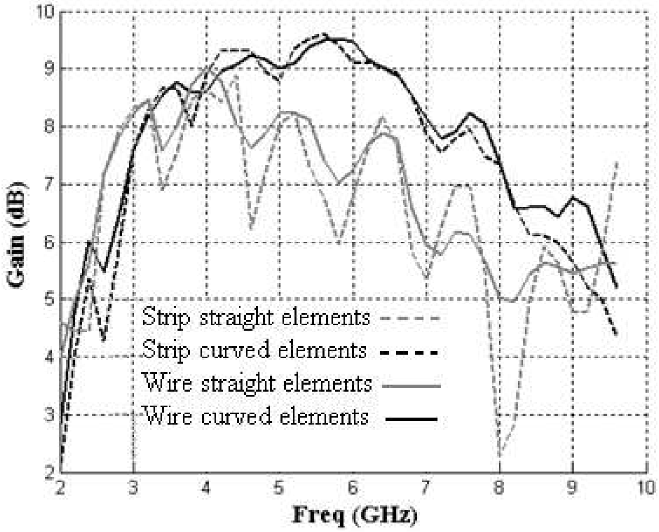

Fig. 5 Variation of gain of the LPDA antenna for the straight and curved strips, and straight and curved wire elements.

IV. CONCLUSIONS

It has been shown that the three types of antenna configurations described provide a 2-10 GHz impedance bandwidth, on average 6.5-8.5 dBi gain (and low cross polarization level). Curving elements of LPDA have a lower VSWR as well as higher gain over most of the frequency range of 2-10GHz can be obtained. The curved element LPDA has almost 2dB higher gain over most of the frequencies and 20% size reductions compared to the usual straight wire LPDA. Also it has been shown that a strip plate which is more compact, lower in weight and simpler to construct can replace the cylindrical curved wire while producing the same performance.

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