Analysis, design, and simulation of a Log Periodic Antenna for Mobile Communication bands

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Abstract: - The Log-Periodic Loop Antenna (LPA) is investigated as a new type of antenna, whose properties vary periodically with the logarithm of frequency, and provides wide bandwidth, broad beam width, and high gain. This antenna has smaller transverse dimensions than another antenna types.
In this paper the analysis, design, and simulation of log periodic dipole antenna (LPDA) is presented, which is suitable and particular for mobile communication bands from 1150 MHz up to 2450 MHz. ZPLOTS simulation program shows acceptable results and confirm the theoretic basics.

Key-Words: - Log periodic antenna, mobile communication.

1 Introduction

Data transmission at higher rates requires wider bandwidths for the elements constituting a communication link. This required wideband antennas be designed and used [1].
The dimensions of a log-periodic dipole antenna (LPDA), when expressed in terms of wavelength, vary with frequency, it's usually exhibit different radiation properties at different frequencies, and can be designed for any band, HF to UHF, and can be built to meet the amateur's requirements at nominal cost: high forward gain, good front-to-back ratio, low VSWR, and a boom length equivalent to a full sized three-element Yagi [2]. The LPDA exhibits a relatively low SWR (usually not greater than 2 to 1) over a wide band of frequencies. A well-designed LPDA can yield a 1.3-to-l SWR over a 1.8-to-1 frequency range with a typical directivity of 9.5 dB. Directivity is the ratio of maximum radiation intensity in the forward direction to the average radiation intensity from the array. With assuming no resistive losses in the antenna system, 9.5 dB directivity equal to the 9.5 dB gain over an isotropic radiator or approximately 7.4 dB gain over a half-wave dipole [1,2].
The LPDA consists of a system of driven elements, but not all elements in the system are active on a single frequency of operation. Depending upon its design parameters the LPDA can be operated over a range of frequencies. The log-periodic array consists of several dipole elements which each are of different lengths and different relative spacing. A distributive type of feeder system is used to excite the individual elements. The element lengths and relative spacing, beginning from the feed point for the array, are seen to increase smoothly in dimension, being greater for each element than for the previous element in the array. This is the feature upon which the design of the LPDA is based, and which permits changes in frequency to be made without greatly affecting the electrical operation. With changes in operating frequency, there is a smooth transition along the array of the elements which comprise the active region [3]. The bandwidth of a LPDA is limited by the size and figure accuracy of the elements and by the feed which couples focused radiation to the receiver. Although an LPDA contains a large number of dipole elements, only 2 or 3 are active at any given frequency in the operating range. The electromagnetic fields produced by these active elements add up to produce a unidirectional radiation pattern, in which maximum radiation is off the small end of the array. The radiation in the opposite direction is typically 15 - 20 dB below the maximum. The ratio of maximum forward to minimum rearward radiation is called the Front-to-Back (FB) ratio and is normally measured in dB [3,4].

Figure 1 shows the schematic diagram of LPDA,

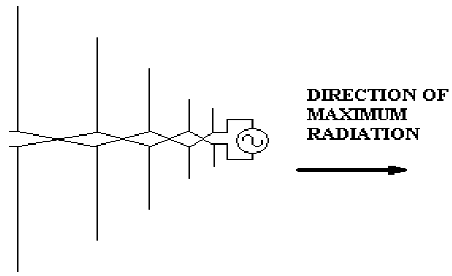

Figure 1. Schematic diagram of LPDA

As mentioned the LPDA is frequency independent in that the electrical properties such as the mean resistance level R_O , characteristic impedance of the feed line Z_O , and driving-point admittance Y_O , vary periodically with the logarithm of the frequency. As the frequency f_l is shifted to another frequency f_2 within the pass band of the antenna, the relationship is [5];

$f_2=f_l/\tau$

Where, τ is a design parameter ($\tau<1.0$)

$f_3=f_l/\tau^2$, $f_3=f1/\tau^3$ and, $f_n=f1/\tau^{n-1}$

f_l is lowest frequency
f_n is highest frequency

τ is used to determining the element length L, and the element spacing d [4,5],

$L_2=\tau/1$, $L_3=\tau/2$, and $L_n=\tau/n-1$

Where, L_n is the shortest element length.

$d_{2-3}=\tau\ d_{1-2}$, $d_{3-4}=\tau\ d_{2-3}$……..$d_{(n-1)-n}=d_{(n-2)-(n-1)}$

Where d_{2-3} is spacing between elements 2 and 3.
The design parameter or constant τ is determined from the diagram shown in figure 2 corresponding to the desired gain G [6],

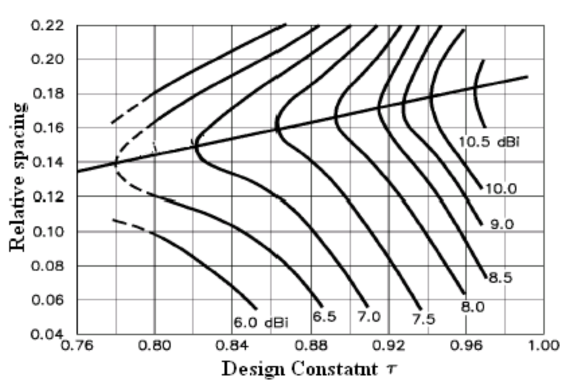

Figure 2. LPDA gain as a function of τ

2 LPDA Field Strength Model

The electric field strength of a LPDA in dB [V/m] is obtained from [3,7],

$$E(dB/V) = V(dBV)+AF(dB1/m)+a\ (dB) \quad \ldots(1)$$

Where, V is the receiver, AF is antenna factor, and “a” is cable loss, if cable losses are non-negligible. For immunity testing, the electric field strength generated at a distance “d” can be approximated by [7],

$$E(V/m) = 30^{0.5}\ p\ g\ /\ d \quad \ldots(2)$$

Where, “d” is in meters, “g” is the numeric gain 10^G[dB]/10, and “P” is antenna net input power in watts. The estimation of the power required for any field strength E can be obtained from the “Typical Performance Data”, which shows power required in watts in free space condition to generate 1 V/m. For any other field strength not multiple the power in watts by the desired E-field squared [7,8],

$$P(EV/m) = E^2P(1V/m) \quad ..(3)$$

3 LPDA Antenna design

The broadband of the LPDA antenna make better for operation over a wider frequency range. It consists of small closely spaced half-wave dipoles. The length ratio between adjacent dipoles is a constant (τ) as mentioned before, and the ratio of element spacing to twice the next larger element length is a constant (σ) [9]. The dipoles are connected to the source using a twin transmission line in such a way that the phase is reversed at each connection relative to the adjacent elements as shown in figure 1. Figure 3 shows the connecting of the dipoles to a transmission line. Each dipole is effective over a narrow band of frequencies determined by its length. When they are all connected to the twin transmission line, their narrow bandwidths add up to give a wider bandwidth [9,10].

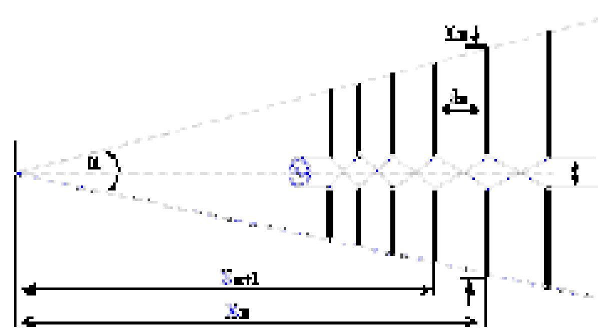

Figure 3. LPDA connecting to a transmission line

The τ is chosen such that the antenna's performance will be uniform over the whole bandwidth. The shortest dipole corresponds to the highest frequency band and the longest dipole to the lowest frequency band of an antenna. A number of the dipoles whose frequency bands are in the vicinity of the selected resonant frequency will also be active. The bandwidth ratio (B) is given approximately by $B = B_s/B_{ar}$ where B_s is the structure Bandwidth and B_{ar} is the bandwidth of the active region. The single LPDA designed to cover the entire HF spectrum from about 4 to 30 MHz [10].

$$\tau = \frac{X_{n+1}}{X_n} \qquad N=1,2,3,\ldots,n \qquad \ldots(4)$$

The angle α is given by:

$$\alpha = Tan^{-1}\left(\frac{1-\tau}{4\sigma}\right) \qquad \ldots(5)$$

The length L is given by [10.11]:

$$L = \frac{\lambda_{max}}{4}\left(1 - \frac{1}{B_s}\right)\cot(\alpha) \qquad \ldots(6)$$

The bandwidth of the active region B_{ar} is:

$$B_{ar} = 1.1 + 7.7(1-\tau)^2 \cot\alpha \qquad \ldots(7)$$

The number of dipoles required is obtained from the formula determined from [11]:

$$N = 1 + \frac{\log B_s}{\log(\frac{1}{\tau})} \qquad \ldots(8)$$

The characteristic impedance of the elements of LPDA varies with frequency, and it can be determined from:

$$Z_a = 120\left(\ln\frac{h}{a} - 2.25\right) \qquad \ldots(9)$$

The dipoles are mounted on two boom structures of transmission lines, these booms can be isolated from each other by using dielectric spacers. The impedance of this parallel rod feeder can be obtained by [10,12]:

$$Z_0 = \frac{R_0^2}{8\sigma' Z_a} + R_0\sqrt{\left(\frac{R_0}{8\sigma' Z_a}\right)^2 + 1} \qquad \ldots(10)$$

R_0 is the input impedance of the LPDA:

$$R_0 = \frac{Z_0}{\sqrt{1 + \frac{Z_0}{4\sigma' Z_a}}} \qquad \ldots(11)$$

Here σ' is mean spacing factor, it is equal to $\frac{\sigma}{\sqrt{\tau}}$

The center-to-center distance (S) between the booms is:

$$S = \left(\frac{diam}{2}\right) \times 10^{Z_0/276} \qquad \ldots(12)$$

Where, d_{iam} is the diameter of the booms [5,10,12].

4 LPDA Simulation results for mobile communication bands

The design procedure of log periodic antenna for mobile communication bands (1150-2450 MHz) using ZPLOT simulator program with the element layout is as follows,

DESIGN INPUTS

Lowest frequency	1150	MHz
Highest frequency	2450	MHz
Structure Constant Tau	0.80	
Structure Constant Sigma	0.06	
Feeder Z	113	ohm
Feeder Dia.	0.012	in

DESIGN OUTPUTS

Number of Elements (N)	8	
Array Gain (dBi).	12.6	dBi
Structure constant sigma	0.06	
Boom Length	0.13	ft
length of longest element	0.71	ft
diameter of longest element	0.031	in
stub length	0.064	in
Feeder separation	0.071	in

ZPLOT input and output parameters

And the LPDA layout is sketched in ZPLOt as shown in figure 4:

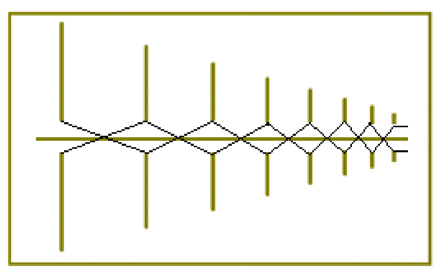

Figure 4. LPDA Elements layout

The designed antenna can cover the frequency mobile communication bands from 1150-up to 2450 MHz, with constant gain, similar radiation patterns and high performance.

5 Conclusion

The log-periodic dipole array is the simplest antenna with reliable bandwidth and gain. When the frequency increased slightly the LPDA starts to operate. The operating frequency of an antenna depends on the length of dipoles, the rear most dipole could be replaced with a slight longer dipole so that the antenna starts radiating at a frequency of 1150 MHz.

The design, analysis, and simulation of an 1150-2450 MHz log-periodic dipole antenna have been presented. In the whole band the measured antenna gain is 12.6 dBi and VSWR is below the desired limit of 1.5.

The directivity test results showed that the LPDA is a directional antenna.

So, it is clear that the design, analysis, of LPDA by using ZLOT simulating program by the described way can be useful and successful for all mobile communication bands.

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