The Design and Simulation of Feederlines of Log-periodic Dipole Antenna in Microwave Band

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***Abstract*-This paper studied the impact of different distance and angles of feedlines to the log-periodic dipole antenna (LPDA). The study found that in the parallel manner (angle is 0) and different distance between feederlines(d is modified from 2mm to 14mm), VSWR is larger than 3. So the optimization is proposed that the feederlines are inclined by 5° to get wider work band (from 0.47GHz to 3.8GHz) with 8dB gain as well as low VSWR. Thanks to this modification, the LPDA can provide superior performance in the measurement of multiple polarization directions and omni-direction pattern above 2GHz.**

I. INTRODUCTION

Log periodic dipole antenna (namely LPDA) was proposed in 1957, and its characteristics are logarithm cycle changed with frequency. Because the change of the antenna characteristics in a cycle is little, therefore LPDA belongs to the non-frequency-dependent antenna. Because of its simple structure, lower price, good quality, easy to install and so on, the LPDA is the representative of the popular broadband antennas. LPDA is widely used in communications, direction finding, searching and electronic countermeasures within the field of shortwave and FM, as well as microwave-band [1]. LPDA can be used to simultaneously measure the multiple polarization direction and nearly omni-directional pattern, which possess the advantages of the horn antenna and the biconical antenna. The feederlines are important in the design of this antenna. Here the design of feederlines in microwave band is proposed, and the simulation is given by CST [2]. In this paper, we conclude that the LPDA can perform well with good front-to-rear ratio characteristics and high gain, as well as wide work band above 2GHz.

II. THE STRUCTURAL DESIGN OF THE LPDA

LPDA is one of the classic non-repeat forms of frequency varying antenna, its impedance and radiation characteristics are repeated by the logarithm of the frequency. Its main feature is the ultra-wideband and low cross-polarization level. The transmission of electromagnetic energy is from feed point along the antenna structure to push forward. The resonance occurs at the teeth of a quarter-wavelength and then the radiation occurs. The remaining little part of energy will move forward, and then reflect back at the end of the antenna, where the energy is very weak.

When the frequency is changed, the resonant point will move, but the geometric form of the LPDA ensures the characteristics of the antenna will not be affected by the move of the resonant point [3]. The feed way of LPDA is cross power feeding. The feeder is a cross-connect between two adjacent poles, and the purpose is to ensure the poles in the radiation area can obtain appropriate phase relationship, so that the phase of long poles are before the short ones, thereby the result is the end fire pointing to the vertex direction. The feederlines are supported by a parallel dual-pipeline. The coaxial cable outputted by the transmitter is cable through a pipeline, and the skin is connected to the metal tube, as well as the core wire to another metal tube shown in Figure.1. The length of pole arm equals to the half wavelength of the corresponding frequency. The cross-connect of the coaxial cable is to achieve one-way radiation of the short pole directions.

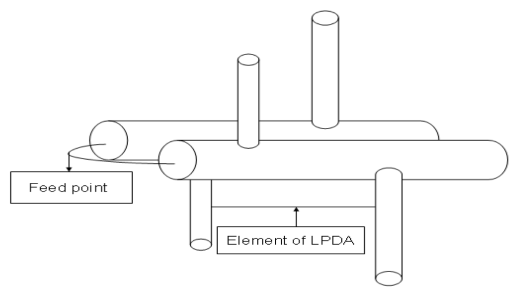

Figure.1 structure of the LPDA

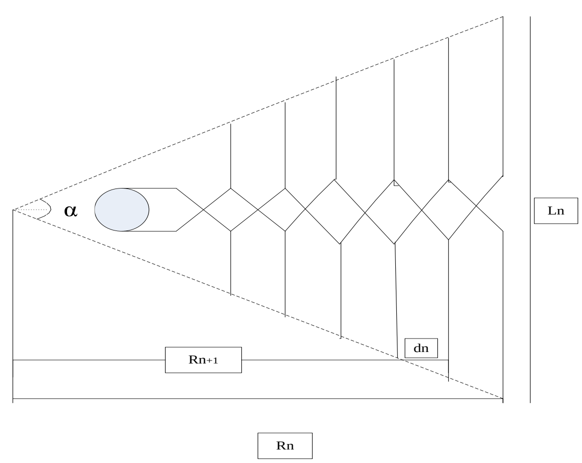

Figure.2 schematic of the LPDA

The feature of pattern, gain and impedance depends on τ and σ.
Scale factor τ is

$$\tau = \frac{R_{n+1}}{R_n} = \frac{L_{n+1}}{Ln} < 1 \tag{1}$$

The ratio of the distance of successive pole equals to the ratio of the length of the successive pole.
The interval factor of LPDA is:

$$\sigma = \frac{d_n}{2L_n} \tag{2}$$

The element spacing is:

$$d_n = R_n - R_{n+1} \tag{3}$$

Because of $R_{n+1} = \tau R_n$, and $R_n = \frac{L_n}{2\tan(\alpha/2)}$,so:

$$d_n = (1-\tau)\frac{L_n}{2\tan(\alpha/2)} \tag{4}$$

Bring these formulas into the definition of σ, the result is

$$\sigma = \frac{d_n}{2L_n} = \frac{1-\tau}{4\tan(\alpha/2)} \tag{5}$$

All dimensions into the following proportions:

$$\tau = \frac{R_{n+1}}{R_n} = \frac{L_{n+1}}{L_n} = \frac{d_{n+1}}{d_n} = \frac{\rho_{n+1}}{\rho_n} \tag{6}$$

In the formula (6), l is the length of the pole, ρ is the radius of the pole, s is the distance between the longest and the shortest poles.

At the end of the feederlines, it can be connected with a resistance equal to its characteristic impedance, as well as can be up to the back of the unit within $\lambda_{\max}/8$ distance. The characteristic impedance of the feeder can affect the input impedance of the antenna. Its relationship is expressed as [4]:

$$Z_c = \frac{Z_0}{\sqrt{1+\frac{Z_0\sqrt{\tau}}{4\sigma Z_a}}} \tag{7}$$

III. THE DESIGN OF LPDA'S FEEDERLINES

When the distance between feederlines(namely d) is too small, the current amplitude will be inverted, so that in the far-field region it will affect each other. When LPDA works at the high frequency, the beam of the inner core wire will be deflected to the top of the feederline. This assumes that the core wire is self-induced. Thereby the high frequency characteristics of the antenna will be limited. When d increases, it means that the distance of the inner core of the collection line increases, thus the coefficient of self-induction increases too, so does the load impedance Z_l. Therefore, the distance d requires multiple simulations to optimize its design.

In the design, the parameters τ and σ are: 0.928 and 0.0864. The VSWR of LPDA with different d (namely d = 2 mm, 6mm and 14mm respectively) is shown in Figure.3.

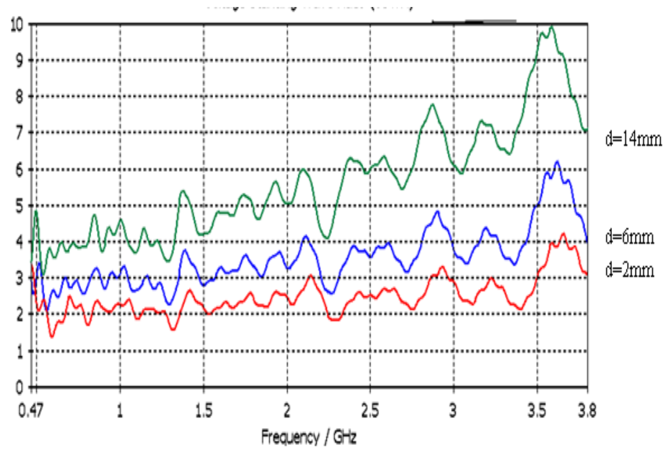

Figure.3. The VSWR of LPDA

In figure.3, even if the distance d = 2 mm, VSWR is also substantially greater than 2 in the whole frequency band. Through the different simulation comparative study, we can conclude that if the feederlines are theoretically parallel, the VSWR is not ideal. Hence a change in the design of the feederlines is put forward. The idea is that the distance between feederlines is linearly varied, the front is closer (less than 2 mm, so here is 1.4mm) ,and the rear is less than 15mm.The reasons to this design are : (1) to achieve the impedance match. A pair of poles on different feederlines is to form a dipole (shown in Figure 4). But the size of C will perform a great influence in the microwave band to the antenna, also C can affect the symmetry of the dipole, as well as the impedance matching, so in the microwave band C should be small enough; (2) to facilitate the matching of the feed point. When the distance between feederlines changed, it will be easier to match with a 50-ohm coaxial cable, the radiated energy at the feed point is reduced, and the pattern will gain better performance; (3) to reduce their own radiation.

Finally, the design of the feederlines is inclined. The value of τ and σ are 0.928 and 0.0864 respectively. The total length of feederlines is 771mm, which front part is 335mm with 8mm radius and the rear part is 436mm with 10mm radius. The LPDA utilizes 33 pairs of poles. The radius of pole is varied from 1.5mm to 6mm. The short circuit is 26.3mm distance to the longest pole. In the modeling process, considering that the current focus**es** on the model surface, the feeders and pole can be solid metal in the work band(shown in Figure. 4).

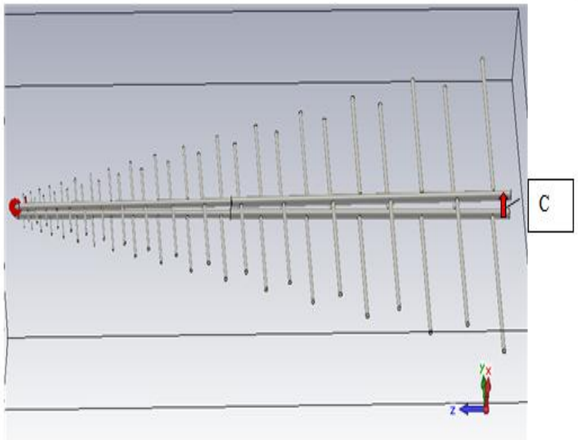

Figure.4 A 3D view of the feederlines

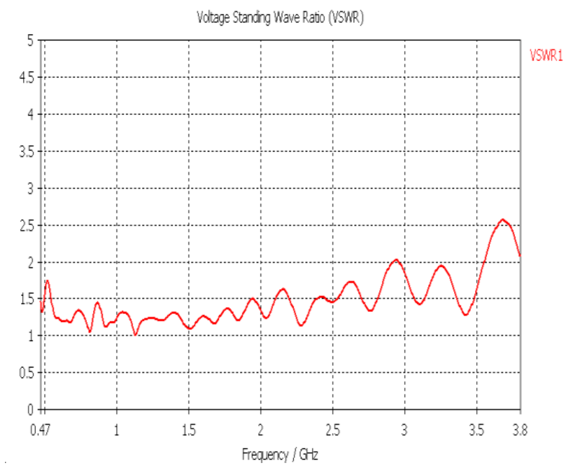

Figure.5. The VSWR of the antenna with inclined feederlines

Figure.5 shows that the antenna with inclined feederlines possesses a wide work band (0.47GHz ~ 3.8GHz) and low VSWR(less than 2).

In Figure.6 the gain of LPDA is larger than 8dB in the full work band.

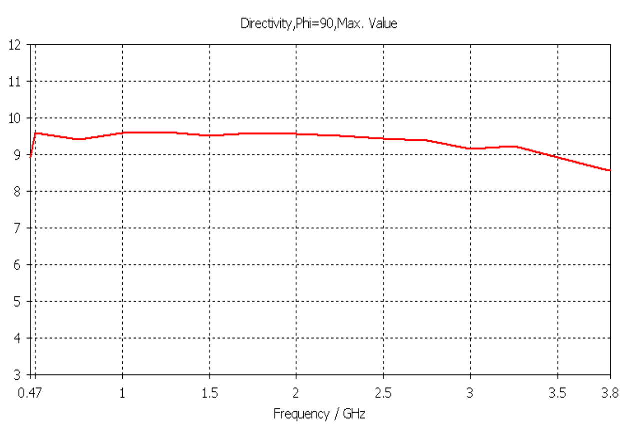

Figure.6. The full band gain of LPDA

The radiation direction of LPDA is toward the short pole. Figure.7-Figure.10 are the patterns of E-plane (red) and H-plane (blue) at 0.47GHz, 0.9GHz,1 .9GHz, 3.8GHz, respectively. The blue line is the 3dB direction.

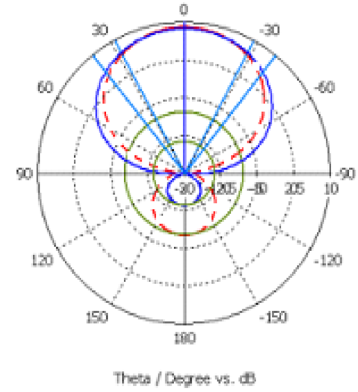

Figure.7 0.47GHz

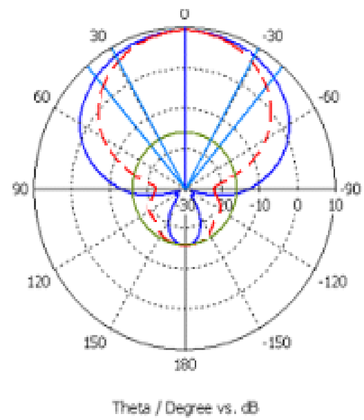

Figure.8 0.9GHz

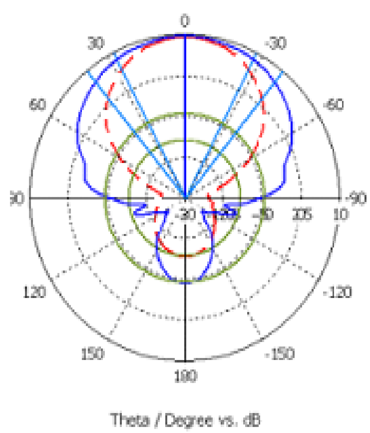

Figure.9 1.9GHz

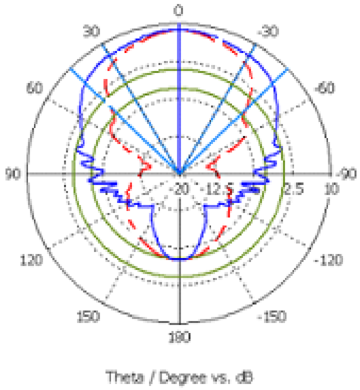

Figure.10 3.8GHz

In Figure.7-figure.10, the 3dB beamwidths of E-plane patterns at different frequencies are about 60 °, which in H-planes are basically less than 80 °. A tail flap is existed in these figures, and the level is -20 ~ -11dB. The ratio of front-and-rear at different frequencies is about 20dB.

IV. MEASURED DATA AND ANALYSIS

A prototype is fabricated as Figure.11, and the VSWR measurement result is shown in Figure.12.

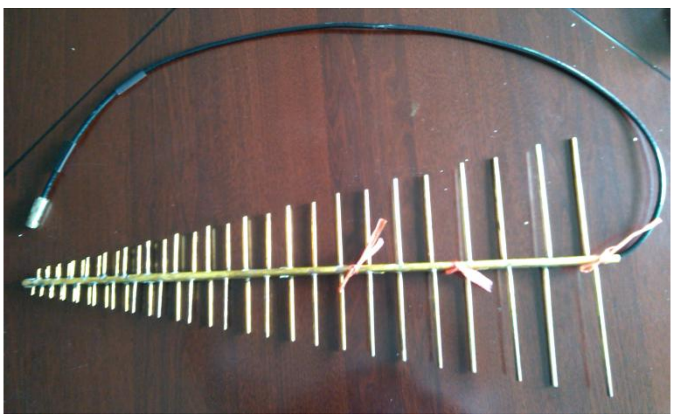

Figure.11 The LPDA model

In Figure.12, the VSWR in the whole work band (0.47GHz-3.8GHz) is less than 2. It can be found the observed performance have a good agreement with the simulated results which confirms the improved structure has excellent performance.

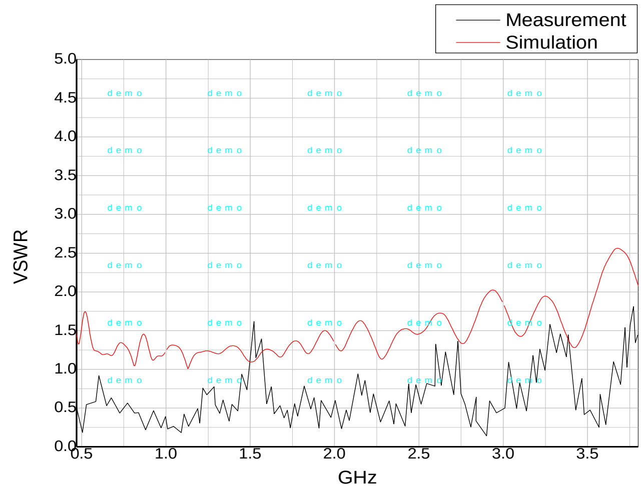

Figure.12 The measurement results of VSWR

V. CONCLSUION

In this paper, different design of feederlines is discussed, we found that parallel manner can’t ensure the VSWR and high gain in microwave band by CST simulation. Therefore an improved design of feederlines is proposed. The feederlines are inclined by 5 °. The distance between feedlines at front is smaller to ensure the feed and VSWR in high frequency. The distance between the feederlines at the rear is larger to reduce radiation itself. So the high gain and low VSWR, as well as broad work band can be obtained at the same time.

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